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**LATE HOLOCENE VEGETATION HISTORY
OF GREVENA PROVINCE,
NORTHWESTERN GREECE**

Volume I – Text

by

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Abstract

Palynological investigations aimed at reconstructing the vegetation history of the Grevena Province, northwestern Greece were conducted in association with an archaeological research project. Fossil pollen, spores, microscopic charcoal particles, and sediment stratigraphies of radiocarbon-dated sediment cores from three sites in pine, beech, and oak woodland zones provide evidence of climatic changes, land use, and erosion during the last 3500 years. Identification of pollen and spores was aided by an extensive reference collection of local species and construction of a pollen key modelled on that of Faegri & Iversen (1989).

Extant vegetation units are characterized by their contemporary pollen assemblages. Surface samples collected along an elevational transect show that a fairly direct relationship exists between the major vegetation zones and pollen deposition: pine, beech, and oak pollen predominate in their respective zones. Over-representation of pine pollen is notable.

The sequence from Gomara site in the pine wood-pasture zone at 1750 m asl covers the time span *c.* 1340 BC to 700 AD. A local open pine wood was gradually replaced by beech after *c.* 890 BC, perhaps through reduced disturbance and/or increased precipitation. A herbaceous pollen spike at *c.* 80 BC resulted from deposition of volcanic ash. Pine wood replaced beech at *c.* 330 AD. Two periods of accelerated erosion coincide with the pine wood phases and with anthropogenic burning and grazing. These periods are separated by a period of abandonment when the climate was probably wetter.

The sequence from Anelia site in the beech wood zone at 1440 m asl spans *c.* 1560-1989 AD. The site was surrounded by beech wood for the duration of the sequence. Regional and local burning of vegetation is indicated by an abundance of microscopic charcoal particles from *c.* 1560 until *c.* 1730 AD, when it ceased. Periods of erosion occurred during this period. After *c.* 1730 AD a homogeneous peat formed on the wetland, suggesting a period of greater landscape stability. From pollen evidence, a variety of land-use practices such as cereal cultivation, grazing, coppicing, and lumbering were carried out in the vicinity of the site especially before *c.* 1730 AD, but these diminished after 1920 AD.

The lower part of the sequence from Kellia site in the oak wood-steppe zone at 580 m asl is insecurely dated, but the upper part spans *c.* 1230-1989 AD. The lowlands were covered with deciduous/semi-evergreen oak woods for the duration of the sequence. Since *c.* 1230 AD land close to the site was intensively cultivated with a variety of cereals. Burning occurred frequently throughout the period. The ratio of deciduous to semi-evergreen oak pollen is correlated with temperature and indicates a decline from *c.* 1230-1680 AD, after which temperature increased, a pattern similar to that of the Little Ice Age.

Frontispiece The cultural landscape of Grevena Province looking NE towards the Vourinos Mountains on the eastern border of Grevena, from a prominent hill about 1¼ km NW of the modern village of Itea. In the foreground is the stubble of a wheat field. Beyond is an 18th century church dedicated to Aghia Panaghia. The middle ground is the steppe oak wood pasture of Grevena plains. Recent erosion on the sides of gullies can be seen here, even though they appear to be well vegetated.

Frescoes in the church are shown in the enlargement. It stands on a registered archaeological site, Grevena Project 108 (21° 36.18' E, 40° 04.29' N, 640 m asl) that covers more than 10,000 m². Archaeological evidence dating to Early Iron Age, Archaic, Classical, Hellenistic, Roman, Early Medieval and Ottoman periods has been recorded.

This thesis is dedicated to my father

Hugh Chester

1913-1990

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Chapter 1. Introduction

1.1 Aims of the study

Palynological techniques are used to determine the chronosequence of vegetation during the last 3500 years in Grevena Province (Γρεβενά Νομός), western Greek Macedonia, northwest Greece (Figure 1.1). This study was undertaken in association with the Grevena Project, an interdisciplinary archaeological research project run from Carleton College, United States of America, under the auspices of Dr Gallis of the IE' Ephoreia of Prehistoric and Classical Archaeology in Larisa, Greece, and the American School of Classical Studies in Athens. The principal aim of the project is to reconstruct the environmental and cultural history of Grevena Province since human settlement began there. Little was known of the area archaeologically before the project began.

The major aim of this thesis is to describe the natural environmental background, vegetation, and climatic conditions contemporary with the archaeological cultures found to have occupied Grevena since the Late Bronze Age, as determined by archaeologists of the Grevena Project conducting an initial all-period regional survey. Past human cultures cannot be properly understood without knowing what natural environmental conditions existed while they were extant and what natural resources were available. How humans behaved and interacted within particular natural environmental conditions and exploited natural resources is of major interest to archaeologists.

Another aim is to provide information on anthropogenic vegetation changes and the consequent landscape changes from land-use practices of agriculture, pastoralism (grazing by sheep and goats and fodder collection), cutting of wood for fuel and industrial purposes, and building settlements. This research is directed towards distinguishing natural from human-induced changes in vegetation, assessing the effects of land use (mostly agriculture and pastoralism) on the environment, and establishing a chronology of hillslope erosion and deposition.

By assessing the intensity of the impact of land use at different times and at different localities some idea of variation in population size and distribution is gained.

1.2 Physical setting of the study area

Grevena Province, formed in 1951 (Wilkie 1987), occupies a small (75 x 45 km) inland basin in remote mountainous northwestern Greece, close to the borders of Albania and Macedonia of former Yugoslavia. The capital of Grevena Province is Grevena, hereafter referred to as Grevena city (the province as Grevena) (Figure 1.1). Transliteration of Greek place names varies because English letters do not correspond exactly to Greek sounds, but an

Figure 1.1 Location of Grevena Province; places referred to in the text.

attempt has been made to follow the system used in Collins Gem Greek Dictionary (Hionides 1987), except where a difference from the usage of previous authors would create confusion.

1.2.1 Location

Currently Greece is divided into 51 provinces (*nomoi*) and 13 regions (Parker 1995:14). Grevena forms the south-west corner of the Greek region called Macedonia. Greek Macedonia is part of a larger area also called Macedonia, well known for its prominence in European history during the reigns of Philip II and his son Alexander the Great, which includes parts of former Yugoslavia and Bulgaria. Greek Macedonia in north-central mainland Greece borders the Aegean Sea which lies to the south and east.

Grevena borders the better-known Greek regions of Epirus to the west and Thessaly to the south. The provinces of Kastoria (NW) and Kozani (NE) border it to the north, Ioanninon to the west, Larisa to the east, and Trikala to the south.

1.2.2 Physiography and geology

Grevena landscape resembles Central European landscapes of mountains and plains. The province is bordered by mountains on three sides; in the west the Pindos massif reaches elevations of 2250 m asl, in the east the Vourinos Mountains reach elevations of 1850 m asl, and in the south the lesser hills of the Chasia Mountains reach 1482 m. The Pindos and Vourinos ranges run almost parallel from NNW to SSE. Smolikas (2637 m), the highest peak in the Pindos range, is just across the northwestern border of Grevena, while many peaks in Grevena are over 2000 m. The lower peaks of the Vourinos are generally closer to 1500 m. The northern border of the province is not well defined topographically, although part of it is formed by the middle reaches of the Aliakmon River, the main drainage of Grevena. The central plains of the basin undulate between 400 and 700 m asl (Figure 1.1).

The province is drained by the Aliakmon and its major tributary, the Venetikos, which have incised up to 200 m (Savina 1993).

Thus Grevena can be divided into five major topographic regions: Pindos mountains, Pindos foothills, central plains or lowlands, flood plains, and the slopes of the Vourinos Mountains. At higher elevations towards the mountains to the east and west the slopes are steeper and more dissected, with more ravines and gullies than the central lowlands. The generally gently rolling hills of the lowlands cover almost half the total area of the province.

These topographic regions reflect the bedrock structure, which is well documented by the maps of the Greek national geological survey (Institute for Geology and Subsurface Research 1959, 1960, 1972; Institute for Geological and Mining Research 1979; Institute of Geology and Mineral Exploration 1980, 1987a, b). The Pindos and Vourinos mountain ranges

are primarily Mesozoic ophiolites and early Cenozoic flysch (the Pindos Flysch). The Pindos include the full ophiolitic suite of ultramafic rocks, pillow basalts, chert, limestone, and clastic marine sediments, while the Vourinos Mountains include both ultramafic rocks and limestone. Structure is complex within the Pindos range, where many different lithologies are juxtaposed over short distances (Savina 1989). The central lowlands are underlain mainly by marine Oligocene to Miocene sediments of the Mesohellenic Trench. These range from interbedded siltstones and sandstones to thick conglomerate units, the last mainly basal. Near the Aliakmon River, older Tertiary sediments are covered unconformably by Plio-Pleistocene deposits, dominantly thick gravels derived from the Pindos and Vourinos, but also including thinly bedded clays and silts (probably lake deposits) and thicker sands and silts (possibly wind-blown) (Savina 1989). In the southeast the margins of the Deskati and Dasochorion basins are markedly different, being underlain by Paleozoic igneous and metamorphic rocks (the Pre-Alpine basement). These basins as well as the Karperon basin, also in the southeast, are filled with mainly fine-grained lacustrine sediments (marls, clays, and sandstones) of Pliocene to early Pleistocene age.

West of the Aliakmon, the Cenozoic sedimentary rocks dip to the northeast gently to steeply. South of the Venetikos and east of the Aliakmon the orientation of the Cenozoic rocks is more variable.

Quaternary deposits have been described by Savina (1993), and Doyle (1990). Holocene aggradation terraces formed over the last 10,000 years occur along many reaches of the Aliakmon and Venetikos rivers and also along many tributaries. Most catchments have at least one Holocene aggradation terrace that is younger than about 2300 years, e.g. broad fill terraces, generally less than 3 m above river bed. In the Leipsokouki catchment near Sindendron there are four terraces below 10 m above the modern stream, all of which formed during the last 2500 years (Doyle 1990).

Colluvial deposits ranging in age from Late Pleistocene to Late Holocene are distributed widely. In many parts of the Pindos range above 1000 m elevation a mantle of thick colluvium covers most hillslopes on which soils are well-developed. In the Vourinos broad colluvial fans mantle toeslopes. These also have well-developed soils. Elsewhere colluvium occurs either as thin sheets on hillslopes, especially on sandstone dip slopes, or as the filling of bedrock depressions. Most catchments appear to have several ages of Holocene fill. One or more periods of alluviation/colluviation occurred in most catchments during the last 2300 years (Figure 1.2).

The dominant orders and suborders of soils of the Grevena region are classified as mountain soils with various moisture and temperature regimes on steep slopes and variable relief and elevation; the soils vary greatly within short distances (Orvedal 1990:18 & 19).

Sources: Cultural Periods in Grevena, Savina per comm. 1996; Occupation, Savina 1993; Alluviation, Savina 1989; Vegetation Zones, Bottema 1974 and Gerasimidis & Athanasiadis 1995; Climate Periods, Gamper & Suter 1982; Glacial Fluctuations in the eastern Alps, Rothlisberger 1986 (after Grove 1988)

Figure 1.2 Late Holocene chronologies.

During a detailed study of cultivated soils in every village in Grevena, Oikonomou *et al.* (1988) analysed 1,072 surface soils and 1,040 subsoils.

Entisols occurred on recent alluvial deposits along rivers. In low hilly regions and on old plains, where the parent materials have a small to moderate (or no) content of free calcium carbonate, the soils formed are chiefly Alfisols ("red earths", mostly moderately heavy). On parent material where calcium carbonate is abundant (marl, usually) and there is little erosion, the soils are Mollisols ("blackearths", heavy), and of lesser extent Vertisols (the typically very heavy "black earths"). Vertisols are found chiefly on old plains and to a very small extent on low hilly areas. Where marls occur at shallow depths below the soil surface and/or on the surface due to severe erosion, the soils are Inceptisols ("white earths" or "grey", heavy soils) and Entisols ("white earths"). On many low hilly areas and old plains where the parent material is mixed (e.g. sandstones, conglomerate, gravel, sand, clay, marly sandstones) the soils are Inceptisols (moderately heavy and usually gravelly). They are usually dark brown and/or yellow soils. In the foothills of the Vourinos Mountains, where the parent material is chiefly serpentinites or peridotites, the soils are Inceptisols ("chocolate" or "red", heavy). Where the soils have formed from acid rocks (e.g. gneisses, mica schists, sandstones) the soils are Inceptisols ("yellow" to "red", light to moderately heavy) and also Alfisols ("red earths", moderately heavy).

In the semi-mountainous regions where relief varies greatly and erosion is more severe than in the low hilly regions, the steeper slopes and the general composition of the alluvium results in the soils of the oldest of the river terraces being friable and much less calcareous (sandstones, conglomerates, gravels, sands, and, on the fertile land, clays and marls). Relatively friable also are the compositions of the parent material in those areas where the provenance of the soils is from micaceous schist, gneiss, and sandstone. Generally the soils are gravelly, leached, usually moderately heavy, and with lower "active" depths.

Almost all the surface soils and subsoils vary from heavy to moderately heavy. The heavy soils are formed mostly on low hilly regions and old plains. Sixty-six percent of the soils ranged from slightly acid to slightly alkaline, and 22% were found to be very acid to exceedingly acid. Twenty-two percent of cultivated land in Grevena was too acid ($\text{pH} \leq 5.5$) for cultivation of wheat and barley (two crops most sensitive to acid) and corn, sunflower, soybeans, tobacco, fruit trees, vine, and garden crops (alfalfa and sugar beets require an even higher pH) and required lime. The acid soils occur on the lowlands.

A characteristic diagnostic property of almost all the soils during the dry season of the year is cracking. Cracks may be small to very large (e.g. in the Vertisols). The clay content is largely composed of montmorillonites, which are swelling clays. These cracks contribute to large losses of water (and also fertilizer), which together and with the presence

of gravel in the soils make them even drier, especially on steep slopes.

Currently Grevena appears to be an area of low seismicity with few active faults (Savina 1993), although an earthquake in 1995 destroyed many buildings, including the hotel we stayed in during our 1989 field season (Wilkie, pers. comm.). Faults with probable Holocene movement bound the Karperon basin on the north, and there are deformed lake deposits near Katakali on the south, indicating that deformation took place after sediment deposition. They trend W-E to WSW-ENE and may still be actively subsiding (Savina 1993:61). Other faults with apparent Quaternary movement in the Sarakina-Palaiochorion area and southwest of Grevena trend ENE-WSW (Savina 1993:61). Grevena is slowly rising at a rate of about 40-45 cm/10³ year (Savina 1993).

1.2.3 Climate

Grevena has a Mediterranean climate characterised by winter rainfall and a long dry summer season (Trewartha 1990:8-9). However, inland Grevena, 140 km from the coast and at 40° N latitude, is near the northern limit of this climatic zone and is influenced by continental European climate, so winter temperatures are colder (snow falls at even the lowest elevations) and summer rainfall is generally greater than for more southerly or coastal Mediterranean climates (Walter *et al.* 1975:5; Sakellariou 1988:19).

In winter the weather system is controlled by the anticyclonic Eurasian high-pressure axis, the subtropical Azores high, and the frontal depressions of low pressure over the warm Mediterranean Sea (Biel 1944:5; Furlan 1977:216; Martyn 1992:127). There are regional highs over the northern Balkans and Serbia, and a centre of particularly low pressure occurs over the Adriatic. In winter the eastern Mediterranean becomes a principal region of cyclonic activity (Furlan 1977:192).

In summer the high pressure over the Balkans weakens, the Azores high moves westward, and the low-pressure centres over the Mediterranean are less pronounced. The main feature of the summer pressure pattern is a persistent heat low over Asia Minor. The transition to winter is abrupt and much more pronounced than the transition to summer conditions in April. In September east-bound disturbances start as the west-east gradient over the Mediterranean weakens, and high pressure is established over the cooling northern Balkans (Biel 1944:6-7). Depressions originate mainly over the central Adriatic and pass eastward, particularly in autumn. Though fairly weak, these lows are persistent (Martyn 1992:127).

The mountainous topography of northern Greece produces very different climates at different elevations (Walter *et al.* 1975:29, map 9), and there is a noticeable climatic difference between high- and lowlands in Grevena. Unfortunately climatic data for this part

of Greece are scanty and mostly from the lowlands: climatic data have been collected from two stations within Grevena Province, one near Grevena city and one at Kranea in the southwest, over the last 20 years, but only limited records are available. Doyle (1990) analysed data from the Grevena station for the period 1978-1987, and this information can be compared with longer-period records from two lowland stations outside the province: Bitola (Bitolj, Monastir) in the mountainous region of Yugoslavian Macedonia, and Trikala on the plains of northern Thessaly (Biel 1944); and one station at high elevation, Pertouli in the Pindos to the south of Grevena between Trikala and Ioanninon (Athanasiadis 1975). For these stations climate diagrams (Walter *et al.* 1975) are shown in Figure 1.3. The typical Mediterranean climate pattern of winter rainfall and summer drought is exhibited at Trikala, while at Bitola the summer drought season is less pronounced. Because of its elevation, Pertouli displays the Mediterranean winter rainfall regime to a very marked degree, and this pattern can be expected to occur at higher elevations in the Grevena Pindos also.

Biel (1944) and Espenshade (1990) provide upper-level wind data from two Balkan stations, Drama in eastern Macedonia and Bitola. The net drift at 3 km above the surface is consistent: directions are west to northwest in winter, west-southwest to west-northwest in spring, west to north in summer, and west-southwest to north-northwest in autumn. January high-level winds reach 3-4 on the Beaufort scale, but in July the strength is very weak, Beaufort 0-3.

Local wind direction and velocity at the ground surface may vary greatly due to the great differences in relief and the ruggedness of the mountains. Except at high elevations, surface winds in Grevena are usually light, but two characteristic southeast European winds which probably do occur are the dry summer northerly wind (*Etesian*), which starts its steady drift around mid May and lasts until mid September, although breaks particularly in July are not unusual; and a cold, gusty winter northerly similar to the *Vardarac* of the Vardar Valley to the northeast (Biel 1944).

Annual precipitation is high in the Pindos and may reach 2000 mm (Martyn 1992:131). Convective clouds in the mountains are responsible for increased precipitation there during the summer. In winter most precipitation falls as snow and continues to lie till early summer. Above 1000 m snow may lie from mid-December to early March, while above 2000 m continuous snow may lie till mid-May (Moody & Rackham pers. comm.; Polunin 1988:22). There is a high probability for the first snowfall to occur by mid-September (Furlan 1977: 210). Last snowfall is about late March in the lowlands, but April or even May in the highlands.

Figure 1.3 Climate diagrams for four Balkan stations

The form of the diagrams follows the convention established by Walter *et al* (1975). The abscissa represents the months from January to December, the warm season being in the centre of the diagram. Following the name of the station in the top left-hand corner is the height above sea level in metres; below this is the number of years of records. In the top right-hand corner is the mean annual temperature (°C), then mean annual precipitation (mm). The curves represent the mean monthly temperatures (scale on right, in °C), and mean monthly precipitation (scale on left, in mm). The dotted field indicates the relatively droughty season, and that with vertical lines the relatively humid season. As frost data is unavailable for some stations, this normal feature of Walter-diagrams is not shown.

The Pindos act as an effective barrier to the predominantly westerly rain-bearing depressions (Furlan 1977:191) and cause a pronounced rain shadow. Mean annual rainfall thus decreases from about 750-1000 mm in the foothills to under 500 mm in the east of the province. Grevena weather station received an average of 643 mm of rainfall annually (Doyle 1990). Maximum rainfall months were in autumn, November being the wettest month with 108 mm average rainfall. Minimum rainfalls occurred in summer, with July at 22 mm the driest. The variability of annual precipitation is likely to be about 15-20% (Espenshade 1990:12-15).

The mean annual temperature at the Grevena weather station during the 1978-1987 period was 12.7° C (Doyle 1990). January was the coldest month at 3.2° C, and July the warmest at 22.7° C. Doyle (1990) estimated an annual average of 40 days of ground frost. These figures appear to be typical of the mountain basins of inland Macedonia (*cf.* Furlan 1977; Martyn 1992). In winter there is commonly a temperature inversion: in January valleys and basins are 2-3° C colder than mountain slopes and peaks at the same height; the temperatures in basins occur on peaks 400-600 m higher (Furlan 1977:196). In summer the effect is less pronounced, and environmental lapse rates are higher. In general, the environmental lapse rate is 5.7° C per 1000 m (Savina 1993:60), but the highlands probably have a lower annual temperature range than is recorded in Grevena city, due to the cooling effects of prolonged snow lie and greater cloudiness.

Cloudiness is greatest in December and January and may be as high as 70-80% (Biel 1944). In summer to the east of the Pindos there is little cloudiness (probably <20%), which contributes to strong insolation. Doyle (1990) calculated mean monthly potential evaporation and soil moisture balance for the Grevena station, using the Thornthwaite & Mather 1957 formula. Low rainfall and high monthly potential evaporation in summer (with a peak of 110 mm in July) cause a high summer soil-moisture deficit. Cooler temperatures and high rainfall in autumn result in recharging of soil moisture in September and early October, and soil-moisture surplus occurs throughout late autumn, winter, and spring. Minimum monthly potential evaporation is a mere 8 mm in January, and there is a net moisture surplus of 25 mm annually.

1.2.4 Vegetation

The landscape of Grevena is intensively used and little if any unmodified vegetation remains. The current vegetation of Grevena is described in detail in Chapter 3. Only the main features are mentioned here.

There are two conspicuous features of the vegetation in Grevena; it varies according to elevation and moisture. The highest elevations are occupied by alpine meadows and pine

woods, the intermediate elevations by a mosaic of pine woods, beech woods, and mixed woods, and the drier rolling plains by deciduous oak woods and agricultural land. The west-to-east moisture gradient results in the western Pindos being much more moist and more vegetated than the eastern Vourinos Mountains. Woodland covers over half the entire land area.

Grevena differs greatly from southern Greece in both wild and cultivated plants. The province is very rich in flowering plants, but these tend not to be plants associated with Mediterranean climates characteristic of Greece, and even many 'sub-Mediterranean' plants associated with the fringes of the Mediterranean zone are rare or absent, winter conditions in Grevena being too harsh (Moody & Rackham, in prep.). In fact, Grevena flora has a Central European character, with a number of species not found elsewhere in Greece. Some are characteristic of the steppes of the northern Balkans, Hungary, and south Russia, and many species are at or near their southern limit.

Plant growing season is limited by cold winters and dry summers (Moody & Rackham 1988). The growth of most plants stops both in winter, as in Central Europe, and in summer, as in south Greece. The growing season is short – in most years only April, May and June. Even in mid May some of the more arid steppes begin to dry up (Moody & Rackham 1988). For some wild plants, there is a second growing season in autumn (Moody & Rackham, in prep.).

1.2.5 Recent land use

The entire landscape of Grevena is a resource base, there are no unproductive wastelands. The current land-use activities that have most impact on the landscape are agriculture, pastoralism, tree felling, burning, and settlements. These activities selectively favour some plant species over others, e.g. deciduous oaks invade abandoned land readily. They are resistant to browsing and have probably been encouraged at the expense of other trees.

Major landscape change has occurred this century due to the mechanization of agriculture, which has resulted in a reduction in cultivation in the Pindos Mountains and foothills, with a subsequent expansion of woodland and pasture. In the plains there has been a huge expansion of cultivation at the expense of oak wood and grassland. Today everything too steep to plough mechanically is pasture or woodland.

1.2.5.1 Agriculture

In Grevena arable land represents only 14% of total surface area (Sakellariou 1988:24). The current agricultural economy in Grevena is based mostly on a few cereal cash crops and is confined mostly to the central plains. The most important crop is wheat (*Triticum*), then barley (*Hordeum*), and to a lesser extent rye (*Secale cereale*) (Figure 1.4). Rye is usually planted in fields with poor fertility or on the edges of wheat fields (Aschenbrenner 1988). A small amount of maize (*Zea mays*) is grown.

Vines (*Vitis*) are grown mostly for household use only. Other minor crops include tobacco (*Nicotiana tabacum*); alfalfa (*Medicago sativa* subsp. *sativa*); sunflowers (*Helianthus annuus*); soybeans (*Glycine max*); chickpeas (*Cicer arietinum*); melons (*Cucumis melo*); nut trees, e.g. almond (*Prunus dulcis*) and walnut (*Juglans regia*); and garden crops such as sugar beets (*Beta vulgaris*) and various brassicas (Brassicaceae). Walnut is the most important cultivated tree. Its cultivation, however, is somewhat precarious, as it may be damaged by frost. Almond is common and often planted as hedges (Moody & Rackham, in prep.). Sunflowers and tobacco are very recent introductions. Tobacco is grown widely but requires irrigation in the northeast of the province. Irrigation is also used to grow grass for fodder hay.

Modern mechanized wheat/barley cultivation involves once-a-year ploughing in autumn when the soils are moist and soft, followed by seeding. Seeds remain in the soil over the winter and germinate in the warmth of spring. The growing season lasts only a few months in spring and summer, and harvest is July-August. Between harvest and late September-early October stubble covers the fields prior to being burnt after the first autumn rain, just before ploughing (Figure 1.5). Agricultural soils lay bare during autumn and winter (Aschenbrenner, in prep.).

By the 1960s mechanized agricultural practices had replaced manual practices. In the plains great new fields were levelled with bulldozers from about 1973 to 1985, obliterating most of the traditional small fields (Aschenbrenner, in prep.; Moody & Rackham, in prep.). Today, the foothills still retain most of the old pattern of small fields, lanes, hedges, and isolated trees in fields. In some places these survive in use, but on steeper land they have been turned into pasture or woodland. In the mountains almost all previously cultivated land has become pasture or woodland.

Before mechanization manual subsistence agriculture was practised. Numerous relatively steep slopes were cultivated, including many areas above 1000 m in the Pindos with very thin soils. Some of these fields were ploughed in autumn, others in early spring. Pre-mechanized agriculture required the use of draught animals, which required fodder (crops and woodland). Both rye and wheat are known to have been much more extensively

Figure 1.4 Cereal cropping. A field of barley stubble near Asprokamos on the central plains.

Figure 1.5 Burning stubble. Wheat stubble being set alight adjacent to the pollen analysis site at Kellia near Grevena city. Stubble burning was introduced after mechanized agriculture was introduced mainly to prevent machinery getting clogged.

grown in historic times, in the foothills and even in the mountains (Leake 1835). Vines (*Vitis*) were extensively grown, e.g. around Spilaion.

For this study it is appropriate to look at pre-1940 agricultural systems, that is, before tractor-powered cultivation was employed and fertilizers were used. Prior to 1940, with the exception of the introduction of the iron mould-board plough in 1917, it is thought that there were few changes in the agricultural system for several centuries (*cf.* the archaeological remains at Nea Nikomedeia dated c. 5600 BC (van Zeist & Bottema 1971; Rodden 1972; Theocharis 1973:43)). Most of the following data come from enquiries of informants (Aschenbrenner 1988 & in prep.).

The pre-mechanized agricultural economy was fundamentally a peasant subsistence type, for most households had insufficient land holdings to produce any significant surplus. Agriculture and pastoralism were integrated systems, even the transhumant communities of the Pindos Mountains practised a small amount of agriculture. In general each household grew a diversity of crops for human consumption (wheat; barley, probably mainly for livestock; maize; rye; beans; chickpeas; vegetables; fruits; nuts; and vine for table grapes, wine, and tsipouro). As well, a household grew crops for fodder (barley, oats, and several legume varieties, esp. vetch, pea hay, and alfalfa). Household livestock included oxen, cows, horses, mules, donkeys, pigs, chickens, and either goats or sheep or both. Animals served for draught and transport as well as providing food, e.g. meat, milk, cheese, and fat (Aschenbrenner 1988). A minimum complement of household livestock would include: one or two oxen, one donkey or horse or mule, one to two pigs, ten chickens, and 15-20 goats/sheep (Aschenbrenner, in prep.). Some households had a secondary occupation of commercial transport and kept mules (since they take less specialized feed). The size of a household's goat/sheep flock depended on personnel to herd them, available grazing areas, and cooperative arrangements with others for herding. In Milea and in Agios Georgios many also kept a cow, with which to produce calves and thus oxen, or animals to sell. Asia Minor refugees tended more often to keep cows, even for milk to drink, while indigenous Greeks tended to keep small herds of sheep/goats (Aschenbrenner 1988).

The cereal crops of wheat, barley, oats, and rye were rotated with either maize or a legume. The choice of rotation crop was based on considerations such as total cultivated area of a household, its need for bread and other cereal-based food, the needs of its draught animals, and the quality of its cultivatable land. Some households had difficulty meeting these needs and at the same time following the above rotation system. Two modes of compromise used were: either maize and rye were used instead of wheat, or the main group of cereal crops were rotated among themselves; but the same cereal crops were never planted in the same field in successive years. The latter was recognized as less desirable

but was forced on people by poverty (Aschenbrenner 1988). Rotation was sometimes organized on a village-wide basis, e.g. at Agios Georgios, so that vast tracts of fields would be sown in cereals and another large tract in legumes. This allowed animals to more freely graze over cereal stubble without risk of their getting into a still unharvested legume field (Aschenbrenner 1988).

Fallowing was seldom practised because most households had so little land. When practice regularly it was by the few with large holdings, and then only fields of poor fertility were fallowed. Deliberate soil-fertility improvement other than crop rotation and fallowing was achieved by adding manure. This was done in two ways, either by grazing live stock (in herds or staked individually) in the stubble fields or by collecting manure from stables, yards, or sheep/goat pens and distributing it over the fields. This was done to fields with the poorest fertility. Reports vary as to how extensively or regularly this was done (Aschenbrenner 1988).

The introduction of the iron mould-board plough, which turned soil over, meant a dramatic increase in production. Prior to this the wooden, usually iron-tipped, scratch or ard plough was used. Ploughing of the predominantly clay-rich soils of the plains would have been difficult if not impossible. Ploughing of the higher-altitude soils would have been easier. By far the most common draught animal for ploughing was the ox, but a few used the horse. After 1923, refugee villages used water buffalo. Ploughing with draught animals tended to follow contours of the land. Hand-reaping left only short stubble, and the straw was taken to the threshing floor as part of grain sheaves. Only occasionally did a farmer prepare for ploughing by raking the corn stalk stubble into a heap to burn (Aschenbrenner 1988).

Grevena has a range of weeds of cereals. Weed seeds were discarded when crop seeds were selected. During the growing season a farmer would do as much weeding as time permitted, and many farmers said they could not do as much as they thought was necessary. Some weeds were fed to livestock (Aschenbrenner 1988).

Irrigable areas were scarce and small and hence devoted mainly to vegetable gardens. These plots were close to springs and streams. At Spilaion there are numerous springs, all with associated irrigated plots. These were up to 7 km from the village (Aschenbrenner 1988).

Average yields were 100 kg/str (1 stremma = 1000 m²) for wheat with a ratio of seed to yield 1:3, but not infrequently yields only equalled the seed planted (Aschenbrenner 1987). At minimum a household needed to have about 32 str allocated to production in the following manner: wheat 15 str; rye 2 str; maize 4 str; legumes/yoke oxen 6 str; oats/ horse or mule 2 str; vegetable garden 1 str; vineyard 2 str (Aschenbrenner 1988). In addition to

the 32 str cultivated in various crops, a subsistence household required access to pasture and woodland, as a source of winter fodder and fuel (Aschenbrenner 1988).

A typical arrangement of fields would be a zone near the settlement in which each household had its vineyard. These fields often had fruit and nut trees surrounding them (Aschenbrenner, in prep.). Beyond this were grain fields with scattered large oak or pear trees. They were edged by a row of fruit or nut trees or a strip of scrub oak. The best fields were on stream terraces, where irrigated vegetable gardens were located. Most fields were within an hour's distance by foot from the settlement (Aschenbrenner 1988).

At Sindendron on the plains, where an unusually large amount of erosion has occurred, fields were most often cultivated ridge tops and segments of the gentler slopes. A few springs permitted irrigated gardens (Aschenbrenner 1988). At Spilaion in the Pindos foothills, where relief is greater, cultivated land included valley-bottom terraces (some irrigated), gentler slopes west of the village, and numerous isolated patches set on south-facing slopes in pine woods. Numerous springs were used for small irrigated gardens and bean fields. The distance to both grain fields and gardens was up to 2½ hours by foot. Nut and fruit trees, e.g. cherry and apple, were often planted on steeper slopes. Spilaion devoted such a relatively great proportion of its cultivated land to vineyards that wine could be exported to cover the deficiency in grain production. Many families had a second, fully-equipped house in which they lived permanently near distant cultivations.

During the twentieth century prior to mechanization, there was episodic widespread land clearance either to expand fields or open new fields. This type of abrupt widespread clearance may provide a model close to earlier land clearance, rather than the gradual pattern often suggested. In 1908 in the Lipsokouki Valley an area of oak wood and pasture changed hands and was subsequently quickly converted into cultivation fields. In 1924 when ethnic Turkish families returned to Turkey and Greek refugees came to Grevena from Turkey, land was allocated to the refugees, who set about fully exploiting and expanding their newly gained property. At Agios Georgios uncultivated areas were cleared by state work teams and added to the redistributed land (Aschenbrenner, in prep.).

1.2.5.2 Pastoralism and agro-pastoralism

The pastoral economy in Grevena is based on the herding of sheep and goats. Koster (1987) identified eight different zones of pastoral exploitation based on degree of dependence on transhumance or 'village pastoralism', ethnicity, vegetation types, and stocking rates. The two extremes in the system are the "Vlachohoria" in the Pindos, which are strictly transhumant, practice virtually no agriculture, use pastures seasonally, have moderate to high stocking rates and are ethnically Vlach; and the lowland agricultural areas,

which are grazed by year-round 'village pastoralists', who practice intensive cereal cultivation, have high stocking rates, and are ethnically Kapatshar and/or Pindi. The following data on pastoralism and agro-pastoralism are taken from Koster (1987).

Almost the entire area is accessible to sheep and goats, and flocks are usually shepherded. Grazing restrictions are sometimes put in place by various authorities who administer public land, e.g. the parish council and the Forest Service. However, restrictions are not always adhered to. In parts of the Pindos National Park grazing is prohibited, but evidence of grazing is as great there as in areas where grazing is permitted. In much of the Pindos the Forest Service tries to confine grazing to designated areas by building huts and digging waterholes. A deterrent for grazing some areas of the Pindos is the presence of bears and wolves, which are legally protected; sheep and goats are rounded up into protective corrals at night, and large dogs are kept to protect the flocks.

The Grevena region is well known for the practice of transhumance, long-distance seasonal flock movement of small stock to and from winter and summer pastures (Figure 1.6). The mountain villages of Samarina, Perivolion, Avdella, and Smixi in the Pindos are some of the largest transhumance villages in Greece and are famous for their large flocks of sheep. They are also among the highest villages in Greece. The pastures around these villages are used exclusively in summer, May-October. However, in 1986 flock figures, though incomplete, suggested that less than 50% of the sheep in Grevena belonged to long-distance transhumant flocks as opposed to local forms of village pastoralism.

Village pastoralists are herders who are socially oriented toward a village throughout the year. They tend to have smaller flocks than the transhumant. In many of the more agricultural villages of Grevena, numbers of goats and sheep seem to be declining; a decline in village flocks by 20% of the total regional herd has been noted. In 1929 agricultural census figures for Grevena show a total of 140,646 small stock; in 1961, 184,725; in 1971 there was little change; but in 1986 there was a decline of over 40,000, which brought the number of stock close to the 1929 figure again. This decline is almost entirely in village pastoralists and may be a response to a decline in available grazing land due to an increase in cultivated land, but there are also areas where both grazing and cultivation are declining. There is, however, an increase in villages in the south and east of the province.

In contrast, in the Vlachohoria small-stock numbers have stabilized over the past two decades: although there are fewer flocks, they are larger. In the highlands the average working flock today is about 425 animals, and there are about 200 families practising transhumance from the four Vlach villages. There were an estimated 420 families in 1967. Shepherds tend to return to the same milking and folding areas. Often two distinct grazing areas are used. The best pasture is reserved for milking ewes, while non-milking animals

Figure 1.6 Transhumance pastoralism. A flock of sheep and goats grazing in the Pindos near Perivolion.

Figure 1.7 Transhumant transportation. Flocks being transported by truck, the usual mode of transport these days, from summer pastures in the Pindos to winter coastal pastures outside Grevena, probably in either Thessaly or Central Macedonia.

graze among snowfields just below peaks, sometimes above 2400 meters. Flock territories are apparently not closely defended and are entirely informal, so that herders can adjust flock distribution to pasture condition. If pasture is poor, as noted for 1987 due to an unusually hot dry summer, flocks may leave the summer pastures early. Most herders keep some pack animals, as they graze their flocks up to as much as 7 hours travelling distance from their village.

The majority of transhumant flocks in the mountains are sheep, although there are also large goat flocks, and a small proportion of goats are kept with most sheep flocks. There are also 1800 head of cattle in the Vlachohoria. Before mechanized agriculture was introduced and more pasture existed in the lowlands, flocks would be transported on foot between summer and winter pastures, taking circuitous routes and grazing on stubble or natural pasture during the journey. Today they are usually trucked (Figure 1.7).

At lower altitudes in northern Pindos pastoralism is based primarily on seasonal summer pasture and mostly transhumance, but more villagers and flocks over-winter in the villages than in the Vlachohoria. Like the Vlachohoria there is a preference for sheep (except at Prosvorron, where there are large goat flocks). Currently there is very little agriculture (mostly irrigable), but subsistence cereal agriculture was practiced in the past. There are high stocking rates in this zone. Oak trees grow in this area and are shredded (see below) to provide either fresh forage or winter fodder. The same structures are built in this area as in the Vlachohoria, with the addition of well constructed winter folds and storage facilities for winter fodder. Ethnically this area is Kupatshar.

On the Pindos foothills there is a shift to a dominance of year-round village pastoralism. Most villages have transhumant flocks, but the majority of flocks over-winter in the village. Subsistence agriculture is integrated with herding. Both sheep and goats are herded, and stocking rates are low to moderate but were higher in the past. This area has the same structures as the area above. Ethnically this area is Kupatshar, but has some Pondi.

In the central agricultural villages where cereal cultivation is dominant, village pastoralism is year-round with no transhumance. Herding is an integral part of the production system. Although there has been a decline in stock numbers, stocking rates are high to moderate, with a preference for sheep. This area has undergone great changes since the introduction of mechanized agriculture. With the formation of large fields, which are planted continuously in cereals, much previously available grazing land has disappeared. In mid-summer herds graze on cereal stubble until it is burnt ready for ploughing. In winter they are taken into folds and fed alfalfa, straw, grain and, oak leaves. During the two periods between winter folding and cereal-stubble grazing, flocks are now forced to graze

on reduced areas of pasture. Ethnically this area is Pondi today, but in the recent past was Valakhades and Kupatshar.

North of the central villages, in deeply eroded hill country, village pastoralism is dominant, but there is some transhumance. Herding is well integrated with cultivation, which involves about 1/3 of the land surface. Stocking rates are moderate to low, with equal numbers of sheep and goats, except at Sindendron and Kirakali, where goats are dominant. The same structures that are associated with rear-round village pastoralism are found here. Ethnically this area is Valakhades, Kupatshar, and Pondi.

Village pastoralism is practised on the slopes of the Vourinos Mountains. Cereal cultivation is widespread. Stocking rates are some of the lowest in the province, with usually roughly equal sheep and goats, except in Palaiochorion and Chromion, where there are more goats, and Exarchos, Piloroi, and Pondini, where there are more sheep. A current practice is to graze in the Vourinos until winter and then descend to winter folds, where fodder of alfalfa, oak leaves, straw, and barley is supplied. The ethnicity of this area is unknown.

East of the central agricultural area along the Aliakmon River much of the surface area is thickly forested with deciduous oaks, and agriculture is limited. Village pastoralism is practiced, and there are few transhumants. Stocking rates are usually low to moderate with strong preference for goats. Winter folds are usual. Ethnicity is unknown.

The southern border of the province, except the Pindos, provides winter pasturage for many transhumant flocks belonging to the province. There are also many local village pastoral flocks. Large grazing areas are available, as well as stubble from well-developed agriculture. Stocking rates are moderate to high, with a dominance of sheep.

1.2.5.3 Woodland management

Grevena has very extensive woodlands for the size of its population. All woodlands have a history of management, which includes tree-felling, coppicing, pollarding, shredding and grazing. Pines are felled but not usually coppiced, pollarded, or shredded, while beech and oak and less dominant woodland trees may be felled, coppiced, pollarded, or less often shredded. Trees in woods are usually coppiced; free-standing oaks in pastures or fields are pollarded.

Timber production was well established 180 years ago (Leake 1835). In the past the main export of high-altitude villages such as Smixi and Samarina was milled pine planks (Figure 1.8). Beech and oak are also felled for timber – many local houses and out-buildings contain beams of oak. Today planks are produced for local use and for export. A recently established industry is that of particleboard manufacture (Figure 1.9). Wood

Figure 1.8 Pine felling. Pine logs on the side of the road in the Pindos Mountains between Zakas and Perivolion.

Figure 1.9 Beech felling. Beech billets for firewood or particleboard manufacture stacked beside the road between Avdella and Smixi in the Pindos.

cutting has been nominally controlled by law since the late 1930's, but this law was not enforced until 1955; now there is more careful control (Aschenbrenner, in prep.). Chainsaws appeared in 1965, and widespread cutting of larger trees commenced in the late 1970's.

Coppicing, pollarding, and shredding are all ways of increasing the number of stems per tree. In coppice-woods, the majority of trees are cut down every so many years then allowed to sprout again from the stump, while scattered timber trees are allowed to grow longer to produce beams and planks. Pollards are cut like coppice stools but at 4 m above ground, while shredding is the removal of side branches so that successive crops of stems are produced (Figure 1.10). Stems are used mostly for winter fodder and fuel.

Coppicing has been widespread for many centuries, e.g. *Tilia* (lime) stools in the Aetia gorge measure 2½ m diameter, and at Anelia annual rings indicate that a beech stool was about 300 years old when last cut about 20 years ago. The practice still continues but on a diminished scale (Moody & Rackham, in prep.). The coppicing methods used in Grevena are unusual in that the interval between cutting is unusually long (between 30 and 75 years), woods have no fixed boundaries but adjoin grassland or fields with no intervening earthwork, timber trees are sometimes left in groups (not scattered among the underwood), and animals are sometimes allowed to browse the young shoots for a time. Coppice is used for many purposes but usually for fuel.

Pollarding and shredding are both commonly used to provide leaf fodder. Leaf fodder production is a major industry (Figure 1.11). All oak species are so treated, but perhaps most frequently *Quercus brachyphylla*. Pollarding has been practiced for many centuries: in Aetia the stump of an oak was found that was first pollarded in 1556 AD (from annual tree-ring count). Pollarding and shredding has occurred at very irregular intervals, from 4 to 75 years, with no apparent pattern. Almost all oaks have been cut or pollarded within the last 50 years (Moody & Rackham, in prep.).

1.2.5.4 Burning

The natural vegetation of Grevena, except bracken (*Pteridium*) and juniper (*Juniperus*), is not very flammable. Many large pine trees have large lightning-strike scars but have not burnt. Steppe burns occasionally and this could limit trees by setting back juniper, which would protect young trees from browsing.

Since mechanized cultivation was introduced cereal stubble has been burnt (Figure 1.5). Although controlled by regulations these fires often spread into oak wood or steppe. The fires are lit when much of the vegetation is dormant, during summer drought, but plants

Figure 1.10 Pollarded oaks. Pollarded oaks, scattered in pasture near Mavranaioi, are cut about 4 m above ground level so that livestock cannot reach regrowth.

Figure 1.11 Leaf fodder. Oak leaves provide much of the winter food supply for stabled animals.

that have an autumn growing season would be expected to be set back. Fire frequency has thus increased on the plain, but this does not seem to have changed the vegetation much, apart from the disappearance of the fire-sensitive juniper.

Burning natural communities to increase pasture is mentioned in the literature (Turrill 1929:210). I have not seen this done, but patches of *Pteridium* growing in pasture in the Pindos is indicative of this.

1.2.5.5 Habitations and communication systems

Today Grevena is one of the most sparsely populated areas of Greece. Grevena city, as the capital of the province, has become the commercial and manufacturing as well as administrative centre: its population in 1971 was 35,385 (Stevenson 1977:462). There are now approximately 100 modern villages and two cities in the province. Most of the population outside Grevena city is concentrated in the plains and rolling country to the west of the Aliakmon. Those engaged in agriculture tend to reside in villages rather than hamlets or isolated houses. There are relatively few villages in the mountains – in the Pindos because of the extreme winter conditions villages are occupied only during the summer. The relatively dry climate in the Vourinos limits agriculture and pastoralism.

Before World War II the structure of relations between settlements, their relative size, and their locations were different. Before the war Grevena city settlement was merely one of several small market towns hosting weekly markets and annual animal fairs: the relatively prosperous farming in the plains today has developed over the last 40 years. Farmers lived more often in hamlets and isolated houses than in villages as they do today. The principal structures associated with pre-mechanized farming have been described above.

The economy of the province was based on commerce in animal and timber products rather than those of local agriculture. Traditionally people in the Grevena region made their living by trade, especially in wool, the raising of sheep and goats, and cutting timber (Wilkie 1987). Settlements in the plains conducted their trade mostly on a local basis. Pindos villages, which were involved in long-distance trade, appear to have been more prosperous than those in the lowlands, and there were more and larger villages in the foothills and mountains than in the plains (Clark, M. 1988; Moody & Rackham, in prep.).

There has been considerable instability of settlement in the lowlands over the last few hundred years. Settlements have formed and been abandoned. In recent times many villages have coalesced to form one new village closer to main roads. In the eighteenth and nineteenth century frequently the reverse was true as villages tried to avoid Turkish tax collectors.

There is relatively easy access into Grevena basin, allowing much movement through this area. In historical times that movement has taken the form of trade, transhumant herding, migration, brigandage, and war (Clark, M. 1988). Many of the trading routes were along the edges of rivers and streams. The former trading passes over the Pindos have been retained as roadways, e.g. from Samarina to Fourka (the most northern pass), Smixi to Distraton (past Vasilitsa), through Avdella and Perivolion to Vovoussa, and in the south from Kranea to Metsovon (Koster 1987:25). In 1912, Wace and Thompson (1972) traced the transhumant route from the coastal plains through Dasochorion to the Pindos Mountains. There are also several easy passes through the Chasia Mountains, at Velemishti as well as at Kutsophilani (Koster 1987:25).

The Greek Military Staff map of Grevena in 1929 shows cobbled roads in the lowlands (Clark, M. 1988). These radiated from larger villages such as Agios Georgios and Kivotos. The cobbled roads radiating out from Agios Georgios, Kivotos, and Amigdaleai also connected those villages. Roads also ran from Grevena to Kirakali and to Elatos and connected certain villages such as Mirsina and Asprokampos. There was a main road between Kalambaka and Kozani.

1.3 Prehistory & history

Most of the following information is taken from the Grevena Project surface survey (Savina 1995; Wilkie 1995). The prehistoric cultural period represented by the largest number of archaeological sites is the Hellenistic period, next is the Early Iron Age. In historic times the Roman and Ottoman Periods are represented by many more sites than the Byzantine Period. Figure 1.2 indicates the periods of densest occupation based on abundance of archaeological sites.

Archaeological sites containing Late Bronze Age sherds are not numerous, less than 10. Some of the sites are typical citadels and capable of being fortified and controlling large areas of agricultural land.

The Early Iron Age seems to have been a period in which occupation of the region increased dramatically. Over 30 sites have been identified as definitely containing Early Iron Age material, and another 20 as possibly containing Early Iron Age material. Early Iron Age sites extend from the lowlands to elevations near 1000 m asl. Often these sites are on commanding promontories; some are probably quite large. At a number of sites archaeological material is common in the colluvium on the steep slopes (Wilkie 1988).

After the Iron Age there seems to have been a reduction in occupation. Only a few sites belonging to the Archaic and Classical Periods have been found: less than 40 from both periods. Both periods are represented mostly in the lowlands by settlement sites.

These are mostly in the central plains and in the southeast of the province. There are a few fortified sites in the Pindos foothills.

In the Hellenistic Period the number and size (up to 10 hectares) of sites increases greatly: over 50 sites are definitely identified as representing this period, from the form of architecture and numerous sherds. Many Hellenistic sites are fortifications in the Pindos foothills, close to the upper elevation limit of permanent, year-round occupation. These sites are generally at elevations of approximately 1000 m (but not higher). There are also many sites of this period in the central part of the province – a number of quite large sites are scattered more or less evenly over the lowlands. Pottery was made locally. Loomweights are found for the first time, and in abundance. Sheep or goat bone and wheat/barley seeds have been found in association with Hellenistic sites. Parts of Grevena with few Hellenistic sites include areas above 1000 m in the Pindos and much of the eastern side of the province.

Archaeological sites dating to the Roman Period are more widespread than those of earlier periods. Romans occupied many places that have little record of Pre-Roman settlement, e.g. the northern part of Grevena, the Ventzia (between the Aliakmon River and Vourinos Mountains), and the south-central part of the province. Over 150 sites have been identified as belonging to this period, but the period spans a much longer time interval than the previous periods. There are more sites belonging to Early and Middle Roman times than to Late Roman times. North and northwest Grevena seem to have been virtually abandoned during Late Roman times, leaving only a few fortified outposts in the northwest and west. Most sites over 800 m in elevation were abandoned in the Late Roman Period. Roman settlements tend to be grouped, but do not exhibit a systematic hierarchical pattern. Road-building was introduced during this period. There was a substantial local ceramic industry, and wine was made locally (Savina 1995).

The Medieval and Byzantine Periods are represented by 80 to 90 sites. During the Early Medieval Period there are more than 40 certain and about 15 possible sites in Grevena, the same order of magnitude as the number of Late Roman sites. Slavic pottery has been recognized at only 3 sites. The areas that Late Roman sites occupied, that is, central Grevena, the Ventzia, and south-central Grevena, continued to be occupied, the Karperon basin was abandoned, but there was renewed settlement in the Deskati-Dasochorion basin, and in the north and northwest. There are only a few Early Medieval sites at 1000 m or higher. Early Medieval sites tend to be widely spaced. About five Early Medieval sites were fortifiable, but at only one is it clear that the fortifications date from the Early Medieval Period or the following Medieval Byzantine Period. Some of the church crypts and mosaics in Grevena may date to the Early Medieval, or may be even

older. A local ceramic industry existed, but production was reduced. The economy of Early Medieval times may have been based on agriculture and pastoralism: most of the lower elevation sites are in places suitable for agriculture. They are near a water source but not on main thoroughfares. The occupation of sites in the Pindos Mountains at about 1000 m elevation resembles the distribution of modern transhumant villages.

Compared to the number of Late Roman and Early Medieval sites, there are relatively few Medieval Byzantine sites in Grevena. There are 12 sites with definite Medieval Byzantine material. Of the five sites with many sherds of the period, all are in the central part of the province or the Ventzia. The two major sites in the drier Ventzia are associated with high-discharge springs. There are no fortified sites of this period in Grevena.

The Late Byzantine is represented by only 3 confirmed sites. The oldest standing church in Grevena (Agios Nikolaos near Perivolion, in the Pindos) was built in 1303 AD.

Grevena came under Ottoman control in about 1360. In contrast to the lack of settlement during the Byzantine Period, there are about 90 archaeologically recognizable Ottoman Period settlements distributed throughout the province, including central and south-central Grevena, the Ventzia, the Karperon basin, Dasochorion-Deskati basins, and the Pindos foothills. There are relatively few sites in the north. Some villages were highly specialized, e.g. Filippaioi was a community of technicians, including gunsmiths; Tziani had jewellery makers; and Ventzia, around Knidi, had charcoal making. Many villages had one or more grain storehouses. The agricultural areas were divided into large estates. Transhumant pastoralism was practised in the Pindos mountains and foothills. An extensive road and bridge network was built during the Ottoman Period. Lodges were built along these roads. There are also mill sites on several rivers.

Many Christian churches in Grevena date to the Ottoman period. A church at Spilaion, built in 1633 AD, is well known because it was attached to a famous monastery. It was decorated with frescoes between 1640 and 1658 AD (Kokkini 1976:48, in Savina 1995). According to local tradition, the monastery was very wealthy and had extensive estates.

At the end of Turkish rule, the former economic and cultural ties Grevena had with the continental hinterland weakened, and ties with the Greek peninsula and the Mediterranean strengthened. Turkish immigrants were transported back to Turkey and Greek refugee families living in Turkey were resettled in Grevena.

Between 1941 and 1950 Grevena suffered the effects of two wars, World War II and the Greek Civil War. Villages in Grevena, particularly in the Pindos, were bombed, and many people left the province. Fewer people have returned to the Pindos than the lowland

villages and many of the houses in the Pindos today are used as only summer holiday homes. Today Grevena belongs to the parliamentary republic of Greece.

1.4 Summary of late Holocene pollen studies on mainland Greece

No late-Holocene pollen sequences have been studied previously in Grevena, but a number of studies have been undertaken elsewhere in mainland Greece, in areas with contrasting ecological conditions, current vegetation, and land-use history. In pollen diagrams that span the last few thousand years human activity appears to be a major factor influencing changes in the vegetation. The following account summarises the evidence presented by various researchers. Sites are presented more or less in chronological order of first examination. Figure 1.12 shows the location and elevation of the pollen-analysed sites; the site numbers are also given in the text below.

Van der Hammen *et al.* (1965) published the first late-Holocene pollen diagram from mainland Greece, from the **Tenaghi Philippon** marsh [4] on the Plain of Drama. Three pollen samples taken from above a level radiocarbon dated at 7850 ± 50 BP (Wijmstra 1969) showed a dense forest dominated by *Quercus* and *Pinus*, but *Tilia*, *Ulmus*, *Carpinus*, and *Alnus* also occurred.

Wijmstra (1969) published a more detailed diagram from Tenaghi Philippon marsh. The base of the uppermost zone is placed where *Quercus* begins to rise after an *Artemisia*-*Chenopodiaceae* zone, just below a radiocarbon date of 7850 ± 50 BP. By extrapolation the upper two subzones (Z4-Z5) are assigned to the last 5000 years. They are characterised by an open *Quercus ilex/coccifera*-*Pistacia-Juniperus* forest with *Corylus* and *Ostrya*. The forest became increasingly open, with the lower subzone being characterised by an increase in *Fagus* and *Ericaceae*, while the upper subzone is defined by increasing values of *Pistacia* and non-arboreal pollen and the presence of *Rhus* and *Arbutus unedo*.

Greig & Turner (1974) and Turner & Greig (1975) recored the Tenaghi Philippon marsh and analysed two overlapping cores from the most recently formed peat. A total of six radiocarbon dates were obtained, the oldest being 7556 ± 85 BP and the most recent 2867 ± 60 BP at 75 cm depth. Both pollen diagrams showed similar changes in pollen frequencies, and a local zonation scheme was applied to the diagrams. Six pollen-assemblage subzones were recognized spanning the Early Neolithic to Classical Periods. At the base of the sequence, between 6500 and 2500 BC, is a *Quercus-Tilia* pollen assemblage; this changed to a *Quercus-Tilia-Fagus-Ericaceae* assemblage between 2500 and 1900 BC. Evidence of human disturbance begins in the *Quercus-Olea*-herbaceous zone between 1900-1360 BC, when there was a decline in *Ulmus* and *Tilia*. Dates for the 3 zones above this are extrapolated; these change from a zone with increased weedy species

Figure 1.12 Location of Holocene pollen analysis sites, with altitudes (where known).

1 Rhodopi 1520 m (Athanasiadis *et al* 1993); 2 Lailias 1420 m (Gerasimidis 1985); 3 Gravouna c.0 m (Turner & Greig 1975); 4 Tenaghi Philippon 40 m (Van der Hammen *et al* 1965; Wijmstra 1969; Greig & Turner 1974; Turner & Greig 1975); 5 Strimon c.0 m (Atherden 1989); 6 Volvi c.100 m (Bottema 1981, 1982); 7 Voras 1640 m (Athanasiadis & Gerasimidis 1986); 8 Giannitsa c.10 m (Bottema 1974, 1975); 9 Edessa 350 m (Bottema 1974, 1975); 10 Paikon 1080 m (Athanasiadis & Gerasimidis 1987); 11 Vegoritis 570 m (Bottema 1981, 1982; Bottema & Woldring 1990); 12 Khimaditis c.560 m (Bottema 1974, 1975); 13 Kastoria 650 m (Bottema 1974, 1975); 14 Pieria - Kokkini Brysi 1420 m & Flampoura 1650 m (Gerasimidis 1985); 15 Litochoro 25 m (Athanasiadis 1975); 16 Kellia 600 m (this study); 17 Gomara 1750 m (this study); 18 Anelia 1440 m (this study); 19 Rezina 1800 m (Willis 1989, 1992b, c, 1994); 20 Gramousti 285 m (Willis 1989, 1992a, c, 1994); 21 Ioannina 470 m (Bottema 1967, 1974, 1975); 22 Pertouli 1275 m (Athanasiadis 1975); 23 Vitiis c.50 m (Bottema 1979); 24 Halos c.0 m (Bottema 1988, 1990); 25 Korone 10 m (Yasuda 1985); 26 Xinias 500 m (Bottema 1978, 1979); 27 Voukaria c.0 m (Wright 1972); 28 Trikhonis 20 m (Bottema 1980, 1981, 1982, 1990; Bottema & Woldring 1990); 29 Kopais 95 m (Greig & Turner 1974; Turner & Greig 1975; Allen 1986, 1990); 30 Kleonai (Nemea) (Atherden *et al* 1993); 31 Lerna (Jahns 1990, 1993); 32 Kiladha Bay -10.2 m (Bottema 1990); 33 Port Kheli c.0 m (Sheehan 1979); 34 Thermisia c.0 m (Sheehan 1979); 35 Saktouri c.0 m (Sheehan 1979); 36 Lake Agoulinitza c.0 m (Gennett 1982); 37 Kaiafa c.0 m (Wright 1972); 38 Osmanaga -0.20 m (Wright 1972) & Navarino No.3 c.5 m (Kraft *et al* 1980; Gennett 1982); 39 Zileria 1.5 m (Reinders & Bottema 1983; Bottema 1994).

(*Quercus*-herbaceous) to one from 1000-550 BC characterised by small amounts of *Olea* (*Quercus*-*Olea*-herbaceous) to one of increased weedy species again. It is interesting that oak forest appears to remain dominant (although it decreases slightly) throughout the diagram when there is archaeological evidence indicating that this area was occupied in the Neolithic and later times (Renfrew, C. 1971). Unfortunately the authors were not able to distinguish between evergreen and deciduous oak pollen or to separate Cereales from other Gramineae due to poor pollen preservation. *Fagus* appears with a coinciding increase in Ericaceae between levels dated to 4193 ± 120 and 3722 ± 100 BP. An increase in *Fagus* is also characteristic of Wijnstra's subzones Z4 and Z5.

Bottema (1967) published a preliminary diagram from **Ioanninon [21]**, west of the Pindos Mountains. Four pollen zones were distinguished, but only the uppermost is relevant to this study, having a radiocarbon date near its base of 10200 ± 90 BP. *Quercus* (deciduous) played an important part in the forest cover of this zone, and in the second half *Ostrya/Carpinus orientalis* pollen type appears and becomes quite abundant. *Quercus ilex* appears and steadily increases soon afterwards. Bottema provides further details in a comprehensive pollen-analytical study of sites in northern Greece published in 1974 (see below).

Bottema (1974, 1975) analysed wetland sediment sequences from four basins in western Macedonia; **Edessa [9]**, **Khimaditis [12]** (cores I, III & IV), **Kastoria [13]**, and **Giannitsa [8]**; as well as re-examining the Ioanninon sequence (cores I & II) (Bottema 1967). Bottema established a series of zones based on characteristic tree pollen assemblages, reflecting the sequence of climatic changes and intensity of anthropogenic disturbance. The upper part of subzone Y2 and zone Z cover the late Holocene for the area northeast of the Pindos (Figure 1.2). The vegetation development in the Ioanninon area, farther south and to the west of the Pindos, differs in some aspects from the more northern area east of the Pindos. Subzone Y2 of the northeast area and zone Y (Bottema 1975, fig.3) of the southwest are contemporaneous and are both characterized by a sudden increase of *Carpinus orientalis/Ostrya*. During zone Y (subzone Y2) changes took place in the deciduous mixed oak forest. North of the Pindos some of the constituents of the mixed oak forest such as *Corylus*, *Tilia*, and *Ulmus* decreased in numbers, but *Quercus* does not decrease considerably. At higher elevations the situation did not change noticeably, as conifers maintained their position. *Fagus* was present in low numbers. The end of zone Y is difficult to date. At the northern sites radiocarbon dates of 4080 ± 55 BP (at Kastoria), 5260 ± 65 BP (at Edessa), and 3995 ± 60 BP (at Khimaditis I) were obtained. In the south, Ioanninon II gave a radiocarbon date of 4535 ± 40 BP.

Zone Z is divided into subzones in the northern area, based on rather local pollen assemblages, but not in the south. The main characteristic of subzone Z1 is the expansion of *Fagus* in the belt of the *Pinus* and *Abies* forests. The deciduous forest below the conifer belt expanded upwards, while *Abies* and *Pinus* moved to higher elevations. More to the interior, north of the Pindos this was less pronounced, particularly at higher elevations, where coniferous forest gave way gradually to *Quercus* forest and *Fagus*. Coincident with the increase of *Fagus* was an expansion of Ericaceae in the mountains in both the north and south areas. In the south conifers were not affected, but they played only a restricted role. At medium elevations, in the upper *Quercus* (deciduous) belt, *Corylus* and *Tilia* decreased in abundance.

In the north the Z1/Z2 boundary is based on the increase of *Juglans*, *Platanus* and *Castanea* and is dated at 3135 ± 70 BP in the Khimaditis III sequence and 3280 ± 55 BP in Edessa. *Juglans* and *Castanea* appeared for the first time, although in the south *Juglans* and *Castanea* did not appear until quite recently. Together with these trees, pollen of *Vitis*, cereal-type, *Xanthium*, *Centaurea solstitialis*-type, *Plantago*, and *Humulus/Cannabis* was found. The subzone Z2/Z3 boundary at Kastoria is dated 1095 ± 60 BP. The subzones Z3 and Z4 are based on the intensity of human disturbance, Z4 showing much greater disturbance. Farming decreased during Z3, as indicated by the lower abundances of weeds and cereal-type at Khimaditis I and Edessa.

Wright (1972) published pollen data from three sites on the west coast, **Osmanaga Lagoon [38]**, **Kaiafa Lagoon [37]** and **Lake Voulkaria [27]**. Two overlapping cores from Osmanaga Lagoon were analysed, with the base of the longer core being radiocarbon dated to 3940 ± 270 BP. All changes in this sequence are attributed to human activities. The two pollen sequences were divided into 3 zones. The lowest zone is dominated by *Pinus*, *Quercus*, and *Erica*-type. *Pinus* disappeared during the Middle Bronze Age or early in the Late Bronze Age, perhaps due to woodcutting. The middle zone is dominated by two peaks of *Olea* separated by a maximum of *Quercus* (probably evergreen); *Pistacia* pollen becomes common in this zone. A radiocarbon date of 3220 ± 120 BP at the beginning of the *Olea* rise and another of 2820 ± 100 BP at maximum frequency places widespread olive cultivation at 1100-700 BC. In the top zone *Quercus* is reduced and declines steadily. Another peak in *Olea* occurs at the base of this zone in one of the sequences and may have occurred during the first millennium after Christ. A later study from nearby was carried out by Kraft *et al.* (1980) – see Navarino Bay, below.

Two basal radiocarbon dates are provided by Wright (1972) for the pollen sequence from Kaiafa Lagoon, 1680 ± 100 and 1650 ± 100 BP. No zonation is provided, but there is a change in the dominant tree type midway up the sequence from *Quercus* at the base to

Pinus at the top. *Olea* and *Pistacia* are present throughout the sequence at low levels while *Phillyrea* comes and goes. The increase in *Pinus* may be due to pine plantations.

No pollen diagram was provided by Wright (1972) from Lake Voulkaria, but it is described as having high pollen values of *Quercus* (deciduous) and Gramineae, with rare *Olea* in the lower half of the 8 m core. The upper half is marked by a rise in *Olea* pollen, followed by a decrease. Pollen of *maquis* plants such as *Quercus* (evergreen), *Pistacia* and *Phillyrea* are more abundant than below while *Quercus* (deciduous) remains about the same, but *Pinus* declines. *Juglans* (walnut), *Castanea* (chestnut), and *Platanus* (plane tree) are continuously represented, whereas below they are absent. A basal radiocarbon date gives 10900 ± 300 BP and one just below the *Olea* rise is 3040 ± 120 BP.

Two pollen diagrams were published for a sediment core taken from **Lake Kopais [29]** in 1968 (Greig & Turner 1974; Turner & Greig 1975). This core was zoned in an independent, local scheme. One radiocarbon date of 5205 ± 120 BP dates a zone boundary at about 225 cm, where *Quercus* and total tree pollen frequencies decrease markedly and do not recover. The zone immediately above this date is characterised by low *Quercus* and high *Olea* pollen with herbaceous pollen. *Tilia* and *Ulmus* also disappear during this zone. In the zone above *Olea* disappears but then appears again in the next zone. Erosion may have increased during the periods represented by the two zones with *Olea* present. Forest clearance and grazing are thought to have begun before the level of the radiocarbon date.

A second long sediment core (core KA) was pollen analysed from Kopais Basin and published by Allen (1986, 1990). The upper part of the core has a radiocarbon date of 9900 ± 110 BP and is also dated by correlation with a nearby exposure with a basal date of 9970 ± 120 BP and two more recent dates of 4620 ± 150 BP and 3480 ± 150 BP. The pollen stratigraphy for core KA was found to closely resemble that previously found in the Kopais Basin. The postglacial record is dominated by *Quercus* until this declines after about 5000 BP. At a core depth of 3.9 m *Quercus* and Gramineae concentrations begin to decline, while *Ostrya/Carpinus* increases and Ericaceae appears. This level may correspond, assuming constant sedimentation rates, to the level in the Greig and Turner (1974) pollen sequence where a marked drop in *Quercus* pollen is noted. There are only 6 samples above this level, and the age of the top of the core is uncertain but may be about 2500 years BP. *Tilia* and *Fagus* are present in small amounts in these samples. In the top 3 pollen samples, above 3.2 m, *Olea* increases while *Quercus* continues declining. The source of the *Olea* pollen may be wild plants rather than cultivated, but the relatively high percentage suggests the possibility of cultivation. There is a coincident inwash of eroded topsoil from the catchment, identified by mineral magnetic analysis at 2 and 4 m. The onset of indications of human activity are thought to begin with the decline in *Quercus*.

Turner & Greig (1975) analysed lake sediments from **Gravouna [3]**, farther east from Tenaghi Philippon on the Plain of Drama. Two major pollen-assemblage zones were recognized, a *Quercus* zone at the base and a *Pinus*-Gramineae-herbaceous zone at the top, with a transitional zone. The lowest zone resembles the top of their Tenaghi Philippon diagram, with *Quercus* the major pollen type. At the top of the sequence *Quercus* frequency drops significantly and the pollen assemblage is dominated by grasses and other herbs indicative of a non-forested landscape, and cereal-type pollen increases. The rather long transitional zone indicates that the disappearance of the oak forest took place fairly slowly, in at least two stages, the oak at first being replaced by *Corylus* and later by grass. No radiocarbon dates were obtained for this core, but the major deforestation may belong to the Medieval Period. The forest did not recover.

Athanasiadis (1975) published a pollen diagram from the Pindos Mountains, **Pertouli [22]**, and another from near the east coast, **Litochoro [15]**. The sediment core from Pertouli was radiocarbon-dated at three levels, to 1290 ± 110 , 1899 ± 80 , and 1699 ± 80 BP (the lowest date is the youngest and is probably not reliable). The pollen diagram was divided into zones that correspond to those of Bottema (1974; Figure 1.2). Part of zone Y2 is represented and zone Z is divided into two subzones, Z1-3 and Z4. Zone Y2 is divided into two phases, a and b, which differ in their dominant arboreal pollen: there is a shift from an *Abies-Quercus* dominance to *Quercus-Corylus* dominance in phase b. Phases a and b are similar in other arboreal types represented, which include *Tilia*, *Ulmus*, *Ostrya-Carpinus orientalis*-type, *Carpinus betulus*, and *Corylus* in relatively high frequencies. *Pinus*, *Fraxinus*, *Alnus*, *Acer*, and *Salix* are present in small numbers, while *Castanea* and *Juglans* are present in phase b in very small numbers. High frequencies of non-arboreal pollen are characteristic of both subzones, mainly *Pteridium* and cereal-type, but also including Compositae, Cruciferae, *Rumex-Oxyria*, *Polygonum*, and Leguminosae. Subzone Z1-Z3 is characterised by dominant *Abies*, *Quercus*, and *Corylus* and an increase in the frequency of arboreal to non-arboreal pollen. *Fagus*, *Ulmus*, *Alnus*, and *Acer* increase slightly; *Carpinus betulus* and *Ostrya-Carpinus orientalis*-type decline slightly but are still quite abundant; while other arboreal pollen types remain about the same. *Pteridium* remains the dominant non-arboreal type, other herbs such as Cruciferae and Compositae increase slightly, while the frequency of cereal-type pollen declines but is still significant. Subzone Z4 is divided into three phases (d-f). The base of phase d is radiocarbon-dated to 1890 ± 80 BP. This phase is remarkable for its dramatic increases in *Fagus* and *Pteridium* and decline in *Corylus*. *Ostrya-Carpinus orientalis*-type increases, although *Abies* and *Quercus* are the dominant arboreal types. Herbaceous pollen of Cruciferae and Compositae increases. The boundary between phases d and e is radiocarbon dated to 1690 ± 80 BP.

Phase e is characterised by its richness in non-arboreal pollen, mostly Compositae and *Plantago*. Other herbaceous pollen types that increase include cereal-type, Liliaceae, Leguminosae, and *Sanguisorba-Poterium*-type. *Pteridium* declines dramatically. *Quercus* is the dominant arboreal type, but there is a significant increase in *Castanea* and an increase in *Alnus*. Phase f is characterised by increases in *Abies* and *Juniperus*. *Quercus* declines along with *Ostrya-Carpinus orientalis*-type. Herbaceous types decline and *Pteridium* becomes the non-arboreal dominant again.

Three radiocarbon dates are provided by Athanasiadis (1975) for the core from Litochoro: from lowest to highest 2400 ± 110 (base of core), 800 ± 100 , and 940 ± 100 BP. This diagram has also been divided into zones Y2 and Z1 to Z4 according to the Bottema (1974) scheme (Figure 1.2). In zone Y2 arboreal pollen is much more abundant than non-arboreal pollen: *Pinus*, *Quercus*, and *Alnus* all have high frequencies, and *Abies*, *Ostrya-Carpinus orientalis*-type, *Salix*, and *Corylus* are relatively abundant. *Vitis* has high frequency and *Pteridium* is also well represented and is the most abundant non-arboreal pollen. A variety of herbs is represented in small amounts, including Compositae and Chenopodiaceae. In subzone Z1 arboreal pollen continues to be much more abundant than non-arboreal pollen, with *Pinus*, *Alnus*, and *Quercus* dominant. *Pinus* increases in frequency, *Alnus* remains about the same, while *Quercus* declines. The frequencies of *Abies*, *Ostrya-Carpinus orientalis*-type, and *Salix* remain about the same, while *Corylus* increases and *Vitis* declines somewhat; herbaceous pollen is relatively unimportant. The importance of non-arboreal pollen increases in subzone Z2, dominated by *Pteridium*. A variety of other non-arboreal types is also well represented. *Salix* dramatically increases during this subzone. *Alnus* also increases, but much less dramatically, as does *Vitis*, which increases from the middle of this subzone; *Juglans* forms a continuous curve, and *Castanea* appears in very low values. Other arboreal types either remain at the same frequency or decline slowly, e.g. *Quercus*. *Alnus* becomes the dominant arboreal type in subzone Z3, while all other arboreal types decline except *Salix*, which increases slightly; *Juglans* and *Castanea* disappear. *Pteridium* almost disappears, and only aquatic non-arboreal pollen appears in significant numbers. The base of subzone Z4 is radiocarbon-dated to 940 ± 100 BP. This subzone is divided into three phases, e to g. Phase e is characterised by the increased importance of non-arboreal pollen, represented mostly by Cyperaceae and *Lythrum*. *Pinus* and *Alnus* are the two most important arboreal types: *Pinus* increases in importance towards the centre of this phase then declines, while *Alnus* does the reverse. Phase f is characterised by another major increase in *Salix* and a corresponding increase in *Alnus*. Other arboreal types decline except *Juglans* and *Castanea*, which appear in small numbers, and *Vitis* increases towards the end of the phase. Non-arboreal pollen is less

important than in the phase below. In phase g non-arboreal pollen increases dramatically, particularly Chenopodiaceae and Compositae. *Pinus* also becomes much more abundant, while *Alnus* declines; other arboreal pollen continues to decline or disappears, except *Salix*.

A pollen diagram from former **Lake Xinias** [26] was first published in 1978 (Bottema). The uppermost zone, X, characterised by high arboreal values, had a basal radiocarbon date of 10680 ± 90 BP. There are only 5 pollen samples above this date and so the diagram lacks the detail required for late-Holocene studies. A second pollen diagram was published in 1979: in this the zone above the radiocarbon date is shown in more detail and is divided into four subzones (Bottema 1979). Here subzone Z3 appears to correlate with zone Y2 of the Bottema 1974 zonation (Figure 1.2). At Xinias Z3 begins with an increase in *Carpinus orientalis/Ostrya* and *Corylus*. Arboreal pollen percentages and significant values of *Poterium*-type point to rather open forest. The climate responsible for this vegetation would have had dry and hot summers. *Pistacia* and possibly *Poterium* point to winters with a Mediterranean character, at least not extremely cold. *Quercus cerris*-type declines while *Abies*, *Pinus*, and *Fraxinus excelsior* increase and *Fagus* is present in small amounts. *Plantago lanceolata* appears. Subzone Z4 has high values of *Quercus cerris*-type, whereas several other arboreal pollen types including *Pistacia*, *Fraxinus ornus*, *Ulmus*, *Tilia*, and *Fraxinus excelsior* quite suddenly decrease or disappear. Ericaceae and *Centaurea solstitialis*-type appear. Subzone Z5 is characterised by relatively high *Fagus* values, and Ericaceae increases correspondingly. *Abies* as well as *Quercus coccifera*-type also increase. *Olea* becomes quite abundant. The appearance of *Juglans* and *Castanea* in this zone is dated to 3000 BP by comparison with their Holocene appearance in pollen diagrams from Edessa and Khimaditis.

A description of a pollen diagram from a sediment core taken from **Lake Viviis** [23] is given in this same publication, but unfortunately there is no pollen diagram (Bottema 1979). There are no radiocarbon dates, but the base of zone 2 is thought to date to about 6500 BP because of an increase in *Carpinus orientalis/Ostrya* (by correlation with zone Y2 in Bottema 1974). Ericaceae appearing at this time is rather earlier than at Xinias. Zone 2 also has abundant *Quercus* (deciduous), *Corylus*, and *Carpinus betulus*, while *Pinus* has low values. Zone 3 is characterised by a brief increase of *Pinus*, which is not seen at Xinias. Zone 4 shows a constant decline of arboreal pollen values. *Pinus* and *Quercus cerris*-type decrease considerably and *Ostrya*-type, *Ulmus*, *Tilia*, *Corylus*, and *Carpinus betulus* disappear. *Abies* and *Fagus* are still present in low numbers. *Castanea*, *Platanus*, and *Olea* appear in the uppermost spectrum. *Pteridium* appears in this zone. Only a low percentage of cereal-type pollen occurs in one spectrum near the top of the core. It is

thought that the uppermost part of the sequence is missing and that the top of the core may be a few thousand years old, perhaps about 4000 BP based on the absence of *Juglans*.

Sheehan (1979; also Whitehead & Sheehan 1981) analysed coastal deposits from three lagoons in the Argolid Peninsula, **Lake Thermisia** [34], **Lake Saktouri** [35] and **Port Kheli** [33]. Chronology of the three pollen diagrams is based on a radiocarbon date of 2280 ± 80 BP near the base of the core from Lake Saktouri and a basal date of 4375 ± 90 BP from Lake Thermisia. The pollen sequence from the three sites was divided into 7 zones. In zone 1 (4500-4200 BP) *Pinus*, *Quercus* (evergreen), and *Quercus* (deciduous) are dominant. A variety of herbs is represented, particularly Liguliflorae, Umbelliferae, *Plantago*, and Cistaceae. Zone 2 (4200-4000 BP) has extremely low pollen concentrations, but *Pinus* is dominant. Zone 3 (4000-3900 BP) is characterised by its low ratio of arboreal pollen to non-arboreal pollen. A wide diversity of herbaceous pollen is represented, but mostly Compositae. The pollen concentrations of zone 4 (3900-2700 BP) are too low to make a reliable interpretation. In zone 5 (2700-2000 BP) *Olea* and *Pistacia* become important. *Pinus*, *Quercus*, *Abies*, and *Poterium* increase, as well as Ericaceae pollen towards the top of this zone. In zone 6 (2000-1200 BP) *Olea* pollen is dominant, and *Pinus*, *Quercus*, *Pistacia*, and *Phillyrea* are also very abundant, with relatively abundant *Poterium* and Ericaceae. Zone 7 (1200 BP-present) shows a rapid decline in *Olea* pollen, but this reverses at the end of this zone. *Pinus*, *Quercus*, and *Pistacia* remain dominant while *Phillyrea* declines. Herbaceous pollen increases, particularly Liguliflorae. Lake Thermisia spans all 7 of these zones while the Lake Saktouri core spans only zones 5, 6, and 7, and Port Kheli sediments probably represent only zones 6 and 7.

The coring of **Lake Trikhonis** [28] was principally for palaeomagnetic investigation (Readman *et al.* 1976). The first published pollen diagram from this core is not very detailed, but it does show a layer of volcanic material (Bottema 1980). The pollen spectra of this volcanic ash layer are distinctive because the percentages of *Quercus cerris*-type (deciduous oak) increase dramatically, while at the same time *Quercus coccifera*-type shows much lower values. Bottema interprets this as evidence of regeneration and assumes that the volcanic ash comes from the Santorini eruption dated at 3370 ± 100 BP and 3527 ± 44 BP (Opdyke *et al.* 1972), based on comparison of palynological data of this core with others from Greece. However, this is not in agreement with the findings of Creer *et al.* (1981), who associate the ash with the Pompeii eruption of Soma-Vesuvius in 79 AD (1870 BP), based on comparison of archaeomagnetic records of radiocarbon dated sediment cores taken from the same lake. Bottema (1981) published a further note on the relative dating of this core by palynological correlation plus two other cores collected from Lakes Volvi and Vegorititis on the same expedition, also principally for the purposes of

palaeomagnetic investigation. The palynological sequences of these lakes were correlated with radiocarbon-dated pollen sequences from nearby sites. The pollen types *Ostrya/Carpinus orientalis*, *Fagus*, *Juglans*, *Platanus*, and *Zea mays* were of particular importance, as well as the arboreal/non-arboreal ratio.

The basal sediments of the pollen core analysed from Lake Trikhonis are assumed to be younger than 6500 BP, since the increase in *Carpinus orientalis/Ostrya* characteristic of zone Y2 of Bottema's 1974 scheme has already occurred (Figure 1.2). The level of 300-320 cm is dated at 3100-3300 BP according to the curves of *Juglans* and *Platanus*. The upper part of the core is dated younger than 1700 AD at 110 cm since pollen of *Zea mays* was identified at this level (Bottema 1981). The lowest date is in close accord with a radiocarbon date from about the same depth in another core taken from this lake, but the two upper dates are much younger than the radiocarbon dates from similar levels in another core (Creer *et al.* 1981).

A pollen diagram prepared from this core was published later (Bottema 1982, 1990; Bottema & Woldring 1990). The diagram is divided into five zones. Zone I demonstrates lower arboreal pollen values than the following zones. *Quercus* (mostly deciduous) and *Carpinus orientalis/Ostrya* are co-dominant. An upper subzone is based on higher values of *Artemisia*, *Plantago lanceolata*-type, and *Centaurea solstitialis*-type. In zone II *Juglans* appears and *Platanus* begins a continuous curve, increasing to the top of the diagram. By comparison with other Greek diagrams the beginning of this zone is dated to about 3500 BP. Zone II includes the layer of volcanic ash discussed above. During zone II the percentages of *Quercus cerris*-type increase and those of *Quercus coccifera*-type decrease dramatically. *Artemisia* values decrease. In zone III *Quercus cerris* decreases and *Quercus coccifera*-type increases, a response perhaps to renewed human use of the landscape. Zone IV shows another increase in *Quercus cerris*-type, and in zone V there is a steady decline of *Quercus cerris*-type while *Quercus coccifera*-type increases.

At Lake Volvi [6], the oldest part of the core is argued to be younger than 4000 BP, based on correlation with Tenaghi Philippon, as *Fagus* is already present in the lowest spectrum (Bottema 1981). Further, presence of *Juglans* at that level dates the sediment as even younger than 3000 BP. High *Olea* values found at 480-600 cm, together with high cereal-type percentages, may point to the end of the Classical Period and the beginning of the Roman Period at about 2200 BP. The decrease in arboreal pollen and the increase of cereal-type pollen at about 350 cm may represent the end of the Byzantine Period and the beginning of the Turkish occupation. An increase in arboreal pollen at about 190 cm may correspond to the return of Christian refugees to the lowlands about 570 BP. The level at 70 cm must be younger than about 250 years, from the presence of pollen of *Zea mays*. A

radiocarbon date of another core taken from the lake of 1743 ± 55 BP at 384-416 cm compares well with the palynological correlations, but another radiocarbon date of 844 ± 50 BP at 124-159 cm is a few hundred years older (Creer *et al.* 1981). The pollen diagram (Bottema 1982) is divided into five pollen zones. Zone A is defined by relatively low arboreal pollen values, but *Olea* is very well represented. *Vitis*, *Juglans*, and *Platanus* are present. Some herbaceous pollen types represented in relatively important frequencies include *Artemisia*, *Plantago*, *Humulus/Cannabis*, cereal-type, *Sanguisorba minor/Poterium*, *Rumex acetosa*-type, *Rumex hydrolapathum*-type, and spores of *Pteridium*. Zone B is characterised by an increase of arboreal pollen, especially *Quercus* (deciduous), *Carpinus orientalis/Ostrya*, *Pinus*, and *Fagus* (inferred to come from higher elevations), but *Quercus coccifera*-type decreases. *Vitis* and *Juglans* are less important. Zone C is characterised by an increase in herbaceous pollen, especially Gramineae. Zone D shows similar characteristics to zone B. Zone E is characterised by a pronounced decrease in arboreal pollen, especially in *Quercus cerris*-type.

At Lake Vegoritis [11], the lowest sample was dated younger than 6500 BP, as *Ostrya/Carpinus orientalis* is already present. Values of *Tilia* and *Ulmus* suggest that the lowest part is not much younger than 6000 BP. From 410-440 cm the percentages of *Fagus* increase, so this level is placed at about 4000 BP. *Juglans* and *Platanus* appear between 300 and 340 cm. This level is dated to 3100-3300 BP. At 30 cm *Zea mays* was identified, so a date of less than 250 BP is inferred. These dates are somewhat younger than dates obtained from radiocarbon dating of a different core from the same lake, but they agree with the magnetic age-depth curve (Bottema 1981). A pollen diagram published the following year (Bottema 1982; Bottema & Woldring 1990) is divided into pollen zones Y and Z. Zone Y is subdivided into subzones Y1 and Y2. During the time of subzone Y1 a forest of *Pinus* and *Abies* grew on the higher ground, while a deciduous forest dominated by *Quercus* (deciduous) and an admixture of *Carpinus orientalis* and/or *Ostrya carpinifolia*, *Ulmus*, *Tilia*, *Corylus*, and *Carpinus betulus* grew at lower altitudes. Low herbaceous pollen percentages suggest a closed canopy. Very low values of *Fagus* are recorded, and there is an absence of anthropogenic indicators. In subzone Y2 pollen of cereal-type, Chenopodiaceae, *Artemisia*, *Sanguisorba minor/Poterium*, and *Polygonum aviculare*-type appear. Zone Z is characterised by a sharp decline of coniferous pollen types, the appearance or increase of *Juglans*, *Platanus*, *Vitis*, *Plantago lanceolata*-type, cereal-type, Gramineae, *Rumex acetosa*-type, *Polygonum aviculare*-type, and higher values of *Pteridium* spores. Zone Z is subdivided into subzones based on the fluctuating arboreal/non-arboreal pollen ratio: in subzone Z1 it is low; in Z2 it increases due to increases in *Pinus* and *Abies*; in Z3 it is low again.

Kraft *et al.* (1980) presented a palaeogeomorphic study of Navarino Bay on the southwestern Peloponnese coast, with pollen analysis of a core, **Navarino No.3** [35], by Gennett. The upper part of the core is dated by two radiocarbon samples reported as 6983 and 4280 years BP. By 6963 BP a coastal *Pinus* forest probably dominated the area, but between 6963 and 4280 BP sand began to be deposited at the coring site, and pollen becomes very sparse, so no pollen spectra above that dated by interpolation as 6700 BP are shown on the pollen diagram. Pollen types identified in higher levels are reported to have included *Pinus*, *Ostrya-Carpinus*, *Quercus*, *Juniperus*, *Ulmus*, *Alnus*, *Olea*, *Chenopodiaceae*, *Compositae*, and *Caryophyllaceae*, so the coastal *Pinus* forest phase is thought to have continued to 4000 BP. There is no pollen evidence after this time.

Gennett later (1982) published a note without pollen diagrams on the Navarino Bay sequence and an additional site, **Lake Agoulinita** [36]. She reported that the pollen record at Lake Agoulinita begins shortly after 4850 BP. Initially (at 190 cm) *Pinus* and *maquis* plants such as *Quercus* and *Erica* are represented equally well. Pine percentages increase until, at the 100 cm level, almost no *maquis* taxa are found. Above this level, *Quercus* and *Erica* are again important, but there are substantial amounts of herbaceous pollen, especially that of *Gramineae* and *Compositae*.

Yasuda (1985) published a pollen diagram from the analysis of sediments from **Korone** moor in coastal Epirus [25]. A basal radiocarbon date of 6360±30 BP suggests that the moor was formed about 6500 years BP; another date from about 4 m is 4500±35 BP. Charcoal abundance was calculated as well as pollen percentages. Unfortunately only *Quercus* pollen percentages are shown against the charcoal curve, but there is a clear correspondence between peaks of charcoal abundance and low frequency of *Quercus* pollen. Between 6000 and 4500 years BP charcoal is very abundant but fluctuating. *Quercus* abundance fluctuates in correspondence to the charcoal, and the sedimentation rate is rapid during this period. Evidence for cereal cultivation begins at the beginning of this period also. Pollen of *Abelia*[], *Pinus*, *Rhododendron*[], and *Ericaceae* is reported as having high values during this time. (The pollen types reported as *Abelia* (*Caprifoliaceae*) and *Rhododendron* (*Ericaceae*) are thought to be spurious. *Abelia* may be a misspelling of *Abies*, and *Rhododendron* might be another member of the *Ericaceae* family misnamed.) After 4500 years BP charcoal abundance is very low, and there is a corresponding increase in *Quercus*. *Olea* and *Pistacia* also increase, but a decrease is reported in cereal-type, *Ericaceae*, *Rhododendron*[], and *Abelia*[]. After about 1500 years BP charcoal increases again and *Quercus* type pollen decreases, while cereal-type pollen and *Olea* increase.

An alluvial sediment core from near the archaeological site of **Halos** [24] has been pollen-analysed (Bottema 1988, 1990). The pollen diagram has been divided into three pollen zones, I-III, and radiocarbon dated at 4 levels. The radiocarbon date of 6520 ± 100 BP dates the base of zone II, which corresponds to zone Y2 of Bottema's 1974 zonation scheme (Figure 1.2). It is characterised by high arboreal pollen percentages, including *Quercus cerris*-type and *Pinus*, with a conspicuous increase in *Carpinus orientalis* and/or *Ostrya carpinifolia*. The boundary with the next zone, III, is drawn where arboreal pollen percentages decrease, about 2900 BP. Zone III shows low arboreal pollen values and high herbaceous frequencies, dominantly Chenopodiaceae, *Plantago*-types, Liguliflorae, *Polygonum aviculare*-type, and *Sparganium*-type.

Two sediment cores from the **Strimon** delta [5] (Strimon 1, from Tuzla Marsh at the eastern end of the delta; and Strimon 3, from the north side of a lagoon in the central part of the delta) have been pollen-analysed by Atherden (1989), but only preliminary results are available. Neither core has been radiocarbon-dated. The presence of *Platanus*, *Castanea*, and *Juglans* at the base of the Strimon 1 core suggests that this level post-dates 3200 BP. In the Strimon 1 pollen diagram there are two main sections of good pollen preservation, 90-210 cm and 260-310 cm. In the lower zone *Pinus* and *Quercus* have relatively low abundance along with other trees. High values for *Olea* and the presence of cereal-type suggest agricultural land nearby. The upper zone has higher *Pinus* and *Quercus* (especially deciduous oak), lower *Olea*, and less cereal-type pollen, suggesting a decrease in agricultural activity. Higher values for Chenopodiaceae are probably from saltmarsh plants becoming established in the local area as the water became shallower. Ericaceae is represented throughout the diagram. Again in the Strimon 3 core there are two sections where pollen preservation is relatively good: from 2.7-2.0 m and 1.4-0.7 m. The first of these zones is dominated by pollen of grasses and sedges, probably derived mainly from local marsh plants, but agricultural activity in the vicinity of the site is suggested by the records for *Olea* and *Vitis* pollen and also for many weed species. Cereal pollen is represented by only one record. A wide range of tree species are represented, but all are at low frequencies: *Pinus* has the highest value, while *Quercus* (both deciduous and evergreen) is present in small numbers; other trees include *Alnus*, *Carpinus*, *Corylus*, *Abies*, *Salix* and *Platanus*. Pollen of *maquis* species is also present. Towards the top of this zone Chenopodiaceae increases until in the upper zone it is dominant. *Olea* is still present, although at slightly lower values, but *Vitis* and cereals have disappeared. Pollen frequencies of tree and shrub species are similar to that for the earlier zone and the *maquis* elements are also fairly stable throughout the diagram. This may be interpreted as woodland and *maquis* vegetation at some distance from the site.

Willis (1989, 1992a, b & c, 1994) published data from two pollen studies close to Grevena, but on the western side of the Pindos Mountains in Epirus. These sites, **Gramousti Lake [20]** and **Rezina Marsh [19]**, are only 20 km apart but differ greatly in elevation, being at 285 and 1800 m respectively. Sediment chemistry and mineral magnetic analyses were undertaken on the cores, which were dated by AMS radiocarbon dating of individual macrofossils. Within the section of interest of the core from Gramousti there is one accepted radiocarbon date of 1930 ± 180 BP. This section has been divided into two pollen-assemblage zones, GL5 and GL6. The rate of sedimentation is constant throughout these two zones. The date of the base of zone GL5, 5200 BP, is extrapolated from a lower radiocarbon date of 6330 ± 180 BP. The base of this zone is delimited by a sharp increase in the percentage of *Quercus* pollen (exceptionally high influx levels of *Quercus* are recorded) and a large decrease in the frequency of Gramineae and all other non-arboreal taxa. *Pinus* is present as are *Carpinus orientalis/Ostrya carpinifolia*, *Corylus*, *Abies*, and *Phillyrea* but at lower values, and *Alnus* is present at an even lesser extent. Organic content of the sediment increases along with a decrease in sediment influx, indicating a stable phase in the sedimentary history of the basin. Zone GL6 (4320-1200 BP) extends to the top of the core. It is characterised by a reduction in *Quercus* and an increase in Gramineae. *Pinus* remains at about the same frequency until it declines near the top of the sequence. *Carpinus orientalis/Ostrya carpinifolia*, *Corylus*, *Abies*, and *Phillyrea* are present throughout the zone at relatively high frequencies, but *Olea* has lower frequency and is confined to the top of the zone. Non-arboreal taxa such as Ranunculaceae, Cruciferae, *Plantago* type, and *Centaurea* occur in low frequencies. Sediment chemistry and mineral magnetic analysis suggest that erosion occurred between about 4300 and 3500 BP and suddenly decreased about 3500-3000 BP before resuming between about 2500 and 2000 BP.

The upper part of the Rezina Marsh sequence has been divided into four pollen assemblage zones, RM5-8, and dated by interpolation between four radiocarbon dates, 6320 ± 130 , 4440 ± 150 , 3830 ± 60 and 2990 ± 80 BP. The base of zone RM5 about 6160 BP, is characterised by a large increase in non-arboreal pollen and a reduction in the pollen frequency of most arboreal taxa, although *Pinus*, *Quercus*, *Abies*, and *Carpinus orientalis/Ostrya* are all well represented. *Corylus*, *Ulmus*, and *Acer* occur in smaller numbers. *Carpinus betulus* increases towards the top of the zone. Gramineae is the dominant herbaceous pollen, and only small percentages of other herbaceous pollen types occur: Chenopodiaceae, Umbelliferae, *Poterium sanguisorba*, Rubiaceae, and Caryophyllaceae. The base of zone RM6 (4250-1900 BP) is characterised by a further increase in Gramineae, as well as in *Rumex* and other herbaceous taxa. A further decline

in arboreal taxa (excluding *Pinus*) occurs: only *Quercus*, *Carpinus orientalis/Ostrya carpinifolia*, *Abies*, *Corylus*, and *Phillyrea* show a continuous presence in this zone. The frequency of *Pinus*, however, increases towards the middle of the zone and then declines. RM7 (1900-1170 BP) is a narrow zone characterised by a large and sudden increase in the percentage of *Pinus* and a rapid decline in Gramineae. In RM8 (1170-100 BP) there is a decrease in the percentage of *Pinus* and an increase in Gramineae. All other arboreal taxa maintain a low presence, while *Abies* declines further. At the very top of the zone *Quercus* increases along with *Plantago*, Umbelliferae, Caryophyllaceae, *Rumex*, Compositae Tubuliflorae, and Compositae Liguliflorae. Before about 4500 BP sedimentation was slow, but after this time accumulation of sediment increased dramatically with a large increase in the concentration of magnesium and calcium, suggesting that erosion of the surrounding terrain was occurring. Erosion declined after about 3500 BP, but further erosion took place about 2000 BP.

Pinus is continuously higher at Rezina than at Gramousti, peaking at about 4000 BP and 2000 BP. *Abies* decreases at both sites from 4500 BP, but, except at about 2000 BP, it is almost continuously higher at Rezina than at Gramousti. *Quercus* values are continuously higher at Gramousti than at Rezina. *Carpinus orientalis/Ostrya* is higher at Rezina except between about 3500 and 1500 BP. *Corylus*, *Ulmus*, *Tilia*, *Phillyrea*, and *Salix* show about the same abundance at each site throughout the sequence. Gramineae is more abundant at Rezina until about 2500 BP, when after a slight fluctuation it becomes more abundant at Gramousti at about 2000 BP.

A pollen diagram of sediment core OK 85/11 collected from **Kiladha Bay** [32] was published by Bottema in 1990. The base of the sediments is dated to about 6700 BP, based on sea-level-change data and radiocarbon dates of nearby cores. The pollen diagram is divided into two zones, I (thought to correspond to the later Neolithic and Bronze Age) and II. Zone I is characterised by low arboreal pollen frequencies (although *Quercus cerris*-type, including deciduous and semi-evergreen oaks, is quite abundant), low conifer and mediterranean xerophytes; and a large variety of herbaceous pollen types with relatively high values. There is a wide range of anthropogenic indicators, including *Plantago lanceolata*, *Vitis*, and very high values for Cerealia (higher than Gramineae). High concentrations of cereal-type pollen may be due to summer-deposited dust containing cereal chaff or by in-wash from streams. These two factors may also be responsible for the very high percentages of Chenopodiaceae and Liguliflorae pollen types. Zone II is characterised by high arboreal pollen percentages and is dominated by *Pinus*, while Mediterranean xerophytic species also show high values. This zone is divided into two subzones. Zone IIa begins perhaps about 2700 BP and may correspond to the Iron Age. It is characterised

by increasing arboreal pollen values. Cereal-type pollen is still present with high values. Subzone IIb has high arboreal pollen values and is dominated by *Pinus*, *Olea*, and *Quercus coccifera*-type, with deciduous oak also well represented, and pollen from other deciduous trees such as *Corylus*, *Tilia*, and *Ulmus* is present. *Platanus* becomes more common, and Ericaceae becomes important. An abundance of small charcoal particles was observed in the sediment of zone I, but these decrease in zone II. Sedimentation rates are calculated to be higher during zone I than in subzone IIa and may be even higher in subzone IIb.

A pollen diagram has been drawn from a sediment core 5.57 m long from former **Lake Lerna [31]** on the Argive Plain (Jahns 1990, 1993). Chronology of the sequence is based on 9 radiocarbon dates (there are two inversions). The pollen-bearing sequence begins at 6800 BP and is divided into 4 zones (I-IV). Zone I (6800-6300 BP) is characterised by large amounts of pollen of deciduous oak and other deciduous trees such as *Corylus*, *Fraxinus ornus*, and *Carpinus orientalis/Ostrya*. Some evergreen taxa such as *Phillyrea*, *Pistacia*, *Quercus coccifera/ilex*, and *Juniperus* as well as non-arboreal pollen types display relatively high values. This zone may have been influenced by human impact. Zone II (6300-4800 BP) is characterised by a decrease of *Pistacia* and *Phillyrea* values and an increase in *Quercus pubescens* type. This dense deciduous oak woods lasted until the beginning of the Bronze Age. During this zone *Erica* shows a continuous curve, and single grains of *Myrtus*, *Castanea*, and *Platanus* occur for the first time. Zone III (4800-1100 BP) is characterised by a decrease in *Quercus pubescens* values and an increase of *Pinus* and *Carpinus orientalis/Ostrya*. Zone III is divided into two subzones, a and b. Subzone b differs from a by showing a decrease in *Carpinus orientalis/Ostrya* and an increase of *Olea*. From zone IIIb *Juglans* shows an almost continuous curve. The zone border between zones III and IV is marked by a decrease in *Olea*. During zone IV *Pinus* is dominant and *Quercus pubescens* declines continuously. *Juniperus* and *Quercus coccifera/ilex* show relatively high values. During zones III and IV strong human influence is indicated by the spread of *maquis*, phrygana, and pine. After about 2700 BP there is evidence of extensive olive farming.

Atherden *et al.* (1993) published a pollen diagram from **Kleonai [30]** in the Nemea valley of the northern Peloponnese, in which pollen preservation is patchy and only two zones, 4 (57-87 cm) and 5 (0-10 cm), corresponding to the Bronze and Roman Periods, contained countable quantities of pollen. Radiocarbon dates at 61-64 cm, 79-83 cm, and 95-99 cm giving ages of 3345 ± 70 BP, 3820 ± 50 BP, and 4770 ± 70 BP respectively, provide good age control of the pollen-bearing Bronze Age sediments. The age of the top of the core was extrapolated to 1820 BP. During zone 4 there is an expansion of *maquis* elements, including *Quercus coccifera*-type, *Phillyrea*, *Pistacia*, and Leguminosae.

Records for *Pinus* and *Abies* increase slightly. Deciduous trees include *Quercus pubescens*-type, *Tilia*, *Ostrya*, *Castanea*, *Juglans*, and *Platanus*. There are significant records for *Olea*. Gramineae is very abundant, and weed species are well represented. In zone 5 there is a decrease of deciduous trees and an increase of *Pinus* and *maquis* shrubs, including *Quercus coccifera*-type and *Juniperus*. *Olea* and *Cereales* are recorded. Weed species and Gramineae are present. The authors note that similarities exist between zone 4 in this diagram and zone III from the former Lake Lerna: the higher ratio of pine to deciduous oaks, the records for *Juglans* and *Olea*, and the importance of *maquis* elements. The apparent increased human impact on the landscape during the Bronze Age fits well with other pollen records from the Peloponnese (Wright 1972; Sheehan 1979; Whitehead & Sheehan 1981; Bottema 1990; Jahns 1990, 1993).

Five pollen-analytical investigations by Athanasiadis and Gerasimidis have been undertaken in mountainous areas in northern Greece; **Lailias [2]** (Gerasimidis 1985); Flampouro and Kokkini Brysi at **Pieria [14]** (Gerasimidis 1985); **Voras [7]** (Athanasiadis & Gerasimidis 1986); **Paikon [10]** (Athanasiadis & Gerasimidis 1987); and **Rhodopi [1]** (Athanasiadis *et al.* 1993). The results of these studies have been published in either Greek or German, but Gerasimidis & Athanasiadis (1995) have published a review in English with pollen diagrams. They found that overall trends in the woodland history at these sites were comparable, but there were also substantial differences that they attributed to the effects of human influence. An early phase (A), corresponding to the Atlantic period, is characterised by thermophilous mixed deciduous woodlands with *Quercus* or *Tilia* as the main components (Figure 1.2). Phase B represents the Subboreal period (Firbas zone VIII) and is characterised by coniferous woodlands dominated by *Abies* and *Pinus* (Figure 1.2). At this time *Fagus* gradually expanded except at Paikon where, at the end of the phase, *Fagus* was reduced and *Quercus* expanded. At Rhodopi, severe destruction of the upland woodlands, evidently by people, affected the pattern of vegetation development and favoured *Betula* which, as a pioneer species, spreads in areas cleared of woodland. The relatively strong representation of *Quercus* probably reflects oak growing in low-lying areas, which appear to have been unaffected by human activity.

Phase C relates to the earlier Subatlantic (Firbas zone IX) and is characterised by conifer and beech woodlands. *Fagus* competed with *Pinus* and *Abies*, as well as with *Picea* in Rhodopi. Beech woodlands dominated especially at Voras. *Quercus* representation remained steady while the other deciduous trees continued to be reduced and became extinct in most areas by the end of this phase. A feature of the phase is reduction in the ratio of arboreal pollen to non-arboreal pollen, especially at the top. In the Lailias profile arboreal pollen values fall at the beginning of this phase, while at Paikon arboreal pollen

representation is low throughout. This suggests that woodland clearance, especially in the uplands, was quite severe. At Voras, Paikon, and Lailias *Juglans* pollen is recorded at the beginning of the phase and, at the first two sites, *Castanea* is also recorded. These two trees are normally regarded as associated with human manipulation of vegetation (Athanasiadis 1975; Bottema 1974, 1980), so the presence of their pollen is a further indication of intensive and systematic human disturbance. The record of *Juglans* at the base of the Rhodopi profile is probably due to the existence of a natural population in this area. It is assumed that people were largely responsible for its spread from centres of natural populations such as that at Rhodopi (Athanasiadis *et al.* 1993; Turrill 1929).

Phase D relates to the later Subatlantic (Firbas zone X). The woodland vegetation of the mountains in northern Greece looked more or less similar to that of the present day. *Fagus* is of greater importance than *Quercus*, and *Pinus* is the main conifer except at Rhodopi, where *Picea* is also important. *Abies* has very low representation at the base of this phase and subsequently almost disappears after a sharp decline in arboreal pollen which is recorded in all profiles. The division into subphases D1 and D2 marks the latter development. Clearance of woodland has not necessarily taken place at the same time in the various mountain ranges, but that recorded at the D1/D2 boundary probably coincides with the Turkish occupation of Greece in the 14-15th century.

More recently a review of the prehistoric environment of Greece has been published by Bottema (1994), in which he also includes new palynological data from Zileria [39]. The sediments of the small lake of Mikro Zileria were deposited very rapidly. A pollen diagram is shown of selected characteristic pollen types identified in a sediment core. The base of the core has been radiocarbon dated to 1440 ± 90 BP. From 500 to 1500 AD there are four periods dominated by deciduous oak pollen, separated by periods of grass pollen dominance. A large variety of tree pollen (other than oak) maintains constant low percentages and represents trees growing at a distance. The periods (200 years on average) alternating between oak and grass dominance are thought to represent cycles of oak clearance and regeneration. Bottema suggests that the presence of high values for *Sanguisorba minor*-type during the clearance phases indicates that no intensive cultivation of crops took place, and sheep grazing prevented regeneration of oaks. Above these clearance cycles the environment of Zileria appears to have changed; the sediment changes from gyttja to clay and oak pollen almost vanishes. The plain was changed into a steppe that lacked protective cover. There is some regeneration of trees, including oaks, in the uppermost 20 cm.

In his review Bottema (1994) points out that many of the palynological studies undertaken in Greece, all during the last 30 years, have been undertaken in conjunction with

archaeological projects and were focused towards reconstructing the botanical environment of prehistoric people and to explain past climate. He suggests that the field of research should be oriented towards the relation between the natural evolution of vegetation and human impact on plant regimes. A summary of Bottema's review is given below.

Around 6500 BP, the Greek landscape changed. The cause of this change is not known, but it may have been human disturbance. Universally on the Greek mainland *Ostrya carpinifolia* (hop hornbeam) and *Carpinus orientalis* (eastern hornbeam) expanded in the deciduous tree belt (zone Y2, in Figure 1.2). Other changes in the pollen record and related vegetation had a regional character (due mostly to variations in elevation). In northern Greece in both the mountains and lowlands we have evidence of a further expansion of the coniferous forest, and *Fagus* (beech) appears for the first time, probably in the coniferous belt. On the Epirus (west) side of the Pindos Mountains and in Thessaly, the quantities of beech and needle-leaved tree pollen remained unchanged. Increased forest canopy cover is inferred from the disappearance of light-demanding types such as *Sanguisorba minor* (burnet). At Halos, on the coast, there is no change. Kopais, in Boetia, which has a much more pronounced Mediterranean climate today, displayed comparable differences during this period.

There is clear proof of human impact upon vegetation from about 4000 BP (zone Z1, in Figure 1.2). At this time a series of herb-pollen types appears; these include primary human disturbance indicators such as cereal-type pollen and secondary indicator types such as the weeds *Plantago* and *Polygonum*. Besides pollen of plants that are the direct result of farming, secondary changes in the vegetation triggered by human activities can be seen. A sudden increase in *Fagus* in the northern mountain belt and the Epirotic part of the Pindos Mountains may be the result of vegetation disturbance by humans. At higher elevations in Thessaly *Pinus* increased and replaced *Juniperus*. At this time some leaching of the soil may have taken place through increased precipitation, as concluded from the appearance of Ericaceae.

At about 3200 BP (zone Z1/Z2 boundary, in Figure 1.2) a suite of trees exploited by humans appears – *Juglans regia* (walnut), *Castanea sativa* (sweet chestnut), *Fraxinus ornus* (manna ash), and *Platanus orientalis* (plane tree). Coincident with this is an increase or appearance of primary and secondary types indicative of farming. In the stratigraphic record this palynological event directly follows a Santorini volcanic event that can be identified by tephra. Furthermore, there are indications of a change in sedimentation. Climatic conditions were cooler, moister, or even cloudier between about 3200 and 1500 BP.

1.5 Research strategy

Previous pollen-analytical studies in Greece are summarised in the preceding section. Some generalities that can be extracted include the following:

- Many studies were directed towards a vegetation history of the area in terms of glacial/interglacial climatic cycles and not primarily directed towards a study of the impact of humans upon natural vegetation. In general, zones were identified based on characteristic tree-pollen spectra, reflecting the sequence of climatic changes through the Late Glacial and Holocene. Each of these zones may cover two or three millennia.
- Many sequences are not continuous to the present day.
- The abundance of microscopic charcoal, giving a fire history, was calculated for only one site.
- Some of the cores have no absolute dating, and none has sufficient absolute dating to be sure of chronology.
- Most are too coarse-grained to show changes in the vegetation that may have been caused by humans, and sample intervals are too large for a detailed study of human impact on the vegetation.

It appears from the pollen studies undertaken so far in Greece that very local variation occurs. This is not surprising, since there is such a great variation in altitude and topography over short distances. Turner & Greig (1975:203) found a difference of over three thousand years in the time at which the major part of the oak forest was destroyed in the Kopais and Tenaghi Philippon regions of Greece. In general, however, although there is evidence of domesticated plants at Franchthi in northeastern Peloponnese as early as c. 8000 years BP (Hansen 1985:177), extensive forest clearance and plant cultivation is not recorded in pollen diagrams until about 3500 years ago, when major reduction in tree pollen occurred, along with expansion of agricultural weeds and increase or appearance of such cultivated types as *Juglans* (walnut), *Castanea* (chestnut), *Olea* (olive), and *Vitis* (grape).

These observations encourage one to expect that a local vegetation-history investigation, undertaken in conjunction with archaeological, geomorphic, and human-ecological studies, may make a contribution to understanding the wider picture, particularly if close attention is paid to obtaining a record of the past few thousand years, to radiocarbon dating, and to identification of pollen-analytical indicators of human activity.

The primary objective of this thesis, then, is to reconstruct the vegetation history of Grevena since the Late Bronze Age and to seek possible causes and mechanisms of any vegetation changes found. Subsurface samples of unconsolidated sediments from soils and wetland sequences were collected for analysis. Fossil pollen, spores, and microscopic

charcoal were the principal items identified, but the composition of the sediments was also analysed. Identification of pollen and spores was aided by an extensive reference collection of local species and construction of a pollen key modelled on that of Faegri & Iversen (1989). An absolute chronology was provided by radiocarbon dating of organic detritus within the sediments.

An attempt is made to shed light on the history of agriculture and pastoralism, and the intensity of land use through time. The recognition of anthropogenic activities and their palynological signal is based on knowledge of present-day and historically documented conditions, especially old cultivation techniques. By backwards extrapolation the recent pollen deposition of such landscapes can serve as a guide to the vegetational interpretation of pollen diagrams.

Wetland sites are the usual focus of pollen-analytical studies because pollen is usually preserved best in water-logged situations. Preservation of pollen in dryland sites is less common than in wetland sites, but pollen is preserved at dryland sites if some factor, such as aridity or high acidity, exists in the microenvironment that inhibits microbiological decay (Dimbleby 1985:1; Andersen 1986; Chester 1991; Matthews 1994). Some soils in Grevena are both arid and high in acidity (Oikonomou *et al.* 1988). To obtain direct evidence of the local vegetation contemporary with particular archaeological cultures, ten samples were collected from horizons in soil sequences where evidence of human occupation occurred (Andersen 1986). These were dry localities, and it was hoped that information could be gained (that would be masked in a regional pollen study) on the environmental background of the particular archaeological cultures and their land-use practices, such as cultivation of food plants for humans and draught animals, and animal husbandry (Dimbleby 1985). Unfortunately, no palynomorphs were found in these samples.

Four freshwater wetlands were selected from the three major topographic regions of Grevena; the high Pindos Mountains, low Pindos Mountains, and the central plains or lowlands, for the collection of palynological samples for the study of regional vegetation history. The distribution of these sampling sites, although to a large degree limited by the distribution of suitable wetlands, was selected to assist with distinguishing between natural and human-induced changes in the vegetation so that, in particular, the history of settlement patterns and the development of agriculture and pastoralism in Grevena could be deduced. The four sites differ in elevation, physiography, and vegetation. Land-use practices at each site are quite different today and probably they were also in the past. The highest wetland site, Gomara, is in an area that is sparsely populated today and may have been so in the past, and it would thus be expected to reveal a history of vegetation little disturbed by human activity. It is also at an elevation where the vegetation would be sensitive to

relatively small climate changes. The second highest site, Anelia, although also sparsely populated, showed much evidence of woodland management over the past few hundred years. Only one of the two lowland sites was pollen-analysed – Kellia. This site is on the densely populated plains of Grevena and is surrounded by cultivated fields, which would contribute eroded sediment to this fen. The fen is within the boundaries of a designated archaeological site. A core collected from the other lowland site, Mirsina, was not pollen-analysed, as a radiocarbon date from the base of this sequence gave a radiocarbon age of less than 100 years. The diversity of the remaining sites, however, made it possible for the relationship between vegetation history, land use, and climate change to be investigated in different ecological zones.

Close sampling of the core sequences was undertaken so that the time period between each sample was reduced. Both concentration and influx data were obtained to assist with interpretation of the significance of fluctuations in relative pollen abundance. Concentration data give the absolute number of pollen grains per unit of sediment, rather than relative percentages, dependent on the frequency of other pollen taxa. Pollen influx (grains per unit area per year) was calculated for the highland site where sedimentation accumulation was relatively steady and where slow successional changes may have occurred.

Surface pollen samples were collected from representative plant communities (including both little disturbed and much disturbed "anthropogenic" communities) in conjunction with local vegetation surveys, to study the relationship of the modern vegetation to the contemporary pollen deposition, and as modern analogues for comparison with fossil spectra. The ecological tolerance of individual extant plant species and communities (particularly of anemophilous taxa) determined from surveys of the current vegetation, was used to interpret climatic change. In addition, the flora on each wetland was recorded so that a correlation could be made between the deposit-forming plant communities and sediment type and the wetland trophic state.

To obtain a history of the environment of the wetlands, sediments were characterised by the Troels-Smith classification system, estimating moisture content, bulk density, organic content, carbonate content, and non-carbonate inorganic content. Plant macrofossils and gastropods encountered during sediment description were noted and also give evidence of local conditions. Diatoms identified in sediments from the highland site assisted in palaeoecological interpretation of that wetland. Ostracods were sought in the lowland sediments but none was found.

Close determination of palynomorphs was undertaken, as many anthropogenic indicator species are morphologically similar to natural species, e.g. wild species of

Leguminosae and those grown for fodder, cereal-pollen types and wild Gramineae species. Pollen counts, where possible, were made large enough so that weeds associated with human disturbance were represented despite low relative abundance, e.g. especially at the highland site where anemophilous *Pinus* is over-represented. Even early cereals were self-pollinated and the legumes are insect-pollinated, so the pollen of neither of these groups of domesticated plants is well-represented in the pollen rain (Wright 1985:189). However, plant communities associated with agriculture can often be identified by indicator species such as the weeds of cultivation or ruderals, for example *Agrostemma githago*, *Centaurea cyanus*, *Plantago lanceolata*, or *Rumex acetosa*, although many of these also have low representation.

A reduction in canopy cover, interpreted from a reduction in the arboreal to non-arboreal pollen ratio, may result from either climatic factors or land-use practices such as wood cutting, pastoralism, and fodder production. An often used method of effecting deforestation is fire. To assist with establishing the causes of deforestation, a fire history of Grevena was established by obtaining the fire history of each pollen core site from counts of microscopic charcoal particles. Also pyrophytic plants may have a palynological record, e.g. those that sprout readily after a fire (*Pteridium*) and those that are fire sensitive (*Juniperus*).

The chronology of slope erosion and valley alluviation in response to natural (e.g. climatic, tectonic) and human factors (primarily agriculture and pastoralism) was also investigated through sediment analyses. The organic content of the wetland sediments was determined so that changes in the ratio of inorganic content to organic content could be seen. Special attention was paid to the timing of increases in sedimentation and possible correlation with changes in vegetation seen through pollen analysis, e.g. reduction of forest or changes in grazing and agriculture. Rates of sediment accumulation were also calculated, as increased accumulation may indicate soil erosion.

Finally, results of the present study were compared with other results of the Grevena Project, such as changing population density estimated from the number of archaeological sites found by surface survey, investigations of lowland soil stratigraphy and landscape stability, and vegetation history and archaeological results farther afield.

Chapter 2. Field and laboratory techniques

2.1 Introduction

In general, the techniques used in this study follow usual Quaternary palynological and palaeoecological techniques as outlined in the standard palynology and palaeoecological textbooks (Wodehouse 1935; Brown 1960; Kummel & Raup 1965; Erdtman 1969; Faegri & Iversen 1975, 1989; Moore & Webb 1978; Birks & Birks 1980; Birks & Gordon 1985; Dimbleby 1985; Berglund 1986a; Moore *et al.* 1991).

2.2 Modern pollen study

Interpretation of fossil pollen sequences is generally made via reconstruction of the original plant communities. Unfortunately, the ratio of the abundance of pollen of plants represented in the pollen diagram to abundance in the original vegetation is never unity, due to differences in relative pollen production, transport, and preservation (Prentice 1986a). In addition, a landscape such as that of Grevena with a long cultural history has been subject to many human activities, such as arable and pastoral farming, timber cutting, building settlements, and communication systems, which have altered the natural plant communities and created new complex communities.

2.2.1 Field techniques

To assist with the reconstruction of past plant communities from fossil pollen assemblages, the modern vegetation of Grevena was studied by compiling detailed modern vegetation maps and species lists, and by undertaking vegetation surveys in conjunction with surface pollen sampling. These studies were undertaken to formulate modern analogues of plant communities that might be preserved in the wetland sequences, and to gain an understanding of the ecological demands of species extant in Grevena, for example, species with well-defined narrow ecological tolerance that can be used as indicator species. Surface pollen samples were collected so that the pollen spectra representative of plant communities could be compared with fossil assemblages and to assist with compensating for the variability in pollen representation in fossil pollen spectra. The contemporary pollen rain was studied by comparing vegetation surveys with pollen representation in surface pollen samples. The major extant vegetation zones are classified according to land-use, physiognomy, and floral composition and follow Moody & Rackham (in prep.).

It was important to obtain a modern vegetation map of Grevena so that a research strategy could be followed that covered all the major vegetation zones. Moreover, since lack of time in the field precluded extensive vegetation surveys and numerous surface pollen

sample collections, obtaining a modern vegetation map of Grevena was necessary to assist with interpretation of the modern pollen rain in the study area. An unpublished 1:50 000 scale vegetation map of Grevena, hand-coloured by the Greek Forest Service and held in their Grevena office, was copied (Karasavvidis, unpub.). In addition, a detailed vegetation map (at 1:20 000 scale) of the wetland fossil pollen sampling site of Anelia was also hand-copied from hand-coloured maps. Unfortunately no 1:20 000-scale vegetation maps were available for the other wetland sites.

I also obtained of an unpublished vegetation survey from the NE Pindos Mountains (Adamakopoulos 1989). The species list from that survey and the species list compiled by a member of the Grevena Project have been of great assistance in gaining an overall understanding of the vegetation in Grevena (Rackham 1991).

The modern vegetation of Grevena was studied by surveying a variety of sites by both qualitative and quantitative methods. In the site surveys, herbarium specimens were prepared from plants that could not be identified in the field, a total of 363 being prepared (Appendix I). Identifications were made by Dr O. Rackham, Cambridge University.

Reconnaissance surveys (qualitative surveys where a species list only was made) were undertaken at six sites. These surveys were focused mostly towards plant communities of disturbed areas; rather than plant communities of the main vegetation zones of the province. Pollen of species of these disturbed areas was expected to be mostly zoophilous and thus grossly under-represented on a regional scale, but grossly over-represented on a very local scale. Therefore no surface pollen sample was collected. However, the presence of species of disturbed areas taken collectively in the pollen diagram may be important in the interpretation of anthropogenic disturbance of the vegetation, so it was important to know something of their abundance and habitats.

Qualitative surveys were also undertaken at three sites of special interest where surface pollen samples were collected. A composite moss polster was collected from around a mountain lake. This lake has the potential of providing a long pollen sequence dating to before human disturbance. Unfortunately, this site is located in the Pindos National Park and the permit required by Greek authorities for coring in the lake was not granted until the field season had ended. In any case this site provided a useful surface sample from the Pindos Mountains. Several large pine trees had been cut down, leaving annual rings exposed in the remaining stumps. The number of annual rings of three trees were counted, providing a standard from which the age of other pine trees could be estimated and additional ecological data of this area could be interpreted. In the Pindos foothills, a composite moss polster was collected from the edge of a mixed wood in a limestone gorge. The type of mixed wood (described in Chapter 3) at this site is rare in Grevena and is thought to be a relic of preglacial

forests. On the plains, surface soil was collected randomly over an entire 100 x 100 m barley field which had been harvested of its crop a few weeks prior, and weeds were beginning to grow (Lewis & Ogden 1965:615; Dumbleby 1985; Wright 1985; Hall 1989). A vegetation survey was made of the field to gain some information about weeds of cultivation.

Quantitative vegetation data and surface pollen samples were collected at seven sites representing the major vegetation zones from a transect across Grevena (Wright *et al.* 1967; Moore & Chapman 1986; Jahns 1993). These sites also represent the major physiographic regions of Grevena and span the altitudinal range of the province, from mountains to lowlands. At sites where the vegetation comprised mostly herbaceous plants, quantitative vegetation surveys were undertaken of 2 x 2 m plots; where the vegetation being surveyed included many woody plants, quadrats of usually 30 x 30 m (under tree canopies) or larger were surveyed (Andersen 1973; Birks 1977). Relative abundance of species was estimated by making a visual assessment of percent cover (Andersen 1970, 1973; Birks 1973, 1977; Greig-Smith 1983; Moore & Chapman 1986). Where more than one vegetational layer was present, each stratum was considered separately for estimating the relative cover values. Taxa absent from the plot but present nearby in a stand were also recorded.

Pollen surface samples from these sites composed of the green parts of composite moss polsters (except for one litter sample (Lewis & Ogden 1965:615)), were collected randomly at ground level near the centre of the surveyed area. Neither the period of accumulation nor the extent of preservation of accumulated pollen is known precisely in these types of sample (Faegri & Iversen 1964:35; Bradshaw 1981; Boyd 1986) (Benninghoff (1960) suggested less than 10 years, while Bradshaw (1981:50) suggests perhaps only 5 years if only the green moss stems and leaves are sampled), but, to a greater or lesser degree, these samples simulate the collection of pollen by a bog or lake surface and can be used to study the relationship between pollen frequency and vegetation, and the relative representation of pollen taxa (Carroll 1943; Potter & Rowley 1960; Andersen 1967; Wright *et al.* 1967; Markgraf 1980; Bradshaw 1981; Prentice 1986a; Fall 1992).

Surface pollen samples were also collected and both quantitative and non-quantitative vegetation surveys undertaken, in the same manner as described above, on the wetland and in the vicinity of the coring sites.

2.2.2 Laboratory preparation of surface pollen samples

Extraction of pollen and charcoal particles from the surface samples was carried out in the laboratory of the Research School of Earth Sciences, Geology Department, Victoria University of Wellington. Care was taken to ensure that samples were not contaminated with pollen circulating in the laboratory air.

The surface pollen samples are composed of a variety of materials, including wet undecomposed surface peat, moist moss polsters from wetland surfaces, wet and dry mud from wetlands, dry ground-surface moss polsters, dry woodland litter, and surface soil from an agricultural field (Lewis & Ogden 1965:615; Wright 1985:185). Laboratory preparation techniques to extract the pollen, spores, and charcoal were chosen so that unwanted minerals and organic debris were removed, and the pollen, spores, and charcoal were concentrated.

All moss polster and litter samples were prepared for analysis in the same way. Seven steps were used; hot potassium hydroxide solution (KOH) treatment, wet sieving, cold dilute hydrochloric acid (HCl) treatment, cold hydrofluoric acid (HF) treatment, acetolysis, cold KOH and distilled water wash, and filtration, before being dehydrated in tertiary butyl alcohol (TBA) so that evaporation would be complete when mounting in silicone oil. Appendix II details the procedure followed.

The soil surface sample was prepared in the same manner as the subsurface soil samples (those abandoned after processing since they were devoid of pollen), the main difference from the moss and litter samples being steps to disperse the soil and cause more effective removal of siliceous matter and other minerals. Extra steps undertaken were an initial step to disaggregate the sample, a stronger HF treatment (hot rather than cold), and the inclusion of a concentrated HCl treatment following the HF treatment. Appendix II describes the procedure followed.

Wetland surface samples were prepared when the subsurface wetland samples were prepared (see below).

The concentrated pollen and spores were not stained. Silicone oil was used as the mounting medium, so that the orientation of the grains could be changed during examination, especially for critical identification such as for the Gramineae. Silicone oil has many favourable features for viewing palynomorphs microscopically. These features include a low refractive index (1.40 at 2000 centistokes viscosity), availability in a wide range of viscosities, non-volatility, and chemical purity and stability. Moreover, pollen grains mounted in it do not swell as they do in glycerine and glycerine jelly (Andersen 1960, 1978; Whitehead 1961). Mounting techniques are described in Appendix II.

Identification of palynomorphs followed the procedures outlined below. Palynomorphs were counted along evenly spaced traverses of the microscope slide until at least 400 grains had been counted; in one exceptional case many slides were counted before a total of only 200 grains was reached, due to sparse pollen. Identification and calculation of abundance of charcoal particles followed the procedures outlined below for the subsurface samples.

2.3 Fossil pollen study

The three pollen-analysed wetlands were found by examination of air photographs, 1:50 000 topographic maps, reconnaissance by car, and revisiting wetlands where preliminary palynological investigation had been done the previous year by members of the Grevena Project.

2.3.1 Field techniques

The main aim of fieldwork was to collect uncontaminated samples of the deposits for pollen analysis, to define as exactly as possible the conditions under which the samples were taken, to determine sediment types of the deposits, and to explain the origin of the stratigraphy. Additional aims, described in other sections, were to describe the present vegetation of the site, make a floral list, survey the plant communities of the surrounding area, and note the geology and geomorphology of the surrounding area.

2.3.1.1 Sampling equipment

Four different types of samplers were used to explore the stratigraphy of the wetland sites and collect cores for pollen analysis, depending upon the texture (organic and minerogenic content), water content, and consolidation of the sediment: stationary piston corer; Russian corer; Hiller corer; and soil auger (Wright *et al.* 1965:494-509; Aaby & Digerfeldt 1986:182-7; Faegri & Iversen 1989:60-5; Moore *et al.* 1991:31-4).

The stationary piston corer is end-filling and superior to side-filling corers, such as the Russian and Hiller corers, for the collection of uncontaminated cores for pollen analysis. With the stationary piston corer an undisturbed continuous core can be extracted. The outside surface of the core is smeared along the whole length of the jacket, but this thin smear can be easily removed in the laboratory. The continuous core allows study of the entire sediment and pollen sequence. Unfortunately, although it works well in homogeneous fine grained sediments, this type of corer is unsuitable for very fibrous, very compact or very fluid deposits.

For the collection of pollen cores in Grevena, a modified Livingstone stationary piston corer was machined in Victoria University workshop using specifications of Walker (1964). The major modification is in the mechanism that holds the piston in place while the sampler is inserted to the required depth ready for driving. Retractable pins at the bottom of the piston have been replaced by a long shaft mounted above the piston, which is locked into position with lugs until sampling begins, then released by rotating the piston rod. The principles of construction and operation are described in detail in Walker (1964), Deevey (1965:521-529), Wright *et al.* (1965:498-506), Aaby & Digerfeldt (1986:184-7). This particular corer had a

100 cm long chamber, with an internal diameter of 47 mm. The internal diameter of the removable cutting shoe at the open end of the chamber was 45 mm.

The Russian corer had a chamber with D-shaped section 5 cm in diameter and 48 cm long. The Hiller corer had a cylindrical chamber of 3 cm diameter and a length of 50 cm with a cone shaped bottom and was used for reconnaissance sampling only. The operation of these samplers is described in detail in Aaby & Digerfeldt (1986:182-1984), Faegri & Iversen (1989:60-63), and Moore *et al.* (1991:31-3). The soil auger had a 5 cm diameter and 20 cm long chamber and was used only where sediments were too stiff to penetrate with the other samplers (Wright *et al.* 1965:508-9).

2.3.1.2 Wetland profiles

Before the most suitable location for extracting cores for pollen analysis can be chosen, something of the origin and history of the wetland must be known, so that the general shape can be deduced (Faegri & Iversen 1975:98). Usually the deepest deposits of the wetland are sampled, where least erosional loss has occurred and the most complete section through the deposit occurs. At the Gomara site it was apparent that the wetland filled a small basin, and chances of erosional loss were small (Faegri & Iversen 1989:57), so a core was taken close to the centre of the basin, after only a couple of exploratory cores had been checked for stratigraphic integrity (Faegri & Iversen 1965:491; 1989:57).

At Anelia and Kellia the origin and history, and thus the shape, of the wetland was not immediately obvious from surface evidence. Therefore, the profiles of these two wetlands were more fully investigated, so that stratigraphic cross sections, or profiles, could be drawn. First, a transect through the longest axis of the wetland was investigated, then a transect at 90° to it through the centre of the wetland. The Anelia wetland was probed at 5 m intervals, along the two intersecting transects, to find the base of the wetland, then exploratory cores were extracted with the Hiller corer at 10 m intervals, to examine the stratigraphy. At Kellia, the Hiller corer and soil auger were used to extract cores for examination at mostly 10 or 20 m intervals. The composition and texture of the sediments were described by observation and feel; the colour by using a standard Munsell soil colour chart (Oyama & Takehara 1967). A Brunton pocket transit was used for levelling. From these data the shape of the wetland could be determined and the best position for the extraction of cores for pollen analysis selected.

2.3.1.3 Extraction of cores for pollen analysis

Sampling of the wetlands was done either from the sides of pits dug into the wetland, or by use of one of the hand-operated samplers described above: stationary piston and Russian corers or a soil auger. Successive retrieval of material was necessary to extract deposits to the

base of each wetland sequence. Sampling alternated between two adjacent holes, an overlap being maintained between successive samples.

The preferred method of collecting pollen samples in peat deposits is by cutting vertical pillars, or monoliths, from exposed profiles (Faegri & Iversen 1989:58-60). This method avoids the sediment distortion, compression, and contamination associated with use of coring devices. The upper peaty material of the sequences at Anelia and Kellia was collected in this manner. A large hole was first dug to expose a face, then an approximately 15 cm square monolith was cut with a sharp knife from the top of the sequence to the bottom to reduce the risk of contamination (Faegri & Iversen 1975:87). At Anelia one continuous monolith was cut down to 110 cm, while at Kellia four overlapping monoliths from two contiguous columns were cut to a depth of 215 cm. The monoliths were wrapped tightly in polythene sheet and sealed with plastic tape for removal to the field laboratory.

Where possible, deposits beneath the peaty material were collected with the stationary piston corer, the preferred corer for collection of pollen samples. At the Kellia site, the piston corer was used to extract a core from 2-3 m. Below this the deposits were very stiff, so the soil auger was used to retrieve the remainder of the core. At Anelia the Russian corer was used alternately with the piston corer (in alternate holes), down to 2.40 m. The lowest 10 cm were retrieved with the soil auger. Corers were cleaned between each sampling with clean water and paper towelling.

The piston corer was used to extract the wetland sequences from Gomara and Mirsina. The cores were extruded from the piston corer in the field into longitudinally split 48 mm internal diameter rigid plastic tubing, which was lined with a strip of polythene sheet. The polythene sheet was sealed immediately with plastic tape (to avoid moisture loss), and wooden plugs were placed between sections of uncut core and at the ends of the tubes. The plastic tubes were then sealed and labelled with the site name, indication of upper end of the core, initial depth, final depth, and length of core. The cores were then ready for packing into boxes for shipment to New Zealand.

All the deposits collected for pollen analysis (except those extracted with the piston corer) were cut and packaged for shipment in the field laboratory, to ensure stratigraphic integrity of the samples would be maintained. To reduce contamination of the pollen samples, 2 cm slices were cut away from the outside of monoliths, and smaller amounts were cut away from the outside of samples collected with coring devices. Profile samples (about 30 cm long, 10 cm wide, and 2 cm thick) were first cut from the face of monoliths, then the monoliths were cut horizontally into 1 cm thick slices. The remainder of the samples for shipment were also cut into 1 cm slices. Care was taken not to cross-contaminate samples. The knife was cleaned between each cut with paper towelling, which was discarded after each cleaning. These

samples were all packaged in zip-lock plastic bags and placed in square plastic containers with airtight lids to avoid moisture loss. The samples were shipped to New Zealand.

2.3.2 Sediment analysis

The aim of the sediment analysis was to obtain information that would elucidate the origin of the sediments, the environment in which they were deposited, and events occurring in the catchment area. Information provided by the character of the deposits is integral to the study – it both provides supplementary evidence and aids in the interpretation of the past environment derived from pollen analysis. For example, plants forming a deposit will probably have produced their own pollen, whereas sediments originating from eroded material will bring pollen and spores from the parent material. Further, the physical and chemical characteristics of the deposits influence the state of preservation of palynomorphs.

Stratigraphic analysis and sediment analysis are two facets of physical description of sediments of a wetland site. Stratigraphic evidence is based on the stratigraphy of the entire swamp/basin in which the pollen core was collected. As described above, transects bored across two of the wetland sites to obtain a stratigraphic cross section (profile) assisted with interpretation of the stratigraphic history of these basins and thus the sequences of the pollen-analysis cores.

Detailed field descriptions and laboratory analyses were undertaken so that the sediments could be described following the Troels-Smith classification system for unconsolidated sediments (Troels-Smith 1955). In the field at the time of core collection details of the component elements, physical properties, humification, and colour (with a Munsell colour chart) were recorded (Oyama & Takehara 1967). In the laboratory, field descriptions were checked and refined during subsampling; and again after laboratory analyses had been done. Laboratory analyses included testing the degree of humicity of organic matter with an alkali solubility test and measuring the proportions of the major components moisture, organic matter, carbonate, and non-carbonate inorganic matter using a Leco carbon analyser (Davis 1976:141; Nelson & Sommers 1982).

In addition, the flora of the wetland was recorded at the time when the sediment samples were collected so that a correlation could be made among the deposit-forming plant communities, sediment type, and wetland trophic state.

2.3.2.1 Sediment description

The sediments are described in detail so that the maximum amount of environmental information can be extracted. Because of the predominantly organic character of the sediments, the Troels-Smith classification system for unconsolidated sediments is used

(Troels-Smith 1955). This is not an exact characterization, but a semi-quantitative estimation based on observation. An advantage of this classification system is that it is purely descriptive and does not require a knowledge of the origin of the sediments prior to description, although origin of the sediments can be deduced from these descriptions. Other advantages include the possibility of describing admixtures of elements, and producing standard formulas to describe the sediments. A detailed description of the terms used in this classification system can be found in Appendix III.

Troels-Smith suggests using a standard colour chart to describe the exact colour of the sediments. The Munsell system, Standard Soil Colour Chart was used (Oyama & Takehara 1967).

Sediments were first described in the field by the scheme outlined above. During subsampling in the pollen laboratory descriptions were checked and additions made, mostly of macrofossils, e.g. gastropods and seeds. Additional observations were made on degree of humification during chemical processing of pollen samples. Every pollen sample was treated with alkali in which humic acids (products of decomposition) are soluble: 10% potassium hydroxide (KOH) solution was added to the samples, which were placed in a boiling waterbath for ten minutes. The colour of the extract after boiling was compared to those on the Munsell chart: highly humified samples produce a brown or blackish brown extract, while those little humified produce straw-coloured or colourless extracts. Description of the sediments is also based on other laboratory analyses described below.

For each wetland site a stratigraphic column has been drawn, with symbols indicating the major component elements and the proportions in which they occurred, the accessory elements, the degree of humicity of the organic matter (unless *detritus*), and the degree of definition of boundaries between strata (*limes*) (the columns are included in the pollen diagrams in simplified form.) To the side of each column is a formula also indicating the relative proportions of the major component elements and the degree of humicity of the organic matter (*humositas*). The fresh colour of the sediments, as noted in the field according to the Munsell chart, is also noted as well as structural properties of the sediments (*structura*). Additional columns have been drawn showing the physical properties of *nigror*, *stratificatio*, *elasticitas*, and *siccitas*.

2.3.2.2 Moisture content

Water content varies widely according to depositional environment. General decrease in water content with depth in sediment cores is due to compaction, but vertical variation in the water content also depends on other factors, such as the rate of sedimentation, the particle

size and composition of the deposits, and the degree of bioturbation (Bengtsson & Enell 1986:427).

Moisture loss from the time of collection to the time of analysis was avoided as much as possible by wrapping samples in plastic and placing them in airtight containers. They were stored at 5° C once they reached New Zealand.

The moisture content was measured by calculating weight loss between the original state of the sediment and after oven-drying. This was accomplished in the following manner. One cc of wet sample (in its natural state) was subsampled with a 1 cc disposable syringe with the needle cut off. The sample was immediately placed in a tared 50 ml centrifuge tube with an airtight cap and weighed on a Mettler PE 360 single pan electronic balance with precision to 0.001 g. The sample was then dried in an oven at 50° C for 24 hours, placed in a desiccator to cool, then weighed again. The loss in weight represents the moisture content. The moisture content was calculated as a percentage of the wet weight ('natural state' of the sediment):

$$\text{Moisture content} = \frac{(\text{wet weight} - \text{dry weight}) \times 100}{\text{wet weight}} \%$$

2.3.2.3 Bulk density

The bulk density (dry density) is often measured to indicate the degree of decomposition of peat materials. As decomposition proceeds, the size of organic particles decreases, resulting in smaller pores and higher bulk density (Boelter 1969:607; Keys 1982:120). It also reflects the proportions of organic matter to inorganic matter in mixed sediments. Organic matter has densities of less than 0.4 g/cc. As organic matter decreases the value of this ratio increases. Many peats (composed almost entirely of organic matter) have bulk densities of 0.5 g/cc or less, while the average density of mineral soils is about 1.25 g/cc.

The term bulk density (dry density) refers to the weight of oven-dry material held per unit volume of material in its natural state (Klemetti & Keys 1982). This should be contrasted with the bulk density (wet density) based on the wet-sample weight (Bengtsson & Enell 1986:427).

The bulk density was calculated on an oven-dry weight-wet bulk volume basis, using the measurements detailed above, as follows:

$$\text{Bulk density} = \frac{\text{weight of oven-dried sample}}{\text{volume of sample in 'natural state'}} \text{ g/cc}$$

2.3.2.4 Organic content

To determine the organic content of the sediments, the elemental carbon content was determined by using a Leco RC-412 multiphase carbon analyser (Dean 1974:247; Nelson & Sommers 1982). This was achieved by drying about 5-10 cc of wet sample at 100° C. The dried sample was ground with a mortar and pestle to a fine powder. A small amount (usually much less than a gram) of the powder was placed in a 'boat' and weighed immediately prior to placing it in the analyser furnace. The furnace chamber was heated to 550° C for 6 minutes while oxygen was added (Ball 1964; Davis 1976). On ignition of organic matter, carbon dioxide was evolved and measured by infra-red analysis. This machine expresses results in the form of elemental carbon as a proportion of the dry weight of the original sample (percent dry weight).

Inspection of the elemental carbon values obtained from the Leco carbon analyser indicated that a 47% elemental carbon value correlated to 100% organic matter in the sediment, suggesting that a conversion factor of 2.13 should be used to convert the instrument values to organic-matter content (as a proportion of dry weight). This conversion factor is the same as that found by Dean (1974:244) when he compared loss on ignition (at 550° C) values with those of organic carbon determined chromatographically.

Values were corrected to a wet-weight basis using the moisture contents previously determined. As a check, duplicate samples from the Gomara core were measured. Degree of reproducibility was good, the difference between samples usually being less than 1 percent.

2.3.2.5 Carbonate content

Carbonate content was also determined by measuring evolved gas in the Leco RC-412 multiphase carbon analyser (Dean 1974:247). This was achieved by leaving the sample in the furnace after the organic carbon had been burnt, increasing the temperature of the furnace from 550° to 900° C, and holding it at that temperature for 3 minutes (Nelson & Sommers 1982).

The analyser expresses the results in terms of elemental carbon as a percentage of dry weight of the original sample. Assuming the carbonate to be all in the form of calcium carbonate (CaCO_3), the percentage of carbonate on a dry weight basis is obtained by multiplying by the molecular weight ratio 100/12 (8.33). Values were corrected to a wet-weight basis using the moisture contents previously determined.

Duplicate samples from the Gomara core were put through the analyser, and good reproducibility was again demonstrated.

Samples were also tested during pollen preparation with dilute hydrochloric acid (HCl), and the presence/absence of resultant effervescence of carbon dioxide was recorded.

2.3.2.6 Non-carbonate inorganic content

Inorganic matter was calculated by subtracting the sum of the three measured components above (organic matter, carbonate, moisture) from the total, and expressed as a percentage.

$$\text{Inorganic matter} = \frac{100 \times (\text{total wt} - (\text{organic matter wt} + \text{carbonate wt} + \text{moisture wt}))}{\text{wet weight}} \%$$

2.3.2.7 Tephra analysis

The wetland sediment sequences were examined for the presence of chronological markers such as abrupt stratigraphic changes, e.g. tephras. In the Gomara sequence a band of fine-grained sediment between 108.2 and 107.2 cm below ground surface was examined by Mr John Carter, Geology Department, Victoria University of Wellington, for the presence of glass shards. An attempt was then made by Mr John Paterson, Victoria University of Wellington, to identify the volcanic eruption from which the tephra had derived by determining the chemical composition of the glass shards.

2.3.3 Plant-macrofossil identification

Plant macrofossils are direct evidence that the particular plant was present nearby. Plant macrofossils are complementary to pollen data for reconstructing local plant communities, as they are not generally dispersed far from their source. Resources did not permit a detailed macrofossil analysis, however: only obvious, larger, fruits encountered during sediment description were identified.

2.3.4 Miscellaneous micro- and macrofossils

Other fossils likely to be preserved in the sediments besides pollen and spores, such as diatoms, ostracods, and gastropods were searched for where appropriate.

Diatoms, unicellular algae with silica tests, are useful as palaeoecological indicators, as they have distinct ecological tolerances determined by such conditions as water depth, pH of water, and nutrient level. Several samples from both upland mires were tested for the presence of diatoms. No diatoms were found in the samples from the Anelia site, but abundant diatoms were found at the Gomara site. Ten samples of 0.5 gm were analysed from the Gomara core. The diatoms were identified and counted by Dr Margaret Harper, Geology Department, Victoria University of Wellington. The extraction technique is detailed in Appendix II.

Ostracods, minute crustaceans with calcified shells, are best preserved under calcareous or saline conditions. It has been demonstrated that they are useful as ecological indicators

(Delorme 1969; Delorme *et al.* 1977). The sediment of the lower parts of the Kellia sequence appeared to be suited to the preservation of ostracods. Two samples at 3.91-3.92 m and 3.35-3.36 m were analysed by a staff member of the Geology Department, Victoria University of Wellington, Stephen Eager, but no ostracods were found.

Molluscs are reliable indicators of local habitat conditions near the site of deposition, but not of regional conditions, as they can occupy locally favourable microhabitats in generally unfavourable conditions. Freshwater molluscs thrive best in alkaline situations where there is a readily available supply of calcium carbonate for their shells. Their shells are also preserved best in such conditions (Birks & Birks 1980:121). Molluscs are useful indicators of the destruction of woodland and the creation of grassland habitats (Birks & Birks 1980:127). Gastropods were noted in the lower sediments of the Kellia sequence but not specifically identified.

2.3.5 Radiocarbon dating

The establishment of accurate age control within the wetland sediment cores is important for temporal and spatial correlation of events and for analysis of rates of change. Chronologies are based on a series of dates obtained from radiocarbon dating. A total of 13 radiocarbon dates are provided: 5 for Kellia, 3 for Anelia, and 5 for Gomara. (Two dates were also obtained from the Mirsina sequence.) All material dated was taken from within the core sediments used for pollen analysis. Initially, two samples were dated from each core, one near the bottom and one at intermediate depth, to determine the age range of the sediments. After identification and counting of palynomorphs further dates were obtained to date more precisely particular events seen in the pollen record.

The first set of 8 samples were sent to two different radiocarbon-dating laboratories. Seven samples were submitted to the University of Waikato radiocarbon-dating laboratory, Hamilton, where the liquid-scintillation technique is used (Hogg 1989), and one, which contained only a small amount of carbon, to the Rafter laboratory, Institute of Geological and Nuclear Sciences, Lower Hutt, where accelerator mass spectrometry is used (Lowe & Judd 1987; Wallace *et al.* 1987). Subsequently 7 samples were submitted to the Rafter radiocarbon-dating laboratory, for dating using accelerator mass spectrometry. The radiocarbon ages of these samples were compatible with those from the laboratory using the liquid-scintillation technique.

2.3.5.1 Pretreatments

All pretreatments carried out were done by the dating-laboratory technicians. Pretreatments usually carried out at the Rafter laboratory for peats, soils, charcoals, leaf litter, and degraded woods consist of leaching with dilute hot (80° C), 2N hydrochloric acid for 15-30 minutes to remove carbonates; rinsing with distilled water to a neutral pH; treatment with dilute alkali solution (0.1M sodium hydroxide and sodium pyrophosphate) for 15-30 minutes at 80-90° C to extract humic acids; and subsequent washing with distilled water to a neutral pH. Finally, the insoluble fraction from the alkali treatment, humin, is acidified to remove carbon dioxide absorbed during the alkali treatment; rinsed with distilled water to a neutral pH; and oven dried (Goh & Molloy 1972). The acid and alkali treatments are repeated if necessary. The samples are centrifuged or filtered and oven-dried between each step.

Two samples from lake sediment and two peat samples from a bog, dated at the University of Waikato dating laboratory, received no pretreatment: Gomara 81-87 cm; Gomara 186-190 cm; Anelia 81-83 cm, and Anelia 240-245 cm. Two organic samples from the Kellia calcareous fen, 166-168 cm and 296-307 cm, were pretreated with acid washes (0.5M HCl at 80° C) for 1 hour, then washed thoroughly with distilled water. These were also dated at the University of Waikato.

Sediment samples dated in the Rafter laboratory contained less organic material than those dated in the University of Waikato dating laboratory so required careful pretreatment. Where possible plant material was removed from the sediments for dating, then treated consecutively with hot solutions of acid, alkali, and acid, as described above. The samples treated in this manner were: Anelia 124-125 cm, Gomara 156-157 cm, and Kellia 71-72 cm. The remaining samples had little visible plant material, so they were ground and then treated consecutively with hot solutions of acid, alkali, and acid. Thus the humin fraction (acid and alkali insoluble) of the entire sediment was extracted and dated (Goh & Molloy 1972). Samples treated in this manner were: Kellia 315-316 cm, Kellia 394-395 cm, Gomara 52-53 cm, and Gomara 111-112 cm.

It is assumed in this study that all the samples dated in this method formed in isotopic (^{14}C) equilibrium with atmospheric CO_2 , so no allowance has been made for reservoir effect. Although the samples from Gomara are from lake sediments, the lake was very small and probably shallow, so the reservoir effect is probably absent. Also the contribution of submerged plants, which if present would result in a radiocarbon age too old, was probably minimal.

Many samples dated could have contained organic matter washed in from the surrounding catchment, some of which could have been older than the contemporary vegetation. This kind of contamination would be most likely in the inorganic samples from

the Kellia site, less likely in samples from Gomara, and least likely in the peat samples of Anelia.

The samples from Anelia and Kellia, which are spring-fed wetlands, may have been subject to ground water with either an elevated or depleted carbon content.

2.3.5.2 Calibration

The dating of these samples was done over the course of some years, and the results of the radiocarbon ages were reported differently. Furthermore, atmospheric radiocarbon is modulated by the geomagnetic field, causing long-term variations and cosmic ray intensity causing short-term variations (Stuiver 1971, 1980; Webb & Webb 1988; Aitken 1990). To standardize the results, correct for secular variations, and convert the radiocarbon years to calendar years, all the conventional radiocarbon ages that had been determined and reported by the radiocarbon-dating laboratories were calibrated. The conventional radiocarbon ages based on the half-life of 5568 years were normalized to $\delta^{13}\text{C} = -25$ per mil in the PDB-scale and related to the international dating standard.

The computerized calibration program of Stuiver and Reimer (1993), CALIB 3.0.3c (revised version 1995), available on the Internet at the University of Washington ftp site, was used. CALIB runs on any IBM compatible computer with MS-DOS and at least 480kB available memory.

CALIB converts the radiocarbon age to calibrated calendar years. It yields single or multiple calibrated ("Cal") AD/BC (BP) ages that are compatible with a certain ^{14}C age, the range(s) of calibrated ages that correspond(s) to the standard deviation in the ^{14}C age (and calibration curve), and the probability that a certain calibrated age is the actual sample age. An option to calibrate selected radiocarbon ages by a simple intercept with a linear interpolation of the data points is also available. That option was not chosen. The conventional radiocarbon ages and calibration results are presented in text and graphs, edited output from the program, in Appendix IV.

Calibration is based on the Seattle-Belfast bidecadal calibration curve derived from the radiocarbon age of tree rings of known age (Pearson & Stuiver 1993; Stuiver & Pearson 1993). The ^{14}C age errors are small because most bidecadal data points were obtained by averaging two Seattle decadal ^{14}C ages and one Belfast bidecadal ^{14}C age. It is assumed that the radiocarbon age of these trees from the northern hemisphere would be very similar to the radiocarbon ages of coeval samples from Grevena, and that there would be no systematic difference.

The radiocarbon-age error reported by the Rafter radiocarbon laboratory comprises statistical errors in sample and standard determinations, as well as a system error component of 0.6, so a laboratory error multiplier (K) of 1.0 was chosen. On the other hand, the reported radiocarbon age error margin from the University of Waikato of ± 1 standard deviation was based on counting statistics alone, so a laboratory error multiplier (K) of 1.6 was chosen to increase the standard deviation for samples dated in that laboratory (Stuiver & Pearson 1986:807).

To smooth the calibration curve and minimize multiple calibrated age ranges for samples spanning more than 30 years, a weighted moving average of the data set was used. Samples with an estimated calendar-year span of 30 years or less were calibrated without any smoothing.

Two radiocarbon dates, in addition to those reported above, were obtained on samples from the Mirsina wetland. Samples were sent to the two dating laboratories used for this study. The upper sample, 94.5-100 cm, was sent to the University of Waikato radiocarbon dating laboratory and the basal sample, 328-331 cm, to the Rafter radiocarbon dating laboratory. Pretreatment of the basal sample was carried out in the Rafter laboratory and consisted of extracting plant material by wet sieving, then washing the plant material in hot water and acid. A radiocarbon age of less than 100 years was obtained. The upper sample received no pretreatment and also gave a 'modern' radiocarbon age. No further analyses were undertaken on this sequence.

Radiocarbon ages are expressed as ^{14}C years before 1950 AD (years BP) and calendar ages are expressed as years Cal BC or AD.

2.3.6 Laboratory preparation of fossil pollen samples

Sediments for fossil pollen analysis were processed so that the actual numbers of palynomorphs in a sample (concentration) could be calculated as well as the relative frequencies. This required precise subsampling and special procedures and care during extraction procedures and counting of grains on microscope slides. To avoid volume or biochemical changes between field collection and subsampling, wetland samples were stored in a cool store at 5° C in the Biological Sciences Department, Victoria University of Wellington.

2.3.6.1 Subsampling

High-precision measurements of wetland sediment samples were taken so that calculations could be made of pollen concentrations, the number of grains per unit weight or volume of wet (fresh) sediment, could be calculated (grains/cc or grains/gm) (Birks & Birks 1980:206). Samples were subsampled volumetrically and weighed.

Subsampling was done in the palynology laboratory of the Geology Department, Victoria University, where an air filtration system had been fitted.

Two different methods were used to determine palynomorph concentration, a direct method (aliquot method), which estimates the actual number of palynomorphs in a sample, and an indirect method, which relies on the addition of a known concentration of exotic marker grain or tracer (Benninghoff 1962; Davis 1965, 1966; Matthews 1969; Bonny 1972). Both methods require precise measurement of a volume or weight of sample.

The cores collected with the piston corer were shipped to New Zealand intact, so after removing the surface smear of disturbed sediment, transversely with a sharp knife, the length of the core, lithology, and stratigraphy were checked against field notes. These cores were then sliced into equal units in the laboratory at Victoria University just prior to subsampling. Because the cores were collected with the removable cutting shoe attached to the bottom end of the piston corer and the internal diameter of the chamber is greater than the internal diameter of the removable shoe, depths within core segments had to be adjusted to compensate for the reduction in length of the sediment. Slices of 1 cm 'true' length were cut.

Samples were chosen for analysis from these slices and those cut in the field laboratory. Generally samples were taken at 5 cm intervals. The selection of samples was based on a combination of uniform and structural subsampling principles (Bengtsson & Enell 1986:424). Initially, a uniform 5 cm interval was chosen, but where changes in sediments occurred within that interval samples were taken at closer intervals, so that all sediment types are represented. This resulted in all samples from Kellia being either 5 cm or less apart except between 2.95 and 3.05 m where an interval of 10 cm exists because the sample at 3.00 m was used for radiocarbon dating. The Anelia sampling interval is 5 cm or less, except in the upper 1.00 m, where radiocarbon dates showed that deposition may have been extremely rapid, so the sampling interval was increased to 10 cm. The sampling interval for the Gomara site is 5 cm or less, but samples above 25 cm, except the surface sample, were not analysed since the top 25 cm of the lake had been trampled and was dry and cracked. This resulted in 82 samples from Kellia, 39 from Anelia, and 36 from Gomara: a total of 157.

All wetland fossil pollen samples were volumetrically measured and weighed before laboratory processing. Two subsamples of 1 cc each were taken from the centre of the slices chosen for analysis, one for pollen analysis, and one for sediment analysis (see above).

Subsamples were taken from the wet slices with a disposable 1 cc syringe with the needle cut off. The samples were immediately extruded into weighed 50 ml polypropylene centrifuge tube with airtight screw top lids. The centrifuge tubes plus the samples were then weighed to 0.001 g precision using a Mettler AK160 scale. The difference between the wet weights of the duplicate pairs averaged 1% of the mean weight of each pair for the Gomara and Anelia cores and only 0.5% for the Kellia core. The samples remained in these centrifuge tubes in a cool store at 5° C to discourage biochemical activity, until extraction or sediment analyses were carried out.

The subsampling with the 1 cc disposable syringe was relatively easy where the sediment was not very fibrous, but it was much more difficult and time-consuming where the sediments were fibrous, e.g. the top one metre of Anelia and almost the entire Gomara sequence.

2.3.6.2 Palynomorph concentration calculation

Pollen concentrations reflect more closely the actual plant populations in the past than proportional pollen frequencies. They give information on the absolute abundance of each pollen taxon that is not dependent upon fluctuations in other taxa.

2.3.6.2.1 Aliquot method

The direct method or aliquot method, described by Davis (1965, 1966) is based on methods described by Erdtman (1943). This method was used for samples from the Gomara site where palynomorphs were abundant.

The precisely measured volume of wet ('fresh') sample was processed in the laboratory to extract palynomorphs as described below, and the residue remaining after the extraction process was suspended in a known volume of tertiary butyl alcohol (TBA). Aliquots of known volume were withdrawn from this suspension and mounted on a microscope slide in silicone oil. This is described in detail in Appendix II.

The number of pollen grains in the original suspension is derived from the number of grains found on the slide. A significant error could be introduced in this method by using aliquots of small volume. This error is reduced by diluting the sample with a volatile liquid to a size where aliquots can be measured more accurately (Davis 1965:674).

All pollen grains should be counted on the microscope slide. This means that assumptions must be made initially concerning the approximate pollen density so that a reasonable dilution and aliquot volume can be estimated. Initially a few test slides were processed, then estimates were made from counted slides before processing subsequent samples.

2.3.6.2.2 Exotic marker grain (tracer) method

The indirect method, exotic pollen or tracer method, described first by Benninghoff (1962) and subsequently tested and described more fully by Matthews (1969), Pennington & Bonny (1970), and Bonny (1972), compares the ratio of the number of native fossil pollen grains to the known number of exotic marker or tracer pollen grains (or other appropriate particles) added to a known volume of sediment prior to preparation. During analysis the tracers are counted with the native pollen of the sample. All subsequent abundance determinations can then be carried out in relation to counts of the tracer grains.

$$\text{Fossil pollen concentration} = \frac{\text{fossil pollen counted}}{\text{exotic pollen counted}} \times \frac{\text{exotic pollen added}}{\text{sample size}}$$

This method was used for all three wetland sites.

The first requirement for this technique is a suspension of known concentration of an exotic marker grain (or other marker particle) of an appropriate size, which disperses easily in a suspension medium and does not agglomerate into clumps, is easily recognized to the observer, and does not occur naturally in the pollen sample. *Lycopodium* spores were chosen as the exotic marker because they do not occur in the flora of Grevena and are easily recognized and of a suitable size. A spike of *Lycopodium* spores with a concentration of 82900 *Lycopodium* grains/ml was prepared. Briefly the preparation consisted of acetolysis to rid the spores of waxes, oils, and protoplasm; staining; suspending the spores in a known volume of suitable liquid; then calibrating the concentration of the spores in the suspension. Calibration was achieved by mounting microscope slides with a known volume of the suspension, then counting all the spores on the slide. Stockmarr (1973) found that this method of calibration gave almost identical results to calibrating with a Coulter counter (Stockmarr 1973:89). Appendix II details the preparation procedures.

Aliquots of known volume of the *Lycopodium* suspension were added to samples before extraction was begun, so any fossil grains lost during processing would be accompanied by an equivalent loss in the exotic grains, and the overall proportion of fossil grains to exotic grains would remain unchanged. A tally was kept of the number of *Lycopodium* spores encountered during counting of microscopic slides made from a prepared pollen sample. The pollen concentration of any taxon or of total pollen in a given sample could then be determined as above.

The number of marker grains to be added to a sample depends upon the expected pollen density in the fossil sample. As pollen density varies widely, often according to sediment type, several samples from different sediment types were mounted and counted, so that the approximate number of *Lycopodium* spores to be added could be estimated. The ideal goal,

according to Maher (1981) is two exotic grains for each fossil native grain, although Berglund & Ralska-Jasiewiczowa (1986:456) have found that the relationship of counted fossil pollen /counted exotic grains should be about 1:1. *Lycopodium* spores were added at an estimated ratio of 2 exotic grains for each fossil grain.

2.3.6.3 Extraction

Special attention was paid to prevent contamination of these samples because of the paucity of palynomorphs in some sediments and the abundance of aerial pollen in New Zealand that belongs to the same types as those occurring in Grevena.

Extraction techniques usually vary according to the characteristics (e.g. lithology, compaction, age, degree of weathering) of the material from which the palynomorphs are being extracted. Although the characteristics of the sediments from the Grevena wetlands varied from organic to mineral, only one set of extraction procedures was followed, to reduce differences in proportions of species between samples.

A known volume (and weight) of sediment, in this case 1 cc, of sample in its original state was placed in a 50 ml centrifuge tube, then a known volume of the exotic marker (*Lycopodium* spores) was added to the tube. The extraction procedures that followed were standard methods outlined above (Appendix II).

2.4 Pollen identification and counting

In modern pollen analysis it has become clear that palaeoecological interpretations are much enhanced by a detailed determination of pollen types. Frequently it becomes impossible to key out the fossil types to the species level, but identification of the pollen grains to taxa of the lowest possible rank is highly desirable, so that as many pollen taxa as possible are ecologically meaningful.

Although there are pollen keys of western-European Quaternary pollen floras such as those of Faegri & Iversen (1950, 1964, 1975, 1989) (NW European pollen flora), Beug (1961a, b) (pollen flora of middle Europe), Erdtman *et al.* (1961, 1963) (Scandinavian pollen flora), Moore & Webb (1978) (British pollen flora), Belmonte *et al.* (1986) (Iberian Peninsula pollen flora), Valdes *et al.* 1987 (pollen flora of the Andalucia Occidental), and Moore *et al.* (1991) (mostly British pollen flora), none exists for the Balkan Peninsula. Keys treating special taxonomic or other groups are available, such as Cerceau (1959) – Umbelliferae, Chanda (1962) – Caryophyllaceae, Praglowski (1962) – Swedish trees, Punt (1976-91), Andersen (1979) – Gramineae, and Uberta *et al.* (1988) – *Plantago*. These are also mainly of western European species.

Palynomorph identification was aided by use of a modern pollen and spore reference collection and both a written key and a photographic key of the pollen and spore flora of Grevena.

2.4.1 Reference pollen

A reference collection of pollen and spores representative of pollen and spore taxa likely to be found in late-Holocene palynological samples from Grevena was made to assist with identification of fossil grains. This permitted greater precision in the identification of fossil grains than could have been made with only keys or published photographs, for direct comparisons could be made.

A species list of the recent and extant flora in Grevena was compiled from the following publications: Pouqueville (1826), Leake (1835), Turrill (1929), Tutin *et al.* (1964-80), Wace & Thompson (1972), Sfikas (1978), Polunin & Huxley (1987), Polunin (1988), Huxley & Taylor (1989), Strid (1989), Strid & Tan (1991), and the following unpublished literature from Grevena Project members: Moody & Rackham (1988), Chester (1989a), Chester (1989b), Chester (1989c), Rackham (1991), Moody & Rackham (in prep.), and an unpublished Greek Forest Service report: Adamakopoulos (1989). The species list includes 143 families and almost 800 genera. Specimens for the reference collection were based on this species list.

Throughout this study taxonomic names of vascular European species follow Tutin *et al.* (1964-80). In some exceptional cases, for example where taxa have been described more recently than the publication of the above volumes, taxonomic names follow those used in Strid (1989) and Strid & Tan (1991). Taxonomic names of non-vascular species follow Watson (1968).

The pollen and spore reference collection was prepared from 1517 plant specimens, both dried herbarium specimens and fresh living plants, and lacks few important taxa from the modern Grevena flora. Anthers and sporangia were collected from two herbaria holding world-wide collections; the Natural History Unit, Museum of New Zealand, Wellington (WELT) and the Biological Sciences Department, Victoria University of Wellington (WELTU). Anthers taken from these collections rendered well preserved pollen suitable for comparative identification purposes. Six hundred and thirty-nine herbarium sheets were sampled from WELT and 689 from WELTU.

Living plant material was collected in Grevena. Herbarium specimens were prepared from the plant material (often whole plants) according to Fosberg (1960). Although fieldwork in Grevena was undertaken from the middle to the end of summer, a large number of plants, especially herbs, were in flower. Weeds, particularly those growing in cultivated fields, disturbed areas, and woodland clearings, were sought, as these are particularly important in

interpreting changes in pollen diagrams. Weeds of cultivation are particularly important indicator plants due to the difficulty of distinguishing cereal pollen from that of other grass genera and the low numbers of cereal pollen grains found in pollen diagrams (Faegri & Iversen 1989:127). One hundred and thirty seven plants collected in Grevena had flowers from which pollen was extracted for the reference collection. It was subsequently fumigated and added to the Southern European herbarium collection of the Victoria University of Wellington Biological Sciences Department. A catalogue of the pollen reference slides made from these specimens was deposited with the herbarium specimens.

Living plants were also collected from various gardens in the Wellington area, mainly the Wellington City Council Botanic Garden, but also private and public gardens in Lower Hutt and my own garden in Johnsonville. These were also prepared as herbarium specimens and deposited in the Biological Sciences Department herbarium.

The collection of pollen followed the recommendations of Traverse (1965). The laboratory preparation of the reference collection was undertaken in the Palynology Section of the Institute of Geological and Nuclear Sciences, Lower Hutt. Pollen and spores were extracted from plant material, concentrated, and mounted on microscope slides. Duplicate microscope slides were made. One set of slides of the reference collection is held in the Geology Department, Victoria University, and the other is held in the Palynology Section of the Institute of Geological and Nuclear Sciences, where it is incorporated in their modern pollen reference collection. A detailed description of the laboratory procedures appears in Appendix II.

In addition to the reference material described above, prepared slides (296) were obtained by exchange with Dr Margaret Atherden, College of Rippon & York, York, England, and Dr Tony Stevenson, Newcastle University, Newcastle-on-Tyne, England.

The reference collection is listed in Appendix V. The following data are included: reference collection registration number (VUWG etc. number), taxonomic data (family, genus, species), herbarium collection number (where applicable), and location where the plant grew.

2.4.2 Written key

In the written key pollen and spores of extant plants (those occurring naturally and in cultivation) in Grevena, are described at the lowest possible morphological rank with a light microscope (Appendix VI). Descriptions of the grains were collected from many sources, the main literary sources being the major morphological works of Erdtman (1943, 1952, 1957, 1965, 1969), Ikuse (1956), Erdtman *et al.* (1961), Erdtman *et al.* (1963), Erdtman & Sorsa (1971), Faegri & Iversen (1975, 1989), Belmonte *et al.* (1986), Ferrarini *et al.* (1986), Moore *et al.* (1991), Nilsson *et al.* (1977), various articles in The Northwest European Pollen Flora,

volumes 1-6, edited by Punt (1976-1991, in the key these are referred to by "NW" followed by the volume number), Roure (1985), Valdes *et al.* (1987), and smaller works in the journals of *Grana palynologica*, *Grana*, and *Review of paleobotany and palynology*. In addition, to assist with the description of pollen and spores reference was made to the comprehensive pollen and spore reference collection of local species from plants collected in Grevena and from herbarium specimens. Although this key was made to cover extant species in northwestern Greece, it is likely that it would cover most of the common pollen and spores encountered in Quaternary deposits in the Central Balkans. A full list of species included in each pollen type is given at the end of this key. Unfortunately the morphology of many species still remains unexamined, but the probable morphology of these species can be based on plant taxonomy, allowing them to be placed in the most likely pollen type. These species are listed at the end of each species list and can be identified by the "?" that precedes them. Nomenclature follows *Flora Europaea* (Tutin *et al.* 1964-80).

The purpose of this key is to supply a practical means of identifying pollen and spores without specialist pollen-morphological knowledge. The key is intended for use with a light microscope, mostly with a X40 objective and occasionally an oil immersion X100 objective. The terms *nexine* and *sexine* are used to describe the strata of the exine because the sculptured *sexine* is easily distinguished from the unsculptured *nexine* when viewed with a light microscope, while the *ektekine* and *endexine* layers are difficult to distinguish with a light microscope (Faegri & Iversen 1989:225). The *sexine* is considered to be made up of (from outermost to innermost layer) sculpture element (*sexine* 3), tectum (*sexine* 2), and columella (*sexine* 1). The *nexine* is made up of the footlayer (*nexine* 1) and the *endexine* (*nexine* 2) (Moore *et al.* 1991:64).

Special attention has been paid to closely identifying pollen and spores of particular interest to the archaeologist, e.g. cultivated plants, weeds of cultivation, and plants indicating disturbance of the natural vegetation, especially indicator species. Unfortunately, among the major cereals only *Secale cereale* (rye) and *Zea mays* (maize) are specifically identifiable. *Triticum* (wheat), *Hordeum* (barley), and *Avena* (oats) can be distinguished only to the level of types, including several closely related species, not all of which are or have been cultivated. Other important cultivated species such as *Vicia faba* (broad bean) and *Pisum sativum* (pea) can be identified, but *Isatis tinctoria* (woad) and *Camelina sativa* (gold-of-pleasure), and most other crucifers and legumes cannot be specifically identified. The same pertains to many important weeds and ruderal species.

The key has been modelled on the key in Faegri & Iversen (1989), and a glossary to most terms used can be found in that text. The principle of the terminology is to use terms in a strictly descriptive sense, for example the polar axis is defined as the "unique axis of

maximum symmetry" and not in terms of ontogeny (Faegri & Iversen 1989:219). Some important terms describing aperture shape are *anulus*, *margo*, *costae*, *vestibulum*, and *fastigium*.

The definition of these terms follows Moore *et al.* (1991:71):

anulus – a sudden thickening or thinning of the *sexine* around an ectoporus, e.g. *Plantago lanceolata*;

margo – a sudden thickening or thinning of the *sexine* around an ectocolpus, e.g. *Euphorbia*;

costae – thickening or thinning of the *nexine* around an endoaperture or below the edge of an ectoaperture, e.g. *Polygonum aviculare*;

vestibulum – the cavity formed at the edge of the pore in porate grains when the *sexine* and *nexine* separate, e.g. *Betula*;

fastigium (*geniculus* in van Benthem *et al.* 1984:87) – the cavity formed around pores in colporate grains, e.g. *Quercus*.

In principle the key is binary, but more than two entries at the same level have been used where taxa are very similar. Aperture type, number, shape, and arrangement of apertures, is the major entry in the key. Exine structure and sculpture, as defined by Faegri & Iversen (1989:227-9), are considered next. Because these features vary and are sometimes difficult to discern, some pollen taxa occur in more than one place in the key. After the above features have been considered, measurements given should be considered and used cautiously. During the course of researching the morphology of the pollen and spores included in this key many widely differing measurements were found in the literature for the same pollen and spore taxa. Also different chemical treatments will affect the size of pollen and spores variously (Reitsma 1969). Thus, no particular attention has been paid to the mounting mediums used, and the measurements should be considered approximate. Measurements do, however, give a rough guide to whether the grains are large or small. Occasionally size is used as a distinguishing feature, as for example in *Quercus*, where it has been used prudently. Particular distinguishing features have been italicized.

Spores are placed here in the aperture classes originally devised to separate angiosperm pollen grains, for example pteridophyte spores with one groove are included under monocolpate instead of being in a class on their own, that is, monolete.

The right-hand column gives the ultimate breakdown to taxa. A genus name alone refers to species of that genus only; similarly a species name signifies only that species belongs to the pollen taxon. The addition of the term 'type', abbreviated "t.", implies a pollen morphological type common to several families, genera, or species, as the case may be.

2.4.3 Photographic key

Photographs of pollen and spores were taken using a Carl Zeiss Oberkochen mark III photomicroscope with X40 and X100 oil-immersion objectives; X1.25, 1.6, 2, and 3.2 tube magnification; and Ilford PanF 50ASA and TMX 100 ASA films.

The photographs were mounted on cards with full latin name, common name, and pollen type; morphological details were added with major references to descriptions of the pollen type; and ecological data, including life form and habitat and method of pollination.

2.4.4 Counting

Palynomorphs were identified with a Zeiss Standard LAB 06 microscope, with tube factor X1.25 and phase-contrast capability. Eye pieces with magnification of X10 were used. The objectives used for counting palynomorphs were Plan X40 (non-phase and phase), and an Achromat X100 oil-immersion objective when higher magnification and resolution was required. For regular identifications a total magnification of X500 was used. A 35 mm SLR Olympus 2N camera with automatic exposure was fitted to the microscope so that those grains not identified immediately could be photographed and identified at a later date. Palynomorphs were photographed on Fujicolor Super HGII, 100 and 400 ASA film. A comparison microscope was used to view reference material.

Counting was carried out along contiguous transects of the microscope slides. The scale on an eye-piece micrometer was used as a gauge for advancing the stage. At the completion of each traverse, the stage was advanced a distance equal to the length of the scale. This method of advancement is more accurate than using the scale on the microscope stage as a gauge. All grains that lay within the scale or overlapped the upper edge were counted, those that overlapped the lower edge were not counted. In this way all grains on the microscope slide were counted once.

Within the Gomara sequence, where pollen was less abundant, at least 250 pollen grains representing trees and shrubs were counted, but where pollen was more abundant many more were counted, to maintain a diversity in the count despite the dominance of *Pinus* (Rull 1987:472). In the samples from Anelia and Kellia the pollen content was much lower than in the Gomara sequence, and the dominating effect of *Pinus* was lower. At Anelia, at least 200 grains of trees and shrubs were counted. In the samples from Kellia pollen and spores were counted until about 200 grains of woody plants had been counted (Barkley 1934; Rull 1987).

In the case of the Gomara samples where the aliquot method for calculating pollen concentrations was used, as well as the exotic marker grain method, the entire slide was always counted, but in the samples from Anelia and Kellia, where the exotic marker grain

method only was used, sometimes only part of a slide was counted, if pollen of woody plants was abundant. In these cases, counting transects were spaced evenly over the slide, to avoid a statistically inaccurate sample due to an uneven distribution of pollen under the cover slip (Brookes & Thomas 1968).

Many of the *Pinus* grains were broken at the junction between the body and bladder, so each body or bladder of a *Pinus* grain was counted as $\frac{1}{3}$ of a grain.

2.5 Charcoal analysis

An understanding of fire history is important in evaluating interactions between vegetation, climate, and human disturbances. Analyses were undertaken to assist with reconstructing the intensity, size, and distance of fires from the site of charcoal deposition. Generally, large heavy particles and those with a high ratio of volume to surface area tend to move shorter distances (Patterson *et al.* 1987:5).

To obtain the fire history of each pollen-core site microscopic charcoal fragment numbers, individual fragment areas, and size classes were determined for each pollen sample using a semiautomatic computerized image-analysing system. Relative abundances of charcoal particles in surface samples were also quantified to assist with interpretation of the core sequences.

Microscopic analyses were performed on the same slides as were scanned for pollen. Care was taken not to break charcoal particles during sample preparation by using a vortex stirrer instead of a stirring rod wherever possible (Clark, R. 1984:564). All samples were sieved through a 260 μm mesh sieve before microscope slide preparation: residues retained on the sieve were later inspected by eye to determine relative abundance of large charcoal particles.

The charcoal-scanning equipment consisted of a high-resolution JVC colour video camera mounted on a Zeiss Photomicroscope II with a X16 objective. The camera was interfaced to an IBM-compatible PC and monitor with 486DX processor and 16 Mb of RAM, using an Oculus-TCX video digitizing board (Raine *et al.* 1996). The commercial image-analysis software package Optimas 5.1 was used to access the active image in the digitizing board. Optimas delimits images by colour and brightness; thresholds were set with a 3-colour mode. Charcoal was identified based on optical density (opacity), following interactive adjustments of microscope light intensity, camera sensitivity, and software parameters. Once a set of values had been optimised for charcoal particle discrimination, these were used for all further measurements. The digital image dimensions were calibrated into Optimas by measuring a microscope micrometer slide: for the X16 objective and microscope/camera optical arrangement the imaged area was 245 x 181 μm . Operating information was displayed

on the PC monitor. A second monitor attached to the digitizing board displayed the microscope image. The microscope mechanical stage was positioned by hand.

Under control of an Optimas macro program the system outlined individual particles of interest and performed an initial classification based on average grey value, tagging as "charcoal" those with density and maximum dimension greater than a predetermined threshold (minimum particle size for consideration by Optimas was set at 5 μm). The resulting classified image was then presented on the second monitor for observer approval.

Some workers have found that charcoal concentrations calculated using an automated scanner correlate well with charcoal concentrations determined using standard visual techniques: although visual estimates are usually slightly higher, they display the same variations and lead to the same interpretation. MacDonald *et al.* (1991) have attributed this result to small particles being missed by the imaging system, and to light 'bleeding' at the edges of charcoal particles. Horn *et al.* (1992:8) attributed their higher visual counts to the image analyser missing out-of-focus particles. These workers used a more completely automated system than the system used here, with a mechanical stage positioned by the computer system, but with a set focus. They suggested that improvements to the method could be made by specialised extraction techniques to remove optically dense non-charcoal particles such as mineral grains or darkly stained pollen or plant material. They also suggested using an automatic focus control and thinner-than-normal slides specifically prepared for charcoal scanning, as well as the development of artificial intelligence techniques (which, however, would require more sophisticated hardware and software).

The preparation of special slides and development and availability of elaborate software and hardware were beyond the scope and resources of the present study. The difficulties mentioned above, and also the problem of overlapping particles in dense or clumped slide preparations, were overcome by using a semi-automatic technique, interactively modifying the data being recorded while following the guidelines of Griffin & Goldberg (1979) and R.L. Clark (1984:571-2) for charcoal particle identification. After the image-analysis system completed its initial classification and displayed the result, discrimination of charcoal particles was checked for each frame by viewing the frame area on the monitor and microscope. Particles classed as charcoal, but which through visual examination could be correctly identified as mineral grains, could quickly be reclassified using the computer "mouse" as a pointer. In cases of charcoal-particle overlap, or partly out-of-focus particles being incorrectly outlined, the outline of the charcoal could be traced by hand, again with the mouse. Frames could also be repeated to record particles at different focus levels.

Once an acceptable classification had been obtained (and in most cases the macro produced an entirely acceptable result), a computer keystroke initiated export of particle area,

maximum linear dimension, etc. of the individual charcoal particles to a linked Excel spreadsheet.

To enable abundances of measured charcoal particles to be related to pollen abundances, each pollen-counted microscope slide from the wetland sequences was scanned for charcoal using 100 fields each 245 x 181 μm evenly spaced over the area of the cover slip. (In the case of surface-sample pollen slides, charcoal was recorded in fields spaced 1 mm apart along pollen-counted traverses.) The raw measurement data were tabulated in size classes based on the area of individual particles following a geometric progression: <25, 25-50, 50-100, 100-200, 200-400, and >400 μm^2 (Patterson *et al.* 1987:18). The frequency of the size classes is expressed as a percentage of the pollen sum. Charcoal influx is also calculated for the Gomara site only.

2.6 Pollen-diagram construction

To aid interpretation of the plant taxa represented in the surface and wetland samples, the pollen-analytical data are expressed in a series of graphs or pollen diagrams. The pollen diagrams were produced on an "IBM compatible" personal computer, and output on a laser printer with a PostScript interpreter. Diagrams were plotted using *psimpoll* 2.23 (Bennett 1994). Files include data on: sediment stratigraphy (using the Troels-Smith notation), radiocarbon dates, local pollen assemblage zones, pollen and spore counts, charcoal abundance, rarefaction analysis, and rate-of-change (for the Gomara wetland site only).

Pollen diagrams of wetland sequences are presented by depth and, in the case of the surface pollen study, sample-site name. Pollen diagrams of the wetland sequences are separated into two types: local (wetland) taxa and extra-local and regional (terrestrial) taxa (Janssen 1973). Wetland pollen diagrams include a summary curve showing the ratio of mire to aquatic taxa, and the number of wetland types identified and total number of wetland taxa counted.

Terrestrial pollen diagrams include summary curves showing the ratio of woody plants to herbaceous plants, and of taxa grouped according to habitat preference. The number of pollen grains counted of trees and shrubs, the total number of all terrestrial pollen and spores, and the total of all pollen and spores counted in the sequence (wetland and terrestrial) is given. The number of terrestrial pollen types (not normalized for unequal pollen sums) is also included for each spectrum.

2.6.1 Pollen statistics

In the case of the surface samples, the pollen-analytical data are expressed in relative frequencies only. However, by obtaining absolute data from the wetland sequences, both relative and absolute frequencies of pollen abundance could be calculated, so the changing abundance of plant taxa are illustrated as both relative proportions and absolute concentration (by volume). Pollen influx rates were calculated for the Gomara site only, where a relatively uniform rate of sedimentation has been assumed.

2.6.1.1 Relative frequency pollen calculations

The main pollen diagram for each site is a percentage diagram. In these diagrams the relative proportions of the pollen taxa are expressed as percentages of a pollen sum. Diagrams of this type are the most readily produced, as they do not require knowledge of pollen concentrations or sedimentation rates and in fact smooth out variations in these factors. A further advantage of using percentages is that all components within the pollen sum are less than 100%, whereas many large numbers of certain taxa may have to be plotted on concentration or influx diagrams. The principal and important disadvantage is that each pollen type influences all other types within the sum.

Pollen taxa included in the pollen sum vary according to the question being asked. The pollen sum of the surface pollen study and wetland sequences of terrestrial (extra-local and regional) pollen types includes all identified terrestrial pollen and spore types and excludes obligate aquatic plants and swamp, bog, and fen species (Janssen 1973:36). A pollen sum including only wetland pollen types is used for the wetland (local) pollen diagrams.

2.6.1.2 Pollen influx calculations

The pollen-influx diagram is the most meaningful one in an ecological context, as it allows variations in abundance of the various taxa to be assessed entirely independently, but it can only be calculated where the rate of sedimentation can be deduced (Davis & Deevey 1964; Maher 1972).

Pollen influx (also termed pollen-accumulation rate or pollen-deposition rate), the net number of grains accumulated per unit area of sediment surface per unit time, was calculated for only one site, Gomara, where the rate of sedimentation of the deposit could be calculated with reasonable confidence.

Pollen influx = Pollen concentration x sediment accumulation rate (grains/cm²/year), where the sediment-matrix accumulation rate is the net thickness of sediment accumulated per unit time after compaction and diagenesis (cm/year).

2.6.1.3 Absolute pollen concentration calculations

Pollen concentration diagrams also have the advantage that each pollen taxon can be evaluated separately but are more difficult to interpret than pollen-influx diagrams, for concentrations vary with non-vegetation factors such as changing sediment type and variations in deposition rate. Concentration diagrams were drawn for the two wetland sites of Anelia and Kellia, where the rate of sedimentation is very variable.

2.6.1.4 Zonation

The sequences of pollen spectra have been divided into local pollen-assemblage zones (Hedberg 1976). Zones are based mostly on relative frequency pollen and spore data and are formed to simplify discussion and interpretation of the pollen diagram and facilitate a discussion of the vegetational events and comparison with other pollen sequences. The zone boundaries are placed where change in the pollen spectra is most marked so that the enclosed units are relatively homogeneous. They can be juxtaposed with the climate periods of Blytt and Sernander (considered as chronozones) (de Beaulieu 1982) and cultural periods.

Numerical zonation by the optimal divisive method, using information content (Bennett 1994) was used to assist with the determination of the number of zones to be used and the placement of zone boundaries. The broken-stick model was used to assess the significance of zones based on the structure in the data set, by using a model of random distribution of zones within the sequences as a comparison. Simulation modelling was used to assess the reliability of zone-boundary locations, given the errors of the original data (Bennett 1996). A threshold value of 5% was used (Bennett 1996), but this was reduced to 2% for the diagrams of terrestrial pollen types from the Gomara and Anelia sites, where the pollen of *Pinus* is greatly over-represented, and the remaining subset data were recalculated to proportions of the sum of types included in the subset. Final selection of the best number of zones to be used and the placement of the zonation boundaries was determined by visual inspection and by consideration of influx and concentration data and rate of vegetation change (see below).

2.6.1.5 Palynological richness

The number of taxa recorded per spectrum is of interest, for an opening of a forest canopy above a site of deposition will permit the entry of more light, thus allowing light-demanding plants an opportunity to grow and also permitting entry of a wider variety of pollen taxa, for more of the canopy and regional component pollen types enter the sedimentary environment. Increasing numbers of taxa may therefore indicate canopy opening and may lead to interpretative conclusions about forest catastrophe or human impact.

Palynological richness (diversity) is estimated by rarefaction analysis. Rarefaction analysis standardises the sum on which palynological richness is determined and provides minimum variance unbiased estimates of the expected number of taxa for the standardised sum in each sample (Birks & Line 1992; Bennett 1994). Estimates of palynological richness are shown with 95% confidence intervals.

2.6.1.6 Rate-of-change

Rates of vegetation change were calculated for the Gomara wetland site only. The dissimilarity coefficient of Chi-squared coefficient 2 was used on unsmoothed pollen and spore relative frequency data and calibrated radiocarbon ages (Bennett 1994; Bennett & Humphry 1995).

2.6.2 Pollen taxon groupings

Vegetation communities can best be reconstructed by grouping together taxa with similar known ecological preferences. Groupings are based mostly on results of vegetation surveys and surface pollen analyses in Grevena (see Chapter 3) and data from Turrill (1929) and Ellenberg (1988). The main terrestrial groups are: alpine shrubs, alpine herbs, coniferous and deciduous canopy trees, woodland understorey trees and shrubs, woodland herbs, riverine trees, evergreen woodland trees, plants of open dry rocky habitats, herbs of open ground, and cultivars. Wetland taxa have been divided into two main vegetation-community types: aquatic (open water) and emergent taxa.

A number of problems are connected with arranging ecological groups from pollen types:

- 1) Each pollen type must be assigned to one of the basic groups on the basis of the present ecological amplitude of the species. But the ecological amplitudes may have been different in the past. The climate may have fluctuated in the time span considered here, but the flora was probably not too different from that of today. It is therefore assumed that competition among the various species was similar to that found today, and ecological groups have been so constructed.

- 2) The flora of some plant communities is discrete, but there is overlap between others, for example the floras of steppe and woodland edge have many species or higher taxa in common with weeds of cultivation (Moody & Rackham, in prep.).

- 3) Many pollen types cannot be identified to species level. Pollen types may thus comprise species with contrasting ecological requirements and consequently may be placed in more than one ecological group.

4) An interpretation of pollen assemblages in terms of plant communities largely depends on knowing the source of the pollen grains, i.e. whether or not a pollen assemblage comes from plants that could have occurred together in the area.

5) It is difficult to determine the present ecological amplitude of a species. Comprehensive surveys over the whole range of plant communities in Grevena have not been completed. Thus characteristic and differential species have been determined on the basis of a small part of the vegetation. Comparison of the fossil assemblages with recent plant communities was aided by the work of Dr O. Rackham (Moody & Rackham, in prep.).

Chapter 3. Modern pollen deposition study – vegetation & pollen data

3.1 Introduction

This chapter discusses the flora and vegetation of Grevena and the relationship between the extant vegetation and pollen deposition. First the flora and vegetation of Greece are presented to provide a wider context for Grevena, then the flora and vegetation of Grevena are discussed. The relative dispersal and representation of pollen and spores found in surface samples from the major extant vegetation types in Grevena is presented. Abundance of microscopic charcoal particles recorded in these surface samples is also presented.

3.2 'Natural' flora and vegetation of Greece

It is ninety years since a detailed comprehensive flora of Greece was published (Halácsy 1900-08, in Strid 1989). Unfortunately, the forthcoming *Flora Hellenica* has not yet been published. *Flora Europaea* (Tutin *et al.* 1964-80) represents a milestone in European floristics; it is, however, very brief and Greece is probably the country with least coverage. The two volumes of Strid (1989) and Strid and Tan (1991) provide better coverage of the mountain flora. They describe all vascular plants commonly occurring above an altitude of 1800 m within the borders of present-day Greece, with an emphasis on the mountains in northern Greece. In addition, taxa that only occasionally reach this altitude or are commonly found in open tree-less habitats above 1500 m have also been included but are more briefly treated. The rules were interpreted with some flexibility because the treeline, although often lying around 1800 m, varies greatly as a consequence of anthropogenic disturbance, e.g. logging and fire. The aim of their study was to exclude typical forest taxa and to include all taxa of open subalpine and alpine habitats, thus excluding many taxa extant in Grevena and also many taxa of importance to palynological studies in general and the present study in particular. Strid and Tan (1991) found that 1/3 of the taxa they recorded had not been recorded for Greece in *Flora Europaea* or were recorded under a different name and/or with a different taxonomic rank.

Today about 85% of the ground surface of Greece is bare of trees. This 85% is covered with scrubland (*maquis*), fields, and pasturage, as well as land completely barren and eroded (Sfikas 1978). Most of the forests in Greece are found at intermediate altitudes, on the flanks of the larger mountain ranges in the north in Thrace, Macedonia, and Epirus and in central Greece at high elevations. These woodlands are rich in species. The greater part of Greek forests consists of conifers, with deciduous trees such as *Fagus* (beech), *Castanea* (chestnut), and *Quercus* (oak). Other species grow rather sporadically and scattered in the forests, on scrubland or in fields, and are rarely found in extensive or homogenous stands (Sfikas 1978).

Most of the trees found in Greece are common to all of Europe. However, there are also some Asian species, e.g. *Fagus moesiaca*, which does not exist in other European countries (Sfikas 1978:10). Several coniferous trees commonly occurring in Greece, and indeed Grevena, are endemics to the Balkan area, for example *Abies cephalonica*, *Pinus heldreichii*, and *Pinus leucodermis*. Also several trees and shrubs which, although they originated in other countries, have become very common in certain regions and have acclimatised themselves so well that they grow like native species, e.g. *Ailanthus altissima* (tree of heaven) from Asia and *Robinia pseudacacia* (false acacia) from America.

The most common Greek forests can be roughly divided into three categories, according to the predominant species:

- 1) Coniferous forests – coniferous highland forests throughout Greece, made up of different species of *Pinus* (pine) and *Abies* (fir);
- 2) Deciduous forests – deciduous highland forests in the north, consisting of *Fagus* (beeches), either by themselves or mixed in with other deciduous trees;
- 3) Evergreen forest – Mediterranean forests on the lower mountain slopes where *Pinus halepensis* (aleppo pine) is by far the most common, often mingling with other needled conifers; *Quercus coccifera* (kerm-oak or holly oak); *Quercus ilex* (holm-oak); *Fraxinus* (ash); and various shrub species (Sfikas 1978:9-10).

3.3 Flora and vegetation of Grevena

In contrast to the bareness of much of Greece (Rackham 1982), Grevena province is covered by large tracts of woodland. Of the 200 tree and large shrub species (belonging to about 85 different genera) growing in Greece today, according to Sfikas (1978), about 149 of these species (and 63 genera belonging to 69 pollen taxa) are probably extant in Grevena (Tutin *et al.* 1964-80; Moody & Rackham 1988; Polunin 1988; Adamakopoulos 1989; Strid 1989; Rackham 1991; Strid & Tan 1991; Appendices I, VII & VIII; Moody & Rackham, in prep.). Ninety seven additional tree and large shrub species, 39 trees (including 7 that are not native, but planted), and 58 shrubs have been identified as probably also extant in Grevena. In addition, 83 dwarf shrubs and woody climbers have been identified, making a total of 329 woody plants. About 118 of these woody species have been observed by Grevena Project members, and an additional 8 woody species were recorded by Adamakopoulos (1989) during her survey of the NE Pindos.

The flora of Grevena is very rich in herbaceous species also. Factors contributing to this rich flora include:

- 1) the proximity of other floras, notably the central European, Anatolian, and Pontic floras from which migration has taken place;
- 2) an isolated mountain range, which has resulted in the fragmentation, isolation, and migration of species;
- 3) an old flora containing many Tertiary species that have survived the Quaternary glaciations; and
- 4) the profound influence of humans in destroying and changing the natural plant cover, creating new habitats, and introducing species from outside the Balkan Peninsula (Turrill 1929).

Plant communities of Grevena are varied and complex. With decreasing elevation they range from alpine vegetation of mountain peaks, mountain pine woods and beech and fir woods of Central European aspect, deciduous oak woods in the foothills, to lowland Mediterranean-type woods containing some evergreen species such as *Quercus coccifera* and *Phillyrea media*, and dry steppe reminiscent of the Hungarian and Russian steppe. A unique local climate coupled with the wide differences in bedrock formation, altitude, and aspect, as well as the varied origin of species, make for great diversity in plant communities. In consequence of these many unique factors the vegetation of Grevena has many local variants and exceptions.

As yet there is no published study of the vegetation of the province *per se*. For this study, much ecological information on the vegetation of Grevena is taken from studies made of the Balkan Peninsula, especially the phytogeographical study of Turrill (1929) and the study of Polunin (1988).

3.3.1 Classification of extant vegetation

The systematic classification of Mediterranean vegetation began in France with the Braun-Blanquet hierarchical classification based on floristics (Whittaker 1962). This is a formalized system with Latin names analogous to those used for naming plant species, genera, and families. The system became fashionable among European phytosociologists and has been extended to many countries, including Greece. The extant vegetation of Grevena is the result of centuries of interaction of wild plants and animals with anthropogenic activities including woodcutting, grazing, burning, cultivation, and building settlements and communication systems, so this type of formal classification is not suited to its description. Recently Moody & Rackham (in prep.) classified the extant vegetation of Grevena using a less formal system that is more pragmatic and more suited to the extant vegetation of Grevena and

to this study. They divide the vegetation into woodland, steppe, and riverine vegetation. Woodland is the dominant vegetation type in Grevena and covers about half the province. The woodlands are divided into pine and beech woods of the Pindos Mountains, mixed woods on limestone outcrops at the upper altitudes of the Pindos foothills, deciduous oak woods of the Pindos foothills and lowland plains, and pseudo-*maquis* woodland in the southeast.

Distinct vegetation zones coincide with five geographic sub-regions of Grevena:

- 1) Pindos mountains,
- 2) Pindos foothills,
- 3) lowland plains,
- 4) flood plains,
- 5) and eastern mountains.

Generally in the Pindos Mountains over 1000 m woodland is dominated by *Pinus* (pine), less commonly *Fagus* (beech). Pasture also occurs, but very little of the past cultivation now remains. In the Pindos foothills oak wood now usually predominates over cultivation, although there are abundant remains of former small fields. On the lowland plains cultivation predominates over woodland except in the valleys, but where woodland occurs it is usually deciduous oak. The flood plains have a band of riverine woodland of *Salix* (willow), *Tamarix* (tamarack), and *Platanus* (plane) and other riverine vegetation, as well as some cultivation. The eastern mountains are less well vegetated than the Pindos Mountains – where vegetation exists it is mostly dry shrubbery (Figure 3.1).

Plant communities within these zones are described below according to physiognomy, land use, and floral composition. These descriptions are based on fieldwork carried out during summer field seasons between 1987 and 1989, mostly by Dr O. Rackham. The author spent one field season (1989) with Dr Rackham as well as conducting her own botanical fieldwork. An unpublished Greek Forest Service 1:50 000 map provides abundant detail on the extant vegetation of Grevena (Karasavvidis, unpub.), which, although based on dominant trees, can be interpreted in terms of the Moody & Rackham classification (Figure 3.2).

3.3.1.1 Pindos Mountains

The highest elevations are occupied by alpine meadows and pastures. (These were not studied but are adequately covered in Polunin (1988).) Below the treeline, about 1800-2100 m, and above 800 m are mountain pine woodlands. Within the pine woods at intermediate elevations is a mosaic of pine-beech-fir woods.

Figure 3.1 Diagrammatic altitudinal profile of vegetation, from W to E across the province.

Figure 3.2. Extant vegetation of Grevena showing surface pollen sample sites (adapted from unpublished Greek Forest Service map by Georgios Karasavridis)

The growth of trees within these woods is episodic: any one area has trees of two or three different ages (estimated from tree-ring data), rather than a range of ages. This may reflect the history of grazing and to some degree woodcutting, although a contributory effect from weather cycles cannot be ruled out.

In general, in the last 200 years pine has invaded former pasture land. Beech, much of which 200 years ago seems to have been reduced to bush size through grazing, has increased at the expense of pine and of pasture (Leake 1835). Fir has probably declined (Turrill 1929), and in many areas is represented by only scattered giant trees. There has been a slight encroachment on the mountain zone by oak wood from lower altitudes. Much of the younger pine and beech is of an age to have started growing during and after the second World War. There are also many young trees of both the 1930s and 1950s. There is evidence that some of the beeches have been shredded and coppiced in the past (Moody & Rackham 1988).

Fire is not a major ecological factor here. The woods, even the pine woods, do not burn easily; their leaf-litter is compact and soon rots. Evidence of frequent lightning strikes without subsequent conflagration is abundant. Juniper, which fire kills, is abundant almost everywhere (Moody & Rackham 1988).

Mountain pine woods and wood-pastures

Of the three pine species that grow in the pine zone of the Pindos, *Pinus nigra* is a local variant of a species fairly widespread in Central and sub-Mediterranean Europe. The other two pines, *P. leucodermis* and *P. heldreichii*, are Balkan endemics. The ecological differences between these three are not great. *P. leucodermis* tends to grow at the highest altitudes, with *P. heldreichii* intermediate.

Pines are not very palatable and are not used as fodder. *P. leucodermis* can survive being grazed to a bush but retains a gnarled, twiggy base if it later grows into a tree. Pines are killed by felling. They will pollard, but this is rarely done in Grevena. These pines have shallow-spreading roots.

There are two types of vegetation structure resulting from two different land uses, pine woods and pine wood-pastures. In pine woods, trees grow close together and often all three pine species grow mixed together, e.g. between Zakas to Agios Nikolaos (Appendix VII, i). They are usually young (up to 150 years) and commonly two or three generations of pines grow in any one place. Juniper grows as an understorey shrub in pine woods and acts as a nurse plant to seedling pines. Pines are felled for timber.

In pine wood-pasture the pines are scattered and set in grassland or bracken (*Pteridium aquilinum*); species are not mixed together but grow according to elevation preferences. This type of vegetation occurs around the wetland core site of Gomara and at Avgo (Appendices

VII, ii & VIII) (Figure 3.3). Occasionally pines are pollarded (e.g. at Samarina). They often carry the pine variant of *Viscum album*, the most widespread European mistletoe. The shapes of pines in this vegetation structure indicate that they have always been free-standing – at least since they were very young – and are not the remains of a continuous wood.

Some pines are of great age and huge size. Ancient pines are commonly 30-40 m high and 1½-2½ m in diameter (Figure 3.4). Tree-ring counts show that growth-rate varies according to altitude: thus a big *P. nigra* at 1200 m below Smixi is no more than 195 years old while a similar-size tree at 1400 m above Smixi is about 420; pines on the pass to Distraton (1750 m) are 470-550 years old; *P. leucodermis* at Avgo (1760 m), up to 1.4 m diameter, are 630-700. About half the ancient pines have been struck by lightning, some of them many times. This can burn a great scar down one side of the tree without killing it.

There is a tendency for beech to invade pine areas. There are frequent beech coppices among the giant pines in areas that must have once been pine wood-pasture. A few pollard oaks extend well into the pine zone. These are either along watercourses or associated with settlements (e.g. beside the church of Agios Nikolaos). In the latter situation especially, this may indicate that pine has lost ground to oak wood-pasture, but below Kranea, in the southwest, there is some evidence of pine moving down to invade oak wood and oriental hornbeam (*Carpinus orientalis*) wood.

Grassland of the pine wood-pastures is dominated by species of *Festuca* and other perennial grasses. Among the grasses is a rich flora of mainly perennial herbs, such as *Arabis subflava*, *Doronicum orientale*, *Geranium macrostylum*, *Valeriana tuberosa*, and *Vicia lathyroides*.

Mountain beech and fir woods

The European beech, *Fagus sylvatica*, and the endemic fir, *Abies cephalonica*, form woods in the Pindos between 600 and 1600 m. Although most of the beech woods in Grevena are pure *Fagus sylvatica*, as around the wetland core site of Anelia (Appendix VIII) (Figure 3.5), *Fagus moesiaca* occurs with *F. sylvatica* in the southwest of the province in Pindos National Park. In Grevena *Fagus* is close to its southern limit and *Abies cephalonica* to its northern limit.

Beech and fir overlap with the pine zone and tend to replace pine in the more westerly mountains. This is probably due to the higher rainfall to the west. On a local scale, beech and fir tend not to mix with pine. They grow in the damper areas. Beech sometimes, but not often, mixes with a few other trees, notably *Sorbus aucuparia*.

Fir is much less abundant than beech, often occurring only as scattered individuals of great age among the beeches. Between Samarina and Fourka an *Abies* tree, the oldest of four

Figure 3.3 Pine wood-pasture at Gomara (1750 m asl).

Figure 3.4 A huge *Pinus leucodermis* tree at Avgo (1760 m asl). A person stands near the base of the tree (arrowed).

Figure 3.5 Beech woods around the wetland coring site of Anelia (1440 m asl). Pine grows above the beech.

Figure 3.6 Pindos foothills. Limestone ridge behind the village of Zakas (on the righthand side of the photograph, arrowed). Deciduous oak wood-pasture covers the lower slopes, with mixed wood above.

generations, was estimated to be 35 m in height and 1 m in diameter; the second generation was about 300 years old.

Both trees occasionally form wood-pastures, but less often than pines or oaks. A common pattern is for beech woods to occur in small valleys while the rest of the landscape is grassland with or without scattered pines.

Both *Fagus sylvatica* and *Abies cephalonica* can survive long periods of browsing when young. They do not burn. Beech sprouts when felled, but fir is killed. Both can be pollarded, but this is rarely seen in Grevena. Beech can be very shallow-rooted.

Beech woods are generally of coppice type, felled every 40-75 years, but many have not been cut for centuries. Beeches with stems up to 1.5 m in diameter and at least 300 years old are locally common, e.g. around the Anelia coring site. Coppice stools are up to 3 m across, and are presumably many centuries old. Some stools were last coppiced 250-320 years ago. The growth-rate of beech is very variable from decade to decade, due either to weather or to damage: many old beeches have lost their tops.

Buxus sempervirens (box) is common in mountain beech woods. It replaces juniper as an understorey shrub, perhaps on more calcareous soils. Beech-fir woods are rich in flowering plants, for example *Helleborus cyclophyllus* (hellebore), *Primula vulgaris* (primrose – a west European plant which does not like drought), *Cardamine bulbifera*, *Scilla bifolia*, *Crocus biflorus*, *Erica herbacea*, *Lilium martagon*, *Primula veris*, and *P. elatior*, a coppice plant (cf. Appendix VII, iii, where plants were noted in a disturbed area in beech wood near the wetland core site of Anelia). Lichen are prolific on trees in the beech woods, indicating an unpolluted atmosphere.

Castanea sativa (chestnut) woods, which are widespread but local in the wetter mountains of Greece, occur just north and west of Grevena (Moody & Rackham, in prep.).

3.3.1.2 Pindos foothills

The slopes are steeper and more dissected here than anywhere else in the province, with many ravines and gullies. There are large areas of continuous deciduous oak wood on these slopes and two small patches of mixed woods (Figures 3.6 & 3.7).

Deciduous oak woods

Grevena is one of the most oak-dominated regions in Europe (Moody & Rackham, in prep.). At least seven species (perhaps up to 12, Appendix VI.2) of deciduous (includes deciduous or semi-evergreen) oaks are extant: *Quercus brachyphylla*, *Q. cerris*, *Q. frainetto*, *Q. pedunculiflora*, *Q. pubescens*, *Q. trojana*, and *Q. virgiliana* (Moody & Rackham, in press). Only *Quercus trojana* (deciduous or semi-evergreen) stands out as a clearly defined species;

Figure 3.8 Oak wood at Mavranaiioi on the plains. This dense patch of stunted oaks growing close together is perhaps a result of allowing oaks that were grazed to grow up into trees in recent years. The shallow root system of the oaks can be seen in the road cutting.

the others appear to hybridize and form a continuum in which some individuals are more or less typical of one or other species, but many are intermediate. Any one area is usually a mixture of at least three species. There is little ecological difference among the oaks except that *Q. trojana* frequents warmer and drier sites.

The oak woods are usually pure stands. Only occasionally other trees such as *Fraxinus ornus* (manna-ash) and *Sorbus torminalis* (service) occur in them. *Juniperus* (juniper) sometimes forms an understorey, this is less common in the foothills than in the plains.

Availability of moisture appears to be a factor in the spacing of the oak trees. Oaks in the foothills grow closer together than those on the drier plains. Much oak wood is interspersed with areas of grassland, usually of a very dry type. The growth of oaks has been episodic: in any one area there are usually two or three distinct ages of pollards or other big oaks. (The age of one giant oak was estimated at 700-1000 years old from annual rings.)

The structure of oak woods in the foothills varies from wood-pasture (scattered big oaks in grassland) to coppice-woods and sometimes to 'oak-pasture' (tracts of deciduous oak grazed by sheep and goats to less than 2 m high, sometimes with upstanding pollard trees as well). Oak wood-pasture is more common in the foothills than in the plains and usually occurs at the highest altitudes of the oak woods, with coppice-woods at a lower altitude. 'Oak-pasture' occurs mostly in the north.

The grassland between the trees of the oak wood-pasture includes many steppe species. The dominant grasses are perennials, species of *Festuca* and *Poa timoleontis*. Perennial herbs include *Acinos alpinus* subsp. *alpinus*, *Erysimum linariifolium* (a Balkan endemic), *Euphorbia myrsinites*; legumes such as *Astragalus monspessulanus*, *Lathyrus digitatus*, *Trifolium physodes*; and bulbs such as *Muscari neglectum*. Annuals include *Cerastium brachypetalum* subsp. *pindigenum* (endemic), *Evax pygmaea*, *Lamium bifidum* subspecies *balcanicum* (Balkan endemic), and *Scleranthus uncinatus* (cf. species noted near the surface sample site at Polinerion listed in Appendix VII, iv).

In their shady uncut state the ground vegetation of oak woods is rather sparse; it includes *Aremonia agrimonoides*, *Buglossoides purpureocaerulea*, *Cephalanthera damasonium* (an orchid), *Cyclamen repandum*, *Fragaria vesca*, *Scilla autumnalis*, and *Stachys alopecuroides* (cf. Mirsina oak-wood quadrat, Appendix VIII). Vegetation is richer at the edges of woods, characteristic species being *Dictamnus albus*, *Lathyrus laxiflorus*, *L. nissolia*, and *Melittis melissophyllum* (Rackham & Moody, in prep.).

Oaks produce acorns in the later part of each coppicing cycle, except *Quercus frainetto*, which takes at least 50 years. Pollards often carry the oak mistletoe *Loranthus europaeus*. After felling, coppice-woods develop a varied and characteristic flora of herbaceous plants distinct from (though overlapping with) the floras of steppe, woodland edges, and cultivation.

They include perennials that are present (but suppressed) before felling such as *Fragaria* sp., *Lathyrus laxiflorus*, *Melittis melissophyllum*, *Symphytum ottomanum*; steppe plants (perhaps present in patches of steppe) such as *Arenaria conferta* (an endemic), *Bellis sylvestris*, *Polygala nicaeensis*, *Trifolium repens*; seed plants (growing from seed buried since last felling) *Euphorbia amygdaloides*, possibly *Cerastium brachypetalum* subsp. *tenoreanum*, *Lathyrus aphaca*, *Ranunculus* cf. *constantinopolitanus*, *Veronica chamaedrys*, and *Vicia grandiflora*; plants with a dispersal mechanism that allows them to move around the wood from one felled area to another, e.g. *Cardamine* cf. *hirsuta*, *Senecio squalidus*; and another plant of unknown origin *Geranium asphodeloides* (Moody & Rackham, in prep.).

Near Polinerion at over 1000 m, numerous pockets of deep soil were cultivated about 50 years ago, but probably not for long (Appendix VIII, Polinerion plot a). These areas are still very distinct from the adjacent undisturbed steppe. They are dominated by the annual grass *Taeniatherum caput-medusae* and other annual grasses, e.g. *Bromus* species and *Cynosurus elegans*, annual herbs such as *Galium setaceum*, and weeds such as *Convolvulus arvensis* and *Polygonum aviculare* (Moody & Rackham, in prep.).

Oaks are resistant to grazing; they are quite palatable to livestock but can live even if grazed to less than a metre high. They are not killed by felling but sprout from the stump. They do not burn easily, but their litter can be ignited by adjacent stubble or grass fires, and young oaks are killed to the ground but sprout (Moody & Rackham, in prep.). Oaks (except *Q. frainetto*) easily invade abandoned farmland and have undoubtedly increased at the expense of pasture: early last century there were probably wider areas of grazed oaks than there are now (Leake 1835).

Mixed woods

Two small limestone outcrops, one near Aetia and another above Spilaion and Zakas, have small areas of woodland growing on them that include a much greater number of species than any of the other woods in Grevena. Most of these species are rare or do not occur anywhere else in the province. These woods have been supposed to be relics of preglacial forests (Moody & Rackham, in prep.). The woodland in the Aetia gorge, at 1000 m, is very distinctive, with the common trees of Grevena missing apart from occasional oaks (Appendix VIII). Trees growing in the wood include a mixture of north European, central European, Balkan, and sub-Mediterranean species, including a surprising number of thermophilous trees for such a high altitude. This wood is partly inaccessible, due to the steep sides of the gorge, but where it is accessible there are scattered pollards, including such seldom-pollarded trees as *Acer monspessulanum*, *Prunus mahaleb*, and *Tilia tomentosa*, and intervening trees are coppiced and sometimes browsed.

The mixed wood above Spilaion and Zakas includes most of the trees of the mixed wood near Aetia but differs from it in that it is dominated by *Abies cephalonica* and includes the two Mediterranean trees *Phillyrea media* and *Pistacia terebinthus* (terebinth) (Figure 3.7). This wood is browsed but has a protective understorey of unpalatable *Buxus* (box). With the protection of box, palatable species such as *Phillyrea* and hornbeam can grow into trees. This mixed wood continues on to flysch and ophiolite on the damp north side of Mount Orliakas. Here *Tilia rubra* (lime), *Ulmus glabra* (elm), *Populus tremula* (aspen), and *Prunus avium* (cherry) grow amongst the lower edge of the mountain beech and fir woods (Moody & Rackham, in prep.).

Another mixed wood occurs on the southwestern boundary of the province between Kranea and Milea on ophiolite and gabbro cliffs. This wood differs from the two above on limestone in that there is not such a range of species, and the more common *Fagus* and *Abies* are usually dominant. *Carpinus* and *Ostrya* (hop-hornbeam) are frequent in this wood. Rare trees include *Aesculus* (horse-chestnut), *Tilia tomentosa* (silver lime), and *Acer obtusatum* (Moody & Rackham, in prep.).

3.3.1.3 Lowland plains

The deciduous oak woods of the plains are discussed separately because their physiognomy, use, and structure differ from those of the oak woods of the foothills. Today cultivation dominates over oak woods on the lowland plains.

Deciduous oak woods

The plains are more arid than the foothills, and the effects of moisture deficit are greater. The plains are too arid to support continuous oak woodland as in much of the foothills. Intervals between trees covered with very dry grassland (steppe) are much larger than those of the foothills; the shadier north-facing slopes are covered with more trees than the south-facing slopes or the ridgetops (where not cultivated). Oaks have shallow roots that extend under the grassland and take moisture from it, creating a mosaic of oaks and steppe (Figure 3.8).

Moisture also appears to limit the growth of oak. Oaks in woods are extremely slow-growing and often dead at the top. They can take 70 years to reach 15 cm in diameter, but free-standing oaks between fields in better-watered places can put on annual rings of 5 mm or more (Moody & Rackham, in prep.). The present structure of patches of dense, stunted oak wood and patches of steppe may be to some extent artificial. It may be a result of allowing oaks that were grazed in the past to grow up into trees in recent years and compete with each

other for moisture. The natural state would probably be a thin scatter of bigger oaks, with widely spreading root systems, within grassland (Figure 3.8).

Juniper, *Juniperus oxycedrus*, grows mostly as an understorey shrub in the lowland oak woods. In some areas it is more abundant than in others, forming a continuous understorey. It is not very shade-tolerant, and its dead remains (which persist for many decades) are evidence that the woods were once more open. In many areas juniper is completely absent, even in well-lit situations. This probably results from a history of burning the steppe or the leaf-litter of the woods: juniper is much more sensitive to fire than oak. The presence of juniper may also be related to the history of pasturage or of erosion (Moody & Rackham 1988). The rare mistletoe *Arceuthobium oxycedri* grows on this juniper.

In very dry places wild pear, *Pyrus amygdaliformis*, is scattered among oaks (Moody & Rackham, in prep.). Steppe in the plains may have a small component of undershrubs that belong to the Mediterranean garrigue, e.g. *Teucrium polium* and *Cistus incanus*. There is a great variety of herbaceous plants in plains steppe. Some are deep-rooted perennials like *Galium verum* and *Dictamnus albus*, or annuals such as *Xeranthemum annuum*. The steppe contains many endemics, including *Achillea grandifolia*, the *Centaurea* species, *Iris reichenbachii*, *Onobrychis ebenoides*, *Stachys scardica*, and *Cerastium brachypetalum* subspecies *pindigenum*. Many of the steppe species have affinities with Eastern Europe, and especially the Hungarian plain. These include the perennial pink *Dianthus pontederæ* subspecies *giganteiformis*, *Inula ensifolia*, and *Veronica chamaedrys* subspecies *vindobonensis* (additional species are listed in Appendix VII, v & vi).

Grasses of the steppe are perennials of an arid kind, a mixture of Mediterranean species such as *Hyparrhenia hirta*, *Dichanthium ischaemum*, and *Chrysopogon gryllus* and of Central European steppe grasses, e.g. *Phleum phleoides*, *Koeleria splendens*, and members of *Festuca*. There are also annual grasses such as *Cynosurus echinatus* and *Aegilops* and *Bromus* species.

Hornbeam woods

On the eastern side of the plains and on the less arid bases of the eastern mountains are hornbeam woods. Hornbeam (*Carpinus orientalis*) grows in damper places and has fewer patches of steppe than the plains oak wood. Near Mirsina hornbeam grows on the damper NW-facing slopes, while oak woods and shrubbery grow on the drier SW-facing slopes (Moody & Rackham, in prep.). These woods are an alternative to oak wood and intergrade with it. They are not as pure as oak woods, having *Fraxinus ornus* (manna-ash) and *Acer monspessulanum* (maple) frequently occurring in them. Hornbeam is commonly grazed in the manner of oak-pasture. It is also coppiced, but not pollarded or shredded, for leaf fodder.

Mixed wood

Eight km SE of Grevena on the Venetikos River is a mixed wood of an unusual type. It is dominated by deciduous oaks (at least 4 species occur here) with much hornbeam. There are also many other trees, some Balkan and sub-Mediterranean (e.g. *Acer opalus*, *Cornus mas*, *Fraxinus ornus*, *Tilia rubra*), and some from central and northern European (*Acer campestre*, *Corylus avellana*, *Salix caprea*, *Sorbus torminalis*). A row of *Tilia tomentosa* overhangs the river. The rich flora of this small wood includes the rare *Carex depauperata*, *C. depressa* subsp. *transsilvanica*, *Lathyrus laxiflorus*, *Primula elatior*, and *P. vulgaris*. The flora is very much richer than oak woods apparently growing on similar soil (Moody & Rackham, in prep.). This wood with its richer-than-usual flora may resemble more closely a natural vegetation than the more common pure stands.

Shiblyak

A Balkan-type of shrubbery, *shiblyak*, of long-lived deciduous plants, often deep-rooted, forms brushwood plant communities in dry places, particularly in the plains (Moody & Rackham, in prep.). Although oak wood may develop from this *shiblyak*, it also forms a narrow permanent zone between woodland and steppe. It is more extensive on south-facing slopes and especially on eroding slopes too unstable for trees to become established, and without enough soil for grassland. *Cotinus coggygria* is characteristic of the latter situation; it appears to be adapted to having its roots exposed by erosion. On stable sites, shrub thickets often include *Prunus spinosa*, *Colutea arborescens*, and *Paliurus spina-christi*. *Juniperus oxycedrus* is a very abundant shrub in permanent *shiblyak*.

Weeds and ruderals

Weeds of arable land and ruderals of the Balkans have been defined by Turrill (1929). The following families are the most important, on the basis of the number of species contributing to the weed and ruderal floras: Compositae, Leguminosae, Cruciferae, Umbelliferae, and Gramineae. Unfortunately some of the weeds and ruderals, such as the ruderal grass *Cynodon dactylon* and the weed *Cyperus rotundus*, cannot be distinguished palynologically from other species that are not weeds or ruderals.

Extant weeds of cereals include Mediterranean, Balkan, and general European species such as: *Consolida regalis* subsp. *paniculata*, *Dasypyrum villosum*, *Nigella arvensis* subsp. *arvensis*, *Orlaya kochii*, *Vicia pannonica* subsp. *striata*, *Buglossoides arvensis* subsp. *sibthorpiana*, *Agrostemma githago*, *Centaurea cyanus*, *Asperula arvensis*, *Brassica nigra*, *Erysimum cheiranthoides*, *Galium tricornutum*, and *Ranunculus arvensis* (Moody & Rackham, in prep.).

Hedges

There is no tradition of planted hedges in Grevena, except for rows of almonds (*Prunus dulcis*). A few hedges occur around villages, defining small irregular fields. They are usually comprised of a mixture of species and usually include a greater variety of trees than woods; *Ulmus* (elms) and *Fraxinus ornus* being common. Sometimes they consist of only undershrubs such as bramble. Often they consist of shrubs with oaks at intervals. A common plant of hedges is *Sambucus ebulus* (danewort). Hedges may have been more common in the past before mechanized agriculture was introduced.

3.3.1.4 Flood plains

Most of the river terraces are cultivated, but a variety of wild vegetation survives in unstable areas. The flood plains of the Aliakmon, Venetikos, and Pramoritza and their bigger tributaries support woods of *Alnus glutinosa* (alder) and the willows *Salix elaeagnos*, *S. alba*, and *S. amplexicaulis*. The Balkan *Tamarix parviflora* (tamarisk) forms thickets in places with the Central European *Myricaria germanica*. Smaller woods of *Platanus* (plane) grow on the flood plains of the Aliakmon and Venetikos and their bigger tributaries, reaching 970 m above Kranea, high for a Mediterranean tree (Moody & Rackham, in prep.). River gravels often have a rich flora, including endemics such as *Silene haussknechtii*, *Dianthus gracilis* subsp. *haussknechtianus*, and plants washed down from higher altitudes (*Euphorbia myrsinites*).

Along smaller watercourses are patches of suckering *Populus alba* (poplar) and *Ulmus minor* (elm). Springs often feed little clayey fens with thickets of *Salix* (willow) and *Prunus cerasifera* (cherry-plum), patches of bramble (*Rubus* species), and herbaceous plants that are often of widespread European species such as *Equisetum telmateia*, *Lythrum salicaria*, *Anchusa arvensis*, *Scirpus holoschoenus*, and *Teucrium scordium* (cf. Kellia, Appendix VIII).

3.3.1.5 Eastern mountains

Vegetation is usually very sparse on these extremely dry mountains and there are few trees. Exceptions to this occur in the south, where small patches of *Abies*, *Pinus*, and *Fagus* grow. *Buxus sempervirens* (box) forms permanent shrubbery in places in these mountains, especially on the dry serpentinite.

Pseudo-maquis

In the southeast corner of Grevena on a patch of limestone with red soils is a brushwood community of mixed evergreen and deciduous trees, pseudo-maquis. This corresponds to the pseudomacchie of Turrill (1929). Pseudo-maquis is related to the 'true' maquis of coastal and southern Greece, but unlike the 'true' maquis, which has several dominants, pseudo-maquis

is usually dominated by only one species, such as *Quercus coccifera*, and can withstand harsher climatic conditions than 'true' *maquis*.

The stand in Grevena includes the Mediterranean evergreens of *Quercus coccifera* (prickly oak) and *Phillyrea media*; deciduous Mediterranean species *Acer sempervirens*, *Crataegus heldreichii* (hawthorn), and *Pistacia terebinthus* (terebinth); *Cornus mas* and *Paliurus spina-christi*; and the deciduous temperate trees *Quercus brachyphylla*, *Q. trojana*, and *Carpinus orientalis* (hornbeam).

The stand forms a kind of oak-pasture structure, in which most of the trees are browsed into shrubs, with occasional pollards of deciduous oak and maple. Some of the pollards are 200-300 years old. Although sheep and goats still browse in winter, some prickly oaks (evergreen oaks) are growing into trees, often through the protection of juniper bushes.

3.3.2 'Natural' vegetation of Grevena

The extant vegetation of Grevena resembles to some extent the 'natural' undisturbed vegetation cover that would grow in similar climatic conditions, especially in the dominant tree flora and vegetation. The major vegetation zones of pine at the highest montane altitudes, *Fagus/Abies* at lower montane altitudes and oak woods in the foothills and lowlands are probably close to major altitudinal zones that would exist in undisturbed vegetation. The tree line, however, would probably be higher, as it has probably been depressed by grazing.

The vegetation of the foothills and lowland plains is limited by rainfall. Coppicing has increased the number of tree stems per area, so increased competition between trees results in a slow growth rate. In wood-pasture the number of trees per area has been reduced, resulting in a relatively fast growth rate. The natural undisturbed state would thus be one of fewer trees in the coppice woods and more trees in wood-pasture.

Small patches of mixed woods growing in the less disturbed areas of today, scattered amongst almost pure stands in disturbed areas, suggest that an undisturbed vegetation would be more varied in taxa than is common today. In the foothills and lowlands oaks would be dominant, but there would be a wider range of trees, especially lime and hornbeam. The common two-layer structure of much of the woodland today, with ground and canopy cover only and little or no understorey, is probably a result of grazing. Undisturbed woodlands would have more luxuriant understorey. In the foothills trees would be more continuous, but the lowlands would be more savannah-like. *Shiblyak* would be abundant, especially on unstable land.

3.4 Surface samples

The results of a study investigating the relationship between the extant vegetation of Grevena and pollen deposition are given below. Due to the time constraints of the field season (and the impossibility of quantifying many relevant variables – Lichti-Federovich & Ritchie 1965), which resulted in the small sample size of the present study, a rigorous statistical analysis (e.g. Davis 1963; Webb *et al.* 1981; Bradshaw & Webb 1985; Prentice 1986a) was not attempted, and a semiquantitative approach is adopted instead. A comparison is made between the actual distribution of the vegetation units described above, the relative abundance of plant taxa within these units, and relative frequencies of contemporary pollen spectra. Microscopic charcoal abundance and dispersal is also reported. Counts of all pollen and spore types and charcoal particles are listed in Appendix IX.

3.4.1 Sample collection sites

The selection and description of surface-sample sites is based on the Moody and Rackham classification. The aim was to sample the range of major vegetation communities described by Moody and Rackham (in prep.) along a west-to-east transect beginning in the Pindos Mountains and traversing the Pindos foothills and the lowland plains. Unfortunately, time precluded sampling the slopes of the Vourinos Mountains in the east. The locations of the 14 surface samples of the present study (and those of Bottema 1974, see below) are shown in Figure 3.2. Site descriptions and species lists, with numerical ratings where quantitative surveys were undertaken, are given in Appendix VIII.

The geographic area represented by the pollen data (pollen source area) varies, but where duplicate samples were collected from the same plant community they are approximately the same (Andersen 1970; Jacobson & Bradshaw 1981; Prentice 1986a). The two mountain sites in the pine wood-pasture plant community, Avgo and Gomara, are both small closed-drainage lakes (basin size less than 200 m diameter with no inlet streams) in open environments. The beech-wood sites at Anelia are approximately 30 m apart; one in the woods and the other on a small bog (90 x 50 m) surrounded by the beech wood. Samples from the two mixed woods growing on limestone in the Pindos foothills, Zakas and Aetia, were both collected under the canopy of the woods. In the lowlands, two samples were collected from open environments surrounded by cultivated fields (although one site is a fen, Kellia, and the other a cultivated field, Asprokampos). Samples collected from the oak woods, Asprokampos and Mirsina, in the lowlands were both collected under the canopy of open woods.

3.4.2 Sample material and pollen preservation

Several different types of sample material were used; peat from the surface of wetlands, moss polsters, soil, and litter. In general preservation of palynomorphs was good in all samples. Preservation was best in samples from the wetlands, where it was excellent. Palynomorphs extracted from moss polsters collected from damp locations were well preserved, except that in some samples pollen of *Fagus* had been attacked by fungus (e.g. samples from Anelia woods and Agios Nikolaos). Pollen and spores from dry samples were less well preserved, being broken and crumpled (but the exine is normal – Cushing 1967), or in the worst cases degraded (thinning of exine) (Delcourt & Delcourt 1980). The latter case applies to samples from Asprokamos woods and Polinerion, where the maximum percentage frequency of indeterminate grains of 9% was recorded. The dry-litter sample collected from Mirsina woods contained poorly preserved, degraded palynomorphs, while the palynomorphs extracted from the surface soil at Asprokamos suffered little degradation, perhaps because of a shorter period of accumulation.

In some cases poor preservation prevented identification of grains, but the composition of the pollen flora was probably not altered greatly, judging from the small amount of corrosion seen (Havinga 1984).

3.4.3 Pollen diagram

Pollen and spore relative frequencies are presented in Figure 3.9 (in two parts – in pocket). The pollen sum on which the relative frequencies are based includes all identified terrestrial pollen and spore taxa and excludes marsh and aquatic taxa. Relative frequencies of 0.2% or less are indicated with a dot.

Pollen spectra have been arranged according to landform and vegetation zones (more or less from highest elevation to lowest) following the west-east sampling transect and the above description of extant vegetation.

Pollen and spore types are arranged according to habitats drawing on data from Turrill (1929) and other sources (Appendix X). Many pollen types contain species that grow in a variety of habitats, and assignment to a particular habitat presents some difficulties. In general in such cases assignment is based on consideration of the habitat where plants of that pollen type were seen growing and/or the type of site where the surface sample was collected. A separate group for steppe plants is not included, as plants growing in steppe are not exclusive to that community; they all occur in other communities.

Two plant groups associated with anthropogenic activities (anthropogenic indicators) have been added: cultivars and herbaceous plants of open ground. The latter group includes herbaceous plants that are light-demanding and are therefore increased by human activities

(and natural catastrophes), which remove forest cover. This group includes many weeds and ruderals (Bottema 1982). Many of these plants may also grow in natural grasslands. In this study the terms 'plant communities', 'weeds', and 'ruderals' follow the definitions of Art (1993).

Pollen types within habitat groups are arranged alphabetically except for the dominant tree types of *Pinus* (*Diploxylon*), *Fagus*, *Quercus frainetto* type, and *Quercus trojana* type, which are placed at the beginning of the 'coniferous and deciduous canopy trees' group.

Two summary diagrams are shown in part 2 of the diagram: one showing the ratio of terrestrial woody (trees and shrubs) to herbaceous plants; and the other, summary curves of each habitat group. A curve of palynological richness (rarefaction analysis) follows (Birks & Line 1992; Bennett 1994). The number of terrestrial pollen types (not normalized for unequal pollen sums) in each spectrum is shown next. Then the number of pollen grains of trees and shrubs, the total number of all terrestrial pollen and spores, and the total of all pollen and spores counted is given.

Charcoal abundance is expressed as frequency of particles of charcoal, in size classes based on the projected particle area, relative to the terrestrial pollen sum (Patterson *et al.* 1987).

3.4.4 Relative pollen dispersal and representation of various plant taxa

Reconstruction of past vegetation from fossil pollen spectra can be considerably aided with information regarding the dispersal potential of different species. This assists with interpreting the source area of represented taxa and thus the distribution of the original vegetation (Oldfield 1970). Difficulties in interpretation arise because a well dispersed pollen type might be abundant in a pollen diagram, but this does not necessarily imply that the parent species was growing close to the sample site. On the other hand, abundance of a poorly dispersed pollen type indicates that the parent plant was growing in the vicinity. Hamilton (1972) introduced a three-class classification of pollen types in terms of dispersal power (termed 'relative export' by Flenley (1973:137)). Pollen types that occur in all or almost all surface samples wherever collected are designated of high dispersal power. Those that occur in samples from adjacent areas are of medium dispersal power, and pollen types occurring only in samples from vegetation in which parent plants are growing are of low dispersal power. This classification assists with the distinction of the pollen source area and thus with reconstructing the actual distribution of the vegetation from fossil assemblages. The concepts of local and regional pollen deposition as defined by Janssen (1973) are adhered to in this study.

Relative dispersal and representation of pollen and spore types whose source plants were noted in the areas surveyed and/or whose pollen was present in the surface pollen samples are

summarized in Appendix XI. The term 'representation' refers to the relationship between the registration of a taxon in the pollen count and in the actual vegetation (Faegri & Iversen 1989:3). It differs to a large extent due to differences in pollen productivity, dispersal, deposition, and preservation (and the various treatments that analysts apply and their ability to identify pollen and spores (Bottema 1982)) (Havinga 1964, 1967, 1984; Tauber 1965; 1967; Erdtman 1969; Webb *et al.* 1978; Prentice 1985). Known pollination mechanisms have been included in Appendix XI as an indication of pollen production, that is, anemophilous plants generally produce much more pollen than plants with other pollination mechanisms (Knuth 1906:7; Erdtman 1969).

A discussion of the relative dispersal and representation of various taxa follows. This discussion is based on surface samples and so does not take differential preservation in sediments into account. The spectra from the surface sample of the wetland core sites provides the best modern analogue for that wetland sequence (although they may contain pollen that would not have been preserved). It is not easy to assess the dispersal abilities of pollen types with low frequencies. Accordingly, the dispersal abilities of common pollen types produced by common species are evaluated mostly. The failure of many pollen types to appear in the spectra is attributed to low pollen production, poor dispersal, or differential decomposition.

Pinus The long-distance dispersal capability and enormous production of *Pinus* pollen is well known (Moore *et al.* 1991; Faegri & Iversen 1989). Results of this study are consistent with these characteristics. Even pollen spectra of the lowland plains sites record pollen relative frequencies that are quite high (13.5 to 19.8%). An exception is the cereal field site at Asprokampos, where large relative frequencies of local weeds suppress the pine relative frequency to 3.5%.

Abies *Abies* is strongly under-represented in the pollen record of the site where it is growing. At Zakas *Abies cephalonica* forms 60% of the canopy, but it is represented by less than 15% in the pollen diagram. Thus pollen production appears to be small, but dispersal is good as small relative frequencies are recorded in the pollen record at most sites, even though it is known to grow at only two locations in Grevena, at Zakas, and in the southeast (Figure 3.2).

Fagus Relative dispersal and representation of *Fagus* pollen are similar to that of *Abies*; it is under-represented at sites where it grows but is dispersed long distances at small relative frequencies. *Fagus* pollen is recorded at all sites, but the sample collected beneath a beech wood canopy, where pollen deposition is expected to be primarily local (Anderson 1970, 1974), recorded only 29.4% relative frequency. The bog beside the wood recorded 23.5%.

Quercus *Quercus* has been divided into three pollen types: *Quercus frainetto* type includes deciduous species only, *Quercus trojana* type includes mostly species that are semi-evergreen or deciduous (one species, *Q. cerris*, is deciduous), and *Q. coccifera* type includes evergreen species (van Benthem *et al.* 1984).

Habit and pollen morphology of the species that belong to *Quercus frainetto* type and *Quercus trojana* type are very similar, so pollen production and dispersal are probably also very similar. They have high relative dispersal power and are recorded at almost all sites. The species belonging to these two pollen types occur in a number of different vegetation communities, and relative pollen representation differs according to plant community. At Perivolion, where oaks (*Q. frainetto* and *Q. trojana* types) represent 1/3 of the tree canopy and pine the remaining 2/3, only 5.7% oak pollen is recorded. At Polinerion in oak wood-pasture, where oak represents only 5% of the vegetation, 26.5% is recorded in the pollen spectrum. In the steppe/oak woods at Asprokampos, where the canopy is made up entirely of oaks (although this is only 50% cover), oaks record 40% pollen relative frequency. Representation may be affected by coppicing and pollarding.

The habit and pollen morphology of the two evergreen species, *Q. coccifera* and *Q. ilex*, included in the *Quercus coccifera* pollen type, are different from the species included in the above types. *Quercus coccifera* type is represented in almost every pollen sample but does not grow at any of the sampling sites. Only *Q. coccifera* is known to grow in Grevena and then only in a small stand in the southeast corner. Pollen representation is greatest on the western side of the province. Pollen in these spectra are presumed to be transported from woods on the western (windward) side of the Pindos Mountains (Moody & Rackham, in prep.). Bottema (1974) also found *Q. coccifera* is over-represented.

Carpinus type and Ostrya type These two types are combined because the same three species occur in both pollen types, although in different proportions; *Carpinus* type is represented mostly by *Carpinus betulus*, while *Ostrya* type is represented mostly by *Ostrya carpinifolia* and *Carpinus orientalis* (Bottema 1974:23). Both types have good dispersal as they appear in almost all spectra. However, production may not be very high, as the relative frequencies of pollen recorded at sites where species belonging to these types occur are about the same as at sites where no plants are growing. At the sampling site of Mirsina woods, *Carpinus* sp. forms 15% of the sub-canopy layer under an oak canopy, but pollen of *Carpinus* type records only 1.9% and *Ostrya* type 1%. Species which belong to the two types occur as canopy trees in the mixed deciduous woods at Zakas and Aetia, but only 0.5% and 0.7% of *Carpinus* type are recorded at the two sites respectively, while *Ostrya* type records 5.8% and 3% respectively. These relative pollen frequencies are no higher than at sites where species of this types are not recorded, e.g. at Anelia bog *Ostrya* type is 4.8% and at Asprokampos

woods 4.5%. The situation is the same for *Carpinus* type, but the relative frequencies are lower. Bottema (1974) also found that low shrubs of *Carpinus orientalis* are poorly represented.

Corylus *Corylus* also has good dispersal, but pollen production is not very high. *Corylus* pollen is represented at almost all sampling sites yet is recorded growing only at Aetia and near Mirsina fen. The surface sample from Aetia was collected beneath a *Corylus* canopy tree, and even here the pollen relative frequency is only 5.9%. Pollen relative frequencies recorded where no *Corylus* is growing reach 2% at Asprokamos woods.

***Tilia cordata* type** *Tilia* species grow as canopy trees in the two mixed deciduous woods at Zakas and Aetia. Relative pollen frequencies of 0.02% were recorded at each of these sites. Pollen was not recorded at any other sites. Pollen relative dispersal is low, so *Tilia* is under-represented (it is entomophilous).

Castanea sativa *Castanea sativa* is represented by very low frequencies in several spectra. No trees of this species were seen in Grevena, but dense woods exist just to the north and west (Bottema 1974; Polunin 1988; Moody & Rackham, in prep.).

Platanus orientalis *Platanus orientalis* is self-propagating in Grevena but is probably also planted. It does not grow at any of the sampling sites, but it forms part of the riverine vegetation. Pollen was identified in most of the samples at very low relative frequencies (usually less than 2%), suggesting that dispersal is medium. Perhaps production is not very high.

Juglans regia *Juglans regia* is the most cultivated tree in Grevena. No trees were recorded close to any of the sampling sites, but pollen grains were recorded at several sites at very low relative frequencies. Dispersal is probably high, but perhaps production of pollen is not very high.

Fraxinus ornus Although *Fraxinus ornus* trees were recorded at only three sampling sites, it is probably quite widespread in the extant vegetation of Grevena, albeit scattered and sparse. Pollen was recorded at several sites, thus relative dispersal of pollen is good. Relative representation is recorded as "over" in the summary table (Appendix XI) because pollen was identified at sites where no plants had been recorded. However, when relative frequencies of pollen abundance are compared to the relative abundance of its occurrence in the vegetation at the sampling site, it does not appear to be over-represented. Bottema (1974) found *Fraxinus ornus* to be well-represented.

Salix triandra *Salix triandra* pollen was identified in samples from Anelia bog, Kellia fen, Asprokamos field, Mirsina woods, and Mirsina fen. *Salix* species grow at the Kellia and Asprokamos sites. The Mirsina sites are close to the Aliakmon River, and *Salix* species, although not *Salix triandra*, have been identified in the flood plain vegetation of Grevena.

Salix may have been growing in the vicinity of Anelia bog. No estimates were made of the relative cover of *Salix* at the sampling sites. At the two fen sites relative pollen frequencies of 11.9% and 14.4% are recorded. The available data suggest that *Salix triandra* has low relative dispersal but is locally well-represented.

Juniperus Juniper is widespread in Grevena. It is represented in all the surface sample spectra except that of Avgo in the Pindos Mountains. Relative frequencies are greatest in the foothill sites but are never greater than 16%.

It is impossible to determine the relative dispersal of juniper pollen, as plants are so widespread in Grevena. The relative representation of juniper pollen appears rather erratic, probably because it grows in such a variety of plant communities and is affected by the relative frequencies of other pollen types in the same way as the deciduous oaks. However, it is probably under-represented. It is interesting to note that the digestion of juniper pollen by *Collembola* has been recorded (Scott & Stojanovich 1963).

Buxus sempervirens *Buxus* is also widespread in Grevena. Relative dispersal is poor; it is only represented in the pollen spectra where it occurs at the sampling site. Relative representation is probably good. Bottema (1974) found that *Buxus* has rather good pollen production but poor dispersal.

Cotinus coggygria This shrub is widespread in the plains as part of the *shiblyak* community. No pollen was found. Bottema (1974:42) obtained a similar result.

***Polygonum aviculare* type** *Polygonum aviculare* type includes well known ruderals and weeds of cultivation. Species belonging to this type were recorded at the sites of Polinerion, Kellia fen, Gomara bog, and Asprokampos field. At Gomara bog *Polygonum* sp. (probably *P. aviculare*) covered over 40% of the surface of the plot in the driest zone of the bog. At Asprokampos, *Polygonum aviculare* was the dominant weed growing in the cereal field.

Polygonum aviculare type pollen occurs in the pollen spectra of all the sampling sites except Anelia woods and Aetia. Relative pollen frequency is always less than 1% except at Kellia fen, where 2.2% relative pollen frequency was recorded, and Gomara bog and Asprokampos cereal field. At the latter two sites, 3.1% and 26% respectively were recorded. It is difficult to compare the relative importance of *Polygonum aviculare* type at these two sites because of the effect of the over-representation of pine pollen suppressing the relative frequencies of other pollen types. The effect would be much greater at the mountain site of Gomara, where 51.3% relative frequency is recorded for pine, than at the lowland site of Asprokampos, where only 3.5% is recorded.

Although this type is autogamous and entomophilous implying low pollen production and dispersal, it is well represented, and its dispersal capability is greater than expected. This can be explained by its system of autogamy. Self-fertilization is achieved by pollen falling

from the anthers onto the stigma (Knuth 1909:348). During this process some pollen would undoubtedly drop to the ground (and perhaps later be caught up in wind currents) while other pollen may be dispersed by wind currents when falling.

***Plantago lanceolata* type** Plants belonging to this pollen type were recorded at the sites of Anelia bog, Polinerion, and Asprokampos field. *Plantago lanceolata* type is represented in all the pollen spectra, except at Avgo. Relative pollen frequency is usually less than 1% at sites where it was not recorded in the vegetation. At sample sites where plants were recorded, usually between 2 and 4% cover, relative pollen frequency is between 2.3 and 2.5%.

The relative dispersal of this pollen type is medium. It is considered to be over-represented because it is present in the pollen spectra for sites where it is not growing locally. At sites where it is growing it appears to be well-represented.

Chenopodiaceae The only sampling site where species belonging to this pollen type were recorded was Asprokampos field. Pollen of this type is recorded in spectra from all sites except Aetia. Relative pollen frequencies are less than 1%, except at the sites of Anelia bog, Kellia fen, Asprokampos fields, and Asprokampos woods, where relative frequencies range from 1.2% to 2.55%. This pollen type has high relative dispersal and is over-represented.

***Rumex acetosa* group** Plants belonging to this pollen group were not observed at any of the sampling sites. Pollen belonging to the group is represented in the pollen spectra of most of the open sampling sites. Relative pollen frequencies are less than 1%, except at Anelia bog, Kellia fen, and Asprokampos field. This pollen type has medium relative dispersal and is over-represented.

Compositae A number of Compositae pollen types are represented in the pollen spectra. They are all represented by extremely low relative frequencies (usually less than 0.5%), even when they are abundant in the local vegetation. This is expected, for they are mostly entomophilous. The highest relative pollen frequencies occur in the spectrum of the Kellia fen site, where these weeds are abundant, but even here, where *Cirsium* is recorded as "frequent" on the fen and recorded with 20% cover in one of the plots, relative pollen frequency reaches only 8.6%. With the exception of *Artemisia*, Compositae pollen types are extremely under-represented and dispersal is low.

Artemisia, on the other hand, is recorded in several pollen spectra (relative frequencies less than 0.7%), although not recorded in the vegetation at the sampling sites. It is known to be anemophilous and well dispersed.

Pteridium *Pteridium* grows in the woods and around the bog at the Anelia sites and as understorey at Agios Nikolaos (30% cover), Perivolion (10% cover), and Zakas (15% cover). *Pteridium* spores occur in only five pollen-diagram spectra: at the four wetland sites and at

Zakas. Relative frequency is less than 1% except in the Gomara spectra, where it is 1.3%. *Pteridium* has medium relative dispersal and is under-represented.

***Dactylis* type** Species belonging to this pollen type grow in the wetland sites of Avgo, Anelia ("+"), and Kellia and in vegetation surrounding the bog at Anelia (up to 10% cover in one plot) and Mirsina fen (up to 15% cover in one of the plots). It also grows in woodlands and grasslands: Perivolion (15% ground cover), Polinerion (up to 5% ground cover in one of the plots), Zakas (0.5% ground cover), and Asprokampos woods and Mirsina woods (15% ground cover).

Pollen is recorded in all pollen spectra except that of Agios Nikolaos. Relative pollen frequencies are less than 1% at Avgo, Anelia woods, Polinerion, Zakas, and Aetia, but at Gomara 6.4%, Anelia bog 5.4%, Perivolion 1%, Kellia fen 2.8%, Asprokampos field 15.6%, Asprokampos woods 4.5%, Mirsina woods 5.6%, and Mirsina fen 5% is recorded.

Relative representation of this pollen type is difficult to determine because pollen may be contributed by either the local vegetation of the wetland and/or the regional vegetation. Relative representation of this pollen type is lower than expected. This may be due to grazing preventing flowering.

***Festuca* type** Species contributing to the *Festuca* type grow at the sites of Avgo, Agios Nikolaos (30% ground cover), Polinerion (dominant ground cover), Zakas, in steppe close to Kellia fen, Asprokampos woods, Mirsina woods (5% ground cover), and Mirsina fen (15% ground cover in plot d).

This pollen type comprises wild grasses of grassland. *Festuca* type occurs in every pollen spectrum except that of Perivolion. Relative pollen frequencies are lowest at the wetland sites of Anelia bog, Kellia fen, and Mirsina fen, where they range from 0.9 to 1.4%. They are also low in the Pindos Mountains, but this may be partly due to the over-representation of pine. The highest relative frequencies of 23% are recorded at Polinerion in an oak wood-pasture.

Pollen of this type is probably severely affected by grazing, e.g. the relative pollen frequencies at the sites of Avgo and Gomara in pine wood-pasture are only 3.3% and 2% respectively, while that at the site of Anelia woods under the canopy of beech wood is 3%. Pollen of this type is probably mostly contributed from regional sources.

Avena This pollen type includes pollen from both domesticated cereals and wild species. Domesticated cereals (oats) belonging to *Avena* are known to have been grown in Grevena before 1940 but are not known to be cultivated now. Plants producing *Avena* pollen are recorded in the vegetation of only one site, the Asprokampos cereal field. The species is probably the wild *Avena sterilis*. Relative pollen frequencies are less than 0.5% in three of the

four sites where it is recorded. In the spectrum from the cereal field at Asprokampos, the relative frequency increases to 3.1%.

The pollen record appears to be one of wild species of *Avena* (domesticated cereals producing pollen of this type are autogamous, and domesticated oats is pseudo-cleistogamous). The pollen source at Asprokampos is probably wild plants, such as *Avena sterilis*, behaving as weeds of cereals (perhaps growing from seed in contaminated seed-stocks), and/or cultivation relics (Thurston 1982).

***Hordeum* type** This pollen type includes both domesticated cereals (barley and einkorn) and wild grasses. Only one grain of this pollen type was identified (from Kellia fen). No pollen was identified in the sample from the cereal field at Asprokampos, which had been planted in barley the previous season.

Plants with pollen that possibly belongs to this pollen type occurred at only two other sampling sites; Polinerion and Asprokampos woods. No pollen was identified in either of the samples from these sites. Domesticated barley is cleistogamous (Knuth 1906-9).

Secale cereale This pollen type includes pollen of only the cereal *Secale cereale* (rye). No vegetation at the sampling sites included plants of *Secale cereale*, but it is currently planted as a crop on a small scale. Pollen of this type is recorded in several spectra in very low relative frequencies, 0.6% and less, even at the sites surrounded by cultivated fields.

***Triticum* type** This pollen type includes only domesticated cereal species. Plants that produce *Triticum*-type pollen were identified at two sampling sites; Asprokampos field and Mirsina fen. Pollen is recorded in several spectra with relative frequencies less than 0.6%. In three pollen spectra relative frequencies are higher; Kellia fen, Asprokampos field, and Asprokampos woods, reaching 4.4% in the Asprokampos field sample. Wheat may have been planted in the field prior to the year it was sampled. These relative frequencies are extremely low considering the amount of wheat cultivated in Grevena, especially in the lowland plains.

Zea mays *Zea mays* was not recorded in the vegetation at any of the sampling sites, but pollen was identified in four samples; one grain only being identified in the sample from Gomara. Relative frequencies of 0.8%, 2.1%, and 0.2% were recorded at the lowland sites of Kellia fen, Asprokampos field, and Mirsina woods respectively. These relative frequencies are very low in comparison with the amount of *Zea mays* cultivated in Grevena.

***Carex flacca* type and *Carex hallerana* type** *Carex* species were identified in the vegetation of several sampling sites. *Carex hallerana* type includes species that grow in marshes as well as some that prefer dry habitats, while *Carex flacca* type includes mostly species that prefer damp sites. In agreement with this distribution, *Carex hallerana* type pollen is recorded in many pollen spectra, both wetland and dryland, while *Carex flacca* type pollen is recorded in the spectra of samples from only wetland sites.

***Cyperus longus* type** Species that produce *Cyperus longus* type pollen grow on the fens at Kellia and Mirsina. This pollen type is represented in the pollen record for these two fens as well as for the Gomara wetland site and the Anelia woods site. Pollen representation for the last site may be due to small numbers of plants growing on the bog 30 m away and not to long-distance dispersal; it is present in upper levels of the Anelia core. It is the most abundant (by far) marsh pollen type represented in the Kellia fen spectra.

Cyperus michelianus This species was not identified in the vegetation at any of the sampling sites, but some of the *Cyperus* species that grow on the fens at Kellia and Mirsina may be *C. michelianus*. Pollen from this species is recorded at the wetland sites of Avgo, Gomara, Anelia bog, Kellia fen, and Mirsina fen. It was also recorded in the spectra from Asprokampos field (at very low frequency).

***Glyceria* type** At Gomara *Glyceria* species cover 20% of the ground in the driest sampling plot. Pollen is recorded at the four wetland sites, including Gomara, where it is most abundant. It was not recorded in the vegetation at the other wetland sites and may occur in the pollen spectra as a result of long-distance dispersal, but it is more likely that it actually grew at the wetland sites since some of the species belonging to this type are marsh plants.

Phragmites australis Pollen of this species is recorded in spectra of samples from all the wetland sites as well as from the Asprokampos field site. Mirsina fen is the only sampling site where *Phragmites australis* grows close to the sampled area. Here it completely covers the fen, but pollen relative frequency is not much greater than that of *Cyperus michelianus*. *Carex hallerana* and *Cyperus longus* also have high relative frequencies.

Sparganium erectum Kellia fen is the only sampling site where *Sparganium erectum* was seen growing. Pollen of this marsh plant was identified in samples from Kellia fen, Mirsina woods, and Mirsina fen. At Kellia this pollen type recorded quite high relative frequency. At the other two sites relative frequency is low.

Sparganium angustifolium Few pollen grains of aquatic plants are recorded; relative frequencies are less than 1% with the exception of *Sparganium angustifolium*, which reaches 1.7% in the spectrum of Kellia fen.

3.4.5 Characterisation of the vegetation zones in the pollen spectra

Inspection of Figure 3.9 shows that the pollen composition of each vegetation zone as classified by Moody & Rackham (in prep.) is distinctive. The ranges of relative frequencies of dominant tree species for each zone are given in Table 3.1. The Pindos Mountains are characterised by large relative pollen frequencies of *Pinus* and *Fagus* and small relative frequencies of *Quercus* pollen (Perivolion an exception with very low relative frequencies of *Fagus*). The Pindos foothills are characterised by lower relative frequencies of *Pinus* pollen

and higher relative frequencies of *Quercus* and *Juniperus* pollen than in the mountains, very small relative frequencies of *Fagus* pollen, and high relative frequencies of *Festuca* type pollen. The lowlands are characterized by low relative frequencies of *Pinus* pollen, almost no *Fagus* pollen, high relative frequencies of *Quercus*, high relative frequencies of herbs of open ground and cultivated cereals.

Table 3.1

Range of pollen relative percentages by vegetation zone

	Pindos Mountains	Pindos foothills	Lowland Plains
<i>Pinus</i> (<i>Diploxylon</i>)	30.3-84.8%	18.5-26.5%	3.5-19.8%
<i>Fagus</i>	0.5-29.4%	0.05-2.3%	0.6-1.4%
<i>Quercus frainetto</i> type	0.3-8.8%	14.6-21.9%	1.2-19.8%
<i>Quercus trojana</i> type	0.0-0.5%	0.7-18.8%	3.1-39.5%
<i>Abies</i>	0.0-0.6%	0.2-14.6%	0.2-4.2%
<i>Ostrya</i> type	0.8-4.8%	1.7%-5.8%	0.4-4.5%
<i>Juniperus</i>	0.0-6.6%	12.3-16%	0.4-5.1%
<i>Festuca</i>	0.0-4%	8.7-32.1%	0.9-11.2%
Herbs of open ground (excluding <i>Festuca</i> type)	2.3-21.5%	4.7-7.7%	14.6-64%
Cereales (excluding <i>Avena</i>)	0.0-0.5%	0.0-0.2%	0.6-6.9%

The relative pollen frequencies of vegetation communities within these zones are discussed below.

3.4.5.1 Pindos Mountains

Pine wood-pasture, *Pinus leucodermis* The pine wood-pasture vegetation community is characterised by the combination of very high relative frequencies of pine pollen (50-70%), with reasonably high relative frequencies of *Fagus* (3.9%) and also of herbs of open ground (14.6-23.4%). Herbs that are particularly well represented are *Dactylis* type and *Festuca* type: 3.4% at Avgo and 6.5% at Gomara (both pollen types combined). The *Plantago* pollen types and Compositae (both Tubuliflorae and Liguliflorae) are abundant at the Gomara site.

Only the pine woods and pine/oak woods communities record such high relative pollen frequencies of pine. Pine wood-pasture is distinguished from those vegetation communities by its higher relative frequency of *Fagus* and the occurrence of herbs of open ground.

Beech woods The beech wood community is distinguished from all other plant communities by its high relative frequency of *Fagus* pollen (29.4%), which is much higher than in any other community.

Pine woods, *Pinus nigra* The pine woods community is characterised by high relative frequencies of pine pollen (64%). The spectrum for this community is very similar to that of the pine/oak woods, and indeed the relative frequency of *Quercus* is slightly higher in the pine woods spectrum than in the pine/oak woods spectrum. This is probably a result of the small-scale mosaic nature of the plant communities in this particular area of the pine woods. A distinguishing feature between these two communities might be the greater relative frequency of juniper (6.6%, in this spectrum) in the pine woods.

Pine/oak woods As discussed above, the pollen spectrum of this community is very similar to that of the pine woods. In an ideal situation, one would expect a greater relative frequency of oak to be the distinguishing feature between the two communities. The relative frequency of pine in the spectrum from this community is 84.8%, while *Quercus* is 5.7%.

3.4.5.2 Pindos foothills

Oak wood-pasture The pollen spectrum of this community has a much reduced relative frequency of pine pollen (18.5%) compared to the plant communities of the Pindos Mountains. Oak relative frequency (*Q. frainetto* 21.9% and *Q. trojana* 4.6%) is greater than those of the Pindos Mountain communities. *Juniperus* (16%) and *Festuca* type (23.1%) pollen are also more abundant.

Mixed woods The two mixed woods are characterised by their diversity of tree pollen types. However, only *Pinus* and *Quercus* (deciduous and semi-evergreen) record higher than 20% relative frequency. Apart from *Abies*, which is the dominant canopy tree at Zakas and is represented by 14.6% relative frequency, *Corylus* and *Ostrya* record the next highest relative frequencies of not more than 5.9%. The relative frequency of the remainder of the trees is very low, less than 1%.

3.4.5.3 Lowland plains

Cultivated fields The two sites of Kellia fen and Asprokampos field are surrounded by cultivated fields of mostly cereals. The pollen spectra from these sites are distinct from those of the other lowland sites in their high relative frequencies of herbs of open ground and lower *Quercus* frequencies. Herbs of open ground reach 36.3% for Kellia and 70% for Asprokampos field. At Asprokampos *Polygonum aviculare* type is particularly well represented at 26.7%. Other herbs of open ground that exhibit higher relative frequencies at these sites than at other sites are *Rumex acetosa* group (1.7 and 1.9%), Chenopodiaceae (2.1

and 2.5%), *Plantago lanceolata* type (2.3% at both sites), *Solidago* type (3 and 1.9%), and Compositae (Tubuliflorae – *Kellia* 13% and Asprokampos 6.5% and Liguliflorae – *Kellia* 1.8% and Asprokampos 5%), particularly *Cirsium* type and *Centaurea solstitialis* type.

Pollen types that include domesticated cereals are highest in these two spectra and reach relative frequencies of 3.5% for *Kellia* and 6.9% for Asprokampos field (*Avena* is excluded as it is not now cultivated in Grevena, although it was in the recent past). The main contributing pollen type is *Triticum*.

Oak woods At the two sites of Asprokampos woods and Mirsina woods the surface samples were collected from beneath the canopy of stands of oak. The spectra of these two sites differ from the other lowland sites mostly in their higher relative frequencies of *Quercus* pollen types. The relative frequencies of *Quercus frainetto* type reach 19.8% for Asprokampos woods, while at Mirsina woods only 1.2% is recorded. *Quercus trojana* type reaches 13.6% for Asprokampos woods and 39.5% for Mirsina woods.

The relative frequencies of herbs of open ground are lower at these sites than for the cultivated fields, being 26.7% for Asprokampos woods and 25.2% for Mirsina woods. Pollen types that include domesticated cereals are not as well represented in the spectra from these two sites as those from the cultivated fields, aggregating only 2.4% and 1.2%.

Steppe/oak woods The Mirsina fen site is only about 40 m from the Mirsina woods sampling site. The relative frequencies of *Quercus* types, *Quercus frainetto* type (16.6%), and *Quercus trojana* type (3.6%) are intermediate between those of the cultivated fields and the oak woods of the lowlands.

The relative frequencies of herbs of open ground are lower than at the sites surrounded by cultivated fields, but higher than the two oak wood sites, being 32.4% for Mirsina fen (this higher frequency is probably due to the steppe surrounding the fen). The 0.6% relative frequency of pollen types that include domesticated cereals is lower than for all the other lowland sites.

3.4.5.4 Wetlands

Pollen and spore types of wetland plants are seldom recorded outside the wetland sites, except those that include species that grow also on dry land, e.g. *Carex hallerana* type, *Filipendula*, *Mentha* type; or grow in other damp habitats, e.g. *Chrysosplenium alternifolium*, *Gratiola officinalis*, *Lychnis flos-cuculi*, *Salix fragilis* type; or have good dispersal, e.g. *Phragmites australis*, *Sparganium erectum*, *Typha angustifolia* type. At dryland sites all these record less than 1%, except for *Phragmites australis* (2.7% for Asprokampos field) and *Carex hallerana*, which is recorded at several sites and probably represents plants growing on dry land.

Lakes The only aquatic pollen types represented for the Avgo lake site are *Hydrocotyle vulgaris* (0.3%) and *Myriophyllum spicatum* (0.3%). At this site the two *Carex* pollen types record the highest relative frequencies of wetland types (*Carex flacca* type 13.1% and *Carex hallerana* type 3.6%). All other wetland types reach only 0.3%.

The site at Gomara is an ephemeral lake. Representation of aquatic pollen types is also low for this site: *Hydrocotyle vulgaris* (0.2%) and *Ranunculus aquatilis* group (0.2%). This site is distinguished from the lake at Avgo by a much greater representation of wetland pollen types: *Carex hallerana* (6.5%), *Cyperus michelianus* (8.2%), *Glyceria* type (4.9%), and *Phragmites australis* (2.9%).

Bog The bog community of Anelia is characterized by records of the following pollen types: *Carex flacca* type (1.2%); *Carex hallerana* type (3%); *Cyperus michelianus* (3.6%); *Glyceria* (0.6%); *Phragmites australis* (1.8%); *Mentha* type (1.8%), and *Parnassia palustris* (3%).

Fens The two fen communities of Kellia and Mirsina differ from the bog community in having higher relative frequencies of pollen of *Cyperus longus* type (Kellia 116.4% and Mirsina 11.4%) and *Cyperus michelianus* (27%, 21.9%), and by the records of *Equisetum* (5.8%, 2.2%) and *Sparganium erectum* (16.6%, 0.3%). (*Sparganium erectum* grows very abundantly on Kellia fen.) Other wetland pollen types which are recorded for both bog and fen communities include *Carex flacca* type (22.6%, 2.8%), *Carex hallerana* type (2.6%, 14.4%), *Glyceria* (2.8% for both fens), and *Phragmites* (1.2%, 27.4%). The last forms a canopy over the fen at Mirsina. Pollen of *Mentha* type is recorded in both fen spectra (2.3%, 2.5%), as well as *Salix fragilis* type (1.2%, 1.7%).

3.4.6 Charcoal

Relative frequencies of charcoal particles of different size classes found in surface pollen samples provide a basis for interpretation of relative frequencies of charcoal particles in the wetland sequences. The wild vegetation of Grevena is not very flammable and, as something is known of the current anthropogenic fire regime, charcoal abundance and size of particles can be correlated with distance from the source of charcoal.

The sampling site at Avgo is within a national park, where lighting of fires is prohibited, and few if any fires are intentionally lit in the foothills, but the lowland sites are in a region where the stubble of cereals is burnt annually.

The relative frequencies of various size classes of charcoal particles counted in the surface samples show distinct patterns. The site at Avgo provides a good reference for an area where anthropogenic fires do not occur. Very low relative frequencies of all size classes are recorded here. Indeed, all mountain sampling sites record very low frequencies for all size

classes of particles. (The high frequency for charcoal less than $25\ \mu\text{m}^2$ at the Anelia bog site is unreliable, due to small sample size, and must be disregarded.) Gomara records higher frequencies than the other mountain sites. This may be due to occasional burning to encourage summer pasture growth; no tradition of controlled burning to improve pasture is known to be practised in Grevena, although it is common in other parts of Greece (Forbes & Koster 1976).

Sites in the foothills record slightly higher relative frequencies than the mountain sites, but only in the size classes containing charcoal particles smaller than $100\ \mu\text{m}^2$.

Relative frequencies recorded in the lowland vary greatly but are greater than those of the mountains or foothills. Fires are known to have occurred recently on or very near the sites of Kellia fen, Asprokampos field, and Mirsina fen. Charcoal of all size classes is abundant from these sites, especially from the two wetlands, where charcoal may have been washed in. Fires are not known to have occurred recently at the two lowland woodland sites, which show a marked contrast to the above three sites in having much lower charcoal particle frequencies in all size classes.

It can be concluded that charcoal particles of less than $25\ \mu\text{m}^2$ occur everywhere and must be transported long distances, while those of larger than $400\ \mu\text{m}^2$ are extremely local.

3.5 Discussion

3.5.1 Previous surface-sample study in Grevena

As part of a geographically wider study, Bottema (1974) analysed five surface pollen samples (numbers 74-78) from a north-south transect through the steppe/oak woods in the lowland plains of Grevena (Figure 3.2). The pollen sum included all pollen and spores of ferns (a second sum was introduced if one or more types were thought to be over-represented). The relative frequencies of *Pinus* pollen type range between about 5 and 10%, while *Fagus* records less than 5% for the first pollen sum, but up to 10% for the second. *Quercus robur*-type records a wide range, with sample numbers 76-78 recording much higher relative frequencies (between about 30 and 70%) than samples 74 and 75 (about 10 and 5% respectively). Another prominent woody pollen type, *Juniperus*, generally fluctuates between about 5 and 10%, but one spectrum of one sample, #77, records about 12%. *Abies* records very low relative frequencies but reaches about 3% in the second pollen sum. *Carpinus orientalis/Ostrya* pollen type (equivalent to the *Ostrya* type in the present study) records less than 2% in the first pollen sum, but reaches about 4% in the second. Gramineae records between about 5 and 12%. *Cerealia*-type and *Zea mays* pollen types added together record between about 0 and 5% in the first pollen sum, but almost 10% in the second. Many herbaceous pollen types are recorded with very low relative frequencies. However, there are a few which are recorded more consistently and/or are more abundant. These pollen types

include: Chenopodiaceae, *Plantago lanceolata* type, *Sanguisorba minor*-type, Umbelliferae, Cruciferae, Liguliflorae, *Matricaria*-type (equivalent to the *Achillea* type of the present study), *Centaurea solstitialis*-type, Other Tubuliflorae, Leguminosae, *Rumex acetosa*-type, and *Polygonum aviculare*-type. All these types include many weeds and ruderals. Sample site number 74 is in a cultivated area and records higher frequencies of these than the other sites.

These pollen relative frequencies, which can be thought of as characterizing the steppe/oak vegetation zone of the lowland plains, are very close to those resulting from the present study (Table 3.1).

3.5.2 Arboreal pollen to herbaceous pollen ratio

The summary diagram showing the ratio of pollen frequency of trees and shrubs to that of herbaceous plants in each spectrum shows that the frequency of pollen of woody species is higher in the mountain and foothill spectra than in the lowland spectra.

The mountain and foothill spectra derived from sites which have canopies that are more than 50% closed have higher ratios than those with open canopies. This also applies to the lowland spectra. The ratio is greatest at the three sites of Anelia woods (0.916:0.084), Agios Nikolaos (0.906:0.094), and Perivolion (0.950:0.041). The samples from these three sites were collected under the canopy of a beech wood, pine wood, and pine/oak wood respectively. Samples collected from two foothill sites under the canopy of mixed deciduous woods have lower ratios of 0.803:0.197 (Zakas) and 0.854:0.146 (Aetia). The spectra from two samples collected beneath the canopy of lowland oak woods have lower ratios of 0.657:0.343 (Asprokampos woods) and 0.728:0.272 (Mirsina woods).

Two samples collected from open sites in pine wood-pasture recorded ratios of 0.803:0.197 (Avgo) and 0.699:0.301 (Gomara). The open oak wood-pasture site at Polinerion recorded a ratio of 0.671:0.329. The lowest ratio by far is that recorded for the Asprokampos field site (0.165:0.835).

3.5.3 Palynological richness

Although the size of the pollen sum varies considerably, the diversity of vegetation at the sampling sites is reflected in the pollen spectra. Spectra with the greatest number of terrestrial pollen types are those from the two pine wood-pasture sites (with 53 and 84 pollen types), and the lowland plains sites (range from 40 to 66 types). These are open sites apart from the two oak wood sites of Asprokampos and Mirsina.

Rarefaction analysis was carried out to standardize diversity, taking into account the varied pollen sums. The curve of the expected number of terrestrial pollen and spore types shows the same pattern as the unstandardized diversity, except that the Anelia bog spectrum

now falls into the group of greater palynological richness (30 or above). The Anelia bog spectrum had previously had the lowest taxon count and estimates were based on it so no confidence interval is shown for this sample. The expected number of taxa for the group of lower palynological richness is from 15 to 25.

In general, the results show a trend towards greater diversity for more open sites, and probably reflect in part a greater pollen source area for these sites. The greatest palynological richness (based on the rarefaction analysis) is recorded in the spectra from the wetland sites. Although pollen of marsh and bog, and of aquatic plants has been excluded from the sums used, herbaceous plants growing on the dry margins of these wetlands would contribute to the pollen sum. The palynological richness of the spectra from Asprokampos field and Polinerion is lower than expected, when the openness of the sites and the larger potential source area are considered, but this can be explained. In each case the lower diversity is a result of human disturbance. Asprokampos field is surrounded by cultivated fields, and local vegetation is mostly herbaceous and is ploughed each year except perhaps a narrow strip at the edge of the field. At Polinerion heavy grazing has greatly reduced diversity.

The relatively open oak woods with incomplete canopies record intermediate palynological richness, while woods with closed canopies have low palynological richness. The sample collected from beneath the canopy of the beech woods at Anelia records only 26 pollen taxa in the pollen spectra (and remains the same after rarefaction analysis), while the mixed woods at Zakas and Aetia record 36 and 33 pollen taxa respectively (but drop to almost 25 after rarefaction analysis). The lowest diversity (17 pollen taxa in the spectra, and after rarefaction) is recorded for the pine/oak woods in the Pindos Mountains.

Bottema (1982:270) identified surface pollen from a short transect across the Pindos just south of the Grevena border (with levels of identification similar to those of the present study). He identified 51 pollen types in a cultivated area in a valley, 49 in a herb-rich meadow just below a fir forest with bracken and forest at some distance, and 20 in samples within both a fir/beech forest and a beech forest. (His data were not corrected for dissimilar pollen sums, but his pollen sums were large, ranging from 700 to 1800.) In the present study, pollen samples from more or less comparable sites in Grevena displayed similar diversity: 40-66 pollen types (unstandardized sums) from the lowland plains, 33 pollen types from herb-rich meadows with bracken and forest at some distance (Polinerion), 36 from inside an *Abies*-dominated mixed wood on the Pindos foothills (Zakas), and 26 from a beech wood (Anelia woods).

3.5.4 Degraded vegetation

Special mention is made of two vegetation communities, pseudo-*maquis* and *shiblyak*, because of their potential importance in the interpretation of fossil sequences in terms of human disturbance. It has been recorded that both these communities can be created from natural communities and maintained either directly or indirectly by anthropogenic disturbance (Turrill 1929), although *shiblyak* may also form a permanent community in Grevena (Moody & Rackham, in prep.). Thus palynological recognition of these communities might indicate anthropogenic disturbance of an area. Pseudo-*maquis* is confined to a small area in Grevena, but *shiblyak* is widespread in the plains. Unfortunately, no surface samples were collected from these communities, but something can be said about their relative pollen dispersal and representation based on data from my study and previous studies.

Palynologically, pseudo-*maquis* is difficult to distinguish. In Grevena pseudo-*maquis* would be represented by *Quercus coccifera* type only. Other characteristic species of this vegetation community such as *Juniperus*, *Buxus*, *Pistacia*, and *Phillyrea* either occur in other plant communities or their pollen representation is very poor (Bottema 1974).

In Grevena *shiblyak* is characterised by *Cotinus coggygria*, *Prunus spinosa*, *Colutea arborescens*, and *Paliurus spina-christi*. All of these species are very poorly represented in the pollen record. Other characteristic taxa listed by Turrill (1929:153) that might occur in Grevena are *Quercus pubescens*, *Berberis vulgaris*, *Rhus coriaria*, *Prunus amygdalus*, *Viburnum lantana*, and *Cercis siliquastrum*. The first of these occurs in other plant communities while the remainder have very poor pollen representation.

3.6 Implications for late-Holocene pollen studies in Grevena

Although the number of samples is small and preservation variable, the relative frequency spectra of these surface pollen samples reveal much about the relationship between extant vegetation of Grevena and pollen deposition that is applicable to the reconstruction of palaeovegetation and environment from fossil pollen spectra. The data mainly reflect differences between pollen production and dispersal properties between taxa.

3.6.1 The natural vegetation

The extant vegetation of Grevena is dominated by woodland, which covers over half the entire land area; grassland and cultivation cover the remainder. The landscape is intensively used and little if any unmodified vegetation remains. Today land use includes agriculture, pastoralism, removal of trees by cutting, and maintenance of trees by coppicing, pollarding, and shredding. In spite of this intensive land use, the composition and structure of the woodlands varies according to elevation and moisture and forms distinct vegetation zones

dominated by only a few tree genera. The highest elevations are occupied by alpine meadows and *Pinus* woods, at intermediate elevations by a mosaic of *Pinus* woods, *Fagus* woods, and mixed coniferous/deciduous woods, while the lower slopes of the Pindos foothills are dominated by deciduous *Quercus* woods and the plains by a mosaic of deciduous *Quercus* woods and steppe, and agricultural land. The west-to-east moisture gradient results in the dry eastern Vourinos Mountains supporting few trees. The trees that dominate the landscape, *Pinus*, *Fagus*, and *Quercus*, are also dominant in the surface pollen spectra, and the major vegetation zones which these trees dominate are characterized by corresponding high pollen relative frequencies: 51-84% *Pinus* (*Diploxylon*) in pine wood, 23.5-29.4% *Fagus* in beech woods, and 26.5-40.7% *Quercus frainetto* and *Quercus trojana* types combined in deciduous oak woods.

As has been found in many other surface pollen studies, the proportion of pollen recorded in the pollen spectra is different from that of corresponding plant taxa in vegetation. An obvious feature of the results of this study is the over-representation of pine pollen, which suppresses the relative frequencies of all other pollen types. No site contained less than 13.6% *Pinus* pollen (Asprokampos field excepted), even in the lowlands where the sampling sites are 25 km from the main source of pine pollen (although there is a small stand of pine near Grevena city, 7 km from the sample sites). This extreme over-representation of *Pinus* necessitates that a high pollen sum be counted in samples collected from pine vegetation zones so that other pollen taxa may attain reasonable representation, and should be taken into account when interpreting the fossil sequences.

By extrapolating back from the extant disturbed vegetation in Grevena to an hypothetical undisturbed vegetation, given the same climatic and edaphic conditions, it is apparent that the same dominant tree vegetation and flora would exist at approximately the same elevations, but there would be greater diversity of trees. Small pockets of less disturbed vegetation such as the mixed woods growing on flysch and ultrabasics at the end of the limestone ridge above Zakas and Spilaion or the mixed wood growing in the oak/steppe zone are indicative of two types of mixed woods of different composition and habitats that presumably would be much more extensive. A former mixed wood of damp habitats and at an altitude between the mountain beech woods and oak wood of the foothills might include such species as *Tilia rubra* (lime), *Ulmus glabra* (elm), *Populus tremula* (aspen), and *Prunus avium* (cherry). A mixed wood of drier habitat and lower altitude might comprise *Carpinus orientalis*, *Acer opalus*, *Cornus mas*, *Fraxinus ornus*, *Tilia rubra*, *Acer campestre*, *Corylus avellana*, *Sorbus torminalis*, and *Tilia tomentosa* and be widespread in the oak/steppe zone in the plains.

The relative dispersal and representation of pollen of these trees varies (as demonstrated by the two surface samples collected from beneath the canopy of the relic mixed woods

currently growing on limestone), but they all have lower relative dispersal and representation than *Pinus*, *Fagus*, and *Quercus*. In general the taller anemophilous trees contribute most pollen to the pollen rain. Many trees of the mixed woods are entomophilous and contribute almost no pollen, e.g. *Acer*, *Cornus*, and *Tilia* and genera of Rosaceae. *Fraxinus ornus* is also primarily entomophilous. If pollen of these trees is found in the pollen record they must have grown close to the sampling site. Poor representation of pollen of these trees makes detection of greater diversity of trees in woodlands difficult. A decline in the pollen of these types as a whole would probably be indicative of anthropogenic disturbance of the forests. *Corylus avellana* and *Carpinus betulus* are anemophilous, but although dispersal is good little pollen is produced, although production may be variable. *Corylus* is known to produce varying amounts of pollen depending upon its structural position in woods, i.e. it produces little pollen as an understorey shrub but produces much as a canopy tree (Iversen 1941; Moore 1976). A few pollen grains of *Corylus* may thus arise from a distant or local source.

One of the biggest problems in interpreting pollen data is defining the size of the area that contributes to the pollen rain. It is often impossible to tell whether a small percentage comes from a few trees in the vicinity or from stands at a distance. In a basin such as Grevena with distinct belts of vegetation zones at different elevations, it is possible to measure pollen dispersal distances from source vegetation. Long-distance transport of some pollen types identified in the surface pollen samples is apparent. Surface samples of the lowlands that contain pollen of trees that grow in the mountains, such as *Pinus* and *Fagus* are evidence of long-distance transport as are samples collected in the mountains that contain pollen of trees that grow in the lowlands and foothills, e.g. *Quercus*. A relative frequency of as much as 13%, in samples from the lowland oak woods of Grevena is not indicative of pine growing on or near the site at the time of deposition of the pollen. Similarly threshold values for *Fagus* and *Quercus* (*Q. frainetto* and *Q. trojana* types combined) of 1% and 6.5% respectively are proposed for Grevena. Another pollen type that clearly displays long-distance dispersal is *Quercus coccifera*, whose appearance in samples collected in the Pindos Mountains must be a result of long-distance transport from the western side of the mountains, taking into account the prevailing westerly winds.

Fagus pollen is relatively large and heavy, so although it is anemophilous only a small proportion of released pollen is carried very far. Evidence of this comes from the two sampling sites Avgo and Gomara, where scattered beech trees grow about 55 meters from each site and show only 3.9% maximum relative frequency. At other Pindos Mountain sites the relative frequency declines to 1.7% or less, similar to that recorded in lowland sites. Two sites were sampled in the beech wood at Anelia, one under the canopy of the beech wood and the other on the surface of a bog (90 x 50 m) within the woods. Thus it is expected that the

greatest proportion of pollen is derived from local and extra-local source areas (Tauber 1965; Andersen 1970). Relative frequency of *Fagus* pollen recorded at these two sites is somewhat similar, 29.4% and 23.5%, the greater frequency recorded in the woods. So a relative frequency of 20-30% would probably indicate that beech trees were growing close to the sampling site and dominate within the first half kilometre (but not that beech was dominating in the whole region). As shown, *Fagus* pollen is deposited mostly on a local and extra-local basis, and a record of a beech wood in the sediments at Anelia bog would indicate a local wood.

Dispersal patterns of oak are difficult to determine because oak trees are so widespread in Grevena and because of the possibility of long-distance transport of *Quercus* pollen from the western (windward) side of the Pindos. Some of the *Quercus* pollen recorded in samples collected from the Pindos Mountains may be a result of vertical transport from lower elevations in Grevena, but it is impossible to distinguish between a pollen source area on the western side of the Pindos Mountains from one on the eastern side (*cf.* Markgraf 1980).

In the late Holocene a change in the climate to cooler, moister, or even cloudier conditions between about 3200 and 1500 BP has been suggested, based on the expansion of *Fagus* (Chapter 1). The modern micro-climatic patterns of Grevena are evident in the contemporary distribution of vegetation belts that change according to elevation. A change in climatic conditions of sufficient magnitude would result in a corresponding shift in the vegetation belts. The most obvious record of these changes in the palynological record would be in changes in the curves of the pollen of the dominant trees of these belts. Trees most sensitive to climatic changes are those near the limits of their ecological amplitude, especially *Fagus*, which is close to its southern limit, and *Abies cephalonica*, which is close to its northern limit.

Wetter or drier conditions might also be reflected in the palynological record of the wetlands as changes in hydrological conditions. Changes in the relative abundances of aquatic pollen types can indicate changes in water levels. Aquatic plants also react quicker than forest trees to thermal climatic changes, as water temperature changes relatively quickly and seed dispersal of water plants is good (Iversen 1964). Data from this study show that pollen from marsh and aquatic plants is mostly dispersed locally.

A problem in pollen analysis has been the differentiation between aquatic grasses and those representing terrestrial grasslands. A pollen curve comprising grasses from both habitats would severely reduce the diagnostic value of terrestrial grasses. Although the sample size is small and caution must be exercised, this study shows a positive correlation between the *Festuca* pollen type with pasture, and the *Glyceria* type and *Phragmites* type with wetlands. Iversen (1964:426) also noted that this distinction was possible. The distinction between

terrestrial and wetland grasses allows more certain interpretation of a landscape becoming more open.

It was not possible to distinguish morphologically between pollen of terrestrial and wetland sedge plants in the *Carex hallerana* type. Thus plants growing locally on the wetland and those potentially growing in the regional vegetation are combined in one pollen type. Most of the plants recorded in the vegetation survey were from wetland sites, and the surface sample sites that record the greatest relative frequencies of *Carex hallerana* type are both fens, so it is probable that most of the pollen contributed to this type is actually from wetland plants. *Carex hallerana* type should therefore be excluded from a terrestrial taxa pollen sum.

3.6.2 Land clearance

The first signs of anthropogenic impact on the vegetation in the Balkan region have been recognized as a reduction or change in woodland composition, accompanied by the expansion of open-ground herbaceous types typical of disturbed agricultural ground in southeast Europe, as well as the presence of cereals (in combination with supporting evidence necessary because of the difficulty in distinguishing wild from domesticated grasses) (Willis & Bennett 1994). Archaeological evidence suggests that the size and extent of the human population of Grevena have fluctuated. The number of archaeological sites recorded from surface surveys increases dramatically in the Early Iron Age (3000 BE), and sites extend from the lowlands to elevations near 1000 m asl. After a decline in the number of sites in the Archaic and Classic Periods, the number in the Hellenistic Period increases and again extends to the elevations previously occupied in the Early Iron Age. Many Hellenistic Period sites are fortifications in the Pindos foothills, and there is evidence for pastoralism and agriculture (Chapter 1). A corresponding successive reduction and regeneration of the woodland trees would be expected as populations requiring large areas of cleared land for their settlements, communication systems, and agriculture cleared land that later became abandoned when the population size reduced.

Agricultural economies require land on which to grow their crops, while pastoralists require grassland to feed their animals – woodland is an obstacle. Woodland can be destroyed by cutting or by burning; perhaps both methods have been employed in Grevena. The extant wild vegetation of Grevena is not very flammable, except *Juniperus* and *Pteridium aquilinum*, although steppe burns occasionally. *Juniperus* is killed by fire, and its absence may indicate the presence of fires. *Juniperus* is widespread in Grevena today, occurring in many different vegetation communities, but pollen representation is not very high. On the other hand, *Pteridium aquilinum* is encouraged by fire, regrowing quickly from rhizomes after being burnt. It is under-represented in the pollen record, so a continuous record may indicate anthropogenic burning.

A guide to the frequency/intensity of fires at a site may also be gained from analysis of microscopic charcoal particles. Charcoal particles of less than 25 μm^2 represent charcoal derived from a distant source, while particles of 400 μm^2 and greater represent charcoal from a very local source.

Reduction of the canopy allows more light to penetrate to the forest floor, thus allowing herbaceous plants that require light to grow. Thus the ratio of non-arboreal pollen (NAP) to arboreal pollen (AP) has been used as a guide to the density of forest cover. In this study, higher ratios were found in the mountain and foothill woods than in open vegetation. The ratio was also found to vary according to tree genera forming the canopy. The ratio is higher in the mountain and foothill pine and beech woods than in the lowland oak woods. The lowest ratio was recorded, as expected, in the most open vegetation in the cultivated area of the lowlands.

Results from the present study show some correlation between openness of sites and palynological richness interpreted from estimated numbers of pollen and spore taxa standardized to a common count size using rarefaction analysis (Birks & Line 1992). The values of expected number of taxa were highest for most open sites, while woods with closed canopies have the lowest values. Woods with incomplete canopies have intermediate palynological richness. Intensive land use, such as the current grazing at Polinerion and the agriculture at Asprokampos, lowered palynological richness. Other researchers have found that intermediate levels of disturbance, either natural or anthropogenic, are important in maximizing richness at the landscape scale (Birks & Line 1992). Changes in palynological richness are interpreted as reflecting predominantly the changing floristic richness of the vegetation types in the pollen source area. These changes may be the result of many and varied causes. A reduction, or small openings, in a canopy would permit entry of a wider variety of pollen taxa from regional sources to fall on the deposition site and thus increase palynological richness.

3.6.3 Pastoralism

Pasture is today most abundant in the Pindos Mountains, where some of the largest modern transhumant Vlach villages are located. The earliest evidence of occupation above 1000 m in the Pindos Mountains in Early Medieval times is from archaeological sites distributed in a pattern similar to that of modern transhumant villages, which suggests the existence of a pastoral economy. Transhumant pastoralism is known to have been practised in the Pindos Mountains and foothills in the Ottoman Period. Today the Pindos pine wood-pastures are intensively grazed during summer. This intensive grazing has reduced the number of trees to below the natural carrying capacity by not allowing seedlings to grow, and a

reduction in grazing would result in regeneration of many more trees. Such a change in the density of trees would be recorded in the Gomara wetland site, which registers regional pollen deposition. The current relatively high frequencies of Compositae and *Plantago* at this site would probably decrease.

Intensive grazing in the dry south-east corner of Grevena has led to the development of pseudo-*maquis*. Unfortunately the extent and location of a degraded vegetation of pseudo-*maquis* would be difficult to determine from the pollen record. The only pollen type indicative of this vegetation with reasonable representation is *Quercus coccifera*, which is over-represented and is transported long-distances. Recognition of *shiblyak*, whether human-induced or natural, would also be difficult to detect due to poor pollen representation and the lack of characteristic pollen types.

The production of leaf-fodder for animal sustenance during winter is part of the pastoral economy in Grevena today. Iversen (1941) correlated the use of leaf-fodder of elm with the decline of elm pollen in pollen diagrams from Denmark during the Neolithic Period, although more recently Dutch elm disease has been suggested as a possible cause for the elm decline (Perry & Moore 1987). Leaf-fodder production practised in Grevena today plays a vitally important role in animal husbandry (Chapter 1). The tree most used is *Quercus*, but there is much evidence that both *Quercus* and *Fagus* were regularly coppiced in the past few centuries. Coppicing of oak is most common at lower altitudes in the Pindos foothills, while pollarding of oak is most common in the lowlands. Unfortunately, no surface samples were collected from the coppice oak woods of the foothills, but the two oak woods that were sampled in the lowlands had been coppiced. Pollen relative frequencies of these woods were high (33.4 and 40.7%), but it is impossible to say if coppicing has depressed pollen deposition, as no data are available against which to compare these frequencies. Oaks produce flowers in the later part of each coppicing cycle (30-40 years), except *Quercus frainetto*, which takes at least 50 years. It is not known how long *Fagus* takes to regrow and flower after coppicing, but if a species is regularly prevented from flowering, e.g. because it is regularly harvested before reaching flowering age, it will not show in a pollen diagram, even if it is common in the area.

3.6.4 Cultivation

It has been demonstrated that an increase in the pollen of *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* is associated with anthropogenic disturbance of woodlands in Greece (Bottema 1974, 1980, 1982; Bottema & Woldring 1990). These trees are thought to have either profited from human-induced changes in habitats or were planted in prehistoric times. *Juglans regia* and *Platanus orientalis* are anemophilous, but pollen production is not very high. Thus low relative percentages in the pollen record may be due to long-distance dispersal or to a few trees growing in the vicinity of the sampling site. *Castanea sativa* is entomophilous primarily, but from the results of this study it appears capable of long-distance dispersal also. Long-distance dispersal of *Castanea* pollen has been reported by others (Ruffaldi 1994). The sap of *Fraxinus ornus* was used to make syrup in the past, but it is not known if this tree was planted (Bottema & Woldring 1990). The relative dispersal and representation of this tree is discussed above.

Agriculture has a long history in Grevena, for archaeological surface surveys undertaken by the Grevena Project have revealed wheat/barley seeds in association with Hellenistic sites, and ethnoarchaeological studies indicate that a variety of crops was grown prior to 1940 – before mechanization of agriculture (Chapter 1). The domesticated cereals of wheat, barley, rye, oats, and maize were grown for human consumption and animal fodder. Other crops included beans, chickpeas, vegetables, fruits, nuts, vines (grapes), vetch, pea hay, and alfalfa. Apart from maize these crops are likely to have been grown in Grevena in prehistoric times also (*Secale cereale* only since Roman times) (van Zeist & Bottema 1971; Dennell 1972; Renfrew, J. 1969, 1973a, b; Hansen & Renfrew, J. 1978; Hansen 1978, 1988; Jones 1981).

The results of the present study indicate that the cereal pollen types of *Hordeum*, *Triticum*, *Secale cereale*, and *Zea mays* are severely under-represented. *Hordeum* is cleistogamous and autogamous. No pollen of the *Hordeum* pollen type was found in the sample collected from the cultivated field where barley had been grown that summer and only one other grain of this type was found. *Triticum* type is better represented than that of *Hordeum*: although it is autogamous some pollen is released for atmospheric dispersal. *Secale cereale* is cross-pollinated by wind (Faegri & Iversen 1989:127). The severe under-representation and poor dispersal of the domesticated cereals of *Hordeum*, *Secale cereale*, and *Triticum* demonstrated in this study is consistent with results from other studies of surface samples from cultivated fields (Vuorela 1972, 1973; O'Connell 1986; Hall 1989). Hall (1989), in a study of surface grass samples spaced only 5 m apart, found that although values of between 9 and 23% cereal pollen were recorded in surface samples from beneath crops, only 1-2% (3% from moss polsters) were recorded at distances of more than 1.5 m from the edge of the crop. No assessment of the representation of domesticated *Avena* could be made from

the current study, but Vuorela (1972, 1973) found that *Avena* is well represented in pollen diagrams, although its pollen-dispersal capacity is less than that of *Secale* but greater than that of *Triticum* and considerably greater than that of *Hordeum*. On the other hand, O'Connell (1986) found that *Avena* representation is exceptionally low. Vuorela (1972, 1973) suggested that most cereal pollen is dispersed during harvest-time and not during the flowering season. *Zea mays* is anemophilous, but Raynor *et al.* (1972) found from experimentation that dispersal of *Zea mays* pollen is very poor: the concentration of pollen remaining airborne at 60 m from the source in the downwind direction is about 1% of that at 1 m. The poor dispersal (and under-representation) makes representation of cereal-type pollen in a time-series study unlikely unless the sampling site is close to the fields that were cultivated.

Prior to mechanization of agriculture, if oxen were kept for draught a large proportion (a minimum of just over 1/5 (Chapter 1)) of the productive arable land was required for growing legume crops for fodder. Legumes are entomophilous, and their pollen has very low probability of being preserved in detectable frequencies in wetland deposits. Also it is difficult to differentiate crop pollen types from wild types. *Medicago sativa* subsp. *sativa* (alfalfa) is still grown as a fodder crop today in Grevena. A few pollen grains of the *Medicago sativa* pollen type were identified, but from locations that suggest they were from the wild subspecies. Chickpeas are also grown as a fodder crop today, but no pollen was identified.

Although no grape vine plants were recorded in the vegetation survey and no pollen was identified, they are mentioned here because they are known to have been grown much more extensively than they are in the household gardens of today, and because pollen of vines has been recorded in pollen diagrams from Greece (Chapter 1). Wine was made locally during Roman times (Chapter 1). Ethnographic studies of pre-1940's agriculture indicate that the minimum area of land required for a subsistence household for the production of grape vines was 2000 m² (Chapter 1) and that extensive vineyards near Spilaion produced a surplus that was exported. Vine pollen is probably under-represented and has low dispersal power. Vines were usually planted close to settlements, so a sampling site such as Kellia, which is close to a settlement, might record this production. Fruit and nut trees usually surrounded the vineyards, so they might also be recorded in sites close to settlements.

While the pollen of herbaceous cultivars is under-represented in the pollen record, several weeds associated with cultivated fields are better represented. The surface sample from the cereal field at Asprokampos contained the pollen types of *Polygonum aviculare* type, *Plantago lanceolata* type, *Rumex acetosa* group, and Chenopodiaceae, which all include weed species. All of these except the first are anemophilous, and all have medium to high relative dispersal and are well- to over-represented. Pollen of several Compositae species were also identified in this sample. These pollen types are entomophilous, dispersing their pollen

locally. Species belonging to these pollen types are light-demanding, and an increase in their relative frequency would provide evidence of an opening vegetation. These pollen types are included in Bottema's (1982) and Bottema & Woldring's (1990) lists of anthropogenic indicator species.

In conclusion, plant communities characterised in this study may not provide modern analogues of past pollen assemblages because of the recent changes in land-use patterns, especially the contraction of agriculture to the lowlands since mechanisation (Chapter 1). Thus the indicator approach may be more helpful for interpretation. Indicator pollen types, especially those identifiable to species level or those of species groups that have a clearly defined ecology, are particularly diagnostic. Pollen types of the major trees would be the best indicators of climatic change, especially *Fagus*, which is near its ecological limits. Indicator pollen types of disturbance of woodland, whether anthropogenic or natural, would be those of weeds, ruderals, and pioneers. Herbaceous pollen types of cultivars, as well as weeds and ruderals, especially those that can be identified to species and those that are not sensitive to climatic influence, e.g. cereals, weeds, *Pteridium aquilinum*, would be particularly important for the interpretation of anthropogenic disturbance.

Chapter 4. Gomara

4.1 Introduction

This chapter includes a description of the site and sediments of the Gomara wetland coring site and then presents the results of pollen analysis of a sediment sequence 190 cm long. The wetland was first identified as a potentially suitable pollen-analysis site by Moody & Rackham (1988). These authors named the site 'Limni', a Greek word meaning lake, suggesting that the wetland was filled with water in early summer when they discovered it. Preliminary palynological investigations suggested that the sediments of this wetland were suitable for a full palynological study; fossil pollen was very abundant, and preservation was excellent (Huber & Rapp 1988).

4.2 Site description

Gomara wetland is situated in the Pindos Mountains (latitude 40° 03' N, longitude 21° 04' E) on the pass between Smixi and Distraton at an elevation of 1750 m asl (Figure 1.1). It is about 1 km west of the Grevena border in the province of Ioanninon and about 4.5 km west of the Vlach village of Smixi (Figures 3.2, 4.1 & 4.2). The pass was a trading route during the Ottoman Period, and currently there is a small commercial ski field on the southern side of the pass on the slopes of Vasilitsa mountain. The Gomara-Vasilitsa area has pastures that are leased by herders of the Grevena transhumant (Vlach) villages of Smixi, Samarina, and Avdella (Koster 1987).

4.2.1 Physiographic description

Today an ephemeral lake, Gomara wetland is about 10 m north of the road between Smixi and Distraton in subalpine meadows (Figures 4.1 & 4.2). It is perched on a bench that drops steeply down to the Dristis River drainage, a narrow steep valley to the south. High peaks rise to the north and south, but the site is open to the west and east. The peak of Gomara (2126 m) rises to the NNW about 2 km from the wetland coring site, while the lesser peak Tambouri (2026 m) rises almost due north of the site and only about 0.8 km from it. To the SSE the slightly more distant (about 2.5 km) and higher peak of Vasilitsa (2248 m) rises steeply (Hellenic Army Geographic Service 1970). The name given to the wetland site in this thesis is taken from Gomara peak.

The wetland is rheotrophic, receiving water not only directly from the atmosphere in the form of rain and snow but also from run-off. There is a shallow (about 25 cm deep) intermittent overflow channel from the lake to the SSE (Figure 4.2). Water was noted in the wetland basin at the beginning of the field season in 1989 (mid summer), but three weeks later

Figure 4.1 View of Gomara site from Smixi-Distraton road, looking NNE, across the dried lakebed. A small stand of beech trees can be seen on the right and scattered dead and living standing pine trees beyond.

Figure 4.2 Location of Gomara wetland in relation to local topography: Gomara-Tambouri-Vasilitsa peaks area of the Pindos Range. Contour interval 100 m. The fen and core sites are shown in detail at right.

when coring was undertaken it was dry, and cracks had appeared on the surface of the lakebed (Figure 4.1). Presumably high water occurs in early summer following snow melt. The very strong westerly winds experienced while doing field work would act as a strong evaporative force.

The wetland is enclosed in a shallow almost circular basin, 65 m long and 50 m wide (3250 m² in area). This is slightly smaller than the 5000 m² (½ ha) ideal size suggested by Faegri & Iversen (1975:86, 1989:57) for pollen analysis. The catchment of the wetland basin is approximately 75 ha with a SSW aspect and a mean slope of 19° (estimated from contours) (Hellenic Army Geographic Service 1970).

4.2.2 Regional and local vegetation

The regional vegetation is the pine wood-pasture community described in Chapter 3 and is very similar to that surrounding the Avgo site, with the exception that it is grazed more intensively. The vegetation is very open, a characteristic of this vegetation type, with scattered trees, mostly *Pinus leucodermis* (the alpine pine), growing in grassland. About 30% of the ground is bare. In the vicinity of the lake pine trees are mostly about 20 m tall, and many are dead but still standing. A stand of *Fagus sylvatica* (beech) trees grows in a small valley close to the lake (Figure 4.1). They reach a maximum height of only 6 m. Some grazing and coppicing of beech has occurred. Tree seedlings are grazed, thus prohibiting regeneration, and the slope below the lake has been logged recently.

The dried lakebed has a distinct seasonal fen vegetation (Appendix VIII). When fieldwork was undertaken vegetation on the lakebed was very low and sparse, and there was no hydrosere surrounding the perimeter of the lake.

4.2.3 Geology of site

Bedrock is mapped as the Pindos ophiolite ultramafics: peridotites and serpentinites (Institute for Geology and Subsurface Research 1960). These rocks weather easily and produce extensive screes (Strid 1989). Coarse well-draining colluvium with some large blocks surrounds the site. Soils in the catchment are brown, shallow, and stony. It has been speculated that "the coarse stone content and shallowness [of serpentinite soils] must result in a low water-holding capacity and a restricted soil depth for root penetration, and plants growing in these soils are likely to suffer from drought" (Proctor & Woodell 1971:255).

The genesis of the lake basin is unknown, but impoundment may have been the result of glacial activity, for example a kettlehole, glacial scour, or moraine-damming; local faulting; earthquake-induced slope failure; or human disturbance. Glacial activity is an unlikely cause since glacial activity in the Pindos Mountains during the last glaciation resulted in only

relatively small glaciers forming on north and east facing slopes (Turrill 1929:71; Institute for Geology and Subsurface Research 1960; Savina 1993), and there are no obvious moraine features in the catchment. A more likely explanation is the coalescing of colluvial debris flows triggered by tectonic movement or a heavy rainstorm. Open vegetation cover, perhaps cleared by humans (Turrill 1929), may have predisposed the site to such an occurrence. Furthermore, landslides are a common feature of areas underlain by Pindos ophiolite (Institute for Geology and Subsurface Research 1960; Savina 1990).

The hardness of the sediment immediately below the lowest sample collected for pollen analysis suggests that 190 cm is about the full depth of the sedimentary basin. Rackham (pers. comm.) also managed to penetrate the sediments in the centre of the wetland to only 205 cm below surface.

4.3 Sediment analysis

The location of the coring sites is shown in Figure 4.2 and the results of the Troels-Smith (1955) classification and laboratory analyses of the physical properties of the pollen-analysed sediment sequence are reported below. Two borings 25 cm apart and overlapping 21 cm were made with a piston corer. In the diagrams and text, datum for depth (given in cm) is the ground surface.

4.3.1 Stratigraphy

An illustrated description of the sediments of the pollen-analysed core is given in Figure 4.3. The Troels-Smith (1955) classification scheme using symbols and formulas is followed (Appendix III). Columns show the component elements, accessory elements, physical properties, and boundary definitions of the sediments. Component elements are shown in the first two columns in symbols and formulas. The proportion in which each element occurs is given as well as occurrence of accessory elements (in symbols only). The degree of definition of boundaries between strata (*limes*) is indicated where sediment composition changes, in symbols in the stratigraphic column and in numeric form to the right of the column (based on a 5-class scale). Notes on the *structura* of the sediments are given in the next column. Formulas (and text description) of the fresh colour of the sediments taken from standard Munsell colour charts (Oyama & Takehara 1967) follow. Other physical properties, *nigror*, *stratificatio*, *elasticitas*, and *siccitas* are shown in symbolic form in columns on the right. (Since the whole sequence is water saturated, *siccitas* is 2 throughout.) Numbers indicating the degree of each of these properties (based on a 5-class scale) are shown to the right of the column. Colours are all fresh colours.

Figure 4.3 Troels-Smith classification of Gomara core sediments. Symbols are defined in Appendix III.

This sequence comprises minerogenic and organic deposits washed into the wetland from the catchment. No samples effervesced in 10% HCl, indicating the absence of calcium carbonate. This is consistent with a soil derived from the local bedrock of serpentinite (Spence 1957).

Macrofossils of superterranean fragments of herbaceous plants or parts of plants (*Detritus herbosus*) occur throughout the core, but from 83-157 cm macrofossils of superterranean woody parts of plants (*Detritus lignosus*) occurred. These are very abundant from 83-110 cm, but they occur down to 157 cm decreasing in abundance with depth. Time constraints precluded a systematic numerical study of these macrofossils. Many of the fragments were twigs and pieces of wood that were not easily identifiable, but many were identifiable beech nuts, suggesting that beech grew in the vicinity of the wetland (Ryvarden 1971, 1975; Watts 1978; Glaser 1981; Wasylikowa 1986). The lowest beech nut was found at 155 cm. A pine cone scale was noted at 107 cm and a piece of wood 4 cm thick was found from 127-131 cm.

190.0-181.5 cm The basal sediments are composed of *Argilla steatodes* (mineral particles <0.002 mm) with only a trace of *Detritus herbosus* (organic detrital material derived from herbaceous plants). The sediments are brownish black (10YR 2/2), somewhat plastic and cohesive, and homogeneous (*stratificatio* 0). Small particles of charcoal were noted.

181.5-157.0 cm The boundary is relatively distinct (*limes* 3) at 181.5 cm where the sediment becomes gritty with the addition of coarser-grained particles of *Grana saburralia* (mineral particles 0.6-2.0 mm) (As3 Gs1 Dh+). This sediment is slightly drier, less cohesive, less plastic, and slightly lighter in colour (brownish black, 2.5Y 3/1) than the unit below.

157.0-135.5 cm Sediment composition changes gradually with an indistinct boundary (*limes* 1) at 157.0 cm. *Grana saburralia* is replaced by *Detritus herbosus*, and *D. lignosus* (organic detrital material derived from ligneous plants) appears as a trace (As3 Dh1 D1+). Charcoal particles were noted. The sediments are very dark in colour (black, 10YR 2/1), very slightly stratified (*stratificatio* 1), not elastic, and wetter than in the unit below.

135.5-110.0 cm Again the sediment composition changes gradually at an indistinct boundary (*limes* 1) at 135.5 cm, where the proportion of *Detritus herbosus* increases relative to *Argilla steatodes* (As2 Dh2 D1+). The colour of the sediments becomes less black (brownish black, 10YR 2/2), and the physical properties of *stratificatio* (1) and *elasticitas* (0) remain unchanged.

110.0-106.0 cm Above another indistinct boundary at 110.0 cm, the preceding unit grades into a transitional unit below a thin but very distinct unit from 108.2-107.2 cm. A sharp boundary (*limes* 4) occurs at 107.2 cm, above which is another transitional unit of 0.8 cm thickness (up to 106.0 cm). Between 108.2 and 107.2 cm a very distinct band of

laminated dark greyish-yellow (2.5Y 4/2) pure *Argilla steatodes* (As4) occurs. On both sides of this band the narrow transitional bands of *Argilla steatodes* with *Detritus herbosus* (As3 Dh1) are brownish black (2.5Y 3/2), the lower band differing from the upper by being weakly laminated. These units are not elastic (*elasticitas* 0).

106.0-49.0 cm Above these distinct units the sediment composition changes to one that is predominantly felted *Detritus herbosus* up to 49.0 cm. At the base of this unit the sediments are composed of *Detritus herbosus* with some *Argilla steatodes* and a trace of *Detritus lignosus* (Dh3 As1 D1+). The proportion of *Detritus herbosus* increases upwards; the sediment becomes pure *Detritus herbosus* (Dh4) at the top of the unit. This unit is dark brown (10YR 3/3), does not split easily into thin horizontal layers (*stratificatio* 1-2), but is somewhat elastic (*elasticitas* 1-3, increasing with depth).

49.0-25.7 cm An indistinct boundary (*limes* 1) occurs at about 49.0 cm, where *Argilla steatodes* is mixed with *Detritus herbosus*. Above this boundary are several units comprised of a mixture of *Detritus herbosus* and *Argilla steatodes* in varying proportions. These units are alternating bands of firstly equal proportions of *Argilla steatodes* and *Detritus herbosus* (As2 Dh2) brownish black (10YR 2/2) in colour, then *Detritus herbosus*-rich *Argilla steatodes* (As3 Dh1) brownish black (10YR 3/2) in colour. These units are not laminated (*stratificatio* 0) or elastic (*elasticitas* 0).

25.7-0 cm The top 25.7 cm is highly disturbed by animal trampling and cracking (Figure 4.1 & 4.3). Cracking is a characteristic property of almost all Grevena soils during the annual dry season, due to swelling clays (Chapter 1). The deposit consists of *Argilla steatodes* with varying amounts of *Detritus herbosus*. A pebble at c. 24 cm may have been pushed in by animals trampling. This sedimentary unit is mottled with iron staining, but the general colour is greyish yellow brown to dull yellowish brown (10YR 4/2-4/3), which results in reduced *nigror* (2). These sediments are not laminated (*stratificatio* 0), or elastic (*elasticitas* 0).

4.3.2 Physical properties

Organic matter, inorganic matter, moisture content, and dry density are plotted against depth and stratigraphy in Figure 4.4. The first three properties are expressed as a percentage of the original wet weight of the sample. Diatoms, although present, are thought to comprise only a minor proportion of total inorganic sediment. The curve of diatom concentration follows that of the inorganic matter (Appendix XII). Physical properties of the sediments suggest a division of the sequence into 8 sections (A-H), corresponding closely to the sediment types described above. The physical properties of the sediments are described below.

Figure 4.4 Gomara sediment physical properties: sediment type column (Troels-Smith classification 1955), organic matter, inorganic matter, moisture and bulk (dry) density. Sediment sections based on physical properties are indicated on the right.

Section H, 190.0-181.5 cm The sediment in this section is moderately rich in organic matter (3.5-4.4%), and moisture content is high (54.0-76.0%). Dry density values of 0.31-0.60 g/cc also suggests an organic sediment. Inorganic matter increases from 20.5 to 41.6% at the top of the section.

Section G, 181.5-157.0 cm This section is characterised by the highest inorganic-matter content of the sequence (peaking at 65.7%), and correspondingly high dry density (peaking at 1.12 g/cc, which is close to the 1.25 g/cc average dry density of a mineral soil). Moisture content is the lowest of the sequence, decreasing to 31.6%, where inorganic matter content is greatest. Organic matter ranges from 2.2-2.8% and are the lowest of the sequence, with the exception of the uppermost sample, which increases to 5.3%.

Section F, 157.0-135.5 cm This section is characterised by higher organic content (5.7-5.9%) than that of the section below, high moisture content (67.4-72.2%), and much decreased but relatively high dry density (0.32-0.38 g/cc). Inorganic content is only 21.9-26.8%.

Section E, 135.5-110.0 cm Organic matter and moisture content are higher (and increase slightly upwards) in this section (maximum values of 10.7% and 78.7%, respectively) than in that below, while inorganic matter and dry density are lower and decline slightly upwards (minimum values 11.8% and 0.23 g/cc, respectively).

Section D, 110.0-106.0 cm This section is represented by only one sample. The physical properties of this sample are very different from those in the adjacent sections: organic and inorganic matter and dry density all increase (15.3%, 36.6% and 0.73 g/cc, respectively), while moisture content decreases (48.1%).

Section C, 106.0-49.0 cm Organic matter content is very high (9.4-13.2%), recording maxima of the sequence, with the exception of section D. Moisture content is correspondingly very high, reaching a maximum of 87.5% and in general recording the maxima of the sequence. Inorganic matter content is the lowest of the sequence: values are lower in the upper half of the section (minimum of 0.5% at 60.0 cm). Dry density is also the lowest of the sequence and generally decreases upwards ranging from 0.13-0.27 g/cc.

Section B, 49.0-25.7 cm This section is characterised by an increase in inorganic content, which reaches 19.5% at 40.0 cm. Dry density also increases (peaking at 0.32 g/cc at 40.0 cm), while moisture content declines to a minimum of 72.1%, again at 40.0 cm. Organic content declines slightly (8.4-11.0%).

Section A, 25.7-0 cm Two samples were analysed in this section; a surface sample and one at 25.0 cm. The physical properties of these samples differ from those below by having lower organic matter (7.6 and 3.2%), higher inorganic matter (33.0 and 28.0%), lower moisture content (59.4 and 69.0%), and higher dry density (0.51 and 0.36 g/cc).

4.4 Chronostratigraphy

The chronology of the Gomara sequence is based on radiocarbon ages of organic matter contained within the sediments. Samples for radiocarbon dating were selected to provide ages for various depositional events inferred from lithologic characteristics so are not evenly spaced.

The results of five critically positioned radiocarbon-dated samples are presented in Table 4.1. Conventional radiocarbon ages are shown with an analytical error of one standard deviation. These ages have been calibrated by tree-rings (Appendix IV).

Calibrated radiocarbon years before present (1950) and sidereal years are plotted against depth and stratigraphy (Figure 4.5). In Figure 4.5 the calibrated calendar date, if only one date results from calibration, or the median of the calibrated calendar dates, if several result from calibration, are joined by straight-line segments, indicating mean rate of sediment deposition. (This assumes a constant rate of sedimentation.) The line between the highest two radiocarbon ages has been extended to the next change in sediment composition. The solid line above this sediment change has been drawn with the same slope as that at 156.5-111.5 cm because of the similarity in the sediment compositions in these two intervals. Above 25.0 cm organic sediment is absent and oxidation has occurred, so the line is dashed.

Most of these sediments were apparently continuously deposited under gradually changing conditions and processes, so mean sediment-accumulation rates between dated samples were based on a linear age/depth function (Figure 4.5). A major change in the mean sediment-accumulation rate can be seen near the centre of the sequence, where a corresponding change in sediment composition occurs. However, mean sediment-accumulation rates either side of this major change are very similar. In the lower part of the sequence the two mean rates of sediment accumulation are 0.069 and 0.058 cm/yr, while sediments above accumulated more than twice as rapidly at 0.152 and 0.145 cm/yr. This rapid accumulation rate is attributed to the coarseness of incompletely decomposed organic matter. The lower, more slowly accumulating sediment comprises mostly fine-grained mineral particles. These rates are close to the optimal rate of 1 mm/year, and the normal accumulation rate of 0.5 mm/year suggested for pollen-analysis sites in lakes (Berglund 1986b:119).

These mean accumulation rates do not measure possible rapid sediment accumulation episodes of short duration. One obvious change in sediment type which is likely to represent a rapid depositional event is that at 108.2-107.2 cm. Unfortunately, this sediment has not been bracketed by radiocarbon ages. However, it is interpreted as a tephra (see below) and considered to be deposited 'instantaneously'.

Table 4.1

Radiocarbon dating results – Gomara

Sample depth (cm)	Laboratory number	Pretreatment	Fraction dated	$\delta^{13}\text{C}$ ‰ wrt PDB	% modern	Radiocarbon age (years BP $\pm 1\sigma$)	Calibrated age(s) (years AD/BC)
52-53	NZA 3481	Hot acid/alkali/acid	Sediment humin	-28.45	80.03 $\pm$ 0.64	1747 $\pm$ 64	261, 286, 325 AD
81-87	Wk 1810	None	Entire sediment	-28.9	78.50 $\pm$ 0.6	1940 $\pm$ 96	76 AD
111-112	NZA 3482	Hot acid/alkali/acid	Sediment humin	-27.15	76.57 $\pm$ 0.70	2103 $\pm$ 73	105 BC
156-157	NZA 3477	Hot acid/alkali/acid	Plant material	-27.21	70.65 $\pm$ 0.58	2749 $\pm$ 66	897, 871, 867 BC
186-190	Wk 1811	None	Entire sediment	-30.7	68.30 $\pm$ 0.7	3070 $\pm$ 144	1367, 1354, 1314 BC

Radiocarbon dating laboratory reference numbers:

NZA = Rafter radiocarbon laboratory, Nuclear Sciences Group, Institute of Geological and Nuclear sciences, Lower Hutt.

Wk = Waikato radiocarbon dating laboratory, University of Waikato, Hamilton.

Percent modern means absolute percent relative to the NBS I oxalic acid standard.

$\delta^{13}\text{C}$ represents the measured difference, in parts per thousand, between the ratio of carbon-13 to carbon-12 in the sample to the ratio for the chosen standard (PDB carbonate). It is useful as a check on natural fractionation and on fractionation during sample preparation (Aitken 1990).

Radiocarbon Age BP is the conventional radiocarbon age before 'present' (years BP), based on the half-life of 5568 years, as defined by Stuiver & Polach (1977), the present being 1950 AD.

The radiocarbon age error margin reported by the University of Waikato included only counting statistics errors, so a laboratory error multiplier of 1.6 was used to increase the standard deviation for samples dated in that laboratory.

The computerized calibration program of Stuiver & Reimer (1993), CALIB 3.0.3c (revised version 1995) available on the Internet at the University of Washington ftp site, was used (Appendix IV).

Pollen samples of one centimetre thickness from below 107.0 cm span a time interval of about 14.5-15.2 years, while those above span about 5.8-6.9 years. The intervals between each sample in the lower part of the sequence represent about 58-61 years, while those in the upper part represent about 23-28 years. These time resolutions fall within the range of 20-50 years for a sample of 1 cm thickness recommended for pollen analysis reference sites of 100-300 m diameter in open mountainous areas (Berglund 1986b:114).

The calibrated calendar dates and the rates of sediment accumulation are considered to be a reasonable approximation of the 'true' time span represented by the sediments in this sequence, so a timescale has been derived for this sequence using the age/depth function of Figure 4.5.

4.5 Tephra

On visual examination of the sediment sequence it was suspected that the layer at 108.2-107.2 cm was a tephra because of the absence of plant material. On microscopic examination small glass shards were seen, so it is almost certainly a volcanic ash (J. Carter, pers. comm.). Unfortunately, microprobe analysis proved difficult because of alkaline etching of the glass shards, so identification of a particular eruption based on chemical composition of the shards could not be determined (J. Paterson, pers. comm.). Thus the tephra could not be used as a chronological marker.

The small size of the glass shards suggests that it has been transported a long distance. A radiocarbon date just below the tephra (111-112 cm) of 105 BC suggests that the tephra is from an Italian volcanic eruption at Etna, Monte Albano, or Vulcano (Simkin *et al.* 1968).

4.6 Diatom analysis

Only eleven samples were analysed, so these are much more widely spaced than samples for sediment and pollen analyses, but all the major sediment types and pollen-assemblage zones are sampled. Samples 1 cm thick were analysed at 1, 10, 35, 56, 84, 106, 119, 139, 154, 172, and 189 cm, and at least 200 frustules per sample were counted. The results of the diatom identifications made by Dr M. Harper are presented in Appendix XII in relative frequency graphs, where diatoms have been grouped according to their various ecological tolerances (van Dam *et al.* 1994). Separate graphs have been drawn of pH tolerance, moisture requirements, habitat, trophic levels, oxygen requirements, and organic nitrogen uptake metabolism. A summary of the results, according to the local wetland pollen assemblage zones is also presented in Appendix XII.

Figure 4.5 Age-depth plot. Calibrated radiocarbon ages (Table 4.1, Appendix IV) plotted against depth of sediment from Gomara. Length of cross-arms indicates uncertainty ($\pm 1\sigma$) of age measurement (horizontal) and thickness of dated sediment (vertical). Most probable dates are indicated by crosses: either the calibrated calendar date if only one date results from calibration, or the median of the calibrated calendar dates if several results from calibration are joined by straight line segments. Corresponding sediment accumulation rates are shown, the rate between the highest radiocarbon date and the upper limit of undisturbed sediment being extrapolated.

4.7 Pollen analysis results

4.7.1 Introduction

Relative frequency as well as concentration data are used to interpret the vegetation history of the Gomara area. Concentration data are converted to influx rates, using the sediment deposition rates calculated from the radiocarbon chronology. Both the aliquot and exotic marker grain (tracer) methods of calculating palynomorph concentrations were used, and pollen diagrams using the results from these two methods show a high degree of correlation. Separate diagrams are drawn for local (wetland) taxa, extra-local and regional (terrestrial) taxa, and microscopic charcoal data. Data used to calculate pollen and spore concentrations, all pollen and spore types counted, and charcoal abundances are tabulated in Appendix XIII.

4.7.1.1 Pollen preservation/pollen abundance

Palynomorphs are very abundant and preservation excellent. The principal mode of deterioration of grains is breakage, and this is usually confined to gymnosperm pollen with bladders that are easily separated from the body of the pollen grain. The ratio of broken pine grains to the total number of pine grains counted is highest at 140-55 cm. An index of pollen preservation is given by the abundance of indeterminable pollen (not included in the pollen sum because they could be either wetland or terrestrial taxa). Indeterminate grains are usually less than 4%, exceeding 5% in only 2 spectra. Unidentified monolete spores are rare, being recorded at 0.1% in 3 spectra. Unidentified trilete spores are even rarer, being recorded in one spectrum at 0.2%. Unknown grains are rare, exceeding 1% in only one spectrum.

In general, concentration values were highest in inorganic sediments of low accumulation rate and lowest in organic sediments of high accumulation rate. The highest concentration of total terrestrial pollen and spores is in samples at 180-160 cm ($222-433 \times 10^3$ grains/cm³). The two basal samples (189 and 185 cm) and those from 155-107 cm, at 25 cm, and the surface display the next highest concentrations. Concentrations are lowest from 105-30 cm (very low at 70-55 cm, $12-45 \times 10^3$ grains/cm³).

The total terrestrial influx curve differs somewhat from this pattern (Figure 4.10). Samples at 180-160 cm have some of the highest values, but the two samples at 110 and 107 cm have equally high influx of $25-30 \times 10^3$ grains/cm²/year, and samples at 105-75 cm have the next highest influx of $10-12 \times 10^3$ grains/cm²/year, while those at 155-115 cm have lower influx ($5-10 \times 10^3$ grains/cm²/year). The depth interval recording lowest influx is 70-0 cm ($2-7 \times 10^3$ grains/cm²/year).

The concentration curve of total wetland taxa is similar to that of total terrestrial taxa, displaying highest values near the base of the sequence in inorganic sediments at 185-160 cm

($92-181 \times 10^3$ grains/cm³). But the basal sample and those at 155-107 cm are lower, while those at 107 cm, at 50 cm and at 45 cm are higher; concentrations are similarly high at 25 cm and at the surface sample. Lowest concentrations are displayed from 105-55 cm, with very low concentrations at 85-70 cm ($5.5-8.5 \times 10^3$ grains/cm³).

Total wetland taxa influx also displays high values at the base of the sequence and peaks at 107 cm, at 50 cm, and at 45 cm, with lower values in the more organic deposits from 155-110 cm and 105-55 cm (Figure 4.7). The influx curve differs from the concentration curve in displaying low influx from 40 cm to the surface.

4.7.2 Wetland pollen analysis

4.7.2.1 Pollen diagram construction

Pollen and spore relative frequencies are presented graphically in Figure 4.6 and influx data in Figure 4.7. Pollen and spore types are arranged according to the degree of wetness of habitat of plant communities from which they derive. Wetland plant communities are divided into the two broad habitat groups of emergent and open water (aquatic macrophytes). Emergent plants are divided into the habitat groups of wet-soil and sedge and reed swamp, while the aquatic macrophytes are divided into the habitat groups of floating-leaved and submerged macrophytes. Floating-leaved macrophytes are those that have leaves that float on the surface of the water at least for part of the time, while the submerged macrophytes are totally submerged or only flowers emerge above the surface of the water. The pollen sum on which the relative frequencies are based includes all wetland pollen and spore taxa. Relative frequencies of 0.2% or less are indicated with a dot. Only diagrams showing relative frequency and influx, using data obtained from the exotic spike method, are shown.

Pollen spectra are arranged according to cm depth below sediment surface. The column next to the depth column shows the sidereal timescale estimated from the radiocarbon chronology. The column to the right shows the major sediment types in the sequence according to the Troels-Smith classification (1955). The final column before the curves of pollen and spores indicates the conventional radiocarbon ages of sediment samples.

On the right of the resolved diagram, a summary diagram shows the ratio of emergent types to aquatic types. A curve of palynological richness (rarefaction analysis) follows (Birks & Line 1992; Bennett 1994); rarefaction analysis is based on the smallest total count of the wetland pollen and spores, 48 at 110 cm. The number of wetland types (not normalized for unequal pollen sums) in each spectrum is shown next. Rates of vegetation change were calculated using the dissimilarity coefficient of Chi-squared coefficient 2 on unsmoothed pollen frequencies of the 11 most abundant pollen and spore types (that is, those that were $\geq 5\%$ of total wetland pollen and spores) and calibrated radiocarbon ages (Bennett & Humphry

Figure 4.6 Gomara - relative frequency pollen diagram, wetland taxa
(pollen sum is total wetland taxa)

Figure 4.7 Gomara - influx pollen diagram, wetland taxa

Figure 4.7

1995). The types included in the calculations are *Caltha* type, *Carex flacca* type, *Carex hallerana* type, *Cyperus longus* type, *Cyperus michelianus*, *Glyceria* type, *Phragmites australis*, *Sparganium erectum*, *Typha angustifolia* type, *Hydrocotyle vulgaris*, and *Sagittaria sagittifolia*. Lastly, the total of all wetland pollen and spores counted is given.

4.7.2.2 Pollen record of wetland plant communities

Wetland plant communities are floristically and ecologically more uniform throughout the Balkan Peninsula than any other group of plant communities, and division into Mediterranean and Central European domains is less clearly indicated than for other communities. Relatively few Balkan Peninsula types and endemics occur in them, and the species found are mostly such as are distributed in similar habitats throughout a large part of Europe. Wetland plant communities discussed below are based mostly on information from four sources: Turrill (1929); Haslam *et al.* (1975); Ellenberg (1988); and the fieldwork carried out for this research (Chapter 3).

Although a high proportion of wetland pollen and spore types can be identified to species level, some types present problems because they include plants that grow in dryland habitats, for example *Bromus* species that grow in dry habitats have pollen morphology similar to that of *Glyceria maxima* (Appendix VI.2). Also the comparative pollen morphology of a few wetland plants is unknown, e.g. *Phalaris arundinacea*, a grass that grows in reed and sedge swamps.

Wetland plant communities are often under-represented by pollen and spores and are often represented by only a few species (Chapter 3). A maximum of only 15 pollen and spore types were identified in any spectrum from Gomara; average is 10. Estimates of palynological richness by rarefaction analysis are low (5-9 expected types).

Emergent communities The wetland pollen and spore sequence is dominated by types that derive from emergent plant communities of swamp and fen habitats which commonly form marginal belts around lakes, according to depth of water (Figures 4.6 & 4.7). These plant communities usually grow in water to a maximum depth of 2 m (Spence 1982). Pollen and spores of types belonging to sedge- and reed-swamp communities are most numerous. Sedge swamps have many species in common with reed swamps, and they both belong to the same order, Phragmitetalia (Ellenberg 1988). Many of the species included in the *Carex flacca* type (Appendix VI.2) have been placed by Ellenberg (1988) in the tall-sedge swamp alliance (Magnocaricion). Those included are: *Carex appropinquata*, *C. distans*, *C. disticha*, *C. elata*, *C. paniculata*, *C. riparia*, *C. rostrata*, and *C. vulpina*. The species *Cyperus longus* and *Oenanthe fistulosa* are also included. *Cladium mariscus* often grows in a mixed sedge and reed swamp. *Berula erecta* and *Veronica anagallis-aquatica* belong to the stream-reed swamp

alliance (Sparganio-Glycerion). Species belonging to the true-reed swamps (Phragmition alliance) are: *Phragmites australis*, *Glyceria maxima* (*Glyceria* type), *Sagittaria sagittifolia*, *Sparganium erectum*, and *Typha angustifolia* and *T. latifolia* (comprising *Typha angustifolia* type) (Ellenberg 1988).

Most of the species included in the types placed in the habitat group of 'wet soil' (Figures 4.6 & 4.7) grow in wet marshy ground and are included in the orders Molinietales, of moist meadow and stream-bank communities, and Cyperetales fuscii, of dwarf plant communities that are inundated in winter but dry out in summer (Ellenberg 1988). Included are the species of *Anagallis tenella* type, *Angelica sylvestris*, *Elatine alsinastrium*, *Gratiola officinalis*, *Lychnis flos-cuculi*, *Lythrum salicaria* type, and *Ophioglossum vulgatum*. *Caltha palustris*, included in the *Caltha* type, is also placed in the order Molinietales, while the other species in this type, *Myosurus minimus* and *Aquilegia vulgaris*, are placed in the wet-soil plant communities of the order Agrostietales stoloniferae, which form pioneer swards of flooded and damp places, and the class Querco-Fagetea of broadleaved woods and scrub on more fertile soils, respectively. *Saxifraga stellaris* belongs to the wet-soil community of the order Montio-Cardaminetales of spring communities. *Chrysosplenium alternifolium* is included in the wet-soil order of Fagetales, alliance Alno-Ulmion of alder and noble broadleaved woods of flood plains (Ellenberg 1988).

Some pollen and spore types in the 'wet soil' habitat group include a mixture of species from wetland and dryland communities. One of the two species comprising *Filipendula* (Appendix VI.2) belongs to the order Molinietales, while the other grows in dry grassland and belongs to the dryland plant communities of the class Festuco-Brometea. *Gentiana lutea* type includes one species included in order Molinietales, one that grows mainly on soils of average dampness (but absent from both wet ground and places which may dry out), and one in order Brometales erecti (communities of more or less arid swards). *Mentha* type includes some species that belong to emergent wetland communities as well as some species that grow in dryland communities. *Ranunculus acris* type includes several species; they grow in wet-meadow communities mostly (Ellenberg 1988).

Species in the *Carex hallerana* type are not included in Ellenberg's (1988) classification scheme. They have a wide range of habitats, which include damp soils at high altitude. *Samolus valerandi* is not included in Ellenberg's (1988) classification, but Turrill (1929) identifies it as part of the Balkan marsh community. *Galega officinalis* grows in damp meadows and by rivers (Polunin 1988).

Aquatic communities A few pollen and spores of aquatic types occur sporadically throughout the sequence, suggesting the possibility of an open-water habitat, at least sporadically (Figures 4.6 & 4.7). All free-floating aquatics are warmth-requiring, preferring

waters that remain ice-free and require water that is protected from wind; these factors may partly account for the lack of pollen and spores identified from these communities (Ellenberg 1988). Floating-leaved communities usually grow on the lakeward side of reed swamps in water depths to a maximum of 2.5 m (Spence 1982), and submerged communities grow in the innermost belt in deeper water, usually at a depth of about 3 m (although they may grow in water depths up to 15 m) (Spence 1982).

Types that include species of floating-leaved communities are: Lemnaceae, *Nymphaea alba*, *Ranunculus aquatilis* group, *Salvinia natans*, and *Sparganium angustifolium*. *Lemna minor* is the only species of the Lemnaceae type which occurs at altitudes higher than 1000 m, so it is probably the species represented here. It belongs to the free-floating still-water communities of waters more or less rich in nutrients, order Lemnetalia (Ellenberg 1988). *Salvinia natans* also belongs to the order Lemnetalia (Ellenberg 1988). *Nymphaea alba* belongs to rooted waterplant communities (order Potamogetonetalia). Most species of the *Ranunculus aquatilis* group (*Ranunculus aquatilis*, *R. peltatus*, and *R. trichophyllus*) are also placed in the order Potamogetonetalia. *Sparganium angustifolium* belongs to the shore-hairgrass shallow-water swards and related communities, order Littorelletalia (Ellenberg 1988).

Types that include species that may belong to submerged communities are: *Hydrocotyle vulgaris*, *Montia fontana*, *Myriophyllum spicatum*, *Myriophyllum verticillatum*, *Potamogeton crispus* type, and *Potamogeton pectinatus*. *Hydrocotyle vulgaris* and *Montia fontana* may be submerged or emergent (Haslam *et al.* 1975). Species included in the *Potamogeton crispus* type belong to rooted waterplant communities (order Potamogetonetalia) and are capable of living in either deep or shallow water, either submerged or floating, and subterrestrially in dried-up situations. *Myriophyllum spicatum*, *Myriophyllum verticillatum*, and *Potamogeton pectinatus* are exclusively submerged. They also belong to the order Potamogetonetalia (Ellenberg 1988).

4.7.2.3 Wetland (local) pollen assemblage zones

Wetland pollen diagrams are divided into six local pollen assemblage zones GW-1 to GW-6, based mostly on relative frequency data. These are defined below.

Zone GW-6, 190.0-157.5 cm This basal zone is characterised by high relative frequencies of *Carex flacca* type (12.5-41.6%, with the exception of the lowest spectrum at 3.7%), *Carex hallerana* type (19.9-49.2%, except in the upper two spectra at about 7.0%), and *Cyperus michelianus* (25.2-43.0%). *Glyceria* type (3.0-11.8%) and *Phragmites australis* (1.8-10.0%) are represented at moderate frequencies, while *Cyperus longus* type occurs at moderate frequencies at the base of the zone (6.6 and 10.9%) then declines sharply (zero at the top).

Several other emergent types occur at very low frequencies, but only *Typha angustifolia* type exceeds 1.0%, and this is in the uppermost spectrum only. Aquatic types are very poorly represented, occurring in only four spectra, and total relative frequency exceeds 1.0% in only one spectrum. Individual aquatic types (*Hydrocotyle vulgaris*, Lemnaceae, *Montia fontana*, *Nymphaea alba*, *Potamogeton crispus* type, *Ranunculus aquatilis* group, and *Salvinia natans*) all occur at less than 1.0%.

Zone GW-5, 157.5-133.0 cm The boundary with the preceding zone is marked by a sudden decline in *Carex flacca* type (11.3-15.9%, then declines further in the uppermost spectrum to 4.0%) and a sudden increase in *Phragmites australis*, which is the dominant type (27.5-38.7%). *Carex hallerana* type, *Cyperus michelianus*, and *Glyceria* type are also important throughout this zone. *Carex hallerana* type rises steadily to a maximum of 17.5% and then declines steadily to 8.0%. The curve of *Cyperus michelianus* has the converse pattern; 35.0% at the bottom of the zone, 5.5% in the middle, then 28.0% at the top. *Glyceria* type increases from the bottom of the zone to the top, 4.8-15.9%.

A few other emergent types record significant relative frequencies. *Ranunculus acris* group appears sporadically, recording a maximum of 3.8% at the bottom of the zone. *Sparganium erectum* also appears sporadically, reaching a maximum of 4.6% at 145 cm. *Sagittaria sagittifolia* appears at 150 cm with 7.9%, drops to 0.5% in the spectrum above, then disappears. Several types occur only once: *Chrysosplenium alternifolium* at 140 cm (1.9%), *Cyperus longus* type at 145 cm (16.1%), *Mentha* type at the bottom of the zone (1.3%), and *Veronica anagallis-aquatica* type at the top of the zone (1.3%).

The only aquatic type that exceeds 1.0% is *Hydrocotyle vulgaris*. It appears at 140 cm at 0.9%, then increases to 1.3% in the spectrum above at the top of the zone.

Zone GW-4, 133.0-108.5 cm The boundary with the preceding zone is marked by a dramatic increase in the relative frequency of *Carex hallerana* type and an increase in *Sparganium erectum*. The zone is characterised by high relative frequencies in general of *Phragmites australis* (33.3-40.3%, but the lowest spectrum records 2.5%) and of *Carex hallerana* type (18.8-48.3%, but one spectrum falls to 10.2%), and fluctuating but moderate frequencies of *Cyperus michelianus* (zero in the lowest spectrum, otherwise 8.2-23.4%), moderate frequencies of *Glyceria* type (declines from 21.7-2.7%, then increases in the top spectrum to 10.4%), a continuous curve of *Sparganium erectum* (1.5-8.4%), the presence of *Caltha* type (occurs in 3 of 5 spectra in the middle of the zone, 2.7-7.3%), and generally lower frequencies of *Carex flacca* type (2.7-9.2%, but the top spectrum records 14.6%) than those of the zone below.

Other emergent types that occur in significant abundance are: *Chrysosplenium alternifolium* (occurs in 2 spectra, 1.4 and 2.2%), *Cyperus longus* (zero in one spectrum, but

reaches a maximum of 2.7%), *Ranunculus acris* group (occurs in the bottom spectrum only, 2.5%), and *Typha angustifolia* type (occurs in the 3 lowest spectra, reaching a maximum of 2.9%).

Aquatic types are again very poorly represented; all types record less than 1.0%.

Zone GW-3, 108.5-106.0 cm This zone comprises one spectrum only, but it is quite distinct from the zone below. *Phragmites australis* (54.2%) and *Glyceria* type (23.1%) increase, while *Carex flacca* type (2.3%), *Carex hallerana* type (10.1%, but influx increases slightly), *Cyperus longus* (0.6%), *Cyperus michelianus* (1.3%), and *Sparganium erectum* (0.6%) decline. Other emergent types that occur in significant abundance are *Caltha* type (1.3%), *Mentha* type (2.9%), and *Saxifraga stellaris* (1.6%). No aquatic types occur.

Zone GW-2, 106.0-47.5 cm The boundary with the preceding zone is marked by an increase in relative frequency of *Carex hallerana* type, *Carex flacca* type, *Cyperus michelianus*, and a decrease in *Phragmites australis* and *Glyceria* type. The zone is characterised by the dominance of *Carex hallerana* type (29.5-61.8%) and is more similar to zone GW-4 than to GW-3 but differs from it in having higher relative frequencies of *Carex hallerana* type and *Carex flacca* type and lower frequencies of *Phragmites australis* and *Sparganium erectum*.

The relative frequency curves suggest a division of this zone at 77.5 cm, as indicated by numerical zonation based on relative frequency data. At this level a change occurs in the relative frequencies of the dominant emergent types of *Carex hallerana* type, *Carex flacca* type, *Cyperus michelianus*, *Glyceria* type, and *Phragmites australis*, and frequencies remain reasonably consistent above this change, while below this level frequencies fluctuate.

Curves of the concentration and influx diagrams do not display such a convincing division. No significant change occurs in *Carex hallerana* type until the uppermost spectrum of the zone, where concentration and influx increase (a slight increase is shown below this, not a decrease as shown in the relative frequency diagram). *Carex flacca* type and *Cyperus michelianus* begin to increase in concentration and influx but not until 65 cm, while there is no significant change in *Phragmites australis* and *Glyceria* type. Rate of change is higher between several spectra in the lower part of the zone (that is, at 102.5 cm and at 92.5 and 87.5 cm, where it is very high) than at 77.5 cm, where it is moderately low.

On the relative frequency diagram *Carex flacca* type increases in general from the base of the zone upwards (ranging from 6.3 to 32.3%). *Cyperus michelianus* is more abundant from 75 cm; below this level it fluctuates from 0-6.0%, while above it fluctuates from 16.3-33.6%. *Glyceria* type displays a declining trend from about 14.3% to around 1.0-2.0%. The curve of *Phragmites australis* also displays a declining trend from about 19.0% to less than 1.0%. *Cyperus longus* type fluctuates (0-7.9%), being most abundant from the middle

of the zone upwards. *Caltha* type fluctuates (0-28.0%), and highest frequencies are from 90-80 cm. *Sparganium erectum* occurs at highest frequency (4.5%) at the base of the zone and then declines to occur sporadically at 1.5% or less. *Typha angustifolia* type occurs most often towards the base of the zone (4.0% maximum). Other less abundant emergent types include *Chrysosplenium alternifolium*, which occurs infrequently and always at less than 2.0%. *Samolus valerandi* occurs twice but at 1.0% and less. *Filipendula* occurs only at 85 cm, at 1.5%.

Aquatic types appear sporadically and always at very low relative frequencies. Those exceeding 1.0% are *Hydrocotyle vulgaris*, which occurs three times (5.3% at the base of the zone, 2.3% in the middle, and 0.2% at the top), and *Potamogeton pectinatus* and *Sparganium angustifolium*, which occur at the base of the zone only (1.5% each).

Zone GW-1, 47.5-0 cm The boundary with the preceding zone is marked by a decline in *Carex hallerana* type and an increase in *Glyceria* type. The zone is characterized by declining *Carex hallerana* type. *Carex hallerana* type and *Cyperus michelianus* are co-dominant (25.5-40.3% and 17.0-34.3%, respectively). *Carex flacca* type fluctuates from 16.6-23.7% in the lowest spectra, to zero, then to 19.1%, before declining to 0.6 and 2.6% in the two top spectra. The curve of *Cyperus longus* type is the reverse of that of *Carex flacca* type reaching a maximum of 24.0% when *Carex flacca* type declines to zero. *Cyperus longus* type then drops to 0.8% before increasing to 5.2 and 3.8% in the two top spectra. *Glyceria* type is about 9.0% in the two lowest spectra, then declines to 3.0% before increasing dramatically in the two top spectra (17.3 and 19.2%). *Phragmites australis* has very low values at the base of the zone, declining to zero, but then increasing again to reach a maximum of 11.5% at the top of the sequence. Fluctuations in relative frequencies are reflected in high rates of change, but increases in relative frequencies at the top of the zone are not supported by influx data, particularly for *Cyperus michelianus*, *Glyceria* type, and *Phragmites australis*. Total influx steadily declines upwards. Other emergent types recording 1.0% or more are *Caltha* type (2.5% at 40 cm and 1.0% at 25 cm) and *Chrysosplenium alternifolium* (1.0% in the surface spectrum).

Aquatic types are poorly represented; only *Ranunculus aquatilis* group exceeds 1.0%, occurring three times with relative frequencies ranging from 0.8 to 1.5%.

4.7.2.4 Sedimentary and local vegetation history

The combination of evidence from deposited sediments and the wetland pollen sequence indicates a hydrosere succession from a permanently wet environment (small lake) to a seasonally wet fen as the deposition basin filled in from c. 1340 BC to 700 AD. (Dates are interpolated from the radiocarbon chronology.) The sediments were continuously wet and

there is good pollen preservation throughout the sequence until c. 700 AD when intermittent drying of the lake bed and oxidation of surface deposits began. Currently the fen is too wet for forest trees yet sufficiently dry in summer to prevent effective accumulation of peat. Diatom results (Appendix XII) are somewhat difficult to interpret due to the small number of samples analysed, but in general they are in agreement with those of pollen analysis.

The permanent water was shallow, probably fluctuating between 1 and 2 m depth. Water condition throughout the sequence was fresh, slightly alkaline, and rich in oxygen. The wetland has never been nutrient-poor. Trophic level is highest at the base of the sequence (eutrophic), and organic nitrogen compounds are most abundant at the base and top. In the centre of the sequence the trophic level drops to meso-eutrophic, and organic nitrogen levels are low. A marginal swamp vegetation of sedges and reeds, with a *Carex* swamp community on the landward side of the reed swamp, surrounded the lake. Only occasional submerged and floating-leaved aquatic macrophytes from a deeper water zone inside the *Phragmites australis* belt were identified.

Broadly, the sediments represent two episodes of soil erosion, indicated by sediments with a high proportion of inorganic matter, separated by a period of reducing soil erosion and increasing soil stability from c. 80 BC to 330 AD when sediments were highly organic. Proportions of inorganic to organic matter contained in the sediments do not correspond to influx of wetland pollen, so it is proposed that organic matter as well as inorganic matter in the lake sediments is derived from soils on the catchment rather than from production within the lake (Pennington & Lishman 1971). This is also consistent with Walker's (1970) claim that *Phragmites australis* swamps do not leave any visible organic remains. Only one abrupt stratigraphical change occurs, that at 107.2 cm, where a catastrophic event is represented – a volcanic ash fall. All other changes in lithology are indistinct and represent slower environmental changes.

The sedimentary history of the basin is closely linked to the local wetland vegetation history, so major sedimentary units defined above coincide with the established wetland pollen zones. These zones are used, for convenience, in the discussion below.

Zone GW-6, 190.0-157.5 cm, c. 1340-890 BC At the base of the sequence the dominant plant community is a tall-sedge-swamp community. A wet-soil community has developed and a small reed swamp exists. Both floating-leaved and submerged communities of open water are represented by a few pollen and spore types. In the upper half of the zone, the wet-soil community decreases while the sedge-swamp community increases.

Development of a wetland plant community from the base of the sequence is suggested by low initial influx of pollen and spores, comparatively high palynological richness (8 expected types) at the base of the zone indicative of a colonising wetland plant community,

and the occurrence of a greater proportion of diatoms that live on silt rather than on plants. Two sedimentary sections were described above that correspond to this zone. The lower section at the base of the sequence between 190.0 and 181.5 cm comprises clay with detritus, an indication of open water rather than fen or bog conditions at the time of sedimentation. Further evidence of open-water conditions are the dominance of diatoms that live on silt or in shallow water rather than on plants, and the presence of plant species that grow in shallow open-water conditions, e.g. Lemnaceae, *Nymphaea alba*, *Potamogeton crispus*, *P. pectinatus*, *Ranunculus aquatilis*, and *Salvinia natans*. Marginal fen and sedge communities establish around the edge of the lake, with a reed community on the lakeside in deeper water.

Small particles of charcoal incorporated within the sediment of this lowest section suggest that burning of vegetation may have contributed to the onset of erosion.

At the base of the next sediment section at 181.5 cm (c. 1250 BC) sediments become gritty with the addition of coarser-grain particles, which would require higher transport energy, perhaps increased storminess (Bormann *et al.* 1974). The proportion of inorganic matter in the sediments reaches the highest levels for the sequence, and the average sediment-accumulation rate in this zone is higher than that in other highly inorganic sediments in the sequence. Also, the colour of the sediment is lighter, perhaps as a result of less litter being humified. This could result from fewer trees in the catchment producing litter, and perhaps from grazing destroying the litter horizon. Once bare soil is exposed to alternating rain and drought, oxidation of organic matter is accelerated. The soil structure has been modified, losing its aggregation properties and becoming incohesive (Butzer 1974).

Diatom evidence also points to increasing erosion, with increasing abundance of alkaliphilous diatoms and increasing levels of nutrients. Alkalinity of the lake sediments, which increases in the second section of this zone, is consistent with soil derived from local bedrock. Eutrophication also corresponds to elevated levels in the amounts of soluble nutrients being washed into lake basins (Oldfield 1977). High nutrient level and correspondingly depressed oxygen content, as shown in the diatom record in this zone to increase in the second section of the zone, may thus be an expression of erosion of nutrient-rich soils (van Dam *et al.* 1994).

There is parallel evidence from the pollen record for high nutrient levels. Several types indicative of high nutrient levels were identified, e.g. Lemnaceae, *Nymphaea alba*, *Lychnis flos-cuculi*, and *Glyceria*, which indicate eutrophic conditions; and *Ranunculus aquatilis* group and *Sagittaria sagittifolia*, which indicate meso- to eutrophic conditions (Haslam *et al.* 1975; Ellenberg 1988). Marginal plant communities dominated by *Phragmites australis* and *Carex* species indicate mesotrophic nutrient levels in the lake (Ellenberg 1988).

Lower water depth or greater seasonal fluctuation in water depth is indicated in the second section of this zone by the high relative frequency of diatoms that live in ephemeral water, which increases while those that live in permanent water falls. The only aquatic plant represented at this time, *Hydrocotyle vulgaris*, can also live as an emergent.

Zone GW-5, 157.5-133.0 cm, c. 890-480 BC The lower boundary of this zone coincides with a change in the sediment composition to one that suggests less intense erosion; coarse-grain mineral particles disappear, and organic detritus from both herbaceous and ligneous plants occurs. This suggests the accumulation of humus under an expanding woody vegetation in the catchment. The colour of the sediments is darker than that in the zone below. Less intense erosion is also suggested by a much reduced influx of inorganic matter, and a decline in nutrient level of the lake as shown by diatoms. Also, the average sediment-accumulation rate of this and the following zone is lower than that of zone GW-6.

A steadier water level and an increase in water depth is suggested by an increase in diatoms that live in permanent water and a decline in those that live in ephemeral water. Pollen evidence also supports this; pollen of the shallower-water plant communities of wet-soil and sedge swamp declines, while that of the reed swamp increases and becomes dominant. *Phragmites australis* is the dominant species of the reed swamp. At Gomara *Phragmites australis* is probably close to its ecological limit, considering current climatic conditions. (Chapter 1 – no precise climatic data are available for the Gomara site). Studies show that vegetative growth of *Phragmites australis* only begins when the temperature has risen to about 8-10° C. In trial tanks without water *Phragmites australis* was killed in January at temperatures of -8.7° C and in March could only tolerate -0.8° C (Dykyjová *et al.* 1971 in Ellenberg 1988). This raises doubts about the identification of the grains assigned to this pollen type based on their small size (Appendix VI), for they may belong to another species of Gramineae, the grain size of which has been reduced due to harsh growing conditions. However, the dense stand of *Phragmites australis* described in Chapter 3 and Appendix VIII on Mirsina fen in the lowlands of Grevena survives through winter minimum temperatures of 3.2° C and 40 days of ground frost and snow. The Gomara wetland site is at a much higher altitude than the Mirsina fen, but in winter there is commonly a temperature inversion: in January valleys and basins are 2-3° C colder than mountain slopes and peaks at the same altitude. Occurrence of pollen of other reed-swamp plants, such as *Sagittaria sagittifolia*, *Sparganium erectum*, and *Typha* species, supports the identification of *Phragmites*, and the morphology of the pollen in the Gomara sequence compares well with reference pollen collected from Mirsina fen (Appendix V). No macrofossil evidence of *Phragmites australis* was noted, but it is thought that *Phragmites australis* swamps do not leave any visible organic remains (Walker 1970). *Phragmites australis* usually dominates at an average water depth of

1.2 to 2 m, although its ecological amplitude is great and it can tolerate short periods of dry ground (Ellenberg 1988).

The floating-leaved aquatic community is not represented, and only *Hydrocotyle vulgaris*, which may be emergent, represents the submerged aquatic community.

Macroscopic charcoal particles were observed again, suggesting that burning of vegetation was taking place in the vicinity.

Zone GW-4, 133.0-108.5 cm, c. 480-80 BC The sediments of this zone indicate a further decline in the intensity of erosion taking place in the catchment. The proportion of organic detritus to clay increases and the occurrence of macrofossils such as beech nuts indicates the presence of beech trees in the catchment. Supporting evidence for reduced erosion is the lower relative abundance of alkaliphilous diatoms and the lower nutrient status indicated by the diatom record.

The reed-swamp community remains the dominant community, but the wet-soil community has expanded, *Caltha* type giving support to *Carex hallerana* type. The tall-sedge swamp has declined but is still a prominent community. The aquatic communities are again poorly represented, with no record of the floating-leaved community and extremely low representation of the submerged community.

An increase in marginal lake vegetation is suggested by an increase in the influx of *Phragmites australis* pollen as well as that of *Carex hallerana* type. An increase in the relative abundance of epiphytic/epilithic diatoms is also suggestive of an increase in plants growing in water. There is also an increase in diatoms that live in fairly permanent water and ephemeral water, while those that live in permanent water decline. This may indicate a lower water level and greater seasonal fluctuation. High palynological richness (about 8 expected types) also supports this.

The short severe decline in *Phragmites australis* at the base of the zone may be a result of anthropogenic activity, such as cutting the grass for fodder. Bottema (1974:66) noticed inhabitants at Lake Khimadhitis performing such a task.

Zone GW-3, 108.5-106.0 cm, c. 80 BC The sediment at 108.2-107.2 cm is interpreted as a tephra. It represents primary deposition, as indicated by the absence of detrital materials from surrounding soils, and has a very distinct upper boundary. Deposition would have been almost instantaneous. Thus the pollen assemblage is representative only of species flowering at the time the tephra was deposited.

Zone GW-2, 106.0-47.5 cm, c. 80 BC-330 AD This is a period of steady water level, probably of greatest depth reached, as shown by the abundance of diatoms living in permanent water and an increase in pollen of aquatic macrophytes. Declining palynological richness (8-5 expected types) suggest that the water level rose at the base of the zone, then remained at a

high level with little seasonal fluctuation. The fine-grained tephra deposit may have contributed to an increased permanence of depth by reducing the permeability of the lake bottom.

The sediments become increasingly organic until, near the top of this zone at 60 cm, they are composed almost entirely of organic matter, and deposition of minerogenic material has almost ceased. This results in a decline in the trophic status of the lake. The coarse nature of the detritus is indicative of several factors: detritus derived from forest canopy/forest soil; slow decomposition; and lack of torrential outflow from the lake. At 60 cm a closed forest canopy produced abundant organic matter, which covered the forest floor and left no mineral soil exposed for erosion.

Average rate of sediment accumulation is the highest for the entire sequence. This is attributed to the coarse nature of the organic detritus and the high moisture content.

The marginal swamp vegetation is reduced to a narrow band of mostly plants of a wet-soil habitat. The reed swamp is much reduced at the base of the zone and continues to decline, perhaps due to lowered trophic level, until the uppermost spectrum, where influx of *Glyceria* type increases slightly. The tall-sedge swamp increases in importance in the upper part of the zone, and the wet-soil community is important throughout the zone.

Pollen-influx data suggest that the marginal vegetation expanded prior to a visually detectable change in sediment composition at 49 cm. This may be due to an increase in inwashed nutrients. Bormann *et al.* (1974) found that the first and immediate response of the ecosystem to deforestation is increased solubilization of nutrients; that is, more nutrients are dissolved in drainage water than was the case in the undisturbed ecosystem. They found that between 1.5 and 2.5 times the expected total annual uptake of nitrogen in the forested ecosystem was lost as dissolved nitrogen during the first 2 years of deforestation. Unfortunately diatom samples are too widely spaced around this transition to detect the onset of nutrient inwash, but an increase in organic nitrogen compounds is displayed by diatom data at 56 cm, when the proportion of inorganic matter in the sediments begins to increase (Figure 4.4).

Zone GW-1, 47.5-0 cm, c. 330-700 AD & present Sediments of this zone are remarkably similar to the minerogenic sediments in the two zones immediately below the tephra and are interpreted as evidence of the onset of another period of more intense soil erosion, when the woodland canopy is open. Inorganic sedimentation begins again just below the pollen-zone boundary, and a change in sediment composition can be seen at 49 cm. In this zone alkaliphilous diatoms and those tolerant of organic nitrogen increase. Trophic level increases, as indicated by diatom evidence and the presence of pollen types such as *Lychnis flos-cuculi* and *Ranunculus aquatilis* group and an increase in *Glyceria* type. Accumulation

rate of the sediments is unknown, due to an absence of dated material, but it is assumed to be similar to that of zones GW-4 and GW-5, where sediments are of a similar particle size and composition.

Wet-soil and tall-sedge swamp communities are dominant but reduced. Some reed swamp still exists, but it is now probably dominated by *Glyceria*, which currently grows at Gomara. The floating-leaved community has very low representation, as has the submerged community, but the high abundance of diatoms that live in permanent water and low abundance of those that live in fairly permanent water and ephemeral water suggest that water level was high with little seasonal fluctuation.

At about 25 cm below surface the infill of the lake reached a threshold where seasonal lowering of water level through evaporation and outflow caused the lake to become ephemeral, with a dry bed in the summer.

4.7.3 Terrestrial pollen analysis

4.7.3.1 Pollen diagram construction

Pollen and spore relative frequencies are presented in Figures 4.8 and 4.9 (in pocket). Pollen and spore types are included in habitat groups defined in Chapter 2. The pollen sum on which the relative frequencies are based includes all identified terrestrial pollen and spore taxa and excludes wetland taxa. Relative frequencies of 0.2% or less are indicated with a dot.

Style of the pollen diagrams is similar to that of the wetland diagram (Figure 4.6). Figure 4.8, the summary diagram, shows the coniferous and deciduous canopy trees group in resolved form, then a summary column showing the ratio of terrestrial trees and shrubs to terrestrial herbaceous plants. This is followed by summary curves of each habitat group, then a curve of palynological richness derived from rarefaction analysis and based on the smallest total count of terrestrial pollen and spores, 292 at 70 cm (Birks & Line 1992; Bennett 1994). This is followed by the number of terrestrial types in each spectrum (not normalized for unequal pollen sums). A curve of the rate of vegetation change is shown next. Rates of vegetation change were calculated using the dissimilarity coefficient of Chi-squared coefficient 2 on unsmoothed pollen frequencies of the 10 most abundant types (that is, those that were $\geq 5\%$ of total terrestrial pollen and spores) and calibrated radiocarbon ages (Bennett 1994; Bennett & Humphry 1995). The pollen types included in the calculations are: *Pinus* (*Diploxylon*), *Fagus*, *Quercus frainetto* type, *Q. trojana* type, *Abies*, *Betula pendula*, *Ostrya* type, *Dactylis* type, *Festuca* type, and *Rumex acetosa* group. Finally, the number of pollen grains of trees and shrubs, the total number of all terrestrial pollen and spores, and the total of all pollen and spores counted in this sequence (wetland and terrestrial) are given.

Figure 4.8 Gomara - summary relative frequency pollen diagram, terrestrial taxa; pollen sum is total terrestrial taxa; scale interval 5% for all taxa and groups (resolved canopy trees taxa have 1.5x scale of groups), percentages less than 0.2% shown by dots.

Figure 4.8

The fully resolved diagram, Figure 4.9 (in pocket), displays all terrestrial pollen and spore taxa recognised in the sequence, in order of habitat groups. Within these groups they are arranged alphabetically except for the dominant tree types of *Pinus* (*Diploxylon*), *Fagus*, *Quercus frainetto* type, and *Quercus trojana* type, which are placed at the beginning of the 'coniferous and deciduous canopy trees' group.

Pollen and spore influx data are presented in Figure 4.10, in which are included only influx of pollen and spore types recorded in significant abundance; habitat groups; and total terrestrial herbs, total terrestrial trees and shrubs, and total terrestrial pollen and spores. The influx diagram takes a form similar to the relative frequency diagram.

4.7.3.2 Terrestrial pollen assemblage zones

Terrestrial pollen diagrams are divided into 6 local pollen assemblage zones, based mostly on relative frequency data; boundaries occur at the same level as those of the wetland sequence. They are prefixed by the site designation 'G'. These zones are defined below. Influx data are discussed in the following section.

Zone G-6, 190.0-157.5 cm The basal zone is characterised by high relative frequencies of *Pinus* (*Diploxylon*) (43.7-55.4%), the highest frequencies of the sequence of *Corylus* (1.0-3.0%) and *Picea abies* (2.0% maximum), and lowest of *Fagus* (1.1-4.0%, with the exception of the basal spectrum, which reaches 7.9%). *Quercus frainetto* type and *Quercus trojana* type occur at frequencies that are about average for the sequence (8.5-14.1% and 2.0-5.8%, respectively). *Abies* occurs at quite low frequencies (1.3-2.6%), while *Betula pendula* records very low values (0.1-2.1%). Other types of the 'coniferous and deciduous canopy trees' habitat group are very poorly represented, with the exception of *Ostrya* type (2.8-8.5%).

Relative frequencies of the pollen types in the habitat groups of 'alpine shrubs' and 'alpine herbs' are extremely low (0.3% maximum). The habitat group of 'woodland understorey trees and shrubs' is extremely poorly represented; no individual type exceeds 0.7%. 'Woodland herbs' occur at about average frequencies for the sequence (0.6-2.2%), while individual pollen types in this group are extremely poorly represented (0.9% maximum). The group 'riverine trees' records, in general, the maximum frequencies of the sequence, but reaches only 3.3%. *Alnus glutinosa* is the most abundant pollen type of this group (0.5-1.9%). The group 'evergreen woodland trees' records extremely low frequencies (0.7% maximum). Frequencies of the group 'plants of open dry rocky habitats' are slightly higher (2.1% maximum).

Figure 4.10 Gomara - influx pollen diagram, selected terrestrial taxa.

HERBS OF OPEN GROUND

Figure 4.10

'Herbs of open ground' (12.6-18.1%) is the second most abundant habitat group after 'coniferous and deciduous canopy trees'. Many of the types of this group are represented, the most important are: the two grasses, *Dactylis* type and *Festuca* type, *Pteridium aquilinum*, *Rumex acetosa* group, *Urtica dioica*, and *U. urens* type. Chenopodiaceae type, *Plantago lanceolata* type, and *Solidago* type are also important. Frequencies of *Dactylis* type are highest in the lower half of the zone (reaching 3.9%), while *Festuca* type records low values in the two lowest spectra, then increases (2.4-3.9%). *Pteridium aquilinum* reaches a maximum (2.6%) in the second spectrum from the base of the zone, then declines, but reaches 2.1% in the spectrum second from the top. Frequencies of *Rumex acetosa* group are highest at the base and the top of the zone (5.3% maximum). *Urtica dioica* and *U. urens* type both have continuous curves, but at 2.2% or less. Chenopodiaceae type, *Plantago lanceolata* type, and *Solidago* type occur mostly at less than 1.0%.

Representation of the 'cultivars' group is very poor; no individual type exceeds 0.3%.

Zone G-5, 157.5-133.0 cm The boundary with the preceding zone is marked by a decline in the relative frequencies of *Pinus* (*Diploxylon*) and *Quercus frainetto* type, and an increase in *Fagus* and *Artemisia*. The zone is characterised by low relative frequencies of *Pinus* (*Diploxylon*); increased frequencies of *Fagus*, *Betula pendula*, *Ostrya* type, *Artemisia*, *Festuca* type, and the habitat group of 'herbs of open ground'; and decreased frequencies of *Quercus frainetto* type, *Corylus*, *Picea abies*, and the habitat group of 'coniferous and deciduous canopy trees'.

The habitat groups of 'alpine shrubs' and 'alpine herbs' continue to be very poorly represented; no individual pollen type exceeds 0.7%.

'Coniferous and deciduous canopy trees' decline, although some pollen types within this group increase. *Pinus* (*Diploxylon*) declines (29.7-39.5%) to comparatively low frequencies for this sequence, while *Fagus* increases, ranging from 7.1% (only one spectrum) to 17.8%. *Quercus frainetto* type declines slightly (6.8-9.0%, with the exception of one spectrum of 14.8%). *Quercus trojana* type and *Abies* fluctuate between the same frequencies as those of the preceding zone. In the second spectrum from the base of the zone *Betula pendula* increases dramatically to 10.1%, declines to 5.2%, then 0.5%, and then increases to 5.4%. *Carpinus* type increases very slightly (maximum of 2.3% at the base of the zone). *Corylus* declines slightly (0.2-2.3%). *Ostrya* type increases slightly (12.4% maximum). *Picea abies* almost disappears, occurring in only two spectra (0.3% maximum). Other pollen types in this habitat group either remain at very low relative frequencies or do not appear.

The habitat group of 'woodland understorey trees and shrubs' continues to be very poorly represented (maximum 0.5%); only *Juniperus* and *Buxus* occur. Frequencies of 'woodland herbs' remain very low (less than 1.5%), as do those of 'riverine trees' (2.0% maximum).

Alnus glutinosa is again the most abundant type of the latter group, occurring at the same values as those of the preceding zone. 'Evergreen woodland trees' record a maximum of 0.4%. Representation of 'plants of open dry rocky habitats' is also low (maximum 1.2%).

'Herbs of open ground' is again the second most abundant habitat group, increasing to a maximum of 25.2%. Most types of this group are represented. The most abundant types are: *Artemisia*, *Chenopodiaceae* type, *Dactylis* type, *Festuca* type, *Plantago lanceolata* type, *Pteridium aquilinum*, *Rumex acetosa* group, *Solidago* type, *Urtica dioica*, and *U. urens* type. Most of these types have frequencies of about the same value as those in the preceding zone, but a few have increased: *Artemisia* (1.0-2.0%), *Dactylis* type and *Festuca* type (increase slightly to maximum frequencies of 4.2% and 8.9%, respectively), and *Pteridium aquilinum* (increases to 3.7%, in the centre of the zone).

'Cultivars' are again extremely poorly represented; no individual type exceeds 0.2%.

Zone G-4, 133.0-108.5 cm The boundary with the preceding zone is marked by an increase in the relative frequencies of *Pinus* (*Diploxylon*), *Fagus*, and the habitat group of 'coniferous and deciduous canopy trees'; a decrease in *Betula pendula*; and a slight decline in *Ostrya* type and the habitat group of 'herbs of open ground'. This zone is characterised by increased relative frequencies, in general, of *Pinus* (*Diploxylon*); increased and increasing frequencies of *Fagus* and of the habitat group of 'coniferous and deciduous canopy trees'; and decreased frequencies of *Betula pendula*, *Ostrya* type and the habitat group of 'herbs of open ground'.

'Alpine shrubs' and 'alpine herbs' continue to be very poorly represented, no type exceeds 0.3%.

'Coniferous and deciduous canopy trees' increase (maximum 85.3%); *Pinus* (*Diploxylon*) increases (39.2-41.9%), *Fagus* increases steadily towards the top of the zone (17.6-20.9%), *Abies* increases slightly, while *Quercus frainetto* type and *Carpinus* type occur with frequencies similar to those in the zone below, and *Quercus trojana* type, *Ostrya* type, *Corylus*, *Betula pendula*, and *Picea abies* decline. The latter two almost disappear, occurring only once at 0.4% and 0.2%, respectively.

'Woodland understorey trees and shrubs' are again extremely poorly represented, with only *Juniperus* exceeding 0.2%, and then in only one spectrum and at 0.9%. 'Woodland herbs' increase slightly (maximum 3.2%), representation being mostly from *Anemone nemorosa* group (0.2-1.4%) and *Thalictrum aquilegifolium* (0.4% in two spectra and 1.3% in one spectrum). Frequencies of 'riverine trees' remain very low (1.4-2.3%), as do those of 'evergreen woodland trees' (0.9% maximum) and 'plants of open dry rocky habitats' (1.0% maximum).

Although frequencies of 'herbs of open ground' have declined (9.0-14.9%), many types within this group continue to be represented but at lower frequencies. 'Cultivars' are again extremely poorly represented; no individual type exceeds 0.3%.

Zone G-3, 108.5-106.0 cm This zone includes only one spectrum. The boundary with the preceding zone is marked by a dramatic decline in *Pinus* (*Diploxylon*), *Fagus*, and *Quercus frainetto* type, resulting in a reduction in the 'coniferous and deciduous canopy trees' habitat group. Herbaceous plants increase, with the exception of those that grow in woodlands. This results in an increase in the habitat groups of 'plants of open dry rocky habitats' and 'herbs of open ground'.

'Alpine shrubs' are not represented, but 'alpine herbs' are represented by three types, each at 0.1%. 'Coniferous and deciduous canopy trees' drop to 28.4%. Frequencies of the most important types in this group all decline dramatically; *Pinus* (*Diploxylon*) to 12.2%, *Fagus* to 6.5%, and *Quercus frainetto* type to 1.8%. Other types in this group such as *Quercus trojana* type, *Abies*, *Carpinus* type, *Corylus*, and *Ostrya* type also decline, while *Fraxinus ornus* and *Ulmus glabra* type either increase very slightly or remain at very low frequencies.

'Woodland understorey trees and shrubs' are represented by only *Juniperus* (0.1%). 'Woodland herbs' and 'riverine trees' decline slightly to 2.2% and 2.3%, respectively. Representation of 'evergreen woodland trees' remains very low at 0.3%.

The habitat groups of 'plants of open dry rocky habitats' and 'herbs of open ground' which include many herbaceous plants, both increase dramatically, the former to 11.4% and the latter to 51.8%. Some types appear for the first time, while others increase. 'Cultivars' also increase, owing to an increase in *Medicago sativa* which in this situation is probably represented by a native wild subspecies.

Zone G-2, 106.0-47.5 cm This zone is characterised by relative frequencies of almost all types returning to the values at the top of zone G-4 and those of *Pinus* (*Diploxylon*) and *Fagus* increasing steadily to the centre of the zone and then declining slightly.

'Alpine shrubs' increase slightly to 0.6%, but 'alpine herbs' reach a maximum of only 0.3%.

The most abundant types in the group 'coniferous and deciduous canopy trees', *Pinus* (*Diploxylon*) and *Fagus*, both reach maximum relative frequencies of the sequence (58.2% and 38.6%, respectively). The relative frequencies of *Quercus frainetto* type fluctuate with high frequencies at the top and bottom of the zone, and lower frequencies in the centre, where, in general, minima of the sequence for this type occur (minimum 0.3%). *Quercus trojana* type and *Abies* increase slightly to maxima of 5.1% and 4.9%, respectively. Relative frequencies of *Carpinus* type remain extremely low (0.1-1.4%), and those of *Corylus* (0.9% maximum) and *Ostrya* type (6.8% maximum) decline slightly.

Relative frequencies of 'woodland understorey trees and shrubs' remain low, with *Juniperus* continuing to be the most abundant type but with a maximum of only 0.7%. 'Woodland herbs' increase slightly at the base of the zone but then decline again (0.6-3.4%). Frequencies of 'riverine trees' (1.7% maximum) and 'evergreen woodland trees' (0.9% maximum) continue to be extremely low, and 'plants of open dry rocky habitats' return to the extremely low relative frequencies of zone G-4 (0.8% maximum).

'Herbs of open ground' record the lowest relative frequencies of the sequence (4.7-12.7%). Types of this group that dominated in the lower zones continue to be dominant but at lower values.

'Cultivars' continue to record extremely low relative frequencies but increase slightly at the top of the zone, reaching a maximum of 1.9%. This is due mostly to *Juglans regia* (0.6% maximum at 100 cm) and *Secale cereale* (1.5% maximum at 55 cm).

Zone G-1, 47.5-0 cm The boundary with the preceding zone is marked by an increase in the relative frequencies of *Quercus frainetto* type, *Dactylis* type, *Festuca* type, and the habitat group 'herbs of open ground'; and a decrease in *Fagus* and the habitat group of 'coniferous and deciduous canopy trees'. This uppermost zone is characterised by declining relative frequencies of *Fagus*, increasing relative frequencies of *Quercus frainetto* type (apart from the top two samples), and high relative frequencies of *Dactylis* type.

'Alpine shrubs' and 'alpine herbs' continue to be very poorly represented, as they have been throughout the sequence, with a maximum of 0.6% for both groups.

Relative frequency curves of the most abundant types in 'coniferous and deciduous canopy trees' form different patterns. The curve of *Pinus (Diploxylon)* increases rapidly from low values, then declines slightly (from a minimum of 21.4% to a maximum of 55.0%, then to 51.3% in the surface spectrum). The curve of *Quercus frainetto* type is similar to that of *Pinus (Diploxylon)*; bottom spectrum 12.2%, peaks at 30 cm at 22.1%, and surface spectrum 4.4%). However, it peaks in a spectrum above the maximum of *Pinus (Diploxylon)*. The curve of *Fagus* declines from a maximum of 17.4% in the spectrum second from the bottom to 3.9% in the surface spectrum. Other types in this group record frequencies very similar to those in the zone below.

'Woodland understorey trees and shrubs', 'woodland herbs', 'riverine trees', and 'evergreen woodland trees' all remain at very low frequencies, although *Juniperus* increases to 1.8% in the surface spectrum. 'Plants of open dry rocky habitats' increase and reach a maximum of 4.0% in the surface spectrum.

Relative frequencies of 'herbs of open ground' fluctuate, being highest at the base (26.3%) and top (23.4%) of the zone, with a minimum of 8.1% in the second spectrum from the base. *Dactylis* type follows a similar pattern, fluctuating from 1.4 to 7.9%. Frequencies

of *Festuca* type (3.0% maximum), *Pteridium aquilinum* (3.3% maximum), *Rumex acetosa* group (1.9% maximum), *Urtica dioica* (1.0% maximum), and *U. urens* (2.1% maximum) are higher than those in the zone below.

'Cultivars' continue to show the slightly elevated values of the top of the preceding zone (1.9% maximum). Pollen types contributing most pollen are again *Juglans regia* (0.5% maximum at 45 cm) and *Secale cereale* (1.2% maximum at 45 cm).

4.7.3.3 Terrestrial vegetation history

This sequence records the vegetation history of the Gomara area from c. 1340 BC to 700 AD, at 25 cm. (Dates are interpolated from the radiocarbon chronology.) The lake basin is a hollow within a small steeply sided drainage basin so it receives a substantial proportion of pollen from run-off from the catchment as well as directly from the atmosphere. Given the small size of the lake basin and catchment it is reasonable to assume that a large proportion of the pollen derives from extra-local plants, but a regional pollen source is also represented.

Pollen of the habitat group 'coniferous and deciduous canopy trees' are by far the most abundant throughout the sequence. *Pinus* (*Diploxylon*) is the most abundant pollen type in this habitat group, with *Fagus* and *Quercus frainetto* type next most abundant. The second most abundant group is 'herbs of open ground'. All the remaining habitat groups are poorly represented.

The terrestrial vegetation history of the Gomara area is discussed according to local pollen assemblage zones below.

Zone G-6, 190.0-157.5 cm, c. 1340-890 BC *Pinus* (*Diploxylon*) occurs at consistently very high relative frequencies; values are similar to those of the surface spectrum from this site. However, influx data suggest that initially influx is relatively low (but twice that of the surface spectrum), then increases three-fold before returning to values similar to those recorded initially. Both relative frequency and influx values of *Fagus* are very low and follow the same pattern of higher at the base and top of the zone, a pattern opposite to total influx. Relative frequencies of *Quercus frainetto* type (deciduous oaks), although in general slightly higher than in any other zone (with the exception of zone G-1), is only slightly higher than the maximum recorded in surface samples in the Pindos Mountains (Table 3.1), suggesting that the source of pollen may not be closer to the site than that of today, that is, the Pindos foothills (Chapter 3). The influx values of this pollen type are the highest for the sequence (with the exception of one spectrum at 110 cm). Relative frequencies of *Quercus trojana* type (semi-evergreen oaks) and *Abies* are similar to those throughout the sequence, but influx values are the highest for the sequence. Influx of *Abies* is lower at the base and top of the zone. Relative frequencies of *Ostrya* type fluctuate, but in general are about average for the sequence, while

influx values are the highest for the sequence (with the exception of two spectra – 110 and 90 cm) and are of a consistent value. The highest relative frequencies and influx values of the sequence are recorded for *Corylus* and *Picea abies*; influx curves form a pattern similar to those of *Pinus* (*Diploxylon*) and *Abies*.

The habitat groups 'alpine shrubs' and 'alpine herbs' are very poorly represented in this zone, and indeed, throughout the sequence. In general plants from these habitats are poor pollen producers. 'Woodland understorey trees and shrubs' and 'woodland herbs' are poorly represented, suggesting an absence of a layered woodland structure or canopy cover. The relative frequencies and influx values of 'riverine trees' are so low that a presence in the vicinity of the site is very unlikely. Similarly, extremely low relative frequencies and influx values of the habitat groups of 'evergreen woodland trees' and 'plants of open rocky habitats' point to the absence of a Mediterranean-type vegetation. The relative frequency and influx values of 'herbs of open ground' are high and suggest an open-canopy vegetation.

Palynological richness values declining from very high values of 40 and 45 expected types at the base of the zone to high values of 30 and 35 at the top suggest that the canopy was very open at the base of the zone and then began to close. The number of terrestrial taxa is also high to very high, the maximum of 84 occurring in the spectrum second from the base, where palynological richness is highest. The ratio of terrestrial trees and shrubs to terrestrial herbs also suggests an open-canopy vegetation; terrestrial herbs represent about 20% of total terrestrial pollen throughout this zone.

The vegetation surrounding the Gomara site at this time was an open pine or mixed conifer-deciduous wood, but it was not as open as it is today. Two possibilities of the spatial distribution of woodland represented can be envisaged. Either an almost pure pine wood surrounds the site with a deciduous wood growing at a lower altitude or an open woodland of predominantly pine with scattered other conifers and deciduous species is widespread. Although no mixed coniferous-deciduous wood exists in Grevena today at high altitude on Pindos ophiolite ultramafics, a woodland that might resemble the vegetation represented by the pollen and spores of this zone occurs just across the Grevena border in the Pindos Mountains near Samarina at 1300 m. Here *Pinus nigra*, *Taxus baccata*, *Ostrya carpinifolia*, *Fagus sylvatica*, *Sorbus aucuparia*, *Acer obtusatum*, *Euonymus latifolius*, and *Fraxinus excelsior* occur together (Polunin 1988). (A notable difference from this woodland is the absence of *Fagus* from the catchment.) In addition, the occurrence of such entomophilous (but sometimes anemophilous) pollen types as *Tilia cordata* type, *Sorbus* type, and *Fraxinus ornus* (this species may have been planted (Bottema & Woldring 1990)) suggests the possibility of the latter reconstruction. The light demanding colonizer *Corylus* was probably growing in the catchment.

Zone G-5, 157.5-133.0 cm, c. 890-480 BC In zone G-5 the relative frequencies of *Pinus* (*Diploxylon*) decline to low values for the sequence. Influx values also decline to very low values, suggesting a decline in the pollen source within the catchment. The relative frequencies and influx of *Fagus* increase indicating the occurrence of *Fagus* in the catchment. Relative frequency and influx values of *Betula pendula* increase, while both values of *Corylus* decline and *Picea abies* almost disappears. *Sorbus* type, *Taxus baccata*, and *Tilia cordata* type disappear completely. The changes in pollen abundance of these types may represent changes taking place in the vegetation within the catchment or regionally, whereas that of *Abies* (in which relative frequencies remain about the same but influx declines) probably represents a change in the regional woodland. Trees represented by oak pollen types, *Ostrya* type, and *Carpinus* type probably occur at lower altitude. The relative frequencies of semi-evergreen oaks increase slightly, although influx values decrease, while both relative frequencies and influx values of deciduous oaks decline. The relative frequencies of *Ostrya* type and *Carpinus* type increase, but influx values decline slightly.

The habitat groups 'alpine shrubs' and 'alpine herbs' are again very poorly represented. 'Woodland understorey trees and shrubs' and 'woodland herbs' are represented by even fewer pollen grains. Similarly, the values of 'riverine trees', 'evergreen woodland trees', and 'plants of open dry rocky habitats' either remain unchanged or decline. Relative frequencies of 'herbs of open ground' increase due to a decrease in 'coniferous and deciduous canopy trees', while influx values decline due to a decline in total influx. However, values are relatively high and suggest an open-canopy vegetation. The most abundant herbs of this group are the same as previously, with the exception of an increase in *Artemisia*.

High palynological richness values of 30-40 expected types, and the declining ratio of terrestrial trees and shrubs to terrestrial herbs (terrestrial herbs comprising over 25% of total terrestrial pollen and spores in the centre of the zone) also suggest an open-canopy vegetation.

The pine wood has declined and the diversity of the extra-local/regional coniferous-deciduous woodland is reduced. *Abies* and *Picea abies* have almost disappeared. *Fagus* and *Betula pendula* have expanded. At 155 cm the abundance of beech pollen rises to exceed 15.0%, and a beech nut found at the same depth supports the occurrence of beech trees in the catchment. *Betula pendula*, a pioneer, now plays a more significant role, perhaps as a result of increased exposure of mineral soils. The pioneering role is now played more strongly by *Betula pendula* than by *Corylus*. *Betula pendula* is here identified to the species level based on the current distribution of species of *Betula* (Tutin *et al.* 1964-80; Sfikas 1978) and size of pollen grains (Birks 1968; Prentice 1981; Roure 1985).

Zone G-4, 133.0-108.5 cm, c. 480-80 BC In zone G-4 the relative frequency and influx values of *Pinus* (*Diploxylon*), *Fagus*, and *Abies* increase, while those of *Corylus*, the

deciduous oaks, and *Carpinus* type remain unchanged. Both values of the semi-evergreen oaks and *Ostrya* type decline in all spectra with the exception of the uppermost, in which an increase occurs in the influx value. A similar increase occurs in most types of the 'coniferous and deciduous canopy trees' group in this spectrum. *Betula pendula* has almost disappeared.

The habitat groups 'alpine shrubs' and 'alpine herbs' are again very poorly represented. 'Woodland understorey trees and shrubs' and 'woodland herbs' are represented by a slightly higher number of pollen grains. Again, the values of 'riverine trees', 'evergreen woodland trees' and, 'plants of open dry rocky habitats' either remain unchanged or decline. While the values of palynological richness (35 expected types at the base of the zone and 30 at the top) are still indicative of an open canopy, decreased frequency and influx values of 'herbs of open ground' and an increase in pollen influx of the habitat groups indicative of woodlands suggest that the canopy is closing. An increase in the ratio of the total terrestrial trees and shrubs to terrestrial herbs also suggests a slight closing of the canopy, terrestrial trees and shrubs representing 82.0-88.4% of total terrestrial pollen.

Pine woods have expanded and/or become denser as well as beech woods. Representation of *Fagus* pollen now reaches 20.0% relative frequency. The surface sample from Anelia bog, which is surrounded by beech wood, recorded only 23.5% (Chapter 3). Since beech pollen is heavy and usually does not travel far from its source, this high relative frequency value suggests that beech woods were growing extra-locally. In support of an extra-local beech wood is the steadily increasing abundance of beech nut macrofossils.

Abies has increased to a maximum of 4.6%. *Abies* was found to be greatly under-represented but well dispersed (Chapter 3), so this value may or may not represent an extra-local occurrence.

Zone G-3, 108.5-106 cm, c. 80 BC Zone G-3 includes only one spectrum. The ratio of terrestrial trees and shrubs to terrestrial herbs declines dramatically; terrestrial herbs comprise about 70% of total terrestrial pollen and spores.

Sediment of this spectrum comprises a tephra, which was deposited very rapidly, that is, deposition took less than a full pollination season, and it therefore does not contain the full annual pollen and spore complement. Changes in palynomorph representation in this zone thus do not represent a change in vegetation.

There are no significant differences in palynomorph content of the sediments directly above and below the tephra. Mehringer *et al.* (1977) obtained the same result when pollen analysing sequences including known tephtras.

Zone G-2, 106.0-47.5 cm, c. 80 BC-330 AD In zone G-2 the pollen record of the vegetation history of the Gomara area is continuous with the top of zone G-4. Relative frequencies of *Pinus* (*Diploxylon*) and *Fagus* increase slightly and influx values of these

pollen types are high until the upper part of the zone. The decline in influx values at the top of the zone may be due to an increased sedimentation rate (which has not been completely compensated), or a decline in pollen in-wash. Relative frequency and influx values of the deciduous oaks, *Carpinus* type, *Corylus*, and *Ostrya* type decline slightly, while those of semi-evergreen oaks and *Abies* increase slightly.

The habitat groups 'alpine shrubs' and 'alpine herbs' are again very poorly represented, but increase slightly. 'Woodland understorey trees and shrubs' are very poorly represented. 'Woodland herbs' increase slightly at the base of the zone, but then decline. This fluctuation is interpreted as a response firstly to an increasing woodland canopy cover, then to a closed canopy cover of a *Fagus* woodland, which usually has few plants growing under its dense canopy. 'Riverine trees', 'evergreen woodland trees', and 'plants of open dry rocky habitats' all decline.

'Cultivars' increase towards the top of the zone due to a slight increase in the nut tree *Juglans regia* and the cereal *Secale cereale*, but pollen representation is very low and may result from wild plants or from long-distance dispersal from cultivated areas.

'Herbs of open ground' also declines and palynological richness declines (30 or less expected types), suggesting that canopy cover is complete. A high ratio of terrestrial trees and shrubs to terrestrial herbs (highest ratio of the sequence, peaking near the centre of the zone, where trees and shrubs represent more than 90% of total terrestrial pollen) is supporting evidence for complete canopy cover.

High relative frequencies of *Fagus* are indicative of a closed canopy beech wood surrounding the site. The relative frequencies of *Fagus* are higher than those recorded under the beech wood at Anelia (Chapter 3). *Fagus* woodland has now replaced the former pine wood or mixed coniferous-deciduous wood in the catchment. At the present time a small stand of beech grows in a small valley close to the coring site. Where beech and pines occur together in Grevena today, the former tends to expand at the expense of the latter. Beech has a much greater power of rejuvenation than pine, owing to its ability to develop dormant or adventitious buds, which form a dense brushwood of stumps and broken branches long before conifer seedlings can become established. A noticeable feature of Balkan vegetation today is that on non-calcareous rocks beech is usually dominated by the pines, fir, and spruce, where they occur together, and the latter retain their dominance unless they have been cleared by humans. There are, however, exceptions to this where beech forms a complete zone up to the tree limit (Turrill 1929).

Zone G-1, 47.5-0 cm, c. 330-700 AD and present In zone G-1 relative frequency and influx values of *Pinus* (*Diploxylon*), semi-evergreen oaks, *Abies*, *Corylus*, and *Ostrya* type continue at about the same values as at the top of zone G-2. The relative frequency and influx

values of beech and *Carpinus* type decline while those of the deciduous oaks increase initially and then decline. *Betula pendula* reappears.

The habitat groups 'alpine shrubs' and 'alpine herbs' are again very poorly represented. A slight increase in 'woodland understorey trees and shrubs' towards the top of the zone is due to an increase in *Juniperus*, which grows as an understorey shrub in the open pine woods of today. Both frequency and influx values of 'woodland herbs' remain about the same as at the top of zone G-2. 'Riverine trees', 'evergreen woodland trees', and 'plants of open dry rocky habitats' all increase slightly: this is interpreted to result from a regional pollen source due to reduced extra-local arboreal pollen production. However, plants that grow in dry rocky habitats may have increased extra-locally due to surface soils becoming drier through a reduction in canopy cover and greater evaporation at ground surface.

Pollen of the 'cultivars' of *Juglans regia* and *Secale cereale* initially occur at the same abundance as that of the preceding zone and then decline. *Juglans regia* does not occur in the surface spectrum. Again the pollen source may be either wild plants or distant cultivated areas.

Palynological richness fluctuates from very high (45 expected types at the base of the zone) to low (minimum value of 25) near the centre and then to high values again (40 expected types at the top of the zone), suggesting an open, then more closed, then open canopy. The number of terrestrial taxa counted also fluctuates from high to low and then to high again. Rate of change is high, reflecting these fluctuations. The curve of the ratio of terrestrial trees and shrubs to terrestrial herbs follows this pattern also (at the base of the zone terrestrial trees and shrubs contribute about 65% of total terrestrial pollen, increase to 90%, then decline to about 65%), suggesting an open, then closed, then open canopy. This pattern is also followed by the habitat group 'herbs of open ground'. This is interpreted as a more open canopy of the catchment vegetation due to a reduction in the extra-local beech wood at c. 330 AD. Pine wood recovers somewhat, replacing beech wood, but then declines at c. 600 AD.

4.8 Charcoal analysis and fire history

4.8.1 Microscopic charcoal analysis

Results of microscopic charcoal particle analyses are presented as relative frequencies and influx in Figures 4.11 and 4.12. The local zonation scheme of the terrestrial pollen and spores is used for convenience of correlation. Curves show abundance of charcoal of different size classes and total abundance. The charcoal record shows continuous registration of charcoal particles in the total charcoal curves. High total charcoal abundance occurs in zones G-6, G-5, G-3, and G-1, while in zones G-4 and G-2 total charcoal abundance is very low.

Figure 4.11 Gomara - charcoal particle percentage diagram (based on pollen sum of total terrestrial taxa).

Figure 4.12 Gomara - charcoal particle influx diagram.

In zone G-6 relative frequencies of total charcoal fluctuate from the highest recorded of the sequence in the basal spectrum to about average in the centre of the zone, to one of the highest peaks of the sequence in the uppermost spectrum. Influx total charcoal data also show very high charcoal levels and confirms the very high peaks at the base and top of the zone, suggesting that fires were more intense/frequent in the region at that time. Charcoal particles are much more abundant in the smaller than in the larger size classes, and the peaks in the total charcoal curve are reflected in the three smallest size classes. Charcoal particles of the four smallest size classes, that is up to $200 \mu\text{m}^2$, are represented in all spectra. In the two largest size classes, no charcoal particles are recorded at 175 cm in the $200\text{-}400 \mu\text{m}^2$ size class and at 170 cm none is recorded in the $>400 \mu\text{m}^2$ size class. At 160 cm no particles were recorded for either of these classes. Charcoal particles in the size class $>400 \mu\text{m}^2$ are frequent in the lower half of this zone, suggesting that fires occurred in the catchment.

Zone G-5 exhibits high charcoal content. The total relative frequency curve shows abundances similar to those of the basal zone, with a peak in the centre of the zone (at 145 cm and 140 cm), while influx data suggest that abundances were lower than those in the basal zone. The total influx curve also displays the peak in the centre of the zone. Charcoal particles of the smaller size classes are again much more abundant than those of the larger sizes and occur continuously, whereas those of the larger sizes occur sporadically. In the size class $200\text{-}400 \mu\text{m}^2$ no particles were recorded at 150, 140, and 135 cm. In the largest size class, that of $>400 \mu\text{m}^2$, no particles were recorded at 135 cm. The peak recorded by the total charcoal curve in the centre of the zone is reflected only in the three smallest size classes ($<100 \mu\text{m}^2$) in the relative frequency and influx curves, although a peak is shown at 140 cm in the $100\text{-}200 \mu\text{m}^2$ size class and one at 145 cm in the $200\text{-}400 \mu\text{m}^2$ size class. Charcoal particles in the size class $>400 \mu\text{m}^2$ are frequent, with the exception of the uppermost spectrum, suggesting that fires occurred in the catchment (Chapter 3).

Zone G-4 exhibits low charcoal content. The total relative frequency and influx curves show much reduced charcoal content. Particle abundance of all size classes has declined, with the exception of a peak in the uppermost spectrum (of equal abundance to values in the lower two zones in the largest size class). Occurrence is sporadic in all size classes apart from the two smallest, i.e. smaller than $50 \mu\text{m}^2$.

Zone G-3 exhibits very high total charcoal content (in the influx diagram as high as that in the basal spectrum of the sequence) in the one spectrum that comprises this zone, and charcoal particles of all size classes are recorded. The smaller size classes are the most abundant.

Zone G-2 exhibits very low charcoal content. Total charcoal content is extremely low and all size classes occur sporadically, apart from the two smallest size classes (particles $<50 \mu\text{m}^2$).

In zone G-1 charcoal abundance increases in all size classes. Two peaks occur, at 40 cm and 30 cm, when fires in the region were probably more intense or more frequent. These peaks are recorded in all size classes, with the exception of the peak at 40 cm in the largest two size classes ($200\text{--}400 \mu\text{m}^2$ and $>400 \mu\text{m}^2$). The upper peak is the larger of the two and reaches relative frequencies similar to those in the basal spectrum of the sequence, especially in the larger size class particles. However, the influx curve is much lower. The surface spectrum shows greatly reduced charcoal abundance.

4.8.2 Fire history

There is continuous accumulation of microscopic charcoal particles throughout the sediment sequence. Visual inspection of residues retained by the $260 \mu\text{m}$ mesh sieve during pollen-sample preparation, prior to mounting the processed samples onto microscope slides, showed that optically visible charcoal occurred in only those samples where the largest-sized particles were observed through the microscope.

Interpretation of charcoal data is complicated because erosion after a fire and the redeposition of sediment within the lake basin could produce smoothed peaks or even anomalous peaks. Also, the magnitude of a charcoal peak may be obscured if a sample spanning several years contains only a few years of high influx that are then averaged over the total number of years spanned by the sample. Thus the frequency of individual fires cannot be interpreted from the microscopic charcoal data, but periods when fires occurred more frequently or more intensely can be distinguished.

Two phases of more frequent/intense fires are evident; from *c.* 1340 to 480 BC, and from *c.* 500 to 700 AD at the top of the undisturbed sediments. In the former phase the charcoal record shows continuously high values of charcoal influx of particles in the four lower size classes and almost continuous influx in the two largest size classes. During this period fire was widespread and of major ecological importance in the region of the site, and perhaps also in the catchment. Optically visible charcoal particles in the sediments from 190.0–181.5 cm and 157.0–133.0 cm provide supporting evidence for the importance of fires during this phase. In the later phase, total charcoal abundance is lower, but again the four smaller and the two largest size classes are continuously represented are also continuously represented. Separating these two phases is a period of about 900 years when fires were more distant and/or sporadic and were of little ecological significance. Today fire is not a major ecological factor around the Gomara site.

Pollen evidence also suggests a high frequency of fires in the Gomara region in the lower part of the sequence. Between 190.0 and 157.5 cm, the pollen assemblage zone (G-6) where charcoal is most abundant, the curve of total influx of pollen and spores is the mirror image of that of total charcoal influx. This is interpreted as resulting from the depletion of the pollen source through the vegetation being burnt. Total influx of pollen and spores is also low in the following pollen assemblage zone, where charcoal is also abundant. The influx of pollen of the conifers *Pinus*, *Picea*, and *Abies*, which are slow to recover from burning because they become established by seed reproduction only, declines during the phase of frequent fires in the lower part of the sequence. Influx of pollen of the early successional genera of *Betula pendula*, *Corylus*, *Pteridium*, and Gramineae, which can sprout from underground root collars following destruction of above-ground biomass after burning, is highest in that part of the sequence.

4.9 Synthesis of environmental changes

A summary of the major environmental changes in the wetland and its catchment from c. 1340 BC to 700 AD is given in Table 4.2.

There is close correspondence between changes in the composition of the sediment and changes in the pollen profiles of both wetland and terrestrial pollen and spore types. This close correspondence is explained by these three elements responding to environmental changes in the catchment. Thus the boundaries of the wetland and terrestrial pollen zones are synchronous. Further, this synchronism implies that many of the pollen and spores in the sediments derive from the catchment: the terrestrial pollen record reflects primarily the extra-local rather than regional vegetation.

The Gomara wetland is continuously wet and comprised a small lake 1-2 m deep from c. 1340 BC to 700 AD. After this period seasonal drying of the lake bed occurred. The water of the lake is fresh, slightly alkaline, and oxygen-rich. The highland regional vegetation is pine wood throughout the sequence.

The genesis of the wetland, radiocarbon dated at c. 1340 BC, is coincident with soil erosion in the catchment as evidenced by the high proportion of inorganic matter of the wetland sediment, high trophic level (eutrophic), and high organic nitrogen content of the lake water. At c. 1250 BC erosion intensifies, as indicated by coarser sediment particles, increased alkaliphilous diatoms, and increased nutrient levels of the lake.

Table 4.2

Major environmental changes in Gomara wetland and its catchment, c. 700 AD to 1340 BC

Date BC/AD	Water level	Wetland vegetation	Catchment vegetation	Erosion & sedimentation	Charcoal
c. 700-330 AD	High, steady water level	Marginal sedge & reed swamp – <i>Carex hallerana</i> type & <i>Cyperus michelianus</i> dominant	Open canopy – <i>Pinus</i> dominant, increased <i>Pteridium</i> & herbs of open ground, fluctuating palynological richness	Erosion begins again; high inorganic matter, increasing trophic level, high organic nitrogen	Increasing; microscopic
c. 330 AD-80 BC	Greatest depth. Steady water level	Marginal sedge & reed swamp – <i>Carex hallerana</i> type dominant, <i>Phragmites australis</i> reduced	Closed canopy – <i>Fagus</i> dominant, reduction in herbs of open ground, much reduced <i>Pteridium</i> , reduction in palynological richness	Very little erosion; very high organic content, meso-eutrophic, low organic nitrogen	None except in two samples; microscopic
c. 80 BC				Tephra	Abundant; microscopic
c. 80-480 BC	Decreased. Seasonal fluctuation	Marginal sedge & reed swamp – <i>Phragmites australis</i> & <i>Carex hallerana</i> type co-dominant	Closing canopy – <i>Pinus</i> , increasing <i>Fagus</i> , reduced herbs of open ground & <i>Pteridium</i> , lower palynological richness	Decreasing erosion; fine grained sediments with increased organic detritus, decreasing inorganic matter, meso-eutrophic, low organic nitrogen	Almost none; microscopic
c. 480-890 BC	Increased. Steady water level	Marginal sedge reduced, reed swamp expanded; <i>Phragmites australis</i> dominant	Open canopy – <i>Pinus</i> , increasing <i>Fagus</i> , abundant herbs of open ground, <i>Pteridium</i> present, high palynological richness	Erosion less intense; high inorganic matter but of finer grain size, meso-eutrophic, lower organic nitrogen	Abundant; macroscopic & microscopic particles
c. 890-1340 BC	High, then ?lower. Seasonal fluctuation	Marginal sedge & reed swamp – tall-sedge community dominant	Open canopy – <i>Pinus</i> dominant, abundant herbs of open ground, <i>Pteridium</i> present, high palynological richness	Erosion of increasing intensity; high inorganic matter, eutrophic, high organic nitrogen	Abundant; macroscopic & microscopic particles

Between c. 1340 and 890 BC a marginal sedge and reed swamp vegetation surrounds the lake with the tall-sedge-swamp community dominant. The water level fluctuates seasonally and average water level may decline. The catchment vegetation is either an open canopy pine or mixed conifer-deciduous wood, although not as open as today. Pine wood occurs over a wide area, either pure or mixed with other conifers and deciduous trees. *Abies*, *Picea abies*, *Corylus*, and *Betula pendula* are present either extra-locally and/or regionally. 'Herbs of open ground' are abundant especially terrestrial grasses, *Rumex* species, *Urtica* species, and *Pteridium aquilinum*. Species belonging to the pollen types Chenopodiaceae type, *Plantago lanceolata* type, and *Solidago* type are also important. A mixed oak wood including *Ostrya* and *Carpinus* occurs at lower elevation. Burning of the catchment and regional vegetation is suggested by the occurrence of abundant macroscopic and microscopic charcoal particles, lower influx of coniferous pollen (*Pinus*, *Abies*, and *Picea abies*) where charcoal is most abundant, and, perhaps, the presence or greater abundance of pollen of early-successional genera such as *Betula pendula*, *Corylus*, and Gramineae and spores of *Pteridium aquilinum*.

Between c. 890 and 480 BC less intense soil erosion is suggested by finer grain size of inorganic matter, a reduced average sedimentation-accumulation rate, a decline in trophic level to meso-eutrophic, and lower organic-nitrogen content of the lake. Water depth increases and there is less seasonal fluctuation. In the mixed marginal sedge and reed vegetation *Phragmites australis* becomes more important. Vegetation of the catchment changes to an open canopy mixed pine-beech wood. The woodland extra-locally and/or regionally is less diverse with tree pollen types such as *Sorbus* type, *Taxus baccata*, and *Tilia cordata* type disappearing. *Picea abies* and *Corylus* decline, but *Betula pendula* expands. 'Herbs of open ground' are abundant; most abundant herbs are the same as previously, with the exception of an increase in *Artemisia*. A mixed oak wood occurs at lower altitude. Burning of the catchment and regional vegetation is again suggested by the occurrence of abundant macroscopic and microscopic charcoal particles and the greater abundance of pollen of the early successional *Betula pendula* and Gramineae, and the occurrence of *Pteridium aquilinum* spores.

Between c. 480 and 80 BC soil erosion declines further; minerogenic sediments are fine-grained, organic detritus increases, lake trophic level is meso-eutrophic, and organic nitrogen content is low. Water level probably declines and there may be greater seasonal fluctuation. A mixed marginal sedge and reed community surrounds the lake, with *Carex hallerana* type and *Phragmites australis* co-dominant. Vegetation of the catchment is now mostly beech wood with a much reduced pine component, but regionally pine is still dominant. 'Herbs of open ground' and the early successional types of *Corylus* and *Betula*

pendula decline as the canopy of the catchment woodland becomes more closed. A mixed oak wood still occurs at lower altitude, but semi-evergreen oaks and species of the *Ostrya* pollen type have declined. An almost complete absence of charcoal particles and *Pteridium aquilinum* spores suggests burning of the catchment and regional vegetation has almost ceased.

At c. 80 BC a volcanic ash fell; perhaps originating from an Italian volcanic eruption from Etna, Monte Albano, or Vulcano (Simkin *et al.* 1968).

Between c. 80 BC and 330 AD little soil erosion occurs; minerogenic sedimentation declines and the proportion of organic detritus increases until sediments are almost entirely organic. Trophic level of the lake water is meso-eutrophic, and organic nitrogen content is low. Water level increases and is probably at its highest levels with little seasonal fluctuation, as shown by the abundance of diatoms living in permanent water and an increase in pollen of aquatic macrophytes. The marginal vegetation is now dominated by plants of the *Carex hallerana* pollen type. Vegetation of the catchment is a closed-canopy beech wood; 'herbs of open ground' record the lowest relative pollen frequencies of the sequence. The regional highland vegetation is pine wood. At lower elevations a mixed oak wood is extant. *Juglans regia* and *Secale cereale* pollen occurs at very low abundance and may result from wild plants or from long-distance dispersal from cultivated areas. Burning of vegetation is not occurring, except perhaps at a long distance from the catchment.

Between c. 330 and 700 AD more intense soil erosion occurs. In the wetland inorganic sedimentation occurs; alkaliphilous diatoms increase, the trophic level increases, and organic-nitrogen content increases. Water level is probably high with little seasonal fluctuation. The lake-margin vegetation comprises a sedge-swamp community dominated by plants of the *Carex hallerana* pollen type and *Cyperus michelianus* with a small reed swamp growing on the lakeside. The beech wood in the catchment begins to decline at c. 330 AD. 'Herbs of open ground' increase; particularly the dryland grasses of *Dactylis* type and *Festuca* type, *Pteridium aquilinum*, *Rumex acetosa* group, *Urtica dioica*, and *U. urens*. *Juglans regia* and *Secale cereale* occur at the same very low abundance as previously. Pine wood replaces the beech wood, but then it declines at c. 600 AD, and an open canopy pine wood similar to that of today forms. This open pine wood is widespread. A mixed oak wood is extant at lower elevations. Burning of the catchment and regional vegetation occurs again from c. 500 AD, both locally and regionally, and almost reaches the levels of frequency/intensity of that between c. 1340 and 480 BC.

Sediments younger than c. 700 AD (above 25 cm) are oxidized, and there is no accumulation of organic deposits. The palynological record is probably incomplete, thus no sample except the surface sample was pollen-analysed. Sediments of this horizon are

disturbed by surface cracking when the lake bed dries out during summer and by cattle trampling so they are mixed, but they indicate that erosion of catchment soils has occurred. Diatom analysis of samples at 10 and 1 cm indicate that wetland conditions are similar to those at 35 cm. The pollen analysed surface sample shows that the wetland vegetation is similar to that at c. 700 AD: a much reduced wetland vegetation community mostly of plants indicative of high nutrient levels. The extra-local and regional vegetation differs from that at c. 700 AD: *Fagus*, *Quercus*, and *Abies* are less abundant, and *Betula pendula* is absent, but *Juniperus* and plants of open dry rocky habitats are more abundant. Burning is much less than that at c. 700 AD.

Chapter 5. Anelia

5.1 Introduction

This chapter includes a description of the site and sediments of the Anelia wetland coring site and then presents the results of pollen analysis of a sediment and peat sequence 250 cm long. The site was discovered on the 1:50 000 topographic map for the Metsovon area and is named after the name appearing on that map (Hellenic Army Geographic Service 1970).

5.2 Site description

Anelia bog is situated in the Pindos Mountains (latitude 39° 57' 30" N, longitude 21° 05' 30" E) at an elevation of 1440 m asl (Figures 3.2, 5.1 & 5.2). It is in Grevena Province about 3.5 km southwest of Perivolion, near the pass between Perivolion and Vovoussa, which was used as a trading route during the Ottoman Period. It is located approximately 150 m north and 50 m below the Perivolion-Vovoussa road and can be reached by turning off this road at the sign indicating the direction to Vovoussa, then driving about 1.5 km eastwards along a track. It is about 500 m distant from the Katarramtis River, a tributary of the Aoos.

There is plenty of evidence that this area is often used by humans and animals. Cattle dung was noted on the surface of the bog, and the bog vegetation was grazed between our visits to it. On two occasions while we were visiting the site shepherds drove flocks of sheep and goats along the track at the northern end of the wetland (Figure 5.3). A dry area close to the track at the northern end appears to be a picnic area, perhaps used by shepherds. The remains of several small fires as well as plastic cups and food wrappers were seen in this area.

5.2.1 Physiographic description

The wetland at Anelia is currently a bog with a fringing fen (Figure 5.3). The surface of the bog has a slope of 2-5° (inclinometer measurement) up to the south. On the slopes near the site are alternating ridges and ravines or hollows that are closely and relatively equally spaced, averaging 75-150 m between ridges. The bog is situated in a widening of a narrow valley of one of the ravines. There is a steep slope from the bog up to the Perivolion-Vovoussa road (average slope of about 28° (Savina 1990)). The bog has a shady N-NE aspect and is 90 m long (N/S) and 50 m wide (E/W), covering about 1/3 ha.

A small stream emerges from a spring on the valley floor about 50 m upstream from the bog (Figure 5.3). At the southern margin of the mire the stream bifurcates and runs along either side of the bog. The western branch continues only a short distance while the eastern branch runs the full length of the bog then drains across the track at the northern end of the bog. The bog drains into the eastern stream, which is entrenched. The bog is mainly supplied

Figure 5.1 Anelia bog, looking SSW. A very lush bog vegetation can be seen with *Cirsium* dominating the foreground on relatively dry ground at the edge of the bog, *Carex* is dominant on the wetter central part of the bog. The pure *Fagus sylvatica* woods in the background grow close to the edge of the bog.

Figure 5.2 Location of Anelia bog in relation to local topography (contour interval 100 m). Vegetation distribution is adapted from unpublished maps of the Greek Forest Service.

Figure 5.3 Anelia mire with location of exploratory borings and pollen core site.

with water from the spring, but the central part is slightly raised and is thus somewhat ombrogenous, relying partly on precipitation in the form of rain and snow. It is probably perennially waterlogged. We visited it at the end of summer, the driest season, and the water table was at the surface of the bog. Precipitation is higher at this elevation than at lower elevations – it rained several times when we were visiting the site, when no rain had fallen at lower elevations.

5.2.2 Regional and local vegetation

The bog is situated in the mountain beech vegetation zone and is almost completely surrounded by pure beech (*Fagus sylvatica*) wood with an almost completely closed canopy (Figures 5.1 & 5.2), described in Chapter 3 and Appendix VIII. Open beech wood, pine wood, and pine wood-pasture also occur in the vicinity, but a large proportion of the vegetation in the east, especially around the Aspropotamos catchment, is grassland and steppe, which is used by transhumant pastoralists for grazing sheep and goats (Figure 5.2).

The central bog is covered by a mixed vegetation of mosses and various sedges, grasses, herbs, and related vascular species (Figure 5.1). It is carpeted with the mosses *Acrocladium cuspidatum* and *Cratoneuron* sp., comprising together about 70% of the vegetation cover in the wetter areas of the bog and about 30% in the drier. In the drier areas of the bog *Carex* spp. are dominant (60% of the vegetation cover). This vegetation would form a mixed sedge and moss peat. The vegetation of the bog has been described in Appendix VIII.

Around the edge of the bog the influence of supplementary nutrients from surface and ground water and perhaps from grazing animals can be seen in the herb communities dominated by *Caltha palustris* (near spring drainage) and *Cirsium* (on fen).

Many ruderals grow on the dry land on the edge of the beech wood.

5.2.3 Geology of site

Bedrock is not exposed at or near the site, but is mapped as the Pindos ophiolite ultramafics, peridotites, and serpentinites (Institute for Geology and Subsurface Research 1959), the same as that at the Gomara site. About 300 m upslope of the site the bedrock type changes to Pindos flysch, which continues to the top of the saddle and ridge above the bog. The contact between these two bedrock units is a major thrust fault. An important feature of areas underlain by the Pindos ophiolite and flysch is the abundance of landslides observable on both the ground and on air photographs.

A geological survey of the area surrounding this site was undertaken by Dr M. Savina, geologist of the Grevena Project (Savina 1990). The following data are extracted from her report. The Anelia site is surrounded by landslide colluvium that appears to be part of a large

slump, about 5000-9000 years old, through which modern streams have eroded. Colluvium is exposed in ridges where erosion has removed the soil and vegetation. Most of the cobbles and pebbles in the colluvium near the site are ultramafic and some are dolerite. The maximum intermediate diameter of blocks in the colluvium is about 1.5 m.

Recent large-scale debris movement in the bog valley has not occurred, although there is evidence for some in the next valley. The most important current mass-movement erosional processes in the wood above the site are creep, tree throws, and small debris slides. Creep and tree throw are in most places responsible for relatively steady downslope movement. Some more rapid erosion probably also occurs in the form of small debris slides, but most material transported to the bog area probably moves down the valley by stream transport rather than directly by mass movement, although mass movement supplies the sediment to the stream.

Soil developed on landslide colluvium on the west side of the bog valley about 8 m above and 20 m distant from the bog was about 90 cm deep, well-drained with medium-sized stones covering about 1% of the surface. The dominant lithology in clasts was serpentinite. The pH values of the soil ranged between 5.2 and 5.7 and that of the parent material was 6.3. There was evidence of mantle creep.

5.3 Sediment analysis

The results of the exploratory borings of the mire, the Troels-Smith (1955) classification and laboratory analyses of the physical properties of the pollen analysed core sequence are reported below. In the diagrams and text, datum for depth (given in cm) is the bog surface.

5.3.1 Wetland profile

The location of the exploratory borings is shown in Figure 5.3. Main features of the stratigraphy of the exploratory cores are shown in Figure 5.4; detailed logs of the boreholes are in Appendix XIV. Exploratory cores were bored with a Hiller corer at 10 m intervals in two intersecting transects across the bog in N/S and E/W directions.

The bog consists of a thick upper horizon of up to 110 cm of fibrous peat, which is thickest in the centre of the bog. At core sites "k" and "j" at the southern end of the bog, the lower part of the peat is mixed with gravel, inwash from the stream feeding the bog, but to the north the peat is homogeneous. The peat layer is underlain by stratified clay, silt, sand, and fine gravel with peaty horizons. It is possible to trace some of these horizons through adjacent borings, but no extensive marker units were found.

The lower stratified unit is interpreted as a fan-like deposit of the stream resulting from a reduction in gradient below the steeper slope upstream. As transportation energy of the stream varied and the stream course changed location, so varied sediments were deposited

Figure 5.4 Longitudinal and transverse sections through Anelia bog, with generalised stratigraphy. Detailed logs of the exploratory cores are in Appendix XIV. The Troels-Smith profile of pollen-analysed monolith/piston core "o" is projected onto the lines. Vertical exaggeration 8x.

within the wetland. Eventually peat formation became general, with a permanently marginal stream.

After examination of these data it was decided that location 'o' was a suitable location for extracting a core for pollen analysis because it contained a near-maximum thickness of peat and minerogenic sediments. A central location also avoided gravel-rich sediments at the southern end of the bog, where the stream inlet is located.

5.3.2 Stratigraphy

An illustrated description of the deposits of the pollen-analysed core is given in Figure 5.5. The upper 110 cm were recovered by removing a monolith, and the lower sediments down to 240 cm were removed alternately with a Russian corer (110-150 and 162-200 cm) and a piston corer (140-180 and 195-244 cm) in alternate holes 50 cm apart. The lowest section (240-250 cm) was recovered with a soil auger. The Troels-Smith (1955) classification scheme using symbols and formulas (Appendix III) is followed in the same manner as in Chapter 4. Colours are all fresh colours.

The deposits of this site are more complex than those of the Gomara wetland. They comprise a series of peat (*Turfa herbacea*) horizons separated by minerogenic horizons of varying grain size, indicating varied transport energy and depositional environment; gravel, sand, silt, and clay all occur in varying proportions. The upper 94 cm comprises fairly uniform peat. (Since the whole sequence is water saturated, *siccitas* is 2 throughout.) No samples effervesced in 10% HCl, indicating the absence of calcium carbonate.

250-245 cm Basal sediments are composed of *Grana arenosa* (Ga) (mineral particles 0.06-0.6 mm), *G. glareosa majora* (Gg(maj)) (mineral particles 6.0-20.0 mm), and *G. glareosa minora* (Gg(min)) (mineral particles 2.0-6.0 mm). The smallest mineral particles comprise half the sediment composition while the two larger-sized particle classes comprise the remaining half in equal proportions. The broad distribution of the grain size indicates a stream flood deposit, and the inclusion of large grains indicates high energy transport. The sediments are dark olive grey (2.5GY 4/1). Physical properties are *nigror* 2, *stratificatio* 0, and *elasticitas* 0.

245-240 cm A sharp boundary (*limes* 3) at 245 cm marks a change to a homogeneous brownish black (7.5YR 2/2) *Turfa herbacea* (Th) (root systems, and stems and leaves connected to the roots of herbaceous plants). The plant structure is partly decayed though distinct, *humositas* is equivalent to 2, indicating that the bog surface was periodically dry. The darker colour of organic matter is reflected in *nigror* 3; *elasticitas* increases to 2. Other physical properties remain unchanged (*stratificatio* 0).

Figure 5.5 Troels-Smith classification of Anelia core sediments. Symbols are defined in Appendix III.

240-235 cm Another sharp boundary (*limes* 3) occurs at 240 cm, where the sediment colour is again the same as that of the basal horizon, dark olive grey (2.5GY 4/1) (*nigror* 2). Sediment composition is very similar to that of the basal horizon, but the proportions of the mineral components differ slightly, being equal proportions of *Grana glareosa majora* and *G. arenosa*; *Turfa herbacea* of *humositas* 2 occurs as a trace. *Stratificatio* is 0 and *elasticitas* 0.

235-222 cm The boundary at 235 cm is again sharp (*limes* 3) and signals a change to homogeneous brownish black (7.5YR 2/2) *Turfa herbacea*. This horizon is very similar to that at 245-240 cm. Again the darker colour of the deposit (*nigror* 3) reflects the organic content. *Stratificatio* does not change, while *elasticitas* changes to 3-4.

222-213 cm The boundary at 222 cm is not as sharp as those below (*limes* 2). This horizon differs from that below by the inclusion of *Grana arenosa*. The two components, *Turfa herbacea* and *Grana arenosa*, occur in equal proportions. The plant structure of the *Turfa herbacea* is well preserved, with a homogeneous ground substance; *humositas* is 1, indicating an increase in bog-surface wetness. The deposit colour becomes paler due to the addition of the mineral component, dark olive grey (2.5GY 4/1). *Stratificatio* is 2; it splits somewhat easily into very thin horizontal layers. It has no elasticity (*elasticitas* 0), and *nigror* is 2.

213-209 cm The boundary at 213 cm is sharp, *limes* 3. This narrow band comprises dark olive grey (2.5GY 4/1) *Grana arenosa*. Physical features include *nigror* 2, *stratificatio* 0, and *elasticitas* 0.

209-202 cm A change to finer-grained mineral sediment occurs at a sharp boundary (*limes* 3) at 209 cm. Sediment of *Argilla granosa* (Ag) (particles of clay 0.002-0.06 mm) indicates lower-energy transportation of sediment and deposition. The trace of *Turfa herbacea* of *humositas* 1 has well preserved plant structure, indicating a continually wet environment. Colour of the deposit and physical properties are unchanged.

202-199 cm This narrow horizon is demarcated with a sharp lower boundary (*limes* 3). Sediment grain size decreases to that of *Argilla steatodes* (As) (<0.002 mm), otherwise components and physical properties remain unchanged.

199-192 cm A less sharp boundary (*limes* 2) at 199 cm signals an increase in particle grain size to that of *Grana arenosa* and *G. glareosa*, which occur in equal proportions. Colour remains unchanged, but there is a slight tendency towards splitting into very thin horizontal layers (*stratificatio* 0-1). Other physical properties remain unchanged.

192-184 cm Another conspicuous boundary (*limes* 2) occurs at 192 cm, where the composition of the sediments changes to a mixture of *Argilla granosa* to *A. steatodes*, and

Grana glareosa minora in the proportions of 3:1. Colour and *elasticitas* are unchanged. *Stratificatio* is 0.

184-170 cm Between 184 and 170 cm is a series of interbedded layers of *Grana arenosa*, and mixtures of *Argilla granosa* to *A. steatodes*, *Grana arenosa*, and *G. glareosa*. The colour of all these horizons is dark olive grey (2.5GY 4/1). Physical properties are *stratificatio* 0 and *elasticitas* 0. The definition of the boundaries between these layers varies: at 184 cm a sharp boundary (*limes* 3) signals a change to a very narrow band of *Grana arenosa*; at 182 cm another sharp boundary (*limes* 3) marks a change to a horizon of *Argilla granosa* to *A. steatodes* and other mineral particles ranging from *Grana arenosa* to *G. glareosa minora* in the ratio of 3:1; at 178 cm the boundary is diffuse (*limes* 1) and the composition of the sediments changes to *Argilla granosa* to *A. steatodes* (3) and *Grana glareosa minora* (1); at 175 cm the boundary is sharp (*limes* 3) and the sediment comprises *Grana arenosa*; and at 172 cm the boundary is sharp (*limes* 3) and sediment comprises *Argilla steatodes*.

170-157 cm The boundary at 170 cm is diffuse (*limes* 1). Sediments of this thicker horizon are composed of *Grana glareosa majora*, and a mixture of *Grana arenosa* to *G. saburralia* (mineral particles from 0.6 to 2.0 mm) and *Argilla steatodes* to *A. granosa* in the proportions of 3:1. Other properties remain unchanged.

157-138 cm A diffuse boundary (*limes* 1) at 157 cm marks the base of another relatively thick horizon. Sediment comprises *Argilla steatodes* to *A. granosa* with a trace of *Turfa herbacea* of *humositas* 0-1. Other properties remain unchanged.

138-133 cm The boundary at 138 cm is diffuse (*limes* 1) as the deposit becomes increasingly organic. The deposit is characterised as *Argilla steatodes* to *A. granosa* and *Turfa herbacea* of *humositas* 0-1, in the proportions of 3:1. Other properties remain unchanged.

133-130 cm A conspicuous boundary at 133 cm marks the base of a narrow band of *Turfa herbacea* of *humositas* 0-1, and *Argilla steatodes* in the proportions of 3:1. *Grana glareosa minora* occurs as a trace. Colour becomes darker (brownish black, 10YR 3/2), and *nigror* increases to 3. Other physical properties remain unchanged.

130-126 cm A diffuse boundary at 130 cm marks a narrow less organic horizon of *Argilla steatodes* and *Turfa herbacea* (*humositas* 0-1) in the proportions of 3:1. Colour becomes paler again (dark yellowish grey, 2.5Y 5/2) and *nigror* reduces to 2. Other properties remain unchanged.

126-121 cm Another diffuse boundary (*limes* 1) marks another highly organic horizon of *Turfa herbacea* (*humositas* 0-1) and *Argilla steatodes* in the proportions of 3:1. Colour becomes darker (brownish black, 10YR 3/2) and *nigror* increases to 3. Other properties remain unchanged.

121-116 cm A diffuse boundary (*limes* 1) at 121 cm signals a change in the proportions of the component elements, which are now represented in equal proportions. Colour becomes paler due to the reduction in organic matter (dark yellowish grey, 2.5Y 5/2), and *nigror* reduces to 2. Other properties remain unchanged.

116-110 cm A sharp boundary (*limes* 3) occurs at 116 cm, and the deposit becomes much more minerogenic in composition, comprising *Grana glareosa majora* and *G. arenosa* in equal proportions with traces of *Argilla granosa* to *A. steatodes* and *Turfa herbacea* (*humositas* 0-1). Colour of the deposit is now grey (5Y 5/1). Other properties are unchanged.

110-102 cm A diffuse boundary (*limes* 1) at 110 cm marks a change to *Argilla steatodes* and *Grana glareosa*, which are represented in equal proportions. Other properties are the same as in the horizon below.

102-94 cm Another diffuse boundary (*limes* 1) at 102 cm marks a change to *Argilla steatodes*. The colour of the sediment changes to dark olive grey (2.5Y 4/3), but *nigror* is unchanged. *Elasticitas* increases, 0-1. *Stratificatio* (0) remains unchanged. This horizon contains fine roots from the overlying *Turfa herbacea*.

94-0 cm A very sharp boundary (*limes* 4) occurs at the contact between the *Argilla steatodes* of the horizon below and the *Turfa herbacea* of this very thick horizon. *Humositas* decreases upwards from 2 to 0, indicating increasing bog surface wetness (Blackford 1994). The peat is dark brown (7.5YR 3/3) and *nigror* is 3. *Elasticitas* increases from 3 at the base to 4 at the top of the horizon. *Stratificatio* (0) remains unchanged.

5.3.3 Physical properties

Organic matter, inorganic matter, moisture content, and dry density are plotted against depth and stratigraphy in Figure 5.6. The first three properties are expressed as a percentage of the original wet weight of the sample. The results suggest a division of the sequence into 6 sections (A-F), described below.

Section F, 250-245 cm The sediment in this section is rich in inorganic matter (50.7%) with a correspondingly high dry density of 1.03 g/cc. Organic matter is low (2.0%) and moisture content is low (47.4%).

Section E, 245-213 cm Inorganic matter declines greatly (1.1%) at the bottom of this section, but rises again at the top (53.9%). Dry density has corresponding low (0.07 g/cc) and high (0.90 g/cc) values. Organic matter is high throughout this section, reaching a maximum of 12.8%, which is almost as high as the highest value of the sequence, but is lower at the bottom and top (9.0 and 5.3% respectively). These high values of organic matter are indicative of peat formation. Moisture content is very high for most of the section, reaching a maximum of 89.9%, but declines to 40.8% at the top.

Figure 5.6 Anelia sediment physical properties: sediment type column (Troels-Smith classification 1955), organic matter, inorganic matter, moisture and bulk (dry) density. Sediment sections based on physical properties are indicated on the right.

Section D, 213-157 cm This section is characterised by the maxima of inorganic matter (61.0-88.0%) and dry density (1.08-1.61 g/cc) of the sequence. Organic matter is low (0.8-3.8%) but reaches 4.5% at 170 cm. Moisture content values are minima of the sequence (11.1-34.5%). The characteristics of this section indicate deposition of allochthonous mineral material.

Section C, 157-116 cm This section is characterised by intermediate values for all components. Organic matter ranges from 2.4-7.7%, inorganic matter ranges from 24.2-60.4%, moisture content ranges from 37.3-68.1%, and dry density ranges from 0.38-1.02 g/cc. Deposition of allochthonous mineral material steadily decreases while peat formation increases.

Section B, 116-94 cm Inorganic matter (61.0-65.6%) and dry density (1.10-1.20 g/cc) increase in these three samples, while organic matter (2.3-3.0%) and moisture content decrease (32.1-36.5%). The sediments of this section represent an influx of allochthonous mineral material.

Section A, 94-0 cm This section is characterised by high organic-matter values and very high moisture content. Organic matter has consistently high values (with the exception of the surface sample, 1.8%) of 7.3-11.4%, reaching maxima of 15.2 and 14.1% at 20 and 10 cm respectively. Moisture content always exceeds 84.8%, and the surface sample is almost entirely water (97.6%). Inorganic matter declines to zero in three samples, while the maximum value reached is only 3.8%. Dry-density values are very low throughout this section, never exceeding 0.15 g/cc. Initially deposition of allochthonous mineral matter declines sharply, then continues to decline until it ceases and deposition in the wetland is composed entirely of *in situ* peat formation.

5.4 Chronostratigraphy

5.4.1 Radiocarbon dating

An attempt was made to establish a chronology of the Anelia sequence based on radiocarbon ages of organic matter contained within the sediments. Intervals of the core containing considerable amounts of peat were selected to provide a higher percentage of carbon per sample, thus providing more precise radiocarbon ages, and also avoiding contamination of older soil carbon from alluvial inwash (Tolonen 1980). Therefore dated samples are not evenly spaced.

Radiocarbon dating results are tabulated in Table 5.1. Conventional radiocarbon ages are shown with an analytical error of one standard deviation. These ages have been calibrated by tree-rings (Appendix IV).

Table 5.1

Radiocarbon dating results – Anelia

Sample depth (cm)	Laboratory number	Pretreatment	Fraction dated	$\delta^{13}\text{C}$ ‰ wrt PDB	% modern	Radiocarbon age (years BP $\pm 1\sigma$)	Calibrated age(s) (years AD/BC)
81-83	Wk 1812	None	Entire sediment	-27.6	99.0 $\pm$ 0.6	Modern	
124-125	NZA 3480	Hot acid/alkali/acid	Plant material	-25.15	96.21 $\pm$ 0.73	268 $\pm$ 61	1651 AD
240-245	Wk 1813	None	Entire sediment	-28.2	95.7 $\pm$ 0.7	360 $\pm$ 96	1511, 1600, 1616 AD

Radiocarbon dating laboratory reference numbers:

NZA = Rafter radiocarbon laboratory, Nuclear Sciences Group, Institute of Geological & Nuclear sciences, Lower Hutt.

Wk = Waikato radiocarbon dating laboratory, University of Waikato, Hamilton.

$\delta^{13}\text{C}$ represents the measured difference, in parts per thousand, between the ratio of carbon-13 to carbon-12 in the sample to the ratio for the chosen standard (PDB carbonate). It is useful as a check on natural fractionation and on fractionation during sample preparation (Aitken 1990).

Percent modern means absolute percent modern relative to the NBS I oxalic acid standard.

Radiocarbon Age BP is the conventional radiocarbon age before 'present' (years BP), based on the half-life of 5568 years, as defined by Stuiver & Polach (1977), the present being 1950 AD.

The radiocarbon age error margin reported by the University of Waikato included only counting statistics errors, so a laboratory error multiplier of 1.6 was used to increase the standard deviation for samples dated in that laboratory.

The computerized calibration program of Stuiver & Reimer (1993), CALIB 3.0.3c (revised version 1995) available on the Internet at the University of Washington ftp site, was used (Appendix IV).

Initially, the basal and the uppermost samples were dated in the University of Waikato radiocarbon dating laboratory with the liquid scintillation counting method. Dated samples received no pretreatment. On receipt of the results of these samples the intermediate sample was submitted to the Rafter laboratory, Institute of Geological and Nuclear Sciences, for direct dating using accelerator mass spectrometry. Recognizable plant remains were removed for dating and given a pretreatment of alternating washes of hot acid, alkali, and acid. The radiocarbon ages of this sample are concordant with those of the first pair of samples dated and the ratio of carbon-13 to carbon-12 ($\delta^{13}\text{C}$) of all samples dated is consistent with average values for that of wood, charcoal, and peat (and the standard value used in radiocarbon age determinations) (Olsson 1986:286; Aitken 1990:63), thus the possibility of laboratory error or contamination, e.g. contamination within the measurement system or during sample preparation is minimal. Furthermore, these samples were collected in the same way as those of the Gomara site, which are considered to accurately reflect the age of the sediments of that sequence.

Despite these precautions, radiocarbon ages obtained for this wetland sequence are problematic. At 68% confidence level the basal and intermediate ages are not statistically different (Aitken 1990); nor are the intermediate and uppermost ages. Furthermore, the uppermost age could represent any calendar date in the last 250 years. Also at 68% level of confidence, the intermediate calibrated calendar date at 125-124 cm has four separate age ranges, the older two overlapping the calibrated calendar age range of the lowest dated sediments.

5.4.2 Age/depth plot

Mean sediment-accumulation rates were calculated in a manner similar to that of Chapter 4, that is, by linearly interpolating between contiguous calibrated dates (Figure 5.7).

Accumulation rates of clastic sediment can vary greatly depending upon type of material deposited and deposition regime. The clastic sediments of the lower part of the sequence indicate rapid episodic deposition, such as 'instantaneous' flood deposits separated by only partially decomposed peat. This suggests a relatively rapid accumulation rate, and therefore the high rate of 1.35 cm/year is considered possible.

Based on the radiocarbon chronology, the uppermost 94 cm of peat accumulated at about 0.37 cm/year. The peat decreases in decomposition from moderate to weak towards the surface, indicating relatively rapid accumulation due to the coarseness of incompletely decomposed peat and high moisture content. Also there is a tendency towards higher accumulation rates for younger peat layers due to lessening autocompaction (Aaby 1986). Berglund (1986b:119) has indicated that peat growth in Scandinavian bogs typically ranges

Figure 5.7 Age-depth plot. Calibrated radiocarbon ages (Table 5.1, Appendix IV) plotted against depth of sediment from Anelia. Length of cross-arms indicates uncertainty ($\pm 1\sigma$) of age measurement (horizontal) and thickness of dated sediment (vertical). Most probable dates are indicated by crosses: the calibrated calendar date at 124.5 cm depth has been joined to the median of the calibrated dates at 242.5 cm, and the corresponding sediment accumulation rate is shown. A rate has also been calculated for the upper part of the section.

between 0.02 and 0.10 cm/year, but Webb & Webb (1988) indicated a wide range from 0.008 to 0.408 cm/year in deposition rate of organic sediments (detritus and peat) in mid-latitude North America; the Anelia site is in the upper part of this range.

A check on the duration of deposition of the Anelia sequence can be made with pollen-concentration figures. Influx rates have been calculated for the Gomara sequence (Chapter 4). Although the sediment types at Gomara differ from Anelia, the catchment size and terrestrial vegetation represented are in many ways similar, being a mosaic of beech, pine, and pasture. Applying the Gomara mean terrestrial pollen influx rate of 14748 grains/cm²/year to the Anelia sequence, the mean Anelia terrestrial pollen concentration of 19625 grains/cm³ represents a deposition rate of 0.75 cm/year (or 1.33 yr/cm). This leads to a duration of deposition of 330 years for the 250 cm sequence, in good agreement with the basal radiocarbon date.

A general chronology for the site based on radiocarbon dates is therefore accepted. Because of calibration uncertainties and the likelihood that the course of the interpolated age/depth function in the lower part of the sequence is complicated by irregular sedimentation, pollen influx rates have not been calculated. The timescale derived for this sequence should be regarded as tentative.

5.5 Pollen analysis results

5.5.1 Introduction

Relative frequency as well as concentration data are used to interpret the vegetation history of the Anelia area. Concentration data are not converted to influx rates because of the uncertainty of the reliability of the reported radiocarbon ages and erratic deposition of deposits. Only the exotic marker grain (tracer) method of calculating palynomorph concentrations was used for this sequence. Separate diagrams are drawn for local (wetland) taxa, extra-local and regional (terrestrial) taxa, and microscopic charcoal. Data used to calculate pollen and spore concentrations, all pollen and spore types counted, and charcoal abundances are tabulated in Appendix XIII.

5.5.1.1 Pollen preservation/pollen abundance

Palynomorph preservation is variable and closely related to lithology. The principal modes of deterioration of grains are breakage and degradation (thinning of exine) (Delcourt & Delcourt 1980). There is a clear correlation between those spectra with the highest proportion of degraded and broken grains, and mineral sediments of larger particle size, that is, spectra at 160-210 cm. Grains from peat are usually better preserved than those from the mineral sediments except where the surface of the peat has been intermittently dry, then

oxidation of the exine occurs. Some palynomorphs from the humified peat have suffered from oxidation. Indeterminate grains are usually less than 3% and this is exceeded in only four spectra. These are from the lower (more humified) part of the upper horizon of peat – 40 to 90 cm. Unknown grains are rare, reaching 0.2% in only two spectra.

Concentration of total terrestrial pollen and spores fluctuates, but in general is highest in the lower part of the sequence (below 115 cm), being usually more than 15×10^3 grains/cm³ (Figure 5.12). There is no constant correlation between dry density of the sediments and terrestrial pollen and spore concentrations. Maximum concentrations are at 245-215 cm ($23-52 \times 10^3$ grains/cm³) and 155-115 cm ($15-37 \times 10^3$ grains/cm³) where sediments comprise mostly moderately humified peat and moderately-weakly humified peat mixed with fine grained sediment. Minimum concentrations occur at 210 cm in sand (7×10^3 grains/cm³), 190 cm in gravelly mud (8×10^3 grains/cm³), 165-160 cm in muddy sandy gravel (4×10^3 grains/cm³), 110 cm in muddy sandy gravel (9×10^3 grains/cm³), 50-20 cm in moderately-weakly humified peat ($7-10 \times 10^3$ grains/cm³), and at the surface in unhumified peat (5×10^3 grains/cm³).

There is an inverse correlation between dry density of sediment and wetland (local) pollen concentration; where values of dry density are lower, pollen concentration is higher. Concentration of wetland pollen and spores ranges from $1-20 \times 10^3$ grains/cm³, being highest in spectra from moderately humified peat and moderately-weakly humified peat mixed with fine grained sediment (225-215, 155-115 and 90-70 cm, where concentrations usually range from $7-20 \times 10^3$ grains/cm³) and, in general, lowest in minerogenic deposits of sand, muddy sandy gravel, and clay (Figure 5.9). Lowest concentrations are recorded in the basal sample, at 210, 165, 160, and 100 cm, and the surface sample where concentrations range from $1-2 \times 10^3$ grains/cm³.

5.5.2 Wetland pollen analysis

5.5.2.1 Pollen diagram construction

Pollen and spore relative frequencies are presented graphically in Figure 5.8 and concentration data in Figure 5.9. Style of the diagrams is as for Gomara site (Chapter 4). Pollen and spore types are arranged according to the degree of wetness of habitat of plant communities from which they derive. Habitat groups are the same as those in Chapter 4. Within these groups, types are arranged in order of appearance. The pollen sum on which the relative frequencies are based includes all wetland pollen and spore taxa. Relative frequencies of 0.2% or less are indicated with a dot.

A summary diagram is shown on the right of the relative frequency diagram showing the ratio of emergent types to aquatic types. A curve of palynological richness (rarefaction

Figure 5.8

analysis) follows (Birks & Line 1992; Bennett 1994); rarefaction analysis is based on the smallest total count of the wetland pollen and spores, 29 at the surface of the bog. The number of wetland types (not normalized for unequal pollen sums) in each spectra is shown next. Lastly, the total of all wetland pollen and spores counted is given.

Many weeds and ruderals were observed growing on the drier areas of the bog and on the marginal fen. These species are included in the *Cirsium* type, *Dactylis* type, *Dianthus* type, *Helleborus*, *Plantago lanceolata* type, *Pteridium aquilinum*, *Scrophularia* type, *Scutellaria* type, *Trifolium repens* type, *Urtica dioica*, *U. pilulifera* type, and *U. urens* type. These pollen and spore types have been included in the terrestrial pollen diagram as they are typically terrestrial in habitat. They are all included in the habitat group of 'herbs of open ground' with the exception of *Helleborus*, a genus typically of woodland herbs.

5.5.2.2 Pollen record of wetland plant communities

The wetland plant communities are represented by a few dominant pollen and spore types. *Carex hallerana* type is dominant throughout the sequence, with the exception of the spectrum at 60 cm where *Phragmites australis* is dominant. A maximum of only 18 pollen and spore types were identified in any spectrum; average is 10. Estimates of palynological richness by rarefaction analysis range from 2-11 expected types.

Emergent communities The wetland pollen and spore sequence is dominated by types that derive from emergent plant communities. Pollen and spore types belonging to the 'wet soil' habitat group are most numerous; *Carex hallerana* type being the dominant type. *Phragmites australis* and *Glyceria* type of the 'true-reed swamp' group also play a prominent role.

See Chapter 4 for a discussion of the classification of wetland types into the ecological groups. Those types not included in the wetland pollen diagram of Chapter 4, or that require further elucidation are discussed below.

Salix fragilis type includes many species; they belong to the order of Salicetalia purpureae, the willow communities of lowland flood plains (Ellenberg 1988). Only *Lysimachia vulgaris* of the five species included in the pollen type *Lysimachia* is mentioned by Ellenberg (1988), who places it in the order Molinietalia, but the other species in this type grow in similar habitats of damp ground (Polunin 1988). *Parnassia palustris* belongs to the vegetation class Scheuchzerio-Caricetea nigrae (fuscae), a small-sedge vegetation of intermediate mire and swamp swards. The type *Equisetum* includes a number of species that grow in a variety of habitats from wet meadows, stream banks, flood plains to reed swamps (Ellenberg 1988).

Iris spuria type includes *Iris spuria*, and several other species that may belong to this pollen type (*Iris reichenbachii*, *I. sintenisii*, *I. suaveolens*). These species are not classified in Ellenberg (1988). *Iris spuria* grows in wet places, but the other species grow in dry habitats (Polunin 1988). *Narthecium scardicum* and *Linum catharticum* are also not classified by Ellenberg (1988), but they are known to grow in marshy places in the Pindos Mountains (Strid 1989; Strid & Tan 1991).

Iris pseudacorus belongs to the tall-sedge-swamp community of the order Phragmitetalia. *Oenanthe aquatica* group also belongs to the order Phragmitetalia, but to the community of the true-reed swamp. The species included in the *Oenanthe pimpinelloides* group (*Oenanthe pimpinelloides* and possibly *Oenanthe tenuifolia*) are not classified by Ellenberg (1988). The habitat of *Oenanthe pimpinelloides* is not known, but *O. tenuifolia* grows in marshes.

Aquatic communities Pollen and spores of aquatic types occur sporadically throughout the sequence. Floating-leaved communities are better represented than submerged communities. Floating-leaved communities often grow in pools of water on bog surfaces.

Eight types that include species of floating-leaved communities are represented. Three of these, *Hydrocharis morsus-ranae*, *Stratiotes aloides*, and *Salvinia natans* belong to Ellenberg's (1988) Lemnetalia order of floating communities of waters more or less rich in nutrients. *Nuphar lutea* and most of the species of the *Ranunculus aquatilis* group belong to the order Potamogetonalia of rooted water plant communities, while *Sparganium angustifolium* belongs to the shore hairgrass shallow-water swards and related communities, order Littorelletalia (Ellenberg 1988). *Vallisneria spiralis* and *Damasonium alisma* are not classified by Ellenberg (1988). The former grows submerged in still nutrient-rich water, but its flowers float to the surface when open and pollination occurs at the water surface (Willis 1951; Haslam *et al.* 1975; Polunin 1988). The latter grow in still shallow water usually as a floating plant, but sometimes as a submerged plant (Haslam *et al.* 1975; Polunin 1988).

Pollen types representing the submerged macrophyte group are: *Hydrocotyle vulgaris*, *Myriophyllum spicatum*, and *Potamogeton crispus* type. Representation of submerged macrophytes is low and only *Myriophyllum spicatum* is exclusively submerged (Ellenberg 1988).

5.5.2.3 Wetland (local) pollen assemblage zones

Wetland pollen diagrams are divided into 9 local pollen assemblage zones AW-1 to AW-9, based mostly on relative frequency data. These are defined below.

Zone AW-9, 250.0-227.5 cm This basal zone is characterised by high relative frequencies of *Carex hallerana* type (49.3-61.3%), *Phragmites australis* (7.1-17.3%), *Cyperus*

melichianus (7.1-12.0%, except the top spectrum at 2.5%), and *Glyceria* type (6.7-16.1%). The only other emergent type that occurs continuously is *Cyperus longus* type (2.4% maximum). *Sparganium erectum* occurs in all spectra except the basal (2.7% maxima). *Caltha* type occurs at 235 cm only, at 5.3%. No other emergent type exceeds 1.8%.

Aquatic types occur in all spectra and total relative frequency reaches 7.2% in the basal spectrum, which is the highest for the sequence. All aquatic types occur sporadically. Highest frequency of an aquatic type is that of *Hydrocharis morsus-ranae*, which reaches 3.6% in the basal spectrum. *Hydrocotyle vulgaris* occurs sporadically and reaches a maximum of 3.1% at 230 cm. Several other aquatic types occur at more than 1.0%: *Myriophyllum spicatum* (1.3% at 235 cm); *Salvinia natans* (1.2, 1.3 and 1.8%); and *Stratiotes aloides* (0.8 and 1.8%).

Zone AW-8, 227.5-212.5 cm The boundary with the preceding zone is marked by an increase in the relative frequency of *Carex hallerana* type, the disappearance of *Cyperus melichianus* and *Sparganium erectum*, and a decline in *Phragmites australis*. *Carex hallerana* type is the dominant type, at around 80%. *Glyceria* type is important (9.1-13.3%). *Phragmites australis* declines to 2.6%, then increases steadily to 5.0%. No other emergent type exceeds 1.0%.

Aquatic types occur in all spectra; maximum total frequency is only 1.1% at 225 cm. No individual type exceeds 0.7%.

Zone AW-7, 212.5-157.0 cm The boundary with the preceding zone is marked by a dramatic increase in the relative frequency of *Glyceria* type and a decline in *Carex hallerana* type. This zone is characterised by alternately fluctuating relative frequencies of *Carex hallerana* type and *Glyceria* type. Frequencies of *Carex hallerana* type are generally high (56.1-88.0%, except the basal spectrum of 33.3%). *Glyceria* type fluctuates between 6.3 and 50.0%. *Phragmites australis* occurs continuously at 0.8-6.1%. *Carex flacca* occurs sporadically, but reaches a maximum of 10.7% at 175 cm. *Cyperus melichianus* also occurs sporadically, recording significant relative frequencies (maximum 12.6% at 175 cm). *Cyperus longus* type and *Saxifraga stellaris* also occur sporadically and reach a maxima of 2.1% at 210 cm. *Mentha* type occurs sporadically (maximum 4.2% at 210 cm). No other emergent type exceeds 1.6%.

Aquatic types occur in only 8 of the 11 spectra; total frequency does not exceed 2.4%. Only *Hydrocotyle vulgaris* and *Salvinia natans* exceed 0.5%, reaching 2.1% at 210 cm and 1.6% at 180 cm, respectively.

Zone AW-6, 157.0-117.5 cm The boundary with the preceding zone is indistinct, but marked by an increase in the relative frequency of *Cyperus longus* type. The zone is characterised by an increase in *Carex hallerana* type (mostly more than 83.0%) and *Cyperus longus* (mostly more than 1.5%, with maximum of 4.7%). *Phragmites australis* increases

slightly (1.0-9.0%, but usually more than 3.0%). *Glyceria* type fluctuates, but declines (24.8% in the bottom spectrum and 3.3% in the top). *Cyperus michelianus* occurs sporadically at less than 0.5%, except at 150 cm where 13.8% is recorded. *Mentha* type also occurs sporadically at low relative frequencies with the exception of 6.0% at 140 cm. No other emergent type exceeds 1.5%.

Aquatic types occur in 5 of the 8 spectra; total frequency does not exceed 2.9%. Only two types exceed 0.5%: *Hydrocotyle vulgaris* reaches 1.5% at 140 cm and *Nuphar lutea* reaches 2.5% at 125 cm.

Zone AW-5, 117.5-95.0 cm This is a narrower zone comprising only three spectra. The interval between the two upper spectra has been increased from 5 to 10 cm. The boundary with the preceding zone is marked by a decline of *Carex hallerana* type and *Cyperus longus* type, and an increase in *Phragmites australis* and *Glyceria* type. *Carex hallerana* type continues to be the dominant type (88.6-46.0%). The distinct character of this zone is more apparent in the concentration diagram due to a dramatic decline in the concentration of *Carex hallerana* type. In the uppermost spectrum where concentration and relative frequency of *Carex hallerana* type is most reduced *Glyceria* type increases greatly (38.0%). The frequency of *Phragmites australis* is also low where *Glyceria* type increases, but in the concentration diagram both follow similar curves with lower concentration values in the upper two spectra.

Other characteristics of this zone are the almost complete disappearance of *Cyperus longus* type (maximum 0.8%) and of *Cyperus michelianus*, which occurs in only one spectrum at only 0.4%. *Caltha* type becomes more prominent, recording 2.8 and 1.4% in two spectra. No other emergent type exceeds 2.0%.

Aquatic types occur in all spectra; total frequencies are 0.4, 2.0, and 4.0%. Only two types exceed 0.4%: *Stratiotes aloides* reaches 1.4% at 110 cm and *Hydrocotyle vulgaris* reaches 4.0% at 100 cm.

Zone AW-4, 95.0-65.0 cm The boundary with the preceding zone is marked by an increase of *Carex hallerana* type, a slight decline in *Phragmites australis* and a more pronounced decline in *Glyceria* type.

This zone is characterised by relative frequencies of *Carex hallerana* type that are generally higher and fluctuate less than those in the zone below (72.9-86.0%), and lower relative frequencies of *Phragmites australis* (1.3-1.7%) and *Glyceria* type (6.6-7.0%). *Equisetum* occurs in the centre of the zone at 80 cm where it reaches 17.4%. *Cyperus michelianus* occurs in the uppermost spectrum only, at 3.1%. No other emergent type exceeds 1.3%.

Aquatic types occur in all spectra; total frequencies are only 1.1, 0.2, and 2.0%. No individual type exceeds 0.7%.

Zone AW-3, 65.0-45.0 cm Only two spectra comprise this narrow zone. The boundary with the preceding zone is marked by a sharp decline in *Carex hallerana* type and a very dramatic increase of *Phragmites australis*. The zone is characterised by low relative frequencies of *Carex hallerana* type (26.9 and 62.7%), very low relative frequencies of *Cyperus michelianus* (0.6 and 0.3%), and high frequencies of *Phragmites australis* (58.4 and 27.3%). *Glyceria* type remains almost unchanged at 6.1 and 5.8%. *Caltha* type has a continuous curve, but records only 1.2 and 1.6%. No other emergent type exceeds 1.1%.

Aquatic types occur in both spectra; total frequencies of the spectra are only 0.9 and 2.1%. One individual type exceeds 0.3%; *Hydrocotyle vulgaris* reaches 1.9% at 60 cm.

Zone AW-2, 45.0-5.0 cm Four spectra comprise this zone. The boundary with the preceding zone is marked by an increase of *Carex hallerana* type, a slight increase of *Cyperus longus*, and a decrease of *Phragmites australis* and *Glyceria* type. This zone is characterised by high relative frequencies of *Carex hallerana* type (76.3-93.9%), increased frequencies of *Cyperus longus* (1.6-2.5%, except in the uppermost spectrum where it disappears), declining frequencies of *Phragmites australis* (1.4-7.3%), and low frequencies of *Glyceria* type (1.4-3.0%). *Caltha* type persists at 1.1-1.6%, until it disappears in the uppermost spectrum. *Cyperus michelianus* declines from 4.3% in the basal spectrum to zero in the uppermost. No other emergent type exceeds 1.9%.

Aquatic types occur in all spectra; total frequencies are 1.4, 1.1, 0.2, and 1.0%. No individual type exceeds 0.7%.

Zone AW-1, 5.0-0 cm Only one spectrum comprises this narrow zone. The boundary with the preceding zone is marked by a sharp decline in the relative frequency of *Carex hallerana* type (17.2%); the appearance of *Parnassia palustris* (17.2%); an increase in the relative frequencies of *Mentha* type (10.3%), *Cyperus michelianus* (20.7%), *Carex flacca* type (6.9%), and *Phragmites australis* (10.3%); and an increase in the relative frequencies of the aquatics *Hydrocharis morsus-ranae* (3.4%) and *Damasonium alisma* (3.4%). The emergents *Angelica sylvestris* (3.4%), *Caltha* type (3.4%), and *Glyceria* type (3.4%) are also recorded in this spectrum. No other emergent or aquatic types are recorded.

5.5.2.4 Sedimentary and local vegetation history

Stratigraphic data indicate that the wetland formed in a hollow of a ravine, a typical landscape feature of this area. Broadening of the ravine and reduction in stream gradient caused reduction in velocity of spring-stream water flow, and deposition of sediments and formation of peat. The landform may owe its origin to tectonic movements associated with the fault upslope (Section 5.2.3).

The wetland consists of a thick upper horizon of up to 110 cm of fibrous peat, which is thickest in the centre of the wetland. At the southern end, the lower part of the peat is mixed with gravel, inwash from the stream feeding the wetland, but to the north the peat is homogeneous. The peat layer is underlain by stratified clay, silt, sand, and fine gravel with peaty horizons, the oldest sediments recovered being dated at c. 1560 AD. This lower stratified unit is interpreted as a combination of fan-like deposits of the stream, stream-bed deposits, and the formation of peat on waterlogged deposits; as transport energy of the stream varied and the stream channel(s) location changed, so varied sediments were deposited across the wetland, with mire vegetation establishing itself on the stream margins. After c. 1750 AD peat formation became general, with a permanently marginal stream channel.

In the pollen analysed core, deposits above 94 cm comprise homogeneous peat, while those below 94 cm are very heterogeneous and comprise inorganic sediments that alternate or are mixed into peat horizons. These deposits represent periods of run-off and erosion of the valley catchment above the wetland site manifest by minerogenic sediments, and periods of greater landscape stability manifest by organic deposits when peat formation occurred on the wetland. Sediments of sand and gravel indicating high energy sediment transportation occur at 250-245, 240-235, 222-209, 199-157, 133-130, and 116-102 cm. Peat formation occurs at 245-213 (between 240-235 muddy, sandy gravel is washed in and from 222 cm sand is washed in), 209-199 (trace of peat with fine grained sediments), 157-110 (varying proportions of peat and minerogenic sediments), and 94-0 cm. Accumulation of these deposits was erratic and many of the boundaries between deposits of differing composition are conspicuous indicating rapid changes in deposition processes, and perhaps erosion of wetland deposits.

There is very little apparent variation in the local wetland vegetation. It is dominated throughout the sequence by sedges of the *Carex hallerana* type of the 'wet soil' habitat group, which are probably indicative of a small-sedge-swamp community, although they may also represent dry habitats such as open woodland (Appendix X). The reeds of the types *Phragmites australis* and *Glyceria* type are also prominent. Communities of floating-leaved and submerged macrophytes are poorly represented and probably derive from a few plants growing in small pools on the wetland. The influence of minerals supplied by water from a soft-water spring, which maintained a high level of available nutrients, is evident throughout the sequence. Additional nutrient supply from anthropogenic activities (e.g. manure from grazing) is therefore difficult to detect. Where peat formation occurred surface peat was either continuously wet or only intermittently dry (probably only during the driest part of summer).

The sedimentary history of the wetland area is closely linked to the local wetland vegetation history, thus major sedimentary units defined above usually coincide with the

established wetland pollen zones. These zones are used, for convenience, in the discussion below.

Zone AW-9, 250.0-227.5 cm, c. 1560-1575 AD The dominant plant community is the wet-soil community that includes moist meadow, stream bank, and dwarf plant communities that are inundated in winter but dry out in summer. A bog community resembling that of today is indicated by the dominance of the *Carex hallerana* type and the occurrence of *Mentha* type and *Ranunculus acris* group, which grow on the wetter areas of the bog today as well as on the marginal fen. A true-reed swamp community has also developed. Both floating-leaved and submerged communities of open water are represented by a few pollen and spore types.

This zone comprises two minerogenic sediment horizons with an interbedded peat horizon, and the lower part of an overlying peat horizon. The lowest horizon (250-245 cm) comprises muddy sandy gravel indicating high energy sediment transportation (stream flood) and accelerated erosion in the catchment, and corresponds to sediment section F, which is characterised by low organic and moisture content and high inorganic content. Ponding of water is suggested by the occurrence of spores and pollen of the floating-leaved aquatic macrophytes *Salvinia natans*, *Stratiotes aloides*, and *Hydrocharis morsus-ranae*, and the submerged macrophyte *Hydrocotyle vulgaris* in the basal spectrum. These macrophytes usually grow in shallow ponds; *Hydrocotyle vulgaris* may also be emergent (Ellenberg 1988). Total wetland pollen and spore concentration is very low (2×10^3 grains/cm³) and palynomorphs may be partly derived from the overlying peat.

The next horizon (245-240 cm) is included in sediment section E. It comprises peat with very high organic and moisture content and very low inorganic matter indicating a period of landscape stability and waterlogging of the cored area. The level of humicity of the peat indicates that there was intermittent drying of surface peat, probably seasonally during summer (Blackford 1994). Total wetland pollen and spore concentration increases (5×10^3 grains/cm³), but is low by comparison with other peat horizons in this sequence. This may be because the local wetland vegetation covers a small area and is in a formative stage, or due to rapid deposition. The presence of the annual *Cyperus michelianus* and the early hydrosere *Sparganium erectum* is supporting evidence for a colonizing vegetation (Ellenberg 1988), and the species represented by the pollen type *Cyperus longus* type may be the colonizer *Eriophorum angustifolium* (Ellenberg 1988). High palynological richness (6 expected types) is supporting evidence for a colonizing community.

The overlying sediment horizon (240-235 cm) is very similar to that of the basal sandy gravel horizon, but it contains a trace of peat also. No analyses of the physical properties of this horizon were undertaken, but the Troels-Smith classification of the sediment suggests that this was another period of high energy sediment transportation (stream flood) and accelerated

erosion in the catchment. Eroded sediments inundated the peat forming vegetation but did not halt peat formation entirely. The overlying peat horizon (235.0-227.5 cm) is similar to that below and again indicates a period of landscape stability in the catchment and waterlogging of the cored area. Humicity level of the peat is the same as that for the lower peat horizon, indicating seasonal drying of surface peat. Total concentration of pollen and spores increases again and may indicate an expanding wetland vegetation (6×10^3 grains/cm³).

Throughout the zone *Carex hallerana* type, *Cyperus michelianus*, *Phragmites australis*, and *Glyceria* type are the most abundant types (no sample from the upper gravel and sand horizon was pollen analysed) and plants represented by these types and mosses, as suggested by the presence of *Caltha* type pollen (Ellenberg 1988), probably formed the peat. The dominant type is *Carex hallerana* type that includes the species *Carex hallerana*, which grows in dry places, *Scirpus holoschoenus* and *S. sylvaticus*, which grow in damp, usually shady places, and probably other *Carex* and *Scirpus* species, and *Blasmus compressus*, which grow in a variety of habitats from marshes and other damp places to woods and dry grassland (Tutin *et al.* 1964-80). Pollen of this type may thus derive from a variety of habitats such as the local wetland, or more distant woodlands or grasslands (Chapter 3). Since *Carex* forms 60% of the vegetation cover in the drier areas of the bog today, it is highly likely that plants of this genus grew on the wetland in the past.

The level of available nutrients is high as indicated by the presence of *Glyceria* type, *Oenanthe aquatica* group, *Sparganium erectum*, *Salvinia natans*, *Stratiotes aloides*, *Hydrocharis morsus-ranae*, and *Myriophyllum spicatum* (Ellenberg 1988). Nutrients may be contributed to the wetland via washed in sediment, spring water or from direct or indirect human activity. *Caltha palustris*, which often grows in soft-water spring fed mires (Ellenberg 1988), occurs in this zone. Today *Caltha palustris*, which is included in the *Caltha* type, is the dominant plant (about 90%) growing in the area around the spring-fed stream inlet (Chapter 3). Rapid establishment of a wetland community would be assisted by the high level of available nutrients (Ellenberg 1988), and perhaps some of the plants represented, e.g. species belonging to the *Ranunculus acris* group, had been already growing on the stream bank before waterlogging and peat formation occurred.

Zone AW-8, 227.5-212.5 cm, c. 1575-1585 AD This zone corresponds to the upper part of the peat horizon of the zone below and an overlying horizon of sandy peat, and to the upper part of sediment section E. The lower part of this zone, composed entirely of peat, has high organic and moisture content and very low inorganic matter content. Towards the top of the zone organic matter and moisture content decline and inorganic matter increases. These changes occur as increasing amounts of sand are washed onto the peat forming vegetation.

The communities of wet-soil habitats continue to be the dominant wetland communities. The true-reed swamp is still represented in about the same proportions but a shift in dominance from *Phragmites australis* to *Glyceria* type has occurred, perhaps as a response to increased nutrients. The floating-leaved and submerged aquatic communities are much reduced.

Humicity of peat decreases as sand is washed onto the peat forming vegetation, indicating increasing wetness of the peat surface. Aquatic plants decline, perhaps due to a constant flow of water close to the core site and former pools on the peat surface being filled in with sediment.

Total concentration of wetland pollen and spores representing emergent plants increases greatly, reaching a maximum of 13×10^3 grains/cm³ at 220 cm, (but declines slightly at the top of the zone) indicating expanded and well developed sedge and reed communities. The disappearance of the annual *Cyperus michelianus* and the early hydrosere *Sparganium erectum* is supporting evidence for a well developed reed community. Low palynological richness (4 expected types) is also indicative of the monospecific stands that well developed reed-swamp communities of *Glyceria* and *Phragmites australis* can form. The dominant type is *Carex hallerana* type with *Phragmites australis* and *Glyceria* type also prominent; *Glyceria* type is now the more abundant of the latter two. The appearance of *Saxifraga stellaris* suggests that mosses are still part of the peat forming vegetation (Ellenberg 1988) in combination with sedges and reeds.

The available nutrient level is still high, as indicated by the presence of *Glyceria* and *Salvinia natans*. The presence of *Saxifraga stellaris* suggests that at least some of the nutrients derive from spring water (Ellenberg 1988).

Zone AW-7, 212.5-157.0 cm, c. 1585-1625 AD This zone corresponds to the sediment section D, which is characterised by low organic and moisture content and high inorganic content. Seven different sediment horizons have been identified. With the exception of two horizons at 209-202 and 202-199 cm where a trace of peat occurs all deposits are composed of sediment of varying grain size representing transportation and deposition of sediment into the wetland at varying levels of energy.

Again the plant communities of wet-soil habitats are the dominant wetland communities. A tall-sedge community has developed and the true-reed-swamp community has expanded, dominated by *Glyceria* type. The communities of open water have not changed significantly. *Hydrocotyle vulgaris* is the only submerged aquatic represented and it is not exclusively submerged.

At 213-209 cm peat formation ceases, perhaps due to inundation of sediment, and concentration of total wetland pollen and spores is extremely low (1×10^3 grains/cm³).

Sediment comprises sand sized particles probably washed in by stream flood. Organic and moisture content of the sediment is very low and inorganic matter is very high. No aquatic types occur with the exception of *Hydrocotyle vulgaris*, which may grow as an emergent.

The two mud horizons between 209 and 199 cm indicate lower energy transport of sediments, which may derive from run-off of bared soils. Organic and moisture content of the sediment increases while inorganic matter decreases. Peat formation begins again and total wetland pollen concentration increases ($6-10 \times 10^3$ grains/cm³), indicating greater landscape stability in the catchment and waterlogging of the wetland. The peat surface is continually wet but no aquatic types occur, with the exception of *Salvinia natans*, which occurs at 200 cm at very low abundance.

Between 199 and 192 cm another episode of erosion in the catchment is indicated by deposition of coarse grained sediment of pebbly fine sand. Peat formation ceases, due to inundation by sediments, and total concentration of wetland pollen and spores is low (4×10^3 grains/cm³). At 192 cm the sediment changes to mud with some gravel, indicating slightly lower energy transport of sediment.

Several thin sediment horizons of coarse and mixed grain sizes between 184 and 170 cm, and a thicker horizon of muddy sandy gravel above 170 cm indicate a period of landscape instability with multiple episodes of sediment influx. Many boundaries between these horizons are conspicuous indicating rapid changes in deposition processes. No peat forms, due to rapid sediment influx.

Total concentration of wetland pollen and spores fluctuates, but is generally low ($1-10 \times 10^3$ grains/cm³). Almost all types represent emergent plants; *Carex hallerana* type, *Carex flacca* type, *Phragmites australis*, and *Glyceria* type are dominant, although their relative frequencies and concentrations fluctuate. *Glyceria* type is associated with deposition of larger grain-sized minerogenic sediment (sand and larger). This type includes the species *Glyceria maxima*, which is known to tolerate influx of minerogenic sediment (Ellenberg 1988), although the association may also be interpreted as pollen of the terrestrial species included in the type being washed into the wetland. Peaks in relative frequency of *Carex hallerana* type coincide with sediments of smaller grain size and periods of lesser sediment influx reflecting quick recolonisation after inundation of relicts of the previous community. In this zone, *Carex flacca* type probably represents species such as *Eriophorum*, which can tolerate fluctuating water levels and grow on bare soil (Ellenberg 1988). Fluctuations in the annual *Cyperus michelianus* reflect the behaviour of a coloniser. Concentration values of *Phragmites australis* are very low during the periods of greatest instability. A fluctuating (3-6 expected types) palynological richness curve also suggests periods of greater instability on the wetland.

The continued presence of *Saxifraga stellaris* and *Caltha* type suggest continued influence of a soft-water spring. The water level of the wetland area may be quite low as pollen of floating-leaved or submerged macrophytes is rare. Humicity of the peat at 209-199 cm indicates that the surface of the peat was continuously wet. The appearance of the mostly entomophilous *Salix fragilis* type at 195 cm may indicate that a part of the surface of the wetland was dry enough to allow willow to grow on it.

The level of available nutrients is still high as suggested by the presence of *Glyceria* type, *Oenanthe aquatica* group, *Sparganium erectum*, *Typha domingensis* type, *Typha angustifolium* type, *Salvinia natans*, and *Hydrocharis morsus-ranae* (Ellenberg 1988).

Zone AW-6, 157.0-117.5 cm, c. 1625-1670 AD This zone corresponds to sediment section C, which is characterised by intermediate values for all components and represents a period of much greater landscape stability in the catchment. Deposition of allochthonous mineral material steadily decreases while peat formation increases. Several horizons comprise this zone, they are all mixtures of peat and minerogenic sediment; grain size of sediments is never larger than silt size, with the exception of a trace of fine gravel between 126-130 cm.

The lowest horizon comprises clay and silt with a trace of peat, which increases upwards, suggesting landscape stability when only fine-grained mineral sediments were washed into the wetland. The proportion of peat increases further in the overlying horizon and continues increasing up to the top of the next horizon. In this horizon (133-130 cm) some fine gravel is washed in, suggesting a stream flood event of short duration. The overlying horizon comprises an increased proportion of minerogenic sediment and a decreased proportion of peat indicating an increased rate of sediment influx. The two uppermost horizons both comprise at least half peat and indicate landscape stability in the catchment and waterlogging of the wetland.

Wet-soil communities continue to be the dominant communities and the tall-sedge-swamp community has expanded. The true-reed-swamp community continues about the same, but *Phragmites australis* has expanded slightly. Aquatic communities occur only sporadically, but the obligate submerged plant *Myriophyllum spicatum* occurs in the uppermost spectrum.

Humicity of the peat indicates that the peat surface is continuously wet. Aquatic plants are very sparse, but occur in the horizons with the highest proportion of peat suggesting that they are growing in pools within a bog.

Total wetland pollen and spore concentration fluctuates greatly ($4-20 \times 10^3$ grains/cm³), being highest at the base and top of the zone where it reaches the maximum for the sequence. Again almost all pollen and spores are contributed by types representing emergent plants. The dominant types are *Carex hallerana* type, *Cyperus longus* type, *Phragmites australis*, and *Glyceria* type, and parent plants and mosses probably form the peat. The most abundant type;

Carex hallerana type, is very abundant, suggesting that a well developed small-sedge swamp has developed; the annual *Cyperus michelianus* occurs in significant abundance in only the second to bottom spectrum, indicating that colonization of bare ground declines. The concentration of *Glyceria* type increases greatly at the base of the zone, perhaps due to the influx of fine sediment with abundant nutrients. *Cyperus longus* type increases, indicating an expanded tall-sedge community and a more stable environment where perennials can establish. Palynological richness fluctuates but is generally low at about 4 expected types, which indicates a stable environment.

The presence of *Lysimachia*, *Glyceria* type, *Salvinia natans*, *Stratiotes aloides*, *Nuphar lutea*, and *Ranunculus aquatilis* group indicate a high available nutrient level (Ellenberg 1988).

Zone AW-5, 117.5-95.0 cm, c. 1670-1730 AD This zone corresponds to sediment section B, which is characterised by high inorganic matter and low organic content, corresponding to influx of allochthonous mineral material. Three sediment horizons occur; the two lower horizons contain coarse grained sediments and indicate high energy stream input and perhaps accelerated erosion in the catchment, while the uppermost horizon comprises small grain-size mineral particles and represents declining stream energy or sediment yield from the catchment. The basal horizon, a mixture of peat and sandy muddy gravel, is transitional from the zone below: peat is inundated by coarse sediment until it is eventually overwhelmed. Humicity of the peat in the basal horizon indicates that surface peat is continuously wet. An increase in the occurrence of aquatic types suggests that the water level has risen.

Plant communities of wet-soil habitats continue to be dominant. The true-reed-swamp community continues about the same and then expands with an increase of *Glyceria* type in the uppermost spectrum. The tall-sedge-swamp community almost disappears. Aquatic communities expand slightly and pollen of *Myriophyllum spicatum* occurs in the basal spectrum.

Total concentration of wetland pollen and spores declines to a very low value at the top of the zone (10×10^3 grains/cm³ in the basal spectrum and 1×10^3 grains/cm³ in the top), probably as wetland vegetation is destroyed by inundation of sediments, and comprises mostly types representing emergent plants. Palynological richness is low at 4 expected types, until the top of the zone where it increases to 6. The increase in richness probably reflects the colonization of fresh nutrient-rich sediment. The dominant types of *Carex hallerana* type, *Phragmites australis*, and *Glyceria* type plus mosses probably form the peat in the basal horizon.

The presence of *Glyceria* type, *Sparganium erectum*, *Stratiotes aloides*, *Hydrocharis morsus-ranae*, and *Ranunculus aquatilis* group indicate a high available nutrient level (Ellenberg 1988).

Zone AW-4, 95.0-65.0 cm, c. 1730-1810 AD This zone corresponds to the basal part of a peat horizon, which is continuous to the surface of the current bog. It also corresponds to the basal part of sediment section A, which extends to the top of the sequence, and which is characterised by high organic and moisture content and low inorganic content, and is indicative of landscape stability in the catchment and waterlogging of the wetland area. Low palynological richness, ranging from 4-5 expected types, also indicates a stable environment. The level of humicity of the peat indicates that there was intermittent drying of surface peat, probably seasonally during summer. The occurrence of pollen of floating-leaved macrophytes suggests that pools existed on the peat surface, but the occurrence of the mostly entomophilous *Salix fragilis* type suggests that some part of the wetland was dry enough for willow growth.

Plant communities of wet-soil continue to be dominant with *Carex hallerana* type the dominant type, but a peak in *Equisetum* occurs in the centre of the zone. The tall-sedge community is poorly represented, but increases slightly at the top of the zone. The true-reed-swamp community is reduced as well as the aquatic communities.

Total wetland pollen and spore concentration increases and the highest overall values for a zone are scored (13×10^3 grains/cm³). The dominant types are *Carex hallerana* type and *Glyceria* type and species represented by these types and mosses are the main peat forming plants.

A sudden peak in *Equisetum* may be related to the condition of the bog, but the source of the spores may also be from a greater distance; for example from the arable weed *Equisetum arvense* (Ellenberg 1988). The reduction in *Phragmites australis* may be due to grazing or harvesting.

The presence of *Glyceria* type, *Typha domingensis* type, *Stratiotes aloides*, *Hydrocharis morsus-ranae*, and *Ranunculus aquatilis* group indicate a high available nutrient level (Ellenberg 1988).

Zone AW-3, 65.0-45.0 cm, c. 1810-1865 AD This zone corresponds to the central part of sediment section A where less minerogenic sediment is washed into the wetland than in the zone below. Palynological richness is low again, 4-5 expected types, suggesting a stable environment. Humicity of the peat indicates a higher water level as surface peat is now continuously wet, but representation of aquatic macrophytes remains extremely low.

Total concentration of wetland pollen and spores is high ($6-10 \times 10^3$ grains/cm³), but declines from the preceding zone, perhaps due to greater waterlogging.

The true-reed-swamp community becomes dominant with a large expansion of *Phragmites australis*. The wet-soil communities are reduced as well as the tall-sedge community. The dominant types are: *Carex hallerana* type, *Phragmites australis*, and *Glyceria* type. Species of these types plus mosses are the main peat forming plants.

The dramatic rise in *Phragmites australis* is probably a succession following a reduction in grazing; the usual hydrosere of spring swamps is from small-sedge communities to *Phragmites australis* (Ellenberg 1988).

The presence of *Berula erecta*, *Glyceria* type, *Oenanthe aquatica* group, *Hydrocharis morsus-ranae*, and *Potamogeton crispus* type indicate available nutrient level is high (Ellenberg 1988).

Zone AW-2, 45.0-5.0 cm, c. 1865-1975 AD This zone corresponds to the upper part of sediment section A, where organic and moisture content are exceptionally high, although the latter is slightly lower than in the preceding zone and almost no minerogenic sediments are washed into the wetland. This is indicative of landscape stability in the catchment and waterlogging of the wetland. Low palynological richness of 5-2 expected values reflects the landscape stability. Humicity of the peat indicates that the surface peat is continuously wet.

Carex hallerana type of the wet-soil communities regains its dominance. The tall-sedge-swamp community expands slightly, but the true-reed swamp is greatly reduced. Representation of the floating-leaved aquatic community remains sparse and the submerged community almost disappears, being represented by only *Hydrocotyle vulgaris*.

Total concentration of wetland pollen and spores is similar to the top of the preceding zone ($4-8 \times 10^3$ grains/cm³). *Carex hallerana* type is dominant. Peat is probably now formed by species represented by the *Carex hallerana* type and mosses. *Glyceria* type and *Phragmites australis* have declined, perhaps due to grazing on the bog.

The presence of *Glyceria* type, *Sparganium erectum*, *Typha domingensis* type, and *Salvinia natans* indicate available nutrient level is high (Ellenberg 1988).

Zone AW-1, 5.0-0.0 cm, c. 1975-1989 AD This zone comprises the surface spectrum only. Moisture content increases sharply while organic matter decreases sharply and inorganic matter content is extremely low. Humicity of the peat indicates that surface peat is continuously wet. Several aquatic types occur, albeit at very low concentration values. A dead pine tree at the north end of the bog may be a response to increased wetness in the bog, waterlogging killing the tree by cutting off the oxygen supply to its roots.

The wet-soil communities decline and the tall-sedge-swamp community expands, while the true-reed swamp increases slightly. The floating-leaved aquatic community expands and the submerged aquatic community disappears. A high palynological richness, 11 expected types, may be due to differential preservation of grains normally destroyed in burial.

Total concentration of wetland pollen and spores is low (1×10^3 grains/cm³), perhaps due to high non-pollen biomass or water content and perhaps also to wash-down of pollen into slightly lower peat. The dominant types are *Mentha* type, *Parnassia palustris*, *Carex hallerana* type, *Carex flacca* type, *Cyperus michelianus*, and *Phragmites australis*. Species of these types were noted growing on the wetland, with the exception of *Cyperus michelianus* and *Phragmites australis* (Appendix VIII). The main peat forming species are sedges and mosses. The presence of *Glyceria* type and *Hydrocharis morsus-ranae* indicate available nutrient level is high (Ellenberg 1988).

5.5.3 Terrestrial pollen analysis

5.5.3.1 Pollen diagram construction

Pollen and spore relative frequencies are presented in Figures 5.10 and 5.11 (in pocket). Pollen and spore types are arranged according to habitat groups defined in Chapter 2. The pollen sum on which the relative frequencies are based includes all identified terrestrial pollen and spore taxa and excludes wetland taxa. Relative frequencies of 0.2% or less are indicated with a dot. Style of the pollen diagrams is similar to that of the wetland diagram (Figure 5.8).

Figure 5.10, the summary diagram, shows the coniferous and deciduous canopy trees group in resolved form, then a summary column showing the ratio of terrestrial trees and shrubs to terrestrial herbaceous plants. This is followed by summary curves of each habitat group, then a curve of palynological richness derived from rarefaction analysis and based on the smallest total count of terrestrial pollen and spores, 166 (Birks & Line 1992; Bennett 1994). This is followed by the number of terrestrial types in each spectrum (not normalized for unequal pollen sums). Finally, the number of pollen grains of trees and shrubs, the total number of all terrestrial pollen and spores and the total of all pollen and spores counted in this sequence (wetland and terrestrial) are given.

The fully resolved diagram, Figure 5.11 (in pocket), displays all terrestrial pollen and spore taxa recognised in the sequence, in order of habitat groups. Within these groups they are arranged alphabetically with the exception of the dominant tree types *Pinus* (*Diploxylon*), *Fagus*, *Quercus frainetto* type, and *Quercus trojana* type, which are placed at the beginning of the 'coniferous and deciduous canopy trees' group.

Pollen concentration data are presented in Figure 5.12. Only concentration of pollen and spore types recorded in significant abundance, habitat groups, and total pollen and spores are included. The concentration diagram takes a similar form to the relative frequency diagram.

Figure 5.10 Anelia - summary relative frequency pollen diagram, terrestrial taxa; pollen sum is total terrestrial taxa; scale interval 5% for all taxa and groups (resolved canopy trees taxa have 1.5x scale of groups), percentages less than 0.2% shown by dots.

Figure 5.10

Figure 5.12 Anelia - concentration pollen diagram, selected terrestrial taxa.

Figure 5.12.

5.5.3.2 Terrestrial pollen assemblage zones

Terrestrial pollen diagrams are divided into 5 local pollen assemblage zones A-1 to A-5, based mostly on relative frequency data. These are defined below. Concentration data are discussed in the following section.

Zone A-5, 250.0-212.5 cm This basal zone is characterised by high relative frequencies of *Pinus* (*Diploxylon*) (16.7-35.7%), and about average frequencies (of the sequence as a whole) of *Fagus* (3.9-13.6%), *Quercus frainetto* type (2.4-4.4%), and *Abies* (2.6-9.8%). *Ostrya* type occurs at lowest frequencies (0.3-1.1%) for the sequence. Other types belonging to the 'coniferous and deciduous canopy trees' habitat group do not exceed 0.7%.

No 'alpine shrubs' are represented. Four types of 'alpine herbs' are represented; only *Veratrum* exceeds 0.3%, and it reaches a maximum of only 1.5%. 'Woodland understorey trees and shrubs' are represented by only the types *Buxus sempervirens* (0.1% maximum) and *Juniperus* (0-2.9%). 'Woodland herbs' are better represented, reaching the maximum relative frequency of the sequence of 11.6% at 235 cm. Most abundant are the ferns *Asplenium* type (0.5-3.2%) and *Blechnum spicant* (1.3-7.5%). Other groups poorly represented are 'riverine trees' (1.1% maximum), 'evergreen woodland trees' (no type exceeds 0.4%), and 'plants of open dry rocky habitats' (no type exceeds 0.6%).

'Herbs of open ground' are almost as abundant (28.8-48.1%) as the group 'coniferous and deciduous canopy trees', and have a curve the inverse of that of the latter group. Many of the types of this group are represented, the most important are: *Dactylis* type (1.7-4.7%), *Festuca* type (1.0-2.6%), and *Pteridium aquilinum* (lowest in the basal spectrum at 15.9%, then rises to 22.3-31.4%). *Artemisia*, *Chenopodiaceae* type, *Cirsium* type, *Hieracium* type, *Hornungia* type, *Plantago lanceolata* type, *Rumex acetosa* group, and *Solidago* type are also quite important, but do not exceed 2.1%.

'Cultivars' reach the maximum of the sequence of 5.6% at 230 cm. Types that are most abundant are cereals: *Secale cereale* (0.8-3.7%) and *Triticum* type (0.1-1.3%). *Avena* occurs in the three central spectra, but does not exceed 0.2%. Cereals are known to have been cultivated in the Pindos Mountains in historic times (Chapter 1). *Secale cereale* may have been grown mostly for fodder. *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* occur sporadically and do not exceed 0.8%. *Vitis vinifera* occurs in one spectrum, but at 0.1% only.

Zone A-4, 212.5-157.0 cm The boundary with the preceding zone is marked by an increase in the relative frequencies of *Abies* and *Ostrya* type, a decline in *Pteridium aquilinum* and an increase in the ratio of terrestrial trees and shrubs to terrestrial herbs. The zone is characterised by high relative frequencies of *Pinus* (*Diploxylon*) and *Pteridium aquilinum*; increased relative frequencies of *Fagus*, *Abies*, *Quercus frainetto* type, and *Ostrya* type; and increased ratio of terrestrial trees and shrubs to terrestrial herbs.

'Alpine shrubs' and 'alpine herbs' are very poorly represented; no type exceeds 0.2%.

'Coniferous and deciduous canopy trees' have increased (54.4-67.0%). *Pinus* (*Diploxylon*) has high relative frequencies (18.1-37.0%) and *Fagus* has increased (7.1-22.2%, with the exception of one spectrum of 4.6%). *Quercus frainetto* type increases slightly from the centre of the zone (2.9-7.4%). The curve of *Abies* has the reverse shape to that of *Quercus frainetto* type. Initially *Abies* increases to the maximum of the sequence of 16.4% in the second spectrum, then declines gradually to 5.5%. *Ostrya* type is represented at 1.6-6.4%, but mostly about 3.0-4.0%. No other type of this group exceeds 1.4%.

'Woodland understorey trees and shrubs' are again poorly represented, although *Arceuthobium oxycedri* is represented as well as *Buxus sempervirens* and *Juniperus*. *Arceuthobium oxycedri* and *Buxus sempervirens* occur sporadically and do not exceed 0.2%. *Juniperus* occurs continuously and increases slightly to reach a maximum of 2.9% in the centre of the zone. 'Woodland herbs' decline slightly towards the top of the zone (2.1-6.4%). *Blechnum spicant* is the most abundant type at 1.8-5.7%. *Asplenium* type has declined to less than 1.0%. No other type in this group exceeds 0.8%. Other groups poorly represented are 'riverine trees' (2.0% maximum), 'evergreen woodland trees' (no type exceeds 0.5%), and 'plants of open dry rocky habitats' (2.4% maximum).

'Herbs of open ground' decline, but remain the second most abundant habitat group (23.3-34.3%). Again the curve is more or less the inverse of that of 'coniferous and deciduous canopy trees' and again a wide variety of herbs are represented. *Dactylis* type, *Festuca* type, and *Pteridium aquilinum* remain the most abundant types, but *Pteridium aquilinum* has declined (9.1-21.1%). Frequencies of other types in this group do not change significantly.

'Cultivars' decline (0.8-2.7%), due mostly to a decline in *Secale cereale* (0.4-2.2%). *Triticum* type, and *Avena* occur sporadically (0.8 and 0.5% maximum, respectively). *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* occur sporadically again and decline to a maximum of 0.4%. *Vitis vinifera* has disappeared.

Zone A-3, 157.0-95.0 cm The boundary with the preceding zone is marked by an increase in *Pinus* (*Diploxylon*) and a decline in *Ostrya* type. This zone is characterised by an increase in *Pinus* (*Diploxylon*), *Fagus*, and the ratio of terrestrial trees and shrubs to terrestrial herbs; and a decrease in *Abies*, *Ostrya* type, *Blechnum spicant*, and *Pteridium aquilinum*.

'Alpine shrubs' and 'alpine herbs' are extremely poorly represented; 0.4% maximum.

In the habitat group 'coniferous and deciduous canopy trees' *Pinus* (*Diploxylon*) reaches the maximum of the sequence (48.4%). Relative frequencies of *Fagus* fluctuate, but are generally higher than in all other zones except the uppermost (5.5-21.6%). *Quercus frainetto* type sustains frequencies around 4.5% until the uppermost spectrum, where it declines to 1.8%. The curve of *Abies* declines from around 8.0% to 0.9%, but then increases in the

uppermost spectrum to 6.2%. Frequencies of *Ostrya* type are generally lower (usually less than 3.0%). No other type in this group exceeds 1.3%.

'Woodland understorey trees and shrubs' increase slightly (maximum 3.6%). The number of types represented has increased (6) and the relative frequencies of *Juniperus* have generally increased slightly (maximum 3.6%). 'Woodland herbs' decline in the lower half of the zone (1.3% minimum), although they increase again in the upper half where they reach 8.0%. *Blechnum spicant* continues as the most abundant type in this group (0.3-5.5%). *Thalictrum aquilegifolium* increases in the upper half of the zone, reaching a maximum of 1.9%. All other types of this group occur at less than 1.0% with the exception of *Asplenium* type in the uppermost spectrum (1.9%). Other groups poorly represented are 'riverine trees' (decline slightly to a maximum of only 1.4%), 'evergreen woodland trees' (no pollen count exceeds 0.8%), and 'plants of open dry rocky habitats' (usually less than 2%, although a peak in *Herniaria* type in the basal spectrum reaches 5.4%).

'Herbs of open ground' decline slightly, but remain the second most abundant habitat group (16.8-36.4%), and again the curve is more or less the inverse of that of 'coniferous and deciduous canopy trees'. There is little change in the representation of the individual types, with the exception that, in general, *Pteridium aquilinum* continues to decline (7.2-16.8%, except for the spectrum at 130 cm in which it reaches 25.0%) and *Hieracium* type increases towards the top of the zone (2.4% maximum).

'Cultivars' decline slightly (0.8-2.6%, except in the basal spectrum 3.4%) due to a slight decline in *Secale cereale* (0-0.8%). *Triticum* type and *Avena* continue to occur sporadically (0.6 and 0.7% maximum, respectively). *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* continue to occur sporadically, but reach higher frequencies (2.3, 0.4, and 1.2%, respectively).

Zone A-2, 95.0-25.0 cm The boundary with the preceding zone is marked by a decline in *Pinus* (*Diploxylon*), the near disappearance of *Abies*, *Ostrya* type, and *Blechnum spicant*, and an increase in *Plantago lanceolata* type and *Solidago* type. This zone is characterised by a decline in the relative frequencies of *Pinus* (*Diploxylon*) and *Fagus*, and the near disappearance of *Abies* and *Ostrya* type. Other characteristics are the increase in *Juniperus* and several types of 'herbs of open ground' and the decreased ratio of terrestrial trees and shrubs to terrestrial herbs.

'Alpine shrubs' and 'alpine herbs' are again extremely poorly represented; 0.6% maximum.

In the habitat group 'coniferous and deciduous canopy trees' *Pinus* (*Diploxylon*) declines to 15.3%, the minimum of the sequence, in the centre of the zone. Relative frequencies of *Fagus* describe a curve similar to that of *Pinus*, reaching the zonal minimum value of 3.6%

in the centre of the zone. Relative frequencies of *Quercus frainetto* type remain about the same except that they drop to about 2.5% in the central spectra. *Abies* almost disappears, recording a maximum of only 0.7%. *Ostrya* type also declines (maximum 2.0%). No other type of the group exceeds 1.1%.

'Woodland understorey trees and shrubs' increase to a maximum of 11.2%, due to an increase in *Juniperus*, which reaches a maximum of 10.8%. 'Woodland herbs' decline (1.7-4.3%). *Blechnum spicant* is greatly reduced, being represented only sporadically and reaching a maximum of only 1.6%. *Thalictrum aquilegifolium* increases slightly, now occurring continuously and reaching a maximum of 2.5%. No other type of this group exceeds 1.0%.

'Riverine trees' increase slightly, due to a slight increase in several tree types: *Alnus glutinosa*, *Salix triandra*, and *Tamarix*; but frequencies of these types do not exceed 1.6%. 'Evergreen woodland trees' are very poorly represented; no type exceeds 0.7%. Relative frequencies of 'plants of open dry rocky habitats' are also extremely low although a peak in the centre of the zone reaches 5.2% due to increased frequencies of several types including *Campanula erinus* type, *Helianthemum*, *Herniaria* type, and *Jasione*, but no type exceeds 1.2%.

'Herbs of open ground' increase in the centre of the zone to the maximum of the sequence of 61.8% at 60 cm, and in this spectrum are more abundant than 'coniferous and deciduous canopy trees'. Several types increase including *Dactylis* type, *Festuca* type, *Hieracium* type, *Lotus* type, *Plantago coronopus*, *Plantago lanceolata* type, *Plantago major*, *Plantago media*, *Rumex acetosa* group, *Solidago* type, and *Urtica dioica*. *Pteridium aquilinum* fluctuates, but in general declines.

'Cultivars' increase slightly (1.6-5.0%), due mostly to an increase in *Castanea sativa*, which now occurs continuously and reaches a maximum of 2.1%. The other trees, *Juglans regia* and *Platanus orientalis*, continue occurring sporadically. *Secale cereale* and *Triticum* type occur sporadically (0.9 and 1.0% maximum, respectively). *Hordeum* type occurs in the basal spectrum only at 0.2%. *Avena* disappears.

Zone A-1, 25.0-0.0 cm This zone comprises only three spectra, including the spectrum from the surface sample. The boundary with the preceding zone is marked by an increase in *Fagus*, a decline in *Pteridium aquilinum*, and a decline in 'herbs of open ground'. This zone is characterised by an increase in the relative frequencies of *Pinus* (*Diploxylon*) and *Fagus*, high frequencies of *Juniperus* and a decline in several types of the habitat group of 'herbs of open ground', and an increase in the ratio of terrestrial trees and shrubs to terrestrial herbs.

'Alpine shrubs' are not represented and 'alpine herbs' are represented in one spectrum at 0.2%.

In the habitat group 'coniferous and deciduous canopy trees' *Pinus* (*Diploxylon*) records about 42.0% in the two lower spectra, then declines to 30.1%. *Fagus* rises sharply from 18.4% at the base of the zone to 40.1% in the centre, then falls to 23.5%. *Quercus frainetto* type remains about the same. *Abies* reaches a maximum of 1.2%, while *Ostrya* type increases from 0.6% at the base of the zone to 4.8% at the top. No other type of the group exceeds 1.2%.

'Woodland understorey trees and shrubs' maintain a high relative frequency (9.5%) in the basal spectrum, then decline to 1.2% (values are due entirely to *Juniperus*). 'Woodland herbs' decline slightly and reach a maximum of only 2.5%. All types in this group decline. 'Riverine trees' remain more or less unchanged (1.0-2.4%), although *Salix triandra* declines slightly. *Quercus coccifera* type, the only type of the 'evergreen woodland trees' group represented, records 3.0% in the surface spectrum. Frequencies of 'plants of open dry rocky habitats' are extremely low and no type exceeds 0.5%.

'Herbs of open ground' decline to the lowest values of the sequence (7.5-20.5%). *Pteridium aquilinum* declines sharply to a maximum of 1.8% in the basal spectrum. All other taxa of the group either remain unchanged or decline. 'Cultivars' decline slightly, then increase again in the surface spectrum. *Secale cereale* is the only cereal occurring in this zone and it occurs in the middle spectrum only at 0.2%. *Castanea sativa* and *Juglans regia* occur sporadically at low values. *Platanus orientalis* occurs continuously but reaches a maximum of only 2.4% in the surface spectrum.

5.5.3.3 Terrestrial vegetation history

This sequence records the vegetation history of the Anelia area over the past c. 450 years. Pollen of the habitat group 'coniferous and deciduous canopy trees' is the most abundant throughout the sequence with the exception of two spectra, at 230 and 60 cm, when pollen of 'herbs of open ground', is more abundant. *Pinus* (*Diploxylon*) is the most abundant pollen type in the former habitat group, with *Fagus*, *Abies* (below 100 cm), and *Quercus frainetto* type the next most abundant. 'Woodland herbs' and 'cultivars' are well-represented throughout the sequence and 'woodland understorey trees and shrubs' well-represented above 75 cm.

There is close correspondence between changes in the composition of the sediment and changes in the terrestrial pollen profile, indicating that changes in the pollen assemblages are largely a response to changes in the catchment. This correspondence implies that much of the pollen and spores in the sediments derive from the catchment, so the pollen record reflects primarily the extra-local vegetation. However, the primary source of the pollen and spores preserved in this sequence would vary according to the amount of allochthonous material

being washed into the wetland and the amount of canopy cover in the catchment. Where catastrophic erosion has occurred most palynomorphs would be washed-in from a wide area of the catchment. During peat formation a higher proportion of pollen and spores (apart from local pollen) would arrive from the air, possibly with a larger regional component.

Lack of corrosive deterioration suggests that pollen derived from erosion of older sediments is minimal and inwashed pollen is derived from surface materials containing pollen derived from plants living at or shortly before the time of redeposition.

The terrestrial vegetation history of the Anelia area is discussed below according to the local pollen assemblage zones.

Zone A-5, 250.0-212.5 cm, c. 1560-1585 AD *Pinus (Diploxylon)* occurs at high relative frequencies (apart from one spectrum at 230 cm); values are similar to those of the surface sample from this site. Today pine does not grow in abundance close to the Anelia site, so perhaps the *Pinus (Diploxylon)* pollen in this zone is derived mostly from a regional pollen source. Concentration data indicate that initially concentration was very low (but about twice that of the surface sample). There are two peaks in the concentration curve separated by two spectra with values slightly more than the initial value. The peaks reach values three and four times greater than that of the initial value. Values of *Fagus* are about average for the sequence in both relative frequency and concentration, although relative frequencies are much lower than those of the surface sample concentration values are very similar and suggest an extra-local pollen source. Both the relative frequency and concentration values of *Quercus frainetto* type (deciduous oaks) are also about average for the sequence and relative frequencies are very similar to those of the surface sample, which probably indicates a regional pollen source. Relative frequency and concentration values of *Abies* are also about average for this sequence, but much greater than those of the surface sample. Estimation of pollen source for *Abies* is difficult because of its current absence from the vicinity of the site and its current sparseness in Grevena Province. However, from the limited surface sample investigation of this pollen type, and considering the size of the pollen, long distance transport is probably not likely to result in such high values. *Ostrya* type occurs at its lowest values; pollen of this type is anemophilous, has high relative dispersal, and is over-represented (Appendix XI). It may derive from trees that grow in a variety of habitats (but mostly in damp environments) at various elevations (Chapter 3, Appendix X). The pollen source may be extra-local or regional, or both.

Alpine shrub and herb types are extremely poorly represented in this zone, and indeed throughout this sequence, which is probably indicative of the absence of alpine vegetation in the vicinity and their low pollen production. 'Woodland understorey trees and shrubs' are poorly represented in this zone indicating a poorly developed woodland understorey, but the

'woodland herbs' are quite well-represented. However, the most abundant members of the latter group, the ferns *Asplenium* and *Blechnum spicant* may actually be growing on the bog and not under the cover of a woodland canopy. The relative frequency and concentration values of 'riverine trees' are so low that an extra-local presence is very unlikely; the pollen may derive from trees growing near more distant streams. 'Evergreen woodland trees' and 'plants of open rocky habitats' are also extremely poorly represented indicating the absence of a Mediterranean-type vegetation. The relative frequency and concentration values of 'herbs of open ground' are very high, with highest concentration values for the sequence, but this may be due, in part, to higher total concentrations. Of particular interest is the occurrence of *Centaurea cyanus* type, *Galium* type, and *Sinapis* type, albeit at low abundance, which include species that are weeds of cereal fields.

'Cultivars' are abundant and have the highest concentration values for the sequence, perhaps in part due to higher total concentrations. The most abundant pollen type in this group is the cereal *Secale cereale*, but *Triticum* is also abundant, and the cereal *Avena* is also represented. The trees *Castanea sativa*, *Juglans regia*, and *Platanus orientalis*, which may have been planted or profited from human induced changes in habitats, are also present (Chapter 3). *Vitis vinifera* is also represented, but it may have been growing wild on or near the wetland (Appendix X). Distinction between different cereal pollen types is difficult; the identification of cereal type pollen is more certain. The abundance of the cereal type pollen suggests that cereals were grown close by. Dispersal of pollen of the two cereals *Avena* and *Triticum* is very poor (Chapter 3) so they must have been cultivated extra-locally. Dispersal of pollen of the cereal *Secale cereale* is better (being anemophilous), thus extra-local cultivation is not necessary. This cereal was introduced into Greece during the Roman Period (Renfrew, J. 1969, 1973a), suggesting that the base of this zone is not older than 146 BC, in conformity with suggested dating.

Great abundance of 'herbs of open ground' and moderately high palynological richness values (expected number 25-30) suggest the possibility of an open canopy extra-locally. The ratio of terrestrial trees and shrubs to terrestrial herbs is low; the sum of terrestrial trees and shrubs represents 38.0-61.8% of total terrestrial pollen and spores. However, it is lowest in the centre of the zone coinciding with peat formation and many of the herbs contributing to these high values may have been growing on the bog.

The extra-local vegetation surrounding the Anelia site at this time was probably a woodland mosaic of beech and fir with an open canopy. The open canopy may be due in part to coppicing – beech coppices at least 300 years old are locally common around the wetland (Chapter 1). Modern analogues of this type of woodland can be found at intermediate elevations in the Pindos Mountains today (Chapter 3). Pine woods probably grew at a higher

elevation, while deciduous oak woods grew at lower elevations on the foothills. Cereals were cultivated extra-locally and the nut trees of *Castanea sativa* and *Juglans regia* may have been planted either sparsely in the vicinity of the site or more abundantly at a greater distance. A habitat suitable for *Platanus orientalis* may have been created by human disturbance of the natural extra-local vegetation, or this tree may have been growing wild either extra-locally or at a greater distance from the site (Chapter 3).

Zone A-4, 212.5-157.0 cm, c. 1585-1625 AD Relative frequencies of *Pinus* (*Diploxylon*) remain almost unchanged apart from a decline in the uppermost spectrum, but concentration values are much lower than in the zone below and are extremely low in the two uppermost spectra. These lower concentration values are reflected in the total concentration values and are probably related to the influx of minerogenic sediments (and therefore more rapid deposition). Relative frequencies of *Fagus* increase, but concentration values remain about the same, except for lower values in the basal spectrum in a sand horizon, and in two gravel horizons in the centre and at the top of the zone. The relative frequencies of *Quercus frainetto* type remain unchanged until the centre of the zone where they increase slightly. However, concentration values of *Quercus frainetto* type remain very low and decline in the same manner as those of *Fagus*. Relative frequency and concentration values of *Abies* both increase; concentration values are again low where minerogenic sediments occur. Relative frequencies and concentrations of *Ostrya* type increase; again the influence of the influx of the minerogenic sediments can be seen in the concentration curve.

'Alpine shrubs' and 'alpine herbs' are again very poorly represented. The relative frequencies of 'woodland understorey trees and shrubs' have increased slightly, due to an increase in *Juniperus* although the increase in this type is not enough to be significant and there is no change in concentration values. Relative frequency and concentration values of 'woodland herbs' decline, due mostly to declining values of *Asplenium* and *Blechnum spicant*. The values of 'riverine trees', 'evergreen woodland trees', and 'plants of open dry rocky habitats' remain unchanged. Relative frequency and concentration values of 'herbs of open ground' are reduced and the concentration curve displays the influence of the influx of the minerogenic sediments. The reduction in this group is due mostly to reductions in the values of *Pteridium aquilinum*, the concentration curve of which follows the same pattern as the habitat group. Of particular interest is the occurrence of *Agrostemma githago*, *Centaurea cyanus* type, *Galium* type, *Nigella*, and *Sinapis* type, albeit at low abundance, which include species that are weeds of cereal fields. 'Cultivars' decline, due mostly to a reduction in *Secale cereale*, but values are still high.

The great abundance of 'herbs of open ground' and moderately high palynological richness suggest an open canopy extra-local woodland. However, the ratio of terrestrial trees

and shrubs to terrestrial herbs has increased; trees and shrubs represent 57.8-70.8% of total terrestrial pollen. *Fagus* and *Abies*, which are interpreted as comprising the main components of the extra-local woodland, both increase and the habitat group 'herbs of open ground' declines. This is thought to indicate either an incompletely closed canopy or an expanded extra-local woodland.

The regional pine woods of the mountains decline while the deciduous oak woods of the foothills are unchanged. The extra-local woodland mosaic of *Fagus* and *Abies* expands or becomes more dense. Cultivation of *Secale cereale* may have declined slightly, while the other cereals are still cultivated extra-locally and the nut trees, *Castanea sativa* and *Juglans regia*, and the shade-tree *Platanus orientalis* continue to grow (either planted or encouraged by human disturbance) either sparsely extra-locally or perhaps more abundantly at a greater distance from the site.

Zone A-3, 157.0-95.0 cm, c. 1625-1730 AD Relative frequencies of *Pinus* (*Diploxylon*) increase. Concentration values also increase, except in the two uppermost spectra where sediments of sandy muddy gravel occur. (These fluctuations in concentrations are also seen in total concentration.) Relative frequencies of *Fagus* also increase in general, but are lower in the three lowest spectra and in the uppermost. The curve of the concentration diagram also follows this pattern except that the two uppermost spectra, where the minerogenic sediments occur, are lower in value. Relative frequency values of *Quercus frainetto* type remain almost constant, but the concentration values are lower in the spectra where the minerogenic sediments occur. Both relative frequency and concentration values of *Abies* and *Ostrya* type are lower and decline steadily upwards.

'Alpine shrubs' and 'alpine herbs' are again very poorly represented. Relative frequencies of 'woodland understorey trees and shrubs' increase slightly due to an increase in *Juniperus*, and there is a slight increase in concentration values. Relative frequency and concentration values of 'woodland herbs' increase towards the top of the zone due mostly to an increase in the values of *Asplenium* and *Blechnum spicant*, which may have been growing on the bog. The values of 'riverine trees', 'evergreen woodland trees', and 'plants of open dry rocky habitats' remain unchanged, apart from an increase in the 'plants of open dry rocky habitats' in the lowest spectrum due to an increase in *Herniaria* type. Species of this pollen type may have been growing on eroded gravel.

Relative frequencies of 'herbs of open ground' are in general lower than in the zone below, due to lower values of *Pteridium aquilinum*, but concentration values remain unchanged except for reduced values in the two uppermost spectra where minerogenic sediments occur. The concentration curve of *Pteridium aquilinum* follows the curve of the habitat group to which it belongs. Of particular interest is the occurrence of *Galium* type and

Sinapis type, albeit at low abundance, which include species that are weeds of cereal fields. The values of 'cultivars' remain unchanged, and there is no change in pollen type representation.

Palynological richness is between 25 and 30 expected types except for a decrease in the centre of the zone where it declines to 20. These values are similar to those of the basal zone, where supporting evidence indicates an open canopy, however in this zone (A-3) other evidence points towards a partially closed canopy. The ratio of terrestrial trees and shrubs to herbs increases. Trees and shrubs represent 58.2-78.4% of total terrestrial pollen. The habitat group of 'coniferous and deciduous canopy trees' increases, in general *Fagus* increases and the habitat group 'herbs of open ground' declines. These changes are interpreted as indicative of a further closing of canopy and/or an expansion of extra-local woodland, but not to a degree affecting the diversity of types.

The regional pine woods of the mountains expand and the deciduous oak woods of the foothills remain unchanged. The proportion of the *Fagus* component of the extra-local woods increases while that of *Abies* steadily declines. The level of intensity of extra-local cereal cultivation remains unchanged. The possible small-scale extra-local or more distant larger-scale cultivation of *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* continues at about the same level of intensity also.

Zone A-2, 95.0-25.0 cm, c. 1730-1920 AD Relative frequencies of *Pinus* (*Diploxylon*), *Fagus*, and *Quercus frainetto* type decline in the centre of the zone displaying very low values in the spectrum at 60 cm. Concentration values of these types continue more or less the same as those of the preceding zone until 60 cm where they decline. They remain at lower values to the top of the zone. This pattern of concentration values is reflected in total concentration. Lower concentration values at the top of the zone are probably due to more rapid peat accumulation. *Ostrya* type declines to very low values, but follows the same pattern as the types above. *Abies* is greatly reduced at the base of the zone and almost disappears.

'Alpine shrubs' and 'alpine herbs' are again very poorly represented. 'Woodland understorey trees and shrubs' increase significantly from 70 cm, due to an increase in *Juniperus*. The concentration curve also shows this increase, although not as prominently due to the more rapid peat accumulation. Relative frequency values of 'woodland herbs' are generally slightly higher than in the zone below, although concentration values are lower. Relative frequencies of 'riverine trees' increase slightly, but concentration values are very low. The values of 'evergreen woodland trees' remain extremely low as do those of 'plants of open dry rocky habitats', apart from an increase at 60 cm due to the appearance (at low value) or slight increase in several types.

Relative frequencies of 'herbs of open ground' are higher than those of the zone below and a sharp peak occurs in the relative frequency curve at 60 cm. Frequencies of individual types of this group are in general higher than in the zone below, i.e. in *Dactylis* type, *Festuca* type, *Hieracium* type, *Lotus* type, several *Plantago* pollen types, *Rumex acetosa* group, *Solidago* type, and *Urtica dioica*. Concentration values follow the total concentration curve; they increase in the lower half of the zone, then decline. Both relative frequency and concentration values of *Pteridium aquilinum* decline steadily. Of particular interest is the occurrence of *Buglossoides arvensis* type, *Centaurea cyanus* type, *Galium* type, *Nigella*, *Ranunculus arvensis* type, and *Sinapis* type, which include species that are weeds of cereal fields.

Relative frequencies of 'cultivars' increase, although concentration values of the group are almost unchanged. However, changes have occurred in the representation of individual types. Cereal types have declined slightly with *Secale cereale* now occurring sporadically. *Triticum* type continues to occur sporadically and *Avena* disappears; *Hordeum* type appears once. *Castanea sativa* increases and now occurs continuously. *Juglans regia* and *Platanus orientalis* continue to occur sporadically.

Palynological richness increases to values mostly about 35 expected types and above indicating an open canopy. The ratio of terrestrial trees and shrubs to herbs declines, with a sharp decline in the centre of the zone where trees and shrubs represent only 29.6% of total terrestrial pollen. When this spectrum is excluded terrestrial trees and shrubs represent from 57.3-71.5% of total terrestrial pollen. Other supporting evidence for an open canopy is the decline of 'coniferous and deciduous canopy trees', the near disappearance of *Abies*, and an increase of 'herbs of open ground'.

Regional pine woods of the mountains are reduced. The deciduous oak woods of the foothills are probably unchanged. The *Fagus* component of the extra-local woods is reduced and *Abies* declines sharply at 90 cm. Representation values of *Abies* are similar to those of the surface sample suggesting that only scattered trees remain (Chapter 3). The decline in *Abies* may be due to lumbering, which is known to have been well established in the early 19th century (Leake 1835). *Juniperus* increases significantly above 70 cm. Today *Juniperus* is ubiquitous in Grevena growing at elevations from the lowlands to the mountains. The source of this pollen may be extra-local and/or regional. The level of intensity of extra-local cereal cultivation probably declines slightly. Extra-local or regional cultivation of the nut tree *Castanea sativa* may have increased. *Juglans regia* and *Platanus orientalis* continue to grow either sparsely extra-locally or perhaps more abundantly at a greater distance from the site.

Zone A-1, 25.0-0.0 cm, c. 1920-1989 AD Relative frequency and concentration values of *Pinus* (*Diploxylon*) and *Fagus* increase, while those of *Quercus frainetto* type continue at

about the same values. *Abies* does not recover, but *Ostrya* type increases a little in the surface sample.

The habitat group 'alpine shrubs' is not represented and 'alpine herbs' are represented in only one spectrum at an extremely low value. 'Woodland understory trees and shrubs' decline towards the surface sample, due to declining values in *Juniperus*, while 'woodland herbs' remain constant at comparatively low values. 'Riverine trees' also remain constant at low values. 'Evergreen woodland trees' increase in the surface sample to reach the maximum of the sequence. This is due entirely to a count of *Quercus coccifera* type. Values of 'plants of open dry rocky habitats' are extremely low in the basal spectra then the group disappears.

'Herbs of open ground' record the lowest values of the sequence; all types either decline or disappear. *Galium* type, *Nigella* (in the basal spectrum only), and *Sinapis* type, which include species that are weeds of cereal fields, occur. 'Cultivars' decline slightly, due mostly to a reduction in *Castanea sativa*, the near disappearance of cereals, and an increase in *Platanus orientalis*. The only cereal present is *Secale cereale*, which occurs in the central spectrum only at low abundance. Pollen of *Secale cereale* is anemophilous so this pollen may be long-distance transported, or may derive from wild plants, thus no cereal cultivation may be occurring extra-locally at this time. *Juglans regia* continues to occur sporadically.

Palynological richness fluctuates between 30 and 20, which is indicative of a closed canopy. The very high ratio of terrestrial trees and shrubs to terrestrial herbs also supports the establishment of a closed canopy. Trees and shrubs contribute about 75-90% of total terrestrial pollen. A closed canopy is also indicated by the low values of 'herbs of open ground'.

The regional pine woods of the mountains decline in the surface sample. The deciduous oak woods of the foothills probably continue about the same. *Fagus* increases and an extra-local beech wood with scattered *Abies* and a closed canopy is indicated. Extra-local cultivation of cereals has probably ceased (no cereal cultivation occurs in the vicinity of this wetland today). *Castanea sativa* and *Juglans regia* are scarce. *Platanus orientalis* increases.

5.6 Charcoal and fire history

5.6.1 Microscopic charcoal analysis

Results of the microscopic charcoal particle analyses are presented as relative frequencies in Figure 5.13. The local zonation scheme of the terrestrial pollen and spores is used for convenience of correlation. The charcoal record shows high total charcoal frequencies in zones A-5 and A-3, extremely high total charcoal frequencies in zone A-4, and almost none in zones A-2 and A-1. An extremely high peak in total charcoal frequency (more than three times the value in any other spectrum) occurs at 160 cm in zone A-4. Visual

Figure 5.13 Anelia - charcoal particle percentage diagram (based on pollen sum of total terrestrial taxa).

inspection of residues retained by the 260 μm mesh sieve during sample preparation, showed that optically visible charcoal occurred in only those samples where the largest sized particles were observed through the microscope.

In zone A-5 all size classes are represented in every spectra. Charcoal particles are generally more abundant in the smaller size classes up to 200 μm^2 , but are also abundant in the larger size classes including that $>400 \mu\text{m}^2$, suggesting that fires occurred in the catchment (Chapter 3). Peaks in total charcoal abundance occur in the basal spectrum and at 235 cm. These peaks occur in all size classes, with the exception of the peak at 235 cm in the smallest size class.

Zone A-4 records extremely high charcoal particle abundance and again all size classes are represented in every spectrum. Again charcoal particles are most abundant in the smaller size classes (that is less than 200 μm^2) and abundance has increased three fold from that in zone A-5, but the larger size classes are also abundant, being generally approximately twice the value of those in zone A-5. A peak occurs in the basal spectrum in all size classes and again at 160 cm. A peak occurs between 190 and 185 cm in the $>400 \mu\text{m}^2$ size class, which is not recorded in the smallest size class but is reflected in all other size classes. Another peak occurs at 170 cm in the $>400 \mu\text{m}^2$ size class, which is not reflected in any other size class.

Zone A-3 displays moderate charcoal particle abundance, which is much lower than that of the zone below. Total charcoal abundance is similar to that in the basal zone. Again all size classes are represented, with the exception of the 200-400 μm^2 size class at 125 cm. The smaller size classes are again more abundant than the larger, but the smallest size class has increased in proportion to the largest size classes. A peak occurs in the size class 25-50 μm^2 at 140 cm, which is reflected poorly in all larger size classes. Another peak occurs at 130 cm, but is recorded in the smallest size class only. A peak in the largest size class in the uppermost spectrum is reflected in all other size classes except that of 200-400 μm^2 .

Total charcoal abundance is extremely low in zone A-2. Only the smallest size classes, up to 100 μm^2 are continuously represented. Charcoal particle abundance in the largest two size classes is very low. A peak at 70 cm is recorded in the smallest size class.

Total charcoal abundance in the uppermost zone is extremely low: no charcoal is recorded in the largest two size classes, and a continuous record exists for only the smallest size class.

5.6.2 Fire history

Today fire is not a major ecological factor, but charcoal analysis suggests greater importance in the past. There is continuous accumulation of microscopic charcoal particles of all size classes from the base of the sequence up to 100 cm, with the exception of the

200-400 μm^2 size class at 125 cm; above this depth microscopic charcoal particles of all size classes are sparse (Figure 5.13). Interpretation of charcoal data is complicated by the non-uniform sedimentation of this sequence because erosion after burning of the catchment vegetation could produce smoothed peaks or even anomalous peaks. In this sequence higher charcoal abundance coincides with influx of allochthonous minerogenic sediments into the wetland, but charcoal particles of the largest size class occur in the interbedded peat indicating that charcoal abundance is not entirely due to that washed in.

Microscopic charcoal evidence suggests that the fire history of the Anelia wetland sequence can be divided into four phases according to frequency/intensity and location. Most intense/frequent fires both extra-locally and regionally occur between c. 1585-1625 AD (terrestrial pollen assemblage zone A-4), although charcoal abundance is probably enhanced due to greater influx of minerogenic sediments. Between c. 1560-1585 AD (zone A-5) and c. 1625-1730 AD (zone A-3) fire regimes are very similar in intensity/frequency and location, being of high intensity/frequency, but not as high as that of the period between, and occurring both extra-locally and regionally. Between c. 1730-1989 AD (zones A-2 and A-1) fires do not occur extra-locally and are much reduced regionally.

Pollen evidence also suggests a high frequency of fires in the Anelia area in the lower part of the sequence. The lower pollen concentration of 'coniferous and deciduous canopy trees' between c. 1585-1625 AD (zone A-4) is thought to result from the depletion of the pollen source through the burning of the surrounding woodland vegetation (unfortunately no influx data are available to check this). Also during this period, lowered concentration values of *Pinus* (*Diploxylon*) are interpreted as due to reduction in the source of regional pine pollen through burning. *Pteridium aquilinum* spores are more abundant in the lower part of the sequence between c. 1560-1730 AD (below 95 cm), being highest in the basal zone (c. 1560-1585 AD), and may indicate greater frequency of extra-local fires as *Pteridium aquilinum* spores have only moderate relative dispersal (Chapter 3). Fire sensitive *Juniperus* is most abundant in the upper part of the sequence, especially above 70 cm.

5.7 Synthesis of environmental changes

A summary of the major environmental changes in the Anelia wetland and the surrounding area from c. 1989-1560 AD is given in Table 5.2.

There is closer correspondence between changes in the composition of the deposits and changes in the pollen profiles of wetland taxa than of the pollen profiles of terrestrial taxa. The lack of exact correspondence is due to deposition of pollen and spore types from both taxa washed in from the catchment and of taxa deposited from the atmosphere from regional and

Table 5.2

Major environmental changes in Anelia wetland and the surrounding region, c. 1989-1560 AD

Date AD	Humidity	Wetland vegetation	Extra-local vegetation	Sedimentology of pollen core	Charcoal
1989-1920 (zone A-1)	Low – continuously wet peat surface	<i>Carex hallerana</i> type dominant	Closed canopy: abundant <i>Fagus</i> , <i>Abies</i> of low abundance, lowest abundance of herbs of open ground, <i>Juniperus</i> abundant, <i>Pteridium</i> <i>aquilinum</i> almost absent, cereal cultivars almost absent, low palynological richness	Extremely high organic matter content, fibrous peat. Little-no minerogenic influx	Almost none: only smallest size class continuously represented
1920-1730 (zone A-2)	Low, then moderate – continuously wet, then intermittently dry peat surface	<i>Carex hallerana</i> type dominant, except at 60 cm where <i>Phragmites australis</i> is dominant. <i>Glyceria</i> type abun- dant from 50 cm	Open canopy: <i>Fagus</i> of moderate abundance, <i>Abies</i> almost absent, very abundant herbs of open ground, <i>Juniperus</i> abundant, <i>Pteridium aquilinum</i> of low abundance, <i>Plantago lanceolata</i> type increased, abundant cereal cultivars, high palynological richness	Very high organic matter content, very little inorganic matter, fibrous peat. Little minerogenic influx	Almost none: no charcoal in larger size classes – no extra-local burning & reduced regional burning
1730-1625 (zone A-3)	Low – continuously wet peat surface (110-157 cm)	<i>Carex hallerana</i> type dominant. <i>Glyceria</i> type abundant down to 110 cm, then also <i>Phragmites australis</i>	Partly closed canopy: moderately high <i>Fagus</i> values, increased <i>Abies</i> , herbs of open ground reduced (still abundant), <i>Juniperus</i> reduced, <i>Pteridium aquilinum</i> & cereal cultivars abun- dant, moderately high palynological richness	95-116 cm – increased inorganic matter & decreased organic matter, fine (clay) then coarse-grained sediments (sandy gravel). 116-157 – increased organic matter & decreased inorganic, fine-grained sediments	Abundant: all size classes – extra-local & regional burning
1625-1585 (zone A-4)	Low – continuously wet peat surface (199-209 cm)	<i>Carex hallerana</i> type dominant. <i>Glyceria</i> abundant	Partly closed canopy: <i>Fagus</i> of moderate abun- dant, <i>Abies</i> abundant, herbs of open ground as above, <i>Juniperus</i> of very low abundance, <i>Pteridium</i> abundant, cereal cultivars abundant, moderately high palynological richness	Multiple episodes of minerogenic influx – very high inorganic & low organic matter content. Horizons of sandy gravel, sand, mud with gravel, silt & clay (run-off, high energy erosion & stream flood)	Most abundant: all size classes – widespread extra- local & regional burning
1585-1560 (zone A-5)	Moderate – intermittently dry peat surface	<i>Carex hallerana</i> type dominant. <i>Glyceria</i> type abundant to 230 cm, then <i>Phragmites</i> <i>australis</i> & <i>Cyperus</i> <i>michelianus</i> also	Open canopy: <i>Fagus</i> & <i>Abies</i> of moderate abundance, abundant herbs of open ground, <i>Juniperus</i> of very low abundance, <i>Pteridium</i> <i>aquilinum</i> most abundant, most abundant cereal cultivars, moderately high palynological richness	Two episodes of high energy sediment transportation (235-240 & 245-250 cm) high inorganic & low organic content: sandy gravel – erosion & stream floods. Overlying peat mixed with sand above 222 cm, interbedded peat (245-240 cm)	Abundant: all size classes – extra-local & regional burning

extra-local source areas. Thus the terrestrial pollen record reflects both the extra-local and regional vegetation.

The wetland formed in a hollow of a ravine a typical landscape feature of this area, which may owe its origin to tectonic movements associated with a fault about 300 m upslope. Broadening of the ravine and reduction in gradient caused impedance of spring-stream water flow with consequent deposition of sediments and formation of peat. As transport energy of the stream varied and the stream course changed location, so varied sediments were deposited across the wetland. Thus between c. 1560 and 1730 AD the wetland was in-filled with stratified clay, silt, sand, fine gravel, and peat, and mire vegetation established itself temporarily away from the stream course. At c. 1730 AD peat formation became general with a permanently marginal stream channel. This situation has persisted until today.

Water level of the wetland varied as indicated by humicity of peat horizons indicating that some surface peat was continuously wet while other surface peat was intermittently dry, probably seasonally during the driest part of summer. Pollen evidence indicates that available nutrient level of the wetland is high throughout the sequence and nutrients are supplied from a soft-water spring. Nutrients were probably also contributed to the wetland via washed in sediments and from direct or indirect human activities.

There is very little apparent variation in the local wetland vegetation. It is dominated throughout the sequence (with the exception of the spectrum at 60 cm where *Phragmites australis* is dominant) by sedges of the *Carex hallerana* type of wet-soil plant communities, which are probably indicative of a small-sedge-swamp community similar to that growing on the bog today. Reeds of *Phragmites australis* and *Glyceria* type of true-reed-swamp communities are also prominent. Communities of floating-leaved and submerged macrophytes are poorly represented and usually represent a few plants growing in small pools on the surface of peat. Sedges, reeds, and mosses probably formed the peat deposits.

Terrestrial pollen evidence suggests that pine woods grew at higher elevations on the Pindos Mountains and deciduous oak woods grew on the foothills for the duration of the sequence. Between c. 1560 and 1730 AD the extra-local vegetation is dominated by the canopy trees *Fagus* and *Abies*, but after c. 1730 AD it is dominated by *Fagus* only. A variety of cereals were cultivated extra-locally for the duration of the sequence, except perhaps after c. 1920 AD, and may have been rotated (Chapter 1). The nut trees *Castanea sativa* and *Juglans regia*, which occur sporadically from the base of the sequence, may have been planted or growing wild either sparsely in the vicinity of the site or more abundantly at a greater distance. The shade tree *Platanus orientalis*, which also occurs sporadically from the base of the sequence, may also have been planted or growing wild either sparsely extra-locally or

more abundantly at a greater distance from the site. These three trees may have profited from changes in habitats caused by humans.

There is continuous accumulation of microscopic charcoal particles of all size classes including the largest size class ($>400\text{ }\mu\text{m}^2$), with the exception of the size class of 200-400 μm^2 at 125 cm, from c. 1560 AD (the base of the sequence) until c. 1730 AD. After this microscopic charcoal particles of all size classes are sparse.

A synthesis of environmental changes as indicated by the pollen analysed core follows. The genesis of the wetland, radiocarbon dated at c. 1560 AD, is coincident with high energy erosion in the catchment as evidenced by sediments containing a high proportion of inorganic matter, low organic matter, and comprising a mixture of sand size and larger particles. This deposit (250-245 cm) may represent a single catastrophic event such as a severe storm of very short duration on a landscape with an open-canopy vegetation. The occurrence of pollen and spores of floating-leaved and submerged aquatic macrophytes, at highest relative frequency of the sequence, in this sediment suggests that shallow ponding of water occurred. Between 245 and 213 cm peat formed at the coring site, which suggests a period of landscape stability in the catchment and waterlogging of the wetland. At 240-235 cm coarse grained sediments were again deposited at the core site, indicating another episode of high energy erosion in the catchment and stream flooding. This erosion was probably also of very short duration as peat formation continued and the pollen record does not change, and may have resulted because the tree canopy was open. Increasing amounts of sand are washed onto the peat surface from 222 cm until at 213 cm peat formation ceases, probably due to inundation by the sand, and the deposit is composed entirely of fine to medium sand. Humicity level of the peat indicates that there was intermittent drying of surface peat, until sand is washed onto the peat surface, then humicity decreases indicating continuously wet surface peat, perhaps due to stream water flowing across the peat.

Coincidentally, between c. 1560-1585 AD (250.0-212.5 cm) a bog community resembling that of today establishes. The dominant local plant communities are wet soil communities with sedges of the *Carex hallerana* type dominant. Below 230 cm reeds of *Phragmites australis* and *Glyceria* type of the true-reed-swamp community are equally abundant and the early hydrosere *Sparganium erectum* is prominent, while the annual *Cyperus michelianus* of the tall-sedge-swamp community is very abundant. Above this sedges of the *Carex hallerana* type become much more abundant, *Cyperus michelianus* and *Sparganium erectum* disappear and reeds of *Glyceria* type become more abundant than *Phragmites australis*. The extra-local vegetation at this time was probably a woodland mosaic of beech and fir with an open canopy. The open canopy may be due in part to coppicing – beech coppices at least 300 years old are locally common around the wetland (Chapter 1). Modern

analogues of this type of woodland can be found today at intermediate elevations on the Pindos. Herbs of open ground are almost as abundant as coniferous and deciduous canopy trees and *Pteridium aquilinum* is more abundant than at any other time. Other herbs of open ground that are very abundant are the terrestrial grasses *Dactylis* type and *Festuca* type, *Artemisia*, Chenopodiaceae type, *Cirsium* type, *Hieracium* type, *Hornungia* type, *Plantago lanceolata* type, *Rumex acetosa* group, and *Solidago* type. Pollen types including species that are likely to have been cultivated reach maximum concentration of the sequence at 245-220 cm; the most abundant are the cereal types *Secale cereale* and *Triticum* type. *Secale cereale* may have been grown mostly for fodder. *Avena* also occurs. *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* occur sporadically and *Vitis vinifera* occurs in one spectrum. At this time pine woods probably grew at a higher elevations than that of the Anelia site on the Pindos Mountains, while deciduous oak woods grew at lower elevations on the foothills. Burning of the catchment and regional vegetation is suggested by the abundance of microscopic charcoal particles of all size classes and of spores of *Pteridium aquilinum*. Fire-sensitive *Juniperus* occurs at very low abundance. Peaks in microscopic charcoal particle abundance correspond to influx of sediments.

Between c. 1585 and 1625 AD there is greater instability in the catchment landscape as evidenced by continuous influx of minerogenic sediments of varying grain size, and peat forms at the core site only at 209-199 cm. Fine to medium sand is deposited up to 209 cm, during moderate energy stream flow over the core site, then fine-grained sediments (clay and silt) are deposited, indicating low energy transportation and deposition, while peat forms. Humicity of the peat indicates that surface peat is continuously wet. These fine-grained sediments probably derive from run-off from bared soils in the catchment. At 199 cm coarse-grained inorganic sediment is deposited. This probably represents another catastrophic event of high energy erosion in the catchment and stream flood. Erosion, perhaps of longer duration, follows as indicated by the mixture of coarse- and fine-grained inorganic sediment from 192-157 cm, signalling a period of increased landscape instability in the catchment, when an open canopy allows accelerated erosion. Interbedded sand deposits at 184-182 and 175-172 cm represent periods when the stream flowed over the core site at moderate levels of energy flow.

During this period local plant communities of wet soil habitats are dominant, with sedges of the *Carex hallerana* type dominant. A tall-sedge community develops dominated by sedges of *Carex flacca* type, *Cyperus michelianus*, and *Cyperus longus* type (the pollen of each type occurs sporadically, due to unstable conditions on the wetland) and the true-reed swamp is dominated by reeds of *Glyceria* type; *Phragmites australis* has declined, probably due to a lack of tolerance to 'silting', which the former type tolerates. Aquatic macrophytes

occur rarely at very low abundance and the appearance of *Salix fragilis* type pollen at 195 cm suggests that part of the surface of the wetland was dry enough to allow willow growth. The extra-local woodland mosaic of *Fagus* and *Abies* expands or becomes more dense with greater canopy cover. Herbs of open ground decline, but are still abundant. The most abundant types in this group are the same as previously. *Pteridium aquilinum* declines, but is still abundant. Cultivation of *Secale cereale* may have declined slightly, but it and the other cereals of the *Triticum* type and *Avena* are still cultivated extra-locally. The nut trees, *Castanea sativa* and *Juglans regia*, and the shade-tree *Platanus orientalis* continue to grow (either planted or encouraged by human disturbance) either sparsely extra-locally or perhaps more abundantly at a greater distance from the site. The regional mountain pine woods decline while the deciduous oak woods of the foothills are unchanged. Most abundant microscopic charcoal particles occur at this time; values increase two-three times those below, but abundances are enhanced by sediment influx. Lowered concentration values of *Pinus* (*Diploxylon*) are interpreted as due to the source of regional pine pollen being reduced through burning. High abundance of *Pteridium aquilinum* spores supports extra-local burning of vegetation and *Juniperus* occurs at very low abundance.

Between c. 1625 and 1730 AD greater landscape stability in the catchment and waterlogging of the wetland is indicated as peat formation begins again while fine-grained sediments are deposited. Deposition of allochthonous mineral material steadily decreases up to 130 cm and grain size is never larger than silt size, with the exception of a trace of fine gravel between 130-126 cm, which may represent a stream flood event of short duration. The fine-grained sediments are indicative of low energy transport and are probably deposited as run-off. Influx of fine-grained sediment increases between 130-126 cm, but declines sharply at 126 cm. At 116 cm another period of high energy stream input and accelerated erosion of the catchment begins when sediment of mostly coarse-grained particles begins inundating the peat until at 110 cm peat forming vegetation is overwhelmed. Humicity of the peat indicates that the peat surface is continuously wet. Erosion of the catchment and deposition of sediment of a mixture of fine- and coarse-grained particles at the core site continues until 102 cm then fine-grained inorganic sediment representing declining stream energy or sediment yield from the catchment is deposited.

Plant communities of wet soil habitats continue to be the dominant wetland communities and sedges of the *Carex hallerana* type are by far the most abundant plants represented suggesting the establishment of a well developed small-sedge-swamp community. The tall-sedge-swamp community is dominated by sedges of the *Cyperus longus* type up to 120 cm when it almost disappears and *Cyperus michelianus* declines indicating a more stable wetland vegetation. Reeds of *Glyceria* type and *Phragmites australis* are the most abundant plants of

the true-reed-swamp community. Those of *Glyceria* type are dominant and *Phragmites australis* is less abundant above 110 cm where peat formation ceases and influx of sediments increases. Pollen of aquatic macrophytes is generally very sparse and probably represents aquatic plants growing in pools on peat surface, with the exception of an increase at 100 cm, which may indicate ponding of water. The *Fagus* component of the extra-local mosaic woods increases while that of *Abies* steadily declines, perhaps due to lumbering, and the canopy may become slightly more closed. Herbs of open ground decline slightly, but are still abundant and the most abundant types of this group are the same as previously. *Pteridium aquilinum* declines, but is still abundant. *Secale cereale* and the other cereals of the *Triticum* type and *Avena* are still cultivated extra-locally. *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* continue to grow either sparsely extra-locally or perhaps more abundantly at a greater distance from the site. The regional mountain pine woods expand or become more dense, while the deciduous oak woods of the foothills are unchanged. Abundance of microscopic charcoal particles of all size classes is reduced to an abundance similar to that between c. 1560 and 1585 AD, but indicate that extra-local and regional burning is occurring. *Pteridium aquilinum* spores are abundant and *Juniperus* is of low abundance, supporting extra-local and regional burning of vegetation.

Landscape stability of the catchment and on the wetland is indicated between c. 1730 and 1920 AD when the lower part, 95.0-25.0 cm, of the fibrous peat horizon of the current bog formed. It is characterised by very high organic and low inorganic content and very little minerogenic influx occurs. The level of humicity of the peat declines from 2 at the base of the horizon, where surface peat is intermittently dry, to 1, where surface peat is continuously wet. The occurrence of pollen of floating-leaved macrophytes suggests that pools existed on the peat surface, but the occurrence of pollen of *Salix fragilis* type suggests that some part of the wetland was dry enough for willow growth. Plant communities of wet soil continue to be dominant on the wetland, and sedges of the *Carex hallerana* type are dominant, with the exception of the spectrum at 60 cm when the true-reed-swamp community becomes dominant with a large increase in *Phragmites australis*. The dramatic rise in *Phragmites australis* is probably a succession following a reduction in grazing on the wetland or other limiting factors. The tall-sedge community is poorly represented and the true-reed-swamp community is dominated by reeds of *Glyceria* type, with the exception of *Phragmites australis* at 60 and 55 cm. This community is much reduced above 40 cm. The extra-local woodland is now an open canopy beech wood with scattered *Abies* trees. The canopy is probably open due to lumbering of *Abies* trees and the coppicing of *Fagus* for fuel and fodder. Lumbering was well established in the early 19th century (Leake 1835). Herbs of open ground increase at 60 cm to the maximum of the sequence, and in this spectrum are more abundant than coniferous and

deciduous canopy trees. Types of this group that increase are the grasses *Dactylis* type and *Festuca* type, and *Hieracium* type, *Lotus* type, several *Plantago* pollen types, *Rumex acetosa* group, *Solidago* type, and *Urtica dioica*, suggesting increased grazing. *Pteridium aquilinum* fluctuates, but in general declines. Extra-local cereal cultivation may decline as *Secale cereale* pollen now occurs sporadically and *Avena* disappears. *Triticum* type continues occurring sporadically and *Hordeum* type appears once. *Castanea sativa* now occurs continuously and the other trees, *Juglans regia* and *Platanus orientalis*, continue occurring sporadically. Regional mountain pine woods are reduced, perhaps through increased grazing pressure. The deciduous oak woods of the foothills are probably unchanged. Almost no microscopic charcoal was recorded during this period and only the smallest size classes, up to 100 μm^2 are continuously represented. No extra-local burning of vegetation occurs and regional burning is much reduced. Declining abundance of *Pteridium aquilinum* spores and increased abundance of *Juniperus* pollen at 70 cm supports reduced burning of vegetation.

Between c. 1920 and 1989 AD stability of the catchment landscape and on the wetland is again indicated. The upper part of the fibrous peat horizon, 25.0-0 cm, is characterised by almost no inorganic matter content – very little or no minerogenic influx occurs – and extremely high organic matter content (with the exception of the surface sample where the proportion of organic matter content falls due to an increase in moisture content). An increase in wetness of the bog surface is also indicated by an increase in the floating-leaved aquatic macrophytes in the surface sample (although submerged aquatic macrophytes disappear) and a recently dead pine tree at the north end of the bog may be a response to increased wetness in the bog. This increased wetness may be due to greater humidity caused by a closed canopy beech wood growing close to the wetland, as it does today. Humicity of the peat indicates that surface peat is continuously wet. Wetland plant communities are the same as those below until the surface sample where wet soil communities decline slightly, perhaps as a response to greater wetness of the bog surface. Within this community changes occur in the abundances of pollen types: *Carex hallerana* type declines and pollen of *Parnassia palustris* is equally abundant, while *Mentha* type increases to its highest relative frequency of the sequence. This is probably due to plants of the entomophilous *Parnassia palustris* and *Mentha aquatica*, which are abundant on the bog today, growing near the sampling site. The tall-sedge-swamp community expands with *Cyperus michelianus* and *Carex flacca* type increasing, while the true-reed swamp increases due to an increase in *Phragmites australis*, which becomes more abundant than *Glyceria* type. In the surface sample, palynological richness increases to the highest number of expected types for the sequence but this may be due to differential preservation of grains normally destroyed in burial. The extra-local woodland is a closed canopy beech wood with scattered *Abies*. Coppicing of beech for fodder for draft animals has

probably ceased. Herbs of open ground decline to the lowest abundances of the sequence; *Pteridium aquilinum* is much reduced. Extra-local cultivation of cereals has probably ceased – only the cereal *Secale cereale* occurs and only at very low abundance at 10 cm. This is consistent with a known reduction of cereal cultivation in the Pindos Mountains during this century due to the introduction of mechanized agriculture (Chapter 1). Otherwise possible cultivars are represented by low abundance of *Castanea sativa*, *Juglans regia*, and *Platanus orientalis*. Pine woods persist at higher elevations on the Pindos Mountains and the deciduous oak woods of the foothills probably continue unchanged. An almost complete absence of microscopic charcoal particles and *Pteridium aquilinum* spores, and increased *Juniperus* pollen suggest burning of the catchment and regional vegetation has ceased.

About 15% of the bog surface was open water when field work was undertaken. The central bog is covered by a mixed vegetation of various sedges, grasses, herbs, and related vascular species as indicated by the surface pollen spectrum, and mosses. It is carpeted with the mosses *Acrocladium cuspidatum* and *Cratoneuron* sp., which are dominant in the wetter areas of the bog, and in the drier areas *Carex* spp. are dominant. The similarity of the pollen spectrum of the surface sample with those throughout the sequence and the high level of available nutrients as indicated by pollen evidence suggest that mosses were part of the peat forming vegetation in the past as they are today – the current vegetation forms a mixed sedge and moss peat. Around the edge of the bog the influence of supplementary nutrients from surface and ground water, and perhaps from grazing animals can be seen in the herb communities dominated by *Caltha palustris* (near spring drainage) and *Cirsium* (on fen) and many ruderals grow on the dry land on the edge of the beech wood. The bog is situated in the mountain beech vegetation zone and is almost completely surrounded by pure beech (*Fagus sylvatica*) wood with an almost completely closed canopy. Beech wood grows to the edge of the wetland. Open beech wood, pine wood, and pine wood-pasture occur at a greater distance from the bog, and most of the vegetation in the east, especially around the Aspropotamos catchment is grassland and steppe, which is used by transhumant pastoralists for grazing sheep and goats. No cereal cultivation occurs in the vicinity of the wetland today and no burning of extra-local and regional vegetation occurs today.

Chapter 6. Kellia

6.1 Introduction

This chapter includes a description of the site and deposits of the Kellia wetland coring site and then presents the results of pollen analysis of a 396 cm long sediment and peat sequence. The wetland was first identified as potentially suitable for pollen analysis by Moody & Rackham (1988). Preliminary palynological investigations suggested that the sediments of this wetland were suitable for a full palynological study; but fossil pollen and spore content was 'scarce and preservation fair' (Huber & Rapp 1988).

6.2 Site description

Kellia fen is situated in the lowland plains about 2 km NW of the modern city of Grevena (latitude 40° 06' N, longitude 21° 25' E) at an elevation of 580 m asl (Figures 3.2, 6.1, 6.2 & 6.3). The well-travelled main road between Grevena and Megalo Seirini runs along the western boundary of the fen and a minor road runs along the northern margin. The name of this site is taken from a 1:50 000 topographic map, Grevena sheet (Hellenic Army Geographic Service 1970). This name appears at this location, although there is now no village here. The origin of the name is unknown.

The fen is adjacent to a designated archaeological site, number 216 on the Grevena Project register of sites, which covers an area of >10,000 m² on the north and northeast facing slopes of the fen catchment (Wilkie 1995). The site was used for settlement: prehistoric and historic periods represented by archaeological evidence are Early to Middle Bronze Age, Early Iron Age, Late Archaic to Classical, Classical to Hellenistic, Roman, and possibly Early Medieval. Artefacts recorded at the site include a shaft hole axe and scattered pottery sherds. The density of pottery scatter is variable, but mainly light.

It is evident that the fen is occasionally grazed: a shepherd drove his flock onto the fen while we were doing fieldwork. A stock water trough catching water from a spring close by is used frequently.

6.2.1 Physiographic description

Kellia fen is situated in an alluviated valley. It is rheotrophic, receiving water not only directly from the atmosphere, but also from run-off from the surrounding hillslopes and a spring. The fen is in a major side valley in the lower Leipsokouki catchment, which has been subject to much erosion in the recent past (Doyle 1990). Gentle hillslopes surround Kellia fen and the catchment covers about 2.5 km² (Figure 6.2).

Figure 6.1 Kellia fen. Many members of the lush mixed fen vegetation can be seen in this view looking north across the fen. *Cirsium* is prominent in the foreground. Prominent genera on the fen are *Typha*, *Cyperus*, *Juncus*, *Equisetum*, *Scirpus* and *Sparganium*. The cultivated cereal field in the background has been harvested.

Figure 6.2 Location of Kellia fen in relation to local topography. Contour interval 20 m.

Figure 6.3 Kellia fen, showing location of pollen core site and exploratory borings (a-q). Except for shrubby and steppe surrounding the fen, the rest of the area comprises cereal fields.

The fen has a gentle slope of about 0.5° (inclinometer measurement) up to the north and west where water is supplied to the fen by two streams. A channel running along its southern boundary was dry from halfway along the edge of the fen when fieldwork was undertaken. A spring to the south of the channel has been tapped and a concrete tank constructed for watering animals.

6.2.2 Regional and local vegetation

Kellia fen is surrounded by cultivated fields of mostly cereals with a few scattered pollarded oaks. The typical regional vegetation of the lowlands has been described in Chapter 3.

The fen is well vegetated with a mixture of brushwood and tall luxuriant marsh plants (Figure 6.1). Numerous small plots surveyed on the fen and on the edge of the fen (Appendix VIII) showed that the bryophyte *Eurhynchium praelongum* and the rush *Juncus inflexus* were most abundant with small and poorly developed *Typha* in the wetter areas on the fen, but in wet areas close to the spring *Typha* was lush and dominant, with *Sparganium* very abundant. In drier areas on the fen *Cirsium*, *Cyperus*, and *Equisetum* were most abundant. Other important plants on the fen are: *Scirpus*, *Mentha aquatica*, *Rumex conglomeratus*, and *Potentilla*. Two herbaceous species were noted as indicative of disturbance on the fen: *Pulicaria dysenterica* and *Lythrum salicaria*. Brushwood on the fen includes *Pteridium aquilinum*, *Rubus caesius*, *Prunus spinosa*, and *Salix*.

Scattered *Salix* trees also grow along the channel to the south of the fen (Figure 6.3). Immediately surrounding the fen is shrubbery and steppe. To the south of the fen, on the north facing slope where many steppe plants grow, *Centaurea* and the bryophyte *Camptothecium lutescens* were almost equally dominant. To the north the shrubbery and steppe is taller and includes the brushwood plants of the fen.

6.2.3 Geology of site

Bedrock in this area is mapped as Pliocene-Pleistocene fluvial and lacustrine deposits in terraces: loose conglomerates, blue-green clays, sands, and loose sandstones of variable grain size and also conglomerates and red clays in their upper parts (Institute for Geology and Subsurface Research 1972). These terraces are up to 120 m thick.

Fine sands and silts that comprise the alluvial substrate have been washed into the fen from the surrounding slopes. A thick (15 cm) organic horizon covers most of the fen and is indicative of a low sedimentation rate.

6.3 Sediment analysis

The results of the exploratory borings of the fen, the Troels-Smith (1955) classification and laboratory analyses of the physical properties of the pollen analysed core sequence are reported below. In the diagrams and text, datum for depth (given in cm) is the fen surface.

6.3.1 Wetland profile

The location of the exploratory borings is shown in Figure 6.3, and main features of the stratigraphy of the exploratory cores in Figure 6.4. Detailed logs of the boreholes are in Appendix XIV. Exploratory cores were bored with a Hiller corer and a soil auger at mostly 10 m, occasionally 20 m, intervals in two intersecting transects across the fen in N/S and E/W directions. All exploratory cores were bored to 100 cm initially, then a few were selected for deeper boring.

Three major units can be distinguished. The uppermost *c.* 20 cm consists of silty peat in cores from the western and southern part of the fen, i.e. those closest to the spring. The organic content of this unit is generally higher than that of horizons rich in organic matter lower in the sequence. Towards the northern edge and the eastern (downstream) end of the fen, the unit becomes less peaty and is replaced by brown clay with a sandy layer at the base. This unit may be related to establishment of the modern sealed road and its causeway that may have reduced transportation of sediment into the fen from the catchment upstream.

Below the uppermost unit, up to 450 cm of greyish olive to olive black clay with variable proportions of calcareous grit, peat, and organic detritus was penetrated. Thin (5-15 cm) non-calcareous sand horizons are rare. Some of the peaty or sandy horizons can be traced through adjacent boreholes, but the disturbance and sometimes poor recovery of Hiller and soil auger samples limits the extent to which this can be done. Persistent organic-rich horizons occur at about 100 and 230 cm. Below about 300 cm, there is little organic matter in the stiff to soft greyish olive clay comprising the basal part of the unit. Occasional small mollusc shells and fruits or corms were noted in some cores, but no pattern to their occurrence was determined.

The lowest unit, somewhat heterogeneous, consists of muddy yellow sand and yellow-brown silt and clay with ferruginous mottling and nodules. In the most easterly borehole (a), gravel occurs at the base of sequence. The depth of the top of this unit varies, possibly reflecting a stream-bank topography established on partially weathered stream sediments of this unit that were later overtopped by the calcareous fen deposits of the middle unit. In this interpretation, the fen developed in an old stream course, which ran from west to east with a terrace on the northern side. An alternative is that the ferruginous mottling is due to subsurface water circulation and not weathering. The unit may then include all sediments

Figure 6.4 Longitudinal (E-W) and transverse (N-S) sections through Kellia fen. Columns a-q are based on Hiller sampler and soil auger cores (see Fig. 6.3), with the exception of site 'i', which is based on the monolith and piston core collected for pollen analysis. Peaty horizons in the exploratory cores are shaded, and matching sediment features joined by dashed lines. Vertical exaggeration 8x.

below c. 300 cm, including the organic-poor clay mentioned above. These would represent a combination of fen and low-energy stream deposits.

After examination of these data it was decided that location 'i' was suitable for extracting a core for pollen analysis because it contained a relatively thick accumulation of sediments rich in peaty horizons and was thus likely to contain a pollen record.

6.3.2 Stratigraphy

An illustrated description of the sediments of the pollen-analysed core is given in Figure 6.5. The upper 215 cm were recovered by removing four overlapping monoliths from two contiguous columns (0-90, 70-115, 110-150, and 142-215 cm). The piston corer was used to extract a core from 2-3 m. Below this the deposits were very stiff, so the soil auger was used to retrieve the remainder of the core. The Troels-Smith (1955) classification scheme using symbols and formulas (Appendix III) is followed in the same manner as in Chapter 4. Colours are all fresh colours. The whole sequence is water saturated, so *siccitas* is 2 throughout.

The major component of the sediments of the fen is stiff greyish-olive clay (*Argilla steatodes* and *A. granosa*) with varying amounts of silt, sand, and plant fragments that have been washed into the wetland from the surrounding catchment. Calcareous grit is common (all samples in this sequence effervesced in 10% HCl), but the source of it is uncertain; it may be allochthonous (derived from calcic soils of the catchment) or autochthonous (precipitated from the spring water) or both. Two horizons of a mixture of peat (*Turfa herbacea*) and minerogenic sediment (sand, clay and silt) occur above 183.0 cm (0-32.5 and 67.5-183.0 cm).

Macrofossils were found scattered throughout the deposits. No systematic study of these was undertaken, but those that were identified were of *Equisetum*; others were probably from swamp plants currently growing on the fen. Scattered gastropods occurred at 312.0-376.0 cm. No ostracods were found in this sequence.

396.0-376.0 cm Basal sediments are composed of a mixture of *Argilla steatodes* (As) (particles of clay <0.002 mm) to *A. granosa* (Ag) (particles of clay 0.002-0.06 mm) and *Grana saburralia* (Gs) (mineral particles 0.6-2.0 mm) in a ratio of 3:1, the larger particles being calcareous and ferruginous grit. The sediment is mottled, but the overall colour is 2.5Y 4/2 (dark greyish yellow) which is a medium shade and *nigror* is 2. The sediment is very stiff and homogeneous (*stratificatio* 0). The clay is plastic (*elasticitas* 0).

376.0-312.0 cm A very diffuse boundary of *limes* 0 separates this horizon from that below. The sediments are now *Argilla granosa* to *A. steatodes* with only a trace of *Grana saburralia* and *Detritus herbosus* (Dh) (fragments of herbaceous plants >2 mm). The colour is 7.5Y 4/2 (greyish olive). *Nigror* remains at 2. *Stratificatio* increases to 1 as the deposit tends to split into thin horizontal layers due to horizontal layering of plant material. The clay

Figure 6.5 Troels-Smith classification of Kellia core sediments. Symbols are defined in Appendix III.

is plastic (*elasticitas* 0), soft, and sticky. There are scattered gastropods throughout this horizon.

312.0-287.5 cm Another very diffuse boundary (*limes* 0) separates this horizon from that below. Plant fragments now form a higher proportion of the sediment; *Argilla granosa* to *A. steatodes*, and *Detritus herbosus* are in equal proportions. The colour returns to that of the basal horizon, 2.5Y 4/2 (dark greyish yellow); *nigror* remains at 2. *Stratificatio* remains at 1 due to horizontal layering of herbaceous material. The deposit remains plastic (*elasticitas* 0).

287.5-271.0 cm Another very diffuse boundary (*limes* 0) separates this horizon from that below. The proportion of plant fragments has declined slightly (*Detritus herbosus* 1) and smaller grained mineral particles have become more abundant (*Argilla granosa* 2 and *A. steatodes* 1). The colour changes to 5Y 5/1 (grey), but *nigror* remains at 2. The sediment is stiff and plastic (*elasticitas* 0). *Stratificatio* (1) is unchanged.

271.0-268.0 cm This thin sandy horizon is separated from the horizon below by a very diffuse boundary (*limes* 0) and comprises a mixture of equal proportions of *Argilla granosa* to *A. steatodes* and *Grana arenosa* (Ga) (mineral particles 0.06-0.6 mm) plus a trace of *Detritus herbosus*. This larger grain size indicates higher energy transport. Physical properties remain unchanged (*nigror* 2, *stratificatio* 1, and *elasticitas* 0).

268.0-264.0 cm This is another thin horizon separated from the horizon below by a very diffuse boundary (*limes* 0). It is composed of sediments the same as those in the horizon below the sandy horizon.

264.0-248.0 cm This is a thicker horizon separated from the horizon below by a very diffuse boundary (*limes* 0). It is a mixture of *Argilla granosa*, *A. steatodes*, and *Grana arenosa* in the proportions of 2:1:1 plus a trace of *Detritus herbosus*. Physical properties are unchanged. Charcoal particles were noted.

248.0-235.0 cm Another very diffuse boundary (*limes* 0) separates this horizon from that below. The sediments are composed of *Argilla steatodes* to *A. granosa* plus traces of *Detritus herbosus* and *Grana saburralia*. Physical properties are unchanged apart from *stratificatio*, which is slightly reduced, 0-1. Charcoal particles were noted.

235.0-216.0 cm The boundary between this horizon and that below is diffuse, but slightly sharper than all the boundaries below being *limes* 1. *Detritus herbosus* increases to 2, and *Argilla steatodes* and *A. granosa* share the remaining half of the mixture. Physical properties are unchanged except that *stratificatio* returns to a score of 1.

216.0-200.0 cm The boundary between this horizon and that below is again diffuse (*limes* 1). The sediments are now composed of *Argilla steatodes* with traces of *Detritus*

herbosus and *Grana saburralia*. The clay is stiff and the grit is calcareous. Physical properties are unchanged.

200.0-196.0 cm This thin horizon is separated from the horizon below by a very diffuse boundary (*limes* 0). Sediments comprise a mixture of equal proportions of *Argilla steatodes* and *Grana saburralia* plus a trace of *Detritus herbosus*. The sediment is homogeneous (*stratificatio* 0) and friable. The grit is calcareous. Other physical properties are unchanged.

196.0-183.0 cm Another very diffuse boundary (*limes* 0) separates this horizon from that below. Sediment in this horizon is the same as that at 216.0-200.0 cm.

183.0-165.0 cm A sharp boundary (*limes* 3) between this horizon and that below marks the beginning of peat formation. The deposit is a mixture of *Argilla steatodes* to *A. granosa*, and *Turfa herbacea* in equal parts. The colour of this horizon is 5Y 3/2 (olive black); *nigror* is 3. *Stratificatio* increases to 2, but *elasticitas* remains at 0. The plant structure of the peat is well-preserved; *humositas* is 1 indicating that the surface of the peat was probably continuously wet.

165.0-143.0 cm A very sharp boundary of *limes* 4, possibly indicating erosion of wetland sediments marks a change to increased *Argilla steatodes* to *A. granosa*, and decreased *Turfa herbacea* (3:1). *Humositas* remains at 1. Colour of the sediment is paler (5Y 5/2, greyish olive), probably due to the increase in the minerogenic component; *nigror* has reduced to 2. The clay is cohesive and stiff. The deposit becomes homogeneous again (*stratificatio* 0), but *elasticitas* (0) is unchanged.

143.0-133.0 cm A very diffuse boundary (*limes* 0) at 143.0 cm separates this horizon from the peaty horizon below. The sediments of this horizon are a mixture of *Grana saburralia* (non-calcareous coarse to very coarse sand and calcareous grit) and *Argilla steatodes* in the proportions of 3:1. *Turfa herbacea* declines to a trace, but *humositas* remains at 1. Physical properties are unchanged.

133.0-132.0 cm This very narrow band is demarcated by very sharp boundaries (*limes* 4). The sediment comprises *Argilla steatodes* and *Turfa herbacea* in the proportions of 3:1. *Humositas* is 1. No physical properties change.

132.0-121.0 cm This horizon is composed of the same sediment as that at 143.0-133.0 cm.

121.0-77.5 cm This thick horizon is separated from the horizon below by a sharp boundary of *limes* 3. The deposit is a mixture of *Argilla steatodes* and *Turfa herbacea* in the proportions of 3:1 plus a trace of *Detritus herbosus*. *Humositas* is 1. Physical properties are unchanged with the exception of *elasticitas*, which increases to 1.

77.5-67.5 cm A very diffuse boundary *limes* 0 separates this horizon from that below. Deposits are now a mixture of *Turfa herbacea* and *Detritus herbosus* in equal proportions plus

a trace of *Argilla steatodes*. *Humositas* is 1. Colour of the deposit is darker at 7.5Y 3/2 (olive black). *Stratificatio* increases to 1 and *elasticitas* to 2.

67.5-52.0 cm Another very diffuse boundary (*limes* 0) marks a change in the deposit to one that includes more inorganic material. Sediments comprise *Argilla steatodes* to *A. granosa*, and *Detritus herbosus* in the proportions of 3:1. Colour is paler (5Y 5/2, greyish olive) and *nigror* reduces to 2. *Stratificatio* increases to 1-2 and *elasticitas* decreases to 0.

52.0-32.5 cm A diffuse boundary (*limes* 1) marks a change to sediments of larger grain size. They comprise a mixture of *Grana arenosa* and, *Argilla steatodes* to *A. granosa* in the proportions of 3:1 plus a trace of *Detritus herbosus*. Physical properties including colour are unchanged.

32.5-18.0 cm Another diffuse boundary of *limes* 1 marks the boundary between this horizon and that below. The deposit is a mixture of *Argilla steatodes* to *A. granosa*, *Detritus herbosus*, and *Turfa herbacea* in the proportions of 2:1:1. *Humositas* is 0-1. Physical properties are unchanged. Living roots of plants growing on the fen penetrate into this horizon.

18.0-0 cm The uppermost horizon is separated from the horizon below by a very diffuse boundary (*limes* 0). The deposit comprises a mixture of *Turfa herbacea* and *Detritus lignosus* (fragments of ligneous plants >2 mm) in the proportions of 3:1 plus a trace of *Argilla granosa*. *Humositas* is 0-1. The colour is darker (7.5Y 3/2, olive black) and *nigror* increases to 3. *Stratificatio* decreases to 0 and *elasticitas* increases to 3.

6.3.3 Physical properties

Organic matter, inorganic matter, moisture content, and dry density are plotted against depth and stratigraphy in Figure 6.6. The first three properties are expressed as a percentage of the original wet weight of the sample. The results suggest a division of the sequence into 14 sections (A-N), described below.

Section N, 396.0-376.0 cm This sediment is very rich in inorganic matter (73.8-78.4%), with correspondingly high dry density values (1.1-1.5 g/cc). Organic matter is very low (0.8%), being minima of the sequence. Moisture content is also very low recording the minimum of the sequence in the basal sample (19.6-24.4%). Carbonate content is very low (1.0-1.6%).

Section M, 376.0-312.0 cm Physical properties are very similar to those in the section below, but inorganic matter and dry density decline upwards (65.0-76.0% and 1.1-1.5 g/cc, respectively), while organic matter and moisture content increase (0.8-1.6% and 22.0-32.2%, respectively). Carbonate content continues to be very low (0.9-1.6%).

Figure 6.6 Kellia sediment physical properties: sediment type column (Troels-Smith classification 1955), organic matter, carbonate, inorganic matter, moisture and bulk (dry) density. Sediment sections based on physical properties are indicated on the right.

Section L, 312.0-287.5 cm This section is characterised by significantly decreased inorganic matter (46.7-55.3%) and dry density (0.7-0.9 g/cc), while organic matter and moisture content increase (3.8-4.6% and 39.1-47.4%, respectively). Carbonate content is moderate (1.4-1.6%).

Section K, 287.5-235.0 cm This section is characterised by very high inorganic matter and dry density (64.0-70.8% and 1.2-1.5 g/cc, respectively) and corresponding low organic matter and moisture content (0.8-2.2% and 22.4-33.4%, respectively). Carbonate content is generally slightly higher (0.9-2.6%).

Section J, 235.0-216.0 cm This section includes the sample at 235.0 cm. The section is characterised by increased organic content (2.9-4.4%) and correspondingly higher moisture content (32.4-41.4%). Inorganic matter and dry density decline (53.4-62.8% and 0.9-1.1 g/cc). Carbonate content declines (0.8-1.8%).

Section I, 216.0-200.0 cm This narrow section comprises three samples (excluding the sample at 200.0 cm). Organic matter and moisture content decline (1.5-2.0% and 26.6-35.6%, respectively), and inorganic matter and dry density increase (61.5-70.4% and 1.1-1.3 g/cc, respectively). Carbonate content remains low (0.9-1.5%).

Section H, 200.0-165.0 cm This section is characterised by increased organic content (2.7-4.8%). Moisture content increases (34.4-51.7%). Inorganic matter and dry density decline (43.2-60.8% and 0.7-1.1 g/cc, respectively). Carbonate content increases slightly at the base of this section, but then declines upwards (0.9-2.2%).

Section G, 165.0-143.0 cm Again this section demonstrates a reversal to lower organic matter and moisture content (1.5-2.7% and 29.0-39.9%) to higher inorganic and dry density values (56.3-68.0% and 0.9-1.2 g/cc, respectively). Carbonate content remains low (0.9-1.4 g/cc).

Section F, 143.0-121.0 cm Inorganic matter (67.8-75.5%) and dry density (1.2-1.5 g/cc) are very high and continue to increase, while organic matter and moisture content remain very low (0.82-1.6% and 21.0-29.2%, respectively). Carbonate content increases reaching the maximum of the sequence at 135.0 cm (1.4-3.7%).

Section E, 121.0-77.5 cm Organic matter and moisture content increase slightly (1.5-3.0% and 24.0-37.8%, respectively). Inorganic matter and dry density decline (58.5-70.0% and 1.0-1.4 g/cc). Carbonate values remain high at first, but then decline to low values (0.9-3.6%).

Section D, 77.5-67.5 cm This narrow section comprises two samples of organic-rich matter (4.1 and 5.5%). Maximum moisture content of the sequence of 72.9% is reached at 65.0 cm (the other sample records 57.0%). Inorganic matter and dry density decline

dramatically (21.0-37.6% and 0.3-0.6 g/cc, respectively). Carbonate values remain low (0.5-1.5%).

Section C, 67.5-32.5 cm Inorganic matter dramatically increases to values similar to those of the section below the preceding section (62.2-76.0%). Dry density also increases dramatically (1.1-1.6 g/cc). Organic matter and moisture content decline to low levels (0.8-2.2% and 19.8-33.3%, respectively). Carbonate values increase steadily upwards (1.4-3.3%) almost reaching the maxima of the sequence.

Section B, 32.5-18.0 cm Organic content and moisture content increase again (2.7-4.3% and 36.0-43.5%, respectively), and inorganic matter and dry density decline (51.3-59.4% and 0.82-1.0 g/cc, respectively). Carbonate values decline slightly (1.5-2.0%).

Section A, 18.0-0 cm This section is characterised by highest organic matter content of the sequence; increasing to 9.3%, then to 36.3% at the surface. Moisture content rises to almost the maxima of the sequence at 10.0 and 5.0 cm (70.1 and 69.7%, respectively), but declines to only 5.4% in the surface sample. Inorganic matter declines sharply in samples at 15.0, 10.0, and 5.0 cm (29.4, 20.6, and 19.9%, respectively), but increases in the surface sample to 56.4%. Dry density is very low (0.3-0.5 g/cc). Carbonate values continue to decline (1.0-2.2%).

6.4 Chronostratigraphy

6.4.1 Radiocarbon dating

Samples for radiocarbon dating were selected to provide ages for various depositional events inferred from lithologic characteristics. Where possible samples were taken from intervals of the core containing considerable amounts of peat to provide a higher percentage of carbon per sample, thus providing more precise radiocarbon ages, and also avoiding contamination of older soil carbon from alluvial inwash (Tolonen 1980), so they are not evenly spaced.

Radiocarbon dating results are tabulated in Table 6.1. Conventional radiocarbon ages are shown with an analytical error of one standard deviation. These ages have been calibrated by tree-rings (Appendix IV).

The sequence contains few *in situ* peat horizons. The two uppermost samples dated radiometrically were taken from deposits that contained peat. As no peat horizons occurred below the lower of these samples less reliable sediment material had to be dated. Between 296 and 307 cm sediment from an organic detritus-rich horizon was dated. The two lowest samples are clay-rich sediment containing very little organic matter. The humin fraction of these sediments was used for dating. All samples received a pretreatment with hot acid, which removes calcium carbonate and fulvic acid, and three samples were also treated with an alkali to remove humic acids (Taylor 1987).

Table 6.1

Radiocarbon dating results – Kellia

Sample depth (cm)	Laboratory number	Pretreatment	Fraction dated	$\delta^{13}\text{C}$ ‰ wrt PDB	% modern	Radiocarbon age (years BP $\pm 1\sigma$)	Calibrated age(s) (years AD/BC)
71-72	NZA 3478	Hot acid/alkali/acid	Plant material	-26.33	98.63 $\pm$ 0.72	69 $\pm$ 59	*1955 AD
166-168	Wk 1808	Hot acid (1 hr)	Entire sediment	-27.4	94.20 $\pm$ 0.6	480 $\pm$ 88	1436 AD
296-307	Wk 1809	Hot acid (1 hr)	Entire sediment	-27.5	93.50 $\pm$ 0.6	540 $\pm$ 88	1416 AD
315-316	NZA 6894	Hot acid/alkali/acid	Sediment humin	-31.2	62.99 $\pm$ 0.63	3669 $\pm$ 80	2031, 1992, 1989 BC
394-395	NZA 3483	Hot acid/alkali/acid	Sediment humin	-25.79	71.02 $\pm$ 0.70	2707 $\pm$ 79	830 BC

Radiocarbon dating laboratory reference numbers:

NZA = Rafter radiocarbon laboratory, Nuclear Sciences Group, Institute of Geological & Nuclear sciences, Lower Hutt.

Wk = Waikato radiocarbon dating laboratory, University of Waikato, Hamilton.

Percent modern means absolute percent modern relative to the NBS I oxalic acid standard.

$\delta^{13}\text{C}$ represents the measured difference, in parts per thousand, between the ratio of carbon-13 to carbon-12 in the sample to the ratio for the chosen standard (PDB carbonate). It is useful as a check on natural fractionation and on fractionation during sample preparation (Aitken 1990).

Radiocarbon Age BP is the conventional radiocarbon age before 'present' (years BP), based on the half-life of 5568 years, as defined by Stuiver & Polach (1977), the present being 1950 AD. (*1955 denotes influence of bomb C-14.)

The radiocarbon age error margin reported by the University of Waikato included only counting statistics errors, so a laboratory error multiplier of 1.6 was used to increase the standard deviation for samples dated in that laboratory.

The computerized calibration program of Stuiver & Reimer (1993), CALIB 3.0.3c (revised version 1995) available on the Internet at the University of Washington ftp site, was used (Appendix IV).

The uppermost sample (71-72 cm) is close to modern but has calibrated age ranges (Appendix IV), at 68% confidence level, of 1698-1722 and 1817-1920 AD. After calibration the radiocarbon sample at 166-168 cm gives three age ranges at 68% confidence level (1323-1338, 1393-1514, and 1593-1620 AD), with a most probable calibrated calendar date of 1436 Cal AD. The radiocarbon sample at 296-307 cm gave a younger most probable calibrated age than expected, 1416 Cal AD, not statistically different from the one above. However 68% confidence level calibrated age range for this sample is 1324-1447 AD.

The lower two radiocarbon ages are in reverse order and much older than those above. Although the reversal may indicate unreliability of these dates, it is considered that these lower sediments are older than those above and that an hiatus occurs at 312 cm, also there is the possibility that sediments from 312-376 cm derive from older soils than those below. The sample at 315-316 cm shows a higher negative value for the ratio of carbon-13 to carbon-12 ($\delta^{13}\text{C}$) than the sample at 394-395 cm, even though it contains more organic matter. This may indicate a contribution of inorganic carbonates (Jansen 1984:36). Thus the date obtained for the lowest sample is considered the more reliable.

6.4.2 Age/depth plot

An age/depth plot (Figure 6.7) has been drawn in the same manner as those of the two preceding chapters to illustrate the relationship between the dates obtained from radiocarbon dating and the depths of the deposits. As a first approximation, a straight line has been fitted to the three dates above 312 cm. If deposition of the sediments occurred at a constant rate, this would suggest that either Wk1808 is older than expected, or that Wk1809 is younger than expected. Contamination of these samples by older or younger material sufficient to cause such deviation is unlikely (Taylor 1987). However the line passes either within, or close to the 68% confidence level age ranges, and within the 95% ranges.

The variation in organic matter content suggests that sediment deposition rate may have been variable. A check on this was made by plotting cumulative *Pinus* pollen concentration against depth (Figure 6.8), after the manner of Middelorp (1982). As a long-distance transported component of the pollen rain, *Pinus* would be expected to have relatively constant pollen deposition at the site. The plot shows variation in the depth rate of accumulation, but also considerable intervals of uniform accumulation. Low rates are associated with organic-rich sediment, and high rates with sandy and organic-poor sediment, consistent with low sedimentation rate of sediment during periods of peat accumulation and *vice versa*. The radiocarbon date Wk1809 falls at about twice the accumulated *Pinus* pollen value as Wk1808,

Figure 6.7 Age-depth plot. Calibrated radiocarbon ages (Table 6.1, Appendix IV) plotted against depth of sediment from Kellia. Length of cross-arms indicates uncertainty ($\pm 1\sigma$) of age measurement (horizontal) and thickness of dated sediment (vertical). Most probable dates are indicated by crosses. The horizontal line at 312 cm depth indicates a hiatus in sedimentation deduced from other data. A tentative line of correlation is shown above this level.

Figure 6.8 Cumulative *Pinus* pollen deposition (upper x-axis) plotted against depth for Kellia pollen analysis core site. The lower x-axis shows calendar age assuming constant *Pinus* pollen deposition rate and with best fit to radiocarbon dates (see text); calibrated radiocarbon date ranges shown are 2σ , with 1σ ranges in heavier line. Sediment column on right.

in agreement with the linear approximation of Figure 6.7. A linear calendrical scale has therefore been fitted to Figure 6.8. Although the depositional regime is not a simple closed system like the autochthonous peats treated by Middelorp (1982), the pollen accumulation curve can be treated as an age-depth plot. Since it takes into account variations in sedimentation rate, it is used as a best estimate of ages of pollen zones.

The exact dating of the core interval below 312 cm is uncertain, as indicated above, although the lower radiocarbon date of 830 BC is preferred. Because of the uncertainty, no ages are assigned to pollen zones from this interval. Figure 6.8 indicates that *Pinus* pollen accumulation rate in the interval below 312 cm is similar to that obtained in the interval 120-30 cm. The section 396-312 cm therefore probably accumulated over a time interval of approximately 200 years.

6.5 Pollen analysis results

6.5.1 Introduction

Relative frequency and concentration data are used to interpret the vegetation history of the Kellia area. Concentration data are not converted to influx rates because of the uncertainty of the reliability of the reported radiocarbon ages and possible erratic deposition of deposits. Only the exotic marker grain (tracer) method of calculating palynomorph concentrations was used for this sequence. Separate diagrams are drawn for local (wetland) taxa, extra-local and regional (terrestrial) taxa, and microscopic charcoal. Data used to calculate pollen and spore concentrations, all pollen and spore types counted, and charcoal abundances are tabulated in Appendix XIII.

6.5.1.1 Pollen preservation/pollen abundance

Palynomorph preservation is generally good, but abundance is very low. The principal modes of deterioration of grains are breakage and crumpling, leaving the exine in good condition. In samples below 312 cm some exines have been degraded by oxidation (Delcourt & Delcourt 1980). Only one spectrum records more than 4.0% indeterminate grains (4.2% at 124 cm). Unknown grains and unidentified monolete spores are rare, each reaching a maximum of 0.2% in two spectra.

Concentration values of total terrestrial pollen and spores are comparatively constant (Figure 6.13). It is highest between the base of the sequence and 355, 310-285, and 235-145 cm where it generally exceeds 7×10^3 grains/cm³; and in the surface spectrum (22×10^3 grains/cm³). With the exception of the surface sample, no spectrum exceeds 16×10^3 grains/cm³. The lowest concentrations occur from 270-245, 140-135, 75-70, and at 45 and 25 cm, where concentrations are less than 4×10^3 grains/cm³. There is no obvious correlation

between dry density of the sediments and terrestrial pollen and spore concentrations. There is some correlation between concentration and sediment type; in general, low concentrations occur in sand and grit horizons, and high concentrations in clay that is rich in plant detritus.

Concentration values of total wetland pollen and spores are highly variable ($0.4\text{--}45 \times 10^3$ grains/cm³) (Figure 6.10). Highest concentrations occur 310–290 cm ($26\text{--}42 \times 10^3$ grains/cm³), at 230 cm (39×10^3 grains/cm³) (both plant detritus-rich clay sediment) and at the surface (45×10^3 grains/cm³). With the exception of three spectra (all less than 10×10^3 grains/cm³) all remaining concentrations are only about 5×10^3 grains/cm³ or less. There is no correlation between dry density of the sediments and wetland pollen and spore concentration.

6.5.2 Wetland pollen analysis

6.5.2.1 Pollen diagram construction

Pollen and spore relative frequencies are presented graphically in Figure 6.9 and pollen concentration data in Figure 6.10. Style of the resolved and summary relative frequency diagram is as for the Anelia site (Chapter 5). In both diagrams, pollen and spore types are arranged in the same manner as in Chapter 5. Similarly, within habitat groups, types are arranged in order of appearance. The pollen sum includes all wetland pollen and spore taxa. Relative frequencies of 0.2% or less are indicated with a dot. Rarefaction analysis is based on the smallest total count of the wetland pollen and spores, 55 in the fourth spectrum from the top of the sequence.

Many weeds and ruderals were observed growing on the drier and disturbed areas of the fen. These species are included in the pollen types *Calystegia*, *Cirsium* type, *Cuscuta* types, *Galium* type, *Hypericum perforatum* type, *Lactuca* type, *Nigella*, *Potentilla*, *Rubus* type, *Rumex conglomeratus* group, *Solidago* type, *Sonchus* type, and *Teucrium* and are not included in the wetland diagram as they are typically terrestrial in habitat. With the exception of *Rubus* type, which is included in the 'woodland understorey trees and shrubs' habitat group, all these pollen types are included in the habitat group of 'herbs of open ground'.

6.5.2.2 Pollen record of wetland plant communities

The wetland communities are represented by several dominant pollen and spore taxa: *Carex hallerana* type, *Equisetum*, *Schoenus nigricans*, *Carex flacca* type, *Cyperus longus* type, *Cyperus michelianus*, *Glyceria* type, *Phragmites australis*, *Sparganium erectum*, *Scirpus*, and *Sparganium angustifolium*. The dominance of these types alternates. A maximum of 23 pollen and spore types were identified in any spectrum; average is 14. Estimates of palynological richness by rarefaction analysis range between 4 and 16 expected types.

Figure 6.9 Kellia - relative frequency pollen diagram, wetland taxa
(pollen sum is total wetland taxa)

EMERGENTS

TALL SEDGE SWAMP

STREAM REED SWAMP

Cyperus michelianus

Alisma

Cladium mariscus
Berula erecta

Veronica anagallis-aquatica type
Glyceria type

Phragmites australis

Oenanthe aquatica group
Sparganium erectum

WET SOIL

Figure 6.10 Kellia - concentration pollen diagram, wetland taxa

Emergent communities The wetland pollen and spore sequence is dominated by types that derive from emergent plant communities. Pollen and spore types belonging to the 'wet soil' habitat group are most numerous, although relative frequency values of the 'true reed swamp' habitat group are highest throughout the sequence except from 305-280 cm, where the relative frequencies of the 'wet soil' habitat group are higher, and at 35, 30, 20 cm, and the surface, where relative frequencies of the 'tall sedge swamp' habitat group are higher.

Chapters 4 and 5 include discussions on the classification of wetland pollen and spore types into ecological groups. Only types not discussed previously are discussed below.

Several types of the habitat group 'wet soil' identified in the Kellia sequence were not identified in the other two sequences. *Succisa pratensis* is placed in the order Molinietalia (moist meadow and stream bank communities) and *Ludwigia palustris* and *Radiola linoides* in the order Cyperetalia fusci (dwarf plant communities, which are inundated in winter but dry out) (Ellenberg 1988). Many other types of the 'wet soil' habitat group also belong to these orders. *Schoenus nigricans* is placed in the order Tofieldietalia of calcareous small-sedge beds and related communities. *Corrigiola litoralis* is placed in the class Chenopodietea of communities of waste ground and related arable and garden weed communities and described as a damp-site indicator that grows mainly on constantly damp, but not wet, soils (Ellenberg 1988). Although usually growing at low altitudes, it has been found at c. 1850 m in mainland Greece (Strid 1989). *Thelypteris palustris* belongs to the order Alnetalia of alder swamp woods (Ellenberg 1988).

Dipsacus type includes the two species *Dipsacus fullonum* and *D. laciniatus*, and possibly also *Cephalaria ambrosioides*, *C. flava*, and *C. transylvanica*. *Dipsacus fullonum* is placed in the order Calystegio-Alliarietalia of hedgerow veil communities and semi-shade communities (Ellenberg 1988) but it, as well as *D. laciniatus* sometimes also grows in marshes (Polunin 1988), while the species of the genus *Cephalaria* probably grow in semi-shade communities (Polunin 1988).

Epilobium hirsutum type includes several species (*Epilobium hirsutum*, *E. montanum*, *E. palustre*, *E. parviflorum*, *E. tetragonum*) and probably several others (*Epilobium adenocaulon*, *E. alsinifolium*, *E. anagallidifolium*, *E. dodonaei*, *E. gemmascens*, *E. lanceolatum*, *E. obscurum*, *E. roseum*). The species *Epilobium hirsutum*, *E. montanum*, and *E. parviflorum* that definitely belong to this type are classified by Ellenberg (1988) into a variety of plant communities. *Epilobium hirsutum* is placed in the order Brometalia erecti of suboceanic more or less arid swards, *E. montanum* is placed in the order Fagetalia of noble broadleaved woods and related communities, and *E. parviflorum* is placed in the order Calystegio-Alliarietalia of hedgerow veil communities and semi-shade communities. These species are indicated as growing in water conditions ranging from damp soils to water-

saturated soils. *E. palustre* is a wet-site indicator, often in water-saturated badly aerated soils and *E. tetragonum* is a moist-site indicator (Ellenberg 1988). Several species of *Epilobium* were noted growing on Kellia fen; *Epilobium hirsutum*, *E. cf. parviflorum*, and *E. cf. adenocaulon*. In Grevena the genus *Epilobium* was observed growing mostly in wet places, especially along margins of water courses, on fens, and in disturbed places.

The following species are not classified by Ellenberg (1988): *Phytolacca americana* grows in marshes and ruderal places, *Triglochin bulbosa* grows in marshes (freshwater- or salt-marshes), *Althaea officinalis* grows in damp places and field verges, and *Lythrum portula* in wet places and in shallow pools (Polunin 1988; Strid 1989).

Only one additional pollen type of the 'tall sedge swamp' habitat group occurs, that of *Alisma*. Three species are included in this type: *Alisma gramineum*, *A. lanceolatum*, and *A. plantago-aquatica*. *A. plantago-aquatica* is placed in the order Phragmitetalia. *Alisma gramineum* and *A. lanceolatum* are not classified by Ellenberg (1988). They grow in damp places and shallow water (Haslam *et al.* 1975; Polunin 1988).

Aquatic communities Aquatic pollen and spore types are poorly represented, although types of the 'floating-leaved macrophytes' habitat group are more numerous and better represented than the habitat group of 'submerged macrophytes'.

'Floating-leaved macrophytes' are represented in almost all spectra, although usually at very low relative frequencies. Three of these taxa, *Hydrocharis morsus-ranae*, *Stratiotes aloides*, and *Salvinia natans* belong to Ellenberg's (1988) Lemnetalia order of floating communities of waters more or less rich in nutrients. With the exception of *Sparganium angustifolium* of the order Littorelletalia and *Vallisneria spiralis*, which is not classified but grows submerged in still nutrient-rich water (Willis 1951; Haslam *et al.* 1975; Polunin 1988), the remainder of the taxa in this habitat group belong to the order Potamogetonetalia of rooted water plant communities; this includes three types (*Callitriche stagnalis* type, *Callitriche obtusangula*, and *Trapa natans*), which were not identified in the sequences from the Gomara and Anelia wetlands (Ellenberg 1988). *Sparganium angustifolium* (floating bur-reed) is abundant in zone KW-5, being more abundant than any other aquatic type in this sequence. It grows in still water in lakes of oligotrophic to dystrophic nutrient levels or pools at a water depth of 0.5-2.0 m and roots in fine organic soil (Haslam *et al.* 1975).

The only macrophytes included in the 'submerged macrophyte' habitat group that are exclusively submerged are those included in the pollen types of *Myriophyllum spicatum*, *Myriophyllum verticillatum*, and *Potamogeton pectinatus*. These types occur sporadically at low relative frequencies. *Potamogeton crispus* type, which includes species capable of living in either deep or shallow water, either submerged or floating, and subterrestrially in dried-up

situations, also occurs infrequently at low relative frequencies. *Hydrocotyle vulgaris*, which may be submerged or emergent, occurs more often and at higher relative frequencies.

6.5.2.3 Wetland (local) pollen assemblage zones

Wetland pollen diagrams are divided into 14 local pollen assemblage zones KW-1 to KW-14, based mostly on relative frequency data. These are defined below.

Zone KW-14, 396.0-372.5 cm This basal zone is characterised by high relative frequencies of *Glyceria* type (45.3-68.7%) and *Carex flacca* type (19.5-36.5% in the three lowest spectra, but then at 0-9.4%). *Carex hallerana* type fluctuates from 1.2-8.2% and *Mentha* type from 1.2-10.1%. Several emergent types occur sporadically, but reach significant abundance when they occur: *Phragmites australis* reaches 6.1% in the basal spectrum, *Scirpus* and *Sparganium erectum* reach zonal maxima in the uppermost spectrum (3.6% and 7.9%, respectively), *Cyperus longus* type reaches 7.3% in the basal spectrum, and *Equisetum* occurs at 380 cm only at 3.7%. All other emergents are represented at 2.0% or less.

Although poorly represented aquatic types occur in all spectra except the basal one, but total relative frequency does not exceed 2.8% (recorded in the top spectrum). Five types occur. Two types exceed 1%; *Sparganium angustifolium* reaches 1.4% at 375 cm and *Hydrocotyle vulgaris* reaches 2.4% at 390 cm and 1.4% at 385 cm.

Zone KW-13, 372.5-347.5 cm The boundary with the preceding zone is marked by a decline in the relative frequency of *Glyceria* type and an increase in *Scirpus*. This zone is characterised by the co-dominance of *Scirpus* and *Glyceria* type. Both types generally record from about 32-42% with the exception of the spectrum second from the top where *Scirpus* increases to 71.5% and *Glyceria* type declines to 16.8%. *Carex hallerana* type records 8.6% in the basal spectrum, but then drops to 3.1% and then declines further to 1.8% in the uppermost spectrum. Frequencies of *Mentha* type are highest in the centre of the zone reaching a maximum of 12.2%, but the basal spectrum records 4.1% and the two uppermost record 2.2 and 2.7%. Several emergent types occur sporadically: *Carex flacca* type is absent apart from the uppermost spectrum where it records 12.5%, *Phragmites australis* is absent apart from the spectrum second from the top where 2.9% is recorded, *Schoenus nigricans* occurs in only the basal and following spectra (2.5 and 0.5%), and *Sparganium erectum* reaches highest values in the basal and uppermost spectra (5.1 and 13.4%, respectively), but other values are only 2.2% or less. No other emergent type exceeds 1.8%.

Representation of aquatic types is very low; total frequency does not exceed 1.5%. *Sparganium angustifolium* and *Hydrocotyle vulgaris* only are represented at 1.1% or less.

Zone KW-12, 347.5-312.5 cm The boundary with the preceding zone is marked by a further decline in *Glyceria* type and a dramatic increase in *Sparganium erectum*. The zone is

characterised by the co-dominance of *Sparganium erectum* (21.1-66.0%, except at 325 cm where only 3.6% is recorded) and *Scirpus* (18.4-64.6%). Relative frequencies of *Glyceria* type are still comparatively high (7.3-18.7%). *Carex hallerana* type ranges from 2.7-10.3%, being highest in the centre three spectra. *Mentha* type has declined (2.2% and less). *Cyperus longus* type occurs sporadically, but reaches 7.7% at 325 cm. *Cyperus michelianus* also occurs sporadically, but reaches 2.6% at 330 cm. No other emergent type exceeds 2.0%.

Aquatic types are again very rare, occurring in 4 of the 7 spectra of the zone; total frequency does not exceed 2.5%. More types are represented (7) than in the zone below, but only *Sparganium angustifolium* exceeds 1.0%, reaching 1.4% at 335 cm.

Zone KW-11, 312.5-287.5 cm The boundary with the preceding zone is marked by an increase in the relative frequency of *Carex hallerana* type and *Cyperus michelianus*, and a decrease in *Glyceria* type and *Sparganium erectum*. The zone is characterised by high relative frequencies of *Carex hallerana* type (24.0-62.1%) and *Scirpus* (19.3-65.3%), with *Cyperus michelianus* (4.9-14.0%) also abundant. *Glyceria* type declines to 2.0% and less. No other emergent type exceeds 2.0%.

Aquatic types are again very rare but occur in all spectra; total frequency does not exceed 0.2%. Five types are represented, but no individual type exceeds 0.1%.

Zone KW-10, 287.5-237.5 cm The boundary with the preceding zone is marked by a decline in the relative frequency of *Carex hallerana* type and an increase in *Glyceria* type. The zone is characterised by high relative frequencies of *Cyperus michelianus*, *Glyceria* type, *Sparganium erectum*, and *Scirpus*. *Carex hallerana* type is also abundant. Frequencies of these types fluctuate, being most constant in *Scirpus* (17.7-50.0%). *Glyceria* type records 7.4-33.6%, *Cyperus michelianus* 2.0-18.9% (with one exceptionally high value of 33.9%), *Sparganium erectum* 0.8-37.3%, and *Carex hallerana* type 5.8-45.2%. *Mentha* type and *Equisetum* occur sporadically, but reach 15.5% and 17.9%, respectively. *Schoenus nigricans* and *Phragmites australis* also occur sporadically and reach lower values of 3.2% and 5.7%, respectively. No other emergent type exceeds 2.1%.

Aquatic types occur in all spectra except the basal spectrum; total frequency exceeds 2.0% at only 240 cm where it reaches 3.3%. Five types are represented, but only *Hydrocotyle vulgaris* exceeds 1.0%, reaching 1.4% at 270 cm and 2.9% at 240 cm.

Zone KW-9, 237.5-202.5 cm The boundary with the preceding zone is marked by an increase in the relative frequency of *Scirpus* and a decline in *Glyceria* type and *Sparganium erectum*. The zone is characterised by high relative frequencies of *Carex hallerana* type (20.9-30.3% with the exception of the basal spectrum, which is 8.6%) and *Scirpus* (33.1-68.0%). *Cyperus michelianus* and *Glyceria* type are comparatively abundant recording 4.0-5.9% (with one exceptionally high value of 16.6%) and 2.1-10.5% (with one exceptionally

high value of 21.1%), respectively. *Mentha* type occurs in all spectra usually at less than 3.0%, but increases to 8.2% at 210 cm. *Equisetum* occurs in all spectra except one at 0.1-2.9%, with the exception of the uppermost spectrum where it increases to 18.2%. No other emergent type exceeds 1.7%.

Aquatic types occur in all spectra, but total frequency does not exceed 1.7%. Four types are represented; only *Ranunculus aquatilis* exceeds 0.5%, reaching 1.7% at 214 cm.

Zone KW-8, 202.5-163.5 cm The boundary with the preceding zone is marked by an increase in the relative frequency of *Schoenus nigricans*, *Carex flacca* type, *Cyperus longus* type, and *Sparganium erectum*, and a decline in *Carex hallerana* type and *Cyperus michelianus*. The zone is characterised by high relative frequencies of *Schoenus nigricans*, *Glyceria* type, and *Scirpus*. *Schoenus nigricans* shows a general increase from the basal spectrum to the uppermost (6.7-20.6%). *Scirpus* also shows a general increase from the basal spectrum to the uppermost (39.2-58.4%) with the exception of a decline to 29.4% at 170 cm, while *Glyceria* type is reasonably constant (11.7-28.0%). *Carex flacca* type reaches its highest value of 5.5% at 190 cm. *Cyperus longus* type increases in the lower part of the zone (5.7-9.7%), but then declines (0.7-1.7%). Frequencies of *Sparganium erectum* increase in the lower part of the zone (3.2-9.0%), but then decline (1.3-2.2%). *Phragmites australis* fluctuates from 0.7-4.7% generally, but at 170 cm increases to 13.6%. *Equisetum* shows a steadily declining trend from 10.3% in the basal spectrum to 0.7% in the uppermost. *Carex hallerana* type and *Cyperus michelianus* have declined and occur sporadically. They exceed 2.0% in only two spectra and neither exceeds 3.0%. No other emergent type exceeds 1.8%.

Aquatic types occur in 6 of the 9 spectra of this zone. Total frequency exceeds 2.0% only at 170 cm, reaching 2.9%. Five types are represented, but only *Sparganium angustifolium* and *Stratiotes aloides* exceed 1.0%, reaching 1.1% at 197 cm and 2.5% at 170 cm, respectively.

Zone KW-7, 163.5-142.5 cm The boundary with the preceding zone is marked by an increase in the relative frequency of *Carex hallerana* type and a decline in *Scirpus*. The zone is characterised by high relative frequencies of *Carex hallerana* type, *Schoenus nigricans*, *Glyceria* type, and *Scirpus*. *Glyceria* type records the highest frequencies (22.0-42.1%). *Carex hallerana* type records 13.5-15.8% with the exception of the uppermost spectrum where it declines to 0.9%. *Schoenus nigricans* records slightly lower frequencies (5.6-11.6%), except in the uppermost spectrum, where it increases (15.8%). *Scirpus* declines from a basal value of 35.8% to 6.1% in the uppermost spectrum.

Other emergent types that record 2.0% or more are: *Phragmites australis* (2.1-7.9%); *Mentha* type (0.9-9.3%); *Cyperus longus* type, which has declined (0.9-4.2%); *Carex flacca* type, which occurs in the three lower spectra only (3.1-4.8%); *Saxifraga stellaris*, which

occurs in the three centre spectra only (0.8-2.3%); *Cyperus michelianus*, which also occurs in the three centre spectra only (1.0-2.4%); *Chrysosplenium alternifolium*, which occurs in the four upper spectra (0.8-6.1%); *Sparganium erectum*, occurs in the four upper spectra also (2.3-13.2%); *Berula erecta*, which occurs sporadically, but reaches 2.0% at 160 cm; *Filipendula*, which occurs in two spectra (0.4 and 2.3%); *Equisetum*, which occurs in one spectrum only (4.2%); and *Typha angustifolia* type, which occurs in two spectra (0.9 and 16.4%).

Aquatic taxa are represented in 4 of the 5 spectra; total frequency exceeds 2.0% in only 2 spectra, 3.2% at 162 cm and 3.5% at 150 cm. Four types are represented, only 3 types exceed 1.0%: *Hydrocotyle vulgaris* (2.1% at 162 cm and 2.3% at 150 cm), *Myriophyllum verticillatum* (1.2% at 150 cm), and *Sparganium angustifolium* (1.1% at 162 cm).

Zone KW-6, 142.5-117.5 cm The boundary with the preceding zone is marked by an increase in the relative frequency of *Cyperus longus* type and decrease in *Carex hallerana* type and *Schoenus nigricans*. The zone is characterised by high relative frequencies of *Cyperus longus* type, *Glyceria* type, and *Scirpus*. *Glyceria* type has the highest frequencies of the zone (32.1-53.5%). *Cyperus longus* type rises steadily from 8.5% in the basal spectrum (with the exception of 5.1% in the second spectrum) to 15.5% in the uppermost spectrum. *Scirpus* rises from 9.9% in the basal spectrum to a maximum of 19.2% in the centre of the zone, then declines to 13.1% in the uppermost spectrum. *Phragmites australis* is comparatively abundant, recording 4.1-6.0%, with a peak in the centre of the zone at 132 cm of 20.2%.

Many emergent types occur at low frequencies: *Berula erecta* (5 spectra at 0.6-4.6%); *Carex flacca* type (first 4 spectra at 0-1.8%, then 13.7 and 10.7%); *Carex hallerana* type (sporadic occurrence, but reaches 8.9% at 135 cm); *Chrysosplenium alternifolium* (sporadic occurrence, reaches 2.7 and 2.4% in 2 spectra); *Cyperus michelianus* (sporadic occurrence, reaches 7.5% at 124 cm); *Equisetum* (1.4-5.5% in lower 4 spectra); *Mentha* type (sporadic occurrence, but exceeds 2.0% in 2 spectra – 5.6 and 4.1%); *Sparganium erectum* (sporadic occurrence, reaches 9.5% at 120 cm); and *Caltha* type (sporadic occurrence, but reaches 2.4 cm at 120 cm). No other emergent type exceeds 2.0%.

Aquatic types are represented in all spectra. Total frequency exceeds 2.0% in 3 of the 6 spectra; 4.2% at 140 cm, 5.5% at 132 cm, and 2.5% at 124 cm. Only five aquatic types are represented, but frequencies have increased. Five types exceed 1.0%: *Hydrocotyle vulgaris* (2.8% at 140 cm, 1.3% at 135 cm, 1.4% at 130 cm, and 1.9% at 124 cm), *Myriophyllum spicatum* (2.8% at 132 cm), *Sparganium angustifolium* (1.2% at 120 cm), *Hydrocharis morsus-ranae* (1.8% at 132 cm), and *Stratiotes aloides* (1.4% at 140 cm).

Zone KW-5, 117.5-77.5 cm The boundary with the preceding zone is marked by an increase in the relative frequency of *Sparganium erectum* and *Sparganium angustifolium*. The zone is characterised by high relative frequencies of *Cyperus longus* type, *Glyceria* type,

Sparganium erectum, and *Sparganium angustifolium*. The first three types represent emergent plants while the last represents a plant that is usually a floating-leaved aquatic. Although *Glyceria* type has declined, in general it has the highest relative frequencies of the zone – usually from 20.3-31.7% (2 spectra record only 7.6 and 9.3%). *Sparganium erectum* fluctuates also, but in general records 10.7-30.7% (only 1.6% and 7.3% in the two uppermost spectra). *Cyperus longus* type displays a general increase (10.9-34.1%). *Sparganium angustifolium* ranges from 4.8-25.0% in the lower 6 spectra, then disappears.

Other emergents that are abundant are: *Scirpus* (4.8-12.2%), *Phragmites australis* recording mostly 3.8-10.8% (but declining to 0.7 and 1.2% in two spectra), and *Typha angustifolia* type and *Typha domingensis* type both occurring sporadically but recording comparatively high frequencies where they occur (maximums of 7.6% and 9.5%, respectively). Other emergents that are less abundant, but record 2.0% or more are: *Berula erecta* (occurs sporadically, but reaches 3.3 and 4.8% in 2 spectra); *Caltha* type (occurs sporadically, reaches 3.2% at 85 cm); *Carex flacca* type (occurs sporadically, reaches 4.8 and 2.4% in 2 spectra); *Carex hallerana* type (occurs sporadically, reaches 11.1 and 2.5% in two spectrum); *Cyperus michelianus* (occurs sporadically, reaches 2.2% in one spectrum); *Mentha* type (occurs sporadically, reaches 4.8% in 2 spectra and 2.4% in one spectrum); *Samolus valerandi* (occurs sporadically, reaches 3.2% in one spectrum); and *Schoenus nigricans* (occurs in only the basal spectrum at 6.5%).

Aquatic types are represented in all spectra; total frequency exceeds 2.0% in all spectra except the surface spectrum. Only four types are represented, but frequencies have increased again. All types represented exceed 1.0%: *Hydrocotyle vulgaris* (3.2% at 105 cm and 1.2% at 80 cm), *Salvinia natans* (1.2% at 90 cm and 1.6% at 85 cm), *Sparganium angustifolium* (discussed above), and *Hydrocharis morsus-ranae* (1.2% at 90 cm and 1.6% at 85 cm).

Zone KW-4, 77.5-67.5 cm The boundary with the preceding zone is marked by an increase in the relative frequency of *Sparganium erectum* and a decline in *Cyperus longus* type and *Glyceria* type. The zone is characterised by high relative frequencies of *Cyperus longus* type (19.9 and 23.4%) and *Sparganium erectum* (57.7 and 35.5%). Other emergents exceeding 2.0% are: *Carex flacca* type (3.4 and 4.7%), *Carex hallerana* type (one spectrum only at 2.8%), *Cyperus michelianus* (0.7 and 2.8%), *Glyceria* type (4.1 and 10.3%), *Mentha* type (1.1 and 3.7%), *Scirpus* (4.5 and 5.6%), and *Typha domingensis* type (basal spectrum only at 3.7%).

Aquatic types are represented in both spectra; total frequency exceeds 2.0% in both. Only three types are represented. Two types exceed 1.0%; *Ranunculus aquatilis* type (1.9% at 70 cm) and *Sparganium angustifolium* (1.9% at 75 cm and 4.7% at 70 cm).

Zone KW-3, 67.5-32.5 cm The boundary with the preceding zone is marked by increases in the relative frequency of *Carex hallerana* type and *Glyceria* type and a decline in *Sparganium erectum*. The zone is characterised by high relative frequencies of *Carex hallerana* type, *Cyperus longus* type, *Glyceria* type, *Phragmites australis*, and *Scirpus*. *Glyceria* type has the highest overall relative frequencies (12.0-50.0%). *Scirpus* records an initial low relative frequency (7.0%), increases to 25.3%, then declines (2.4-12.2% in the upper four spectra). *Cyperus longus* type declines irregularly from 36.8 to 4.9% before a final increase to 42.3%. *Carex hallerana* type fluctuates also (1.8-16.4%). *Phragmites australis* is absent from the basal spectrum, records low values in the next two spectra and the two uppermost spectra (3.6-10.0%), and peaks in the two central spectra (32.5-18.3%).

Other emergent types that occur at 2.0% or greater are: *Carex flacca* (0-3.6%), *Cyperus michelianus* (5.9-15.8% at the top and bottom of the zone, but 1.2-2.0% in the centre), *Mentha* type (0.9-4.8%), *Ranunculus acris* group (0 except for two central spectra, which record 1.0 and 3.6%), *Schoenus nigricans* (0 except for two spectra recording 1.0 and 5.0%), *Sparganium erectum* (0 in one spectrum, elsewhere 1.2-8.2%), *Typha angustifolia* type (0-2.3%), and *Typha domingensis* type (0 and 0.5%, but one spectrum reaches 3.5%).

Aquatic types are represented in 5 of the 7 spectra; total frequency exceeds 2% at only 55 and 50 cm. Four aquatic types are represented, but only three of these exceed 1.0%; *Hydrocharis morsus-ranae* (1.8% at 60 cm), *Hydrocotyle vulgaris* (1.8% at 65 cm, 2.0% at 55 cm, and 6.0% at 50 cm) and *Ranunculus aquatilis* type (1.2% at 50 cm).

Zone KW-2, 32.5-17.5 cm The boundary with the preceding zone is marked by an increase in the relative frequency of *Sparganium erectum* and decreases in *Carex hallerana* type, *Glyceria* type, and *Scirpus*. The zone is characterised by high relative frequencies of *Cyperus longus* type (19.0-45.5%), *Glyceria* type (16.0-22.6%), and *Sparganium erectum* (10.9-31.0%). *Carex hallerana* type is comparatively abundant, recording 5.5-7.6%.

Other emergent types that exceed 2.0% are: *Caltha* type (the uppermost spectra reaches 2.3%), *Cyperus michelianus* (reaches 3.6% in the central spectrum), *Narthecium scardicum* (occurs in the central spectrum only at 2.4%), *Schoenus nigricans* (occurs sporadically, but reaches 5.5% in one spectrum), *Scirpus* (occurs in only two spectra at 3.6 and 2.3%), and *Typha angustifolia* type (occurs sporadically, but reaches 3.1% in the uppermost spectrum).

Aquatic types are represented in all spectra; total frequency exceeds 2.0% only at 25 cm. Only three types are represented, and all exceed 1.0%: *Callitriche stagnalis* type (3.6% at 25 cm), *Ranunculus aquatilis* type (1.8% at 30 cm), and *Sparganium angustifolium* (1.2% at 25 cm).

Zone KW-1, 17.5-0 cm The boundary with the preceding zone is marked by an increase in the relative frequency of *Carex flacca* type and *Cyperus longus* type, and a decrease in

Glyceria type, *Phragmites australis*, *Sparganium erectum*, and *Scirpus*. The zone is characterised by high relative frequencies of *Cyperus longus* type (37.3-81.4%) and *Carex flacca* type (3.3-11.0%, with a sharp increase in the second spectrum to 44.6%). Other emergent types represented are: *Cyperus michelianus*, which occurs sporadically but increases to 13.1% in the surface sample, *Glyceria* type, which is comparatively abundant but declines from 8.8-1.4%, and *Sparganium erectum*, which fluctuates from 1.3-9.7%. Less abundant emergent types are: *Carex hallerana* type (occurs sporadically but records a maximum of 7.9% in the basal spectrum), *Equisetum* (occurs sporadically but reaches 2.8% in the surface spectrum), and *Mentha* type (reaches a maximum of 2.0%). No other emergent type exceeds 2.0%.

Aquatic types are poorly represented, but occur in all spectra; total frequency does not exceed 1.1%. The number of types represented has increased to six, but no type exceeds 1.0%.

6.5.2.4 Sedimentary and local vegetation history

This sequence records the local (wetland) vegetation and sedimentary history of the Kellia wetland site. Radiocarbon dating suggests that it covers two periods of alluviation, an older period below 312 cm (occurring perhaps after 830 BC and spanning 200 years, see section 6.4.2) and a younger one above, which may span about the last 760 years beginning c. 1230 AD.

Stratigraphic data indicate that Kellia fen may have formed in an old stream course that ran from west to east with a terrace on the northern side (Figures 6.2 & 6.4). The entire sequence represents a combination of fen and stream deposits and consists of three major units. The uppermost c. 20 cm consists of silty peat on the western and southern part of the fen, close to the spring. The organic content of this unit is generally higher than that of horizons rich in organic matter lower in the sequence. Towards the northern edge and the eastern (downstream) end of the fen, the unit becomes less peaty and is replaced by brown clay with a sandy layer at the base. This unit may be related to establishment of the modern sealed road and its causeway, which may have reduced the transport of sediment into the fen from the catchment upstream. Below this uppermost unit are up to 450 cm of greyish olive to olive black clay with variable proportions of calcareous grit, peat, and organic detritus. Thin (5-15 cm) noncalcareous sand horizons are rare. Persistent organic-rich horizons occur at c. 100 and 230 cm. Below about 300 cm, there is little organic matter in the stiff to soft greyish olive clay comprising the basal part of the unit. Occasional small mollusc shells and fruits or corms were noted in some cores, but no pattern to their occurrence was determined. The lowest unit, somewhat heterogeneous, consists of muddy yellow sand, yellow-brown silt,

and clay with ferruginous mottling and nodules. In the most easterly borehole, gravel occurs at the base of sequence.

In the pollen analysed core, sediments are mostly greyish olive calcareous clay. Deposits of the current fen area are partly derived from soils of the catchment area, with a proportion being contributed by internal wetland productivity, i.e. autochthonous peat. Changes in the non-carbonate content of sediments reflect past changes in the catchment area related to differing rates of soil erosion. Peat developed during periods of relative soil stability in the catchment when water level was sufficient, at 183.0-67.5 and 32.5-0 cm. However, during these periods of relative stability some minerogenic sediments were washed into the fen area. Organic rich deposits containing organic detritus also indicate periods of comparative landscape stability when plants were able to become established in the catchment. These occur from 312.0-287.5 and 235.0-216.0 cm. Periods of high energy stream flow are indicated where minerogenic sediments of larger grain size (sand) occur; 271.0-268.0, 264.0-235.0, 143.0-133.0, 132-121, and 52.0-32.5 cm. The source of carbonate in the sediments is uncertain; it may be allochthonous (derived from calcic soils of the catchment) or autochthonous (precipitated from the spring water).

Several changes occur in the dominant local vegetation. At the base of the sequence local vegetation is dominated by the wetland reed-grass pollen type of *Glyceria* type. However, oxidation may have selectively removed some pollen types. In the overlying sediment horizon *Glyceria* type is co-dominant with *Scirpus* species, then *Scirpus* species and *Sparganium erectum* become co-dominant. When influx of minerogenic sediments declines at 312.0 cm, species belonging to the *Carex hallerana* type, *Cyperus michelianus* and *Scirpus* are co-dominant. At 287.5 cm where influx of minerogenic sediments increases the concentration of all pollen and spore types declines dramatically and *Scirpus* species become dominant again, with *Cyperus michelianus*, *Glyceria*, and *Sparganium erectum* also abundant. At 237.0 cm where minerogenic influx declines again and total concentration of pollen and spores increases, *Scirpus* species increase dramatically, but species of *Carex hallerana* type, *Cyperus michelianus*, and wetland reed-grasses of the *Glyceria* type are again prominent. During the next phase of minerogenic influx *Scirpus* species and the wetland reed-grasses maintain their dominance and *Schoenus nigricans* also becomes prominent. These species continue to be dominant during the formation of peat at 183 cm, but at 165 cm when additional minerogenic sediment is deposited *Scirpus* declines. *Schoenus nigricans* continues to be important up to 145 cm and *Carex hallerana* type increases between 162 and 150 cm. *Glyceria* type increases from 162 cm and *Cyperus longus* type begins steadily increasing at 140 cm. Wetland reed-grasses and species of the *Cyperus longus* type dominate the remainder of the sequence from 140 cm, with the exception of *Sparganium erectum* becoming prominent

during peat formation at 121.0-67.5 cm and reed-grasses almost disappearing at the surface. At the surface *Cyperus longus* type is dominant, and *Carex flacca* type, *Cyperus michelianus*, and *Sparganium erectum* increase.

The sedimentary history of the fen is intimately linked to the local wetland vegetation history, thus major sedimentary units defined above usually coincide with the established wetland pollen zones. These zones are used, for convenience, in the discussion below.

Zone KW-14, 396.0-372.5 cm, within range c. 830-630 BC The lowest sediment section plus a small part of the overlying section correspond to this zone (sections N and M). The basal section at 396-376 cm comprises very stiff mottled grey and brown clay with calcareous and ferruginous grit. Ferruginous grit and mottling may indicate weathering prior to deposition of an overlying unit or subsurface water circulation. The sediments contain little organic matter and carbonate content is low.

At the base of the sequence the dominant plant community is the true-reed swamp, which is represented almost entirely by *Glyceria* type. A tall-sedge-swamp community has also developed, but declines towards the top of the zone. A small wet-soil community exists with *Carex hallerana* type and *Mentha* type being most abundant. Both floating-leaved and submerged communities of open water are represented by a few pollen and spore types.

The dominant type, *Glyceria* type, includes the reed-grasses *Glyceria maxima* and *G. spicata* as well as many species of the genus *Bromus*. The *Glyceria* species are perennials that grow in marshy ground or shallow water and currently grow on the seasonally dry lakebed at the Gomara core site. The *Bromus* species grow on dryland and are mostly annual weeds and ruderals, but also grow in grassland. However, the presence of members of the tall-sedge-swamp community suggests that the environment of deposition at this time was that of a flood plain with seasonal flooding; a river-bank reed strip (Ellenberg 1988). Of the two submerged aquatic macrophytes that are represented, *Hydrocotyle vulgaris* and *Myriophyllum spicatum*, the former may be submerged or emergent, while the latter is exclusively submerged and may have been growing in holes within the reed strip, i.e. in shallow and relatively humus-rich water. Concentration of wetland pollen and spores is low (total concentration of this horizon does not exceed 1.7×10^3 grains/cm³) and selective oxidation in this horizon may complicate the picture by removing particular pollen and spore types. The low palynological richness (mostly 6-8 expected types) of this horizon may be a result of this. Nutrient level is probably very high as *Glyceria maxima* grows in eutrophic conditions and *Carex* species of the *Carex flacca* type grow in meso- to eutrophic conditions (Ellenberg 1988).

The overlying sediment horizon, above 376 cm comprises sticky soft grey clay with scattered gastropods and a trace of calcareous grit. Carbonate and organic content are unchanged from the horizon below, and there is little visible plant material. Total

concentration of wetland pollen and spores increases to the maximum of the zone of 2.4×10^3 grains/cm³ at 375 cm and palynological richness is slightly greater than 10 expected types. The concentration of *Glyceria* type increases at the top of the zone while that of *Carex flacca* type declines, perhaps due to more rapid influx of minerogenic sediments (*Glyceria* is able to tolerate silting, often growing on clay or alluvium where silting occurs (Haslam *et al.* 1975)). The appearance of the aquatic plants of *Nymphaea alba* (floating-leaved macrophyte) and *Potamogeton crispus* type (probably the submerged macrophyte *Potamogeton natans*) suggests the presence of eutrophic standing water with a community of *Myriophyllum-Nupharetum* (Ellenberg 1988). This standing water may be on the side of a stream or on a fen.

Zone KW-13, 372.5-347.5 cm, within range c. 830-630 BC The sediments of this zone are included in sediment section M and are the same as those described above, but the vegetation changes. The true-reed-swamp community continues to be the dominant community, but *Scirpus* is now abundant and is co-dominant type with *Glyceria* type. The wet-soil community continues to be represented at about the same level, although *Mentha* type has become more important than *Carex hallerana* type. The tall-sedge community has almost disappeared and the stream-reed-swamp community has very low representation. Representation of the aquatic communities has declined slightly at the base of the zone and continues to decline towards the top. Both the floating-leaved and submerged macrophytes are represented; the former by *Sparganium angustifolium* and the latter by *Hydrocotyle vulgaris*.

The *Scirpus* pollen type includes two species of the genus *Scirpus*: *Scirpus lacustris* and *S. maritimus*. These species grow in lakes, ponds, and streams; in still to moderately fast flowing water. In still sheltered water they grow in water depths between one and two metres, but in flowing water they usually grow in water between 30 and 80 cm deep. They grow in eutrophic conditions in flowing water to oligotrophic in still water. They can be submerged or emergent. *Scirpus maritimus* can tolerate summer drought (Haslam *et al.* 1975), while *Scirpus lacustris* can grow in water and carry out photosynthesis while submerged (Ellenberg 1988). *Scirpus maritimus* usually grows in saline conditions so the species represented here is probably *S. lacustris* (Tutin *et al.* 1964-80). *Scirpus lacustris* (Common Clubrush) has two subspecies *S. lacustris* subsp. *lacustris* grows in fresh water while *S. lacustris* subsp. *tabernaemontani* grows in brackish water (Tutin *et al.* 1964-80). In calm lakes *Scirpus* is known to be a pioneer (Ellenberg 1988). Plants of the genus *Scirpus* are abundant on the fen today (Chapter 3). *Scirpus* may be colonising newly deposited sediment.

Available nutrient level is high as indicated by the abundance of *Glyceria* type and *Scirpus* and the occurrence of *Sparganium erectum* (Haslam *et al.* 1975; Ellenberg 1988).

Zone KW-12, 347.5-312.5 cm, within range c. 830-630 BC The sediments of this zone are included in sediment section M and are the same as those of zone KW-13, but organic content increases slightly, inorganic matter declines steadily, and the moisture content increases. The true-reed-swamp community continues to be the dominant community, but *Sparganium erectum* is now co-dominant with *Scirpus*. *Glyceria* type has declined further, but continues to be prominent. The wet-soil community continues to be represented at about the same level, but there is a shift from *Mentha* type to *Carex hallerana* type being the most abundant. The tall-sedge-swamp community continues to have low representation, and the stream-reed-swamp community has declined. Aquatic communities have declined further (but increase in the uppermost spectrum) and are represented only sporadically.

Sparganium erectum (the Branched Bur-reed) grows in lakes, ponds, ditches, and streams, in still to moderately fast flowing water rooted on margins up to 1 m deep, and also just above mean water level (Haslam *et al.* 1975). It is a widely distributed stream plant and flourishes in a weak current (Ellenberg 1988). It grows in mesotrophic to eutrophic conditions on mineral or organic soil, but often on clay. It is usually emergent but sometimes is submerged or floating (Haslam *et al.* 1975). *Sparganium erectum* does not form dense stands and seldom exceeds 1 m in height. Thus it plays only a subordinate role in established reed swamps, and is succeeded by large-sedge swamps (Ellenberg 1988). Here, it may be forming part of a succession of fen plants with the pioneer *Scirpus*. *Sparganium erectum* is abundant on the fen today (Chapter 3). It is one of the most productive plants in the temperate zone (Ellenberg 1988), so may contribute much of the organic material recorded in the sediments of this zone.

The number of aquatic types increases to 6 in the uppermost spectrum. This may be indicative of an expansion of fen aquatic vegetation. Palynological richness increases from the base of the zone to the top (6-8 expected types). Total wetland pollen and spore concentration increases slightly reaching a maximum of 4.3×10^3 grains/cm³ at 335 cm.

Available nutrients are high as indicated by the abundance of *Glyceria* type, *Sparganium erectum*, and *Scirpus* and the presence of *Callitriche stagnalis* type (which here may be growing in temporary pools (Haslam *et al.* 1975)), *Ranunculus aquatilis* group, *Hydrocharis morsus-ranae*, which grows in nutrient rich shallow ponds of lowland flood plains, and *Salvinia natans*, which grows in holes within a flooded sedge fen, i.e. in shallow and relatively humus-rich water (Haslam *et al.* 1975; Ellenberg 1988).

Zone KW-11, 312.5-287.5 cm, c. 1230-1320 AD This zone corresponds to sediment section L. The lower boundary of this zone coincides with a change in sediment composition to one of muddy detritus with horizontal layering of herbaceous material. Organic content increases significantly, inorganic matter declines, and carbonate content increases slightly.

Community dominance has abruptly shifted from the *Sparganium erectum*-*Scirpus* dominated true-reed swamp of KW-12 to the wet-soil community where *Carex hallerana* type is the dominant type. All other types in this community are extremely poorly represented, with the exception of *Schoenus nigricans*. The second most important community is that of the true-reed swamp, with *Scirpus* the dominant type. The tall-sedge-swamp community has expanded and is next most abundant, with *Cyperus michelianus* the only type represented. The stream-reed-swamp community continues to be extremely poorly represented. Aquatic communities have declined even further and have almost disappeared.

Total wetland pollen and spore concentration increases to more than eight times that of the preceding zone ($26-42 \times 10^3$ grains/cm³) and reaches a maximum similar to that of today. A sudden increase in concentration, at the boundary with the preceding zone, to more than five times that of the preceding zone, together with the change in wetland communities suggests that a catastrophic event took place. This evidence, as well as two radiocarbon dates (one at the top of the preceding zone and one at the base of this zone, which differ by perhaps c. 1800-3300 years), suggests that a hiatus occurs at the boundary between this and the zone below. This hiatus may be caused by erosion, or sediment by-passing due to a deeper stream channel.

Emergent plants that the dominant types probably represent: *Scirpus lacustris* (a pioneer), *Cyperus michelianus* (an annual), and *Scirpus holoschoenus* and *S. sylvaticus* (of the pollen type *Carex hallerana* type); and the aquatic plants represented suggest an environment of an establishing sedge and reed fen swamp with pools of water.

Available nutrients are high as suggested by the abundance of *Scirpus* and the presence of *Hydrocharis morsus-ranae*, *Myriophyllum verticillatum*, *Potamogeton crispus* type, and *Potamogeton pectinatus* (Haslam *et al.* 1975; Ellenberg 1988).

Zone KW-10, 287.5-237.5 cm, c. 1320-1370 AD This zone corresponds to sediment section K. The lower boundary of this zone coincides with a change in sediment composition to stiff clay and silt with detritus that continues up to 271 cm. Three further complete sediment horizons and part of another are also included. These horizons comprise a series of minerogenic sediments (some sandy) with high inorganic content, high carbonate content, and low organic and moisture content, and represent a period of accelerated erosion and stream flooding. Between 264 cm and the top of the zone charcoal particles were observed in the sediments, suggesting that land clearance by fire led to the erosion. Sandy horizons occur at 271-268 and 264 cm to the top of the zone, perhaps due to unusually heavy rain falling on bared soils and/or stream flooding.

The dominant community is again the true-reed-swamp community. Although *Scirpus* is the dominant type, *Glyceria* type and *Sparganium erectum* are also important with *Phragmites australis* playing a minor but significant role. The wet-soil and tall-sedge-swamp

communities are almost equally abundant. The dominant types in the wet-soil community are *Carex hallerana* type and *Equisetum*, with *Mentha* type less abundant. In the tall-sedge-swamp community the annual *Cyperus michelianus* is again the only type of any importance, suggesting an unstable environment. The stream-reed-swamp community has gained slightly, with *Berula erecta* increasing. The frequency of the aquatic types increases slightly towards the top of the zone, due mostly to an increase in *Hydrocotyle vulgaris*.

Available nutrient level is high as indicated by the abundance of *Scirpus*, *Sparganium erectum*, and *Glyceria* type, and the occurrence of *Ranunculus aquatilis* group, *Hydrocharis morsus-ranae*, *Salvinia natans*, and *Vallisneria spiralis* (Haslam *et al.* 1975; Ellenberg 1988).

Total concentration of wetland pollen and spores is very low ($0.6\text{--}3.9 \times 10^3$ grain/cm³) except in the lowest spectrum, which records 8.7×10^3 grain/cm³, suggesting rapid accumulation of sediments and reduced wetland vegetation. *Scirpus* is the only type with many pollen grains represented and even this type reaches a maximum of only 2×10^3 grain/cm³.

Palynological richness increases from the base of the zone to the top to comparatively moderate values for this sequence (6-11 expected types) due to an increase in types representing the wet-soil communities.

Zone KW-9, 237.5-202.5 cm, c. 1370-1480 AD The sediments of this zone correspond to the sediment sections of J and I. A change in sediment composition occurs at 235 cm where sediments become highly organic and moisture content increases; carbonate content and inorganic matter decline. This horizon consists of a mixture of equal proportions of coarse herbaceous detritus and clay. At 216 cm sediment composition changes to one with a higher proportion of inorganic sediment, slightly more carbonate, and lower organic matter and moisture content: this is sediment section I – stiff grey clay with a trace of coarse herbaceous detritus and calcareous grit.

The dominant community continues to be the true-reed-swamp community with *Scirpus* the dominant type. *Glyceria* type is still important, but *Sparganium erectum* has almost disappeared and *Phragmites australis* has declined. The wet-soil community is the second most prominent community; *Carex hallerana* type is dominant with *Mentha* type and *Equisetum* playing minor but significant roles. The tall-sedge-swamp community has declined in importance and the stream-reed-swamp community has also declined. Aquatic communities have also declined again especially the submerged macrophytes community, which has almost disappeared.

Total concentration of wetland pollen and spores increases quickly in the lower part of the zone to a maximum almost as high as that of the preceding organic detritus-rich zone (KW-11), a level similar to that of today (39×10^3 grains/cm³). The dominant types *Carex*

hallerana type, *Cyperus michelianus*, and *Scirpus* are also the same as those of the preceding detritus-rich zone. Rapid increase in the concentration of these types suggests that the plants represented by these types have recolonised the fresh sediment surface from a few relicts of the former vegetation on the site able to survive the deposition of sediment.

Total concentration of wetland pollen and spores declines rapidly with the influx of minerogenic sediment in the upper part of the zone ($3-8 \times 10^3$ grains/cm³), indicating very rapid sediment accumulation.

Available nutrient level is high as indicated by the abundance of *Scirpus*, *Glyceria* type, and the presence of *Ranunculus aquatilis* group, *Nuphar lutea*, and *Stratiotes aloides* (Haslam *et al.* 1975; Ellenberg 1988).

Zone KW-8, 202.5-163.5 cm, c. 1480-1640 AD This zone corresponds to sediment section H, which is characterised by high organic and moisture content and low inorganic matter and carbonate content. Several changes in sediment composition occur. Up to 200 cm sediments are stiff grey clay, as in the zone below. Between 200 and 196 cm the sediment comprises a mixture of equal proportions of friable calcareous grit and clay. It then changes to a stiff grey clay. At 183 cm peat formation begins indicating greater landscape stability. Initially peat is mixed with clay in equal proportions, then at 165 cm the clay content increases indicating increased inwashed sediment.

The true-reed-swamp community continues to be dominant, with *Scirpus* the dominant type. *Glyceria* type is the next most abundant, with *Phragmites australis* and *Sparganium erectum* playing equally significant roles. The wet-soil community is next most important with *Schoenus nigricans* the dominant type and *Equisetum* also important. *Carex hallerana* type and *Mentha* type have almost disappeared. The tall-sedge-swamp community is the next most important community. *Carex flacca* type and *Cyperus longus* type are now the most important types in this community; *Cyperus michelianus* has declined. The stream-reed-swamp community has expanded due to the increase of *Berula erecta*. Aquatic communities continue to be poorly represented with the exception of a peak of *Stratiotes aloides* in the second to uppermost spectrum. Otherwise, the floating-leaved macrophytes community is represented almost completely by *Sparganium angustifolium*.

Concentration of total wetland pollen and spores remains at about the same value (6.2×10^3 grains/cm³ maximum) as in the upper part of the preceding zone, which is relatively high for this sequence. Palynological richness increases to comparatively moderate values for this sequence, fluctuating between 8 and 12, except for the uppermost spectrum, which is about 7.

Available nutrients remain high, as indicated by the presence of the reed and sedge fen plants such as *Glyceria*, *Scirpus*, and *Sparganium erectum*, and the aquatic macrophytes of

Callitriche obtusangula, *Hydrocharis morsus-ranae*, and *Stratiotes aloides* (Haslam *et al.* 1975; Ellenberg 1988).

Vegetation on the wetland indicates a more stable environment, with lower values of the pioneer *Scirpus* and the annual *Cyperus michelianus* and greater abundance of *Carex flacca* type and *Cyperus longus* type of the tall-sedge-swamp community, which occur continuously. The early hydrosere *Sparganium erectum* has also declined. *Schoenus nigricans* of the small-sedge fen community has also increased significantly, indicating the establishment of the typical zonation of a sedge fen.

Zone KW-7, 163.5-142.5 cm, c. 1640-1680 AD This zone corresponds to sediment section G, where organic and moisture content decline and inorganic content increases. Carbonate content is low. The sediment of this zone is a mixture of mostly clay with some peat, with the exception of the uppermost 0.5 cm where the sediment comprises mostly coarse to very coarse noncalcareous sand with some calcareous grit and includes some clay and a trace of peat.

The true-reed-swamp community continues to be dominant, but *Glyceria* type is now the dominant type. *Scirpus* is now only slightly more important than *Phragmites australis* and *Sparganium erectum*. *Typha angustifolia* type displays a sudden peak in the basal spectrum. The wet-soil community is the next most prominent community; *Schoenus nigricans* continues to be important, but *Carex hallerana* type has expanded and is equally important. *Mentha* type and *Chrysosplenium alternifolium* are also important and *Equisetum* occurs only sporadically. The tall-sedge-swamp community has declined; *Carex flacca* type and *Cyperus longus* type have both declined and *Cyperus michelianus* continues at the same low level of representation. The stream-reed-swamp community increases very slightly due to an increase in *Berula erecta*. Aquatic communities increase due to an increase in *Hydrocotyle vulgaris*.

Available nutrients remain high, as indicated by the presence of the reed and sedge fen plants such as *Glyceria*, *Scirpus*, *Sparganium erectum*, *Typha domingensis* type, and *Typha angustifolia* type, and the aquatic macrophytes of *Nuphar lutea* and *Myriophyllum verticillatum* (Haslam *et al.* 1975; Ellenberg 1988).

Concentration of total wetland pollen and spores declines upwards and becomes very low at the top of the zone ($0.7-3.8 \times 10^3$ grains/cm³). This is probably due to increasing amounts of minerogenic soil being washed in and diluting the pollen concentration. The dominance of *Glyceria* may be due to the greater tolerance of that type to 'siltling'.

Minerogenic inwash, however, is not sufficient to interrupt development of the reed and sedge fen vegetation, although it is reduced; a variety of reed and sedge plants are represented and the pioneer *Scirpus* declines. *Salix fragilis* type now appears (today *Salix alba* grows on the fen and along the channel to the south of the fen (Chapter 3)).

Zone KW-6, 142.5-117.5 cm, c. 1680-1720 AD This zone corresponds to sediment section F, which is characterised by high inorganic and carbonate content and low organic and moisture content. The sediments comprise mostly coarse to very coarse noncalcareous sand with some calcareous grit and includes some clay and a trace of peat. A narrow band at 133-132 cm comprises clay with some peat. Above 121 cm is peaty clay (see zone KW-5).

The true-reed-swamp community is again the dominant community and *Glyceria* type the dominant type, perhaps being favoured again by the influx of minerogenic sediment. *Scirpus* retains its position of next most important before *Phragmites australis* and *Sparganium erectum*. The next most important community now shifts to the tall-sedge-swamp community with *Cyperus longus* type the dominant type increasing steadily. *Carex flacca* type becomes prominent in the upper part of the zone. The wet-soil community is next most important, but its importance has declined. Several types occur sporadically, but reach significant abundance. These include *Carex hallerana* type, *Mentha* type, and *Equisetum*. The stream-reed-swamp community has again increased slightly; again due to an increase in *Berula erecta*. The aquatic communities increase slightly, due to an increase in *Hydrocotyle vulgaris*.

Available nutrients remain high, as indicated by the presence of the reed and sedge fen plants such as *Glyceria*, *Scirpus*, and *Sparganium erectum*, and the aquatic macrophytes of *Hydrocharis morsus-ranae*, *Stratiotes aloides*, and *Myriophyllum spicatum* (Haslam *et al.* 1975; Ellenberg 1988).

Concentration of total wetland pollen and spores is very low with total concentration reaching only 1.4×10^3 grains/cm³. This is probably due to increasing amounts of minerogenic soil being washed in and diluting the pollen concentration. The dominance of *Glyceria* may be due to the greater tolerance of that type to 'silting'.

Zone KW-5, 117.5-77.5 cm, c. 1720-1790 AD This zone corresponds to sediment section E, which is characterised by comparatively high organic matter and moisture content and low inorganic content. Carbonate content declines upwards. The sediments are peaty clay, as at the top of the zone below. Total concentration of the wetland pollen and spores is again very low (only 2.2×10^3 grains/cm³ maximum).

The true-reed-swamp community continues to be the dominant community. *Glyceria* type and *Sparganium erectum* are co-dominant. *Phragmites australis* and *Scirpus* are about equally important. *Typha domingensis* type and *Typha angustifolia* type have gained in importance. The tall-sedge-swamp community is second most prominent, with *Cyperus longus* type the dominant type. *Carex flacca* type and *Cyperus michelianus* have both declined. The wet-soil community continues to be represented sporadically by a few types: *Carex hallerana* type, *Mentha* type, and *Schoenus nigricans*. The stream-reed swamp is

represented sporadically. As a whole the aquatic communities increase significantly due to a large increase in *Sparganium angustifolium*.

Available nutrients remain high, as indicated by the presence of the reed and sedge fen plants such as *Cyperus longus* type, *Glyceria*, *Scirpus*, *Sparganium erectum*, *Typha domingensis* type, and *Typha angustifolia* type, and the aquatic macrophytes of *Hydrocharis morsus-ranae* and *Salvinia natans* (Haslam *et al.* 1975; Ellenberg 1988).

The decline in *Glyceria* type is probably due to a reduction in minerogenic sediments being washed onto the fen, which allows other fen plants to be more competitive. *Cyperus longus* type increases steadily and is indicative of an expanding tall-sedge community. The increase in *Sparganium erectum* may be a result of the fen vegetation recovering from the reduction sustained during influx of sediment in the preceding zone. *Sparganium angustifolium* is usually a floating-leaved aquatic, but may also be submerged. It grows in still water in lakes or ponds of oligotrophic to dystrophic nutrient level on fine organic soil at 0.5-2 m depth. The abundance of *Sparganium angustifolium* suggests that pools of water at least 0.5 m deep are extant on the fen.

Zone KW-4, 77.5-67.5 cm, c. 1790-1810 AD This zone corresponds to sediment section D, which is characterised by high organic matter, very high moisture content, and very low inorganic matter and carbonate content. This high organic content may indicate that the core site was a low area of the fen and water had pooled in it. The sediment comprises equal quantities of peat and organic detritus.

The true-reed-swamp community is again the dominant community, now due to a large increase in *Sparganium erectum*. *Glyceria* type and *Scirpus* have both declined and are about equally important, while *Phragmites australis*, *Typha domingensis* type, and *Typha angustifolia* type have declined to insignificant values. The tall-sedge-swamp community is the second most important community, with *Cyperus longus* the dominant type. The wet-soil community has almost disappeared and the stream-reed-swamp community is not represented. Aquatic communities have declined again, but *Sparganium angustifolium* continues to be represented by significant values.

Available nutrients remain high, as indicated by the presence of the reed and sedge fen plants such as *Cyperus longus* type, *Glyceria*, *Scirpus*, *Sparganium erectum*, *Typha domingensis* type, and *Typha angustifolia* type, and the aquatic macrophyte of *Ranunculus aquatilis* type (Haslam *et al.* 1975; Ellenberg 1988).

Total concentration of pollen and spores increases slightly (2.5×10^3 grains/cm³) due mostly to high concentration of *Sparganium erectum*, which may have been growing close to the site of deposition. The concentration of *Glyceria* type has declined and that of *Cyperus*

longus type increased. This zone appears to represent a well developed sedge and reed swamp vegetation with little sediment influx.

Zone KW-3, 67.5-32.5 cm, c. 1810-1880 AD This zone corresponds to sediment section C, which is characterised by low organic matter and moisture content, high inorganic matter, and comparatively high carbonate content. Sediments up to 52 cm comprise mostly clay with some organic detritus, with muddy fine to medium sand above this level.

The true-reed-swamp community is again the dominant community. The dominant types are now *Glyceria* type, *Phragmites australis*, and *Scirpus*. *Sparganium erectum* is also important. The second most important community is that of the tall-sedge swamp. The dominant type is *Cyperus longus* type. *Cyperus michelianus* fluctuates. The wet-soil community increases in importance with an increase in *Carex hallerana* type. The stream-reed-swamp community has only minor representation. The aquatic communities display a peak in the centre of the zone due to an increase in *Hydrocotyle vulgaris*, then decline towards the top of the zone.

Available nutrients remain high, as indicated by the presence of the reed and sedge fen plants such as *Cyperus longus* type, *Glyceria*, *Scirpus*, *Sparganium erectum*, *Typha domingensis* type, and *Typha angustifolia* type and the aquatic macrophytes of *Ranunculus aquatilis* type, *Hydrocharis morsus-ranae*, and *Nuphar lutea* (Haslam *et al.* 1975; Ellenberg 1988).

Total concentration of wetland pollen and spores is low (3.1×10^3 grains/cm³ maximum). The concentration of *Glyceria* type increases as well as that of *Phragmites australis* and *Scirpus*. The increases in *Glyceria* type and *Scirpus* are probably responses to the increase in mineral influx, *Glyceria* expanding because of its competitive advantage due to a tolerance of minerogenic influx and *Scirpus* as a pioneer on freshly deposited sediment. The annual *Cyperus michelianus* also increases, which indicates unstable soil conditions. *Cyperus longus* type declines where *Glyceria* type increases, perhaps due to inundation with sediments.

Zone KW-2, 32.5-17.5 cm, c. 1880-1910 AD This zone corresponds to sediment section B, which is characterised by high organic and moisture content, low inorganic matter, and moderately high carbonate content. Sediment consists of one horizon of clay and silt with some detritus and peat, and living roots.

Tall-sedge-swamp and true-reed-swamp communities are co-dominant. In the tall-sedge-swamp community *Cyperus longus* type contributes almost all the pollen, while in the true-reed-swamp community several types contribute significant amounts of pollen – *Glyceria* type, *Phragmites australis*, and *Sparganium erectum*. The wet-soil community declines, with

only *Carex hallerana* type contributing significant amounts of pollen. The stream-reed-swamp community is not represented. Aquatic communities continue to be poorly represented, but *Callitriche stagnalis* type displays a small peak in the centre of the zone.

Available nutrients remain high, as indicated by the presence of the reed and sedge fen plants such as *Cyperus longus* type, *Glyceria*, *Scirpus*, *Sparganium erectum*, and *Typha angustifolia* type, and the aquatic macrophytes of *Callitriche stagnalis* type and *Ranunculus aquatilis* type (Haslam *et al.* 1975; Ellenberg 1988).

Total concentration of wetland pollen and spores is low (1.5×10^3 grains/cm³). *Cyperus longus* type is the most abundant with *Glyceria* type and *Sparganium erectum* also abundant. As before *Sparganium erectum* succeeds *Scirpus* as the fen vegetation recovers from an influx of minerogenic sediment, and *Cyperus longus* type recovers. *Glyceria* type declines as the other types increase.

Zone KW-1, 17.5-0 cm, c. 1910-1989 AD This zone corresponds to sediment section A, which is characterised by the highest organic and moisture content of the sequence, lowest inorganic matter, and low to moderately high carbonate content. One sediment horizon coincides with this zone comprising slightly silty peat with woody detritus and calcareous grit.

The tall-sedge-swamp community becomes dominant, with *Cyperus longus* dominant and *Carex flacca* type also contributing a large amount of pollen. *Cyperus michelianus* contributes a significant amount in the surface sample. All other communities have declined greatly.

Available nutrients remain high, as indicated by the abundance of the reed and sedge fen plants such as *Carex flacca* type, *Cyperus longus*, and *Typha angustifolia* type (Ellenberg 1988). No aquatic macrophytes indicating high nutrient levels occur.

Total concentration of wetland pollen and spores increases from low at the base of the zone (4.1×10^3 grains/cm³) to the maximum recorded of this sequence at the top of the zone (45×10^3 grains/cm³). Several types record significant concentration values, especially in the surface sample. These are *Carex hallerana* type, *Mentha* type, *Equisetum*, *Carex flacca* type, *Cyperus longus* type, *Cyperus michelianus*, *Glyceria* type, *Sparganium erectum*, *Typha angustifolia*, *Sparganium angustifolium*, and *Salix fragilis* type. Species of *Mentha* type, *Equisetum*, *Cyperus longus* type, *Sparganium erectum*, and *Typha angustifolia* were identified growing abundantly on the fen and species that may belong to *Carex hallerana* type, *Carex flacca* type, *Cyperus michelianus*, *Glyceria* type, *Sparganium angustifolium*, and *Salix fragilis* type were also identified (Appendix VIII).

6.5.3 Terrestrial pollen analysis

6.5.3.1 Pollen diagram construction

Pollen and spore relative frequencies are presented in Figures 6.11 and 6.12 (in pocket). Pollen and spore types are arranged according to habitat groups defined in Chapter 2. The pollen sum on which the relative frequencies are based includes all identified terrestrial pollen and spore taxa and excludes mire and aquatic taxa. Relative frequencies of 0.2% or less are indicated with a dot. Style of the summary and fully resolved relative frequency diagrams and the arrangement of pollen and spore types is the same as in Chapter 5. Rarefaction analysis is based on the smallest total count of terrestrial pollen and spores, 323.

Pollen concentration data are presented in Figure 6.13, which takes a similar form to the relative frequency diagram. Only concentrations of pollen and spore types recorded in significant abundance, habitat groups, and total pollen and spores are included.

6.5.3.2 Terrestrial pollen assemblage zones

Terrestrial pollen diagrams are divided into 14 local pollen assemblage zones K-1 to K-14, based mostly on relative frequency data. These are defined below. Concentration data are discussed in the following section.

Zone K-14, 396.0-372.5 cm This basal zone is characterised by high relative frequencies of the habitat groups of 'herbs of open ground' and 'cultivars'. The former group records 62.8-72.4% of terrestrial taxa, the latter 1.2-6.1%. The most important type in the 'herbs of open ground' group is *Pteridium aquilinum* (8.4-21.9%). Other types of importance in this habitat group recording more than 2.0% are: *Centaurea solstitialis* type (3.0-6.9%), *Cichorium* type (1.8-4.6%), *Dactylis* type (1.8-11.3%), *Festuca* type (1.4-2.9%), *Galium* type (0.5-2.7%), *Hieracium* type (11.6-29.2%), *Lactuca* type (1.7-3.2%), *Plantago lanceolata* type (0.5-2.9%), *Solidago* type (1.2-3.2%), *Sonchus* type (0.0-9.1%), and *Taraxacum* type (0.1-4.1%). The most abundant types represented in the habitat group 'cultivars' are the cereals *Secale cereale* (maximum 3.5%) and *Triticum* type (maximum 1.8%). Other 'cultivars' represented are *Avena* (maximum 0.4%), *Castanea sativa* (maximum 0.2%), *Hordeum* type (maximum 0.2%), *Juglans regia* (maximum 0.1%), *Platanus orientalis* (maximum 0.4%), and *Vicia sativa* type (maximum 0.3%).

The dominant canopy tree type is *Quercus trojana* type (7.5-12.1%). Other important types of the habitat group 'coniferous and deciduous canopy trees' are *Pinus* (*Diploxylon*) (7.0-9.5%), *Quercus frainetto* type (4.1-7.5%), and *Ostrya* type (2.7-1.0%). No types of 'alpine shrubs' are represented. Only the types *Ligusticum* and *Veratrum* of 'alpine herbs' are represented recording only 0.2%. The habitat group of 'woodland understorey trees and shrubs' is also poorly represented with only the types *Ilex aquifolium* and *Juniperus*

Figure 6.11 Kella - summary relative frequency pollen diagram, terrestrial taxa; pollen sum is total terrestrial taxa; scale interval 5% for all taxa and groups (resolved canopy trees taxa have 1.5x scale of groups), percentages less than 0.2% shown by dots.

Figure 6.11

Figure 6.13

represented (with a maximum of 0.3%). 'Woodland herbs' are also poorly represented, recording less than 1.0%. 'Riverine trees' reach a maximum of 1.8%, with *Alnus glutinosa* (maximum 0.6%), *Salix triandra* (maximum 0.3%), and *Tamarix* (maximum 0.9%) most abundant. Pollen types of 'evergreen woodland trees' record 0.2% or less with the exception of *Quercus coccifera* type, which records from 1.0-2.0%, except in one spectrum where only 0.3% is recorded. No type of 'plants of open dry rocky habitats' exceeds 0.5%.

Zone K-13, 372.5-312.5 cm The boundary with the preceding zone is marked by increases in the relative frequencies of *Pinus* (*Diploxylon*), *Quercus frainetto* type, *Quercus trojana* type; a decline in *Pteridium aquilinum* and 'herbs of open ground'; and an increase in the ratio of terrestrial trees and shrubs to terrestrial herbs. This zone is characterised by high relative frequencies of the habitat groups of 'herbs of open ground' and 'cultivars' and of *Pteridium aquilinum*, and increased relative frequencies of the habitat group 'coniferous and deciduous canopy trees' and the pollen types *Quercus frainetto* type and *Quercus trojana* type.

'Herbs of open ground' have declined, but relative frequencies are still high (41.5-61.8%). *Pteridium aquilinum* has declined but is still abundant at 5.8-12.6%. Other types in this group exceeding 2.0% are the same as those in the preceding zone, and record similar frequencies. Exceptions are *Chenopodiaceae* type (1.3-3.1%) and *Polygonum aviculare* type (1.2-4.5% except the basal spectrum, which is 0.6%), which increase; *Cirsium* type, which increases in the upper part of the zone to 1.6-3.9%; *Plantago lanceolata* type, which declines to less than 2.0%, and *Hieracium* type, which has also declined (4.5-11.8%).

'Cultivars' continue at similar relative frequencies (1.0-5.1%), but changes occur within the group: *Secale cereale* declines (maximum 2.2%); *Triticum* type disappears; *Avena*, *Hordeum* type, and *Platanus orientalis* increase slightly, recording maximum relative frequencies of 1.8%, 1.4%, and 1.4%, respectively; and *Zea mays* was identified in one spectrum at 0.3%. (*Zea mays* probably represents *Triticum* type or *Avena*, see explanation below.) *Castanea sativa* and *Juglans regia* remain unchanged (they occur sporadically and do not exceed 0.3%) and *Vicia sativa* type disappears.

In the habitat group 'coniferous and deciduous canopy trees' *Quercus frainetto* type and *Quercus trojana* type increase significantly. In the centre of the zone *Quercus frainetto* type reaches 21.6%, which is close to the maximum of the sequence. *Quercus trojana* type displays its overall zonal maxima, reaching 17.2% at 350 cm. *Pinus* (*Diploxylon*) increases slightly reaching its maximum of the zone (16.2%) in the second spectrum from the base. The only other type in this group that exceeds 1.0% is *Ostrya* type (maximum 3.4%).

Again 'alpine shrubs' are not represented. Six types of 'alpine herbs' occur, but these are all represented once only and at 0.2%. 'Woodland understorey trees and shrubs' are represented by only *Ilex aquifolium* (0.4% in one spectrum) and *Juniperus* (maximum 0.8%).

'Woodland herbs' reach a maximum of only 1.6%. 'Riverine trees' have declined slightly, reaching a maximum of 1.3%; *Alnus glutinosa* and *Salix triandra* are unchanged, but *Tamarix* disappears. 'Evergreen woodland trees' are represented by only *Ephedra fragilis* (maximum 0.4%) and *Quercus coccifera* type (0.0-1.4%). No type of 'plants of open dry rocky habitats' exceeds 0.8%, with the exception of *Agropyron* type (0.4-2.2%).

Zone K-12, 312.5-287.5 cm The boundary with the preceding zone is marked by an increase in the relative frequencies of *Pinus* (*Diploxylon*) and *Quercus frainetto* type, and a decline in *Quercus trojana* type and *Pteridium aquilinum*. This zone is characterised by high relative frequencies of the habitat groups of 'herbs of open ground' and 'cultivars' and the types of *Pinus* (*Diploxylon*), *Quercus frainetto* type, and *Quercus trojana* type.

Frequencies of 'herbs of open ground' are comparatively low (39.5-54.0%). *Pteridium aquilinum* has declined (2.3-4.5%). Other types in this group exceeding 2.0% are the same as those in the preceding zone with the exception that *Plantago lanceolata* type has increased (uppermost spectrum reaches 2.6%), and *Galium* type has declined to less than 2.0%.

'Cultivars' continue at similar frequencies (1.3-4.5%). Frequencies of individual types within this group are more or less constant except for *Platanus orientalis*, which declines (0-0.2%). *Secale cereale* remains the most abundant cereal, while other cereals, including *Zea mays*, continue occurring sporadically at low values.

'Coniferous and deciduous canopy trees' increase from 42.7% in the basal spectrum to 56.1% in the uppermost. *Pinus* (*Diploxylon*) also increases from the basal spectrum (14.0%) to the uppermost (24.6%). *Quercus frainetto* type displays constantly high frequencies (16.3-19.9%). *Quercus trojana* type has declined (6.1-12.4%). No other type in this group exceeds 2.0%.

'Alpine shrubs' and 'alpine herbs' are not represented. 'Woodland understorey trees and shrubs' are represented by *Juniperus* only (maximum 0.8%). 'Woodland herbs' reach a maximum of 1.6%. 'Riverine trees' have declined and only *Salix triandra* is represented (maximum 0.8%). 'Evergreen woodland trees' are represented by *Ephedra fragilis* and *Quercus coccifera* type; both record 0.2% in one spectrum. 'Plants of open dry rocky habitats' have declined; no type exceeds 0.5%.

Zone K-11, 287.5-237.5 cm The boundary with the preceding zone is marked by an increase in the relative frequencies of *Quercus trojana* type, and a decrease in *Pinus* (*Diploxylon*) and *Quercus frainetto* type. This zone is characterised by high relative frequencies of the habitat groups of 'herbs of open ground' and 'cultivars' and the types *Quercus frainetto* type and *Quercus trojana* type.

Frequencies of 'herbs of open ground' are about average for this sequence (47.5-58.6%) and those of *Pteridium aquilinum* are unchanged from the preceding zone (2.0-4.8%). Other

types in this group exceeding 2.0% are the same as those in the preceding zone with the exception of *Galium* type, which increases to a maximum of 2.4%.

'Cultivars' increase (2.4-5.1%). The cereals *Avena* and *Secale cereale* occur continuously and reach 1.1% and 2.7%, respectively. Other cereals occur sporadically – *Hordeum* type 0.7% maximum and *Zea mays* 0.9% maximum. *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* occur more often than in the preceding zone, but at low frequencies (0.9%, 0.5%, and 0.7% maxima, respectively). *Vitis vinifera* appears at 260 cm for the first time then again at 255 and 240 cm, at 0.2%.

'Coniferous and deciduous canopy trees' fluctuate from 31.8-42.8%. *Pinus* (*Diploxylon*) has declined (9.0-16.5%). *Quercus frainetto* type declines in the lower part of the zone (7.5%), but reaches a maximum of 16.2% near the top. *Quercus trojana* type increases in the lower part of the zone to 17.2%, declines to 4.9% in the centre of the zone, then increases again to 13.5%. *Ostrya* type increases from the centre of the zone, recording overall maxima of the sequence (3.4% maximum). No other type in this group exceeds 2.0%.

'Alpine shrubs' are not represented and no type of 'alpine herbs' exceeds 0.5%. 'Woodland understorey trees and shrubs' are represented by more types (4), but only *Juniperus*, which reaches a maximum of 2.7%, exceeds 0.2%. 'Woodland herbs' reach a maximum of 1.6%. 'Riverine trees' are represented by 7 types but none exceed 0.7% except *Salix triandra*, which reaches 2.6% in the lowest spectrum. 'Evergreen woodland trees' (1.9% maximum), are also represented by more types (*Ephedra fragilis*, *Phillyrea*, *Pistacia*, and *Quercus coccifera* type). Only *Quercus coccifera* type, which reaches a maximum of 1.9%, exceeds 0.3%. 'Plants of open dry rocky habitats' increase slightly (maximum 5.1% at 260 cm), due mostly to an increase in *Agropyron* type (but this type never exceeds 1.0%) and *Crupina* (one exceptional spectrum records 4.5%).

Zone K-10, 237.5-202.5 cm The boundary with the preceding zone is marked by an increase in *Quercus frainetto* type and decline in *Quercus trojana* type. This zone is characterised by high relative frequencies of the habitat groups of 'herbs of open ground' and 'cultivars'; high and increasing relative frequencies of *Pinus* (*Diploxylon*); and high relative frequencies of *Quercus frainetto* type and *Quercus trojana* type.

Frequencies of 'herbs of open ground' are again about average for this sequence (46.3-56.1%). *Pteridium aquilinum* has declined (1.5-3.4%). Other types in this group exceeding 2.0% are the same as those in the preceding zone with the exception of *Bilderdykia*, which increases to 2.0 and 2.1% in two spectra and *Cichorium* type which declines to less than 2.0%.

'Cultivars' increase again (2.3-8.1%), due to increases in *Avena* (maximum 2.2%) and *Platanus orientalis* (maximum 1.5%). The cereals *Avena* and *Secale cereale* (maximum 3.5%) occur continuously, while *Hordeum* type and *Zea mays* occur sporadically. *Hordeum*

type increases at the base of the zone to 1.4%, then declines. *Zea mays* has declined and reaches only 0.2% in three of the seven spectra. *Castanea sativa* continues to occur at low values (maximum 0.6%). *Juglans regia* disappears in the upper part of the zone. *Vitis vinifera* occurs only at 225 cm at 0.6%.

'Coniferous and deciduous canopy trees' increase slightly, but fluctuate (35.5-47.1%). *Pinus* (*Diploxylon*) increases steadily from the relative frequencies of the preceding zone (basal spectrum 11.5%) to 27.6% in the uppermost spectrum. *Quercus frainetto* type maintains frequencies similar to those of the preceding zone to the centre of this zone, then declines slightly to 10.2%. *Quercus trojana* type declines (6.4-8.2%). *Ostrya* type has declined to less than 2.0%. No other type in this group exceeds 2.0% except for *Fraxinus ornus*, which reaches 2.8% in the basal spectrum.

'Alpine shrubs' are not represented and no type of 'alpine herbs' exceeds 0.2%. 'Woodland understorey trees and shrubs' are represented by only three types: *Juniperus* records 0.7-3.4%; *Buxus sempervirens* 0.4% in one spectrum; *Ilex aquifolium* 0.2% in one spectrum. 'Woodland herbs' reach a maximum of only 1.3%. 'Riverine trees' are represented by fewer types (4) than in the preceding zone but none exceed 0.6% with the exception of *Tamarix*, which reaches 1.0% in two spectra. 'Evergreen woodland trees' decline (0.8% maximum). *Ephedra distachya* type, *Ephedra fragilis*, and *Quercus coccifera* type are represented, but only *Quercus coccifera* type exceeds 0.2% (it occurs sporadically and reaches 0.8%). 'Plants of open dry rocky habitats' decline (2.3% maximum); only *Agropyron* type (maximum 1.1%) exceeds 0.4%.

Zone K-9, 202.5-177.5 cm The boundary with the preceding zone is marked by increases in the relative frequencies of the habitat groups of 'plants of open dry rocky habitats' and 'cultivars', a decrease in 'coniferous and deciduous canopy trees', and a sharp decrease in *Quercus trojana* type. This zone is characterised by very high relative frequencies of 'cultivars'; high relative frequencies of 'herbs of open ground', *Pinus* (*Diploxylon*), and *Chenopodiaceae* type; increasing frequencies of *Juniperus*; and low frequencies of 'coniferous and deciduous canopy trees', *Quercus frainetto* type, and *Quercus trojana* type.

'Herbs of open ground' again display about average relative frequencies, but in general these increase from the bottom of the zone to the top (ranging from 49.9-61.3%). *Pteridium aquilinum* increases slightly from the preceding zone (2.9-4.8%). Other types in this group exceeding 2.0% are the same as those in the preceding zone with the exception of *Cichorium* type, which increases to a maximum of 5.0%. Notable changes in the relative frequencies of types in this group are a decline in *Bilderdykia* to 0.2% and less, a decline in *Centaurea solstitialis* type (only one spectrum exceeds 2.0%), and an increase in *Chenopodiaceae* type (maximum 17.1% at 185 cm).

'Cultivars' increase significantly (5.4-11.4%), due to increases in the cereals *Avena*, *Hordeum* type, *Secale cereale*, and *Zea mays* (2.6%, 2.9%, 3.8%, and 1.5% maxima, respectively). All these types are continuously represented. The cereal *Triticum* type occurs in only one spectrum at 0.2%. *Castanea sativa* continues to occur sporadically at low values (0.9% maximum) and *Humulus lupulus* appears in the uppermost spectrum at 0.2%. *Platanus orientalis* declines again (0.8% maximum). *Vicia sativa* type occurs in one spectrum at 0.2%.

'Coniferous and deciduous canopy trees' decline to almost the minima of the sequence (24.4-35.0%). *Pinus* (*Diploxylon*) has comparatively high relative frequencies (20.2-21.4%, with one spectrum recording only 17.9%). *Quercus frainetto* type declines (6.8-10.5%, with the exception of one spectrum 3.9%). *Quercus trojana* type declines even further (1.2-2.6%). No other type in this group exceeds 2.0%.

'Alpine shrubs' are not represented and no type of 'alpine herbs' exceeds 0.6%. 'Woodland understorey trees and shrubs' are represented by only two types and only *Juniperus* exceeds 0.2%; it increases (2.6-4.5%). 'Woodland herbs' reach a maximum of only 1.3%. 'Riverine trees' are represented by 5 types but none exceeds 0.3% except for *Salix triandra*, which reaches 1.4% at 195 cm. 'Evergreen woodland trees' remains at the reduced value (maximum 0.8%). Only *Ephedra fragilis* and *Quercus coccifera* type are represented and neither exceed 0.5% in any spectrum. 'Plants of open dry rocky habitats' increase (maximum 3.1%) due to an increase in *Agropyron* type (2.2% maximum).

Zone K-8, 177.5-157.5 cm The boundary with the preceding zone is marked by increases in the relative frequencies of 'coniferous and deciduous canopy trees' and *Quercus frainetto* type; and a decline in 'herbs of open ground', 'cultivars' and *Chenopodiaceae* type. This zone is characterised by high relative frequencies of 'herbs of open ground', 'cultivars', *Pinus* (*Diploxylon*), *Quercus frainetto* type, and *Juniperus*; increased relative frequencies of 'coniferous and deciduous canopy trees'; and low relative frequencies of *Pteridium aquilinum*.

'Herbs of open ground' decline (38.7-54.8%). *Pteridium aquilinum* also declines (1.8-2.7%, except in the uppermost spectrum where it increases to 5.8%). Other types in this group recording more than 2.0% are the same as those in the preceding zone with the exception of *Daucus*, reaches 3.3% at 162 cm. Notable changes in the relative frequencies of types are the general increase in *Centaurea solstitialis* type, which exceeds 2.0% in two of the five spectra, and the decline in *Chenopodiaceae* type (5.2% at the base to 1.3% in the spectrum second from the top).

'Cultivars' decline, but still record high frequencies (2.6-4.6%). Reductions in this group are seen mostly in the cereals. *Avena*, *Hordeum* type, and *Secale cereale* although still occurring in all spectra, decline (0.2-0.9%, 0.2-1.3%, and 0.2-2.0%, respectively). *Zea mays* does not occur in the basal spectrum, but occurs in all other spectra at 0.2%. *Triticum* type

does not occur. *Castanea sativa* is unchanged. *Juglans regia* occurs in the uppermost three spectra at a maximum of only 0.4%. *Morus nigra* appears for the first time at 165 and 170 cm at 0.4 and 0.5%. *Platanus orientalis* occurs in two spectra only; 160 cm (1.6%) and 170 cm (0.2%).

'Coniferous and deciduous canopy trees' increase to comparatively high frequencies (32.6-49.0%). In general, *Pinus* (*Diploxylon*) has comparatively high frequencies (24.1-25.9%, but declines to 16.7% in the second spectrum and to 15.0% in the uppermost spectrum). *Quercus frainetto* type increases (11.9-19.8%), while *Quercus trojana* type remains at low frequencies (1.3-3.0%). No other type in this group exceeds 2.0%.

One type of 'alpine shrubs' is represented but at only 0.2%, and only two types of 'alpine herbs' are represented. These do not exceed 0.6%. 'Woodland understorey trees and shrubs' are represented by *Juniperus* only, which reaches 6.4% in the centre of the zone. 'Woodland herbs' reach a maximum of 1.4%. 'Riverine trees' are represented by 6 types but none exceeds 0.4% with the exception of *Salix triandra*, which reaches 1.5% at 165 cm. 'Evergreen woodland trees' reach only 0.5%. 'Plants of open dry rocky habitats' decline slightly (maximum 2.1%) due to a decline in *Agropyron* type (maximum 1.6%).

Zone K-7, 157.5-142.5 cm The boundary with the preceding zone is marked by an increase in the relative frequencies of 'herbs of open ground'; and a decline in 'coniferous and deciduous canopy trees', *Pinus* (*Diploxylon*), and *Quercus frainetto* type. The zone is characterised by high relative frequencies of 'herbs of open ground', 'cultivars', *Quercus frainetto* type, *Juniperus*, and *Polygonum aviculare* type.

'Herbs of open ground' increase to the second highest overall values for a zone (57.7-67.9%) (the basal zone is higher). *Pteridium aquilinum* increases slightly (2.0-4.5%). Other types in this group exceeding 2.0% are the same as those in the preceding zone with the exception of *Chenopodiaceae* type, *Daucus*, and *Festuca* type, which have declined to less than 2.0%; *Galium* type, which increases (basal spectrum records 2.5%); and *Polygonum aviculare* type, which increases to its maximum of the sequence (41.2%).

'Cultivars' decline further, but still record high relative frequencies (1.9% in the basal spectrum, then 3.3 and 3.0%). The cereals *Avena*, *Hordeum* type, and *Secale cereale* all continue to be represented continuously, but their maximum frequencies have declined; 0.6%, 0.7%, and 1.0%, respectively. *Zea mays* does not occur in the basal spectrum, but increases to 0.6 and 0.3% in the upper two spectra. *Triticum* type occurs in the basal spectrum (0.2%). *Castanea sativa* occurs in the basal spectrum only at 0.5%. *Juglans regia* and *Morus nigra* disappear. *Platanus orientalis* increases from 0.2% in the basal spectrum to 1.3% in the uppermost.

'Coniferous and deciduous canopy trees' decline to the lowest overall values for a zone (22.4-30.9%). *Pinus* (*Diploxylon*) declines (8.5-14.6%). *Quercus frainetto* type declines also (9.6-13.4%), and *Quercus trojana* type remains at low frequencies declining from 4.1% in the basal spectrum to 0.9% in the two uppermost. No other type in this group exceeds 2.0%.

'Alpine shrubs' are not represented and 'alpine herbs' are represented by one type at 0.5%. 'Woodland understorey trees and shrubs' are again represented by *Juniperus* only, which reaches 5.2%. 'Woodland herbs' reach a maximum of 1.2%. 'Riverine trees' decline to reach a maximum of only 0.9%. Three types are represented; *Salix triandra* is the most abundant at 0.5% maximum. 'Evergreen woodland trees' are represented in one spectrum only at 0.5%. 'Plants of open dry rocky habitats' decline slightly (1.6% maximum).

Zone K-6, 142.5-117.5 cm The boundary with the preceding zone is marked by increases in the relative frequencies of 'coniferous and deciduous canopy trees', *Quercus frainetto* type, *Quercus trojana* type, and *Quercus coccifera* type; and a decline in 'herbs of open ground'. This zone is characterised by high relative frequencies of 'herbs of open ground', 'cultivars', and *Quercus frainetto* type; and increased relative frequencies of *Quercus trojana* type, *Juniperus*, *Quercus coccifera* type, and *Pteridium aquilinum*.

'Herbs of open ground' decline (40.3-51.1%). *Pteridium aquilinum* increases (3.0-7.7%). Other types in this group exceeding 2.0% are the same as those in the preceding zone, with the exception of those types that decline to less than 2.0% in all spectra (*Cirsium* type, *Galium* type, and *Sonchus* type); and those types where at least one spectrum reaches or exceeds 2.0% (*Bilderdykia*, *Centaurea cyanus* type, *Rumex acetosa* group, *Chenopodiaceae* type, and *Festuca* type). *Polygonum aviculare* type declines (2.5-6.3%).

'Cultivars' increase in the upper half of the zone (3.4% in the basal spectrum and 4.7% in the uppermost spectrum). *Avena* occurs sporadically and fluctuates (maximum 2.5%). Frequencies of *Hordeum* type also fluctuate (0.2-2.5%). *Secale cereale* increases in the upper part of the zone (0.2-1.6%). *Zea mays* occurs in all spectra with the exception of the second from the bottom (0.2-0.9%). *Triticum* type occurs in the second to bottom spectrum only, at 0.2%. *Castanea sativa* occurs in the upper four spectra (0.2-0.8%). *Platanus orientalis* occurs at 0.7-1.7%.

'Coniferous and deciduous canopy trees' increase to 36.3-37.2%, then increase again to 43.4% in the uppermost spectrum. *Pinus* (*Diploxylon*) continues to record low frequencies (10.1-13.4%, and in the uppermost spectrum 16.4%). *Quercus frainetto* type increases to comparatively high frequencies (16.1-20.4%). *Quercus trojana* type also increases, but remains at comparatively low frequencies (3.7-6.3%). No other type in this group exceeds 2.0%.

One type only of 'alpine shrubs' is represented, recording 0.2% maximum. Two types of 'alpine herbs' are represented, but do not exceed 0.9%. 'Woodland understorey trees and shrubs' are again represented by *Juniperus* only, which increases to a maximum of 7.6%. 'Woodland herbs' decline to a maximum of 1.0%. 'Riverine trees' remain at very low frequencies and reach a maximum of only 1.1%. Six types are represented, but all occur sporadically with *Ulmus minor* recording the maximum of only 0.8%. *Salix triandra* occurs most often, but never exceeds 0.5%. 'Evergreen woodland trees' increase due to an increase in *Quercus coccifera* type, which fluctuates from 0.4-2.8%. 'Plants of open dry rocky habitats' remain at low values (maximum 2.0%).

Zone K-5, 117.5-77.5 cm The boundary with the preceding zone is marked by increases in the relative frequencies of *Pinus* (*Diploxylon*) and *Abies*, and decreases in *Quercus frainetto* type and *Quercus trojana* type. This zone is characterised by high and increasing relative frequencies of 'herbs of open ground'; high relative frequencies of 'cultivars'; increased relative frequencies of *Pteridium aquilinum*; and declining relative frequencies of 'woodland understorey trees and shrubs', and *Juniperus*.

'Herbs of open ground' increase from frequencies similar to those of the preceding zone (43.6% in the basal spectrum) to comparatively high values (59.7% maximum). *Pteridium aquilinum* increases (4.1-9.0%). Other types in this group exceeding 2.0% are the same as those in the preceding zone, with the exception of *Bilderdykia* and *Centaurea cyanus* (the former type disappears and the latter occurs in one spectrum only at 0.2%). Of significance is an increase in *Polygonum aviculare* type (11.8% maximum).

'Cultivars' remain at the elevated frequencies of the upper part of the preceding zone (3.0-5.7%). *Avena* occurs in all except the basal spectrum (0.2-1.6%). *Hordeum* type declines, recording the highest frequency of 1.6% in the basal spectrum. *Secale cereale* records 0.2-1.9%. *Triticum* type and *Zea mays* occur sporadically, both recording a maximum of 0.8%. *Castanea sativa* continues to occur sporadically at low frequencies (0.7% maximum). *Juglans regia* reappears and occurs sporadically at low values (0.3% maximum) and *Platanus orientalis* now occurs sporadically (maximum 1.7%). *Vitis vinifera* occurs in one spectrum only at 0.2%.

'Coniferous and deciduous canopy trees' fluctuate from 30.9-45.8%. *Pinus* (*Diploxylon*) increases to 11.8-18.7%. *Quercus frainetto* type fluctuates from 12.3-18.6%, then increases to 23.2%. *Quercus trojana* type declines (2.9-4.7%). *Abies* increases to reach a maximum of 1.9%. All other types in this group score lower relative frequencies.

One pollen type only of 'alpine shrubs' is represented (0.2%). Several types of 'alpine herbs' are represented, but none exceeds 0.2%. 'Woodland understorey trees and shrubs' are represented by *Ilex aquifolium* and *Juniperus*. *Ilex aquifolium* occurs sporadically and reaches

a maximum of only 0.5% while *Juniperus* is continuously represented but declines from 6.6-0.5%. 'Woodland herbs' increase slightly to a maximum of 1.5%. 'Riverine trees' remain at very low values and again reach only 1.1%. Five types are represented, but all are represented sporadically with the exception of *Salix triandra*, which records 0.2-0.5%. Other types do not exceed 0.5%. 'Evergreen woodland trees' decline in the upper part of the zone due to a decline in *Quercus coccifera* type, which fluctuates from 0.2-1.8% (with the exception of one spectrum where it does not occur). The group never exceeds 2.3% in any spectrum. 'Plants of open dry rocky habitats' remain poorly represented (maximum 2.0%).

Zone K-4, 77.5-57.5 cm The boundary with the preceding zone is marked by increases in the relative frequencies of 'coniferous and deciduous canopy trees', *Pinus (Diploxylon)*, and *Salix triandra*; and a decline in the relative frequencies of 'herbs of open ground' and *Pteridium aquilinum*. This zone is characterised by high relative frequencies of 'herbs of open ground', 'cultivars', *Pinus (Diploxylon)*, and *Quercus frainetto* type; increased relative frequencies of *Abies* and *Salix triandra*; and decreased *Juniperus* and *Pteridium aquilinum*.

'Herbs of open ground' decline to the minima of the sequence (25.1-37.4%). *Pteridium aquilinum* declines to the minimum of the sequence of 1.1% at 70 cm (3.4% maximum). Other types in this group exceeding 2.0% are the same as those in the preceding zone with the exception of those that decline to less than 2.0% – *Centaurea solstitialis* type, *Festuca* type, *Lactuca* type, *Rumex acetosa* group, and *Solidago* type; and those that increase to more than 2.0% – *Cirsium* type (maximum 8.6% at 70 cm), *Galium* type (2.3% at 65 cm), and *Plantago major* (3.8% at 60 cm). Of note is the decline of *Polygonum aviculare* type, which now records 1.2-5.3% and *Rumex acetosa* group, which now occurs in only the two central spectra at 0.5 and 0.8%.

'Cultivars' increase from 2.4% in the basal spectrum to 6.7% in the uppermost. *Avena* declines, but occurs in all spectra (0.2-0.6%). *Hordeum* type occurs in the two central spectra only at 0.2 and 0.6%. *Secale cereale* does not occur in the basal spectrum, but increases to a maximum of 2.3% in the uppermost. *Triticum* type occurs at 70 cm only, at 0.8%. *Zea mays* is represented in every spectrum (0.5-0.6%). *Castanea sativa* is also represented continuously (0.2-1.2%). *Juglans regia* occurs sporadically (0.3% maximum). *Platanus orientalis* is again represented continuously and increases (3.4% maximum).

'Coniferous and deciduous canopy trees' increase to the maximum of the sequence; 58.6% at 60 cm. *Pinus (Diploxylon)* also increases to very high frequencies; 26.0-30.6%, with a decline to 18.7% at 65 cm. Frequencies of *Quercus frainetto* type are the overall highest of the sequence (18.1-22.3%). *Quercus trojana* type continues unchanged at 2.5-4.7%. *Abies* increases again to a maximum of 3.6% in the uppermost spectrum. No other type in this group exceeds 2.0%.

'Alpine shrubs' are not represented and only three types of 'alpine herbs' are represented, but only one exceeds 0.3%; *Soldanella* records 1.0% at 75 cm. 'Woodland understory trees and shrubs' are represented by *Juniperus* only, which increases from 1.2% in the basal spectrum to 4.4% in the uppermost. 'Woodland herbs' decline slightly and occur sporadically (maximum 1.2%). 'Riverine trees' increase to reach a maximum of 3.6% in the basal spectrum, but decline to 0.6% in the uppermost. The increase is due to an increase in *Salix triandra*, which records 2.7% in the basal spectrum and then declines to 0.6%. All other types of this group occur sporadically and do not exceed 0.5%. 'Evergreen woodland trees' occur sporadically, again at low values. *Quercus coccifera* type contributes almost all pollen, reaching a maximum of 2.0% in the uppermost spectrum. 'Plants of open dry rocky habitats' record 1.7% maximum.

Zone K-3, 57.5-32.5 cm The boundary with the preceding zone is marked by increased relative frequencies of 'herbs of open ground', 'cultivars', *Dactylis* type, *Avena*, and *Secale cereale*; and a decline in 'coniferous and deciduous canopy trees', *Pinus* (*Diploxylon*), and *Abies*. This zone is characterised by high relative frequencies of 'herbs of open ground', 'cultivars', *Quercus frainetto* type, *Dactylis* type, *Avena*, and *Secale cereale*; increased relative frequencies of *Juniperus* and *Quercus coccifera* type; and low relative frequencies of *Pinus* (*Diploxylon*), *Quercus trojana* type, and *Pteridium aquilinum*.

'Herbs of open ground' increase (40.2-54.4%). *Pteridium aquilinum* continues at low values (2.0-4.4%). Other types in this group exceeding 2.0% are the same as those in the preceding zone with the exception of *Cichorium* type, which declines and in no spectrum reaches 2.0%; *Festuca* type, which increases, exceeding 2.0% in several spectra and reaching a maximum of 2.4%; *Galium* type, which reaches 2.0% at 45 cm and 2.2% at 35 cm; and *Plantago media*, which occurs sporadically, but increases sharply to 14.5% at 55 cm. A notable change is the sharp increase in *Dactylis* type (9.0-23.1%).

'Cultivars' increase to the maximum relative frequencies of the sequence (6.1-12.3%), mostly due to the cereal types of *Avena* and *Secale cereale* increasing to their maximum of the sequence, 5.0% and 5.4% respectively. *Hordeum* type occurs sporadically again and reaches only 0.5%. *Triticum* type also occurs sporadically, but reaches 1.5% in the uppermost spectrum. *Zea mays* is represented continuously (0.2-1.1%). *Castanea sativa* is also represented continuously (0.2-0.4% with the exception of one spectrum, which increases to 2.3%). *Juglans regia* is represented in the two uppermost spectra only (0.2 and 0.4%). *Lathyrus sativus* and *Morus alba* are both represented in the basal spectrum only, at 0.2% and 0.6%, respectively. *Platanus orientalis* declines to 0.4% in the uppermost spectrum.

'Coniferous and deciduous canopy trees' decline to almost the minimum of the sequence at 40 cm. Overall, relative frequencies are very low (24.7-42.7%). *Pinus* (*Diploxylon*)

declines to low frequencies (8.0-13.6%). *Quercus frainetto* type shows high overall frequencies, but fluctuates (10.7-21.9%). *Quercus trojana* type continues unchanged at 3.0-4.8%. *Abies* declines and reaches 0.9% only. *Ostrya* type records 0.7-0.9% except at 50 cm where it increases to 3.1%. No other type in this group exceeds 0.4%.

'Alpine shrubs' are not represented and only 3 types of 'alpine herbs' are represented, but none exceeds 0.7%. 'Woodland understorey trees and shrubs' are represented by 3 types but only *Juniperus* exceeds 0.4%. The overall frequencies of *Juniperus* have increased (2.5-5.0%). 'Woodland herbs' occur continuously, but continue at low values (1.1% maximum). 'Riverine trees' continue at slightly elevated values (0.7-2.4%) with *Salix triandra* contributing most of the pollen. Other types in this group occur sporadically and at 0.5% or less. All pollen of 'evergreen woodland trees' (0.7-1.8%) is contributed by *Quercus coccifera* type with the exception of 0.2% contributed by *Ephedra fragilis* in one spectrum. 'Plants of open dry rocky habitats' record 1.6% maximum.

Zone K-2, 32.5-17.5 cm The boundary with the preceding zone is marked by increases in the relative frequencies of 'coniferous and deciduous canopy trees', *Pinus (Diploxylon)*, *Abies*, and *Quercus coccifera* type; and decreases in 'herbs of open ground', *Juniperus*, *Dactylis* type, and *Avena*. This zone is characterised by high relative frequencies of 'coniferous and deciduous canopy trees', 'herbs of open ground', 'cultivars', *Pinus (Diploxylon)*, and *Quercus frainetto* type; comparatively high relative frequencies of *Quercus coccifera* type; and low relative frequencies of *Juniperus*.

'Herbs of open ground' decline to almost the lowest values of the sequence (28.2-36.7%). *Pteridium aquilinum* declines to very low values (1.2-2.8%). Other types in this group exceeding 2.0% are the same as in the preceding zone with the exception of *Galium* type, *Plantago major*, *Plantago media*, *Polygonum aviculare* type, and *Taraxacum* type, which decline to less than 2.0%; and *Solidago* type, which increases to 2.5% mid-zone.

'Cultivars' decline but frequencies remain high (3.4-8.0%), with cereal types contributing most pollen. However, *Avena* has declined and occurs in the two lower spectra only (0.6 and 1.2%), while *Hordeum* type is represented in the two upper spectra only (maximum 0.8%). *Secale cereale* is represented continuously (0.9-2.8%). *Triticum* type occurs in the two upper spectra only (1.2 and 3.0%). *Zea mays* increases slightly, occurring in all spectra (0.5-1.9%). The tree types *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* all occur in the two uppermost spectra, but at only 0.3-0.6%.

'Coniferous and deciduous canopy trees' increase to 57.3% (almost the maximum of the sequence) in the basal spectrum, then decline to 48.8%. *Pinus (Diploxylon)* also records high values in the basal spectrum (30.1%), then declines to 20.1%. *Quercus frainetto* type records high frequencies (16.7-18.8%) and *Quercus trojana* type continues unchanged at 3.4-5.1%.

Abies increases, but to only 1.6%. *Ostrya* type increases (1.2-3.5%). No other type in this group exceeds 1.5%.

Two types of 'alpine shrubs' and one of 'alpine herbs' are represented at 0.3%. 'Woodland understorey trees and shrubs' decline and are represented by *Juniperus* only, which reaches a maximum of 2.0%. 'Woodland herbs' occur continuously, but remain at low values (1.8% maximum). 'Riverine trees' continue at slightly elevated values (0.9-3.7%) and *Salix triandra* continues to contribute most of the pollen. Other types in this group occur sporadically (0.6% maximum). 'Evergreen woodland trees' increase due to an increase in *Quercus coccifera* type (1.5-3.4%). *Ephedra fragilis* (0.6% in one spectrum) is the only other type represented in this group.

Zone K-1, 17.5-0 cm The boundary with the preceding zone is marked by increases in the relative frequencies of *Salix triandra* and *Cirsium* type; and a decline in the relative frequencies of 'coniferous and deciduous canopy trees' and *Quercus frainetto* type. This zone is characterised by high relative frequencies of 'herbs of open ground', 'cultivars', and *Pinus* (*Diploxylon*); increased relative frequencies of *Salix triandra*; and decreased relative frequencies of 'coniferous and deciduous canopy trees' and *Quercus frainetto* type.

'Herbs of open ground' increase to a moderate value (57.1%), then decline to low values (33.9-36.0%). *Pteridium aquilinum* remains at low abundance (0.8-2.5%). Other types in this group exceeding 2.0% are the same as those in the preceding zone with the exception of *Festuca* type, which declines (no spectrum reaches 2.0%); and those that increase to exceed 2.0% – *Galium* type (1.4-5.0%), *Lactuca* type (0.0-2.1%), and *Polygonum aviculare* type (2.2% maximum). A notable change is the increase in *Cirsium* type, which increases to 33.3% in the basal spectrum then declines to 8.6% in the uppermost.

'Cultivars' decline but frequencies remain high (3.3-5.0%). Cereal types still contribute most pollen of this group, although *Avena* has almost disappeared, being represented in the uppermost spectrum only at 0.3%. *Hordeum* type is also very poorly represented; only the basal and uppermost spectra are represented (0.3 and 0.1%). *Secale cereale* is represented continuously, but has declined (0.6-0.7%). *Triticum* type is also continuously represented (0.3-1.9%). *Zea mays* declines occurring sporadically and reaching only 0.8%. *Castanea sativa* increases to reach 1.6% in the second spectrum, but disappears in the uppermost. *Elaeagnus angustifolia* appears for the first time in the uppermost spectrum at 0.1%. *Juglans regia* occurs in one spectrum, at 0.2%. *Platanus orientalis* is represented continuously and increases slightly (1.2% maximum). *Vicia sativa* type occurs in the basal spectrum at 0.2%.

'Coniferous and deciduous canopy trees' decline, fluctuating from 30.9-48.2%. *Pinus* (*Diploxylon*) fluctuates from 19.0% in the basal spectrum to 37.0% at 10 cm, then to 17.6% in the uppermost. *Quercus frainetto* type has declined (4.2-11.6%). *Quercus trojana* type is

unchanged (3.2-5.5%) with the exception of the basal spectrum value of 0.9%. *Abies* fluctuates from 0.6-2.4%. No other type in this group exceeds 1.5%.

'Alpine shrubs' are not represented. Three types of 'alpine herbs' are represented, but at 0.3% or less. All pollen of 'woodland understorey trees and shrubs' (0.7-2.8%) is contributed by *Juniperus* with the exception of 0.1% of *Frangula* in the uppermost spectrum. 'Woodland herbs' occur continuously, remaining at low frequencies (2.4% maximum). 'Riverine trees' increase dramatically (5.0-20.5%) due to an increase in *Salix triandra*, which reaches the maximum of 19.7% in the spectrum second from the surface. Other types in this group occur sporadically and at 0.7% or less. 'Evergreen woodland trees' decline due to a decline in *Quercus coccifera* type, which contributes almost all the pollen of this group (0.3-1.3%).

6.5.3.3 Terrestrial vegetation history

This sequence records two periods of the vegetation history of the Kellia area, an older one of about 200 years duration beginning perhaps c. 830 BC (see section 6.4.2) and a younger one, which may span about the last 760 years beginning c. 1230 AD.

The habitat groups of 'herbs of open ground' and 'coniferous and deciduous canopy trees' are the most abundant groups in this sequence, as demonstrated in both the relative frequency and concentration diagrams (Figures 6.11 & 6.13). The former group is usually the more abundant, and other habitat groups are much less abundant. Total abundance of 'herbs of open ground' is shared mostly by 22 types, the most abundant of which are *Centaurea solstitialis* type, Chenopodiaceae type, *Cichorium* type, *Cirsium* type, *Dactylis* type, *Festuca* type, *Galium* type, *Hieracium* type, *Lactuca* type, *Plantago lanceolata* type, *Polygonum aviculare* type, *Pteridium aquilinum*, *Solidago* type, *Sonchus* type, and *Taraxacum* type. Total abundance of the habitat group 'coniferous and deciduous canopy trees' is shared mostly between the three types of *Pinus* (*Diploxylon*), *Quercus frainetto* type (deciduous oaks), and *Quercus trojana* type (deciduous/semi-evergreen oaks); *Abies* and *Ostrya* type also contribute significant amounts of pollen. The habitat group of 'cultivars' is well represented throughout the sequence and that of 'woodland understorey trees and shrubs' above 210 cm.

There is some correspondence between changes in the composition of the sediments and changes in the pollen profiles of both wetland and terrestrial pollen and spore types. Absence of total synchrony of these three factors is due to a significant contribution of pollen and spores derived from outside the catchment. This lowland site is today surrounded by cultivated fields and redeposition of cultivated soils is an important factor. The open fields are subject to sheet erosion and if the surface layers incorporate older pollen material it can be redeposited in the wetland basin.

The terrestrial vegetation history of the Kellia area is discussed below according to the local pollen assemblage zones. In this discussion pollen and spore types of the habitat groups 'herbs of open ground' and 'cultivars' are mentioned first because of their importance in the vegetation history of this site.

Zone K-14, 396.0-372.5 cm, within range c. 830-630 BC 'Herbs of open ground' is the dominant habitat group: two types *Pteridium aquilinum* and *Hieracium* type record maxima concentrations of this zone. They also record maxima concentrations of their respective types of the sequence and these are at much higher values than those of the surface sample. *Hieracium* type is entomophilous, has medium relative dispersal, and can be over-represented (Chapter 3). It grows mostly in dry open habitats on disturbed ground, often as a weed. In New Zealand it is a well known pasture weed in open dry land. The source of pollen for this type is probably extra-local, from within the catchment. *Pteridium aquilinum* has medium relative dispersal and is well-represented, so the distance of the source cannot be determined. *Pteridium aquilinum* is a cosmopolitan pioneer. It is pyrophytic, not affected by cattle grazing, and often gregarious in woodland clearings.

Other types in this habitat group that are abundant are *Centaurea solstitialis* type, *Cichorium* type, *Galium* type, *Lactuca* type, *Plantago lanceolata* type, *Solidago* type, *Sonchus* type, *Taraxacum* type, and the grasses *Dactylis* type and *Festuca* type. Species of the Compositae family and those represented by *Galium* type are entomophilous and thus usually not dispersed long distances, while those of *Plantago lanceolata* type are anemophilous as well as entomophilous and the grasses are anemophilous (Knuth 1906-9), thus having the potential to disperse their pollen further. The species of these types are ecologically heterogeneous, but comprise mostly weeds or ruderals and grow on disturbed waste land and cultivated fields (Appendix X). Of particular interest is the occurrence of *Agrostemma githago*, *Buglossoides arvensis* type, *Centaurea cyanus* type, *Galium* type, and *Sinapis* type, which include species that are weeds of cereal cultivation. Some of the species represented also grow in damp places such as fens and marshes and may have been growing on the fen, e.g. species included in *Galium* type, *Solidago* type, and *Taraxacum* type.

'Cultivars' are abundant. The most abundant type in this group is the cereal *Secale cereale*, but *Triticum* is also abundant. The cereals *Avena* and *Hordeum* type are also represented. The nut trees *Castanea sativa* and *Juglans regia*, and *Platanus orientalis* (often grown for shade), which may have been planted (Bottema 1980), are also represented. *Vicia sativa* type is represented, but this pollen type includes several wild species as well as cultivated species of *Vicia sativa*, and probably also the cultivated species *Vicia ervilia* and the weed of cultivation *Vicia pannonica*. *Vicia sativa* (vetch) was cultivated in the Pindos foothills and on the Grevena plains before 1940 for fodder on a subsistence basis. It is no

longer cultivated to the same extent. Seeds of domesticated *Vicia ervilia* (bitter vetch) were found in Macedonia at the archaeological sites of Nea Nikomedeia and Sitagroi in contexts dating to the Neolithic (Hansen 1988). The seeds are thought to have been used for human consumption (Renfrew, J. 1973a:116).

Identification of cereal pollen types is difficult and the types *Avena* and *Hordeum* type include some wild species as well as cultivars. Dispersal of pollen of *Avena*, *Hordeum*, and *Triticum* is very poor (Chapter 3) so they were either cultivated extra-locally or in the case of the former two may have grown wild in the vicinity. Dispersal of the pollen of the cereal *Secale cereale* is better, being anemophilous, thus extra-local cultivation is not necessarily indicated. This cereal was introduced into Greece during the Roman Period (Renfrew, J. 1969, 1973a), suggesting that the base of this zone is not older than 146 BC. This is more recent than the 830 BC date calculated from radiocarbon dating. Van Zeist (1976) has indicated that prior to introduction domesticated rye was inadvertently dispersed by prehistoric agriculturalists as a field weed.

The second most abundant habitat group is that of 'coniferous and deciduous canopy trees'. The most abundant canopy tree type is *Quercus trojana* type (deciduous/semi-evergreen oak); values of both concentration data and relative frequencies are higher than those of the surface sample. *Quercus frainetto* type (deciduous oak) is also abundant, but occurs at lower concentrations and relative frequencies than in the surface spectrum. Comparison between former abundance of oak trees and the current abundance, based on pollen representation, is complicated by the woodland management practice of coppicing, which tends to decrease pollen yield. Coppicing is carried out extensively today, and although many ancient stools have been noted the exact extent of former coppicing is not known. Deciduous and semi-evergreen oaks are the dominant trees in the lowlands and foothills of Grevena today. The constant occurrence in the pollen diagram of types representing these trees suggests that the source of pollen has not changed significantly. *Pinus (Diploxylon)* occurs at lower concentrations and relative frequencies than in the surface spectrum. Today there are no sources of *Pinus (Diploxylon)* pollen on the lowland with the exception of a small (planted) stand near Grevena city. Thus the source of *Pinus (Diploxylon)* is considered to be from a regional source. *Ostrya* type occurs at about the same relative frequencies and concentrations as it does in the surface spectrum, and indeed throughout the sequence. Trees comprising this pollen type are scarce in Grevena today and grow in a variety of habitats (but mostly in damp environments) at various elevations (Chapter 3, Appendix X). The pollen source may be extra-local or regional, or both.

The habitat groups of alpine shrubs and herbs are extremely poorly represented in this zone and indeed throughout the sequence, reflecting the long distance of alpine vegetation

from the site and its low pollen production. 'Woodland understorey trees and shrubs' and 'woodland herbs' are poorly represented, indicating a poorly developed woodland understorey vegetation. The relative frequencies and concentrations of 'riverine trees' are so low that a local or an extra-local presence is unlikely; the pollen probably derives from more distant streams. 'Evergreen woodland trees' are very poorly represented. *Quercus coccifera* type (evergreen oak) is the most abundant type in the group. The concentrations of this type are about the same as those of the surface spectrum. Today *Quercus coccifera* grows in a small stand of pseudo-*maquis* in the southeast corner of Grevena. *Quercus coccifera* is anemophilous, has high relative dispersal, and is over represented (Chapter 3). It is pyrophytic and takes advantage of destruction of primary forests (Behre 1990). The poor representation of this habitat group and that of 'plants of open rocky habitats' suggests that a Mediterranean-type vegetation does not occur extra-locally, and forms only a small part of the regional vegetation, as at present.

The sum of terrestrial trees and shrubs represents from 24.4-33.7% of total terrestrial pollen and spores; the minima of the sequence. The low ratio of terrestrial trees and shrubs to terrestrial herbs, high palynological richness values (25-40 expected types), and high relative frequencies and concentrations of the habitat group of 'herbs of open ground' are indicative of an open canopy.

The extra-local and regional lowland vegetation surrounding the Kellia wetland at this time was probably a highly disturbed vegetation with scattered open canopy deciduous and semi-evergreen oak woodland with a poorly developed understorey of herb-rich steppe, rather than shrubs and woodland herbs. The occurrence of *Pteridium aquilinum* suggests the presence of a pioneer vegetation, perhaps created by the burning of oak woodland. Cereals were cultivated extra-locally and the pulses *Vicia sativa* and *Vicia ervilia* may have been also. The nut trees *Castanea sativa* and *Juglans regia* may have been planted either extra-locally or further from the site. A habitat suitable for *Platanus orientalis* may have been created by human disturbance of the natural vegetation extra-locally or further from the wetland, or this tree may have been growing wild on flood plains. Riverine trees grew on more distant flood plains and pine woods grew at higher elevations further from the site in the Pindos Mountains.

Zone K-13, 372.5-312.5 cm, within range c. 830-630 BC 'Herbs of open ground' remain the most abundant group, although concentration values are lower due to a decline in *Hieracium* type and *Pteridium aquilinum*. These types still record higher values than those of the surface sample, but have concentrations similar to those of *Centaurea solstitialis* type and *Dactylis* type whose concentrations are unchanged from the preceding zone. *Cichorium* type, *Festuca* type, *Galium* type, *Lactuca* type, *Solidago* type, *Sonchus* type, and *Taraxacum* type continue to be abundant. *Chenopodiaceae* type, *Cirsium* type, and *Polygonum aviculare*

type now become abundant while *Plantago lanceolata* type declines. Of particular interest is the occurrence of *Centaurea cyanus* type, *Galium* type, *Nigella*, and *Sinapis* type, which include species that are weeds of cereal cultivation.

'Cultivars' are still abundant, but concentration values have declined slightly with the disappearance of *Triticum* type and *Vicia sativa* type, and a decline in *Secale cereale*. *Secale cereale* is still the most abundant cultivar type and the cereal types *Avena* and *Hordeum* type are abundant, increasing slightly. The pollen type *Zea mays* occurs at low abundance at 330 cm, and small numbers of this pollen type were counted in samples at higher levels. Identification of these large Gramineae pollen grains followed the key set out in Appendix VI (and references therein). *Zea mays* was introduced into Europe from the New World after 1500 AD, and did not become widespread in cultivation until c. 1700 AD (Huber 1962 in Bottema 1980; Bottema 1981). Radiocarbon dating indicates that these pollen grains cannot be *Zea mays*. It is most likely that they should be attributed to *Triticum* type or *Avena*, which although usually having smaller pollen grains, also have relatively large *porus annuli*, and are closest in morphology among the cereal group. The shade tree *Platanus orientalis* increases slightly and the nut trees *Castanea sativa* and *Juglans regia* remain unchanged. The occurrence of *Castanea sativa* and *Juglans regia* in this and the zone below suggests that the vegetation of these two zones grew at a time before 1628-1626 BC (Bottema 1980; Bottema 1981; Bottema 1994; Bottema & Woldring 1990). This is not consistent with the radiocarbon age of c. 2000 BC at the top of this zone, but the estimated date (830 BC) from the radiocarbon date at the base of the sequence is more recent.

The habitat group of 'coniferous and deciduous canopy trees' has increased in relative frequency and concentration values, but is still the second most abundant habitat group. The increases are due to increases in *Pinus* (*Diploxylon*), *Quercus frainetto* type, and *Quercus trojana* type. Relative frequencies and concentration values of *Pinus* (*Diploxylon*) increase slightly to about the average of the sequence, which is much less than the values of the surface sample. Deciduous and semi-evergreen oaks are co-dominant and increase to relative frequency maxima of the sequence and concentrations that are also close to the maxima of the sequence. Relative frequencies and concentrations of *Ostrya* type are about the same as those of the preceding zone.

Alpine shrub and herb types are again extremely poorly represented. 'Woodland understory trees and shrubs' and 'woodland herbs' are also extremely poorly represented. 'Riverine trees' decline slightly. 'Evergreen woodland trees' are again poorly represented; *Quercus coccifera* type declines slightly. 'Plants of open dry rocky habitats' are poorly represented with the exception of *Agropyron* type, which becomes abundant. This pollen type includes mostly wild grasses that grow in dry habitats with the exception of one species that

may belong to this type, *Panicum miliaceum* (broomcorn millet). This small grained species was formerly widely cultivated as a cereal (Tutin *et al.* 1964-80).

The sum of terrestrial trees and shrubs represents from 35.2-52.9% of total terrestrial pollen and spores. The low ratio of terrestrial trees and shrubs to terrestrial herbs, high palynological richness values (30-40 expected types), and high relative frequencies and concentrations of the habitat group of 'herbs of open ground' (especially of the pioneer *Pteridium aquilinum*) are indicative of an open canopy.

The extra-local and regional lowland vegetation is still highly disturbed with an open canopy deciduous and semi-evergreen oak woodland with an understorey of herb-rich steppe, rather than of shrubs and woodland herbs. An increase in the concentrations of both the deciduous and deciduous/semi-evergreen oak pollen types suggest that either the oak wood has expanded or become more dense. A decline in concentration values of 'herbs of open ground' and *Pteridium aquilinum*, and an increase in the ratio of terrestrial trees and shrubs to terrestrial herbs support the latter. Cultivation of cereals is carried out extra-locally and the nut trees of *Castanea sativa* and *Juglans regia*, and the shade-tree *Platanus orientalis* continue to grow either sparsely extra-locally or more abundantly at a greater distance. Distant high elevation pine woods continue at about the same abundance.

Zone K-12, 312.5-287.5 cm, c. 1230-1320 AD 'Herbs of open ground' are co-dominant with the habitat group of 'coniferous and deciduous canopy trees'. The relative frequencies of 'herbs of open ground' are low for the sequence, but concentrations are very high. This is due to an increase in total concentration. *Pteridium aquilinum* declines further to very low concentration values at the top of the zone, where concentrations are almost as low as those of the surface sample. The pollen types *Polygonum aviculare* type, *Solidago* type, *Sonchus* type, and *Taraxacum* type with increased relative frequencies from the preceding zone; and *Centaurea solstitialis* type, Chenopodiaceae type, *Cichorium* type, *Cirsium* type, *Hieracium* type, *Lactuca* type, *Plantago lanceolata* type, *Dactylis* type, and *Festuca* type are abundant. *Galium* type has declined and the only other pollen type, *Sinapis* type, which includes species that are weeds of cereal cultivation occurs in the basal spectrum only.

'Cultivars' are again abundant, occurring at similar relative frequencies as in the preceding zone. Concentration values are increased in the lower part of the zone due to an increase in *Secale cereale* type and the presence of '*Zea mays*' type. *Secale cereale* remains the most abundant cereal type. Other cereals of *Avena* and *Hordeum* type occur sporadically at about the same abundance as in the preceding zone. The nut trees *Castanea sativa* and *Juglans regia* continue at similar abundance while *Platanus orientalis* declines.

The habitat group of 'coniferous and deciduous canopy trees' has increased in relative frequency and concentration values, due to increases in *Pinus* (*Diploxylon*) and *Quercus*

frainetto type. The frequency of *Quercus trojana* type has declined, but concentration values are high, probably due to the increase in total concentration. Deciduous oaks (*Quercus frainetto* type) are now more abundant than deciduous/semi-evergreen oaks (*Quercus trojana* type). *Ostrya* type has declined slightly.

Alpine shrubs and herbs are not represented. 'Woodland understorey trees and shrubs' and 'woodland herbs' are again extremely poorly represented. 'Riverine trees' have declined further and only *Salix triandra* is represented, at extremely low values. 'Evergreen woodland trees' and 'plants of open dry rocky habitats' have almost disappeared.

The sum of terrestrial trees and shrubs represents from 40.9-58.1% of total terrestrial pollen and spores. The low ratio of terrestrial trees and shrubs to terrestrial herbs, high palynological richness values (30-40 expected types), and high relative frequencies and concentrations of 'herbs of open ground' are indicative of an open canopy.

The extra-local and regional lowland vegetation is still highly disturbed and has an open canopy and an understorey of herb-rich steppe. The oak woodland now comprises more deciduous oaks than deciduous/semi-evergreen oaks. The higher proportion of deciduous oaks may be due to a reduction of coppicing (*Quercus frainetto*, which today is the preferred coppice-tree, takes at least 50 years to produce flowers after coppicing whereas other oaks produce flowers in the later part of each coppicing cycle (30-40 years)), selective preservation of deciduous oaks for the purpose of coppicing or to an increase in climatic wetness. Increased concentrations of the pollen types representing the oak wood may be due to a denser or expanded woodland and/or to slower sediment accumulation. A decline in the frequencies of 'herbs of open ground' and *Pteridium aquilinum* and an increase in the ratio of terrestrial trees and shrubs to terrestrial herbs support the first two, while sediments rich in organic detritus support the last. The near disappearance of *Quercus coccifera* type may be due to a reduction in direct or indirect human disturbance of the vegetation (e.g. burning), or to more humid climatic conditions. The reduction in *Pteridium aquilinum* suggests a reduction in burning of the woodland. Cereals are cultivated extra-locally. The trees *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* continue to grow naturally or are planted, either sparsely extra-locally or more abundantly regionally. Mountain pine woods may have increased slightly.

Zone K-11, 287.5-237.5 cm, c. 1320-1370 AD 'Herbs of open ground' are dominant in the relative frequency diagram, while in the concentration diagram they are co-dominant with 'coniferous and deciduous canopy trees'. Relative frequencies of 'herbs of open ground' have increased but concentration values are low, due to low total concentration values. Relative frequencies and concentrations of *Pteridium aquilinum* have now declined to values as low as those of the surface sample. Types of this habitat group that are abundant are the same as

in the preceding zone, with the addition of *Galium* type, which has increased. Of particular interest is the occurrence of *Agrostemma githago*, *Buglossoides arvensis*, *Centaurea cyanus* type, *Galium* type, *Nigella*, and *Sinapis* type, which include species that are weeds of cereal cultivation.

'Cultivars' are again abundant; relative frequencies have increased due to increases in *Avena*, *Platanus orientalis*, and *Secale cereale* types. Concentration values have declined due to a decline in total concentration. The cereal types *Avena* and *Secale cereale* occur continuously while those of *Hordeum* type and *Zea mays* occur sporadically. *Vitis vinifera* occurs for the first time at low abundance. *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* continue to occur sporadically at low abundances, although they now occur more often.

The habitat group of 'coniferous and deciduous canopy trees' declines in relative frequency due to decreases in *Pinus* (*Diploxylon*) and *Quercus frainetto* type. The relative frequencies of *Quercus trojana* type fluctuate but in general they have increased and are high for this sequence. Concentration values are low due to low total concentration. *Ostrya* type occurs at low abundance, but at highest relative frequencies of the sequence.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understorey trees and shrubs' and 'woodland herbs' are poorly represented but the number of types represented has increased and *Juniperus* has increased slightly in relative frequency. 'Riverine trees' are also represented by more types, but at very low values. 'Evergreen woodland trees' and 'plants of open dry rocky habitats' are also represented by more types but at very low values.

The sum of terrestrial trees and shrubs represents from 35.5-47.6% of total terrestrial pollen and spores. The low ratio of terrestrial trees and shrubs to terrestrial herbs, very high palynological richness values (40-60 expected types), and high relative frequencies and concentrations of 'herbs of open ground' are indicative of an open canopy.

The extra-local and regional lowland vegetation surrounding the wetland continues to be highly disturbed open canopy oak woodland with a herb-rich steppe understorey. Deciduous and deciduous/semi-evergreen oaks occur in about the same proportion due to a decline in *Quercus frainetto* type and an increase in *Quercus trojana* type. These changes may be related to increased coppicing of the deciduous oaks or to drier climatic conditions. An increase in the relative frequencies of 'herbs of open ground' and in palynological richness, and a decline in the ratio of terrestrial trees and shrubs to terrestrial herbs may indicate increased disturbance of the woodland. Concentrations of *Quercus frainetto* type and *Quercus trojana* type are very low and is probably due to rapid sedimentation of minerogenic sediments. *Quercus coccifera* type occurs at extremely low abundance. Cultivation of cereals continues in the vicinity and perhaps viticulture has begun, but *Vitis vinifera* may be growing wild on

the wetland. The nut trees and *Platanus orientalis* may be growing wild or are planted either extra-locally or regionally. High elevation pine woods may have declined.

Zone K-10, 237.5-202.5 cm, c. 1370-1480 AD 'Herbs of open ground' are dominant again and relative frequencies are high, being the same as those of the preceding zone; concentrations have increased due to an increase in total concentration. The relative frequencies of *Pteridium aquilinum* have decreased slightly, while concentrations have increased slightly. Types of this group that are abundant are the same as those in the preceding zone, with the addition of *Bilderdykia*, which has increased. The following types that occur include species that are weeds of cereal cultivation: *Centaurea cyanus* type, *Galium* type, *Nigella*, and *Sinapis* type.

'Cultivars' are again abundant; relative frequencies and concentrations have increased due to increases in *Avena*, *Hordeum* type, *Platanus orientalis*, and *Secale cereale* types. The cereal types *Avena* and *Secale cereale* occur continuously while *Hordeum* type and *Zea mays* occur sporadically. *Vitis vinifera* occurs in one spectrum only. *Castanea sativa* and *Juglans regia* occur sporadically at low values.

The habitat group of 'coniferous and deciduous canopy trees' is the second most abundant group. Relative frequencies are unchanged but concentration values increase due to an increase in total concentration. The concentrations of *Pinus* (*Diploxylon*) are comparatively high and relative frequencies increase. Relative frequencies of *Quercus frainetto* type are unchanged to the centre of the zone but then they decline, concentrations have increased due to an increase in total concentration. The relative frequencies of *Quercus trojana* type have declined while concentrations have increased. The deciduous oaks (*Quercus frainetto* type) are again more abundant than the deciduous/semi-evergreen (*Quercus trojana* type). *Ostrya* type has declined while *Fraxinus ornus* occurs at low but significant abundance.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understorey trees and shrubs' and 'woodland herbs' are poorly represented; the number of types represented by the former group declines to three. *Juniperus* increases steadily but still occurs at low values. 'Riverine trees' are poorly represented and the number of types represented declines. 'Evergreen woodland trees' and 'plants of open dry rocky habitats' decline to very low abundance.

The sum of terrestrial trees and shrubs represents from 38.4-50.3% of total terrestrial pollen and spores. The low ratio of terrestrial trees and shrubs to terrestrial herbs, very high palynological richness values (40-55 expected types), and high relative frequencies and concentrations of the habitat group of 'herbs of open ground' are indicative of an open canopy.

The extra-local and regional lowland vegetation surrounding the wetland continues to be highly disturbed open canopy oak woodland with an understorey of herb-rich steppe; although *Juniperus* increases slightly. Deciduous oaks are more abundant than deciduous/semi-evergreen oaks due to a decline in *Quercus trojana* type. This decline may be caused by wetter climatic conditions. *Quercus coccifera* type continues at extremely low abundance. Slightly lower abundance of *Pteridium aquilinum* may indicate a reduction in burning. An increase in total pollen concentration, unchanged relative frequencies of the habitat group 'herbs of open ground', and the absence of a change in the ratio of terrestrial trees and shrubs to terrestrial herbs may indicate greater stability in the landscape. Cultivation of cereals continues in the vicinity, perhaps at increased intensity. Cultivation of *Vitis vinifera* may occur and the nut trees of *Castanea sativa* and *Juglans regia*, and *Platanus orientalis* may be planted or grow naturally either extra-locally or regionally. Mountain pine woods increase.

Zone K-9, 202.5-177.5 cm, c. 1480-1580 AD 'Herbs of open ground' increase in the upper half of the zone and are dominant again. Relative frequencies are high in the lower half of the zone and become very high in the upper half. Concentrations are also high and increase. These increases are partly due to a dramatic increase in Chenopodiaceae type. Relative frequencies and concentrations of *Pteridium aquilinum* increase slightly. Types of this group that are abundant are the same as those in the preceding zone. Several types that occur include species that are weeds of cereal cultivation: *Agrostemma githago*, *Centaurea cyanus* type, *Galium* type, *Nigella*, and *Sinapis* type.

'Cultivars' increase to highest values of the sequence in relative frequency and concentration, due to increases in *Avena*, *Hordeum* type, *Secale cereale*, and *Zea mays* types, which are continuously represented, and the representation of more types – *Triticum* type, *Humulus lupulus*, and *Vicia sativa* type occur in one spectrum. Trees that may have been planted decline: *Castanea sativa* occurs sporadically, *Juglans regia* disappears, and *Platanus orientalis* declines.

The habitat group of 'coniferous and deciduous canopy trees' is the second most abundant group. Relative frequencies have declined to almost the lowest of the sequence, due to a dramatic decline in *Quercus trojana* type and a less pronounced decline in *Quercus frainetto* type. Concentration values of the group are unchanged because the decline in the two oak types is off-set by an increase in *Pinus (Diploxylon)*. Deciduous oaks continue to be more abundant than deciduous/semi-evergreen oaks.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understorey trees and shrubs' and 'woodland herbs' are poorly represented: the only type that occurs in significant abundance is *Juniperus*, which continues to increase in relative frequency and concentration. 'Riverine trees' are poorly represented. 'Evergreen woodland trees' are also

poorly represented, but 'plants of open dry rocky habitats' increase slightly due to an increase in *Agropyron* type.

The sum of terrestrial trees and shrubs represents 29.9-41.1% of total terrestrial pollen and spores. The very low ratio of terrestrial trees and shrubs to terrestrial herbs, high palynological richness values (about 37-47 expected types), and high relative frequencies and concentrations of 'herbs of open ground' are indicative of an open canopy.

The extra-local and regional lowland vegetation continues to be highly disturbed open canopy oak woodland of deciduous and semi-evergreen oaks, with deciduous oaks dominant. The understorey may now include *Juniperus* as well as a herb-rich steppe. A reduction in canopy cover is suggested by a dramatic decline in deciduous/semi-evergreen oaks, and an increase in 'herbs of open ground', particularly in the pioneer *Pteridium aquilinum*. The cause of the reduction in the deciduous/semi-evergreen oaks may be due to more humid climatic conditions, although deciduous oaks decline also. *Quercus coccifera* type continues at extremely low abundance. A dramatic increase in Chenopodiaceae type may result from increased clearance for cultivation fields (extra-locally) or increased grazing. Increases in the cereal pollen types supports the former, while the latter is supported by an increase in *Juniperus*. The increase in *Agropyron* type may be due to *Panicum miliaceum* (broomcorn millet) being cultivated, or to wild grasses growing in dry habitats. Wetter climatic conditions are supported by the development of peat on the wetland. Mountain pine woods have increased.

Zone K-8, 177.5-157.5 cm, c. 1580-1650 AD 'Herbs of open ground' decline and overall relative frequencies and concentration are about the same as those of 'coniferous and deciduous canopy trees'. Relative frequencies and concentrations of *Pteridium aquilinum* decline to very low values, almost as low as those of the surface sample. No significant changes occur in the other most abundant types of this group, with the exception of Chenopodiaceae type returning to an abundance similar to that of zone K-10. Four types that occur include species that are weeds of cereal cultivation: *Centaurea cyanus* type, *Galium* type, *Nigella*, and *Sinapis* type.

'Cultivars' decline in relative frequency and concentration, due to reductions in all constituent taxa, but are still abundant. The decline in concentration is partially due to a decline in total concentration. *Avena*, *Hordeum* type, and *Secale cereale* types occur continuously while the type *Zea mays* occurs in all except the basal spectrum. *Triticum* type disappears. *Morus nigra* appears in two spectra at low values. The trees *Castanea sativa*, *Juglans regia* (reappears), and *Platanus orientalis* all occur sporadically at low values.

Relative frequencies of 'coniferous and deciduous canopy trees' increase to comparatively high values due to an increase in *Quercus frainetto* type. *Pinus* (*Diploxylon*)

continues at comparatively high values, while *Quercus trojana* type continues at low relative frequencies. Concentrations of *Quercus frainetto* type increase slightly, those of *Pinus* (*Diploxylon*) fluctuate and decline slightly, while those of *Quercus trojana* type continue at similar values to those of the zone below.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understory trees and shrubs' and 'woodland herbs' are poorly represented with the exception of *Juniperus*, which continues to increase, perhaps encouraged by grazing. 'Riverine trees' are poorly represented 'Evergreen woodland trees' and 'plants of open dry rocky habitats' decline slightly, due to a decline in *Agropyron* type.

The sum of terrestrial trees and shrubs increases to 40.1-58.1% of total terrestrial pollen and spores. The low ratio of terrestrial trees and shrubs to terrestrial herbs, very high palynological richness values (about 42-55 expected types), and high relative frequencies and concentrations of 'herbs of open ground' are indicative of an open canopy.

The extra-local and regional lowland vegetation continues to be highly disturbed open canopy oak woodland dominated by deciduous oaks, semi-evergreen oaks play a minor role. The understory may now include more *Juniperus*. Steadily increasing *Juniperus* may be indicative of grazing in the area, or a reduction in extra-local burning. A slight increase in canopy cover of the oak wood is suggested by an increase in the concentration of *Quercus frainetto* type and a slight decrease in 'herbs of open ground', particularly in *Pteridium aquilinum*. The decline of cereal pollen suggests a reduction of cultivation. *Quercus trojana* type does not recover and peat continues to form on the wetland. *Quercus coccifera* type continues at extremely low abundance. Pine woods may decline slightly.

Zone K-7, 157.5-142.5 cm, c. 1650-1680 AD 'Herbs of open ground' again become dominant and relative frequencies are the highest of the sequence with the exception of the basal zone. *Pteridium aquilinum* increases slightly. No significant changes occur in the most abundant types of this group. A dramatic increase in *Polygonum aviculare* type in two spectra are probably due to species of this type growing on the wetland close to the coring site. Three types that occur include species that are weeds of cereal cultivation: *Centaurea cyanus* type, *Galium* type, and *Nigella*.

'Cultivars' are abundant, but their relative frequencies decline slightly, due to a slight decline in all cereal types. Concentrations are similar to those in the preceding zone. The types of *Avena*, *Hordeum* type, and *Secale cereale* are represented continuously, while those of *Triticum* type and *Zea mays* occur sporadically. *Platanus orientalis* occurs continuously at low values. *Castanea sativa* occurs sporadically and *Juglans regia* disappears.

Relative frequencies and concentrations of 'coniferous and deciduous canopy trees' decline and are the minimum overall values for a zone. Concentration values are

comparatively low, but not minima of the sequence. This decline is due to a decline in relative frequencies and concentrations of *Pinus* (*Diploxylon*), *Quercus frainetto* type, and *Quercus trojana* type.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understorey trees and shrubs' and 'woodland herbs' are also poorly represented with the exception of *Juniperus*, which continues at the same abundance as in the preceding zone. 'Riverine trees' decline to very low abundance. 'Evergreen woodland trees' and 'plants of open dry rocky habitats' continue at very low abundance.

The sum of terrestrial trees and shrubs declines to very low values of 29.4-36.9% of total terrestrial pollen and spores. The low ratio of terrestrial trees and shrubs to terrestrial herbs, high palynological richness values (35-45 expected types), and very high relative frequencies and concentrations of the habitat group of 'herbs of open ground' are indicative of an open canopy.

Extra-local and regional lowland vegetation continues to be highly disturbed open canopy oak woodland dominated by deciduous oaks with semi-evergreen oaks now a very minor component. An understorey the same as in the preceding zone is indicated. A decrease in canopy cover of the oak wood is suggested by the increase in 'herbs of open ground', particularly of *Pteridium aquilinum*, and a decrease in the ratio of terrestrial trees and shrubs to terrestrial herbs. Evergreen oaks continue at extremely low abundance. A slight decrease in cereal pollen types suggests that cultivation of cereals has declined slightly. The abundance of *Juniperus* suggests that grazing of the woodland is occurring.

Zone K-6, 142.5-117.5 cm, c. 1680-1720 AD 'Herbs of open ground' decline to comparatively low relative frequencies and concentration values. Low concentration values are partly due to low total concentration values. Relative frequencies of *Pteridium aquilinum* increase while concentration values decrease but this decrease is due to a decrease in total concentration values. No significant changes occur in the most abundant types of this group. Four types that occur include species that are weeds of cereal cultivation: *Agrostemma githago*, *Centaurea cyanus* type, *Galium* type, and *Sinapis* type.

'Cultivars' are abundant and increase in the upper part of the zone in both values due to increases in *Avena*, *Hordeum* type, and *Secale cereale*. *Hordeum* type and *Secale cereale* occur continuously, while *Avena*, *Triticum* type, and *Zea mays* occur sporadically. *Platanus orientalis* occurs continuously at low values, while *Castanea sativa* occurs sporadically.

Relative frequencies of 'coniferous and deciduous canopy trees' increase, while concentrations of this group decline, then increase in the uppermost sample. The decline in concentration is due to the decline in total concentration. The increase in relative frequency is due to increases in *Quercus frainetto* type and *Quercus trojana* type. *Quercus frainetto* type

increases to comparatively high relative frequencies for this sequence while *Quercus trojana* type increases to comparatively low relative frequencies and remains less abundant than the former type.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understorey trees and shrubs' and 'woodland herbs' are also poorly represented with the exception of *Juniperus*, which increases to highest relative frequencies of the sequence. 'Riverine trees' are poorly represented. 'Evergreen woodland trees' and 'plants of open dry rocky habitats' are poorly represented, but the pollen type *Quercus coccifera* type fluctuates and reaches its highest relative frequencies of the sequence in several spectra.

The sum of terrestrial trees and shrubs increases to 44.2-54.8% of total terrestrial pollen and spores, about average values for the sequence. The low ratio of terrestrial trees and shrubs to terrestrial herbs, high palynological richness values (about 40 expected types), and very high relative frequencies and concentrations of 'herbs of open ground' are indicative of an open canopy.

Extra-local and regional lowland vegetation continues to be highly disturbed open canopy oak woodland dominated by deciduous oaks. Semi-evergreen oaks have increased importance but are still a minor component and *Juniperus* is an important part of the understorey. An increase in canopy cover, at least extra-locally, is suggested by the decrease in 'herbs of open ground', an increase in the relative frequencies of deciduous and deciduous/semi-evergreen oaks, and an increase in the ratio of terrestrial trees and shrubs to terrestrial herbs, but the abundance of *Juniperus* suggests that the canopy is still open. *Pteridium aquilinum* increases; the source of the spores may be local, extra-local or regional. An increase in cereal cultivar types in the upper part of the zone suggests that cultivation of cereals has expanded. The increase in *Quercus coccifera* type may be due to degradation of the deciduous and semi-evergreen oak woodland, either extra-locally or regionally, into pseudo-*maquis* or to long distance transport (Chapter 3). Mountain pine woods remain at the reduced abundance of the preceding zone.

Zone K-5, 117.5-77.5 cm, c. 1720-1790 AD 'Herbs of open ground' are dominant. Relative frequencies increase towards the top of the zone. Concentrations fluctuate, following the curve of total concentration, and are slightly higher in general due to an increase in total concentration. Relative frequencies and concentrations of *Pteridium aquilinum* increase. No significant changes occur in the other most abundant types of this group. An increase in *Polygonum aviculare* type in two spectra may be due to species of this type growing on the wetland close to the coring site. Three types that occur include species that are weeds of cereal cultivation: *Centaurea cyanus* type, *Galium* type, and *Sinapis* type.

'Cultivars' are abundant. In general relative frequencies and concentrations are the same as those in the preceding zone. *Hordeum* type and *Secale cereale* occur continuously, while *Avena*, *Triticum* type, and *Zea mays* occur sporadically. *Vitis vinifera* occurs in one spectrum. *Castanea sativa* continues occurring sporadically at low abundance, *Juglans regia* reappears and occurs sporadically, and *Platanus orientalis* declines and occurs only sporadically.

Relative frequencies of 'coniferous and deciduous canopy trees' increase again due to increases in *Pinus* (*Diploxylon*) and *Abies*. *Abies* increases to relative frequencies similar to those of the surface sample. Concentrations increase; there is an increase in total concentration also. Relative frequencies and concentrations of *Quercus frainetto* type and *Quercus trojana* type decline slightly and *Quercus frainetto* type remains the dominant type.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understory trees and shrubs' and woodland herbs' are also poorly represented with the exception of *Juniperus*, which now begins to decline. 'Riverine trees' are poorly represented. 'Evergreen woodland trees' and 'plants of open dry rocky habitats' are poorly represented with the exception of *Quercus coccifera* type, which has declined slightly.

The sum of terrestrial trees and shrubs increases to 36.5-50.1% of total terrestrial pollen and spores. The low ratio of terrestrial trees and shrubs to terrestrial herbs, high palynological richness values (35-45 expected types), and very high relative frequencies and concentrations of 'herbs of open ground' are indicative of an open canopy.

Extra-local and regional lowland vegetation continues to be highly disturbed open canopy oak woodland with trees represented by *Quercus frainetto* type dominant, and those of *Quercus trojana* type playing a minor role. The importance of *Juniperus* in the understory is declining. A slight decrease in canopy cover may occur as suggested by an increase in 'herbs of open ground', a slight decline in the abundance of deciduous and semi-evergreen oaks, and a decline in the ratio of terrestrial trees and shrubs to terrestrial herbs. An increase in *Pteridium aquilinum* may be due to the reduction in canopy cover, although declining *Juniperus* suggests a closing canopy. Cultivation of cereals appears to continue at about the same level of intensity. The increase in the montane conifers *Pinus* (*Diploxylon*) and *Abies* may be due to a reduction in burning of the montane vegetation. A mixed *Pinus/Abies* wood similar to that growing in part of the Pindos today may have developed (Chapter 3).

Zone K-4, 77.5-57.5 cm, c. 1790-1840 AD 'Herbs of open ground' are the second most abundant habitat group; relative frequencies decrease to the lowest of the sequence. Concentrations decline, but total concentrations also decline. Relative frequencies and concentrations of *Pteridium aquilinum* decline. No significant changes occur in the other most abundant types of this group. Pollen types including species that are weeds of cereal cultivation have declined and include only *Galium* type and *Sinapis* type.

'Cultivars' are abundant. Relative frequencies and concentrations increase through the zone due to an increase in *Platanus orientalis*. All cereal types have declined with the exception of *Zea mays*, which occurs continuously at similar abundance to that in the preceding zone. *Platanus orientalis* occurs continuously at increased levels of abundance. *Castanea sativa* occurs continuously at low abundance and *Juglans regia* occurs sporadically at low abundance.

Relative frequencies of 'coniferous and deciduous canopy trees' increase to the highest of the sequence, due to a large increase in *Pinus* (*Diploxylon*) and small increases in *Quercus frainetto* type and *Abies*. This is the first zone where 'coniferous and deciduous canopy trees' are the dominant habitat group. Concentration values of these pollen types remain about the same although total concentration declines. Relative frequencies of *Quercus trojana* type are unchanged and concentrations decline slightly.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understorey trees and shrubs' are poorly represented. *Juniperus* declines to relative frequencies slightly more and concentrations less than those of the surface sample. 'Riverine trees' increase due to an increase in *Salix triandra*, which is part of the current riverine flood plain vegetation of Grevena. It occurs at much lower abundance than that of the surface sample. 'Evergreen woodland trees' and 'plants of open dry rocky habitats' are poorly represented; *Quercus coccifera* type occurs sporadically.

The sum of terrestrial trees and shrubs increases to 58.4-69.4% of total terrestrial pollen and spores, which is the maximum of the sequence. The low ratio of terrestrial trees and shrubs to terrestrial herbs, high palynological richness values (40-45 expected types), and high relative frequencies and concentrations of 'herbs of open ground' are indicative of an open canopy.

Extra-local and regional lowland vegetation continues to be highly disturbed open canopy oak woodland with deciduous oaks dominant and semi-evergreen oaks playing a minor role. An increase in canopy cover is suggested by a decline in 'herbs of open ground', an increase in the abundance of deciduous oaks, and a decline in the ratio of terrestrial trees and shrubs to terrestrial herbs. A decrease in *Pteridium aquilinum* and *Juniperus* may be due to more canopy cover. Cultivation of cereals has declined. An increase in *Platanus orientalis* and *Salix triandra* suggests an expansion of the riverine flood plain vegetation of the province. *Salix* may also be growing on the fen, as it does today. The distant *Pinus* (*Diploxylon*)/*Abies* woodland, probably mostly on the Pindos Mountains, expands.

Zone K-3, 57.5-32.5 cm, c. 1840-1880 AD 'Herbs of open ground' are dominant. Relative frequencies increase to high values. Concentrations increase, but total concentration increases also. Relative frequencies and concentrations of *Pteridium aquilinum* remain at low

values. No significant changes occur in the other most abundant types of this group, with the exception of an increase in *Dactylis* type. Three types that occur include species that are weeds of cereal cultivation: *Centaurea cyanus* type, *Galium* type, and *Sinapis* type.

'Cultivars' are abundant, have increased, and almost reached the maxima of the sequence (zone K-9) due to increases in the types *Avena* and *Secale cereale*, which reach their maximum relative frequencies of the sequence. *Zea mays* occurs continuously. *Hordeum* type and *Triticum* type occur sporadically. *Lathyrus sativus* and *Morus alba* both occur in the basal spectrum only. *Platanus orientalis* occurs continuously but declines steadily. *Castanea sativa* also occurs continuously and *Juglans regia* occurs sporadically at about the same level of abundance as previously.

Relative frequencies of 'coniferous and deciduous canopy trees' decline to almost the minimum of the sequence due to a dramatic decline in *Pinus* (*Diploxylon*) and *Abies*, and a smaller decline in *Quercus frainetto* type. *Quercus trojana* type continues unchanged.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understory trees and shrubs' are poorly represented; *Juniperus* increases slightly. 'Riverine trees' continue at the increased values of the preceding zone with *Salix triandra* the dominant type. 'Evergreen woodland trees' and 'plants of open dry rocky habitats' are poorly represented; *Quercus coccifera* type occurs continuously but at low values.

The sum of terrestrial trees and shrubs declines but fluctuates: 34.0-54.4% of total terrestrial pollen and spores. The very low ratio of terrestrial trees and shrubs to terrestrial herbs, high palynological richness values (40-45 expected types), and high relative frequencies and concentrations of 'herbs of open ground' are indicative of an open canopy.

Extra-local and regional lowland vegetation continues to be highly disturbed open canopy oak woodland with deciduous oaks dominant and semi-evergreen oaks playing a minor role. *Juniperus* probably forms a significant part of the understory. A decrease in canopy cover is indicated by an increase in the habitat group of 'herbs of open ground', a decline in the abundance of deciduous oaks, and a decline in the ratio of terrestrial trees and shrubs to terrestrial herbs. An increase in *Juniperus* also supports a decrease in canopy cover. Cultivation of cereals increases greatly. The riverine flood plain vegetation may have declined slightly as indicated by a decline in *Platanus orientalis* although concentration values of the habitat group of 'riverine trees' are unchanged. The distant higher elevation *Pinus* (*Diploxylon*)/*Abies* woodland declines.

Zone K-2, 32.5-17.5 cm, c. 1880-1910 AD 'Herbs of open ground' are the second most abundant habitat group; relative frequencies and concentrations decrease. *Pteridium aquilinum* declines. No significant changes occur in the other most abundant types of this

group. Four types that occur include species that are weeds of cereal cultivation: *Centaurea cyanus* type, *Galium* type, *Nigella*, and *Sinapis* type.

'Cultivars' are abundant, although they have declined. The decline is due to reductions in *Avena* and *Platanus orientalis*. *Hordeum* type occurs sporadically. *Triticum* type and *Zea mays* increase. *Secale cereale* still occurs continuously. *Castanea sativa* and *Juglans regia* occur sporadically.

Relative frequencies of 'coniferous and deciduous canopy trees' increase to almost the maximum of the sequence due to increases in *Pinus* (*Diploxylon*) and *Abies*. Concentrations also increase. The oaks remain unchanged.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understorey trees and shrubs' are poorly represented; *Juniperus* declines to relative frequencies similar to those of the surface sample, although concentrations are much lower (total concentrations are lower). 'Riverine trees' continue at the increased values of the preceding two zones, with *Salix triandra* the dominant type. 'Evergreen woodland trees' and 'plants of open dry rocky habitats' are poorly represented; *Quercus coccifera* type occurs continuously and increases slightly.

Although the sum of terrestrial trees and shrubs is very high for this sequence, 55.4-66.3% of total terrestrial pollen and spores, the ratio of terrestrial trees and shrubs to terrestrial herbs is low. This low ratio, high palynological richness values (40-50 expected numbers), and high relative frequencies and concentrations of the habitat group 'herbs of open ground' are indicative of an open canopy.

Extra-local and regional lowland vegetation surrounding the wetland continues to be highly disturbed open canopy oak woodland with deciduous oaks dominant and semi-evergreen oaks playing a minor role. The understorey comprises mostly herb-rich steppe. Extra-local canopy cover probably remains about the same, or increases as suggested by a decrease in the 'herbs of open ground' and a decrease in *Juniperus*. Cultivation of cereals may have declined but the cereal types of *Avena* and *Hordeum* type have become less important while those of *Triticum* type and *Zea mays* increase in importance. *Secale cereale* is still important. The riverine flood plain vegetation continues unchanged. The distant higher elevation *Pinus* (*Diploxylon*)/*Abies* woodland increases.

Zone K-1, 17.5-0.0 cm, c. 1910-1989 AD 'Herbs of open ground' are co-dominant with 'coniferous and deciduous canopy trees'. Relative frequencies and concentrations of 'herbs of open ground' increase. *Pteridium aquilinum* continues at the same low abundance. No significant changes occur in the other most abundant types of this group, with the exception of a sharp increase in *Cirsium* type. Four types that occur include species that are weeds of cereal cultivation: *Centaurea cyanus* type, *Galium* type, *Nigella*, and *Sinapis* type.

'Cultivars' are abundant, although they have declined again in relative frequency and concentration, with the exception of an increase in concentration of the surface sample due to an increase in total concentration. The decline is due to a reduction of all the cereal types. *Avena* almost disappears, while *Hordeum* type and *Zea mays* occur sporadically. *Secale cereale* and *Triticum* type occur continuously. *Elaeagnus angustifolia* and *Vicia sativa* type both occur in one spectrum only. *Castanea sativa* and *Juglans regia* occur sporadically. *Platanus orientalis* occurs continuously and increases slightly.

Relative frequencies of 'coniferous and deciduous canopy trees' decline due to a decline in *Quercus frainetto* type. The relative frequencies of *Pinus* (*Diploxylon*) fluctuate but are about the same as in the preceding zone. Those of *Abies* continue at similar values. *Quercus trojana* type continues at similar values also. Concentrations of all these pollen types continue at similar values as those in the preceding zone and then increase following the curve of the total concentration curve.

Alpine shrubs and herbs are extremely poorly represented. 'Woodland understorey trees and shrubs' are poorly represented; *Juniperus* continues at the low relative frequencies and concentrations of the preceding zone (it increases sharply in concentration in the surface sample but this is due to total concentration increasing greatly). The low abundance of *Juniperus* in this and the preceding zone may be related to increased burning of extra-local vegetation and to a closing canopy – dead remains (which may persist for many decades) observed in oak woods in the lowlands (Chapter 3) are evidence that the woods were once more open. In some parts of the lowland oak woods it was noted that Juniper was absent. This is probably due to the burning of steppe understorey or the leaf-litter of the woods. Juniper is much more sensitive to fire than oaks. Oaks resprout after burning while Juniper dies. 'Riverine trees' increase dramatically due to an increase in *Salix triandra*. 'Evergreen woodland trees' and 'plants of open dry rocky habitats' are poorly represented; *Quercus coccifera* type declines.

The sum of terrestrial trees and shrubs increases from the comparatively low value of 39.2% in the basal spectrum to comparatively high values from 57.0-63.0% of total terrestrial pollen and spores. The low ratio of terrestrial trees and shrubs to terrestrial herbs, high palynological richness values (40-50 expected types), and high relative frequencies and concentrations of 'herbs of open ground' are indicative of an open canopy.

Extra-local and regional lowland vegetation continues to be highly disturbed open canopy oak woodland. Deciduous and semi-evergreen oaks are almost equally abundant. The change in the proportions of these oaks may be due to more coppicing of the trees represented by *Quercus frainetto* type. The understorey is herb-rich steppe. Extra-local canopy cover probably declines, as indicated by the increased abundance of 'herbs of open ground', and a

decline in the deciduous oaks. Cultivation of cereals may have declined further. The dramatic increase in *Salix triandra* may be due to it growing on the fen: today willows grow on the fen and along the channel on the southern boundary of the fen. The montane *Pinus* (*Diploxylon*)/*Abies* woodland remains unchanged.

6.6 Charcoal analysis and fire history

6.6.1 Microscopic charcoal analysis

Results of the microscopic charcoal particle analyses are presented as relative frequencies in Figure 6.14. The local zonation scheme of the terrestrial pollen and spores is used for convenience of correlation. The charcoal record shows high total charcoal relative frequencies in all zones with the exception of zone K-12 where relative frequencies are very low. Extremely high total charcoal relative frequencies occur in zones K-14, K-13, and K-11. Most residues retained by the 260 μm mesh sieve during sample preparation included charcoal particles except between 310-265, 240-160, and 105-55 cm.

In zones K-14 and K-13 charcoal particles of all size classes is very abundant in every spectrum. Peaks of total charcoal abundance which may reflect periods of more intense/frequent burning occur at 380, 355-350, and 330 cm and are reflected in the curves of all size classes except the uppermost peak in the largest size class. The largest size class displays a peak at 315 cm which is reflected in the 200-400 μm^2 size class. In comparison with other zones in the sequence, these two zones record the highest relative frequencies in the three smallest size classes (particles less than 100 μm^2) while those of the middle size range (particles 100-400 μm^2) are very abundant and the largest size class (>400 μm^2), although abundant, is not as abundant as in some higher zones (especially the two uppermost zones).

In zone K-12 total charcoal particle abundance is extremely low and all size class frequencies are extremely low; no charcoal was recorded in the >400 μm^2 size class at 305 cm.

Total charcoal particle abundance increases again in zone K-11 and in general records frequencies higher than in other zones with the exception of K-14 and K-13. Three peaks occur in the total charcoal frequencies. The highest peak, which is exceeded only by the three highest peaks of the two basal zones, occurs at 270 cm. The two lower peaks occur at 260 and 250 cm. A general decline from 270 cm displayed in the total charcoal curve is reflected in the size classes of 100-200 μm^2 and smaller. The two largest size classes do not decline.

In zones K-10 to K-8 total charcoal particle abundance declines to about the average frequency for the remainder of the sequence. These three zones maintain a constant level of abundance of total particle frequency with the exception of a small peak at 170 cm, which is reflected in the smallest size classes (up to 200 μm^2). The smaller size classes are still

Figure 6.14 Kellia - charcoal particle percentage diagram (based on pollen sum of total terrestrial taxa).

relatively abundant while the largest size class ($>400\text{ }\mu\text{m}^2$) has declined to very low frequencies.

In zone K-7 charcoal particle abundance increases in the two largest size classes while in the smaller size classes it remains unchanged. A peak at 155 cm is seen in all size classes. In zone K-6 total charcoal abundance increases and displays two peaks at 135 and 125 cm. The lower peak is due to a peak recorded in the three smaller size classes and the largest size class while the second is due to a peak in the two smallest size classes. Particle frequency is very high in the four largest size classes in the lower part of the zone then declines, while the two smallest size classes are high throughout the zone.

In zone K-5 total charcoal particle abundance declines slightly, but displays a small peak at 100 cm. This peak is reflected in all size classes. The largest sized particles ($>400\text{ }\mu\text{m}^2$) have low abundance at the base of the zone, but increase to relatively high frequencies in the uppermost spectrum. Charcoal particles of the middle size classes show the same general increasing trend as that of the largest size class but display a more pronounced peak at 100 cm. The two smallest size classes have declined and maintain relatively constant frequencies.

In zone K-4 total charcoal particle abundance declines slightly again, but fluctuates in concordance with the frequencies of all the size classes except the largest and smallest. The largest size class is much diminished, while other size classes remain at about the same abundance. In zone K-3 total charcoal particle abundance increases from the centre of the zone. This increase is reflected in the two largest size classes. A peak at 45 cm is reflected in the smaller size classes. In zone K-2 total charcoal particle abundance peaks in the centre of the zone. This peak is reflected in all size classes; a very prominent peak occurs in the larger size classes, but only a small peak occurs in the smaller size classes. Similar curves are repeated in zone K-1, but the peak of the larger size classes in the centre of the zone is not so prominent.

6.6.2 Fire history

There is continuous accumulation of microscopic charcoal particles throughout the sequence. The non-uniform sedimentation of this sequence may influence charcoal particle abundance but a general history of the frequency and intensity of fires on an extra-local and regional basis is possible based on microscopic charcoal particle frequencies. There are two phases when more intense/frequent fires occurred in the Kellia region and were of major ecological significance. These are between the base of the sequence, radiocarbon dated at *c.* 830 BC, and 315 cm (radiocarbon dated at *c.* 2000 BC, but probably younger *c.* 630 BC) and between *c.* 1340-1350 AD.

In the former phase the charcoal record shows continuously high values of charcoal particles in all size classes and indicates widespread extra-local and regional burning. In the latter phase total charcoal is slightly lower than that of the lower phase but the smaller size classes are less abundant while the larger size classes are more abundant. Greater abundance of the largest size class suggests more intense/frequent extra-local burning than in the basal phase. Optically visible charcoal particles in the sediments between c. 1340-1370 AD (264-235 cm) provide supporting evidence for the importance of fires during the latter phase.

Between these two phases when fires were of major ecological significance is a period between c. 1230-1340 AD (312-270 cm) when fires were more distant and/or sporadic and were of little ecological significance in the vicinity of Kellia. Between c. 1370-1650 AD (240-160 cm; zones K-10 to K-8) extra-local burning declines and is of little significance, while regional burning also declines it is probably still important ecologically. At c. 1650-1690 AD (155-125 cm; zones K-7 and most of K-6) extra-local burning increases and regional burning increases slightly from c. 1680 AD (140 cm). At c. 1710-1740 AD (120-105 cm; top of zone K-6 and bottom of zone K-5) extra-local and regional burning decline. At c. 1750-1790 AD (100-80 cm; upper part of zone K-5) both extra-local and regional burning increase again. At c. 1800 AD (75 cm; base of zone K-4) extra-local burning is greatly reduced, while regional burning continues. Extra-local and regional burning increase at c. 1860 AD (45 cm). Fluctuating abundances in the largest and middle size classes above this depth suggest two periods of intense/frequent fires extra-locally and more distant, at c. 1890 AD (25 cm) and c. 1940 AD (5 cm). The former period has an assigned date that is close to the 1908 AD date of known land clearance in the Lipsokouki Valley (Chapter 1). The most recent increase in microscopic charcoal particle abundance could be related to the return of Greek refugees in 1924 and the subsequent land clearance, and the introduction of stubble burning with the mechanization of agriculture (Chapter 1).

Pollen evidence also suggests high frequency/intensity of fires both extra-locally and regionally during two phases in the lower part of the sequence; the pyrophytes *Pteridium aquilinum* and *Quercus coccifera* type are more abundant below 315 cm and concentration values (unfortunately no influx data are available) of *Pinus* (*Diploxylon*) are lower below 315 cm and between c. 1340-1350 AD (275-245 cm). *Pteridium aquilinum* increases between c. 1350-1360 AD (255-240 cm) and the fire-sensitive *Juniperus* is less abundant in the lower part of the sequence before c. 1370 AD (below 235 cm). After c. 1370 AD *Juniperus* increases. *Pteridium aquilinum* becomes abundant from c. 1640-1790 AD (160-80 cm). *Quercus coccifera* type is more abundant before c. 1680 AD (above 140 cm), but fluctuations do not correspond exactly to those of the charcoal curve; other factors such as climatic conditions and human disturbance of the vegetation such as grazing, cultivation, lumbering

or various woodland practices may, particularly in this situation, also affect the abundance of this pyrophyte. Low concentration values of *Pinus* (*Diploxylon*), although subject to fluctuations in sedimentation rates, appear to correspond to peaks in the small size classes of microscopic charcoal particles at c. 1600 AD, 1650 AD, 1680 AD, 1690 AD, 1750 AD, and 1860 AD (170, 155, 135, 125, 100, and 45 cm).

6.7 Synthesis of environmental changes

A summary of the major environmental changes in the Kellia wetland and its surrounding area between perhaps c. 830-630 BC and from c. 1230-1989 AD is given in Table 6.2.

The sedimentary history of the fen is intimately linked to the local wetland vegetation history and there is close correspondence between the composition of deposits and changes in the pollen profiles of the wetland but there is less correspondence between sediment composition and terrestrial pollen and spore profiles. Absence of total synchrony of these three factors is due to a significant contribution of pollen and spores derived from outside the catchment.

Stratigraphic data indicate that Kellia fen probably formed at the side of a stream course that ran from west to east on the southern side of the fen. Radiocarbon dating of the pollen-analysed core suggests that two periods of alluviation are recorded in the fen sediments, an older period below 312 cm (beginning perhaps c. 830 BC and spanning about 200 years, see section 6.4.2) and a younger one above, which may span about the last 760 years beginning c. 1230 AD, although pollen evidence (presence of *Secale cereale* type pollen) suggests a more recent age, of perhaps after 146 BC, for the lower older period. A hiatus occurs in the sequence between these two periods of alluviation, perhaps caused by erosion or sediment bypassing due to a deeper stream channel. The fen sediments comprise greyish olive to olive black clay with variable proportions of calcareous grit, peat, and organic detritus. Thin (5-15 cm) noncalcareous sand horizons are rare. Persistent organic-rich horizons occur at about 100 and 230 cm. Below about 300 cm, there is little organic matter in the stiff to soft greyish olive clay comprising the older period of alluviation. The uppermost c. 20 cm (c. 1900-1989 AD) of the fen consists of silty peat on the western and southern part of the fen, close to the spring. Towards the northern edge and the eastern (downstream) end of the fen, the unit becomes less peaty and is replaced by brown clay with a sandy layer at the base. This unit may be related to the establishment of the modern sealed road and its causeway, which may have reduced the transport of sediment into the fen from the catchment upstream. Occasional small mollusc shells and fruits or corms were noted in some sediment exploratory

Table 6.2

Major environmental changes in Kellia wetland and the surrounding region, c. 1989-1230 AD (and ? c. 630-830 BC)

Date AD/BC	Humidity	Wetland vegetation	Extra-local vegetation	Sedimentology of pollen core	Charcoal
1989-1910 AD (zone K-1)	Continuously wet peat surface	Tall-sedge swamp – <i>Cyperus longus</i> type dominant	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> type present in low abundance, <i>Salix triandra</i> abundant (increases upwards), <i>Juniperus</i> at low abundance, herbs of open ground abundant, most abundant <i>Cirsium</i> type, <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars at reduced abundance, very high palynological richness	Peat with fine grained minerogenic sediment, woody detritus & calcareous grit. Extremely high organic matter & extremely low inorganic matter. Carbonate content low to moderately high	Very abundant in larger size classes & abundant in smaller size classes – much extra-local burning. Regional burning also occurs
1910-1880 AD (zone K-2)	Continuously wet peat surface	Tall-sedge & true-reed swamps – <i>Cyperus longus</i> type, <i>Glyceria</i> type & <i>Sparganium erectum</i> dominant	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), sl. increased <i>Q. coccifera</i> , <i>Salix triandra</i> present at low abundance, <i>Juniperus</i> at low abundance, decreased herbs of open ground but still abundant, <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars abundant, very high palynological richness	Peat with fine grained minerogenic sediment & herbaceous detritus. High organic matter & low inorganic matter. Carbonate content moderately high	Greatest abundance in larger size classes, smaller sizes same as above – increased extra-local burning, regional burning unchanged
1880-1840 AD (zone K-3)	True-reed swamp – <i>Glyceria</i> type, <i>Phragmites australis</i> & <i>Scirpus</i> dominant		Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> present at low abundance, <i>Salix triandra</i> present at low abundance, <i>Juniperus</i> sl. increased, increased herbs of open ground (v. abundant), <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars increase (v. abundant), very high palynological richness	Fine to medium sand with some fine grained sediment & herbaceous detritus. High inorganic matter & low organic matter. High carbonate content. Below 52 cm (c. 1850 AD), same sediments as at top of zone below	Abundant all size classes – extra-local & regional burning

1840-1790 AD (zone K-4)	Peat below 67.5 cm with continuously wet surface True-reed swamp – <i>Scirpus</i> & <i>Glyceria</i> type dominant with <i>Cyperus longus</i> type of the tall-sedge swamp down to 65 cm, then <i>Sparganium erectum</i> is dominant Continuously wet peat surface True-reed swamp – <i>Glyceria</i> type & <i>Sparganium erectum</i> co-dominant (<i>Cyperus longus</i> type of the tall-sedge swamp also important)	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> present in low abundance, <i>Salix triandra</i> present at low abundance, <i>Juniperus</i> reduced (but still abundant), decreased herbs of open ground but still abundant, <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars abundant, very high palynological richness Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> type present in low abundance, <i>Juniperus</i> declining upwards, very abundant herbs of open ground, <i>Pteridium aquilinum</i> at increased abundance, cereal cultivars abundant, very high palynological richness	Fine grained minerogenic sediment with herbaceous detritus (low organic matter & high inorganic matter) down to 67.5 cm, then peat with herb. detritus & trace fine grained minerogenic sediment (high organic matter & very low inorganic matter). Carb. content moderately high at top, then low Peat with fine grained minerogenic sediment & herbaceous detritus. Moderately low inorganic matter & moderately high organic matter. Carbonate content low, increases below 105 cm	Low abundance of largest size class, other size classes remain about the same – reduced extra-local burning, but regional burning continues unchanged Abundant all size classes – extra-local & regional burning. Both decline below 100 cm (c. 1750 AD)
1790-1720 AD (zone K-5)	Continuously wet peat surface True-reed swamp – <i>Glyceria</i> type dominant	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> slightly increased, <i>Juniperus</i> of high abundance, herbs of open ground reduced but still very abundant, <i>Pteridium aquilinum</i> at increased abundance, cereal cultivars abundant, very high palynological richness	Peaty clay above 121 cm (see above) Below 121 cm: non-calcareous sand & calcareous grit with some fine grained minerogenic sediment & a trace of peat. High inorganic matter & low organic matter. High carbonate content	Abundant all size classes – extra-local & regional burning
1720-1680 AD (zone K-6)	Continuously wet peat surface True-reed swamp – <i>Glyceria</i> type dominant	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> type almost absent, <i>Juniperus</i> of high abundance, increased herbs of open ground (very abundant), most abundant <i>Polygonum aviculare</i> type, <i>Pteridium aquilinum</i> at increased abundance, cereal cultivars abundant, very high palynological richness	Fine grained minerogenic sediment with some peat. Moderately low inorganic matter & moderately high organic matter. Low carbonate content	Abundant all size classes – extra-local & regional burning
1680-1650 AD (zone K-7)	Continuously wet peat surface True-reed swamp – <i>Glyceria</i> type dominant (<i>Carex hallerana</i> and <i>Schoenus nigricans</i> of the wet-soil communities are abundant)	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> type almost absent, <i>Juniperus</i> of high abundance, increased herbs of open ground (very abundant), most abundant <i>Polygonum aviculare</i> type, <i>Pteridium aquilinum</i> at increased abundance, cereal cultivars abundant, very high palynological richness	Fine grained minerogenic sediment with some peat. Moderately low inorganic matter & moderately high organic matter. Low carbonate content	Abundant all size classes – extra-local & regional burning

1650-1580 AD (zone K-8)	Continuously wet peat surface	True-reed swamp – <i>Scirpus</i> & <i>Glyceria</i> type dominant (<i>Schoenus nigricans</i> of the wet-soil communities is abundant)	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> type almost absent, <i>Juniperus</i> of high abundance, herbs of open ground reduced but still very abundant, <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars very abundant, very high palynological richness	Peat with some fine grained minerogenic sediment. High organic matter (increases downwards) & low inorganic matter (decreases downwards). Low carbonate content	Low abundance of larger size classes, abundant smaller size classes – reduced extra-local burning, regional burning unchanged
1580-1480 AD (zone K-9)	Peat down to 183 cm with continuously wet surface	True-reed swamp – <i>Scirpus</i> & <i>Glyceria</i> type dominant (<i>Schoenus nigricans</i> of the wet-soil communities is abundant)	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> type almost absent, <i>Juniperus</i> abundant (increases upwards), herbs of open ground very abundant, most abundant Chenopodiaceae type, sl. increased <i>Pteridium aquilinum</i> , cereal cultivars increase (very abundant), very high palynological richness	As above down to 183 cm (c. 1550 AD), then same as below except between 196-200 cm where calcareous grit increases. Decreased inorganic matter & increased organic matter. Low-moderate carbonate content	Abundance same as above
1480-1370 AD (zone K-10)	True-reed swamp – <i>Scirpus</i> dominant, wet-soil communities have increased importance – <i>Carex hallerana</i> type important	True-reed swamp – <i>Scirpus</i> dominant, wet-soil communities have increased importance – <i>Carex hallerana</i> type important	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type, <i>Q. coccifera</i> type almost absent, <i>Juniperus</i> of moderate abundance (increases upwards), herbs of open ground very abundant, <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars very abundant, very high palynological richness	Above 216 cm: fine grained minerogenic sediment and coarse herbaceous detritus with a trace of calcareous grit. 216-235 cm: coarse herbaceous detritus with fine grained minerogenic sediments. Below 235 cm same as below. Low inorganic matter & high organic matter. Low carbonate content	Abundance same as above
1370-1320 AD (zone K-11)	True-reed swamp – <i>Scirpus</i> , <i>Glyceria</i> type & <i>Sparganium erectum</i> dominants (<i>Cyperus michelianus</i> of the tall-sedge swamp also important)	True-reed swamp – <i>Scirpus</i> , <i>Glyceria</i> type & <i>Sparganium erectum</i> dominants (<i>Cyperus michelianus</i> of the tall-sedge swamp also important)	Open canopy – <i>Quercus frainetto</i> type & <i>Q. trojana</i> type co-dominant, <i>Q. coccifera</i> type of very low abundance, <i>Juniperus</i> of low abundance, herbs of open ground very abundant, <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars very abundant, very high palynological richness	Several horizons of minerogenic sediment (some fine & some of sand grain size) with herbaceous detritus. High inorganic matter & low organic matter. High carbonate content	Very abundant all size classes, esp. largest size class – widespread burning extra-locally & regionally. Also macroscopic charcoal 235-264 cm

1320-1230 AD

(zone K-12)

Wet-soil community
– *Carex hallerana*
type dominant
(*Cyperus*
michelianus &
Scirpus also
important)
Open canopy – *Quercus frainetto* type more
abundant than *Q. trojana* type, *Q. coccifera*
type almost disappears, *Juniperus* of very low
abundance, herbs of open ground reduced but
are still very abundant, *Pteridium aquilinum*
at reduced abundance, cereal cultivars
abundant, high palynological richness

Fine grained minerogenic sediment
& herbaceous detritus. Low
inorganic matter & high organic
matter. Moderate carbonate
content
Very low abundance
all size classes
– reduced
extra-local &
regional burning

Within range c. 630-830 BC:

312.5-372.5

(zone K-13)

True-reed swamp –
Scirpus/
Sparganium
erectum
co-dominant down
to 345 cm, then
Scirpus/*Glyceria*
type co-dominant
Open canopy – *Quercus frainetto* type &
Q. trojana type co-dominant, *Q. coccifera*
type present in low abundance,
Juniperus of very low abundance,
very abundant herbs of open ground,
Pteridium aquilinum very abundant,
cereal cultivars abundant, high
palynological richness

Fine grained minerogenic sediment
with a trace of herb. detritus &
calcareous grit. Very high inorganic
matter & low organic matter. Low
carbonate content. Scattered
gastropods. Same as below, from
376 cm
Low-moderate
abundance of
largest size class,
high abundance
of all other size
classes – some
extra-local burning,
widespread
regional burning

372.5-396.0

(zone K-14)

True-reed swamp –
Glyceria type
dominant
Open canopy – *Quercus trojana* type more
abundant than *Q. frainetto* type, *Q. coccifera*
type present in low abundance, *Juniperus*
almost absent, most abundant herbs of open
ground, most abundant *Pteridium aquilinum*
& *Hieracium* type, cereal cultivars abundant,
moderately high palynological richness

Fine grained minerogenic sediment
with calcareous & ferruginous grit.
Very high inorganic matter & low
organic matter. Low carbonate
content
Abundance
same as above

cores, but no pattern to their occurrence was determined although in the pollen analysed core they appeared to be more abundant between 376-312 cm. No ostracods were found in the pollen analysed core. Where peaty horizons occur in the pollen analysed core at 183.0-67.5 and 32.5-0 cm, humicity of peat indicates that surface peat was continuously wet.

The local wetland vegetation is dominated by pollen and spore types that derive from emergent plant communities of wet-soil, tall-sedge-swamp and true-reed-swamp communities. Pollen and spore types of wet-soil plant communities are most numerous, although total relative frequencies of the true-reed-swamp communities are highest throughout the sequence except at 305-280 cm, where frequencies of types of wet-soil communities are higher, and in several spectra above 35 cm (35, 30, 20, and 0 cm), where frequencies of pollen types of the tall-sedge-swamp communities are higher. The true-reed-swamp communities are dominated by reeds of the *Glyceria* type and *Scirpus* mostly, and to a lesser extent by *Phragmites australis* and *Sparganium erectum*. The wet-soil communities are dominated by sedges of the *Carex hallerana* type and *Schoenus nigricans*, and *Equisetum* occurs sporadically throughout the sequence and displays two peaks, at 265 and 205 cm. Pollen types that dominate the tall-sedge-swamp communities are *Carex flacca* type, *Cyperus longus* type, and *Cyperus michelianus*. Communities of floating-leaved and submerged macrophytes are poorly represented, the former being better represented than the latter and are more abundant above 185 cm. They probably represent a few plants growing in small pools on the surface of peat.

The available nutrient level is high throughout the sequence as evidenced by the abundance of several pollen types representing emergent plants, which are indicative of high trophic status, such as *Carex flacca* type, *Cyperus longus* type, *Glyceria* type, *Scirpus*, *Sparganium erectum*, *Typha angustifolia* type, and *Typha domingensis* type; and the occurrence of several pollen and spore types of aquatic macrophytes indicative of high trophic status such as *Callitriche stagnalis* type, *Hydrocharis morsus-ranae*, *Nuphar lutea*, *Nymphaea alba*, *Ranunculus aquatilis* group, *Salvinia natans*, *Stratiotes aloides*, *Vallisneria spiralis*, *Myriophyllum spicatum*, *Myriophyllum verticillatum*, *Potamogeton crispus* type, and *Potamogeton pectinatus*. Nutrients may be contributed to the wetland via washed in sediments, spring water or from direct or indirect human activities, e.g. land clearance, cultivation or grazing.

Terrestrial pollen evidence suggests that pine woods grew at higher elevations on the Pindos Mountains for the duration of the sequence, perhaps mixed with *Abies* at intermediate elevations. The extra-local vegetation is open canopy deciduous/semi-evergreen oak woods

dominated by the canopy trees of *Quercus frainetto* type (deciduous oaks) and *Q. trojana* type (deciduous/semi-evergreen oaks). *Ostrya* type occurs at low abundance almost continuously. *Quercus coccifera* type (evergreen oaks) occurs sporadically; greatest abundance is from 396-315 cm (perhaps c. 830-630 BC) and from 140-0 cm (c. 1680-1989 AD). The shrub *Juniperus* is more abundant above 235 cm (c. 1370 AD), while *Pteridium aquilinum* is most abundant below 315 cm (perhaps before c. 630 BC) and from 160-80 cm (c. 1650-1790 AD). Several herbs of open ground occur almost continuously throughout the sequence at significant abundance, the most abundant being: *Centaurea solstitialis* type, Chenopodiaceae type, *Cichorium* type, *Cirsium* type, *Dactylis* type, *Festuca* type, *Galium* type, *Hieracium* type, *Lactuca* type, *Plantago lanceolata* type, *Polygonum aviculare* type, *Solidago* type, *Sonchus* type, and *Taraxacum* type. A variety of cereals were cultivated extra-locally for the duration of the sequence and the nut trees *Castanea sativa* and *Juglans regia*, which occur sporadically from the base of the sequence, may have been planted, or growing wild, either sparsely in the vicinity of the site or more abundantly at a greater distance. The shade tree *Platanus orientalis*, which also occurs sporadically from the base of the sequence, may also have been planted or growing wild either sparsely extra-locally or more abundantly at a greater distance from the site. These three trees may have profited from changes in habitats caused by humans.

There is continuous accumulation of microscopic charcoal particles throughout the sequence. Two phases when more intense/frequent fires are indicated in the Kellia region are between the base of the sequence (396 cm) and 315 cm (perhaps c. 830-630 BC) and from 270-250 cm (c. 1340-1350 AD). In the former phase the charcoal record shows continuously high values of charcoal particles in all size classes and indicates some extra-local and widespread regional burning. In the latter phase total charcoal abundance is slightly lower but greater abundance of the largest size class indicates more intense/frequent extra-local burning than in the basal phase. Optically visible charcoal particles in the sediments at 264-235 cm provide supporting evidence for the importance of fires during the latter phase.

A synthesis of environmental changes as indicated by the pollen analysed core follows. The age of sediments and thus the period of vegetation history represented below 312.0 cm is uncertain but the basal deposits of the pollen analysed core have been radiocarbon dated at c. 830 Cal BC at 394-395 cm. Between 396-376 cm deposits comprise very stiff mottled grey and brown clay with calcareous and ferruginous grit. Calcareous grit may be allochthonous (derived from calcic soils of the catchment) or autochthonous (precipitated from the spring water), or both. Sediments contain little organic matter and low carbonate content. They are

small grain sized (clay) representing low energy transported sediments and are indicative of relative landscape stability in the catchment. They are distinct because of their ferruginous mottling and inclusion of ferruginous grit, which may be due to weathering or subsurface water circulation. Above 376 cm sediments are again fine grained and represent low energy transport comprising sticky soft grey clay with scattered gastropods and a trace of calcareous grit; carbonate and organic content are unchanged from the horizon below, and there is little visible plant material.

At this time wetland palynomorph concentration and palynological richness are very low, and the dominant local plant community of the true-reed swamp is represented almost entirely by *Glyceria* type, which is able to tolerate 'silting'. A small wet-soil community also exists with *Carex hallerana* type and *Mentha* type being most abundant. At the base of the sequence a tall-sedge-swamp community, dominated by *Carex flacca* type also occurs, but soon declines. Both floating-leaved and submerged macrophyte communities are represented by a few types, especially at the top of the zone. Of the two submerged aquatic macrophytes represented *Hydrocotyle vulgaris* and *Myriophyllum spicatum* the former may be submerged or emergent while the latter is exclusively submerged and may have been growing in holes within the reed strip, i.e. in shallow and relatively humus-rich water. The extra-local and regional lowland vegetation is open canopy oak woods dominated by canopy trees of *Quercus trojana* type (deciduous/semi-evergreen oaks), but canopy trees of *Quercus frainetto* type (deciduous oaks) are also abundant. The understorey comprises mostly herb-rich steppe; woodland understorey woody and herbaceous plants are poorly represented – *Juniperus* occurs at extremely low abundance. *Quercus coccifera* type occurs at an abundance, which although low, is comparatively high for this sequence. Herbs of open ground are the dominant habitat group and occur at the highest relative frequencies of the sequence; *Pteridium aquilinum* and *Hieracium* type are particularly prominent – both occur at their greatest abundance for the sequence. Cereal types of *Secale cereale*, *Triticum* type, *Avena*, and *Hordeum* type are represented and may have been cultivated extra-locally, although radiocarbon dating would suggest that the time period is too early for the cultivation of *Secale cereale*. The pulses *Vicia sativa* and *V. ervilia* may also have been cultivated. The nut trees *Castanea sativa* and *Juglans regia* may have been planted either extra-locally or further from the site. *Platanus orientalis* may have been growing in a disturbed or natural habitat, such as flood plains, extra-locally or further from the wetland. Riverine trees grew on more distant flood plains and pine woods grew at higher elevations distant from the site in the Pindos Mountains. Microscopic

charcoal particles are very abundant in the smaller size classes and of moderate abundance in the largest size class indicating widespread regional burning and also some extra-local burning. The very high abundance of spores of *Pteridium aquilinum* suggests burning of extra-local and regional vegetation. The occurrence of *Quercus coccifera* type may be due to burning of semi-evergreen oak woods. Lowered concentration values of *Pinus* (*Diploxylon*) may be due to the source of regional pine pollen being reduced through burning. Fire-sensitive *Juniperus* has very low abundance.

The age of sediments between 372.5 and 312.0 cm is uncertain, as sediments at 315-316 cm were radiocarbon dated to *c.* 2000 Cal BC, but cumulative concentration of *Pinus* (*Diploxylon*) (Figure 6.8) implies that sediments took 200 years to accumulate between the base of the sequence, radiocarbon dated at 830 BC, and 312 cm, which would suggest that sediments at this level are *c.* 630 BC. Sediments are the same as those below. Concentration of wetland palynomorphs continues to be very low. Up to 345 cm the true-reed-swamp community continues to be the dominant wetland plant community but the pioneer *Scirpus* is now co-dominant with *Glyceria* type, perhaps due to slower influx of sediments into the fen. The wet-soil community continues to be represented at about the same level, although *Mentha* type has become more important than *Carex hallerana* type. The tall-sedge community has almost disappeared and the stream-reed-swamp community has very low representation. Aquatic communities decline but both floating-leaved and submerged macrophytes are represented; the former by *Sparganium angustifolium* and the latter by *Hydrocotyle vulgaris*. Above 345 cm the true-reed-swamp community continues to be the dominant plant community, but the early hydrosere *Sparganium erectum* is now co-dominant with *Scirpus*. *Glyceria* type declines further, but continues to be prominent. The wet-soil community continues to be represented at similar abundance but *Carex hallerana* type is now more abundant than *Mentha* type. The tall-sedge-swamp community continues to have low representation and the stream-reed-swamp community declines. Aquatic communities decline further, although the number of aquatic types represented increases in the uppermost spectrum. Pollen of the extra-local and regional lowland canopy trees of *Quercus trojana* type and *Quercus frainetto* type is now equally abundant. A similar understorey to that below is indicated: *Juniperus* occurs at very low abundance. *Quercus coccifera* type continues at a similar abundance. Herbs of open ground remain the dominant habitat group, although abundance has declined. *Pteridium aquilinum* declines, but remains very abundant. 'Cultivars' are still abundant and cereals are cultivated extra-locally. *Platanus orientalis* increases

slightly and *Castanea sativa* and *Juglans regia* remain unchanged. Mountain pine woods continue at similar abundance. Abundance of microscopic charcoal particles is very similar to that below indicating widespread regional burning and some extra-local burning. High abundance of spores of *Pteridium aquilinum* supports burning of extra-local and regional vegetation, while the abundance of *Quercus coccifera* type, which is similar to that below, suggests burning of semi-evergreen oak wood. Again lowered concentration values of *Pinus* (*Diploxylon*) may be due to the source of regional pine pollen being reduced through burning and fire-sensitive *Juniperus* remains at low abundance.

Between c. 1230-1320 AD (312.0-287.5 cm) greater landscape stability in the catchment is suggested by a large increase in the concentration of wetland palynomorphs, slow accumulation rate of the deposits, and by the inclusion of abundant fragments of herbaceous plants (thought to derive from plants growing in the catchment) in fine-grained mineral sediments. Sediments comprise muddy detritus with horizontal layering of herbaceous material; organic content increases significantly, inorganic matter declines, and carbonate content increases slightly. Local plant communities are dominated by a wet-soil community and sedges of *Carex hallerana* type are dominant. All other types in this community are extremely poorly represented, with the exception of *Schoenus nigricans*. The second most important community, that of the true-reed swamp, is dominated by species of the *Scirpus* type. The tall-sedge-swamp community increases and is next most abundant; only the annual *Cyperus michelianus* is represented suggesting some instability in the catchment. The stream-reed-swamp community continues to be extremely poorly represented. Aquatic communities have almost disappeared. Pollen of the extra-local and regional lowland canopy trees of *Quercus frainetto* type is now more abundant than that of *Quercus trojana* type. A similar understorey to that below is indicated; *Juniperus* occurs at very low abundance. *Quercus coccifera* type almost disappears. Herbs of open ground remain the dominant habitat group, although relative frequencies decline. *Pteridium aquilinum* declines, but remains abundant. 'Cultivars' are still abundant. Extra-local cultivation of the cereals continues. The trees *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* continue to grow or are planted, either sparsely extra-locally or more abundantly regionally. Mountain pine woods increase. Microscopic charcoal particle abundance is extremely low in all size classes and no particles in the $>400 \mu\text{m}^2$ size class were recorded at 305 cm. Declining abundance of *Pteridium aquilinum* spores supports reduced burning of extra-local and regional vegetation, while the near disappearance of *Quercus coccifera* type suggests a reduction in burning of semi-

evergreen oak woods (but the coinciding decline in *Quercus coccifera* type and *Quercus trojana* type could also be interpreted as indicative of an increase in humidity). Increased concentrations of *Pinus* (*Diploxylon*) may be due to a reduction of burning of mountain pine woods.

Between c. 1320-1370 AD (287.5-237.5 cm) is a period of greater landscape instability in the catchment: pollen concentration of wetland taxa is again very low. Sediments are characterised by high inorganic matter and carbonate content, and low organic matter content. At c. 1320 AD (287.5 cm) accumulation rate of deposits begins to increase and influx of fine grained sediments increases, while that of herbaceous detritus declines. Between c. 1340-1350 AD (271-248 cm) the accumulation rate of deposits increases sharply and influx of larger grain sized particles (fine-medium noncalcareous sand) suggests greater energy of transport of sediments. Between c. 1350-1370 AD (248-235 cm) the accumulation rate of deposits declines and influx of fine grained (silt and clay) increases, although some influx of noncalcareous sand still occurs. The dominant local plant community is again the true-reed swamp. Although *Scirpus* is the dominant type represented, *Glyceria* type and *Sparganium erectum* are also important. The wet-soil and tall-sedge-swamp communities are almost equally abundant. The dominant types in the wet-soil community are *Carex hallerana* type and *Equisetum*, with *Mentha* type less abundant. In the tall-sedge-swamp community *Cyperus michelianus* is again the only type of any importance. The stream-reed-swamp community has gained slightly, with *Berula erecta* increasing. The frequency of the aquatic types increases slightly towards the top of the zone, due mostly to an increase in *Hydrocotyle vulgaris*. Pollen of the extra-local and regional lowland canopy trees of *Quercus frainetto* type and *Quercus trojana* type is almost equal in abundance. A similar understorey to that below is indicated; *Juniperus* still occurs at very low abundance. *Quercus coccifera* type remains at the very low abundance. Herbs of open ground remain the dominant habitat group and relative frequencies increase to very high values. *Pteridium aquilinum* continues at the reduced abundance of below. 'Cultivars' are still abundant. Extra-local cereal cultivation continues. *Vitis vinifera* occurs for the first time at low abundance. *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* continue to occur sporadically at low abundances, although they now occur more often. Mountain pine woods decline. Abundance of microscopic charcoal particles is very similar to that below 312 cm, although particles of the largest size class are more abundant (especially between 270-250 cm, c. 1340-1350 AD) suggesting more intense/frequent extra-local burning; widespread regional burning also occurs. Macroscopic charcoal particles were

noted from 264-235 cm. Although *Pteridium aquilinum* spores occur at reduced abundance, they are still abundant and indicative of burning of extra-local and regional vegetation. Lowered concentration values of *Pinus* (*Diploxylon*) may, in part, be due to the source of regional pine pollen being reduced through burning. Fire-sensitive *Juniperus* occurs at low abundance.

Between c. 1370-1480 AD (237.5-202.5 cm) is a period of relative stability in the catchment: sediments are characterised by low inorganic and high organic matter, and low carbonate content. Between c. 1370-1430 AD (235-216 cm) influx of herbaceous detritus increases and concentration of wetland palynomorphs increases sharply to very high values at 230 cm, then declines but remains comparatively high indicating an expanded and less disturbed wetland vegetation. Accumulation rate of deposits declines slightly. Between c. 1430-1480 AD (216-200 cm) influx of herbaceous detritus declines and influx of small mineral particles (clay) increases. Calcareous grit also occurs in small amount but the origin of this is unknown and may be allochthonous or autochthonous, or both. The dominant local plant community continues to be the true-reed swamp with *Scirpus* the dominant type. *Glyceria* type is still important, although reduced, and *Sparganium erectum* has almost disappeared. The wet-soil community is the second most prominent community; *Carex hallerana* type is dominant with *Mentha* type and *Equisetum* playing minor but significant roles. The tall-sedge swamp, represented by *Cyperus michelianus*, and the stream-reed swamp decline. Aquatic communities have also declined again especially the submerged macrophytes community, which has almost disappeared. Pollen of the extra-local and regional lowland canopy trees of *Quercus frainetto* type is more abundant than that of *Quercus trojana* type. A similar understorey to that below is indicated, but *Juniperus* increases slightly. *Quercus coccifera* type continues at the very low abundance. Herbs of open ground remain the dominant habitat group. *Pteridium aquilinum* continues at reduced abundance. 'Cultivars' are again abundant. Extra-local cereal cultivation continues. *Vitis vinifera* occurs in one spectrum only. *Platanus orientalis* increases and *Castanea sativa* and *Juglans regia* occur sporadically at low values. Pollen of mountain pine woods steadily increases. Abundance of microscopic charcoal particles declines in all size classes. The largest size class declines to very low frequencies, but the smaller size classes are still relatively abundant indicating that regional burning is still widespread while extra-local burning is reduced. *Pteridium aquilinum* declines slightly and *Juniperus* increases, perhaps as a response to a reduction in burning extra-local and regional vegetation. *Quercus coccifera* type occurs at very low abundance and

concentration of *Pinus* (*Diploxylon*) increases, suggesting a reduction in burning of regional vegetation.

Between c. 1480-1580 AD (202.5-177.5 cm) increasing landscape stability in the catchment is indicated by the occurrence of peat from c. 1550 AD (183 cm). Accumulation rate of deposits is the slowest of the sequence and sediments are characterised by high organic and low inorganic matter, and low carbonate content. Sediments are the same as those above until peat formation begins with the exception of a narrow band (200-196 cm) where sediments comprise a mixture of equal proportions of friable calcareous grit and clay. Influx of fine grained (clay) sediments continues as peat forms. Locally the true-reed-swamp community continues to be dominant, with *Scirpus* the dominant type; *Glyceria* type increases and is next most abundant. The wet-soil community is next most important with *Schoenus nigricans* the dominant type and *Equisetum* also important. *Carex hallerana* type and *Mentha* type have almost disappeared. The tall-sedge-swamp community is the next most important community. *Carex flacca* type and *Cyperus longus* type are now the most important types in this community; *Cyperus michelianus* has declined. The stream-reed-swamp community has increased due to an increase of *Berula erecta*. Aquatic communities continue to be poorly represented with the exception of a peak of *Stratiotes aloides* in the second to uppermost spectrum. Otherwise, the floating-leaved macrophytes community is represented almost completely by *Sparganium angustifolium*. Pollen of the extra-local and regional lowland canopy trees of *Quercus frainetto* type continues to be more abundant than that of *Quercus trojana* type. Both types have declined; the latter type more than the former. The understorey shrub *Juniperus* continues increasing and is now a significant component in the understorey. *Quercus coccifera* type continues at the very low abundance. Herbs of open ground remain the dominant habitat group; relative frequencies increase slightly due to a slight increase in *Pteridium aquilinum* and a dramatic increase in Chenopodiaceae type. Cereal pollen types increase to the highest values of the sequence indicating extensive extra-local cereal cultivation. *Humulus lupulus* and *Vicia sativa* type occur in one spectrum. Trees that may have been planted decline: *Castanea sativa* occurs sporadically, *Juglans regia* disappears, and *Platanus orientalis* declines. An increase in *Agropyron* type may be due to *Panicum miliaceum* (broomcorn millet) being cultivated, or to wild grasses growing in dry habitats. *Pinus* (*Diploxylon*) is abundant. Abundance of microscopic charcoal particles suggests that extra-local and regional burning continues at the same level of intensity/frequency as below. Pollen evidence supports continued reduced burning of vegetation; *Pteridium aquilinum* and

Juniperus increase slightly, *Quercus coccifera* type remains at very low abundance, and concentrations of *Pinus* (*Diploxylon*) increase slightly.

Between c. 1580-1650 AD (177.5-157.5 cm) represents a period of relative stability in the catchment landscape with continuous peat formation, although influx of fine grained sediment (clay) increases at 165 cm. Sediments are characterised by high organic and low inorganic matter content, and low carbonate content, but above 165 cm organic matter declines and inorganic matter increases. An apparent change in the accumulation rate of deposits at c. 170 cm corresponds to a peak in the small size classes of microscopic charcoal particle frequencies suggesting that the changes in the cumulative *Pinus* deposition (Figure 6.8) are due to changes in the deposition of *Pinus* (*Diploxylon*) pollen rather than changes in accumulation rate of deposits (this is supported by concentration data of *Pinus* pollen). Accumulation of the fen deposits are probably reasonably steady and comparatively slow. The true-reed-swamp community continues to be dominant locally, with *Scirpus* the dominant type and *Glyceria* type next most abundant up to 162 cm, where *Scirpus* declines and *Glyceria* type becomes dominant probably as a response to the increased influx of fine grained sediments. The wet-soil community is next most important with *Schoenus nigricans* the dominant type and *Equisetum* also important, but declining. *Carex hallerana* type and *Mentha* type have almost disappeared, but *Carex hallerana* type increases from 162 cm. The tall-sedge-swamp community declines; *Carex flacca* type and *Cyperus longus* type have both declined and *Cyperus michelianus* continues at the same low values. The stream-reed-swamp community increases very slightly due to an increase in *Berula erecta*. Aquatic communities continue to be poorly represented with the exception of a peak of *Stratiotes aloides* at 170 cm. Otherwise, the floating-leaved macrophytes community is represented almost completely by *Sparganium angustifolium* and the submerged communities by *Hydrocotyle vulgaris*. Pollen of the extra-local and regional lowland canopy trees of *Quercus frainetto* type continues to be more abundant than that of *Quercus trojana* type; the former type increases while the latter is unchanged. *Juniperus* increases, now occurring at high abundance and probably forms a significant part of the understorey along with herb-rich steppe. *Quercus coccifera* type continues at the very low abundance. Herbs of open ground remain the dominant habitat group. *Pteridium aquilinum* declines to values almost as low as those of the surface sample. 'Cultivars' decline, due to reductions in all constituent taxa, but extra-local cereal cultivation continues. *Morus nigra* appears in two spectra at low values. The trees *Castanea sativa*, *Juglans regia* (reappears), and *Platanus orientalis* all occur sporadically at low values. Pollen

of mountain pine woods is abundant. Abundance of microscopic charcoal particles suggests that extra-local and regional burning continues at similar intensity/frequency as previously. In general pollen evidence again supports burning of vegetation at similar frequency/intensity; *Pteridium aquilinum* declines slightly, while *Juniperus* continues increasing and *Quercus coccifera* type remains at very low abundance. Concentration of *Pinus* (*Diploxylon*) declines slightly; very low concentration value is displayed at 170 cm where a peak occurs in smaller sized microscopic charcoal particles suggesting that more intense/frequent burning of regional vegetation occurred at that time.

Between c. 1650-1680 AD (157.5-143.0 cm) is a period of comparative landscape stability in the catchment but increasing instability is suggested by the greater influx of sediment beginning at 165 cm (see above) and concentration values of wetland palynomorphs is again very low from 155 cm. Sediments are the same as those previously and are characterised by moderately low inorganic and moderately high organic matter content, and low carbonate content. An apparent sudden increase in the accumulation rate of deposits at c. 155 cm corresponds to a peak in the frequencies of small size classes of microscopic charcoal particles suggesting that the changes in the cumulative *Pinus* deposition (Figure 6.8) are due to changes in the deposition of *Pinus* (*Diploxylon*) pollen rather than changes in accumulation rate of deposits (this is supported by concentration data of *Pinus* pollen). However, the accumulation rate of the fen deposits probably does increase to a moderate rate. Locally the true-reed-swamp community continues to be dominant; *Glyceria* type continues to be the dominant type. *Scirpus* is now only slightly more important than *Phragmites australis* and *Sparganium erectum*. The wet-soil community is the next most prominent community; *Schoenus nigricans* continues to be important, and *Carex hallerana* type continues to be equally important. *Mentha* type and *Chrysosplenium alternifolium* are also important and *Equisetum* occurs sporadically. The tall-sedge-swamp community continues at decreased abundance and the stream-reed-swamp community continues at slightly increased values due to an increase in *Berula erecta*. Aquatic communities increase due to an increase in *Hydrocotyle vulgaris*. Extra-local and regional lowland vegetation is very similar to previously. Pollen of the extra-local and regional lowland canopy trees of *Quercus frainetto* type continues to be more abundant than that of *Quercus trojana* type. *Juniperus* continues at high abundance and probably forms a significant part of the understorey along with herb-rich steppe. *Quercus coccifera* type continues at extremely low abundance. Herbs of open ground remain the dominant habitat group and increase to almost the highest relative

frequencies of the sequence, those of the basal zone. *Pteridium aquilinum* increases slightly. *Polygonum aviculare* type displays a peak in this zone. 'Cultivars' are still abundant and extra-local cereal cultivation continues. *Platanus orientalis* and *Castanea sativa* occur sporadically. *Juglans regia* disappears. Mountain pine woods decline. Abundance of microscopic charcoal particles of the largest two size classes increase while that of smaller size classes is unchanged, indicating increased extra-local burning and continued regional burning. A slight increase in *Pteridium aquilinum* may be indicative of increased burning of the extra-local vegetation, while high abundance of *Juniperus* suggests a lack of burning of extra-local and regional vegetation at least in some areas. Concentration of *Pinus* (*Diploxylon*) declines and a very low concentration value is displayed at 155 cm, where a peak occurs in smaller-sized microscopic charcoal particles suggesting that more intense/frequent burning of regional vegetation occurred at that time.

Between c. 1680-1720 AD (143.0-117.5 cm) is a period of instability in the catchment landscape as indicated by influx of large grain sized minerogenic particles until c. 1710 AD (121.0 cm), although peat formation continues. Two episodes of influx of coarse grained sediment occur separated by a narrow band (133-132 cm) of fine grained (clay) sediments. Non-calcareous coarse and very coarse sand forms the greatest proportion of the coarse grained minerogenic deposits while calcareous grit is less abundant. Unfortunately the source of the calcareous grit is unknown – it may be allochthonous or autochthonous, or both. Accumulation rate of the deposits increases sharply and they were probably deposited over a short period of time. Concentration values of wetland palynomorphs are the lowest of the sequence. Locally the true-reed-swamp community is again dominant and *Glyceria* type the dominant type. *Scirpus* retains its position as next most important before *Phragmites australis* and *Sparganium erectum*. The tall-sedge swamp becomes the next most abundant community with *Cyperus longus* type the dominant type increasing steadily. *Carex flacca* type becomes prominent at c. 1690 AD (130 and 125 cm). The wet-soil community is next most important but it has declined with *Carex hallerana* type, *Mentha* type, and *Equisetum* occurring sporadically. The stream-reed-swamp community has again increased slightly; again due to an increase in *Berula erecta*. Aquatic communities increase slightly due to an increase in *Hydrocotyle vulgaris*. Extra-local and regional lowland vegetation is very similar to that previously. Pollen of the extra-local and regional lowland canopy trees of *Quercus frainetto* type continue to be more abundant than that of *Quercus trojana* type, but *Quercus trojana* type now plays a slightly more important role. *Juniperus* occurs at highest relative frequencies of

the sequence and must be an important part of the understorey; herb-rich steppe also occurs. *Quercus coccifera* type occurs sporadically, but when it occurs abundance is greater than that below 315 cm and reaches highest relative frequencies of the sequence in several spectra. Herbs of open ground remain the dominant habitat group, although relative frequencies decline. *Pteridium aquilinum* increases to comparatively high relative frequencies. 'Cultivars' are abundant and increase in the upper part of the zone due to increases in several cereal pollen types. Extra-local cereal cultivation continues. *Platanus orientalis* occurs continuously at low values and *Castanea sativa* occur sporadically. Mountain pine woods remain at reduced abundance. Microscopic charcoal particles increase in all size classes, but mostly in the largest two size classes, indicating increased extra-local burning and slightly increased regional burning. Increases in *Pteridium aquilinum* and *Quercus coccifera* type may be indicative of increased burning of the extra-local and regional vegetation, while high abundance of *Juniperus* suggests an absence of burning at least in some areas. Low concentrations of *Pinus* (*Diploxylon*) pollen at c. 1680-1690 AD (135 and 125 cm) where peaks occur in the frequencies of the smaller sized microscopic charcoal particles suggest that increased regional burning of vegetation occurred at that time.

Between c. 1720-1790 AD (117.5-77.5 cm) comparative stability in the catchment landscape is again indicated as peat continues to form while fine grained sediment and herbaceous detritus are washed into the fen. Accumulation rate of deposits declines and becomes moderate. Sediments are peaty clay and are characterised by comparatively high organic matter and low inorganic matter content. Carbonate content is high below 105 cm but declines upwards. Concentration values of wetland palynomorphs is very low. Locally the true-reed-swamp community continues to be the dominant plant community. *Glyceria* type and *Sparganium erectum* are co-dominant. *Phragmites australis* and *Scirpus* are about equally important. *Typha domingensis* type and *Typha angustifolia* type have gained in importance. The tall-sedge-swamp community is second most prominent, with *Cyperus longus* type dominant. *Carex flacca* type and *Cyperus michelianus* have both declined. The wet-soil community continues to be represented sporadically by a few types: *Carex hallerana* type, *Mentha* type, and *Schoenus nigricans*. The stream-reed swamp is represented sporadically. Aquatic communities increase significantly due to a large increase in *Sparganium angustifolium*. Extra-local and regional lowland vegetation is very similar to previously. Pollen of the extra-local and regional lowland canopy trees of *Quercus frainetto* type continues to be more abundant than that of *Quercus trojana* type. Although declining

Juniperus still forms a major part of the understorey. *Quercus coccifera* type occurs at similar abundance to that below 315 cm. Herbs of open ground remain the dominant habitat group and increase in relative frequency. *Pteridium aquilinum* increases to relative frequencies almost as great as those between 372-312 cm. 'Cultivars' are abundant and extra-local cereal cultivation continues. *Vitis vinifera* occurs in one spectrum. *Castanea sativa* continues to occur sporadically at low abundance, *Juglans regia* reappears and occurs sporadically, and *Platanus orientalis* declines and occurs only sporadically. The montane conifers *Pinus* (*Diploxylon*) and *Abies* increase; *Abies* to relative frequencies similar to those of the surface sample. Abundance of microscopic charcoal particles of all size classes remains high and suggests that extra-local and regional burning is occurring. High abundance of *Pteridium aquilinum* spores supports extra-local and regional burning of vegetation and declining *Juniperus* may be due to a declining pollen source due to burning of vegetation. The abundance of *Quercus coccifera* type suggests some degradation of semi-evergreen oak woods, perhaps also through burning.

Between c. 1790-1840 AD (77.5-57.5 cm) represents an initial period of stability in the catchment landscape and then one of reduced stability. Until c. 1810 AD (67.5 cm) deposits comprise equal quantities of peat and herbaceous detritus and are characterised by high organic matter, and very low inorganic matter and carbonate content. After this, peat formation ceases, perhaps due to inundation of fine grained mineral sediments, and deposits comprise mostly clay with some herbaceous detritus suggesting that the catchment was vegetated. These sediments are characterised by low organic matter, high inorganic matter, and comparatively high carbonate content. Accumulation rate of deposits declines and becomes slow. Concentration values of wetland palynomorphs are again low. Locally the true-reed-swamp community is again dominant. Before c. 1810 AD (below 67.5 cm) *Sparganium erectum* is dominant. After this, *Glyceria* type and *Scirpus* are dominant. *Phragmites australis*, *Typha domingensis* type, and *Typha angustifolia* type have declined to insignificant values. The tall-sedge-swamp community is the second most important community, with *Cyperus longus* the dominant type but a peak occurs in *Cyperus michelianus* at c. 1820 AD (65 cm). The wet-soil community almost disappears but *Carex hallerana* type increases at c. 1820-1840 AD (65 and 60 cm). The stream-reed-swamp community is not represented. Aquatic communities have declined again but *Sparganium angustifolium* continues to be represented by significant values. Extra-local and regional lowland vegetation is very similar to that below. Relative frequencies of pollen of the extra-local and regional

lowland canopy trees of *Quercus frainetto* type increase and are again higher than those of *Quercus trojana* type. Although reduced *Juniperus* still forms a major part of the understorey. *Quercus coccifera* type occurs sporadically at low values similar to those below. Relative frequencies of herbs of open ground decline to the lowest of the sequence and are now lower than those of the habitat group coniferous and deciduous canopy trees. *Pteridium aquilinum* declines to low relative frequencies similar to those of the surface sample. Although all cereals have declined, extra-local cereal cultivation is still indicated. *Castanea sativa* and *Platanus orientalis* occur continuously, the former at low abundance and the latter at increased abundance. *Juglans regia* occurs sporadically at low abundance. *Salix triandra* displays a significant increase. Coniferous and deciduous trees become the dominant habitat group for the first time. This is due mostly to increases in *Pinus* (*Diploxylon*) and *Abies*, which reach their highest relative frequencies of the sequence. Low abundance of microscopic charcoal particles of the largest size class suggests that extra-local burning has declined while unchanged abundances of all other size classes suggests that regional burning continues at similar frequency/intensity. Decreased *Pteridium aquilinum* and increasing *Juniperus* support a decline in extra-local and regional burning of vegetation. However, the abundance of *Quercus coccifera* type suggests some degradation of semi-evergreen oak woods, perhaps through burning.

Between c. 1840-1880 AD (57.5-32.5 cm) greater instability in the catchment landscape is indicated by the influx of larger grain sized particles. Until c. 1850 AD (52 cm) sediments are the same as those previously, then fine to medium noncalcareous sand, indicating greater energy of transport, is deposited with a small amount of fine grained (mud) sediment and a trace of herbaceous detritus. This was probably deposited over a short time span (accumulation rate of deposits is fast). Sediments are characterised by low organic matter, high inorganic matter, and comparatively high carbonate content. Concentration of wetland palynomorphs is again low. Locally the true-reed-swamp community is again dominant. The dominant types are now *Glyceria* type, *Phragmites australis*, and *Scirpus*; *Sparganium erectum* is also important. The second most important community is that of the tall-sedge swamp, where the dominant type is *Cyperus longus* type; *Cyperus michelianus* fluctuates. The wet-soil community increases in importance with increasing *Carex hallerana* type. The stream-reed-swamp community has only minor representation. Aquatic communities display a peak at 50 cm due to an increase in *Hydrocotyle vulgaris*, then decline. Extra-local and regional lowland vegetation is very similar to that previously. Pollen of the extra-local and

regional lowland canopy trees of *Quercus frainetto* type continues to be more abundant than that of *Quercus trojana* type. *Juniperus* increases and *Quercus coccifera* type occurs continuously at low values. Herbs of open ground regain dominance; relative frequencies increase to high values. *Pteridium aquilinum* remains at the reduced values. 'Cultivars' increase and almost reach the maxima of the sequence due to increases in cereal pollen types; extra-local cereal cultivation is indicated. *Lathyrus sativus* and *Morus alba* both occur at 55 cm only. *Platanus orientalis* occurs continuously but declines steadily. *Castanea sativa* also occurs continuously and *Juglans regia* occurs sporadically at similar abundance as previously. *Salix triandra* continues at the same abundance as previously. The montane *Pinus* (*Diploxylon*)/*Abies* woodland declines sharply. Increasing abundance of microscopic charcoal particles of the larger size classes and unchanged abundance of the smaller size classes suggests that extra-local burning is increasing, while the intensity/frequency of regional burning remains the same. Reduced *Pteridium aquilinum* and increased *Juniperus* suggests a decline in extra-local and regional burning of vegetation. However, the abundance of *Quercus coccifera* type suggests some degradation of semi-evergreen oak woods, perhaps through burning. Concentration values of *Pinus* (*Diploxylon*) decline at c. 1860 AD (45 cm) where the smaller size classes of microscopic charcoal particles display a peak suggesting that increased burning of regional vegetation occurred at that time.

Between c. 1880-1910 AD (32.5-18 cm) is a period of comparative landscape stability in the catchment. Peat formation begins again at 32.5 cm indicating greater landscape stability in the catchment and water logging of the wetland. Fine grained sediments (clay and silt) are deposits coincidentally with a small amount of herbaceous detritus. Sediments are characterised by high organic and low inorganic matter and moderately high carbonate content. Accumulation rate of the deposits declines and is slow. Concentration of wetland palynomorphs is again low. Locally tall-sedge-swamp and true-reed-swamp communities are co-dominant. *Cyperus longus* type contributes almost all pollen of the tall-sedge-swamp community, while several types of the true-reed-swamp community contribute significant amounts of pollen – *Glyceria* type, *Phragmites australis*, and *Sparganium erectum*. The wet-soil community declines and only *Carex hallerana* type contributes significant amounts of pollen. The stream-reed-swamp community is not represented. Aquatic communities continue to be poorly represented, but *Callitriche stagnalis* type displays a small peak at 25 cm. Extra-local and regional lowland vegetation is very similar to that previously. Pollen of the extra-local and regional lowland canopy trees of *Quercus frainetto* type continues to be

more abundant than that of *Quercus trojana* type. *Juniperus* has declined to relative frequencies similar to that of the surface sample. *Quercus coccifera* type occurs continuously and increases slightly to relative frequencies greater than that of the surface sample. Relative frequencies of herbs of open ground decline to almost the lowest values of the sequence and are the second most abundant habitat group after coniferous and deciduous canopy trees. *Pteridium aquilinum* declines. 'Cultivars' are abundant, although they have declined due to reduced *Avena* and *Platanus orientalis*. Extra-local cereal cultivation is still indicated. *Castanea sativa* and *Juglans regia* occur sporadically. *Salix triandra* continues at the same abundance as previously. Coniferous and deciduous trees are the dominant habitat group and increase to almost the maximum relative frequencies of the sequence due to increases in *Pinus* (*Diploxylon*) and *Abies*. Abundance of microscopic charcoal particles of the largest size class increases to the highest values of the sequence at c. 1890 AD (25 cm), suggesting most intense/frequent extra-local burning took place at that time. Abundance of other size classes, except the smallest also increases to high values. Decreased *Juniperus* pollen suggests the possibility of an increase in extra-local and regional burning of vegetation, while reduced abundance of *Pteridium aquilinum* spores suggests a decline in the burning of vegetation. However, increased abundance of *Quercus coccifera* type suggests degradation of semi-evergreen oak woods, which may be caused by burning.

Between c. 1910-1989 AD (18-0 cm) is a period of apparent stability in the catchment. Peat formation continues while only a very small amount of fine-grained (silt) sediment and woody detritus is washed in. The apparent stability in the catchment is thought to be due to the establishment of the modern sealed road and its causeway, which may have reduced the transport of sediment into the fen from the catchment upstream. Woody detritus probably derives from shrubby plants growing on drier parts of the fen. A very small amount of calcareous grit was noted in these deposits. The sediments are characterised by the highest organic and lowest inorganic matter of the sequence and low to moderately high carbonate content. Accumulation rate of these deposits is very slow and concentration values of wetland palynomorphs increase until very high. Locally the tall-sedge-swamp community becomes dominant with *Cyperus longus* dominant. Species of *Carex flacca* type also contribute a large amount of pollen and *Cyperus michelianus* contributes a significant amount in the surface sample. All other wetland communities have declined greatly. Pollen of the extra-local and regional lowland canopy trees of *Quercus frainetto* type continues to be more abundant than that of *Quercus trojana* type, although *Quercus frainetto* type has declined. *Juniperus*

continues at the same low values as previously. *Quercus coccifera* type declines. Herbs of open ground increase and are co-dominant with coniferous and deciduous canopy trees. *Pteridium aquilinum* occurs at low abundance while *Cirsium* increases sharply. 'Cultivars' are abundant although they have declined again. The decline is due to a reduction of all the cereals but extra-local cereal cultivation is indicated. *Elaeagnus angustifolia* and *Vicia sativa* type both occur once only. *Castanea sativa* and *Juglans regia* occur sporadically. *Platanus orientalis* occurs continuously and increases slightly. A dramatic increase in *Salix triandra* occurs. The montane *Pinus* (*Diploxylon*)/*Abies* woodland remains unchanged. Abundance of microscopic charcoal particles of the largest size class increases to the second highest values of the sequence at 5 cm, suggesting intense/frequent extra-local burning. This is perhaps due to the introduction of mechanized agriculture and the practise of stubble burning. Abundance of other size classes are lower than below, but they are still abundant. Low abundance of *Pteridium aquilinum* does not support widespread burning of vegetation while low abundance of *Juniperus* pollen suggests the possibility of extra-local and regional burning of vegetation. However, low abundance of *Quercus coccifera* type suggests degradation of semi-evergreen oak woods, which may be caused by burning.

Chapter 7. Discussion and conclusions

Preceding chapters set out the basis of the chronology and vegetation history of the three sites studied. In addition to summarizing these results, this chapter attempts to interpret the data in terms of the history of climate and land use over the past 3000 years. Since the lower part (below 312 cm) of the Kellia sequence is not dated satisfactorily it is not included in the discussions.

7.1 Vegetation and interpretation of fossil pollen sequences

The extant vegetation of Grevena is dominated by woodland, which covers over half the entire land area; grassland and cultivation cover the remainder. The landscape is intensively used and little, if any, unmodified vegetation remains. Today land use includes agriculture; pastoralism; removal of trees by cutting; and harvesting of trees by coppicing, pollarding, and shredding. In spite of this intensive land use, the composition and structure of the woodlands varies according to elevation and moisture, and forms distinct vegetation zones dominated by only a few tree genera. The highest elevations are occupied by alpine meadows and *Pinus* woods; intermediate elevations by a mosaic of *Pinus* woods, *Fagus* woods and mixed coniferous/deciduous woods; the lower slopes of the Pindos foothills by deciduous *Quercus* woods; and the plains by a mosaic of deciduous *Quercus* woods and steppe, and agricultural land. The west-to-east moisture gradient results in the dry eastern Vourinos Mountains supporting few trees. The trees that dominate the landscape, *Pinus*, *Fagus*, and *Quercus*, are also dominant in the surface pollen spectra, and the major vegetation zones that these trees dominate are characterized by corresponding high pollen relative frequencies: 51-84% *Pinus* in pine wood, 23.5-29.4% *Fagus* in beech woods, and 26.5-40.7% *Quercus frainetto* and *Quercus trojana* types combined in oak woods.

As has been found in many other surface pollen studies, the proportion of pollen recorded in the pollen spectra is different from that of corresponding plant taxa in vegetation. An obvious feature of the results of this study is the over-representation of pine pollen, which suppresses the relative frequencies of all other pollen types. This extreme over-representation of *Pinus* necessitates that a high pollen sum be counted in samples collected from pine vegetation zones, so that the frequencies of other pollen taxa may be reasonably accurately estimated, and it should be taken into account when the fossil sequences are interpreted.

The relative dispersal and representation of pollen of other less abundant trees varies (as demonstrated by the two surface samples collected from beneath the canopy of the relic mixed woods growing on limestone), but they all have lower relative dispersal and representation than *Pinus*, *Fagus* and *Quercus*. In general the taller anemophilous trees contribute most to

the pollen rain. Many trees of the mixed woods are entomophilous and contribute almost no pollen to the pollen rain, e.g. *Acer*, *Cornus*, and *Tilia* and genera of Rosaceae. *Fraxinus ornus* is also primarily entomophilous. If pollen of these trees is found in the pollen record it is likely to have a source close to the sampling site. Poor representation of pollen of these trees makes detection of greater diversity of trees in woodlands difficult. *Corylus avellana* and *Carpinus betulus* are anemophilous, but although dispersal is good often little pollen is produced. *Corylus* is known to produce varying amounts of pollen depending upon its structural position in woods, i.e. it produces little pollen as an understorey shrub, but produces much as a canopy tree (Iversen 1941; Moore 1976). A few pollen grains of *Corylus* may thus arise from an extra-local or regional source.

One of the biggest problems in interpreting pollen data is defining the size of the area that contributes to the pollen rain. It is often impossible to tell whether a small percentage comes from a few trees in the vicinity or from stands at a distance. In a basin such as Grevena with distinct belts of vegetation zones at different elevations, it is possible to measure pollen dispersal distances from source vegetation. Long-distance transport of some pollen types identified in the surface pollen samples is apparent. The occurrence of pollen of trees that grow in the mountains, such as *Pinus* and *Fagus*, in surface samples of the lowlands are evidence of long-distance transport; as are pollen of trees that grow in the lowlands and foothills, e.g. *Quercus*, in surface samples collected in the mountains. A *Pinus* relative frequency of as much as 13%, in samples from the lowland oak woods of Grevena, is not indicative of pine growing on or near the site at the time of deposition of the pollen. Threshold values for *Fagus* and *Quercus* (*Q. frainetto* and *Q. trojana* types combined) of 1% and 6.5% respectively are proposed for Grevena. Another pollen type that clearly displays long-distance dispersal is *Quercus coccifera*, whose appearance in samples collected in the Pindos Mountains must be a result of long-distance transport from the western side of the mountains, taking into account the prevailing westerly winds.

7.2 Chronology

An attempt was made to develop a chronology by radiometrically dating material within the sediments of the pollen-analysed cores and by identification of stratigraphic markers; a number of problems were encountered.

The radiocarbon dating and derived chronology for the Gomara sequence is thought to be reasonable, on the basis of sediment-accumulation rates and palynology, and they span the sidereal years from 1340 BC at the base of the sequence to 700 AD at the top of the undisturbed sediments. In the Gomara sequence a sediment horizon identified as tephra by the presence of glass shards could not be correlated by chemical analysis with known

eruptions because of alkaline etching of the glass shards. Thus the tephra could not be used as a chronological marker, although a radiocarbon date of 105 Cal BC just below the tephra suggests that it derives from an Italian volcanic eruption at Etna, Monte Albano, or Vulcano (Simkin *et al.* 1968).

In the Anelia sequence radiocarbon dating provided ages that, at 60% confidence, were not statistically different for contiguous samples; one sample included four separate calibrated age ranges, and the uppermost sample could represent any calendar date in the last 250 years. Two different laboratories using two different techniques of radiocarbon dating were used. The radiocarbon ages obtained by the two laboratories were compatible and each laboratory carried out pretreatments appropriate to the material being dated, to minimize erroneous results (Chapter 2). Thus the possibility of laboratory error or contamination, e.g. contamination within the measurement system or during sample preparation, is minimal. Mean sediment-accumulation rates for contiguous samples were calculated and checked by applying the mean terrestrial pollen influx rate of the Gomara sequence to the mean terrestrial pollen concentration of the Anelia sequence. A mean deposition rate resulted that implied a basal age for the Anelia sequence in good agreement with the basal radiocarbon date of c. 1560 Cal AD. This chronology is in conformity with pollen data, and a general chronology for the site based on radiocarbon dates is therefore accepted, although the timescale derived for this sequence should be regarded as tentative.

Radiocarbon ages of the Kellia sequence suggest that sediments represent two periods of deposition with a hiatus between. The upper period spans c. 1230-1989 AD. The two lowest radiocarbon ages, based on humin extracted from slight organic deposits, are much older than those of the richly organic deposits above, and they occur in reverse order, giving calendar dates of 830 Cal BC (lower sample) and 2031, 1992 or 1989 Cal BC (upper sample). The reversal may be due to older deposits being washed in on top of sediments from younger deposits. However, the occurrence of *Castanea sativa* and *Juglans regia* in the basal pollen assemblage zone suggests that the base of the sequence is younger than 1628-1626 BC (Athanasiadis 1975; Bottema 1980; Bottema 1981; Bottema & Woldring 1990; Bottema 1994), while the occurrence of *Secale cereale*, introduced during the Roman Period (Renfrew, J. 1969, 1973a), suggests that the sediments may have been deposited after 146 BC. Identification of individual cereal pollen types is difficult. Although pollen of rye is reasonably distinctive, the pollen identified as rye (*Secale cereale*) may actually represent another cereal, perhaps one that has been cultivated in Grevena for a longer period, such as wheat or barley, the seeds of which have been found associated with Hellenistic sites in Grevena (Chapter 1), or oats. Evidence of the cultivation of wheat, barley, and oats dates back to the Neolithic in west Macedonia and Thessaly (Renfrew, J. 1969, 1973a & b; Hansen 1988).

Another possibility is that it was introduced as a field weed (Stutz 1972; van Zeist 1976). The age of the lower period of deposition is thus uncertain. Variations in the composition of deposits of the Kellia sequence suggest variation in sediment-deposition rate, thus cumulative concentration of *Pinus* pollen (as a constant component of long-distance transport unlikely to be affected by climatic variation in the time span being considered) was plotted against depth (Middeldorp 1982) and a calendrical scale fitted in compatibility with that suggested by the linearly interpolated radiocarbon age/depth plot. Since this plot takes into account variations in sedimentation rate it was used as a best estimate for the chronology of the younger period of the sequence. This plot also implies that the older period of deposition lasted over about 200 years.

Thus the highland site of Gomara spans the period 1340 BC to 700 AD. Then there is a gap in the time sequence until 1230 AD when the lowland site of Kellia is dated reliably. From 1560 AD to the present, the sequences from the Kellia and Anelia sites overlap, offering a comparison between highland and lowland sites. It must be remembered that, although calendrical chronologies are presented, dates are based on interpolation between radiocarbon ages. Because of statistical uncertainties in sampling and calibration associated with radiocarbon dates and variations in sedimentation rates, all given calendar dates must be taken as approximate. The magnitude of the uncertainty varies according to the sequence and depth, and it is difficult to attach precise figures. However, the combination of multiple radiocarbon dates with sedimentation and pollen deposition data reduce the uncertainty below levels associated with single radiocarbon dates.

7.3 Climatic reconstruction

As vegetation is related in a broad way to climate, a vegetation history can be used to reconstruct an approximate climatic history. Because of the severe impact that humans have had on the vegetation of Grevena, the small number of samples of the modern-pollen deposition study and the lack of modern climatic data, transfer functions (Birks 1981) could not be determined for the reconstruction of former climates. Thus a method similar to that of Iversen (1944), using a limited number of indicator pollen and spore taxa of known ecological and climatic preferences, is employed. Unfortunately, autecological data are difficult to obtain, and much comes from outside the region of study, where climatic factors that may affect plant distribution such as solar radiation are different. Thus the climatic reconstruction is very approximate. For this study, the use of indicator species is more appropriate than plant communities because communities have been altered by human disturbance (Birks 1981), but ecological preferences of major vegetation types are used.

There are limitations to this approach. Plant distributions may be caused in part by non-climatic factors such as competition or edaphic conditions. Also, vegetation may not be in equilibrium with climate at the relevant scales of time and space (Davis 1978; Birks 1981; Prentice 1983; Davis & Botkin 1985; Gajewski 1993). Moreover, temperature and precipitation do not vary independently of each other, and the interdependence of these two factors is not so well known that we can precisely separate their individual effects in the vegetation (Prentice *et al.* 1992). Finally, there is a limit to the resolution that can be recorded in pollen diagrams, due to sedimentation rates and post-depositional mixing.

Since no meteorological data are available for this part of the Pindos Mountains, approximate modern-day climatic parameters of the highland site at Gomara have been calculated by use of the 1978-1987 meteorological data collected and analysed by Doyle (1990) from the lowland station at Grevena (550 m asl) and of the altitudinal temperature lapse rate of 5.7° C per 1000 m (Savina 1993). An approximate estimate of the mean temperature of the warmest month (July) at Gomara is 15.9° C. This does not take into account the probable cooling effects of prolonged snow lie and greater cloudiness in the mountains. The mean temperature of the coolest month (January), calculated on the same basis, is about -3.6° C. However, in winter there is commonly a temperature inversion in valleys, and mountain slopes and peaks at the same height are 2-3° C warmer (Furlan 1977:196), so the January mean at Gomara may be up to 3° C higher. These data make it possible to reconstruct some approximate climatic parameters in the highlands from 1340 BC to 700 AD and deduce minimal deviations from modern values. The climatic reconstruction for the lowlands is based mostly on a *Quercus* index. This depends on the relative abundance of different groups of *Quercus* species with different temperature requirements.

1340-890 BC (pollen zone G-6) The climate in the Pindos at this time appears to have been warm and dry. *Ilex aquifolium*, *Viscum album*, and *Hedera helix* are ideal indicator species because their pollen is identifiable to species level, they are entomophilous so problems of long-distance transport do not arise, and the plants are rapidly dispersed by birds eating their berries, hence their distribution is likely to be in equilibrium with the climate (Knuth 1906, 1908, 1909; Iversen 1944). Also they are evergreen, so their survival depends on winter as well as summer temperatures (Birks 1981). *Hedera helix*, *Ilex aquifolium*, and *Viscum album* all occur during this period; the former two species occur near the base of the sequence (c.1300-1200 BC), while the last occurs at c. 1000 BC. These species occur at very low abundance, but this is to be expected because they are entomophilous and because of the over-representation of *Pinus* pollen. *Ilex aquifolium* (holly) is intolerant of cold winters, as its cambium is killed by frost. Iversen (1944), working in Denmark, correlated the northern and eastern limit of *Ilex aquifolium* with the -0.5° C isotherm of the coldest month of the year.

Hedera helix is tolerant of lower winter temperatures. It cannot flower or produce fruit below -1.5°C , but it requires warmer summers than *Ilex* (Iversen 1944). *Viscum album* (mistletoe) is tolerant of cold winter temperatures, the limiting temperature being *c.* -8°C , but it requires warmer summers. The limiting summer temperature is *c.* 15.5°C (Faegri & Iversen 1989). The presence of *Ilex aquifolium* suggests that the mean temperature of the coldest month was warmer than -0.5°C , perhaps 3.2°C warmer than today, while *Hedera helix* would require that the coldest month was about 2°C warmer than at present. These estimates are very approximate and do not take the possibility of inversions into account; if the modern January mean at Gomara were estimated $2\text{--}3^{\circ}\text{C}$ higher, taking into account the probable topographic inversion at Grevena station, these taxa would be close to their climatic limit. Thus their occurrence in this period may reflect slightly warmer winter temperatures than at present. The current estimated temperature for the warmest month of the year (15.9°C) would allow marginal growth of *Viscum album*, which requires that the mean temperature of the warmest month be greater than 15.5°C .

Woodland pollen data suggest that other thermophilous species absent today were growing at this highland site. The occurrence of such primarily entomophilous pollen types as *Tilia cordata*, *Sorbus*, *Cornus sanguinea*, *Crataegus*, and *Fraxinus ornus* suggests that they were growing in the catchment. Current distribution data from Grevena are not useful in establishing the ecological limits of these taxa as they occur largely as relics in places inaccessible to grazing animals. Prentice *et al.* (1992) indicate that temperate deciduous woods occur where the relative moisture availability index (E/PE , E = actual evapotranspiration, PE = potential evapotranspiration) is greater than 0.65 and winter temperatures are between -2°C and 5°C . Assuming that $E/PE > 0.65$, the occurrence of these trees in the catchment gives support to the postulated slightly warmer winter temperature, although the trees would require a temperature only 1.7°C higher than that estimated for the present day. Further, the occurrence of these trees indicates that the mean summer temperature (July) was above 13°C (Iversen 1954); this is lower than the present estimated temperature and does not imply a difference.

The presence of *Picea abies*, whose current distribution range is more northern, does not appear to be in accord with a warmer climate (Tutin *et al.* 1964:31; Strid 1989:41). Today *Picea abies* (Norway spruce) grows only in NE Greece near the Bulgarian border in the Kara-Dere woodland in the Rhodope Mountains (*c.* 300 km northeast of Gomara), where it forms extensive woodland at *c.* 1400–1900 m, partly in pure stands and partly together with *Pinus sylvestris* and *Fagus sylvatica*. This is its current southern limit (Sfikas 1978; Strid 1989). Ecological and palynological studies suggest that the distribution of some species of *Picea* is more strongly influenced by competition with other species than by climatic factors (Bormann

et al. 1970; Davis 1978). Data from Norway indicate that for seeds to mature a mean July temperature of over 18-19° C is injurious and a mean January temperature below -2° C to -3° C is required (Tallantire 1972). This is lower than the temperature required by *Ilex aquifolium*. Since *Ilex aquifolium* is entomophilous it seems that it was growing close to the site, so explanations for the presence of *Picea abies* need to be sought. Long-distance transport is an obvious explanation and indeed occurrences of very long-distance transport of *Picea* pollen has been reported (Tyldesley 1973), but a different prevailing wind direction would be required to transport it from northern localities. It could be a relic of an earlier period when winter temperatures were colder or snow cover provided the cold temperatures required. If *Picea abies* were growing close to the site it seems that it was close to its environmental tolerance. At the end of this time period it disappeared. Not only warm winter temperatures but early summer drought or strong winds due to an open canopy (as seedlings require protection from wind – Tallantire 1972) may have been the prevailing conditions unfavourable to *Picea*. Disease also cannot be discounted (Tallantire 1977). Human influence does not seem a likely cause of its disappearance, as it is not palatable and does not burn easily.

Palynologically it is difficult to estimate precipitation by analogy with today's conditions. At this time the extra-local vegetation was probably an open canopy pine wood mixed with a few deciduous trees, but not as open as today. Land-use practices in the highlands included burning, which is absent today. The predominance of *Pinus*, which is more drought tolerant than *Fagus*, and the very low relative frequencies of *Fagus* (which are lower than those of the surface sample) suggest that summer precipitation was lower than that of today. Pollen of the xeric habitat group, plants of open dry rocky habitats, is most diverse in this part of the sequence. This may also be indicative of slightly lower summer precipitation.

From c. 1250 BC diatom evidence indicates that the water level of the Gomara lake fluctuated seasonally and the average water level declined, indicating a progressively drying and/or warming climate, although lower water levels may also result from increased evaporation due to an increasingly open woodland structure, or from use by grazing domesticated animals. On the other hand, an open canopy would reduce the amount of moisture taken up in evapotranspiration and the relative amount of run-off would increase. In climatic terms, seasonal fluctuation of the water level implies dry summers. Representation of aquatic macrophyte taxa declines at this time: the only aquatic plant represented, *Hydrocotyle vulgaris*, can live as an emergent. The addition of coarser particles of mineral sediments may be due to increased storminess but could also be caused by greater exposure of mineral soils through anthropogenic reduction in vegetation cover. Reduced organic matter

may result not only from less litter being produced by a reduced canopy but also from an increased oxidation rate of litter in drier soils.

890-480 BC (pollen zone G-5) During this period the climate appears to have been wetter and colder than the preceding period. In the Gomara diagram *Fagus* expands at the expense of *Pinus*. It exhibits an increase in both relative frequency and in absolute abundance. *Fagus* is not a pioneer tree and is not light-demanding. Today *Fagus* overlaps with the pine zone, but this is only in damp areas. The slopes of the Gomara site have a sunny SSW aspect and are open to the prevailing westerly winds. Today this creates a local climate marginal for beech growth due to droughty conditions in summer; a few small *Fagus sylvatica* trees grow in a small valley close to the lake, where soil moisture is greater.

The temperatures determined for the preceding period combined with an open canopy of mostly pine suggests that, if wind conditions were the same as today, summer drought conditions would have been similar to or worse than those of today. Soils of this area have low water-holding capacity. The growth of more extensive beech wood at this site would require wetter summers without droughty conditions (Ellenberg 1988). Therefore an increase in summer precipitation must have occurred and perhaps also an increase in summer cloudiness.

Anthropogenic disturbance is less intense than in the preceding period (less erosion and less burning are indicated). This reduction in anthropogenic disturbance in combination with increased summer precipitation resulted in the rapid expansion of *Fagus*, whose competitive advantage over pine, given suitable climatic conditions, is well known (Turrill 1929) and can be seen today in Grevena.

Increases in *Fraxinus ornus* and *Ostrya* type also support an increase in precipitation. The abundance and diversity of pollen of the xeric taxa of the habitat group 'plants of open dry rocky habitats' declined. Sediment organic-matter content rose steadily, perhaps as a closing canopy (and one that included *Fagus*) produced more litter, and oxidation rate of litter declined in wetter soils. A denser canopy would have reduced evaporation by shielding the lake from strong winds. Diatom evidence indicates that water level in the lake increased. No seasonal fluctuations are indicated, suggesting that summer precipitation was greater than in the preceding period.

Betula pendula pollen increased during this period and was probably growing extra-locally (based on its abundance). *Betula pendula* (silver birch) is not known in Grevena today and currently grows only in north Greece in the west Rhodopi mountain range close to the northeast border of Greece. Turrill (1929:143) recorded it in the montane beech and fir forests further north on the Balkan Peninsula. It is the only species of *Betula* growing in Greece today. Pollen was identified to species level based on its current distribution (Tutin *et al.*

1964-80; Sfikas 1978) and size of pollen grains (Birks 1968; Prentice 1981; Roure 1985). It was not identified in the surface samples (Chapter 3). The species occurs throughout most of Europe, from 69° N in Norway to Sicily; it is local in the south and confined to mountains (Tutin *et al.* 1964:58; Sfikas 1978; Polunin 1988; Strid 1989). Since *Betula pendula* now has a more northern distribution it is likely that the current climatic regime of Gomara is too warm for it, suggesting that the increase in pollen in this zone is due a climatic change to conditions cooler than in the preceding period, and cooler than today.

The alpine shrub *Vaccinium myrtillus* (Ericaceae) increased slightly, supporting a change to cooler conditions. Disappearance of *Ilex aquifolium*, *Hedera helix*, and the entomophilous temperate trees (with the exception of *Fraxinus ornus*, which is partly anemophilous) in this zone suggests that winter temperatures declined. The absence of these species cannot be attributed to anthropogenic disturbance, as this is a period of reduced disturbance. *Ulmus glabra* type also declined slightly, perhaps also owing to cooler winter temperatures.

Viscum album occurs at very low abundance at c. 700 BC, suggesting climatic limits higher than c. -8° C for minimum winter temperature and a minimum summer temperature of at least 15.5° C.

480-80 BC (pollen zone G-4) The climate appears to have been warmer and perhaps wetter than the preceding period. During this period the regional pine woods and extra-local beech wood expanded and/or became denser. This may have been partly due to increased precipitation and also to a further reduction in anthropogenic disturbance. An increase in *Abies* and *Fraxinus ornus* may be related to increased precipitation. Organic-matter content of the lake deposits continued to rise steadily as litter production rose and oxidation rates declined in moist soils beneath an extensive canopy cover. A decline in the steppe taxa of *Artemisia* and Chenopodiaceae supports moister soil conditions in the catchment, and these heliophytes may also have declined due to greater shading by a denser canopy cover. Diatom and wetland pollen evidence points to a reduction in lake water level and seasonal fluctuation, which may indicate reduced precipitation.

A sharp decline in *Betula pendula* occurs at the lower boundary of this zone. As discussed above, *Betula pendula* currently has a more northerly geographic range. Thus its near disappearance in this zone suggests that summer temperatures increased. However, its extra-local disappearance may also be partly due to shading by the expanding *Fagus* woodland. An increase in *Typha angustifolia* type may also be a response to warmer temperatures (Iversen 1954).

At c. 80 BC (pollen zone G-3) a tephra was deposited. There are no significant differences in palynomorph content of the sediments directly above and below the tephra,

indicating that the ash caused insufficient climate change to affect vegetation growth either extra-locally or regionally.

80 BC-330 AD (pollen zone G-2) The climate was probably wetter than today and warmer than the preceding period. A closed canopy *Fagus* woodland surrounded Gomara lake, replacing the former pine wood of the catchment. *Abies* and *Fagus* gradually increased and a parallel gradual increase in precipitation may have occurred, although *Fagus* may have been still responding to a former increase in precipitation. The vegetation may have reached a particular threshold where greater vegetation cover and greater wetness were self-sustaining, i.e., that there was more convection and therefore more rainfall (Lamb 1982:320).

Water level increased and was probably at its highest level, with little seasonal fluctuation, as shown by the abundance of diatoms living in permanent water and an increase in pollen of aquatic macrophytes. The lake deposits are highly organic, suggesting the soils in the catchment were very moist and that little oxidation of litter was occurring. The combination of organic lake deposits and increased lake water level also argues for increased precipitation.

The reappearance of *Ilex aquifolium* and entomophilous temperate tree pollen types such as *Acer*, *Crataegus*, *Cornus sanguinea*, *Cornus mas*, *Sorbus*, and *Tilia cordata* suggests that winter temperatures were warmer than today and were higher than in the preceding period. At c. 200 AD the presence of *Ilex aquifolium* suggests that the mean temperature of the coldest month was warmer than -0.5°C , perhaps 3.2°C warmer than today. *Viscum album* occurs at 85 cm, suggesting at least 15.5°C minimum mean summer temperature (Iversen 1944).

330-700 AD (pollen zone G-1) The climate was probably similar to that of today. In the catchment pine wood expanded at the expense of *Fagus*, and the canopy was open. The decline in *Fagus* suggests reduced summer precipitation: *Fagus* cannot tolerate summer drought like *Pinus*. This is a period when anthropogenic disturbance is evident, so the decline in *Fagus* may be partly due to the direct exploitation of *Fagus* for fodder and grazing and/or clearance to create pastureland. Pine is a more favoured tree in pasture, as it allows light to penetrate to the ground and pasture plants to grow. Also pine is not as palatable as *Fagus* so has a better chance of regeneration in pastureland. A reduction in soil moisture, unfavourable to *Fagus*, may also have been caused by the reduced canopy cover, which would allow greater evaporation. A reduction in soil moisture is supported by the increased abundance in pollen of the habitat group 'plants of open dry rocky habitats'.

The pollen of a few entomophilous temperate tree pollen types such as *Cornus mas*, *Sorbus*, and *Tilia cordata* occurs, suggesting a mild climate, but *Hedera helix* and *Ilex aquifolium*, which were present in the preceding period, are absent. Their absence could be due to a decline in winter temperature or to anthropogenic disturbance. An increase in

Quercus coccifera type during this period suggests a regional increase in temperature (as this pollen must be transported from low elevations), or alternatively greater anthropogenic disturbance such as grazing at lower elevations. An increase in temperature would have increased evaporation rates.

Lake-sediment organic-matter content remained high. This may have been due to an increased rate of erosion caused by greater exposure of soils due to reduced canopy cover. Lake water level was probably high, with little seasonal fluctuation. The level probably increased due to increased run-off.

1230 AD to present Data are available from the lowland site of Kellia (580 m asl), which is close to Grevena meteorological station (550 m asl) (Chapter 1). The Anelia site (1440 m asl) spans the period from c. 1560 AD to present.

Anelia lies within the beech wood zone and is not at present close to the climatic limit of major tree species. Also, the record of woodland vegetation at the site displays the effects of clearance and other anthropogenic disturbance in the vicinity of the site, and it is therefore difficult to discern climatically linked vegetation changes.

The oak woodlands of the lowlands provide a better opportunity for investigation of climatic change. Prentice *et al.* (1992) note that temperate deciduous forests occur in winter temperatures (mean coldest month) from -2°C to 5°C where $E/PE > 0.65$, whereas evergreen trees require winter temperatures of more than 5°C where $E/PE > 0.65$. At Grevena meteorological station the mean temperature of the coldest month (January) is 3.2°C , and the mean temperature of the warmest month (July) is 22.7°C . In the lowlands of Grevena today three different types of oaks occur, that is, deciduous, semi-evergreen, and evergreen. The distribution of these oak types varies according to temperature, with deciduous oaks occurring in the coldest sites and evergreen oaks occurring in the warmest sites, which are restricted to the southeast corner of the province. Ellenberg (1988) points out that evergreen oaks are more susceptible to frost than deciduous oaks. Semi-evergreen oaks occupy intermediate sites.

Pollen types were established on the basis of the pollen-morphological descriptions of van Benthem *et al.* (1984) and examination of reference pollen. The main distinguishing features are the surface texture, which varies from scabrate/verrucate (deciduous), to scabrate (semi-evergreen), and indistinctly scabrate/rugulate (evergreen), as well as size of the grain. It is easier to distinguish deciduous and semi-evergreen species from evergreen species than to distinguish deciduous species from semi-evergreen species. *Quercus frainetto* type includes deciduous species only, *Quercus trojana* type includes a semi-evergreen species, two semi-evergreen or deciduous species and one deciduous species, and *Q. coccifera* type includes only evergreen species (Appendix VI).

Figure 7.1 Relative abundance of the three *Quercus* pollen types (*coccifera* - evergreen, *trojana* - semi-evergreen/deciduous, and *frainetto* - deciduous) since 1230 AD at Kellia site, compared with estimated course of annual temperatures in central England over the same period (this latter curve adapted from Lamb 1982, fig. 30a - the shaded area indicates a range of uncertainty). In the *Quercus* pollen curves the inferred sense of temperature increase is towards the right (increasing proportion of evergreen and semi-evergreen/deciduous oak pollen, decreasing proportion of deciduous oak pollen).

Curves have been drawn for the Kellia site (Figure 7.1) showing the relative abundances (i.e. one to another, with total oak pollen count taken as 100%) of the three oak pollen types *Quercus frainetto* type (deciduous oaks), *Quercus trojana* type (semi-evergreen/deciduous oaks), and *Quercus coccifera* type (evergreen oaks). Set against these curves is the estimated course of temperatures prevailing in central England based on fifty-year averages for the whole year as derived from historical records (Lamb 1982). These curves include the period known as the Little Ice Age, which is a period of lower global temperatures, although there are fluctuations and extreme conditions were more frequent, following a period of warmth in the Middle Ages (Grove 1988). There is no agreement on when precisely the Little Ice Age started; it ended at the end of the nineteenth century (Whyte 1995). After a decline in temperature in the thirteenth and fourteenth centuries there was an interval of more favourable conditions before a return of more severe weather between the mid-sixteenth and mid-nineteenth centuries (Grove 1988). Absolute temperatures from central England reflect a more oceanic climate and are not expected to correspond exactly to those of Grevena. Nevertheless, the two sets of data show the same general trends. The period of greatest abundance of *Quercus frainetto* type pollen, lowest abundance of *Quercus trojana* type pollen, and low abundance of *Quercus coccifera* type between c. 1580-1680 AD corresponds well with the low temperatures recorded in England between 1550-1690 AD. Two other periods when colder temperatures are indicated for Grevena by the greater abundance of *Quercus frainetto* type, lower abundance of *Quercus trojana* type, and low abundance of *Quercus coccifera* type are between c. 1480-1520 AD and c. 1790-1850 AD. These also correspond well with periods of low temperatures in England. Furthermore, the greatest abundance of the deciduous oaks (*Quercus frainetto* type) and the lowest abundance of semi-evergreen/deciduous oaks (*Quercus trojana* type) occurs at c. 1680 AD and shows good correspondence with the lowest temperatures indicated at 1690 AD and the culmination of the Little Ice Age, which occurred c. 1660-1680 AD (Lamb 1982; Grove 1988).

The curve of the evergreen oaks (*Quercus coccifera* type) does not closely follow the curves of the other two types, although it is to some degree positively correlated with that of the semi-evergreen oaks. This is thought to be due partly to the different pollen-source areas. It was found in Chapter 3 that *Quercus coccifera* type is over-represented, and much pollen is contributed from a long distance. Bottema (1974) also noted this phenomenon while researching pollen dispersal in northern Greece. The other two pollen types contribute pollen mostly from extra-local and regional source areas. Another possible cause for the difference in the curves may be due to anthropogenic disturbance. It has been found that evergreen oaks are favoured by human disturbance such as forest clearance and grazing (Trabaud 1970; Reille & Pons 1992; Chapter 3).

The correlation between the *Quercus* curves of lowland Grevena and the temperature curves of Lamb (1982) suggests that the relative abundances of the different groups of oak trees are changing according to broadscale climatic changes. It also appears that these oak species are responding quickly to climatic change, and there is little or no time lag between changes in temperature and the production of oak pollen. While longer-term climatic change (over several decades or longer) could be expected to be reflected in migration of oak communities, a more likely explanation for the short-term rapid response is that flowering of the more sensitive species is temporarily suppressed by cold spells.

7.4 Land use

By the seventh millennium BC small farming communities were established in the lowlands of mainland Greece, including Thessaly and Macedonia (Renfrew, J. 1973a & b; Halstead 1981). In the fossil pollen record the first signs of anthropogenic impact on the vegetation in the Balkan region have been recognized as a reduction or change in woodland composition, accompanied by the expansion of open-ground herbaceous types typical of disturbed agricultural ground in southeast Europe, and the presence of cereals (in combination with supporting evidence, required by the difficulty in distinguishing wild from domesticated grasses) (Willis & Bennett 1994). Forest clearance and plant cultivation is not recorded in Greek pollen diagrams until c. 3500 years ago, when major reduction in tree pollen occurred, along with expansion of agricultural weeds and increase or appearance of such cultivated types as *Juglans* (walnut), *Castanea* (chestnut), *Olea* (olive), and *Vitis* (grape). Today the landscape of Grevena is intensively used. Current land-use practices are chiefly grazing (including transhumance pastoralism); agriculture; and tree felling and other woodland management practices such as coppicing, pollarding, and shredding.

7.4.1 Woodland clearance

Agricultural economies require land on which to grow crops, while pastoralists require grassland to feed the animals – woodland is an obstacle. Woodland can be destroyed by cutting or by burning, and perhaps both methods have been employed in Grevena. In this study several lines of evidence are used to identify woodland clearance: the abundance of charcoal particles; appearance of burned-ground successional species (pyrophytes); reduction of woodland species; and appearance/increase in light-demanding herbs and cultigens. Increased erosion reflected in increased sediment and nutrient influx to depositional sites has also been used to indicate woodland clearance: these are discussed in the following section.

Fire has frequently been used as a tool by people to clear land for pastoralism and cultivation, to promote palatability of grazing, and to drive game from forests (Turrill 1929;

Mellars 1975, 1976; Rackham 1982, 1983; Stevenson & Moore 1988). The intentional or accidental spread of fire when grazing areas were burnt off, or deliberate clearance of trees by means of fire, both contributed to the destruction of woodland. On the other hand (and this seems less likely), Chambers (1993) pointed out that the association of human artifacts with stratified charcoal does not necessarily imply that fire had a human cause, for human groups may have moved into areas locally devastated by natural fire. To assist with establishing the causes of deforestation, a fire history of Grevena was established by obtaining the fire history of each pollen site from counts of microscopic charcoal particles.

Many researchers have used charcoal particles incorporated in sediments as evidence of anthropogenic woodland clearance by burning (Iversen 1941; Tolonen 1978), although the only Greek pollen diagram that displays microscopic charcoal abundance is that from Korone moor, coastal Epirus (Yasuda 1985). Clark (1988) examined charcoal transport in relation to particle size and considered that fine particles (such as those found on microscope slides for pollen analysis) are transported over long distances and do not necessarily reflect fires in the immediate catchment. A comparison of the abundance of microscopic charcoal particles found in surface samples with the known current fire regime of Grevena suggested that particles of $400\text{ }\mu\text{m}^2$ and greater represent charcoal from a very local source, while those of less than $25\text{ }\mu\text{m}^2$ represent charcoal derived from a distant source. These data are used in determining the location of fires.

The extant wild vegetation of Grevena is not very flammable. In the pine woods of Grevena, soil conditions and the small amount of ground litter minimize the incidence of natural fires begun by lightning strikes. Evidence of frequent lightning strike on pine trees without subsequent conflagration is abundant, for about half the ancient pines having been struck by lightning, some of them many times (Chapter 3). According to Wilson (1979), in the Mediterranean region only 2-3% of fires are lightning-induced. In times past denser pine woods would have produced more litter, thus perhaps making them more vulnerable to burning. Also if the climate were warmer and drier this may have increased vulnerability. Both *Fagus sylvatica* and *Abies cephalonica* do not burn easily, and in the oak woods there is little evidence of fires. These do not burn easily; their litter can be ignited by adjacent stubble or grass fires and young oaks are killed to the ground, but these later sprout from surviving root collars (Moody & Rackham, in prep.). *Juniperus* is killed by fire and its absence may indicate the presence of fires; it is widespread in Grevena today, occurring in many different vegetation communities, but pollen representation is not very high. Steppe burns occasionally and this could limit trees, by setting back juniper which would protect young trees from browsing.

Since mechanized cultivation was introduced cereal stubble has been burnt (Figure 1.5). Although controlled by regulations these fires often spread into oak wood or steppe. The fires are lit when much of the vegetation is dormant, during summer drought, but plants that have an autumn growing season would be expected to be set back. Fire frequency has thus increased on the plain, but this does not seem to have changed the vegetation much, apart from reduction in the fire-sensitive juniper.

In pollen diagrams, clearance of woodland by fire may be indicated by an increase in pyrophytic plants such as *Betula pendula* and *Pteridium aquilinum*. *Betula pendula* possesses the ability to sprout from root collars; in an experiment Iversen (1973) found that it sprouted in quantity after burning, but only very sparsely outside the burned area. Thus in Denmark Iversen (1941) and in France Reille & de Beaulieu (1988) found it to be the tree that profited most from the clearance fire. After non-fire woodland clearances in fertile regions *Betula pendula* does not usually appear: its seed germinates only when the soil conditions are favourable, especially on ashy soil. *Betula pendula* is a pioneer requiring light for growth and is typically short-lived (about 100 years). It therefore is a poor competitor and succumbs in competition with other trees (Iversen 1960, 1973; Rackham 1980). In Grevena, *Betula* has occurred only at the Gomara site, where its presence may have been limited by climate, as discussed in the preceding section. *Pteridium aquilinum* is also encouraged by fire, regrowing quickly from deep-lying rhizomes after being burnt (Iversen 1973). It is under-represented in the pollen record, so a continuous record may indicate anthropogenic burning, although as a light-demanding species other forms of clearance would also favour it.

Initial reduction of the canopy allows more light to penetrate to the woodland floor, allowing herbaceous plants that require light to grow (herbs of open ground). Thus the pollen ratio of terrestrial trees and shrubs to that of herbs has been used as a guide to changes in the density of woodland cover. However, a reduction in canopy cover may result either from climatic factors or land-use practices such as clearance by fire, wood cutting, pastoralism and fodder production. In the modern pollen deposition part of this study higher ratios were found in the mountain and foothill woods than in open vegetation, but the ratio varied according to tree genera forming the canopy; the ratio being higher in the mountain and foothill pine and beech woods than in the lowland oak woods. The lowest ratio was recorded, as expected, in the most open vegetation in the cultivated area of the lowlands. In the fossil sequences, extent and density of woodland is also interpreted from changes in abundance (concentration, influx) of the major tree species.

Palynological richness is another measure used to indicate openness of the canopy. Results from the present study show some correlation between openness of sites and palynological richness interpreted from estimated numbers of pollen and spore taxa

standardized to a common count size using rarefaction analysis (Birks & Line 1992). The values of expected number of taxa were highest for most open sites, while woods with closed canopies have the lowest values. Woods with incomplete canopies have intermediate palynological richness. Intensive land use, such as the current grazing at Polinerion and the agriculture at Asprokampos, lowered palynological richness. Other researchers have found intermediate levels of disturbance, either natural or anthropogenic, important in maximizing richness at the landscape scale (Birks & Line 1992). Changes in palynological richness are interpreted as reflecting predominantly the changing floristic richness of the vegetation types in the pollen source area. These changes may be the result of many and varied causes. A reduction, or small openings, in a canopy would allow a wider variety of pollen taxa from regional sources to fall on the deposition site and thus increase palynological richness. Regeneration of a more diverse woodland following cessation of grazing may also increase the palynological richness.

The scale of the woodland mosaic (i.e. size of openings in the canopy) might be interpreted from indicator species. For example *Hedera helix* cannot flower under the closed canopy of a *Fagus* wood, and the presence of its pollen suggests that the canopy was open (Troels-Smith 1960). The canopy trees *Fagus*, *Ulmus*, and *Tilia* are among the group growing in the weakest light; *Corylus*, *Fraxinus*, *Alnus*, and *Quercus* require more light; *Betula pendula* and *Pinus* require the most light and do not tolerate any shade (Iversen 1941). *Juniperus* and *Pteridium* are other light-demanding indicator species.

Light-demanding herbs that occur in Greek pollen diagrams spanning the Würm glacial period (van der Hammen *et al.* 1965; Bottema 1967; Wijmstra 1969; Turner & Greig 1975; Allan 1986, 1990; Willis 1992a, 1992b) include Gramineae, *Polygonum aviculare*, *Plantago*, *Xanthium*, *Rumex*, Chenopodiaceae and Compositae. All of these relatively well-represented (and for the most part anemophilous) taxa continue to be important indicators of open ground in the Holocene. Distinction among species of some of the genera mentioned should be made, e.g. *Plantago lanceolata* demands full sunlight, in contrast to *Plantago major*, and will not grow in grazed woodland (Iversen 1973). Spread of these indigenous plants (apophytes) is influenced by human activity, but of course also occurs naturally.

Pollen of most cultigens is direct evidence of local cultivation, as is that of other plants introduced by man, including weeds of cultivation, ornamentals, etc. (anthropochores), although associated clearance may not necessarily be of a large scale. The significance of various species is discussed further below.

Deforestation increases run-off volume and variability, and this has an expression in lake water level and wetland saturation. Similarly, grazing and agriculture may be expected to influence wetland vegetation. To some degree, then, the relative proportions of wetland plant

communities (e.g. submerged and floating versus emergent) can be interpreted in relation to the history of the terrestrial vegetation.

7.4.2 Erosion

Factors which are important for erosion to occur are local topography, vegetation cover, climate (both general and extreme weather conditions), soil conditions and tectonics (earthquake shaking and local displacements). Of these, vegetation cover and soil conditions are subject to human influence.

The connection of valley-floor alluviation with erosion and its causes, and the chronology of episodes of alluviation have been the subject of much debate. In 1969 Vita-Finzi proposed that in the Mediterranean region two phases of alluviation could be recognised, both with a climatic origin: an Older Fill deposited in late-glacial time, and a Younger Fill laid down in a single phase of alluviation from around 400 AD until about 1800 AD. Since then a large number of studies in Greece (Bintliff 1977; Davidson 1980; Pope & van Andel 1984; van Andel *et al.* 1986; Demitrack 1986; Finke 1988; van Andel & Zangger 1990; Doyle 1990; Savina 1993) have shown that there has been more than one phase of aggradation and incision during the timespan of the Younger Fill and that phases of aggradation occurred between the 'Older' and 'Younger' phases of Vita-Finzi. Explanation of alluviation phases has fluctuated between schools of climatic and cultural determinism (Bintliff 1992). In Grevena, one or more periods of alluviation and more or less synchronous colluviation occurred in most catchments during the last 2300 years (Doyle 1990; Savina 1993).

The chronology of slope erosion and valley alluviation in response to natural factors and human activities (forest clearance, forest exploitation, agriculture, and pastoralism) was investigated through pollen analysis (of both wetland and terrestrial vegetation), sediment-accumulation rates, wetland-sediment organic/inorganic content, size of sediment particles, and diatom indications of lake nutrient level.

It is well known that removal of woodland vegetation accelerates erosion by reducing rain interception and evapotranspiration, so enhancing run-off. This increases the loss of particulate and dissolved materials from catchments (Leopold 1956; Bormann *et al.* 1969a, 1969b, 1974; Davis 1976; Stumm & Baccini 1978). Mass movements or slope wash as a result of the aftermath of woodland fire may be severe (Bloemendal *et al.* 1979). Increased sediment load and supply of nutrients have profound effects both on the hydrology and on the biology of downstream aquatic systems (Mackereth 1966).

Deforestation markedly increases erodibility, but according to Bormann *et al.* (1974) its full expression occurs only after a considerable lag period. This suggests that organic decomposition, particularly in the upper few centimetres of the soil, requires several years to

surpass the boundary limits of stability inherent from residual organic matter. Primary factors involved in this decrease are soil moisture and soil temperature conditions more favourable to rapid decomposition, and a major increase in the process of nitrification.

Bormann *et al.* (1974) found that deforestation has a pronounced effect on the amount and size of particulate matter exported from a catchment, the proportion of organic to inorganic material, and the origin of organic material from within the catchment. Brief intense run-off is the major factor in removing particulate matter from both forested and deforested catchments – storm periods greatly increase removal of particulate matter. In the Grevena sites studied, increased rates of inorganic-sediment accumulation and greater sediment particle size are used as a guide to accelerated erosion. In the wetland sites, varying inorganic-sediment influx is partly expressed in the inorganic-to-organic sediment ratio. Relatively pure peat and organic detritus sedimentation, in conjunction with palynological data, have been interpreted to represent periods of low erosion, landscape stability, and extensive vegetation cover.

Increased sedimentation rates led to enrichment of wetlands with nutrients, followed by changes in chemical and biological composition of the aquatic habitats. With deforestation concentrations of most dissolved nutrients in stream water increase several fold (Bormann *et al.* 1974). However, this increase in nutrients declines as the source of organic matter reduces. Diatoms were used to interpret the trophic history of the lake basin at Gomara. Hydrosere succession is also encouraged by greater input of nutrients to wetlands, and this was considered in interpretation of wetland vegetation. At Anelia and Kellia the situation for some wetland species is complicated by a contribution of nutrients from spring water.

7.4.3 Pastoralism

The modern pastoral economy in Grevena is based on the herding of sheep and goats. Koster (1987) identified eight different zones of pastoral exploitation based on degree of dependence on transhumance or 'village pastoralism', ethnicity, vegetation types, and stocking rates, but two main groups can be distinguished: the well-known "Vlachohoria" in the Pindos, which are strictly transhumant, practice virtually no agriculture, use pastures seasonally, and have moderate to high stocking rates; and the lowland agricultural areas, which are grazed by year-round 'village pastoralists' using smaller flocks (Chapter 1).

Pasture is often temporarily improved by burning of grassland or open woodland. Trees are browsed by many kinds of livestock, and the cropping of leaves for cattle feed. Overstocking – beyond the carrying-capacity of pasture at its seasonal minimum productivity – is bad with all species. Sheep have the additional trait of grazing down to root level, often destroying beneficial grasses and permanently opening up the ground mat, with only partial

recolonization by shrubby vegetation. Goats are notorious for indiscriminate grazing, resulting in destruction of trees and their seedlings. Large aggregations of livestock in fenced plots or through nightly collecting of herds in enclosures also serves to destroy the plant cover, not least through trampling. In many ways, therefore, pastoralism can promote accelerated soil erosion on a scale that vies with the impact of cultivation (Butzer 1974).

Pastoralism is dependent on gaining access to adequate grazing. Forest grazing without effective woodland clearance is difficult to detect in pollen diagrams. Once woodland clearance takes place and is followed by grazing, openings occur in the woodland canopy, allowing illumination by sunlight, and indicator plants for rough grazed pasture appear. Palynological evidence for pastoralism in Grevena consists of partial or complete woodland clearance in situations not consistent with agriculture (Section 7.4.1), decrease in abundance of palatable plants (with resultant loss in diversity), rise in abundance of plants favoured by grazing, and systematic variations in abundance of plants harvested for fodder (Sections 7.4.4 – crops, 7.4.5 – woodland leaf harvesting). Burning to increase pasture extent and palatability has been mentioned in the preceding section and has been interpreted from charcoal-particle abundance. Increased nutrient run-off resulting from stocking has been detected from its effects on the trophic status of wetlands, although nutrient flux is also increased temporarily by forest clearance (Section 7.4.2). Kabailiené (1988) found that the diatom flora of sediments of small lakes fed by surface water from small catchments under intense agriculture is dominated by species characteristic of eutrophication of human origin. High concentrations of phosphate are produced by the decay of human and animal excreta (Shackley 1975).

In Grevena there is greater floristic diversity in woods that are inaccessible to grazing animals (Chapter 3); the more palatable trees remain, e.g. *Fraxinus*, *Tilia*, and *Ulmus*. In woods that are grazed palatable species such as these are rare (Rackham 1982). Iversen (1941) also noted that *Tilia* and *Ulmus* are more palatable than oak. In the pollen record, a decline in the variety of deciduous trees, and especially of the more palatable species, could be due to grazing.

The dominant trees of Grevena woodlands are all resistant to grazing. Both *Fagus sylvatica* and *Abies cephalonica* can survive long periods of browsing when young. Pines are not very palatable and are not used as fodder. Grazing also favours *Juniperus*, but other understorey shrubs are destroyed. Intensive grazing in the dry southeast corner of Grevena has led to the development of pseudo-*maquis*. Unfortunately, the extent and location of a degraded vegetation of pseudo-*maquis* is difficult to determine from the pollen record. The only pollen type indicative of this vegetation with reasonable representation is *Quercus coccifera*, which is over-represented and is transported long distances.

Palynological evidence for pastoral activity is supported by the identification of pollen from plant taxa indicative of pastureland: non-cultivated grasses (Gramineae) and the ribwort plantain (*Plantago lanceolata*) are usually included in lists of pastoral indicators (Buckland & Edwards 1984). *Rumex acetosa/acetosella*, *Artemisia*, *Trifolium repens*, Chenopodiaceae, are other taxa recognised by various authors (Iversen 1941, 1960, 1973; Tinsley & Smith 1974; van Zeist & Woldring 1978; Bottema 1982; Stevenson 1985; Behre 1990; Reille & de Beaulieu 1988; Bottema & Woldring 1990).

All of the taxa mentioned are also weeds of agricultural lands (e.g. the cereal field at Asprokampos – Chapter 3). Some researchers have devised ratios of arable to pastoral taxa in order to evaluate more objectively changing trends in prehistoric farming practices (reviewed in Behre 1981). Steckhan (1961) and Lange (1975) use the ratio of cereals to *Plantago lanceolata* pollen, Kramm (1978) employs cereal:non-cultivated Gramineae, while Turner's arable/pastoral index expresses the number of *Plantago* grains as 'a percentage of the total number of *Plantago*, Compositae, cereal, Cruciferae, *Artemisia*, and Chenopodiaceae pollen grains' (Turner 1964:81). Problems in interpretation may arise. Pastoral indicator pollen types may represent the growth of field-edge weeds or even grassland lying fallow between bouts of cultivation. Donaldson & Turner (1977) use *Rumex acetosa/acetosella* type as a pastoral indicator, whilst Riezebos & Slotboom (1978) use undifferentiated *Rumex* as an arable indicator. Behre (1981) considers *Rumex cf. acetosa* to be particularly indicative of wet meadows and pasture, while *Rumex cf. acetosella* may not only be an important weed of winter cereal crops but of various types of grassland also.

It might fairly be assumed that a pastoral episode would be indicated by pollen spectra displaying high grass and plantain values with an absence of cereals and reduced values for arable weed 'indicators' and woodland taxa. *Plantago lanceolata* demands full sunlight, in contrast to *Plantago major*, and will not grow in grazed woodland (Iversen 1973). *Trifolium repens* (white clover), on the other hand, will grow in grazed woodland if the shade is not too close, but it flowers more richly and is more frequent on open pasture. If pollen of *Trifolium repens* occurs it must have been growing locally (Iversen 1973). Ruderals, plants that favour ground manured by stock, include *Urtica* species. The occurrence of these taxa in the Gomara sequence coincides with other evidence for grazing.

7.4.4 Cultivation

On mainland Greece the earliest evidence for agriculture, in the form of carbonised seeds of cultivated plants, comes from several archaeological sites: Franchthi cave (the Argolid), Gediki, Achilleion, Sesklo, Argissa, Soufli (Thessaly), Nea Nikomedeia (western Macedonia), and Elateia (Boetia) dated to c. 6000 BC (Renfrew, J. 1973a & b; Hansen 1988).

In Grevena, archaeological surface surveys undertaken by the Grevena Project have recorded wheat/barley seeds in association with Hellenistic sites. In the pollen record, apart from evidence for clearance of natural vegetation, the most important indicator plants for agriculture are the cultivated plants themselves. Weeds associated with cultivation are also of significance.

A list of plants that may have been cultivated in Grevena since the Late Bronze Age was constructed based on ethnographic studies in Grevena (Aschenbrenner 1987, 1988, in prep.) and from botanical macrofossil studies in mainland Greece (Renfrew, J. 1969, 1973a & b; van Zeist & Bottema 1971; Hansen 1978, 1985, 1988; Hansen & Renfrew, J. 1978; Hubbard 1979; Jones 1981). These include the cereals *Triticum monococcum* (einkorn), *T. dicoccon* (emmer), *T. aestivum* (bread wheat), *Hordeum distichon* (two-row barley), *H. vulgare* (six-row barley), *Avena sativa* (oats) and *Panicum miliaceum* (millet), which have all been found in Neolithic contexts. *Secale cereale* (rye) and *Zea mays* (maize) are more recent introductions, the former in the Roman Period and the latter probably c. 1700 AD (Huber 1962 in Bottema 1980; Bottema 1981). The pulses include *Pisum sativum* (peas), *Lens culinaris* (lentils), *Vicia ervilia* (bitter vetch), *Vicia faba* (broad bean), and *Cicer arietinum* (chickpea), which have all been found in Neolithic contexts. Other crops may have included *Vicia sativa* (vetch), *Lathyrus sativus* (pea hay/grass pea), *Humulus lupulus* (hop), and *Linum usitatissimum* (flax). Other species such as *Urtica dioica* (nettle), *Polygonum aviculare*, and species of *Chenopodiaceae*, which are commonly found with seeds of domesticated plants, may also have been cultivated, collected from the wild for human consumption, or grown as weeds of cultivation. These are not included in the list of cultivars. Macrofossil evidence indicates that *Vitis vinifera* (grape) was domesticated by the Late Bronze Age in Macedonia (Hansen 1988). Macrofossils collected from archaeological sites often include stones of fruit and nut trees such as *Quercus* (acorns), *Corylus* (hazel nut), *Prunus* sp., and *Cornus mas*, but it is not known if these trees were planted. These are also not included in the list. Several other trees that are thought to have been cultivated include the nut trees *Castanea sativa* and *Juglans regia*; a tree that today is often planted for shade, *Platanus orientalis*; and *Elaeagnus angustifolia* (Bottema 1980). *Morus alba* and *M. nigra* may have been cultivated in recent times.

The macrofossil data suggest that the most important cultigens were the cereals *Triticum monococcum* (einkorn), *T. dicoccon* (emmer), *Hordeum distichon* (two-row barley), and *H. vulgare* (six-row barley), and the pulses *Pisum sativum* (pea), *Lens culinaris* (lentil), and *Vicia ervilia* (bitter vetch). In the Bronze Age, in northern Greece, *Triticum monococcum* (einkorn) was the most common cultivated wheat, and *H. vulgare* (six-row barley) appears to have replaced *Hordeum distichon* (two-row barley) by the beginning of the Bronze Age.

In the sequences from Grevena no pollen of the pulses *Vicia faba* (broad bean), *Pisum sativum* (pea), *Lens culinaris* (lentil), and *Cicer arietinum* (chick peas) was identified. These species all belong to the family Leguminosae and are entomophilous (Knuth 1908). Thus their absence from the pollen record may be a result of their poor pollen production and dispersal: it is impossible to say if they were cultivated or not.

The following pollen types, which include prehistoric and historic cultivars, were identified: *Lathyrus sativus*, *Medicago sativa*, *Vicia sativa* type, *Elaeagnus angustifolia*, *Humulus lupulus*, *Morus alba*, *Morus nigra*, *Linum usitatissimum* type, *Castanea sativa*, *Juglans regia*, *Platanus orientalis*, *Vitis vinifera*, *Avena*, *Hordeum* type, *Secale cereale*, *Triticum* type, *Zea mays*, and *Agropyron* type. It was possible to identify some cultigens to species level, but many of these species are severely under-represented in the pollen record, e.g. the legume *Lathyrus sativus*, which before 1940 was cultivated in the Pindos foothills and the Grevena plains for fodder on a subsistence basis. Seeds of *L. sativus* (grass pea) are found quite widely in archaeological sites as old as early Neolithic and may have been cultivated for both human consumption and fodder. Another legume, *Medicago sativa* subsp. *sativa* (alfalfa), is still grown as a forage crop in Grevena. In addition to being severely under-represented it cannot be distinguished from other subspecies of *Medicago sativa* that are wild, or from the wild *Trifolium montanum* (Appendix VI.2).

Vicia sativa type includes several wild species as well as cultivated species of *Vicia sativa*, and probably also the cultivated species *Vicia ervilia* and the weed of cultivation *Vicia pannonica*. *Vicia sativa* (vetch) was cultivated for fodder on a subsistence basis in the Pindos foothills and on the Grevena plains before 1940, but is no longer cultivated to the same extent. Seeds of domesticated *V. ervilia* (bitter vetch) were found in Macedonia at the archaeological sites of Nea Nikomedeia and Sitagroi in contexts dating to the Neolithic (Hansen 1988). The seeds are thought to have been used for human consumption (Renfrew 1973a:116). This pollen type is also entomophilous and therefore under-represented. As it occurs very sparsely in the pollen record, no conclusions about cultivation of leguminous fodder and forage can be made.

Morus alba and *Morus nigra* are cultivated in the Balkans (Polunin 1988) but were not seen growing in Grevena. They each occur only once in the pollen diagrams, and at very low abundance. No details of their pollen representation are known, but as they are anemophilous their occurrence is quite possibly due to long-distance transport, and they perhaps were never cultivated in Grevena. *Humulus lupulus* is widely cultivated in Europe, but it grows naturally in hedges, bushy places and on river banks. It was not seen growing in Grevena and is very sparse in the pollen record. *Elaeagnus angustifolia* is today planted for ornamentation and is probably a recent introduction. It was identified in the surface sample only at one site.

The *Linum usitatissimum* pollen type includes two species: *Linum bienne* and *L. usitatissimum*. *Linum bienne* is a wild biennial to perennial of grassy, stony places, native to south and west Europe, while *L. usitatissimum* (flax) is cultivated and sometimes naturalized and of uncertain origin. Flax was formerly cultivated throughout most of Europe for fibre and oil from the seed (linseed). It is now much less commonly grown but is still recorded as a casual throughout Europe. A large number of flax seeds were found in Early Bronze Age deposits at Lerna, in the Argolid, and flax cultivation at Servia in Thessaly during the early Neolithic was suggested in a preliminary report (Hubbard 1979). It is uncertain if flax was cultivated in Grevena, so this pollen type was not placed in the cultivars group in the pollen diagrams. It occurs in one spectrum only, at very low abundance.

Only a very few pollen grains of *Vitis vinifera* were recorded, even from the lowland site where settlements have existed in the past. Vine pollen has been found to be poorly dispersed and is probably under-represented (Chapter 3), although it has been found at comparatively high relative frequencies where derived from a local source (Stevenson & Moore 1988). Today grapes are grown in household gardens, but ethnographic studies suggest that grapes were grown on a much larger scale in the past (Chapter 1).

The three trees *Castanea sativa*, *Juglans regia*, and *Platanus orientalis* are of interest. It has been demonstrated that an increase in the pollen of these taxa is associated with anthropogenic disturbance of woodlands in Greece (Bottema 1974, 1980, 1982; Bottema & Woldring 1990). There is no evidence for *Juglans regia* or *Castanea sativa* appearing post-glacially in Greece before about 3500 BP (Bottema 1980). (*Juglans regia* occurred in the Balkans during the Eem Interglacial but disappeared during the Würm Glacial – Bottema 1980.) The average time of arrival or increase of *Juglans*, *Castanea*, and *Platanus* in western Macedonia is about 3100-3300 BP for those areas adjacent to the coast or not very far inland (Bottema 1974). *Castanea* and *Juglans* appear in Litochoro (altitude 25 m) at about 3000 BP, in Pertouli (1275 m) about 1000 BP, although rare grains appear before 3200 BP (Athanasiadis 1975). At Xinias (500 m) pollen of this group is found in only the top sample (Bottema 1979). Pollen of these trees also appears late at Tenaghi Philippon (40 m) (Wijmstra 1969). At Trikhonis *Juglans* appears at either about 3425 BP or 79 AD, according to interpretations of different authors (Bottema 1980). *Juglans regia* and *Platanus orientalis* are anemophilous, but pollen production is not very high. These trees are thought to have either profited from human-induced changes in habitats or were planted in prehistoric times. Thus low relative percentages in the pollen record may be due to long-distance dispersal or to a few trees growing in the vicinity of the sampling site, and they may or may not have been cultivated but perhaps established spontaneously. *Castanea sativa* is entomophilous primarily, but from the results of this study it appears capable of long-distance dispersal. Long-distance dispersal of

Castanea pollen has been reported by others (Ruffaldi 1994). Ethnographic studies suggest that fruit and nut trees would be planted around vineyards close to settlements (Chapter 1). At the Gomara site low abundances of *Castanea sativa* and *Platanus orientalis* occur from the base of the sequence c. 1340 BC, but *Juglans regia* does not appear until c. 450 BC. At Kellia and Anelia *Juglans regia* occurs at low abundance throughout, while *Castanea sativa* and especially *Platanus orientalis* increase at c. 1800 AD, probably reflecting regional increase. However, abundance is not sufficient to imply local planting of these trees near any of the sites.

The poor dispersal properties of cereals have been discussed (Chapter 3). Another problem associated with pollen of cereal crop plants is the distinction of their pollen from one genus to another and from wild species. The identification of cereal pollen to the genus level is difficult, but the distinction from wild grass is usually easier. Cereal-type pollen differs from wild grass in being much larger and having a relatively large *porus annulus* (Appendix VI). The pollen types *Zea mays*, *Triticum* (except *T. monococcum*), *Secale cereale*, and *Avena* are reasonably distinct from wild grasses, but the *Avena* pollen type includes some wild species of *Avena*. *Hordeum* type, which includes *Triticum monococcum*, is less distinct from wild grasses, and the wild genus *Elymus* cannot be distinguished from the cultivated cereals included in this type. The wild grass pollen type *Agropyron* is very similar to the *Hordeum* type. *Panicum miliaceum* (millet) unfortunately cannot be distinguished from wild grasses (Andersen 1979). Poor dispersal, under-representation and difficulties in distinguishing cereal grains makes interpretation of cereal cropping strategies difficult. *Hordeum* may never be represented in the pollen record, and any grains attributed to this type are probably either *Triticum monococcum* (einkorn) or a wild genus. *Avena* type pollen may represent cereal crop species or weeds of disturbed and waste ground, including cultivated ground. If identified correctly, the occurrence of pollen grains of *Triticum* type, *Secale cereale*, and *Zea mays* probably indicates cultivation of species included in those pollen types. From the pollen production and dispersal characteristics, cultivation of *Avena*, *Triticum*, and *Zea mays* would likely be close to the pollen-occurrence site, while that of *Secale cereale* could be more distant. At the Gomara site in the lower part of the sequence there is sporadic low abundance of cereal-type pollen, which may be due to large-grained wild grasses, minor nearby cultivation, or long-distance transport from cultivated areas. The most notable feature of the cereal group distribution in this sequence is the relatively high abundance of *Secale cereale* in late Roman times, which may reflect widespread cultivation of rye in the region. At Anelia the only cereal pollen present in significant abundance is that of *Secale cereale* and *Triticum* type; these are present from the base of the sequence c. 1560 AD until c. 1920 AD. The record is interpreted as indicating nearby cultivation of wheat and possibly other cereals. At Kellia

there is a continuous record of most cereal pollen types. *Avena*, *Hordeum* type, and *Secale cereale* occur in greater abundance throughout the sequence than at the other two sites, while *Triticum* type is mainly present after c. 1870 AD. *Zea mays* occurs sporadically, and its earlier occurrences in the sequence are difficult to reconcile with its known date of introduction into Europe, after 1500 AD. The pollen record indicates that cereal cultivation was an important land use in the vicinity of this site since c. 1230 AD.

In conclusion, while ethnographic studies suggest that prior to mechanization of agriculture, each household grew a diversity of crops for human consumption (wheat; barley, probably mainly for livestock; maize; rye; beans; chickpeas; vegetables; fruits; nuts; and vines for table grapes, wine, and *tsipouro*) and for fodder (barley, oats, and several legume varieties, esp. vetch, pea hay, and alfalfa), few of these crops are represented in the pollen record. Cereals are a group better represented than others, but due to differences in pollen representation and dispersal, and the difficulty of reliably distinguishing between the pollen of different cereals the relative importance of cereal crops can be assessed only tentatively. Nevertheless, different patterns of cultivation at different times are suggested.

Among weeds associated with agriculture are a number of anemophilous species with a large pollen production, and these are prominent in the pollen flora, but most of these do not occur exclusively in cultivated fields. The surface sample from the cereal field at Asprokampos contained the pollen types of *Polygonum aviculare* type, *Plantago lanceolata*, *Rumex acetosa* group, and Chenopodiaceae. All except the first are anemophilous, and all have medium to high relative dispersal and are well- to over-represented. Pollen of several Compositae species were also identified in this sample. These pollen types are entomophilous, dispersing their pollen locally. They are included in Bottema's (1982) and Bottema & Woldring's (1990) lists of anthropogenic indicator species. As these weeds are native to Greece, their occurrence is not by itself sufficient indication of human activity.

However, agriculture can perhaps be identified by 'specialist' weeds closely associated with cultivation. Extant weeds of cereals in Grevena include *Agrostemma githago*, *Asperula arvensis*, *Brassica nigra*, *Buglossoides arvensis* subsp. *sibthorpiana*, *Centaurea cyanus*, *Consolida regalis* subsp. *paniculata*, *Dasypyrum villosum*, *Erysimum cheiranthoides*, *Galium tricornutum*, *Nigella arvensis*, *Orlaya kochii*, *Ranunculus arvensis*, *Sinapis arvensis*, and *Vicia pannonica* subsp. *striata* (Moody & Rackham, in prep.). Of these, *Agrostemma githago*, a classic weed of cultivation (Tutin *et al.* 1964-80), is the only species belonging to its pollen type. *Asperula arvensis* and *Galium tricornutum* belong to the pollen type *Galium*, which includes a large number of herbs of various habitats (Appendix VI). *Brassica nigra* and *Erysimum cheiranthoides* belong to the *Sinapis* type, another type which includes many species of varied habitat (Appendix VI). *Buglossoides arvensis* subsp. *sibthorpiana*, belongs

to the *B. arvensis* type, which includes two species of dry open habitats as well as cultivated ground. *Centaurea cyanus* belongs to the *Centaurea cyanus* type, which includes two other species also weeds of cultivation and dry stony places (Tutin *et al.* 1964-80). Pollen of *Consolida regalis* subsp. *paniculata* and *Orlaya kochii* was not identified in the fossil pollen sequences. The grass *Dasypyrum villosum* could not be distinguished from other wild grasses. *Nigella arvensis* belongs to the pollen type *Nigella*, which also includes two cultivated species, sometimes naturalized (Tutin *et al.* 1964-80). *Ranunculus arvensis* belongs to *Ranunculus arvensis* type, which may include species of varied habitats (Appendix VI). *Vicia pannonica* subsp. *striata* is included in *Vicia sativa* type, which includes several wild species, so its presence is not a reliable indication of cultivation (Appendix X).

In summary indicator pollen types which are best indicators of cultivation are those which include only species of similar preference, i.e., *Agrostemma githago*, *Centaurea cyanus* type, *Nigella*, and *Buglossoides arvensis* type. These unfortunately are all entomophilous so occur in low abundance in the pollen diagrams, but where they do occur they may be presumed to grow nearby. For example, *Centaurea cyanus* type occurs in the set of surface samples only at the cereal field at Asprokampos and at Kellia fen, which is in close proximity to cereal fields.

At Anelia site, *Agrostemma githago* and *Centaurea cyanus* type both occur in the lower part of the sequence where cereal pollen is most abundant. *Buglossoides arvensis* type and *Nigella* also occur sporadically in low abundance. At Kellia site, all four pollen types occur throughout the sequence from c. 1230 AD to the present but most abundantly between c. 1320 and 1720 AD. At Gomara site, only *Buglossoides arvensis* type and *Nigella* occur, both rarely and at very low abundance. As noted above these two pollen types include some species not so exclusively associated with agriculture.

7.4.5 Woodland management

Grevena has very extensive woodlands for the size of its population (Chapter 3). All woodlands have a history of intensive management, which includes tree-felling, coppicing, pollarding, shredding, and grazing (Section 7.4.3) and little, if any, unmodified woodland remains. Pines are felled but not usually coppiced, pollarded, or shredded, while beech and oak and less dominant woodland trees may be felled, coppiced, pollarded, or less often shredded. Trees in woods are usually coppiced; free-standing oaks in pastures or fields are pollarded.

Coppicing, pollarding, and shredding are all ways of increasing the number of stems per tree. In coppice-woods, the majority of trees are cut down every so many years, then allowed to sprout again from the stump, while scattered timber trees are allowed to grow longer to

produce beams and planks. Pollards are cut like coppice stools but at 4 m above ground, while shredding is the removal of side branches so that successive crops of stems are produced.

It is likely that systematic woodland management, the management of wild trees as a renewable resource to produce a permanent succession of crops of timber and underwood, began in the Neolithic in Greece (Rackham 1982:180). In Grevena coppicing has been widespread for many centuries, e.g. *Tilia* (lime) stools in the Aetia gorge measure 2½ m diameter, and at Anelia annual rings indicate that a beech stool was about 300 years old when last cut about 20 years ago. The practice still continues but on a diminished scale (Moody & Rackham, in prep.). Coppice is used for many purposes, but usually for fuel.

Pollarding and shredding are both commonly used to provide leaf fodder. Pollarding has been practised at least since the Middle Ages: in Aetia the stump of an oak was found which was first pollarded in 1556 AD (from annual tree-ring count). Pollarding and shredding has occurred at very irregular intervals, from 4 to 75 years, with no apparent pattern. Leaf-fodder production is a major industry, and almost all oaks have been cut or pollarded within the last 50 years (Moody & Rackham, in prep.).

Pollen production would be severely reduced after cutting of a coppice-wood, although the scattered timber trees left standing might produce more pollen per individual tree than when previously surrounded by other trees (Bonny 1976). Two oak woods that were sampled in the lowlands had been coppiced. *Quercus* relative frequencies in these woods were high (33.4 and 40.7%), but it is impossible to say if coppicing has depressed pollen deposition, as no data are available against which to compare these frequencies. Oaks produce flowers in the later part of each coppicing cycle (30-40 years), except *Quercus frainetto*, which takes at least 50 years. The unusually long interval (40-75 years) between cutting of coppice-woods in Grevena may therefore have reduced the effect in pollen sequences. Coppicing could not only reduce the pollen production of the trees coppiced but would also reduce the canopy of the woods, allowing in more light, so that light-demanding species could grow. Both the regional pollen component of the pollen rain, and the woodland understorey component would assume greater prominence in the pollen spectra. At Anelia, more intense use of the contemporary beech woodland in the past is suggested by extant beech trees which, formerly coppiced, have been left uncoppiced for many years. The resulting increased flowering is probably reflected in the rise in beech pollen at the top of the sequence.

Timber production was well established 180 years ago (Leake 1835). In the recent past the main export of high-altitude villages such as Smixi and Samarina was milled pine planks. Beech and oak are also felled for timber – many local houses and out-buildings contain beams of oak. *Abies* is also a well known timber tree elsewhere (Tutin *et al.* 1964-80). A sudden and sustained decline in *Abies* in the Anelia pollen sequence at c. 1730 AD (90 cm) is similar to

that seen in other pollen diagrams from northern Greece ((Bottema 1974; Gerasimidis & Athanasiadis 1995). This decline occurs at different times in different localities, suggesting human-induced destruction rather than climate or other natural factor as the cause. At Anelia it is a local event as abundance of *Abies* in the Kellia sequence increases slightly at this time, indicating that the regional pollen source area remains almost uniform. The decline is interpreted as selective logging of *Abies* at Anelia. Selective exploitation of *Abies* is also known from other parts of the Mediterranean (Reille 1992).

7.5 Synthesis of environmental history

Details of vegetation change at the three sites studied have been given in preceding chapters, and various aspects of the interpretation of these sequences in terms of climatic and cultural history have been discussed above. This section draws together these aspects in interpreting the ecological history of each site and evidence for cultural activity, summarized in Table 7.1.

7.5.1 Gomara c. 1340 BC - 700 AD

As noted in Chapter 4, there is close correspondence between changes in the composition of the sediment and changes in the pollen profiles of both wetland and terrestrial pollen and spore types. This close correspondence is explained by these three elements responding to environmental changes in the catchment. Thus the boundaries of the wetland and terrestrial pollen zones are synchronous. Further, this synchronism implies that many of the pollen and spores in the sediments are derived from the catchment: the terrestrial pollen record reflects primarily the extra-local rather than regional vegetation.

The combination of evidence from deposited sediments and the wetland pollen sequence indicates a hydrosere succession from a permanently wet environment (small lake) to a seasonally wet fen as the deposition basin filled in from c. 1340 BC to 700 AD. Diatom results are in general agreement with those of pollen analysis. The permanent water was shallow, probably fluctuating between 1 and 2 m depth. Water condition throughout the sequence was fresh, slightly alkaline, and rich in oxygen. A marginal swamp vegetation of sedges and reeds, with a *Carex* swamp community on the landward side of the reed swamp, surrounded the lake. Only occasional submerged and floating-leaved aquatic macrophytes from a deeper water zone inside the *Phragmites australis* belt were identified. The wetland has never been nutrient-poor. Trophic level is highest at the base of the sequence (eutrophic), and organic nitrogen compounds are most abundant at the base and top. In the centre of the sequence the trophic level drops to meso-eutrophic, and organic nitrogen levels are low.

Table 7.1

Major environmental changes in Grevena

Date AD/BC	Hydrology	Wetland vegetation	Terrestrial vegetation	Climate	Land use	Sediments & erosion	Anthropogenic fire history
Highlands = data from the Anelia site Lowlands = data from the Kellia site							
1989 AD	Highlands: Gomara – seasonally wet & dry Anelia – continuously wet peat surface Lowlands: Kellia – continuously wet peat surface	Highlands: Gomara – open rush/ grass fen Anelia – sedge & moss bog Lowlands: Kellia – reeds, sedge, rushes, ruderals	Highlands: Gomara – pine wood-pasture Anelia – beech wood Lowlands: oak wood-steppe/ cultivated cereal fields	Highlands: Gomara (1750 m asl) winter min. c. -3.7° C, summer max. c. 15.9° C, Anelia (1440 m asl) winter min. -1.9° C, summer max. c. 17.6° C Lowlands: Grevena (550 m asl) winter min. c. 3.2° C, summer max. c. 22.7° C	Highlands: transhumant pastoralism Lowlands: intensive cereal cultivation/ village pastoralism		Highlands: no burning Lowlands: cereal stubble burning
1989-1910 AD	Highlands: Continuously wet peat surface Lowlands: Continuously wet peat surface	Highlands: Small sedge swamp – <i>Carex hallerana</i> type dominant Lowlands: Tall sedge swamp – <i>Cyperus longus</i> type dominant	Highlands: Closed canopy: abundant <i>Fagus</i> , <i>Abies</i> of low abundance, lowest abundance of herbs of open ground, <i>Juniperus</i> abundant, <i>Pteridium</i> almost absent, cereal cultivars almost absent, low palynological richness Lowlands: Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> type present in low abundance, <i>Salix triandra</i> increasing upwards, <i>Juniperus</i> at low abundance, herbs of open ground abundant, most abundant <i>Cirsium</i> type, <i>Pteridium</i> at reduced abundance, cereal cultivars at reduced abundance, very high palynological richness	Temperatures increase to greater than today, then decline	Highlands: No cereal cultivation or coppicing c. 1920 to 1989 AD; grazing continues Lowlands: cereal cultivation – barley, rye, wheat & maize	Highlands: Fibrous peat, little-no minerogenic influx. Extremely high organic & almost no inorganic matter content Lowlands: Peat with fine grained sediment, woody detritus & calcareous grit. Extremely high organic & extremely low inorganic matter content. Carbonate content low to moderately high	Highlands: no burning Lowlands: much extra-local & some regional burning
1910-1880 AD	Highlands: Continuously wet peat surface	Highlands: Small sedge swamp – <i>Carex hallerana</i> type is dominant	Highlands: Open canopy: <i>Fagus</i> of moderate abundance, <i>Abies</i> almost absent, very abundant herbs of open ground, <i>Juniperus</i> abundant,	Temperatures slightly lower than today	Highlands: cereal cultivation – rye & wheat; grazing; coppicing	Highlands: Fibrous peat, little minerogenic influx. Very high organic matter & very low inorganic matter content	Highlands: no burning Lowlands: increased

Lowlands:
Peat with fine grained minerogenic sediment & herbaceous detritus – high organic matter, low inorganic matter. Carbonate content moderately high

Lowlands:
cereal cultivation – oats, barley, rye, wheat & maize

Lowlands:
extra-local burning, regional burning unchanged

Pteridium of low abundance, *Plantago lanceolata* type increased, abundant cereal cultivars, high palynological richness

Lowlands:
Continuous Tall sedge & true wet peat surface
reed swamps – *Cyperus longus* type, *Glyceria* type & *Sparganium erectum* dominant

Lowlands:
Open canopy – *Quercus frainetto* type more abundant than *Q. trojana* type (low abundance of latter), sl. increased *Q. coccifera*, *Salix triandra* present at low abundance, *Juniperus* at low abundance, decreased herbs of open ground but still abundant, *Pteridium* at reduced abundance, cereal cultivars abundant, very high palynological richness

Highlands:
Same as above

Lowlands:
Fine to medium sand with some fine grained sediment & herbaceous detritus. High inorganic & low organic matter. High carbonate content above c. 1850 AD, then same as below

Highlands:
cereal cultivation – rye & wheat; grazing; coppicing

Lowlands:
cereal cultivation – oats, barley, rye, wheat & maize

Cooler than today, reaches today's temperature near middle of period

Highlands:
Same as above

Lowlands:
Open canopy – *Quercus frainetto* type more abundant than *Q. trojana* type (low abundance of latter), *Q. coccifera* present at low abundance, *Salix triandra* present at low abundance, *Juniperus* sl. increased, increased herbs of open ground (very abundant), *Pteridium* at reduced abundance, cereal cultivars increase (very abundant), very high palynological richness

Highlands:
Continuous Small sedge swamp – *Carex hallerana* type dominant

Lowlands:
No peat

Lowlands:
True reed swamp – *Glyceria* type, *Phragmites australis* & *Scirpus* dominant

1880-1840 AD

Highlands:
Same as above

Lowlands:
Fine grained minerogenic sediment reduced with herbaceous detritus (low organic matter & high inorganic matter) above c. 1820 AD, then peat formation with herbaceous detritus (high organic matter content & extremely low inorganic matter). Carbonate content moderately high at top, then low

Highlands:
cereal cultivation – rye & wheat; grazing; coppicing

Lowlands:
cereal cultivation – oats, barley, rye, wheat (low abundance) & maize

Cooler than today

Highlands:
Same as above, except v. high herbs at c. 1830

Lowlands:
Open canopy – *Quercus frainetto* type more abundant than *Q. trojana* type (low abundance of latter), *Q. coccifera* present in low abundance, *Salix triandra* present at low abundance, *Juniperus* declined (but still abundant), decreased herbs of open ground but still abundant, *Pteridium* at reduced abundance, cereal cultivars abundant, very high palynological richness

Highlands:
Continuous Small sedge swamp – *Carex hallerana* type dominant

Lowlands:
Peat before c. 1820 AD continuously with wet surface

Lowlands:
True reed swamp – *Scirpus* & *Glyceria* type dominant with *Cyperus longus* type of the tall sedge community down to c. 1820 AD, then *Sparganium erectum* is dominant

1840-1790 AD

1790-1720 AD	Highlands: Peat until c. 1730 AD with intermittently dry surface Lowlands: Peat with continuously wet surface	Highlands: Small sedge swamp – <i>Carex hallerana</i> type dominant. <i>Glyceria</i> type prominent. Lowlands: True reed swamp – <i>Glyceria</i> type & <i>Sparganium erectum</i> co-dominant (<i>Cyperus longus</i> type of the tall sedge community also important)	Fluctuating from about the same temperature as today to cooler	Highlands: Same as above c. 1730 AD, then fine clay. Low organic & high inorganic matter Lowlands: Peat with fine grained minerogenic sediment & herbaceous detritus. Moderately low inorganic matter & moderately high organic matter. Carbonate low at top, high at the base	Highlands: burning ends c. 1730 AD extra-locally & regionally Lowlands: much extra-local & regional burning
1720-1680 AD	Highlands: No peat Lowlands: Peat until c. 1710 AD with continuously wet surface	Highlands: Same as above Lowlands: True reed swamp – <i>Glyceria</i> type dominant	About the same temperature as today	Highlands: Fine clay above c. 1710 AD, then coarse grained minerogenic sediments (sandy gravel). Low organic & high inorganic content Lowlands: Peaty clay as above after c. 1710 AD, then noncalcareous sand and calcareous grit with some fine grained minerogenic sediment & a trace of peat. High inorganic content & low organic content. High carbonate content	Highlands: some extra-local & regional burning Lowlands: much extra-local & regional burning
1680-1650 AD	Highlands: Peat from c. 1670 AD with continuously wet surface Lowlands: Continuously wet peat surface	Highlands: Same as above Lowlands: True reed swamp – <i>Glyceria</i> type dominant	Colder than today. Coldest phase of Little Ice Age	Highlands: As above, after c. 1670 AD, then peat with some fine grained minerogenic sediment. Peat has moderate organic matter & reduced inorganic content Lowlands: Fine grained minerogenic sediment extra-local with some peat. Moderately low inorganic content & moderately high organic content. Low carbonate content	Highlands: some extra-local & regional burning Lowlands: much extra-local & regional burning

1650-1580 AD	<p>Highlands: Peat after c. 1625 AD with continuously wet surface, before no peat after c. 1585 AD when peat surface is intermittently dry</p> <p>Lowlands: Continuously wet peat surface</p>	<p>Highlands: Same as above, but <i>Glyceria</i> type increases</p> <p>Lowlands: True reed swamp – <i>Scirpus</i> & <i>Glyceria</i> type dominant</p>	<p>Highlands: Same as above after c. 1625 AD, before canopy remains partially closed, <i>Fagus</i> is slightly reduced and <i>Abies</i> increases, herbs of open-ground same as above, <i>Juniperus</i> of very low abundance, <i>Pteridium</i> abundant, cereal cultivars abundant, moderately high palynological richness</p> <p>Lowlands: Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> type almost absent, <i>Juniperus</i> of high abundance, herbs of open ground sl. reduced but still very abundant, <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars very abundant, very high palynological richness</p>	Colder than today	<p>Highlands: cereal cultivation – oats, rye & wheat; grazing: woodland management</p> <p>Lowlands: cereal cultivation – oats, barley, rye & ?maize</p>	<p>Highlands: Peat as above, after c. 1625 AD, then multiple episodes of minerogenic sediment influx, horizons of sandy gravel, sand, mud with gravel, silt & clay. Minerogenic sediments have low organic & high inorganic content</p> <p>Lowlands: As above, after c. 1620 AD, then peat with some fine grained minerogenic sediment. High organic matter increases downwards, inorganic matter low (decreases downwards). Low carbonate content</p>	<p>Highlands: much extra-local & regional burning</p> <p>Lowlands: little extra-local burning</p>
Antelia sequence ends at c. 1560 AD:							
1580-1480 AD	<p>Highlands: Peat with intermittently after c. 1575 AD dry surface until c. 1565 AD, then no peat</p> <p>Lowlands: True reed swamp – <i>Scirpus</i> & <i>Glyceria</i> type dominant (c. 1550 AD with continuously wet surface</p>	<p>Highlands: Same as above when <i>Phragmites australis</i> & <i>Cyperus michelianus</i> decrease</p> <p>Lowlands: True reed swamp – <i>Scirpus</i> & <i>Glyceria</i> type dominant (c. 1550 AD with continuously wet surface communities is abundant)</p>	<p>Highlands: Same as above after c. 1585 AD, before the canopy is open. <i>Fagus</i> & <i>Abies</i> reduced, abundant herbs of open ground, <i>Juniperus</i> of very low abundance, <i>Pteridium</i> most abundant, most abundant cereal cultivars, moderately high palynological richness</p> <p>Lowlands: Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (low abundance of latter), <i>Q. coccifera</i> type almost absent, <i>Juniperus</i> increasing upwards, herbs of open ground very abundant, most abundant <i>Chenopodiaceae</i> type, sl. increased <i>Pteridium aquilinum</i>, cereal cultivars very abundant & increase, very high palynological richness</p>	Colder than today	<p>Highlands: from 1560 AD cereal cultivation – oats, rye & wheat; grazing: woodland management</p> <p>Lowlands: cereal cultivation – oats, barley, rye, wheat</p>	<p>Highlands: Interbedded peat & sandy gravel</p> <p>Lowlands: Same as above after c. 1550 AD, before fine grained sediment as below. Calcareous grit between c. 1490-1510 AD. Decreased inorganic matter & increased organic matter. Low-moderate carbonate content</p>	<p>Highlands: little extra-local & regional burning</p> <p>Lowlands: same as above</p>
Data from lowland site of Kellia only:							
1480-1370 AD	No peat	True reed swamp – <i>Scirpus</i> dominant, wet soil habitat group has increased importance – <i>Carex hallerana</i> type important	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type (but <i>Q. trojana</i> has increased), <i>Q. coccifera</i> type almost absent, <i>Juniperus</i> increasing upwards, herbs of open ground very abundant, <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars very abundant, very high palynological richness	Warmer than today	Cereal cultivation – oats, barley, rye	Fine grained minerogenic sediment Same as above and coarse herbaceous detritus (more detritus after c. 1430 AD). Low inorganic content & high organic content. Some calcareous grit before c. 1430 AD. Low carbonate content	

1370-1320 AD	No peat	True reed swamp – <i>Scirpus</i> , <i>Glyceria</i> type & <i>Sparganium erectum</i> dominants (<i>Cyperus michelianus</i> of the tall sedge swamp community is also important)	Open canopy – <i>Quercus frainetto</i> type & <i>Q. trojana</i> type co-dominant, <i>Q. coccifera</i> type of very low abundance, <i>Juniperus</i> of very low abundance, increased herbs of open ground (very abundant), <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars very abundant, very high palynological richness	Warmer than today	Cereal cultivation – oats, barley, rye	Several horizons of minerogenic sediment (some fine & some of sand grain size) with herbaceous detritus. High inorganic matter content & low organic matter content. High carbonate content charcoal (macroscopic 235-264 cm)	Widespread burning extra-locally & regionally (macroscopic charcoal 235-264 cm)
1320-1230 AD	No peat	Wet soil habitat group – <i>Carex hallerana</i> type dominant (<i>Cyperus michelianus</i> & <i>Scirpus</i> also important)	Open canopy – <i>Quercus frainetto</i> type more abundant than <i>Q. trojana</i> type, <i>Q. coccifera</i> type almost disappears, <i>Juniperus</i> of very low abundance, herbs of open ground reduced but are still very abundant, <i>Pteridium aquilinum</i> at reduced abundance, cereal cultivars abundant, high palynological richness	Warmer than today	Cereal cultivation – oats, barley, rye	Fine grained sediment & herbaceous detritus – low inorganic matter & high organic matter. Moderate carbonate content	Little extra-local & regional burning
Highlands = data from the Gomara site							
c. 700-330 AD	Lake water level high, no seasonal fluctuation	Marginal sedge & reed swamp – <i>Carex hallerana</i> type & <i>Cyp. michelianus</i> dominant	Open canopy – <i>Pinus</i> dominant, increased <i>Pteridium</i> & herbs of open ground, fluctuating palynological richness	Similar to today. Reduced summer precipitation from preceding period (declining <i>Fagus</i>) warm summer temp., (entomophilous temperate trees)	Woodland clearance, grazing: ?regional cultivation of rye/wheat	Erosion begins again; high inorganic matter, increasing trophic level, high organic nitrogen	Much extra-local & regional burning
c. 330 AD-80 BC	Greatest lake water depth. No seasonal fluctuation	Marginal sedge & reed swamp – <i>Carex hallerana</i> type dominant, <i>Phragmites australis</i> reduced	Closed canopy – <i>Fagus</i> dominant, reduction in herbs of open ground, much reduced <i>Pteridium</i> , reduction in palynological richness	Wetter than today, warmer than in preceding period. c. 200 AD mean temperature of the coldest month > -0.5° C (<i>Ilex aquifolium</i>), mean temperature of warmest month > 15.5° C (<i>Viscum album</i>)	?Regional cultivation of rye	Very little erosion, very high organic content, meso-eutrophic, low organic nitrogen	Almost no extra-local burning, much reduced regional burning
c. 80 BC							
c. 80-480 BC	Decreased lake water depth. Seasonal fluctuation	Marginal sedge & reed swamp – <i>Phragmites australis</i> & <i>Carex hallerana</i> type co-dominant	Closing canopy – <i>Pinus</i> , increasing <i>Fagus</i> , reduced herbs of open ground & <i>Pteridium</i> , lower palynological richness	Wetter than today (<i>Fagus</i> abundance greater than today). Warmer than preceding period (disappearance of <i>Betula pendula</i>)	Little, if any grazing ?regional cultivation of cereals, <i>Juglans regia</i>	Decreasing erosion; fine Grained sediments with increased organic detritus, decreasing inorganic matter, meso-eutrophic, low organic nitrogen	Same as above tephra
c. 480-890 BC	Increased lake water depth. No seasonal fluctuation	Marginal sedge reduced, reed swamp expanded; <i>Phragmites australis</i>	Open canopy – <i>Pinus</i> , increasing <i>Fagus</i> , abundant herbs of open ground, <i>Pteridium</i> present, high palynological richness	Wetter & cooler summers than today (abundance of <i>Fagus</i> & <i>Betula pendula</i>). Cooler winters (disappearance of evergreen & ?cultivation of cereals)	Extra-local grazing (<i>Plantago lanceolata</i> type, <i>Rumex acetosa</i> group, <i>Urtica urens</i> type)	Erosion less intense; high inorganic matter but of finer grain size, meso-eutrophic, lower organic nitrogen	Much extra-local & regional burning

fluctuation dominant		temperate trees) than in preceding period. Mean temp. of warmest month > 15.5° C (<i>Viscum album</i>)	
c. 890-1340 BC	High water depth, then ?lower with seasonal fluctuation	<p>Marginal sedge & reed swamp – tall sedge community dominant</p> <p>Open canopy – <i>Pinus</i> dominant, abundant herbs of open ground, <i>Pteridium</i> present, high palynological richness</p> <p>Drier summer/warmer wetter winter than today (+3.2° C). Mean temperature of coldest month > -0.5° C (<i>Ilex aquifolium</i>), mean temperature of warmest month > 15.5° C (<i>Viscum album</i>), but <19° C (<i>Picea abies</i>)</p> <p>Extra-local grazing (<i>Plantago lanceolata</i> type, <i>Rumex acetosa</i> group, <i>Urtica urens</i> type) ?cultivation of cereals</p>	<p>Much extra-local & regional burning</p> <p>Erosion of increasing intensity; high inorganic matter, eutrophic, high organic nitrogen</p>

Broadly, the sediments represent two episodes of higher soil erosion rate, represented by sediments with a high proportion of inorganic matter, separated by a period of little soil erosion from c. 80 BC to 330 AD when sediments were highly organic. Only one abrupt stratigraphical change occurs; that at 107.2 cm, c. 80 BC, where a catastrophic event is represented, that of a volcanic eruption. All other changes in lithology are indistinct and represent slower environmental changes.

Abundant microscopic charcoal particles were deposited during the period 1340-890 BC, indicating frequent/intense regional burning of vegetation. After 890 BC regional burning continued at a reduced but high level of frequency/intensity until c. 500 BC at the end of the Archaic period. The largest microscopic charcoal particles, which probably derive from the catchment, were most abundant during the Late Bronze Age (1340-1100 BC), then declined sharply during the Iron Age until c. 850 BC, when local burning increased again and continued through the Archaic period. During the Classical and Hellenistic periods and most of the Roman Period little burning of regional highland and local vegetation around the Gomara site is indicated, with the exception of a short period at c. 200-250 AD, until the end of the Roman Period, c. 475 AD, when both regional highland and local burning around the Gomara site increased. During the Early Medieval, from c. 580-700 AD regional and local burning increased. Relative frequency data suggest that the intensity/frequency of burning at this time is similar to that of the Late Bronze Age, the most recent half of the Iron Age, and the Archaic, while influx data suggest lower intensity/frequency.

The highland regional vegetation was predominantly pine wood throughout the sequence, but the vegetation in the catchment changed greatly. Between c. 1340 and 890 BC the catchment vegetation was an open canopy pine wood with a few deciduous trees, not as open as today. After 890 BC there was increasing *Fagus* in the catchment, and the lake was surrounded by beech wood soon after this time. The beech wood was dominant in the catchment from c. 480 BC until 330 AD, forming a very dense cover from 80 BC. At about 330 AD a rapid decline in *Fagus* occurred, and pine wood-pasture similar to that of today is indicated.

Between c. 1340 and 890 BC various herbs that may be indicative of grazing are abundant, especially terrestrial grasses, Chenopodiaceae type, *Plantago lanceolata* type, *Rumex* species, *Solidago* type, and *Urtica* species. *Urtica* in particular is nitrophilous and highly suggestive of animal-fertilised areas. The coincidence of evidence of burning of local vegetation, soil erosion, high lake trophic status and nitrogen content, and weeds possibly indicative of grazing all point to a landscape subject to active pastoralism. In addition the presence of cereal pollen in low abundance may indicate minor local cereal cultivation.

Between c. 890 and 480 BC less intense soil erosion is suggested by finer grain size of inorganic matter, a reduced average sedimentation accumulation rate, a decline in trophic level to meso-eutrophic and lower organic nitrogen content of the lake. However, herbs associated with pastoralism continued to occur in abundance, with an increase in *Artemisia*. Burning of the catchment and regional vegetation is again suggested by the occurrence of abundant macroscopic and microscopic charcoal particles and the greater abundance of pollen of the early-successional *Betula pendula*, and the occurrence of *Pteridium aquilinum* spores. It is inferred that pastoral activity continued, with repeated clearance of beech and pine woodland.

From c. 480 BC to 80 BC soil erosion declined further; minerogenic sediments are fine-grained, organic detritus increases, lake trophic level is meso-eutrophic and organic nitrogen content is low. Vegetation of the catchment was now mostly beech wood, with a much reduced pine component. The early successional types of *Corylus* and *Betula pendula* decline as the canopy of the catchment woodland becomes more closed. An almost complete absence of charcoal particles and *Pteridium aquilinum* spores suggests that burning of the catchment and the regional vegetation had almost ceased. Herbs associated with pastoralism declined, especially *Urtica*, but continued to be present. Pastoralism had effectively ceased during this period, although abundance of light-demanding herbs suggests that some open ground surrounded the lake, perhaps occasionally visited by stock being herded via the nearby mountain pass.

Between c. 80 BC and 330 AD little soil erosion occurs; minerogenic sedimentation declines and the proportion of organic detritus increases until sediments are almost entirely organic. Trophic level of the lake water is meso-eutrophic, and organic nitrogen content is low. Vegetation of the catchment is a closed-canopy beech wood. Burning of vegetation is not occurring, except perhaps at a long distance from the catchment. Light-demanding herbs record the lowest relative pollen frequencies of the sequence, and human cultural activity is inferred to be very minor. *Juglans regia* and *Secale cereale* pollen occurs at very low abundance, but at increased levels compared with previously; both may result from wild plants or from long-distance dispersal from cultivated areas.

Between c. 330 and 700 AD more intense soil erosion occurred. In the wetland, inorganic sedimentation occurred; alkaliphilous diatoms increased, the trophic level increased, and organic-nitrogen content increased. The beech wood in the catchment began to decline at c. 330 AD. Pine wood replaced the beech wood, but then it declined at c. 600 AD, and an open canopy pine wood similar to that of today formed. Burning of the catchment and regional vegetation occurred again from c. 475 AD, both locally and regionally, and almost reached the levels of frequency/intensity of that between c. 1340 and

480 BC. Light-demanding herbs increase; particularly *Urtica dioica* and *U. urens*. These changes are interpreted to result from woodland clearance, initially by cutting, later by burning associated with pastoral activity.

Earliest finds of loomweights in Grevena date to the Hellenistic Period, and sheep/goat bone was found in association with a Hellenistic site in the lowlands, Grevena Project 318 (Wilkie 1995). The earliest archaeological evidence of occupation above 1000 m in the Pindos Mountains in Early Medieval times is from sites distributed in a pattern similar to that of modern transhumant villages, which suggests the existence of a pastoral economy. From historical information, transhumant pastoralism is known to have been practised in the Pindos Mountains and foothills in the Ottoman Period. The palynological interpretation presented above indicates two periods of pastoralism at Gomara: one of Late Bronze Age to Archaic, spanning c. 1340 BC (or earlier) to 480 BC, the other Late Roman to Early Medieval or later, c. 330-700+ AD. The latter is coincident with the earliest Grevena Project highland archaeological sites, but the earlier period is so far unknown from archaeological data. However, from palynological study Willis (1992) has described woodland clearance and ensuing pastoralism dating from c. 4250-1900 BP at Rezina Marsh (1800 m asl) in the Pindos Mountains to the southwest.

During the period of pastoral abandonment of the site, c. 480 BC to 330 AD, *Fagus* was dominant in the catchment. Bottema (1994:58) noted that the initial appearance or expansion of *Fagus* "all over Europe is always connected with human activity ... it profits from the appearance of abandoned, impoverished land, and clearings resulting from lumbering or from meadows that are no longer grazed". However, in the same paper Bottema (cf. Bottema & Woldring 1990) concludes that a change to wetter conditions may have lasted from c. 3200 to 1500 BP.

The climatic pattern interpreted from this site (Section 7.3) is a warm dry period from 1340 to 890 BC (possibly with drier summers and warmer wetter winters than today), followed by a cooler period with wetter summers, then from 480-80 BC a period that was wetter and warmer than today. From 80 BC to 330 AD the climate is interpreted as wetter than today and warmer than the preceding period. Between 330-700 AD climatic conditions were similar to today; summer precipitation was reduced from the preceding period and summer temperatures were warmer. This pattern of climatic change accords with the north and central European climatic sequence during the Sub-boreal/Sub-atlantic transition and early Sub-atlantic period described by Lamb (1982:132-135). Detailed pollen-analytical records from Greece and from sites of climatic sensitivity for the period in question are few, most sequences studied being from the lowlands and insufficiently dated (Chapter 1). However, Gerasimidis & Athanasiadis (1995) have also described vegetation change in

northern Greek mountains in terms of Blytt-Sernander climatic zones, noting an expansion of *Fagus* in the early Sub-atlantic. More well-dated pollen sequences are required to confirm a general pattern. At Gomara, while the expansion of beech woodland appears to have been aided by human abandonment, the primary role of climate is favoured.

7.5.2 Anelia c. 1560 - 1989 AD

At this site there is closer correspondence between changes in the composition of the deposits and changes in the pollen profiles of wetland taxa than of the pollen profiles of terrestrial taxa. The lack of exact correspondence is due to deposition of pollen and spore types both of taxa washed in from the catchment and of taxa deposited from the atmosphere from regional and extra-local source areas. Thus the terrestrial pollen record reflects both the extra-local and the regional vegetation.

There is very little apparent variation in the local wetland vegetation. It is dominated throughout the sequence by sedges of the *Carex hallerana* type of the 'wet soil' habitat group, which are probably indicative of a small sedge swamp community, although they may also represent dry habitats such as open woodland. The reeds of the types *Phragmites australis* and *Glyceria* type are also prominent. Communities of floating-leaved and submerged macrophytes are poorly represented and probably derive from a few plants growing in small pools on the wetland. The influence of minerals supplied by water from a soft-water spring, which maintained a high level of available nutrients, is evident throughout the sequence. Additional nutrient supply from anthropogenic activities (e.g. manure from grazing) is therefore difficult to detect. Where peat formation occurred surface peat was either continuously wet or only intermittently dry (probably only during the driest part of summer).

The sedimentary history of the wetland area is closely linked to the local wetland vegetation history, so major sedimentary units usually coincide with wetland pollen zones. The wetland formed in a hollow of a ravine. Broadening of the ravine and reduction in gradient caused impedance of spring-stream water flow, with consequent deposition of sediments. Between c. 1560 and 1730 AD the wetland was in-filled with stratified clay, silt, sand, fine gravel, and peat, and mire vegetation established itself temporarily away from the stream course. At c. 1730 AD peat formation became general, with a permanently marginal stream channel. This situation has persisted until today.

Microscopic charcoal evidence suggests that the most intense/frequent fires, both extra-locally and regionally, occurred between c. 1585-1625 AD. Between c. 1560-1585 AD and c. 1625-1730 AD fire regimes were very similar in intensity/frequency and location, being of high intensity/frequency, but not as high as that of the period between, and occurring both extra-locally and regionally. From c. 1730 AD to the present fires did not occur extra-locally

and were much reduced regionally. The charcoal data are supported by pollen analysis. Fire-encouraged *Pteridium aquilinum* is more abundant in the lower part of the sequence between c. 1560-1730 AD, being highest in the basal zone, c. 1560-1585 AD. In contrast, fire sensitive *Juniperus* was most abundant in the upper part of the sequence, especially after 1800 AD.

Between c. 1560 and 1730 AD the extra-local vegetation was a woodland dominated by *Fagus* and *Abies*, but after c. 1730 AD it was dominated by *Fagus* only. For most of the period, the woodland canopy was open, but after 1920 AD the beech woodland assumed a denser character.

For the period 1560-1730 AD, rapid and coarse-grained sedimentation and evidence for extra-local fires suggest woodland disturbance in the vicinity and possibly also regionally, although woodland surrounded the site itself. Pollen of light-demanding herbs is abundant, especially *Artemisia*, *Chenopodiaceae* type, *Cirsium* type, *Dactylis* type, *Festuca* type, *Hieracium* type, *Plantago lanceolata* type, *Rumex acetosa* group, and *Solidago* type. Together with abundant pollen of the ruderal *Urtica* this suggests grazing in the neighbourhood of the site.

From 1730 AD absence of anthropogenic fires coincides with steady peat formation, suggesting reduction in soil erosion in the catchment. Pastoralism continued unabated, however, judging from the continued high abundance of herbs associated with grazing. The steady increase in *Fagus* after c. 1920 AD is thought to be due to cessation of woodland coppicing; evidence for former practise of this activity has been noted (Chapter 1).

A steady decline in *Abies* from c. 1600 AD to 1730 AD, followed by abrupt near disappearance is interpreted as result of selective lumbering. The coincidence of the latter date with cessation of burning and erosion may indicate that lumbering activities contributed to these effects, or that the lumbering formed part of a cultural land-use system, which changed after that date.

Cereal pollen, particularly *Secale cereale* and *Triticum* type, occur throughout the sequence before c. 1920 AD; *Avena* occurs until 1730 AD. The highly characteristic weeds of cultivation *Agrostemma githago* and *Centaurea cyanus* type also occur in a number of samples prior to c. 1920 AD. Together, these suggest nearby cultivation of wheat and oats, and possibly rye (although the last could be more distant). The trees *Castanea sativa* and *Platanus orientalis* were more abundant after c. 1730 AD, but not in such frequency to suggest extra-local cultivation. The increase is seen at Kellia (and other sites in northern Greece – Bottema 1974), and is probably due to increased planting regionally.

The association of grazing, lumbering, coppicing, and cereal cultivation reflects a highly exploited landscape and a cultural style similar to that reported for the Vlach villages

by Leake (1835). The reduction in woodland management and cereal cultivation since c. 1920 AD also matches well the changes in land use that have accompanied the introduction of mechanised transport and farming methods and disruption caused by war.

7.5.3 Kellia c. 1230 - 1989 AD

The sedimentary history of Kellia fen is intimately linked to the local wetland vegetation history, and there is close correspondence between the composition of deposits and changes in the pollen profiles of the wetland, but there is less correspondence between sediment composition and terrestrial pollen and spore profiles. Absence of total synchrony of these three factors is due to a significant contribution of pollen and spores derived from outside the catchment.

Stratigraphic data indicate that Kellia fen probably formed at the side of a stream course, which ran from west to east on the southern side of the fen. Radiocarbon dating of the pollen-analysed core suggests that two periods of alluviation are recorded in the fen sediments, an older period below 312 cm (beginning perhaps c. 830 BC and spanning about 200 years, see Section 6.4.2) and a younger one above which may span about the last 760 years, beginning c. 1230 AD. Since the earlier period is not securely dated, it is not further discussed here.

The fen sediments comprise greyish olive to olive-black clay with variable proportions of calcareous grit, peat, and organic detritus. Thin (5-15 cm) noncalcareous sand horizons are rare. Persistent organic horizons occur at about 100 and 230 cm. The uppermost c. 20 cm (c. 1900-1989 AD) of the fen consists of silty peat and brown clay with a sandy layer at the base. This unit may be related to the establishment of the modern sealed road and its causeway, which may have reduced the transport of sediment into the fen from the catchment upstream.

The local wetland vegetation is dominated by pollen and spore types derived from emergent plant communities of wet-soil, tall-sedge-swamp and true-reed-swamp communities, the last contributing the most pollen. The true-reed-swamp communities are dominated by reeds of *Glyceria* type and *Scirpus* and to a lesser extent by *Phragmites australis* and *Sparganium erectum*. The wet-soil communities are dominated by sedges of the *Carex hallerana* type and *Schoenus nigricans*, and *Equisetum* occurs sporadically. Pollen types that dominate the tall-sedge-swamp communities are *Carex flacca* type, *Cyperus longus* type, and *Cyperus michelianus*. Communities of floating-leaved and submerged macrophytes are poorly represented; they probably comprise a few plants growing in small pools on the surface of peat. The available nutrient level is high throughout the sequence,

as evidenced by the abundance of several pollen types representing wetland plants indicative of high trophic status.

From microscopic charcoal particles, during the period c. 1230-1320 AD fires were apparently uncommon either extra-locally or regionally. After c. 1320 AD until c. 1370 AD there was considerable extra-local and probably also regional burning. From c. 1370 AD regional burning continued at a fairly uniform frequency/intensity, but extra-local burning was at a low level until c. 1650 AD. From this date, extra-local burning fluctuates, with peaks during the periods c. 1650-1690 AD, c. 1750-1790 AD, c. 1860-1880 AD, and at c. 1890 AD and c. 1940 AD. *Pteridium aquilinum* increased between c. 1350-1360 AD, and the fire-sensitive *Juniperus* was less abundant in the lower part of the sequence before c. 1370 AD. After c. 1370 AD *Juniperus* increased. *Pteridium aquilinum* again became abundant from c. 1640 to 1790 AD.

The extra-local and regional lowland vegetation is open canopy deciduous/semi-evergreen oak woods dominated by the canopy trees of *Quercus frainetto* type (deciduous oaks) and *Q. trojana* type (deciduous/semi-evergreen oaks). *Ostrya* type occurs at low abundance almost continuously. The ratio of tree and shrub pollen to that of terrestrial herbs fluctuates through the period c. 1230 AD to present, but generally high herb levels indicate a low density of trees and extensive steppe and open land. This is supported by high levels of palynological richness.

Weeds typical of human disturbance occur continuously throughout the sequence at significant abundance, especially: *Centaurea solstitialis* type, Chenopodiaceae type, *Cichorium* type, *Cirsium* type, *Galium* type, *Hieracium* type, *Lactuca* type, *Plantago lanceolata* type, *Polygonum aviculare* type, *Solidago* type, *Sonchus* type, and *Taraxacum* type.

A variety of cereals was cultivated extra-locally for the duration of the sequence, pollen types identified being *Avena*, *Hordeum* type, *Secale cereale*, *Triticum* type, and *Zea mays*. A notable peak in frequency in most types (except *Triticum*) occurred between c. 1480-1580 AD. *Triticum* type occurs in very low abundance before c. 1730 AD but is relatively common after c. 1870 AD, while *Avena* almost disappears after c. 1900 AD. As noted in Section 7.4.4, weeds of cultivation are prevalent, particularly *Centaurea cyanus* type. Low frequencies of *Castanea sativa* and *Juglans regia* occur sporadically from c. 1230 AD in insufficient abundance to suggest any extensive planting in the vicinity of the site. The shade tree *Platanus orientalis* increases, although rather irregularly, after c. 1650 AD. The increased abundance of pollen of this species regionally has already been noted in discussion of the Anelia results.

The abundance of cereal pollen supports intensive extra-local cereal cultivation since c. 1230 AD. In the presence of cultivation, it is difficult to distinguish the signature of pastoralism, as most weeds of disturbance occur in association with both activities.

A climate sequence, based on the ratio of pollen of *Quercus frainetto* type (deciduous oaks) to *Quercus trojana* type (semi-evergreen/deciduous oaks) and *Quercus coccifera* type (evergreen oaks) discussed in Section 7.3, has been used to interpret temperature changes in the lowlands (Table 7.1). The record of the deciduous/semi-evergreen *Quercus* pollen curve agrees in its general features with tree-ring and documentary records from Europe (Lamb 1982). For example, the coldest periods indicated by the Kellia oak curve match the cold periods indicated by tree-ring density from Lauenen, Switzerland (Stuiver 1980). The greatest abundance of the deciduous oaks (*Quercus frainetto* type) and the lowest abundance of semi-evergreen/deciduous oaks (*Quercus trojana* type) occurs at c. 1680 AD and shows good correspondence with the lowest temperatures indicated at 1690 AD and the culmination of the Little Ice Age, which occurred between c. 1660 and 1680 AD (Lamb 1982; Grove 1988).

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**LATE HOLOCENE VEGETATION HISTORY
OF GREVENA PROVINCE,
NORTHWESTERN GREECE**

Volume II – Appendices

by

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Appendix I

Herbarium specimens collected in Grevena Province

Taxonomic names follow :

Tutin, T. G. *et al.* (eds) 1964-80. *Flora Europaea*. Volumes 1-5. Cambridge University Press, Cambridge.

Common names follow:

Polunin, O. 1988. *Flowers of Greece and the Balkans*. Oxford University Press, Oxford.

Identifications were made by Dr Oliver Rackham, Cambridge University.

Herbarium specimens were collected from the following geographic areas and vegetation:

- 1) Perivolion/Vovoussa (mountains) - understory (beech wood)
- 2) Anelia (mountains) - bog (beech wood)
- dry land on edge of bog (beech wood)
- road verge (beech wood)
- 3) Kellia (lowland plains) - margin of fen (agricultural fields)
- field margin steppe (agricultural fields)
- fen (agricultural fields)
- 4) Mavranaiioi (lowland plains) - road verge (oak wood-pasture)
- 5) Polynierion (foothills) - steppe on ridge top (oak wood-pasture)
- steppe on east facing hillslope (oak wood-pasture)
- 6) Aetia (foothill limestone gorge) - limestone gorge (mixed wood)
- 7) Mirsina (lowland plains) - *Phragmites* fen (oak wood)
- margin of *Phragmites* fen (oak wood)
- steppe near *Phragmites* fen in oak wood
- ground cover (oak wood)
- understory (oak wood)
- 8) Gomara (mountains) - dried lakebed (pine, *Pinus leucodermis*, wood-pasture)
- alpine pasture below lake (pine, *Pinus leucodermis*, wood-pasture)
- 9) Zakas to Agios Nikolaos (mountains) - road verge (pine wood-pasture)
- 10) Perivolion/Avdella (mountains) - understory (pine/oak wood)
- 11) Lowland plains - cultivated fields
- 12) Agios Nikolaos (mountains) - understory (*Pinus nigra*/oak wood)
- understory (*Pinus nigra* wood)
- 13) Above Zakas (foothill limestone outcrop) - mixed wood on limestone (mixed wood)
- road verge (pine wood-pasture)
- 14) Asprokampos (lowland plains) - weeds (cultivated barley field)
- road verge (agricultural fields)
- understory (oak wood)
- oaks (oak wood)
- 15) Avgo (mountains) - pine (mountain pine, *Pinus leucodermis*, wood-pastures)

Note: A "P" in the left margin indicates that a pollen reference slide from this specimen has been placed in the Geology Department, Victoria University of Wellington, European pollen reference collection.

No.	Genus & species	Common name	Family
Perivolvion/Vovousa - understorey in beech wood:			
P 1	<i>Myosotis</i> sp.		Boraginaceae
P 2	<i>Digitalis grandiflora</i> Miller	Large yellow foxglove	Scrophulariaceae
P 3	<i>Prunella laciniata</i> (L.) L.	Cut-leaved self-heal	Labiatae
P 4	<i>Dianthus</i> sp.	Pink	Caryophyllaceae
P 5	<i>Centaurea</i> sp.	Knapweed	Compositae
P 6	<i>Campanula</i> sp.	Bellflower	Campanulaceae
P 7	<i>Leontodon</i> or related genus		Compositae
P 8	<i>Lotus</i> sp.	Birdsfoot-trefoil	Leguminosae
P 9	<i>Lathyrus</i> sp.	Pea, Vetch	Leguminosae
P 10	<i>Viola</i> sp.	Violet, Pansy	Violaceae
P 11	<i>Euphrasia</i> sp.		Scrophulariaceae
Anelia - bog in beech wood:			
P 12	<i>Parnassia palustris</i> L.	Grass of Parnassus	Parnassiaceae
P 13	<i>Epilobium adenocaulon</i> Hausskn.	Willow-herb	Onagraceae
P 14	<i>Trifolium pratense</i> L.	Red clover	Leguminosae
P 15	<i>Mentha aquatica</i> L.	Water mint	Labiatae
P 16	<i>Juncus inflexus</i> L.	Rush	Juncaceae
P 17	<i>Cynosurus cristatus</i> L.		Gramineae
P 18	<i>Juncus articulatus</i> L.	Rush	Juncaceae
Kellia - margin of fen in agricultural fields:			
P 19	<i>Verbena officinalis</i> L.	Vervain	Verbenaceae
P 20	<i>Ononis spinosa</i> L.	Spiny restharrow	Leguminosae
Kellia - disturbed area on fen in agricultural fields:			
P 21	<i>Pulicaria dysenterica</i> (L.) Bernh.	Fleabane	Compositae
Kellia - margin of fen in agricultural fields:			
P 22	<i>Potentilla reptans</i> L.	Creeping cinquefoil	Rosaceae
Kellia - on fen in agricultural fields:			
P 23	<i>Sparganium erectum</i> L.	Bur-reed	Sparganiaceae
Kellia - margin of fen in agricultural fields:			
P 24	<i>Mentha aquatica</i> L.	Water mint	Labiatae
P 25	<i>Torilis japonica</i> (Houtt.) DC		Umbelliferae
P 26	<i>Daucus carota</i> L.		Umbelliferae
P 27	<i>Cichorium intybus</i> L.	Chicory	Compositae
Kellia - on fen in agricultural fields:			
P 28	<i>Epilobium hirsutum</i> L.	Great hairy willow-herb, Codlins & cream	Onagraceae
P 29	<i>Epilobium cf. adenocaulon</i> Hausskn.		Onagraceae
Kellia - disturbed area on fen in agricultural fields:			
P 30	<i>Lythrum salicaria</i> L.	Purple loosestrife	Lythraceae
Kellia - margin of fen in agricultural fields:			
P 31	<i>Centaurea napulifera</i> Rochel		Compositae
P 32	<i>Colchicum autumnale</i> L.	Meadow saffron, Autumn crocus	Liliaceae
P 33	<i>Consolida</i> sp.		Ranunculaceae

No.	Genus & species	Common name	Family
Kellia - on fen in agricultural fields:			
P 34	<i>Teucrium scordium</i> L.	Water germander	Labiatae
P 35	<i>Galium rivale</i> (Sibth. & Sm.) Griseb.	Bedstraw	Rubiaceae
P 36	<i>Rubus caesius</i> L.	Dewberry	Rosaceae
P 37	<i>Lycopus europaeus</i> L.	Gipsy-wort	Labiatae
P 38	<i>Nigella</i> sp.	Love-in-a-mist	Ranunculaceae
P 39	<i>Calystegia</i> sp. ? <i>sepium</i> (L.) R. Br.	Greater bindweed	Convolvulaceae
P 40	<i>Kickxia elatine</i> (L.) Dumort	Fluellen	Scrophulariaceae
P 41	<i>Cuscuta</i> sp.	Dodder	Convolvulaceae
P 42	<i>Galium rivale</i> (Sibth. & Sm.) Griseb.	Bedstraw	Rubiaceae
43	<i>Berula erecta</i> (Hudson) Coville	Water-parsnip	Umbelliferae
44	<i>Lysimachia nummularia</i> L.		Primulaceae
45	<i>Rumex conglomeratus</i> Murray	Dock, Sorrel	Polygonaceae
Kellia - agricultural field margin steppe:			
46	<i>Cirsium eriophorum</i> (L.) Scop.	Woolly thistle	Compositae
P 47	<i>Kickxia spuria</i> (L.) Dumort	Fluellen	Scrophulariaceae
P 48	<i>Cirsium</i> cf. <i>vulgare</i> (Savi) Ten.		Compositae
49	<i>Galium verum</i> subsp. <i>wirtgenii</i> (F.W. Schultz) Oborny	Lady's bedstraw	Rubiaceae
50	<i>Clinopodium vulgare</i> L.	Wild basil	Labiatae
P 51	<i>Dorycnium graecum</i> (L.) Ser.		Leguminosae
P 52	<i>Lotus</i> cf. <i>corniculatus</i> L.	Birdsfoot-trefoil	Leguminosae
P 53	<i>Thesium</i> sp.	Bastard toadflax	Santalaceae
P 54	<i>Polygonum</i> cf. <i>aviculare</i> L.	Knotgrass	Polygonaceae
Mavranaiioi - road verge in oak wood-pasture:			
P 55	<i>Echinops microcephalus</i> Sibth. & Sm.	Globe thistle	Compositae
P 56	<i>Scabiosa</i> sp. ? <i>atropurpurea</i> L.	Scabious	Dipsacaceae
P 57	<i>Centaurea</i> sp.	Knapweed	Compositae
58	<i>Lactuca viminea</i> (L.) J. & C. Presl	Pliant lettuce	Compositae
P 59	<i>Alyssum</i> cf. <i>murale</i> Waldst. & Kit, or ? <i>Neslia paniculata</i> (L.) Desv.		Cruciferae
P 60	<i>Dorycnium hirsutum</i> (L.) Ser.		Leguminaceae
P 61	<i>Clinopodium vulgare</i> L.	Wild basil	Labiatae
62	<i>Sorbus torminalis</i> (L.) Crantz	Wild service tree	Rosaceae
P 63	<i>Crepis</i> sp.	Hawksbeard	Compositae
P 64	<i>Xanthium strumarium</i> L.	Cocklebur	Compositae
P 65	<i>Plantago lanceolata</i> L.	Ribwort, Plantain	Plantaginaceae
P 66	<i>Anthemis</i> sp.	Chamomile	Compositae
67	<i>Euphorbia</i> ? <i>segetalis</i> L.	Spurge	Euphorbiaceae
P 68	<i>Plantago lanceolata</i> L.	Ribwort, Plantain	Plantaginaceae
69	<i>Convolvulus arvensis</i> L.		Convolvulaceae
P 70	<i>Chondrilla juncea</i> L.		Compositae
Polynierion - steppe on ridge top in oak wood-pasture:			
P 71	<i>Thymus</i> sp.	Thyme	Labiatae
P 72	<i>Dianthus</i> sp.	Pink	Caryophyllaceae
P 73	<i>Acinos suaveolens</i> (Sibth. & Sm.) G. Don fil. in Loudon		Labiatae
P 74	<i>Erodium</i> cf. <i>cicutarium</i> (L.) L'Her	Common storksbill	Geraniaceae
P 75	<i>Anthemis</i> sp., or <i>Achillea</i> sp.	Chamomile	Compositae
P 76	<i>Hieracium</i> / <i>Pilosella</i> agg.		Compositae
P 77	<i>Centaurea solstitialis</i> L.	St. Barnaby's thistle	Compositae

No.	Genus & species	Common name	Family
P 78	<i>Xanthium spinosum</i> L.	Spiny cocklebur	Compositae
P 79	<i>Eryngium amethystinum</i> L.	Blue eryngo	Umbelliferae
80	<i>Euphorbia myrsinites</i> L.	Broad-leaved glaucous spurge	Euphorbiaceae
P 81	<i>Cyclamen</i> sp.		Primulaceae
82	No specimen		
Polynerion - steppe on east facing hillslope in oakwood-pasture:			
P 83	<i>Filago pyramidata</i> L.		Compositae
84	<i>Hieracium/Pilosella</i> agg.		Compositae
85	<i>Leontodon</i> sp. (or could be <i>Crepis</i> sp.)	Hawkbit	Compositae
86	<i>Convolvulus arvensis</i> L.		Convolvulaceae
87	<i>Cynodon dactylon</i> (L.) Pers.	Bermuda grass	Gramineae
P 88	<i>Sanguisorba minor</i> Scop.		Rosaceae
89	<i>Galium rivale</i> (Sibth. & Sm.) Griseb.	Bedstraw	Rubiaceae
P 90	<i>Cynosurus elegans</i> Desf.		Gramineae
91.	<i>Piptatherum miliaceum</i> (L.) Cosson		Gramineae
92	<i>Festuca</i> cf. <i>glauca</i> Vill.		Gramineae
93	<i>Lolium perenne</i> L.	Ryegrass	Gramineae
94	<i>Agropyron</i> sp.		Gramineae
95	<i>Bromus hordeaceus</i>		Gramineae
96	<i>Taeniatherum caput-medusae</i> (L.) Nevski		Gramineae
97	<i>Lactuca viminea</i> (L.) J. & C. Presl.	Pliant lettuce	Compositae
P 98	<i>Lotus</i> cf. <i>corniculatus</i> L.	Birdsfoot-trefoil	Leguminosae
99	<i>Aegilops neglecta</i> Req. ex Bertol.		Gramineae
P100	<i>Polygonum aviculare</i> L.	Knotgrass	Polygonaceae
P101	<i>Cirsium</i> sp.	Thistle	Compositae
102	<i>Rumex tenuifolius</i> (Wallr.) A. Love	Dock, Sorrel	Polygonaceae
103	<i>Prunella grandiflora</i> (L.) Scholler	Large self-heal	Labiatae
P104	<i>Trifolium campestre</i> Schreber	Hop trefoil	Leguminosae
105	<i>Trisetum</i> sp. ? <i>flavescens</i> (L.) Beauv.		Gramineae
106	<i>Cynosurus cristatus</i> L.		Gramineae
107	<i>Phleum</i> sp. ? <i>pratense</i> L.		Gramineae
108	<i>Carex</i> sp.	Sedge	Cyperaceae
109	<i>Piptatherum miliaceum</i> (L.) Cosson		Gramineae
110	<i>Helianthemum nummularium</i> (L.) Miller		Cistaceae
111	<i>Potentilla</i> sp.	Cinquefoil	Rosaceae
112	<i>Agrostis</i> cf. <i>tenuis</i> Sibth.		Gramineae
113	<i>Lolium perenne</i> L.		Gramineae
114	<i>Carex</i> sp.	Sedge	Cyperaceae
115	<i>Juncus inflexus</i> L.	Rush	Juncaceae
Aetia - limestone gorge in mixed wood:			
116	<i>Euonymus verrucosus</i> Scop.	Warted spindle-tree	Celastraceae
117	<i>Ostrya</i> sp.		Corylaceae
Mirsina - <i>Phragmites</i> fen in oakwood:			
P118	<i>Phragmites australis</i> (Cav.) Trin. ex Steudel		Gramineae
119	<i>Carex</i> sp.	Sedge	Cyperaceae
120	<i>Lycopus europaeus</i> L.	Gipsy-wort	Labiatae
121	<i>Epilobium</i> sp.		Onagraceae
P122	<i>Equisetum palustre</i> L.		Equisetaceae

No.	Genus & species	Common name	Family
Mirsina - margin of <i>Phragmites</i> fen in oakwood:			
P123	<i>Mentha aquatica</i> L.	Water mint	Labiatae
P124	<i>Teucrium scordium</i> L.	Water germander	Labiatae
P125	<i>Pulicaria dysenterica</i> (L.) Bernh.	Fleabane	Compositae
P126	<i>Cirsium creticum</i> (Lam.) D'Urv.		Compositae
P127	<i>Cyperus</i> cf. <i>longus</i> L.	Sedge	Cyperaceae
P128	<i>Juncus inflexus</i> L.	Rush	Juncaceae
Mirsina - steppe near <i>Phragmites</i> fen in oakwood:			
129	<i>Corylus avellana</i> L.	Hazel	Corylaceae
P130	<i>Agrimonia eupatoria</i> L.	Agrimony	Rosaceae
P131	<i>Dorycnium graecum</i> (L.) Ser.		Leguminosae
P132	<i>Daucus carota</i> L.		Umbelliferae
P133	<i>Crepis</i> sp.	Hawksbeard	Compositae
134	<i>Brachypodium sylvaticum</i> (Hudson) Beauv.		Gramineae
P135	<i>Teucrium polium</i> L.	Felty germander	Labiatae
136	<i>Buglossoides purpureocaerulea</i> (L.) I. M. Johnston		Boraginaceae
137	<i>Teucrium chamaedrys</i> L.	Wall germander	Labiatae
138	<i>Cuscuta</i> sp.	Dodder	Convolvulaceae
139	<i>Carex</i> sp.	Sedge	Cyperaceae
140	<i>Taraxacum</i> sp. (glaucus)		Compositae
141	<i>Teucrium polium</i> L.	Felty germander	Labiatae
P142	<i>Petrorhagia fasciculata</i> (Margot & Reuter) P.W. Ball & Heywood		Caryophyllaceae
P143	<i>Alyssum murale</i> Waldst. & Kit.		Cruciferae
144	<i>Thymus</i> sp.	Thyme	Labiatae
145	<i>Galium verum</i> L.	Lady's bedstraw	Rubiaceae
146	<i>Dactylis glomerata</i> (agg.)		Gramineae
147	<i>Phleum</i> sp.		Gramineae
P148	<i>Scabiosa</i> sp.	Scabious	Dipsacaceae
P149	<i>Scilla autumnalis</i> L.		Liliaceae
P150	<i>Anchusa azurea</i> Miller	Large blue alkanet	Boraginaceae
151	<i>Melica ciliata</i> L.		Gramineae
P152	<i>Cichorium intybus</i> L.	Chicory	Compositae
153	<i>Salvia ?viridis</i> L.	Red-topped sage	Labiatae
Mirsina - ground cover in oak wood:			
154	<i>Cyclamen</i> sp.		Primulaceae
155	<i>?Thalictrum</i> sp.	Meadow rue	Ranunculaceae
156	<i>Elymus ?caninus</i> (L.) L.		Gramineae
157	<i>Tussilago farfara</i> L.	Coltsfoot	Compositae
P158	<i>Bupleurum asperuloides</i> Heldr. ex Boiss		Umbelliferae
Anelia - road verge in beech wood:			
P159	<i>Verbascum macrurum</i> Ten.		Scrophulariaceae
Anelia - dry land on edge of bog in beech wood:			
P160	<i>?Stachys</i> sp.	Woundwort	Labiatae
P161	<i>Lychnis coronaria</i> (L.) Desr. in Lam.	Rose campion	Caryophyllaceae
P162	<i>Geranium</i> sp.	Cranesbill	Geraniaceae
P163	<i>Digitalis ferruginea</i> L.	Rusty foxglove	Scrophulariaceae

No.	Genus & species	Common name	Family
Mirsina - steppe near <i>Phragmites</i> fen in oak wood:			
P164	<i>Opopanax hispidus</i> (Friv.) Griseb.		Umbelliferae
Gomara - dried lakebed in pine, <i>Pinus leucodermis</i>, wood-pasture:			
165	<i>Convolvulus arvensis</i> L.		Convolvulaceae
166	<i>Euphorbia myrsinites</i> L.	Broad-leaved glaucous spurge	Euphorbiaceae
P167	<i>Trifolium repens</i> L.		Leguminosae
168	<i>Juncus</i> sp.	Rush	Juncaceae
169	<i>Glyceria</i> sp.		Gramineae
Gomara - below lake in pine, <i>Pinus leucodermis</i>, wood-pasture:			
P170	<i>Echinops</i> cf. <i>?microcephalus</i> Sibth. & Sm.	Globe thistle	Compositae
Zakas to Agios Nikolaos - road verge in pine wood-pasture:			
171	<i>Cornus mas</i> L.	Cornelian cherry	Cornaceae
Perivolion/Avdella - pine/oak wood understorey:			
P172	<i>Hedera helix</i> L.	Ivy	Araliaceae
P173	<i>Lotus aegaeus</i> (Griseb.) Boiss		Leguminosae
P174	<i>Dorycnium pentaphyllum</i> Scop.		Leguminosae
P175	<i>Cuscuta</i> sp.	Dodder	Convolvulaceae
176	<i>Veronica</i> cf. <i>chamaedrys</i> L.	Germander speedwell	Scrophulariaceae
P177	<i>Teucrium</i> sp.	Germander	Labiatae
P178	<i>Alyssum murale</i> Waldst. & Kit.		Cruciferae
179	<i>Dactylis</i> sp.		Gramineae
180	<i>?Festuca</i> sp.		Gramineae
181	<i>Centaurea</i> sp.	Knapweed	Compositae
182	<i>?Hieracium/Pilosella</i> agg.		Compositae
183	<i>Pyrus communis</i> L.	Pear	Rosaceae
184	<i>Crataegus</i> sp.	Hawthorn	Rosaceae
Lowland plains - cultivated fields:			
185	<i>Triticum durum</i> Desf.	Durum wheat	Gramineae
186	<i>Triticum durum</i> Desf.	Durum wheat	Gramineae
187	<i>Hordeum distichon</i> L.	Two-rowed barley	Gramineae
Agios Nikolaos - understorey <i>Pinus nigra</i> wood:			
188	<i>Stachys</i> cf. <i>officinalis</i> (L.) Trevisan	Woundwort	Labiatae
189	<i>Prunella ?vulgaris</i> L.	Common self-heal	Labiatae
190	<i>Potentilla</i> sp.	Cinquefoil	Rosaceae
191	<i>Rubus caesius</i> L.	Dewberry	Rosaceae
192	<i>Viola</i> sp.	Violet, Pansy	Violaceae
193	cf. <i>Plantago</i>		
194	<i>?Daucus</i> sp.		Umbelliferae
195	<i>Echinops</i> sp.	Globe thistle	Compositae
196	<i>Thymus</i> sp.	Thyme	Labiatae
197	<i>Festuca ovina</i> L.		Gramineae
198	<i>Festuca ovina</i> L.		Gramineae
199	<i>Lathyrus</i> sp.	Pea, Vetch	Leguminosae

No.	Genus & species	Common name	Family
Above Zakas - mixed wood on limestone:			
200	<i>Rubus corylifolius</i> Sm.		Rosaceae
201	<i>Veronica</i> cf. <i>chamaedrys</i> L.	Germander speedwell	Scrophulariaceae
202	<i>Euphorbia</i> cf. <i>amygdaloides</i> L.		Euphorbiaceae
203	? <i>Lathyrus laxiflorus</i> (Desf.) O. Kuntze		Leguminosae
204	<i>Potentilla</i> sp. ? <i>sterilis</i> (L.) Garcke		Rosaceae
205	<i>Viola</i> sp.	Violet, Pansy	Violaceae
206	<i>Quercus</i> cf. <i>petraea</i> (Mattuschka) Liebl.		Fagaceae
207	<i>Pteridium aquilinum</i> (L.) Kuhn in Decken		Hypolepidaceae
208	<i>Acer opalus</i> Miller	Maple	Aceraceae
209	<i>Galium</i> sp.	Bedstraw	Rubiaceae
210	<i>Fagus sylvatica</i> L.	Beech	Fagaceae
211	<i>Abies cephalonica</i> Loudon	Greek fir	Pinaceae
212	<i>Primula elatior</i> (L.) Hill	Oxlip, Paigle	Primulaceae
213A	Indeterminate		
213B	<i>Luzula sylvatica</i> (Hudson) Gaudin	Wood rush	Juncaceae
214	<i>Brachypodium sylvaticum</i> (Hudson) Beauv.		Gramineae
214A	<i>Festuca</i> sp., <i>rubra</i> group		Gramineae
215	<i>Festuca</i> sp., <i>rubra</i> group		Gramineae
Above Zakas - road verge in pine wood-pasture:			
216	<i>Populus tremula</i> L.	Aspen	Salicaceae
P217	<i>Campanula trachelium</i> subsp. <i>athoa</i> (Boiss. & Heldr.) Hayek		Campanulaceae
Asprokampos - weeds in a barley field a few weeks after harvest:			
P218	<i>Consolida</i> sp.		Ranunculaceae
P219	<i>Polygonum aviculare</i> L.	Knotgrass	Polygonaceae
220			Gramineae
221			Gramineae
222			Gramineae
223	<i>Setaria</i> sp.		Gramineae
P224	<i>Avena</i> cf. <i>sterilis</i> L.	Wild oats	Gramineae
P225	<i>Triticum aestivum</i> L.	Bread wheat	Gramineae
P226	<i>Plantago lanceolata</i> L.		Plantaginaceae
P227	<i>Heliotropium hirsutissimum</i> Grauer		Boraginaceae
P228	<i>Hibiscus trionum</i> L.	Bladder ketmia	Malvaceae
229	<i>Anagallis</i> sp.	Pimpernel	Primulaceae
P230	<i>Solanum nigrum</i> L.	Black nightshade	Solanaceae
231	Indeterminate		
232	<i>Anagallis</i> sp.	Pimpernel	Primulaceae
232A	<i>Kickxia</i> sp.	Fluellen	Scrophulariaceae
233	<i>Eryngium</i> sp.		Umbelliferae
P234	<i>Chenopodium</i> cf. <i>album</i> L.	Goosefoot	Chenopodiaceae
235	<i>Plantago lanceolata</i> L.	Ribwort plantain	Plantaginaceae
236	<i>Cirsium arvense</i> (L.) Scop.	Creeping thistle	Compositae
237	<i>Sinapis alba</i> L.	White mustard	Cruciferae
238	<i>Geranium</i> sp. ? <i>molle</i> L.	Dove's-foot cranesbill	Geraniaceae
239	<i>Convolvulus arvensis</i> L.		Convolvulaceae
240	<i>Salix</i> sp.	Willow	Salicaceae
241	? <i>Atriplex</i> sp.	Oraches	Chenopodiaceae
242	Indeterminate		
243	<i>Lactuca viminea</i> (L.) J. & C. Presl.	Pliant lettuce	Compositae
244	<i>Lactuca viminea</i> (L.) J. & C. Presl.	Pliant lettuce	Compositae

No.	Genus & species	Common name	Family
245	<i>Lactuca virosa</i> L.	Poisonous lettuce	Compositae
246	<i>Cuscuta</i> sp.	Dodder	Convolvulaceae
Asprokamos - road verge in agricultural fields:			
P247	<i>Centaurea</i> sp.	Knapweed	Compositae
P248			Dipsacaceae
P249	<i>Mentha suaveolens</i> Ehrh.	Mint	Labiatae
P250	<i>Verbena officinalis</i> L.	Vervain	Verbenaceae
251	<i>Lactuca viminea</i> (L.) J. & C. Presl.	Pliant lettuce	Compositae
P252	<i>Salvia</i> sp.	Clary, Sage	Labiatae
P253	? <i>Sinapis alba</i> L.	White mustard	Cruciferae
P254	? <i>Scorzonera</i> sp.	?Vipergrass	Compositae
255	<i>Lactuca viminea</i> (L.) J. & C. Presl.	Pliant lettuce	Compositae
Asprokamos - oak wood understorey :			
256	<i>Alyssum murale</i> Waldst. & Kit.		Cruciferae
257	<i>Potentilla sterilis</i> (L.) Garcke		Rosaceae
258	<i>Scilla autumnalis</i> L.		Liliaceae
259	<i>Viola</i> sp.	Violet, Pansy	Violaceae
260	<i>Carlina corymbosa</i> L.	Flat-topped carline thistle	Compositae
261	<i>Dactylis</i> sp.		Gramineae
262	<i>Agrimonia</i> sp.	Agrimony	Rosaceae
263	<i>Teucrium chamaedrys</i> L.	Wall germander	Labiatae
264			Leguminosae
265	<i>Veronica chamaedrys</i> L.	Germander speedwell	Scrophulariaceae
266	<i>Crataegus monogyna</i> Jacq.	Hawthorn	Rosaceae
267	<i>Rosa</i> sp.		Rosaceae
268	<i>Buglossoides purpureocaerulea</i> (L.) I.M. Johnston	Gromwell	Boraginaceae
269	<i>Veronica</i> sp.	Speedwell	Scrophulariaceae
270	<i>Lotus</i> or <i>Dorycnium</i> sp.		Leguminosae
271	<i>Thymus</i> sp.	Thyme	Labiatae
272	<i>Potentilla</i> sp.	Cinquefoil	Rosaceae
273	<i>Chrysopogon gryllus</i> (L.) Trin.		Gramineae
274	<i>Teucrium polium</i> L.	Felty germander	Labiatae
275	<i>Arabis</i> sp.	Rock-cress	Cruciferae
276	<i>Prunella</i> sp.		Labiatae
P277	<i>Anthemis</i> sp. or <i>Leucanthemum</i> sp.	Chamomile	Compositae
278	<i>Veronica</i> cf. <i>chamaedrys</i> L.	Germander speedwell	Scrophulariaceae
279	<i>Clinopodium vulgare</i> L.	Wild basil	Labiatae
280	<i>Festuca</i> sp.		Gramineae
281	<i>Festuca</i> sp.		Gramineae
282	<i>Festuca</i> sp.		Gramineae
283	<i>Festuca</i> sp.		Gramineae
284	<i>Festuca</i> sp.		Gramineae
285	<i>Festuca ovina</i> L.		Gramineae
286	<i>Elymus</i> sp.		Gramineae
287			Leguminosae
288	<i>Hieracium</i> / <i>Pilosella</i> agg.		Compositae
289	<i>Sanguisorba minor</i> Scop.		Rosaceae
290	<i>Koeleria</i> sp.		Gramineae
291	<i>Koeleria</i> sp.		Gramineae
292	<i>Koeleria</i> sp.		Gramineae
293	<i>Galium verum</i> L.	Lady's bedstraw	Rubiaceae

No.	Genus & species	Common name	Family
294	<i>Fragaria vesca</i> L.	Wild strawberry	Rosaceae
295	<i>Stachys alopecuroides</i> (L.) Benth	Yellow betony	Labiatae
Avgo - mountain pine, <i>Pinus leucodermis</i>, wood-pasture:			
P306	<i>Pinus leucodermis</i> Antoine		Pinaceae
Asprokambos - oak wood			
<i>Quercus</i> leaves			
a	<i>Quercus cerris</i> L.	Turkey oak	Fagaceae
b	<i>Q. ?brachyphylla</i> Kotschy	Oak	Fagaceae
c	<i>Q. cerris</i> L. hybrid	Turkey oak	Fagaceae
d	<i>Q. cf. frainetto, ?cerris</i> L. x <i>frainetto</i> Ten.	Oak	Fagaceae
e	<i>Q. brachyphylla</i> Kotschy	Oak	Fagaceae
f	<i>Q. sp.</i>	Oak	Fagaceae
g	<i>Q. sp.</i>	Oak	Fagaceae
h	<i>Q. sp.</i>	Oak	Fagaceae
i	<i>Q. sp.</i>	Oak	Fagaceae
j	<i>Q. sp.</i>	Oak	Fagaceae
k	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
l	<i>Q. sp.</i>	Oak	Fagaceae
m	<i>Q. cf. cerris</i> L.	cf. Turkey oak	Fagaceae
n	<i>Q. cf. cerris</i> L.	cf. Turkey oak	Fagaceae
o	<i>Q. brachyphylla</i> Kotschy	Oak	Fagaceae
p	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
q	<i>Q. cerris</i> L. [x <i>virgiliana</i> ? (Ten.) Ten.]	Oak	Fagaceae
r	<i>Q. brachyphylla</i> Kotschy [x <i>cerris</i> L.?]	Oak	Fagaceae
s	<i>Q. pubescens</i> Willd., hybrid	White or Downy oak	Fagaceae
t	<i>Q. sp.</i>	Oak	Fagaceae
u	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
v	<i>Q. cerris</i> L., ?hybrid	Turkey oak	Fagaceae
w	<i>Q. sp.</i>	Oak	Fagaceae
x	<i>Q. sp.</i>	Oak	Fagaceae
y	<i>Q. sp.</i>	Oak	Fagaceae
z	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
aa	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
bb	<i>Q. sp.</i>	Oak	Fagaceae
cc	<i>Q. sp.</i>	Oak	Fagaceae
dd	<i>Q. sp.</i>	Oak	Fagaceae
ee	<i>Q. cerris</i> L., hybrid	Turkey oak	Fagaceae
ff	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
gg	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
hh	<i>Q. cerris</i> L., hybrid	Turkey oak	Fagaceae
ii	<i>Q. sp.</i> [cf. <i>cerris</i> L.]	Oak	Fagaceae
jj	<i>Q. sp.</i> [cf. <i>cerris</i> L.]	Oak	Fagaceae
kk	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
ll	<i>Q. sp.</i>	Oak	Fagaceae
mm	<i>Q. sp.</i>	Oak	Fagaceae
nn	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
oo	<i>Q. sp.</i>	Oak	Fagaceae
pp	<i>Q. sp.</i>	Oak	Fagaceae
qq	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
rr	<i>Q. sp.</i>	Oak	Fagaceae
ss	<i>Q. sp.</i>	Oak	Fagaceae

No.	Genus & species	Common name	Family
tt	<i>Q. cerris</i> L., hybrid [mainly <i>cerris</i> L.]	Turkey oak	Fagaceae
uu	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
vv	<i>Q. cerris</i> L., hybrid	Turkey oak	Fagaceae
ww	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
xx	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
yy	<i>Q. sp.</i>	Oak	Fagaceae
zz	<i>Q. sp.</i>	Oak	Fagaceae
aaa	<i>Q. brachyphylla</i> Kotschy	Oak	Fagaceae
bbb	<i>Q. cerris</i> L.	Turkey oak	Fagaceae
ccc	<i>Q. trojana</i> Webb in Loudon	Oak	Fagaceae
ddd	<i>Q. sp.</i>	Oak	Fagaceae
eee	<i>Q. sp.</i>	Oak	Fagaceae
fff	<i>Q. sp.</i>	Oak	Fagaceae
ggg	<i>Q. sp.</i>	Oak	Fagaceae

Appendix II

Laboratory preparation techniques for pollen and charcoal analysis

The object of these preparation techniques was to concentrate the palynomorphs and microscopic charcoal and remove extraneous matter. The process involves the step-by-step removal of carbonates, humic acids, silica, and cellulose by appropriate methods, separated by washing with distilled water and concentration using a centrifuge, followed by mounting and storage. Sieving to remove both coarse and fine unwanted material was also used.

Texts consulted for routine techniques of preparation of pollen samples were: Brown 1960; Kummel & Raup 1965; Erdtman 1969; Reitsma 1969; Faegri & Iversen 1975 & 1992; Moore & Webb 1978; Shackley 1981; Dimbleby 1985; Vidal 1988; Moore *et al* 1991 and Raine & Tremain 1992.

In the laboratory the highest standards of safety were followed (Muir 1977; Marshall 1981). A laboratory coat, rubber gloves and protective shoes were worn during all laboratory procedures. In addition, a face shield was worn while hydrofluoric acid (HF) and sulphuric acid (H₂SO₄) were being used. Both of these chemicals were handled under a fume hood. A paste of glycerin and magnesium oxide for the treatment of hydrofluoric acid burns/suspected burns was kept next to the fume cupboard.

Slides used throughout were 1-1.5 mm thick and 26 x 76 mm. Coverslips were number 1, 22 x 22 mm.

II.1 Laboratory preparation of moss polsters and litter, soil and wetland sequences

These laboratory preparations were carried out in the Palynology Laboratory, Geology Department, Victoria University of Wellington. Care was taken to ensure that samples were not contaminated with pollen circulating in the air. Ideally, the laboratory would be pollen-sterile with non-opening windows and any air ventilation should be through window spaces covered with filters. Before processing began, as a check on the sterility of the laboratory, microscope slides with glycerine jelly on their surface were left exposed in the laboratory for a month and then sealed. These slides were checked for any contaminant pollen circulating in the laboratory air. This was repeated several times. Initially the test slides captured significant numbers of pollen grains, so all the shelves and glassware were washed. Plastic tape was put around the windows, latex closed cell foam was placed around the door to stop draughts and an air filter was fitted to the only air inlet, a window into an internal hallway. This was particularly important since air extractors used under the fume hoods draw air into the room. Atmospheric pollen surveys carried out in Wellington show that *Pinus*, *Quercus*, *Cupressus*, *Populus*, *Fraxinus*, *Salix*, *Rumex*, *Chenopodiaceae*, *Plantago* and *Gramineae* are all present in the air in significant quantities at various times of the year (Clark 1951; Licitis 1953; Mirams 1953). These pollen types represent plant taxa extant in Grevena. After carrying out the above precautions contaminant pollen was minimal.

Polypropylene heat resistant Falcon 2070, 50 ml screw cap, conical based centrifuge tubes were used throughout the laboratory processing. A 5338 adapter was fitted to a Heraeus centrifuge to accommodate the tubes.

Samples were washed between each chemical treatment by adding distilled water to the centrifuge tube, centrifuging and decanting, twice. Samples were centrifuged at 3000 rpm for 4 minutes, unless otherwise stated, before being decanted to get rid of unwanted liquid. The distilled water was tested from time to time for contaminant pollen; none were found.

Extreme care was taken to avoid contamination. Each sample was given a laboratory number and equipment was used for that particular sample only, except the sieve, which was cleaned between each sample use. Glass rods were not allowed to come into contact with each other and care was also taken to ensure that cross contamination did not occur when centrifuge tubes were boiling together in water baths. All glassware and containers were washed in very hot water and laboratory grade detergent.

Only minor details differ between the extraction procedures used to extract palynomorphs from the moss polsters and litter, soil and wetland sequences. The subsurface samples from soil profiles and wetland sequences were prepared for absolute as well as relative counting procedures, so a vortex mechanical stirrer was used, where possible, in preference to stirring rods.

II.1.1 Laboratory preparation of moss polsters and litter samples

Seven steps were used to extract pollen, spores and microscopic charcoal from moss polsters and litter samples; hot potassium hydroxide (KOH) treatment, wet sieving, cold dilute hydrochloric acid (HCl) treatment, cold hydrofluoric acid (HF) treatment, acetolysis, cold potassium hydroxide and distilled water wash, and filtration. This was followed by dehydration in alcohol and silicone oil mounting.

The procedure used:

1) Potassium hydroxide treatment

This treatment was carried out to remove humic acids and effect deflocculation. The main purpose of the treatment was to break up the moss and allow effective sieving.

An amount of moss about the size of a matchbox was placed in 100 ml pyrex beaker, 80 ml 10% potassium hydroxide solution was added to the beaker before it was placed on a hot plate and boiled for 10 minutes while being stirred vigorously with a glass stirring rod to break up the moss.

The sample was not washed at this stage, but sieved first.

2) Wet sieving

This procedure was undertaken to remove the coarse inorganic and organic particles.

The samples were sieved and washed through a 260 μm aperture diameter sieve into 50 ml centrifuge tubes by squirting distilled water onto the residue on the sieve.

The same sieve was used for each sample so care was taken to clean the sieve thoroughly between each sample. This was done by squirting the sieve with a jet of water, then burning any residual organic matter by placing the sieve over a bunsen burner until the sieve was red hot. Distilled water was then squirted on the sieve to cool it.

The samples were then centrifuged and decanted, and washed in distilled water until the supernatant was clear.

The residue retained on the sieve was put into a glass vial with a mixture of 1:1 distilled water and glycerol with a small amount of phenol, for later inspection.

3) Cold hydrochloric acid treatment

This treatment was undertaken to dissolve carbonates. This must be done before hydrofluoric acid treatment to ensure that insoluble calcium fluoride (CaF_2) precipitates do not form.

20 ml 10% hydrochloric acid was added to each sample in the centrifuge tubes, stirred and left to stand overnight.

Next morning the samples were centrifuged and decanted.

4) Hydrofluoric acid digestion

This removed siliceous material and reduced the expansion of grains during acetolysis (Faegri & Iversen 1992:78).

15 ml of 40% hydrofluoric acid was added to the centrifuge tubes. This was stirred with teflon stirring rods (glass rods cannot be used as hydrofluoric acid corrodes glass) and left to stand overnight. The samples were centrifuged and decanted in the morning.

15 ml 10% hydrochloric acid was added to the centrifuge tubes which were placed in a water bath and gently heated to remove the silicofluorides and effect deflocculation. The samples were left in the water bath until the supernatant had turned a greenish-yellow colour. They were left in the water bath a few more minutes until the supernatant had become clear, then centrifuged and decanted. If the supernatant was not completely clear the hydrochloric acid treatment was repeated.

5) Acetolysis

This treatment destroyed cellulose and some other organic compounds.

The standard procedure for acetolysis was followed. Firstly, the samples were dehydrated (because sulphuric acid reacts with water) by adding 15 ml glacial acetic acid to the centrifuge tube, centrifuging and decanting. The acetolysis mixture of 1:9, concentrated sulphuric acid: acetic anhydride was then mixed by pouring the sulphuric acid very slowly into the acetic anhydride, as the procedure is exothermic and generates heat very rapidly to great temperatures. 15 ml of this mixture (it must be used fresh) was added to the centrifuge tubes which were then placed in a boiling water bath for 4 minutes while they were stirred. The tubes were removed from the bath and 5 ml glacial acetic acid was added to stop acetolysis. The samples were then centrifuged and decanted.

15 ml glacial acetic acid was then added to the centrifuge tubes and left to stand for 5 minutes to ensure that acetolysis had stopped.

The samples were then centrifuged and decanted, and washed in distilled water.

6) Potassium hydroxide wash

This neutralized any residual acid and washed the sample.

20 ml 10% potassium hydroxide solution was added to the centrifuge tube which was then centrifuged and decanted. The samples then had 20 ml distilled water added, and were centrifuged and decanted thrice.

7) Filtration

To remove very fine organic and mineral particles, and insoluble fluorides, and concentrate the pollen.

The samples were filtered through a 6.5 μ m nylon monofilament mesh filter cloth with distilled water using a Sartorius membrane filtering unit SM165-10, fitted to a laboratory stand, and supplied with normal/inverted vacuum suction (Raine & Tremain 1992; Vidal 1988).

8) Dehydration

The samples required treatment with absolute alcohol so that evaporation would be complete when mounting in silicone oil.

Samples were washed in 95% ethanol, then tertiary butyl alcohol = 2-methyl propan-2-ol (TBA), in the following manner:

30 ml of 95% ethanol was added to the centrifuge tubes, stirred on a mechanical stirrer, then centrifuged and decanted. This was repeated.

20 ml tertiary butyl alcohol was added to the centrifuge tubes, stirred on a mechanical stirrer, then centrifuged and decanted. This was repeated.

9) Mounting

Silicone oil, refractive index 1.40, was used as the mounting media. Silicone oil "200 Fluid" at 1000 centistokes and "200 Fluid" at 12500 centistokes was supplied by Ajax Chemicals, Auckland. These two viscosities were blended by weight to achieve the required 2000 cs viscosity.

A microscope slide was heated on a histology hotplate to about 110° C. About 4 drops of silicone oil was deposited on the centre of the slide, using a 0.5 ml disposable insulin syringe. The required amount of oil varied according to the thickness of the thickest particles on the slide. The oil has to completely cover the area under a 22 mm square coverslip without oozing out the sides of it.

Using a micropipetter (Finnpipette, 200-1000 μ l) with disposable polypropylene tips (Finntip 61, for volume range 200-1000 μ l), a volume of agitated suspension was transferred to the drop of silicone oil on the slide (the volume did not need to be known as these slides were prepared for relative pollen frequency calculations only). All the suspension in the micropipette tip was dispensed very slowly onto the slide and the tip discarded. The tertiary butyl alcohol was allowed to completely evaporate. The slide was removed from the hotplate and allowed to cool a little before the cover slip was placed over the oil. The slide was returned to the hotplate for the oil to completely fill the space under the coverslip.

The slide was cooled and sealed carefully with clear nail varnish. Slides were kept horizontal.

II.1.2 Laboratory preparation of soil samples

The laboratory preparation of these samples was undertaken in the Palynology Section laboratory of the Institute of Geological and Nuclear Sciences, Lower Hutt.

These samples were prepared for the calculation of the absolute concentration of palynomorphs as well as relative frequency, therefore they were dried then volumetrically measured and weighed prior to processing. To minimize sample loss, a mechanical stirrer was used where possible in preference to using stirring rods and the samples remained in the same centrifuge tubes for the entire extraction procedure except when wet sieving was carried out.

The extraction procedure was very similar to that carried out for the moss polster and litter samples. The differences were that two steps were added at the beginning of the procedure, one to disaggregate the samples and the other to remove carbonates, and stronger hydrochloric acid was used to effect deflocculation after the hydrofluoric acid treatment.

1) Disaggregation

20 ml 5 % Calgon (sodium hexametaphosphate) solution was added to the centrifuge tubes. The tubes were placed on a rotating shaker table overnight, centrifuged and decanted the following morning, then washed.

2) Hydrochloric acid treatment

To remove carbonates.

20 ml 10% hydrochloric acid was added to the centrifuge tube and the amount of effervescence recorded, as an indication of the amount of calcareous material present. When the effervescing ceased, samples were centrifuged and decanted, then washed twice in distilled water.

3) Potassium hydroxide treatment

To remove humic acids and effect deflocculation.

20 ml 10% potassium hydroxide solution was added to the centrifuge tube. A glass rod was used to disperse the sample. The centrifuge tubes were placed in a hot water bath and stirred for 10 minutes.

4) Wet sieving

To remove the coarse inorganic and organic particles.

The samples were sieved and washed through a 260 μm aperture diameter sieve into 50 ml centrifuge tubes in the same manner as for the moss polster and litter samples.

5) Hydrofluoric acid digestion

To remove siliceous material and reduce the expansion of grains during acetolysis.

Hydrofluoric acid treatment for the soil samples was different from that for the moss polster and litter samples in that the sample was treated with hot hydrofluoric acid.

The samples were first washed in cold 10% hydrochloric acid (to ensure the removal of carbonates and prevent the formation of calcium fluoride precipitate), then 10 ml 40 % hydrofluoric acid was added to the centrifuge tubes. The tubes were then placed in a hot water bath for one hour. The water bath was turned off, but the samples were left in it overnight. In the morning fresh hydrofluoric acid was added and the samples stirred, then the water bath was turned on again for one hour. If the silicates had not dissolved, further treatment was given, by adding fresh hydrofluoric acid and heating. When all the silicates had dissolved, the samples were centrifuged and decanted and given a hot hydrochloric acid treatment similar to that given to the moss polster and litter samples, except 25% hydrochloric acid was used initially to effect deflocculation, then the samples had cold 10% hydrochloric acid added before centrifugation and washing.

6) Acetolysis

Acetolysis destroys cellulose and some other organic compounds.

This was carried out in the same manner as for the moss polster and litter samples.

7) Filtration

To remove very fine organic and mineral particles, and insoluble fluorides, and concentrate the pollen.

The samples were filtered in the same manner as for the moss polster and litter samples.

As a check the filtrate which passed through the filter cloth was retained and examined for palynomorphs; none were found.

8) Dehydration

The samples were washed in 95% ethanol twice, then tertiary butyl alcohol twice in the same manner as for the moss polster and litter samples.

9) Mounting

Silicone oil, blended as described above, was used as the mounting media.

A standard microscope slide was heated on a histology hotplate to about 110° C. About 4 drops of silicone oil was deposited on the centre of the slide, using a 0.5 ml disposable insulin syringe. The required amount of oil varied according to the thickness of the thickest particles on the slide. The oil had to completely cover the area under a 22 mm square coverslip without oozing out the sides of it.

Using a micropipetter (Finnpipette, 200-1000 μ l) with disposable polypropylene tips (Finntip 61, for volume range 200-1000 μ l), a known volume ("aliquot") of agitated suspension was transferred to the drop of silicone oil on the slide. All the suspension in the micropipette tip was dispensed very slowly onto the slide and the tip discarded. The tertiary butyl alcohol was allowed to completely evaporate. The slide was removed from the hotplate and allowed to cool a little before the cover slip was placed over the oil. The slide was returned to the hotplate for the oil to completely fill the space under the coverslip.

The slide was cooled and sealed carefully with clear nail varnish. Slides were kept horizontal.

II.1.3 Laboratory preparation of wetland samples

These laboratory preparations were carried out in the Palynology laboratory, Geology Department, Victoria University of Wellington.

These samples were prepared for the calculation of the absolute concentration of palynomorphs as well as relative frequency, therefore they were volumetrically measured and weighed prior to processing. To minimize sample loss, a mechanical stirrer was used where possible in preference to using stirring rods and the samples remained in the same centrifuge tubes for the entire extraction procedure except when wet sieving was carried out.

All samples were processed uniformly.

The extraction procedure was very similar to that carried out for the soil samples. The differences were that a spike of *Lycopodium* spores was added to the sample before extraction began, so that pollen, spore and charcoal concentrations could be calculated using the exotic marker grain method; no initial disaggregation treatment was given, the initial hydrochloric acid treatment included heating the samples, and no filtering was done.

1) Spike added

A known volume of a prepared spike of *Lycopodium* spores was added to the 1 cc wet sample in the 50 ml centrifuge tube, so that pollen concentration could be calculated.

2) Hydrochloric acid treatment

20 ml 10% hydrochloric acid was added to the centrifuge tubes and the amount of effervescence recorded, as an indication of the amount of calcareous material present. When the effervescing had ceased, the tubes were placed in a hot water bath either for 5 minutes or until the effervescing stopped. Centrifuged and decanted. 15 ml of 10% hydrochloric acid was then added to the tubes. The sample was centrifuged and decanted and washed twice in distilled water.

3) Potassium hydroxide treatment

This was carried out using the same procedures as for the soil samples except the colour of the supernatant, after heating, was compared to the Munsell Chart and recorded, as a measure of humification.

4) Wet sieving

Wet sieving was carried out in the same manner, as for the soil samples.

5) Hydrofluoric acid digestion

Hydrofluoric acid digestion was effected in the same manner as for the soil samples.

However, flocculation of some of the samples persisted after the hot hydrochloric acid treatment, especially in samples from the Gomara sequence. It was found that the mechanical stirrer did not effect dispersal. When this occurred the centrifuge tube was suspended in a Unisonics 40 KHz ultrasonic transducer tank for a few seconds only, until dispersal was achieved (Gray 1965:534-5). Although prolonged ultrasonic treatment may damage delicate pollen (McIntyre & Norris 1964; Dodson 1983), it appeared that in the Grevena samples only pine grains may have been subject to breakage, bladders being broken off bodies, but it is not certain that this occurred during ultrasonic irradiation. The following treatment with 95% ethanol assisted with dispersal of the organic particles.

6) Acetolysis

Acetolysis was carried out in the same manner as for the soil samples.

7) Dehydration

The samples were washed in 95% ethanol twice, then tertiary butyl alcohol twice, in the same manner as the soil samples.

8) Mounting

Samples from the Anelia and Kellia sites where the exotic marker grain technique for pollen and spore concentration calculates only was used were mounted using the technique described above for the soil samples.

Samples from the Gomara site where the aliquot technique for calculating pollen and spore concentrations was used, as well as the exotic marker grain technique, were mounted with precisely measured known volumes (aliquots) from a suspension of known volume, as outlined below.

Special technique of measuring aliquots from a suspension for pollen and spore concentration calculations:

a) The residue was carefully washed into a volumetric flask (either 10 or 25 ml depending on the volume of residue), using a small glass funnel and wash bottle with warm tertiary butyl alcohol. The volume of the suspension was made up to the graduation mark with tertiary butyl alcohol, using a micropipette for fine control. The flask was stoppered and the suspension mixed by shaking the flask. Once the suspension was completely mixed it was quickly tipped into a labelled, straight sided, soda glass Samco specimen tube with polythene stopper. This is the first dilution, and when the residue was sufficiently diluted it was used directly for slide making. When further dilution was necessary, this was achieved by the method outlined in (b) below.

b) The residue in the specimen tube vial was agitated to completely suspend it, then 1 ml was promptly withdrawn using a graduated, spring-loaded measuring syringe (Manostat Varipet). The 1 ml was discharged into a 10 ml volumetric flask and the volume made up to the graduation mark. This second dilution was then 1/10 of the concentration of the initial dilution.

c) A standard 26 x 76 mm microscope slide was heated on a histology hotplate to about 110° C. About 4 drops of 2000 cs viscosity silicone oil (Dow Corning "200 Fluid") was deposited on the centre of the slide, using a 0.5 ml disposable insulin syringe. The amount of oil varied according to the thickness of the thickest particles on the slide. The oil had to completely cover the area under a 22 mm square coverslip without oozing out the sides. This was most important because the aliquot method of calculating pollen concentration requires that the total number of palynomorphs placed on the slide be counted.

d) Using a micropipetter (Finnpipette, 200-1000 μ l) with disposable polypropylene tips (Finntip 61, for volume range 200-1000 μ l), a known volume ("aliquot") of agitated suspension was transferred to the drop of silicone oil on the slide. All the suspension in the micropipette tip was dispensed very slowly onto the slide and the tip discarded. The tertiary butyl alcohol was allowed to completely evaporate. The slide was removed from the hotplate and allowed to cool a little before the cover slip was placed over the oil. The slide was returned to the hotplate for the oil to completely fill the space under the coverslip. The slide was cooled and sealed carefully with clear nail varnish. Slides were kept horizontal.

II.1.4 *Lycopodium* spike preparation

Preparation, calibration, and addition of the spike to samples are all quantitative procedures so special care was taken at each step to ensure accuracy. Statistical calculations are treated by Maher (1981).

Preparation of spike

0.5 g of *Lycopodium* spores, donated by Greer Laboratories, Inc., North Carolina, U.S.A. were placed in a 50 ml conical bottom centrifuge tube.

1) Wetting

The *Lycopodium* spores were washed 2x in distilled water with a very small amount of liquid detergent added. Centrifuged and decanted after each.

2) Acetolysis

The spores were dehydrated in glacial acetic acid. Centrifuged and decanted.

The acetolysis mixture of 9 ml acetic anhydride followed by 1 ml concentrated sulfuric acid was mixed. This was poured onto the spores in the tube, stirred, and placed in an actively boiling water bath for 2 minutes only; centrifuged and decanted.

Rinsed 1x with glacial acetic acid. Centrifuged and decanted.

Rinsed 4x with distilled water. Centrifuged and decanted after each.

3) Staining

About 10 drops of 0.5% safranin were added with a little water and left for one or two minutes. The spores were then washed with 95% ethanol, then distilled water.

4) Suspension

The stained *Lycopodium* spores were washed into a 250 ml glass conical flask containing a magnetic flea. The flask was filled with a 1:1 mixture of glycerine and water with 3 or 4 grains of phenol to act as a preservative.

5) Calibration

To determine the exact concentration of *Lycopodium* spores in the spike, aliquots of known volume were mounted on microscope slides. The *Lycopodium* spores were then counted.

The following procedure was followed:

The suspension was thoroughly stirred on a magnetic stirrer, then one ml was withdrawn with a Manostat Varipet dispenser (a calibrated syringe, 1-10 ml). This was diluted to 10 mls in a volumetric flask. Two hundred microlitres was put on a microscope slide using a micropipetter (Finnpipette, 200-1000 μ l) with disposable polypropylene tips (Finntip 61, for volume range 200-1000 μ l) and all the *Lycopodium* on the slide were counted. Five microscope slides were made from this dilution (Dilution 1). Another dilution was made as above and 5 more slides were made, then the *Lycopodium* counted (Dilution 2).

6) Storage

The standardized mixture was stored in the 250 ml glass conical flask it was mixed in. The magnetic flea was left in the flask. The flask was covered tightly with parafilm, to minimize evaporation, and stored in a refrigerator. The calibration was checked from time to time.

7) Usage

An aliquot of the spike was added to each sample at the beginning of pollen extraction procedure. The following procedure was followed:

(a) Mixing: The flask was placed on a magnetic stirring plate for 3/4 hour before dispensing. Just before using, the flask was hand-swirled so that no grains were trapped on the sides or in vortex patterns.

(b) Dispensing: The Manostat Varipet or the Finnpipette as described above were used for dispensing.

II.1.5 Laboratory procedure for diatom extraction

Ten samples were prepared for diatom analysis by removing organic matter and sand in the following way:

1) Weighing of sample

Samples were weighed so that approximate concentration calculations could be made. 0.5 g of wet sample was weighed and placed in 50 ml centrifuge tubes.

2) Oxidation to remove organic matter

The samples were boiled in 30% hydrogen peroxide (H_2O_2) for 4 hours. The samples were then washed in distilled water twice, being centrifuged at 3000 rpm for 8 minutes each time.

3) Removal of sand by decantation

The 50 ml centrifuge tubes were filled to the 45 ml graduation mark with distilled water. The tubes

were shaken for about ¼ minute (until no sediment was adhering to the base of the tube), then let stand for ¾ minute, before being decanted into another 50 ml centrifuge tube. (The diatoms were then in the decanted suspension). The sand was discarded from original tube and the process repeated, returning the suspension to the original tube. Tubes were centrifuged for 8 minutes at 3000 rpm and decanted.

4) Dilution

The samples were diluted with 5 ml of ethanol.

5) Mounting

Diatom suspensions were mounted in Hyrax diluted with toluene (methyl benzene).

II.2 Laboratory preparation of pollen reference material

The laboratory preparation of the reference collection was undertaken in the Palynology Section laboratory of the Institute of Geological and Nuclear Sciences, Lower Hutt.

The main objectives of this procedure are the removal of protoplasm and expansion of the palynomorph to make the morphology of the exine clearly visible. This also leaves the grains in a physical condition more similar to fossilized grains.

Sixteen samples were processed simultaneously, in 15 ml conical bottom polypropylene centrifuge tubes with self-attached press-on tops. Centrifuging was done at 2500 revolutions per minute for three minutes.

Both herbarium and fresh plant material were treated in the same manner except that, in the case of fresh material, an initial step was added, the samples being soaked in 95% ethanol for about 10 minutes to remove any oils or fats from the plant material.

1) Wetting

Each sample was soaked overnight in 3 ml of wetting agent (a few drops of liquid detergent added to a 400 ml squirt bottle of distilled water), to assist the removal of cell contents by hydrating and softening the plant material.

The sample was then boiled in a water bath (lid open) for at least 10 minutes to further soften and wet the plant material, then centrifuged and decanted.

2) Acetolysis

Most importantly this step removes the protoplasm of the grains. It also destroys cellulose and some other organic compounds, thus removing organic debris.

Three to four ml of glacial acetic acid (CH_3COOH) was added to the centrifuge tubes to dehydrate the plant material and prevent a reaction between the water and the acetolysis mixture. This was centrifuged then decanted. The acetolysis mixture was then mixed under a fume cupboard.

The acetolysis mixture consists of 9 parts (90 ml) acetic anhydride ($(\text{CH}_3\text{CO})_2\text{O}$) and 1 part (10 ml) concentrated sulphuric acid (H_2SO_4). The sulphuric acid is added to the acetic anhydride very slowly to prevent overheating. The mixture was poured into a 250 ml glass beaker to mix the two liquids. The quantities given above made a double quantity of the mixture. Since this mixture needs to be used fresh it was important that two batches of samples were processed close together.

Three ml of the acetolysis mixture was drawn-up into a graduated glass pipette, then added to the centrifuge tube which was placed in a boiling waterbath for 4 minutes. The sample was stirred frequently with a glass rod. The tubes were then removed and glacial acetic acid was added to the tubes up to 5 ml to stop acetolysis. The samples were immediately centrifuged and decanted.

Three ml glacial acetic acid was added to the centrifuge tube to dissolve the soluble products of acetolysis (e.g. cellulose acetate). This was stirred with a vortex mechanical mixer, then centrifuged and decanted.

3) Rinsing

The samples were rinsed at least twice, usually thrice, in distilled water by adding 3 ml distilled water, stirring, centrifuging and decanting.

4) Bleaching

In a very few cases, that is, with thick walled pollen such as that of Geraniaceae, the standard acetolysis procedure followed rendered the pollen too dark for identification. In these cases the pollen was bleached. This also had the benefit of removing some extraneous plant material. The following procedure was used:

1. 10 ml stock bleach (31 g NaOCl (sodium hypochlorite)/1000 ml distilled water) was added to 90 ml distilled water.
2. 1 ml of this diluted bleaching solution was added to the centrifuge tube of the pollen to be bleached. This was stirred on a mechanical stirrer and allowed to stand for 5 minutes.
3. The centrifuge tube was then filled up to 10 mls with distilled water to slow the bleaching action, then immediately centrifuged.
4. The residue was washed twice in distilled water.

5) Mounting and sealing

No stain was added to the pollen.

Glycerine jelly, refractive index less than 1.47 (about 1.43), was used as a mounting media. The following glycerine jelly mixture was used: 35 g sheet gelatin, 95 ml distilled water, 165 g glycerol and 5 g phenol.

A drop of residue was placed on a microscope slide with a disposable pipette which was then discarded. The slide was warmed on a hot-plate (80-100° C) and the water was allowed to almost completely evaporate. A drop of warm melted glycerine jelly was added to the residue and gently mixed with a toothpick until uniformly spread. The mixture was allowed to spread to almost the size of the coverslip before the coverslip was placed over the residue.

When the slide had cooled, clear nail-varnish was painted around the coverslip to seal the edges.

6) Storage of residue

Excess residue was left in the centrifuge tubes. A small amount of 1:1 distilled water and glycerol with a small amount of phenol (a fungicide) was added, then the centrifuge tubes were sealed.

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Appendix III

Sediment description

III.1 Troels-Smith characterization of unconsolidated sediments

Troels-Smith, J. 1955. Karakterisering af løse jordarter. Characterisation of unconsolidated sediments. *Danm. Geol. Unders. Ser. IV*, 3(10), 73pp.

Basic terms of this classification system are explained under the following headings:

- 1) Component elements
- 2) Accessory elements
- 3) Physical properties and *limes*
- 4) Humicity

Characterization is based on a 5 - class scale, 0 indicating a lack of the feature and 4 indicating maximum expression of that feature. The values are:

Class value	0 - absence of
	1 - minor presence of
	2 - medium presence of
	3 - major presence of
	4 - maximum, or sole, presence of
Traces	+ - slight presence of

1) Component elements

Substantia humosa (*Sh*) - humous substance, consists of completely disintegrated, or nearly disintegrated, or decomposed, organic substances or precipitated humic acids. Completely humified *Turfa* (peat) may be characterized as *Substantia humosa*.

Turfa (*T*) - macroscopic structure consisting of mosses, or roots of woody or herbaceous plants. Stumps, trunks, stems, belong to *Turfa* if connected with the root system.

T. bryophytica (Tb^{0-4}) - moss peat. +/- humous substance (superscript indicates degree of humicity).

T. lignosa (Tl^{0-4}) - root systems of woody plants, and stumps, trunks, branches, etc connected to the roots. +/- humous substance.

T. herbacea (Th^{0-4}) - root systems and stems and leaves connected to the roots of herbaceous plants. +/- humous substance.

Detritus (*D*) - consists of fragments, varying in size, of the superterranean parts of plants not connected to root systems, thus forming a contrast to *Turfa*.

D. lignosus (*DI*) - fragments of ligneous plants > 2 mm.

D. herbosus (*Dh*) - fragments of herbaceous plants > 2 mm.

D. granosus (*Dg*) - fragments of ligneous and herbaceous plants, and, sometimes, of animal fossils (except molluscs) > c. 0.1 < 2 mm.

Limus (L) - mudlike (gyttja), homogeneous deposit, consisting of particles or colloids < 0.1 mm.

L. detritus (Ld^0) - plants and animals (except diatoms, needles of spongi, siliceous skeletons, etc, of organic origin), or fragments of these. Particles < c. 0.1 mm. +/- humous substance.

L. humosus ($Lh = Ld^4$) - 'dy' i.e. completely humified, colloidal material.

L. siliceus organogenes (Lso) - diatoms, needles of spongi, siliceous skeletons, etc, of organic origin, or parts of these. Particles < c. 0.1 mm.

L. calcareus (Lc) - marl, not hardened like calcareous tufa; lime and the like. Particles < c. 0.1 mm.

L. ferrugineus (Lf) - rust, non-hardened. Particles < c. 0.1 mm.

Argilla (A) - mineral particles < 0.06 mm.

A. steatodes (As) - particles of clay < 0.002 mm.

A. granosa (Ag) - particles of clay 0.002 to 0.06 mm.

Grana (G) - solid particles > 0.06 mm.

G. arenosa (Ga) - mineral particles 0.06 to 0.6 mm.

G. saburralia (Gs) - mineral particles 0.6 to 2.0 mm.

G. glareosa minora ($Gg (min)$) - mineral particles 2.0 to 6.0 mm.

G. glareosa majora ($Gg (maj)$) - mineral particles 6.0 to 20.0 mm.

2) Accessory elements

Trunci et rami - trunks, branches, and twigs

[Roman numerals I to IV indicate thickness

I	=	< 5 mm
II	=	5 - 20 mm
III	=	20 - 50 mm
IV	=	< 50 mm]

3) Physical properties and *limes*

Nigror - degree of darkness.

nigror 0 the lightest shades occurring in deposits, e.g. clear quartz sand.

nigror 1 light shades, e.g. calcareous clay.

nigror 2 medium shades, e.g. fresh swamp peat.

nigror 3 dark shades, e.g. partly decayed swamp peat.

nigror 4 darkest shades occurring in deposits, e.g. completely decomposed peat.

Stratificatio - degree of stratification. May manifest itself in the ease with which the deposit splits horizontally, in the horizontal position of macro-detritus, or in the division of the deposit into minor layers.

stratificatio 0 indicates complete homogeneity of the deposit in question, or/and that the deposit breaks with equal ease in all directions.

stratificatio 1 to 3 indicates intermediate stages between *stratificatio* 0 and 4.

stratificatio 4 indicates that the deposit in question consists of very thin minor layers, or/and that it splits very easily in very thin horizontal layers.

Elasticitas - degree of elasticity. The ability of the sediment to regain its original form after being exposed to pressure, squeezing, or bending; the greater its power of resistance, the greater its degree of elasticity.

elasticitas 0 indicates total absence of elasticity: e.g. plastic clay, sand, diatom deposits, fen peat, completely disintegrated swamp peat.

elasticitas 1 to 3 indicate intermediate stages between *elasticitas* 0 and 4.

elasticitas 4 indicates the highest degree of elasticity occurring in deposits, e.g. fresh sphagnum peat, and swamp peat.

Siccitas - degree of dryness. The basis of classification here is dryness (dry substance), not humidity (water).

<i>siccitas</i> 0	indicates clear water.
<i>siccitas</i> 1	indicates a deposit thoroughly saturated with water, its consistency being very soft, or like thick gruel.
<i>siccitas</i> 2	indicates a deposit saturated with water, i.e. the condition in which deposits normally occur below the ground water level. It should be noted that the percentage of water content may vary considerably in different deposits having <i>siccitas</i> 2.
<i>siccitas</i> 3	indicates a deposit not saturated with water.
<i>siccitas</i> 4	indicates a deposit air-dry.

Structura - the 5 - class scale is not used for this, but notes should include properties such as plasticity, cohesion, adhesion.

Limes - the boundary between two sediment units which are different as regards physical conditions. The smaller the zone of mixing between two deposits, the more well-defined the boundary. Sharpness of boundary is indicated in the following way:

	<i>lim.</i> 0 -	boundary area > 1 cm
-----	<i>lim.</i> 1 - <i>diffusus</i>	boundary area < 1 cm & > 2 mm
———	<i>lim.</i> 2 - <i>conspicuus</i>	boundary area < 2 mm & > 1 mm
———	<i>lim.</i> 3 - <i>manifestus</i>	boundary area < 1 mm & > 0.5 mm
———	<i>lim.</i> 4 - <i>acutus</i>	boundary area < 0.5 mm

4) Humicity

Humositas - the degree of disintegration or decomposition observable in the organic substance of all kinds of *Turfa* and *Limus detritus* - indicates the quantity of humic acids (soluble in potassium hydroxide). Increasing degrees of *humositas* are shown symbolically by increasing the thickness of the strokes. In formula it is shown in superscript. In this category, 4 indicates total disintegration, whereas 0 indicates that disintegration processes have not yet begun.

<i>humositas</i> 0	indicates plant structure fresh and well-preserved, no homogeneous ground substance present. A lump of peat, when squeezed in the hand, yields clear, colourless water.
<i>humositas</i> 1	indicates plant structure well-preserved, homogeneous ground substance present in slight quantity. Squeezing yields more or less dark-coloured, perhaps turbid, water. One-fourth, at most, of the mass is squeezed out between the fingers, in the form of a homogeneous ground substance.
<i>humositas</i> 2	indicates plant structure partly decayed, though distinct. Squeezing yields up to half the mass in the form of a homogeneous substance.

- humositas 3* indicates plant structure in advanced stage of decay, and indistinct. Squeezing yields up to three-fourths of the mass in the form of a homogeneous ground substance.
- humositas 4* indicates plant structure hardly discernible, or completely absent. By squeezing, the whole of the peat mass, or nearly the whole of it, passes out between the fingers.

III.2 Comparison of grain size class scales of inorganic sediments

Troels-Smith			Udden/Wentworth
Argilla			Mud
<i>A. steatodes</i>	<i>As</i>	Clay particles <0.002 mm	Clay <0.0039 mm
<i>A. granosa</i>	<i>Ag</i>	Clay particles 0.002 to 0.06 mm	Silt; coarse, medium, fine, v.fine 0.0039 to 0.0625 mm
Grana			Sand
<i>G. arenosa</i>	<i>Ga</i>	Mineral particles 0.06 to 0.6 mm	Sand; v.fine, fine, medium 0.0625 to 0.5 mm
<i>G. saburralia</i>	<i>Gs</i>	Mineral particles 0.6 to 2.0 mm	Sand; coarse, v.coarse 0.5 to 2.00 mm
<i>G. glareosa minora</i> <i>Gg(min)</i>		Mineral particles 2.0 to 6.0 mm	Gravel Granule 2.0 to 4.0 mm
<i>G. glareosa majora</i> <i>Gg(maj)</i>		Mineral particles 6.0 to 20.0 mm	Pebble 4.0 to 64.0 mm

Appendix IV

Radiocarbon dating results and calibration

Guide:

Radiocarbon dating laboratory reference numbers:

NZA = Rafter radiocarbon laboratory, Nuclear Sciences Group, Institute of Geological & Nuclear sciences, Lower Hutt.

Wk = Waikato radiocarbon dating laboratory, University of Waikato, Hamilton.

Calibrated ages were calculated using the CALIB program of Stuiver & Reimer (1995).

Radiocarbon Age BP is the conventional radiocarbon age before 'present' (years BP), based on the half-life of 5568 years, as defined by Stuiver and Polach (1977), the present being AD1950.

†This standard deviation (error) includes a laboratory error multiplier.

1 σ = square root of (sample std. dev.² + curve std. dev.²)

2 σ = 2 x square root of (sample std. dev.² + curve std. dev.²)

*1955 denotes influence of bomb C-14

NOTE: Calibrated ("Cal") ages and ranges are rounded to the nearest year which is too precise since all the standard deviations in the radiocarbon age are greater than 50 years. Rounding to the nearest 10 years would be more appropriate.

Following the textual reporting of the results and calibration are graphical representations.

Gomara 52-53 cm

NZA 3481

Radiocarbon Age BP 1747 $\pm$ 64

Calibrated ages: Cal AD 261, 286, 325

Reference: Stuiver and Pearson 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal AD age ranges	relative area under probability distribution
68.3 (1 σ)	Cal AD 239 - 387	1.00
95.4 (2 σ)	Cal AD 135 - 426	1.00

Gomara 81-87 cm

Wk 1810

Radiocarbon Age BP 1940 $\pm$ 96†

Calibrated age: Cal AD 76
(40 year moving average)

Reference: Stuiver and Pearson 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal AD/BC age ranges	relative area under probability distribution
68.3 (1 σ)	Cal BC 25 - Cal AD 160	0.85
	Cal AD 161 - 203	0.15
95.4 (2 σ)	Cal BC 166 - Cal AD 269	0.98
	Cal AD 288 - 325	0.02

Gomara 111-112 cm
NZA 3482

Radiocarbon Age BP 2103 ± 73

Calibrated age: Cal BC 105

Reference: Stuiver and Pearson 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal AD/BC age ranges	relative area under probability distribution
68.3 (1 σ)	Cal BC 195 - 30	0.93
	27 - 7	0.07
95.4 (2 σ)	Cal BC 359 - 283	0.11
	255 - Cal AD 60	0.89

Gomara 156-157 cm
NZA 3477

Radiocarbon Age BP 2749 ± 66

Calibrated ages: Cal BC 897, 871, 867

Reference: Pearson and Stuiver 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal BC age ranges	relative area under probability distribution
68.3 (1 σ)	Cal BC 973 - 967	0.03
	933 - 818	0.97
95.4 (2 σ)	Cal BC1028 - 800	1.00

Gomara 186-190 cm
Wk 1811

Radiocarbon Age BP 3070 ± 144

Calibrated ages: Cal BC 1367, 1354, 1314
(40 year moving average)

Reference: Pearson and Stuiver 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal BC age ranges	relative area under probability distribution
68.3 (1 σ)	Cal BC1501 - 1487	0.03
	1466 - 1118	0.97
95.4 (2 σ)	Cal BC1617 - 925	1.00

Anelia 124-125 cm
NZA 3480

Radiocarbon Age BP 268 ± 61

Calibrated age: Cal AD 1651

Reference: Stuiver and Pearson 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal AD age ranges	relative area under probability distribution
68.3 (1 σ)	Cal AD 1515 - 1592	0.41
	1621 - 1676	0.39
	1774 - 1800	0.13
	1942 - *1955	0.07
95.4 (2 σ)	Cal AD 1469 - 1693	0.73
	1727 - 1815	0.19
	1922 - *1955	0.08

Anelia 240-245 cm
Wk 1813

Radiocarbon Age BP 360 ± 96

Calibrated ages: Cal AD 1511, 1600, 1616

Reference: Stuiver and Pearson, 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal AD age ranges	relative area under probability distribution
68.3 (1 σ)	Cal AD 1464 - 1638	1.00
95.4 (2 σ)	Cal AD 1404 - 1684	0.93
	1743 - 1807	0.05
	1932 - *1955	0.02

Kellia 71-72 cm
NZA 3478

Radiocarbon Age BP 69 ± 59

Calibrated age: Cal AD *1955

Reference: Stuiver and Pearson 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal AD age ranges	relative area under probability distribution
68.3 (1 σ)	Cal AD 1698 - 1722	0.18
	1817 - 1920	0.82
95.4 (2 σ)	Cal AD 1679 - 1768	0.31
	1802 - 1939	0.69

Kellia 166-168 cm
Wk 1808

Radiocarbon Age BP 480 ± 88

Calibrated age: Cal AD 1436

Reference: Stuiver and Pearson 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal AD age ranges	relative area under probability distribution
68.3 (1 σ)	Cal AD 1323 - 1338	0.06
	1393 - 1514	0.83
	1593 - 1620	0.11
95.4 (2 σ)	Cal AD 1307 - 1362	0.12
	1377 - 1635	0.88

Kellia 296-307 cm
Wk 1809

Radiocarbon Age BP 540 ± 88

Calibrated age: Cal AD 1416
(80 year moving average)

Reference: Stuiver and Pearson 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal AD age ranges	relative area under probability distribution
68.3 (1 σ)	Cal AD 1324 - 1447	1.00
95.4 (2 σ)	Cal AD 1272 - 1506	0.97
	1571 - 1611	0.03

Kellia 315-316 cm
NZA 6894

Radiocarbon Age BP 3669 ± 80

Calibrated age(s) Cal BC 2031, 1992, 1989

Reference: Pearson and Stuiver 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal BC age ranges	relative area under probability distribution
68.3 (1 σ)	Cal BC 2140 - 1922	1.00
95.4 (2 σ)	Cal BC 2280 - 2210	0.05
	2210 - 1872	0.91
	1840 - 1811	0.02
	1809 - 1780	0.02

Kellia 394-395 cm
NZA 3483

Radiocarbon Age BP 2707 ± 79

Calibrated age: Cal BC 830

Reference: Pearson and Stuiver 1993

Cal AD/BC age ranges (Cal ages as above) from probability distribution:

% area enclosed	Cal BC age ranges	relative area under probability distribution
68.3 (1 σ)	Cal BC 921 - 800	1.00
95.4 (2 σ)	Cal BC 1112 - 1102	0.00
	1063 - 761	0.99
	626 - 596	0.01
	572 - 569	0.00

References

- Pearson, G.W. and M. Stuiver 1993. High-precision bidecadal calibration of the radiocarbon time scale, 500-2500 BC. *Radiocarbon* 35: 25-33.
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- Stuiver, M. and H.A. Polach 1977. Discussion reporting of ^{14}C data. *Radiocarbon* 19(3): 355-363.
- Stuiver, M. and P.J. Reimer 1993. Extended ^{14}C data base and revised CALIB radiocarbon age calibration program. *Radiocarbon* 35: 215-230.
- Stuiver, M. and P.J. Reimer 1995. *CALIB user's guide rev. 3.0.3c*. Quaternary isotope laboratory, University of Washington.

Appendix V

Modern pollen and spore reference collection

This is a register of all the pollen and spore reference slides used to assist with making a pollen key and identifying fossil pollen and spores in surface samples and wetland sequences collected in Grevena Province. The collection has been ordered alphabetically according to family.

Slide numbers prefixed 'VUWG' are held in the Geology Department of Victoria University of Wellington, those prefixed 'NUNG', 'DUDB' or 'CRYG' were made in England from reference pollen residues held in the following respective universities: Newcastle Upon Tyne (Department of Geography), Durham (Department of Botany) and the College of Ripon & York (Department of Geography). Permission to use these residues was given by the following individuals who had prepared the residues: Drs A. Stevenson, B. Huntley and M. Atherden.

Herbaria are identified thus:

WELT = Natural History Unit, National Museum of New Zealand, Wellington, New Zealand.

WELTU = Biological Sciences, Victoria University of Wellington, Wellington, New Zealand.

Taxonomic names are taken from the herbarium sheets, where applicable, and because some of the specimens were collected last century they do not always follow *Flora Europaea* (1964-80). The taxonomic names of pollen and spores collected from living plants follow texts as outlined: taxonomic names of vascular European species follow Tutin *et al.* (1964-80), except where taxa have been described more recently in Strid (1989) and Strid & Tan (1991). Taxonomic names of non-vascular species follow Watson (1968).

Pollen/spore reference number	Family	Genus & species	Collector of herbarium specimen (if known)/herbarium, slide herbarium collection number (if known) & place of collection of herbarium specimen
PTERIDOPHYTA SPHENOPSIDA			
NUNG	4 Equisetaceae	<i>Equisetum arvense</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG	775 Equisetaceae	<i>Equisetum palustre</i>	Chester 122. Mirsina, Grevena Pr., NW Greece.
FILICOPSIDA			
NUNG	174 Aspleniaceae	<i>Asplenium septentrionale</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG	90 Aspleniaceae	? <i>Asplenium</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
SPERMATOPHYTA GYMNOSPERMAE			
NUNG	34 Cupressaceae	? <i>Cupressus macrocarpa</i>	Stevenson, Newcastle Upon Tyne University, England.
DUDB	309 Cupressaceae	<i>Cupressus</i> sp.	Huntley, Durham University, England.

Pollen/spore reference slide #		Family	Genus & species	Collector (if known)/herbarium, herbarium # (if known), place of collection
DUDB	310	Cupressaceae	<i>Cupressus</i> sp.	Huntley, Durham University, England.
VUWG	1290	Cupressaceae	<i>Juniperus virginiana</i>	WELTU box 204; Rotorua, N.Z.
NUNG	93	Cupressaceae	<i>Juniperus</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
NUNG	94	Ephedraceae	<i>Ephedra fragilis</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG	1287	Pinaceae	<i>Abies cephalonica</i>	WELTU 15257; Rotorua, N.Z.
VUWG	810	Pinaceae	<i>Abies ?nordmanniana</i>	Chester 331. Ewen Bridge, Lower Hutt, N.Z.
NUNG	231	Pinaceae	<i>Abies pinsapo</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG	226	Pinaceae	<i>Cedrus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG	58	Pinaceae	<i>Picea abies</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG	218	Pinaceae	<i>Picea abies</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG	100	Pinaceae	<i>Picea marina</i>	Stevenson, Newcastle Upon Tyne University, England.
CRYG	294	Pinaceae	<i>Pinus halepensis</i>	Atherden, College of Rippon & York, England.
VUWG	774	Pinaceae	<i>Pinus leucodermis</i>	Chester 306. Lakkos, Grevena Pr., NW Greece.
VUWG	786	Pinaceae	<i>Pinus mugo</i>	Chester 307. Wellington Botanic Gardens, N.Z.
NUNG	179	Pinaceae	<i>Pinus mugo</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG	10	Pinaceae	<i>Pinus nigra</i>	Stevenson, Newcastle Upon Tyne University, England.
DUDB	295	Pinaceae	<i>Pinus nigra</i>	Huntley, Durham University, England.
VUWG	824	Pinaceae	<i>Pinus</i> sp.	Chester 345. Victoria University, Wellington, N.Z.
NUNG	219	Taxaceae	<i>Taxus baccata</i>	Stevenson, Newcastle Upon Tyne University, England.

ANGIOSPERMAE

Dicotyledones

VUWG	1420	Acanthaceae	<i>Acanthus mollis</i>	WELTU; Wellington, N.Z.
VUWG	317	Acanthaceae	<i>Acanthus mollis</i>	WELT 69900a; Wairau Ck, Milford, N.Z.
VUWG	318	Acanthaceae	<i>Acanthus mollis</i>	WELT 60469c; Kelburn, Wellington, N.Z.
VUWG	319	Acanthaceae	<i>Acanthus mollis</i>	WELT no #; Seatoun Rd, Wellington, N.Z.
VUWG	320	Acanthaceae	<i>Acanthus mollis</i>	WELT 60469b; Kelburn, Wellington, N.Z.
VUWG	1139	Acanthaceae	<i>Aclathoda vesica</i>	WELTU; Old Delhi, India.
VUWG	1140	Acanthaceae	<i>Barleria cristata</i>	WELTU; India.
VUWG	957	Aceraceae	<i>Acer campestre</i>	WELTU box 97; Holland.
VUWG	405	Aceraceae	<i>Acer parviflorum</i>	WELT no #.

Pollen/spore reference slide #	Family	Genus & species	Collector (if known)/herbarium, herbarium # (if known), place of collection
VUWG 404	Aceraceae	<i>Acer pseudoplatanus</i>	WELT 61195; S Karori Rd, Wellington, N.Z.
VUWG 809	Aceraceae	<i>Acer pseudoplatanus</i>	Chester 330. Ewen Bridge, Lower Hutt, N.Z.
DUDB 296	Aceraceae	<i>Acer pseudoplatanus</i>	Huntley, Durham University, England.
VUWG 956	Aceraceae	<i>Acer tegmentosum</i>	WELTU box 97; Russia.
VUWG 610	Amaranthaceae	<i>Amaranthus</i> sp.	WELT 62832; Kaiti Hill, Gisborne, N.Z.
VUWG 611	Amaranthaceae	<i>Amaranthus</i> sp.	WELT 62642; Auckland City, N.Z.
VUWG 612	Amaranthaceae	<i>Amaranthus</i> sp.	WELT 70543; Pukerua Bay, Wellington, N.Z.
VUWG 613	Amaranthaceae	<i>Amaranthus</i> sp.	WELT 69990; Pukerua Bay, Wellington, N.Z.
VUWG 614	Amaranthaceae	<i>Amaranthus</i> sp.	WELT 70063; Rongotai, Wellington, N.Z.
NUNG 173	Anacardiaceae	<i>Pistacia lentiscus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 192	Anacardiaceae	<i>Pistacia lentiscus</i>	Stevenson, Newcastle Upon Tyne University, England.
CRYG 281	Anacardiaceae	<i>Pistacia lentiscus</i>	Atherden, College of Rippon & York, England.
NUNG 53	Anacardiaceae	<i>Pistacia terebinthus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 18	Anacardiaceae	<i>Rhus typhina</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 162	Anacardiaceae	<i>Schinus molle</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 396	Apocynaceae	<i>Nerium oleander</i>	WELT 59811; Muriwai, Auckland, N.Z.
VUWG 392	Apocynaceae	<i>Vinca major</i>	WELT 60724; S Karori Rd, Wellington, N.Z.
VUWG 393	Apocynaceae	<i>Vinca major</i>	WELT 60705; Raroa Rd, Wellington, N.Z.
VUWG 394	Apocynaceae	<i>Vinca major</i>	WELT 63331; Lake Pupuke, Milford, N.Z.
VUWG 395	Apocynaceae	<i>Vinca minor</i>	WELT 60864; Karori, Wellington, N.Z.
VUWG 744	Araliaceae	<i>Hedera helix</i>	Chester 172. Agios Nicholas, Grevena Pr., NW Greece.
VUWG 932	Araliaceae	<i>Hedera helix</i>	WELTU box 95; Holland.
DUDB 306	Betulaceae	<i>Alnus cordata</i>	Huntley, Durham University, England.
VUWG 1292	Betulaceae	<i>Alnus glutinosa</i>	WELTU 10304; Wanganui, N.Z.
VUWG 423	Betulaceae	<i>Alnus glutinosa</i>	WELT 70134; near Tuakau, Franklin Co., N.Z.
VUWG 778	Betulaceae	<i>Alnus glutinosa</i>	WELTU 10304; Wanganui, N.Z.
VUWG 859	Betulaceae	<i>Alnus glutinosa</i>	WELTU box 86; Whakarara, Hawke Bay, N.Z.
VUWG 814	Betulaceae	<i>Alnus ?glutinosa</i>	Chester 335. Wellington City, N.Z.
DUDB 304	Betulaceae	<i>Alnus incana</i>	Huntley, Durham University, England.

Pollen/spore reference slide #		Family	Genus & species	Collector (if known)/herbarium, herbarium # (if known), place of collection
DUDB	305	Betulaceae	<i>Alnus incana</i>	Huntley, Durham University, England.
VUWG	858	Betulaceae	<i>Alnus ?viridis</i>	WELTU box 86; Switzerland.
VUWG	777	Betulaceae	<i>Betulus alba</i>	WELTU 10305; Botanic Gardens, Wellington, N.Z.
VUWG	860	Betulaceae	<i>Betula manshurica</i>	WELTU box 86; Russia.
VUWG	1291	Betulaceae	<i>Betula pendula</i>	WELTU; Wellington Botanic Gardens, N.Z.
VUWG	812	Betulaceae	<i>Betula pendula</i>	Chester 333. Riddiford Gardens, Lower Hutt, N.Z.
CRYG	291	Betulaceae	<i>Betula</i> sp.	Atherden, College of Rippon & York, England.
VUWG	733	Boraginaceae	<i>Anchusa azurea</i>	Chester 150. Mirsina, Grevena Pr., NW Greece.
VUWG	946	Boraginaceae	<i>Anchusa officinalis</i>	WELTU box 97; Holland.
VUWG	198	Boraginaceae	<i>Borago officinalis</i>	WELT 60707; Norway St, Wellington, N.Z.
VUWG	199	Boraginaceae	<i>Borago officinalis</i>	WELT 61247; Island Bay, Wellington, N.Z.
VUWG	818	Boraginaceae	<i>Borago officinalis</i>	Chester 339. Garden, Johnsonville, Wellington, N.Z.
VUWG	200	Boraginaceae	<i>Cerinthe major</i>	WELT 60831; Dr Thomson's Garden, Hawera, N.Z.
VUWG	201	Boraginaceae	<i>Cerinthe major</i>	WELT 62660; E Coast Rd, Milford, Waitemata Co., N.Z.
VUWG	202	Boraginaceae	<i>Echium plantagineum</i>	WELT 69892a; Wairau Ck Estuary, Milford, N.Z.
VUWG	203	Boraginaceae	<i>Echium plantagineum</i>	WELT 69892b; Wairau Ck Estuary, Milford, N.Z.
VUWG	204	Boraginaceae	<i>Echium plantagineum</i>	WELT 60815
VUWG	205	Boraginaceae	<i>Echium vulgare</i>	WELT 9217
VUWG	206	Boraginaceae	<i>Echium vulgare</i>	WELT 59819; Desert Rd, Central Nth Is., N.Z.
VUWG	207	Boraginaceae	<i>Echium vulgare</i>	WELT 63485; Te Awanga, Hawkes Bay, N.Z.
VUWG	947	Boraginaceae	<i>Heliotropium ellipticum</i>	WELTU box 97; India.
VUWG	755	Boraginaceae	<i>Heliotropium hirsutissimum</i>	Chester 227. Asprokampos, Grevena Pr., NW Greece.
VUWG	208	Boraginaceae	<i>Lithospermum arvense</i>	WELT (no #)
VUWG	209	Boraginaceae	<i>Lithospermum arvense</i>	WELT 60829; Otago, N.Z.
VUWG	210	Boraginaceae	<i>Lithospermum arvense</i>	WELT 60828; Auckland, N.Z.
VUWG	805	Boraginaceae	<i>Lithospermum ?diffusa</i>	Chester 326. Wellington Botanic Gardens, N.Z.
VUWG	948	Boraginaceae	<i>Lithospermum</i> sp.	WELTU box 97; Switzerland.
VUWG	1399	Boraginaceae	<i>Myosotis arvensis</i>	WELTU 15241; Karori, Wellington, N.Z.
VUWG	214	Boraginaceae	<i>Myosotis arvensis</i>	WELT 63225; nr Mangatuna, Waiapu County, N.Z.
VUWG	215	Boraginaceae	<i>Myosotis arvensis</i>	WELT 9210; Waikanae, N.Z.
NUNG	50	Boraginaceae	<i>Myosotis arvensis</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG	216	Boraginaceae	<i>Myosotis discolor</i>	WELT 62881; Mitimiti, Nth Hokianga, N.Z.

Pollen/spore reference slide #	Family	Genus & species	Collector (if known)/herbarium, herbarium # (if known), place of collection
VUWG 217	Boraginaceae	<i>Myosotis discolor</i>	WELT 60820; Crib Ck, Kaikoura, N.Z.
VUWG 218	Boraginaceae	<i>Myosotis discolor</i>	WELT 60819; Hills above Crib Ck, Kaikoura, N.Z.
VUWG 219	Boraginaceae	<i>Myosotis laxa caespitosa</i>	WELT 2494; Western Bay, Taupo, N.Z.
VUWG 220	Boraginaceae	<i>Myosotis laxa caespitosa</i>	WELT 42845
VUWG 222	Boraginaceae	<i>Myosotis scorpioides</i>	WELT 63496; Lake Wairarapa, N.Z.
VUWG 223	Boraginaceae	<i>Myosotis scorpioides</i>	WELT 62587; Kenepuru Valley, N.Z.
VUWG 225	Boraginaceae	<i>Myosotis scorpioides</i>	WELT 45433c; Wellington, N.Z.
VUWG 226	Boraginaceae	<i>Myosotis scorpioides</i>	WELT 45431; Wellington, N.Z.
VUWG 221	Boraginaceae	<i>Myosotis scorpioides</i>	WELT 70396; Clinton to Matura Rd, N.Z.
VUWG 224	Boraginaceae	<i>Myosotis scorpioides</i> subsp. <i>strigulosa</i>	WELT 60825; Wellington, N.Z.
VUWG 227	Boraginaceae	<i>Myosotis sylvatica</i>	WELT 70361; Kitchener Rd, Milford, N.Z.
VUWG 228	Boraginaceae	<i>Myosotis sylvatica</i>	WELT 60366; Sth Karori Rd, Wellington, N.Z.
VUWG 229	Boraginaceae	<i>Myosotis sylvatica</i>	WELT 60365; Karori, Wellington, N.Z.
VUWG 639	Boraginaceae	<i>Myosotis</i> sp.	Chester 1. Anelia, Grevena Pr., NW Greece.
VUWG 211	Boraginaceae	<i>Symphytum officinale</i>	WELT 70181; Rotorua, N.Z.
VUWG 212	Boraginaceae	<i>Symphytum officinale</i>	WELT 61316; Johnsonville, Wellington, N.Z.
VUWG 213	Boraginaceae	<i>Symphytum officinale</i>	WELT 60368; Karori, Wellington, N.Z.
VUWG 950	Boraginaceae	<i>Symphytum officinale</i>	WELTU box 97; Holland.
VUWG 951	Boraginaceae	<i>Symphytum officinale</i>	WELTU box 97; Holland.
VUWG 952	Boraginaceae	<i>Symphytum officinale</i>	WELTU box 97; Holland.
VUWG 382	Butomaceae	<i>Butomus umbellatus</i>	WELT no #; Medway Tanbridge, Kent, UK.
VUWG 416	Buxaceae	<i>Buxus sempervirens</i>	WELT no #; Surrey, England.
VUWG 57	Calyceraceae	<i>Acicarpa tribuloides</i>	WELT 63172
VUWG 1167	Campanulaceae	<i>Campanula latifolia</i>	WELTU; Voguez nr Strasburg, France.
VUWG 1168	Campanulaceae	<i>Campanula persicifolia</i>	WELTU.
VUWG 1434	Campanulaceae	<i>Campanula persicifolia</i>	WELTU; Wellington, N.Z.
VUWG 1169	Campanulaceae	<i>Campanula rapunculoides</i>	WELTU; Holland.
VUWG 191	Campanulaceae	<i>Campanula rapunculoides</i>	WELT 63154a; Miramar, Wellington, N.Z.
VUWG 192	Campanulaceae	<i>Campanula rapunculoides</i>	WELT 60733a; Norway St, Wellington, N.Z.
VUWG 193	Campanulaceae	<i>Campanula rapunculoides</i>	WELT 60733b; Norway St, Wellington, N.Z.
VUWG 1170	Campanulaceae	<i>Campanula rapunculus</i>	WELTU; Holland.
VUWG 1171	Campanulaceae	<i>Campanula rotundifolia</i>	WELTU.
NUNG 207	Campanulaceae	<i>Campanula rotundifolia</i>	Stevenson, Newcastle Upon Tyne University, England.

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NUNG 188	Campanulaceae	<i>Campanula trachelium</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 750	Campanulaceae	<i>Campanula trachelium</i> subsp. <i>athoa</i>	Chester 217. Above Ziakas, Grevena Pr., NW Greece.
VUWG 1166	Campanulaceae	<i>Campanula</i> sp.	WELTU; Germany.
VUWG 644	Campanulaceae	<i>Campanula</i> sp.	Chester 6. Anelia, Grevena Pr., NW Greece.
VUWG 194	Campanulaceae	<i>Solenopsis laurentia</i>	WELT 70717; Houhora Cemetery, Northland, N.Z.
VUWG 195	Campanulaceae	<i>Trachelium caeruleum</i>	WELT 62677; Symonds St Cemetery, Auckland, N.Z.
VUWG 196	Campanulaceae	<i>Trachelium caeruleum</i>	WELT 59812; Muriwai, Auckland, N.Z.
VUWG 197	Campanulaceae	<i>Wahlenbergia marginata</i>	WELT 70621; Taylors Mistake, Canterbury, N.Z.
VUWG 869	Cannabaceae	<i>Cannabis sativa</i>	WELTU box 86; Holland.
VUWG 38	Caprifoliaceae	<i>Leycesteria formosa</i>	WELT 62579; Picton, N.Z.
VUWG 1436	Caprifoliaceae	<i>Lonicera japonica</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 33	Caprifoliaceae	<i>Lonicera japonica</i>	WELT 60467; Sth Karori, Wellington, N.Z.
VUWG 34	Caprifoliaceae	<i>Lonicera japonica</i>	WELT 8401; Opunake, N.Z.
VUWG 35	Caprifoliaceae	<i>Lonicera japonica</i>	WELT 60637; Wadestown, Wellington, N.Z.
VUWG 36	Caprifoliaceae	<i>Lonicera japonica</i>	WELT 60468; Karori, Wellington, N.Z.
VUWG 37	Caprifoliaceae	<i>Lonicera nitida</i>	WELT 60721; Sth Karori Rd, Wellington, N.Z.
VUWG 1155	Caprifoliaceae	<i>Lonicera periclymenum</i>	WELTU; Holland.
VUWG 1156	Caprifoliaceae	<i>Sambucus ebulus</i>	WELTU; Switzerland.
VUWG 1157	Caprifoliaceae	<i>Sambucus nigra</i>	WELTU; Holland.
VUWG 1437	Caprifoliaceae	<i>Sambucus nigra</i>	WELTU; Wellington, N.Z.
VUWG 1438	Caprifoliaceae	<i>Sambucus nigra</i>	WELTU 10397; Dunedin, N.Z.
VUWG 39	Caprifoliaceae	<i>Sambucus nigra</i>	WELT 63177
VUWG 40	Caprifoliaceae	<i>Sambucus nigra</i>	WELT 63017; Pukerua Bay, Wellington, N.Z.
VUWG 41	Caprifoliaceae	<i>Sambucus nigra</i>	WELT 63016; Wellington, N.Z.
NUNG 227	Caprifoliaceae	<i>Sambucus nigra</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 157	Caprifoliaceae	<i>Sambucus nigra</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1158	Caprifoliaceae	<i>Sambucus racemosa</i>	WELTU; Holland.
VUWG 42	Caprifoliaceae	<i>Viburnum tinus</i>	WELT 60900; Sth Karori Rd, Wellington, N.Z.
VUWG 43	Caprifoliaceae	<i>Viburnum tinus</i>	WELT 60774; Tinakori Rd, Wellington, N.Z.
VUWG 892	Caryophyllaceae	<i>Agrostemma githago</i>	WELTU box 87; Holland.
VUWG 1314	Caryophyllaceae	<i>Arenaria serpyllifolia</i>	WELTU 7654; Granity Pass, Owen Ra., N.Z.
VUWG 622	Caryophyllaceae	<i>Arenaria serpyllifolia</i>	WELT 62133.
VUWG 623	Caryophyllaceae	<i>Arenaria serpyllifolia</i>	WELT 61881.
VUWG 624	Caryophyllaceae	<i>Arenaria serpyllifolia</i>	WELT 13644.
VUWG 1315	Caryophyllaceae	<i>Cerastium arvense</i>	WELTU 10274; Taieri Plain, N.Z.

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VUWG 625	Caryophyllaceae	<i>Cerastium arvense</i>	WELT 13627; Broken River Basin, Canterbury, N.Z.
VUWG 626	Caryophyllaceae	<i>Cerastium fontanum triviale</i>	WELT 61886; Campbell Island, N.Z.
VUWG 628	Caryophyllaceae	<i>Cerastium glomeratum</i>	WELT 70098a; Milford, Waitemata Co., N.Z.
VUWG 629	Caryophyllaceae	<i>Cerastium glomeratum</i>	WELT 60934; Hokio Beach, Levin, N.Z.
VUWG 630	Caryophyllaceae	<i>Cerastium glomeratum</i>	WELT 60935; Hokio Beach, Levin, N.Z.
NUNG 65	Caryophyllaceae	? <i>Cerastium glomeratum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 893	Caryophyllaceae	<i>Cerastium semidecandrum</i>	WELTU box 87; Holland.
VUWG 627	Caryophyllaceae	<i>Cerastium vulgare</i>	WELT 13626; Waikanae, N.Z.
VUWG 1316	Caryophyllaceae	<i>Dianthus armeria</i>	WELTU 15219; Mt Richmond, N.Z.
VUWG 1317	Caryophyllaceae	<i>Dianthus barbatus</i>	WELTU 10272; Cape Wanbrow, Oamaru, N.Z.
VUWG 894	Caryophyllaceae	<i>Dianthus carthusianorum</i>	WELTU box 87; Black Forest, Germany.
VUWG 631	Caryophyllaceae	<i>Dianthus deltoides</i>	WELT 70417; Rakaia River, Canterbury, N.Z.
VUWG 642	Caryophyllaceae	<i>Dianthus</i> sp.	Chester 4. Anelia, Grevena Pr., NW Greece.
VUWG 700	Caryophyllaceae	<i>Dianthus</i> sp.	Chester 72. Polineri, Grevena Pr., NW Greece.
VUWG 832	Caryophyllaceae	<i>Dianthus</i> sp.	Chester 353. Victoria University, Wellington, N.Z.
VUWG 802	Caryophyllaceae	<i>Dianthus</i> sp. [cultivar]	Chester 323. Wellington Botanic Gardens, N.Z.
VUWG 803	Caryophyllaceae	<i>Dianthus</i> sp. [cultivar]	Chester 324. Wellington Botanic Gardens, N.Z.
VUWG 804	Caryophyllaceae	<i>Dianthus</i> sp. [cultivar]	Chester 325. Wellington Botanic Gardens, N.Z.
VUWG 632	Caryophyllaceae	<i>Holosteum umbellatum</i>	WELT 78162; Central Otago, N.Z.
VUWG 738	Caryophyllaceae	<i>Lychnis coronaria</i>	Chester 161. Anelia, Grevena Pr., NW Greece.
VUWG 895	Caryophyllaceae	<i>Lychnis diurna</i>	WELTU box 87; Holland.
VUWG 896	Caryophyllaceae	<i>Lychnis flore alba</i>	WELTU box 87; Holland.
VUWG 898	Caryophyllaceae	<i>Lychnis vespertina</i>	WELTU box 87; Holland.
VUWG 897	Caryophyllaceae	<i>Lychnis viscida</i>	WELTU box 87; Holland.
VUWG 899	Caryophyllaceae	<i>Moehringia muscosa</i>	WELTU box 87; Switzerland.
VUWG 729	Caryophyllaceae	<i>Petrorhagia fasciculata</i>	Chester 142. Mirsina, Grevena Pr., NW Greece.
VUWG 633	Caryophyllaceae	<i>Sagina procumbens</i>	WELT 70913; Rakaia River, Canterbury, N.Z.
VUWG 634	Caryophyllaceae	<i>Sagina procumbens</i>	WELT 70813; Belmont, Hutt Valley, N.Z.
VUWG 635	Caryophyllaceae	<i>Sagina procumbens</i>	WELT 60540; S Karori, Wellington, N.Z.
VUWG 900	Caryophyllaceae	<i>Saponaria officinalis</i>	WELTU box 87; Holland.
VUWG 901	Caryophyllaceae	<i>Saponaria officinalis</i>	WELTU box 87.
VUWG 902	Caryophyllaceae	<i>Saponaria officinalis</i>	WELTU box 87.

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VUWG 903	Caryophyllaceae	<i>Scleranthus annuus</i>	WELTU box 87; Holland.
VUWG 638	Caryophyllaceae	<i>Silene alba</i>	WELT 13617.
NUNG 139	Caryophyllaceae	<i>Silene alpestris</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 637	Caryophyllaceae	<i>Silene armeria</i>	WELT 61803; S Karori, Wellington, N.Z.
VUWG 636	Caryophyllaceae	<i>Silene dioica</i>	WELT 60872; S Karori, Wellington, N.Z.
VUWG 1318	Caryophyllaceae	<i>Silene gallica</i>	WELTU 10267; Andersons Bay, Dunedin, N.Z.
VUWG 1319	Caryophyllaceae	<i>Silene gallica</i>	WELTU.
VUWG 1320	Caryophyllaceae	<i>Silene gallica</i>	WELTU 15217; Wellington, N.Z.
NUNG 201	Caryophyllaceae	<i>Silene gallica</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 217	Caryophyllaceae	<i>Silene micropetala</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 890	Caryophyllaceae	<i>Silene nutans</i>	WELTU box 87; Holland.
NUNG 196	Caryophyllaceae	<i>Silene otites</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 889	Caryophyllaceae	<i>Silene vulgaris</i>	WELTU box 87; Holland.
VUWG 1321	Caryophyllaceae	<i>Silene vulgaris maritima</i>	WELTU.
VUWG 794	Caryophyllaceae	<i>Silene vulgaris</i> subsp. <i>maritima</i>	Chester 315. Wellington Botanic Gardens, N.Z.
VUWG 1322	Caryophyllaceae	<i>Silene</i> sp.	WELTU; Karori, Wellington, N.Z.
VUWG 905	Caryophyllaceae	<i>Stellaria alsine</i>	WELTU box 87; Holland.
VUWG 1323	Caryophyllaceae	<i>Stellaria graminea</i>	WELTU 10277; Taieri Plain, N.Z.
VUWG 904	Caryophyllaceae	<i>Stellaria graminea</i>	WELTU box 87; Holland.
CRYG 284	Caryophyllaceae	<i>Stellaria holostea</i>	Atherden, College of Rippon & York, England.
VUWG 906	Caryophyllaceae	<i>Stellaria media</i>	WELTU box 87; India.
NUNG 48	Caryophyllaceae	<i>Stellaria</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1324	Chenopodiaceae	<i>Atriplex patula</i>	WELTU 11569; Cape Turakirae, Wellington, N.Z.
VUWG 1325	Chenopodiaceae	<i>Atriplex patula</i>	WELTU 10289; Waipiro Bay, N.Z.
VUWG 603	Chenopodiaceae	<i>Atriplex patula</i>	WELT 70720; Taieri, Otago, N.Z.
NUNG 174	Chenopodiaceae	<i>Atriplex</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
NUNG 43	Chenopodiaceae	<i>Beta vulgaris</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1326	Chenopodiaceae	<i>Chenopodium album</i>	WELTU 15311; Waikanae, N.Z.
VUWG 1327	Chenopodiaceae	<i>Chenopodium album</i>	WELTU 10286; Dunedin, N.Z.
VUWG 1328	Chenopodiaceae	<i>Chenopodium album</i>	WELTU 10285; Napier, N.Z.
VUWG 604	Chenopodiaceae	<i>Chenopodium album</i>	WELT 70875; Wakanui, Ashburton, N.Z.
VUWG 605	Chenopodiaceae	<i>Chenopodium album</i>	WELT 70719; Nelson, N.Z.
VUWG 606	Chenopodiaceae	<i>Chenopodium album</i>	WELT no #; Pukerua Bay, Wellington, N.Z.
VUWG 886	Chenopodiaceae	<i>Chenopodium album</i>	WELTU box 87; India.
VUWG 759	Chenopodiaceae	<i>Chenopodium</i> cf. <i>album</i>	Chester 234. Asprokamos, Grevena Pr., NW Greece.
VUWG 887	Chenopodiaceae	<i>Chenopodium bonus-henricus</i>	WELTU box 87; Switzerland.
VUWG 607	Chenopodiaceae	<i>Chenopodium murale</i>	WELT 70562; Mana Island, N.Z.

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VUWG 608	Chenopodiaceae	<i>Chenopodium murale</i>	WELT 69973; Pukerua Bay, Wellington, N.Z.
VUWG 609	Chenopodiaceae	<i>Chenopodium murale</i>	WELT 52295; Breaker Bay, Wellington, N.Z.
NUNG 59	Cistaceae	<i>Cistus albidus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 109	Cistaceae	<i>Cistus crispus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 129	Cistaceae	<i>Cistus incanus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 124	Cistaceae	<i>Cistus monspeliensis</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 190	Cistaceae	<i>Cistus populifolius</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 41	Cistaceae	<i>Cistus psilosepalus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1313	Cistaceae	<i>Cistus purpureus</i>	WELTU; Victoria University, Wellington, N.Z.
NUNG 142	Cistaceae	<i>Cistus salvifolius</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 271	Cistaceae	<i>Cistus salvifolius</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 277	Cistaceae	<i>Cistus salvifolius</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 87	Cistaceae	<i>Cistus varius</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 258	Cistaceae	<i>Cistus</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
NUNG 140	Cistaceae	<i>Fumana procumbens</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 853	Cistaceae	<i>Helianthemum nummularium</i>	WELTU box 93; Germany.
VUWG 772	Cistaceae	<i>Helianthemum ?nummularium</i>	Chester 304. Mirsina, Grevena Pr., NW Greece.
VUWG 795	Cistaceae	<i>Helianthemum</i> sp.	Chester 316. Wellington Botanic Gardens, N.Z.
VUWG 703	Compositae	? <i>Anthemis</i> sp.	Chester 75. Polineri, Grevena Pr., NW Greece.
VUWG 767	Compositae	? <i>Anthemis</i> sp.	Chester 277. Asprokamos, Grevena Pr., NW Greece.
VUWG 727	Compositae	? <i>Crepis</i> sp.	Chester 133. Mirsina, Grevena Pr., NW Greece.
VUWG 645	Compositae	? <i>Leontodon</i> sp.	Chester 7. Anelia, Grevena Pr., NW Greece.
VUWG 766	Compositae	? <i>Scorzonera</i> sp.	Chester 254. Asprokamos, Grevena Pr., NW Greece.
VUWG 1172	Compositae	<i>Achillea millefolium</i>	WELTU; Holland.
VUWG 1173	Compositae	<i>Achillea millefolium</i>	WELTU; Holland.
VUWG 1442	Compositae	<i>Achillea millefolium</i>	WELTU; Tinakori Hill, Wellington, N.Z.
VUWG 1443	Compositae	<i>Achillea millefolium</i>	WELTU; Tinakori Hill, Wellington, N.Z.
VUWG 1444	Compositae	<i>Achillea millefolium</i>	WELTU 15254; Victoria University, Wellington, N.Z.

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VUWG 58	Compositae	<i>Achillea millefolium</i>	WELT 70822a; Hutt River, Wellington, N.Z.
VUWG 59	Compositae	<i>Achillea millefolium</i>	WELT 61785; Castlepoint, Wairarapa, N.Z.
VUWG 60	Compositae	<i>Achillea millefolium</i>	WELT 61451; Seatoun, Wellington, N.Z.
VUWG 1174	Compositae	<i>Achillea nobilis</i>	WELTU; Kaiserstuhl nr Freiburg, Germany.
VUWG 1175	Compositae	<i>Achillea ptarmica</i>	WELTU; Holland.
NUNG 161	Compositae	<i>Achillea ptarmica</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 61	Compositae	<i>Anthemis cotula</i>	WELT 62624; Keith George Pk, Hutt Valley, N.Z.
VUWG 62	Compositae	<i>Anthemis cotula</i>	WELT 62627; Pukemokemoke, Hamilton, N.Z.
VUWG 63	Compositae	<i>Anthemis cotula</i>	WELT 60429; Makara, Wellington, N.Z.
VUWG 696	Compositae	<i>Anthemis</i> sp.	Chester 66. Mavrani, Grevena Pr., NW Greece.
NUNG 66	Compositae	<i>Anthemis</i> or <i>Chamomilla</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 65	Compositae	<i>Arctium minus</i>	WELT 61401; Cliffs towards Waimea, Nelson, N.Z.
VUWG 66	Compositae	<i>Arctium minus</i>	WELT 70714a; Waipapa Bay, Marlborough, N.Z.
VUWG 1446	Compositae	<i>Artemisia absinthium</i>	WELTU 10399; Taieri Plain, N.Z.
VUWG 68	Compositae	<i>Artemisia absinthium</i>	WELT 61405; Auckland, N.Z.
VUWG 69	Compositae	<i>Artemisia absinthium</i>	WELT 61404; Auckland, N.Z.
VUWG 70	Compositae	<i>Artemisia absinthium</i>	WELT (Ex CHR 420888); Waitaki Valley, Otago, N.Z.
VUWG 67	Compositae	<i>Artemisia arborescens</i>	WELT 60442; Karori, Wellington, N.Z.
NUNG 151	Compositae	<i>Artemisia genipi</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 146	Compositae	<i>Artemisia umbelliformis</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1177	Compositae	<i>Artemisia vulgaris</i>	WELTU; Holland.
NUNG 32	Compositae	? <i>Aster tripolium</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1447	Compositae	<i>Bellis perennis</i>	WELTU 15183; Victoria University, Wellington, N.Z.
VUWG 71	Compositae	<i>Bellis perennis</i>	WELT 70838; Belmont, Hutt Valley, N.Z.
VUWG 796	Compositae	<i>Bellis perennis</i>	Chester 317. Wellington Botanic Gardens, N.Z.
VUWG 819	Compositae	<i>Bellis perennis</i>	Chester 340. Garden, Johnsonville, Wellington, N.Z.
NUNG 3	Compositae	<i>Carduus acanthoides</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 13	Compositae	<i>Carduus acanthoides</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1178	Compositae	<i>Carduus crispus</i>	WELTU; Holland.
VUWG 1449	Compositae	<i>Carduus crispus</i>	WELTU 10403; Oamaru, N.Z.

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VUWG 1448	Compositae	<i>Carduus lanceolatus</i>	WELTU 10402; Dunedin, N.Z.
VUWG 1179	Compositae	<i>Carduus marianus</i>	WELTU; Switzerland.
VUWG 72	Compositae	<i>Carduus nutans</i>	WELT 16169; Hakataramea Valley, N.Z.
VUWG 73	Compositae	<i>Carduus pycnocephalus</i>	WELT 61444; Otago, N.Z.
VUWG 74	Compositae	<i>Carduus pycnocephalus</i>	WELT 70626; Sydenham, Christchurch, N.Z.
VUWG 75	Compositae	<i>Carduus pycnocephalus</i>	WELT 61335
VUWG 1180	Compositae	<i>Carlina acaulis</i>	WELTU; Switzerland.
VUWG 76	Compositae	<i>Centaurea calcitrapa</i>	WELT 61339a; Akaroa, N.Z.
VUWG 1182	Compositae	<i>Centaurea cyanus</i>	WELTU; Holland.
VUWG 77	Compositae	<i>Centaurea cyanus</i>	WELT 61188; Sth Karori Rd, Wellington, N.Z.
VUWG 1181	Compositae	<i>Centaurea jacea</i>	WELTU; Holland.
NUNG 154	Compositae	<i>Centaurea jacea</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 78	Compositae	<i>Centaurea melitensis</i>	WELT 61344; Island Bay, Wellington, N.Z.
VUWG 79	Compositae	<i>Centaurea melitensis</i>	WELT 78173; Huangarua River, Martinborough, N.Z.
VUWG 669	Compositae	<i>Centaurea ?napulifera</i>	Chester 31. Kellia, Grevena Pr., NW Greece.
NUNG 198	Compositae	<i>Centaurea nigra</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 166	Compositae	<i>Centaurea scabiosa</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 8	Compositae	<i>Centaurea sphaerocephala</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1451	Compositae	<i>Centaurea solstitialis</i>	WELTU 10405; Clutha Valley, N.Z.
VUWG 705	Compositae	<i>Centaurea solstitialis</i>	Chester 77. Polineri, Grevena Pr., NW Greece.
NUNG 80	Compositae	<i>Centaurea triumphetti</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 643	Compositae	<i>Centaurea</i> sp.	Chester 5. Anelia, Grevena Pr., NW Greece.
VUWG 689	Compositae	<i>Centaurea</i> sp.	Chester 57. Mavrani, Grevena Pr., NW Greece.
VUWG 760	Compositae	<i>Centaurea</i> sp.	Chester 247. Asprokampos, Grevena Pr., NW Greece.
VUWG 769	Compositae	<i>Centaurea</i> sp.	Chester 299. Mirsina, Grevena Pr., NW Greece.
VUWG 80	Compositae	<i>Centaurea</i> sp.	WELT 70914; Tauherenikau Valley, Tararua Ra., N.Z.
VUWG 789	Compositae	<i>Centaurea</i> sp. [cultivar]	Chester 310. Wellington Botanic Gardens, N.Z.
VUWG 1445	Compositae	<i>Chamaemelum nobile</i>	WELTU 10400; Port Chalmers, N.Z.
VUWG 698	Compositae	<i>Chondrilla juncea</i>	Chester 70. Mavrani, Grevena Pr., NW Greece.
VUWG 81	Compositae	<i>Chondrilla juncea</i>	WELT 63329; Gt Nth Rd, New Lynn, Auckland, N.Z.
VUWG 82	Compositae	<i>Chrysanthemum coronarium</i>	WELT 70342; Auckland, N.Z.

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VUWG 83	Compositae	<i>Chrysanthemum coronarium</i>	WELT 16142; Seatoun, Wellington, N.Z.
VUWG 84	Compositae	<i>Chrysanthemum coronarium</i>	WELT 61431; Near Railway Stn, Wellington, N.Z.
VUWG 116	Compositae	<i>Chrysanthemum leucanthemum</i>	WELT 60428; Sth Karori Rd, Wellington, N.Z.
VUWG 85	Compositae	<i>Chrysanthemum segetum</i>	WELT 60426; Sth Karori Rd, Wellington, N.Z.
VUWG 86	Compositae	<i>Chrysanthemum segetum</i>	WELT 60427; Happy Valley, Wellington, N.Z.
VUWG 87	Compositae	<i>Chrysanthemum segetum</i>	WELT 60743; Karori Cemetery, Wellington, N.Z.
VUWG 1450	Compositae	<i>Cichorium intybus</i>	WELTU; Mt Victoria, Wellington, N.Z.
VUWG 665	Compositae	<i>Cichorium intybus</i>	Chester 27. Kellia, Grevena Pr., NW Greece.
VUWG 734	Compositae	<i>Cichorium intybus</i>	Chester 152. Mirsina, Grevena Pr., NW Greece.
VUWG 1184	Compositae	<i>Cirsium arvense</i>	WELTU; Holland.
VUWG 1185	Compositae	<i>Cirsium arvense</i>	WELTU; Holland.
VUWG 1452	Compositae	<i>Cirsium arvense</i>	WELTU; Wellington, N.Z.
VUWG 1453	Compositae	<i>Cirsium arvense</i>	WELTU 10407; Queen Charlotte Sound, N.Z.
VUWG 88	Compositae	<i>Cirsium arvense</i>	WELT 16118; Opunake, N.Z.
VUWG 721	Compositae	<i>Cirsium creticum</i>	Chester 126. Mirsina, Grevena Pr., NW Greece.
VUWG 1186	Compositae	<i>Cirsium eriophorum</i>	WELTU; Holland.
NUNG 108	Compositae	<i>Cirsium oleraceum</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 118	Compositae	<i>Cirsium palustra</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 60	Compositae	<i>Cirsium spinosissimum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1454	Compositae	<i>Cirsium vulgare</i>	WELTU 11309; Cape Turakirae, Wellington, N.Z.
VUWG 90	Compositae	<i>Cirsium vulgare</i>	WELT 61356
VUWG 682	Compositae	<i>Cirsium</i> sp.	Chester 48. Kellia, Grevena Pr., NW Greece.
VUWG 715	Compositae	<i>Cirsium</i> sp.	Chester 101. Polineri, Grevena Pr., NW Greece.
NUNG 42	Compositae	<i>Cirsium</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1190	Compositae	<i>Conyza canadensis</i>	WELTU; Holland.
VUWG 1457	Compositae	<i>Conyza canadensis</i>	WELTU; Waikanae R., N.Z.
VUWG 1187	Compositae	<i>Crepis aurea</i>	WELTU; Switzerland.
VUWG 1455	Compositae	<i>Crepis capillaris</i>	WELTU 11262; Cape Turakirae, Wellington, N.Z.
VUWG 1456	Compositae	<i>Crepis capillaris</i>	WELTU 10409; Kaingaroa, N.Z.
VUWG 91	Compositae	<i>Crepis capillaris</i>	WELT 70808b; Kelburn, Wellington, N.Z.
VUWG 92	Compositae	<i>Crepis capillaris</i>	WELT 70752; Totaranui Bay, Nelson, N.Z.
VUWG 93	Compositae	<i>Crepis capillaris</i>	WELT 16120; Ihaia, N.Z.

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VUWG 693	Compositae	<i>Crepis</i> sp.	Chester 63. Mavrani, Grevena Pr., NW Greece.
VUWG 1188	Compositae	<i>Doronium grandiflorum</i>	WELTU; Switzerland.
VUWG 687	Compositae	<i>Echinops microcephalus</i>	Chester 55. Mavrani, Grevena Pr., NW Greece.
VUWG 768	Compositae	<i>Echinops microcephalus</i>	Chester 297. Mirsina, Grevena Pr., NW Greece.
VUWG 743	Compositae	<i>Echinops</i> cf. <i>microcephalus</i>	Chester 170. Gomara, Grevena Pr., NW Greece.
VUWG 1189	Compositae	<i>Erigeron alpinus</i>	WELTU; Switzerland.
VUWG 1458	Compositae	<i>Erigeron karvinskianus</i>	WELTU; Wellington, N.Z.
VUWG 1459	Compositae	<i>Erigeron karvinskianus</i>	WELTU; Wellington, N.Z.
VUWG 799	Compositae	<i>Erigeron</i> sp.	Chester 320. Wellington Botanic Gardens, N.Z.
VUWG 709	Compositae	<i>Filago pyramidata</i>	Chester 83. Polineri, Grevena Pr., NW Greece.
VUWG 1191	Compositae	<i>Filago</i> sp.	WELTU; Switzerland.
VUWG 94	Compositae	<i>Hieracium aurantiacum</i>	WELT 63391; Lake Rotoiti, N.Z.
VUWG 95	Compositae	<i>Hieracium aurantiacum</i>	WELT 63391b; Lake Rotoiti, N.Z.
VUWG 96	Compositae	<i>Hieracium caespitosum</i>	WELT 16185; Springfield, N.Z.
VUWG 1194	Compositae	<i>Hieracium pilosella</i>	WELTU; Holland.
VUWG 1461	Compositae	<i>Hieracium pilosella</i>	WELTU 7657; Owen Range, N.Z.
VUWG 100	Compositae	<i>Hieracium praealtum</i>	WELT 70705; Pivot Ck, Westland, N.Z.
VUWG 101	Compositae	<i>Hieracium praealtum</i>	WELT 16182; Broken River Basin, N.Z.
VUWG 99	Compositae	<i>Hieracium praealtum</i>	WELT 16172; Hakataramea Valley, N.Z.
VUWG 1195	Compositae	<i>Hieracium umbellatum</i>	WELTU; Holland.
VUWG 704	Compositae	<i>Hieracium</i> / <i>Pilosella</i> agg.	Chester 76. Polineri, Grevena Pr., NW Greece.
VUWG 102	Compositae	<i>Hypochoeris glabra</i>	WELT 61089a; Hepburn St, Auckland, N.Z.
VUWG 103	Compositae	<i>Hypochoeris glabra</i>	WELT 70545; Pukerua Bay, N.Z.
VUWG 104	Compositae	<i>Hypochoeris radicata</i>	WELT 70684; Charles Bay, Stephenson Is., N.Z.
VUWG 105	Compositae	<i>Hypochoeris radicata</i>	WELT 38850; Chatham Islands, N.Z.
VUWG 106	Compositae	<i>Hypochoeris radicata</i>	WELT 51429; Red Rocks, Wellington, N.Z.
VUWG 1196	Compositae	<i>Inula conyza</i>	WELTU; Holland.
VUWG 107	Compositae	<i>Lactuca virosa</i>	WELT 63195; Raroa Reserve, Pukerua Bay, N.Z.
VUWG 108	Compositae	<i>Lactuca virosa</i>	WELT 63502; old Hutt River bed, Heretaunga, N.Z.
VUWG 109	Compositae	<i>Lactuca virosa</i>	WELT 63503; old Hutt Rd, Hutt Valley, N.Z.
VUWG 110	Compositae	<i>Lapsana communis</i>	WELT 61256; Sth Karori Rd, Wellington, N.Z.
VUWG 111	Compositae	<i>Lapsana communis</i>	WELT (no #)
VUWG 112	Compositae	<i>Lapsana communis</i>	WELT 61102; Near Wellington, N.Z.
VUWG 1198	Compositae	<i>Lapsana communis</i>	WELTU; Holland.

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VUWG 1199	Compositae	<i>Lapsana communis</i>	WELTU.
VUWG 1200	Compositae	<i>Lapsana communis</i>	WELTU.
VUWG 1201	Compositae	<i>Leontodon hispidus danubialis</i>	WELTU; Holland.
VUWG 113	Compositae	<i>Leontodon taraxacoides</i>	WELT 62837; Pukerua Bay, N.Z.
VUWG 114	Compositae	<i>Leontodon taraxacoides</i>	WELT 60449; Island Bay, Wellington, N.Z.
VUWG 115	Compositae	<i>Leontodon taraxacoides</i>	WELT 61105; Kilburnie, Wellington, N.Z.
VUWG 1202	Compositae	<i>Leontodon taraxacoides</i>	WELTU; Holland.
VUWG 1462	Compositae	<i>Leontodon taraxacoides</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 1192	Compositae	<i>Logfia arvensis</i>	WELTU; Holland.
VUWG 117	Compositae	<i>Logfia gallica</i>	WELT 70713; Redwood Pass, Marlborough, N.Z.
VUWG 118	Compositae	<i>Matricaria chamomilla</i>	WELT 70843; Wakanui, Ashburton, N.Z.
VUWG 119	Compositae	<i>Matricaria chamomilla</i>	WELT 70536; Pukerua Bay, Wellington, N.Z.
VUWG 1197	Compositae	<i>Mycelis muralis</i>	WELTU; Holland.
VUWG 120	Compositae	<i>Mycelis muralis</i>	WELT 70171b; Taranua Ra., Palmerston Nth, N.Z.
VUWG 121	Compositae	<i>Mycelis muralis</i>	WELT 61123; Ure River Valley, Marlborough, N.Z.
VUWG 1464	Compositae	<i>Mycelis muralis</i>	WELTU 7659; Granity Pass, Owen Range, N.Z.
VUWG 123	Compositae	<i>Olearia gunniana</i>	WELT 39072; Invercargill, N.Z.
VUWG 124	Compositae	<i>Olearia gunniana</i>	WELT 61125
VUWG 125	Compositae	<i>Olearia gunniana</i>	WELT 61126; Near Fairfield, Otago, N.Z.
VUWG 1465	Compositae	<i>Onopordum acanthium</i>	WELTU 11337; Cape Turakirae, Wellington, N.Z.
VUWG 126	Compositae	<i>Picris echioides</i>	WELT 16165; Kapiti Is, N.Z.
VUWG 127	Compositae	<i>Picris echioides</i>	WELT 60447; Makara, Wellington, N.Z.
VUWG 128	Compositae	<i>Picris echioides</i>	WELT 60435; Between Otaki & Waikanae, N.Z.
VUWG 129	Compositae	<i>Picris hieracioides</i>	WELT 70117; Rakitu (Arid) Is., Nth Is., N.Z.
VUWG 130	Compositae	<i>Picris hieracioides</i>	WELT 63293; Mahenotiti Is., Bay of Is., N.Z.
VUWG 1204	Compositae	<i>Prenanthes purpurea</i>	WELTU; Switzerland.
VUWG 1205	Compositae	<i>Pulicaria dysenterica</i>	WELTU; Holland.
VUWG 659	Compositae	<i>Pulicaria dysenterica</i>	Chester 21. Kellia, Grevena Pr., NW Greece.
VUWG 720	Compositae	<i>Pulicaria dysenterica</i>	Chester 125. Mirsina, Grevena Pr., NW Greece.
VUWG 1206	Compositae	<i>Senecio aquaticus</i>	WELTU; Holland.
VUWG 143	Compositae	<i>Senecio cineraria</i>	WELT 61025; Westshore, N.Z.
VUWG 144	Compositae	<i>Senecio jacobaea</i>	WELT 24172A; Hawkes Bay, N.Z.
VUWG 145	Compositae	<i>Senecio jacobaea</i>	WELT 24172B; Hawke Bay, N.Z.
VUWG 1467	Compositae	<i>Senecio jacobaea</i>	WELTU; Wellington, N.Z.
NUNG 138	Compositae	<i>Senecio paludosus</i>	Stevenson, Newcastle Upon Tyne University, England.

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NUNG 39	Compositae	<i>Senecio squalidos</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1466	Compositae	<i>Senecio sylvaticus</i>	WELTU 15296; Victoria University, Wellington, N.Z.
VUWG 1207	Compositae	<i>Senecio vulgaris</i>	WELTU; Holland.
VUWG 131	Compositae	<i>Siegesbeckia orientalis</i>	WELT 61142; Near Fairburn, N.Z.
VUWG 132	Compositae	<i>Siegesbeckia orientalis</i>	WELT 61151; Coral Bay, Sunday Is.
VUWG 133	Compositae	<i>Siegesbeckia orientalis</i>	WELT 14376; Shruts Bay.
VUWG 134	Compositae	<i>Silybum marianum</i>	WELT 51428; Red Rocks, Wellington, N.Z.
VUWG 135	Compositae	<i>Silybum marianum</i>	WELT 61153; Near Wellington, N.Z.
VUWG 136	Compositae	<i>Silybum marianum</i>	WELT 60908a; Waikanae Rd, Paraparaumu, N.Z.
VUWG 1209	Compositae	<i>Solidago canadensis</i>	WELTU; Holland.
VUWG 1210	Compositae	<i>Solidago gigantea</i>	WELTU; Black Forest, Germany.
VUWG 1211	Compositae	<i>Solidago virgaurea</i>	WELTU; Holland.
VUWG 1212	Compositae	<i>Solidago virgaurea</i>	WELTU; Holland.
VUWG 1213	Compositae	<i>Solidago virgaurea</i>	WELTU; Holland.
VUWG 137	Compositae	<i>Sonchus asper</i>	WELT 70675; Orongorongo Valley, Wellington, N.Z.
VUWG 138	Compositae	<i>Sonchus asper</i>	WELT 61322a; Sth Karori Rd, Wellington, N.Z.
VUWG 139	Compositae	<i>Sonchus asper</i>	WELT 9577; Waikaremoana, N.Z.
VUWG 1468	Compositae	<i>Sonchus asper</i>	WELTU 15548; Auckland Island.
VUWG 1469	Compositae	<i>Sonchus asper</i>	WELTU 15181; Waikanae River estuary, N.Z.
NUNG 88	Compositae	<i>Sonchus asper</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 140	Compositae	<i>Sonchus oleraceus</i>	WELT 70840; Kelburn, Wellington, N.Z.
VUWG 141	Compositae	<i>Sonchus oleraceus</i>	WELT 63400; Little Barrier Is., N.Z.
VUWG 142	Compositae	<i>Sonchus oleraceus</i>	WELT 60430; Sth Karori, Wellington, N.Z.
NUNG 28	Compositae	<i>Sonchus oleraceus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1214	Compositae	<i>Tanacetum</i> sp.	WELTU; Holland.
VUWG 1215	Compositae	<i>Tanacetum</i> sp.	WELTU; Switzerland.
VUWG 1471	Compositae	<i>Tanacetum vulgare</i>	WELTU 10429; Taieri Plain, N.Z.
VUWG 1208	Compositae	<i>Taraxacum officinale</i>	WELTU.
VUWG 1470	Compositae	<i>Taraxacum officinale</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 162	Compositae	<i>Tripleurospermum inodorum</i>	WELT 70625; Ross Rd, Canterbury Plains, N.Z.
VUWG 163	Compositae	<i>Tripleurospermum inodorum</i>	WELT 70842; Wakanui, Ashburton, N.Z.
VUWG 164	Compositae	<i>Tripleurospermum inodorum</i>	WELT 61116
VUWG 706	Compositae	<i>Xanthium spinosum</i>	Chester 78. Polineri, Grevena Pr., NW Greece.
VUWG 1217	Compositae	<i>Xanthium strumarium</i>	WELTU; India.

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VUWG 694	Compositae	<i>Xanthium strumarium</i>	Chester 64. Mavrani, Grevena Pr., NW Greece.
NUNG 44	Compositae	<i>Xeranthemum annuum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 240	Convolvulaceae	<i>Calystegia sepium</i>	WELT 60398; Days Bay, Wellington, N.Z.
VUWG 783	Convolvulaceae	<i>Calystegia sepium</i>	WELTU 7328; Lake Wairarapa, N.Z.
VUWG 677	Convolvulaceae	<i>Calystegia</i> , prob. <i>sepium</i>	Chester 39. Kellia, Grevena Pr., NW Greece.
VUWG 237	Convolvulaceae	<i>Calystegia silvatica</i>	WELT 70828; Belmont, Hutt Valley, N.Z.
VUWG 238	Convolvulaceae	<i>Calystegia silvatica</i>	WELT 4637; Waikanae, N.Z.
VUWG 239	Convolvulaceae	<i>Calystegia silvatica</i>	WELT 4649; Wellington, N.Z.
VUWG 1400	Convolvulaceae	<i>Convolvulus arvensis</i>	WELTU 10370.
VUWG 241	Convolvulaceae	<i>Convolvulus arvensis</i>	WELT 63505; Eastbourne, Wellington, N.Z.
VUWG 242	Convolvulaceae	<i>Convolvulus arvensis</i>	WELT 61724; Wellington, N.Z.
VUWG 243	Convolvulaceae	<i>Convolvulus arvensis</i>	WELT 63500; Brooklyn, Wellington, N.Z.
VUWG 770	Convolvulaceae	<i>Convolvulus arvensis</i>	Chester 300. Mirsina, Grevena Pr., NW Greece.
VUWG 943	Convolvulaceae	<i>Convolvulus arvensis</i>	WELTU box 97; Holland.
NUNG 236	Convolvulaceae	<i>Convolvulus arvensis</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 944	Convolvulaceae	<i>Convolvulus pluricaulis</i>	WELTU box 97; India.
VUWG 244	Convolvulaceae	<i>Cuscuta epithymum</i>	WELT 62914; Picton, N.Z.
VUWG 245	Convolvulaceae	<i>Cuscuta epithymum</i>	WELT 62923; Picton, N.Z.
VUWG 945	Convolvulaceae	<i>Cuscuta epithymum</i>	WELTU box 97; Holland.
VUWG 235	Convolvulaceae	<i>Cuscuta suaveolens</i>	WELT 61727; Near Christchurch, N.Z.
VUWG 236	Convolvulaceae	<i>Cuscuta suaveolens</i>	WELT 61725
VUWG 784	Convolvulaceae	<i>Cuscuta suaveolens</i>	WELTU 5952; Tereinakau, N.Z.
VUWG 679	Convolvulaceae	<i>Cuscuta</i> sp.	Chester 41. Kellia, Grevena Pr., NW Greece.
VUWG 747	Convolvulaceae	<i>Cuscuta</i> sp.	Chester 175. Agios Nicholas, Grevena Pr., NW Greece.
VUWG 785	Convolvulaceae	<i>Dichondra brevifolia</i>	WELTU 5945; Nydia Bay, Marlborough Sounds, N.Z.
VUWG 247b	Convolvulaceae	<i>Ipomoea congestus</i>	WELT 70111; Waiwera, Rodney County, N.Z.
VUWG 1401	Convolvulaceae	<i>Ipomoea purpurea</i>	WELTU 15242; Victoria University, Wellington, N.Z.
VUWG 1382	Cornaceae	<i>Cornus capitata</i>	WELTU; New Plymouth, N.Z.
VUWG 933	Cornaceae	<i>Cornus capitata</i>	WELTU 9383.
VUWG 406	Cornaceae	<i>Cornus sanguinea</i>	WELT no #; Uppsala, Sweden.
NUNG 22	Cornaceae	<i>Cornus suecica</i>	Stevenson, Newcastle Upon Tyne University, England.
DUDB 313	Corylaceae	<i>Carpinus betulus</i>	Huntley, Durham University, England.
VUWG 425	Corylaceae	<i>Corylus avellana</i>	WELT no #; ex Otago Museum, N.Z.
VUWG 861	Corylaceae	<i>Corylus avellana</i>	WELTU box 86; Belmont.

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CRYG 286	Corylaceae	<i>Corylus avellana</i>	Atherden, College of Rippon & York, England.
DUDB 298	Corylaceae	<i>Ostrya carpinifolia</i>	Huntlet, Durham University, England.
NUNG 96	Crassulaceae	<i>Pistorinia hispania</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1367	Crassulaceae	<i>Sedum acre</i>	WELTU 10339; Cardrona R., Otago, N.Z.
VUWG 962	Crassulaceae	<i>Sedum acre</i>	WELTU box 97; Holland.
VUWG 963	Crassulaceae	<i>Sedum ?acre</i>	WELTU box 97; Holland.
VUWG 964	Crassulaceae	<i>Sedum album</i>	WELTU box 97; Belgium.
VUWG 965	Crassulaceae	<i>Sedum reflexum</i>	WELTU box 97; Switzerland.
VUWG 960	Crassulaceae	<i>Sedum</i> sp.	WELTU box 97; Holland.
VUWG 961	Crassulaceae	<i>Sedum</i> sp.	WELTU box 97; Holland.
VUWG 1301	Cruciferae	<i>Alyssum alyssoides</i>	WELTU 10307; Waiareka Valley, N.Z.
VUWG 997	Cruciferae	<i>Alyssum montanum</i>	WELTU box 97; Holland.
VUWG 749	Cruciferae	<i>Alyssum murale</i>	Chester 178. Agios Nicholas, Grevena Pr., NW Greece.
VUWG 730	Cruciferae	? <i>Alyssum murale</i>	Chester 143. Mirsina, Grevena Pr., NW Greece.
VUWG 690	Cruciferae	? <i>Alyssum cf. murale</i>	Chester 59. Mavrani, Grevena Pr., NW Greece.
VUWG 996	Cruciferae	<i>Arabis blepharophylla</i>	WELTU box 97; Sonoma Co., California, USA.
VUWG 1302	Cruciferae	<i>Barbarea vulgaris</i>	WELTU 10308; Maori Hill, Dunedin, N.Z.
VUWG 999	Cruciferae	<i>Brassica napus</i>	WELTU box 97; Holland.
VUWG 998	Cruciferae	<i>Brassica nigra</i>	WELTU box 97; Holland.
VUWG 1304	Cruciferae	<i>Brassica oleracea</i>	WELTU 11018; North Harbour, Auckland, N.Z.
VUWG 1000	Cruciferae	<i>Brassica rapa</i>	WELTU box 97; Holland.
VUWG 1303	Cruciferae	<i>Brassica rapa</i>	WELTU 10309; Maori Hill, Dunedin, N.Z.
VUWG 1305	Cruciferae	<i>Brassica rapa</i>	WELTU 15209; Victoria University, Wellington, N.Z.
VUWG 1001	Cruciferae	<i>Cardamine hirsuta</i>	WELTU box 97; Holland.
VUWG 1306	Cruciferae	<i>Cardamine hirsuta</i>	WELTU 10315; Khandallah, Wellington, N.Z.
VUWG 1307	Cruciferae	<i>Cardamine hirsuta</i>	WELTU 10312; Wellington Botanic Gardens, N.Z.
VUWG 1308	Cruciferae	<i>Cardamine hirsuta</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 1002	Cruciferae	<i>Cardamine pratensis</i>	WELTU box 97; Holland.
VUWG 806	Cruciferae	<i>Erysimum</i> sp.	Chester 327. Wellington Botanic Gardens, N.Z.
VUWG 1004	Cruciferae	<i>Lunaria annua</i>	WELTU box 97; Holland.
VUWG 1005	Cruciferae	<i>Lunaria annua</i>	WELTU box 97; Germany.
VUWG 1309	Cruciferae	<i>Lunaria annua</i>	WELTU 15203; Karori, Wellington, N.Z.
NUNG 14	Cruciferae	<i>Lunaria</i> sp.	Stevenson, Newcastle Upon Tyne University, England.

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VUWG 1310	Cruciferae	<i>Nasturtium officinale</i>	WELTU 11355; Cape Turakirae, Wellington, N.Z.
VUWG 1311	Cruciferae	<i>Nasturtium officinale</i>	WELTU 15202.
VUWG 765	Cruciferae	? <i>Sinapis alba</i>	Chester 253. Asprokamos, Grevena Pr., NW Greece.
VUWG 1006	Cruciferae	<i>Thlaspi arvense</i>	WELTU box 97; Germany.
VUWG 1007	Cruciferae	<i>Thlaspi arvense</i>	WELTU box 97; Holland.
NUNG 119	Dioscoreaceae	<i>Borderea pyrenaica</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 761	Dipsacaceae		Chester 248. Asprokamos, Grevena Pr., NW Greece.
VUWG 52	Dipsacaceae	<i>Dipsacus fullonum</i>	WELT 59833; Albany, Auckland, N.Z.
VUWG 1163	Dipsacaceae	<i>Dipsacus pilosus</i>	WELTU; Holland.
VUWG 53	Dipsacaceae	<i>Dipsacus sylvestris</i>	WELT 62809; Grays Hill, Gisborne, N.Z.
VUWG 1164	Dipsacaceae	<i>Knautia arvensis</i>	WELTU; Switzerland.
VUWG 55	Dipsacaceae	<i>Scabiosa atropurpurea</i>	WELT 63169; Near Wellington, N.Z.
VUWG 56	Dipsacaceae	<i>Scabiosa atropurpurea</i>	WELT 84425; Near Port Ahuriri, N.Z.
VUWG 688	Dipsacaceae	<i>Scabiosa ?atropurpurea</i>	Chester 56. Mavrani, Grevena Pr., NW Greece.
VUWG 1441	Dipsacaceae	<i>Scabiosa arvensis</i>	WELTU 10398; Roslyn, Dunedin, N.Z.
VUWG 1165	Dipsacaceae	<i>Scabiosa succisa</i>	WELTU; Holland.
VUWG 731	Dipsacaceae	<i>Scabiosa</i> sp.	Chester 148. Mirsina, Grevena Pr., NW Greece.
VUWG 621	Droseraceae	<i>Drosera anglica</i>	WELT no #; Tollstad, Ostergotland, Sweden.
NUNG 45	Ericaceae	<i>Erica arborea</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 105	Ericaceae	<i>Erica australis</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 163	Ericaceae	<i>Erica ciliaris</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1071	Ericaceae	<i>Erica herbacea</i>	WELTU box 91; Switzerland.
VUWG 1394	Ericaceae	<i>Erica lusitanica</i>	WELTU; Wellington, N.Z.
VUWG 1395	Ericaceae	<i>Erica lusitanica</i>	WELTU 11299; Cape Turakirae, Wellington, N.Z.
NUNG 73	Ericaceae	<i>Erica lusitanica</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 178	Ericaceae	<i>Erica lusitanica</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 75	Ericaceae	<i>Erica multiflora</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 256	Ericaceae	<i>Erica scoparia</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1073	Ericaceae	<i>Erica tetralix</i>	WELTU box 91; Holland.
NUNG 205	Ericaceae	<i>Erica tetralix</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 191	Ericaceae	<i>Erica umbellata</i>	Stevenson, Newcastle Upon Tyne University, England.

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NUNG 63	Ericaceae	<i>Erica</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1066	Euphorbiaceae	<i>Euphorbia amygdaloides</i>	WELTU box 91; Lac de la Gilleppe, Belgium.
VUWG 511	Euphorbiaceae	<i>Euphorbia helioscopia</i>	WELT 60898; Karori, Wellington, N.Z.
NUNG 247	Euphorbiaceae	<i>Euphorbia helioscopia</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1069	Euphorbiaceae	<i>Euphorbia hirta</i>	WELTU box 91; India.
VUWG 512	Euphorbiaceae	<i>Euphorbia lathyris</i>	WELT 70764; Ohariu Valley, Wellington, N.Z.
VUWG 1070	Euphorbiaceae	<i>Euphorbia palustris</i>	WELTU box 91; Holland.
NUNG 121	Euphorbiaceae	<i>Euphorbia paralias</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1383	Euphorbiaceae	<i>Euphorbia peplus</i>	WELTU; Stokes Valley, Lower Hutt, N.Z.
VUWG 1384	Euphorbiaceae	<i>Euphorbia peplus</i>	WELTU 11302; Cape Turakirae, Wellington, N.Z.
VUWG 513	Euphorbiaceae	<i>Euphorbia peplus</i>	WELT 63321; Wairau Ck, Milford, N.Z.
VUWG 514	Euphorbiaceae	<i>Euphorbia peplus</i>	WELT 60731; Webb St, Wellington, N.Z.
VUWG 515	Euphorbiaceae	<i>Euphorbia peplus</i>	WELT 63357; Pukerua Bay, Wellington, N.Z.
VUWG 516	Euphorbiaceae	<i>Euphorbia platyphyllos</i>	WELT 70695; Auckland City, N.Z.
VUWG 517	Euphorbiaceae	<i>Euphorbia</i> sp.	WELT 70119; Oakura Bay, Whangarei, N.Z.
NUNG 2	Fagaceae	<i>Castanea sativa</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 21	Fagaceae	<i>Castanea sativa</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 55	Fagaceae	<i>Quercus cerris</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 110	Fagaceae	<i>Quercus cerris</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 54	Fagaceae	<i>Quercus coccifera</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 177	Fagaceae	<i>Quercus coccifera</i>	Stevenson, Newcastle Upon Tyne University, England.
CRYG 287	Fagaceae	<i>Quercus coccifera</i>	Atherden, College of Rippon & York, England.
NUNG 64	Fagaceae	<i>Quercus faginea</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 68	Fagaceae	<i>Quercus faginea</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 135	Fagaceae	<i>Quercus fruticosa</i>	Stevenson, Newcastle Upon Tyne University, England.
CRYG 288	Fagaceae	<i>Quercus macrolepis</i>	Atherden, College of Rippon & York, England.
DUDB 297	Fagaceae	<i>Quercus petraea</i>	Huntley, Durham University, England.
NUNG 224	Fagaceae	<i>Quercus pyrenaica</i>	Stevenson, Newcastle Upon Tyne University, England.

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VUWG 811	Fagaceae	<i>Quercus robur</i>	Chester 332. Wellington Botanic Gardens, N.Z.
NUNG 175	Fagaceae	<i>Quercus suber</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 158	Fagaceae	<i>Quercus suber</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 79	Fagaceae	<i>Quercus suber</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 165	Gentianaceae	<i>Blackstonia perfoliata</i>	WELT 70741; Paihia, Bay of Is., N.Z.
VUWG 166	Gentianaceae	<i>Centaurium erythraea</i>	WELT 70335; Hen & Chickens Is., N.Z.
VUWG 167	Gentianaceae	<i>Centaurium erythraea</i>	WELT 70468; Poor Knight Is., N.Z.
VUWG 170	Gentianaceae	<i>Centaurium erythraea</i>	WELT 63290; Forest Hill, Waitemata Co., N.Z.
VUWG 171	Gentianaceae	<i>Centaurium erythraea</i>	WELT 60378; Karori, Wellington, N.Z.
NUNG 234	Gentianaceae	<i>Centaurium erythraea</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 169	Gentianaceae	<i>Centaurium minus</i>	WELT 6234; Seatoun, Wellington, N.Z.
VUWG 168	Gentianaceae	<i>Centaurium tenuiflorum</i>	WELT 63493; Lake Ellesmere Flat, N.Z.
VUWG 934	Gentianaceae	<i>Centaurium venustum</i>	WELTU 9378; Amador Co., California, USA.
VUWG 935	Gentianaceae	<i>Gentiana andrewsii</i>	WELTU 9387; Shelburne Falls, Mass., USA.
VUWG 936	Gentianaceae	<i>Gentiana asclepiadea</i>	WELTU box 97; England.
VUWG 938	Gentianaceae	<i>Gentiana lutea</i>	WELTU box 97.
VUWG 941	Gentianaceae	<i>Gentiana pneumonanthe</i>	WELTU box 97; Switzerland.
VUWG 940	Gentianaceae	<i>Gentiana utriculosa</i>	WELTU box 97; Switzerland.
VUWG 939	Gentianaceae	<i>Gentiana verna</i> gr.	WELTU box 97; Switzerland.
VUWG 937	Gentianaceae	<i>Gentianella campestris</i>	WELTU box 97; Switzerland.
VUWG 1048	Geraniaceae	<i>Erodium cicutarium</i>	WELTU box 91; Amsterdam, Holland.
VUWG 1329	Geraniaceae	<i>Erodium cicutarium</i>	WELTU 11300; Cape Turakirae, Wellington, N.Z.
VUWG 1330	Geraniaceae	<i>Erodium cicutarium</i>	WELTU 10341; Moeraki, N.Z.
VUWG 567	Geraniaceae	<i>Erodium cicutarium</i>	WELT 63481; Riverside Rd, Havelock North, N.Z.
VUWG 568	Geraniaceae	<i>Erodium cicutarium</i>	WELT 62598; Keith George Park, Hutt Valley, N.Z.
VUWG 569	Geraniaceae	<i>Erodium cicutarium</i>	WELT 60380; S Karori Rd, Wellington, N.Z.
NUNG 228	Geraniaceae	<i>Erodium cicutarium</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 702	Geraniaceae	<i>Erodium cf. cicutarium</i>	Chester 74. Polineri, Grevena Pr., NW Greece.
VUWG 570	Geraniaceae	<i>Erodium moschatum</i>	WELT 60895; S Karori Rd, Wellington, N.Z.
VUWG 559	Geraniaceae	<i>Geranium dissectum</i>	WELT 62851; Auckland City, N.Z.

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VUWG 560	Geraniaceae	<i>Geranium dissectum</i>	WELT 61318; S Karori Rd, Wellington, N.Z.
NUNG 19	Geraniaceae	<i>Geranium dissectum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1331	Geraniaceae	<i>Geranium molle</i>	WELTU.
VUWG 1332	Geraniaceae	<i>Geranium molle</i>	WELTU 11275.
VUWG 561	Geraniaceae	<i>Geranium molle</i>	WELT 62886; Auckland City, N.Z.
VUWG 562	Geraniaceae	<i>Geranium molle</i>	WELT 6059; Karaka Bay, Wellington, N.Z.
VUWG 563	Geraniaceae	<i>Geranium molle</i>	WELT 60379; S Karori, Wellington, N.Z.
VUWG 826	Geraniaceae	<i>Geranium molle</i>	Chester 347. Garden, Johnsonville, Wellington, N.Z.
VUWG 1054	Geraniaceae	<i>Geranium ?molle</i>	WELTU box 91; Holland.
VUWG 1049	Geraniaceae	<i>Geranium pusillum</i>	WELTU box 91; Holland.
VUWG 1051	Geraniaceae	<i>Geranium pyrenaicum</i>	WELTU box 91; Kaiserstuhl nr. Freiburg, Germany.
VUWG 564	Geraniaceae	<i>Geranium robertianum</i>	WELT 63389; Willis St, Wellington, N.Z.
VUWG 565	Geraniaceae	<i>Geranium robertianum</i>	WELT no #; Karori, Wellington, N.Z.
VUWG 566	Geraniaceae	<i>Geranium robertianum</i>	WELT 60376; Karori, Wellington, N.Z.
VUWG 828	Geraniaceae	<i>Geranium robertianum</i>	Chester 349. Garden, Johnsonville, Wellington, N.Z.
NUNG 222	Geraniaceae	<i>Geranium robertianum</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 220	Geraniaceae	<i>Geranium robertianum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1053	Geraniaceae	<i>Geranium ?sylvaticum</i>	WELTU box 91; Holland.
VUWG 739	Geraniaceae	<i>Geranium</i> sp.	Chester 162. Anelia, Grevena Pr., NW Greece.
VUWG 321	Globulariaceae	<i>Globularia alypum</i>	WELT no #.
VUWG 548	Guttiferae	<i>Hypericum androsaemum</i>	WELT no #, Upper Hutt, N.Z.
VUWG 843	Guttiferae	<i>Hypericum androsaemum</i>	WELTU box 93; Holland.
NUNG 208	Guttiferae	<i>Hypericum calycinum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 844	Guttiferae	<i>Hypericum elodes</i>	WELTU box 93; Holland.
NUNG 76	Guttiferae	<i>Hypericum elodes</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 845	Guttiferae	<i>Hypericum hirsutum</i>	WELTU box 93; Holland.
NUNG 132	Guttiferae	<i>Hypericum hirsutum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 846	Guttiferae	<i>Hypericum montanum</i>	WELTU box 93; Holland.
VUWG 847	Guttiferae	<i>Hypericum nummularium</i>	WELTU box 93; Holland.
VUWG 550	Guttiferae	<i>Hypericum perforatum</i>	WELT 69885; Wellington, N.Z.
VUWG 551	Guttiferae	<i>Hypericum perforatum</i>	WELT 60627; nr Atimuri, Taupo, N.Z.
VUWG 848	Guttiferae	<i>Hypericum perforatum</i>	WELTU box 93; Holland.
NUNG 24	Guttiferae	<i>Hypericum</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1369	Hydrangeaceae	<i>Deutzia scabra</i>	WELTU; Wellington, N.Z.

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VUWG 1368	Hydrangeaceae	<i>Philadelphus mexicanus</i>	WELTU; Stokes Valley, Lower Hutt, N.Z.
VUWG 1295	Juglandaceae	<i>Juglans regia</i>	WELTU 10303; Wellington Botanic Gardens, N.Z.
VUWG 325	Labiatae	<i>Acinos arvensis</i>	WELT 61687; Porter Rd, Castle Hill, N.Z.
VUWG 326	Labiatae	<i>Acinos arvensis</i>	WELT 14205; Broken River Basin, Canterbury, N.Z.
VUWG 701	Labiatae	<i>Acinos suaveolens</i>	Chester 73. Polineri, Grevena Pr., NW Greece.
VUWG 375	Labiatae	<i>Ajuga australis</i>	WELT no #; King River, Victoria, Australia.
VUWG 1080	Labiatae	<i>Ajuga genevensis</i>	WELTU box 91; Black Forest, Germany.
VUWG 376	Labiatae	<i>Ajuga genevensis</i>	WELT no #.
VUWG 1081	Labiatae	<i>Ajuga reptans</i>	WELTU box 91; Holland.
VUWG 1419	Labiatae	<i>Ajuga reptans</i>	WELTU; Karori, Wellington, N.Z.
VUWG 327	Labiatae	<i>Ajuga reptans</i>	WELT 70349; Waikanae Rd, Wellington, N.Z.
VUWG 822	Labiatae	<i>Ajuga reptans</i>	Chester 343. Garden, Johnsonville, Wellington, N.Z.
NUNG 99	Labiatae	<i>Ajuga reptans</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 790	Labiatae	<i>Ajuga</i> sp.	Chester 311. Wellington Botanic Gardens, N.Z.
VUWG 377	Labiatae	<i>Calamintha grandiflora</i>	WELT no #; Transylvania.
VUWG 1082	Labiatae	<i>Clinopodium vulgare</i>	WELTU box 91; Switzerland.
VUWG 328	Labiatae	<i>Clinopodium vulgare</i>	WELT 63178; Banks Peninsula, Canterbury, N.Z.
VUWG 692	Labiatae	<i>Clinopodium vulgare</i>	Chester 61. Mavrani, Grevena Pr., NW Greece.
VUWG 378	Labiatae	<i>Galeopsis tetrahit</i>	WELT no #; Transylvania.
VUWG 379	Labiatae	<i>Galeopsis versicolor</i>	WELT no #; Bothwell Spott, Haddingtonshire, UK.
VUWG 1083	Labiatae	<i>Lamium album</i>	WELTU box 91; Holland.
VUWG 1084	Labiatae	<i>Lamium album</i>	WELTU box 91; Holland.
VUWG 1085	Labiatae	<i>Lamium maculatum</i>	WELTU box 91; Holland.
VUWG 330	Labiatae	<i>Lamium purpureum</i>	WELT 70399; Mt Roskill, Auckland, N.Z.
VUWG 331	Labiatae	<i>Lamium purpureum</i>	WELT 69977; Pukerua Bay, Wellington, N.Z.
VUWG 791	Labiatae	? <i>Lamium</i> sp.	Chester 312. Wellington Botanic Gardens, N.Z.
VUWG 833	Labiatae	<i>Lavandula angustifolia</i>	Chester 354. Victoria University, Wellington, N.Z.
VUWG 821	Labiatae	<i>Lavandula</i> sp.	Chester 342. Garden, Johnsonville, Wellington, N.Z.
VUWG 1086	Labiatae	<i>Lycopus europaeus</i>	WELTU box 91; Holland.
VUWG 675	Labiatae	<i>Lycopus europaeus</i>	Chester 37. Kellia, Grevena Pr., NW Greece.
VUWG 333	Labiatae	<i>Marrubium vulgare</i>	WELT 61675; Onehunga, Auckland, N.Z.
VUWG 334	Labiatae	<i>Marrubium vulgare</i>	WELT 61678.

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VUWG 335	Labiatae	<i>Marrubium vulgare</i>	WELT 61680; Pukerua Bay, Wellington, N.Z.
VUWG 336	Labiatae	<i>Marrubium vulgare</i>	WELT 62666; Devonport, Auckland, N.Z.
VUWG 1087	Labiatae	<i>Melissa officinalis</i>	WELTU box 91; Mediterranean.
VUWG 337	Labiatae	<i>Melissa officinalis</i>	WELT 69884; W Hutt Rd, Wellington, N.Z.
VUWG 1088	Labiatae	<i>Melittis melissophyllum</i>	WELTU box 91; Black Forest, Germany.
VUWG 1089	Labiatae	<i>Mentha aquatica</i>	WELTU box 91; Holland.
VUWG 1090	Labiatae	<i>Mentha aquatica</i>	WELTU box 91.
VUWG 1422	Labiatae	<i>Mentha aquatica</i>	WELTU; Wellington, N.Z.
VUWG 662	Labiatae	<i>Mentha aquatica</i>	Chester 24. Kellia, Grevena Pr., NW Greece.
VUWG 718	Labiatae	<i>Mentha aquatica</i>	Chester 123. Mirsina, Grevena Pr., NW Greece.
NUNG 189	Labiatae	<i>Mentha longifolia</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 363	Labiatae	<i>Mentha x piperita</i>	WELT 70227a; Birchfield, Buller, N.Z.
VUWG 364	Labiatae	<i>Mentha x piperita</i>	WELT 70227b; Birchfield, Buller, N.Z.
VUWG 365	Labiatae	<i>Mentha x piperita</i>	WELT 69932a; Inverness Rd, Waitemata, N.Z.
VUWG 1092	Labiatae	<i>Mentha pulegium</i>	WELTU box 91; Holland.
VUWG 1424	Labiatae	<i>Mentha pulegium</i>	WELTU 11369; Cape Turakirae, Wellington, N.Z.
VUWG 367	Labiatae	<i>Mentha pulegium</i>	WELT 59823; Piha, Auckland, N.Z.
VUWG 368	Labiatae	<i>Mentha pulegium</i>	WELT 59831; Karekare, Auckland, N.Z.
VUWG 369	Labiatae	<i>Mentha pulegium</i>	WELT 61781; Castlepoint, Wairarapa, N.Z.
VUWG 1093	Labiatae	<i>Mentha rotundifolia</i>	WELTU box 91; Holland.
VUWG 370	Labiatae	<i>Mentha spicata</i>	WELT 70135; Kaiwhata Rd, Te Wharua, N.Z.
VUWG 371	Labiatae	<i>Mentha spicata</i>	WELT 69908a; East Coast Rd, Milford, N.Z.
VUWG 372	Labiatae	<i>Mentha spicata</i>	WELT 69908b; East Coast Rd, Milford, N.Z.
VUWG 373	Labiatae	<i>Mentha suaveolens</i>	WELT 70386; L. Wairarapa, N.Z.
VUWG 762	Labiatae	<i>Mentha suaveolens</i>	Chester 249. Asprokampos, Grevena Pr., NW Greece.
VUWG 653	Labiatae	<i>Mentha</i> sp.	Chester 15. Anelia, Grevena Pr., NW Greece.
VUWG 338	Labiatae	<i>Nepeta cataria</i>	WELT 62693; Stronvar, Wairarapa, N.Z.
VUWG 339	Labiatae	<i>Nepeta cataria</i>	WELT 60792; Kenepuru Valley, N.Z.
VUWG 340	Labiatae	<i>Nepeta cataria</i>	WELT 61673; Tarakohe, Golden Bay, N.Z.
VUWG 341	Labiatae	<i>Origanum vulgare</i>	WELT 62553; Standen St, Karori, Wellington, N.Z.

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VUWG 342	Labiatae	<i>Origanum vulgare</i>	WELT 62647; Silverstream Rd, Wellington, N.Z.
VUWG 343	Labiatae	<i>Origanum vulgare</i>	WELT 60851.
NUNG 98	Labiatae	<i>Phlomis purpurea</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1094	Labiatae	<i>Prunella grandiflora</i>	WELTU box 91; Kaiserstuhl nr. Freiburg, Germany.
VUWG 641	Labiatae	<i>Prunella laciniata</i>	Chester 3. Anelia, Grevena Pr., NW Greece.
VUWG 1426	Labiatae	<i>Prunella vulgaris</i>	WELTU 10374; Kennedy Bay, Coromandel Peninsula, N.Z.
VUWG 1427	Labiatae	<i>Prunella vulgaris</i>	WELTU 11437; Cape Turakirae, Wellington, N.Z.
VUWG 344	Labiatae	<i>Prunella vulgaris</i>	WELT 70166a; Kahuteraura Rd, Taratua Ra., N.Z.
VUWG 345	Labiatae	<i>Prunella vulgaris</i>	WELT 63231; Tokomaru Bay, Mangatuna, N.Z.
VUWG 346	Labiatae	<i>Prunella vulgaris</i>	WELT 62614; Keith George Park, Hutt Valley, N.Z.
NUNG 16	Labiatae	<i>Rosmarinus officinalis</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1095	Labiatae	<i>Salvia glutinosa</i>	WELTU box 91; Switzerland.
NUNG 102	Labiatae	<i>Salvia glutinosa</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1098	Labiatae	<i>Salvia pratensis</i>	WELTU box 91; Donau R., Germany.
VUWG 1097	Labiatae	<i>Salvia roemeriana</i>	WELTU 9413; Mt Bonnel, Travis Co., USA.
VUWG 352	Labiatae	<i>Salvia sclarea</i>	WELT 14203; Seatoun, Wellington, N.Z.
VUWG 349	Labiatae	<i>Salvia verbenacea</i>	WELT 61691; Auckland, N.Z.
VUWG 350	Labiatae	<i>Salvia verbenacea</i>	WELT 61693; Kaikoura, N.Z.
VUWG 351	Labiatae	<i>Salvia verbenacea</i>	WELT 60846; Kaikoura, N.Z.
VUWG 1096	Labiatae	<i>Salvia verticillata</i>	WELTU box 91; Switzerland.
VUWG 764	Labiatae	<i>Salvia</i> sp.	Chester 252. Asprokamos, Grevena Pr., NW Greece.
VUWG 788	Labiatae	<i>Salvia</i> sp. [cultivar]	Chester 309. Wellington Botanic Gardens, N.Z.
VUWG 353	Labiatae	<i>Stachys arvensis</i>	WELT 62616; Keith George Park, Hutt Valley, N.Z.
VUWG 354	Labiatae	<i>Stachys arvensis</i>	WELT 60700; S Karori Rd, Wellington, N.Z.
VUWG 1099	Labiatae	<i>Stachys palustris</i>	WELTU box 91; De Steeg, Holland.
VUWG 355	Labiatae	<i>Stachys palustris</i>	WELT 61704; Whanganui, N.Z.
VUWG 356	Labiatae	<i>Stachys palustris</i>	WELT 61704; Whanganui, N.Z.
VUWG 1100	Labiatae	<i>Stachys recta</i>	WELTU box 91; Holland.
NUNG 145	Labiatae	<i>Stachys recta</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1101	Labiatae	<i>Stachys sylvatica</i>	WELTU box 91; Zandvoort, Holland.
VUWG 1428	Labiatae	<i>Stachys sylvatica</i>	WELTU 15190; Karori, Wellington, N.Z.

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VUWG 1429	Labiatae	<i>Stachys sylvatica</i>	WELTU 15190; Karori, Wellington, N.Z.
VUWG 357	Labiatae	<i>Stachys sylvatica</i>	WELT 70734; Banks Peninsula, Canterbury, N.Z.
VUWG 358	Labiatae	<i>Stachys sylvatica</i>	WELT 60373; S Karori Rd, Wellington, N.Z.
VUWG 359	Labiatae	<i>Stachys sylvatica</i>	WELT 51421; Red Rock, Wellington, N.Z.
NUNG 78	Labiatae	<i>Stachys sylvatica</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 737	Labiatae	? <i>Stachys</i> sp.	Chester 160. Anelia, Grevena Pr., NW Greece.
VUWG 102	Labiatae	<i>Teucrium botrys</i>	WELTU box 91; Holland.
VUWG 1103	Labiatae	<i>Teucrium ?montanum</i>	WELTU box 91; Switzerland.
VUWG 728	Labiatae	<i>Teucrium polium</i>	Chester 135. Mirsina, Grevena Pr., NW Greece.
VUWG 1430	Labiatae	<i>Teucrium scordium</i>	WELTU 10373; Canterbury Plains, N.Z.
VUWG 672	Labiatae	<i>Teucrium scordium</i>	Chester 34. Kellia, Grevena Pr., NW Greece.
VUWG 719	Labiatae	<i>Teucrium scordium</i>	Chester 124. Mirsina, Grevena Pr., NW Greece.
VUWG 1104	Labiatae	<i>Teucrium scorodonia</i>	WELTU box 91; Holland.
NUNG 183	Labiatae	<i>Teucrium scorodonia</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 748	Labiatae	<i>Teucrium</i> sp.	Chester 177. Agios Nicholas, Grevena Pr., NW Greece.
VUWG 1105	Labiatae	<i>Thymus serpyllum</i>	WELTU box 91; Germany.
VUWG 360	Labiatae	<i>Thymus vulgaris</i>	WELT 70409; Roxburgh, Central Otago, N.Z.
VUWG 699	Labiatae	<i>Thymus</i> sp.	Chester 71. Polineri, Grevena Pr., NW Greece.
NUNG 38	Labiatae		Stevenson, Newcastle Upon Tyne University, England.
VUWG 1013	Leguminosae	<i>Astragalus massiliensis</i>	WELTU box 91.
NUNG 7	Leguminosae	<i>Ceratonia siliqua</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 1	Leguminosae	<i>Cercis siliquastrum</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 84	Leguminosae	<i>Colutea arborescens</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 107	Leguminosae	<i>Coronilla repanda</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 429	Leguminosae	<i>Coronilla varia</i>	WELT 69894; Grafton, Auckland, N.Z.
NUNU 101	Leguminosae	<i>Cytisus grandiflorus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 428	Leguminosae	<i>Cytisus scoparius</i>	WELT 60776; S Karori Rd, Wellington, N.Z.
NUNG 47	Leguminosae	<i>Cytisus scoparius</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 114	Leguminosae	<i>Cytisus sessilifolius</i>	Stevenson, Newcastle Upon Tyne University, England.

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VUWG 683	Leguminosae	<i>Dorycnium graecum</i>	Chester 51. Kellia, Grevena Pr., NW Greece.
VUWG 725	Leguminosae	<i>Dorycnium graecum</i>	Chester 131. Mirsina, Grevena Pr., NW Greece.
VUWG 691	Leguminosae	<i>Dorycnium hirsutum</i>	Chester 60. Mavrani, Grevena Pr., NW Greece.
VUWG 746	Leguminosae	<i>Dorycnium pentaphyllum</i>	Chester 174. Agios Nicholas, Grevena Pr., NW Greece.
NUNG 165	Leguminosae	<i>Echinospartun boissieri</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1014	Leguminosae	<i>Genista anglica</i>	WELTU box 91; Holland.
VUWG 1015	Leguminosae	<i>Genista lineus</i>	WELTU box 91; Germany.
VUWG 1016	Leguminosae	<i>Genista pulegium</i>	WELTU box 91; Germany.
VUWG 1017	Leguminosae	<i>Genista tinctoria</i>	WELTU box 91; Germany.
VUWG 1018	Leguminosae	<i>Genista tinctoria</i>	WELTU box 91.
VUWG 1019	Leguminosae	<i>Laburnum anagyroides</i>	WELTU box 91; Holland.
VUWG 1020	Leguminosae	<i>Laburnum anagyroides</i>	WELTU box 91; Holland.
VUWG 1021	Leguminosae	<i>Lathyrus aphaca</i>	WELTU box 91; India.
VUWG 434	Leguminosae	<i>Lathyrus latifolius</i>	WELT 60575; Karori, Wellington, N.Z.
VUWG 435	Leguminosae	<i>Lathyrus latifolius</i>	WELT 62600; Keith George Park, Hutt Valley, N.Z.
VUWG 436	Leguminosae	<i>Lathyrus latifolius</i>	WELT 61329; McKays Crossing, Paekakariki, N.Z.
VUWG 1339	Leguminosae	<i>Lathyrus latifolius</i>	WELTU 15312; Avalon, Lower Hutt, N.Z.
VUWG 1340	Leguminosae	<i>Lathyrus latifolius</i>	WELTU; Wellington, N.Z.
VUWG 1022	Leguminosae	<i>Lathyrus palustris</i>	WELTU box 91; Holland.
VUWG 437	Leguminosae	<i>Lathyrus pratensis</i>	WELT 70405; Waikari, N Canterbury, N.Z.
VUWG 1023	Leguminosae	<i>Lathyrus pratensis</i>	WELTU box 91; Holland.
NUNG 49	Leguminosae	<i>Lathyrus pratensis</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1024	Leguminosae	<i>Lathyrus sulphureus</i>	WELTU 9379; nr. Cool, Eldorado Co., USA.
VUWG 1341	Leguminosae	<i>Lathyrus sylvestris</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 438	Leguminosae	<i>Lathyrus tingitanus</i>	WELT 63489a; Raroa Rd, Karori, Wellington, N.Z.
VUWG 439	Leguminosae	<i>Lathyrus tingitanus</i>	WELT 60581; S Karori Rd, Wellington, N.Z.
VUWG 440	Leguminosae	<i>Lathyrus tingitanus</i>	WELT 61533; Pukerua Bay, Wellington, N.Z.
VUWG 1025	Leguminosae	<i>Lathyrus tuberosus</i>	WELTU box 91; Holland.
VUWG 647	Leguminosae	<i>Lathyrus</i> sp.	Chester 9. Anelia, Grevena Pr., NW Greece.
VUWG 745	Leguminosae	<i>Lotus aegaeus</i>	Chester 173. Agios Nicholas, Grevena Pr., NW Greece.
VUWG 430	Leguminosae	<i>Lotus angustissimus</i>	WELT 70774; Pukerua Bay, Wellington, N.Z.
VUWG 431	Leguminosae	<i>Lotus angustissimus</i>	WELT 70646; Great Island, Three Kings Is, N.Z.

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VUWG 432	Leguminosae	<i>Lotus angustissimus</i>	WELT 70087a; Rodney Cnty, N of Waiwera, N.Z.
VUWG 433	Leguminosae	<i>Lotus corniculatus</i>	WELT 70414; Milton, S Otago, N.Z.
VUWG 1008	Leguminosae	<i>Lotus corniculatus</i>	WELTU box 91; Holland.
NUNG 11	Leguminosae	<i>Lotus corniculatus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 266	Leguminosae	<i>Lotus corniculatus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 684	Leguminosae	<i>Lotus cf. corniculatus</i>	Chester 52. Kellia, Grevena Pr., NW Greece.
VUWG 713	Leguminosae	<i>Lotus cf. corniculatus</i>	Chester 98. Polineri, Grevena Pr., NW Greece.
NUNG 149	Leguminosae	<i>Lotus creticus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1342	Leguminosae	<i>Lotus parviflorus</i>	WELTU; Kaingaroa, N.Z.
VUWG 1343	Leguminosae	<i>Lotus pedunculatus</i>	WELTU; Wellington, N.Z.
VUWG 1344	Leguminosae	<i>Lotus pedunculatus</i>	WELTU; Wellington, N.Z.
VUWG 1009	Leguminosae	<i>Lotus uliginosus</i>	WELTU box 91; Holland.
VUWG 646	Leguminosae	<i>Lotus</i> sp.	Chester 8. Anelia, Grevena Pr., NW Greece.
VUWG 441	Leguminosae	<i>Lupinus angustifolius</i>	WELT 61288; Milford, Waitemata Co., N.Z.
VUWG 442	Leguminosae	<i>Lupinus angustifolius</i>	WELT 61292; Milford, Waitemata Co., N.Z.
VUWG 443	Leguminosae	<i>Lupinus angustifolius</i>	WELT 60917; Hokio Beach, Levin, N.Z.
NUNG 91	Leguminosae	<i>Lupinus hispanicus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 131	Leguminosae	<i>Lupinus polyphyllus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 446	Leguminosae	<i>Medicago arabica</i>	WELT 63267; Hikurangi, N.Z.
VUWG 447	Leguminosae	<i>Medicago arabica</i>	WELT 61471; Cuvier Island, N.Z.
VUWG 448	Leguminosae	<i>Medicago arabica</i>	WELT 60920; S Karori Rd, Wellington, N.Z.
VUWG 444	Leguminosae	<i>Medicago arborea</i>	WELT 61246; Island Bay, Wellington, N.Z.
VUWG 445	Leguminosae	<i>Medicago arborea</i>	WELT 60570; Island Bay, Wellington, N.Z.
VUWG 1010	Leguminosae	<i>Medicago falcata</i>	WELTU box 91; Holland.
VUWG 449	Leguminosae	<i>Medicago lupulina</i>	WELT 70859; Wakanui, Ashburton, N.Z.
VUWG 450	Leguminosae	<i>Medicago lupulina</i>	WELT 70076a; Weranui Rd, Waiwera, N.Z.
VUWG 451	Leguminosae	<i>Medicago lupulina</i>	WELT 63478; Riverside Rd, Havelock North, N.Z.
VUWG 1345	Leguminosae	<i>Medicago lupulina</i>	WELTU 11372; Cape Turakirae, Wellington, N.Z.
VUWG 1346	Leguminosae	<i>Medicago lupulina</i>	WELTU 14934; Raumati, N.Z.
VUWG 1347	Leguminosae	<i>Medicago lupulina</i>	WELTU 10333; N.Z.
VUWG 452	Leguminosae	<i>Medicago minima</i>	WELT 70725; Waipara River, Canterbury, N.Z.

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VUWG 453	Leguminosae	<i>Medicago polymorpha</i>	WELT 61255; S Karori Rd, Wellington, N.Z.
VUWG 454	Leguminosae	<i>Medicago polymorpha</i>	WELT 61487.
VUWG 455	Leguminosae	<i>Medicago polymorpha</i>	WELT 61485; Pukerua Bay, Wellington, N.Z.
VUWG 456	Leguminosae	<i>Medicago sativa</i>	WELT 70888; Vivian St, Wellington, N.Z.
VUWG 457	Leguminosae	<i>Medicago sativa</i>	WELT 70442; Island Bay, Wellington, N.Z.
VUWG 458	Leguminosae	<i>Medicago sativa</i>	WELT 70103; Browns Bay, Waitemata Co., N.Z.
VUWG 1011	Leguminosae	<i>Medicago sativa</i>	WELTU box 91; Holland.
VUWG 1012	Leguminosae	<i>Medicago sativa</i>	WELTU box 91.
VUWG 1348	Leguminosae	<i>Medicago sativa</i>	WELTU; New Plymouth, N.Z.
NUNG 143	Leguminosae	<i>Medicago sativa</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 459	Leguminosae	<i>Melilotus alba</i>	WELT 70861; Pokaka, central N Island, N.Z.
VUWG 460	Leguminosae	<i>Melilotus alba</i>	WELT 61504; Napier, N.Z.
VUWG 1026	Leguminosae	<i>Melilotus alba</i>	WELTU box 91; Holland.
VUWG 1027	Leguminosae	<i>Melilotus altissima</i>	WELTU box 91; Holland.
VUWG 1028	Leguminosae	<i>Melilotus altissima</i>	WELTU box 91.
VUWG 461	Leguminosae	<i>Melilotus indica</i>	WELT 70096; Waiwera, Rodney Co., N.Z.
VUWG 462	Leguminosae	<i>Melilotus indica</i>	WELT 69893; Milford, Waitemata Co., N.Z.
VUWG 463	Leguminosae	<i>Melilotus indica</i>	WELT 61512; Seatoun, Wellington, N.Z.
VUWG 1349	Leguminosae	<i>Melilotus indica</i>	WELTU; Wellington, N.Z.
VUWG 1350	Leguminosae	<i>Melilotus indica</i>	WELTU; Wellington, N.Z.
VUWG 1351	Leguminosae	<i>Melilotus indica</i>	WELTU; Wellington, N.Z.
VUWG 464	Leguminosae	<i>Melilotus officinalis</i>	WELT 70422; Islington, Christchurch, N.Z.
VUWG 465	Leguminosae	<i>Melilotus officinalis</i>	WELT 62807; Tatapouri Bay, Gisborne, N.Z.
VUWG 1029	Leguminosae	<i>Melilotus officinalis</i>	WELTU box 91; Holland.
VUWG 1030	Leguminosae	<i>Melilotus officinalis</i>	WELTU box 91; Holland.
VUWG 1031	Leguminosae	<i>Onobrychis viciifolia</i>	WELTU box 91; Holland.
VUWG 1032	Leguminosae	<i>Onobrychis viciifolia</i>	WELTU box 91; Holland.
VUWG 1033	Leguminosae	<i>Onobrychis viciifolia</i>	WELTU box 91; Switzerland.
NUNG 123	Leguminosae	<i>Ononis baetica</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 466	Leguminosae	<i>Ononis spinosa</i>	WELT 70420; Templeton, Canterbury, N.Z.
VUWG 658	Leguminosae	<i>Ononis spinosa</i>	Chester 20. Kellia, Grevena Pr., NW Greece.
VUWG 1034	Leguminosae	<i>Ononis spinosa</i>	WELTU box 91; Holland.
VUWG 1035	Leguminosae	<i>Ononis spinosa</i>	WELTU box 91; Holland.
NUNG 124	Leguminosae	<i>Ononis subspicata</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 468	Leguminosae	<i>Ornithopis pinnatus</i>	WELT 70699; Stevenson Island, Whangaroa Co., N.Z.
VUWG 467	Leguminosae	<i>Ornithopus pinnatus</i>	WELT 70696; Auckland City, N.Z.

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VUWG 470	Leguminosae	<i>Teline monspessulanus</i>	WELT 60885; Bowen St, Wellington, N.Z.
VUWG 471	Leguminosae	<i>Teline monspessulanus</i>	WELT 63153; Karori, Wellington, N.Z.
VUWG 469	Leguminosae	<i>Teline x spachianus</i>	WELT 63188; Pukerua Bay, Wellington, N.Z.
VUWG 1036	Leguminosae	<i>Trifolium alpinum</i>	WELTU box 91; Switzerland.
NUNG 52	Leguminosae	<i>Trifolium alpinum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 472	Leguminosae	<i>Trifolium arvense</i>	WELT 63311; Nelson City, N.Z.
VUWG 473	Leguminosae	<i>Trifolium arvense</i>	WELT 61603; Karori, Wellington, N.Z.
VUWG 474	Leguminosae	<i>Trifolium arvense</i>	WELT 60580; Paraparaumu, N.Z.
VUWG 1037	Leguminosae	<i>Trifolium arvense</i>	WELTU box 91; Velp, Holland.
NUNG 125	Leguminosae	<i>Trifolium badium</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 476	Leguminosae	<i>Trifolium campestre</i>	WELT 70866; Ashburton, N.Z.
VUWG 716	Leguminosae	<i>Trifolium campestre</i>	Chester 104. Polineri, Grevena Pr., NW Greece.
NUNG 250	Leguminosae	<i>Trifolium campestre</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 477	Leguminosae	<i>Trifolium dubium</i>	WELT 61776; Orongorongo Valley, Wellington, N.Z.
VUWG 478	Leguminosae	<i>Trifolium dubium</i>	WELT 61609; Cuvier Island, N.Z.
VUWG 479	Leguminosae	<i>Trifolium dubium</i>	WELT 61607; Pukerua Bay, N.Z.
NUNG 97	Leguminosae	<i>Trifolium dubium</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 480	Leguminosae	<i>Trifolium glomeratum</i>	WELT 61212; Somes Island, Wellington, N.Z.
VUWG 481	Leguminosae	<i>Trifolium glomeratum</i>	WELT 63187; Eastbourne, Wellington, N.Z.
VUWG 482	Leguminosae	<i>Trifolium glomeratum</i>	WELT 62651; Waipoua State Forest, N.Z.
VUWG 1352	Leguminosae	<i>Trifolium glomeratum</i>	WELTU 11431; Cape Turakirae, Wellington, N.Z.
VUWG 1353	Leguminosae	<i>Trifolium glomeratum</i>	WELTU; Wellington, N.Z.
VUWG 483	Leguminosae	<i>Trifolium hybridum</i>	WELT 70863; Palmerston North, N.Z.
VUWG 484	Leguminosae	<i>Trifolium incarnatum</i>	WELT 61637a; Wellington, N.Z.
VUWG 1038	Leguminosae	<i>Trifolium montanum</i>	WELTU box 91; Switzerland.
NUNG 122	Leguminosae	<i>Trifolium montanum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 485	Leguminosae	<i>Trifolium pratense</i>	WELT 63322; Forest Hill, Waitemata Co., N.Z.
VUWG 486	Leguminosae	<i>Trifolium pratense</i>	WELT 61620; Pukerua Bay, Wellington, N.Z.
VUWG 652	Leguminosae	<i>Trifolium pratense</i>	Chester 14. Anelia, Grevena Pr., NW Greece.
VUWG 1039	Leguminosae	<i>Trifolium pratense</i>	WELTU box 91; Holland.
VUWG 1354	Leguminosae	<i>Trifolium pratense</i>	WELTU; Wellington, N.Z.
VUWG 1355	Leguminosae	<i>Trifolium pratense</i>	WELTU; Wellington, N.Z.
NUNG 213	Leguminosae	<i>Trifolium pratense</i>	Stevenson, Newcastle Upon Tyne University, England.

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VUWG 487	Leguminosae	<i>Trifolium repens</i>	WELT 70358a; Milford, Waitemata Co., N.Z.
VUWG 488	Leguminosae	<i>Trifolium repens</i>	WELT 60564; S Karori Rd, Wellington, N.Z.
VUWG 489	Leguminosae	<i>Trifolium repens</i>	WELT 61261; S Karori Rd, Wellington, N.Z.
VUWG 742	Leguminosae	<i>Trifolium repens</i>	Chester 167. Gomara, Grevena Pr., NW Greece.
VUWG 834	Leguminosae	<i>Trifolium repens</i>	Chester 355. Victoria University, Wellington, N.Z.
VUWG 1041	Leguminosae	<i>Trifolium repens</i>	WELTU box 91; Velp, Holland.
VUWG 1356	Leguminosae	<i>Trifolium repens</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 1357	Leguminosae	<i>Trifolium repens</i>	WELTU; Cape Turakirae, Wellington, N.Z.
VUWG 1040	Leguminosae	<i>Trifolium rubens</i>	WELTU box 91; Kaiserstuhl nr. Freiburg, Germany.
VUWG 490	Leguminosae	<i>Trifolium striatum</i>	WELT 61654; Cashmere Hills, Christchurch, N.Z.
VUWG 491	Leguminosae	<i>Trifolium striatum</i>	WELT 61646; Pukerua Bay, Wellington, N.Z.
VUWG 492	Leguminosae	<i>Trifolium subterraneum</i>	WELT 70363a; Milford, Waitemata Co., N.Z.
VUWG 493	Leguminosae	<i>Trifolium subterraneum</i>	WELT 60871b; S Karori Rd, Wellington, N.Z.
VUWG 494	Leguminosae	<i>Trifolium subterraneum</i>	WELT 61211; Somes Island, Wellington, N.Z.
NUNG 257	Leguminosae	<i>Trifolium subterraneum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 495	Leguminosae	<i>Trifolium tomentosum</i>	WELT 70413; Christchurch, N.Z.
VUWG 496	Leguminosae	<i>Trifolium tomentosum</i>	WELT 61650; Worser Bay, Wellington, N.Z.
VUWG 1358	Leguminosae	<i>Ulex europaeus</i>	WELTU 11325; Cape Turakirae, Wellington, N.Z.
NUNG 6	Leguminosae	<i>Ulex europaeus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 500	Leguminosae	<i>Vicia angustifolia</i>	WELT 63185; Eastbourne, Wellington, N.Z.
VUWG 501	Leguminosae	<i>Vicia angustifolia</i>	WELT 62904; Kenepuru, N.Z.
VUWG 502	Leguminosae	<i>Vicia angustifolia</i>	WELT 61224; S Karori Rd, Wellington, N.Z.
VUWG 497	Leguminosae	<i>Vicia hirsuta</i>	WELT 70384; Pukerua Bay, Wellington, N.Z.
VUWG 498	Leguminosae	<i>Vicia hirsuta</i>	WELT 61577; Seatoun, Wellington, N.Z.
VUWG 499	Leguminosae	<i>Vicia hirsuta</i>	WELT 60875; S Karori Rd, Wellington, N.Z.
VUWG 1044	Leguminosae	<i>Vicia hirsuta</i>	WELTU box 91; Holland.
VUWG 1359	Leguminosae	<i>Vicia hirsuta</i>	WELTU 10366; Dunedin, N.Z.
VUWG 1360	Leguminosae	<i>Vicia hirsuta</i>	WELTU 14935; Raumat, N.Z.
VUWG 1361	Leguminosae	<i>Vicia hirsuta</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 1045	Leguminosae	<i>Vicia ?melanops</i>	WELTU box 91; Holland.

Pollen/spore reference slide #	Family	Genus & species	Collector (if known)/herbarium, herbarium # (if known), place of collection
VUWG 503	Leguminosae	<i>Vicia sativa</i>	WELT 63450; Stephens Island, N.Z.
VUWG 504	Leguminosae	<i>Vicia sativa</i>	WELT 63193; Westport, N.Z.
VUWG 505	Leguminosae	<i>Vicia sativa</i>	WELT 61273; S Karori Rd, Wellington, N.Z.
VUWG 1046	Leguminosae	<i>Vicia sativa</i>	WELTU box 91; Holland.
VUWG 1042	Leguminosae	<i>Vicia sativa</i> subsp. <i>nigra</i>	WELTU box 91; Holland.
VUWG 1047	Leguminosae	<i>Vicia sepium</i>	WELTU box 91; Holland.
NUNG 115	Leguminosae	<i>Vicia sepium</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 506	Leguminosae	<i>Vicia tetrasperma</i>	WELT 63277; Milford, Waitemata Co., N.Z.
VUWG 507	Leguminosae	<i>Vicia tetrasperma</i>	WELT 63273; Hamilton, N.Z.
VUWG 510	Leguminosae	<i>Vicia villosa</i>	WELT 63271; nr Spyre, N Canterbury, N.Z.
VUWG 508	Leguminosae	<i>Vicia villosa varia</i>	WELT 63272; North Canterbury, N.Z.
VUWG 509	Leguminosae	<i>Vicia villosa varia</i>	WELT 63266; HW1 between Spyre & Motunui, N.Z.
VUWG 1137	Lentibulariaceae	<i>Utricularia stellaris</i>	WELTU; Najabgarh, India.
VUWG 1136	Lentibulariaceae	<i>Utricularia vulgaris</i>	WELTU 9872; Zeya R., Amur Territory, USSR.
VUWG 552	Linaceae	<i>Linum bienne</i>	WELT 63473; Havelock North, N.Z.
VUWG 553	Linaceae	<i>Linum bienne</i>	WELT 61778; Wairarapa, N.Z.
VUWG 554	Linaceae	<i>Linum bienne</i>	WELT 61223; S Karori Rd, Wellington, N.Z.
NUNG 167	Linaceae	<i>Linum campanulatum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1057	Linaceae	<i>Linum catharticum</i>	WELTU 7653; Granity Pass, E Owen Ra., N.Z.
VUWG 1058	Linaceae	<i>Linum catharticum</i>	WELTU box 91; Holland.
VUWG 555	Linaceae	<i>Linum catharticum</i>	WELT 6002; Takaka Hill, Nelson, N.Z.
VUWG 556	Linaceae	<i>Linum catharticum</i>	WELT 63365; Mamaku, N.Z.
VUWG 1334	Linaceae	<i>Linum marginale</i>	WELTU.
NUNG 210	Linaceae	<i>Linum maritimum</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 200	Linaceae	<i>Linum narbonense</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 137	Linaceae	<i>Linum strictum</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 212	Linaceae	<i>Linum suffruticosum</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 209	Linaceae	<i>Linum tenuifolium</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 557	Linaceae	<i>Linum trigynum</i>	WELT 70115; Waitemata Co., N.Z.
NUNG 185	Linaceae	<i>Linum viscosum</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 202	Linaceae	<i>Linum</i> sp.	Stevenson, Newcastle Upon Tyne University, England.

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VUWG 872	Loranthaceae	<i>Viscum album</i>	WELTU box 86; Seine valley, France.
VUWG 1378	Lythraceae	<i>Lythrum hyssopifolia</i>	WELTU 10354.
VUWG 1379	Lythraceae	<i>Lythrum hyssopifolia</i>	WELTU; Wellington, N.Z.
VUWG 1380	Lythraceae	<i>Lythrum hyssopifolia</i>	WELTU 10352; Napier, N.Z.
VUWG 579	Lythraceae	<i>Lythrum hyssopifolium</i>	WELT 69979; Pukerua Bay, Wellington, N.Z.
VUWG 580	Lythraceae	<i>Lythrum hyssopifolium</i>	WELT 63480; Riverside Rd, Havelock North, N.Z.
VUWG 581	Lythraceae	<i>Lythrum hyssopifolium</i>	WELT 62609; Keith George Park, Hutt Valley, N.Z.
VUWG 582	Lythraceae	<i>Lythrum salicaria</i>	WELT 70019a; nr Hokio Beach, Levin, N.Z.
VUWG 583	Lythraceae	<i>Lythrum salicaria</i>	WELT 70019b; nr Hokio Beach, Levin, N.Z.
VUWG 668	Lythraceae	<i>Lythrum salicaria</i>	Chester 30. Kellia, Grevena Pr., NW Greece.
VUWG 879	Lythraceae	<i>Lythrum salicaria</i>	WELTU box 94; Holland.
NUNG 25	Lythraceae	<i>Lythrum salicaria</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 880	Lythraceae	<i>Lythrum virgatum</i>	WELTU box 94; Switzerland.
VUWG 838	Malvaceae	<i>Abutilon indicum</i>	WELTU box 93; Okhla, India.
VUWG 756	Malvaceae	<i>Hibiscus trionum</i>	Chester 228. Asprokamos, Grevena Pr., NW Greece.
VUWG 534	Malvaceae	<i>Lavatera arborea</i>	WELT 63504; Buckle St, Wellington, N.Z.
VUWG 535	Malvaceae	<i>Lavatera arborea</i>	WELT no #; Buckle St, Wellington, N.Z.
VUWG 536	Malvaceae	<i>Lavatera arborea</i>	WELT 61270; Happy Valley Rd, Wellington, N.Z.
VUWG 537	Malvaceae	<i>Lavatera cretica</i>	WELT 70895; Pukerua Bay, Wellington, N.Z.
VUWG 538	Malvaceae	<i>Lavatera cretica</i>	WELT 70666; Milford, Waitemata Co., N.Z.
VUWG 539	Malvaceae	<i>Lavatera cretica</i>	WELT 62656; Waimauku, West Auckland, N.Z.
NUNG 150	Malvaceae	<i>Malva alcea</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 540	Malvaceae	<i>Malva nicaeensis</i>	WELT 70473; Pukerua Bay, Wellington, N.Z.
VUWG 541	Malvaceae	<i>Malva nicaeensis</i>	WELT 63494; Wellington City, N.Z.
VUWG 542	Malvaceae	<i>Malva nicaeensis</i>	WELT 63468; Te Awanga, Hawkes Bay, N.Z.
VUWG 841	Malvaceae	<i>Malva pusilla</i>	WELTU box 93; Holland.
VUWG 543	Malvaceae	<i>Malva sylvestris</i>	WELT 63499; Rongotai, Wellington, N.Z.
VUWG 544	Malvaceae	<i>Malva sylvestris</i>	WELT 60488; nr Paekakariki, Wellington, N.Z.
VUWG 545	Malvaceae	<i>Malva sylvestris</i>	WELT 63232; Main Road, Gisborne, N.Z.
VUWG 839	Malvaceae	<i>Malva sylvestris</i>	WELTU box 93.

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NUNG 211	Malvaceae	<i>Malvella shererdiana</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 842	Malvaceae	<i>Sidalcea oregana</i>	WELTU box 93; Enzler 152, nr Placerville, California.
VUWG 415	Meliaceae	<i>Melia azederach</i>	WELT no #; Auckland Domain, N.Z.
VUWG 574	Menyanthaceae	<i>Nymphoides ?peltata</i> or <i>?alba</i>	WELT 792; Herb. University of California, USA.
VUWG 427	Moraceae	<i>Morus alba</i>	WELT no #; Transylvania.
NUNG 253	Musaceae	<i>Musa</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
NUNG 159	Myoporaceae	<i>Myoporum tenuifolium</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 882	Myrtaceae	<i>Eucalyptus stuartiana</i>	WELTU box 94; NSW, Australia.
VUWG 1376	Myrtaceae	<i>Eucalyptus</i> sp.	WELTU 10356; Wellington Botanic Gardens, N.Z.
VUWG 1377	Myrtaceae	<i>Eucalyptus</i> sp.	WELTU 10355; Wellington Botanic Gardens, N.Z.
VUWG 546	Myrtaceae	<i>Myrtus communis</i>	WELT 62448; Wellington, N.Z.
VUWG 547	Myrtaceae	<i>Myrtus communis</i>	WELT 62449; Wellington, N.Z.
VUWG 390	Oleaceae	<i>Jasminium fruticans</i>	WELT no #.
VUWG 391	Oleaceae	<i>Jasminium fruticans</i>	WELT no #.
NUNG 95	Oleaceae	<i>Jasminum nudiflorum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 831	Oleaceae	<i>Jasminum ?polyanthum</i>	Chester 352. Victoria University, Wellington, N.Z.
DUDB 308	Oleaceae	<i>Ligustrum cf. lucidum</i>	Huntley, Durham University, England.
VUWG 388	Oleaceae	<i>Ligustrum ovalifolium</i>	WELT 60455; S Karori Rd, Wellington, N.Z.
VUWG 387	Oleaceae	<i>Ligustrum sinense</i>	WELT 63497; Raroa Rd, Kelburn, Wellington, N.Z.
VUWG 1397	Oleaceae	<i>Ligustrum vulgare</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 389	Oleaceae	<i>Ligustrum vulgare</i>	WELT 45560; Porirua, Wellington, N.Z.
VUWG 955	Oleaceae	<i>Ligustrum vulgare</i>	WELTU box 97; Holland.
NUNG 193	Oleaceae	<i>Olea europaea</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 230	Oleaceae	<i>Olea europaea</i>	Stevenson, Newcastle Upon Tyne University, England.
CRYG 292	Oleaceae	<i>Olea europaea</i>	Atherden, College of Rippon & York, England.
NUNG 82	Oleaceae	<i>Olea euripaea</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 187	Oleaceae	<i>Phillyrea angustifolia</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 240	Oleaceae	<i>Phillyrea angustifolia</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 37	Oleaceae	<i>Phillyrea angustifolia</i>	Stevenson, Newcastle Upon Tyne University, England.

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NUNG 243	Oleaceae	<i>Phillyrea angustifolia</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 35	Oleaceae	<i>Phillyrea latifolia</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 57	Oleaceae	<i>Phillyrea latifolia</i>	Stevenson, Newcastle Upon Tyne University, England.
CRYG 293	Oleaceae	<i>Phillyrea latifolia</i>	Atherden, College of Rippon & York, England.
NUNG 81	Oleaceae	<i>Phillyrea latifolia</i>	Stevenson, Newcastle Upon Tyne University, England.
DUDB 312	Oleaceae	<i>Phillyrea cf. media</i>	Huntley, Durham University, England.
VUWG 589	Onagraceae	<i>Circaea lutetiana</i>	WELT no #; nr Nysted, Lolland, Denmark.
VUWG 1381	Onagraceae	<i>Epilobium adenocaulon</i>	WELTU; Waikanae, N.Z.
VUWG 651	Onagraceae	<i>Epilobium ?adenocaulon</i>	Chester 13. Anelia, Grevena Pr., NW Greece.
VUWG 667	Onagraceae	<i>Epilobium cf. adenocaulon</i>	Chester 29. Kellia, Grevena Pr., NW Greece.
VUWG 584	Onagraceae	<i>Epilobium angustifolium</i>	WELT no #; Japan.
VUWG 883	Onagraceae	<i>Epilobium angustifolium</i>	WELTU 9385; Yellowstone Park, USA.
VUWG 585	Onagraceae	<i>Epilobium collinum</i>	WELT no #; nr Strommen, Ostergotland, Sweden
VUWG 666	Onagraceae	<i>Epilobium hirsutum</i>	Chester 28. Kellia, Grevena Pr., NW Greece.
VUWG 881	Onagraceae	<i>Epilobium hirsutum</i>	WELTU box 94; Holland.
VUWG 586	Onagraceae	<i>Epilobium hornemanni</i>	WELT no #; Jukkasjarvi, L. Tornetrask, Sweden.
VUWG 593	Onagraceae	<i>Epilobium montanum</i>	WELT 40967; Campbell Island, N.Z.
VUWG 594	Onagraceae	<i>Epilobium montanum</i>	WELT 39499; Motueka, N.Z.
VUWG 595	Onagraceae	<i>Epilobium montanum</i>	WELT 42095b; Mt Egmont, N.Z.
VUWG 587	Onagraceae	<i>Epilobium palustre</i>	WELT no #; Boda, nr Grankulla, Oland, Sweden.
VUWG 884	Onagraceae	<i>Epilobium palustre</i>	WELTU box 94; Holland.
VUWG 885	Onagraceae	<i>Epilobium parviflorum</i>	WELTU box 94; Holland.
VUWG 588	Onagraceae	<i>Epilobium rubescens</i>	WELT no #; Boda, nr Grankulla, Oland, Sweden.
VUWG 590	Onagraceae	<i>Fuchsia magellanica</i>	WELT no #; Hawaii.
VUWG 591	Onagraceae	<i>Fuchsia magellanica</i>	WELT no #; Hawaii.
VUWG 592	Onagraceae	<i>Oenothera biennis</i>	WELT no #; Lancashire, UK.
VUWG 314	Orobanchaceae	<i>Orobanche minor</i>	WELT 63173; Pukerua Bay, Wellington, N.Z.
VUWG 315	Orobanchaceae	<i>Orobanche minor</i>	WELT 61744; Otaki Forks, Tararua Rge, N.Z.
VUWG 316	Orobanchaceae	<i>Orobanche minor</i>	WELT 61228; Karori, Wellington, N.Z.
VUWG 1338	Oxalidaceae	<i>Oxalis acetosella</i>	WELTU; Wellington, N.Z.
VUWG 1337	Oxalidaceae	<i>Oxalis articulata</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 1336	Oxalidaceae	<i>Oxalis pes-caprae</i>	WELTU; Mount St, Wellington, N.Z.

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VUWG 1335	Oxalidaceae	<i>Oxalis rubra</i>	WELTU 10342; Mount St, Wellington, N.Z.
VUWG 1056	Oxalidaceae	<i>Oxalis stricta</i>	WELTU box 91; Holland.
VUWG 571	Oxalidaceae	<i>Oxalis</i> sp.	WELT 70429c; Hokio Beach, nr Levin, N.Z.
VUWG 572	Oxalidaceae	<i>Oxalis</i> sp.	WELT 70429b; Hokio Beach, nr Levin, N.Z.
VUWG 573	Oxalidaceae	<i>Oxalis</i> sp.	WELT 60884b; Waikanae, Wellington, N.Z.
NUNG 194	Paeoniaceae	<i>Paeonia broteroi</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 23	Papaveraceae	<i>Fumaria</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 995	Papaveraceae	<i>Papaver rhoeas</i>	WELTU box 97; Holland.
VUWG 994	Papaveraceae	<i>Papaver somniferum</i>	WELTU box 97; Holland.
VUWG 650	Parnassiaceae	<i>Parnassia palustris</i>	Chester 12. Anelia, Grevena Pr., NW Greece.
NUNG 33	Plantaginaceae	<i>Plantago afra</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 127	Plantaginaceae	<i>Plantago afra</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 203	Plantaginaceae	<i>Plantago afra</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 89	Plantaginaceae	<i>Plantago albicans</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1141	Plantaginaceae	<i>Plantago amplexicaulis</i>	WELTU; Roshamara Garden, India.
NUNG 155	Plantaginaceae	<i>Plantago arenaria</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 111	Plantaginaceae	<i>Plantago arenaria</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 179	Plantaginaceae	<i>Plantago australis</i>	WELT (no #); Te Rewarewa Pt, Plimmerton, N.Z.
VUWG 180	Plantaginaceae	<i>Plantago australis</i>	WELT 63046; Black Rocks, N.Z.
VUWG 181	Plantaginaceae	<i>Plantago australis</i>	WELT 63043a; Ngaruawahia, N.Z.
VUWG 176	Plantaginaceae	<i>Plantago coronopus</i>	WELT (CHR 420600); Birdling's Flat, Canterbury, N.Z.
VUWG 178	Plantaginaceae	<i>Plantago coronopus</i>	WELT 63039; Awatere, N.Z.
NUNG 233	Plantaginaceae	<i>Plantago coronopus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 279	Plantaginaceae	<i>Plantago coronopus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 164	Plantaginaceae	<i>Plantago lagopus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1431	Plantaginaceae	<i>Plantago lanceolata</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 183	Plantaginaceae	<i>Plantago lanceolata</i>	WELT 70107b; Wairau Ck Estuary, Milford, N.Z.
VUWG 184	Plantaginaceae	<i>Plantago lanceolata</i>	WELT 60560; Sth Karori Rd, Wellington, N.Z.
VUWG 695	Plantaginaceae	<i>Plantago lanceolata</i>	Chester 65. Mavrani, Grevena Pr., NW Greece.

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VUWG 697	Plantaginaceae	<i>Plantago lanceolata</i>	Chester 68. Mavrani, Grevena Pr., NW Greece.
VUWG 754	Plantaginaceae	<i>Plantago lanceolata</i>	Chester 226. Asprokampos, Grevena Pr., NW Greece.
NUNG 263	Plantaginaceae	<i>Plantago lanceolata</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1433	Plantaginaceae	<i>Plantago major</i>	WELTU 11264; Cape Turakirae, Wellington, N.Z.
VUWG 185	Plantaginaceae	<i>Plantago major</i>	WELT 70837; Belmont, Hutt Valley, N.Z.
VUWG 186	Plantaginaceae	<i>Plantago major</i>	WELT 69968; Pukerua Bay Primary School, N.Z.
VUWG 187	Plantaginaceae	<i>Plantago major</i>	WELT 69910a; Wairau Ck Estuary, Milford, N.Z.
NUNG 237	Plantaginaceae	<i>Plantago media</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 92	Plantaginaceae	<i>Plantago nivalis</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 9	Plantaginaceae	<i>Plantago serraria</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 188	Plantaginaceae	<i>Plantago varia</i>	WELT 63022; Wellington, N.Z.
VUWG 189	Plantaginaceae	<i>Plantago varia</i>	WELT 63025; Happy Valley, N.Z.
VUWG 190	Plantaginaceae	<i>Plantago varia</i>	WELT 63026; Happy Valley, N.Z.
CRYG 285	Plantaginaceae	<i>Plantago</i> sp.	Atherden, College of Rippon & York, England.
VUWG 813	Platanaceae	<i>Platanus</i> ?x <i>hispanica</i>	Chester 334. Riddiford Gardens, Lower Hutt, N.Z.
NUNG 270	Platanaceae	<i>Platanus orientalis</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 175	Plumbaginaceae	<i>Limonium</i> sp.	WELT 70568; Crofton Downs, Wellington, N.Z.
VUWG 1062	Polygalaceae	<i>Polygala amara</i>	WELTU box 91; Switzerland.
VUWG 1063	Polygalaceae	<i>Polygala comosa</i>	WELTU box 91; Switzerland.
VUWG 1064	Polygalaceae	<i>Polygala serpyllifolia</i>	WELTU box 91; Holland.
VUWG 1385	Polygonaceae	<i>Polygonum aviculare</i>	WELTU; Stokes Valley, Lower Hutt, N.Z.
VUWG 1386	Polygonaceae	<i>Polygonum aviculare</i>	WELTU 11450; Cape Turakirae, Wellington, N.Z.
VUWG 1387	Polygonaceae	<i>Polygonum aviculare</i>	WELTU 10300.
VUWG 1388	Polygonaceae	<i>Polygonum aviculare</i>	WELTU; Dunedin, N.Z.
VUWG 597	Polygonaceae	<i>Polygonum aviculare</i>	WELT 62593; Keith George Park, Hutt Valley, N.Z.
VUWG 598	Polygonaceae	<i>Polygonum aviculare</i>	WELT 60504; S Karori, Wellington, N.Z.
VUWG 599	Polygonaceae	<i>Polygonum aviculare</i>	WELT 62204; Pukerua Bay, Wellington, N.Z.
VUWG 714	Polygonaceae	<i>Polygonum aviculare</i>	Chester 100. Polineri, Grevena Pr., NW Greece.
VUWG 752	Polygonaceae	<i>Polygonum aviculare</i>	Chester 219. Asprokampos, Grevena Pr., NW Greece.
VUWG 874	Polygonaceae	<i>Polygonum aviculare</i>	WELTU box 86; Holland.
VUWG 686	Polygonaceae	<i>Polygonum</i> cf. <i>aviculare</i>	Chester 54. Kellia, Grevena Pr., NW Greece.

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VUWG 600	Polygonaceae	<i>Polygonum persicaria</i>	WELT 62698a; S Karori Rd, Wellington, N.Z.
VUWG 601	Polygonaceae	<i>Polygonum persicaria</i>	WELT 62594; Keith George Park, Hutt Valley, N.Z.
VUWG 602	Polygonaceae	<i>Polygonum persicaria</i>	WELT 62804; Pilmer Rd, Gisborne, N.Z.
NUNG 172	Polygonaceae	<i>Polygonum viviparum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1391	Polygonaceae	<i>Rumex acetosella</i>	WELTU 10296; Kaingaroa, N.Z.
VUWG 1392	Polygonaceae	<i>Rumex acetosella</i>	WELTU 10294; Kaingaroa, N.Z.
VUWG 1393	Polygonaceae	<i>Rumex acetosella</i>	WELTU 15314; Wellington, N.Z.
VUWG 875	Polygonaceae	<i>Rumex acetosella</i>	WELTU 10291; Wellington, N.Z.
NUNG 248	Polygonaceae	<i>Rumex bucephalophorus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 268	Polygonaceae	<i>Rumex conglomeratus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1406	Polygonaceae	<i>Rumex crispus</i>	WELTU; Wellington, N.Z.
DUDB 299	Polygonaceae	<i>Rumex crispus</i>	Huntley, Durham University, England.
DUDB 300	Polygonaceae	<i>Rumex crispus</i>	Huntley, Durham University, England.
DUDB 303	Polygonaceae	<i>Rumex crispus</i>	Huntley, Durham University, England.
VUWG 876	Polygonaceae	<i>Rumex dentatus</i>	WELTU box 86; Jumna canal, India.
VUWG 1405	Polygonaceae	<i>Rumex obtusifolius</i>	WELTU; Wellington, N.Z.
VUWG 877	Polygonaceae	<i>Rumex scutatus</i>	WELTU box 86; Switzerland.
NUNG 12	Polygonaceae	<i>Rumex tenuifolius</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1404	Polygonaceae	<i>Rumex</i> sp.	WELTU; Endeavour Inlet, Queen Charlotte Sound, N.Z.
VUWG 1074	Primulaceae	<i>Anagallis arvensis</i>	WELTU box 91; Holland.
VUWG 1396	Primulaceae	<i>Anagallis arvensis</i>	WELTU 10362; Dunedin, N.Z.
VUWG 172	Primulaceae	<i>Anagallis arvensis</i>	WELT 70791; Wakanui, Ashburton, N.Z.
VUWG 173	Primulaceae	<i>Anagallis arvensis</i>	WELT (Ref 435532); Pukerua Bay, N.Z.
VUWG 174	Primulaceae	<i>Anagallis arvensis</i>	WELT 62618; Keith George Pk, Hutt Valley, N.Z.
NUNG 69	Primulaceae	<i>Cyclamen hederifolium</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 708	Primulaceae	<i>Cyclamen</i> sp.	Chester 81. Polineri, Grevena Pr., NW Greece.
VUWG 1078	Primulaceae	<i>Lysimachia nummularia</i>	WELTU box 91; Holland.
VUWG 1076	Primulaceae	<i>Lysimachia thyrsoflora</i>	WELTU box 91; Black Forest, Germany.
VUWG 1077	Primulaceae	<i>Lysimachia vulgaris</i>	WELTU box 91; Holland.
VUWG 1079	Primulaceae	<i>Soldanella alpina</i>	WELTU box 91; Switzerland.
NUNG 204	Primulaceae	<i>Soldanella alpina</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 251	Rafflesiaceae	<i>Cytinus ruber</i>	Stevenson, Newcastle Upon Tyne University, England.

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VUWG 815	Ranunculaceae	<i>Aquilegia vulgaris</i> [cultivar]	Chester 336. Garden, Johnsonville, Wellington, N.Z.
CRYG 290	Ranunculaceae	<i>Aquilegia</i> sp.	Atherden, College of Rippon & York, England.
VUWG 1296	Ranunculaceae	<i>Caltha palustris</i>	WELTU; Massey University, Palmerston North, N.Z.
VUWG 1297	Ranunculaceae	<i>Clematis vitalba</i>	WELTU 15193.
VUWG 908	Ranunculaceae	<i>Clematis vitalba</i>	WELTU box 88; Holland.
VUWG 671	Ranunculaceae	<i>Consolida</i> sp.	Chester 33. Kellia, Grevena Pr., NW Greece.
VUWG 751	Ranunculaceae	<i>Consolida</i> sp.	Chester 218. Asprokampos, Grevena Pr., NW Greece.
NUNG 5	Ranunculaceae	<i>Consolida</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 909	Ranunculaceae	<i>Helleborus hyemalis</i>	WELTU box 88; Germany.
VUWG 910	Ranunculaceae	<i>Nigella sativa</i>	WELTU box 88; Germany.
VUWG 676	Ranunculaceae	<i>Nigella</i> sp.	Chester 38. Kellia, Grevena Pr., NW Greece.
VUWG 911	Ranunculaceae	<i>Ranunculus acris</i>	WELTU box 88; Holland.
NUNG 239	Ranunculaceae	<i>Ranunculus arvensis</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 914	Ranunculaceae	<i>Ranunculus bulbosus</i>	WELTU box 88; Holland.
NUNG 31	Ranunculaceae	<i>Ranunculus bulbosus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 807	Ranunculaceae	<i>Ranunculus ficaria</i>	Chester 328. Wellington Botanic Gardens, N.Z.
VUWG 915	Ranunculaceae	<i>Ranunculus ?hirsutus</i>	WELTU box 88; Holland.
VUWG 916	Ranunculaceae	<i>Ranunculus lingua</i>	WELTU box 88; Holland.
CRYG 280	Ranunculaceae	<i>Ranunculus lingua</i>	Atherden, College of Rippon & York, England.
NUNG 40	Ranunculaceae	<i>Ranunculus ophioglossifolius</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1299	Ranunculaceae	<i>Ranunculus repens</i>	WELTU 15195; Wellington, N.Z.
VUWG 1300	Ranunculaceae	<i>Ranunculus repens</i>	WELTU 10262; Dunedin, N.Z.
VUWG 820	Ranunculaceae	<i>Ranunculus repens</i>	Chester 341. Garden, Johnsonville, Wellington, N.Z.
VUWG 917	Ranunculaceae	<i>Ranunculus repens</i>	WELTU box 88; Holland.
DUDB 301	Ranunculaceae	<i>Ranunculus repens</i>	Huntley, Durham University, England.
VUWG 918	Ranunculaceae	<i>Ranunculus sceleratus</i>	WELTU box 88; Holland.
NUNG 153	Ranunculaceae	<i>Ranunculus sceleratus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 216	Ranunculaceae	<i>Ranunculus trilobus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 919	Ranunculaceae	<i>Ranunculus ?trilobus</i>	WELTU box 88; Switzerland.
VUWG 920	Ranunculaceae	<i>Ranunculus ?trilobus</i>	WELTU box 88; Switzerland.
VUWG 808	Ranunculaceae	<i>Ranunculus</i> sp. 'Bloomingdale' [cult.]	Chester 329. Wellington Botanic Gardens, N.Z.
VUWG 922	Ranunculaceae	<i>Thalictrum aquilegifolium</i>	ELTU box 88; Switzerland.
VUWG 921	Ranunculaceae	<i>Thalictrum flavum</i>	WELTU box 88.
VUWG 959	Rhamnaceae	<i>Rhamnus alaternus</i>	WELTU 12636.
VUWG 412	Rhamnaceae	<i>Rhamnus alpina</i>	WELT no #; Switzerland.

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VUWG 413	Rhamnaceae	<i>Rhamnus catharticus</i>	WELT no #; Cirencester, Gloucester, UK.
VUWG 958	Rhamnaceae	<i>Trymalium daltonii</i>	WELTU box 97; Victoria, Australia.
VUWG 724	Rosaceae	<i>Agrimonia eupatoria</i>	Chester 130. Mirsina, Grevena Pr., NW Greece.
VUWG 971	Rosaceae	<i>Agrimonia eupatoria</i>	WELTU box 97; Holland.
VUWG 972	Rosaceae	<i>Agrimonia eupatoria</i>	WELTU box 97; Holland.
VUWG 973	Rosaceae	<i>Alchemilla alpina</i>	WELTU box 97; Switzerland.
VUWG 974	Rosaceae	<i>Alchemilla alpina</i>	WELTU box 97; Switzerland.
VUWG 976	Rosaceae	<i>Alchemilla xanthochlora</i>	WELTU box 97; Switzerland.
VUWG 1362	Rosaceae	<i>Cotoneaster harroviana</i>	WELTU; Wellington, N.Z.
VUWG 518	Rosaceae	<i>Crataegus monogyna</i>	WELT 62493.
VUWG 977	Rosaceae	<i>Crataegus monogyna</i>	WELTU box 97; Holland.
NUNG 85	Rosaceae	<i>Crataegus monogyna</i>	Stevenson, Newcastle Upon Tyne University, England.
DUDB 307	Rosaceae	<i>Crataegus monogyna</i>	Huntley, Durham University, England.
VUWG 978	Rosaceae	<i>Fragaria vesca</i>	WELTU box 97; Finland.
NUNG 117	Rosaceae	<i>Malus sylvestris</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 67	Rosaceae	<i>Malus</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
CRYG 289	Rosaceae	<i>Malus</i> sp.	Atherden, College of Rippon & York, England.
VUWG 979	Rosaceae	<i>Potentilla anserina</i>	WELTU box 97; Holland.
NUNG 17	Rosaceae	<i>Potentilla anserina</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 519	Rosaceae	<i>Potentilla argentea</i>	WELT 70406; S Canterbury, N.Z.
VUWG 520	Rosaceae	<i>Potentilla argentea</i>	WELT 70392a; Clyde, Central Otago, N.Z.
NUNG 20	Rosaceae	<i>Potentilla fruticosa</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 980	Rosaceae	<i>Potentilla montana</i>	WELTU box 97; Colmar, Alsace-Lorraine, France.
VUWG 660	Rosaceae	<i>Potentilla reptans</i>	Chester 22. Kellia, Grevena Pr., NW Greece.
VUWG 981	Rosaceae	<i>Potentilla reptans</i>	WELTU box 97; Holland.
VUWG 982	Rosaceae	<i>Potentilla supina</i>	WELTU box 97; Jumna River, India.
VUWG 711	Rosaceae	<i>Poterium minus</i>	Chester 88. Polineri, Grevena Pr., NW Greece.
VUWG 521	Rosaceae	<i>Prunus avium</i>	WELT 70509; Nelson, N.Z.
NUNG 30	Rosaceae	<i>Prunus cerasifera</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 522	Rosaceae	<i>Prunus domestica</i>	WELT 60737; Raroa Rd, Wellington, N.Z.
VUWG 523	Rosaceae	<i>Prunus domestica</i>	WELT 60777; S Karori Rd, Wellington, N.Z.
NUNG 26	Rosaceae	<i>Prunus spinosa</i>	Stevenson, Newcastle Upon Tyne University, England.
DUDB 302	Rosaceae	<i>Prunus</i> sp.	Huntley, Durham University, England.

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VUWG 983	Rosaceae	<i>Rosa arizonica</i>	WELTU 9390; Baker Butte, Arizona, USA.
VUWG 985	Rosaceae	<i>Rosa arvensis</i>	WELTU box 97; Holland.
VUWG 984	Rosaceae	<i>Rosa canina</i>	WELTU box 97; Holland.
VUWG 524	Rosaceae	<i>Rosa eglanteria</i>	WELT 70818; Lake Ohau, N.Z.
VUWG 1363	Rosaceae	<i>Rosa rubiginosa</i>	WELTU; Wellington, N.Z.
VUWG 1364	Rosaceae	<i>Rosa rubiginosa</i>	WELTU 11560; Cape Turakirae, Wellington, N.Z.
VUWG 986	Rosaceae	<i>Rosa rubiginosa</i>	WELTU box 97; Holland.
NUNG 130	Rosaceae	<i>Rosa rugosa</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 987	Rosaceae	<i>Rubus adaeus</i>	WELTU box 97; Holland.
VUWG 674	Rosaceae	<i>Rubus caesius</i>	Chester 36. Kellia, Grevena Pr., NW Greece.
NUNG 83	Rosaceae	<i>Rubus caesius</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1365	Rosaceae	<i>Rubus discolor</i>	WELTU 10325; Dunedin, N.Z.
VUWG 1366	Rosaceae	<i>Rubus fruticosus</i>	WELTU; Karori Park, Wellington, N.Z.
VUWG 525	Rosaceae	<i>Rubus fruticosus</i>	WELT 69967; Pukerua Bay, Wellington, N.Z.
VUWG 526	Rosaceae	<i>Rubus fruticosus</i>	WELT 63491; Raroa Rd, Karori, Wellington, N.Z.
VUWG 527	Rosaceae	<i>Rubus fruticosus</i>	WELT 62613; Keith George Park, Hutt Valley, N.Z.
VUWG 989	Rosaceae	<i>Rubus fruticosus</i>	WELTU box 97; Holland.
NUNG 223	Rosaceae	<i>Rubus fruticosus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 225	Rosaceae	<i>Rubus fruticosus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 528	Rosaceae	<i>Rubus laciniatus</i>	WELT 62611; Keith George Park, Hutt Valley, N.Z.
VUWG 529	Rosaceae	<i>Rubus laciniatus</i>	WELT 62526; Tua marina.
VUWG 988	Rosaceae	<i>Rubus nessensis</i>	WELTU box 97; Holland.
VUWG 530	Rosaceae	<i>Rubus ulmifolius</i>	WELT 6049a; Karori Cemetery, Wellington, N.Z.
VUWG 531	Rosaceae	<i>Rubus ulmifolius</i>	WELT 78155; South Auckland, N.Z.
VUWG 771	Rosaceae	<i>Rubus ulmifolius x caesius</i>	Chester 301. Mirsina, Grevena Pr., NW Greece.
VUWG 992	Rosaceae	<i>Sanguisorba minor</i>	WELTU box 97; Holland.
VUWG 990	Rosaceae	<i>Sanguisorba officinalis</i>	WELTU box 97; Germany.
VUWG 991	Rosaceae	<i>Sanguisorba officinalis</i>	WELTU box 97; Switzerland.
NUNG 199	Rosaceae	<i>Sorbus aucuparia</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 215	Rosaceae	<i>Sorbus aucuparia</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1153	Rubiaceae	<i>Asperula cynanchica</i>	WELTU; Switzerland.
VUWG 1154	Rubiaceae	<i>Asperula glaucum</i>	WELTU; Switzerland.
VUWG 1144	Rubiaceae	<i>Galium aparine</i>	WELTU; Holland.
VUWG 1145	Rubiaceae	<i>Galium laevipes</i>	WELTU; Holland.
VUWG 1148	Rubiaceae	<i>Galium palustre</i>	WELTU; Holland.

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VUWG 399	Rubiaceae	<i>Galium palustre</i>	WELT 70427a; Hokio Beach, Levin, N.Z.
VUWG 400	Rubiaceae	<i>Galium palustre</i>	WELT 70427b; Hokio Beach, Levin, N.Z.
VUWG 673	Rubiaceae	<i>Galium rivale</i>	Chester 35. Kellia, Grevena Pr., NW Greece.
VUWG 680	Rubiaceae	<i>Galium rivale</i>	Chester 42. Kellia, Grevena Pr., NW Greece.
VUWG 780	Rubiaceae	<i>Galium trilobum</i>	WELTU 4853; Wanganui Inlet, NW Nelson, N.Z.
VUWG 1146	Rubiaceae	<i>Galium uliginosum</i>	WELTU; Holland.
VUWG 1147	Rubiaceae	<i>Galium uliginosum</i>	WELTU; Holland.
VUWG 1150	Rubiaceae	<i>Galium verum</i>	WELTU; Holland.
VUWG 1151	Rubiaceae	<i>Galium verum</i>	WELTU; Switzerland.
VUWG 1152	Rubiaceae	<i>Galium verum</i>	WELTU; Holland.
VUWG 401	Rubiaceae	<i>Sherardia arvensis</i>	WELT 51346; Red Rocks, Wellington, N.Z.
VUWG 402	Rubiaceae	<i>Sherardia arvensis</i>	WELT 63309; Marsh Ave, Milford, N.Z.
VUWG 403	Rubiaceae	<i>Sherardia arvensis</i>	WELT 63190; Pencarrow, Eastbourne, N.Z.
NUNG 269	Rutaceae	<i>Citrus</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1059	Rutaceae	<i>Eriostemon correfolius</i>	WELTU box 91; upper Yarra, Victoria, Australia.
VUWG 1060	Rutaceae	<i>Phellodendron amurense</i>	WELTU box 91; Russia.
VUWG 1061	Rutaceae	<i>Zieria laevigata</i>	WELTU box 91; NSW, Australia.
NUNG 61	Salicaceae	<i>Populus x euramericana</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 62	Salicaceae	<i>Populus nigra</i>	Stevenson, Newcastle Upon Tyne University, England.
CRYG 283	Salicaceae	<i>Populus</i> sp.	Atherden, College of Rippon & York, England.
VUWG 417	Salicaceae	<i>Salix cinerea</i>	WELT 60865; Banks Peninsula, Canterbury, N.Z.
VUWG 418	Salicaceae	<i>Salix cinerea</i>	WELT 60734; S Karori, Wellington, N.Z.
VUWG 419	Salicaceae	<i>Salix fragilis</i>	WELT 63335; Milford, Waitemata Co., N.Z.
VUWG 420	Salicaceae	<i>Salix fragilis</i>	WELT 63436.
NUNG 156	Salicaceae	<i>Salix herbacea</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 422	Salicaceae	<i>Salix purpurea</i>	WELT 60716; S Karori Stm, Wellington, N.Z.
VUWG 863	Salicaceae	<i>Salix sitchensis</i>	WELTU 9404; Marin Co., California, USA.
VUWG 685	Santalaceae	<i>Thesium</i> sp.	Chester 53. Kellia, Grevena Pr., NW Greece.
VUWG 615	Saxifragaceae	<i>Chrysosplenium</i> sp.	WELT no #; Westfalen, West Germany.
VUWG 616	Saxifragaceae	<i>Deutzia</i> sp.	WELT 8002; Levin, N.Z.
VUWG 617	Saxifragaceae	<i>Saxifraga aizoides</i>	WELT no #; Vallee de la Broye, Switzerland.

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VUWG 966	Saxifragaceae	<i>Saxifraga aizoides</i>	WELTU box 97; Switzerland.
VUWG 967	Saxifragaceae	<i>Saxifraga ?aizoides</i>	WELTU box 97; Switzerland.
VUWG 618	Saxifragaceae	<i>Saxifraga aizoon</i>	WELT no #; Alpes de Bex, Switzerland.
NUNG 152	Saxifragaceae	<i>Saxifraga moschata</i>	Stevenson; Newcastle Upon Tyne University, England.
VUWG 969	Saxifragaceae	<i>Saxifraga paniculata</i>	WELTU box 97; Switzerland.
NUNG 128	Saxifragaceae	<i>Saxifraga paniculata</i>	Stevenson; Newcastle Upon Tyne University, England.
VUWG 968	Saxifragaceae	<i>Saxifraga ?paniculata</i>	WELTU box 97; Switzerland.
VUWG 970	Saxifragaceae	<i>Saxifraga rotundifolia</i>	WELTU box 97; Switzerland.
VUWG 620	Saxifragaceae	<i>Saxifraga stellaris</i>	WELT no #; Jukkasjarvi, L. Tornetrask, Sweden.
NUNG 77	Saxifragaceae	<i>Saxifraga</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 288	Scrophulariaceae	<i>Antirrhinum majus</i>	WELT no #; Gloucestershire, England.
VUWG 259	Scrophulariaceae	<i>Antirrhinum orontium</i>	WELT 62653; Auckland, N.Z.
VUWG 260	Scrophulariaceae	<i>Antirrhinum orontium</i>	WELT 63304; Selwyn Pl., Nelson City, N.Z.
VUWG 261	Scrophulariaceae	<i>Cymbalaria muralis</i>	WELT 70167; Kahuterawa Rd, Palmerston North, N.Z.
VUWG 262	Scrophulariaceae	<i>Cymbalaria muralis</i>	WELT 60730; Norway St, Wellington, N.Z.
VUWG 263	Scrophulariaceae	<i>Cymbalaria muralis</i>	WELT 60513; Happy Valley, Wellington, N.Z.
VUWG 280	Scrophulariaceae	<i>Digitalis ferruginea</i>	WELT no #.
VUWG 740	Scrophulariaceae	<i>Digitalis ferruginea</i>	Chester 163. Anelia, Grevena Pr., NW Greece.
VUWG 1107	Scrophulariaceae	<i>Digitalis grandiflora</i>	WELTU box 91; Black Forest, Germany.
VUWG 281	Scrophulariaceae	<i>Digitalis grandiflora</i>	WELT no #; Transylvania.
VUWG 640	Scrophulariaceae	<i>Digitalis grandiflora</i>	Chester 2. Anelia, Grevena Pr., NW Greece.
VUWG 1109	Scrophulariaceae	<i>Digitalis lutea</i>	WELTU box 91; Black Forest, Germany.
VUWG 282	Scrophulariaceae	<i>Digitalis lutea</i>	WELT no #.
VUWG 283	Scrophulariaceae	<i>Digitalis lutea</i>	WELT no #.
VUWG 284	Scrophulariaceae	<i>Digitalis lutea</i>	WELT no #.
VUWG 1108	Scrophulariaceae	<i>Digitalis purpurea</i>	WELTU box 91; Black Forest, Germany.
VUWG 1411	Scrophulariaceae	<i>Digitalis purpurea</i>	WELTU; Red Rocks, Wellington, N.Z.
VUWG 1412	Scrophulariaceae	<i>Digitalis purpurea</i>	WELTU 15244; Fairlie Tce, Wellington, N.Z.
VUWG 264	Scrophulariaceae	<i>Digitalis purpurea</i>	WELT 63119; Mount Eden, Auckland, N.Z.
VUWG 265	Scrophulariaceae	<i>Digitalis purpurea</i>	WELT 60516; Happy Valley, Wellington, N.Z.
VUWG 266	Scrophulariaceae	<i>Digitalis purpurea</i>	WELT 70093b; Waiwera, Rodney, N.Z.
VUWG 285	Scrophulariaceae	<i>Digitalis purpurea</i>	WELT no #.
VUWG 286	Scrophulariaceae	<i>Digitalis purpurea</i>	WELT no #; Durham, England.

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VUWG 287	Scrophulariaceae	<i>Digitalis purpurea</i>	WELT no #; Norway.
NUNG 134	Scrophulariaceae	<i>Digitalis</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 294	Scrophulariaceae	<i>Erimus alpinus</i>	WELT no #; Switzerland.
VUWG 1111	Scrophulariaceae	<i>Euphrasia micrantha</i>	WELTU box 91; Holland.
VUWG 1110	Scrophulariaceae	<i>Euphrasia rostkoviana</i>	WELTU box 91; Holland.
VUWG 289	Scrophulariaceae	<i>Euphrasia salisburgensis</i>	WELT no #; Switzerland.
VUWG 1113	Scrophulariaceae	<i>Euphrasia</i> sp.	WELTU box 91; Switzerland.
VUWG 649	Scrophulariaceae	<i>Euphrasia</i> sp.	Chester 11. Anelia, Grevena Pr., NW Greece.
NUNG 74	Scrophulariaceae	<i>Euphrasia</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 293	Scrophulariaceae	<i>Gratiola officinalis</i>	WELT no #; Prussia.
VUWG 678	Scrophulariaceae	<i>Kickxia elatine</i>	Chester 40. Kellia, Grevena Pr., NW Greece.
VUWG 681	Scrophulariaceae	<i>Kickxia spuria</i>	Chester 47. Kellia, Grevena Pr., NW Greece.
VUWG 1114	Scrophulariaceae	<i>Linaria alpina</i>	WELTU box 91; Switzerland.
VUWG 290	Scrophulariaceae	<i>Linaria alpina</i>	WELT no #; Bavarian Alps.
VUWG 269	Scrophulariaceae	<i>Linaria arvensis</i>	WELT 70401; Middleton, Christchurch, N.Z.
VUWG 291	Scrophulariaceae	<i>Linaria arvensis</i>	WELT no #; Transylvania.
VUWG 292	Scrophulariaceae	<i>Linaria arvensis</i>	WELT no #.
VUWG 268	Scrophulariaceae	<i>Linaria genistifolia dalmatica</i>	WELT 70727; Govt Gardens, Queenstown, N.Z.
VUWG 1414	Scrophulariaceae	<i>Linaria purpurea</i>	WELTU; Wellington, N.Z.
VUWG 1415	Scrophulariaceae	<i>Linaria purpurea</i>	WELTU; Wellington, N.Z.
VUWG 270	Scrophulariaceae	<i>Linaria vulgaris</i>	WELT 70729; Arrowtown, Queenstown, N.Z.
VUWG 1413	Scrophulariaceae	<i>Linaria</i> sp.	WELTU 15315; Stokes Valley, Lower Hutt, N.Z.
NUNG 206	Scrophulariaceae	<i>Mimulus luteus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 296	Scrophulariaceae	<i>Odontites lutea</i>	WELT no #; Florence, Italy.
VUWG 1112	Scrophulariaceae	<i>Odontites verna</i>	WELTU box 91; Holland.
VUWG 295	Scrophulariaceae	<i>Odontites verna</i>	WELT no #.
VUWG 272	Scrophulariaceae	<i>Parentucellia viscosa</i>	WELT 61777; Castlepoint, Wairarapa, N.Z.
VUWG 273	Scrophulariaceae	<i>Parentucellia viscosa</i>	WELT 63134; Pukerua Bay, Wellington, N.Z.
VUWG 274	Scrophulariaceae	<i>Parentucellia viscosa</i>	WELT 60509; Crofton Downs, Wellington, N.Z.
VUWG 1115	Scrophulariaceae	<i>Pedicularis ?alpina</i>	WELTU box 91; Switzerland.
VUWG 1117	Scrophulariaceae	<i>Pedicularis sylvatica</i>	WELTU box 91; Holland.
VUWG 297	Scrophulariaceae	<i>Pedicularis verticillata</i>	WELT no #; Hungary.
VUWG 298	Scrophulariaceae	<i>Pedicularis verticillata</i>	WELT no #; Switzerland.
VUWG 1118	Scrophulariaceae	<i>Rhinanthus</i> sp.	WELTU box 91; Holland.
NUNG 168	Scrophulariaceae	<i>Scrophularia auriculata</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1119	Scrophulariaceae	<i>Scrophularia canina</i>	WELTU box 91; nr Neu Breenach, Rhineland, Germany.
VUWG 299	Scrophulariaceae	<i>Scrophularia canina</i>	WELT no #.
VUWG 300	Scrophulariaceae	<i>Scrophularia nodosa</i>	WELT no #; Transylvania.

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VUWG 301	Scrophulariaceae	<i>Scrophularia nodosa</i>	WELT no #.
VUWG 302	Scrophulariaceae	<i>Scrophularia nodosa</i>	WELT no #; Dudstone Blantyre, UK.
VUWG 303	Scrophulariaceae	<i>Scrophularia peregrina</i>	WELT no #.
VUWG 1120	Scrophulariaceae	<i>Verbascum blattaria</i>	WELTU box 91; Alsace, France.
VUWG 1416	Scrophulariaceae	<i>Verbascum blattaria</i>	WELTU 10388; West Taieri, N.Z.
VUWG 275	Scrophulariaceae	<i>Verbascum blattaria</i>	WELT 63126.
VUWG 305	Scrophulariaceae	<i>Verbascum blattaria</i>	WELT no #; Vienna, Austria.
VUWG 306	Scrophulariaceae	<i>Verbascum chaixii</i>	WELT no #; Vienna, Austria.
VUWG 1121	Scrophulariaceae	<i>Verbascum lychnitis</i>	WELTU box 91; Holland.
VUWG 736	Scrophulariaceae	<i>Verbascum macrurum</i>	Chester 159. Anelia, Grevena Pr., NW Greece.
VUWG 1122	Scrophulariaceae	<i>Verbascum nigrum</i>	WELTU box 91; Holland.
VUWG 1123	Scrophulariaceae	<i>Verbascum nigrum</i>	WELTU box 91; Holland.
VUWG 1124	Scrophulariaceae	<i>Verbascum thapsus</i>	WELTU box 91; Kowai Valley, N.Z.
VUWG 277	Scrophulariaceae	<i>Verbascum thapsus</i>	WELT 62622; Keith George Park, Hutt Valley, N.Z.
VUWG 278	Scrophulariaceae	<i>Verbascum thapsus</i>	WELT 63128; Pukerua Bay, Wellington, N.Z.
VUWG 279	Scrophulariaceae	<i>Verbascum thapsus</i>	WELT 60512; Makara Beach, Wellington, N.Z.
VUWG 249	Scrophulariaceae	<i>Veronica agrestis</i>	WELT 63090; Hawkes Bay, N.Z.
NUNG 180	Scrophulariaceae	<i>Veronica alpina</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1125	Scrophulariaceae	<i>Veronica alpina</i>	WELTU box 91; Switzerland.
VUWG 246	Scrophulariaceae	<i>Veronica anagallis-aquatica</i>	WELT 70762; Waipatiki Bush Reserve, Napier, N.Z.
VUWG 247a	Scrophulariaceae	<i>Veronica anagallis-aquatica</i>	WELT 69901; Rainbow Springs, Rotorua, N.Z.
VUWG 248	Scrophulariaceae	<i>Veronica anagallis-aquatica</i>	WELT 8406; Te Araroa Swamp, N.Z.
VUWG 1126	Scrophulariaceae	<i>Veronica anagallis-aquatica</i>	WELTU box 91; Okhla, India.
VUWG 309	Scrophulariaceae	<i>Veronica austriaca</i>	WELT no #; Hungary.
VUWG 310	Scrophulariaceae	<i>Veronica austriaca</i>	WELT no #; Transylvania.
VUWG 311	Scrophulariaceae	<i>Veronica austriaca</i>	WELT no #; Transylvania.
VUWG 1131	Scrophulariaceae	<i>Veronica austriaca</i> subsp. <i>teucrium</i>	WELTU; Germany.
VUWG 307	Scrophulariaceae	<i>Veronica beccabunga</i>	WELT no #; Hungary.
VUWG 1128	Scrophulariaceae	<i>Veronica chamaedrys</i>	WELTU; Holland.
NUNG 182	Scrophulariaceae	<i>Veronica chamaedrys</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1129	Scrophulariaceae	<i>Veronica ?officinalis</i>	WELTU; Holland.
VUWG 253	Scrophulariaceae	<i>Veronica persica</i>	WELT 60517; Karori, Wellington, N.Z.
VUWG 254	Scrophulariaceae	<i>Veronica persica</i>	WELT 60701; Sth Karori Rd, Wellington, N.Z.
VUWG 255	Scrophulariaceae	<i>Veronica persica</i>	WELT 70139a; Milford, Waitemata Co., N.Z.
VUWG 313	Scrophulariaceae	<i>Veronica persica</i>	WELT no #.
VUWG 1417	Scrophulariaceae	<i>Veronica serpyllifolia</i>	WELTU 13082.
VUWG 1418	Scrophulariaceae	<i>Veronica serpyllifolia</i>	WELTU 10389; Taieri Plain, N.Z.

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VUWG 257	Scrophulariaceae	<i>Veronica serpyllifolia</i>	WELT 63062; Raroa Reserve, Pukerua Bay, N.Z.
VUWG 258	Scrophulariaceae	<i>Veronica serpyllifolia</i>	WELT 60874; Sth Karori Rd, Wellington, N.Z.
VUWG 312	Scrophulariaceae	<i>Veronica triphyllos</i>	WELT no #; Hungary.
NUNG 71	Solanaceae	<i>Cestrum parqui</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 106	Solanaceae	<i>Datura stramonium</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 234	Solanaceae	<i>Hyoscyamus niger</i>	WELT 60996; Wellington, N.Z.
VUWG 782	Solanaceae	<i>Solanum aviculare</i>	WELT 5926; Te Akatea, Nelson, N.Z.
VUWG 1132	Solanaceae	<i>Solanum dulcamara</i>	WELTU; Holland.
VUWG 1134	Solanaceae	<i>Solanum nigrum</i>	WELTU; Holland.
VUWG 1135	Solanaceae	<i>Solanum nigrum</i>	WELTU; Holland.
VUWG 1407	Solanaceae	<i>Solanum nigrum</i>	WELTU 15178; Victoria University, Wellington, N.Z.
VUWG 1408	Solanaceae	<i>Solanum nigrum</i>	WELTU 13582; Titahi Bay, Wellington, N.Z.
VUWG 1409	Solanaceae	<i>Solanum nigrum</i>	WELTU 8765; Middle Trio Island, Cook Strait, N.Z.
VUWG 1410	Solanaceae	<i>Solanum nigrum</i>	WELTU 10377; Makara, Wellington, N.Z.
VUWG 230	Solanaceae	<i>Solanum nigrum</i>	WELT 70800; Belmont, Hutt Valley, N.Z.
VUWG 231	Solanaceae	<i>Solanum nigrum</i>	WELT 23512
VUWG 232	Solanaceae	<i>Solanum nigrum</i>	WELT 70168a; Kahuteraura Rd, Tararua Ra., N.Z.
VUWG 233	Solanaceae	<i>Solanum nigrum</i>	WELT 70168b; Kahuteraura Rd, Tararua Ra., N.Z.
VUWG 757	Solanaceae	<i>Solanum nigrum</i>	Chester 230. Asprokampos, Grevena Pr., NW Greece.
NUNG 36	Tamaricaceae	<i>Tamarix africana</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 56	Tamaricaceae	<i>Tamarix africana</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 856	Tamaricaceae	<i>Tamarix articulata</i>	WELTU box 93; India.
VUWG 857	Tamaricaceae	<i>Tamarix gallica</i>	WELTU box 93; India.
VUWG 878	Thymelaeaceae	<i>Daphne cneorum</i>	WELTU box 94; Black Forest, Germany.
NUNG 70	Thymelaeaceae	<i>Daphne gnidioides</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 596	Thymelaeaceae	<i>Daphne striata</i>	WELT no #; Alpe Buffalora, Switzerland.
NUNG 229	Thymelaeaceae	<i>Thymelaea hirsuta</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 184	Tiliaceae	<i>Tilia cordata</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 532	Tiliaceae	<i>Tilia europaea</i>	WELT no #; Denmark.
VUWG 837	Tiliaceae	<i>Tilia manshurica</i>	WELTU box 93; Russia.
VUWG 533	Tiliaceae	<i>Tilia vulgaris</i>	WELT no #.
VUWG 1517	Tiliaceae	<i>Tilia x vulgaris</i>	Chester 357; St Orans College; Lower Hutt, N.Z.

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VUWG 836	Tiliaceae	<i>Tilia x vulgaris</i>	WELTU box 93; Holland.
DUDB 311	Ulmaceae	<i>Ulmus cf. canescens</i>	Huntley, Durham University, England.
VUWG 1294	Ulmaceae	<i>Ulmus glabra</i>	WELTU 10301; Wellington Botanic Gardens, N.Z.
VUWG 1293	Ulmaceae	<i>Ulmus</i> sp.	WELTU; Wellington, N.Z.
VUWG 779	Ulmaceae	<i>Ulmus</i> sp.	WELTU 10302; Upland Rd, Wellington, N.Z.
CRYG 282	Ulmaceae	<i>Ulmus</i> sp.	Atherden, College of Rippon & York, England.
VUWG 19	Umbelliferae	<i>Ammi majus</i>	WELT 22887
VUWG 20	Umbelliferae	<i>Ammi majus</i>	WELT 62661a; Mt Eden, Auckland, N.Z.
VUWG 21	Umbelliferae	<i>Angelica sylvestris</i>	WELT 70885b; Newlands, Wellington, N.Z.
VUWG 22	Umbelliferae	<i>Anthriscus caucalis</i>	WELT 70225; Adams Estate, Greendale, Canterbury, N.Z.
VUWG 23	Umbelliferae	<i>Apium graveolens</i>	WELT 62930; Ship Cove, N.Z.
VUWG 24	Umbelliferae	<i>Apium graveolens</i>	WELT 60852; Chatham Is., N.Z.
VUWG 25	Umbelliferae	<i>Apium nodiflorum</i>	WELT 70426a; Ngarara Rd, Waikanae, N.Z.
VUWG 26	Umbelliferae	<i>Apium nodiflorum</i>	WELT 70426b
VUWG 27	Umbelliferae	<i>Apium nodiflorum</i>	WELT 63244; Kerikeri Stm, Whangarei, N.Z.
NUNG 232	Umbelliferae	<i>Apium nodiflorum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 924	Umbelliferae	<i>Berula erecta</i>	WELTU box 95; Holland.
VUWG 735	Umbelliferae	<i>Bupleurum asperuloides</i>	Chester 158. Mirsina, Grevena Pr., NW Greece.
VUWG 28	Umbelliferae	<i>Bupleurum lancifolium</i>	WELT 61817; Auckland, N.Z.
VUWG 29	Umbelliferae	<i>Bupleurum lancifolium</i>	WELT 61817; Auckland, N.Z.
VUWG 925	Umbelliferae	<i>Bupleurum rotundifolium</i>	WELTU box 95; Germany.
VUWG 926	Umbelliferae	<i>Bupleurum ?stellatum</i>	WELTU box 95; Switzerland.
VUWG 30	Umbelliferae	<i>Conium maculatum</i>	WELT 69903a; Wairau Ck Estuary, Milford, N.Z.
VUWG 31	Umbelliferae	<i>Conium maculatum</i>	WELT 69903b; Wairau Ck Estuary, Milford, N.Z.
VUWG 32	Umbelliferae	<i>Coriandrum sativum</i>	WELT 60857; near Dunedin, N.Z.
VUWG 1370	Umbelliferae	<i>Daucus carota</i>	WELTU; Taupiri, N.Z.
VUWG 1371	Umbelliferae	<i>Daucus carota</i>	WELTU; Stokes Valley, Lower Hutt, N.Z.
VUWG 1372	Umbelliferae	<i>Daucus carota</i>	WELTU; Taupiri, N.Z.
VUWG 4	Umbelliferae	<i>Daucus carota</i>	WELT 70066; The Terrace, Wellington, N.Z.
VUWG 664	Umbelliferae	<i>Daucus carota</i>	Chester 26. Kellia, Grevena Pr., NW Greece.
VUWG 726	Umbelliferae	<i>Daucus carota</i>	Chester 132. Mirsina, Grevena Pr., NW Greece.
VUWG 927	Umbelliferae	<i>Daucus carota</i>	WELTU box 95; Holland.
NUNG 112	Umbelliferae	<i>Daucus carota</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 214	Umbelliferae	<i>Echinophora spinosa</i>	Stevenson, Newcastle Upon Tyne University, England.

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VUWG 928	Umbelliferae	<i>Eryngium alpinum</i>	WELTU box 95; Switzerland.
VUWG 707	Umbelliferae	<i>Eryngium amethystinum</i>	Chester 79. Polineri, Grevena Pr., NW Greece.
VUWG 929	Umbelliferae	<i>Eryngium maritimum</i>	WELTU box 95; Holland.
NUNG 15	Umbelliferae	<i>Eryngium maritimum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 5	Umbelliferae	<i>Foeniculum vulgare</i>	WELT 70849; Wellington, N.Z.
VUWG 6	Umbelliferae	<i>Foeniculum vulgare</i>	WELT 70372a; Wairau Ck, Waitemata Co, N.Z.
VUWG 7	Umbelliferae	<i>Foeniculum vulgare</i>	WELT 63226; nr Mangatuna, Waiapu County, N.Z.
NUNG 235	Umbelliferae	<i>Foeniculum vulgare</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 86	Umbelliferae	<i>Ligusticum mutellina</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 9	Umbelliferae	<i>Oenanthe aquatica</i>	WELT 63247; Tua Marina, Marlborough, N.Z.
VUWG 741	Umbelliferae	<i>Opopanax hispidus</i>	Chester 164. Mirsina, Grevena Pr., NW Greece.
VUWG 10	Umbelliferae	<i>Pastinaca sativa</i>	WELT 61779a; Waterside Rd, Greytown, N.Z.
NUNG 46	Umbelliferae	<i>Pastinaca sativa</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 11	Umbelliferae	<i>Petroselinum crispum</i>	WELT 60417; Island Bay, Wellington, N.Z.
VUWG 12	Umbelliferae	<i>Petroselinum crispum</i>	WELT 60416; Sth Karori Rd, Wellington, N.Z.
NUNG 197	Umbelliferae	<i>Pseudorlaya pumila</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 930	Umbelliferae	<i>Sanicula europaea</i>	WELTU box 95; Holland.
VUWG 13	Umbelliferae	<i>Scandix geniculata</i>	WELT 69938; Wainuiomata, Wellington, N.Z.
VUWG 14	Umbelliferae	<i>Sison amomum</i>	WELT 63263; Kerikeri Stm, Whangarei, N.Z.
VUWG 15	Umbelliferae	<i>Sison amomum</i>	WELT 59806; Waiwera Hill, Auckland, N.Z.
VUWG 16	Umbelliferae	<i>Torilis arvensis</i>	WELT 63212; Riverside Rd, Gisborne, N.Z.
VUWG 17	Umbelliferae	<i>Torilis arvensis</i>	WELT 63242; HW1, Sth of Silverdale, N.Z.
VUWG 1373	Umbelliferae	<i>Torilis japonica</i>	WELTU; Tapuwaeroa R., East Cape, N.Z.
VUWG 1374	Umbelliferae	<i>Torilis japonica</i>	WELTU; Tapuwaeroa R., East Cape, N.Z.
VUWG 1375	Umbelliferae	<i>Torilis japonica</i>	WELTU; Napier, N.Z.
VUWG 18	Umbelliferae	<i>Torilis japonica</i>	WELT 63239; Coast Nth of Hundalee Hills, N.Z.
VUWG 663	Umbelliferae	<i>Torilis japonica</i>	Chester 25. Kellia, Grevena Pr., NW Greece.
VUWG 931	Umbelliferae	<i>Torilis japonica</i>	WELTU box 95; Holland.
VUWG 865	Urticaceae	<i>Parietaria debilis</i>	WELTU box 86; Krabe Peninsula, Khasansky, Primorye, USSR

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VUWG 408	Urticaceae	<i>Parietaria diffusa</i>	WELT 70065c; Brooklyn, Wellington, N.Z.
VUWG 409	Urticaceae	<i>Parietaria diffusa</i>	WELT 70065a; Brooklyn, Wellington, N.Z.
VUWG 410	Urticaceae	<i>Parietaria diffusa</i>	WELT 60630; Wadestown, Wellington, N.Z.
VUWG 867	Urticaceae	<i>Urtica dioica</i>	WELTU box 86; Holland.
NUNG 254	Urticaceae	<i>Urtica dioica</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 242	Urticaceae	<i>Urtica dubia</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 160	Urticaceae	<i>Urtica pilulifera</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 103	Urticaceae	<i>Urtica urens</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 411	Urticaceae	<i>Urtica urens</i> (?)	WELT 69937; Pukerua Bay, Wellington, N.Z.
VUWG 1439	Valerianaceae	<i>Centranthus ruber</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 1440	Valerianaceae	<i>Centranthus ruber</i>	WELTU; Wellington, N.Z.
VUWG 50	Valerianaceae	<i>Centranthus ruber</i>	WELT 60528; Happy Valley, Wellington, N.Z.
VUWG 51	Valerianaceae	<i>Centranthus ruber</i>	WELT 60526; Karori, Wellington, N.Z.
VUWG 792	Valerianaceae	<i>Centranthus ruber</i>	Chester 313; Wellington Botanic Gardens, N.Z.
VUWG 829	Valerianaceae	<i>Centranthus ruber</i>	Chester 356; Victoria University, Wellington, N.Z.
VUWG 1159	Valerianaceae	<i>Centranthus</i> sp.	WELTU.
VUWG 1160	Valerianaceae	<i>Valeriana calcitrapa</i>	WELTU; Holland.
VUWG 1161	Valerianaceae	<i>Valeriana dioica</i>	WELTU; Holland.
VUWG 1162	Valerianaceae	<i>Valeriana officinalis</i>	WELTU; Holland.
VUWG 44	Valerianaceae	<i>Valerianella carinata</i>	WELT 61294; Mairangi Bay, Waitemata Co., N.Z.
VUWG 45	Valerianaceae	<i>Valerianella carinata</i>	WELT 78171; Sth of Port Waikato, N.Z.
VUWG 46	Valerianaceae	<i>Valerianella locusta</i>	WELT 63163; Three Kings Is., N.Z.
VUWG 47	Valerianaceae	<i>Valerianella locusta</i>	WELT 63161; Whakatane, N.Z.
VUWG 1421	Verbenaceae	<i>Verbena bonariensis</i>	WELTU 10369; Kennedy Bay, Coromandel Peninsula, N.Z.
VUWG 322	Verbenaceae	<i>Verbena officinalis</i>	WELT 60634a; Taihape Rd, Mangaweka, N.Z.
VUWG 323	Verbenaceae	<i>Verbena officinalis</i>	WELT 63210; Riverside Rd, Gisborne, N.Z.
VUWG 324	Verbenaceae	<i>Verbena officinalis</i>	WELT 63475; Riverside Rd, Havelock North, N.Z.
VUWG 657	Verbenaceae	<i>Verbena officinalis</i>	Chester 19. Kellia, Grevena Pr., NW Greece.
VUWG 763	Verbenaceae	<i>Verbena officinalis</i>	Chester 250. Asprokampos, Grevena Pr., NW Greece.
VUWG 953	Verbenaceae	<i>Verbena officinalis</i>	WELTU box 97; Holland.
VUWG 954	Verbenaceae	<i>Verbena officinalis</i>	WELTU box 97; Holland.

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NUNG 186	Verbenaceae	<i>Vitex agnus-castus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 849	Violaceae	<i>Viola lutea</i> var. <i>calaminariae</i>	WELTU box 93; Limburg, Holland.
VUWG 850	Violaceae	<i>Viola palustris</i>	WELTU box 93; Holland.
NUNG 29	Violaceae	<i>Viola reichenbachiana</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1312	Violaceae	<i>Viola tricolor</i>	WELTU 10351.
VUWG 851	Violaceae	<i>Viola tricolor</i>	WELTU box 93; Holland.
VUWG 852	Violaceae	<i>Viola tricolor</i>	WELTU box 93; Holland.
VUWG 648	Violaceae	<i>Viola</i> sp.	Chester 10. Anelia, Grevena Pr., NW Greece.
VUWG 797	Violaceae	<i>Viola</i> sp.	Chester 318. Wellington Botanic Gardens, N.Z.
VUWG 830	Violaceae	<i>Viola</i> sp. [cultivar]	Chester 351; Victoria University, Wellington, N.Z.
VUWG 414	Vitaceae	<i>Vitis vinifera</i>	WELT no #; Etrusia.
VUWG 835	Vitaceae	<i>Vitis vinifera</i>	WELTU box 93; Germany.
NUNG 126	Vitaceae	<i>Vitis vinifera</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 558	Zygophyllaceae	<i>Tribulus terrestris</i>	WELT no #; Adelaide Plains, South Australia.

Monocotyledones

VUWG 380	Alismaceae	<i>Alisma natans</i>	WELT no #; Transylvania.
VUWG 381	Alismaceae	<i>Alisma plantago-aquatica</i>	WELT 60620; Hunterville, Rangitikei, N.Z.
NUNG 51	Alismaceae	<i>Alisma plantago-aquatica</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 383	Alismaceae	<i>Sagittaria sagittifolia</i>	WELT no #.
VUWG 1276	Amaryllidaceae	<i>Beschorneria yuccoides</i>	WELTU; Cerro Tres Picos, Chiapas, Mexico.
VUWG 1277	Amaryllidaceae	<i>Galanthus nivalis</i>	WELTU; Castle Douglas, Scotland.
VUWG 1516	Araceae	<i>Zantedeschia aethiopica</i>	Chester 356; Johnsonville, Wellington, N.Z.
NUNG 221	Cyperaceae	<i>Carex arenaria</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1224	Cyperaceae	<i>Carex elata elata</i>	WELTU; Holland.
VUWG 1221	Cyperaceae	<i>Carex flacca flacca</i>	WELTU; Holland.
VUWG 1484	Cyperaceae	<i>Carex ovalis</i>	WELTU 14929.
VUWG 1485	Cyperaceae	<i>Carex ovalis</i>	WELTU 10256; Ketetahi Springs track, N.Z.
VUWG 1486	Cyperaceae	<i>Carex ovalis</i>	WELTU 8930; Taurewa, N.Z.
VUWG 1222	Cyperaceae	<i>Carex paniculata</i>	WELTU; Holland.
VUWG 1223	Cyperaceae	<i>Carex pseudocyperus</i>	WELTU; Holland.
VUWG 1483	Cyperaceae	<i>Cyperus congestus</i>	WELTU 9023; Paturau, NW Nelson, N.Z.
VUWG 1478	Cyperaceae	<i>Cyperus eragrostis</i>	WELTU; Waikanae, N.Z.
VUWG 1482	Cyperaceae	<i>Cyperus eragrostis</i>	WELTU 11490; Cape Turakirae, Wellington, N.Z.

Pollen/spore reference slide #	Family	Genus & species	Collector (if known)/herbarium, herbarium # (if known), place of collection
VUWG 722	Cyperaceae	<i>Cyperus cf. longus</i>	Chester 127. Mirsina, Grevena Pr., NW Greece.
VUWG 1225	Cyperaceae	<i>Cyperus rotundus</i>	WELTU; Gazibad, India.
VUWG 1479	Cyperaceae	<i>Cyperus tenellus</i>	WELTU 9507; Lake Taharoa, nr Dargaville, N.Z.
VUWG 1481	Cyperaceae	<i>Cyperus tenellus</i>	WELTU 406.
VUWG 1226	Cyperaceae	<i>Eriophorum angustifolium</i>	WELTU; Holland.
VUWG 1227	Cyperaceae	<i>Scirpus holoschoenus</i>	WELTU; Holland.
VUWG 1228	Cyperaceae	<i>Scirpus lacustris</i>	WELTU; Holland.
VUWG 1229	Cyperaceae	<i>Scirpus maritimus</i>	WELTU; Gazibad, India.
VUWG 1230	Cyperaceae	<i>Scirpus maritimus</i>	WELTU; Holland.
VUWG 1477	Cyperaceae	<i>Scirpus setaceus</i>	WELTU 10257; Horokiwi R., Pauatahanui, N.Z.
VUWG 1491	Gramineae	? <i>Agropogon littoralis</i>	WELTU 15307; Vernon Lagoons, Marlborough, N.Z.
VUWG 1232	Gramineae	<i>Agrostis alpina</i>	WELTU; Switzerland.
VUWG 1231	Gramineae	<i>Agrostis ?alpina</i>	WELTU; Switzerland.
VUWG 1487	Gramineae	<i>Agrostis stolonifera</i>	WELTU 15306; Waikanae R., N.Z.
VUWG 1488	Gramineae	<i>Agrostis stolonifera</i>	WELTU; Wellington, N.Z.
VUWG 1489	Gramineae	<i>Agrostis stolonifera</i>	WELTU 10220; Longwood Range, N.Z.
VUWG 1235	Gramineae	<i>Aira caryophyllea</i>	WELTU; Holland.
VUWG 1234	Gramineae	<i>Anthoxanthum odoratum</i>	WELTU; Holland.
VUWG 1492	Gramineae	<i>Anthoxanthum odoratum</i>	WELTU; Victoria University, Wellington, N.Z.
VUWG 1493	Gramineae	<i>Anthoxanthum odoratum</i>	WELTU 10982; Erebus Cove, Auckland Island.
NUNG 133	Gramineae	<i>Anthoxanthum odoratum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1494	Gramineae	<i>Avena gonzaloi</i>	WELTU 10226.
VUWG 753	Gramineae	<i>Avena cf. sterilis</i>	Chester 224. Asprokamos, Grevena Pr., NW Greece.
VUWG 1237	Gramineae	<i>Brachypodium pinnatum</i>	WELTU; Holland.
VUWG 1238	Gramineae	<i>Brachypodium sylvaticum</i>	WELTU; Holland.
VUWG 1239	Gramineae	<i>Bromus arvensis</i>	WELTU; Holland.
VUWG 1495	Gramineae	<i>Bromus hordaceus hordaceus</i>	WELTU; Wellington, N.Z.
VUWG 1496	Gramineae	<i>Bromus hordaceus hordaceus</i>	WELTU 7722; Granity Pass, Owen Range, N.Z.
VUWG 1240	Gramineae	<i>Bromus muralis</i>	WELTU; Holland.
VUWG 1241	Gramineae	<i>Bromus sterilis</i>	WELTU; Holland.
VUWG 1497	Gramineae	<i>Bromus sterilis</i>	WELTU 8790; Trio Island, Cook Strait, N.Z.
VUWG 773	Gramineae	<i>Calamagrostis arundinacea</i>	Chester 305. Mirsina, Grevena Pr., NW Greece.
VUWG 1242	Gramineae	<i>Calamagrostis canescens</i>	WELTU; Holland.
VUWG 1498	Gramineae	<i>Cynodon dactylon</i>	WELTU; Wellington, N.Z.
VUWG 1499	Gramineae	<i>Cynodon dactylon</i>	WELTU 10229; Upland Road, Wellington, N.Z.
VUWG 1243	Gramineae	<i>Cynosurus cristatus</i>	WELTU; Holland.
VUWG 1500	Gramineae	<i>Cynosurus cristatus</i>	WELTU; Taupo, N.Z.
VUWG 1501	Gramineae	<i>Cynosurus cristatus</i>	WELTU.

Pollen/spore reference slide #	Family	Genus & species	Collector (if known)/herbarium, herbarium # (if known), place of collection
VUWG 655	Gramineae	<i>Cynosurus cristatus</i>	Chester 17. Anelia, Grevena Pr., NW Greece.
NUNG 181	Gramineae	<i>Cynosurus cristatus</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1502	Gramineae	<i>Cynosurus echinatus</i>	WELTU; Wellington, N.Z.
VUWG 712	Gramineae	<i>Cynosurus elegans</i>	Chester 90. Polineri, Grevena Pr., NW Greece.
VUWG 1503	Gramineae	<i>Dactylis glomerata</i>	WELTU 10231.
VUWG 1504	Gramineae	<i>Dactylis glomerata</i>	WELTU 7708; Granity Pass, Owen Range, N.Z.
VUWG 1252	Gramineae	<i>Elymus repens</i>	WELTU; Holland.
VUWG 1505	Gramineae	<i>Festuca ovina</i>	WELTU 10237.
NUNG 170	Gramineae	<i>Festuca ovina</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1506	Gramineae	<i>Festuca rubra</i>	WELTU 10234; Hooker Valley, Mt Cook, N.Z.
VUWG 1245	Gramineae	<i>Glyceria fluitans</i>	WELTU; Holland.
VUWG 1507	Gramineae	<i>Glyceria fluitans</i>	WELTU 15320; Belmont Park, Lower Hutt, N.Z.
VUWG 1246	Gramineae	<i>Holcus lanatus</i>	WELTU; Holland.
NUNG 120	Gramineae	<i>Holcus lanatus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 113	Gramineae	<i>Hordeum distichon</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1508	Gramineae	<i>Hordeum marinum</i>	WELTU; Wellington, N.Z.
VUWG 1244	Gramineae	<i>Leymus arenarius</i>	WELTU; Holland.
VUWG 1247	Gramineae	<i>Lolium perenne</i>	WELTU; New Zealand.
VUWG 1509	Gramineae	<i>Lolium perenne</i>	WELTU 11514; Cape Turakirae, Wellington, N.Z.
VUWG 1248	Gramineae	<i>Melica ciliata</i>	WELTU; Eiffel, Germany.
VUWG 1249	Gramineae	<i>Melica ciliata</i>	WELTU; Holland.
VUWG 1250	Gramineae	<i>Milium effusum</i>	WELTU; Holland.
VUWG 1510	Gramineae	<i>Phleum pratense</i>	WELTU; Waikanae River, N.Z.
NUNG 176	Gramineae	<i>Phleum pratense</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 717	Gramineae	<i>Phragmites australis</i>	Chester 118. Mirsina, Grevena Pr., NW Greece.
VUWG 1511	Gramineae	<i>Setaria viridis</i>	WELTU 10252; Tauranga, N.Z.
VUWG 776	Gramineae	<i>Triticum aestivum</i>	Chester 225. Asprokampos, Grevena Pr., NW Greece.
NUNG 144	Gramineae	<i>Zea mays</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 800	Iridaceae	<i>Ixia</i> sp.	Chester 321. Wellington Botanic Gardens, N.Z.
VUWG 1472	Juncaceae	<i>Juncus articulatus</i>	WELTU 8822; Seatoun, Wellington, N.Z.
VUWG 1473	Juncaceae	<i>Juncus articulatus</i>	WELTU 10204; Taurewa, N.Z.
VUWG 1475	Juncaceae	<i>Juncus articulatus</i>	WELTU 15187; Waikanae, N.Z.
VUWG 656	Juncaceae	<i>Juncus articulatus</i>	Chester 18. Anelia, Grevena Pr., NW Greece.
VUWG 1253	Juncaceae	<i>Juncus bufonius</i>	WELTU; New Zealand.
VUWG 1254	Juncaceae	<i>Juncus bufonius</i>	WELTU; Jumna R., India.
VUWG 1256	Juncaceae	<i>Juncus bulbosus</i>	WELTU.

Pollen/spore reference slide #	Family	Genus & species	Collector (if known)/herbarium, herbarium # (if known), place of collection
VUWG 654	Juncaceae	<i>Juncus inflexus</i>	Chester 16. Anelia, Grevena Pr., NW Greece.
VUWG 723	Juncaceae	<i>Juncus inflexus</i>	Chester 128. Mirsina, Grevena Pr., NW Greece.
VUWG 1255	Juncaceae	<i>Juncus squarrosus</i>	WELTU; Holland.
VUWG 1257	Juncaceae	<i>Luzula luzuloides</i>	WELTU; Black Forest, Germany.
VUWG 1258	Juncaceae	<i>Luzula luzuloides</i>	WELTU; Black Forest, Germany.
VUWG 1260	Juncaceae	<i>Luzula pilosa</i>	WELTU; Holland.
VUWG 1259	Juncaceae	<i>Luzula sylvatica</i>	WELTU; Holland.
VUWG 1220	Juncaginaceae	<i>Triglochin palustris</i>	WELTU; England.
VUWG 576	Liliaceae	<i>Allium neapolitanum</i>	WELT 63151; Wadestown, Wellington, N.Z.
VUWG 575	Liliaceae	<i>Allium roseum bulbiferum</i>	WELT 70649; Mt Wellington, Auckland, N.Z.
VUWG 1263	Liliaceae	<i>Allium schoenoprasum</i>	WELTU; Switzerland.
VUWG 825	Liliaceae	<i>Allium schoenoprasum</i>	Chester 346. Garden, Johnsonville, Wellington, N.Z.
VUWG 1476	Liliaceae	<i>Allium triquetrum</i>	WELTU; Wellington, N.Z.
NUNG 171	Liliaceae	<i>Allium triquetrum</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 169	Liliaceae	? <i>Allium ursinum</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1262	Liliaceae	<i>Allium vineale</i>	WELTU; Switzerland.
VUWG 1261	Liliaceae	<i>Allium</i> sp.	WELTU; Switzerland.
NUNG 104	Liliaceae	<i>Allium</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1264	Liliaceae	<i>Anthericum ramosum</i>	WELTU; Switzerland.
VUWG 1265	Liliaceae	<i>Anthericum ramosum</i>	WELTU; Switzerland.
VUWG 1266	Liliaceae	<i>Anthericum ramosum</i>	WELTU; Kaiserstuhl nr Freiburg, Germany.
VUWG 577	Liliaceae	<i>Asparagus asparagoides</i>	WELT 70434; River Road, Havelock North, N.Z.
VUWG 1267	Liliaceae	<i>Asphodelus fistulosus</i>	WELTU; Delhi, India.
NUNG 136	Liliaceae	<i>Asphodelus ramosus</i>	Stevenson, Newcastle Upon Tyne University, England.
NUNG 141	Liliaceae	<i>Colchium autumnale</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 670	Liliaceae	<i>Colchicum ?autumnale</i>	Chester 32. Kellia, Grevena Pr., NW Greece.
VUWG 1268	Liliaceae	<i>Convallaria majalis</i>	WELTU; Holland.
VUWG 827	Liliaceae	<i>Convallaria majalis</i>	Chester 348. Garden, Johnsonville, Wellington, N.Z.
NUNG 264	Liliaceae	<i>Fritillaria lusitanica</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1269	Liliaceae	<i>Fritillaria</i> sp.	WELTU; Holland.
NUNG 72	Liliaceae	<i>Hyacinthus orientalis</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 578	Liliaceae	<i>Ipheion uniflorum</i>	WELT 60940; Paraparaumu, N.Z.
VUWG 1270	Liliaceae	<i>Lilium martagon</i>	WELTU; Kaiserstuhl nr Freiburg, Germany.
VUWG 798	Liliaceae	<i>Muscari armeniacum</i>	Chester 319. Wellington Botanic Gardens, N.Z.

Pollen/spore reference slide #	Family	Genus & species	Collector (if known)/herbarium, herbarium # (if known), place of collection
VUWG 817	Liliaceae	<i>Muscari armeniacum</i>	Chester 338. Garden, Johnsonville, Wellington, N.Z.
VUWG 1271	Liliaceae	<i>Ornithogalum umbellatum</i>	WELTU; Holland.
VUWG 1272	Liliaceae	<i>Paris quadrifolia</i>	WELTU; Germany.
VUWG 1273	Liliaceae	<i>Polygonatum odoratum</i>	WELTU; Holland.
VUWG 1274	Liliaceae	<i>Polygonatum verticillatum</i>	WELTU; Holland.
VUWG 732	Liliaceae	<i>Scilla autumnalis</i>	Chester 149. Mirsina, Grevena Pr., NW Greece.
NUNG 116	Liliaceae	<i>Smilax aspera</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1275	Liliaceae	<i>Veratrum album</i>	WELTU; Holland.
VUWG 1278	Orchidaceae	<i>Anacamptis pyramidalis</i>	WELTU; nr Freiburg, Germany.
VUWG 1279	Orchidaceae	<i>Cephalanthera damasonium</i>	WELTU; Black Forest, Germany.
VUWG 1282	Orchidaceae	<i>Epipactis helleborine</i>	WELTU; Holland.
VUWG 1283	Orchidaceae	<i>Epipactis ?palustris</i>	WELTU; Holland.
VUWG 1284	Orchidaceae	<i>Neottia nidus-avis</i>	WELTU; Black Forest, Germany.
VUWG 384	Potamogeton- aceae	<i>Potamogeton alpinus</i>	WELT no #.
VUWG 385	Potamogeton- aceae	<i>Potamogeton obtusifolius</i>	WELT no #; Funbo, Switzerland.
VUWG 386	Potamogeton- aceae	<i>Potamogeton perfoliatus</i>	WELT no #; Westfalen, West Germany.
VUWG 661	Sparganiaceae	<i>Sparganium erectum</i>	Chester 23. Kellia, Grevena Pr., NW Greece.
VUWG 1218	Sparganiaceae	<i>Sparganium minimum</i>	WELTU; Finland.
VUWG 1515	Sparganiaceae	<i>Sparganium subglobosum</i>	WELTU 06439; nr. Normandy, Taranaki, N.Z.
NUNG 252	Sparganiaceae	<i>Sparganium</i> sp.	Stevenson, Newcastle Upon Tyne University, England.
NUNG 241	Typhaceae	<i>Typha latifolia</i>	Stevenson, Newcastle Upon Tyne University, England.
VUWG 1514	Typhaceae	<i>Typha orientalis</i>	WELTU 8846; Foxton, N.Z.

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Appendix VI

Pollen key

VI.1 Key

In this key pollen and spores of extant plants (those occurring naturally and in cultivation) in Grevena Province, northwestern Greece are described at the lowest possible morphological rank, using a light microscope. Descriptions of the grains were collected from many sources, the main literary sources being the major morphological works of Erdtman (1943, 1952, 1957, 1965 & 1969); Erdtman, Berglund & Praglowski (1961); Erdtman, Praglowski & Nilsson (1963); Erdtman & Sorsa (1971); Faegri & Iversen (1975 & 1992); Nilsson, Praglowski & Nilsson (1977); Belmonte, Perez-Obiol & Roure (1986); Ferrarini, Ciampolini, Sermolli & Marchetti (1986); Moore, Webb & Collinson (1991); various articles in *The Northwest European Pollen Flora*, volumes 1-6, edited by Punt (1976-1991; in the key these are referred to by "NW" followed by the volume number); Roure (1985); Valdes, Diez & Fernandez (1987); and smaller works in the journals of *Grana palynologica* and *Grana*; and *Review of paleobotany and palynology*. In addition, to assist with the description of pollen and spores reference was made to a comprehensive pollen and spore reference collection of local species from plants collected in Grevena, and from herbarium specimens. Although this key was made to cover extant species in northwestern Greece, it is likely it would cover most common pollen and spores encountered in Quaternary deposits in the Central Balkans. A full list of species included in each pollen type is given in Appendix VI.2 at the end of this key. Unfortunately, the morphology of many species still remains unexamined, but the probable morphology of these species can be guessed at based on plant taxonomy, allowing them to be placed in the most likely pollen type. These species are listed at the end of each species list and can be identified by the '?' which precedes them. Nomenclature follows the *Flora Europaea*.

The purpose of this key is to supply a practical means of identifying pollen and spores without specialist pollen morphological knowledge. The key is intended for use with a light microscope, using mostly a X40 objective and occasionally an oil immersion X1000 objective. Special attention has been paid to closely identifying pollen and spores of particular interest to the archaeologist, e.g. cultivated plants, weeds of cultivation, and plants indicating disturbance of the natural vegetation.

The key has been modelled on the key in Faegri & Iversen (1992) and a glossary to terms used can be found in that text. In principle the key is binary, but more than two entries at the same level have been used where taxa are very similar. The number, shape and arrangement of apertures are the major entries in the key. Exine structure and sculpturing are considered next. Because these features vary and are sometimes difficult to discern, some pollen taxa occur in more than one place in the key. Measurements given should be considered after the above features have been considered, and used cautiously. During the course of researching the morphology of the pollen and spores included in this key many widely differing measurements were found for the same pollen and spore taxa. Also different chemical treatments will affect the size of pollen and spores variously (Reitsma 1969). Thus, no particular attention has been paid to the mounting mediums used and the measurements should be considered approximate. Measurements do however give a rough guide to whether the grains are large or small. Occasionally size is used as a distinguishing feature, as for example in *Quercus*, where it has been used prudently. Particular distinguishing features have been italicized.

The right-hand column gives the ultimate breakdown to taxa. A genus name alone refers to species of that genus only; similarly a species name signifies only that species. The addition of the term 'type', abbreviated 't.', implies a pollen morphological type common to several families, genera or species, as the case may be.

Master key

- A2 Grains with air-sacs Key A
- A1 Grains without air-sacs.
 - B2 Composite grains (tetrads, polyads) Key B
 - B1 Grains single.
 - C2 Grains bilateral Key C
 - C1 Grains isodiametric or one axis longer/shorter, rarely heteropolar.
 - D2 Grains subtetrahedral Key D
 - D1 Grains rotational Key E

Key A. Vesiculate

- (A2 *Three meridional, airsac-like crests* *Trapa natans*)
TRAPACEAE
- A1 Distinct, subglobular or pouch-shaped air-sacs with internal, 3-dimensional reticulum, usually two.
 - B2 Proximal part of the exine ('crest') more than 5 μm thick
 - C2 Body of the grain (excl. air-sacs) 80-100 μm . Air-sacs more than semiglobular . *Abies*
PINACEAE
 - C1 Body of the grain c. 50 μm . Air-sacs semiglobular *Cedrus*
PINACEAE
 - B1 Proximal part of exine less than 5 μm thick.
 - D2 Proximal entry angle of air-sac very blunt; *no obvious constriction* between air-sac and body of the grain
 - E2 Gradual transition between structure of the air-sac and that of the wall of the body of the grain. Colpus membrane smooth *Picea abies*
PINACEAE
 - E1 Abrupt transition between structure of air-sac and that of the wall of the body of the grain. Colpus membrane dotted *Pinus (Haploxylon)*
PINACEAE
 - D1 Proximal entry angle of air-sac sharp; distinct constriction between air-sac and body of the grain. Body of the grain c. 50 μm . Colpus membrane smooth ... *Pinus (Diploxylon)*
PINACEAE

Key B. Composite grains

The 'normal' position of a tetrahedral tetrad is the one in which the polar axis of one grain is parallel with the optical axis of the microscope.

Key B1. Tetrads

A2 Tetrads linear, flat (quadrangular) or irregular. Grains reticulate or rugulate.

B4 Grains with *one pore*, c. 3 µm wide, away from join between grains. Tetrad *linear or flat*.
Typha spp.

C2 Rugulate *Typha angustifolia* t.
TYPHACEAE

C1 Reticulate, lumina c. 2 µm *Typha domingensis* t.
TYPHACEAE

B3 Tetrad *flat*. Grains with *two pores*. *Cytinus hypocistis*
RAFFLESACEAE

B2 Tetrad *irregular*. Grain with *single pore* 6 µm wide (*Epipactis palustris*) or two apertures.
Reticulate, mesh 3-5 µm wide *Epipactis* t.
ORCHIDACEAE

B1 Tetrad *irregular*. Grain with *3-6 pores* situated on dividing walls between grains ...
Periploca graeca
ASCLEPIADACEAE

A1 Tetrads *tetrahedral*, sometimes irregularly so.

D2 Grains psilate, inaperturate. Exine extremely thin, normally not preserved/recognized in
sediments *Juncaceae*
JUNCACEAE

D1 Grains scabrate or verrucate.

E2 Triporate, pores with vestibulum. Grains loosely connected. Cf. Key E15: Triporate
..... *Epilobium hirsutum* t.
ONAGRACEAE

E1 Tricolpate/tricolporate. Tetrads compact, subglobular. Grains united by their
proximal faces, but usually not in a strictly normal position (Y-figure of inner walls
not rectilinear). Colpi regular. Pyrolaceae, Ericaceae.

F2 Colpi *very short*. Costae indistinct *Moneses uniflora*
PYROLACEAE

F1 Colpi *long*, usually with margo. Interior walls with few or no perforations.
Psilate to irregularly scabrate-verrucate.

G2 Costae absent/indistinct. *Pyrola*
PYROLACEAE

G1 Costae distinct.

H2 Thin exine *Vaccinium myrtillus*
ERICACEAE

H1 Thick exine *Erica herbacea*
ERICACEAE

Key B2. Polyads

Polyads irregular; tetrads usually indistinguishable, densely crowded in massulae.

A2 Monoporate grains. *Orchis* t.
ORCHIDACEAE

- A1 Inaperturate grains. *Vincetoxicum*
ASCLEPIADACEAE

Key C. Bilateral grains

Some monocolpate and biporate grains are faintly bilateral or pear-shaped (heteropolar). They are found in Key E.

- A2 With more than one aperture.

- B2 Bi-aperturate: two pores; scabrate *Cytinus hypocistis*
RAFFLESIAACEAE

- B1 Tetra-aperturate, reticulate *Impatiens noli-tangere*
BALSAMINACEAE

- A1 With one or no aperture.

- C2 With columellae. Grain reticulate. Heterobrochate, semitectate, columellae forming muri. Liliaceae, Amaryllidaceae, etc.: see Key E4.

- C1 No columellae. Mostly Pteridophyte spores.

- D2 Perine loose, crested or folded, not echinate but in some spores spinulose.

- E2 Perine saccate

- F3 Perine folded into numerous vesiculae, surface smooth or minutely vermiculate (SEM) *Dryopteris filix-mas* t.
ASPIDIACEAE

- F2 Perine folded into numerous vesiculae, foveolate-reticulate
Gymnocarpium dryopteris
ASPIDIACEAE

- F1 Perine with widely spaced folds, minutely echinate *Dryopteris expansa*
ASPIDIACEAE

- E1 Perine lophate-cristate.

- G2 Crests few, 1-4, long, sometimes as long as the spore *Thelypteris phegopteris*
THELYPTERIDACEAE

- G1 Usually more than 4 crests, which are shorter.

- H2 Crests with few or no spinules *Athyrium distentifolium*
ATHYRIACEAE

- H1 Crests densely spinulose.

- I2 Perine entire or sparsely perforate. Includes *Ceterach*, *Phyllitis*. Keys to species are to be found in Ferrarini *et al.* (1986) ... *Asplenium* t.
ASPLENIACEAE

- I1 Perine densely perforate (lacy) *Polystichum*
ASPIDIACEAE

- D1 No loose outer perine or, if present, not folded or crested.

- J4 Verrucate, sculpturing elements coarse, more than 3 µm high *Polypodium*
POLYPODIACEAE

- J3 Scabrate. (*Najas marina* might be included here, but its exine is not preserved in acetolysis, or, presumably, in fossilisation)
- K2 No perine visible *Athyrium filix-femina*
ATHYRIACEAE
- K1 Perine thin, *slightly wrinkled* *Blechnum spicant*
BLECHNACEAE
- J2 Psilate. (Like *Najas*, *Ceratophyllum* is not preserved in acetolysis)
- L2 Wall double with *loose outer cover* *Isoetes*
ISOETACEAE
- L1 Wall one-layered or outer cover not loose, smooth, structureless. Unidentifiable fern spores that have lost their perispore.
- J1 Echinate, with echinae and (blunt) papillae.
- M2 Mainly papillae *Cystopteris fragilis*
ATHYRIACEAE
- M1 Sculpturing elements *variable* *Thelypteris palustris*
THELYPTERIDACEAE

Key D. Subtetrahedral grains (spores)

- A2 With an outer, loose, folded perine *Equisetum*
EQUISETACEAE
- A1 No loose perine. Cf. *Thesium*, Key E18.
- B3 Grain *subglobular*.
- C3 Spore psilate; aperture obscure, $\pm$ elaters *Equisetum*
EQUISETACEAE
- C2 Spore wall undulose to scabrate (perine flakes off) *Cheilanthes*
SINOPTERIDACEAE
- C1 Spore baculate-clavate (tending to rugulate distally) *Osmunda regalis*
OSMUNDACEAE
- B2 Spore triangular, semi-lobate. Corners rounded
- D2 Verrucate *Anogramma leptophylla*
GYMNOGRAMMACEAE
- D1 Scabrate-fimbriate, usually smooth by loss of ornamentation.
- E3 Average diameter 40-50 μ m, sides in polar view convex, laesurae margins conspicuously ridged *Adiantum capillus-veneris*
ADIANTACEAE
- E2 Average diameter 28-36 μ m, sides in polar view concave, laesurae margins not ridged *Pteridium aquilinum*
HYPOLEPIDACEAE
- E1 Average diameter <25 μ m. Spores similar to *Adiantum* and *Pteridium*, but significantly smaller *Salvinia natans*
SALVINIACEAE
- B1 *Equatorial limb triangular-subcircular*. Polar axis shorter than equatorial diameter.

- F4 Rugulate/verrucate to reticulate. *Equatorial ridge present*.
- G2 Distally rugulate *Pteris cretica*
PTERIDACEAE
- G1 Distally reticulate with verrucae in lumina *Pteris vittata*
PTERIDACEAE
SELAGINELLACEAE
- F3 Foveolate/reticulate with rounded muri. No equatorial ridge. *Ophioglossum*.
- H2 Tiny punctae *Ophioglossum lusitanicum*
OPHIOGLOSSACEAE
- H1 Coarsely reticulate *Ophioglossum vulgatum*
OPHIOGLOSSACEAE
- F2 Verrucate. *Verrucae rounded*, sometimes spinulate. Spore 43-58 µm. Sculpturing on proximal face as distinct as on the distal *Botrychium*
- F1 Minutely echinate or granulate *Selaginella*
OPHIOGLOSSACEAE

Key E. Rotational ellipsoidic (or ovate) grains: main key

- A3 No distinct aperture.
- B2 With meridional grooves and ridges E1 Polyplicate
- B1 No meridional grooves or ridges E2 Inaperturate
- A2 With one aperture.
- C3 Aperture Y-shaped E3 Trichotomocolpate
- C2 Aperture elongate E4 Monocolpate
- C1 Aperture circular E5 Monoporate
- A1 More than one aperture.
- D2 No lacunae or, if present, not in a fixed geometric pattern.
- E2 Apertures not fused.
- F3 With colpi, no pores or transverse endexinous colpi (colpate)
- G3 Two colpi E6 Dicolpate
- G2 Three colpi E7 Tricolpate
- G1 More than three colpi.
- H2 All colpi meridional E8 Stephanocolpate
- H1 Some or all colpi not meridional E9 Pericolpate

F2 Both colpi and distinct pores or transverse colpi present (colporate). Usually one pore per colpus, occasionally missing; in some taxa more than one pore per colpus (not in our material).

13 Two colpi E10 Dicolporate

I2 Three colpi E11 Tricolporate

I1 More than three colpi.

J2 All colpi meridional E12 Stephanocolporate

J1 Some or all colpi not meridional E13 Pericolporate

F1 Free pores present, no colpi (porate)

K3 Two pores E14 Diporate

K2 Three pores E15 Triporate

K1 More than three pores.

L2 Pores confined to a circular (sub-)equatorial belt E16 Stephanoporate

L1 Pores $\pm$ uniformly distributed on the surface of the grain E17 Periporate

E1 Apertures fused to rings or spirals E18 Syncolporate

D1 With lacunae in a fixed geometric pattern

M2 Lacunae elongate, meridional (pseudocolpi) E19 Heterocolporate

M1 Lacunae not elongate E20 Fenestrate

Key E1. Polyplicate

A2 Grooves *branched* *Ephedra distachya* t.
EPHEDRACEAE

A1 Grooves simple. Meridional ridges high, distinct in polar view *Ephedra fragilis*
EPHEDRACEAE

Key E2. Inaperturate

Many cryptogram spores, cysts, etc., are also inaperturate. They are, on the whole, distinguished from pollen grains by the (absence of) structure of the wall. They are not included in the key.

A5 Striate. Araceae *Arisarum vulgare*
ARACEAE

A4 Echinulate or verrucate.

- B3 Echinate. Cf. also Lemnaceae, *Nymphaea*: Key E5 (Monoporate); and *Nuphar*, *Stratiotes*: Key E4 (Monocolpate) *Hydrocharis morsus-ranae*
HYDROCHARITACEAE
- B2 Verrucate. Grain >40 µm. Obscure sulcus *Vallisneria spiralis*
HYDROCHARITACEAE
- B1 Verrucate. Grain <40 µm. cf. *Plantago*, Key E17 (Periporate).
- A3 Scabrate or frustillate (*Najas* is scabrate, bilateral, but its exine is not usually preserved).
- C2 Grain heteropolar, with thin areas (lacunae). Cf. special key. **Cyperaceae**
CYPERACEAE
- C1 Isopolar, ± spherical. No lacunae or perforations.
- D5 Scabrate, tiny echinae. Grain 64-99 µm. **Crocus**
IRIDACEAE
- D4 Scabrate, tiny echinae. Grain 40-46 µm. Exine 1-1.5 µm. **Laurus nobilis**
LAURACEAE
- D3 Scabrate. Grain 40-52 µm. Exine c. 3 µm. **Aristolochia**
ARISTOLOCHIACEAE
- D2 Scabrate, micro-verrucate. Grain 18-25 µm **Orobanche minor** t.
OROBANCHACEAE
- D1 Scabrate, with minute dark dots. Grain 22-30 µm **Populus**
SALICACEAE
- A2 Psilate or gemmate.
- E2 Psilate.
- F2 Grain more than 50 µm.
- G2 Grain c. 60 µm. Obscurely trilete, wall simple or cavate with outer thin layer wrinkled
..... **Equisetum**
EQUISETACEAE
- G1 Grain c. 90 µm **Pseudotsuga menziesii**
PINACEAE
- F1 Grain less than 50 µm. *Ceratophyllum* (grain bilateral, c. 25-30 µm) keys out here, but exine is not usually preserved. Similarly Juncaceae (spheroidal, very thin-walled).
- H2 Grain 25-47 µm. Psilate with tiny echinae (often lost). Araceae.
- I2 Grain bilateral **Arum**
ARACEAE
- I1 Grain spheroidal **Dracunculus** t.
ARACEAE
- E1 Gemmate
- J2 Fossil grains usually two-split. Gemmae scattered, deciduous, rounded, with constricted base, mostly lost in fossil material. Cf. *Pedicularis*, Key E16 **Juniperus**
CUPRESSACEAE
- J1 Gemmae rather crowded, size variable, not deciduous (SEM: microbaculate)
Taxus baccata
TAXACEAE
- A1 Clavate-baculate or reticulate.
- K2 Grain bilateral, elliptical. Reticulate **Callitriche obtusangula**

CALLITRICHACEAE

K1 Grain rotational.

L3 *Rugulose-baculate*. Grain 21-32 μm *Limodorum abortivum*
ORCHIDACEAE

L2 *Isolated clavae/baculae in reticulate pattern* *Callitriche stagnalis* t.
CALLITRICHACEAE

L1 Reticulum distinct.

M2 Columellae distinct.

N2 Diameter of lumina subequal to breadth of muri *Cephalanthera*
ORCHIDACEAE

N1 Diameter of lumina several times the breadth of muri. Potamogetonaceae.

O2 Columellae widely spaced, mostly confined to corners of brochi
Potamogeton pectinatus
POTAMOGETONACEAE

O1 Columellae denser, also between corners of brochi
Potamogeton crispus t.
POTAMOGETONACEAE

M1 Columellae indistinct.

P3 Diameter of lumina subequal to breadth of muri. Muri (indistinctly)
duplicolumellate *Daphne*
THYMELAEACEAE

P2 Muri much narrower than width of lumina, simplicolumellate
Triglochin bulbosa
JUNCAGINACEAE

P1 Lumina c. 4 μm . No apparent columellae *Zannichellia palustris*
ZANNICHELLIACEAE

Key E3. Trichotomocolpate

Triradiate scars are very common in cryptogam spores (cf. Key D). In angiosperm pollen they are found in some taxa, but in the area none is known, apart from occasional faint traces in some grains of *Trapa natans*.

Key E4. Monocolpate

Compare also Key E5, Monoporate, the pore of which may become colpus-like by collapse of the grain.

A6 Verrucate. Verrucae dimorphic, smaller on the proximal side *Gagea pratensis*
LILIACEAE

A5 Clavate-baculate. Rounded clavae/baculae up to 2 μm long *Iris pumila*
IRIDACEAE

A4 Echinete-baculate.

B2 Grains usually prolate. Echinete; echinae more than 5 μm long *Nuphar lutea*
NYMPHAEACEAE

B1 Grains subspherical. Baculate-echinate, large projections less than 5 μm long. Aperture sometimes indistinct *Stratiotes aloides*
HYDROCHARITACEAE

- A3 Rugulate to striate. *Allium*.
- C2 Colpus extends to the proximal side of the grain.
- D2 Grain more than 50 µm *Allium roseum* t.
LILIACEAE
- D1 Grain less than 50 µm *Allium sphaerocephalon* t.
LILIACEAE
- C1 Colpus restricted to the distal side of the grain. Grain less than 50 µm
Allium paniculatum t.
LILIACEAE
- A2 Reticulate (brochi equal to or more than 1 µm).
- E2 Brochi more than 3 µm diameter.
- F2 Heterobrochate. Margo very broad *Anthericum liliago*
LILIACEAE
- F1 Homobrochate or brochi not falling into discrete size groups.
- G2 Columellae ±cylindrical. Extremely coarsely reticulate, brochi 4-18 µm
Iris germanica
IRIDACEAE
- G1 Muri consisting of distinct transverse elements. No free columellae in lumina. Margo present *Lilium*
LILIACEAE
- E1 Brochi 1-3 µm diameter.
- H3 Colpus extends to the proximal side of the grain. *Muscari*.
- I2 Grain more than 40 µm *Muscari comosum*
LILIACEAE
- I1 Grain less than 40 µm *Muscari neglectum* t.
LILIACEAE
- H2 Colpus completely covers the distal pole. Colpus membrane covered with irregularly shaped islands of columellate exine. Grain 44-55 µm *Gynandris sisyrinchium*
IRIDACEAE
- H1 Colpus restricted to the distal side of the grain.
- J2 Heterobrochate.
- K2 Grains long, narrow.
- L2 Few large brochi, mostly on the proximal side of the grain. *Scilla* t.
LILIACEAE
- L1 Lumina variable, rounded, muri about the same size as lumina
Narcissus papyraceus t.
AMARYLLIDACEAE
- K1 Grain almost circular in polar view. Perforate-reticulate with muri and lumina almost the same size over the distal pole, remainder of surface reticulate with lumina twice width of muri *Asphodelus fistulosus* t.
LILIACEAE
- J1 Homobrochate.

- M3 Grain less than 30 μm . Brochi c. 1 μm ; *reticulum decreases towards colpus*
..... *Narthecium scardicum*
LILIACEAE
- M2 Grain 30-50 μm . *Margo present*. Muri narrow. Lumina up to 3 μm . Incl.
Butomus, Veratrum.
- N2 Lumina in mesocolpium decrease sharply to a broad colpus margin that is
clearly tectate-perforate. Grain often circular in outline
Butomus umbellatus
BUTOMACEAE
- N1 Lumina decrease more gradually to colpus margin, which is not tectate-
perforate, i.e. some lumina are still detectable at the very edge. Grain more
often elliptic *Veratrum*
LILIACEAE
- M1 Grain more than 50 μm .
- O2 Pollen often ruptured with ragged colpus edges. No margo. *Free*
columellae in some brochi.
- P3 Brochi 2-3 μm *Hermodactylus tuberosus*
IRIDACEAE
- P2 Brochi 1-2.5 μm *Iris pseudacorus*
IRIDACEAE
- P1 Brochi 1-1.5 μm *Iris spuria* t.
IRIDACEAE
- O1 Margo present. Columellae distinct *Fritillaria*
LILIACEAE
- A1 Microreticulate (brochi less than 1 μm), psilate or scabrate.
- Q2 *Colpus extends to the proximal side of the grain. Allium* - see above.
- Q1 Colpus restricted to the distal side of the grain.
- R2 Grain less than 30 μm .
- S2 Columellae imperceptible.
- T2 Brochi c. 1 μm *Narthecium scardicum*
LILIACEAE
- T1 Psilate (perforate) *Galanthus* t.
AMARYLLIDACEAE
- S1 Columellae distinct. Brochi less than 1 μm *Asparagus*
LILIACEAE
- R1 Grain more than 30 μm .
- U2 *Grain shaped like an orange segment*.
- V4 Microreticulate, brochi c. 1 μm . Grain 50-60 μm *Sternbergia*
AMARYLLIDACEAE
- V3 Perforate to reticulate, brochi < 1 μm . Grain 25-50 μm ... *Narcissus tazetta*
AMARYLLIDACEAE
- V2 Perforate. Polar outline $\pm$ circular *Asphodelus albus*
LILIACEAE
- V1 Psilate to faintly perforate *Polygonatum* t.
LILIACEAE

U1 Grain not segment-shaped.

W2 Reticulate, muri broader than width of lumina.

X2 Homobrochate *Tulipa sylvestris*
LILIACEAE

X1 Heterobrochate *Ornithogalum t.*
LILIACEAE

W1 Psilate-scabrate, perforate.

Y2 Grain about 60 µm. Psilate-perforate and micro-echinate. 2 operculi
over colpus (giving appearance of being 3-colpate) *Gladiolus t.*
IRIDACEAE

Y2 Grain 47-70 µm. Granulate and perforate *Urginea maritima*
LILIACEAE

Y1 Grain less than 50 µm.

Z2 Colpus edges ragged *Gagea lutea t.*
LILIACEAE

Z1 Colpus edges not ragged *Convallaria majalis*
LILIACEAE

Key E5. Monoporate

A3 Pore large, diameter more than half that of the grain, with operculum.

B2 Grain gemmate *Nymphaea alba*
NYMPHAEACEAE

B1 Grain granulate with echinae c. 1 µm projecting above densely crowded granules. *Smilax*
LILIACEAE

A2 Pore diameter about half grain diameter. Grain reticulate or rugulate-verrucate.

C2 Grain reticulate *Cephalanthera*
ORCHIDACEAE

C1 Grain with verrucae and short rugulae *Limodorum abortivum*
ORCHIDACEAE

A1 Pore smaller, diameter usually much less than half that of the grain.

D2 With distinct anulus. Grain tectate, psilate, scabrate, verrucate. Cf. special key **Gramineae**

D1 No anulus. Cf. *Juniperus*, Key E2.

E4 Grain clavate-baculate *Callitriche stagnalis t.*
CALLITRICHACEAE

E3 Grain psilate, densely perforate with *lacunae*, one of which forms a rudimentary pore at
broad end of usually pear-shaped grain. Cf. special key **Cyperaceae**

E2 Grain reticulate/rugulate, heterobrochate. Pore not always distinct.

F4 Microreticulate (lumina < 1 µm) *Sparganium erectum*
SPARGANIACEAE

F3 Reticulate, lumina 1-2 µm *Sparganium angustifolium*
SPARGANIACEAE

- F2 Reticulate, lumina c. 2 μm *Typha domingensis* t.
TYPHACEAE
- F1 Rugulate. Often in tetrads *Typha angustifolia* t.
TYPHACEAE
- E1 Grain echinate, echinae c. 1.5 μm with broad conical base. Pore may be indistinct. Cf.
algal cysts and other microfossils of unknown origin Lemnaceae
LEMNACEAE

Key E6. Dicolpate

- A2 Columellae distinct. Per-reticulate. Margo present *Tamus communis*
DIOSCOREACEAE
- A1 Columellae indistinct. No margo.
- B2 Grain sometimes syncolpate. Grain densely microechinate *Hypecoum*
PAPAVERACEAE
- (B1 Grain usually two-split (syncolpate), edges ragged. Structure and sculpturing very faint
or nil. Cf. Key E18 *Pedicularis*
SCROPHULARIACEAE

Key E7. Tricolpate; Main key to subsections

- A2 Tectate
- B5 Psilate (may be perforate tectum) Key E7.1
- B4 Scabrate Key E7.2
- B3 Baculate, echinate, or verrucate Key E7.3
- B2 Rugulate-striate Key E7.4
- B1 Supra-reticulate Key E7.5
- A1 Semitectate or intectate
- C2 Per-reticulate Key E7.6
- C1 Intectate (clavate, gemmate or baculate) Key E7.7

The crested grains of *Trapa* are not included in this key; see Key A.

Key E7.1 Tricolpate, psilate (may be perforate tectum)

- A3 Colpi very short with nexinous ridges crossing underneath, never gaping *Monotropia hypopitys*
PYROLACEAE
- A2 Colpus without equatorial constriction
- B4 Exine equal to or thicker than 3 μm . Columellae shorter and exine thinner next to colpus.
- C2 Exine 4-6 μm thick. Columellae branched. Grain 45-67 μm *Convolvulus*
CONVOLVULACEAE

- C1 Exine c. 3 µm thick. Columellae simple.
- D2 Grain >30 µm *Putoria calabrica*
RUBIACEAE
- D1 Grain ≤30 µm. *Cuscuta*.
- E2 In centre of mesocolpium sexine about as thick as nexine; columellae short and rather indistinct *Cuscuta epithymum* t.
CONVOLVULACEAE
- E1 In centre of mesocolpium sexine thicker than nexine; columellae longer, easily visible *Cuscuta europaea* t.
CONVOLVULACEAE
- B3 Exine thinner in middle of intercolpium. Colpus narrow, straight, edges sharp. Grain c. 20 µm *Melampyrum*
SCROPHULARIACEAE
- B2 Exine 2-3 µm, even thickness. Edge of colpus clear, not ragged. Grain 21-30 µm *Phytolacca americana*
PHYTOLACCACEAE
- B1 Exine equal to or thinner than 2 µm. Edge of colpus ragged.
- F2 Exine thinner next to colpus, micro-echinate. Columellae distinct and/or irregularly distributed.
- G2 Grain globular-prolate. Exine thicker in polar area, without perforations. Columellae present in colpus, grouped *Veronica triphyllos* t.
SCROPHULARIACEAE
- G1 Grain globular-oblate. No polar thickening of exine. Tectum with perforations. Columellae in colpus, if present, scattered.
- H2 Distinctly micro-echinate. Number of perforations and columellae approximately equal. Columellae in a dense, regular pattern *Spergula*
CARYOPHYLLACEAE
- H1 Not echinate. Perforations fewer than columellae. Columellae irregularly distributed *Spergularia* t.
CARYOPHYLLACEAE
- F1 Exine same thickness throughout, c. 1 µm. Surface smooth
- I2 Grains oblate to spheroidal. Polar area small, index below 0.3
- J2 Grain c. 30 µm. Structure imperceptible *Myricaria germanica*
TAMARICACEAE
- J1 Grain 40-50 µm. Structure distinct. Sometimes 4-colpate *Euphrasia*
SCROPHULARIACEAE
- I1 Grains subglobular/prolate, 30-40 µm. Surface uniform.
- K3 Supratectal granules grouped into circles *Odontites* t.
SCROPHULARIACEAE
- K2 Supratectal granules grouped only as rugulae *Bellardia trixago*
SCROPHULARIACEAE
- K1 Minutely superficially strio-reticulate. Incl. *Orobanche purpurea*
Rhinanthus t.
SCROPHULARIACEAE
- A1 Colpus with equatorial constriction. Cf. Key E11.1
- L2 Colpus with prominent, undulating edges. Special key Rosaceae

L1 Colpus edges flat, straight.

M2 Microreticulate. Columellae imperceptible *Saxifraga stellaris*
SAXIFRAGACEAE

M1 Exine not reticulate.

N2 Columellae imperceptible. Exine thin *Viola hirta* t.
VIOLACEAE

N1 Columellae distinct.

O2 Columellae coarse *Saxifraga bulbifera*
SAXIFRAGACEAE

O1 Columellae irregularly dispersed, minute. Perforations scattered,
irregular *Myricaria germanica*
TAMARICACEAE

Key E7.2. Tricolpate, scabrate

A2 Colpus with equatorial constriction

B2 *Costae colpi distinct*. Equatorial limb triangular. *Cornus*

C2 Grain more than 40 µm, scabrate. Tectum perforate *C. sanguinea*
CORNACEAE

C1 Grain less than 35 µm, with scattered microverrucae. Tectum imperforate ... *C. mas*
CORNACEAE

B1 *No distinct costae colpi*. Columellae crowded, minute *Myricaria germanica*
TAMARICACEAE

A1 Colpus without equatorial constriction

D3 Nexine very thin. Sexine thicker than nexine, distinctly columellate, tectate. Usually
syncolpate *Soldanella*
PRIMULACEAE

D2 Nexine distinct. Exine thick, at any rate in the polar area.

E3 Exine thick in mesocolpia (3.5-5 µm); structure of sexine complex, with 2 layers of
columellae *Nigella*
RANUNCULACEAE

E2 Exine more than 3 µm thick, *crescentic*. Nexine heavy. Columellae distinct, their mutual
distance 1-2 times diameter. Distinct, regularly and widely spaced microechinae. *Colpus*
membrane with columella-like granules.

F2 Grain > 40 µm. Some echinae larger than 1 µm. Exine thicker at poles (6 µm) .
Centranthus
VALERIANACEAE

F1 Grain < 40 µm. Only microechinae. *Valerianella*.

G2 Sexine as thick as nexine in mesocolpium; columellae more scattered and
somewhat larger at poles than elsewhere *Valerianella rimosa* t.
VALERIANACEAE

G1 Sexine thicker than nexine in mesocolpia; columellae not differentiated at poles
.....
Valerianella locusta t.
VALERIANACEAE

- E1 Exine thinner except in polar area.
- H2 Exine thickest *adjacent* (but not actually *at*) poles; endocracks absent. *Granulate colpus operculum*. Colpus edges straight *Teucrium*
LABIATAE
- H1 Exine thickest *at poles*; endocracks present. Colpus with granulate membrane, but *not operculate*.
- I3 Colpus narrow, infolded, margins very prominent with adhering granules, traversed by prominent endocracks; colpus membrane not usually visible. Columellae distinct *Adonis*
RANUNCULACEAE
- I2 Colpus broad; margins ragged, not prominent, traversed by endocracks (but not prominently); colpus membrane covered with numerous distinct granules. Columellae distinct *Consolida* t.
RANUNCULACEAE
- I1 Colpus broad, slightly sunken; margin ragged and indistinct, traversed by faint endocracks; colpus membrane granular. Columellae indistinct ... *Caltha* t.
RANUNCULACEAE
- D1 Not so.
- J3 Without spinules.
- K2 Exine perforate. Grain 27-36 µm *Veronica triphyllos* t.
SCROPHULARIACEAE
- K1 Not perforate. Grain 17-23 µm *Orobanche ramosa* t.
OROBANCHACEAE
- J2 Low ridges at base of spinules form a reticuloid pattern. Exine with multiple perforations. Spinules (scabrae) regularly distributed. Detailed key to species within this type (*P. dubium*, *P. hybridum*, *P. rhoeas*, *P. somniferum*) in NW2 . *Papaver rhoeas* t.
PAPAVERACEAE
- J1 No ridges between bases of spinules.
- L2 Structure and sculpturing very fine. Grain oblate *Myricaria germanica*
TAMARICACEAE
- L1 Structure and sculpturing distinct. Spinules/verrucae irregularly distributed, size variable.
- M3 Tectum ±smooth with very scattered verrucae *Glinus* t.
MOLLUGINACEAE
- M2 Tectum without perforations. Columellae distinct, uniform, rather crowded. Colpus narrow. *Quercus*.
- N3 Indistinctly scabrate/rugulate. Polar diameter 22-28 µm . *Q. coccifera* t.
FAGACEAE
- N2 Scabrate. Polar diameter 30-37 µm *Q. trojana* t.
FAGACEAE
- N1 Distinctly scabrate/verrucate *Q. frainetto* t.
FAGACEAE
- M1 Tectum with perforations, (sub-)verrucate-echinate. Colpus open, membrane granulate. Grains often pericarpate, cf. Key E9. Columellae in open pattern, forming a bright area ('halo') around each spinule. Perforations follow the same pattern. See key to species and groups in NW6. Incl. *Ranunculus p.p.*, *Pulsatilla*, *Anemone*, *Ceratocephalus* & *Clematis* *Ranunculus acris* t.
RANUNCULACEAE

Key E7.3. Tricolpate; baculate, echinate or verrucate

A3 Baculate, baculae c. 2.5 µm long, in groups of 2 and 3. Exine 2-4 µm, tectum complete, infratectum columellate. Grain 42-60 µm *Plumbago europaea*
PLUMBAGINACEAE

A2 Echinate. Grain large, 40 µm or more.

B2 Echinae prominent, widely separated.

C2 Echinae 1-1.5 µm long, supported on shield-shaped verrucae. *Valeriana*.

D2 Echinae considerably shorter than wall thickness, height greater than width
Valeriana officinalis t.
VALERIANACEAE

D1 Echinae about as wide as tall *Valeriana tuberosa*
VALERIANACEAE

(C1 Echinae coarse, not on shield-shaped verrucae. Polar area large. Equatorial limb subtriangular. *Lonicera*. Tricolporate: see Key E11.2)

B1 Echinae smaller, of different size classes. Exine 5-10 µm. Columellae branched. Colpus short, broad, cf. Key E15 (Triporate). Dipsacaceae *p.p.*

E3 Halo surrounding a very short colpus *Dipsacus* t.
DIPSACACEAE

E2 Structural and sculpturing elements regularly distributed. Exine thicker at poles
Scabiosa columbaria t.
DIPSACACEAE

E1 Not so *Succisa pratensis*
DIPSACACEAE

A1 Grains smaller.

F3 Echinae conical, low. Tectum thick. Colpi short, indistinct. Compositae, see Key E11.2: H2
..... *Xanthium*
COMPOSITAE

F2 Grains with prominent mixed echinae and microechinae, irregularly and widely spaced ...
Actaea spicata
RANUNCULACEAE

F1 Grains microechinate, echinae evenly distributed *Nigella*
RANUNCULACEAE

Key E7.4. Tricolpate, rugulate or striate

A2 Exine very thick, 5-7 µm. Striae coarse, multilevelled. Colpi wide *Erodium*
GERANIACEAE

A1 Exine thickness and striation normal and fine.

B2 Exine with or without perforations. Edges of colpi undulating, often prominent. Rosaceae, see special key

B1 Exine perforate. Edges of colpi straight or ragged.

C3 Very finely rugulate-striate *Veronica anagallis-aquatica* t.
SCROPHULARIACEAE

C2 Rugulate-scabrate. *Vallae short*.

D2 Vallae in reticuloid pattern, may be perfectly reticulate. Colpus margins ragged .
Oxalis
OXALIDACEAE

D1 Vallae very faint. Colpus margins straight. *Quercus coccifera* t.
FAGACEAE

C1 Distinctly striate.

E3 Sculpturing fine, striae predominantly meridional. Grain 30 µm or more ... *Acer*
ACERACEAE

E2 Direction of striae variable

F2 Grain smaller than 25 µm. Sculpturing fine *Trollius europaeus*
RANUNCULACEAE

F1 Grain more than 25 µm. Sculpturing coarse. Refer NW2.
Saxifraga oppositifolia t.
SAXIFRAGACEAE

E1 Striation diffuse. Vallae in very low relief. *S. granulata* type of NW2.

G2 Vallae with granulae *Saxifraga tridactylites* t.
SAXIFRAGACEAE

G1 No granulae on vallae *Saxifraga sempervivum* t.
SAXIFRAGACEAE

Key E7.5. Tricolpate, supra-reticulate

A2 Colpus without equatorial constriction or poroid area. No costae.

B2 Meridional limb compressed oval, grain subcylindric, usually prolate-perprolate. Colpus narrow, not boat-shaped.

C3 Muri broader than lumina; lumina of even size, c. 1 µm *Acanthus*
ACANTHACEAE

C2 Muri narrow; all brochi large, c. 1.5 µm *Onobrychis*
LEGUMINOSAE

C1 Muri narrow, brochi small, c. 0.5 µm, or a median field of small brochi in each intercolpium *Hedysarum coronarium*
LEGUMINOSAE

B1 Meridional limb circular, oval or rhomboidal, not compressed. Colpi boat-shaped, often ruptured. Labiatae *p.p.*

D2 Lumina ± uniform in size all over the grain (may be so small as to be microreticulate).

E3 ± Microreticulate.

F2 Grain > 25 µm *Stachys sylvatica* t.
LABIATAE

F1 Grain < 25 µm. Brochi somewhat variable in size *Marrubium*
LABIATAE

E2 Reticulate.

G2 Thick muri (0.5-1.0 µm), baculae in lumina *Stachys arvensis*
LABIATAE

- G1 Muri thin (0.2-0.4 μm), punctae perforating the lumina *Stachys recta*
LABIATAE
- E1 Doubly reticulate *Phlomis*
LABIATAE
- D1 Lumina largest in the centre of each mesocolpium (where muri may appear winding),
decrease in size gradually towards colpi *Scutellaria t.*
LABIATAE
- A1 Equatorial part of colpus constricted or ruptured. Costae interrupted at equator.
- H2 Poroid area large, usually ruptured. Branches of costae colpi short. *Genista t.*
LEGUMINOSAE
- H1 Poroid area small. Branches of costae colpi long. *Hypericum*, see Key E11.5.

Key E7.6. Tricolpate, per-reticulate

- (A3 *Tri-sulcate*, one sulcus oval and occupying the distal pole of the grain, the other two semi-circular and located at the margins of the proximal face *Tulipa praecox t.*)
LILIACEAE
- A2 Colpi without equatorial constriction
- B2 Grain large, more than 50 μm , thick-walled.
- C3 Finely and uniformly reticulate, lumina c. 1 μm .
- D2 Colpus membrane granulate *Leontice leontopetalum*
BERBERIDACEAE
- D1 Not so. Muri broader than lumina *Acanthus*
ACANTHACEAE
- C2 Coarsely reticulate, brochi 4-14 μm . *Columellae not branched*, the heads standing above the muri *spinulose* *Armeria maritima t.*
PLUMBAGINACEAE
- C1 *Columellae branched, fused to a reticulum some distance below their heads*, forming coarse *clavae* on top. See key to groups in NW6 *Geranium*
GERANIACEAE
- B1 Grain smaller.
- E2 Brochi small, less than 1 μm (microreticulate).
- F2 Heterobrochate, brochi larger in mesocolpia.
- G2 Colpi long, margins diffuse, membrane rugate $\pm$ granules. $\pm$ Circular in polar view, prolate. Infratectum clearly columellate *Reseda*
RESEDACEAE
- G1 Colpi short. Angulaperturate, triangular in polar view; suboblate
Comandra elegans
SANTALACEAE
- F1 Homobrochate.
- H2 Grain larger than 25 μm .
- I2 Exine c. 4 μm thick *Cuscuta monogyna*
CONVOLVULACEAE

- I1 Exine 2 μm or less. Colpus margin indistinct. Colpus membrane granulate. Columellae indistinct *Chelidonium majus*
PAPAVERACEAE
- H1 Grain smaller than 25 μm .
- J2 Exine thicker than 1 μm , thinner at colpus margin and in apocolpia. Polar exine not differentiated. Columellae distinct in surface view.
- K3 Exine 2-4 μm thick. Colpus margin distinct. Colpus membrane not granulate. *Arabis*
CRUCIFERAE
- K2 Exine 2 μm or less. Colpus margin distinct. Colpus membrane not granulate *Hornungia t.*
CRUCIFERAE
- K1 Exine 1-3 μm . Colpus membrane granulate. Muri broad . *Tamarix*
TAMARICACEAE
- J1 Exine 1 μm or less, tectate-perforate at poles. Columellae indistinct.
- L2 Exine c. 1 μm thick. Polar area tectate-perforate, not thickened or reticulate *Saxifraga stellaris*
SAXIFRAGACEAE
- L1 Exine less than 1 μm thick. Polar area exine thicker, tectate with few perforations. Obscurely tricolporate, with 2-6 endocolpi
Chrysosplenium alternifolium
SAXIFRAGACEAE
- E1 At least some brochi more than 1 μm .
- M2 *Colpus long*
- N2 Heterobrochate, brochi reduced in size towards colpi.
- O2 Margo distinct, semitectate. Brochi c. 2 μm . Grain $\pm$ spheroidal
Helleborus
RANUNCULACEAE
- O1 Margo thin, tectate.
- P2 Endoaperture apparent. Grain prolate.
- Q2 Brochi 1.5-2 μm . Grain 16-20 μm *Salix triandra*
SALICACEAE
- Q1 Brochi 2-3 μm . Grain 16-27 μm *Salix fragilis t.*
SALICACEAE
- P1 Endoaperture very indistinct. Grain $\pm$ spheroidal *Oxalis*
OXALIDACEAE
- N1 Brochi not reduced in size towards colpi. No distinct margo. Columellae very distant, only their heads joined into a reticulum.
- R2 Exine rather thick. Columellae clear in top view, length decreases next to colpi. Reticulum with narrow muri. Colpus without granules or with a delicate structure. *Sinapis t.*
CRUCIFERAE
- R1 Muri broad. Colpus with scattered granules *Glaucium*
PAPAVERACEAE
- M1 *Colpus short*. Polar area rather large, index c. 0.4.

- S2 Colpus broad, with scattered granules. Grain c. 22 μm . *Platanus orientalis*
PLATANACEAE
- S1 Colpus narrow, covered with granules, broader towards equator, geniculate.
Fraxinus.
- T2 Equatorial outline angular, sides sometimes nearly straight. Nexine about
as thick as sexine. Reticulum fine, brochi $\pm 1 \mu\text{m}$. Grain 18.5-23.5 μm
Fraxinus angustifolia
OLEACEAE
- T1 Equatorial outline circular. Nexine distinctly thinner than sexine.
Reticulum slightly coarser, brochi $>1 \mu\text{m}$. Grain 20-29.5 μm
Fraxinus excelsior t.
OLEACEAE
- A1 Colpi with equatorial constriction. See Key E11.5 (Tricolporate).
- Key E7.7. Tricolpate, intectate (clavate, gemmate and baculate)
- A2 Size of clavae variable.
- B2 Intercolpium and polar area with *scattered, large, free clavae* in addition to many small ones,
more or less fused. Colpus not distinct
- C2 Grain c. 60 μm . Equatorial outline circular *Viscum album*
LORANTHACEAE
- C1 Grain c. 20 μm . Equatorial outline $\pm$ triangular *Arceuthobium oxycedri*
LORANTHACEAE
- B1 All clavae free. *Small clavae scattered beneath the large ones*. Near the colpus there are only
small clavae, forming a margo *Ilex aquifolium*
AQUIFOLIACEAE
- A1 Clavae dimorphic or uniform. Linaceae.
- D2 *Clavae dense, almost contiguous*, fine, 1-1.5 μm , dimorphic, the smaller ones dominant. ..
Linum usitatissimum t.
LINACEAE
- D1 *Clavae/gemmae distinctly separate*.
- E2 Grain smaller than 25 μm . Colpus margins regular, not appearing ruptured. Gemma of
 $\pm$ uniform diameter *Radiola linoides*
LINACEAE
- E1 Grain large, $> 35 \mu\text{m}$. Colpus margins very irregular, ruptured. Clavae uniform or
dimorphic. If dimorphic, both size classes subequally represented.
- F3 Grain c. 80 μm . Clavae uniform. [Rogers 1984 suggests periculpate]
Linum hologynum t.
LINACEAE
- F2 Grain smaller, c. 50-65 μm . Endocolpus lolongate, broad, distinct
Linum austriacum t.
LINACEAE
- F1 Grain 35-70 μm . Endoaperture not, or hardly visible, except at ends. Includes *L.*
catharticum, *L. tenuifolium*, *L. trigynum*, *L. strictum*, *L. hirsutum* - See detailed key
to groups and species in NW3 *Linum catharticum* t.
LINACEAE

Key E8. *Stephanocolpate*

A2 Psilate-scabrate.

B4 Grain large, 60-80 μm . 9-11 broad colpi. Finely pilate-scabrate *Sesamum indicum*
PEDALIACEAE

B3 Grain medium size.

C2 25-28 μm . 11-12 colpi *Sherardia arvensis*
RUBIACEAE

C1 20-35 μm . 4 or 6 colpi. Detailed key to species within this type (*P. dubium*, *P. hybridum*,
P. rhoeas, *P. somniferum*) in NW2 *Papaver rhoeas* t.
PAPAVERACEAE

B2 Grain small.

D2 Grain 15-29 μm . 6-10 narrow colpi. Ornament of circular perforations and scabrae .
Galium t.
RUBIACEAE

D1 Grain 15-21 μm . c. 6 colpi. Ornament of small circular perforations regularly distributed,
together with paired rugae giving a unique band and point pattern *Valantia*
RUBIACEAE

B1 Grain very small, 10-13 μm . 3-4 colpi *Corrigiola litoralis* p.p.
CARYOPHYLLACEAE

A1 Reticulate.

E2 Polar area large, index higher than 0.6

F3 *Supra-reticulate*; no columellae discernible in muri. Colpi 4. Grain oblate in equatorial
view, subrectangular in polar view. *Impatiens noli-tangere*
BALSAMINACEAE

F2 *Reticulate-perforate*. Colpi 4. Grain obtuse-rectangular or quadrangular in equatorial
and polar views *Sideritis*
LABIATAE

F1 *Per-reticulate*.

G3 5-10 colpi *Primula*
PRIMULACEAE

G2 4-6 colpi. Usually tricolpate, see E7.6 *Oxalis*
OXALIDACEAE

G1 4 colpi.

H2 Columellae indistinct *Fraxinus angustifolia*
OLEACEAE

H1 Muri simpli -or duplicolumellate *Fraxinus excelsior* t.
OLEACEAE

E1 Polar area medium-small, index lower than 0.5.

I2 *Supra-reticulate*.

J2 6 or more colpi. Free columellae in lumina *Prunella* t.
LABIATAE

J1 4 colpi. No free columellae (lumina punctate) *Stachys angustifolia*
LABIATAE

I1 *Per-reticulate*. Columellae restricted to muri.

- K3 Muri *scabrate*. Microreticulate *Crucianella*
RUBIACEAE
- K2 Muri *beaded*.
- L2 Reticulum double *Salvia officinalis* t.
LABIATAE
- L1 Reticulum single, $\pm$ rugulate *Salvia verticillata*
LABIATAE
- K1 Muri not beaded *Mentha* t.
LABIATAE

Key E9. Pericarpate

A3 Reticulate.

- B2 Lumina deep, with free, coarse clavae. 30 short colpi in dodecahedral arrangement
Polygonum amphibium
POLYGONACEAE

B1 No free elements in lumina. 4-6 colpi. Cf. Tricolpate, Keys E7.5 and E7.6.

A2 Echinate. Echinae small, irregularly distributed. Tectum perforate. Central area of intercolpium with coarse columellae in reticuloid pattern. 12 colpi

- C2 Exine thickest in mesocolpium, thinning towards colpi *Montia fontana*
PORTULACACEAE

- C1 Exine $\pm$ even thickness *Portulaca oleracea*
PORTULACACEAE

A1 Psilate, microechinate, scabrate, verrucate.

- D3 Irregularly distributed spinules, verrucae or scabrae of varying size. Tectum with perforations (phase, SEM): some Papaveraceae, Ranunculaceae more usually inaperturate or tricolpate (Keys E2, E7) may key out here.

- E2 Psilate. 6- or 12- colpate, usually syncolpate *Corydalis ochroleuca*
PAPAVERACEAE

- E1 Verrucate. 6-colpate, not syncolpate *Corydalis solida* t.
PAPAVERACEAE

- D2 Psilate-scabrate with uniform minute spinules and perforations *Spergula*
CARYOPHYLLACEAE

- D1 Psilate, spinules absent *Spergularia* t.
CARYOPHYLLACEAE

Key E10. Dicolporate

- Prolate, equatorially constricted (bone-shaped). Colpi 2/3 length of grain; ora rectangular, lalongate. Exine tectate, psilate. Includes *Tordylium maximum* *Echinophora* t.
UMBELLIFERAE

Key E11. Tricolporate: main key to subsections

The transition colpate-colpate with equatorial constriction-colporate is not easy to define in categorical terms. Consultation of Key E7 is recommended if Key E11 does not lead to a result.

A3 Tectate.

- B4 Psilate or scabrate Key E11.1
- B3 Echinate Key E11.2
- B2 Striate or rugulate Key E11.3
- B1 Foveolate or supra-reticulate Key E11.4
- A2 Semitectate. Per-reticulate Key E11.5
- A1 Intectate. Clavate Key E11.6

Key E11.1 Tricolporate. Psilate-scabrate

A2 With costae aequatoriales and transverse colpi

- B4 Equatorial limb intersemiangular. *Exine more than 4 µm thick, crescentic.* Columellae coarse, branched. *Centaurea* sect. *Cyanus*
- C2 *Meridional limb compressed oval.* Costae aequatoriales sharply projecting in meridional optical section *C. cyanus* t.
COMPOSITAE
- C1 *Meridional limb oval.* Costae aequatoriales less prominent *C. napulifera* t.
COMPOSITAE
- B3 *Equatorial limb subcircular.* Exine thinner, not crescentic. Columellae finer. *Costae aequatoriales less prominent.* Grain 22-39 µm, colpi long *Polygonum aviculare* t.
POLYGONACEAE
- B2 Equatorial limb intermediate between B4 and B3. Exine slightly crescentic .. *Bilderdykia*
POLYGONACEAE
- B1 Equatorial limb triangular. Exine 1.25-1.5 µm, not crescentic, short columellae. Costae aequatoriales stronger near ectoapertures, colpi short and narrow with parallel sides, often forking slightly at ends. Grain 45-56 µm *Anchusa arvensis* t.
BORAGINACEAE

A1 No costae aequatoriales

- D3 Heteropolar. Exine thin, psilate or punctate, columellae not discernible.

E2 Pear-shaped.

- F2 Grain 10-16 µm. Exine with scattered punctae < 1 µm bordering the apertures ..
Alkanna t.
BORAGINACEAE
- F1 Grain 17-24 µm. Exine comprehensively but faintly micro-suprareticulate *Echium*
BORAGINACEAE
- E1 Grain ± spheroidal, one apocolpium very small, the other larger. Exine psilate.

- G2 Grain > 15 µm. Colpi constricted at equator; endoapertures indistinct
Gratiola officinalis
 SCROPHULARIACEAE
- G1 Grain 10-15 µm. Costae colpi present; endoapertures large and distinct, 8-shaped
Cyclamen
 PRIMULACEAE
- D2 Meridional limb *compressed oval*.
- H2 Grain distinctly *prolate*.
- I2 Grain larger than 20 µm. Exine > 1 µm. For detailed key see NW4; additional taxa described by Cerceau-Larrival (1963 - *Tordylium officinale*; 1967 - *Cachrys*); van Zeist & Bottema (1977 - *Malabaila*)
Umbelliferae
 UMBELLIFERAE
- I1 Grain < 20 µm. Exine < 1 µm *Androsace villosa*
 PRIMULACEAE
- H1 Not so distinctly *prolate*.
- J2 Exine more than 3 µm thick. Grain more than 50 µm, dimorphic, one type with denser structure. Tectum with scattered perforations. *Columellae branched, coarser at poles*.
- K2 Columellae evenly distributed, gaps between columellae less than their diameters *Polygonum viviparum*
 POLYGONACEAE
- K1 Columellae irregularly distributed, more widely spaced *Polygonum bistorta* t.
 POLYGONACEAE
- J1 Exine thin.
- L3 Grain more than 30 µm. *Pore edges distinctly protruding*. Scabrate, polar area suprareticulate *Anthyllis*
 LEGUMINOSAE
- L2 Grain 20-30 µm.
- M2 Pores edges distinctly protruding *Dorycnium*
 LEGUMINOSAE
- M1 Pores not protruding *Ornithopus compressus*
 LEGUMINOSAE
- L1 Grain less than 20 µm, psilate *Lotus* t.
 LEGUMINOSAE
- D1 Meridional limb oval or circular.
- M2 *Intercolpium flattened or concave in polar view*.
- N2 Exine thicker and columellae coarser at poles. Colpus narrow, slit-shaped. Grain subglobular *Hydrocotyle vulgaris*
 UMBELLIFERAE
- N1 Thickness of exine uniform. Colpus not slit-shaped.
- O2 *With transverse colpus*
- P2 Scabrate. Grain c. 35-45 µm, angulaperturate. Tectum perforate

- Q2 Longitudinally oriented rugulae. *Rhus coriaria*
ANACARDIACEAE
- Q1 Micro-foveolate/fossulate. Equatorial sexinal bridge over colpus ...
Styrax officinalis
STYRACACEAE
- P1 Psilate. Tectum not perforate.
- R2 Grain more than 20 µm.
- S2 Irregular outline. H-shaped endoaperture *Verbena*
VERBENACEAE
- S1 Smooth outline. Endoaperture not H-shaped, fastigiate
Solanum nigrum t.
SOLANACEAE
- R1 Grain smaller than 20 µm. Endoaperture fastigiate
Solanum dulcamara
SOLANACEAE
- O1 No transverse colpus.
- T2 Equatorial limb semilobate. Psilate *Frangula*
RHAMNACEAE
- T1 Equatorial limb semiangular. Scabrate.
- U3 Grain 58-64 µm, subprolate, circular equatorial outline. Colpi
long. Exine c. 3 µm, tectum perforate ... *Lagenaria siceraria*
CUCURBITACEAE
- U2 Grain more than 40 µm, angulaperturate ... *Cornus sanguinea*
CORNACEAE
- U1 Grain c. 25 µm, angulaperturate *Cornus mas*
CORNACEAE
- M1 Intercolpium convex.
- V2 Pore edges distinctly protruding.
- W2 Endopore equatorially elongated.
- X2 Grain 23 µm or more.
- Y2 Psilate to sparsely punctate *Osyris alba*
SANTALACEAE
- Y1 Densely punctate/microreticulate (see E11.5) ... *Ricinus communis*
EUPHORBIACEAE
- X1 Grain less than 25 µm.
- Z3 Microechinate, vermiculate *Filipendula*
ROSACEAE
- Z2 Psilate, tectum not perforate *Castanea sativa*
FAGACEAE
- Z1 Scabrate or indistinctly suprareticulate.
- A'2 Operculate *Sanguisorba minor*
ROSACEAE
- A'1 No operculum. Incl. *Medicago sativa* p.p.
Trifolium montanum t.
LEGUMINOSAE

- W1 Endopore circular. Colpus slit-shaped.
- B'2 With vestibulum. *Colpus very short*, about twice the diameter of the pore *Ludwigia palustris*
ONAGRACEAE
- B'1 No vestibulum.
- C'2 Microechinate, columellae in vermiculoid pattern *Filipendula*
ROSACEAE
- C'1 Psilate. Colpi very short. Grain spheroidal to oblate
Elaeagnus angustifolia
ELAEAGNACEAE
- V1 Edges of pore not protruding, *endopore meridionally elongated, isodiametric or indistinct*.
- D'2 Grain perforate. *Colpus slit-shaped, endopore small, completely covered*.
- E'2 With *costae endopori*. See key to species and groups in NW5. Incl. *Oxyria digyna* *Rumex* t.
POLYGONACEAE
- E'1 No *costae endopori*.
- F'2 Grain 33-45 µm *Spartium junceum*
LEGUMINOSAE
- F'1 Grain 16-19 µm. Colpus interrupted at equator . *Samolus valerandi*
PRIMULACEAE
- D'1 Not so.
- G'2 Distinctly prolate. Grain < 30 µm.
- H'2 Scabrate.
- I'2 Scabrate/suprareticulate. Equatorial limb circular with deeply intruding colpi. Colpi long, wide, with densely granulate membrane. Exine thins towards colpi. *Globularia*
GLOBULARIACEAE
- I'1 Scabrate/granulate. Intercolpia flattened or slightly convex. Colpi long and narrow, with psilate membrane *Diospyros lotus*
EBENACEAE
- H'1 Psilate. Crassulaceae.
- J'2 Grain > 27 µm. Colpus membrane slightly granulate
Jovibarba heuffelii
CRASSULACEAE
- J'1 Grain < 27 µm *Umbilicus*
CRASSULACEAE
- G'1 Subprolate to spheroidal.
- K'2 *Colpi long, broad*. Psilate to scabrate. H-endoaperture with equatorial bridge of sexine over colpus. Colpus membrane with coarse granules; margins not intruding, irregular ... *Robinia pseudacacia*
LEGUMINOSAE
- K'1 Colpi short, slit-like.

- L'2 Grain 44-50 μm . Scabrate/rugulate. Endoaperture circular, with thickened sexine (marginate) *Fagus*
FAGACEAE
- L'1 Grain 20-28 μm . Scabrate/granulate. Endoaperture circular, with thickened nexine (costate) *Emex spinosa*
POLYGONACEAE

Key E11.2. Tricolporate, Echinata

This Key mainly comprises Compositae Asteroideae. Their exine is in typical cases multi-layered and consists of, from the inside outwards: (1) foot layer = nexine; sexine composed of (2) inner columella layer, usually with scattered, coarse, often branched columellae; (3) paratectum formed by partial fusion of heads of the inner columellae; (4) outer columellae layer; columellae thinner and more numerous than in the inner layer; (5) (outer) tectum, which is very thin and densely perforated.

A2 Columellae straight, not branched.

B2 Diameter of echinae and columellae equal. Echinae few, scattered. Lonicera.

- C2 Sexine about as thick as nexine, columellae in surface view rather indistinct. Grain usually smaller than 60 μm *L. xylosteum* t.
CAPRIFOLIACEAE

- C1 Sexine much thicker than nexine, columellae in surface view distinct. Grain usually larger than 60 μm .

- D2 Echinae up to 2.5 μm . Ends of ectocolpi usually obtuse *L. alpigena*
CAPRIFOLIACEAE

- D1 Echinae up to 1.5 μm . Ends of ectocolpi usually acute *L. periclymenum* t.
CAPRIFOLIACEAE

- B1 Echinae much coarser than columellae, conical, broad at base. Short colpi, prominent endopores *Abutilon* t.
MALVACEAE

A1 Columellae branched, echinae conical from base. Asteroideae.

- E2 Columellae indistinct in optical section *Solidago* t.
COMPOSITAE

- E1 Columellae prominent in optical section.

- F2 Echinae at least partly joined by low ridges.

- G2 Echinae joined by smooth low ridges which form a coarse reticulum
Picnomon acarna
COMPOSITAE

- G1 Echinae large, partly confluent at bases. Inner columella layer variable, thicker under echinae *Centaurea amplifolia*
COMPOSITAE

- F1 Echinae discrete, not joined by ridges.

- H2 Inner columella layer equal to or thicker than the outer.

- I3 Echinae vestigial.

- J2 Grains large, prolate with *longitudinal thickenings of intercolpia* (intersemiangular) *Echinops*
COMPOSITAE
- J1 Grains small, spherical to oblate *Artemisia*
COMPOSITAE
- I2 *Echinae blunt*, length equal to or smaller than basal diameter. Prolate.
Carlina t.
COMPOSITAE
- I1 *Echinae long, sharp*. Intercolpium in optical section distinctly crescentic. ...
Achillea t.
COMPOSITAE
- H1 *Inner columellae layer thinner than outer*.
- K2 *Echinae vestigial* *Centaurea graeca* t.
COMPOSITAE
- K1 *Echinae distinct*.
- L2 Grains c. 30 µm or smaller. Spherical. Colpi short. *Echinae short* (1-2 µm). Cf. also Key E7.3 *Xanthium*
COMPOSITAE
- L1 Grains larger. Colpi long.
- M3 Prolate. Spines short *Centaurea solstitialis* t.
COMPOSITAE
- M2 Spheroidal to subprolate. *Numerous warts between spines*. Size 40-62 µm *Crupina*
COMPOSITAE
- M1 Oblate. Spines long. Incl. *Carduus* *Cirsium* t.
COMPOSITAE

Key E11.3. Tricolporate. Striate-rugulate

- A2 Operculate. See Special key **Rosaceae**
ROSACEAE
- A1 No operculum.
- B2 *Endoaperture a transversal colpus. Costae transversales present*. Anacardiaceae.
- C2 Colpus long, transverse colpus well defined.
- D2 Nexine and sexine of equal thickness *Schinus molle*
ANACARDIACEAE
- D1 Nexine markedly thinner than sexine *Rhus coriaria*
ANACARDIACEAE
- C1 Colpus shorter, transverse colpus not so well defined, sometimes poroid. Nexine thinner than sexine *Cotinus coggygria*
ANACARDIACEAE
- B1 *Endoaperture not distinctly transversal. No costae transversales*.
- E3 Finely verrucate. *Colpus very short*, about twice the diameter of the pore
Ludwigia palustris
ONAGRACEAE
- E2 Rugulate.

- F2 Colpus short. Distinctly rugulate *Datura stramonium*
SOLANACEAE
- F1 Colpus long. *Finely* rugulate-perforate *Vitex agnus-castus*
VERBENACEAE
- E1 Striate-rugulate. Colpus much longer than the diameter of the pore.
 - G2 Pore indistinct.
 - H2 Edge of colpus undulating. See Special key Rosaceae
ROSACEAE
 - H1 Edge of colpus straight.
 - I2 Striae very distinct. Columellae fine.
 - J2 Costae colpi distinct. Strio-reticulate *Ailanthus altissima*
SIMAROUBACEAE
 - J1 Costae colpi absent or very thin *Saxifraga oppositifolia* t.
SAXIFRAGACEAE
 - I1 Striae indistinct *Saxifraga tridactylites* t.
SAXIFRAGACEAE
 - G1 Pore distinct
 - K2 Grain 25 µm or larger.
 - L2 Polar area pointed. Pore covered. Striae fine *Helianthemum*
CISTACEAE
 - L1 Polar area rounded. Pore not or only partly covered.
 - M2 *All or almost all striae meridional.*
 - N2 Grain c. 40 µm. Endoaperture colpoid.
 - O2 Fastigium large and distinct. Striate in mesocolpium, reticulate or microreticulate at poles *Atropa* t.
SOLANACEAE
 - O1 No fastigium. Faint striae throughout, or ±reticulate in mesocolpium and tectate at poles *Nicotiana*
SOLANACEAE
 - N1 Grain less than 40 µm. Endoaperture poroid.
 - P2 Poles pointed. Endoaperture margins smooth, or with a few coarse granules. P/E >1 *Gentiana lutea* t.
GENTIANACEAE
 - P1 Poles rounded/flattened. Endoaperture margins coarsely granular. P/E usually <1 *Centaurium*
GENTIANACEAE
 - M1 Some striae not meridional.
 - Q2 *Intercolpium median with predominantly meridional striae.*
 - R2 Striae run together at pores and poles to form a reticulum .
Tuberaria guttata
CISTACEAE

- R1 Striae mostly meridional in mesocolpia, sometimes abruptly changing direction, sometimes transverse next to colpi . . .
Centaurium
 GENTIANACEAE
- Q1 Intercolpium median rugulate.
- S3 Grain 47-56 μm . Intercolpium edges meridionally striated. Vestibulae present *Haplophyllum*
 RUTACEAE
- S2 Grain < 30 μm . Intercolpium edges meridionally striated. No vestibulae. *Blackstonia perfoliata*
 GENTIANACEAE
- S1 Grain < 30 μm . Intercolpium edges with groups of non-meridional striae.
- T2 Grain 19-26 μm . Faint costae colpi; H-endoaperture . .
Cicendia filiformis
 GENTIANACEAE
- T1 Grain 22-32 μm . Distinct costae colpi; endoaperture lalongate, not H-shaped *Ruta chalepensis*
 RUTACEAE
- K1 Grain smaller than 25 μm .
- U2 Colpus with coarse echinae *Aesculus hippocastanum*
 HIPPOCASTANACEAE
- U1 Colpus membrane without sculptural elements.
- V2 Sculpturing of intercolpium indistinct.
- W2 Grain prolate, rectangular in equatorial view. Exine c. 1.5 μm .
- X2 Rugulate pattern over all of grain. Each elliptic or 8-shaped endoaperture commonly with "horns" into mesocolpia . . .
Coronilla scorpioides t.
 LEGUMINOSAE
- X1 Rugulate pattern may disintegrate into small reticulations. Each elliptic or 8-shaped endoaperture without "horns" . .
Hippocrepis
 LEGUMINOSAE
- W1 Grain prolate, oval in equatorial view.
- Y2 Exine 3-5 μm , thins towards colpi. Intercolpium edges with groups of non-meridional striae *Cicendia filiformis*
 GENTIANACEAE
- Y1 Exine thinner, even thickness. Striae very indistinct (phase contrast) *Crassula*
 CRASSULACEAE
- V1 Sculpturing of intercolpium uniform, distinct.
- Z2 Columellae distinctly visible *Sempervivum*
 CRASSULACEAE
- Z1 Columellae indistinct-imperceptible.
- A'2 Endoapertures H-shaped *Sedum*
 CRASSULACEAE

A'1 Endoapertures circular or oval *Androsace maxima*
PRIMULACEAE

Key E11.4. Tricolporate. Suprareticulate-foveolate

A2 Heteropolar. Pores near the broad end *Echium*
BORAGINACEAE

A1 Isopolar.

B3 Grain peroblate. Foveolate. Colpi very short. Costae colpi heavy. Exine more than 3 µm thick. *Tilia*.

C2 4-6 brochi/10 µm *Tilia platyphyllos*
TILIACEAE

C1 8-11 brochi/10 µm *Tilia cordata* t.
TILIACEAE

B2 Grain oblate, triangular. Exine 4 µm. Colpi short, endopores large.

D2 Finely rugulate/foveolate. Lumina with granules *Phaseolus*
LEGUMINOSAE

D1 Regular reticulum, brochi 4-7 µm. Incl. *Vigna* *Psoralea* t.
LEGUMINOSAE

B1 Grain not peroblate. Colpus not very short.

E2 Grain prolate. Exine more than 2 µm thick. Columellae very coarse.

F2 Grain oval. Columellae uniform.

G2 Costae colpi thick; *margo of thin sexine along colpi*. Grain subprolate, pores often protruding. Exine c. 3 µm, with densely packed columellae; foveolate to reticulate *Euphorbia*
EUPHORBIACEAE

G1 Costae colpi absent, colpi long; endoaperture slightly lalongate. Grain subprolate to spheroidal, 60 µm; circular in polar view. Exine c. 3 µm, with well-spaced columellae; microrugulate to reticulate *Lagenaria siceraria*
CUCURBITACEAE

F1 Grain compressed oval. Columellae coarser and more scattered at poles.

H2 Channels between columellae at apocolpium ± regular in width, narrow, no wider than columella diameter; branched columellae extending no more than 1/2 way down grain from poles *Polygonum viviparum*
POLYGONACEAE

H1 Channels between columellae at apocolpium irregular in width, often broader than columella diameter; branched columellae often extending from poles almost to equator *Polygonum bistorta* t.
POLYGONACEAE

E1 Grains variable. Exine less than 2 µm thick. Columellae fine or indistinct.

I2 Equatorial limb subangular. Grain oblate. Polar area very small. Costae transversales and pores distinct *Rhamnus* t.
RHAMNACEAE

I1 Equatorial limb circular or semiangular. Grain subspherical or prolate. Polar area medium to large. Mainly Leguminosae.

J3 Reticulum indistinct.

K2 Grain prolate. Pore distinct. Costae colpi present.

L2 Endoaperture lalongate, 8-shaped, covered by a thin, structureless exine. Costae colpi well developed *Vicia cracca* t.
LEGUMINOSAE

L1 Endoaperture $\pm$ circular, not covered *Punica granatum*
PUNICACEAE

K1 Grain subspherical. Pore covered, more or less distinct.

M3 Grain more than 35 μ m. Pore indistinct. Exine thin. Colpus with costae and equatorial bridge *Medicago sativa*
LEGUMINOSAE

M2 Grain more than 30 μ m. Exine thin *Astragalus*
LEGUMINOSAE

M1 Grain < 35 μ m. Exine thick

N2 Grain 30-35 μ m, compressed oval in equatorial view. Endoaperture lalongate *Trifolium montanum* t.
LEGUMINOSAE

N1 Grain < 30 μ m, rhomboidal in equatorial view. Colpus with equatorial bridge. Endoaperture a colpus *Solanum melongena*
SOLANACEAE

J2 Reticulum distinct, some lumina blocked.

O2 Polar area large *Coronilla emerus*
LEGUMINOSAE

O1 Polar area medium *Astragalus*
LEGUMINOSAE

J1 Reticulum distinct. No lumina blocked.

P2 More than 13-15 equatorial brochi per intercolpium.

Q2 Lumina with free columellae *Astragalus*
LEGUMINOSAE

Q1 No free columellae in lumina.

R2 Grain more than 27 μ m *Ononis* t.
LEGUMINOSAE

R1 Grain smaller than 27 μ m *Galega officinalis*
LEGUMINOSAE

P1 Less than 13-15 equatorial brochi per intercolpium.

S2 Meridional limb compressed oval. Colpus with heavy costae. Pore distinct, covered by a thin, almost structureless sexine.

T2 Grain subspheroidal. Lumina with perforations. Breadth of muri less than diameter of lumina *Lathyrus sativus*
LEGUMINOSAE

T1 Grain prolate.

U2 Grain more than 50 μ m.

- V2 With distinct perforations in lumina ... *Pisum sativum*
LEGUMINOSAE
- V1 No perforations in lumina *Vicia faba*
LEGUMINOSAE
- U1 Grain smaller than 50 µm.
- W2 Lumina with distinct perforations *Lathyrus pratensis* t.
LEGUMINOSAE
- W1 No perforations in lumina
- X2 Ectocolpi usually $\frac{3}{4}$ length of polar axis
Vicia sativa t.
LEGUMINOSAE
- X1 Ectocolpi rather short (c. 25 µm) *Lens*
LEGUMINOSAE
- S1 Meridional limb *circular* or more or less *rhomboidal*. Costae colpi
variable. Pore covered by sexine with distinct structure. *Trifolium*.
- Y2 Grain more than 40 µm *T. repens* t.
LEGUMINOSAE
- Y1 Grain smaller than 40 µm *T. dubium* t.
LEGUMINOSAE

Key E11.5. Tricolporate. Per-reticulate - frustillate

A3 Reticulum indistinct or frustillate-perforate.

- B3 Incomplete reticulum, composed of irregular muri *Cistus monspeliensis* t.
CISTACEAE
- B2 Columellae united only by their topmost parts. Colpus with equatorial bridge. *Mercurialis*.
- C2 Exine more than 2 µm thick. Columellae grouped/irregularly distributed. Colpus
membrane not with a row of granules *Mercurialis perennis*
EUPHORBIACEAE
- C1 Exine less than 1.5 µm thick. Columellae evenly distributed. Colpus operculum formed
by a (single) row of granules *Mercurialis annua* t.
EUPHORBIACEAE
- B1 Irregularly reticulate-frustillate-perforate, *lumina larger in the polar area*. Colpus narrow,
slightly wider at both ends. Pore small, covered. Distinctive hexagonal outline in polar view
.....
Vitis vinifera
VITACEAE
- A2 Reticulate-striate. Columellae coarse, isolated at bottom, forming reticulum at middle level and
striations at top; dupli- or simplicolumellate muri *Gentiana verna*
GENTIANACEAE
- A1 Reticulate.
- D2 Brochi more than 1 µm.
- E2 Sexine thick, usually more than 2 µm. Columellae coarse, distinct.

- F2 Muri distinctly *duplicolumellate*. Reticulum irregular; brochi smaller towards colpus. Muri beaded, breadth equal to or less than diameter of lumina. With transverse colpus *Hedera helix*
ARALIACEAE
- F1 Muri usually *simplicolumellate*.
- G3 Lumina with distinct free columellae, those in muri crowded. Transverse colpus short.
- H2 Reticulum very coarse except in the polar area. Equatorial limb subtriangular *Sambucus ebulus*
CAPRIFOLIACEAE
- H1 Reticulum in polar area not different, but finer in narrow margo to ectocolpus. Equatorial limb tricuspid. Sometimes 2- or 4-colporate
Viburnum
CAPRIFOLIACEAE
- G2 No free columellae in lumina. Endoaperture a transverse colpus
Ligustrum vulgare
OLEACEAE
- G1 No free columellae in lumina. Those in muri clearly separated. Endoaperture poroid.
- I2 Grain more than 40 μm .
- J2 Endoaperture circular, indistinct *Jasminum*
OLEACEAE
- J1 Endoaperture circular, distinct.
- K2 Muri spinose *Cistus salvifolius*
CISTACEAE
- K1 Muri not spinose. Exine thicker at apocolpium; sexine > nexine
Gentiana verna
GENTIANACEAE
- I1 Grain less than 40 μm , spheroidal to oblate.
- L2 H-endoaperture. Exine of even thickness; sexine $\pm$ as thick as nexine
Gentianella ciliata
GENTIANACEAE
- L1 Lolate endoaperture, 6 μm . Exine thins towards colpi
Euonymus europaeus t.
CELASTRACEAE
- E1 Exine thin, usually less than 2 μm .
- M2 Columellae distinct, coarse.
- N2 Lumina 1.5-2 μm *Salix triandra*
SALICACEAE
- N1 Lumina 2-3 μm *Salix fragilis* t.
SALICACEAE
- M1 Columellae fine or indistinct.
- O2 Equatorial limb subangular.

- P2 Grain > 30 µm, prolate, polar area pointed. Lumina c. 1.5 µm, meridionally elongated in apocolpia *Dictamnus albus*
RUTACEAE
- P1 Grain 18-22 µm, prolate. Lumina irregular in size, c. 1 µm. Endoaperture indistinct *Sambucus nigra*
CAPRIFOLIACEAE
- O1 Equatorial limb *circular*.
- Q2 Greatest diameter of grain > 20 µm. Transverse colpus/pore distinct.
- R2 Costae equatoriales; "horns" on endoaperture *Anagallis arvensis* t.
PRIMULACEAE
- R1 Not so.
- S2 Distinctly *duplicolumellate* *Lysimachia*
PRIMULACEAE
- S1 *Simplicolumellate* or columellae indistinct.
- T2 Muri broad. With transverse colpus.
- U2 Columellae indiscernible. Margo heavy .. *Lysimachia*
PRIMULACEAE
- U1 Columellae distinct. Margo thin .. *Anagallis tenella* t.
PRIMULACEAE
- T1 Muri narrow. Endoaperture poroid or indistinct.
- V3 Grain large, P = 45-73 µm, prolate, equatorial outline subangular. Brochi c. 1.5-2 µm, decreasing in size towards colpi. Endoaperture a pore *Bryonia*
CUCURBITACEAE
- V2 P < 40 µm, prolate, equatorial outline variable, commonly interlobate. Brochi c. 1 µm. Colpus equat. constricted, endoaperture indistinct .. *Scrophularia* t.
SCROPHULARIACEAE
- V1 P = 19-25 µm, equatorial and polar outlines circular. Lumina 1.5-3.5 µm, smaller towards poles and colpi. Endoaperture a pore *Parnassia palustris*
PARNASSIACEAE
- Q1 Grain smaller, P < 20 µm.
- W2 Endopore indistinct. Lumina not decreasing towards colpi *Phillyrea*
OLEACEAE
- W1 Endoaperture lalongate colpus, usually tapering, sometimes with small horns; margins sharp; costae ± distinct. Lumina decreasing in size towards colpi and apocolpia *Anagallis tenella* t.
PRIMULACEAE
- D1 Micro-reticulate; brochi less than 1 µm.
- X2 Costae aequatoriales; "horns" on endoaperture. Grain 20-25 µm *Anagallis arvensis* t.
PRIMULACEAE
- X1 No costae aequatoriales.
- Y2 Colpus slit-shaped
- Z2 Endoaperture a transverse colpus.

- A'4 Grain large: P = 40 μ m, E = 25 μ m. Endoaperture distinct, with abruptly pointed ends *Andrachne telephioides*
EUPHORBIACEAE
- A'3 P = 14-17 μ m, E = 13-16 μ m. Endoaperture distinct, with tapering ends
Asterolinon linum-stellatum
PRIMULACEAE
- A'2 P = 23-28 μ m, E = 22-28 μ m. Endoaperture distinct, with blunt ends . .
Ricinus communis
EUPHORBIACEAE
- A'1 P = 17-22 μ m, E = 15-20 μ m. Endoaperture indistinct . *Ruta montana* t.
RUTACEAE
- Z1 Endoaperture poroid.
- B'2 P = 18-22 μ m, E = 18-22 μ m. Endopore indistinct, without costae
Fraxinus ornus
OLEACEAE
- B'1 Various sizes. Endopore covered, with distinct costae. Refer E11.1; See key to species and groups in NW5. Incl. *Oxyria digyna* *Rumex* t.
POLYGONACEAE
- Y1 Colpus not slit-shaped.
- C'2 Exine 2 μ m or thicker. Transverse endocolpus prominent, oblong. Ectocolpus sunken. P = 13-28 μ m *Peganum harmala*
ZYGOPHYLLACEAE
- C'1 Exine thinner than 2 μ m.
- D'3 Endoaperture $\pm$ circular.
- E'3 Muri supra-microechinate *Fumana*
CISTACEAE
- E'2 Muri not microechinate. Prolate. Colpus equatorially constricted. Very similar - refer to reference slides.
- F'4 P = 15-23 μ m, E = 10-21 μ m *Elatine alsinastrum*
ELATINACEAE
- F'3 P = 26 μ m, E = 18 μ m *Cercis siliquastrum*
LEGUMINOSAE
- F'2 P < 40 μ m *Scrophularia* t.
SCROPHULARIACEAE
- F'1 P = 15-23 μ m, E = 11-15 μ m *Hypericum perforatum* t.
GUTTIFERAE
- E'1 Muri not microechinate. Colpus fusiform, not constricted, with smooth membrane. P = 20-25 μ m, subprolate, equatorial outline circular ...
Kickxia
SCROPHULARIACEAE
- D'2 Endoaperture lalongate
- G'2 Endoaperture 11-16 μ m broad, with short costae near colpus. P = 28-41 μ m *Hyoscyamus niger*
SOLANACEAE
- G'1 Endoaperture 7-10 μ m broad, without costae. P = 21-24 μ m
Hypericum hircinum t.
GUTTIFERAE
- D'1 Endoaperture area with 2-6 small, $\pm$ distinct, lalongate narrow endocolpi. Saxifragaceae p.p.

- H'2 P > 16.5 µm, E > 14 µm *Saxifraga stellaris*
SAXIFRAGACEAE
- H'1 P < 16.5 µm, E < 14 µm *Chrysosplenium alternifolium*
SAXIFRAGACEAE

Key E11.6. Tricolporate. Intectate-clavate.

Ilex aquifolium is the only taxon properly keying out here, although *Linum* spp. may be considered to have a lolongate endoaperture paralleling the smaller ectoaperture - see Key E7.7 (Tricolporate, clavate).

Key E12. Stephanocolporate

All grains are psilate-scabrate except where otherwise indicated. The transverse colpus in Boraginaceae is blunt-ended, pore-like. The number of colpi varies individually; numbers indicated represent averages.

A2 More than 4 colpi. Cf. also Key E19.

B2 Grain larger than 20 µm.

C2 Endoapertures colpoid.

D2 (Endo-)colpus aequatorialis present. No costae aequatoriales

E2 More than 10 colpi. Grain barrel-like (depressed oval) with an equatorial ridge.

F2 Polar area with several isodiametric lacunae. *Polygala*.

G2 7 lacunae in apocolpium (2-5 µm) *Polygala monspeliaca* t.
POLYGALACEAE

G1 15 lacunae in apocolpium (4-7 µm) *Polygala vulgaris* t.
POLYGALACEAE

F1 Polar area coarsely vermiculate, no round lacunae *Utricularia*
LENTIBULARIACEAE

E1 9-10 colpi. Grain spherical. No equatorial ridge *Borago officinalis*
BORAGINACEAE

D1 Endocolpi distinctly separate.

H2 7-11 meridional colpi. Grain compressed-oval, P = 23-32 µm . *Symphytum*
BORAGINACEAE

H1 Mostly 7 meridional colpi. Grain bone-shaped, P = 14-25 µm
Cerinth t.
BORAGINACEAE

C1 Endoapertures poroid or obscure.

I2 6-7 colpi.

J2 Microreticulate. Grain spherical *Pinguicula*
LENTIBULARIACEAE

J1 Psilate to striate. Grain prolate. Tricolporate with broad colpal operculi, thus appearing 6-colporate *Sanguisorba officinalis*
ROSACEAE

I1 5 colpi (more commonly 4).

- K2 Grain more than 40 μm , subprolate, angulaperturate. Tectate, superficially scabrate except in polar area which has an intectate field of coarse columellae
Viola arvensis t.
 VIOLACEAE
- K1 Grain 30-40 μm , spheroidal, circular in polar view. Reticulate *Citrus*
 RUTACEAE
- B1 Grain smaller than 20 μm .
- L2 Grain bone-shaped. Meridional colpi very short, hardly discernible. Protruding poroid area with free granules ~ operculum.
- M2 Colpi 4-6. P = 14-17 μm *Buglossoides arvensis* t.
 BORAGINACEAE
- M1 Colpi 7. P = 14-25 μm *Cerithe* t.
 BORAGINACEAE
- L1 Grain compressed oval, P = 18-21 μm . Meridional colpi distinct, 7-8
Neatostema apulum
 BORAGINACEAE
- A1 Four colpi.
- N2 Grain larger than 40 μm .
- O2 Transverse colpus distinct.
- P2 Grain prolate, oval in equatorial view. Psilate *Anchusa arvensis* t.
 BORAGINACEAE
- P1 Grain oblate. Echinulate. See key to species in Key E11.2 *Lonicera*
 CAPRIFOLIACEAE
- O1 No transverse colpus. *Viola*.
- Q2 Grain depressed oval (barrel-shaped) to polyedric. Polar area with an intectate field of coarse columellae *Viola arvensis* t.
 VIOLACEAE
- Q1 Grain oval. Exine structure uniform *Viola riviniana* t.
 VIOLACEAE
- N1 Grain smaller than 40 μm .
- R3 Grain elliptic or circular in equatorial view.
- S2 H-endoaperture. Reticulum striate near colpus *Blackstonia perfoliata*
 GENTIANACEAE
- S1 Endoaperture indistinct in surface view. Finely reticulate.
- T2 Colpi slightly sunken in polar view. P = 15-25 μm . (Usually tricolporate) ...
Phillyrea
 OLEACEAE
- T1 Colpi not sunken. P = 23-29 μm *Ceratonis siliqua*
 LEGUMINOSAE
- R2 Grain compressed oval. Equatorial exine reticulate. Transverse colpus present.
- U2 Exine thinner in polar area. Equatorial reticulum coarse *Nonea*
 BORAGINACEAE
- U1 Exine thickness uniform. Grain more than 20 μm

- V2 Meridional colpi with *margo of coarse columellae* *Pulmonaria mollis*
BORAGINACEAE
- V1 Meridional colpi not with coarse columellae.
- W2 Colpi short. Equator constricted. Psilate to punctate
Anchusa officinalis t.
BORAGINACEAE
- W1 Colpi long. Equator not constricted. Reticulate *Citrus*
RUTACEAE
- R1 Grain constricted oval. No transverse colpi. Pores (but not constriction) nearer one pole.
- X2 Poles normally of equal width. Grain > 13 µm . . . *Buglossoides purpureocaerulea*
BORAGINACEAE
- X1 One pole usually considerably wider than the other. Grain < 13 µm
Lithospermum
BORAGINACEAE

Key E13. Pericolporate

Tri- or stephanocolporate grains sometimes appear with more apertures than normal, and are then usually imperfectly isometric. The most important cases are those set out below.

A2 Echinate.

- B2 Apertures arranged in spirals *Gossypium*
MALVACEAE
- B1 Apertures not arranged in spirals. Cf. Key E11.2 *Compositae Asteroideae*
COMPOSITAE

A1 Psilate or reticulate.

- C2 Psilate. Costae aequatoriales present. See Key E11.1 *Polygonum aviculare* t.
POLYGONACEAE
- C1 Psilate with perforations and/or reticulate. Colpus slit-shaped. Pore covered. No costae aequatoriales. Cf. Key E11.1. See key to species and groups in NW5. Incl. *Oxyria digyna*
..... *Rumex* t.
POLYGONACEAE

Key E14. Diporate

A2 Grains elongate with pores near ends

- B2 Scabrate (usually in planar tetrads) *Cytinus ruber*
RAFFLESACEAE
- B1 Reticulate
- C2 Reticulate, muri much narrower than lumina. Pore 10 µm, edges ragged. P = 30-32 µm,
E = c. 60-85 µm *Colchicum*
LILIACEAE
- C1 Perforate to microreticulate, muri ± as wide as lumina. Pore 5 µm, not with ragged edges.
P = 17-24 µm, E = c. 30-45 µm. *Merendera sobolifera*
LILIACEAE

A1 Grains subspheroidal, $\pm$ radially symmetrical

Pollen grains of *Ficus* fit here, but given its highly specialized pollination mechanism it is unlikely that pollen would ever be found in sediments except in exceptional circumstances. The pollen grain is psilate and very small (P = 10 μ m, E = 16 μ m).

D2 Pori distinctly protruding in optical section, annuli broad and distinct . . . *Humulus lupulus*
CANNABACEAE

D1 Pori not or only slightly protruding, annuli narrow or absent

E2 Pori slightly or not protruding, circular in outline, small (diameter 1-2.5 μ m). Grains
small (E = 13-20 μ m) *Urtica dioica*
URTICACEAE

E1 Pori not protruding, usually irregularly elliptic, rather large (diameter 2.5-5 μ m). Grains
larger (E = 18-37 μ m) *Morus alba*
MORACEAE

Key E15. Triporate

A2 With large, cylindrical vestibulum, more than 10 μ m deep. Onagraceae.

B2 Grain 50 μ m or larger *Epilobium angustifolium* t.
ONAGRACEAE

B1 Grain smaller than 50 μ m *Circaea lutetiana*
ONAGRACEAE

A1 Vestibulum smaller, conical, or absent.

C3 Reticulate. Grains large, > 50 μ m.

D2 Pores annulate, not ragged *Cucumis melo*
CUCURBITACEAE

D1 Pore margins ragged (usually diporate) *Colchicum*
LILIACEAE

C2 Distinctly echinate.

E2 Grain more than 50 μ m. Exine thick, more than 4 μ m. Echinae dimorphic, of two size
classes. Dipsacaceae.

F2 Pore with thickened anulus surrounded by halo of thinner exine. Echinae short,
broad-based, scattered.

G2 Exine $\pm$ even thickness.

H2 Microechinae between echinae not distinct. Halo broad. Grain spheroidal
. *Dipsacus* t.
DIPSACACEAE

H1 Microechinae distinct. Halo narrow. Grain oblate . . . *Scabiosa sicula* t.
DIPSACACEAE

G1 Exine much thicker at poles than at equator, often partially detached, forming
sacci *Pterocephalus* t.
DIPSACACEAE

- F1 Anulus indistinct, no halo. Echinae *slender*, crowded; microechinae distinct . . .
Knautia
DIPSACACEAE
- E1 Grain smaller. Echinae uniform, scattered. Campanulaceae.
- H2 Echinae $\geq 1 \mu\text{m}$. Grain $> 25 \mu\text{m}$.
- I2 Echinae c. $1 \mu\text{m}$. Pore annuli $3.5\text{--}4 \mu\text{m}$ *Campanula rotundifolia*
CAMPANULACEAE
- I1 Echinae coarser, longer. Pore annuli thicker. Usually 4-porate . . . *Phyteuma*
CAMPANULACEAE
- H1 Echinae $< 1 \mu\text{m}$.
- J2 Tectum rugulate-perforate. Grain $> 25 \mu\text{m}$ *Campanula erinus* t.
CAMPANULACEAE
- J1 Tectum psilate-perforate. Grain $< 25 \mu\text{m}$ *Jasione*
CAMPANULACEAE
- C1 Psilate-scabrate.
- K2 Equatorial limb almost circular, without protruding pore edges.
- L2 Scabrate; micro-sculpturing faintly rugulate with minute echinae.
- M2 Columellae not visible, even at high magnification; exine $1\text{--}2 \mu\text{m}$. *Morus*
- N2 E = $19\text{--}25 \mu\text{m}$. Outline in polar view circular. (Usually diporate, elliptical)
. *Morus alba*
MORACEAE
- N1 E = $26\text{--}37 \mu\text{m}$. Outline in polar view often $\pm$ angular. Pores not always
equidistant, 3-4 *Morus nigra*
MORACEAE
- M1 Columellae very distinct, scattered; exine c. $2 \mu\text{m}$. Grain more than $20 \mu\text{m}$. .
Celtis
ULMACEAE
- L1 Psilate, columellae delicate.
- O2 Exine very thin, but thickened around pores, with minute projections; pore
margins a little protruding.
- P2 Spinules scattered. 2-5 pores, usually 3-4 *Urtica dioica*
URTICACEAE
- P1 Spinules closer together, more regularly distributed. (*Urtica urens* has 3-4
pores, *Pilea microphylla* 2-3) *Urtica urens* t.
URTICACEAE
- O1 Exine slightly thicker, but not thickened around pores; pore margins not
protruding. Projections slightly coarser. 3-4 pores *Parietaria*
URTICACEAE
- K1 Equatorial limb semiangular, or with protruding pore edges.
- Q3 Psilate. Grain square in equatorial view *Vicia lathyroides*
LEGUMINOSAE
- Q2 Scabrate, $\pm$ verrucose or granular

- R2 Grain very large, prolate, polar axis c. 205 μm . Pores, trumpet-shaped with thickened edges, protrude from circular equatorial outline. Subtecta sexine "spongy", not columellate *Morina persica*
DIPSACACEAE
- R1 Grains 20-40 μm , spheroidal to oblate.
- S2 Pores not protruding, annuli narrow. Outline in polar view often $\pm$ angular (pores not always equidistant) *Morus nigra*
MORACEAE
- S1 Pores protruding, annuli broad. Incl. *Cannabis sativa* and *Humulus lupulus*, which may be distinguished on subtle characters of pore morphology, see NW4 *Humulus t.*
CANNABACEAE
- Q1 Micro-sculpturing and structure *more or less rugulate*, with scattered minute spinules on top of low vallae (phase!). Betulaceae.
- T2 Equatorial limb circular with protruding pores. Nexine and tectum diverge in the pores, forming a vestibulum.
- U2 Vestibulum distinct. Tectum sharply thickened at the pore.
Betula pendula
BETULACEAE
- U1 Vestibulum not distinct. Tectum not appreciably thickened at the pore. Incl. some grains of *Carpinus*, which is usually 4-porate *Ostrya t.*
CORYLACEAE
- T1 Equatorial limb semiangular, pore not protruding. Nexine and tectum do not diverge in the pore. Depth of pore not much greater than thickness of the regular exine *Corylus*
CORYLACEAE

Key E16. Stephanoporate

- A4 Echinate. Echinae distinct, regularly distributed. Campanulaceae. See Key E15: E1. Species of *Phyteuma*, *Asyneuma*, and *Legousia* are usually 4-porate, but occasional grains of some *Campanula* spp. are also stephanoporate.
- B1 Echinae < 1 μm . Incl. *Legousia hybrida* *Asyneuma t.*
CAMPANULACEAE
- B2 Echinae > 1 μm *Phyteuma*
CAMPANULACEAE
- A3 Finely micro-suprareticulate and microechinate; exine 2.5 μm with distinct columellae. 4-8 pores without annuli. P = 23-26 μm *Theligonum cynocrambe*
THELIGONACEAE
- A2 Coarsely and softly rugulate or suprareticulate. Peroblate. 4-7 pores. *Ulmus*.
- C3 Rugulate sculpture on both poles. Angular outline. 5-7 pores, mostly 6 *U. procera*
ULMACEAE
- C2 Rugulate sculpture reduced on proximal pole. Angular outline. 4-6 pores, mostly 4-5
U. glabra t.
ULMACEAE
- C1 Rugulate sculpture reduced on proximal pole. Rounded outline, well-developed annuli lacking. 4-6 pores, mostly 5 *U. minor type*
ULMACEAE
- A1 Psilate, scabrate or very delicately rugulate.

D2 Grain globular. Equatorial limb circular. Pores not distinctly protruding

E2 Rugulate, spinulose. 3-6 pores *Celtis*
ULMACEAE

E1 Psilate. Columellae delicate.

F3 Pores with large cylindrical vestibulum ($>10\text{ }\mu\text{m}$ deep). Grain more than $50\text{ }\mu\text{m}$
Epilobium angustifolium t.
ONAGRACEAE

F2 Pores annulate, protruding; no vestibulum, Mostly 3-porate, cf. Key E15
Humulus t.
CANNABACEAE

F1 Pores annulate, but not protruding or vestibulate.

G2 Exine very thin, structure very delicate. See Key E15: N2 for distinction of
species which are occasionally stephanoporate *Urtica*
URTICACEAE

G1 Exine thicker, structure coarser.

H2 Pores 3 or 4 *Parietaria*
URTICACEAE

H1 Pores 6-12 *Urtica pilulifera* t.
URTICACEAE

D1 Grain oblate. Equatorial limb more or less angular and/or pore edges protruding.

I2 Neighbouring pores (annuli) connected with thickened bands (arci). Pore with thick
anulus. 4-6 pores *Alnus glutinosa*
BETULACEAE

I1 No arci.

J1 4-6 "pores" meridionally elongated with endexinous annuli. *Myriophyllum*.

K2 Anulus distinct, protruding. Pores circular or elliptic *M. spicatum*
HALORAGACEAE

K1 Anulus externally flat, not protruding. Pores colpoid *M. verticillatum*
HALORAGACEAE

J1 Exine thickness uniform. Pores circular, without endexinous annuli.

L2 Equatorial limb angular (square) *Vicia lathyroides*
LEGUMINOSAE

L1 Equatorial limb more or less circular.

M2 Grain more than $40\text{ }\mu\text{m}$. Microsculpturing faintly rugulate with minute
spinules on vallae. Incl. some grains of *Ostrya* *Carpinus* t.
CORYLACEAE

M1 Grain less than $40\text{ }\mu\text{m}$. Microechinate. Pores with narrow annuli, not
always equidistant *Morus nigra*
MORACEAE

Key E17. Periporate: Main key to subsections

- Verrucate or echinate Key E17.1
 Rugulate, striate or reticulate Key E17.2
 Psilate or scabrate Key E17.3

Key E17.1. Periporate. Verrucate or echinate

A2 Verrucate. Special key **Plantaginaceae**

A1 Echinate.

B2 Grains large, > 60 µm

C2 c. 75 pores. Grain c. 80-130 µm. Sexine between echinae composed of crowded baculae. Echinae long (8-11 µm), with *rounded tips, situated at the corners of polygonal ridges formed by longer baculae*, in the centre of each of which are situated the rather indistinct pores. Smaller baculae surround the pores. ***Ipomoea***
CONVOLVULACEAE

C1 Echinae not linked by ridges

D2 Pores 4-12, *large* (diameter 15-26 µm), not spirally arranged, with *operculi*. Grain 90-190 µm. Echinae regularly spaced over whole grain, including over the operculi, which bear a single central echina. Echinae not based on cushions. Numerous microprojections (baculae or microechinae) between echinae. For detailed key to species see Ayala-Nieto *et al.* 1988 ***Cucurbita***
CUCURBITACEAE

D1 Pores 9 to >100, in some species arranged in a spiral, without echinate operculi. Grain > 60 µm. Echinae usually *sharp*, in some species elevated on cushions of thicker exine. See special key **Malvaceae**

B1 Grains < 60 µm

E2 Pores with annuli. Special key **Caryophyllaceae p.p.**

E1 Pores without annuli.

F2 24-28 indistinct pores usually covered by non-operculate membranes with echinae. Grain 44-65 µm. Echinae conical, c. 3 µm long, *irregularly spaced, with broad irregular bases which sometimes coalesce* in groups of 2-3 ***Ranunculus arvensis* t.**
RANUNCULACEAE

F1 Pores 10-15 (diameter 4-6 µm). Grain 26-36 µm. Echinae sharp, about as tall as broad, irregularly distributed but *without broad bases and not coalescent* ***Sagittaria sagittifolia***
ALISMATACEAE

Key E17.2. Periporate. Rugulate, striate or reticulate

A2 Vermiculate-rugulate. Columellae fine. Fewer than 50 pores *Buxus sempervirens*
BUXACEAE

A1 Reticulate.

B2 Pores with annuli. Special key *Caryophyllaceae p.p.*

B1 Annuli absent or indistinct.

C3 *Reticulum* regular, brochi 4-8 µm, *muri simplicolumellate*. Pore in each lumen: 60-75 pores *Tribulus terrestris*
ZYGOPHYLLACEAE

C2 *Reticulum* regular, brochi > 4 µm, *muri duplicolumellate*. Not every lumina with a pore: 12-27 pores. Lumina with pores are smaller than those without
Polygonum persicaria t.
POLYGONACEAE

C1 *Reticulum* imperfect, brochi smaller and not polygonal. Fewer than 50 pores

D2 Pore indistinct, included in a lumen. Lumen with a pore slightly larger than those without. Columellae fused at top into *wedge-shaped elements* in surface view, which are arranged to form a reticulum ("croton" pattern) *Daphne*
THYMELAEACEAE

D1 Pore larger than brochi. Microreticulate. Columellae not fused into wedge-shaped elements *Buxus sempervirens*
BUXACEAE

Key E17.3. Periporate. Psilate-scabrate.

A2 Grain irregular, usually pear-shaped. Pores indistinct. Special key. *Cyperaceae*

A1 Grain regularly ellipsoidic.

B2 Microechinate, dotted.

C2 Columellae fine and evenly distributed, or not visible.

D2 Pores aggregated towards one pole *Juglans regia*
JUGLANDACEAE

D1 Pores ± evenly distributed.

E2 Columellae clear, exine surface undulating. Pores 5-6 *Celtis*
ULMACEAE

E1 Columellae invisible, exine surface smooth. Pores 6-12, usually 7-9
Urtica pilulifera t.
URTICACEAE

C1 Columellae coarse and/or irregularly distributed. Pores evenly distributed.

F2 Anulus distinct. Special key *Caryophyllaceae p.p.*

F1 *Anulus* absent or indistinct.

G2 Surface undulating. Special key *Plantaginaceae*

- G1 Surface even.
- H2 Grain more than 25 μm . Indistinctly intrareticulate.
- I2 Grain sub-polyhedric. *Exine between pores distinctly crescentic*. Pores round.
- J2 Pores with annuli *Alisma*
ALISMATACEAE
- J1 No annuli *Damasonium alisma*
ALISMATACEAE
- I1 Grain (sub-)globular. *Exine not distinctly crescentic*. Pores irregular, indistinct *Papaver argemone t.*
PAPAVERACEAE
- H1 Grain 10-25 μm . No intrareticulum. *Thalictrum*
- K3 Grain > 17 μm . Columellae distinct. Porus margins clearly defined, regular *T. lucidum*
RANUNCULACEAE
- K2 Grain > 17 μm . Columellae distinct. Porus margins poorly defined, irregular *T. minus*
RANUNCULACEAE
- K1 Grain < 17 μm . Columellae usually very indistinct. *T. aquilegifolium*
RANUNCULACEAE
- B1 Not microechinate, dotted.
- L2 *Areas without tectum*, surrounding and connecting pores *Ribes*
GROSSULARIACEAE
- L1 Tectum not reduced.
- M2 Grain large (70-80 μm). *Exine thick* *Calystegia*
CONVOLVULACEAE
- M1 Grain smaller.
- N2 Anulus present.
- O2 Anulus distinct, but often narrow and without structure.
- P2 Tectum without perforations. Number of pores usually higher than 50. Incl. Amaranthaceae and *Sagina* (Caryophyllaceae) *Chenopodiaceae t.*
- P1 Tectum perforate (indistinct in *Sagina*). Pores fewer than 50.
- Q2 6-12 large pores. *Tectum very thick*. *Anulus prominent*. Columellae very fine and short. *Fumaria*.
- R2 Usually 12 pores *F. parviflora*
PAPAVERACEAE
- R1 Usually 6 pores *F. densiflora t.*
PAPAVERACEAE
- Q1 Not so. Special key *Caryophyllaceae p.p.*
- O1 Anulus diffuse. *Columellae widely dispersed in interporia, dense on annuli*. Grain usually polyhedric. Intrareticulate. Alismataceae.

- S2 Grain less than 25 μm *Baldellia ranunculoides*
ALISMATACEAE
- S1 Grain more than 25 μm *Alisma*
ALISMATACEAE
- N1 No annulus.
- T3 Grain 23-42 μm . 4-11 pores. Exine punctate/microreticulate .. *Pistacia*
ANACARDIACEAE
- T2 Grain 10-25 μm . 4-12 pores.
- U2 Grain rounded. Distinct minute echinae. See Key E17.3: H1
Thalictrum
RANUNCULACEAE
- U1 Grain sub-polyhedral. Indistinctly dotted. Incl. *Polycnemum*
(Chenopodiaceae) *Paronychia* t.
CARYOPHYLLACEAE
- T1 Grain c. 10 μm . No echinae. 4 pores *Herniaria* t.
CARYOPHYLLACEAE

Key E18. Syncolpate

Colpi sometimes fuse at one pole also in grains not considered here to be syncolpate.

A3 *Heteropolar*.

B2 Tricolporate with large pores, the three colpi joining *at one pole only*.

C2 *Coarsely reticulate* *Thesium divaricatum* t.
SANTALACEAE

C1 *Psilate to finely verrucate* *Thesium alpinum*
SANTALACEAE

B1 Single encircling colpus, closer to one pole. Microechinate *Smilax*
LILIACEAE

A1 *Isopolar*.

D3 Colpi meridional.

E2 *Two colpi fused to a ring*. Grain usually split, edges of colpus ragged. Cf. *Juniperus*, Key E2.

F2 Grain 17-21 μm . Scabrate (densely microechinate) *Hypecoum*
PAPAVERACEAE

F1 Grain 26-32 μm . Psilate perforate-perfossulate. *Pedicularis*
SCROPHULARIACEAE

E1 More than two colpi.

G2 *Colpi bifurcate*, fused with neighbouring colpi, delimiting a large polar field. Grain larger than 30 μm . Coarsely striated *Nymphoides peltata*
MENYANTHACEAE

G1 *Colpi 3, not bifurcate*.

H4 Grain striate. Tricolporate. Prolate, c. 45 μm *Arachis hypogaea*
LEGUMINOSAE

- H3 Grain scabrate. No endoapertures. Grain subprolate, 18-21 μm . *Soldanella*
PRIMULACEAE
- H2 Grain microverrucate. Grain oblate *Loranthus europaeus*
LORANTHACEAE
- H1 Grain psilate. Oblate, triangular in polar view. Short transverse colpus present
.....
Myrtus communis
MYRTACEAE
- D2 Colpi spirally oriented (various arrangements). Grain spheroidal.
- I3 Grain microechinate, 60-100 μm *Crocus*
LILIACEAE
- I2 Grain with scattered clavae on top of irregularly granulate exine, 110-130 μm
Iris planifolia
IRIDACEAE
- I1 Grain irregularly perforate, 30-50 μm . Exine usually splits *Berberis vulgaris* t.
BERBERIDACEAE
- D1 Peri-syncolpate. Exine divided into angular plates, usually falling apart.
- J3 Exine microechinate, 1.5-3 μm thick, columellae coarse. Colpi 12 or more. Grain
spheroidal, 20-35 μm . See also Key E9 *Montia fontana*
PORTULACACEAE
- J2 Exine psilate, pitted, 1.5 μm thick. Colpi 6 to 16. Grain spheroidal, 30-40 μm
Mahonia aquifolium
BERBERIDACEAE
- J1 Exine psilate, pitted, 2 μm thick. Colpi 6 or 12. Grain spheroidal or a convex
tetrahedron, 40-50 μm *Corydalis ochroleuca*
PAPAVERACEAE

Key E19. Heterocolpate

Grains with three colpi with pores which alternate with three similar without pores.

- A2 Colpi approximately equally long, or aporate colpi longer than porate colpi. Grains flattened at
poles, often dumbbell-shaped (constricted at equator), or compressed oval in equatorial view. Polar
area index large, above 0.5. Boraginaceae. Also see detailed key in NW2.
- B2 Endoapertures join together at equator in a narrow colpus aequatoriales. "Aporate" colpi
longer than those in which the endoapertures are more strongly developed *Cynoglossum* t.
BORAGINACEAE
- B1 Endoapertures discrete, not joined at equator.
- C2 Grain > 30 μm , not constricted at equator *Heliotropium*
BORAGINACEAE
- C1 Grain < 20 μm , constricted at equator.
- D2 Isopolar, endoapertures at equator *Myosotis* t.
BORAGINACEAE
- D1 Heteropolar, 2 endoapertures closer to one pole and 1 closer to the other *Lappula*
BORAGINACEAE
- A1 Aporate colpi distinctly shorter than the porate ones. Polar area smaller. Grain circular to oval in
equatorial view, not flattened at poles, or constricted at equator.
- E2 Exine scabrate-psilate *Vinca herbacea*
APOCYNACEAE

- E1 Non-porate colpi separated from porate colpi by bands of thick, tectate striate exine. *Lythrum*
- F2 Grain asymmetrical, with apertures often arranged irregularly. Non-porate colpi wide areas of intectate, granular exine *Lythrum portula*
LYTHRACEAE
- F1 Grain symmetrical, with apertures clearly zonally arranged. Non-porate colpi do not occupy wide areas, are narrower and shorter than porate colpi ... *Lythrum salicaria* t.
LYTHRACEAE

Key E20. Fenestrate

Grains echinate, lophate (ridged). COMPOSITAE Cichorioideae.

- A1 Ectoapertures pores, surrounded by continuous lophae; paraporal lacunae 2 per mesocolpium; total of 15 lacunae *Scolymus*
- A2 Ectoapertures colpi, broadly rounded to angular and often divided into lacunae by constrictions or short paired ridges.
- B2 Colpi each divided into 2 abporal lacunae by a central constriction or pair of ridges.
- C2 One equatorial lacuna per mesocolpium. Paraporal lacunae absent, interporal lacunae present, total of 15 lacunae *Tragopogon*
- C1 Two equatorial lacunae per mesocolpium. Abporal lacunae extending to an expanded spiny polar area, or to a polar lacuna; total of 18-20 lacunae.
- D2 Polar lacunae absent, extensive echinate polar areas present; total of 18 lacunae .
Scorzonera laciniata t.
- D1 Polar lacunae 1 per pole, large, hexagonal; total of 20 lacunae
Scorzonera hispanica t.
- B1 Colpi each divided into 1 poral and 2 abporal lacunae by 2 pairs of short continuous ridges. Paraporal lacunae 2 per mesocolpium.
- E2 Polar lacunae absent, polar area ranging from a triradiate ridge to an extensive echinate region; total of 15 lacunae (20 in occasional 4-aperturate grains).
- F2 Polar area not more than a triradiate ridge usually with one row of echinae, abporal and paraporal lacunae extending almost to the poles *Lactuca* t.
- F1 Polar area more extensive.
- G2 Grains small, usually $E < 25 \mu\text{m}$ *Hieracium* t.
- G1 Grains larger, $E > 25 \mu\text{m}$.
- H2 Polar area small with 1-(2)-4 isolated central echinae *Cichorium* t.
- H1 Polar area extensive, 4-(5.5)-15 isolated central echinae .. *Taraxacum* t.
- E1 Polar lacunae 3 in each of the extensive polar areas; total of 21 lacunae (28 in occasional 4-aperturate grains) *Sonchus* t.

MALVACEAE

- A3 Tricolporate (Key E11.2) *Abutilon* t.
- A2 Pericolporate (apertures spirally arranged; Key E13) *Gossypium*
- A1 Periporate (apertures spirally or evenly arranged).
 - B2 Supratectal processes all conical echinae
 - C2 Bases of echinae subglobose; porus margins often indistinct *Althaea officinalis*
 - C1 Bases of echinae not subglobose; porus margins distinct
 - D2 <100 pori per grain. Refer to reference material!
 - E3 46-93 pori (3-9 μ m). Echinae c.18 μ m *Hibiscus*
 - E2 60-80 pori (c. 3 μ m). Echinae 4-14 μ m *Malva moschata*
 - E1 78-81 pori (c. 10 μ m). Echinae 22 μ m *Abelmoschus esculentus*
 - D1 >100 pori per grain; distance between pori c. 11 μ m
 - F2 Echinae tapering, forming more than half of the thickness of the exine and frequently curved towards the apex; grains larger than 110 μ m *Althaea hirsuta*
 - F1 Echinae generally straight sided, forming approximately half of the thickness of the exine; grains 60-125 μ m *Malva sylvestris* t.
 - B1 Supratectal processes other than conical echinae present including clavae, verrucae or bluntly rounded echinae
 - G2 Number of pori >200; echinae long, conical, acute, interspersed with smaller rounded clavae; porus diameter 1-2 μ m; sexine-1 and sexine-2 < 1 μ m *Alcea* t.
 - G1 Number of pori <150; echinae either a mixture of conical and blunt, the latter may be almost parallel sided or with rounded verrucae only; porus diameter 2-3 μ m; sexine-1 and sexine-2 > 1 μ m *Malva pusilla*

CARYOPHYLLACEAE (periporate)

(Cf. Chanda 1962; Faegri & Iversen 1992; McNeill & Crompton 1978; Melzheimer 1975; Moore *et al* 1991)

The section *Sperguleae* has colpate grains, cf. Key E7.1.

- A2 Grain c. 10 μ m. 1-8 pores. Incl. *Corrigiola litoralis* p.p. *Herniaria* t.
- A1 Grain larger than 10 μ m.

B2 Grains spheroidal

- C2 Tectum with scattered distinct perforations similar in number to the columellae and spinules, or per-reticulate.
- D2 10-30 pores. Incl. *Arenaria*, *Cerastium*, *Dianthus*, *Lychnis* p.p., *Silene* p.p., *Stellaria* p.p. etc. ***Dianthus* t.**
- D1 Pores 30 or more.
- F3 Grain > 50 µm (c. 63 µm). > 30 pores (up to 45), ± 8 µm ***Agrostemma githago***
- F2 Grain c. 50 µm. Pores 30-35, c. 4.5 µm. Echinulate. ***Silene alba* t.**
- F1 Grain < 45 µm (c. 40 µm). Pores 30-40, c. 6 µm ***Lychnis flos-cuculi***
- C1 Tectum with indistinct perforations, distinctly scabrate. Pores small, more than 24. Incl. *Sagina* and *Amaranthaceae* ***Chenopodiaceae* t.**
- B1 Grains rounded-polyhedral. Pores (+annuli) in depressions, surrounded by a zone without big columellae; the rest of the grain forming a hexagonal pattern of ridges.
- G2 Ridges scabrate or with indistinct sculpturing.
- H3 Grain 8-25 µm. Pores 6-12 (2.5-4 µm). ***Paronychia* t.**
- H2 Grain 20-35 µm. Pores 16-19 (c. 4 µm). ***Scleranthus annuus* t.**
- H1 Grain c. 36 µm. Pores 12 (c. 5 µm). ***Scleranthus perennis***
- G1 Ridges echinate. Grain c. 42 µm. Pores 12 (6 µm). ***Stellaria holostea***

CYPERACEAE

(Faegri & Iversen 1992; Valdes *et al* 1987)

Grains with perforate/granulate tectum with lacunae, i.e. areas where the tectum is broken up into small frustillae, usually forming an areolar sculpturing. The form and arrangement of lacunae is of great diagnostic value. One or two of the lateral lacunae may be smaller than the others; the indices given below do not apply to these.

- A3 Lateral lacunae oblong, length twice as long as the breadth or more. Grain ovoid or pear-shaped.
- B2 Length of lateral lacunae more than half that of the grain.
- C2 Grain 36-43 µm ***Schoenus nigricans***
- C1 Grain 27-37 µm. ***Cyperus longus* t.**
- B1 Length of lateral lacunae less than half of that of the grain. Grain more than 40 µm ***Scirpus***

- A2 Lateral lacunae more or less circular or slightly elongated. Grain ovoid or pear-shaped.
- D2 2-3 small lacunae, length less than 20% that of the grain. Grain more than 40 μm , the narrow end usually projecting like a beak or a finger *Cladium mariscus*
- D1 4-6 lateral lacunae, their length normally more than 20% of that of the grain. Grain smaller than 40 μm , exceptionally (*Carex hirta*) 40-50 μm . The narrow end rounded: *Carex* type.
- E2 Lacunae poroid. Incl. *Scirpus p.p.* *Carex hallerana* t.
- E1 Lacunae colpoid *Carex flacca* t.
- A1 Lacunae irregular, rather large. Grain almost isodiametric, less than 20 μm . Structure rather coarse, columellae distinct *Cyperus michelianus*

GRAMINEAE

(Andersen 1979; Andersen & Bertelsen 1972; Beug 1961; Faegri & Iversen 1992)

Owing to the great importance of grasses, both in natural plant communities and in cultivated areas, and also the importance of certain taxa as cultivation indicators, it would be highly desirable to be able to identify grasses to species. However, the paucity of distinguishing characters limits separation. The Gramineae as a family are easily recognized, but also very monotonous in pollen morphology. The main identifying characters used in this key are: diameter of grain, of pore and of anulus (the latter two being the most reliable). The measurements are taken from grains embedded in glycerol jelly. Where data from Anderson's key (grains embedded in silicon oil) has been used a conversion factor of 1.2 has been applied. However, for the same species, conversion factors may vary between 1.1 and 1.3 for grain size and between 1.1 and 1.5 for pore size.

To make the distinction between the two cereal types, *Triticum* and *Avena*, the less easily seen columellae pattern is used. Two different patterns can be detected. In *single-grain* structure columellae are individually free, and more or less crowded and aggregated. In the *double-grain* structure some or all columellae are united into small frustillae. These patterns are also used to make the less important distinction between the two wild grass types of grasslands, *Dactylis* and *Festuca*. The patterns can be more easily seen using phase contrast.

- A2 Grain > 40 μm . Incl. mostly cereals and very few wild grasses. **Cerealia type.**
- B3 Grain > 60 μm *Zea mays*
- B2 Grain between 40 and 60 μm .
- C2 P/E ratio higher than 1.25. Exine distinctly scabrate. Pore lateral *Secale cereale*
- C1 P/E ratio less than 1.25. Pore (sub-)apical.
- D2 Anulus diameter larger than 12 μm . Exine verrucate.
- E2 Exine with single-grain structure *Triticum* t.
- E1 Exine with double-grain structure *Avena*
- D1 Anulus diameter between 10 and 12 μm . Exine scabrate. Incl. some wild grasses.

- F2 Outer limit of anulus sharp. Incl. *Elymus*, *Triticum monococcum* *Hordeum* t.
- F1 Outer limit of anulus not sharp *Agropyron* t.
- A1 Grain smaller than 40 µm. Anulus diameter less than 10 µm. Incl. most wild-grasses. **Gramineae**
- G2 Grain smaller than 26 µm. Columellae indistinct *Phragmites australis*
- G1 Grain between 26 and 40 µm.
 - H2 Double-grain structure. Columellae distinct. *Dactylis* t.
 - H1 Single-grain structure.
 - I2 Exine thick *Festuca* t.
 - I1 Exine thin. Some aggregation opposite the pore *Glyceria* t.

PLANTAGINACEAE

(Cf. Clarke & Jones 1980 (NW2); Faegri & Iversen 1992; Saad 1986; Uberta, Galan & Guerrero 1988.)

A3 Pore with distinct anulus.

- B2 Pore operculate (operculum may be lost, but then no granules on pore membrane). Markedly protruding anulus. 8-12 pores, 1-3 µm. Distinctly scabrate, verrucate, undulate. Grain 18-33 µm *P. lanceolata* t.
- B1 Pore rarely operculate, but with isolated granules.
 - C2 Markedly protruding anulus. Verrucate, scabrate, undulate. 5-8 pores, 1-3 µm. Grain 17-31 µm *P. coronopus*
 - C1 Exine scabrate, undulate. 5-9 pores, 2-4 µm. Grain 20-29 µm *P. alpina* t.

A2 Pore with incipient anulus.

- D2 Pore operculate.
 - E2 Exine psilate, slightly undulate. Grain 22-33 µm. 6-12 pores, 2-4 µm ... *P. albicans*
 - E1 Exine microechinate, not undulate. Grain 19-24 µm. 8-9 pores, 2-3 µm . *P. argentea*
- D1 Pore not operculate, membrane granulate. Exine undulate-verrucate. Grain 22-28 µm. 4-6 pores, 3-4 µm. *P. amplexicaulis*

A1 Pore without distinct anulus, with granules, no operculum.

- F2 Grain > 25 µm.
 - G2 8-9 pores, 3-4 µm. Verrucate, scabrate. Grain 27-36 µm *P. atrata*

- G1 4-6 pores.
- H2 Verrucae distinct. Pores not sharply defined, 2-4 μm . Grain 21-28 μm *P. arenaria*
- H1 Verrucae indistinct. Pores 2-4 μm . Grain 22-32 μm *P. bellardii*
- F1 Grain < 25 μm . Pores not sharply delimited. Microechinate, or verrucate/undulate.
- I3 Distinctly micro-echinate. Pores 4-7, 1-2 μm . Grain 14-25 μm *P. afra*
- I2 Verrucae very coarse, scabrae distinct. Pores 7-11, 2-5 μm . Grain 18-27 μm ...
P. media
- I1 Verrucae small, scabrae very weak. Pores 5-9, 1-3 μm . Grain 16-22 μm *P. major*

ROSACEAE

(Cf. Faegri & Iversen 1992; Moore *et al* 1991; Teppner 1966)

A2 With tectate operculum.

B2 Psilate-scabrate-echinate, oblate-globular. *Sanguisorba*.

C2 Operculum narrow, colpus very short *S. minor*

C1 Operculum as broad as the intercolpium, colpus long *S. officinalis*

B1 Striate.

D2 Vallae coarse. Perforations not visible. Grain size c.20 μm

E2 Vallae broad, diffuse.

F2 Polar area flattened *Fragaria vesca* t.

F1 Polar area not flattened *Potentilla*

E1 Vallae narrow, distinct.

G2 Colpus ends rounded *Fragaria viridis* t.

G1 Colpus ends acute *Potentilla*

D1 Vallae fine. Tectum perforate.

H2 Vallae transversal, extremely fine. Operculum extremely narrow ... *Agrimonia* t.

H1 Vallae submeridional to subtransversal. Operculum short *Rosa*

A1 No tectate operculum, but colpus membrane occasionally with loose columellae.

I3 Microechinate-echinate. No perforations *Filipendula*

- I2 Rugulate-microstriate/psilate.
 - J3 Rugulate-microstriate. No costae colpi nor granules on colpus membrane. Size 47-52 μm
Mespilus germanica
 - J2 Rugulate to psilate, costae colpi and granules usually present *Cotoneaster t.*
 - J1 Psilate. Polar projection usually subtriangular *Alchemilla t.*
- I1 Striate.
 - K2 Vallae coarse. Colpus with distinct bridge *Geum*
 - K1 Vallae fine.
 - L2 Vallae paired.
 - M3 Striation weak. Size 29-42 μm *Crataegus*
 - M2 Striation definite. Size 30-36 μm *Pyrus*
 - M1 Size 42-58 μm *Cydonia oblonga*
 - L1 Vallae simple.
 - N2 Vallae indistinct. Perforations large *Rubus t.*
 - N1 Vallae distinct.
 - O2 Vallae high, frequently short *Rosa*
 - O1 Vallae low and narrow.
 - P2 Vallae straight, moderately branched.
 - Q2 Perforations distinct. Vallae without dense structure . *Sorbus t.*
 - Q1 Perforations may be unobservable. Vallae with dense structure
Prunus avium t.
 - P1 Vallae curved, branched, anastomosing.
 - R2 Vallae short, strongly curved *Prunus spinosa t.*
 - R1 Vallae moderately curved. With costae colpi, size c. 27 μm
Malus

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VI.2 Pollen types

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- Aschenbrenner, S. 1987. Ethnoarchaeology of agricultural economy. Unpublished Grevena Project report.
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- Wace, A.J.B. and M.S. Thompson 1972. *The nomads of the Balkans*. Methuen & Co. Ltd, London.

Taxonomic names of vascular European species follow:

- Tutin, T. G. *et al* (eds) 1964-80. *Flora Europaea*. Volumes 1-5. Cambridge University Press, Cambridge.

In some exceptional cases, for example where taxa have been described more recently than the publication of the above volumes, taxonomic names follow those used in the following volumes:

- Strid, A. (ed) 1986. *Mountain Flora of Greece*. Volume 1. Cambridge University Press, Cambridge.
- Strid, A. and K. Tan (eds) 1991. *Mountain Flora of Greece*. Volume 2. Edinburgh University Press, Edinburgh.

Taxonomic names of non-vascular species follow:

- Watson, E.V. 1968 (2nd ed.), *British mosses and liverworts*. Cambridge University Press, Cambridge.

PTERIDOPHYTA
LYCOPSIDA

SELAGINELLACEAE

Selaginella

Selaginella denticulata, *S. helvetica*

ISOETACEAE

Isoetes

Isoetes lacustris

?*Isoetes heldreichii*

SPHENOPSIDA

EQUISETACEAE

Equisetum

Equisetum arvense, *E. fluviatile*, *E. palustre*, *E. ramosissimum*, *E. sylvaticum*, *E. telmateia*

FILICOPSIDA

OPHIOGLOSSACEAE

Ophioglossum lusitanicum

Ophioglossum lusitanicum

Ophioglossum vulgatum

Ophioglossum vulgatum

Botrychium

Botrychium lunaria, *B. simplex*

OSMUNDACEAE

Osmunda regalis

Osmunda regalis

SINOPTERIDACEAE

Cheilanthes

Cheilanthes persica

?*Cheilanthes catanensis*, *C. fragrans*, *C. marantae*

ADIANTACEAE

Adiantum capillus-veneris

Adiantum capillus-veneris

PTERIDACEAE

Pteris cretica

Pteris cretica

Pteris vittata

Pteris vittata

GYMNOGRAMMACEAE

Anogramma leptophylla

Anogramma leptophylla

HYPOLEPIDACEAE

Pteridium aquilinum

Pteridium aquilinum

THELYPTERIDACEAE

Thelypteris palustris

Thelypteris palustris

Thelypteris phegopteris
Thelypteris phegopteris

ASPLENIACEAE

***Asplenium* type**

Asplenium adiantum-nigrum, *A. cuneifolium*, *A. fissum*, *A. fontanum*, *A. lepidum*, *A. obovatum*, *A. onopteris*, *A. petrarchae*, *A. ruta-muraria*, *A. septentrionale*, *A. trichomanes*, *A. viride*, *Ceterach officinarum*, *Phyllitis sagittata*, *P. scolopendrium*
? *Asplenium bornmuelleri*, *A. javorkeanum*, *A. macedonicum*

ATHYRIACEAE

Athyrium filix-femina

Athyrium filix-femina

Athyrium distentifolium

Athyrium distentifolium

Cystopteris fragilis

Cystopteris fragilis

ASPIDIACEAE

Polystichum

Polystichum aculeatum, *P. lonchitis*, *P. setiferum*

? *Polystichum x illyricum*

***Dryopteris filix-mas* type**

Dryopteris filix-mas, *D. villarii*, *Gymnocarpium robertianum*

? *Cystopteris dickieana*, *Dryopteris x tavelii*

Dryopteris expansa

Dryopteris expansa

Gymnocarpium dryopteris

Gymnocarpium dryopteris

BLECHNACEAE

Blechnum spicant

Blechnum spicant

POLYPODIACEAE

Polypodium

Polypodium australe, *P. vulgare*

SALVINIACEAE

Salvinia natans

Salvinia natans

SPERMATOPHYTA
GYMNOSPERMAE

PINACEAE

Abies

Abies alba, *A. borisii-regis*, *A. cephalonica*

Pseudotsuga menziesii

Pseudotsuga menziesii

Picea abies

Picea abies

Cedrus

Cedrus atlantica, *C. deodara*

Pinus subgenus Diploxylon

Pinus heldreichii, *P. leucodermis*, *P. nigra*, *P. sylvestris*

Pinus subgenus Haploxylon

Pinus peuce

CUPRESSACEAE

Juniperus

Juniperus communis, *J. excelsa*, *J. foetidissima*, *J. oxycedrus*, *J. sabina*

TAXACEAE

Taxus baccata

Taxus baccata

EPHEDRACEAE

Ephedra fragilis

Ephedra fragilis

Ephedra distachya type

Ephedra distachya, *E. major*

ANGIOSPERMAE

Dicotyledones

SALICACEAE

Salix triandra

Salix triandra

Salix fragilis type

Salix alba, *S. aurita*, *S. caprea*, *S. fragilis*, *S. pedicellata*, *S. pentandra*, *S. purpurea*, *S. viminalis*

?*S. aegyptiaca*, *S. amplexicaulis*, *S. cinerea*, *S. elaeagnos*, *S. retusa*

Populus

Populus alba, *P. canescens*, *P. nigra*, *P. tremula*

JUGLANDACEAE

Juglans regia

Juglans regia

BETULACEAE

Alnus glutinosa

Alnus glutinosa

Betula pendula

Betula pendula

CORYLACEAE

***Carpinus* type**

Carpinus betulus (mostly), *C. orientalis* (pp), *Ostrya carpinifolia* pp.

***Ostrya* type**

Carpinus betulus pp., *C. orientalis* (mostly), *Ostrya carpinifolia* (mostly)

Corylus

Corylus avellana, *C. colurna*, *C. maxima*

FAGACEAE

Fagus

Fagus moesiaca, *F. sylvatica*

Castanea sativa

Castanea sativa

***Quercus coccifera* type**

Quercus coccifera, *Q. ilex*

***Quercus trojana* type**

Quercus cerris, *Q. macrolepis*, *Q. trojana*

?*Quercus brachyphylla*

***Quercus frainetto* type**

Quercus frainetto, *Q. petraea*, *Q. pubescens*, *Q. robur*, *Q. virgiliana*

?*Quercus dalechampii*, *Q. pedunculiflora*, *Q. polycarpa*

ULMACEAE

***Ulmus minor* type**

Ulmus minor

?*Ulmus canescens*

Ulmus procera

Ulmus procera

***Ulmus glabra* type**

Ulmus glabra, *U. laevis*

Celtis

Celtis australis

?*Celtis caucasia*

MORACEAE

Morus nigra

Morus nigra

Morus alba

Morus alba

Ficus carica

Ficus carica

CANNABACEAE

Cannabis sativa

Cannabis sativa

Humulus lupulus

Humulus lupulus

URTICACEAE

Urtica dioica

Urtica dioica

***Urtica urens* type**

Urtica urens, *Pilea microphylla*

***Urtica pilulifera* type**

Urtica dubia, *U. pilulifera*

Parietaria

Parietaria diffusa, *P. lusitanica*, *P. officinalis*

?*Parietaria cretica*

SANTALACEAE

Comandra elegans

Comandra elegans

Osyris alba

Osyris alba

***Thesium divaricatum* type**

Thesium divaricatum, *T. humile*

?*Thesium arvense*, *T. bavarum*, *T. bergeri*, *T. brachyphyllum*, *T. linophyllum*, *T. parnassi*

Thesium alpinum

Thesium alpinum

LORANTHACEAE

Viscum album

Viscum album

Arceuthobium oxycedri

Arceuthobium oxycedri

Loranthus europaeus

Loranthus europaeus

ARISTOLOCHIACEAE

Aristolochia

Aristolochia clematitis, *A. longa*

?*Aristolochia macedonica*, *A. pallida*, *A. rotunda*

RAFFLESIACEAE

Cytinus hypocistis

Cytinus hypocistis

Cytinus ruber

Cytinus ruber

POLYGONACEAE

***Polygonum bistorta* type**

Polygonum bistorta

?*Polygonum alpinum*

Polygonum viviparum

Polygonum viviparum

Polygonum amphibium

Polygonum amphibium

***Polygonum aviculare* type**

Polygonum arenarium, *P. arenastrum*, *P. aviculare*, *P. equisetiforme*, *P. patulum*

?*Polygonum longipes*

***Polygonum persicaria* type**

Polygonum hydropiper, *P. lapathifolium*, *P. mite*, *P. persicaria*

?*Polygonum salicifolium*

Bilderdykia

Bilderdykia convolvulus, *B. dumetorum*

Rumex type

Oxyria digyna

Oxyria digyna

Rumex acetosella group

Rumex acetosella, *R. tenuifolius*

Rumex acetosa group

Rumex acetosa, *R. thyrsiflorus*

?*Rumex arifolius*, *R. gussonii*

Rumex crispus pp.

Rumex crispus pp.

Rumex conglomeratus group

Rumex conglomeratus, *R. pulcher*, *R. scutatus*

?*Rumex nepalensis*, *R. tuberosus*

Rumex obtusifolius group

Rumex alpinus, *R. crispus* pp., *R. obtusifolius*, *R. patientia* pp.

? *Rumex balcanicus*, *R. cristatus*, *R. hydrolapathum*, *R. kernerii*

Rumex palustris group

Rumex crispus pp., *R. palustris*, *R. patientia* pp.

?*Rumex dentatus*

Rumex bucephalophorus group

Rumex bucephalophorus, *R. crispus* pp.

?*Atraphaxis billardieri*

Emex spinosa

Emex spinosa

CHENOPODIACEAE

Chenopodiaceae type

Chenopodiaceae: *Atriplex halimus*, *A. hastata*, *A. hortensis*, *A. littoralis*, *A. oblongifolia*, *A. patula*, *A. rosea*, *A. tatarica*, *Beta vulgaris*, *Camphorosma monspeliaca*, *Chenopodium album*, *C. ambrosioides*, *C. bonus-henricus*, *C. ficifolium*, *C. foliosum*, *C. glaucum*, *C. hybridum*, *C. murale*, *C. opulifolium*, *C. polyspermum*, *C. rubrum*, *C. urbicum*, *C. vulvaria*, *Corispermum nitidum*, *Noaea mucronata*, *Petrosimonia brachiata*, *P. triandra*, *Salsola kali*, *S. soda*

Amaranthaceae: *Amaranthus albus*, *A. deflexus*, *A. hybridus*, *A. lividus*, *A. retroflexus*

Caryophyllaceae: *Sagina apetala*, *S. procumbens*, *S. saginoides*, *S. subulata*

PHYTOLACCACEAE

Phytolacca americana

Phytolacca americana

MOLLUGINACEAE

***Glinus* type**

Glinus lotoides, *Mollugo cerviana*

PORTULACACEAE

Montia fontana

Montia fontana

Portulaca oleracea

Portulaca oleracea

CARYOPHYLLACEAE

Spergula

Spergula arvensis, *S. pentandra*

Spergularia type

Polycarpon tetraphyllum, *Spergularia diandra*, *S. marina*, *S. media*, *S. rubra*

Herniaria type

Corrigiola litoralis pp., *Herniaria cinerea*, *H. glabra*, *H. hirsuta*, *H. incana*, *H. nigrimontium*, *H. parnassica*

Corrigiola litoralis

Corrigiola litoralis pp.

Paronychia type

Paronychia argentea, *P. capitata*, *P. echinulata*

Chenopodiaceae: *Polycnemum arvense*, *P. heuffelii*, *P. majus*

?*Paronychia albanica*, *P. cephalotes*, *P. kapela*, *P. macedonica*, *P. polygonifolia*, *P. taurica*

Dianthus type

Arenaria leptoclados, *A. serpyllifolia*, *Cerastium alpinum*, *C. arvense*, *C. brachypetalum*, *C. cerastoides*, *C. diffusum*, *C. fontanum*, *C. glomeratum*, *C. gracile*, *C. pumilum*, *C. semidecandrum*, *Cucubalus baccifer*, *Dianthus deltoides*, *Holosteum umbellatum*, *Lychnis coronaria*, *L. viscaria*, *Minuartia recurva*, *M. verna*, *Moehringia pentandra*, *M. trinervia*, *Moenchia erecta*, *Myosoton aquaticum*, *Petrorhagia prolifera*, *P. saxifraga*, *Silene apetala*, *S. armeria*, *S. bupleuroides*, *S. cephalenia*, *S. colorata*, *S. congesta*, *S. dichotoma*, *S. fabarioides*, *S. frivaldszkyana*, *S. gallica*, *S. genistifolia*, *S. gigantea*, *S. italica*, *S. linifolia*, *S. multicaulis*, *S. nutans*, *S. oligantha*, *S. otites*, *S. paradoxa*, *S. parnassica*, *S. pindicola*, *S. radicata*, *S. saxifraga*, *S. skorpilii*, *S. thessalonica*, *S. viridiflora*, *S. vulgaris*, *S. waldsteinii*, *Stellaria alsine*, *S. graminea*, *S. media*, *S. neglecta*, *S. nemorum*, *Vaccaria pyramidata*
?*Arenaria biflora*, *A. conferta*, *A. cretica*, *A. filicaulis*, *A. serpentini*, *Bolanthus graecus*, *B. thessalus*, *Bufonia paniculata*, *B. tenuifolia*, *Cerastium banaticum*, *C. decalvans*, *C. dinaricum*, *C. dubium*, *C. moesiacum*, *C. rectum*, *C. smolikanum*, *C. vourinense*, *Dianthus biflorus*, *D. brachyzonus*, *D. capitatus*, *D. cruentus*, *D. degenii*, *D. diffusus*, *D. drenowskianus*, *D. formanekii*, *D. giganteus*, *D. gracilis*, *D. haematocalyx*, *D. leptopetalus*, *D. minutiflorus*, *D. myrtinervius*, *D. pallens*, *D. petraeus*, *D. pinifolius*, *D. pontederiae*, *D. stenopetalus*, *D. sylvestris*, *D. tristis*, *D. viscidus*, *Minuartia baldaccii*, *M. eurytanica*, *M. garckeana*, *M. globulosa*, *M. glomerata*, *M. graminifolia*, *M. hirsuta*, *M. juniperina*, *M. setacea*, *M. stellata*, *Moenchia graeca*, *M. mantica*, *Petrorhagia cretica*, *P. fasciculata*, *P. glumacea*, *P. illyrica*, *Saponaria bellidifolia*, *S. calabrica*, *S. glutinosa*, *S. sicula*, *Silene asterias*, *S. balcanica*, *S. caesia*, *S. chromodonta*, *S. ciliata*, *S. compacta*, *S. cretica*, *S. damboldtiana*, *S. densiflora*, *S. haussknechtii*, *S. lerchenfeldiana*, *S. lydia*, *S. pusilla*, *S. roemerii*, *S. schwarzenbergeri*, *S. supina*, *S. trinervia*, *S. ventricosa*
??*Drypis spinosa*

Silene alba type

Silene alba, *S. conica*

Lychnis flos-cuculi

Lychnis flos-cuculi

Agrostemma githago

Agrostemma githago

Scleranthus perennis

Scleranthus perennis

Scleranthus annuus type

Scleranthus annuus

?*Scleranthus uncinatus*

Stellaria holostea

Stellaria holostea

NYMPHAEACEAE

Nymphaea alba

Nymphaea alba

Nuphar lutea

Nuphar lutea

CERATOPHYLLACEAE

Ceratophyllum

Ceratophyllum demersum, *C. submersum*

RANUNCULACEAE

Helleborus

Helleborus odoratus

?*Helleborus cyclophyllus*

Nigella

Nigella arvensis, *N. damascena*, *N. sativa*

Trollius europaeus

Trollius europaeus

Actaea spicata

Actaea spicata

***Consolida* type**

Consolida orientalis, *C. regalis*, *Delphinium fissum*, *D. peregrinum*

?*Consolida brevicornis*, *Delphinium balcanicum*, *D. hellenicum*

Adonis

Adonis aestivalis, *A. annua*, *A. flammea*, *A. microcarpa*

***Caltha* type**

Aquilegia vulgaris, *Caltha palustris*, *Myosurus minimus*

?*Aquilegia amaliae*, *A. ottonis*

***Ranunculus acris* type**

Ranunculus acris group

Ranunculus acris, *R. bulbosus*, *R. lanuginosus*, *R. muricatus*, *R. nemorosus*, *R. polyanthemus*, *R. repens*, *R. sardous*

?*Ranunculus constantinopolitanus*, *R. serbicus*, *R. velutinus*

Ranunculus lingua

Ranunculus lingua

Ranunculus aquatilis group

Clematis flammula, *Ranunculus aquatilis*, *R. peltatus*, *R. pseudomontanus*, *R. rionii*, *R. sphaerospermus*, *R. trichophyllus*

?*Ranunculus lateriflorus*

Pulsatilla halleri

Pulsatilla halleri

Anemone nemorosa group

Anemone apennina, *A. nemorosa*

?*Anemone blanda*

Clematis vitalba group

Clematis vitalba, *C. viticella*

Ranunculus auricomus group

Ceratocephalus falcatus, *Ranunculus auricomus*, *R. cassubicus*, *R. fallax*, *R. monophyllus*

Ranunculus ficaria

Ranunculus ficaria

Ranunculus ophioglossifolius

Ranunculus ophioglossifolius

Ranunculus sceleratus group

Ranunculus platanifolius, *R. sceleratus*

?*Ranunculus brevifolius*, *R. brutius*, *R. demissus*, *R. marginatus*, *R. neapolitanus*, *R. sartorianus*

***Ranunculus arvensis* type**

Ranunculus arvensis

?*Ranunculus chius*, *R. gracilis*, *R. miliarakesii*, *R. millefoliatus*, *R. millii*, *R. psilostachys*,
R. rumelicus, *R. spruneranus*, *R. subhomophyllus*

Thalictrum aquilegifolium

Thalictrum aquilegifolium

Thalictrum minus

Thalictrum minus

Thalictrum lucidum

Thalictrum lucidum

BERBERIDACEAE

***Berberis vulgaris* type**

Berberis vulgaris

?*Berberis cretica*

Mahonia aquifolium

Mahonia aquifolium

Leontice leontopetalum

Leontice leontopetalum

LAURACEAE

Laurus nobilis

Laurus nobilis

PAPAVERACEAE

Chelidonium majus

Chelidonium majus

Papaver dubium

Papaver dubium

Papaver hybridum

Papaver hybridum

***Papaver rhoeas* type**

Papaver rhoeas

?*Papaver apulum*, *P. lecoqii*

Papaver somniferum

Papaver somniferum

Glaucium

Glaucium corniculatum, *G. leiocarpum*

***Papaver argemone* type**

Papaver argemone, *Roemeria hybrida*

***Fumaria densiflora* type**

Fumaria densiflora, *F. kralikii*, *F. officinalis*, *F. rostellata*

?*Fumaria petteri*, *F. schleicheri*

Fumaria parviflora

Fumaria parviflora

***Corydalis solida* type**

Corydalis bulbosa, *C. solida*

Corydalis ochroleuca

Corydalis ochroleuca

Hypecoum

Hypecoum imberbe, *H. pendulum*

CAPPARIDACEAE

?*Cleome ornithopodioides*

Cleome ornithopodioides

CRUCIFERAE

Hornungia type

Alyssum alyssoides, *A. bertolonii*, *A. caliacrae*, *A. chalcidicum*, *A. chlorocarpum*, *A. corymbosoides*, *A. corymbosum*, *A. cuneifolium*, *A. desertorum*, *A. diffusum*, *A. doerfleri*, *A. foliosum*, *A. heldreichii*, *A. minus*, *A. minutum*, *A. montanum*, *A. murale*, *A. obtusifolium*, *A. petraeum*, *A. pichleri*, *A. pulvinare*, *A. repens*, *A. saxatile*, *A. sibiricum*, *A. smolikanum*, *A. strigosum*, *A. tortuosum*, *A. umbellatum*, *Arabidopsis thaliana*, *Berteroa incana*, *Capsella bursa-pastoris*, *Cardaria draba*, *Descurainia sophia*, *Hornungia petraea*, *Lepidium campestre*, *Thlaspi alpestre*
? *Aethionema saxatile*, *Berteroa mutabilis*, *B. obliqua*, *B. orbiculata*, *Capsella grandiflora*, *C. rubella*, *Lepidium graminifolium*, *L. hirtum*, *L. perfoliatum*, *L. sativum*, *Thlaspi bulbosum*, *T. epirotum*, *T. goesingense*, *T. microphyllum*, *T. ochroleucum*, *T. perfoliatum*, *T. praecox*, *T. rivale*

Arabis

Arabis glabra, *A. turrata*

Sinapis type

Alliaria petiolata, *Arabis alpina*, *Barbarea bracteosa*, *B. sicula*, *B. vulgaris*, *Brassica napus*, *B. nigra*, *B. rapa*, *Bunias erucago*, *Calepina irregularis*, *Camelina microcarpa*, *Cardamine bulbifera*, *C. hirsuta*, *C. pratensis*, *Diplotaxis muralis*, *D. viminea*, *Draba aizoides*, *D. athoa*, *D. lasiocarpa*, *D. muralis*, *D. scardica*, *Erophila minima*, *E. verna*, *Erysimum cephalonicum*, *E. cheiranthoides*, *E. comatum*, *E. cuspidatum*, *E. diffusum*, *E. linariifolium*, *E. microstylum*, *E. odoratum*, *E. pulchellum*, *E. pusillum*, *E. repandum*, *E. sylvestre*, *Iberis saxatilis*, *I. sempervirens*, *I. umbellata*, *Isatis lusitanica*, *I. tinctoria*, *I. vermiculata*, *Lepidium latifolium*, *L. ruderales*, *Lunaria annua*, *L. rediviva*, *Matthiola fruticulosa*, *Raphanus raphanistrum*, *Rorippa amphibia*, *R. prolifera*, *R. pyrenaica*, *R. sylvestris*, *Sinapis alba*, *S. arvensis*, *Sisymbrium altissimum*, *S. irio*, *S. loeselii*, *S. officinale*, *S. orientale*, *S. polyceratum*, *Teesdalia coronopifolia*
? *Alyssoides utriculata*, *Arabis allionii*, *A. bryoides*, *A. caucasica*, *A. collina*, *A. laxa*, *A. muralis*, *A. pseudoturritus*, *A. recta*, *A. sagittata*, *A. subflava*, *Aubrieta deltoidea*, *A. glabrescens*, *A. gracilis*, *A. intermedia*, *Bornmuellera baldaccii*, *B. tymphaea*, *Camelina alyssum*, *C. rumelica*, *C. sativa*, *Cardamine barbaraecoides*, *C. carnosa*, *C. glauca*, *C. graeca*, *C. hirsuta*, *C. pectinata*, *C. plumieri*, *C. raphanifolia*, *Clypeola jonthlaspi*, *Conringia austriaca*, *C. orientalis*, *Coronopus squamatus*, *Eruca vesicaria*, *Hesperis dinarica*, *H. laciniata*, *H. matronalis*, *H. rechingeri*, *H. sylvestris*, *H. theophrasti*, *Hirschfeldia incana*, *Hutchinsia alpina*, *Hymenolobus procumbens*, *Iberis odorata*, *I. pinnata*, *I. pruitii*, *I. umbellata*, *Lobularia maritima*, *Malcolmia africana*, *M. angulifolia*, *M. bicolor*, *M. graeca*, *M. maritima*, *M. orsiniana*, *Myagrum perfoliatum*, *Nasturtium officinale*, *Neslia paniculata*, *Peltaria emarginata*, *Ptilotrichum cyclocarpum*, *Rapistrum rugosum*

RESEDACEAE

Reseda

Reseda lutea, *R. luteola*, *R. phyteuma*

CRASSULACEAE

Umbilicus

Umbilicus erectus, *U. horizontalis*, *U. rupestris*

Jovibarba heuffelii

Jovibarba heuffelii

Crassula

Crassula tillaea, *C. vaillantii*

Sedum

Sedum acre, *S. album*, *S. alpestre*, *S. annuum*, *S. athoum*, *S. atratum*, *S. cepaea*, *S. dasyphyllum*, *S. flexuosum*, *S. hispanicum*, *S. laconicum*, *S. litoreum*, *S. magellense*, *S. ochroleucum*, *S. pallidum*, *S. reflexum*, *S. sartorianum*, *S. sediforme*, *S. telephium*, *S. tenuifolium*

Sempervivum

Sempervivum ballsii, *S. ciliosum*, *S. kindingeri*, *S. marmoreum*, *S. reginae-amaliae*, *S. zeileborii*

SAXIFRAGACEAE

Chrysosplenium alternifolium

Chrysosplenium alternifolium

Saxifraga stellaris

Saxifraga stellaris

Saxifraga tridactylites type

Saxifraga chrysosplenifolia, *S. exarata*, *S. rotundifolia*, *S. tridactylites*

Saxifraga oppositifolia type

Saxifraga adscendens, *S. glabella*, *S. marginata*, *S. oppositifolia*, *S. paniculata*

Saxifraga bulbifera

Saxifraga bulbifera

Saxifraga sempervivum type

Saxifraga porophylla, *S. sempervivum*, *S. sibirnyi*
? *Saxifraga graeca*, *S. grisebachii*, *S. luteoviridis*, *S. scardica*, *S. spruneri*, *S. taygetea*

PARNASSIACEAE

Parnassia palustris

Parnassia palustris

GROSSULARIACEAE

Ribes

Ribes alpinum, *R. multiflorum*

PLATANACEAE

Platanus orientalis

Platanus orientalis

ROSACEAE

Filipendula

Filipendula ulmaria, *F. vulgaris*

Rubus type

Rubus caesius, *R. candicans*, *R. canescens*, *R. corylifolius*, *R. hirtus*, *R. idaeus*, *R. serpens*,
R. thyrsiflorus, *R. ulmifolius*
? *Rubus thessalus*
?? *Spiraea crenata*

Sorbus type

Sorbus aria, *S. aucuparia*, *S. domestica*, *S. graeca*, *S. torminalis*, *S. umbellata*
? *Amelanchier ovalis*

Rosa

Rosa agrestis, *R. andegavensis*, *R. arvensis*, *R. caesia*, *R. canina*, *R. corymbifera*, *R. elliptica*, *R. foetida*, *R. gallica*, *R. majalis*, *R. micrantha*, *R. montana*, *R. moschata*, *R. nitidula*, *R. obtusifolia*, *R. pendulina*, *R. pimpinellifolia*, *R. rubiginosa*, *R. squarrosa*, *R. villosa*, *R. vosagiaca*
? *Rosa caryophyllacea*, *R. glutinosa*, *R. heckeliana*, *R. orientalis*, *R. sempervirens*, *R. turcica*

Cotoneaster type

Cotoneaster integerrimus, *C. nebrodensis*

?*Pyracantha coccinea*

Mespilus germanica

Mespilus germanica

Prunus avium type

Prunus avium, *P. mahaleb*

Prunus spinosa type

Prunus cerasus, *P. domestica*, *P. persica*, *P. spinosa*

?*Prunus armeniaca*, *P. cerasifera*, *P. cocomilia*, *P. dulcis*, *P. prostrata*

Malus

Malus domestica, *M. pumila*, *M. sylvestris*

?*Malus florentina*

Pyrus

Pyrus amygdaliformis, *P. communis*, *P. cordata*, *P. pyraster*

?*Pyrus eleagrifolia*, *P. salvifolia*

Crataegus

Crataegus heldreichii, *C. laciniata*, *C. monogyna*, *C. pentagyna*

?*Crataegus schraderana*

Cydonia oblonga

Cydonia oblonga

Agrimonia type

Agrimonia eupatoria, *Aremonia agrimonoides*

Sanguisorba officinalis

Sanguisorba officinalis

Sanguisorba minor

Sanguisorba minor ssp. *minor*, *S. minor* ssp. *muricata*

Geum

Geum coccineum, *G. molle*, *G. montanum*, *G. reptans*, *G. urbanum*

Potentilla

Potentilla argentea, *P. aurea*, *P. erecta*, *P. inclinata*, *P. micrantha*, *P. recta*, *P. reptans*, *P. sterilis*, *P. supina*

?*Potentilla astracantha*, *P. australis*, *P. detommasii*, *P. geoides*, *P. pedata*, *P. speciosa*

Fragaria viridis type

Fragaria viridis

?*Fragaria x ananassa*

Fragaria vesca type

Fragaria vesca

?*Sibbaldia parviflora*

Alchemilla type

Alchemilla xanthochlora, *Aphanes arvensis*, *A. microcarpa*

?*Alchemilla acutiloba*, *A. cinerea*, *A. fallax*, *A. gorgensis*, *A. heterotricha*, *A. incisa*, *A. plicatula*, *A. straminea*, *A. subglabra* group

LEGUMINOSAE

Genista type

Cytisus decumbens, *C. procumbens*, *C. villosus*, *Genista acanthoclada*, *G. albida*, *G. carinalis*, *G. hassertiana*, *G. januensis*, *G. radiata*, *G. tinctoria*

?*Chamaecytisus austriacus*, *C. ciliatus*, *C. heuffelii*, *C. hirsutus*, *C. polytrichus*, *C. spinescens*, *C. supinus*, *Lembotropis nigricans*, *Podocytisus caramanicus*

Onobrychis

Onobrychis aequidentata, *O. alba*, *O. arenaria*, *O. caput-galli*, *O. ebenoides*,
O. hypargyrea, *O. montana*, *O. oxyodonta*, *O. pindicola*

Hedysarum coronarium

Hedysarum coronarium

Ononis type

Colutea arborescens, *Melilotus alba*, *M. altissima*, *M. indica*, *M. neapolitana*, *M. officinalis*, *M. segetalis*, *Ononis pusilla*, *O. reclinata*, *O. spinosa*

Trifolium dubium type

Medicago lupulina, *Trifolium angustifolium*, *T. arvense*, *T. aureum*, *T. badium*, *T. campestre*, *T. dubium*, *T. lappaceum*, *T. micranthum*, *T. nigrescens*, *T. pallidum*, *T. resupinatum*

?*Medicago aculeata*, *M. ciliaris*, *M. coronata*, *M. disciformis*, *M. orbicularis*, *M. praecox*, *M. prostrata*, *M. rigidula*, *M. scutellata*, *M. turbinata*, *Trifolium alpestre*, *T. aurantiacum*, *T. bocconeii*, *T. cherieri*, *T. dalmaticum*, *T. diffusum*, *T. dolopium*, *T. echinatum*, *T. glomeratum*, *T. heldreichianum*, *T. hirtum*, *T. latinum*, *T. leucanthum*, *T. noricum*, *T. ochroleucon*, *T. pannonicum*, *T. parnassi*, *T. patens*, *T. patulum*, *T. phleoides*, *T. physodes*, *T. pignantii*, *T. pilczii*, *T. purpureum*, *T. sebastianii*, *T. smyrnaeum*, *T. strictum*, *T. suffocatum*, *T. tenuifolium*, *T. trichopterum*, *T. vesiculosum*

Trifolium repens type

Medicago arabica, *M. minima*, *M. polymorpha*, *Scorpiurus muricatus*, *Trifolium fragiferum*, *T. globosum*, *T. hybridum*, *T. incarnatum*, *T. medium*, *T. pratense*, *T. repens*, *T. scabrum*, *T. squarrosum*, *T. striatum*, *T. subterraneum*

Lotus type

Lotus aegaeus, *L. angustissimus*, *L. corniculatus*, *L. ornithopodioides*, *L. palustris*, *L. parviflorus*, *L. stenodon*, *L. tenuis*, *L. uliginosus*, *Tetragonolobus biflorus*, *T. purpureus*, *Trigonella monspeliaca*

?*Glycyrrhiza echinata*, *G. glabra*, *Trigonella caerulea*, *T. foenum-graecum*, *T. procumbens*, *T. spicata*, *T. striata*

??*Hymenocarpus circinnatus*, *Securigera securidaca*

Lathyrus pratensis type

Lathyrus alpestris, *L. aphaca*, *L. cicera*, *L. digitatus*, *L. grandiflorus*, *L. hallersteinii*, *L. hirsutus*, *L. latifolius*, *L. laxiflorus*, *L. niger* (mostly), *L. nissolia*, *L. pallescens*, *L. pratensis*, *L. setifolius*, *L. sphaericus*, *L. sylvestris*, *L. tuberosus*, *L. venetus*, *L. vernus*, *Lupinus albus*, *Trigonella gladiata*

?*Lathyrus ochrus*

Lens

Lens culinaris

?*Lens ervoides*, *L. nigricans*

Vicia sativa type

Vicia cracca (sometimes), *V. hirsuta* (mostly), *V. hybrida*, *V. lutea*, *V. peregrina*, *V. sativa*, *V. sepium* (mostly), *V. tetrasperma* (mostly)

?*Vicia articulata*, *V. barbazitae*, *V. canescens*, *V. cassubica*, *V. dumetorum*, *V. ervilia*, *V. grandiflora*, *V. incana*, *V. melanops*, *V. narbonensis*, *V. onobrychioides*, *V. pannonica*, *V. pubescens*, *V. sibthorpii*, *V. villosa*

Vicia lathyroides

Vicia lathyroides

Vicia faba

Vicia faba

Vicia cracca type

Lathyrus niger (sometimes), *Vicia cracca* (mostly), *V. hirsuta* (sometimes), *V. sepium* (sometimes), *V. tenuifolia*, *V. tetrasperma* (sometimes)

Astragalus

Astragalus depressus, *A. exscapus*, *A. glycyphyllos*, *A. hamosus*, *A. monspessulanus*, *A. onobrychis*, *A. purpureus*, *A. sesameus*, *A. vesicarius*
? *Astragalus angustifolius*, *A. baldaccii*, *A. creticus*, *A. glycyphylloides*, *A. mayeri*, *A. parnassi*, *A. pubiflorus*, *A. sinaicus*, *A. sirinicus*, *A. subuliformis*

Galega officinalis

Galega officinalis

Coronilla scorpioides type

Coronilla scorpioides, *C. valentina*, *C. varia*
? *Coronilla coronata*, *C. cretica*, *C. elegans*, *C. rostrata*

Medicago sativa

Medicago sativa pp.

Ornithopus compressus

Ornithopus compressus

Dorycnium

Dorycnium graecum, *D. hirsutum*, *D. pentaphyllum*, *D. rectum*

Trifolium montanum type

Medicago sativa pp., *Trifolium montanum*

Anthyllis

Anthyllis aurea, *A. montana*, *A. vulneraria*

Coronilla emerus

Coronilla emerus

Spartium junceum

Spartium junceum

Psoralea type

Psoralea bituminosa, *Vigna unguiculata*

Phaseolus

Phaseolus vulgaris

? *Phaseolus coccineus*

?? *Cicer arietinum*, *Glycine max*

Pisum sativum

Pisum sativum

Lathyrus sativus

Lathyrus sativus

Ceratonia siliqua

Ceratonia siliqua

Cercis siliquastrum

Cercis siliquastrum

Hippocrepis

Hippocrepis ciliata, *H. comosa*, *H. unisiliquosa*

Robinia pseudacacia

Robinia pseudacacia

Arachis hypogaea

Arachis hypogaea

OXALIDACEAE**Oxalis**

Oxalis acetosella, *O. corniculata*, *O. pes-caprae*

GERANIACEAE**Geranium**

Geranium robertianum group

Geranium purpureum, *G. pusillum*, *G. pyrenaicum*, *G. robertianum*, *G. rotundifolium*

Geranium bohemicum group

Geranium bohemicum, *G. macrorrhizum*

?*Geranium aristatum*, *G. cinereum*, *G. reflexum*

Geranium pratense group

Geranium pratense, *G. sanguineum*, *G. sylvaticum*

?*Geranium asphodeloides*, *G. macrostylum*, *G. tuberosum*

Geranium molle group

Geranium columbinum, *G. dissectum*, *G. divaricatum*, *G. lucidum*, *G. molle*, *G. versicolor*

?*Geranium brutium*

Erodium

Erodium botrys, *E. ciconium*, *E. cicutarium*, *E. hoefftianum*, *E. malacoides*, *E. moschatum*

ZYGOPHYLLACEAE

Peganum harmala

Peganum harmala

Tribulus terrestris

Tribulus terrestris

LINACEAE

***Linum usitatissimum* type**

Linum bienne, *L. usitatissimum*

***Linum austriacum* type**

Linum austriacum, *L. perenne*, *L. punctatum*

Radiola linoides

Radiola linoides

***Linum catharticum* type**

Linum catharticum

Linum catharticum

Linum tenuifolium

Linum tenuifolium

Linum trigynum

Linum trigynum

Linum strictum group

Linum hirsutum, *L. strictum*

?*Linum pubescens*, *L. spathulatum*

***Linum hologynum* type**

Linum hologynum

?*Linum aroanium*, *L. capitatum*, *L. elegans*, *L. nodiflorum*, *L. tauricum*, *L. thracicum*

EUPHORBIACEAE

Andrachne telephioides

Andrachne telephioides

Mercurialis perennis

Mercurialis perennis

***Mercurialis annua* type**

Mercurialis annua

?*Mercurialis ovata*

Euphorbia

Euphorbia amygdaloides, *E. brittingeri*, *E. chamaesyce*, *E. esula*, *E. exigua*, *E. falcata*, *E. helioscopia*, *E. lathyris*, *E. nicaeensis*, *E. palustris*, *E. peplus*, *E. platyphyllos*, *E. pubescens*, *E. segetalis*, *E. seguierana*, *E. serrulata*, *E. spinosa*, *E. villosa*

?*Euphorbia agraria*, *E. aleppica*, *E. barbelieri*, *E. cyparissias*, *E. deflexa*, *E. epithymoides*, *E. flavicoma*, *E. glabriflora*, *E. heldreichii*, *E. herniariifolia*, *E. lathyris*, *E. lingulata*, *E. lucida*, *E. myrsinites*, *E. oblongata*, *E. phymatosperma*, *E. salicifolia*, *E. taurinensis*

Ricinus communis

Ricinus communis

RUTACEAE

Dictamnus albus

Dictamnus albus

Ruta chalepensis

Ruta chalepensis

***Ruta montana* type**

Ruta montana

?*Ruta graveolens*

Haplophyllum

?*Haplophyllum boissieranum*, *H. coronatum*, *H. patavinum*

Citrus

Citrus aurantium, *C. limon*, *C. sinensis*

SIMAROUBACEAE

Ailanthus altissima

Ailanthus altissima

POLYGALACEAE

***Polygala monspeliaca* type**

Polygala monspeliaca

?*Polygala alpestris*, *P. major*, *P. nicaeensis*, *P. supina*

***Polygala vulgaris* type**

Polygala vulgaris

?*Polygala comosa*

ANACARDIACEAE

Rhus coriaria

Rhus coriaria

Schinus molle

Schinus molle

Pistacia

Pistacia lentiscus, *P. terebinthus*

Cotinus coggygria

Cotinus coggygria

ACERACEAE

Acer

Acer campestre, *A. monspessulanum*, *A. opalus*, *A. platanoides*, *A. pseudoplatanus*

?*Acer heldreichii*, *A. hyrcanum*, *A. obtusatum*, *A. sempervirens*, *A. tataricum*

HIPPOCASTANACEAE

Aesculus hippocastanum

Aesculus hippocastanum

BALSAMINACEAE

Impatiens noli-tangere

Impatiens noli-tangere

AQUIFOLIACEAE

Ilex aquifolium

Ilex aquifolium

CELASTRACEAE

***Euonymus europaeus* type**

Euonymus europaeus

?*Euonymus latifolius*, *E. verrucosus*

BUXACEAE

Buxus sempervirens

Buxus sempervirens

RHAMNACEAE

Frangula

Frangula alnus

?*Frangula rupestris*

***Rhamnus* type**

Paliurus spina-christi, *Rhamnus alpinus*, *R. saxatilis*, *Ziziphus jujuba*, *Z. lotus*

?*Paliurus microcarpus*, *Rhamnus prunifolius*

VITACEAE

Vitis vinifera

Vitis vinifera subsp. *sylvestris*, *V. vinifera* subsp. *vinifera*

TILIACEAE

Tilia platyphyllos

Tilia platyphyllos

?*Tilia rubra*

***Tilia cordata* type**

Tilia cordata, *T. tomentosa*

MALVACEAE

***Abutilon* type**

Abutilon theophrasti, *Malvella sherardiana*

***Alcea* type**

Alcea pallida, *Althaea cannabina*

?*Alcea heldreichii*

Althaea hirsuta

Althaea hirsuta

Althaea officinalis

Althaea officinalis

Malva moschata

Malva moschata

Malva pusilla

Malva pusilla pp.

***Malva sylvestris* type**

Lavatera thuringiaca, *Malva neglecta*, *M. nicaeensis*, *M. pusilla* pp., *M. sylvestris*, *M. verticillata*

Hibiscus

Hibiscus trionum

?*Hibiscus syriacus*

Abelmoschus esculentus

Abelmoschus esculentus

Gossypium

Gossypium herbaceum, *G. hirsutum*

THYMELAEACEAE

Daphne

Daphne blagayana, *D. gnidium*, *D. laureola*, *D. mezereum*, *D. oleoides*

ELAEAGNACEAE

Elaeagnus angustifolia

Elaeagnus angustifolia

GUTTIFERAE

Hypericum hircinum type

Hypericum hircinum

?*Hypericum empetrifolium*

Hypericum perforatum type

Hypericum hirsutum, *H. perforatum*, *H. tetrapterum*

?*Hypericum annulatum*, *H. barbatum*, *H. linarioides*, *H. olympicum*, *H. rumeliacum*, *H. spruneri*, *H. thasium*

VIOLACEAE

Viola hirta type

Viola alba, *V. elatior*, *V. hirta*, *V. odorata*, *V. riviniana* pp.

Viola riviniana type

Viola reichenbachiana, *V. riviniana* pp.

Viola arvensis type

Viola arvensis, *V. kitaibeliana*, *V. tricolor*

?*Viola aetolica*, *V. allchariensis*, *V. brachyphylla*, *V. chelmea*, *V. dukadjinica*, *V. epirota*, *V. eximia*, *V. gracilis*, *V. heterophylla*, *V. magellensis*, *V. orphanidis*, *V. pyrenaica*, *V. rupestris*, *V. sieheana*

CISTACEAE

Helianthemum

Helianthemum apenninum, *H. canum*, *H. ledifolium*, *H. nummularium*, *H. oelandicum*, *H. salicifolium*

Tuberaria guttata

Tuberaria guttata

Cistus monspeliensis type

Cistus monspeliensis

?*Cistus incanus*, *C. parviflorus*

Cistus salvifolius

Cistus salvifolius

Fumana

Fumana aciphylla, *F. arabica*, *F. bonapartei*

TAMARICACEAE

Myricaria germanica

Myricaria germanica

Tamarix

Tamarix dalmatica, *T. hampeana*, *T. parviflora*, *T. smyrnensis*, *T. tetrandra*

ELATINACEAE

Elatine alsinastrum

Elatine alsinastrum

CUCURBITACEAE

Cucumis melo

Cucumis melo

?*Citrullus lanatus*

Bryonia

Bryonia alba, *B. cretica*

Lagenaria siceraria

Lagenaria siceraria

Cucurbita

Cucurbita ficifolia, *C. maxima*, *C. mixta*, *C. moschata*, *C. pepo*

LYTHRACEAE

***Lythrum salicaria* type**

Lythrum hyssopifolia, *L. junceum*, *L. salicaria*, *L. tribracteatum*

?*Lythrum borysthenticum*, *L. virgatum*

Lythrum portula

Lythrum portula

TRAPACEAE

Trapa natans

Trapa natans

MYRTACEAE

Myrtus communis

Myrtus communis

PUNICACEAE

Punica granatum

Punica granatum

ONAGRACEAE

Circaea lutetiana

Circaea lutetiana

Ludwigia palustris

Ludwigia palustris

***Epilobium angustifolium* type**

Epilobium angustifolium, *Oenothera biennis*

***Epilobium hirsutum* type**

Epilobium hirsutum, *E. montanum*, *E. palustre*, *E. parviflorum*, *E. tetragonum*

?*Epilobium adenocaulon*, *E. alsinifolium*, *E. anagallidifolium*, *E. dodonaei*, *E. gemmascens*, *E. lanceolatum*, *E. obscurum*, *E. roseum*

HALORAGACEAE

Myriophyllum verticillatum

Myriophyllum verticillatum

Myriophyllum spicatum

Myriophyllum spicatum

THELIGONACEAE

Theligonum cynocrambe

Theligonum cynocrambe

CORNACEAE

Cornus sanguinea

Cornus sanguinea

Cornus mas

Cornus mas

ARALIACEAE

Hedera helix

Hedera helix

UMBELLIFERAE

Hydrocotyle vulgaris

Hydrocotyle vulgaris

Anthriscus caucalis

Anthriscus caucalis

Torilis nodosa

Torilis nodosa

Physospermum cornubiense

Physospermum cornubiense

Smyrniium

Smyrniium olusatrum, *S. perfoliatum*

Ligusticum

?*Ligusticum lucidum*, *Ligusticum rhizomaticum*

Bupleurum

Bupleurum asperuloides, *B. falcatum*, *B. flavicans*, *B. fruticosum*, *B. gerardi*, *B. glumaceum*, *B. karglii*, *B. lancifolium*, *B. praealtum*, *B. rotundifolium*, *B. tenuissimum*

Sison amomum

Sison amomum

Carum

?*Carum heldreichii*, *C. multiflorum*, *C. rigidulum*

??*Stefanoffia daucoides*

Berula erecta

Berula erecta

Trinia

Trinia dalechampii, *T. glauca*

Sanicula europaea

Sanicula europaea

Conium maculatum

Conium maculatum

Cachrys

?*Cachrys cristata*, *C. ferulacea*

Cnidium silaifolium

Cnidium silaifolium

Seseli type

Opopanax chironium, *Seseli libanotis*, *S. pallasii*, *S. parnassicum*, *S. peucedanoides*, *S. rigidum*, *S. tortuosum*

?*Opopanax hispidus*

Oenanthe type

Oenanthe aquatica group

Oenanthe aquatica, *O. lachenalii*

Oenanthe pimpinelloides group

Oenanthe pimpinelloides

?*Oenanthe tenuifolia*

- Oenanthe silaifolia* group
 - Oenanthe silaifolia*
 - ?*Athamanta macedonica*, *Oenanthe banatica*
- Oenanthe fistulosa*
 - Oenanthe fistulosa*
- Cicuta virosa***
 - Cicuta virosa*
- Chaerophyllum hirsutum* type**
 - Chaerophyllum hirsutum*
 - ?*Chaerophyllum aromaticum*
- Chaerophyllum temulentum* type**
 - Chaerophyllum temulentum*
 - ??*Myrrhoides nodosa*
- Ammi***
 - Ammi majus*, *A. visnaga*
- Pimpinella saxifraga***
 - Pimpinella saxifraga*
- Torilis arvensis***
 - Torilis arvensis*
- Anethum graveolens***
 - Anethum graveolens*
- Falcaria vulgaris***
 - Falcaria vulgaris*
- Peucedanum austriacum* type**
 - Peucedanum austriacum*
 - ?*Peucedanum aegopodioides*, *P. longifolium*, *P. oligophyllum*, *P. stridii*, *P. vittijugum*, *P. vourinense*
- Angelica sylvestris***
 - Angelica sylvestris*
- Petroselinum crispum***
 - Petroselinum crispum*
- Peucedanum schottii***
 - Peucedanum schottii*
- Bunium***
 - Bunium ferulaceum*
 - ?*Bunium tenerum*
 - ??*Huetia cynapioides*
- Foeniculum vulgare* ssp. *vulgare***
 - Foeniculum vulgare* ssp. *vulgare*
 - ??*Ferulago campestris*, *F. nodosa*, *F. sylvatica*
- Anthriscus sylvestris* type**
 - Anthriscus sylvestris*
 - ?*Anthriscus nemorosa*
- Orlaya***
 - Orlaya grandiflora*
 - ?*Orlaya daucorlaya*, *O. kochii*, *O. topaliana*
- Pastinaca sativa***
 - Pastinaca sativa*
- Eryngium***
 - Eryngium campestre*
 - ?*Eryngium amethystinum*, *E. creticum*, *E. palmatum*
- Scandix* type**
 - Caucalis platycarpos*, *Scandix australis*, *S. pecten-veneris*, *Turgenia latifolia*

- Heracleum sphondylium***
Heracleum sphondylium
- Pimpinella anisum* type**
Pimpinella anisum
 ?*Pimpinella peregrina*, *P. tragium*
- Anthriscus cerefolium***
Anthriscus cerefolium
- Laserpitium siler***
Laserpitium siler
- Torilis japonica* type**
Torilis japonica
 ?*Torilis leptophylla*, *T. ucranica*
- Daucus***
Daucus broteri, *D. carota*
 ?*Daucus guttatus*
- Coriandrum* type**
Bifora testiculata, *Coriandrum sativum*
- Aegopodium podagraria***
Aegopodium podagraria
- Chaerophyllum aureum***
Chaerophyllum aureum
- Malabaila***
Malabaila aurea, *M. involucrata*
- Tordylium officinale***
Tordylium officinale
- Echinophora* type**
Echinophora tenuifolia, *Tordylium maximum*
- Conopodium capillifolium*** (= *Conopodium majus* type in NW4)
 ?*Conopodium capillifolium*

PYROLACEAE

- Monotropa hypopitys***
Monotropa hypopitys
- Pyrola***
Pyrola chlorantha, *P. minor*
- Moneses uniflora***
Moneses uniflora

ERICACEAE

- Erica herbacea***
Erica herbacea
- Vaccinium myrtillus***
Vaccinium myrtillus

PRIMULACEAE

- Soldanella***
 ?*Soldanella hungarica*, *S. pindicola*
- Cyclamen***
Cyclamen hederifolium
 ?*Cyclamen graecum*, *C. repandum*
- Androsace villosa***
Androsace villosa
- Androsace maxima***
Androsace maxima

Primula

Primula elatior, *P. veris*, *P. vulgaris*

?*Primula halleri*

Lysimachia

Lysimachia atropurpurea, *L. dubia*, *L. nummularia*, *L. punctata*, *L. vulgaris*

Anagallis arvensis type

Anagallis arvensis, *A. foemina*

Anagallis tenella type

Anagallis minima, *A. tenella*

Asterolinon linum-stellatum

Asterolinon linum-stellatum

Samolus valerandi

Samolus valerandi

PLUMBAGINACEAE

Armeria maritima type

Acantholimon androsaceum, *Armeria canescens*, *A. maritima*, *A. rumelica*, *A. sancta*, *A. undulata*, *Goniolimon tataricum*

Plumbago europaea

Plumbago europaea

EBENACEAE

Diospyros lotus

Diospyros lotus

STYRACACEAE

Styrax officinalis

Styrax officinalis

OLEACEAE

Fraxinus excelsior type

Fraxinus angustifolia ssp. *oxycarpa*, *F. excelsior*

Fraxinus angustifolia

Fraxinus angustifolia

Fraxinus ornus

Fraxinus ornus

Ligustrum vulgare

Ligustrum vulgare

Phillyrea

Phillyrea latifolia, *P. media*

Jasminum

Jasminum fruticans

?*Jasminum humile*

GENTIANACEAE

Gentiana verna

Gentiana verna

Gentianella ciliata

Gentianella ciliata

Cicendia filiformis

Cicendia filiformis

Centaurium

Centaurium erythraea, *C. pulchellum*, *C. tenuiflorum*

Blackstonia perfoliata

Blackstonia perfoliata ssp. *perfoliata*, *B. perfoliata* ssp. *serotina*

***Gentiana lutea* type**

Gentiana asclepiadea, *G. cruciata*, *G. lutea*

MENYANTHACEAE

Nymphoides peltata

Nymphoides peltata

APOCYNACEAE

Vinca herbacea

Vinca herbacea

ASCLEPIADACEAE

Periploca graeca

Periploca graeca

Vincetoxicum

Vincetoxicum hirundinaria

?*Vincetoxicum fuscum*, *V. speciosum*

CONVOLVULACEAE

Convolvulus

Convolvulus arvensis, *C. betonicifolius*, *C. boissieri*, *C. cantabrica*, *C. holosericeus*

***Cuscuta epithymum* type**

Cuscuta epithymum, *C. planiflora*

?*Cuscuta approximata*, *C. australis*, *C. suaveolens*

***Cuscuta europaea* type**

Cuscuta campestris, *C. europaea*, *C. palaestina*

Cuscuta monogyna

Cuscuta monogyna

Calystegia

Calystegia sepium, *C. silvatica*

Ipomoea

Ipomoea batatas, *I. purpurea*

BORAGINACEAE

***Cynoglossum* type**

Cynoglossum creticum, *C. officinale*, *Rindera graeca*

?*Cynoglossum hungaricum*, *C. nebrodense*, *Solenanthus albanicus*

Heliotropium

Heliotropium europaeum, *H. suaveolens*, *H. supinum*

?*Heliotropium hirsutissimum*

***Myosotis* type**

Asperugo procumbens, *Myosotis arvensis*, *M. laxa* ssp. *caespitosa*, *M. nemorosa*, *M. ramosissima*, *M. sicula*, *M. stricta*, *M. sylvatica*, *Omphalodes verna*

?*Myosotis incrassata*, *M. refracta*, *M. sparsiflora*, *M. suaveolens*, *Rochelia disperma*

Lappula

Lappula squarrosa

?*Lappula marginata*

Echium

Echium italicum, *E. plantagineum*, *E. vulgare*

***Alkanna* type**

Alkanna tinctoria

?*Alkanna corcyrensis*, *A. noneiformis*, *A. pindicola*, *Halacsya sendtneri*

Borago officinalis

Borago officinalis

Cerinthe type

Cerinthe minor, *C. retorta*

??*Moltkia petraea*, *Onosma elegantissima*, *O. graeca*, *O. helvetica*, *O. heterophylla*, *O. mattirolii*, *O. montana*, *O. pygmaeum*, *O. rhodopea*, *O. taurica*, *O. visianii*

Symphytum

Symphytum bulbosum, *S. ottomanum*

Buglossoides arvensis type

Buglossoides arvensis

?*Buglossoides tenuiflora*

Neatostema apulum

Neatostema apulum

Anchusa arvensis type

Anchusa arvensis, *A. azurea*

?*Anchusa cretica*

Nonea

?*Nonea pallens*, *N. pulla*, *N. ventricosa*

Pulmonaria mollis

Pulmonaria mollis

Anchusa officinalis type

Anchusa officinalis, *A. stylosa*

?*Anchusa macedonica*, *A. serpentinicola*, *A. thessala*

Lithospermum

Lithospermum officinale

?*Lithospermum goulandriorum*

Buglossoides purpureocaerulea

Buglossoides purpureocaerulea

VERBENACEAE

Verbena

Verbena officinalis, *V. supina*

Vitex agnus-castus

Vitex agnus-castus

CALLITRICHACEAE

Callitriche obtusangula

Callitriche obtusangula

Callitriche stagnalis type

Callitriche stagnalis

?*Callitriche truncata*

LABIATAE

Teucrium

Teucrium chamaedrys, *T. halacsyanum*, *T. montanum*, *T. polium*, *T. scordium*

Stachys sylvatica type

Lamium album, *L. amplexicaule*, *L. maculatum*, *L. purpureum*, *Leonurus cardiaca*, *L. marrubiastrum*, *Melittis melissophyllum*, *Stachys alopecuroides*, *S. alpina*, *S. annua*, *S. cretica*, *S. germanica*, *S. goulimyi*, *S. menthifolia*, *S. officinalis*, *S. palustris*, *S. sylvatica*, ?*Lamiastrum galeobdolon*, *Lamium bifidum*, *L. garganicum*, *Stachys atherocalyx*, *S. balcanica*, *S. cassia*, *S. decumbens*, *S. iva*, *S. leucoglossa*, *S. obliqua*, *S. parolini*, *S. plumosa*, *S. scardica*, *S. serbica*, *S. spinulosa*, *S. thirkei*, *S. tymphaea*

Stachys arvensis

Stachys arvensis

PEDALIACEAE

Sesamum indicum

Sesamum indicum

GESNERIACEAE

?*Ramonda*

?*Ramonda nathaliae*, *R. serbica*

OROBANCHACEAE

Orobanche minor type

Orobanche amethystea, *O. crenata*, *O. gracilis*, *O. minor*, *O. reticulata*

?*Orobanche alba*, *O. cernua*, *O. elatior*, *O. grisebachii*, *O. hederæ*, *O. loricata*, *O. lutea*,
O. oxyloba, *O. pubescens*, *O. rechingeri*, Scrophulariaceae: *Rhynchocorys elephas*

Orobanche ramosa type

Orobanche ramosa, Scrophulariaceae: *Tozzia alpina*

LENTIBULARIACEAE

Pinguicula

Pinguicula alpina, *P. vulgaris*

?*Pinguicula balcanica*, *P. hirtiflora*

Utricularia

Utricularia intermedia, *U. minor*, *U. vulgaris*

RUBIACEAE

Putoria calabrica

Putoria calabrica

Crucianella

Crucianella angustifolia

?*Crucianella latifolia*

Sherardia arvensis

Sherardia arvensis

Galium type

Asperula aristata, *A. arvensis*, *A. cynanchica*, *A. laevigata*, *A. taurina*, *Cruciata laevipes*,
Galium album, *G. aparine*, *G. corrudifolium*, *G. debile*, *G. divaricatum*, *G. elongatum*, *G.*
lucidum, *G. odoratum*, *G. palustre*, *Galium x pomeranicum*, *G. rotundifolium*, *G. setaceum*,
G. spurium, *G. tricornutum*, *G. verrucosum*, *G. verticillatum*, *G. verum*, *Rubia peregrina*,
R. tinctorum

?*Asperula chlorantha*, *A. doerfleri*, *A. involucrata*, *A. lutea*, *A. purpurea*, *A. rumelica*, *A.*
tenella, *Cruciata glabra*, *C. pedemontana*, *Galium absurdum*, *G. advenum*, *G.*
anisophyllum, *G. asparagifolium*, *G. breviramsum*, *G. circae*, *G. degenii*, *G. hellenicum*,
G. humifusum, *G. incanum*, *G. intricatum*, *G. laconicum*, *G. monasterium*, *G. octonarium*,
G. ophiolithicum, *G. oreophilum*, *G. pisoderium*, *G. procurrens*, *G. pseudaristatum*, *G.*
rhodopeum, *G. rigidifolium*, *G. rivale*, *G. sacrorum*, *G. scabrifolium*, *G. speciosum*, *G.*
tenuissimum

Valantia

?*Valantia aprica*, *V. hispida*

PLANTAGINACEAE

Plantago major

Plantago major subsp. *intermedia*, *P. major* subsp. *major*

Plantago afra

Plantago afra

Plantago alpina type

Plantago alpina, *P. serraria*, *P. subulata*

***Plantago lanceolata* type**

Plantago altissima, *P. lagopus*, *P. lanceolata*

?*Plantago cretica*, *P. gentianoides*, *P. holostium*, *P. reniformis*, *P. squarrosa*

Plantago coronopus

Plantago coronopus

Plantago bellardii

Plantago bellardii

Plantago media

Plantago media

Plantago arenaria

Plantago arenaria

Plantago argentea

Plantago argentea

Plantago albicans

Plantago albicans

Plantago amplexicaulis

Plantago amplexicaulis

Plantago atrata

Plantago atrata

CAPRIFOLIACEAE

Sambucus nigra

Sambucus nigra

Sambucus ebulus

Sambucus ebulus

Lonicera alpigena

Lonicera alpigena

***Lonicera periclymenum* type**

Lonicera periclymenum

?*Lonicera etrusca*

***Lonicera xylosteum* type**

Lonicera nigra, *L. xylosteum*

Viburnum

Viburnum lantana, *V. opulus*, *V. tinus*

VALERIANACEAE

***Valerianella rimosa* type**

Valerianella coronata, *V. eriocarpa*, *V. rimosa*

?*Valerianella microcarpa*

Valeriana tuberosa

Valeriana tuberosa

***Valeriana officinalis* type**

Valeriana officinalis

?*Valeriana crinii*, *V. dioscoridis*

Centranthus

Centranthus calcitrapae

?*Centranthus longiflorus*

***Valerianella locusta* type**

Valerianella carinata, *V. locusta*

?*Valerianella costata*, *V. echinata*, *V. pumila*, *V. turgida*

DIPSACACEAE

Succisa pratensis

Succisa pratensis

Scabiosa columbaria type

Scabiosa atropurpurea, *S. columbaria*

?*Scabiosa taygetea*, *S. tenuis*, *S. triniifolia*, *S. webbiana*

Dipsacus type

Dipsacus fullonum, *D. laciniatus*

?*Cephalaria ambrosioides*, *C. flava*, *C. transylvanica*

Knautia

Knautia integrifolia

?*Knautia ambigua*, *K. drymeia*, *K. longifolia*, *K. macedonica*, *K. magnifica*, *K. orientalis*

Scabiosa sicula type

Scabiosa graminifolia, *S. sicula*

?*Scabiosa argentea*, *S. crenata*, *S. epirota*

Pterocephalus type

Pterocephalus papposus

?*Pterocephalus perennis*, *Tremastelma palaestinum*

Morina persica

Morina persica

CAMPANULACEAE

Jasione

?*Jasione heldreichii*, *J. laevis*

Campanula erinus type

Campanula erinus, *C. glomerata*, *C. persicifolia*, *C. rapunculus*, *C. trachelium*

?*Campanula albanica*, *C. cervicaria*, *C. foliosa*, *C. formanekiana*, *C. hawkinsiana*, *C.*

lingulata, *C. macrostachya*, *C. patula*, *C. phrygia*, *C. ramosissima*, *C. scutellata*, *C.*

sparsa, *C. spatulata*, *C. trichocalycina*, *C. tymphaea*, *C. versicolor*, *Edraianthus*

graminifolius, *E. tenuifolius*, *L. speculum-veneris*, *Trachelium jacquinii*

Campanula rotundifolia

Campanula rotundifolia

Asyneuma type

Asyneuma canescens, *Campanula* pp., *Legousia hybrida*

?*Asyneuma limonifolium*

Phyteuma

Phyteuma orbiculare

?*Phyteuma confusum*

COMPOSITAE

Subfamily Asteroideae ('Tubiliflorae type')

Solidago type

Tribe Heliantheae: *Bidens cernua*, *B. tripartita*, *Helianthus annuus*

Tribe Astereae: *Aster alpinus*, *A. amellus*, *A. linosyris*, *A. novi-belgii*, *A. tripolium*, *Bellis*

annua, *B. perennis*, *B. sylvestris*, *Conyza canadensis*, *Erigeron acer*, *E. alpinus*, *E.*

epiroticus, *E. glabratus*, *Solidago virgaurea*

Tribe Inuleae: *Antennaria dioica*, *Dittrichia graveolens*, *D. viscosa*, *Filago pyramidata*, *F.*

vulgaris, *Gnaphalium luteo-album*, *Inula britannica*, *I. conyza*, *I. germanica*, *I. helenium*, *I.*

salicina, *Pallenis spinosa*, *Pulicaria dysenterica*, *P. vulgaris*

Tribe Calendula: *Calendula arvensis*

Tribe Senecioneae: *Petasites hybridus*, *Senecio aquaticus*, *S. doronicum*, *S. erucifolius*, *S.*

fluvialis, *S. gallicus*, *S. integrifolius*, *S. jacobaea*, *S. macedonicus*, *S. othonnae*, *S.*

papposus, *S. scopoli*, *S. squalidus*, *S. thapsoides*, *S. vernalis*, *S. viscosus*, *S. vulgaris*,

Tussilago farfara

Tribe Eupatorieae: *Eupatorium cannabinum*

Tribe Lactuceae (Subfamily Cichorioideae): *Scorzonera austriaca*

?Tribe Senecioneae: *Adenostyles alliariae*, *Doronicum austriacum*, *D. clusii*, *D. columnae*, *D. orientale*

Tribe Inuleae: *Evax pygmaea*, *Filaginella uliginosa*, *Helichrysum italicum*, *H. plicatum*, *H. stoechas*, *Inula ensifolia*, *I. hirta*, *I. oculus-christi*, *I. verbascifolia*, *Logfia arvensis*, *L. gallica*, *L. minima*, *Omalotheca hoppeana*, *O. roeseri*, *O. supina*, *O. sylvatica*, *Phagnalon graecum*

Echinops

Tribe Cardueae: *Echinops bannaticus*, *E. mirocephalus*, *E. ritro*, *E. sphaerocephalus*

Artemisia

Tribe Anthemideae: *Artemisia abrotanum*, *A. absinthium*, *A. alba*, *A. campestris*, *A. eriantha*, *A. vulgaris*

Carlina type

Tribe Cardueae: *Arctium lappa*, *A. minus*, *A. tomentosum*, *Carlina acanthifolia*, *C. acaulis*, *C. corymbosa*, *C. frigida*, *C. vulgaris*, *Carthamus dentatus*, *C. lanatus*, *Onopordum acanthium*, *O. bracteatum*, *O. tauricum*

?*Jurinea glycacantha*, *J. mollis*, *Staelina uniflosculosa*

??Tribe Cardueae: *Cnicus benedictus*

Picnomon acarna

Tribe Cardueae: *Picnomon acarna*

Achillea type

Tribe Anthemideae: *Achillea clypeolata*, *A. coarctata*, *A. millefolium*, *A. nobilis*, *A. ptarmica*, *A. setacea*, *Anthemis altissima*, *A. arvensis*, *A. carpatica*, *A. cotula*, *A. cretica*, *A. tinctoria*, *A. triumfetti*, *Chamomilla recutita*, *Coleostephus myconis*, *Matricaria caucasica*, *M. perforata*, *M. tempskyana*, *M. trichophylla*, *Tanacetum corymbosum*, *T. vulgare*

Tribe Cardueae: *Serratula tinctoria*

?Tribe Anthemideae: *Achillea abrotanoides*, *A. absinthoides*, *A. ageratifolia*, *A. chrysocoma*, *A. clavennae*, *A. clusiana*, *A. collina*, *A. crithmifolia*, *A. depressa*, *A. distans*, *A. fraasii*, *A. grandifolia*, *A. holosericea*, *A. lingulata*, *A. pannonica*, *A. pindicola*, *Anthemis auriculata*, *A. coelopoda*, *A. meteorica*, *A. parnassica*, *A. ruthenica*, *A. segetalis*, *A. tenuiloba*, *A. tomentosa*, *Leucanthemum praecox*, *L. vulgare*, *Tanacetum macrophyllum*

Tribe Cardueae: *Xeranthemum annuum*, *X. cylindraceum*, *X. inapertum*

Centaurea cyanus type

Tribe Cardueae: *Centaurea cyanus*, *C. depressa*, *C. pinardii*

Centaurea napulifera type

Tribe Cardueae: *Centaurea napulifera*, *C. pindicola*, *C. triumfetti*

Cirsium type

Tribe Cardueae: *Carduus acanthoides*, *C. acicularis*, *C. candicans*, *C. cronius*, *C. hamulosus*, *C. kernerii*, *C. pycnocephalus*, *C. thessalus*, *C. tmoleus*, *Cirsium appendiculatum*, *C. arvense*, *C. candelabrum*, *C. creticum*, *C. eriophorum*, *C. erisithales*, *C. heldreichii*, *C. ligulare*, *C. mairei*, *C. tymphaeum*, *C. vulgare*

?Tribe Cardueae: *Carduus macrocephalus*, *C. taygeteus*, *C. thoermeri*

Xanthium

Tribe Heliantheae: *Xanthium spinosum*, *X. strumarium*

Centaurea solstitialis type

Tribe Cardueae: *Centaurea affinis*, *C. alba*, *C. attica*, *C. calcitrapa*, *C. charreltii*, *C. cuneifolia*, *C. diffusa*, *C. grisebachii*, *C. iberica*, *C. jacea*, *C. kalambakensis*, *C. lactiflora*, *C. melitensis*, *C. nicopolitana*, *C. niederi*, *C. orphanidea*, *C. pallidior*, *C. pannosa*, *C. pelia*, *C. solstitialis*, *C. tymphaea*, *C. uniflora*, *C. zuccariniana*, *Cynara scolymus*

?Tribe Cardueae: *Amphoricarpos neumayeri*, *Centaurea deustiformis*, *C. epirota*, *C. immanuelis-loewii*, *C. macedonica*, *C. pannonica*, *C. pawlowski*, *C. stenolepis*, *C. stereophylla*, *C. triamularia*, *C. vlachorum*, *C. weldeniana*, *Ptilostemon afer*, *P. chamaepeuce*, *P. gnaphaloides*, *P. strictus*

Centaurea graeca type

Tribe Cardueae: *Centaurea graeca*, *C. psilacantha*, *C. rupestris*, *C. salonitana*, *C. spruneri*

Centaurea amplifolia

Tribe Cardueae: *Centaurea amplifolia*

Crupina

Tribe Cardueae: *Crupina crupinastrum*, *C. vulgaris*

Subfamily Cichorioideae ('Liguliflorae type', 'Taraxacum type')

Tragopogon

Tragopogon dubius, *T. porrifolius*, *T. pratensis*

?*Tragopogon balcanicus*, *T. crocifolius*, *T. hybridus*, *T. tommasinii*

***Scorzonera laciniata* type**

Scorzonera doria, *S. laciniata*; *S. purpurea*

***Scorzonera hispanica* type**

Scorzonera hispanica

?*Scorzonera cana*, *S. mollis*, *S. parviflora*

***Sonchus* type**

Reichardia picroides, *Sonchus arvensis*, *S. asper*, *S. oleraceus*, *S. tenerrimus*

??*Cephalorrhynchus tuberosus*

***Lactuca* type**

Lactuca quercina, *L. saligna*, *L. sativa*, *L. serriola*, *L. viminea*, *L. virosa*, *Mycelis muralis*,
Rhagadiolus stellatus

?*Lactuca aurea*, *L. graeca*

Scolymus

Scolymus hispanicus, *S. maculatus*

***Cichorium* type**

Cichorium intybus, *Crepis pulchra*

***Hieracium* type**

Hieracium/Pilosella agg., *Hieracium amplexicaule*, *H. dasycraspedum*, *H. epirense*, *H. ferdinandi-coburgi*, *H. lactucella*, *H. naegelianiforme*, *H. necopinum*, *H. pilosella*, *H. trikalense*, *Tolpis barbata*

?*Hieraceum* subgenus *Pilosella*: *Hieracium* x *auriculoides*, *H. caespitosum*, *H. cymosum*,
H. x densiflorum, *H. x fuscitrum*, *H. x halacsyi*, *H. hoppeanum*, *H. x macrotrichum*, *H. pavichii*, *H. piloselloides*, *H. praealtum*, *H. pseudopilosella*, *H. x ruprechtii*, *H. x spurium*,
H. x zizianum

Hieraceum subgenus *Hieraceum*: *H. amplexicaule* group (*H. petraeum*), *H. bifidum* group (*H. caesiiflorum*, *H. stenolepis*), *H. bracteolatum* group (*H. bracteolatum*), *H. dolopicum* group (*H. dolopicum*), *H. eriobasis* group, *H. gaudryi* group (*H. gaudryi*), *H. graecum* group (*H. graecum*), *H. gymnocephalum* group (*H. gymnocephalum*), *H. heldreichii* group, *H. hypochoeroides* group, *H. latifolium* group (*H. brachyphyllum*), *H. lazistanum* group (*H. leithneri*), *H. marmoreum* group (*H. megalothecum*), *H. murorum* group (*H. grandidens*, *H. integratum*, *H. semisilvaticum*), *H. naegelianum* group (*H. naegelianum*), *H. pannosum* group (*H. friwaldii*, *H. pannosum*), *H. parnassi* group (*H. parnassi*, *H. pseudobracteolatum*), *H. pilosissimum* group, *H. pseudorieni* group (*H. scardicum*), *H. racemosum* group (*H. barbatum*, *H. crinitum*, *H. italicum*, *H. racemosum*), *H. sabaudum* group (*H. obliquum*, *H. sabaudum*), *H. sartorianum* group, *H. scapigerum* group, *H. schmidtii* group (*H. pallidum*), *H. sericophyllum* group, *H. silesiacum* group, *H. umbrosum* group (*H. umbrosum*), *H. waldsteinii* group (*H. delpinoi*, *H. waldsteinii*)

***Taraxacum* type**

Crepis capillaris, *C. foetida*, *C. vesicaria*, *Hypochoeris glabra*, *H. maculata*, *H. radicata*, *Lapsana communis*, *Leontodon autumnalis*, *L. crispus*, *L. hispidus*, *L. taraxacoides*, *Picris echioides*, *P. hieracioides*, *Taraxacum apenninum* group, *Taraxacum bithynicum* group (*T. bithynicum*, *T. megalorrhizon*, *T. minimum*), *Taraxacum erythrospermum* group (*T. pindicola*), *Taraxacum fulvum* group, *Taraxacum gasparrinii* group (*T. dorchocarpum*, *T. epirense*, *T. xanthiense*), *Taraxacum officinale* group (*T. copidophyllum*, *T. officinale*), *Taraxacum serotinum* group (*Taraxacum serotinum*)

?*Crepis aurea*, *C. baldaccii*, *C. dioscoridis*, *C. fraasii*, *C. geracioides*, *C. guioliana*,

C. merxmuelieri, *C. neglecta*, *C. rubra*, *C. sancta*, *C. setosa*, *C. turcica*, *C. viscidula*,
Leontodon cichoraceus, *Picris pauciflora*, *P. sprengerana*, *Taraxacum aganippeum*, *T.*
bulgaricum, *T. gionense*, *Taraxacum glaciale*, *T. graecofontanum*, *Taraxacum hoppeanum*
group (*T. amborum*, *T. hoppeanum*, *T. poliochlorum*), *T. nudum*, *Taraxacum palustre*
group (*Taraxacum scaturiginosum*), *T. subolivaceum*
??*Calycocorsus stipitatus*, *Chondrilla juncea*, *C. ramosissima*, *Hedypnois cretica*,
Prenanthes purpurea

Monocotyledones

ALISMATACEAE

Sagittaria sagittifolia

Sagittaria sagittifolia

Baldellia ranunculoides

Baldellia ranunculoides

Alisma

Alisma gramineum, *A. lanceolatum*, *A. plantago-aquatic*

Damasonium alisma

Damasonium alisma

BUTOMACEAE

Butomus umbellatus

Butomus umbellatus

HYDROCHARITACEAE

Hydrocharis morsus-ranae

Hydrocharis morsus-ranae

Stratiotes aloides

Stratiotes aloides

Vallisneria spiralis

Vallisneria spiralis

JUNCAGINACEAE

Triglochin bulbosa

Triglochin bulbosa

POTAMOGETONACEAE

***Potamogeton crispus* type**

Groenlandia densa, *Potamogeton acutifolius*, *P. alpinus*, *P. berchtoldii*, *P. coloratus*, *P.*
compressus, *P. crispus*, *P. lucens*, *P. natans*, *P. nodosus*, *P. obtusifolius*, *P. perfoliatus*, *P.*
polygonifolius, *P. trichoides*

Potamogeton pectinatus

Potamogeton pectinatus

ZANNICHELLIACEAE

Zannichellia palustris

Zannichellia palustris

NAJADACEAE

Najas marina

Najas marina

LILIACEAE

Colchicum

Colchicum autumnale, *C. graecum*, *C. neapolitanum*, *C. triphyllum*
? *Colchicum bivonae*, *C. callicymbium*, *C. cupanii*, *C. hungaricum*, *C. lingulatum*, *C. turcicum*

Merendera sobolifera

Merendera sobolifera

Narthecium scardicum

Narthecium scardicum

Veratrum

Veratrum album
? *Veratrum nigrum*

Asphodelus fistulosus type

Asphodelus aestivus, *A. fistulosus*

Asphodelus albus

Asphodelus albus

Ornithogalum type

Asphodeline liburnica, *A. taurica*, *Ornithogalum arabicum*, *O. collinum*, *O. narbonense*,
O. nutans, *O. orthophyllum*, *O. pyrenaicum*, *O. umbellatum*, *Scilla hyacinthoides*
? *Ornithogalum armeniacum*, *O. comosum*, *O. divergens*, *O. exscapum*, *O. montanum*, *O. oligophyllum*, *O. refractum*, *O. sphaerocarpum*

Fritillaria

Fritillaria epirotica, *F. gussichiae*, *F. messanensis*, *F. mutabilis*, *F. orientalis*, *F. pontica*,
F. thessala

Gagea lutea type

Gagea arvensis, *G. bohémica*, *G. lutea*, *Paris quadrifolia*
? *Gagea amblyopetala*, *G. dubia*, *G. fibrosa*, *G. fistulosa*, *G. minima*, *G. pusilla*, *G. reticulata*, *G. saxatilis*

Gagea pratensis

Gagea pratensis

Tulipa sylvestris

Tulipa sylvestris

Tulipa praecox type

Tulipa gesnerana, *T. praecox*
? *Tulipa boeotica*, *T. clusiana*

Lilium

Lilium albanicum, *L. candidum*, *L. carniolicum*, *L. chalcedonicum*, *L. martagon*

Anthericum liliago

Anthericum liliago

Scilla type

Polygonatum verticillatum, *Scilla autumnalis*, *S. bifolia*, *S. hyacinthoides*
? *Scilla albanica*

Muscari comosum

Muscari comosum

Muscari neglectum type

Muscari neglectum
? *Muscari armeniacum*, *M. botryoides*, *M. cummutatum*, *M. macrocarpum*, *M. parviflorum*,
M. tenuiflorum
?? *Bellevalia ciliata*, *B. dubia*, *B. romana*, *B. trifoliata*, *Hyacinthus orientalis*, *Hyacinthella leucophaea*, *Strangweia spicata*

Allium roseum type

Allium neapolitanum, *A. roseum*

Allium sphaerocephalon type

Allium ampeloprasum, *A. atrovioleaceum*, *A. guttatum*, *A. sativum*, *A. scorodoprasum*, *A. sphaerocephalon*, *A. vineale*

Allium paniculatum type

Allium carinatum, *A. cepa*, *A. chamaemoly*, *A. moschatum*, *A. nigrum*, *A. pallens*, *A. paniculatum*, *A. schoenoprasum*, *A. subhirsutum*, *A. ursinum*
? *Allium amethystinum*, *A. amphipulchellum*, *A. bornmuelleri*, *A. breviradium*, *A. chamaespathum*, *A. favosum*, *A. flavum*, *A. frigidum*, *A. heldreichii*, *A. hirtovaginum*, *A. meteoricum*, *A. phthioticum*, *A. sipyleum*, *A. stamineum*, *A. suaveolens*

Polygonatum type

Polygonatum multiflorum, *P. odoratum*, *Ruscus aculeatus*, *R. hypoglossum*
? *Polygonatum latifolium*

Convallaria majalis

Convallaria majalis

Asparagus

Asparagus acutifolius, *A. officinalis*
? *Asparagus stipularis*, *A. tenuifolius*, *A. verticillatus*

Urginea maritima

Urginea maritima

Smilax

Smilax aspera
? *Smilax excelsa*

AMARYLLIDACEAE

Narcissus papyraceus type

Narcissus papyraceus, *N. poeticus*, *N. serotinus*

Narcissus tazetta

Narcissus tazetta

Sternbergia

Sternbergia lutea
? *Sternbergia colchiciflora*

Galanthus type

Galanthus nivalis, *Leucojum aestivum*
? *Leucojum valentinum*

DIOSCOREACEAE

Tamus communis

Tamus communis

IRIDACEAE

Hermodactylus tuberosus

Hermodactylus tuberosus

Iris pseudacorus

Iris pseudacorus

Iris spuria type

Iris spuria
? *Iris reichenbachii*, *I. sintenisii*, *I. suaveolens*

Iris pumila

Iris pumila

Iris germanica

Iris germanica

Gladiolus type

Gladiolus communis, *G. illyricus*, *G. italicus*, *Romulea bulbocodium*, *R. linariensis*
? *Gladiolus imbricatus*

Gynandriris sisyrinchium

Gynandriris sisyrinchium

Crocus

Crocus biflorus, *C. chrysanthus*, *C. flavus*

?*Crocus boryi*, *C. cvijicii*, *C. hadriaticus*, *C. olivieri*, *C. pulchellus*, *C. robertianus*, *C. sieberi*, *C. veluchensis*

Iris planifolia

Iris planifolia

JUNCACEAE

Juncaceae

Juncus alpinus, *J. anceps*, *J. articulatus*, *J. bufonius*, *J. compressus*, *J. conglomeratus*, *J. effusus*, *J. fontanesii*, *J. hybridus*, *J. inflexus*, *J. minutulus*, *J. sphaerocarpus*, *J. striatus*, *J. subnodulosus*, *J. tenuis*, *J. trifidus*, *Luzula campestris*, *L. forsteri*, *L. luzulina*, *L. multiflora*, *L. pilosa*, *L. spicata*, *L. sylvatica*

?*Juncus atratus*, *J. heldreichianus*, *J. thomasi*, *Luzula italica*, *L. pindica*, *L. sudetica*

GRAMINEAE

***Festuca* type**

Bellardiocloa violacea, *Desmazeria rigida*, *Festuca alpina*, *F. altissima*, *F. amethystina*, *F. arundinacea*, *F. callieri*, *F. circummediterranea*, *F. cyllenica*, *F. dalmatica*, *F. drymeja*, *F. glauca*, *F. graeca*, *F. grandiaristata*, *F. hercegovinica*, *F. heterophylla*, *F. hirtovaginata*, *F. horvatiana*, *F. jeanpertii*, *F. korabensis*, *F. koritnicensis*, *F. loliacea*, *F. nigrescens*, *F. ovina*, *F. paniculata*, *F. penzesii*, *F. peristerea*, *F. pindica*, *F. polita*, *F. pratensis*, *F. rechingeri*, *F. rubra*, *F. spectabilis*, *F. thracica*, *F. valesiaca*, *F. valida*, *F. varia*, *F. violacea*, *F. vizzavonae*, *Lolium multiflorum*, *L. perenne*, *L. remotum*, *L. rigidum*, *L. temulentum*, *Micropyrum tenellum*, *Poa alpina*, *P. angustifolia*, *P. annua*, *P. bulbosa*, *P. cenisia*, *P. chaixii*, *P. glauca*, *P. macedonica*, *P. nemoralis*, *P. ophiolithica*, *P. palustris*, *P. perconcinna*, *P. pratensis*, *P. pumila*, *P. timoleontis*, *P. trivialis*, *P. versicolor*, *Puccinellia distans*, *Sclerochloa dura*, *Vulpia bromoides*, *V. ciliata*, *V. muralis*, *V. myuros*

?*Eleusine indica*, *Eragrostis cilianensis*, *E. minor*, *E. pilosa*

??*Aristida adscensionis*, *Cleistogenes serotina*, *Crypsis aculeata*, *C. alopecuroides*, *C. schoenoides*, *Danthonia alpina*, *D. decumbens*, *Molinia caerulea*, *Tragus racemosus*

***Glyceria* type**

Bromus alopecuroides, *B. arvensis*, *B. benekenii*, *B. cappadocicus*, *B. commutatus*, *B. diandrus*, *B. erectus*, *B. hordeaceus*, *B. intermedius*, *B. japonicus*, *B. lanceolatus*, *B. madritensis*, *B. pindicus*, *B. ramosus*, *B. rigidus*, *B. riparius*, *B. rubens*, *B. scoparius*, *B. secalinus*, *B. squarrosus*, *B. sterilis*, *B. tectorum*, *Glyceria maxima*, *G. spicata*

***Dactylis* type**

Apera spica-vent, *Beckmannia eruciformis*, *Brachypodium distachyon*, *B. phoenicoides*, *B. pinnatum*, *B. retusum*, *B. sylvaticum*, *Briza humilis*, *B. maxima*, *B. media*, *B. minor*, *Catabrosa aquatica*, *Cynodon dactylon*, *Cynosurus cristatus*, *C. echinatus*, *C. elegans*, *Dactylis glomerata*, *Echinaria capitata*, *Festucopsis sancta*, *Lamarckia aurea*, *Melica altissima*, *M. ciliata*, *M. minuta*, *M. nutans*, *M. transsilvanica*, *Mibora minima*, *Nardus stricta*, *Psilurus incurvus*, *Sesleria bielzii*, *S. coerulans*, *S. korabensis*, *S. robusta*, *S. sadlerana*, *S. tenerrima*, *S. vaginalis*

??*Achnatherum calamagrostis*, *Agrostis canina*, *A. capillaris*, *A. castellana*, *A. gigantea*, *A. stolonifera*, *Aira caryophylla*, *A. cupaniana*, *A. elegantissima*, *A. tenorii*, *Alopecurus aequalis*, *A. arundinaceus*, *A. creticus*, *A. myosuroides*, *A. rendlei*, *A. setarioides*, *Ampelodesmos mauritanica*, *Andropogon distachyos*, *Anthoxanthum gracile*, *A. odoratum*, *A. ovatum*, *Arrhenatherum elatius*, *Arundo donax*, *Avellinia michelii*, *Avenula cincinnata*, *A. compressa*, *A. pubescens*, *Brachiaria eruciformis*, *Calamagrostis arundinacea*, *C. varia*, *Chrysopogon gryllus*, *Corynephorus divaricatus*, *Danthoniastrum compactum*, *Dasypyrum villosum*, *Deschampsia cespitosa*, *D. flexuosa*, *D. media*, *Dichanthium ischaemum*, *Digitaria ischaemum*, *D. sanguinalis*, *Echinochloa crus-galli*, *Gastridium ventricosum*,

Hainardia cylindrica, *Helictotrichon convolutum*, *Hemarthria altissima*, *Holcus lanatus*, *H. mollis*, *H. setiglumis*, *Hyparrhenia hirta*, *Imperata cylindrica*, *Koeleria lobata*, *K. macrantha*, *K. pyramidata*, *K. splendens*, *Lagurus ovatus*, *Lophochloa cristata*, *L. hispida*, *Milium effusum*, *M. vernale*, *Molineriella minuta*, *Parapholis pycnantha*, *Parvotrisetum myrianthum*, *Paspalum paspalodes*, *Phacelurus digitatus*, *Phalaris arundinacea*, *P. brachystachys*, *P. canariensis*, *P. coerulescens*, *P. minor*, *P. paradoxa*, *Phleum alpinum*, *P. arenarium*, *P. echinatum*, *P. graecum*, *P. montanum*, *P. paniculatum*, *P. phleoides*, *P. pratense*, *P. subulatum*, *Pholiurus pannonicus*, *Piptatherum coerulescens*, *P. holciformis*, *P. miliaceum*, *Polypogon maritimus*, *P. monspeliensis*, *P. viridis*, *Saccharum ravennae*, *S. strictum*, *Setaria italic*, *S. pumila*, *S. verticillata*, *S. viridis*, *Sorghum halepense*, *Stipa bromoides*, *S. capensis*, *S. capillata*, *S. epilosa*, *S. fontanesii*, *S. joannis*, *S. lessingiana*, *S. pennata*, *S. pulcherrima*, *S. rechingeri*, *S. thessala*, *S. tirsia*, *Trisetum flavescens*, *Trisetum ?flavescens*, *T. tenuiforme*, *Ventenata dubia*

Agropyron type

Aegilops cylindrica, *A. dichasians*, *A. geniculata*, *A. lorentii*, *A. neglecta*, *A. speltoides*, *A. triuncialis*, *A. uniaristata*, *Agropyron cristatum*
?Panicum miliaceum, *P. repens*, *Secale montanum*

Triticum type

Triticum aestivum, *T. compactum*, *T. dicoccon*, *T. durum*, *T. turgidum*

Secale cereale

Secale cereale

Hordeum type

Elymus caninus, *E. elongatus*, *E. hispidus*, *E. repens*, *Hordeum murinum*, *H. vulgare*, *Triticum monococcum*
?Hordelymus europaeus, *Hordeum bulbosum*, *H. distichon*, *H. hystrix*, *H. marinum*, *Taeniatherum caput-medusae*, *Triticum baeoticum*

Avena

Avena byzantina, *A. fatua*, *A. sativa*
?Avena barbata, *A. clauda*, *A. sterilis*, *A. strigosa*

Phragmites australis

Phragmites australis

Zea mays

Zea mays

ARACEAE

Arum

Arum italicum, *A. maculatum*
?Arum orientale, *A. petteri*

Dracunculus type

Dracunculus vulgaris
?Biarum tenuifolium

Arisarum vulgare

Arisarum vulgare

LEMNACEAE

Lemnaceae

Lemna gibba, *L. minor*, *L. trisulca*, *Spirodela polyrhiza*

SPARGANIACEAE

Sparganium erectum

Sparganium erectum

Sparganium angustifolium

Sparganium angustifolium

TYPHACEAE

***Typha angustifolia* type**

Typha angustifolia, *T. latifolia*

***Typha domingensis* type**

Typha domingensis

?*Typha laxmannii*

CYPERACEAE

Scirpus

Scirpus lacustris, *S. maritimus*

Cladium mariscus

Cladium mariscus

Cyperus michelianus

Cyperus michelianus

***Cyperus longus* type**

Cyperus glomeratus, *C. laevigatus*, *C. longus*

?*Cyperus difformis*, *C. esculentus*, *C. flavescens*, *C. flavidus*, *C. glaber*

Schoenus nigricans

Schoenus nigricans

***Carex hallerana* type**

Carex hallerana, *Scirpus holoschoenus*, *S. sylvaticus*

?*Blysmus compressus*, *Carex depressa*, *C. ferruginea*, *C. liparocarpos*, *C. macrolepis*, *C. melanostachya*, *C. sempervirens*, *Scirpus cernuus*, *S. cespitosus*, *S. litoralis*, *S. mucronatus*, *S. setaceus*, *S. supinus*

***Carex flacca* type**

Carex acuta, *C. acutiformis*, *C. appropinquata*, *C. atrata*, *C. caryophyllea*, *C. chordorrhiza*, *C. depauperata*, *C. digitata*, *C. distachya*, *C. distans*, *C. disticha*, *C. divisa*, *C. divulsa*, *C. echinata*, *C. elata*, *C. elongata*, *C. ericetorum*, *C. flacca*, *C. hirta*, *C. hostiana*, *C. humilis*, *C. lepidocarpa*, *C. muricata*, *C. nigra*, *C. otrubae*, *C. ovalis*, *C. pallescens*, *C. panicea*, *C. paniculata*, *C. pendula*, *C. punctata*, *C. remota*, *C. riparia*, *C. rostrata*, *C. serotina*, *C. spicata*, *C. sylvatica*, *C. tomentosa*, *C. umbrosa*, *C. vulpina*, *Cyperus fuscus*, *C. rotundus*, *Eleocharis multicaulis*, *E. palustris*, *Eriophorum angustifolium*, *E. gracile*, *E. latifolium*, *E. vaginatum*

?*Carex davalliana*, *C. hispida*, *C. kitaibeliana*, *Eleocharis acicularis*, *E. quinqueflora*, *E. uniglumis*, *Fimbristylis bisumbellata*

ORCHIDACEAE

***Epipactis* type**

Subfamily Neottioideae: *Epipactis atrorubens*, *E. helleborine*, *E. leptochila*, *E. microphylla*, *E. palustris*, *E. purpurata*, *Listera ovata*, *Neottia nidus-avis*
?*Cypripedium calceolus*, *Epipogium aphyllum*

Limodorum abortivum

Subfamily Neottioideae: *Limodorum abortivum*

Cephalanthera

Subfamily Neottioideae: *Cephalanthera damasonium*, *C. rubra*

***Orchis* type**

Subfamily Orchidoideae: *Aceras anthropophorum*, *Anacamptis pyramidalis*, *Barlia robertiana*, *Coeloglossum viride*, *Dactylorhiza fuchsii*, *D. incarnata*, *D. sambucina*, *D. sulphurea*, *Gymnadenia conopsea*, *Himantoglossum hircinum*, *Neotinea maculata*, *Ophrys apifera*, *O. bombyliflora*, *O. fusca*, *O. reinholdii*, *O. scolopax*, *O. sphegodes*, *O. tenthredinifera*, *Orchis coriophora*, *O. italica*, *O. laxiflora*, *O. mascula*, *O. pallens*, *O. papilionacea*, *O. provincialis*, *O. purpurea*, *O. quadripunctata*, *O. tridentata*, *O. ustulata*, *Platanthera bifolia*, *P. chlorantha*, *Serapias cordigera*, *S. lingua*, *S. vomeracea*

Subfamily Neottioideae: *Spiranthes aestivalis*, *S. spiralis*

?Subfamily Orchidoideae: *Dactylorhiza baumanniana*, *D. cordigera*, *D. iberica*,

D. kalopissii, *D. saccifera*, *Ophrys carmeli*, *O. ferrum-equinum*, *O. fuciflora*, *O. spruneri*,
Orchis simia, *O. spitzelii*, *Pseudorchis frivaldii*
? *Corallorhiza trifida*

Appendix VII

Species lists for reconnaissance vegetation surveys

Several reconnaissance vegetation surveys were undertaken at sites where no samples were collected for pollen analysis, but a note was made of the dominant species present. These vegetation surveys were undertaken to enhance the author's knowledge of the ecology of the indigenous vegetation of Grevena as well as to gain some knowledge of regeneration patterns, and for the collection of pollen reference material, particularly of herbs. Below are listed the species of interest at these sites, which are presented in order of elevation. The vegetation zone in which the site occurs follows the location of the site in brackets.

Taxonomic names of European species follow:

Tutin, T. G. *et al.* (eds) 1964-80. *Flora Europaea*. Volumes 1-5. Cambridge University Press, Cambridge.

The numbers in [] following the species names are herbarium specimen numbers.

An "*" preceding a taxonomic name denotes an exotic species.

i) Zakas to Agios Nikolaos (mountain pine wood)

Dominant tree species were noted at three locations on the road between Zakas and Agios Nikolaos in the mountain pine woods. At the highest elevation (1100 m), all three pine species, *Pinus nigra* (commonest), *P. heldreichii*, and *P. leucodermis*, that occur in Grevena grow together. They grow in a mosaic of small patches of same species and same age trees. The oldest pine tree here is about 150 years old.

Close to Agios Nikolaos, at a lower elevation of about 1025 m asl, a herbarium specimen of *Cornus mas* (collection # 171) was collected on a slope of 15-20° with a southerly aspect. *Malus sylvestris* (crab apple) and *Cichorium intybus* (chicory) were abundant here. There were occasional oaks by the roadside.

Near the church of Agios Nikolaos, in a riverine vegetation zone, are a few *Salix* spp. (willows) trees, some were large; and sparse oak trees.

Genus & species	Common name	Family
Gymnospermae:		
<i>Pinus nigra</i> Arnold	Black pine	Pinaceae
<i>Pinus heldreichii</i> Christ	Balkan pine	Pinaceae
<i>Pinus leucodermis</i> Antoine	Bosnian pine	Pinaceae
Angiospermae:		
Dicotyledones:		
<i>Cornus mas</i> L. [171]	Cornelian cherry	Cornaceae
<i>Malus sylvestris</i>	Crabapple	Rosaceae
<i>Cichorium intybus</i> L.	Chicory	Compositae
<i>Quercus</i> spp.		Fagaceae
<i>Salix</i> spp.	Willows	Salicaceae

ii) Above Zakas (mountain pine wood-pasture)

This mountain pine wood-pasture occurs at 1000-1200 m, below the mountain pine woods of (i) above. *Pinus nigra* dominates this wood. Trees are relatively widely spaced. The wood is grazed, but ground cover is quite thick, comprising *Pteridium aquilinum* and dryish grassland (steppe). Many of the large pine trees in this area have been struck by lightning, but this has not killed them, nor did they burn.

Genus & species	Common name	Family
Pteridophyta:		
<i>Pteridium aquilinum</i> (L.) Kuhn in Decken	Bracken	Hypolepidaceae
Gymnospermae:		
<i>Pinus nigra</i> Arnold	Black pine	Pinaceae
Angiospermae:		
Monocotyledones:		
Gramineae spp.	Grasses	Gramineae

iii) Perivolion/Vovoussa (mountain beech wood)

Plants are listed from a disturbed area in beech wood at 1480 m asl. The site is near the pass between Perivolion and Vovoussa about 1.5 km west of the wetland, Anelia, where pollen analysis was undertaken. The site has stony brown earth and a northeast aspect with a slope of 5°. Particular note was made of herbaceous plants growing on a track along a ridge top under the beech wood. These plants include species that would grow in a coppiced beech wood.

Genus & species	Common name	Family
Angiospermae:		
Dicotyledones:		
<i>Campanula</i> sp. [6]	Bellflower	Campanulaceae
<i>Centaurea</i> sp. [5]	Knapweed	Compositae
<i>Dianthus</i> sp. [4]	Pink	Caryophyllaceae
<i>Digitalis grandiflora</i> Miller [2]	Large yellow foxglove	Scrophulariaceae
<i>Euphrasia</i> sp. [11]		Scrophulariaceae
<i>Lathyrus</i> sp. [9]	Pea, Vetch	Leguminosae
<i>Lotus</i> sp. [8]	Birdsfoot-trefoil	Leguminosae
<i>Leontodon</i> sp. or related sp. [7]		Compositae
<i>Myosotis</i> sp. [1]		Boraginaceae
<i>Prunella laciniata</i> (L.) L. [3]	Cut-leaved self-heal	Labiatae
<i>Viola</i> sp. [10]	Violet, Pansy	Violaceae

iv) Polinerion (foothill deciduous oak wood-pasture)

The area surveyed is about 1.5 km west of Polinerion at about 1200 m asl. The species listed grow in grassland on a ridge top in oak wood-pasture close to the quadrats that were quantitatively surveyed (see Appendix VIII).

Genus & species	Common name	Family
Angiospermae:		
Dicotyledones:		
<i>Acinos suaveolens</i> (Sibth. & Sm.) G. Don fil. in Loudon [73]		Labiatae
<i>Anthemis</i> sp. or <i>Achillea</i> sp. [75]	Chamomile	Compositae
<i>Centaurea solstitialis</i> L. [77]	St. Barnaby's thistle	Compositae
<i>Cyclamen</i> sp. [81]		Primulaceae
<i>Dianthus</i> sp. [72]	Pink	Caryophyllaceae
<i>Erodium</i> cf. <i>cicutarium</i> (L.) L'Her [74]	Common storksbill	Geraniaceae
<i>Eryngium amethystinum</i> L. [79]	Blue eryngo	Umbelliferae
<i>Euphorbia myrsinites</i> L. [80]	Broad-leaved glaucous spurge	Euphorbiaceae
<i>Hieracium/Pilosella</i> agg. [76]		Compositae
<i>Thymus</i> sp. [71]	Thyme	Labiatae
<i>Xanthium spinosum</i> L. [78]	Spiny Cocklebur	Compositae

v) Mavranaioi (lowland plains steppe and deciduous oak wood-pasture)

This site is close to Mavranaioi at about 700 m asl. A road passes close to a dense patch of gnarled oaks, typical of the patches that grow in the mosaic of steppe and deciduous oak woods of the lowland plains. The site has a SW aspect and the substrate was red earth on colluvium.

Oak species growing in this stand included *Quercus cerris*, *Q. frainetto* and *Q. pubescens*. Typically there were many oak hybrids and clinal variations. The oaks had been coppiced. In this vegetation zone, if coppicing stopped, the oaks would probably grow into tall trees and steppe plants would grow as undergrowth. *Juniperus oxycedrus* grows in this stand indicating that it was once more open. The roadside vegetation was a mixture of steppe and ruderal plants.

Genus & species	Common name	Family
Gymnospermae:		
<i>Juniperus oxycedrus</i> L.	Prickly juniper	Cupressaceae
Angiospermae:		
Dicotyledones:		
<i>Alyssum</i> cf. <i>murale</i> Waldst. & Kit. or ? <i>Neslia paniculata</i> (L.) Desv. [59]		Cruciferae
<i>Anthemis</i> sp. [66]	Chamomile	Compositae
<i>Centaurea</i> sp. [57]	Knapweed	Compositae
<i>Chondrilla juncea</i> L. [70]		Compositae
<i>Cichorium intybus</i> L.	Chicory	Compositae
<i>Clinopodium vulgare</i> L. [61]	Wild basil	Labiatae
<i>Convolvulus arvensis</i> L. [69]		Convolvulaceae
<i>Crepis</i> sp. [63]	Hawksbeard	Compositae
<i>Dorycnium hirsutum</i> (L.) Ser. in DC [60]		Leguminosae
<i>Echinops microcephalus</i> Sibth. & Sm. [55]	Globe thistle	Compositae
<i>Euphorbia ?segetalis</i> L. [67]	Spurge	Euphorbiaceae
<i>Lactuca viminea</i> (L.) J. & C. Presl [58]	Pliant lettuce	Compositae
<i>Lotus</i> sp.		Leguminosae

<i>Plantago lanceolata</i> L. [65 & 68]	Ribwort, Plantain	Plantaginaceae
<i>Polygonum</i> sp.	Dock	Polygonaceae
<i>Quercus cerris</i> L.	Turkey oak	Fagaceae
<i>Q. frainetto</i> Ten.	Hungarian oak	Fagaceae
<i>Q. pubescens</i> Willd.	White oak	Fagaceae
<i>Scabiosa</i> sp. ? <i>atropurpurea</i> L. [56]	Scabious	Dipsacaceae
<i>Scrophularia canina</i> L.	Figwort	Scrophulariaceae
<i>Sorbus torminalis</i> (L.) Crantz [62]	Wild service tree	Rosaceae
* <i>Xanthium strumarium</i> L. [64]	Cocklebur	Compositae

vi) Asprokampos (lowland plains steppe and deciduous oak wood)

Weeds were collected from the road verge near Asprokampos in the steppe and oak wood-pasture vegetation zone of the lowland plains at an elevation of 560 m asl. Much of the surrounding area is cultivated fields.

The most common weeds are *Cichorium intybus*, *Mentha* spp., *Galium verum*, *Lotus* spp., *Ononis spinosa*, *Taraxacum* sp. and *Verbena officinalis*.

Genus & species	Common name	Family
Angiospermae:		
Dicotyledones:		
<i>Centaurea</i> sp. [247]	Knapweed	Compositae
<i>Cichorium intybus</i> L.	Chicory	Compositae
Dipsacaceae [248]		Dipsacaceae
<i>Galium verum</i> L.	Slender crosswort	Rubiaceae
<i>Lactuca viminea</i> (L.) J. & C. Presl. [251, 255]	Pliant lettuce	Compositae
<i>Lotus</i> sp.		Leguminosae
<i>Mentha suaveolens</i> Ehrh. [249]	Mint	Labiatae
<i>Ononis spinosa</i> L.	Spiny restharrow	Leguminosae
<i>Salvia</i> sp. [252]	Clary, Sage	Labiatae
? <i>Scorzonera</i> sp. [254]	?Vipergrass	Compositae
? <i>Sinapis alba</i> L. [253]	White mustard	Cruciferae
<i>Taraxacum</i> sp.	Dandelion	Compositae
<i>Verbena officinalis</i> L. [250]	Vervain	Verbenaceae

Appendix VIII

Modern vegetation composition at pollen surface sample collection sites

Vegetation was surveyed at each site where a surface pollen sample was collected. These surveys were undertaken to gain some knowledge of the ecology of species growing in Grevena as well as to study the relationship between vegetational composition and pollen precipitation. This appendix tabulates the (mostly) vascular species growing at and near these sites. Quantitative surveys were undertaken at most sites to gain a rough estimate of relative abundance of species. Visual estimates were made of the percent cover of herbaceous species and woody plants (Andersen 1970, 1973; Birks 1973, 1977; Moore & Chapman 1986). Where more than one vegetational stratum existed, each stratum was considered separately for estimating the relative values. Cover estimates have not been converted into classes but left in their raw percentage estimates as these are more easily compared to pollen relative percentages (+ = under 1%).

Since the main objective was to study the relationship between vegetational composition and pollen precipitation, the selection of survey areas was based on the major vegetation types described by Moody & Rackham (in prep.). The aim was to survey a representation sample of these vegetation types. Thus, a transect from the western Pindos Mountains across the foothills to the lowlands was surveyed. Unfortunately, time precluded a survey of the slopes of the Vourinos Mountains.

Plot characteristics are given above each species list. Altitudes were recorded with an altimeter and checked against geological maps (see References). Aspect and slope were measured in the field with a hand-held compass. Height of canopy was estimated by eye. Life-form classes follow Raunkiaer (1937) (see Appendix X). Identifications were checked by Dr O. Rackham, Cambridge University. Taxonomic names of vascular species follow Tutin *et al.* (1964-80) and of non-vascular species Watson (1968).

Vegetation surveys are presented according to landforms from west to east across Grevena:

PINDOS MOUNTAINS

- Pine wood-pasture, *Pinus leucodermis*
- Beech woods
- Pine woods, *Pinus nigra*
- Pine/oak woods

PINDOS FOOTHILLS

- Oak wood-pasture
- Mixed woods

LOWLAND PLAINS

- Cultivated fields
- Oak woods
- Steppe/oak woods

PINDOS MOUNTAINS

Pine wood-pasture, *Pinus leucodermis*

Avgo

Grid reference: 39° 55' 05" N 21° 07' E

Altitude: 1760 m

Local vegetation: floating sedge mat

Slope: flat

Aspect: northeast

Substrate: peat of Lammos Lake margin

Reconnaissance survey

The site is named after the nearby peak of Avgo. The lake is almost entirely covered with a floating mat of 95% Cyperaceae. Most of the floating mat comprises two species of *Eriophorum* (50%). *Milium* grows as high tussocks on the mat. *Eleocharis* grows in the lake rooted to the bottom while *Utricularia* floats in open water near the edge of the lake. At the peaty margin grow *Eriophorum*, *Carex* spp., *Parnassia palustris*, *Juncus articulatus*, *Blysmus* sp. and *Pinguicula vulgaris*. On the slightly drier margin there are *Festuca* sp., *Nardus stricta* and *Agrostis* sp..

The lake is surrounded by pasture with scattered large *Pinus leucodermis* trees estimated (from annual tree ring counts) to be about 700 years old. On more distant slopes *Pinus leucodermis* provides about 10% tree cover. These trees are estimated to be of two ages; 150 and 700 years old. *Fagus sylvatica* trees grow in small patches in gullies about 55 m from the lake edge with *Buxus sempervirens* understorey. This area is heavily grazed.

% cover	Genus & Species	Family	Pollen type
On lake			
FLOATING MAT			
Angiospermae:			
Dicotyledones:			
	<i>Parnassia palustris</i> L.	Parnassiaceae	<i>Parnassia palustris</i>
	<i>Pinguicula vulgaris</i> L.	Lentibulariaceae	<i>Pinguicula</i>
	<i>Utricularia</i> sp.	Lentibulariaceae	<i>Utricularia</i>
Monocotyledones:			
	<i>Agrostis</i> sp.	Gramineae	?? <i>Dactylis</i> t.
	<i>Blysmus</i> sp.	Cyperaceae	? <i>Carex hallerana</i> t.
	<i>Carex</i> spp. (3)	Cyperaceae	<i>Carex hallerana</i> or <i>C. flacca</i> t.
	<i>Eleocharis</i> sp. ? <i>multicaulis</i> (Sm.) Desv.	Cyperaceae	Prob. <i>Carex flacca</i> t.
	<i>Eleocharis</i> sp.	Cyperaceae	Prob. <i>Carex flacca</i> t.
	<i>Eriophorum</i> spp. (2)	Cyperaceae	<i>Carex flacca</i> t.
	<i>Festuca</i> sp.	Gramineae	<i>Festuca</i> t.
	<i>Juncus articulatus</i> L.	Juncaceae	Juncaceae
	<i>Milium</i> sp.	Gramineae	?? <i>Dactylis</i> t.
	<i>Nardus stricta</i> L.	Gramineae	<i>Dactylis</i> t.
Dryland around lake			
CANOPY TREES			
Gymnospermae:			
	<i>Pinus leucodermis</i> Antoine	Pinaceae	<i>Pinus</i> subgenus <i>Diploxylon</i>
GROUND COVER			
Angiospermae:			
Dicotyledones:			
	<i>Acinos</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
	<i>Armeria maritima</i> (Miller) Willd.	Plumbaginaceae	<i>Armeria maritima</i> t.

% cover	Genus & Species	Family	Pollen type
	<i>Bellis sylvestris</i> Cyr. <i>Campanula</i> sp.	Compositae Campanulaceae	<i>Solidago</i> t. <i>Campanula erinus</i> t., <i>C. rotundifolia</i> or <i>Asyneuma</i> t.
	<i>Carlina acaulis</i> L. <i>Cirsium creticum</i> (Lam.) D'Urv. (5 spp.) <i>Euphorbia myrsinites</i> L. ? <i>Helianthemum</i> sp. <i>Hieracium/Pilosella</i> agg. <i>Huetia</i> sp. <i>Lotus</i> sp. <i>Myosotis</i> sp. <i>Plantago major</i> L. <i>Stellaria graminea</i> L. <i>Taraxacum</i> sp. <i>Trifolium</i> sp.	Compositae Compositae Cruciferae Euphorbiaceae Cistaceae Compositae Umbelliferae Leguminosae Boraginaceae Plantaginaceae Caryophyllaceae Compositae Leguminosae	<i>Carlina</i> t. <i>Cirsium</i> t. Cruciferae ? <i>Euphorbia</i> ? <i>Helianthemum</i> <i>Hieracium</i> t. ?? <i>Bunium</i> <i>Lotus</i> t. Prob. <i>Myosotis</i> t. <i>Plantago major</i> <i>Dianthus</i> t. <i>Taraxacum</i> t. <i>Trifolium dubium</i> t., <i>T. repens</i> t. or <i>T. montanum</i> <i>Urtica dioica</i> , <i>U. urens</i> t. or <i>U. pilulifera</i> t. Prob. <i>Scrophularia</i> t.
	<i>Urtica</i> sp. (in wet flush)	Urticaceae	
	<i>Verbascum</i> sp.	Scrophulariaceae	
Monocotyledones:			
	<i>Carex nigra</i> (L.) Reichard	Cyperaceae	<i>Carex flacca</i> t.

Gomara fen

Grid reference: 40° 03' N 21° 04' E

Altitude: 1750 m

Local vegetation: open rush/grass fen

Slope: small basin on gentle southerly slope

Aspect: south

Substrate: fen peat

2 x 2 m plots

The regional vegetation surrounding this site is very similar to that at Avgo.

The surface of the wetland was dry and cracked. It was covered by very sparse herbaceous plants dominated by *Polygonum* sp. Three 2 x 2 m plots (a, b and c) within the rim of the ephemeral lake were surveyed to find out what pioneer plants grew on the lakebed during seasonal drying. These plots were selected on the basis of dryness. There appeared to be three distinct zones of increasing dryness, the outermost zone being the driest.

% cover	Genus & Species	Family	Pollen type
Plot a - outermost zone of dry lakebed (2 x 2 m plot)			
GROUND COVER			
Angiospermae:			
Dicotyledones:			
2%	<i>Convolvulus arvensis</i> L.	Convolvulaceae	<i>Convolvulus</i>
+	<i>Euphorbia myrsinites</i> L.	Euphorbiaceae	? <i>Euphorbia</i>
40%	<i>Polygonum</i> sp.	Polygonaceae	Prob. <i>Polygonum aviculare</i> t.
+	<i>Trifolium repens</i> L.	Leguminosae	<i>Trifolium repens</i> t.
Plot b - intermediate zone of dry lakebed (2 x 2 m plot)			
GROUND COVER			
Angiospermae:			
Dicotyledones:			
5%	<i>Polygonum aviculare</i> L.	Polygonaceae	<i>Polygonum aviculare</i> t.
Plot c - central zone of dry lakebed (2 x 2 m plot)			
GROUND COVER			
Angiospermae:			
Monocotyledones:			
20%	<i>Glyceria</i> sp.	Gramineae	<i>Glyceria</i> t.
10%	<i>Juncus</i> sp.	Juncaceae	Juncaceae
Close by: (alpine pasture below lake)			
GROUND COVER			
Angiospermae:			
Dicotyledones:			
	<i>Echinops</i> cf. ? <i>microcephalus</i> Sibth. & Sm.	Compositae	<i>Echinops</i>

Beech woods

Anelia woods

Grid reference: 39° 57' 30" N 21° 05' 30" E

Altitude: 1445 m

Local vegetation: beech wood + bracken

Canopy height: 15 m

Slope: 12°

Aspect: east

Substrate: colluvium of mostly ultramafic cobbles and pebbles and some diabase, covered by a soil estimated to be about 5000-9000 years old (Savina 1990)

30 x 30 m quadrat

The canopy cover is 100%. This wood has been coppiced, but not for about 20 years. *Pteridium aquilinum* grew in a small clearing about 10 m to the west of the quadrat.

This quadrat is 30 m west of the bog (described below).

% cover	Genus & Species	Family	Pollen type
CANOPY TREES			
Angiospermae:			
Dicotyledones:			
100%	<i>Fagus sylvatica</i> L.	Fagaceae	<i>Fagus</i>
GROUND COVER			
Angiospermae:			
Dicotyledones:			
	<i>Fragaria</i> sp.	Rosaceae	<i>Fragaria viridis</i> or <i>F. vesca</i> t.
Close by:			
UNDERSTOREY TREES AND SHRUBS			
Filicopsida:			
	<i>Pteridium aquilinum</i> (L.) Kuhn in Decken	Hypolepidaceae	<i>Pteridium aquilinum</i>

Anelia bog

Grid reference: 39° 57' 30" N 21° 05' 30" E

Altitude: 1440 m

Local vegetation: sedge bog

Slope: 2-5°

Aspect: northeast

Substrate: sedge peat

2 x 2 m plots & reconnaissance

Beech wood grows to the edge of the wetland. Three *Pinus nigra* trees (one recently dead), about 40 years old, grow on the edge of the bog. About 15% of the bog surface is open water.

Four 2 x 2 m plots were quantitatively surveyed, two on the bog and two on the edge of the bog. These plots differed in wetness. The bog is carpeted with the bryophyte *Acrocladium cuspidatum*. The drier plot on the bog was dominated by *Carex* sp. The plots on the edge of the bog were drier than those on the bog, the wetter of the two was dominated by *Caltha palustris* while the drier one was dominated by *Cirsium*. A reconnaissance survey was also undertaken of the dry land between the edge of the bog and the beech wood.

% cover	Genus & Species	Family	Pollen type
On bog (2 x 2 m plot)			
GROUND COVER			
Bryophyta:			
50%	<i>Acrocladium cuspidatum</i> (Hedw.) Lindb.	Hypnaceae	
20%	<i>Cratoneuron</i> sp.	Hypnaceae	
Angiospermae:			
Dicotyledones:			
+	<i>Epilobium</i> sp. ? <i>hirsutum</i> L.	Onagraceae	? <i>Epilobium hirsutum</i> t.
+	<i>Hypericum</i> sp. ? <i>tetrapterum</i> Fries	Guttiferae	Prob. <i>Hypericum perforatum</i> t.
+	<i>Mentha aquatica</i> L.	Labiatae	<i>Mentha</i> t.
+	<i>Parnassia palustris</i> L.	Parnassiaceae	<i>Parnassia palustris</i>
3%	<i>Ranunculus repens</i> L.	Ranunculaceae	<i>Ranunculus acris</i> gr.
Monocotyledones:			
+	<i>Agrostis</i> sp. ? <i>canina</i> L.	Gramineae	?? <i>Dactylis</i> t.
3%	<i>Holcus lanatus</i> L.	Gramineae	?? <i>Dactylis</i> t.
+	<i>Juncus articulatus</i> L.	Juncaceae	Juncaceae
3%	<i>Juncus inflexus</i> L.	Juncaceae	Juncaceae
Close by:			
CANOPY TREES			
	<i>Fagus sylvatica</i> L.	Fagaceae	<i>Fagus</i>
Drier area on bog (2 x 2 m plot)			
GROUND COVER			
Bryophyta:			
25%	<i>Acrocladium cuspidatum</i> (Hedw.) Lindb.	Hypnaceae	
5%	<i>Cratoneuron</i> sp.	Hypnaceae	
Angiospermae:			
Dicotyledones:			
5%	<i>Alchemilla</i> sp.	Rosaceae	<i>Alchemilla</i> t.
+	<i>Cerastium</i> sp. ? <i>fontanum</i> subsp. <i>triviale</i> (Link) Jalas	Caryophyllaceae	<i>Dianthus</i> t.
+	<i>Cirsium</i> sp.	Compositae	<i>Cirsium</i> t.
+	<i>Epilobium</i> ? <i>adenocaulon</i> Hausskn.	Onagraceae	? <i>Epilobium hirsutum</i> t.
+	<i>Euphrasia</i> sp.	Scrophulariaceae	<i>Euphrasia</i>

% cover	Genus & Species	Family	Pollen type
+	<i>Linum catharticum</i> L.	Linaceae	<i>Linum catharticum</i>
1%	<i>Parnassia palustris</i> L.	Parnassiaceae	<i>Parnassia palustris</i>
2%	<i>Plantago lanceolata</i> L.	Plantaginaceae	<i>Plantago lanceolata</i> t.
5%	<i>Trifolium pratense</i> L.	Leguminosae	<i>Trifolium repens</i> t.
+	<i>Viola</i> sp.	Violaceae	<i>Viola hirta</i> t., <i>V. riviniana</i> t. or <i>V. arvensis</i> t.

Monocotyledones:

60%	<i>Carex</i> sp.	Cyperaceae	<i>Carex hallerana</i> t. or <i>C. flacca</i> t.
+	<i>Cynosurus cristatus</i> L.	Gramineae	<i>Dactylis</i> t.
4%	<i>Holcus lanatus</i> L.	Gramineae	?? <i>Dactylis</i> t.
1%	<i>Juncus effusus</i> L.	Juncaceae	Juncaceae
+		Orchidaceae	Orchidaceae

Dry ground west side of bog (2 x 2 m plot)

SHRUB LAYER

Filicopsida:

15%	<i>Pteridium aquilinum</i> (L.) Kuhn in Decken	Hypolepidaceae	<i>Pteridium aquilinum</i>
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GROUND COVER

Sphenopsida:

+	<i>Equisetum palustre</i> L.	Equisetaceae	<i>Equisetum</i>
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Angiospermae:

Dicotyledones:

+	<i>Ajuga reptans</i> L.	Labiatae	<i>Scutellaria</i> t.
50%	<i>Cirsium</i> sp.	Compositae	<i>Cirsium</i> t.
10%	<i>Mentha aquatica</i> L.	Labiatae	<i>Mentha</i> t.
15%	<i>Ranunculus repens</i> L.	Ranunculaceae	<i>Ranunculus acris</i> gr.
+	<i>Stellaria graminea</i> L.	Caryophyllaceae	<i>Dianthus</i> t.

Monocotyledones:

10%	<i>Brachypodium sylvaticum</i> (Hudson) Beauv.	Gramineae	<i>Dactylis</i> t.
1%	<i>Carex hirta</i> L.	Cyperaceae	<i>Carex flacca</i> t.
+	<i>Holcus lanatus</i> L.	Gramineae	?? <i>Dactylis</i> t.

Close by:

Angiospermae:

Monocotyledones:

<i>Arum maculatum</i> L.	Araceae	<i>Arum</i>
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South end of bog by water inlet (2 x 2 m plot)

GROUND COVER

Angiospermae:

Dicotyledones:

90%	<i>Caltha palustris</i> L.	Ranunculaceae	<i>Caltha</i> t.
5%	<i>Ranunculus repens</i> L.	Ranunculaceae	<i>Ranunculus acris</i> gr.
5%	<i>Veronica beccabunga</i> L.	Scrophulariaceae	<i>Veronica anagallis-aquatica</i> t.

Monocotyledones:

1%	<i>Carex remota</i> L.	Cyperaceae	<i>Carex flacca</i> t.
1%	<i>Dactylorhiza fuchsii</i> (Druce) Soo	Orchidaceae	<i>Orchis</i> t.

Close by:

Angiospermae:

Dicotyledones:

<i>Oxalis acetosella</i> L.	Oxalidaceae	<i>Oxalis</i>
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% cover	Genus & Species	Family	Pollen type
Dryland on edge of beech wood around bog (reconnaissance survey)			
SHRUB LAYER			
Filicopsida:			
	<i>Pteridium aquilinum</i> (L.) Kuhn in Decken	Hypolepidaceae	<i>Pteridium aquilinum</i>
GROUND COVER			
Angiospermae:			
Dicotyledones:			
	<i>Digitalis ferruginea</i> L.	Scrophulariaceae	? <i>Scrophularia</i> t.
	<i>Geranium</i> sp.	Geraniaceae	<i>Geranium</i>
	<i>Helleborus</i> sp.	Ranunculaceae	Prob. <i>Helleborus</i>
	<i>Lychnis coronaria</i> (L.) Desr. in Lam.	Caryophyllaceae	<i>Dianthus</i> t.
	<i>Salvia</i> sp.	Labiatae	<i>Salvia officinalis</i> t. or <i>S. verticillata</i>
	? <i>Stachys</i> sp.	Labiatae	<i>Stachys arvensis</i> , <i>S. recta</i> , <i>S. angustifolia</i> or <i>S. sylvatica</i> t.
	<i>Urtica</i> sp.	Urticaceae	<i>Urtica dioica</i> , <i>U. urens</i> t. or <i>U. pilulifera</i> t.

Pine woods, *Pinus nigra*

Agios Nikolaos

Grid reference: 39° 59' N 21° 10' E

Altitude: 1100 m

Local vegetation: Pine wood + herbaceous understorey

Canopy height: 30 m

Slope: 20°

Aspect: north

Substrate: rocky with skeletal stony soil on calcareous shist

30 x 30 m quadrat

Open canopy. About 10% of the ground cover was rocks and 5% was covered with litter. There were abundant pine seedlings.

% cover	Genus & Species	Family	Pollen type
CANOPY TREE			
Gymnospermae:			
30%	<i>P. nigra</i> Arnold	Pinaceae	<i>Pinus</i> subgenus <i>Diploxylon</i>
UNDERSTOREY TREES AND SHRUBS			
Filicopsida:			
30%	<i>Pteridium aquilinum</i> (L.) Kuhn in Decken	Hypolepidaceae	<i>Pteridium aquilinum</i>
Angiospermae:			
Dicotyledones:			
+	<i>Buxus</i> sp.	Buxaceae	Prob. <i>Buxus sempervirens</i>
GROUND COVER			
Gymnospermae:			
30%	<i>Pinus nigra</i> Arnold (seedlings)	Pinaceae	<i>Pinus</i> subgenus <i>Diploxylon</i>
Angiospermae:			
Dicotyledones:			
2%	<i>Cyclamen</i> sp.	Primulaceae	Prob. <i>Cyclamen</i>
+	? <i>Daucus</i> sp.	Umbelliferae	? <i>Daucus</i>
+	<i>Echinops</i> sp.	Compositae	<i>Echinops</i>
10%	<i>Helleborus</i> sp.	Ranunculaceae	Prob. <i>Helleborus</i>
+	<i>Lathyrus</i> sp.	Leguminosae	<i>Lathyrus pratensis</i> t., <i>L. sativus</i> or <i>Vicia cracca</i> t.
+	cf. <i>Plantago</i>	Plantaginaceae	Plantaginaceae
2%	<i>Potentilla</i> sp.	Rosaceae	Prob. <i>Potentilla</i>
+	<i>Prunella</i> sp. ? <i>vulgaris</i> L.	Labiatae	<i>Prunella</i> t.
2%	<i>Rubus caesius</i> L.	Rosaceae	<i>Rubus</i> t.
2%	<i>Stachys</i> cf. <i>officinalis</i> (L.) Trevisan	Labiatae	Prob. <i>Stachys sylvatica</i> t.
5%	<i>Thymus</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
1%	<i>Viola</i> sp.	Violaceae	<i>Viola hirta</i> t., <i>V. riviniana</i> t. or <i>V. arvensis</i> t.
Monocotyledones:			
30%	<i>Festuca ovina</i> L.	Gramineae	<i>Festuca</i> t.
+		Orchidaceae	Orchidaceae

Pine/oak woods

Perivolion

Grid reference: 39° 59' N 21° 09' E
 Altitude: 1100 m
 Local vegetation: Pine/oak wood + herbaceous understorey
 Canopy height: 18 m
 Slope: 28°
 Aspect: southwest
 Substrate: skeletal stony soil on serpentine
 30 x 30 m quadrat

Total canopy cover is about 60%. Ground cover is relatively dense with pine litter covering about 40% of the ground surface and rocks about 10%. Grass is the dominant ground cover species.

% cover	Genus & Species	Family	Pollen type
CANOPY TREES			
Gymnospermae:			
40%	<i>Pinus nigra</i> Arnold	Pinaceae	<i>Pinus</i> subgenus <i>Diploxylon</i>
Angiospermae:			
Dicotyledones:			
20%	<i>Quercus frainetto</i> Ten.	Fagaceae	<i>Quercus frainetto</i> t.
UNDERSTOREY TREES AND SHRUBS			
Filicopsida:			
10%	<i>Pteridium aquilinum</i> (L.) Kuhn in Decken	Hypolepidaceae	<i>Pteridium aquilinum</i>
Gymnospermae:			
2%	<i>Juniperus communis</i> L.	Cupressaceae	<i>Juniperus</i>
Angiospermae:			
Dicotyledones:			
+	<i>Crataegus</i> sp.	Rosaceae	<i>Crataegus</i>
+	<i>Pyrus communis</i> L.	Rosaceae	<i>Pyrus</i>
GROUND COVER			
Gymnospermae:			
3%	<i>Pinus nigra</i> Arnold (seedlings)	Pinaceae	<i>Pinus</i> subgenus <i>Diploxylon</i>
Angiospermae:			
Dicotyledones:			
+	<i>Cirsium</i> spp.	Compositae	<i>Cirsium</i> t.
+	<i>Cuscuta</i> sp.	Convolvulaceae	<i>Cuscuta epithymum</i> t., <i>C. europaea</i> t. or <i>C. monogyna</i>
10%	<i>Dorycnium pentaphyllum</i> Scop.	Leguminosae	<i>Dorycnium</i>
+	<i>Euphorbia</i> sp.	Euphorbiaceae	Prob. <i>Euphorbia</i>
3%	<i>Helleborus</i> sp.	Ranunculaceae	Prob. <i>Helleborus</i>
+	<i>Quercus</i> spp. (seedlings)	Fagaceae	<i>Quercus</i>
1%	<i>Rubus</i> sp.	Rosaceae	Prob. <i>Rubus</i> t.
3%	<i>Teucrium</i> sp.	Labiatae	<i>Teucrium</i>
+	<i>Veronica cf. chamaedrys</i> L.	Scrophulariaceae	Prob. <i>Veronica triphyllos</i> t.
+	<i>Viola</i> sp.	Violaceae	<i>Viola hirta</i> t., <i>V. riviniana</i> t. or <i>V. arvensis</i> t.
Monocotyledones:			
15%	<i>Dactylis</i> sp.	Gramineae	<i>Dactylis</i> t.
15%	? <i>Festuca</i> sp.	Gramineae	? <i>Festuca</i> t.

% cover	Genus & Species	Family	Pollen type
Close by:			
Angiospermae:			
Dicotyledones:			
	<i>Alyssum murale</i> Waldst. & Kit	Cruciferae	<i>Hornungia</i> t.
	<i>Centaurea</i> sp.	Compositae	<i>Centaurea cyanus</i> t., <i>C. napulifera</i> t., <i>C. solstitialis</i> t., <i>C. graeca</i> t. or <i>C. amplifolia</i>
	<i>Cichorium intybus</i> L.	Compositae	<i>Cichorium</i> t.
	<i>Clematis</i> sp.	Ranunculaceae	<i>Clematis vitalba</i> gr. or <i>Ranunculus aquatilis</i> gr.
	<i>Cyclamen</i> sp.	Primulaceae	Prob. <i>Cyclamen</i>
	<i>Hedera helix</i> L.	Araliaceae	<i>Hedera helix</i>
	? <i>Hieracium</i> / <i>Pilosella</i> agg.	Compositae	<i>Hieracium</i> t.
	<i>Lotus aegaeus</i> (Griseb.) Boiss.	Leguminosae	<i>Lotus</i> t.

PINDOS FOOTHILLS

Oak wood-pasture

Polinerion

Grid reference: 40° 3.5' N 21° 12' E
 Altitude: 1100 m
 Local vegetation: grassland + scattered oak & juniper
 Slope : 8-19°
 Aspect for 100 x 100 m plot: southeast
 Substrate: shallow stony soil on Pindos flysch
 2 x 2 m plots within 100 x 100 m plot

Oak wood-pasture covers about 20% of Grevena. A large quadrat of 100 x 100 m was surveyed to get a general impression of the woody species and larger more common herbaceous species because woody plants are so sparse in this zone; grasses cover an estimated 90% of this quadrat. Smaller plots (2 x 2 m) were surveyed within this larger one to estimate relative abundance of less obvious plants.

This area is heavily grazed and scattered *Juniperus* are grazed into 1 m diameter cone-shaped bushes. The tops of the juniper develop once the diameter of the bush reaches about 1.5 m, when the bush is too broad for the grazing animals to reach the top. Maximum height of the junipers is 2 m. Juniper also occurs in patches on steeper, eroded slopes with old trunks up to 10 cm diameter.

Three 2 x 2 m plots within the larger quadrat were surveyed in different grassland types: post-cultivation (plot a); non-cultivation (plot b); and a moist non-cultivated area (plot c).

Oak wood-pasture (100 x 100 m quadrat)

% cover	Genus & Species	Family	Pollen type
TREES			
Angiospermae:			
Dicotyledones:			
+	<i>Malus</i> sp.	Rosaceae	<i>Malus</i>
5%	<i>Quercus</i> spp. (<i>Q. brachyphylla</i> , <i>Q. brachyphylla</i> /frainetto, <i>Q. cerris</i> , <i>Q. frainetto</i> , <i>Q. virgiliana</i>)	Fagaceae	<i>Quercus</i>
SMALL TREES AND SHRUBS			
Gymnospermae:			
3%	<i>Juniperus oxycedrus</i> L.	Cupressaceae	<i>Juniperus</i>
Angiospermae:			
Dicotyledones:			
+	<i>Crataegus</i> sp.	Rosaceae	<i>Crataegus</i>
+	<i>Rosa</i> sp.	Rosaceae	Prob. <i>Rosa</i>
GROUND COVER			
Angiospermae:			
Dicotyledones:			
1%	<i>Centaurea solstitialis</i> L.	Compositae	<i>Centaurea solstitialis</i> t.
+	<i>Cirsium</i> sp.	Compositae	<i>Cirsium</i> t.
1%	<i>Euphorbia myrsinites</i> L.	Euphorbiaceae	? <i>Euphorbia</i>
1%	<i>Helleborus cyclophyllus</i> Boiss.	Ranunculaceae	? <i>Helleborus</i>
+	<i>Lotus</i> cf. <i>corniculatus</i> L.	Leguminosae	<i>Lotus</i> t.
+	<i>Ononis spinosa</i> L.	Leguminosae	<i>Ononis</i> t.
Monocotyledones:			
90%		Gramineae	Gramineae

Grassland subplot a - ex-cultivation (2 x 2 m plot)

Aspect: southwest

Slope: 14°

This area was cultivated 40-50 years ago, and has developed a suite of weeds associated with cultivation. About 2% of the ground surface was bare and about 1% of the ground was covered with rocks. The dominance of *Taeniatherum caput-medusae* is remarkable.

% cover	Genus & Species	Family	Pollen type
GROUND COVER			
Angiospermae:			
Dicotyledones:			
+	<i>Cichorium intybus</i> L.	Compositae	<i>Cichorium</i> t.
+	<i>Cirsium</i> sp.	Compositae	<i>Cirsium</i> t.
+	<i>Convolvulus arvensis</i> L.	Convolvulaceae	<i>Convolvulus</i>
+	<i>Dianthus</i> sp.	Caryophyllaceae	Prob. <i>Dianthus</i> t.
+	<i>Euphorbia myrsinites</i> L.	Euphorbiaceae	? <i>Euphorbia</i>
+	<i>Filago pyramidata</i> L.	Compositae	<i>Solidago</i> t.
+	<i>Galium rivale</i> (Sibth. & Sm.) Griseb.	Rubiaceae	? <i>Galium</i> t.
1%	<i>Helleborus cyclophyllus</i> Boiss.	Ranunculaceae	? <i>Helleborus</i>
1%	<i>Hieracium/Pilosella</i> agg.	Compositae	<i>Hieracium</i> t.
+	<i>Lactuca viminea</i> (L.) J. & C. Presl.	Compositae	<i>Lactuca</i> t.
+	<i>Leontodon</i> sp. or <i>Crepis</i> sp.	Compositae	<i>Cichorium</i> t. or <i>Taraxacum</i> t.
+	<i>Lotus</i> cf. <i>corniculatus</i> L.	Leguminosae	<i>Lotus</i> t.
+	<i>Ononis spinosa</i> L.	Leguminosae	<i>Ononis</i> t.
+	<i>Plantago lanceolata</i> L.	Plantaginaceae	<i>Plantago lanceolata</i> t.
+	<i>Polygonum aviculare</i> L.	Polygonaceae	<i>Polygonum aviculare</i> t.
+	<i>Prunella grandiflora</i> (L.) Scholler	Labiatae	<i>Prunella</i> t.
+	<i>Rumex tenuifolius</i> (Wallr.) A. Love	Polygonaceae	<i>Rumex acetosella</i> gr.
+	<i>Sanguisorba minor</i> Scop.	Rosaceae	<i>Sanguisorba minor</i>
+	<i>Taraxacum</i> sp.	Compositae	<i>Taraxacum</i> t.
+	<i>Trifolium campestre</i> Schreber	Leguminosae	<i>Trifolium dubium</i> t.
+	<i>Trifolium</i> sp.	Leguminosae	<i>Trifolium dubium</i> t., <i>T. repens</i> t. or <i>T. montanum</i>
+	<i>Trifolium</i> sp.	Leguminosae	<i>Trifolium dubium</i> t., <i>T. repens</i> t. or <i>T. montanum</i> t.
Monocotyledones:			
+	<i>Aegilops neglecta</i> Reg. ex Bertol.	Gramineae	<i>Agropyron</i> t.
2%	<i>Agropyron</i> sp.	Gramineae	<i>Agropyron</i> t.
+	<i>Agrostis</i> sp.	Gramineae	?? <i>Dactylis</i> t.
5%	<i>Bromus hordeaceus</i>	Gramineae	<i>Glyceria</i> t.
1%	<i>Cynodon dactylon</i> (L.) Pers.	Gramineae	<i>Dactylis</i> t.
5%	<i>Cynosurus elegans</i> Desf.	Gramineae	<i>Dactylis</i> t.
10%	<i>Festuca</i> cf. <i>glauca</i> Vill.	Gramineae	<i>Festuca</i> t.
+	<i>Lolium perenne</i> L.	Gramineae	<i>Festuca</i> t.
+	<i>Piptatherum miliaceum</i> (L.) Cosson	Gramineae	?? <i>Dactylis</i> t.
80%	<i>Taeniatherum caput-medusae</i> (L.) Nevski	Gramineae	? <i>Hordeum</i> t.

Close by plot a:

Angiospermae:

Dicotyledones:

Centaurea solstitialis L.

Compositae

Centaurea solstitialis t.

Grassland subplot b - non-cultivated (2 x 2 m plot)

Aspect: south east

Slope: 15°

About 3% of the ground surface was bare and about 1% of the ground surface was covered with rocks.

% cover	Genus & Species	Family	Pollen type
GROUND COVER			
Angiospermae:			
Dicotyledones:			
30%	<i>Achillea millefolium</i> L.	Compositae	<i>Achillea</i> t.
+	<i>Acinos</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
+	<i>Euphorbia myrsinites</i> L.	Euphorbiaceae	? <i>Euphorbia</i>
+	<i>Helianthemum nummularium</i> (L.) Miller	Cistaceae	<i>Helianthemum</i>
2%	<i>Hieracium/Pilosella</i> agg.	Compositae	<i>Hieracium</i> t.
+	<i>Lotus</i> sp.	Leguminosae	<i>Lotus</i> t.
1%	<i>Lotus corniculatus</i> L.	Leguminosae	<i>Lotus</i> t.
+	<i>Odontites verna</i> (Bellardi) Dumort.	Scrophulariaceae	<i>Veronica anagallis-aquatica</i> t.
+	<i>Ononis spinosa</i> L.	Leguminosae	<i>Ononis</i> t.
4%	<i>Plantago lanceolata</i> L.	Plantaginaceae	<i>Plantago lanceolata</i> t.
2%	<i>Potentilla</i> sp.	Rosaceae	Prob. <i>Potentilla</i>
2%	<i>Prunella</i> sp.	Labiatae	<i>Prunella</i> t.
+	<i>Sanguisorba</i> sp.	Rosaceae	<i>Sanguisorba officinalis</i> or <i>S. minor</i>
3%	<i>Taraxacum</i> sp.	Compositae	<i>Taraxacum</i> t.
1%	<i>Trifolium campestre</i> Schreber	Leguminosae	<i>Trifolium dubium</i> t.
Monocotyledones:			
+	<i>Anthoxanthum</i> sp.	Gramineae	?? <i>Dactylis</i> t.
+	<i>Bromus</i> sp.	Gramineae	<i>Glyceria</i> t.
10%	<i>Carex</i> sp.	Cyperaceae	<i>Carex hallerana</i> t. or <i>C. flacca</i> t.
2%	<i>Cynosurus cristatus</i> L.	Gramineae	<i>Dactylis</i> t.
1%	<i>Cynosurus elegans</i> Desf.	Gramineae	<i>Dactylis</i> t.
10%	<i>Festuca</i> sp. <i>glauca</i> Vill.	Gramineae	<i>Festuca</i> t.
+	<i>Lolium perenne</i> L.	Gramineae	<i>Festuca</i> t.
+	<i>Phleum</i> sp. ? <i>pratense</i> L.	Gramineae	?? <i>Dactylis</i> t.
20%	<i>Piptatherum miliaceum</i> (L.) Cosson	Gramineae	?? <i>Dactylis</i> t.
+	<i>Taeniatherum caput-medusae</i> (L.) Nevski	Gramineae	? <i>Hordeum</i> t.
2%	<i>Trisetum</i> sp. ? <i>flavescens</i> (L.) Beauv.	Gramineae	?? <i>Dactylis</i> t.
Close by plot b:			
Gymnospermae:			
	<i>Juniperus</i> sp.	Cupressaceae	<i>Juniperus</i>
Angiospermae:			
Dicotyledones:			
	<i>Crataegus</i> sp.	Rosaceae	<i>Crataegus</i>
	<i>Dianthus</i> sp.	Caryophyllaceae	Prob. <i>Dianthus</i> t.
	<i>Helleborus</i> sp.	Ranunculaceae	Prob. <i>Helleborus</i>

Grassland subplot c - moist ground (2 x 2 m plot)

Aspect: east

Slope 19°

This type of grassland is less common in this area than those of the other two plots. *Carex* sp. is dominant. About 5% of the ground surface was bare.

% cover	Genus & Species	Family	Pollen type
GROUND COVER			
Angiospermae:			
Dicotyledones:			
+	<i>Acinos</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
+	<i>Centaurium tenuiflorum</i> (Hoffmanns. & Link.) Fritsch	Gentianaceae	<i>Centaurium</i>
4%	<i>Hieracium/Pilosella</i> agg.	Compositae	<i>Hieracium</i> t.
1%	<i>Lotus</i> sp.	Leguminosae	<i>Lotus</i> t.
2%	<i>Plantago lanceolata</i> L.	Plantaginaceae	<i>Plantago lanceolata</i> t.
10%	<i>Potentilla</i> sp.	Rosaceae	Prob. <i>Potentilla</i>
10%	<i>Prunella</i> sp.	Labiatae	<i>Prunella</i> t.
+	<i>Taraxacum</i> sp.	Compositae	<i>Taraxacum</i> t.
2%	<i>Trifolium repens</i> L.	Leguminosae	<i>Trifolium repens</i> t.
Monocotyledones:			
50%	<i>Carex</i> sp.	Cyperaceae	<i>Carex hallerana</i> t. or <i>C. flacca</i> t.
+	<i>Agrostis</i> cf. <i>capillaris</i> Sibth.	Gramineae	?? <i>Dactylis</i> t.
+	<i>Anthoxanthum</i> sp.	Gramineae	?? <i>Dactylis</i> t.
+	<i>Cynodon</i> sp.	Gramineae	<i>Dactylis</i> t.
4%	<i>Cynosurus cristatus</i> L.	Gramineae	<i>Dactylis</i> t.
2%	<i>Festuca ovina</i> L.	Gramineae	<i>Festuca</i> t.
+	<i>Lolium perenne</i> L.	Gramineae	<i>Festuca</i> t.
+	<i>Taeniatherum caput-medusae</i> (L.) Nevski	Gramineae	? <i>Hordeum</i> t.
4%	<i>Trisetum</i> sp.	Gramineae	?? <i>Dactylis</i> t.
15%	<i>Juncus inflexus</i> L.	Juncaceae	Juncaceae
Close by plot c:			
Gymnospermae:			
	<i>Juniperus oxycedrus</i> L.	Cupressaceae	<i>Juniperus</i>
Angiospermae:			
Dicotyledones:			
	<i>Cirsium creticum</i> (Lam.) D'Urv.	Compositae	<i>Cirsium</i> t.
Monocotyledones:			
	<i>Brachypodium pinnatum</i> (L.) Beauv.	Gramineae	<i>Dactylis</i> t.
	<i>Scirpus holoschoenus</i> L.	Cyperaceae	<i>Carex hallerana</i> t.

Mixed woods

Zakas

Grid reference: 40° 02' N 21° 16' E
 Altitude: 1160 m
 Local vegetation: mixed deciduous and coniferous wood
 Canopy height: 15 m
 Slope: 30°
 Aspect: north
 Substrate: shallow stony soil on massive limestone
 30 x 30 m quadrat

This is one of the two areas in Grevena where mixed deciduous woods occur. Both woods grow on limestone. This type of wood differs from other woods in Grevena in the great diversity of trees that grow in it and it is also one of the few woods in Grevena dominated by *Abies*. Many trees were noted growing close to the quadrat that were not growing within it. The canopy cover is about 90%. Ground cover is 80% litter.

% cover	Genus & Species	Family	Pollen type
CANOPY TREES			
Gymnospermae:			
60%	<i>Abies cephalonica</i> Loudon	Pinaceae	<i>Abies</i>
Angiospermae:			
Dicotyledones:			
29%	<i>Acer opalus</i> Miller	Aceraceae	<i>Acer</i>
1%	<i>Fagus sylvatica</i> L.	Fagaceae	<i>Fagus</i>
+	<i>Quercus cf. frainetto</i> (Mattuschka) Liebl.	Fagaceae	Prob. <i>Quercus frainetto</i> t.
UNDERSTOREY TREES AND SHRUBS			
Filicopsida:			
15%	<i>Pteridium aquilinum</i> (L.) Kuhn in Decken	Hypolepidaceae	<i>Pteridium aquilinum</i>
Gymnospermae:			
+	<i>Abies cephalonica</i> Loudon (seedlings)	Pinaceae	<i>Abies</i>
Angiospermae:			
Dicotyledones:			
5%	<i>Rubus corylifolius</i> Sm.	Rosaceae	<i>Rubus</i> t.
GROUND COVER			
Angiospermae:			
Dicotyledones:			
+	<i>Digitalis</i> sp.	Scrophulariaceae	? <i>Scrophularia</i> t.
+	<i>Euphorbia cf. amygdaloides</i> L.	Euphorbiaceae	<i>Euphorbia</i>
+	<i>Galium</i> sp.	Rubiaceae	Prob. <i>Galium</i> t.
+	<i>Helleborus</i> sp.	Ranunculaceae	Prob. <i>Helleborus</i>
+	? <i>Lathyrus laxiflorus</i> (Desf.) O. Kuntze	Leguminosae	? <i>Lathyrus pratensis</i> t.
+	<i>Potentilla</i> sp. ? <i>sterilis</i> (L.) Garcke	Rosaceae	Prob. <i>Potentilla</i>
+	<i>Primula elatior</i> (L.) Hill	Primulaceae	<i>Primula</i>
+	<i>Veronica cf. chamaedrys</i> L.	Scrophulariaceae	Prob. <i>Veronica triphyllos</i> t.
1%	<i>Viola</i> sp.	Violaceae	<i>Viola hirta</i> t., <i>V. riviniana</i> t. or <i>V. arvensis</i> t.

% cover	Genus & Species	Family	Pollen type
Monocotyledones:			
1%	<i>Brachypodium sylvaticum</i> (Hudson) Beauv.	Gramineae	<i>Dactylis</i> t.
+	<i>Festuca</i> sp. <i>rubra</i> group	Gramineae	<i>Festuca</i> t.
+	<i>Luzula sylvatica</i> (Hudson) Gaudin	Juncaceae	Juncaceae
+		Orchidaceae	Orchidaceae
Close by:			
CANOPY TREES			
Angiospermae:			
Dicotyledones:			
	<i>Acer pseudoplatanus</i> L.	Aceraceae	<i>Acer</i>
	<i>Carpinus betulus</i> L.	Corylaceae	<i>Carpinus</i> t. or <i>Ostrya</i> t.
	<i>Ostrya carpinifolia</i> Scop.	Corylaceae	<i>Ostrya</i> t. or <i>Carpinus</i> t.
	<i>Populus tremula</i> L.	Salicaceae	<i>Populus</i>
	<i>Taxus baccata</i> L.	Taxaceae	<i>Taxus baccata</i>
	<i>Tilia rubra</i> DC	Tiliaceae	? <i>Tilia platyphyllos</i> t.
UNDERSTOREY TREES AND SHRUBS			
Angiospermae:			
Dicotyledones:			
	<i>Buxus sempervirens</i> L.	Buxaceae	<i>Buxus sempervirens</i>

Aetia

Grid reference: 40° 4.5' N 21° 12' E
 Altitude: 1000 m
 Local vegetation: mixed deciduous wood
 Canopy height: 12 m
 Slope: 30°
 Aspect: west
 Substrate: shallow stony soil on massive limestone
 Reconnaissance survey

% cover	Genus & Species	Family	Pollen type
CANOPY			
Angiospermae:			
Dicotyledones:			
	<i>Acer monspessulanum</i> L.	Aceraceae	<i>Acer</i>
	<i>A. obtusatum</i> Waldst. & Kit. ex Willd	Aceraceae	Prob. <i>Acer</i>
	<i>A. pseudoplatanus</i> L.	Aceraceae	<i>Acer</i>
	<i>Carpinus orientalis</i> Miller	Corylaceae	<i>Ostrya</i> t. or <i>Carpinus</i> t.
	<i>Cornus mas</i> L.	Cornaceae	<i>Cornus mas</i>
	<i>Corylus colurna</i> L.	Corylaceae	<i>Corylus</i>
	<i>Euonymus latifolius</i> (L.) Miller	Celastraceae	? <i>Euonymus europaeus</i> t.
	<i>E. verrucosus</i> Scop.	Celastraceae	? <i>Euonymus europaeus</i> t.
	<i>Fraxinus ornus</i> L.	Oleaceae	<i>Fraxinus ornus</i>
	<i>Ostrya carpinifolia</i> Scop.	Corylaceae	<i>Ostrya</i> t. or <i>Carpinus</i> t.
	<i>Ostrya</i> sp.	Corylaceae	<i>Ostrya</i> t. or <i>Carpinus</i> t.
	<i>Prunus cerasifera</i> Ehrh.	Rosaceae	? <i>Prunus spinosa</i> t.
	<i>P. mahaleb</i> L.	Rosaceae	<i>Prunus avium</i> t.
	<i>Sorbus graeca</i> (Spach) Kotschy	Rosaceae	<i>Sorbus</i> t.
	<i>S. torminalis</i> (L.) Crantz	Rosaceae	<i>Sorbus</i> t.
	<i>Taxus baccata</i> L.	Taxaceae	<i>Taxus baccata</i>
	<i>Tilia rubra</i> DC	Tiliaceae	? <i>Tilia platyphyllos</i> t.
	<i>T. tomentosa</i> Moench	Tiliaceae	<i>Tilia cordata</i> t.
	<i>Ulmus glabra</i> Hudson	Ulmaceae	<i>Ulmus glabra</i> t.
UNDERSTOREY TREES AND SHRUBS			
Gymnospermae:			
	<i>Juniperus excelsa</i> Bieb.	Cupressaceae	<i>Juniperus</i>
	<i>J. foetidissima</i> Willd.	Cupressaceae	<i>Juniperus</i>
Angiospermae:			
Dicotyledones:			
	<i>Buxus sempervirens</i> L.	Buxaceae	<i>Buxus sempervirens</i>

LOWLAND PLAINS

Cultivated fields

Kellia fen

Grid reference: 40° 06' N 21° 25' E

Altitude: 580 m

Local vegetation: mixed fen

Slope: flat

Aspect: open

Substrate: silty peat

General survey of fen, 2 x 2 m plots & reconnaissance survey

Most of the gently rolling hills surrounding this fen are cultivated with cereal crops. A survey of the fen as a whole was undertaken and relative frequencies noted. Common species on the fen were *Cyperus longus*, *Typha*, *Juncus inflexus*, *Scirpus*, *Equisetum telmateia*, *Sparganium erectum*, *Rumex conglomeratus*, *Mentha aquatica*, *Potentilla* and *Pulicaria*.

To get an idea of the variation of vegetation on the fen, three 2 x 2 m subplots were quantitatively surveyed and percent cover estimated. Plot a was located 3 m west of the core site for the fossil pollen sequence on a drier part of the fen where *Cirsium*, *Cyperus* and *Equisetum* were almost equally abundant. Plot b was located about 20 m southeast of the core site in a wetter area where *Juncus inflexus* and *Eurhynchium praelongum* were equally abundant and *Typha* was small and poorly developed. Plot c was located near a spring on the very wet eastern side of the fen. It was the wettest area surveyed and *Typha* was dominant with *Sparganium* very abundant.

To the south of the fen on a north-facing slope that had not been used for cultivation recently a 2 x 2 m plot was surveyed and percentage cover estimated. Many steppe species grow here; *Centaurea* and *Camptothecium lutescens* were almost equally abundant. About 1% of the ground surface was bare.

Reconnaissance surveys were undertaken to augment the quantitative surveys. Three areas were surveyed in this manner; a disturbed area on the fen, a disturbed area near the fen and the steppe to the south of the fen. Two species were noted as indicative of disturbance on the fen, *Pulicaria dysenterica* and *Lythrum salicaria*. In a disturbed area near the fen, a mixture of those species growing on the fen and ruderals were noted. In a dry area to the south of the fen a variety of steppe species were noted.

% cover	Genus & Species	Family	Pollen type
On fen			
(a=abundant; la=locally abundant; f=frequent; o=occasional; +=present)			
Sphenopsida:			
a	<i>Equisetum telmateia</i> Ehrh.	Equisetaceae	<i>Equisetum</i>
Angiospermae:			
Dicotyledones:			
+	<i>Ajuga reptans</i> L.	Labiatae	<i>Scutellaria</i> t.
f	<i>Berula erecta</i> (Hudson) Coville	Umbelliferae	<i>Berula erecta</i>
f	<i>Calystegia</i> sp. ? <i>sepium</i> (L.) R. Br.	Convolvulaceae	<i>Calystegia</i>
f	<i>Cirsium creticum</i> (Lam.) D'Urv.	Compositae	<i>Cirsium</i> t.
a	<i>Cuscuta</i> sp.	Convolvulaceae	<i>Cuscuta epithymum</i> t., <i>C. europaea</i> t. or <i>C. monogyna</i>
+	<i>Epilobium hirsutum</i> L.	Onagraceae	<i>Epilobium hirsutum</i> t.
+	<i>Epilobium</i> cf. <i>adenocaulon</i> Hausskn.	Onagraceae	? <i>Epilobium hirsutum</i> t.
o	<i>Epilobium</i> cf. <i>parviflorum</i> Schreber	Onagraceae	Prob. <i>Epilobium hirsutum</i> t.
f	<i>Galium rivale</i> (Sibth. & Sm.) Griseb.	Rubiaceae	? <i>Galium</i> t.
o	<i>Galium spurium</i> L.	Rubiaceae	<i>Galium</i> t.
+	<i>Hypericum</i> cf. <i>tetrapterum</i> Fries	Guttiferae	Prob. <i>Hypericum perforatum</i> t.

% cover	Genus & Species	Family	Pollen type
+	<i>Kickxia elatine</i> (L.) Dumort	Scrophulariaceae	<i>Kickxia</i>
+	<i>Lactuca serriola</i> L.	Compositae	<i>Lactuca</i> t.
f	<i>Lycopus europaeus</i> L.	Labiatae	<i>Mentha</i> t.
rare	<i>Lysimachia nummularia</i> L.	Primulaceae	<i>Lysimachia</i>
o	<i>Lythrum salicaria</i> L.	Lythraceae	<i>Lythrum salicaria</i> t.
la	<i>Mentha aquatica</i> L.	Labiatae	<i>Mentha</i> t.
+	<i>Nigella</i> sp.	Ranunculaceae	<i>Nigella</i>
a	<i>Potentilla</i> sp. ? <i>reptans</i> L.	Rosaceae	Prob. <i>Potentilla</i>
a	<i>Pulicaria dysenterica</i> (L.) Bernh.	Compositae	<i>Solidago</i> t.
la	<i>Rubus caesius</i> L.	Rosaceae	<i>Rubus</i> t.
a	<i>Rumex conglomeratus</i> Murray	Polygonaceae	<i>Rumex conglomeratus</i> gr.
o	<i>Rumex pulcher</i> L.	Polygonaceae	<i>Rumex conglomeratus</i> gr.
+	<i>Salix alba</i>	Salicaceae	<i>Salix fragilis</i> t.
+	<i>Sonchus oleraceus</i> L.	Compositae	<i>Sonchus</i> t.
f	<i>Teucrium scordium</i> L.	Labiatae	<i>Teucrium</i>
Monocotyledones:			
f	<i>Agrostis stolonifera</i> L.	Gramineae	?? <i>Dactylis</i> t.
a	<i>Cyperus longus</i> L.	Cyperaceae	<i>Cyperus longus</i> t.
a	<i>Juncus inflexus</i> L.	Juncaceae	Juncaceae
a	<i>Scirpus</i> sp.	Cyperaceae	<i>Carex hallerana</i> t. or <i>Scirpus</i>
a	<i>Sparganium erectum</i> L.	Sparganiaceae	<i>Sparganium erectum</i>
+	<i>Setaria</i> sp.	Gramineae	?? <i>Dactylis</i> t.
a	<i>Typha latifolia</i> L.	Typhaceae	<i>Typha angustifolia</i> t.
Close by:			
Angiospermae:			
Dicotyledones:			
	<i>Prunus spinosa</i> L.	Rosaceae	<i>Prunus spinosa</i> t.
Subplot a - on fen (2 x 2 m plot)			
Sphenopsida:			
20%	<i>Equisetum</i> sp.	Equisetaceae	<i>Equisetum</i>
Angiospermae:			
Dicotyledones:			
20%	<i>Cirsium</i> sp.	Compositae	<i>Cirsium</i> t.
10%	<i>Epilobium</i> cf. <i>parviflorum</i> Schreber	Onagraceae	Prob. <i>Epilobium hirsutum</i> t.
3%	<i>Galium palustre</i> L.	Rubiaceae	<i>Galium</i> t.
1%	<i>Lycopus</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
5%	<i>Lythrum</i> sp.	Lythraceae	<i>Lythrum salicaria</i> t. or <i>L. portula</i>
5%	<i>Mentha aquatica</i> L.	Labiatae	<i>Mentha</i> t.
+	<i>Rumex pulcher</i> L.	Polygonaceae	<i>Rumex conglomeratus</i> gr.
4%	<i>Teucrium</i> sp.	Labiatae	<i>Teucrium</i>
Monocotyledones:			
30%	<i>Cyperus</i> sp.	Cyperaceae	<i>Cyperus michelianus</i> or <i>C. longus</i> t.
2%	<i>Juncus</i> sp.	Juncaceae	Juncaceae

% cover	Genus & Species	Family	Pollen type
Subplot b - on fen (2 x 2 m plot)			
Bryophyta:			
80%	<i>Eurhynchium praelongum</i> (Hedw.) Hobk.	Hypnaceae	
Sphenopsida:			
3%	<i>Equisetum</i> sp.	Equisetaceae	<i>Equisetum</i>
Angiospermae:			
Dicotyledones:			
+	<i>Berula erecta</i> (Hudson) Coville	Umbelliferae	<i>Berula erecta</i>
1%	<i>Cirsium</i> sp.	Compositae	<i>Cirsium</i> t.
8%	<i>Hypericum</i> cf. <i>tetrapterum</i> Fries	Guttiferae	Prob. <i>Hypericum perforatum</i> t.
+	<i>Lycopus</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
+	<i>Lysimachia nummularia</i> L.	Primulaceae	<i>Lysimachia</i>
5%	<i>Lythrum salicaria</i> L.	Lythraceae	<i>Lythrum salicaria</i> t.
1%	<i>Potentilla</i> sp.	Rosaceae	Prob. <i>Potentilla</i>
Monocotyledones:			
+	? <i>Agrostis</i> sp.	Gramineae	?? <i>Dactylis</i> t.
80%	<i>Juncus inflexus</i> L.	Juncaceae	Juncaceae
+	<i>Typha</i> sp.	Typhaceae	<i>Typha angustifolia</i> t. or <i>T. domingensis</i> t.
Subplot c - on fen (2 x 2 m plot)			
Sphenopsida:			
2%	<i>Equisetum telmateia</i> Ehrh.	Equisetaceae	<i>Equisetum</i>
Angiospermae:			
Dicotyledones:			
1%	<i>Cirsium</i> sp.	Compositae	<i>Cirsium</i> t.
+	<i>Galium palustre</i> L.	Rubiaceae	<i>Galium</i> t.
+	<i>Galium spurium</i> L.	Rubiaceae	<i>Galium</i> t.
2%	<i>Lycopus</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
3%	<i>Lythrum</i> sp.	Lythraceae	<i>Lythrum salicaria</i> t. or <i>L. portula</i>
Monocotyledones:			
+	<i>Juncus inflexus</i> L.	Juncaceae	Juncaceae
30%	<i>Sparganium</i> sp.	Sparganiaceae	<i>Sparganium erectum</i> or <i>S. angustifolium</i>
60%	<i>Typha</i> sp.	Typhaceae	<i>Typha angustifolia</i> t. or <i>T. domingensis</i> t.
Disturbed area on fen (reconnaissance survey)			
Angiospermae:			
Dicotyledones:			
	<i>Lythrum salicaria</i> L.	Lythraceae	<i>Lythrum salicaria</i> t.
	<i>Pulicaria dysenterica</i> (L.) Bernh.	Compositae	<i>Solidago</i> t.

% cover	Genus & Species	Family	Pollen type
Disturbed area near fen (reconnaissance survey)			
Angiospermae:			
Dicotyledones:			
	<i>Centaurea</i> sp. ? <i>napulifera</i> Rochel	Compositae	? <i>Centaurea napulifera</i> t.
	<i>Cichorium intybus</i> L.	Compositae	<i>Cichorium</i> t.
	<i>Consolida</i> sp.	Ranunculaceae	Prob. <i>Consolida</i> t.
	<i>Daucus carota</i> L.	Umbelliferae	<i>Daucus</i>
	<i>Mentha aquatica</i> L.	Labiatae	<i>Mentha</i> t.
	<i>Ononis spinosa</i> L.	Leguminosae	<i>Ononis</i> t.
	<i>Potentilla reptans</i> L.	Rosaceae	<i>Potentilla</i>
	<i>Torilis japonica</i> (Houtt.) DC	Umbelliferae	<i>Torilis japonica</i> t.
	<i>Verbena officinalis</i> L.	Verbenaceae	<i>Verbena</i>
Monocotyledones:			
	<i>Colchicum</i> sp. ? <i>autumnale</i> L.	Liliaceae	<i>Colchicum</i>
Steppe south of Kellia fen (2 x 2 m plot)			
Bryophyta:			
60%	<i>Camptothecium lutescens</i> (Hedw.) B.	Hypnaceae	
Angiospermae:			
Dicotyledones:			
40%	<i>Centaurea</i> sp.	Compositae	<i>Centaurea cyanus</i> t., <i>C. napulifera</i> t., <i>C. solstitialis</i> t., <i>C. graeca</i> t. or <i>C. amplifolia</i>
+	<i>Cuscuta</i> sp.	Convolvulaceae	<i>Cuscuta epithymum</i> t., <i>C. europaea</i> t. or <i>C. monogyna</i>
1%	<i>Daucus carota</i> L.	Umbelliferae	<i>Daucus</i>
2%	<i>Dorycnium</i> sp.	Leguminosae	<i>Dorycnium</i>
+	<i>Eryngium</i> cf. <i>campestre</i> L.	Umbelliferae	Prob. <i>Eryngium</i>
2%	<i>Galium verum</i> L.	Rubiaceae	<i>Galium</i> t.
15%	<i>Prunus spinosa</i> L.	Rosaceae	<i>Prunus spinosa</i> t.
+	<i>Sanguisorba minor</i> Scop.	Rosaceae	<i>Sanguisorba minor</i>
+	<i>Thesium</i> sp.	Santalaceae	<i>Thesium divaricatum</i> t. or <i>T. alpinum</i>
Monocotyledones:			
2%	<i>Carex</i> sp.	Cyperaceae	<i>Carex hallerana</i> t. or <i>C. flacca</i> t.
+	<i>Colchicum autumnale</i> L.	Liliaceae	<i>Colchicum</i>
+	<i>Cynosurus cristatus</i> L.	Gramineae	<i>Dactylis</i> t.
5%	<i>Festuca ovina</i> L.	Gramineae	<i>Festuca</i> t.
Steppe south of Kellia fen (reconnaissance survey)			
Angiospermae:			
Dicotyledones:			
	<i>Cirsium eriophorum</i> (L.) Scop.	Compositae	<i>Cirsium</i> t.
	<i>C. mairei</i> Halacsy	Compositae	<i>Cirsium</i> t.
	<i>Cirsium</i> sp. ? <i>vulgare</i>	Compositae	<i>Cirsium</i> t.
	<i>Cirsium</i> cf. <i>vulgare</i> (Savi) Ten.	Compositae	<i>Cirsium</i> t.
	<i>Clinopodium vulgare</i> L.	Labiatae	<i>Mentha</i> t.
	<i>Dorycnium graecum</i> (L.) Ser.	Leguminosae	<i>Dorycnium</i>
	<i>Dorycnium</i> sp.	Leguminosae	<i>Dorycnium</i>
	<i>Galium verum</i> L.	Rubiaceae	<i>Galium</i> t.
	<i>Galium verum</i> subsp. <i>wirtgenii</i> (F.W. Schultz) Oborny	Rubiaceae	<i>Galium</i> t.

% cover	Genus & Species	Family	Pollen type
	<i>Kickxia spuria</i> (L.) Dumort	Scrophulariaceae	<i>Kickxia</i>
	<i>Lotus cf. corniculatus</i> L.	Leguminosae	<i>Lotus</i> t.
	<i>Lotus</i> sp.	Leguminosae	<i>Lotus</i> t.
	<i>Polygonum aviculare</i> L.	Polygonaceae	<i>Polygonum aviculare</i> t.
	<i>Polygonum cf. aviculare</i> L.	Polygonaceae	Prob. <i>Polygonum aviculare</i> t.
	<i>Prunus spinosa</i> L.	Rosaceae	<i>Prunus spinosa</i> t.
	<i>Thesium</i> sp.	Santalaceae	<i>Thesium divaricatum</i> t. or <i>T. alpinum</i>
Monocotyledones:			
	<i>Allium</i> sp.	Liliaceae	<i>Allium roseum</i> t., <i>A. sphaerocephalon</i> t. or <i>A. paniculatum</i> t.

Asprokampos field

Grid reference: 40° 08' 30" N 21° 29' 30" E

Altitude: 560 m

Local vegetation: cereal agricultural field

Slope: flat

Aspect: open

Substrate: brown agricultural soil

Reconnaissance survey

This cereal field is surrounded by other cultivated fields. A reconnaissance survey was undertaken when weeds had begun to grow a few weeks after harvest. The dominant weed was *Polygonum aviculare*. Other abundant weeds were *Consolida* sp. and grasses.

% cover	Genus & Species	Family	Pollen type
TREE			
Angiospermae:			
Dicotyledones:			
	<i>Salix</i> sp.	Salicaceae	<i>Salix triandra</i> or <i>S. fragilis</i> t.
GROUND COVER			
Angiospermae:			
Dicotyledones:			
	<i>Anagallis</i> sp.	Primulaceae	<i>Anagallis arvensis</i> t. or <i>A. tenella</i> t.
	<i>?Atriplex</i> sp.	Chenopodiaceae	Chenopodiaceae t.
	<i>Chenopodium</i> cf. <i>album</i> L.	Chenopodiaceae	Chenopodiaceae t.
	<i>Cirsium arvense</i> (L.) Scop.	Compositae	<i>Cirsium</i> t.
	<i>Consolida</i> sp.	Ranunculaceae	Prob. <i>Consolida</i> t.
	<i>Convolvulus arvensis</i> L.	Convolvulaceae	<i>Convolvulus</i>
	<i>Cuscuta</i> sp.	Convolvulaceae	<i>Cuscuta epithymum</i> t., <i>C. europaea</i> t. or <i>C. monogyna</i>
	<i>Eryngium</i> sp.	Umbelliferae	Prob. <i>Eryngium</i>
	<i>Geranium</i> sp. <i>?molle</i> L.	Geraniaceae	Prob. <i>Geranium molle</i> gr.
	<i>Heliotropium hirsutissimum</i> Grauer	Boraginaceae	<i>?Heliotropium</i>
	<i>Hibiscus trionum</i> L.	Malvaceae	<i>Hibiscus</i>
	<i>Kickxia</i> sp.	Scrophulariaceae	<i>Kickxia</i>
	<i>Lactuca viminea</i> (L.) J. & C. Presl.	Compositae	<i>Lactuca</i> t.
	<i>Lactuca virosa</i> L.	Compositae	<i>Lactuca</i> t.
	<i>Plantago lanceolata</i> L.	Plantaginaceae	<i>Plantago lanceolata</i> t.
	<i>Polygonum aviculare</i> L.	Polygonaceae	<i>Polygonum aviculare</i> t.
	<i>Sinapis alba</i> L.	Cruciferae	<i>Sinapis</i> t.
	<i>Solanum nigrum</i> L.	Solanaceae	<i>Solanum nigrum</i> t.
Monocotyledones:			
	<i>Avena</i> cf. <i>sterilis</i> L.	Gramineae	<i>Avena</i> t.
		Gramineae	Gramineae
	<i>Setaria</i> sp.	Gramineae	<i>??Dactylis</i> t.
	<i>Triticum aestivum</i> L.	Gramineae	<i>Triticum</i> t.

Oak woods

Asprokamos woods

Grid reference: 40° 08' 30" N 21° 30' E

Altitude: 550 m

Local vegetation: oak wood

Canopy height: 8 m

Slope: 20°

Aspect: south

Substrate: skeletal brown soil

30 x 30 m quadrat

This oak wood is heavily grazed. The oaks have been coppiced (although not in the last few years) and some have several stems. Canopy cover is about 50%. Oaks are much hybridized. Scattered *Juniperus* and *Buxus* form an understorey shrubbery. Grasses cover 80% of the ground and about 15% of the ground is bare.

% cover	Genus & Species	Family	Pollen type
CANOPY TREES			
Angiospermae:			
Dicotyledones:			
50%	<i>Quercus</i> spp. (<i>Q. brachyphylla</i> , <i>Q. brachyphylla</i> x <i>?cerris</i> , <i>Q. cerris</i> , <i>Q. cerris</i> hybrid, <i>Q. cerris</i> x <i>?virgiliana</i> , <i>Q. cf. frainetto</i> , <i>Q. pubescens</i> hybrid, <i>Q. trojana</i>)	Fagaceae	<i>Quercus frainetto</i> & <i>Q. trojana</i>
UNDERSTOREY TREES AND SHRUBS			
Gymnospermae:			
1%	<i>Juniperus</i> sp.	Cupressaceae	<i>Juniperus</i>
Angiospermae:			
Dicotyledones:			
+	<i>Buxus sempervirens</i> L.	Buxaceae	<i>Buxus sempervirens</i>
+	<i>Crataegus monogyna</i> Jacq.	Rosaceae	<i>Crataegus</i>
GROUND COVER			
Angiospermae:			
Dicotyledones:			
+	<i>Agrimonia</i> sp.	Rosaceae	<i>Agrimonia</i> t.
+	<i>Alyssum murale</i> Waldst. & Kit.	Cruciferae	<i>Hornungia</i> t.
+	<i>Anthemis</i> sp. or <i>Leucanthemum</i> sp.	Compositae	Prob. <i>Achillea</i> t.
+	<i>Arabis</i> sp.	Cruciferae	<i>Arabis</i> or <i>Sinapis</i> t.
+	<i>Buglossoides purpureo-aerulea</i> (L.) I.M. Johnston	Boraginaceae	<i>Buglossoides purpureo-aerulea</i>
+	<i>Carlina corymbosa</i> L.	Compositae	<i>Carlina</i> t.
+	<i>Clinopodium vulgare</i> L.	Labiatae	<i>Mentha</i> t.
+	<i>Fragaria vesca</i> L.	Rosaceae	<i>Fragaria vesca</i> t.
+	<i>Galium rivale</i> (Sibth. & Sm.) Griseb.	Rubiaceae	? <i>Galium</i> t.
+	<i>Galium verum</i> L.	Rubiaceae	<i>Galium</i> t.
+	<i>Hieracium/Pilosella</i> agg.	Compositae	<i>Hieracium</i> t.
		Leguminosae	Leguminosae
+	<i>Lotus</i> or <i>Dorycnium</i> sp.	Leguminosae	<i>Lotus</i> t. or <i>Dorycnium</i>
+	<i>Potentilla</i> sp.	Rosaceae	Prob. <i>Potentilla</i>
+	<i>Potentilla sterilis</i> (L.) Garcke	Rosaceae	<i>Potentilla</i>
+	<i>Prunella</i> sp.	Labiatae	<i>Prunella</i> t.

% cover	Genus & Species	Family	Pollen type
+	<i>Rosa</i> sp.	Rosaceae	Prob. <i>Rosa</i>
+	<i>Sanguisorba minor</i> Scop.	Rosaceae	<i>Sanguisorba minor</i>
+	<i>Stachys alopecuroides</i> (L.) Benth	Labiatae	<i>Stachys sylvatica</i> t.
+	<i>Teucrium chamaedrys</i> L.	Labiatae	<i>Teucrium</i>
+	<i>Teucrium polium</i> L.	Labiatae	<i>Teucrium</i>
+	<i>Thymus</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
+	<i>Veronica chamaedrys</i> L.	Scrophulariaceae	<i>Veronica triphyllos</i> t.
+	<i>Veronica</i> cf. <i>chamaedrys</i> L.	Scrophulariaceae	Prob. <i>Veronica triphyllos</i> t.
+	<i>Veronica</i> sp.	Scrophulariaceae	<i>Veronica anagallis-aquatica</i> t. or <i>Veronica triphyllos</i> t.
+	<i>Viola</i> sp.	Violaceae	<i>Viola hirta</i> t., <i>V. riviniana</i> t. or <i>V. arvensis</i> t.
Monocotyledones:			
+	<i>Carex</i> sp.	Cyperaceae	<i>Carex hallerana</i> t. or <i>C. flacca</i> t.
80%	(total of taxa below)	Gramineae	
	<i>Dactylis</i> sp.	Gramineae	<i>Dactylis</i> t.
	<i>Chrysopogon gryllus</i> (L.) Trin.	Gramineae	<i>Dactylis</i> t.
	<i>Festuca</i> sp.	Gramineae	<i>Festuca</i> t.
	<i>Festuca ovina</i> L.	Gramineae	<i>Festuca</i> t.
	<i>Elymus</i> sp.	Gramineae	<i>Hordeum</i> t.
	<i>Koeleria</i> sp.	Gramineae	?? <i>Dactylis</i> t.
+	<i>Muscari</i> sp.	Liliaceae	<i>Muscari comosum</i> or <i>Muscari neglectum</i> t.
+		Orchidaceae	Orchidaceae
+	<i>Scilla autumnalis</i> L.	Liliaceae	<i>Scilla</i> t.

Mirsina woods

Grid reference: 40° 08' N 21° 29' 30" E
 Altitude: 500 m
 Local vegetation: oak wood
 Canopy height: about 7.5 m
 Slope: 12°
 Aspect: south
 Substrate: skeletal soil on Pleistocene gravels
 10 x 20 m plot

This plot is irregular because it runs along the tread of a terrace about 40 m above the fen given the same name. The oak wood is of even age, about 30 years. The wood had been coppiced and the area is browsed. As a result of this several woody species are small shrub size. Canopy cover is 75%. Oak seedlings and low coppice shoots covered about 15% of the ground surface and slightly more than 10% was bare.

% cover	Genus & Species	Family	Pollen type
CANOPY TREES			
Angiospermae:			
Dicotyledones:			
+	<i>Pyrus</i> sp.	Rosaceae	Prob. <i>Pyrus</i>
75%	<i>Quercus</i> spp. as below:		
	<i>Quercus brachyphylla</i> Kotschy	Fagaceae	<i>Quercus trojana</i> t. or <i>Q. frainetto</i> t.
	<i>Q. brachyphylla</i> Kotschy x <i>frainetto</i> Ten.	Fagaceae	<i>Quercus trojana</i> t. or <i>Q. frainetto</i> t.
	<i>Q. brachyphylla</i> Kotschy x <i>virgilliana</i> (Ten.) Ten.	Fagaceae	<i>Quercus trojana</i> t. or <i>Q. frainetto</i> t.
	<i>Q. cerris</i> L.	Fagaceae	<i>Quercus trojana</i> t.
	<i>Q. frainetto</i> Ten.	Fagaceae	<i>Quercus frainetto</i> t.
	<i>Q. trojana</i> Webb	Fagaceae	<i>Quercus trojana</i> t. or <i>Q. frainetto</i> t.
	<i>Q. virgiliana</i> (Ten.) Ten	Fagaceae	<i>Quercus frainetto</i> t.
	<i>Q. virgiliana</i> (Ten.) Ten. x <i>frainetto</i> Ten.	Fagaceae	<i>Quercus frainetto</i> t.
SMALL SHRUBS AND GROUND COVER			
Angiospermae:			
Dicotyledones:			
+	<i>Agrimonia eupatoria</i> L.	Rosaceae	<i>Agrimonia</i> t.
+	<i>Buglossoides purpureocaerulea</i> (L.) I.M. Johnston	Boraginaceae	<i>Buglossoides</i> <i>purpureocaerulea</i>
15%	<i>Carpinus</i> sp.	Corylaceae	<i>Carpinus</i> t. or <i>Ostrya</i> t.
+	<i>Clinopodium</i> sp.	Labiatae	<i>Mentha</i> t.
+	<i>Cornus sanguinea</i> L.	Cornaceae	<i>Cornus sanguinea</i>
2%	<i>Crataegus</i> sp.	Rosaceae	Prob. <i>Crataegus</i>
+	<i>Cyclamen</i> sp.	Primulaceae	Prob. <i>Cyclamen</i>
3%	<i>Dorycnium</i> sp.	Leguminosae	<i>Dorycnium</i>
2%	<i>Dorycnium</i> sp.	Leguminosae	<i>Dorycnium</i>
10%	<i>Fragaria vesca</i> L.	Rosaceae	<i>Fragaria vesca</i> t.
2%	<i>Fraxinus ornus</i> L.	Oleaceae	<i>Fraxinus ornus</i>
1%	<i>Galium verum</i> L.	Rubiaceae	<i>Galium</i> t.
+	<i>Lathyrus</i> sp.	Leguminosae	<i>Lathyrus pratensis</i> t., <i>L. sativus</i> or <i>Vicia cracca</i> t.
+	<i>Prunus spinosa</i> L.	Rosaceae	<i>Prunus spinosa</i> t.

% cover	Genus & Species	Family	Pollen type
5%	<i>Rosa arvensis</i> Hudson	Rosaceae	<i>Rosa</i>
3%	<i>Stachys alopecuros</i> (L.) Benth	Labiatae	<i>Stachys sylvatica</i> t.
5%	? <i>Thalictrum</i> sp.	Ranunculaceae	? <i>Thalictrum aquilegifolium</i> , <i>T. minus</i> or <i>T. lucidum</i>
+	<i>Thymus</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
+	<i>Veronica chamaedrys</i> L.	Scrophulariaceae	<i>Veronica triphyllos</i> t.
Monocotyledones:			
5%	<i>Carex</i> sp.	Cyperaceae	<i>Carex hallerana</i> t. or <i>C. flacca</i> t.
15%	<i>Chrysopogon gryllus</i> (L.) Trin.	Gramineae	?? <i>Dactylis</i> t.
5%	<i>Festuca glauca</i> Vill.	Gramineae	<i>Festuca</i> t.
+	<i>Fritillaria</i> sp.	Liliaceae	<i>Fritillaria</i>
+	<i>Scilla autumnalis</i> L.	Liliaceae	<i>Scilla</i> t.
Close by:			
Angiospermae:			
Dicotyledones:			
	<i>Bupleurum asperuloides</i> Heldr. ex Boiss	Umbelliferae	<i>Bupleurum</i>
	<i>Tussilago farfara</i> L.	Compositae	<i>Solidago</i> t.
Monocotyledones:			
	<i>Elymus ?caninus</i> (L.) L.	Gramineae	<i>Hordeum</i> t.

Steppe/oak woods

Mirsina fen

Grid reference: 40° 08' N 21° 30' E

Altitude: 460 m

Local vegetation: depends on plot

Slope: flat

Aspect: open

Substrate: silty peat

2 x 2 m plots & reconnaissance

This is a small fen on a terrace about 20 m above and 40 m west of the Aliakmon River. It is covered with 4 m high *Phragmites australis*. The area was burnt recently (about 15 years before the survey was done). Current browsing is minimal, but there is evidence for heavier browsing in the past (Rackham pers. comm. 1989).

Four 2 x 2 m plots were quantitatively surveyed on and in the vicinity of the fen. The plots are located in areas of increasing dryness: plot a on the fen, plot b on the margin of the fen, plot c on dryland near the fen and plot d on dry ground (steppe) more distant from the fen. In plot b *Phragmites* is replaced mostly by *Scirpus holoschoenus* which covers 50% of the ground. Other prominent species are *Cirsium creticum*, *Juncus inflexus* and *Pulicaria dysenterica*. Plot c is influenced by the fen and damper than ground further from the fen. *Equisetum telmateia* is dominant in this plot. *Carex* is also abundant along with *Crepis*, *Dorycnium* and *Ononis spinosa*. The tallest plants here were 60 cm and the average height of the vegetation was 15 cm.

Plot d is located in open dry grassland (steppe) further from the fen. This dryness is typical of the general area. The plot has a northerly aspect with a 10-15° slope. The dominant species in this plot was *Thymus*. Other abundant species were *Carex*, *Festuca*, *Teucrium chamaedrys* and *Teucrium polium*. *Equisetum palustre* was suckering into this area. About 5% of the ground was bare in this plot.

A reconnaissance survey was undertaken of the species growing between plots c and d. Several shrubby species, for example, *Paliurus spina-christi* (2.5 m tall), *Crataegus* sp. (up to 4 m tall), *Fraxinus ornus* (0.5 m tall), *Euonymus europaeus* (0.20 m tall) and a tall grass (*Calamagrostis arundinaceae*) grew in this area. None of these, except *Crataegus*, grew in the plots quantitatively surveyed.

% cover	Genus & Species	Family	Pollen type
On fen - plot a (2 x 2 m plot)			
CANOPY			
Monocotyledones:			
100%	<i>Phragmites australis</i> (Cav.) Trin. ex Steudel	Gramineae	<i>Phragmites australis</i>
UNDERSTOREY			
Sphenopsida:			
2%	<i>Equisetum palustre</i> L.	Equisetaceae	<i>Equisetum</i>
Angiospermae:			
Dicotyledones:			
+	<i>Epilobium</i> sp.	Onagraceae	<i>Epilobium angustifolium</i> t. or <i>E. hirsutum</i> t.
1%	<i>Lycopus europaeus</i> L.	Labiatae	<i>Mentha</i> t.
Monocotyledones:			
5%	<i>Carex</i> sp.	Cyperaceae	<i>Carex hallerana</i> t. or <i>C. flacca</i> t.

% cover	Genus & Species	Family	Pollen type
Edge of fen - plot b (2 x 2 m plot)			
Sphenopsida:			
3%	<i>Equisetum palustre</i> L.	Equisetaceae	<i>Equisetum</i>
Angiospermae:			
Dicotyledones:			
15%	<i>Cirsium creticum</i> (Lam.) D'Urv.	Compositae	<i>Cirsium</i> t.
5%	<i>Lycopus</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
2%	<i>Mentha aquatica</i> L.	Labiatae	<i>Mentha</i> t.
10%	<i>Pulicaria dysenterica</i> (L.) Bernh.	Compositae	<i>Solidago</i> t.
1%	<i>Teucrium scordium</i> L.	Labiatae	<i>Teucrium</i>
Monocotyledones:			
2%	<i>Cyperus</i> cf. <i>longus</i> L.	Cyperaceae	Prob. <i>Cyperus longus</i> t.
10%	<i>Juncus inflexus</i> L.	Juncaceae	Juncaceae
50%	<i>Scirpus holoschoenus</i> L.	Cyperaceae	<i>Carex hallerana</i> t.
Close by:			
Angiospermae:			
Dicotyledones:			
	<i>Corylus avellana</i> L.	Corylaceae	<i>Corylus</i>
	<i>Potentilla reptans</i> L.	Rosaceae	<i>Potentilla</i>
	<i>Trifolium pratense</i> L.	Leguminosae	<i>Trifolium repens</i> t.
Dryland near fen - plot c (2 x 2 m plot)			
Sphenopsida:			
+	<i>Equisetum palustre</i> L.	Equisetaceae	<i>Equisetum</i>
25%	<i>Equisetum telmateia</i> Ehrh.	Equisetaceae	<i>Equisetum</i>
Angiospermae:			
Dicotyledones:			
2%	<i>Agrimonia eupatoria</i> L.	Rosaceae	<i>Agrimonia</i> t.
1%	<i>Buglossoides purpureocaerulea</i> (L.) I.M. Johnston	Boraginaceae	<i>Buglossoides purpureocaerulea</i>
+	<i>Cirsium eriophorum</i> (L.) Scop.	Compositae	<i>Cirsium</i> t.
2%	<i>Clinopodium vulgare</i> L.	Labiatae	<i>Mentha</i> t.
2%	<i>Corylus avellana</i> L.	Corylaceae	<i>Corylus</i>
1%	<i>Crataegus</i> cf. <i>monogyna</i> Jacq.	Rosaceae	<i>Crataegus</i>
15%	<i>Crepis</i> sp.	Compositae	<i>Cichorium</i> t. or <i>Taraxacum</i> t.
+	<i>Cuscuta</i> sp.	Convolvulaceae	<i>Cuscuta epithymum</i> t., <i>C. europaea</i> t. or <i>C. monogyna</i>
+	<i>Daucus carota</i> L.	Umbelliferae	<i>Daucus</i>
15%	<i>Dorycnium graecum</i> (L.) Ser.	Leguminosae	<i>Dorycnium</i>
10%	<i>Ononis spinosa</i> L.	Leguminosae	<i>Ononis</i> t.
1%	<i>Prunus</i> sp.	Rosaceae	<i>Prunus avium</i> t. or <i>P. spinosa</i> t.
2%	<i>Quercus</i> cf. <i>cerris</i> L.	Fagaceae	Prob. <i>Quercus trojana</i> t.
1%	<i>Rubus</i> cf. <i>ulmifolius</i> Schott	Rosaceae	Prob. <i>Rubus</i> t.
+	<i>Taraxacum</i> sp.	Compositae	<i>Taraxacum</i> t.
1%	<i>Teucrium chamaedrys</i> L.	Labiatae	<i>Teucrium</i>
+	<i>Teucrium polium</i> L.	Labiatae	<i>Teucrium</i>
Monocotyledones:			
7%	<i>Brachypodium silvaticum</i> (Hudson) Beauv.	Gramineae	<i>Dactylis</i> t.
15%	<i>Carex</i> sp.	Cyperaceae	<i>Carex hallerana</i> t. or <i>C. flacca</i> t.

% cover	Genus & Species	Family	Pollen type
Close by:			
Angiospermae:			
Dicotyledones:			
	<i>Opopanax hispidus</i> (Friv.) Griseb.	Umbelliferae	? <i>Seseli</i> t.
Open dry grassland (steppe), not influenced by moisture from fen - plot d (2 x 2 m plot)			
Sphenopsida:			
1%	<i>Equisetum palustre</i> L.	Equisetaceae	<i>Equisetum</i>
Angiospermae:			
Dicotyledones:			
+	<i>Alyssum murale</i> Waldst. & Kit.	Cruciferae	<i>Hornungia</i> t.
7%	<i>Crataegus</i> sp.	Rosaceae	<i>Crataegus</i>
+	<i>Cuscuta</i> sp.	Convolvulaceae	<i>Cuscuta epithymum</i> t., <i>C. europaea</i> t. or <i>C. monogyna</i>
+	<i>Dorycnium</i> sp.	Leguminosae	<i>Dorycnium</i>
+	<i>Eryngium</i> sp. ? <i>campestre</i> L.	Umbelliferae	Prob. <i>Eryngium</i>
7%	<i>Galium verum</i> L.	Rubiaceae	<i>Galium</i> t.
1%	<i>Petrorhagia fasciculata</i> (Margot & Reuter) P.W. Ball & Heywood	Caryophyllaceae	? <i>Dianthus</i> t.
1%	<i>Prunella</i> sp.	Labiatae	<i>Prunella</i> t.
1%	<i>Prunus spinosa</i> L.	Rosaceae	<i>Prunus spinosa</i> t.
+	<i>Sanguisorba minor</i> Scop.	Rosaceae	<i>Sanguisorba minor</i>
10%	<i>Teucrium chamaedrys</i> L.	Labiatae	<i>Teucrium</i>
10%	<i>Teucrium polium</i> L.	Labiatae	<i>Teucrium</i>
25%	<i>Thymus</i> sp.	Labiatae	Prob. <i>Mentha</i> t.
+	<i>Trifolium</i> sp.	Leguminosae	<i>Trifolium dubium</i> t., <i>T. repens</i> t. or <i>T. montanum</i> t.
Monocotyledones:			
15%	<i>Carex</i> sp.	Cyperaceae	<i>Carex hallerana</i> t. or <i>C. flacca</i> t.
5%	<i>Dactylis glomerata</i> agg.	Gramineae	<i>Dactylis</i> t.
15%	<i>Festuca</i> sp. ? <i>glauca</i> Vill.	Gramineae	<i>Festuca</i> t.
+	<i>Phleum</i> sp.	Gramineae	?? <i>Dactylis</i> t.
+	<i>Triticum aestivum</i> L.	Gramineae	<i>Triticum</i> t.
Dry grassland close to plot d; transitional to damper ground of plot c (reconnaissance survey)			
Angiospermae:			
Dicotyledones:			
	<i>Anchusa azurea</i> Miller	Boraginaceae	<i>Anchusa arvensis</i> t.
	<i>Carpinus</i> sp.	Corylaceae	<i>Carpinus</i> t. or <i>Ostrya</i> t.
	<i>Centaurea</i> sp.	Compositae	<i>Centaurea cyanus</i> t., <i>C. napulifera</i> t., <i>C. solstitialis</i> t., <i>C. graeca</i> t. or <i>C. amplifolia</i>
	<i>Cichorium intybus</i> L.	Compositae	<i>Cichorium</i> t.
	<i>Clematis</i> sp.	Ranunculaceae	<i>Clematis vitalba</i> gr. or <i>Ranunculus aquatilis</i> gr.
	<i>Convolvulus arvensis</i> L.	Convolvulaceae	<i>Convolvulus</i>
	<i>Crataegus cf. monogyna</i> Jacq.	Rosaceae	<i>Crataegus</i>
	<i>Dipsacus fullonum</i> L.	Dipsacaceae	<i>Dipsacus</i> t.
	<i>Echinops microcephalus</i> Sibth. & Sm.	Compositae	<i>Echinops</i>
	<i>Euonymus europaeus</i> L.	Celastraceae	<i>Euonymus europaeus</i> t.
	<i>Fragaria vesca</i> L.	Rosaceae	<i>Fragaria vesca</i> t.
	<i>Fraxinus ornus</i> L.	Oleaceae	<i>Fraxinus ornus</i>

% cover	Genus & Species	Family	Pollen type
	<i>Helianthemum</i> sp. ?nummularium (L.) Miller	Cistaceae	<i>Helianthemum</i>
	<i>Nigella</i> sp.	Ranunculaceae	<i>Nigella</i>
	<i>Ononis spinosa</i> L.	Leguminosae	<i>Ononis</i> t.
	<i>Onopordum bracteatum</i> Boiss. & Heldr. in Boiss.	Compositae	<i>Carlina</i> t.
	<i>Paliurus spina-christi</i> Miller	Rhamnaceae	<i>Rhamnus</i> t.
	<i>Rubus ulmifolius</i> Schott x <i>caesius</i> L.	Rosaceae	<i>Rubus</i> t.
	<i>Rumex pulcher</i> L.	Polygonaceae	<i>Rumex conglomeratus</i> gr.
	<i>Salvia</i> ? <i>viridis</i> L.	Labiatae	? <i>Salvia officinalis</i> t.
	<i>Scabiosa</i> sp.	Dipsacaceae	<i>Scabiosa columbaria</i> t. or <i>S. sicula</i> t.
Monocotyledones:			
	<i>Calamagrostis arundinacea</i> (L.) Roth	Gramineae	?? <i>Dactylis</i> t.
	<i>Colchicum autumnale</i> L.	Liliaceae	<i>Colchicum</i>
	<i>Digitaria ischaemum</i> (Schreber) Muhl.	Gramineae	?? <i>Dactylis</i> t.
	<i>Melica ciliata</i> L.	Gramineae	<i>Dactylis</i> t.
	<i>Scilla autumnalis</i> L.	Liliaceae	<i>Scilla</i> t.
Close by:			
TALL TREES			
Angiospermae:			
Dicotyledones:			
	<i>Cornus sanguinea</i> L.	Cornaceae	<i>Cornus sanguinea</i>
	<i>Corylus avellana</i> L.	Corylaceae	<i>Corylus</i>
	<i>Crataegus monogyna</i> Jacq.	Rosaceae	<i>Crataegus</i>
	<i>Prunus spinosa</i> L.	Rosaceae	<i>Prunus spinosa</i> t.

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Appendix IX

Surface samples - Pollen and charcoal counts

Site	Avgo	Gomara bog	Anclia woods	Anclia bog	Agios Nikolaos	Perivolion	Polinerion	Zakas	Aetia	Kellia fen	Asprokampos field	Asprokampos woods	Mirsina woods	Mirsina fen
Slide numbers	1	1	1	1-11	1	1	1	1	1	1-4	1-3	1	1-2	1-3
GYMNOSPERMAE														
<i>Abies</i>	1	9	1	1	12		1	63	1	19	1	5	5	15
<i>Pinus (Diploxylon)</i>	273	837	229	50	346	330	96	114	94	137	18	92	95	49
<i>Juniperus</i>		29	14	2	36	9	83	53	54	22	2	32	15	10
<i>Taxus baccata</i>							1	1	2	2				1
<i>Ephedra fragilis</i>														1
DICOTYLEDONES														
<i>Salix triandra</i>				1						92	1		3	52
<i>Salix fragilis</i> type										9		4		6
<i>Populus</i>		1												2
<i>Juglans regia</i>	2			1	1		1				1	1	1	
<i>Alnus glutinosa</i>	1	4	4	3	4	4	2	3	1	3	1	8	2	1
<i>Carpinus</i> type	1	4	2		2			2	3	2		2	9	2
<i>Ostrya</i> type	9	50	8	8	21	3	9	25	13	12	2	28	5	6
<i>Corylus</i>	2	3	3	2	5		5	1	25	5	1	13	5	4
<i>Fagus</i>	15	63	136	39	9	2	8	10	2	8	3	9	5	3
<i>Castanea sativa</i>		3		1		1	2	1	2			1		
<i>Quercus ilex</i> type	2	19	3	5	3	2	1	5	1	5	3	2		
<i>Quercus trojana</i> type	2	24	12	2	3		24	3	80	25	16	85	190	13
<i>Quercus frainetto</i> type	1	72	8	9	48	22	114	63	62	90	35	124	6	60
<i>Ulmus glabra</i> type		5	1											
<i>Urtica dioica</i>	3	5		1						2				
<i>Urtica urens</i> type			1								1			
<i>Urtica pilulifera</i> type	2													
<i>Arceuthobium oxycedri</i>		1												
<i>Polygonum bistorta</i> type		1												
<i>Polygonum aviculare</i> type	1	51		1	1	1	1	1		17	139	3	2	1
<i>Rumex</i> type	1													
<i>Oxyria digyna</i>	1													
<i>Rumex acetosella</i> group												1		
<i>Rumex acetosa</i> group	1	9		4	2	1				13	10	1	4	3
<i>Rumex crispus</i> pp.	2													
<i>Emex spinosa</i>									2					
<i>Chenopodiaceae</i> type	1	7	4	2	4	1	1	1		16	13	8	4	3
<i>Herniaria</i> type		8			1									
<i>Paronychia</i> type									1					
<i>Dianthus</i> type	3	5												2
<i>Lychnis flos-cuculi</i>	1												1	
<i>Scleranthus annuus</i> type	1													
<i>Stellaria holostea</i>		4						1						
<i>Helleborus</i>				1			1			2				
<i>Nigella</i>										3				
<i>Actaea spicata</i>		2		1				2		1				
<i>Adonis</i>		2												
<i>Caltha</i> type		2		1						2				
<i>Ranunculus aquatilis</i> group		4												
<i>Anemone nemorosa</i> group	6	7	1		7			1	1	1				1
<i>Thalictrum aquilegifolium</i>		8												1
<i>Thalictrum lucidum</i>		2												
<i>Chelidonium majus</i>					3									

Site	Avgo	Gomara bog	Anelia woods	Anelia bog	Agios Nikolaos	Perivolon	Polinerion	Zakas	Aetia	Kellia fen	Asprokamos field	Asprokamos woods	Mirsina woods	Mirsina fen
Slide numbers	1	1	1	1-11	1	1	1	1	1	1-4	1-3	1	1-2	1-3
<i>Papaver rhoeas</i> type		3												
<i>Hornungia</i> type	2			2	2	1	3	2		4		11	6	15
<i>Arabis</i>		1	3		9	5	3	3	2	4		28	1	
<i>Sinapis</i> type	3	12	8	2			1			8		1	4	6
<i>Umbilicus</i>												1		
<i>Chrysosplenium alternifolium</i>		4								2			2	
<i>Saxifraga stellaris</i>														2
<i>Saxifraga tridactylites</i> type														1
<i>Parnassia palustris</i>	1			5										
<i>Platanus orientalis</i>		4		4	2			1	5	9	1		1	4
<i>Filipendula</i>		2	2						2			4	2	
<i>Rubus</i> type		1										2		1
<i>Sorbus</i> type		1												1
<i>Rosa</i>														
<i>Crataegus</i>		1												
<i>Sanguisorba minor</i>		1					2	2				1		
<i>Potentilla</i>		3								1				
<i>Fragaria vesca</i> type														1
<i>Ononis</i> type		2										1		
<i>Lotus</i> type	1	3						2					1	2
<i>Vicia cracca</i> type		2												1
<i>Galega officinalis</i>		1												
<i>Medicago sativa</i>	1											1		1
<i>Dorycnium</i>													1	1
<i>Lathyrus sativus</i>													1	
<i>Geranium</i>											3			
<i>Linum usitatissimum</i> type	1													
<i>Linum austriacum</i> type	1													
<i>Euphorbia</i>		1											1	
<i>Pistacia</i>														
<i>Acer</i>		2												
<i>Buxus sempervirens</i>	2				1									
<i>Tilia cordata</i> type								1	13	1				
<i>Daphne</i>	1													
<i>Elaeagnus angustifolia</i>										1				
<i>Helianthemum</i>												1		
<i>Myricaria germanica</i>														
<i>Tamarix</i>		3	2							3			3	
<i>Lythrum salicaria</i> type										4				1
<i>Lythrum portula</i>										6				
<i>Trapa natans</i>										1				
<i>Myrtus communis</i>		1											2	
<i>Myriophyllum spicatum</i>	1											1		
<i>Theligonum cynocrambe</i>	1												2	
<i>Cornus sanguinea</i>							1							
<i>Cornus mas</i>										1				
<i>Hydrocotyle vulgaris</i>	1	3							1					
<i>Smyrniacum</i>														2
<i>Bupleurum</i>														1
<i>Carum</i>														
<i>Berula erecta</i>										1				2
<i>Trinia</i>		3									2			
<i>Conium maculatum</i>													1	
<i>Cnidium silaifolium</i>														
<i>Seseli</i> type	1	2										1		
<i>Oenanthe aquatica</i> group														
<i>Oenanthe pimpinelloides</i> group										1				

Site	Avgo	Gomara bog	Anelia woods	Anelia bog	Agios Nikolaos	Perivolion	Polinerion	Zakas	Aetia	Kellia fen	Asprokampos field	Asprokampos woods	Mirsina woods	Mirsina fen
Slide numbers	1	1	1	1-11	1	1	1	1	1	1-4	1-3	1	1-2	1-3
<i>Chaerophyllum temulentum</i> type												2	1	
<i>Ammi</i>		2							2	1				
<i>Pimpinella saxifraga</i>		2								6			1	
<i>Angelica sylvestris</i>				1						1				
<i>Bunium</i>										3				
<i>Eryngium</i>		1								1	14			
<i>Pimpinella anisum</i> type												1		
<i>Torilis japonica</i> type		1								2				
<i>Daucus</i>										3		5		2
<i>Coriandrum</i> type										1				
<i>Pyrola</i>	1													
<i>Vaccinium myrtillus</i>	2	3	1		1	1	1	3						
<i>Soldanella</i>	1	3												
<i>Lysimachia</i>	1												1	
<i>Asterolinon linum-stellatum</i>														
<i>Samolus valerandi</i>		1												
<i>Fraxinus excelsior</i> type		1								1		1		
<i>Fraxinus angustifolia</i>												2		
<i>Fraxinus ornus</i>	1	3							4	6	1		1	3
<i>Phillyrea</i>							1		1					
<i>Gentiana lutea</i> type		1												
<i>Cuscuta europaea</i> type										1	8			2
<i>Alkanna</i> type										1				
<i>Callitriche obtusangula</i>										1				
<i>Teucrium</i>					1									3
<i>Prunella</i> type		1										1		
<i>Mentha</i> type	1	3		3					1	18	1		2	9
<i>Solanum dulcamara</i>		4			1		1		4		2	1		1
<i>Solanum nigrum</i> type		2		1						1	1		2	1
<i>Scrophularia</i> type	3			1	1						1	2		
<i>Gratiola officinalis</i>												2		
<i>Veronica triphyllos</i> type												2		
<i>Pedicularis</i>		2												
<i>Galium</i> type		4	2	3						39	1	1	4	4
<i>Plantago major</i>	5	5												
<i>Plantago afra</i>		5												
<i>Plantago alpina</i> type		9							1					
<i>Plantago lanceolata</i> type		28	1	4	3	1	13	4	2	18	12	5	4	1
<i>Plantago coronopus</i>		12		1	1				1	1	1		2	1
<i>Plantago bellardii</i>		3												
<i>Plantago media</i>		2												1
<i>Plantago argentea</i>		4					3	9						1
<i>Plantago albicans</i>		6					1							
<i>Plantago amplexicaulis</i>		1												
<i>Plantago atrata</i>	1													
<i>Valeriana officinalis</i> type				1										1
<i>Scabiosa columbaria</i> type														
<i>Knautia</i>	1													
<i>Campanula erinus</i> type		2				1								
<i>Solidago</i> type	1	3			1		13	1	2	23	10	7	3	25
<i>Artemisia</i>	1	6						3	1			2	3	
<i>Carlina</i> type	1													
<i>Achillea</i> type		2							1	2	1	1		
<i>Centaurea cyanus</i> type										1	9			
<i>Cirsium</i> type	1	10								67	3			8
<i>Centaurea solstitialis</i> type		16								6	11	1		
<i>Centaurea graeca</i> type										1		1		

Site	Avgo	Gomara bog	Anelia woods	Anelia bog	Agios Nikolaos	Perivolon	Polinerion	Zakas	Actia	Kellia fen	Asprokamos field	Asprokamos woods	Mirsina woods	Mirsina fen
Slide numbers	1	1	1	1-11	1	1	1	1	1	1-4	1-3	1	1-2	1-3
<i>Crupina</i>										1				
<i>Lactuca</i> type								1			26			
<i>Cichorium</i> type	1						2			1			1	1
<i>Hieracium</i> type		17	1							11		9		6
<i>Taraxacum</i> type	3	1								2				1
MONOCOTYLEDONES														
<i>Damasonium alisma</i>					1									
<i>Hydrocharis morsus-ranae</i>				1										1
<i>Potamogeton crispus</i> type										1				
<i>Muscari comosum</i>												1		
<i>Muscari neglectum</i> type								1						1
<i>Allium sphaerocephalon</i> type								1						
<i>Asparagus</i>										1				
<i>Gladiolus</i> type	1													
<i>Festuca</i> type	13	32	14	2	22		120	42	37	7	33	70	51	5
<i>Glyceria</i> type		80		1						22				10
<i>Dactylis</i> type	3	104	1	9		4	3	2	4	22	81	28	27	18
<i>Agropyron</i> type		26								1				3
<i>Triticum</i> type			1		2		1		1	15	23	15	3	
<i>Secale cereale</i>	2	2								5	2		2	2
<i>Hordeum</i> type										1				
<i>Avena</i> type	1	3								2	16			
<i>Phragmites australis</i>		48		3						9	14			99
<i>Zea mays</i>		1								6	11		1	
<i>Sparganium erectum</i>										129			1	1
<i>Sparganium angustifolium</i>										13				
<i>Typha angustifolia</i> type										19			1	
<i>Cyperus michelianus</i>	1	134		6						209	1			79
<i>Cyperus longus</i> type		16	1							902				41
<i>Schoenus nigricans</i>										4				
<i>Carex hallerana</i> type	14	106		5	1	1	1		7	20	3	12	10	52
<i>Carex flacca</i> type	51	11		2						175				10
<i>Limodorum abortivum</i>												2		
<i>Cephalanthera</i>												1		
PTERIDOPHYTA														
<i>Equisetum</i>										45				8
<i>Pteridium aquilinum</i>		21		1				2		6				1
<i>Asplenium</i> type	1		1											
<i>Gymnocarpium dryopteris</i>	1													
<i>Blechnum spicant</i>				1	1		1			3				
Indeterminate	2	22	14	5	9	12	47	29	31	28	19	41	18	5
Unknown	6		5		4	2	4	3	13			1	4	
Total trees & shrubs	313	1140	423	128	493	373	349	346	364	452	86	411	350	233
Total terrestrial pollen & spores	390	1631	462	166	544	389	520	431	426	775	520	626	481	361
Total pollen & spores	470	2069	484	200	558	404	572	463	480	2397	558	692	522	685
CHARCOAL														
Charcoal <25 μm^2	14	29	68	2	33	53	100	139	100	244	343	181	146	166
Charcoal 25-50 μm^2	10	13	37		28	84	95	131	80	200	268	178	131	136
Charcoal 50-100 μm^2	9	12	11		18	33	41	65	42	137	150	85	66	68
Charcoal 100-200 μm^2	3	4	4		10	12	11	30	8	46	75	30	15	28
Charcoal 200-400 μm^2	2	2			1	3	1	7	1	21	40	4	3	16
Charcoal >400 μm^2	2	1				1	1	2		20	25	3	2	12

Appendix X

Ecological data of pollen types

This table lists all the pollen and spore types represented in all the pollen diagrams. The names which appear in this table are the same as those used in the pollen key and pollen and spore count tables. Taxonomic names of vascular European species follow Tutin *et al.* (1964-80) and of non-vascular species Watson (1968).

Life-form classification is based on that of Raunkiaer (1937), where plants are classified according to the position of the perennating buds or persistent stem apices in relation to soil level. This classification is a convenient method of indicating how plants pass the unfavourable season, and is useful because of the correlation with climate. The seven primary classes are used mostly; secondary classes are included where data was available. Life-form data was not readily available for many perennial herbs so these have been assigned to the hemicryptophyte class because it is immaterial for this study whether they are herbaceous chamaephytes, hemicryptophytes or geophytes. Symbols and their meanings are as follows:

- 1) Phanerophytes: Woody plants with perennating buds or stem apices more than 25 cm above soil level
 - MM Mega- and Mesophanerophytes with perennating buds or stem apices borne on aerial shoots more than 8 m above the ground (trees)
 - M Microphanerophytes with perennating buds 2-8 m above the ground (small trees, tall shrubs)
 - N Nanophanerophytes with perennating buds between 25 cm and 2 m above the ground (shrubs)
- 2) Chamaephytes: Woody or herbaceous plants with perennating buds or stem apices above soil surface but below 25 cm
 - Chw Woody Chamaephytes (small shrubs)
 - Chh Herbaceous Chamaephytes (herbs)
 - Chc Cushion plants
- 3) Hemicryptophytes: Herbaceous (very rarely woody) plants with perennating buds at ground level or in litter (most biennial and perennial herbs)
 - Hp Protohemicryptophytes, with uniformly leafy stems, but the basal leaves usually smaller than the rest
 - Hs Semi-rosette hemicryptophytes, with leafy stems but the lower leaves larger than the upper ones and the basal internodes shortened
 - Hr Rosette hemicryptophytes, with leafless flowering stems and a basal rosette of leaves
- 4) Geophytes: Herbaceous plants with perennating buds below the soil surface (herbs)
 - Gb Geophytes with bulbs
 - Gr Geophytes with buds on roots
 - Grh Geophytes with rhizomes
 - Grt Geophytes with root tubers
 - Gt Geophytes with stem tubers or corms
- 5) Hel Helophytes: Perennating buds below water level in soil or mud (mire plants)
- 6) Hyd Hydrophytes: Perennating buds below water level in water (aquatic plants)
- 7) Th Therophytes: Perennating bud in seed (annual herbs)

Habitats are given for each pollen type so far as they are known. Ecological data comes from the author's observations, and the following references:

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Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
GYMNOSPERMAE		
<i>Abies</i>	MM	N. temp. Evergreen. Montane fir, between 500 & 2000 m. On limestone or serpentine. Shade tolerant. In Grevena <i>Abies</i> grows in the beech vegetation zone of the Pindos Mtns. Grevena is close to the northern limit of <i>A. cephalonica</i> (endemic to Greece). Fast-growing, rather short-lived. Fir can survive long periods of browsing when young & does not burn. It is killed when felled. Can be pollarded, but this was rarely seen in Grevena. <i>Abies</i> appears to have less power of rejuvenation than oaks and beech & Turrill (1929:143) thinks that its abundance has been much reduced by lumbering.
<i>Picea abies</i>	MM	N. Hemisph. Evergreen. Montane. Forming an extensive forest between c. 1400 m & 1900 m in NE Greece, partly in pure stands & partly together with <i>Pinus sylvestris</i> & <i>Fagus sylvatica</i> . Not known in Grevena today.
<i>Cedrus</i>	MM	Evergreen. Not native; planted for timber in Greece. Not known in Grevena.
<i>Pinus (Diploxylon)</i>	MM	N. temp. Evergreen. <i>P. heldreichii</i> & <i>P. leucodermis</i> are endemic to the Balkans. Form highest altitude forests in Pindos Mtns (600-2300 m). Light demanding. Do not burn easily. Pines are often unable to re-establish themselves in competition with beech with its dense shade (Turrill 1929). Used for building & formerly tapped for the production of resin.
<i>Pinus (Haploxylon)</i>	MM	Evergreen. Forms forests on siliceous mountains of central Balkans. Not known in Grevena.
<i>Juniperus</i>	M, N	N. Hemisph. Evergreen. Light demanding. In Grevena it is ubiquitous from the lowlands to the mtns on dry soils, forming brushwood in the low alpine zone. Pseudo- <i>maquis</i> . Grows in open grassland, as under shrub in open pine & oak woods. Profits from grazing (Bottema 1982:263). Takes advantage of destruction of primary forests (Behre 1990:224). Acts as a nurse crop for regenerating mtn pinewoods. Juniper wood is very flammable. Juniper is rather unpalatable, but where abundant may be an important browsewood. Used for charcoal making & firewood. <i>J. communis</i> is used for making gin.
<i>Taxus baccata</i>	MM or M	N. temp. Evergreen. Grows either on mtns or at lower altitudes in cooler climates. Grows in edaphically wet & atmospherically moist conditions. Usually grows on limestone (but also serpentine), as a scattered tree in beech or mixed woods, 800-2200 m. In Grevena it is scattered in mixed woods on limestone in the Aetia gorge and above Zakas at c. 1000 m. Foliage is poisonous to animals. Long lived & slow growing.
<i>Ephedra fragilis</i>	M	Warm temp. Evergreen. Xerophytic, grows in steppe. Not observed in Grevena
<i>Ephedra distachya</i> type	N	Warm temp. Evergreen. Xerophytic, usually grows in steppe, but <i>E. distachya</i> may grow in very dry alpine areas. Lowlands to 1950 m. Not observed in Grevena.
ANGIOSPERMAE		
DICOTYLEDONES		
<i>Salix triandra</i>	M or N	Cosmop. Deciduous. Commonly found on river banks, by lakesides & growing in damp ravines. Hybridization plays an important role in <i>Salix</i> . Part of current riverine flood plain vegetation of Grevena.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Salix fragilis</i> type	MM, M, N	Cosmop. Deciduous. In Grevena this type grows in damp localities from lowland to montane altitudes, by streams, rivers, on marshes & fens, & in wet woods, scrub, hedgerows & meadows including streams in mtn woods & highland ravines. <i>Salix</i> have been known to be planted as an osier & pollarded. Fast growing.
<i>Populus</i>	MM	N. temp. Deciduous. Light demanding. Grows in damp localities in lowlands & lower highlands, near rivers, damp & muddy areas on hillsides, valleys, hedgerows & in damp montane woodlands (nr Spilaion) as well as on roadsides & fields. Most spp. sucker freely.
<i>Juglans regia</i>	MM	N. Hemisph. Deciduous. Prob. native to the Near East. Walnut does not appear in Greece until the end of the fourth millennium BP, thought to have either profited from changes in habitats caused by humans or been planted in prehistoric times (Bottema 1982:275). Naturally grows scattered among other woodland trees in the highlands. Today it is the most cultivated tree in Grevena, although it is somewhat precarious: every walnut in the region was badly damaged by frost in 1987. Oral tradition includes walnuts as part of the suite of subsistence agricultural products grown for human consumption before 1940. Slow growing.
<i>Alnus glutinosa</i>	M or MM	N. temp. Deciduous. Frequently found growing by water - marshes, banks of rivers & streams & in ravines, but also in stable locations in the mtns, plains & lowlands where there is a sufficient water supply. Deep rooted. Medium shade tolerance & colonizing ability. Sheds thick shade. Woods of alder grow in the riverine vegetation of the Venetikos, Aliakmon & Pramoritza rivers. Pollen emitted before leafing.
<i>Betula pendula</i>	MM	N. temp. Deciduous. Pioneer. Forms woods, particularly on light soils, often secondary after forest destruction. Highly self-propagating, but is short lived, does not grow in shade & is eventually replaced by other, larger species. Local & confined to mountains i.e. cooler climates. Its spread in the sub-Atlantic period may indicate colder conditions, but it may also have been favoured by an increase in the practice of burning, after which it is a common colonizer (Dimbleby 1969:177). Not known in Grevena today, but Turrill (1929:143) records it in the montane beech & fir forests further north on the Balkan Peninsula.
<i>Carpinus</i> type	MM or M	N. temp. Deciduous. <i>Carpinus betulus</i> represents this pollen type mostly, while <i>Carpinus orientalis</i> and <i>Ostrya</i> are minor representatives. In Grevena <i>C. betulus</i> grows in damp woods in the <i>Fagus</i> zone & in the mixed woods at Spilaion.
<i>Ostrya</i> type	MM or M	N. temp. Deciduous. The genus <i>Ostrya</i> and <i>Carpinus orientalis</i> represent this pollen type mostly, while <i>Carpinus betulus</i> is a minor representative. <i>Ostrya</i> usually grows in bushy places on limestone hills & mtns. In Grevena this pollen type grows in mixed woods, at Aetia & Spilaion, on limestone at about 1000 m and between Kranea & Milea on ophiolite & gabbro (where it is frequent). <i>C. orientalis</i> wood is an alternative to oak wood in the lowlands, but grows only in damp areas. It can withstand grazing reasonably well and regenerates quickly. Very palatable (grazed very low in Mirsina wood). Slow growing. Withstands some shade. Used for firewood.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Corylus</i>	MM, M, N	N. temp. Deciduous. Light demanding; colonizer. Known to self-propagate in mixed woods in northern Greece. In Grevena grows in mixed woods at Aetia at 1000 m on limestone and in a mixed oak wood at lower altitude 8 km SE of Grevena. Also grows in the oak wood zone near Mirsina fen. Remains of <i>C. avellana</i> (hazel nuts) are often found in prehistoric archaeological sites. Pollen emitted before leafing.
<i>Fagus</i>	MM	N. temp. Deciduous. Shade tolerant. Beech grows in a colder environment than oak & wetter environment than pine. This type is represented mostly by <i>F. sylvatica</i> . It forms pure stands on well-drained soils between 1000 & 1800 m on the Pindos, usually in damp areas. Sheds thick shade which usually keeps the forest floor bereft of undergrowth. Freely regenerates from fallen seed & after felling. Grevena is close to the southern limit of beech. In Grevena beech woods are usually of coppice type, felled every 40-75 yrs, but many have not been cut for centuries. It can withstand long periods of browsing when young & does not burn. Beech mast occas. occurs in prehistoric food plant remains.
<i>Castanea sativa</i>	MM	N. Hemisph. Deciduous. Native to Greece, but also cultivated. Sweet chestnut grows naturally on well-drained, usually acidic soils, often on slopes at moderate altitudes among other deciduous trees; usually calcifuge. Extensively planted for nuts & timber.
<i>Quercus coccifera</i> type	N (& MM)	Medit. Evergreen. Xerophytic. Suckers. Usually forms thickets on dry stony slopes at low altitudes. In Grevena <i>Q. coccifera</i> grows in the SE on a patch of limestone with red soils in pseudo-maquis as a dense prickly shrub. Pyrophytic (regenerates quickly). Quick growing. Used for firewood. Takes advantage of destruction of primary forests (Behre 1990).
<i>Quercus trojana</i> type	M or MM	Eur. Semi-evergreen or deciduous. Mesophytic. See <i>Q. frainetto</i> below.
<i>Quercus frainetto</i> type	M or MM	Eur. Deciduous. The <i>Q. trojana</i> & <i>Q. frainetto</i> pollen types dominate the foothills of the Pindos and the Grevena plains. They form extensive woods. There is much hybridization. Oaks form a continuum in which some individuals are more or less typical of one or other species, but many are intermediate. Thus the distinction between the two pollen types <i>Q. trojana</i> , which represents mostly semi-evergreen oaks, & <i>Q. frainetto</i> , which represents mostly deciduous oaks, is not very clear morphologically. Oaks are resistant to browsing; they are quite palatable to livestock, but can live indefinitely even if bitten down to less than a metre. They are not killed by felling, but sprout from the stump. They do not burn easily, but the litter can be ignited by adjacent stubble or grass fires. Young oaks are killed to the ground by such fires, but sprout. Oaks easily invade abandoned farmland. Used for building structures, firewood, fodder & pasture. Evidence of acorns being used for human consumption has been found in archaeological sites in Thessaly dating to the Neolithic Period at Sesklo & Achilleion (Renfrew 1973:28).
<i>Ulmus minor</i>	MM	N. temp. Deciduous. Shade tolerant. Frequent vegetative propagation (suckering). Grows particularly by rivers, prefers low altitudes. In Grevena, <i>U. minor</i> occurs in suckering patches along watercourses smaller than the Aliakmon & Venetikos rivers. Pollen emitted before leafing.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Ulmus procera</i>	MM	N. temp. Deciduous. Bushy places. Shade tolerant. Frequent vegetative propagation (suckering). Not seen growing in Grevena.
<i>Ulmus glabra</i> type	MM	N. temp. Deciduous. Usually grow in cool forest locations among other trees. Shade tolerant. <i>U. glabra</i> grows on the damp north facing slopes in the mixed woods at Aetia and Spilaion. Pollen emitted before leafing.
<i>Celtis</i>	MM	S. Eur. Deciduous. Grows in bushy places in the Mediterranean region. Not seen growing in Grevena. Hackberry stones have been found on a number of Near Eastern archaeological sites.
<i>Morus nigra</i>	MM	N. temp. Deciduous. Not native. Widely cultivated. Not seen growing in Grevena.
<i>Morus alba</i>	MM	N. temp. Deciduous. Not native. Cultivated. Not seen growing in Grevena.
<i>Humulus lupulus</i>	Hp	N. temp. Liane. Widely cultivated in Europe, but grows naturally in hedges, bushy places and on river banks. Not seen growing in Grevena.
<i>Urtica dioica</i>	Hp	Temp. Ruderal. The common stinging nettle, grows in somewhat damp, nutrient-rich habitats. Often grows near habitation & where the ground is covered with litter & rubble. It regularly ascends to alpine levels in places where grazing animals congregate, near snow patches, at the base of rock overhangs & by shepherds' huts. Cultivated in prehistory - ?Grevena (Hedrick 1972). Unpalatable.
<i>Urtica urens</i> type	Th	Temp. <i>U. urens</i> is native to Greece while <i>Pilea microphylla</i> has become naturalized in the Balkan Peninsula. They are widespread, but grow at lower than montane altitudes. Ruderal & weed.
<i>Urtica pilulifera</i> type	Th	Temp. Ruderal & weed. Grows in waste places, waysides & cultivated ground.
<i>Parietaria</i>	Th & Hp	Temp. & trop. Often grows on dry rocks & walls. Observed growing in 1½ year-coppiced oak wood.
<i>Viscum album</i>	N	Evergreen. Hemi-Parasite. In Grevena it grows on <i>Pinus</i> .
<i>Arceuthobium oxycedri</i>	N	Hemi-Parasite that grows on <i>Juniperus oxycedrus</i> . It is very abundant near Aetia.
<i>Polygonum bistorta</i> type	H	Cosmop. Montane. <i>P. bistorta</i> grows in damp meadows & forest clearings on acid soil. <i>P. alpinum</i> , which may belong to this type, grows in grassland, rocky places & screes on serpentine, granite or other non-calcareous rocks. Both grow in the Pindos Mtns, 1400-2350 m.
<i>Polygonum aviculare</i> type	Th (mostly) & H	Cosmop. Ruderal & weed of cultivation. Occurs naturally, but is increased by anthropogenic disturbance. Grows in dry, open disturbed communities from the lowlands to the mtns, up to 2500 m. A large number of <i>P. aviculare</i> seeds were found in Neolithic deposits at Sitagroi, northern Greece. This may indicate that they were being cultivated for human consumption. Has been cultivated in historical times (Hedrick 1972) - ?Grevena in prehistory. Leaves may have been consumed (Dennell 1977).

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Bilderdykia</i>	Th	Two spp. belong to this pollen type. <i>B. convolvulus</i> (black bindweed), grows on cultivated ground & in waste places. <i>B. dumetorum</i> (copse bindweed) grows in hedges or among native vegetation. Seeds of black bindweed have been found in a number of samples from Neolithic Bulgaria and also from Sitagroi, northern Greece (Renfrew 1973:181). The seeds are bigger than those of <i>Polygonum aviculare</i> & it may have been use as a supplementary food (Renfrew 1973:182).
<i>Rumex</i> type	Th & H	N. temp. Occurs naturally, but is increased by anthropogenic disturbance. Weeds. Has been cultivated in historical times (Hedrick 1972) - ?Grevena in prehistory.
<i>Oxyria digyna</i>	H	Alpine. Grows in shady, moist rock crevices & screes on a few high peaks in the Pindos, generally near late-lying snow-patches, 2000-2400 m.
<i>Rumex acetosella</i> group	H	Sheep's sorrel is a weed of arable land & poor sandy soils; grows most vigorously on lime-deficient land. Lowland to 2000 m, occas. higher. Observed growing on the peaks of Vasilitsa & Gomara, as well as nr Perivoli & in the Vourinos Mtns. <i>R. tenuifolius</i> observed growing in Grevena on burnt steppe & other dry areas.
<i>Rumex acetosa</i> group	H	Grows mostly in moist meadows, shady slopes & forest clearings on a variety of substrates, 500-2000 m. Seen growing in the Pindos & Vourinos Mtns. The seeds of <i>Rumex acetosa</i> (common sorrel) are commonly found in prehistoric sites in Europe & the Near East. The green parts of this wild plant may have been eaten.
<i>Rumex crispus</i> pp.	H	Common lowland weed. Commonly grows as a ruderal, as well as on river gravels. Rarely occurs in mtns where it is restricted to ruderal habitats.
<i>Rumex conglomeratus</i> group	H	Open places from lowlands to mtns e.g. clearings in woods, along roads & tracks, as well as slopes & screes. <i>R. conglomeratus</i> grows in damp places. Some spp. are ruderals. Observed growing in the Pindos & Vourinos Mtns.
<i>Rumex obtusifolius</i> group	H	Mostly ruderals, from lowlands to mtns.
<i>Rumex bucephalophorus</i> group	Th & H	Lowland ruderal.
<i>Emex spinosa</i>	Th	Medit. Disturbed ground. Weed.
Chenopodiaceae	Th (mostly) & H	Weeds. Many ruderals, weeds of cultivation & waste places, & halophytes occurring in a wide variety of habitats. Found mostly in open habitats esp. steppe. Occurs naturally, but is increased by anthropogenic disturbance. <i>Chenopodium bonus-henricus</i> is a montane ruderal in Grevena. Many sp. belonging to this pollen type have been seen growing in Grevena as ruderals, weeds of cultivation & waste places. Seeds of <i>Chenopodium album</i> are often found on prehistoric sites in Europe, sometimes in large amounts; these seeds may have been used as a food supplement (has been cultivated in historical times (Hendrick 1972)).
<i>Phytolacca americana</i>	Hel	Trop. & subtrop. Introduced. Naturalized in S. Eur. Perennial herb. Marshes & ruderal places.
<i>Glinus</i> type	Th	S. Eur. Xerophytic. Waste places.
<i>Montia fontana</i>	Hyd (Th)	Cosmop. Submerged in water or on mud or seasonally wet open ground, usually calcifuge.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Spergula</i>	Th	Temp. Common weed of cereal fields. Seeds may be used for human consumption (Renfrew 1973:187).
<i>Spergularia</i> type	Th to H	Cosmop. Mostly halophytes. Dry, sandy habitats.
<i>Herniaria</i> type	Th to H	Medit., Eur. Lowland to montane. Usually in dry sandy & rocky places. Pindos, Vourinos Mtns.
<i>Corrigiola litoralis</i>	Hel (Th)	Medit. Seasonally wet sand or clay, often impermanent, usually at low altitudes, but has been found at c. 1850 m on mainland Greece.
<i>Paronychia</i> type	Th & H	Cosmop. Several spp. included. Usually grow in dry, sandy or stony places from the lowland to mtns. Includes weeds & ruderals. Have been observed in Grevena at a variety of altitudes.
<i>Dianthus</i> type	Th, H or Chh	Eur., esp. Medit. Many spp. included in this type, occur at all altitudes & in many different habitats; steppe to bog. Mostly in dry sunny situations. Benefits from forest destruction. Includes coppice plants & many weeds e.g. <i>Stellaria media</i> is a cornfield weed. Many observed in Grevena at all elevations.
<i>Silene alba</i> type	Th & H	Eur. Usually occur as weeds of disturbed areas & cultivation at low altitudes.
<i>Lychnis flos-cuculi</i>	Hel	N. temp. Damp meadows & marshes.
<i>Agrostemma githago</i>	Th	Medit. Corncockle is a weed of cornfields.
<i>Scleranthus perennis</i>	H or Chh	Mountain rocks (800-)1500-2600 m.
<i>Scleranthus annuus</i> type	Th or H	Eur. Dominant weeds on markedly acid sandy soils where they may form a complete carpet; characteristic of non-calcareous sands.
<i>Stellaria holostea</i>	Chh	
<i>Nymphaea alba</i>	Hyd (G)	Trop. & temp. climates. Perennial herb. Shallow fresh water, floating ls and fls. Not seen in Grevena. Still (to slow) flow. Up to 3 m deep.
<i>Nuphar lutea</i>	Hyd (G)	N. temp. and cold climates. Perennial herb. Shallow fresh water, floating ls and fls.
<i>Helleborus</i>	Chh	Eur., Medit. Open woodland & pasture, 700-1900 (-2100) m. Damp habitats in semi-shade in the foothills & mtns. Common & gregarious in pastures at c. 900-1600 m in the Pindos foothills where it is common. Poisonous & avoided by grazing animals.
<i>Nigella</i>	Th	Eur., Medit. Weeds of cereal fields in Grevena.
<i>Trollius europaeus</i>	H	N. temp. & Arctic. Damp mtn meadows, 1400-2100 m.
<i>Actaea spicata</i>	H or G	N. temp. Shady places on loose, humus-rich, calcareous soils 1100-1900 m. Woods.
<i>Adonis</i>	Th	Grassy places & weeds of cultivated ground.
<i>Caltha</i> type	Hel	Temp. Perennial herbs (mostly). Seasonally flooded places. Marshy meadows by streams & brooks, often in partial shade, 1100-2000 m, on a variety of substrates.
<i>Ranunculus acris</i> group	Hel	N. temp. Perennial herbs. Several spp. in this group. Some marsh plants. Habitat is mostly wet meadows between 700 & 1900 m. One ruderal.
<i>Ranunculus aquatilis</i> group	Hyd, H, Th	Mostly marsh or aquatic plants with a floating stem bearing leaves. In water up to 0.5(-1) m deep; still to swift flow.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Anemone nemorosa</i> group	Grh	Cosmop. Woods & shady places between c. 700 & 1800 m.
<i>Clematis vitalba</i> group	N	Cosmop. Deciduous. Liane. Woods & bushy places. Pseudo-maquis.
<i>Ranunculus arvensis</i> type	Th	<i>R. arvensis</i> is a weed of cereals in Grevena.
<i>Thalictrum aquilegifolium</i>	H	N. temp. Woods in mountains, 800-1700 m, but occas. 2000 m. Damp, rocky & shady places.
<i>Thalictrum minus</i>	Hp	N. temp. Dry rocky places in open woodland, scrub & alpine habitats, (300-)800-2000(-2500) m, esp. on limestone.
<i>Thalictrum lucidum</i>	H	N. temp.
<i>Chelidonium majus</i>	H	Bushy & waste places.
<i>Papaver rhoeas</i> type	Th	Eur. Weed of cultivation (common cornfield poppy). Seeds of <i>Papaver rhoeas</i> are commonly found in prehistoric sites in Europe & the Near East. It is collected for flavouring food. A common annual in arable land.
<i>Glaucium</i>	Th to H	Eur. Waste places & cultivated ground.
<i>Papaver argemone</i> type	Th	Eur. Weed of cultivation.
<i>Hornungia</i> type	Th to H	Weeds & ruderals from lowlands to 1800 m.
<i>Arabis</i>	H	N. temp. <i>A. glabra</i> & <i>A. turrita</i> ascend to nearly 1800 m in some places, but is a typical forest spp.
<i>Sinapis</i> type	Th to H	Eur., Medit. Many genera & spp. belong to this type. Many are weeds, a few are marsh plants, some are steppe plants, from lowlands to mtn pine wood-pasture in Grevena. <i>Brassica nigra</i> , <i>Erysimum cheiranthoides</i> , <i>Neslia paniculata</i> & <i>Sinapis arvensis</i> are weeds of cornfields. <i>Camelina sativa</i> which prob. belongs to this pollen type was cultivated as an oil-seed crop (Rackham 1990:496). A bag of <i>S. alba</i> was found in the Late Bronze Age site of Marmariani, Thessaly. Today this sp. is cultivated to provide salad leaves, & also for the manufacture of condiment mustard.
<i>Umbilicus</i>	H	Medit. Shaded rocky places in woods.
<i>Sedum</i>	Th, H or Chh	N. temp. Mostly in dry stony & rocky places, ranging from lowlands to 2000 m in Pindos.
<i>Chrysosplenium alternifolium</i>	Hel	Perennial herb of wet, rocky & shady places, chiefly by small streams in the upper montane zone (900-1600 m, occas. up to 1850 m).
<i>Saxifraga stellaris</i>	Hel	Perennial of mtn streams & other damp places, 1800-2300 m.
<i>Saxifraga tridactylites</i> type	Th & H	Damp shady places in rocky habitats, generally between 500 & 1500 (up to 2900) m. Mtn woods & grassland.
<i>Saxifraga oppositifolia</i> type	H	Mtns. Rocky crevices, damp screes & ravines, up to 2500 m.
<i>Parnassia palustris</i>	Hel	N. temp. Mtn bogs, damp meadows, 600-2100 m.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Platanus orientalis</i>	MM, M	Native to Balkan peninsula, southwards from c. 42° N. Deciduous. Thought to have either profited from changes in habitats caused by humans or been planted in prehistoric times (Bottema 1982:275). Today it is often planted as village shade trees. Naturally it grows in woods in the hills, by rivers. Can grow up to 1500 m if there is enough water. Long lived. Grows naturally in the riverine vegetation along the two main rivers of Grevena, the Venetikos & Aliakmon, and reaches 970 m in Kranea.
<i>Filipendula</i>	Hel	N. temp. Perennial herb. Dry grassland, damp or wet places.
<i>Rubus</i> type	N, Chw	Cosmop., esp. N. temp. An under shrub in open woods & in flushes on the sides of gullies & ravines. Forms natural hedges in Grevena. Seeds from the fruits of <i>R. idaeus</i> (wild raspberry) & <i>R. caesius</i> (dewberry) have been found in many prehistoric archaeological sites esp. in the alpine region.
<i>Sorbus</i> type	MM, M, N	N. temp. Deciduous. Open woods & open stoney cliffs, 700-2000 m. Grevena oak woods.
<i>Rosa</i>	N	N. temp. Deciduous & evergreen. Pindos Mtns. Dry rocky places, stony meadows, open deciduous or mixed woodland, usually between 1000 & 1500 m, occas. up to 2500 m. Rose hips belonging to <i>Rosa canina</i> have been found on a number of archaeological sites in Europe; e.g. Bronze Age in Britian.
<i>Cotoneaster</i> type	N	N. temp. Deciduous. Dry rocky slopes, usually on limestone in meadows, scrub & open woodland (including deciduous woods), mainly in mountains (800-)1200 to 2200(-2426) m.
<i>Prunus avium</i> type	MM	N. temp. Deciduous. <i>P. avium</i> & <i>P. mahaleb</i> grow in the mixed woods on limestone at Aetia & Spilaion at c. 1000 m, as moderate sized trees, or as a tall trees of open habit, on rocks & dry hillsides, thickets & open woods. Coppice when cut. <i>Prunus dulcis</i> (almond) may belong to this pollen type. Almonds are common in Grevena and are often planted as hedges. Cultivated cherry occurs first in Europe in Roman times. Stones of wild cherries are found in archaeological sites in Europe in Neolithic times. <i>P. mahaleb</i> is used for firewood.
<i>Crataegus</i>	M	N. temp. Deciduous. Grows on rocky mountain slopes & in barren soil, in high pasture lands, dry scrubland & woodland mixed with other shrubs or trees from lowland up to 2050 m. Grows in steppe near Mirsina fen & in pseudo- <i>maquis</i> in Grevena. Fruit stones of <i>Crataegus</i> sp. are occas. found in prehistoric contexts.
<i>Sanguisorba officinalis</i>	Hel	N. temp. Perennial herb. Damp fields & streamsides, 1400-2000 m, chiefly on calcareous substrates.
<i>Sanguisorba minor</i> (<i>Poterium spinosum</i>)	H	N. temp. Occurs naturally, but is increased by anthropogenic disturbance. Dry grassy or stony places. Light demanding. Spreads after forest clearance or extensive grazing.
<i>Geum</i>	H	N. & S. temp., arctic. Scattered in open woods, at woodland margins, in ravines & various disturbed habitats, generally at altitudes between 500 & 1700 m, occas. up to 2000 m.
<i>Potentilla</i>	H	Nearly cosmop., chiefly N. temp. & arctic. A variety of habitats from dry & rocky to damp & shady from 500-2400 m. <i>P. argentea</i> is a weed of cultivation & a ruderal.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Fragaria vesca</i> type	H	N. Hemisph. In Grevena grows under deciduous oak woods. Wild strawberry seeds have been found at many prehistoric archaeological sites in Europe.
<i>Alchemilla</i> type	Th & H	Temp. & trop. Open habitats, cultivated fields, meadows, pastures, forest margins, 1500-2350 m.
<i>Hedysarum coronarium</i>	H	N. temp. Cultivated ground.
<i>Ononis</i> type	Th (mostly), H, N	Deciduous. Temp. to sub-trop; Medit., Eur. & S. Eur. to Himal. Mostly weeds or ruderals in open disturbed ground, steppe & open woods.
<i>Trifolium dubium</i> type	Th (mostly) to H	Temp. & subtrop. In scrub, rocky woodland & ruderal habitats; occurring above treeline in dry, rocky, often overgrazed grassland, on cliffs & screes & by tracksides. At lower altitudes in dry or damp places & waste places. Sea level to 2100 m.
<i>Trifolium repens</i> type	Th & H	Temp. & subtrop. Dry grassy places, disturbed places, fields, cultivated ground. Steppe in oak woods in Grevena.
<i>Lotus</i> type	Th & H	Temp. Eur. Many spp. included in this type. Occurs mostly in grassland. <i>L. uliginosus</i> is a marsh plant. <i>Tetragonolobus purpureus</i> is a weed of cultivation. <i>Trigonella foenum-graecum</i> ?cultivated in Greece for fodder. Pindos & Vourinos Mtns.
<i>Lathyrus pratensis</i> type	Th & H	N. temp. Mostly dry places, grasslands, fields, cultivated ground. Sea level to 2100 m. <i>L. pratensis</i> is an exception in growing in marshes. Edge of oak woods in Grevena.
<i>Vicia sativa</i> type	Th & H	N.temp. This pollen type includes several wild spp. as well as one cultivated sp. (& one that prob. belongs to this type <i>V. ervilia</i>) and a weed of cultivation (& <i>V. pannonica</i> which prob. belongs to this type). <i>V. sativa</i> (vetch) was cultivated in the Pindos foothills & on the Grevena plains before 1940 for fodder on a subsistence basis. It is no longer cultivated to the same extent. Seeds of domesticated <i>V. ervilia</i> (bitter vetch) were found in Macedonia at the archaeological sites of Nea Nikomedeia & Sitagroi in contexts dating to the Neolithic (Hansen 1988). The seeds are thought to have been used for human consumption (Renfrew 1973:116).
<i>Vicia cracca</i> type	Th & H	Grassy places, disturbed ground, cultivated ground.
<i>Astragalus</i>	Th & H (mostly)	Cosmop. On a variety of substrates; on mtn rocks, dry rocky slopes, pasture & steppe and +/- xerophytic, up to 2400 m. Often thorny. Grows in steppe in oak wood pasture in Grevena.
<i>Galega officinalis</i>	Hel	S. Eur. Perennial herb. Sometimes cultivated as a fodder plant. Grows naturally in damp meadows & by rivers.
<i>Medicago sativa</i>	H	Eur., Medit. <i>Medicago sativa sativa</i> (alfalfa, lucerne) was cultivated, for fodder & forage, in the Pindos foothills and on the Grevena plains prior to the introduction of mechanized agriculture. It is cultivated on a small scale today mostly in the plains. Unfortunately, <i>M. sativa sativa</i> pollen may occur in the <i>Trifolium montanum</i> and the <i>Medicago sativa</i> pollen types. Also <i>Medicago sativa</i> is native to almost all of Europe and it is not possible to distinguish the cultivated subsp. from the native. The origin of <i>M. sativa sativa</i> is uncertain.
<i>Ornithopus compressus</i>	Th	Medit. Rocks, waysides.
<i>Dorycnium</i>	Chw or H	Medit. Woods, damp bushy places.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Trifolium montanum</i> type	H	<i>T. montanum</i> is new to Greece. This pollen type may also include <i>Medicago sativa</i> (see above).
<i>Lathyrus sativus</i>	Th	N. temp. The origin of this sp. is unknown, it is widely naturalized. From oral history it is known to have been cultivated in the Pindos foothills & the Grevena plains for fodder on a subsistence basis before 1940. Seeds of <i>L. sativus</i> (grass pea) are found quite widely in archaeological sites and may have been cultivated for both human consumption & fodder. They have been found on Early Neolithic sites in Europe.
<i>Oxalis</i>	G, H or Th	Cosmop. Dry open habitats, esp. cultivated ground, waste places, disturbed ground.
<i>Geranium</i>	Th to H (mostly)	Cosmop. esp. temp. Ruderal; often in sheep-manured habitats. Dry rocky places, gravelly slopes, shady places in ravines, woodland, meadows, cultivated ground & waste places, 500-2200 m. Mtn pine wood-pasture & oak woods in Grevena.
<i>Geranium robertianum</i> group	Th, H	Ruderal; often in sheep-manured habitats. Dry rocky places, gravelly slopes, shady places in ravines, woodland, meadows, cultivated ground & waste places, 500-2200 m.
<i>Tribulus terrestris</i>	Th	Medit. Weed & ruderal. Dry habitats, waste places, waysides & cultivated ground.
<i>Linum usitatissimum</i> type	Th to H	S. & W. Eur. Of the 2 spp. in this pollen type <i>L. bienne</i> is a wild biennial to perennial while <i>L. usitatissimum</i> , flax, is of uncertain origin. <i>L. bienne</i> grows in grassy, stony places. Flax was formerly cultivated throughout most of Eur. for fibre & oil from the seed (linseed); now much less commonly grown, but still recorded as a casual throughout Europe. Macrofossils of <i>L. usitatissimum</i> are found in archaeological sites dating to the Neolithic. A large number of flax seeds were found in Early Bronze Age deposits at Lerna, Argolid.
<i>Linum austriacum</i> type	H	Temp. & subtemp., esp. Medit. Rocky & stony slopes, dry meadows & pastures from lowland to c. 2000 m. Pindos Mtns.
<i>Radiola linoides</i>	Hel (Th)	Medit. Seasonally damp, bare, sandy or peaty ground; calcifuge.
<i>Linum catharticum</i>	Hel (Th)	Medit. Annual herb. Marshy slopes & moist, rocky places by streams, 1200-2200 m, rarely at lower altitudes. On various basic substrates. Pindos Mtns.
<i>Linum tenuifolium</i>	H or Chh	Temp. & subtemp., esp. Medit. Rocky places & dry, stony meadows, from lowland to c. 1900 m, on limestone. Pindos & Vourinos Mtns.
<i>Mercurialis perennis</i>	H	Medit, Eur. Woods, shady places. Usually in <i>Quercus</i> or <i>Fagus</i> woods.
<i>Euphorbia</i>	Th, H, Chw	Chiefly subtemp. & warm temp. Many spp. included in this pollen type, from a variety of habitats of both dry & damp places. Many are ruderals & weeds of cultivation. <i>E. salicifolia</i> is unpalatable.
<i>Dictamnus albus</i>	H	Eur. Volatile and inflammable ethereal oil is secreted, so that on hot calm days the air round the plant may sometimes be ignited. Grows at the edge of deciduous oak woods & in the patches of steppe grassland in the oak woods in the Grevena plains.
<i>Rhus coriaria</i>	M	Subtemp. & warm temp. Semi-evergreen. Grows amongst brushwood & in rocky places at low & medium altitudes. Rocky places, waysides. Palatable to stock.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Pistacia</i>	M, N	Medit. Evergreen (<i>P. lentiscus</i>) & deciduous (<i>P. terebinthus</i>). Dry open scrub & woods, usually calcareous substrate. <i>P. lentiscus</i> is very sensitive to cold. <i>P. terebinthus</i> grows in pseudo-maquis in SE Grevena & Pindhos foothills in mixed woods. Quick growing. Takes advantage of destruction of primary forests.
<i>Cotinus coggygria</i>	N	N. temp. Deciduous. Usually grows on dry hills, rocky places & open woods. Low altitude scrubland. On calcareous soil. <i>Shibljak</i> . In Grevena, forms shrubbery on eroding slopes too unstable for trees to be established & without enough soil for grassland.
<i>Acer</i>	N to MM	N. temp. Deciduous. <i>Acer</i> grows in damp woods in Grevena such as in the hornbeam (<i>Carpinus</i>) woods in the eastern plains & the mixed woods at Aetia & Spilaion at c. 1000m. Also in the <i>Abies/Fagus</i> wood between Kranea & Milea, as well as dry pseudo-maquis in the SE corner. Shade tolerant. Used for firewood.
<i>Ilex aquifolium</i>	M or N	Eur. Evergreen. Montane woods & pseudo-maquis. An understorey tree in beech & oak woods. Very flammable, the waxy leaves will burn fiercely, even on the living tree, but suckers will rise quickly in great numbers if the soil is not heated too much. Not subject to cattle grazing. Susceptible to cold winters.
<i>Buxus sempervirens</i>	M or N	Evergreen. Open dry woodland, pseudo-maquis & scrub on serpentine or limestone, from 400-2000 m. Gregarious & locally abundant. Pyrophytic: regenerates quickly after burning by shoots from roots or stem bases. In Grevena box is common in mtn pine woods & beech woods, & oak woods of the foothills. It replaces juniper as an understorey, on more calcareous soils. It occurs only as a shrub in Grevena.
<i>Frangula</i>	M or N	Cosmop. Deciduous. Damp shady places. Rocks, bushy places in mtns, 500-1500 m, sometimes alpine habitats up to 2100 m.
<i>Rhamnus</i> type	M or N	Cosmop. Deciduous. Usually grows on dry slopes, brushwood on limestone rocks, 500-2300 m. <i>Paliurus spina-christi</i> grows in pseudo-maquis in SE Grevena.
<i>Vitis vinifera</i>	M or N	N. Hemisph. Liane. Woods & brushwood. This pollen type includes both a wild & a cultivated subspecies. The wild subsp. grows on river banks & in damp woods. Domesticated vine seeds have been identified at Sitagroi, eastern Macedonia dating to the Early Bronze Age & also in archaeological sites in Thessaly (Iolkos) & central Macedonia (Kastanas) dated to the Late Bronze Age (Renfrew 1973:28; Hansen 1988). The cultivated subsp. is currently cultivated in Grevena for household use only, but it is known to have been cultivated much more in the past, esp. around Spilaion where it was produced beyond subsistence needs and thus was exported.
<i>Tilia platyphyllos</i>	MM	N. temp. Deciduous. Woods, bushy places. Shade tolerant. Very palatable to stock.
<i>Tilia cordata</i> type	MM	N. temp. Deciduous. Woods of mtns. Shade tolerant. Very palatable.
<i>Abutilon</i> type	Th & H	Trop. & subtrop. Cultivated ground & waste damp places.
<i>Althaea officinalis</i>	Hel	Temp. Marsh mallow grows in damp places, field verges. Unpalatable.
<i>Malva moschata</i>	H	N. temp. Cultivated and stony ground. Normally a sp. of low & moderate altitudes, has been found up to 1850 m. Pindos Mtns.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Daphne</i>	N, Chw	Eur., temp. and subtemp. Evergreen & deciduous. Mostly high altitude up to 2100 m, in open woodland or stony slopes or meadows. <i>D. oleoides</i> grows as an undershrub in grazed <i>Pinus heldreichii</i> woods in the Pindos Mtns.
<i>Elaeagnus angustifolia</i>	M or N	Eur. Deciduous. Not native. Naturalized in Greece. Grows nr water; banks of streams & waterfalls, in river silt. Planted for its fruit & fragrant blossoms.
<i>Hypericum hircinum</i> type	Chw	Temp. Damp places, often beside rivers.
<i>Hypericum perforatum</i> type	H	Temp. A variety of habitats, at all elevations.
<i>Viola hirta</i> type	H	Cosmop., chiefly N. temp. Damp grassland, scrub & woodland, generally below 1000 m.
<i>Viola riviniana</i> type	H	Cosmop., chiefly N. temp. Woodlands.
<i>Viola arvensis</i> type	Th	Cosmop., chiefly N. temp. Weeds of fields & open scrubland below c. 1100 m.
<i>Helianthemum</i>	Chw & Th	Eur., Medit. Dry stony alpine & grassy pastures, scrub & woodland clearings, 400 to 2400 m, on a variety of substrates, but most frequently on limestone.
<i>Cistus monspeliensis</i> type	N	Medit. Dry sunny places, scrub, open woods, uncultivated ground, garrigue & <i>maquis</i> . Pyrophytic. <i>C. incanus</i> , which prob. belongs to this type, occurs as an undershrub in the steppe of the oak woods in the Grevena plains.
<i>Myricaria germanica</i>	N	N. temp. River gravels & other open habitats. Forms thickets in riverine vegetation along the Aliakmon & Venetikos.
<i>Tamarix</i>	M or N	Eur., Medit. Halophytic. Damp places, river banks, hedges & roadsides, from lowlands to mountains. <i>T. pariflora</i> (Balkan tamarisk) forms thickets in the riverine vegetation along the Aliakmon & Venetikos.
<i>Elatine alsinastrum</i>	Hel (Th or H)	Temp. Annual or perennial. Shallow, usually still water, on wet mud or sand, or in seasonally flooded places. Submerged roots.
<i>Lythrum salicaria</i> type	Hel (Th & H)	Cosmop. Fens, marshes, riversides. Unpalatable.
<i>Lythrum portula</i>	Hel (Th)	Cosmop. Wet places & shallow pools.
<i>Trapa natans</i>	Hyd	C. & S. Eur. Annual water plant with floating ls and submerged roots. In nutrient rich but not strongly calcareous water. The fruits were used for food in the Alpine region in prehistoric times.
<i>Myrtus communis</i>	M	Medit. & SW Eur. Evergreen. Usually grows only on limestone. Brushy places, damp ground.
<i>Circaea lutetiana</i>	G	N. temp. and arctic. Woody & shady places.
<i>Ludwigia palustris</i>	Hyd	Cosmop. Perennial water plant; still & flowing waters, seasonally flooded places.
<i>Epilobium angustifolium</i> type	H	Temp. & arctic. <i>E. angustifolium</i> grows in woods & shady places, is common in woodland clearings, esp. if fire is used. <i>Oenothera biennis</i> grows on disturbed ground, waste places, dunes.
<i>Epilobium hirsutum</i> type	Hel	Temp. & arctic. Perennial herbs, mostly along margins of water courses, fens & other wet, & disturbed places. Usually at low altitude, but locally up to c. 2200 m. Pindos Mtns.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Myriophyllum verticillatum</i>	Hyd	Cosmop. Perennial herb. Aquatic. Submerged freshwater plant. Still to slow flow. Shallow to 1 m.
<i>Myriophyllum spicatum</i>	Hyd	Cosmop. Perennial herb. Aquatic. Submerged freshwater plant. Still to swift. Up to 2 m.
<i>Theligonum cynocrambe</i>	Th	Stony & dry places, dry rocks & walls & their crevices. Arable fields & ruderal places.
<i>Cornus sanguinea</i>	N	N. temp. Deciduous. Woods, bushy places. Oak woods near Mirsina fen.
<i>Cornus mas</i>	N, M	Eur. Deciduous. Light-demanding. Open woods, bushy places. Brushwood. Steppe/oak woods of the Grevena plains, nr the Aliakmon River. Cornelian cherry stones have been found in Neolithic deposits at Nea Nikomedeia (van Zeist & Bottema 1971) & Sitagroi, northern Greece (Renfrew 1973:142). The fruits may be eaten fresh or preserved or made into brandy, as they do in northern Greece (Renfrew 1973:142).
<i>Hedera helix</i>	Chw	Temp. Evergreen. Climbing on trees, rocks, & walls, or covering the ground in woods. Pseudo-maquis.
<i>Hydrocotyle vulgaris</i>	Hyd	Temp. Aquatic; shallow, still (slow moving), fresh water & damp places.
<i>Anthriscus caucalis</i>	Th	Eur. Dry places.
<i>Smyrnum</i>	H	Medit., Eur. Rocky slopes, meadows, scrub, woodland, roadsides & cultivated places from lowlands up to 2200(-2400) m, chiefly on limestone but also on shist; sometimes gregarious in manured places. Weeds & ruderals.
<i>Ligusticum</i>	H	N. Hemisph. Rocky, gravelly places, 1800-2050 m.
<i>Bupleurum</i>	N, H, Th (mostly)	Eur. Dry open habitats such as cultivated land, waste places, waysides. Weed.
<i>Sison amomum</i>	H	Eur., Medit.
<i>Carum</i>	H	Temp., sub trop. Rocky slopes, meadows & pastures, from lowlands to 2650 m.
<i>Berula erecta</i>	Hel	Perennial herb of shallow water. Still to fast flow.
<i>Trinia</i>	H	Eur., Medit. Gravelly places, rocky & stony meadows & pastures, slopes in open woodland, 500-2650 m. Vasilitsa, Pindos Mtns.
<i>Sanicula europaea</i>	H	Cosmop. Woods in mtns. Grows under <i>Abies borisii</i> woods at 2000 m above Samarina.
<i>Conium maculatum</i>	H or Th	N. Temp. Weed.
<i>Cnidium silaifolium</i>	H	Scree, rocky & stony meadows, slopes in open woodland & forest, 400-2200 m, on a variety of substrates.
<i>Seseli</i> type	H	Eur. Grassy slopes in open woodland & meadows & open rock ledges, 800-2100 m, on a variety of substrates. Pindos Mtns.
<i>Oenanthe aquatica</i> group	Hyd	N. temp. Perennial. <i>O. aquatica</i> grows in still or slow flowing water of seasonally wet places & <i>O. lachenalii</i> in wet grassland.
<i>Oenanthe pimpinelloides</i> group	Hel	N. temp. Perennial herbs. The habitat of <i>O. pimpinelloides</i> is not known, but <i>O. tenuifolia</i> , which might belong to this pollen type, grows in marshes.
<i>Oenanthe fistulosa</i>	Hel	N. temp. Perennial herb of wet places, shallow water.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Chaerophyllum hirsutum</i> type	H	N. temp. In clearings & meadows in woods up to 1800 m, rarely in alpine pastures up to 2000 m. Pindos Mtns.
<i>Chaerophyllum temulentum</i> type	H	N. temp. Weed.
<i>Ammi</i>	Th or H	Medit. Weeds.
<i>Pimpinella saxifraga</i>	H	Old World. Mtn meadows & ravines in woodland, up to 1800 m.
<i>Torilis arvensis</i>	Th	Medit.
<i>Anethum graveolens</i>	Th	Medit.
<i>Falcaria vulgaris</i>	H	Medit.
<i>Peucedanum austriacum</i> type	H	Eur. Pastures, rocky meadows, open woodland, 900-2200 m.
<i>Angelica sylvestris</i>	Hel	N. Hemisph. Perennial herb. Damp, shady places by streams, medium altitude, ascending to c. 1800 m.
<i>Peucedanum schotti</i>	H	Eur. Grassy meadows & rocky, grassy slopes in <i>Pinus</i> woodland, 1200-1700 m, on ophiolitic substrates, occas. on schist.
<i>Bunium</i>	H	Serpentine screes & gravel, c. 1700 m. Pindos Mtns.
<i>Foeniculum vulgare</i> ssp. <i>vulgare</i>	H	Medit., Eur. Dry rocky places.
<i>Anthriscus sylvestris</i> type	H	Eur. In clearings, meadows & by streams in montane & submontane woodland from c. 400-1850 m, predominantly on calcareous substrates, but also on serpentine.
<i>Pastinaca sativa</i>	H	N. temp. Meadows, woodland clearings up to 1500 m (rarely 1950 m).
<i>Eryngium</i>	H	Trop. & temp. Dry places & woods. Often gregarious in pastures, c. 500-2050 m. <i>E. amethystinum</i> grows in the Pindos foothills in the oak wood-pasture and oak pasture vegetation zone. Pindos & Vourinos Mtns.
<i>Scandix</i> type	Th	Eur., Medit. Open habitats, often as weeds. Cultivated & disturbed ground.
<i>Heracleum sphondylium</i>	H	N. temp. & trop. One subsp. grows in open woodland, rocky & gravelly slopes, by mtn roads 700-2200(-2500) m, on a variety of substrates. Another subsp. grows in damp woodland, meadows & streamsides, 500-1950 m, on limestone & schist. Pindos Mtns.
<i>Pimpinella anisum</i> type	Th	Old World. Widely cultivated for its aromatic fruits & often naturalized. <i>Pimpinella anisum</i> (anise) was found in the Late Bronze Age settlement at Thera-Therasia, Greece. It may have been collected for flavouring food. Two wild spp. which may belong to this type grow in dry places. One of these <i>P. tragioides</i> grows in the Pindos (Vasilitsa) & Vourinos Mtns.
<i>Anthriscus cerefolium</i>	Th	Eur. In Europe var. <i>cerefolium</i> cultivated as a herb & often naturalized. Not observed by author in Grevena.
<i>Torilis japonica</i> type	Th to H	Medit. Weed; may occur in arable fields.
<i>Daucus</i>	Th or H	Eur. Weed; may occur in arable fields. Seeds of wild carrot have been found in Neolithic and Bronze Age deposits in Switzerland; the tuberous root may have been used for human consumption (Renfrew 1973:171).

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Coriandrum</i> type	Th	Medit. <i>C. sativum</i> is cultivated for its aromatic fruits & widely naturalized in Europe. <i>C. sativum</i> seeds have occas. been found in prehistoric deposits. They were found in large quantity at Sitagroi, northern Greece, in an Early Bronze Age level. It may have been collected for flavouring food (Renfrew 1973:171).
<i>Pyrola</i>	H & Chh	N. temp. Woods & alpine meadows, c. 1800 m. Pindos Mtns (Perivolion, Vasilitsa).
<i>Erica herbacea</i>	Chw	Eur. esp. Medit. Evergreen. Grows in the Pindos Mtns & foothills on rocky slopes, usually in open <i>Pinus nigra</i> & <i>P. heldreichii</i> woodland, 1000 to 1900 m, on serpentine, and also in beech woods, 600-1600 m.
<i>Vaccinium myrtillus</i>	Chw	N. Hemisph. Deciduous. Mainly in open, somewhat damp subalpine grassland or heath, occas. in woodland (900)1600-2200 m, chiefly on shist & granite where it may be gregarious & dominant, rarely on limestone or serpentine. Bilberries have been recovered from a few archaeological sites in temp. Europe.
<i>Soldanella</i>	H	Alps of Eur. Damp montane places, 1600-2400 m. Pindos Mtns. The fls expand at very low temperatures, often coming up through the snow.
<i>Cyclamen</i>	Gt	Eur. Usually in woods, thickets & rocky places. <i>C. repandum</i> grows in deciduous oak woods in Grevena, but only in shade and is set back when coppicing occurs. <i>Cyclamen</i> sp. grows in the Grevena foothills in the oak wood-pasture and oak pasture near Polinerion.
<i>Androsace villosa</i>	H	N. temp. Tufted xerophytes. Limestone rocks & stabilized scree, 1800-2300 m. Pindos Mtns.
<i>Primula</i>	H	N. hemisph. Moist shady places, in meadows, pastures & woods, 700-2300 m, on a variety of substrates. <i>P. vulgaris</i> is not drought resistant and grows in the beech-fir woods, 600-1600 m. <i>P. veris</i> grows in glades & <i>P. elatior</i> is a coppice plant in the beech-fir woods.
<i>Lysimachia</i>	Hel	Temp. & subtrop. Wet places; wet grassland, wet woods, fens, lake-shores, ditches, river banks, wasteland.
<i>Anagallis arvensis</i> type	Th	Eur. Cultivated ground, waste places.
<i>Anagallis tenella</i> type	Hel	Eur. Perennial herbs of damp open habitats; bogs, ditches & lake shores.
<i>Asterolinum linum-stellatum</i>	Th	Medit. Dry, open habitats.
<i>Samolus valerandi</i>	Hel	Cosmop. Perennial herb of wet, usually saline or calcareous habitats.
<i>Armeria maritima</i> type	H, Chh or Chc	N. temp., E. Eur., E. Medit. Halophytic. Mtn meadows & rocks, 800-2300 m. Pindos Mtns.
<i>Fraxinus excelsior</i> type	MM	Eur. Deciduous. Damp base-rich soils in woods or scrubland at high altitude, also on floodplains & river banks. Burns easily. Rather light demanding, fast growth but short longevity and provides little shade. Used for fuel. Very palatable to stock.
<i>Fraxinus angustifolia</i>	MM	S. & E.C. Eur. Deciduous. Damp places; river banks, floodplains & deciduous woods. Rather light demanding & provides little shade. Used for fuel. Very palatable to stock.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Fraxinus ornus</i>	MM	Medit. & S.C. Eur. Deciduous. Grows naturally at medium altitudes. In Grevena it is frequent in damp hornbeam woods of the eastern plains & scattered in the drier deciduous oak woods of the plains & foothills. Also grows in the mixed woods of the limestone gorge of Aetia at 1000 m. Used in the past for syrup-processing (Bottema & Woldring 1990:260). May have been planted. Firewood. Very palatable to stock.
<i>Ligustrum vulgare</i>	N	Eur. Deciduous or semi-evergreen. Woods margins & scrub, at medium & low altitudes; somewhat calcicole.
<i>Phillyrea</i>	MM, M	Medit. Evergreen. Grows on limestone only. <i>P. media</i> grows in SE Grevena in pseudo- <i>maquis</i> . Quick growing. Used for firewood. Takes advantage of destruction of primary forests.
<i>Centaureum</i>	H, Th (mostly)	Open habitats, damp grassland at low altitudes or dry grassland on plains & mtn slopes, open woodland up to c. 1500 m, or occas. to 2000 m. Pindos Mtns in <i>Pinus</i> woods.
<i>Gentiana lutea</i> type	Hel	Cosmop. Perennial herbs of damp shady places, marshes & pastures in hills & mtns. Pindos Mtns.
<i>Convolvulus</i>	G, H, Chc	Temp. Weeds from low altitudes to 1900 m. In dry habitats.
<i>Cuscuta epithymum</i> type	Th	Trop. & temp. Parasite. <i>C. suaveolens</i> is parasitic on cultivated species of <i>Medicago</i> and <i>Trifolium</i> and other herbs. <i>C. australis</i> is parasitic on <i>Polygonum</i> & other herbs. <i>C. planiflora</i> is parasitic on dwarf shrubs and annuals. <i>C. approximata</i> is mostly on shrubs.
<i>Cuscuta europaea</i> type	Th	Trop. & temp. Parasite. <i>C. europaea</i> is usually on <i>Urtica dioica</i> or <i>Humulus lupulus</i> but also on many other hosts. <i>C. campestris</i> is parasitic on cultivated species of <i>Medicago</i> and <i>Trifolium</i> and other herbs. <i>C. palaestina</i> is parasitic on dwarf shrubs.
<i>Cuscuta monogyna</i>	Th	Trop. & temp. Parasite. Mostly on trees and shrubs.
<i>Calystegia</i>	G, H	Temp. & trop. Hedges, verges, damp places & open ground. Unpalatable.
<i>Cynoglossum</i> type	H	Temp. & subtrop. Dry open habitats. Mtn rocks, waysides, hedges, woods, 800-2300 m.
<i>Heliotropium</i>	Th	Trop. & temp. Cultivated ground, wastepieces & waysides.
<i>Myosotis</i> type	Th (mostly) to H	Old World temp. Several spp. included in this pollen type. Some spp. grow in dry open habitats & rocky pastures while a few grow in wet habitats. Ruderal. Pindos Mtns. <i>M. palustris</i> is unpalatable.
<i>Lappula</i>	Th (mostly) or H	Temp. Dry places; cultivated fields & other disturbed areas.
<i>Echium</i>	Th or H (mostly)	Eur., Medit. Weed of dry stony waysides, cultivated & uncultivated soils.
<i>Alkanna</i> type	H	Medit., S. Eur. Dry, rocky places. Usually between 400 & 2300 m.
<i>Borago officinalis</i>	Th	Medit., Eur. Dry, often waste places.
<i>Buglossoides arvensis</i> type	Th	Dry open habitats & cultivated ground.
<i>Anchusa arvensis</i> type	Th & H	Eur. Weed of cornfields, wastepieces & waysides. <i>A. arvensis</i> grows on the small spring-fed clayey fens at Kellia.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Nonea</i>	Th (mostly) to H	Medit. Sunny hills, stony ground, fields.
<i>Pulmonaria mollis</i>	H	Eur. Woods.
<i>Anchusa officinalis</i> type	Th or H	Eur. Cultivated ground, grassy places, waysides. Generally at low & moderate altitudes, occas. up to 2000 m. Pindos Mtns.
<i>Verbena</i>	Th & H	Trop. & temp. Ruderals. Waste ground, waysides. <i>V. officinalis</i> grows on the road verge on the Grevena plains, in steppe/oak wood vegetation near Asprokamos.
<i>Callitricha obtusangula</i>	Hyd	Cosmop. Perennial herb. Aquatic. Plant with submerged & floating ls in fresh or brackish, usually slow-moving water.
<i>Callitriche stagnalis</i> type	Hyd	Cosmop. Aquatic. Plant with submerged & floating ls in fresh, still or slow moving water.
<i>Teucrium</i>	H, Chw, N	Cosmop. Several spp. included in this pollen type. Some spp. grow in dry places, in open woods, on banks. In mixed deciduous & evergreen open woodland, dry stony meadows & rocky places. Other spp. grow in damp places & beside water. Usually (500-)1000-2400 m. Generally on limestone, occas. on serpentine. <i>T. polium</i> , a Mediterranean garrigue plant, is an undershrub in the oak wood/steppe of the Grevena plains. <i>T. scordium</i> grows on the small spring-fed clayey fen at Kellia.
<i>Stachys sylvatica</i> type	G, Th & H (mostly)	Cosmop. Usually dry, open habitats, waste places, cultivated ground. Grassy meadows, rocky places & screes. Sea-level to 2500 m. Oak woods in Grevena.
<i>Stachys angustifolia</i>	H	Dry places.
<i>Scutellaria</i> type	Th to H (mostly)	Cosmop. Two genera & several spp. are included in this pollen type. Some grow in damp humus rich places, deciduous woods; others grow on dry hills, fields, stony places. Occas. up to 2650 m. <i>Ballota nigra</i> is a ruderal. Pindos Mtns.
<i>Prunella</i> type	G, H	Three genera & several spp. included in this pollen type. Some spp. grow in woods, grassland & waste places, usually in damp soil in shady places. Others grow on rocks, in bushy places, forest clearings & meadows at medium to subalpine altitudes, up to 2100 m.
<i>Salvia officinalis</i> type	Th, H (mostly), N	Trop. & temp. Dry places, rocky places, waysides. Stony alpine meadows, rock ledges or stabilized screes. Scattered in scrub & open woodland, usually at 500-2200 m. <i>S. officinalis</i> widely cultivated as pot herb. Grows on road verge on the plains of Grevena, near Asprokamos.
<i>Mentha</i> type	Hel	Old World. Seven genera & many spp. included in this pollen type. Most grow in marshes, but some grow in dry habitats. <i>Mentha aquatica</i> is unpalatable.
<i>Solanum dulcamara</i>	N	Liane. Grows in damp woods, hedges & river banks. Shade tolerant.
<i>Solanum nigrum</i> type	Th to H	Weed of arable & wasteland.
<i>Scrophularia</i> type	Chh, G, Th, H (mostly)	N. temp. Many genera & spp. included in this pollen type. Grow in a wide variety of habitats from aquatic to dry stony waste land, woodland clearings & disturbed areas; from lowlands to mtns.
<i>Gratiola officinalis</i>	Hel	A perennial herb of ditches, river-banks & wet meadows.
<i>Rhinanthus</i> type	Th	Hemi-parasitic and parasitic. Damp meadows in forest openings, gravel cliffs & ledges, 1300-2300 m. Pindos Mtns.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Odontites</i> type	Th	Medit., S. Eur. Parasitic. Stony mtn slopes or dry hills, sandy or grassy places.
<i>Veronica anagallis-aquatica</i> type	Hel (mostly), Th, Chw	Annual & perennial herbs of two genera are included in this type. <i>Odontites</i> are hemi-parasitic annuals that grow in meadows, pastures, roadsides, cultivated fields & other disturbed habitats. Some <i>Veronica</i> spp. grow in cultivated ground & others grow in marshes.
<i>Veronica triphyllos</i> type	Th, H & Chh	Weeds & ruderals. Dry open habitats. On cultivated ground, waste places, in grassland, thickets, hedges, open <i>Pinus</i> woods, lowlands to c. 2400 m. Pindos Mtns.
<i>Pedicularis</i>	H	N. Hemisph. Hemi-parasitic alpine. <i>P. comosa</i> , <i>P. brachyodonta</i> , <i>P. graeca</i> , <i>P. hoermanniana</i> grow in the Pindos Mtns.
<i>Putoria calabrica</i>	N	Medit. Rocks & rock crevices, often on loose conglomerates, river gravels, hills & road cuttings at low & moderate altitudes, occas. to 2000 m.
<i>Crucianella</i>	Th	Eur., Medit. Dry stony meadows & gravel, 500-2000 m. Pindos Mtns.
<i>Sherardia arvensis</i>	Th	Eur. Blue field madder. Cultivated ground, waste places & dry grassland.
<i>Galium</i> type	Th, H (mostly), Chh	Cosmop. Ecologically heterogeneous, from lowlands to montane (2000 m). Usually dry open habitats. Dry or moist meadows, grassland, pastures, rocky heaths, open woods, waste land & cultivated ground. A few marsh spp.
<i>Plantago major</i>	H	Ruderal & weed of waysides & cultivation.
<i>Plantago afra</i>	Th	Dry places.
<i>Plantago alpina</i> type	H	Lowland & montane. Rocky places, dry pastures.
<i>Plantago lanceolata</i> type	H	Weed of cultivation. Meadows, waysides, waste ground. Occur naturally, but increased by human disturbance. Require open ground. Grow in open disturbed areas and/or sometimes grazed areas.
<i>Plantago coronopus</i>	H	Xerophytic. Waysides.
<i>Plantago bellardii</i>	Th	Dry, sandy ground & waste places.
<i>Plantago media</i>	H	Ruderal. Waysides, somewhat damp meadows, particularly in rocky places, (800-)1600-2500 m.
<i>Plantago arenaria</i>	Th	Poor fields, sandy places, waysides.
<i>Plantago argentea</i>	H	Dry grassy & stony places, 1400-2000 m. Pindos & Vourinos Mtns.
<i>Plantago albicans</i>	H	Dry places.
<i>Plantago amplexicaulis</i>	Th	Dry places.
<i>Plantago atrata</i>	H	Mountain pastures.
<i>Sambucus nigra</i>	N	N. temp. Deciduous. In the wild grows near water, in damp woods, hedges & waste places. Often cultivated in Eur. Seeds of elder have been found on a number of prehistoric sites chiefly in the Alpine region of Europe. Elder berries are used for wine making.
<i>Viburnum</i>	N	Temp. & subtrop. Deciduous & evergreen. Scattered in open damp woods, edges of woods, thickets, hedges, rocky places. Sometimes forms thickets. Highlands sometimes ascending to c. 1800 m. <i>V. tinus</i> used for firewood.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Valerianella rimosa</i> type	Th	Temp. Disturbed ground or other dry, open habitats ascends to 2000 m. Often in heavily grazed areas. Pindos Mtns.
<i>Valeriana tuberosa</i>	H	Eur. Mainly on stony slopes & meadows up to 2100 m. Grows in grassland of pine wood-pasture vegetation in Grevena.
<i>Valeriana officinalis</i> type	H	Bushy places, rocks, woods. Chiefly low & moderate altitudes, but ascending to 2450 m.
<i>Valerianella locusta</i> type	Th	Chiefly low & moderate altitudes, ascending to 2000 m in subalpine screes & grassland, often in heavily grazed areas.
<i>Succisa pratensis</i>	Hel	Damp meadows, marshes, fens, damp woods.
<i>Scabiosa columbaria</i> type	H	Eur., Medit. Dry rocky slopes, forest openings, alpine meadows; lowlands to 1300-2500 m.
<i>Dipsacus</i> type	Hel	Eur., Medit. Biennial herb of woods, waysides, marshes.
<i>Knautia</i>	Th	Eur., Medit. Scrub & disturbed ground, mtn meadows & wood margins, rocky places in subalpine & alpine meadows. May occur up to 2300 m.
<i>Jasione</i>	H	Eur., Medit. Dry rocky alpine meadows & grassland, stabilized screes & gravel or open woodland. Lowland to c. 1800-2500 m. Pindos Mtns (Vasilitsa).
<i>Campanula erinus</i> type	Th to H	N. temp. & esp. Medit. Dry grassy, stony places, scrub & forest margins or open forest, 1000-2300 m.
<i>Campanula rotundifolia</i>	H	N. temp. & esp. Medit. Rock crevices & ledges, rocky meadows, screes c. 1300-2600 m, variety of substrates.
<i>Asyneuma</i> type	H	Steppe & mtn grassland. Fields, stony places, (400-)1200-2200 m.
<i>Solidago</i> type	Th & H mostly, Chh, G	Ecologically heterogeneous. Grows in habitats ranging from alpine rocks, mtn pastures, scrub, woodland pastures, open grassland, cultivated ground & waste places to damp places, fens & marshes. Lowlands to 2300 m. <i>Helianthus annuus</i> (sunflower) is currently cultivated in Grevena. Steppe in oak woods in Grevena.
<i>Echinops</i>	H, rarely Th	Eur. Dry rocky places at low & medium altitude, regularly ascending to subalpine levels.
<i>Artemisia</i>	Chh & H (mostly)	N. Hemisph. Common on arid soil (steppe). Occurs naturally, but is increased by human disturbance (weed).
<i>Carlina</i> type	Th to H	Eur. & Medit. Dry meadows, open rocky places, waste places, cultivation ground, 900-2300 m. Grows in the grazed <i>Pinus heldreichii</i> woods in the Pindos. <i>Onopordon acanthium</i> (Scotch thistle) seeds were found in Early & Middle Bronze Age deposits at Lerna, south Greece.
<i>Picnemon acarna</i>	Th	Cultivated ground, waste places.
<i>Achillea</i> type	Th & H	N. temp. Steppic & alpine weeds. Ecologically heterogeneous. Grows throughout Grevena.
<i>Centaurea cyanus</i> type	Th, rarely H	Dry open places; cultivated ground & waste places. Weed of cereals in Grevena.
<i>Centaurea napulifera</i> type	H	Grassy & stony slopes in mtns & clearings in forests between 1000 & 2100 m, occas. up to 2750 m.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Cirsium</i> type	Th , H & G	N. temp. Mostly weeds & ruderals of pastures, disturbed ground & wasteland. Also grows in grassland, scrub, stony places, damp shady places, wet meadows & marshes (one sp.), 1100-2000(-2200) m.
<i>Xanthium</i>	Th	Medit. Occurs naturally, but is increased by human disturbance. <i>X. spinosum</i> is native of N. America. Weeds. Unpalatable.
<i>Centaurea solstitialis</i> type	Th to H	Several genera & many spp. Occurs naturally, but is increased by human disturbance. Grows in disturbed situations.
<i>Centaurea graeca</i> type	H	Mostly dry grassland, rocky places & scrub on hills & mtns. Also cultivated & waste ground.
<i>Crupina</i>	Th	S. Eur. Dry grassland & stony slopes.
<i>Sonchus</i> type	Th to H	Almost cosmop. Weed. Cultivated ground, fields & waste places.
<i>Lactuca</i> type	Th to H	N. temp. Woods & scrub, damp woodland openings, dry rocky or stony places, waste ground, 1400-2300 m.
<i>Scolymus</i>	Th to H	Medit. Corn fields, cultivated ground, waysides.
<i>Cichorium</i> type	Th to H	Eur., Medit. Ruderal. Dry open habitats, fields, waysides, waste places. Pindos foothills & plains in Grevena.
<i>Hieracium</i> type	Th to H	N. Hemisph. Ecologically heterogeneous. Lowlands to 2500 m. Mostly dry open habitats, disturbed ground. Often as weed.
<i>Taraxacum</i> type	Th to H	Temp. Ecologically heterogeneous. Mostly weeds of dry open habitats, such as meadows, pastures, open woodland, rocky alpine grassland, cultivated fields & waste places. Also shady places, moist & swampy patches. Lowlands ascending to 2000 m. The seeds of <i>Lapsana communis</i> are commonly found in prehistoric sites (from Neolithic times) - the green parts of this plant may have been eaten.
MONOCOTYLEDONES		
<i>Sagittaria sagittifolia</i>	Hyd	Temp. Perennial herb. Marsh or shallow water at the edges of lakes, ponds, canals or slow rivers. Submerged, floating or emergent. Shallow to moderately deep.
<i>Alisma</i>	Hyd	N. temp. Perennial herb. Aquatic. Ls floating, submerged or emergent. Shallow waters (still to slow), muddy places & damp ground.
<i>Damasonium alisma</i>	Hyd	Eur., Medit. Perennial herb. Aquatic; shallow, still water. Floating (submerged).
<i>Hydrocharis morsus-ranae</i>	Hyd	Eur. Perennial herb. Aquatic; floating ls and surface fls.
<i>Stratiotes aloides</i>	Hyd	Eur. Perennial herb. Aquatic. Floats in summer, sinks in autumn.
<i>Vallisneria spiralis</i>	Hyd	S. Eur. Perennial herb. Aquatic. Submerged, but fls float to the surface when open; pollination at surface. Still water.
<i>Triglochin bulbosa</i>	Hel	Medit. Perennial herb. Marshes; fresh water- or salt-marshes.
<i>Potamogeton crispus</i> type	Hyd (G)	Cosmop. Perennial herb. Aquatic. Wide variety of fresh-water habitats - in deep or shallow water, stagnant to fast-flowing. Submerged or floating. Can grow subterrestrially in dried-up situations. Fls wind pollinated above surface.
<i>Potamogeton pectinatus</i>	Hyd (G)	Eur. Perennial herb. Aquatic. Base-rich or brackish water, up to 1 m deep. Fls pollinated below the water surface.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Colchicum</i>	Gt	Eur. Pindos Mtns. Open habitats, rocky or gravelly slopes, grassland, meadows, pastures, cultivated & disturbed ground. Lowlands ascending to 2000 m.
<i>Narthecium scardicum</i>	Hel	N. temp. Marshy places by springs & brooks, 1600-3200 m.
<i>Veratrum</i>	H	N. temp. Scrub, wood margins & mtn meadows, 1200-2000 m. <i>V. nigrum</i> grows on limestone only.
<i>Asphodelus fistulosus</i> type	Th or short-lived Grt	Medit. Steppe plant. Roadsides, cultivated ground. Intolerant of shade.
<i>Asphodelus albus</i>	?Grt	Medit. Steppe plant. Meadows, heaths, open woods & mtn pastures. Intolerant of shade.
<i>Fritillaria</i>	Gb	N. temp. Open woods, scrub & grassy places, 400-2500 m.
<i>Gagea pratensis</i>	Gb	N. temp. Grassland & disturbed ground.
<i>Tulipa sylvestris</i>	Gb	N. temp. Meadows, grassy & rocky places (esp. steppe), occas. in open woodland, (500-)1100-2200 m.
<i>Lilium</i>	Gb	N. temp. Mtn meadows, open woods & scrub, 650-2200 m. Beech woods in Pindos Mtns.
<i>Anthericum liliago</i>	H	Open woods, dry grassland & stony slopes, 500-2000 m.
<i>Scilla</i> type	Gb	Temp. Widespread in dry, open habitats, usually at low & moderate altitudes, occas. ascending to 2400 m. Beech & oak woods in Grevena.
<i>Muscari comosum</i>	Gb	Dry grassland & cultivated ground.
<i>Muscari neglectum</i> type	Gb	Dry places in woods, fields, pastures, meadows, ascending to 2500 m.
<i>Allium sphaerocephalon</i> type	Gb	N. hemisph. Mainly on disturbed ground; prob. spread by human activity. Dry places, fields & cultivated ground, (800-)1400-2200 m. <i>A. sativum</i> (garlic) is widely cultivated.
<i>Asparagus</i>	Grh	Old World. Mostly in dry places. Grows wild in woods & bushy places & pseudo- <i>maquis</i> .
<i>Narcissus papyraceus</i> type	Gb	Eur., Medit. Meadows, pastures & cultivated fields.
<i>Sternbergia</i>	Gb	E. Medit. Open stony slopes & dry scrub, (1000-)1200-2300 m.
<i>Iris pseudacorus</i>	Hel (G)	N. temp. Perennial herb of marshes & ditches.
<i>Iris spuria</i> type	Hel	N. temp. Perennial herb of wet places.
<i>Gladiolus</i> type	Gt	Eur. Common weed of crops. Dry rocky, heath, scrub & open woodland.
<i>Gynandris sisyrinchium</i>	Gt	Medit. Dry places, stony hillsides.
<i>Festuca</i> type	Th, H, Grh & Chh	Cosmop. Wild grasses of grasslands. Often viviparous in mtns. <i>Festuca</i> spp. dominate the grassland of pine wood-pasture vegetation in Grevena. See <i>Dactylis</i> below.
<i>Glyceria</i> type	Th to Grh & Hel	Cosmop. <i>Glyceria</i> spp. are perennial growing in marshy ground or shallow water. <i>Glyceria</i> grows on seasonally dry lakebed at Gomara, 1750 m. <i>Glyceria</i> is eaten by stock. <i>Bromus</i> spp. are mostly annual weeds and ruderals, but grow in grassland also.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Dactylis</i> type	Th, H & Grh	Eur., Medit. Wild grasses of grasslands mostly (some marsh spp. such as <i>Phalaris arundinacea</i>). Irrigation agriculture is used in NE Grevena today to grow grass for fodder. Increased by the establishment of pasture but grazing may reduce the flowering capacity of wild grass, while wood cutting may increase grass pollen values. Two small-grained millets, <i>Echinochloa crus-galli</i> (wild) & <i>Setaria italica</i> (cultivated) may belong to this pollen type. Macrofossils of these have been found in prehistoric contexts in Europe that suggest they were both eaten by humans. <i>Setaria italica</i> is known to have been cultivated for fodder and bird seed in S. Europe where it is often locally naturalized (Tutin <i>et al</i> 1980:264).
<i>Agropyron</i> type	Th & Grh	S. Eur. Mostly wild grasses that grow in dry habitats, except one species which may belong to this pollen type, <i>Panicum miliaceum</i> (broomcorn millet). This small grained species was formerly widely cultivated as a cereal, now more locally & mainly for fodder in C., S. & E. Eur. It has been identified in C. & E. Europe in Neolithic contexts.
<i>Triticum</i> type	Th	Cultivated cereals. Wheat is now the major crop in Grevena. It is grown mostly on the plains, but before mechanized agriculture was introduced it was cultivated in the Pindos Mtns & foothills as well as on the plains on a subsistence basis for bread & pasta. Domesticated wheat of <i>T. dicoccon</i> (emmer) is found in nearly all Neolithic archaeological sites in Greece, including Thessaly, from about 6000 BC (Renfrew 1973:26; Hansen 1988). Domesticated bread wheat <i>T. aestivum</i> has been found in Macedonia & Thessaly in sites dating to the Middle & Late Neolithic respectively (Hansen 1988). Domesticated wheat is self-pollinating.
<i>Secale cereale</i>	Th	Cultivated cereal. Rye has been found in N. & C. European archaeological sites dating to the Neolithic. Introduced into Greece by the Romans (Renfrew 1973:83). Prior to mechanized agriculture, rye was grown in the Pindos Mtns & foothills and on the Grevena plains on a subsistence basis as food for human consumption. Today it is a minor crop, confined mostly to the plains. Cross-pollinated (Hector, in Renfrew 1973:82).
<i>Hordeum</i> type	Th (mostly) & Grh	Includes cultivated cereals as well as some wild grass species. Domesticated barley (<i>H. distichon</i> & <i>H. vulgare</i>) has been identified from Neolithic sites throughout Greece, including Thessaly, along with the domesticated wheat <i>T. monococcum</i> (einkorn), included in this pollen type (Renfrew 1973:26; Hansen 1988). Domesticated barley has been identified in Bulgaria by 5000BC (Dennell 1972). Prior to mechanized agriculture, barley was grown in the Pindos foothills and on the Grevena plains on a subsistence basis as food for human consumption & for fodder. It is the second most important crop grown in Grevena today. Domesticated barley is self-pollinating. The wild species grow on disturbed ground, sometimes as persistent weeds on cultivated ground, in dry grassland, and on dry sandy or stony ground. <i>Elymus caninus</i> grows only in the shelter of woods. <i>Hordelymus europaeus</i> which is new to Greece also grows in woods, as well as other shady places.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Avena</i> type	Th	This pollen type includes cultivated cereals as well as some wild spp. of oats. Evidence of cultivated oats was found at Achilleion, Thessaly, dating to the Neolithic (Renfrew 1973:88). Prior to mechanized agriculture, oats (prob. <i>A. sativa</i>) were grown in the Pindos foothills and on the Grevena plains on a subsistence basis as food for livestock. Not known to be cultivated today. The wild spp. grow on dry, rocky and waste ground including roadsides and as weeds on cultivated ground.
<i>Phragmites australis</i>	Hel (Grh or H)	Cosmop. Wild grass (1-4 m tall). Marsh plant; fresh, shallow water.
<i>Zea mays</i>	Th	Cultivated cereal. Introduced from Am. Some now grown on the plains of Grevena.
<i>Arum</i>	Grt	Eur., Medit. Woods, hedges & disturbed areas.
<i>Dracunulus</i> type	Grt	Medit. Woods & scrub. Shady places.
Lemnaceae	Hyd	Cosmop. Perennial herbs. Aquatic. Free floating. Fronds floating or submerged, fls at water surface.
<i>Sparganium erectum</i>	Hel	N. temp. Marshes (semi-terrestrial). Creeping rhizome with stems projecting out of water with ls & fls higher up. Up to 1 m deep water. Grows on Kellia fen today.
<i>Sparganium angustifolium</i>	Hyd	N. temp. Aquatic; floating, with creeping rhizome with stems projecting out of water with ls & fls higher up. Perennial. 0.5-2 m deep water.
<i>Typha angustifolia</i> type	Hel	Temp. & trop. Perennial herbs of marshes or shallow water, at margins of lakes, ponds and rivers. Grows on Kellia fen today.
<i>Typha domingensis</i> type	Hel	Temp. & trop. Perennial herbs of marshes or shallow water, at margins of lakes, ponds and rivers.
<i>Scirpus</i>	Hel	Cosmop. Lakes, ponds & streams. Still to moderately fast flow. In still sheltered water 1-2+ m deep, in flowing usually 30-80 cm deep. Grows on Kellia fen today.
<i>Cladium mariscus</i>	Hel (G)	Trop. & temp. Fens & lake margins, usually in base-rich water. Stems 125-250 cm. Perennial.
<i>Cyperus michelianus</i>	?Hel	Annual. River-banks, marshes or wet grassland.
<i>Cyperus longus</i> type	Hel	River-banks, marshes or wet grassland. Grows on Kellia fen today.
<i>Schoenus nigricans</i>	Hel	Usually in fens & other at least seasonally wet, base-rich habitats.
<i>Carex hallerana</i> type	Grh	Temp. Terrestrial. Widespread in damp places & in dry, rocky places, scrub & open woodland, ascends to 2500 m.
<i>Carex flacca</i> type	Hel (H, G & T)	Temp. Mostly marsh plants. Marshes, fens, shallow lakes, margins of streams, and grasslands. Ascends to 2200 m.
<i>Epipactis</i> type	G	N. temp. Mostly in undisturbed shady woodland habitats, sometimes on rocky slopes or marshes.
<i>Limodorum abortivum</i>	G	S. Eur. Woods & shady grassland.
<i>Cephalanthera</i>	G	N. temp. Perennial herb. Woods & other shady places. Undisturbed areas.
PTERIDOPHYTA		
<i>Equisetum</i>	Hel (Grh)	Cosmop. Marshes. <i>E. telmateia</i> grows on Kellia fen today.

Pollen type	Life form	Notes on geographic distribution, habit, ecological amplitude, plant communities and uses
<i>Ophioglossum vulgatum</i>	Hel (Gr)	Trop., temp. Damp grassland from low altitudes to c. 2000 m, on varying substrates.
<i>Botrychium</i>	Gr	Cosmop. A variety of habitats from damp grassland to dry, rocky slopes, usually at high altitudes (1500-)1700-2600 m.
<i>Adiantum capillus-veneris</i>	Gr	Damp rocks.
<i>Pteridium aquilinum</i>	Gr	Cosmop. Pioneer. Not affected by cattle grazing. Encouraged by burning. Common and often gregarious in woodland clearings at montane altitudes (generally 500-1400 m), occas. ascends to 1800-1900 m.
<i>Thelypteris palustris</i>	Hel (Gr)	Fens & marshes.
<i>Thelypteris phegopteris</i>	Gr	Shady places.
<i>Asplenium</i> type	H	Cosmop. Mostly small plants of shady rock crevices & ledges, dry to damp. On a variety of substrates, in <i>maquis</i> & woods. Up to 2700 m.
<i>Athyrium filix-femina</i>	H	Damp, shady places by streams, generally in woods, ascending in seepage meadows & by brooks to 1800 m, occas. 2100 m.
<i>Athyrium distentifolium</i>	H	Scree & rocky outcrops on exposed mountains.
<i>Dryopteris filix-mas</i> type	H, G	Shady & semishady places in woods & at high altitudes, also on scree & in rock crevices, 600-2900 m.
<i>Gymnocarpium dryopteris</i>	Gr	Among rocks in woods & in shaded rock crevices, on non-calcareous substrate, 1400-2300 m.
<i>Blechnum spicant</i>	H	Damp humus-rich rocky places up to c. 1700 m. Usually calcifuge.
<i>Polypodium</i>	H	Cosmop. Grows on shaded, mossy rocks, (600-)1200-2100 m.
<i>Salvinia natans</i>	Hyd	Water plant. Free floating & submerged ls. Floating spores. Annual.

Appendix XI

Relative dispersal and representation

This table summarizes relative dispersal and representation of pollen and spore types whose source plants were noted in the areas surveyed and/or were present in surface pollen samples. Known pollination mechanisms have been included as an indication of pollen production, that is, anemophilous plants generally produce more pollen than plants with other pollination mechanisms (Knuth 1906:7; Erdtman 1969). Pollination mechanisms have been derived from Knuth (1906, 1908), Willis (1951), Faegri & van der Pijl (1971), Proctor & Yeo (1973) and Heywood (1978).

Letters used to symbolize types of **pollen dispersal mechanisms (DM)** are:

A = anemophilous; E = entomophilous; H = hydrophilous; EpH = ephydrophilous.

Where two symbols appear, the first is the more common method of dispersal.

Relative dispersal (RD) (termed 'relative export' by Flenley (1973:137)) has been scored (after Flenley 1973) as:

- 1) High: pollen types which occur in all or almost all samples, wherever collected.
- 2) Medium: pollen occurs in samples from adjacent vegetation.
- 3) Low: pollen occurs only in samples from vegetation in which parent plants are growing.

Representation (R) of pollen types has been scored (after Dodson 1976) as:

- 1) Over-represented: where pollen relative percentage is greater than the relative abundance of source species within the vegetation. Those species which have 'high' relative dispersal and therefore appear in areas where the source vegetation is not present are *ipso facto* over-represented.
- 2) Well-represented: where pollen relative percentage approximates source species relative abundance in the vegetation.
- 3) Under-represented: where pollen relative percentage was zero or smaller than source species relative abundance in the vegetation.
- 4) Insufficient data (i.d.): where there is doubt about the presence of the source plant for the pollen or insufficient pollen observed.

Pollen types are presented in the same order as in the pollen diagram: high altitude shrubs, high altitude herbs, coniferous and deciduous woodland trees, woodland understorey trees & shrubs, woodland herbs, riverine trees, evergreen woodland trees, plants of open dry rocky habitats, herbs of open-ground, cultivars, bog & marsh plants, and aquatic plants.

Pollen/spore type	DM	RD	R	Comments
Alpine shrubs				
<i>Armeria maritima</i> type	E	(no pollen)	under	
<i>Daphne</i>	E	i.d.	i.d.	
<i>Vaccinium myrtillus</i>	E	medium	well	
Alpine herbs				
<i>Oxyria digyna</i>	A	i.d.	i.d.	
<i>Pedicularis</i>	E	i.d.	i.d.	
<i>Plantago atrata</i>	A	i.d.	i.d.	
<i>Polygonum bistorta</i> type	E	i.d.	i.d.	
<i>Pyrola</i>	E	i.d.	i.d.	
<i>Soldanella</i>	E	i.d.	i.d.	
Coniferous & deciduous canopy trees				
<i>Pinus</i> (Diploxylon)	A	high	over	Well known over-representation (Wright 1972; Sheehan 1979; Jahns 1993).
<i>Fagus</i>	A	high	under	Coppiced. Represented in the pollen spectra at all sites, but in the sample collected from under the canopy of a beech wood was under-represented.
<i>Quercus frainetto</i> type	A	high	?well	Coppiced.
<i>Quercus trojana</i> type	A	high	?well	Coppiced. Badly or not represented in degraded woods (Bottema 1974).
<i>Abies</i>	A	medium	under	Found to be strongly under-represented in stands where fir was growing (Bottema 1975; Sheehan 1979), but Jahns (1993) found <i>Abies</i> to be better represented.
<i>Acer</i>	E	low	under	Under-represented (Bottema 1974).
<i>Carpinus</i> type	A	medium	well	Good production & usually has good transport, but low shrubs are under-represented (Bottema 1974).
<i>Castanea sativa</i>	E, A	medium	over	Pollen dispersal is poor (Bottema 1974; Bottema & Woldring 1990:260).
<i>Cornus mas</i>	E	low	under	Under-represented (Bottema 1974).
<i>Cornus sanguinea</i>	E	low	under	Under-represented (Bottema 1974).
<i>Corylus</i>	A, E	high	over	It is often noted that <i>Corylus</i> produces much less pollen as an under-shrub than as a tree (Iversen 1941; Ritchie & Lichti-Federovich 1963; Faegri & Iversen 1992:5)

Pollen/spore type	DM	RD	R	Comments
<i>Crataegus</i>	E	low	under	
<i>Euonymus europaeus</i> type	E	(no pollen)	under	
<i>Fraxinus ornus</i>	E	medium	over	Well represented (Bottema 1974).
<i>Malus</i>	E	(no pollen)	under	
<i>Ostrya</i> type	A	high	over	Good production & good transportation (Bottema 1974).
<i>Prunus spinosa</i> type	E	(no pollen)	under	
<i>Pyrus</i>	E	(no pollen)	under	
<i>Rhamnus</i> type	E	(no pollen)	under	
<i>Sorbus</i> type	E, A	low	under	No pollen identified from the site, Aetia, where it was recorded growing, but one grain recorded at Gomara which must be a result of long distance dispersal.
<i>Taxus baccata</i>	A	medium	over	Occurs in only small amount in the mixed woods at Aetia & Zakas. Is represented in these two pollen spectra in small numbers, as well as a few other spectra in small numbers.
<i>Tilia cordata</i> type	E, A	low	under	
<i>Ulmus glabra</i> type	A	medium	under	No pollen recorded at the mixed woods site, Aetia, where it is recorded as growing, but a few grains were recorded in the spectra at Gomara & Anelia which must be the result of long distance dispersal.
Woodland understorey trees & shrubs				
<i>Arceuthobium oxycedri</i>	E	i.d.	i.d.	
<i>Buxus sempervirens</i>	E, A (occas.)	low	well	Rather good production, but poor dispersal (Bottema 1974).
<i>Clematis vitalba</i> group	E	(no pollen)	under	
<i>Hedera helix</i>	E	(no pollen)	under	
<i>Juniperus</i>	A	?medium	under	Found to be under-represented (Sheehan 1979; Jahns 1993).
<i>Rosa</i>	E	low	under	
<i>Rubus</i> type	E	low	under	
Woodland herbs				
<i>Actaea spicata</i>	E	i.d.	i.d.	
<i>Agrimonia</i> type	E	(no pollen)	under	

Pollen/spore type	DM	RD	R	Comments
<i>Anemone nemorosa</i> group	E	high	over	A few grains of this pollen type were found in the spectra of sites where it had not been seen growing.
<i>Arabis</i>	E	medium	over	
<i>Arum</i>	E	(no pollen)	under	
<i>Asparagus</i>	E	i.d.	i.d.	
<i>Asplenium</i> type	A	i.d.	i.d.	
<i>Blechnum spicant</i>	A	medium	over	
<i>Cephalanthera</i>	E	i.d.	i.d.	
<i>Cyclamen</i>	E, A	(no pollen)	under	
<i>Dorycnium</i>	E	low	under	
<i>Eryngium</i>	E	i.d.	i.d.	
<i>Fragaria vesca</i> type	E	low	under	
<i>Fritillaria</i>	E	(no pollen)	under	
<i>Gymnocarpium dryopteris</i>	A	i.d.	i.d.	
<i>Helleborus</i>	E	low	under	
<i>Limodorum abortivum</i>	E	i.d.	i.d.	
<i>Orchis</i>	E	(no pollen)	under	
<i>Pimpinella saxifraga</i>	E	i.d.	i.d.	
<i>Primula</i>	E	(no pollen)	under	
<i>Saxifraga tridactylites</i> type	E	i.d.	i.d.	
<i>Scilla</i> type	E	(no pollen)	under	
<i>Stellaria holostea</i>	E	i.d.	i.d.	
<i>Thalictrum aquilegifolium</i>	A, E	i.d.	i.d.	
<i>Thalictrum lucidum</i>	A, E	i.d.	i.d.	
<i>Umbilicus</i>	E	i.d.	i.d.	
<i>Valeriana officinalis</i> type	E	i.d.	i.d.	
<i>Viola hirta</i> type	E, auto-gamous	(no pollen)	under	
<i>Viola riviniana</i> type	E, auto-gamous	(no pollen)	under	

Pollen/spore type	DM	RD	R	Comments
Riverine trees				
<i>Alnus glutinosa</i>	A	high	over	A few pollen grains recorded in every surface sample, although it is not recorded as growing at any of the surface sample collection sites. It grows in the riverine vegetation of Grevena.
<i>Fraxinus angustifolia</i>	A	medium	over	Not recorded as growing near the surface samples sites.
<i>Fraxinus excelsior</i> type	A	medium	over	Not recorded as growing near the surface samples sites.
<i>Myricaria germanica</i>	E	i.d.	i.d.	
<i>Myrtus communis</i>	E	i.d.	i.d.	
<i>Populus</i>	A	medium	well	Two pollen grains recorded in Mirsina fen, these are probably from the riverine vegetation along the Aliakmon which is closeby. One grain recorded at the Gomara site must be from long distance dispersal.
<i>Salix triandra</i>	E, A	low	well	
<i>Tamarix</i>	E, A	i.d.	i.d.	Poor dispersal (Bottema 1974).
Evergreen woodland trees				
<i>Ephedra fragilis</i>	A	low	under	One grain identified in the Mirsina fen. It may have been growing in the steppe surrounding this site, although it was not observed. It may also be the result of long-distance transport (Ritchie & Lichti-Federovich 1963; Maher 1969; Markgraf 1980:143; Birks 1981; Faegri & Iversen 1992:30).
<i>Phillyrea</i>	E	i.d.	i.d.	oderate pollen production & poor dispersal (Bottema 1974).
<i>Pistacia</i>	A	i.d.	i.d.	Known to be highly under-represented (Bottema 1974; Sheehan 1979; Jahns 1993).
<i>Quercus coccifera</i> type	A	high	over	Over-represented (Bottema 1974).
Plants of open dry rocky habitats				
<i>Agropyron</i> type	A	i.d.	i.d.	
<i>Alkanna</i> type	E	i.d.	i.d.	
<i>Asyneuma</i> type	E	(no pollen)	under	
<i>Bunium</i>	E	i.d.	i.d.	
<i>Campanula erinus</i> type	E	i.d.	i.d.	

Pollen/spore type	DM	RD	R	Comments
<i>Campanula rotundifolia</i>	E	(no pollen)	under	
<i>Carum</i>	E	i.d.	i.d.	
<i>Cnidium silaifolium</i>	E	i.d.	i.d.	
<i>Crupina</i>	E	i.d.	i.d.	
<i>Echinops</i>	E, A	(no pollen)	under	
<i>Euphrasia</i>	E	(no pollen)	under	
<i>Helianthemum</i>	E, A	low	under	
<i>Herniaria</i> type	Auto-gamous, E	i.d.	i.d.	
<i>Linum austriacum</i> type	E	i.d.	i.d.	Poorly represented (Wright 1972:190).
<i>Linum usitatissimum</i> type	E, auto-gamous	i.d.	i.d.	Poorly represented (Wright 1972:190).
<i>Plantago afra</i>	A	i.d.	i.d.	
<i>Plantago albicans</i>	A	i.d.	i.d.	
<i>Plantago alpina</i> type	A	i.d.	i.d.	
<i>Plantago amplexicaulis</i>	A	i.d.	i.d.	
<i>Plantago argentea</i>	A	medium	over	
<i>Scabiosa columbaria</i> type	E	i.d.	i.d.	
<i>Seseli</i> type	E	i.d.	i.d.	
<i>Stachys angustifolia</i>	E	(no pollen)	under	
<i>Trinia</i>	E	i.d.	i.d.	
Herbs of open-ground				
<i>Achillea</i> type	E	medium	under	
<i>Adonis</i>	E	i.d.	i.d.	
<i>Alchemilla</i> type	E	(no pollen)	under	
<i>Allium sphaerocephalon</i> type	E	i.d.	i.d.	
<i>Ammi</i>	E	medium	well	
<i>Anagallis arvensis</i> type	E	(no pollen)	under	
<i>Anchusa arvensis</i> type	E	(no pollen)	under	
<i>Artemisia</i>	A, E	medium	well	Good dispersal (Bottema & Woldring 1990).
<i>Asterolinum linum-stellatum</i>	E	i.d.	i.d.	
<i>Buglossoides purpureocaerulea</i>	E	(no pollen)	under	

Pollen/spore type	DM	RD	R	Comments
<i>Bupleurum</i>	E	i.d.	i.d.	
<i>Calystegia</i>	E	(no pollen)	under	
<i>Carlina</i> type	E	low	under	
<i>Centaurea cyanus</i> type	E	i.d.	i.d.	
<i>Centaurea graeca</i> type	E	i.d.	i.d.	
<i>Centaurea solstitialis</i> type	E	i.d.	i.d.	
<i>Centaureum</i>	E	(no pollen)	under	
<i>Chaerophyllum temulentum</i> type	E	i.d.	i.d.	
<i>Chelidonium majus</i>	E	i.d.	i.d.	
Chenopodiaceae	A, E	high	over	Good production, poor dispersal (Bottema 1974).
<i>Cichorium</i> type	E	low	under	
<i>Cirsium</i> type	E	low	well	
<i>Colchicum</i>	E	(no pollen)	under	
<i>Conium maculatum</i>	E	i.d.	i.d.	
<i>Consolida</i> type	E	(no pollen)	under	
<i>Convolvulus</i>	E	(no pollen)	under	
<i>Coriandrum</i> type	E	i.d.	i.d.	
<i>Cuscuta epithymum</i> type	E	(no pollen)	under	<i>C. epithymum</i> is cleistogamous (Knuth 1906:59).
<i>Cuscuta europaea</i> type	E	i.d.	i.d.	
<i>Cuscuta monogyna</i>	E	(no pollen)	under	
<i>Dactylis</i> type	A	high	under	Grazing may prevent grass from flwring.
<i>Daucus</i>	E	i.d.	i.d.	
<i>Dianthus</i> type	E	i.d.	i.d.	Some spp. are pseudo-cleistogamous & others cleistogamous (Knuth 1906).
<i>Emex spinosa</i>	?E	i.d.	i.d.	
<i>Euphorbia</i>	E	low	under	
<i>Festuca</i> type	A	high	under	Grazing may prevent flwring.
<i>Galium</i> type	E	low	well	
<i>Geranium</i>	E	i.d.	i.d.	
<i>Gladiolus</i> type	E	i.d.	i.d.	
<i>Hibiscus</i>	E	(no pollen)	under	

Pollen/spore type	DM	RD	R	Comments
<i>Hieracium</i> type	E	medium	over	A few grains were identified in several pollen spectra at sample locations where plants had not been identified. Distribution seems erratic.
<i>Hornungia</i> type	E	medium	over	
<i>Hypericum perforatum</i> type	E	(no pollen)	under	
<i>Kickxia</i>	E	(no pollen)	under	
<i>Knautia</i>	E	i.d.	i.d.	
<i>Lactuca</i> type	E	i.d.	i.d.	
<i>Lathyrus pratensis</i> type	E	(no pollen)	under	<i>Lathyrus setifolius</i> & probably other spp. are cleistogamous (Knuth 1906:59)
<i>Lotus</i> type	E	i.d.	i.d.	
<i>Muscari comosum</i>	E	i.d.	i.d.	
<i>Muscari neglectum</i> type	E	i.d.	i.d.	
<i>Myosotis</i> type	E, auto-gamous	(no pollen)	under	
<i>Nigella</i>	E	low	under	
<i>Ononis</i> type	E	low	under	
<i>Oxalis</i>	E	(no pollen)	under	Photo-cleistogamous and sometimes thermo-cleistogamous (Knuth 1906:55)
<i>Papaver rhoeas</i> type	E	i.d.	i.d.	
<i>Paronychia</i> type	E	i.d.	i.d.	
<i>Pimpinella anisum</i> type	E	i.d.	i.d.	
<i>Plantago bellardii</i>	A	i.d.	i.d.	
<i>Plantago coronopus</i>	A	medium	over	
<i>Plantago lanceolata</i> type	A, E	medium	over	Over-represented, high dispersal (Bottema 1974).
<i>Plantago major</i>	A	i.d.	i.d.	
<i>Plantago media</i>	A, E	medium	over	
<i>Polygonum aviculare</i> type	Auto-gamous, E	medium	?	
<i>Potentilla</i>	E	low	under	
<i>Prunella</i> type	E	i.d.	i.d.	
<i>Pteridium aquilinum</i>	A	medium	well	Representation variable (Bottema 1974)
<i>Rumex acetosa</i> group	A	medium	over	
<i>Rumex acetosella</i> group	A	i.d.	i.d.	

Pollen/spore type	DM	RD	R	Comments
<i>Rumex conglomeratus</i> group	A	(no pollen)	under	
<i>Rumex crispus</i> pp.	A	i.d.	i.d.	
<i>Rumex</i> type	A	low	under	
<i>Salvia officinalis</i> type	E	(no pollen)	under	
<i>Salvia verticillata</i>	E	(no pollen)	under	
<i>Sanguisorba minor</i>	A	i.d.	i.d.	
<i>Scleranthus annuus</i> type	E, auto-gamous	i.d.	i.d.	Photo-cleistogamous or sometimes thermo-cleistogamous (Knuth 1906:56).
<i>Scrophularia</i> type	E	medium	well	
<i>Scutellaria</i> type	E	(no pollen)	under	
<i>Sinapis</i> type	E	medium	over	
<i>Smyrniium</i>	E	i.d.	i.d.	
<i>Solanum dulcamara</i>	E	i.d.	i.d.	
<i>Solanum nigrum</i> type	E	medium	under	
<i>Solidago</i> type	E	high	well	
<i>Sonchus</i> type	E	(no pollen)	under	
<i>Stachys sylvatica</i> type	E	(no pollen)	under	
<i>Taraxacum</i> type	E	i.d.	i.d.	
<i>Teucrium</i>	E	low	under	
<i>Theligonum cynocrambe</i>	?E	i.d.	i.d.	
<i>Torilis japonica</i> type	E	i.d.	i.d.	
<i>Trifolium dubium</i> type	E	(no pollen)	under	
<i>Trifolium montanum</i> type	E	(no pollen)	under	
<i>Trifolium repens</i> type	E	(no pollen)	under	
<i>Urtica dioica</i>	A	low	well	
<i>Urtica pilulifera</i> type	A	low	under	
<i>Urtica urens</i> type	A	low	under	
<i>Verbena</i>	E	(no pollen)	under	
<i>Veronica triphyllos</i> type	E	low	under	Some spp. are pseudo-cleistogamous.
<i>Vicia cracca</i> type	E	i.d.	i.d.	
<i>Viola arvensis</i> type	E or auto-gamous	(no pollen)	under	

Pollen/spore type	DM	RD	R	Comments
<i>Xanthium</i>	A	i.d.	i.d.	
Cultivars				
<i>Avena</i> type	A	low	under	Domesticated oats are autogamous & pseudo-cleistogamous (Knuth 1906:56).
<i>Elaeagnus angustifolia</i>	E	i.d.	i.d.	
<i>Hordeum</i> type	A	low	under	Domesticated barley & emmer wheat are autogamous. Barley is cleistogamous & emmer is pseudo-cleistogamous.
<i>Juglans regia</i>	A	high	over	Production & dispersal may be good (Bottema 1974).
<i>Lathyrus sativus</i>	E	i.d.	i.d.	
<i>Medicago sativa</i>	E	i.d.	i.d.	A few grains were identified from locations that suggest they were from the wild subspecies.
<i>Platanus orientalis</i>	A	medium	over	Pollen dispersal is not very good (Bottema & Woldring 1990:260). Under-represented (Bottema 1974).
<i>Secale cereale</i>	A	medium	under	Pseudo-cleistogamous (Knuth 1906:56).
<i>Triticum</i> type	Auto-gamous	medium	over	These scores are based on the local vegetation of the sampling sites. On a regional basis <i>Triticum</i> type is severely under-represented with low relative dispersal.
<i>Zea mays</i>	A	medium	under	These scores are based on the local vegetation of the sampling sites. On a regional basis severely under-represented with low relative dispersal.
Bog & marsh plants				
<i>Anagallis tenella</i> type	E	(no pollen)	under	
<i>Angelica sylvestris</i>	E	i.d.	i.d.	
<i>Berula erecta</i>	E	low	under	
<i>Caltha</i> type	E	i.d.	i.d.	
<i>Carex flacca</i> type	A	low	?well	
<i>Carex hallerana</i> type	A	high	over	
<i>Chrysosplenium alternifolium</i>	E	i.d.	i.d.	
<i>Cyperus longus</i> type	A	low	well	
<i>Cyperus michelianus</i>	A	medium	over	
<i>Dipsacus</i> type	E	(no pollen)	under	
<i>Epilobium hirsutum</i> type	E	(no pollen)	under	

Pollen/spore type	DM	RD	R	Comments
<i>Equisetum</i>	A	low	under	
<i>Filipendula</i>	E	i.d.	i.d.	
<i>Galega officinalis</i>	E	i.d.	i.d.	
<i>Gentiana lutea</i> type	E	i.d.	i.d.	
<i>Glyceria</i> type	A	medium	well	
<i>Gratiola officinalis</i>	E	i.d.	i.d.	
Juncaceae	A	(no pollen)	under	
<i>Linum catharticum</i>	E	(no pollen)	under	
<i>Lychnis flos-cuculi</i>	E	i.d.	i.d.	
<i>Lysimachia</i>	E	low	well	
<i>Lythrum portula</i>	E	low	under	
<i>Lythrum salicaria</i> type	E	low	under	
<i>Mentha</i> type	E	low	under	
<i>Oenanthe aquatica</i> group	E	i.d.	i.d.	
<i>Oenanthe pimpinelloides</i> group	E	i.d.	i.d.	
<i>Parnassia palustris</i>	E	low	well	
<i>Phragmites australis</i>	A	medium	well	
<i>Pinguicula</i>	E	(no pollen)	under	
<i>Ranunculus acris</i> group	E	(no pollen)	under	
<i>Salix fragilis</i> type	E, A	i.d.	i.d.	
<i>Samolus valerandi</i>	E	i.d.	i.d.	
<i>Saxifraga stellaris</i>	E	i.d.	i.d.	
<i>Schoenus nigricans</i>	A	i.d.	i.d.	
<i>Scirpus</i>	A	(no pollen)	under	
<i>Sparganium erectum</i>	A	low	over	
<i>Typha angustifolia</i> type	A	low	well	
<i>Typha domingensis</i> type	A	(no pollen)	under	
<i>Veronica anagallis-aquatica</i> type	E	(no pollen)	under	A few sp. are pseudo-cleistogamous (Knuth 1906:55).
Aquatics				
<i>Callitricha obtusangula</i>	?EpH/A	i.d.	i.d.	
<i>Damasonium alisma</i>	?E	i.d.	i.d.	
<i>Hydrocharis morsus-ranae</i>	E	i.d.	i.d.	

Pollen/spore type	DM	RD	R	Comments
<i>Hydrocotyle vulgaris</i>	E, auto-gamous	i.d.	i.d.	
<i>Myriophyllum spicatum</i>	A, H	i.d.	i.d.	
<i>Potamogeton crispus</i> type	A	i.d.	i.d.	
<i>Ranunculus aquatilis</i> group	E, auto-gamous	i.d.	i.d.	<i>R. aquatilis</i> is autogamous cleistogamously under water where water is too deep for the flowers to reach the surface (Knuth 1906:55)
<i>Sparganium angustifolium</i>	A	low	well	
<i>Trapa natans</i>	Auto-gamous	i.d.	i.d.	Flowers almost always open in air, rarely under water, although there is some hydro-cleistogamy (Knuth 1908:452)
<i>Utricularia</i>	E	(no pollen)	under	

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Appendix XII

Results of diatom analysis

Presented here are relative frequency graphs plotted by Dr M. Harper from the results of the diatom analysis undertaken on the sediment core of the Gomara wetland site. Plots are based on the ecological indicator values of van Dam *et al* (1994) and ecological groups are arranged in order of occurrence.

Figure XII.1 pH tolerance

Figure XII.2 Moisture requirements

Figure XII.3 Habitat

Figure XII.4 Trophic levels

Figure XII.5 Oxygen requirements

Figure XII.6 Organic nitrogen uptake metabolism

Diatom results according to wetland pollen zones

Samples are combined according to the local wetland pollen assemblage zones defined in Chapter 4.

189 & 172 cm (zone GW-6) Diatom concentration is relatively low in the basal sample, but increases twofold in the upper sample. Most species are alkaliphilous (mainly occurring at pH >7) recording 60% in the basal sample and increasing to almost 90% in the upper sample. Diatoms preferring neutral water conditions reach almost 30% in the basal sample, but decline to less than 10% in the upper sample. Alkalibiontic diatoms (exclusively occurring at pH >7) record about 5% in the basal sample, but then drop to less than 1%. Acidophilous diatoms (mainly occurring at pH <7) and those indifferent to water pH record less than 5%.

About 40% of diatoms live in permanent water, while 40-50% live in ephemeral water. Only about 5% live in fairly permanent water. Less than 5% live in wet places (wet soil and mosses) and about 10% live in unknown moisture conditions.

Relative frequencies of epipellic diatoms (those that live on silt) are the highest of the sequence (slightly more than 30% to slightly more than 40%). Representation of diatoms that live in shallow water is also high, being slightly more than 30% to almost 60%, but the lower value (basal sample) is the lowest value of the sequence for this habitat. Epiphytic (those that live on plants) and epilithic diatoms (those that live on rocks) record intermediate values for the sequence (slightly more than 20% in the basal sample, then slightly more than 10%). Less than 1% of the diatoms live in open water.

Relative frequencies of diatoms indifferent to trophic level (oligo- to hypereutraphentic) are the highest of the sequence in zone GW-6 (slightly more than 35% in the basal sample, then about 55%) and those of hypereutraphentic diatoms are the highest of the sequence in the basal sample (about 10%), but then they decline sharply. Frequencies of eutraphentic diatoms are the highest of the sequence in this zone (about 20-25%). Meso- to eutraphentic diatoms record the lowest frequencies of the sequence (about 15-20%). Mesotraphentic, oligo- to mesotraphentic and oligotraphentic diatoms record low relative frequencies (less than 10%).

Diatoms requiring 100% oxygen are dominant occurring at about 55 and 70%. Diatoms requiring >75% oxygen are next most abundant at 25-30% and those requiring >50% and >30% oxygen occur at less than 10%.

Diatoms that are obligately nitrogen-heterotrophic (needing continuously elevated concentrations of organically bound nitrogen) record the highest relative frequencies of the sequence in the basal sample (about 10%), but then decline to zero. Facultatively nitrogen-heterotrophic diatoms (needing periodically elevated concentrations of organically bound nitrogen) record about 1%. Nitrogen autotrophs tolerant of organically bound nitrogen are dominant in this zone, recording slightly more

than 60%, then about 85%. Diatoms intolerant of organically bound nitrogen record 25% in the basal sample, then decline to slightly less than 15%.

154 & 139 cm (zone GW-5) Diatom concentration continues to increase, reaching the highest value for the sequence in the lower sample (with the exception of those samples in zone GW-1) but decreases in the upper sample to below the value of the top sample in zone GW-6.

Alkaliphilous diatoms continue to be dominant (about 80%), and those preferring neutral water conditions are next most abundant (about 15%). Alkalibiontic diatoms increase from about 1% in the lower sample to about 5%. Acidophilous and pH-indifferent diatoms are less than 5%.

Relative frequencies of diatoms that live in permanent water increase dramatically in this zone to over 80%, but then decline to about 60%. The relative frequency of diatoms that live in fairly permanent water remains at about 5% in the lower sample, but then increases sharply to about 30%, whereas the relative frequencies of those diatoms that live in ephemeral water are much reduced (about 10%). Frequencies of diatoms that live in wet places and those whose moisture preference is unknown are very low (<5%).

The relative frequency of epipellic diatoms declines in this zone (about 15% and 20%), while that of epiphytic/epilithic diatoms remains at about 15%. Diatoms that live in shallow water are very abundant (between 60% and 75%), while those of open water habitats remain extremely rare.

A decline in trophic status results in relative frequencies of meso- to eutraphentic diatoms reaching the maximum for the sequence at slightly above 80%; they then decline to 70%. There is a corresponding decline in the relative frequencies of oligo- to hypereutraphentic diatoms (slightly greater than 5%) and eutraphentic diatoms (about 5-10%). Mesotraphentic, oligo- to mesotraphentic and oligotraphentic diatoms are all represented at less than 10%.

Diatoms requiring 100% oxygen remain dominant being represented by relative frequencies of about 75 and 85%. Diatoms requiring >75% oxygen remain next most abundant, but decline to about 10 and 20%. Diatoms requiring >50% and >30% oxygen remain at less than 10%.

Diatoms in the nitrogen autotroph group that are tolerant of organically bound nitrogen remain dominant but have declined to between 55 and 60%. Diatoms intolerant of organically bound nitrogen have increased significantly to about 40%. Facultatively nitrogen-heterotrophic and obligately nitrogen-heterotrophic diatoms represent less than 5%.

119 cm (zone GW-4) Diatom concentration continues to decline in this zone. The relative frequency of alkaliphilous diatoms declines (60%), while that of neutral and pH-indifferent diatoms increases (about 20% and 15%, respectively). The relative frequency of acidophilous and alkalibiontic diatoms remains low (< 5%).

Diatoms that live in permanent water, fairly permanent water and ephemeral water are represented almost equally in this sample, about 30%. This represents a decline in diatoms that live in permanent water, a very slight increase in those that live in fairly permanent water and a sharp increase in those that live in ephemeral water. Those that live in wet places are represented by less than 5% and those in the unknown category have a similar relative frequency.

Diatoms of shallow water habitats decline (about 45%), but remain dominant. Epiphytic/epilithic diatoms increase dramatically to almost 40%, while epipellic diatoms remain unchanged (about 20%), as do open water diatoms.

Meso- to eutraphentic diatoms remain dominant (50%). A possible slight decline in trophic level is shown by an increase in oligo- to hypereutraphentic diatoms (to 15%), although mesotraphentic and eutraphentic diatoms are unchanged (<10% and 10% respectively). Oligotraphentic diatoms remain

at under 5%.

Diatoms requiring 100% oxygen remain dominant at almost 80%. Those requiring >75% oxygen decline very slightly to about 15%, and those requiring >50% and >30% are very low at less than 5%.

Nitrogen autotrophic diatoms intolerant of organic nitrogen now become dominant (about 60%), while diatoms tolerant of organic nitrogen have declined to about 40%.

106 cm (zone GW-3) Diatom concentration increases slightly in this zone. Alkaliphilous diatoms increase slightly to about 70%, while those preferring neutral water conditions remain at about the same relative frequency of about 20% and acidophilous and alkalibiontic remain at less than 5%. Diatoms that are indifferent to water pH conditions decline to about 5%.

The relative frequency of diatoms that live in permanent water increases again (about 65%). Diatoms that live in fairly permanent water and ephemeral water both decline (about 10% and 20%, respectively). Those of wet places and unknown habitat are unchanged (less than 5%).

Shallow water diatoms increase again to almost 60%, epiphytic/epilithic diatoms decline slightly and epipelagic decline more sharply to almost 10% (the minimum of this habitat for the sequence).

Meso- to eutraphentic diatoms remain dominant, increasing slightly to almost 65%. Oligo- to mesotraphentic, mesotraphentic and eutraphentic diatoms decline (the first substantially to about 5%, the others only slightly). Hypereutraphentic diatoms reappear, but at less than 5% and oligotraphentic diatoms remain at about 5%.

Diatoms requiring 100% oxygen remain dominant at almost 80%. Those requiring >75% oxygen decline to less than 10% and those requiring >50% and >30% oxygen increase, but to less than 10%.

Nitrogen autotrophic diatoms tolerant of organic nitrogen again become dominant at about 65%, while diatoms intolerant of organic nitrogen decline to 30%. Facultatively nitrogen-heterotrophic and obligately nitrogen-heterotrophic diatoms increase, but are less than 5%.

84 & 56 cm (zone GW-2) Diatom concentrations in these two samples are minima of the sequence, being extremely low in the upper sample. The relative frequencies of alkaliphilous diatoms increase to almost 80%, then drop to 60%; pH-indifferent diatoms decline to less than 5%, but then increase to almost 15%. Diatoms with a neutral pH tolerance decline to about 15% (both samples). Acidophilous and alkalibiontic diatoms increase slightly to about 5%.

Diatoms that live in permanent water continue to be represented by very high relative frequencies (60-65%). Diatoms living in fairly permanent water and in ephemeral water fluctuate slightly between 10 and 20%. Diatoms of wet places remain rare (<5%), while those of unknown moisture requirements increase (>10%).

Diatoms of shallow water remain dominant with relative frequencies about 50 and 70%. Epiphytic/epilithic diatoms are the next most abundant, recording about 15 and 40%. Epipelagic diatoms increase slightly to almost 15%, while diatoms that live in open water remain at less than 1%.

Meso- to eutraphentic diatoms remain dominant with relative frequencies of about 55 and 75%. Mesotraphentic diatoms increase to almost 10% and then decline to about 5%. Oligotraphentic, oligo- to mesotraphentic and eutraphentic diatoms are all represented at less than 10%.

Diatoms requiring 100% oxygen remain dominant at relative frequencies about 65 and 85%. Diatoms requiring >75% and >50% oxygen both decline slightly in the lower sample, but then increase to about 15%. Those requiring >30% oxygen are represented at less than 5%.

Nitrogen autotrophic diatoms intolerant of organically bound nitrogen are dominant in the lower sample (about 55%), but then decline to 30%, while diatoms tolerant of organic nitrogen record only 40% in the lower sample, but then become dominant at 65%. Diatoms of unknown organic nitrogen tolerance are about 5%.

35, 10 & 1 cm (zone GW-1) Diatom concentration increases dramatically in this zone to highest levels of the sequence. The relative frequencies of alkaliphilous diatoms are maxima of the sequence (with the exception of that recorded at 172 cm). Conversely those of indifferent preferences for water pH condition and alkalibiontic decline to either zero or almost zero. Acidophilous diatoms and those preferring neutral water conditions remain at about the same relative frequencies, the former increasing slightly to almost 10% and the latter declining slightly (10%).

The relative frequency of diatoms that live in permanent water increases slightly, reaching greater than 80% at 1 cm (sharing the sequence maximum with the sample at 154 cm). Diatoms that live in fairly permanent water decline from about 10% to about 1% in the top sample. Diatoms that live in ephemeral water decline slightly to maintain an almost constant relative frequency in this zone at 10%. Those that live in wet places, and those of unknown moisture requirements remain at the same levels as those in the previous zone (less than 5% and about 10%, respectively).

Diatoms that live in shallow water remain dominant and increase to 80% in the top sample. Epiphytic/epilithic diatoms decline to about 10 and 25%. Epipellic diatoms increase slightly and then decline in the top sample to less than 10%. No diatoms of open water are represented.

Meso- to eutraphentic diatoms remain dominant at about 65-80%. Oligotraphentic, oligo- to mesotraphentic, mesotraphentic, eutraphentic and hypereutraphentic diatoms are all represented at relative frequencies of less than 10%, but may show a slightly higher trophic level for this zone than GW-2.

Diatoms requiring 100% oxygen remain dominant and increase to the maximum relative frequency of the sequence of about 95% in the top sample. Diatoms requiring >75% and >50% oxygen decline to less than 5% in the top sample, and those requiring >30% oxygen increase to about 5%.

Nitrogen autotrophic diatoms tolerant of organic nitrogen are dominant in this zone at 70-85%, while diatoms that are intolerant of organic nitrogen are much less abundant at about 15-25%. Facultatively nitrogen-heterotrophic and obligately nitrogen-heterotrophic diatoms are less than 5%.

Reference

- van Dam, H., A. Mertens and J. Sinkeldam 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *Netherlands journal of aquatic ecology* 28 (1): 117-133.

Figure XII.1 pH tolerance.

Figure XII.2 Moisture requirements.

Figure XII.3 Habitat.

Figure XII.4 Trophic levels.

Figure XII.5 Oxygen requirements.

Figure XII.6 Organic nitrogen uptake metabolism.

Appendix XIII

Sediment sequences - Pollen and charcoal counts

Gomara

Depth (cm)	0-1	25-26	30-31	35-36	40-41	45-46	50-51	55-56	60-61	65-66	70-71	75-76
Hole number	1	1	1	1	1	1	1	1	1	1	1	2
Absolute counts data												
Slide numbers	1	1	1	1	1	1	1	1	1&2	1	1	1
Dilution factor	25	25	25	25	25	25	25	25	25	25	25	25
Aliquot size (ul)	200	200	200	200	200	200	200	400	600	200	400	400
Sample weight (g) (wet)	1.241	1.175	1.102	1.097	1.124	1.105	1.053	1.02	1.007	1.023	1.017	1.037
Sample fraction counted	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.016	0.024	0.008	0.016	0.016
<i>Lycopodium</i> suspension added (ml)	2	2	1	1	1	1	1	0.5	0.5	0.5	0.5	2
<i>Lycopodium</i> count	1213	1031	723	535	920	754	480	1049	932	512	993	2832
GYMNOSPERMAE												
<i>Abies</i>	9	26	10	29	19	2	16	33	9	10	9	35
<i>Picea abies</i>												1
<i>Pinus</i> subgenus <i>Diploxylon</i>	837	412	204	282	581	156	181	284	154	220	170	467
<i>Pinus</i> subgenus <i>Haploxylon</i>												2
<i>Juniperus</i>	29	1		1		4	4	3	2		1	1
<i>Taxus baccata</i>			1		10	1					1	
<i>Ephedra fragilis</i>				1								
DICOTYLEDONES												
<i>Salix triandra</i>			1		2	3		3	1		3	
<i>Populus</i>	1	3										
<i>Juglans regia</i>		1			1	4	1	3		1		
<i>Alnus glutinosa</i>	4	4	4		6	9	2	2	4	2	1	8
<i>Betula pendula</i>		1		1								
<i>Carpinus</i> type	4	3	2		8	4	2	1	4	2	1	14
<i>Ostrya</i> type	50	59	20	20	80	47	26	16	15	38	5	35
<i>Corylus</i>	3	5	5	2	8	11	3	2	4	2		3
<i>Fagus</i>	63	76	63	48	212	117	233	154	126	154	42	268
<i>Castanea sativa</i>	3											
<i>Quercus coccifera</i> type	19	6	3	7	3	3	3		1			
<i>Quercus trojana</i> type	24	19	19	6	37	27	10	35	16	18	8	32
<i>Quercus frainetto</i> type	72	99	117	57	97	89	27	66	35	39	18	55
<i>Ulmus glabra</i> type	5	2	1		1	1			1			
<i>Celtis</i>												
<i>Urtica dioica</i>	5	8	5	2	4	7		2	1			2
<i>Urtica urens</i> type		1	11		1			7				7
<i>Urtica pilulifera</i> type		3				1		1	1			1
<i>Parietaria</i>						5	1		1			
<i>Viscum album</i>												
<i>Arceuthobium oxycedri</i>	1	5										
<i>Polygonum bistorta</i> type	1					2						
<i>Polygonum aviculare</i> type	51	4			1	1	2	1		4	1	
<i>Bilderdykia</i>				1								
<i>Rumex acetosella</i> group												
<i>Rumex acetosa</i> group	9	10	4	10	11	14	6	9	3	5	2	5
<i>Rumex crispus</i> p.p.												
<i>Rumex obtusifolius</i> group												
<i>Rumex bucephalophorus</i> group												
Chenopodiaceae type	7	2	1		3	17	1	1	1	2	2	2
<i>Montia fontana</i>												
<i>Spergula</i>		1										
<i>Herniaria</i> type	8		1					1				
<i>Paronychia</i> type												
<i>Dianthus</i> type	5	4		1	3	4	1	1				1
<i>Lychnis flos-cuculi</i>		3				1						
<i>Stellaria holostea</i>	4	1										
<i>Nymphaea alba</i>												
<i>Nigella</i>						2						
<i>Trollius europaeus</i>												
<i>Actaea spicata</i>	2	1			3							
<i>Adonis</i>	2											
<i>Caltha</i> type	2	5			11	6	2		1	4		
<i>Ranunculus acris</i> group												
<i>Ranunculus aquatilis</i> group	4	4		3								
<i>Anemone nemorosa</i> group	7	7	2	3	9	4		3	2	3	2	6
<i>Thalictrum aquilegifolium</i>	8	6			3	5	3	1	3	2		3
<i>Thalictrum minus</i>				1								
<i>Thalictrum lucidum</i>	2										1	
<i>Papaver rhoeas</i> type	3											
<i>Papaver argemone</i> type												

Gomara

Depth (cm)	0-1	25-26	30-31	35-36	40-41	45-46	50-51	55-56	60-61	65-66	70-71	75-76
Hole number	1	1	1	1	1	1	1	1	1	1	1	2
<i>Hornungia</i> type		1			2	2	18	3	1	1		
<i>Arabis</i>	1						2		2	1		1
<i>Sinapis</i> type	12	3						1			1	1
<i>Sedum</i>												
<i>Chrysosplenium alternifolium</i>	4		1		4		1					
<i>Saxifraga stellaris</i>					2	1				1		
<i>Saxifraga oppositifolia</i> type					1							
<i>Platanus orientalis</i>	4	1			1							
<i>Filipendula</i>	2											
<i>Rubus</i> type	1											1
<i>Sorbus</i> type	1				1							
<i>Rosa</i>				1								
<i>Crataegus</i>	1									1		
<i>Sanguisorba minor</i>	1											
<i>Geum</i>												
<i>Potentilla</i>	3	1										
<i>Ononis</i> type	2											
<i>Trifolium dubium</i> type			1								1	
<i>Trifolium repens</i> type												
<i>Lotus</i> type	3	1		1	1	2						
<i>Vicia cracca</i> type	2					1				1		
<i>Astragalus</i>												
<i>Galega officinalis</i>	1											
<i>Medicago sativa</i>												
<i>Dorycnium</i>		1										
<i>Trifolium montanum</i> type												
<i>Lathyrus sativus</i>												
<i>Geranium</i>												
<i>Linum austriacum</i> type												
<i>Mercurialis perennis</i>												
<i>Euphorbia</i>	1											
<i>Dictamnus albus</i>												
<i>Rhus coriaria</i>												
<i>Pistacia</i>												
<i>Acer</i>	2	2								1		
<i>Ilex aquifolium</i>												
<i>Buxus sempervirens</i>												
<i>Rhamnus</i> type												
<i>Tilia cordata</i> type						1			2			
<i>Daphne</i>												
<i>Hypericum perforatum</i> type												
<i>Viola hirta</i> type												
<i>Viola riviniana</i> type												
<i>Viola arvensis</i> type												
<i>Helianthemum</i>					1				1			
<i>Tamarix</i>	3	2	2		2	7				1	1	1
<i>Elatine alsinastrum</i>								1				
<i>Lythrum salicaria</i> type												
<i>Myrtus communis</i>	1	1										
<i>Circaea lutetiana</i>												
<i>Myriophyllum verticillatum</i>							2					
<i>Myriophyllum spicatum</i>						6						
<i>Cornus sanguinea</i>										1		
<i>Cornus mas</i>		1										
<i>Hedera helix</i>												
<i>Hydrocotyle vulgaris</i>	3		1			1	1					3
<i>Ligusticum</i>												
<i>Bupleurum</i>												
<i>Sison anomum</i>				1								
<i>Berula erecta</i>												
<i>Trinia</i>	3											1
<i>Seseli</i> type	2			1								
<i>Oenanthe fistulosa</i>					3							
<i>Chaerophyllum hirsutum</i> type		2					2					
<i>Chaerophyllum temulentum</i> type												
<i>Amni</i>	2	1	1							1		
<i>Pimpinella saxifraga</i>	2				2							
<i>Anethum graveolens</i>												
<i>Falcaria vulgaris</i>						1						
<i>Peucedanum austriacum</i> type		1										

Gomara

Depth (cm)	0-1	25-26	30-31	35-36	40-41	45-46	50-51	55-56	60-61	65-66	70-71	75-76
Hole number	1	1	1	1	1	1	1	1	1	1	1	2
<i>Angelica sylvestris</i>												
<i>Peucedanum schottii</i>			3									
<i>Bunium</i>												
<i>Foeniculum vulgare</i> ssp. <i>vulgare</i>		1			2	2						
<i>Anthriscus sylvestris</i> type								3				
<i>Pastinaca sativa</i>										4		
<i>Eryngium</i>	1											
<i>Anthriscus cerefolium</i>						1						
<i>Torilis japonica</i> type	1											4
<i>Daucus</i>												
<i>Coriandrum</i> type											1	
<i>Vaccinium myrtillus</i>	3		3		1	2		1		1		
<i>Soldanella</i>	3	1			3	4						
<i>Primula</i>												
<i>Anagallis arvensis</i> type												
<i>Anagallis tenella</i> type												
<i>Samolus valerandi</i>	1											
<i>Anmeria maritima</i> type						1						
<i>Fraxinus excelsior</i> type	1											
<i>Fraxinus angustifolia</i>		4	3				1					
<i>Fraxinus ornus</i>	3	5	3	5	9	3	6	5	3	1	2	4
<i>Phillyrea</i>												
<i>Centaureum</i>												
<i>Gentiana lutea</i> type	1											
<i>Calystegia</i>												
<i>Cynoglossum</i> type												
<i>Heliotropium</i>												
<i>Lappula</i>												
<i>Echium</i>						1				1		
<i>Alkanna</i> type						2						
<i>Buglossoides arvensis</i> type				1								
<i>Anchusa arvensis</i> type												
<i>Nonea</i>												
<i>Teucrium</i>												
<i>Stachys angustifolia</i>												
<i>Scutellaria</i> type												
<i>Prunella</i> type	1								1			
<i>Mentha</i> type	3				1				1	1		
<i>Solanum dulcamara</i>	4	2	1		1	1	1	3		1		3
<i>Solanum nigrum</i> type	2				1	2		2	1			1
<i>Scrophularia</i> type					4	3	1		1		1	2
<i>Gratiola officinalis</i>		1										
<i>Rhinanthus</i> type					7							
<i>Veronica anagallis-aquatica</i> type												
<i>Veronica triphyllos</i> type						1						
<i>Pedicularis</i>	2											
<i>Crucianella</i>												
<i>Galium</i> type	4	1	5	3	4	11	2	2	1	3		1
<i>Plantago major</i>	5	5				3						
<i>Plantago afra</i>	5	2			1	1		1				
<i>Plantago alpina</i> type	9	1										
<i>Plantago lanceolata</i> type	28	11	2	1	2	14	4	10	2	2	4	2
<i>Plantago coronopus</i>	12	5				1						
<i>Plantago bellardii</i>	3	1										
<i>Plantago media</i>	2	1			1	1	1		1			
<i>Plantago arenaria</i>												
<i>Plantago argentea</i>	4	4				4		1				1
<i>Plantago albicans</i>	6	1				1						
<i>Plantago amplexicaulis</i>	1	1										
<i>Plantago atrata</i>												
<i>Sambucus nigra</i>										1		
<i>Valeriana tuberosa</i>												
<i>Valeriana officinalis</i> type												
<i>Jasione</i>		2			1	4						2
<i>Campanula erinus</i> type	2											
<i>Solidago</i> type	3	1	1		3	5		1	3	1		1
<i>Echinops</i>					1							
<i>Artemisia</i>	6	5	3	5	6	7	6	3	6	5	1	3
<i>Carlina</i> type			1									
<i>Achillea</i> type	2	1		1		2	2		1	3	1	

Gomara

Depth (cm)

Hole number

	0-1	25-26	30-31	35-36	40-41	45-46	50-51	55-56	60-61	65-66	70-71	75-76
	1	1	1	1	1	1	1	1	1	1	1	2
<i>Centaurea napulifera</i> type											1	
<i>Cirsium</i> type	10			1								
<i>Centaurea solstitialis</i> type	16	6	1		3	2	1		1	1		3
<i>Centaurea graeca</i> type												
<i>Lactuca</i> type					3	1						
<i>Hieracium</i> type	17	3				8	1	3	1		1	1
<i>Taraxacum</i> type	1											
MONOCOTYLEDONES												
<i>Sagittaria sagittifolia</i>												
<i>Potamogeton crispus</i> type												1
<i>Potamogeton pectinatus</i>			1									
<i>Veratrum</i>												
<i>Asphodelus albus</i>					1							
<i>Fritillaria</i>												
<i>Gagea pratensis</i>		1										
<i>Lilium</i>		1										
<i>Scilla</i> type												
<i>Asparagus</i>												
<i>Sternbergia</i>												
<i>Festuca</i> type	32	20	16		20	17	5	1	5	4	2	15
<i>Glyceria</i> type	80	83	7	10	39	67	16	23	4	6	4	11
<i>Dactylis</i> type	104	51	8	11	17	58	17		16	16	8	4
<i>Agropyron</i> type	26											
<i>Secale cereale</i>	2	4		2	7	9	3	10	2	2		4
<i>Avena/Triticum</i> type	3	1			1	1			1			
<i>Phragmites australis</i>	48	44	11		4	11	6	30	2	11	5	19
<i>Zea mays</i>	1											
<i>Dracunculus</i> type												
Lemnaceae												
<i>Sparganium erectum</i>		1		1		1		1	3		1	
<i>Sparganium angustifolium</i>												
<i>Typha angustifolia</i> type		1	1									
<i>Typha domingensis</i> type										2		
<i>Cladium mariscus</i>												
<i>Cyperus michelianus</i>	134	165	73	73	74	212	136	183	109	88	48	21
<i>Cyperus longus</i> type	16	25	2	49	42	47	43		16	6	16	10
<i>Carex hallerana</i> type	106	145	95	68	152	277	334	231	189	115	72	38
<i>Carex flacca</i> type	11	3	45		103	125	101	75	155	89	57	26
<i>Cephalanthera</i>												
PTERIDOPHYTA												
<i>Ophioglossum vulgatum</i>												
<i>Botrychium</i>												1
<i>Adiantum capillus-veneris</i>												
<i>Pteridium aquilinum</i>	21	32	1	6	8	3	8	1	1	2		4
<i>Asplenium</i> type												
<i>Athyrium distentifolium</i>												
<i>Blechnum spicant</i>							1					1
<i>Polypodium</i>												
<i>Salvinia natans</i>												
Unidentified monolete spores												
Unidentified trilete spores				1								
TOTALS												
Indeterminate	22	15	24	10	12	12	4	39	9	6	4	18
Unknown		2			1							
Number of terrestrial types	84	80	36	31	55	64	37	39	41	39	29	42
Total wetland pollen & spores	416	481	236	204	435	755	642	544	480	323	203	129
Total terrestrial trees & shrubs	1144	738	461	460	1079	491	515	608	377	493	262	927
Total terrestrial pollen & spores	1631	962	529	513	1221	730	604	680	437	558	292	1010
Total pollen & spores	2069	1460	789	727	1669	1497	1250	1263	926	887	499	1157
CHARCOAL												
Charcoal <25 um2	3161	5995	2071	654	4033	1090	218	436	109	545	327	545
Charcoal 25-50 um2	1417	3161	3597	872	3379	327		981	436	327	327	109
Charcoal 50-100 um2	1308	2507	2180	654	2834	218		327	545	109	109	218
Charcoal 100-200 um2	436	1199	1635	218	1199	218		109	218	218	218	
Charcoal 200-400 um2	218	327	218	109	218			109		218		109
Charcoal >400 um2	109	436	327	109	109				109	109		

Gomara

Depth (cm)

Hole number

80-81 85-86 90-91 95-96 100-101 105-106 107-108 110-111 115-116 120-121 125-126 131-132

Absolute counts data

Slide numbers	1	1	1	1	1	1	1-3	1	1&2	1&2	1&2	1
Dilution factor	25	25	25	25	25	25	250	250	250	250	250	25
Aliquot size (ul)	400	200	100	200	200	200	1200	400	800	800	800	200
Sample weight (g) (wet)	1.043	1.041	1.077	1.068	1.078	1.115	1.397	1.1	1.08	1.086	1.085	1.12
Sample fraction counted	0.016	0.008	0.004	0.008	0.008	0.008	0.0048	0.0016	0.0032	0.0032	0.0032	0.008
<i>Lycopodium</i> suspension added (ml)	1	1	2	1	1	1	2	2	2	2	2	1
<i>Lycopodium</i> count	1581	1036	1089	904	896	758	794	266	534	584	557	889

GYMNOSPERMAE

<i>Abies</i>	43	29	15	36	36	29	8	5	9	15	23	18
<i>Picea abies</i>										1		
<i>Pinus</i> subgenus <i>Diploxylon</i>	650	322	442	382	359	299	96	122	176	226	218	335
<i>Pinus</i> subgenus <i>Haploxylon</i>	1			3	2							
<i>Juniperus</i>	1	1	2	5	5	2	1			1	5	7
<i>Taxus baccata</i>		3	1		2							
<i>Ephedra fragilis</i>		1							1			

DICOTYLEDONES

<i>Salix triandra</i>	2						1	1		1		2
<i>Populus</i>												
<i>Juglans regia</i>		1	1		5	1		1		1		1
<i>Alnus glutinosa</i>	11	2	2	5	2	5	3	5	3	6	6	6
<i>Betula pendula</i>										2		
<i>Carpinus</i> type	14	5	6	6	7	10	6	5	5	4	4	4
<i>Ostrya</i> type	45	30	58	49	29	40	25	22	37	29	22	48
<i>Corylus</i>	8	3	6	2	1	6	5	4	6	7	7	4
<i>Fagus</i>	551	249	257	243	241	134	51	65	89	115	93	141
<i>Castanea sativa</i>												
<i>Quercus coccifera</i> type	2	6	5	4	5	3	1			5	1	1
<i>Quercus trojana</i> type	18	22	1	22	20	16	4	6	4	8	4	15
<i>Quercus frainetto</i> type	63	41	3	53	58	63	14	30	36	44	49	66
<i>Ulmus glabra</i> type	1	1			5	3	8	3	2	1	2	
<i>Celtis</i>		1	1									
<i>Urtica dioica</i>		1	3		6	2	38			1	1	1
<i>Urtica urens</i> type	1	1		1	3	6	23	2	2			8
<i>Urtica pilulifera</i> type	1	1	3		1	1	1	1				
<i>Parietaria</i>			1		3	3	13					
<i>Viscum album</i>		1				2	1					
<i>Arceuthobium oxycedri</i>												
<i>Polygonum bistorta</i> type	1						1					
<i>Polygonum aviculare</i> type					2		3		1	1		
<i>Bilderdykia</i>												1
<i>Rumex acetosella</i> group									1			
<i>Rumex acetosa</i> group	18	6	1	12	11	10	58	8	14	8	6	13
<i>Rumex crispus</i> p.p.												
<i>Rumex obtusifolius</i> group												2
<i>Rumex bucephalophorus</i> group							1					
Chenopodiaceae type	3	1	2	1	2	2	8			4	3	1
<i>Montia fontana</i>												
<i>Spergula</i>												
<i>Herniaria</i> type							5					
<i>Paronychia</i> type			3			1						
<i>Dianthus</i> type		1			1	2	6			1		6
<i>Lychnis flos-cuculi</i>												
<i>Stellaria holostea</i>				2		1	3					
<i>Nymphaea alba</i>												
<i>Nigella</i>							1					
<i>Trollius europaeus</i>												
<i>Actaea spicata</i>	1	1		4	1		1	1	2	2		
<i>Adonis</i>												
<i>Caltha</i> type	6	3	28		2		4		2	4	10	
<i>Ranunculus acris</i> group						1						3
<i>Ranunculus aquatilis</i> group												
<i>Anemone nemorosa</i> group	7	4	18	2	6	9	5	2	1	3	2	11
<i>Thalictrum aquilegifolium</i>	7	2	2	4	3		4	4	2	2		
<i>Thalictrum minus</i>				1	1							
<i>Thalictrum lucidum</i>												
<i>Papaver rhoeas</i> type												
<i>Papaver argemone</i> type												

Gomara

Depth (cm)

Hole number

	80-81	85-86	90-91	95-96	100-101	105-106	107-108	110-111	115-116	120-121	125-126	131-132
	2	2	2	2	2	2	2	2	2	2	2	2
<i>Hornungia</i> type			4	1		1	4		2		2	2
<i>Arabis</i>	4	2	8	2	6			3				4
<i>Sinapis</i> type			2		1	1	2	1	1	5	1	2
<i>Sedum</i>												
<i>Chrysosplenium alternifolium</i>		1				1	1		1		3	
<i>Saxifraga stellaris</i>				1			5					
<i>Saxifraga oppositifolia</i> type												
<i>Platanus orientalis</i>	1						3					1
<i>Filipendula</i>		1										
<i>Rubus</i> type												
<i>Sorbus</i> type				1								
<i>Rosa</i>										1		
<i>Crataegus</i>												
<i>Sanguisorba minor</i>						1	2			1	1	
<i>Geum</i>							1					
<i>Potentilla</i>							7					
<i>Ononis</i> type							1					
<i>Trifolium dubium</i> type							4					
<i>Trifolium repens</i> type							1					
<i>Lotus</i> type	1						19					1
<i>Vicia cracca</i> type		1					9					
<i>Astragalus</i>							1					
<i>Galega officinalis</i>							2					
<i>Medicago sativa</i>							22					
<i>Dorycnium</i>												
<i>Trifolium montanum</i> type							1					
<i>Lathyrus sativus</i>							1					
<i>Geranium</i>												
<i>Linum austriacum</i> type												
<i>Mercurialis perennis</i>												
<i>Euphorbia</i>												
<i>Dictamnus albus</i>												
<i>Rhus coriaria</i>											1	
<i>Pistacia</i>	1					2						
<i>Acer</i>		1			1							
<i>Ilex aquifolium</i>	1											
<i>Buxus sempervirens</i>				1								
<i>Rhamnus</i> type												1
<i>Tilia cordata</i> type					1	1						
<i>Daphne</i>			1									
<i>Hypericum perforatum</i> type												
<i>Viola hirta</i> type											1	
<i>Viola riviniana</i> type												
<i>Viola arvensis</i> type							1					
<i>Helianthemum</i>			1	1			8				1	
<i>Tamarix</i>	1	3				2	13	1	1	1	1	3
<i>Elatine alsinastrum</i>												
<i>Lythrum salicaria</i> type												
<i>Myrtus communis</i>												
<i>Circaea lutetiana</i>			3									
<i>Myriophyllum verticillatum</i>												
<i>Myriophyllum spicatum</i>												
<i>Cornus sanguinea</i>												
<i>Cornus mas</i>			1									
<i>Hedera helix</i>												
<i>Hydrocotyle vulgaris</i>						7						
<i>Ligusticum</i>												
<i>Bupleurum</i>				2								
<i>Sison animum</i>	1											
<i>Berula erecta</i>							2					
<i>Trinia</i>												
<i>Seseli</i> type												
<i>Oenanthe fistulosa</i>												
<i>Chaerophyllum hirsutum</i> type												
<i>Chaerophyllum temulentum</i> type	1						1					
<i>Ammi</i>					2		4				1	
<i>Pimpinella saxifraga</i>									1			
<i>Anethum graveolens</i>											1	
<i>Falcaria vulgaris</i>												
<i>Peucedanum austriacum</i> type												

Gomara

Depth (cm)

Hole number

	80-81	85-86	90-91	95-96	100-101	105-106	107-108	110-111	115-116	120-121	125-126	131-132
	2	2	2	2	2	2	2	2	2	2	2	2
<i>Angelica sylvestris</i>												
<i>Peucedanum schottii</i>												
<i>Bunium</i>		1										
<i>Foeniculum vulgare</i> ssp. <i>vulgare</i>							1	2				
<i>Anthriscus sylvestris</i> type							1					
<i>Pastinaca sativa</i>												
<i>Eryngium</i>							1					
<i>Anthriscus cerefolium</i>					2		6					
<i>Torilis japonica</i> type							5			1		
<i>Daucus</i>						2			1			5
<i>Coriandrum</i> type												
<i>Vaccinium myrtillus</i>		3	4	2						1		2
<i>Soldanella</i>												
<i>Primula</i>							2					
<i>Anagallis arvensis</i> type												
<i>Anagallis tenella</i> type												
<i>Samolus valerandi</i>			1			1						
<i>Ammeria maritima</i> type												
<i>Fraxinus excelsior</i> type							1			1	1	
<i>Fraxinus angustifolia</i>												
<i>Fraxinus ornus</i>	9	6		3	7	1	6		5	6	3	
<i>Phillyrea</i>							1					
<i>Centaureum</i>												
<i>Gentiana lutea</i> type												
<i>Calystegia</i>												
<i>Cynoglossum</i> type					1		1					
<i>Heliotropium</i>												
<i>Lappula</i>	1											
<i>Echium</i>												
<i>Alkanna</i> type					1		5					2
<i>Buglossoides arvensis</i> type												
<i>Anchusa arvensis</i> type												
<i>Nonea</i>												
<i>Teucrium</i>												
<i>Stachys angustifolia</i>					1		8					
<i>Scutellaria</i> type												
<i>Prunella</i> type				1			2					
<i>Mentha</i> type							9				1	
<i>Solanum dulcamara</i>				2	1		17			4	1	1
<i>Solanum nigrum</i> type	1						2					
<i>Scrophularia</i> type						1	1					
<i>Gratiola officinalis</i>												
<i>Rhinanthus</i> type												
<i>Veronica anagallis-aquatica</i> type												
<i>Veronica triphyllos</i> type							1					
<i>Pedicularis</i>												
<i>Crucianella</i>							1					
<i>Galium</i> type		1			2		15	2		3	3	1
<i>Plantago major</i>							1				1	1
<i>Plantago afra</i>	2	1		2			8					1
<i>Plantago alpina</i> type			4				1			2		
<i>Plantago lanceolata</i> type	3	9		7	5	4	16	1	2	3	2	3
<i>Plantago coronopus</i>			1				23			3	2	2
<i>Plantago bellardii</i>				1							1	
<i>Plantago media</i>	2						9					1
<i>Plantago arenaria</i>							2					
<i>Plantago argentea</i>	1					1	12					
<i>Plantago albicans</i>	1	1					2					1
<i>Plantago amplexicaulis</i>							5					
<i>Plantago atrata</i>												
<i>Sambucus nigra</i>												
<i>Valeriana tuberosa</i>							1					
<i>Valeriana officinalis</i> type												
<i>Jasione</i>							11	1			1	1
<i>Campanula erinus</i> type							3					
<i>Solidago</i> type			1	5	1		3	2	1		1	1
<i>Echinops</i>												
<i>Artemisia</i>	3	1	2	3	2	2			1	1	1	3
<i>Carlina</i> type	1											
<i>Achillea</i> type	1	2	1	2				1	1			1

Depth (cm)
Hole number

XIII-9

Gomara

Depth (cm)

Hole number

135-136 140-141 145-146 150-151 155-156 160-161 165-166 170-171 175-176 180-181 185-186 189-190
2 2 2 2 2 2 2 2 2 2 2 2

Absolute counts data

Slide numbers	1&2	1&2	1	1&2	2	1	1	1	1	1	1	1&2
Dilution factor	250	250	25	250	250	250	25	250	250	250	25	
Aliquot size (ul)	800	800	200	800	400	400	200	400	400	400	200	
Sample weight (g) (wet)	1.108	1.171	1.188	1.132	1.146	1.28	1.625	1.526	1.536	1.461	1.309	1.126
Sample fraction counted	0.0032	0.0032	0.008	0.0032	0.0016	0.0016	0.008	0.0016	0.0016	0.0016	0.008	0.0088
<i>Lycopodium</i> suspension added (ml)	2	2	2	2	2	2	2	6	6	6	4	4
<i>Lycopodium</i> count	512	510	1222	501	258	281	1202	934	917	903	2199	2751

GYMNOSPERMAE

<i>Abies</i>	11	12	16	5	2	5	60	11	20	17	36	20
<i>Picea abies</i>			1	1			21	13	14	10	14	1
<i>Pinus</i> subgenus <i>Diploxylon</i>	148	159	328	122	109	166	1232	337	443	355	769	594
<i>Pinus</i> subgenus <i>Haploxylon</i>						1		2				
<i>Juniperus</i>	2	2	5				1				5	10
<i>Taxus baccata</i>								2	4		1	
<i>Ephedra fragilis</i>	1									1	1	

DICOTYLEDONES

<i>Salix triandra</i>		1	3				2				1	
<i>Populus</i>					1	2		1			14	
<i>Juglans regia</i>												
<i>Alnus glutinosa</i>	3	3	14	4	1	7	11	5	4	4	23	13
<i>Betula pendula</i>	27	2	53	36	2	5	2	3	2	1	14	28
<i>Carpinus</i> type	2	4	9	1	7	1	6	4	4	3	15	16
<i>Ostrya</i> type	41	35	83	44	17	26	99	19	25	19	105	116
<i>Corylus</i>	4	1	23	2	5	4	48	11	24	10	21	13
<i>Fagus</i>	74	32	72	28	53	15	28	8	9	14	61	107
<i>Castanea sativa</i>			1						2			
<i>Quercus coccifera</i> type	1		1	1			4	3	4	4	4	1
<i>Quercus trojana</i> type	12	13	53	10	15	9	133	17	22	22	33	27
<i>Quercus frainetto</i> type	55	36	69	32	25	53	282	71	68	83	137	135
<i>Ulmus glabra</i> type	2	1			2	1	11		9		4	2
<i>Celtis</i>												
<i>Urtica dioica</i>	2	4	1	3	2	2	20	8	14	15	9	2
<i>Urtica urens</i> type	1	2	15	9	1	4	32	12	8	13	3	1
<i>Urtica pilulifera</i> type	1		6			1	6	1	3	7	1	
<i>Parietaria</i>	2										13	
<i>Viscum album</i>			1				2					
<i>Arceuthobium oxycedri</i>											3	1
<i>Polygonum bistorta</i> type												
<i>Polygonum aviculare</i> type									2	1	5	6
<i>Bilderdykia</i>												
<i>Rumex acetosella</i> group												
<i>Rumex acetosa</i> group	13	10	42	8	12	20	25	16	5	7	55	46
<i>Rumex crispus</i> p.p.			1									
<i>Rumex obtusifolius</i> group												
<i>Rumex bucephalophorus</i> group									1			
<i>Chenopodiaceae</i> type	3	8	3	3	1	8	7		4	9	15	9
<i>Montia fontana</i>							1					
<i>Spergula</i>												
<i>Herniaria</i> type	2		1					5	5	1		1
<i>Paronychia</i> type												
<i>Dianthus</i> type	1		1		3	2	2	2			1	
<i>Lychnis flos-cuculi</i>										1		
<i>Stellaria holostea</i>							1				2	
<i>Nymphaea alba</i>											1	
<i>Nigella</i>											1	
<i>Trollius europaeus</i>											1	
<i>Actaea spicata</i>		1									3	2
<i>Adonis</i>												
<i>Caltha</i> type												3
<i>Ranunculus acris</i> group	1		1		3							
<i>Ranunculus aquatilis</i> group											5	4
<i>Anemone nemorosa</i> group	4		7	1			2	1	1	1	8	12
<i>Thalictrum aquilegifolium</i>	1		3		1			1	1		3	7
<i>Thalictrum minus</i>							2					1
<i>Thalictrum lucidum</i>												
<i>Papaver rhoeas</i> type					1							
<i>Papaver argemone</i> type												1

Gomara

Depth (cm)

Hole number

	135-136	140-141	145-146	150-151	155-156	160-161	165-166	170-171	175-176	180-181	185-186	189-190
	2	2	2	2	2	2	2	2	2	2	2	2
<i>Hornungia</i> type			1		1		4	4		1		4
<i>Arabis</i>						3	2			1	2	1
<i>Sinapis</i> type	3	1										2
<i>Sedum</i>												1
<i>Chrysosplenium alternifolium</i>		2								1		
<i>Saxifraga stellaris</i>			1			1	4			1	9	
<i>Saxifraga oppositifolia</i> type												
<i>Platanus orientalis</i>		1								1		
<i>Filipendula</i>			1									1
<i>Rubus</i> type												
<i>Sorbus</i> type										3		
<i>Rosa</i>												
<i>Crataegus</i>	1	1										1
<i>Sanguisorba minor</i>	1	1	7	1				1			1	3
<i>Geum</i>								1				
<i>Potentilla</i>											1	
<i>Ononis</i> type												
<i>Trifolium dubium</i> type												
<i>Trifolium repens</i> type												
<i>Lotus</i> type	1				1				1			
<i>Vicia cracca</i> type												
<i>Astragalus</i>							1					
<i>Galega officinalis</i>												
<i>Medicago sativa</i>												
<i>Dorycnium</i>												
<i>Trifolium montanum</i> type	1											
<i>Lathyrus sativus</i>												
<i>Geranium</i>						1						
<i>Linum austriacum</i> type											1	
<i>Mercurialis perennis</i>											1	
<i>Euphorbia</i>												
<i>Dictamnus albus</i>												1
<i>Rhus coriaria</i>												
<i>Pistacia</i>			1									
<i>Acer</i>												
<i>Ilex aquifolium</i>												2
<i>Buxus sempervirens</i>		1					3	1		1		4
<i>Rhamnus</i> type				1							1	
<i>Tilia cordata</i> type							5	3		2	3	3
<i>Daphne</i>												
<i>Hypericum perforatum</i> type							1				1	
<i>Viola hirta</i> type												
<i>Viola riviniana</i> type											1	
<i>Viola arvensis</i> type												
<i>Helianthemum</i>		2					1				1	3
<i>Tamarix</i>	1	3		1	4	1	16	5	1	4	2	6
<i>Elatine alsinastrum</i>												
<i>Lythrum salicaria</i> type			1									
<i>Myrtus communis</i>											2	
<i>Circaea lutetiana</i>												
<i>Myriophyllum verticillatum</i>												
<i>Myriophyllum spicatum</i>												
<i>Cornus sanguinea</i>											1	
<i>Cornus mas</i>												
<i>Hedera helix</i>											1	
<i>Hydrocotyle vulgaris</i>	1	1					5			1		
<i>Ligusticum</i>									1			
<i>Bupleurum</i>							2					
<i>Sison anomum</i>	1											
<i>Berula erecta</i>												
<i>Trinia</i>											7	2
<i>Seseli</i> type												
<i>Oenanthe fistulosa</i>												
<i>Chaerophyllum hirsutum</i> type					1			4	4	2		
<i>Chaerophyllum temulentum</i> type												
<i>Ammi</i>												
<i>Pimpinella saxifraga</i>	2				1		1					
<i>Anethum graveolens</i>		1										
<i>Falcaria vulgaris</i>												
<i>Peucedanum austriacum</i> type												

Gomara

Depth (cm)

Hole number

	135-136	140-141	145-146	150-151	155-156	160-161	165-166	170-171	175-176	180-181	185-186	189-190
	2	2	2	2	2	2	2	2	2	2	2	2
<i>Angelica sylvestris</i>											4	
<i>Peucedanum schottii</i>												
<i>Bunium</i>												
<i>Foeniculum vulgare</i> ssp. <i>vulgare</i>												
<i>Anthriscus sylvestris</i> type				1								1
<i>Pastinaca sativa</i>	1										1	
<i>Eryngium</i>												1
<i>Anthriscus cerefolium</i>												1
<i>Torilis japonica</i> type							2				1	1
<i>Daucus</i>			1									
<i>Coriandrum</i> type			1									
<i>Vaccinium myrtillus</i>	1	1	5	1	2		5	1		2	2	4
<i>Soldanella</i>												
<i>Primula</i>												1
<i>Anagallis arvensis</i> type							1					
<i>Anagallis tenella</i> type						1						
<i>Samolus valerandi</i>		1	1									1
<i>Ammeria maritima</i> type										1		
<i>Fraxinus excelsior</i> type	3	1	1			1	1	10		1	5	3
<i>Fraxinus angustifolia</i>											8	8
<i>Fraxinus ornus</i>	2	3	5		3	2	4	1	1		6	7
<i>Phillyrea</i>												
<i>Centaurium</i>											2	
<i>Gentiana lutea</i> type												
<i>Calystegia</i>										1		
<i>Cynoglossum</i> type									2			
<i>Heliotropium</i>							1					
<i>Lappula</i>												
<i>Echium</i>												
<i>Alkanna</i> type							1	1				
<i>Buglossoides arvensis</i> type												1
<i>Anchusa arvensis</i> type											1	
<i>Nonea</i>							1					
<i>Teucrium</i>											1	
<i>Stachys angustifolia</i>												
<i>Scutellaria</i> type								1			2	
<i>Prunella</i> type												
<i>Mentha</i> type					1		4	1	1	2	6	2
<i>Solanum dulcamara</i>	1	2	2			2	6					3
<i>Solanum nigrum</i> type									1			
<i>Scrophularia</i> type			4				8					
<i>Gratiola officinalis</i>												
<i>Rhinanthus</i> type												
<i>Veronica anagallis-aquatica</i> type	1											
<i>Veronica triphyllos</i> type												
<i>Pedicularis</i>						1	1	1	2	1	4	
<i>Crucianella</i>												
<i>Galium</i> type	6	2	2		1	3	7	1	1	5	11	5
<i>Plantago major</i>	2				2		2		3		2	
<i>Plantago afra</i>		1					1					1
<i>Plantago alpina</i> type											3	1
<i>Plantago lanceolata</i> type	1	3	13	5	4	2	14	4	7	6	4	2
<i>Plantago coronopus</i>	1	3			1					1	6	1
<i>Plantago bellardii</i>											1	
<i>Plantago media</i>			1					1		3		
<i>Plantago arenaria</i>										1	1	
<i>Plantago argentea</i>				1							2	1
<i>Plantago albicans</i>			1		1		1				2	2
<i>Plantago amplexicaulis</i>												
<i>Plantago atrata</i>		1									1	
<i>Sambucus nigra</i>												
<i>Valeriana tuberosa</i>												
<i>Valeriana officinalis</i> type							1		1			
<i>Jasione</i>	1			1			2	1			1	2
<i>Campanula erinus</i> type			1								2	
<i>Solidago</i> type	6		9		1	2	16	2	9	2	6	3
<i>Echinops</i>												
<i>Artemisia</i>	5	1	12	4	5	1	2		1	1	1	4
<i>Carlina</i> type		4									1	
<i>Achillea</i> type		2				1	1				2	1

Anelia

Depth (cm)

Absolute counts data

	0-1	9-10	19-20	29-30	39-40	49-50	59-60	69-70	79-80	89-90	99-100	110-111	115-116
Slide numbers	1-11	1	1	1	1	1	1-4	1-3	1	1	1&2	1	1
Sample weight (g) (wet)	0.980	1.001	1.002	1.003	0.973	1.008	1.014	1.042	1.004	1.025	1.730	1.604	1.675
<i>Lycopodium</i> suspension added (ml)	2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
<i>Lycopodium</i> count	5726	1167	3172	2553	2273	2669	3545	924	1745	1253	2557	2257	1005

GYMNOSPERMAE

<i>Abies</i>	1	5	5	3	1	1	1	1	3	4	45	4	20
<i>Pinus</i> subgenus <i>Diploxylon</i>	50	172	274	190	142	258	190	172	216	180	331	204	187
<i>Juniperus</i>	2	16	62	19	33	38	25	52	4	13	3	17	6
<i>Taxus baccata</i>					1				2		1	2	
<i>Ephedra fragilis</i>					1	1	1			4		1	

DICOTYLEDONES

<i>Salix triandra</i>	1		1	2	8	2	3	2					
<i>Salix fragilis</i> type							1	1		1			
<i>Populus</i>			2				1						
<i>Juglans regia</i>	1				1		1		1				1
<i>Alnus glutinosa</i>	3	1	2					2	4	9	2	2	3
<i>Betula pendula</i>					1								
<i>Carpinus</i> type			2			1			1	4		1	3
<i>Ostrya</i> type	8	6	4	4	6	4	14	7	11	8	9	12	15
<i>Corylus</i>	2		1	1	2						1	1	
<i>Fagus</i>	39	166	120	56	40	50	45	44	57	74	40	61	66
<i>Castanea sativa</i>	1		3	2	9	6	23	10	2	6	1	2	
<i>Quercus coccifera</i> type	5					1			1				
<i>Quercus trojana</i> type	2		6	4	4	3	6	3	6	6		1	4
<i>Quercus frainetto</i> type	9	7	17	30	13	15	30	12	36	26	13	21	26
<i>Ulmus glabra</i> type							2		5	2	1		
<i>Humulus lupulus</i>							9						
<i>Urtica dioica</i>	1		1				10	9		1	1	3	6
<i>Urtica urens</i> type					2		2	1					
<i>Urtica pilulifera</i> type							2			1			
<i>Parietaria</i>													
<i>Viscum album</i>													
<i>Arceuthobium oxycedri</i>													
<i>Polygonum aviculare</i> type	1			1	1	2	3	1	1	1	1	1	
<i>Oxyria digyna</i>													
<i>Rumex acetosella</i> group		1	3	1		1	4	1		2		1	
<i>Rumex acetosa</i> group	4		4	2	13	4	28	9	3	3	3	4	5
Chenopodiaceae type	2	3	6	5	3	10	9	5	7	4	3	4	4
<i>Glinus</i> type													
<i>Spergula</i>													
<i>Spergularia</i> type								1					
<i>Herniaria</i> type			1			3	12	3	1		4		5
<i>Paronychia</i> type								1					
<i>Dianthus</i> type		1		1			21		1		1		
<i>Lychnis flos-cuculi</i>							7			2	1		
<i>Agrostemma githago</i>													
<i>Scleranthus perennis</i>						2	5						
<i>Scleranthus amius</i> type					2		4						
<i>Stellaria holostea</i>							1						
<i>Nuphar lutea</i>													
<i>Helleborus</i>	1												
<i>Nigella</i>			1				2						
<i>Actaea spicata</i>	1				1		2		1	2		3	2
<i>Caltha</i> type	1		8	3	4	6	11	3		2		6	7
<i>Ranunculus acris</i> group			2				1	1			1	1	
<i>Ranunculus aquatilis</i> group										2		1	
<i>Anemone nemorosa</i> group													
<i>Ranunculus arvensis</i> type										1			
<i>Thalictrum aquilegifolium</i>		2	7	1	6	12	5	12	4	5	2	6	
<i>Thalictrum minus</i>							3				2	1	
<i>Thalictrum lucidum</i>							1						
<i>Papaver argemone</i> type					1								
<i>Homungia</i> type	2	1	4		4	2	9	1	2	1	1	3	
<i>Arabis</i>			1	2		1	7		3	1	1		
<i>Sinapis</i> type	2	1	13	1	1	3	5	2	4	6	2	6	1
<i>Chrysosplenium alternifolium</i>													
<i>Saxifraga stellaris</i>			2	1	7	1	9			2		2	1

Anelia

Depth (cm)

	0-1	9-10	19-20	29-30	39-40	49-50	59-60	69-70	79-80	89-90	99-100	110-111	115-116
<i>Saxifraga oppositifolia</i> type					1								
<i>Parnassia palustris</i>	5												
<i>Platanus orientalis</i>	4	1	7	3	10	4	8		2	3	1	3	2
<i>Filipendula</i>					1		1						1
<i>Rubus</i> type					2								
<i>Sorbus</i> type			1								1		
<i>Rosa</i>						1							
<i>Sanguisorba minor</i>			2				29					2	
<i>Geum</i>			1										
<i>Potentilla</i>		1		1	2		7		1				1
<i>Hedysarum coronarium</i>													
<i>Ononis</i> type				1			4		2	3			
<i>Trifolium dubium</i> type			3			2	2					1	
<i>Trifolium repens</i> type			1										
<i>Lotus</i> type					1		13	3	3	17	3		
<i>Vicia cracca</i> type			1							3			1
<i>Galega officinalis</i>			1		4	1	9	2		5	1	7	1
<i>Ornithopus compressus</i>			1										
<i>Dorycnium</i>									1				
<i>Trifolium montanum</i> type													
<i>Linum austriacum</i> type													
<i>Linum catharticum</i>								2					
<i>Pistacia</i>										1			
<i>Acer</i>			1										
<i>Buxus sempervirens</i>								2					
<i>Frangula</i>					1	1	1						1
<i>Rhamnus</i> type							4						
<i>Vitis vinifera</i>													
<i>Tilia cordata</i> type											2	1	
<i>Daphne</i>								1					
<i>Hypericum perforatum</i> type					1								
<i>Viola hirta</i> type			1										
<i>Helianthemum</i>							10						
<i>Myricaria germanica</i>													
<i>Tamarix</i>		3	3	3	5	4	7	3	1	2	2	1	
<i>Elatine alsinastrum</i>					1	1							
<i>Circaea lutetiana</i>													
<i>Epilobium angustifolium</i> type							3	1					
<i>Myriophyllum spicatum</i>													1
<i>Cornus mas</i>													
<i>Hedera helix</i>							1						
<i>Hydrocotyle vulgaris</i>		1	1	2	2	1	17	2		1	2	1	
<i>Bupleurum</i>							1		1				
<i>Berula erecta</i>							1						
<i>Trinia</i>			1			2	1		1				
<i>Oenanthe aquatica</i> group							1						
<i>Oenanthe pimpinelloides</i> group								1					
<i>Chaerophyllum hirsutum</i> type					1				1				
<i>Chaerophyllum temulentum</i> type													
<i>Amni</i>							3		2				
<i>Pimpinella saxifraga</i>			1				1		2				
<i>Torilis arvensis</i>							1						
<i>Anethum graveolens</i>						1							
<i>Peucedanum austriacum</i> type													
<i>Angelica sylvestris</i>	1												
<i>Anthriscus sylvestris</i> type												1	
<i>Eryngium</i>													
<i>Scandix</i> type						1							
<i>Torilis japonica</i> type							3	2	5				
<i>Daucus</i>						1			4				
<i>Erica herbacea</i>			3	1				1					
<i>Vaccinium myrtillus</i>					1			1	2	1	1		2
<i>Cyclamen</i>													
<i>Androsace villosa</i>													
<i>Primula</i>													
<i>Lysimachia</i>													
<i>Anagallis tenella</i> type													
<i>Asterolinon linum-stellatum</i>													
<i>Samolus valerandi</i>					1		1						
<i>Fraxinus excelsior</i> type						1		4		1			1

Anelia

Depth (cm)

	0-1	9-10	19-20	29-30	39-40	49-50	59-60	69-70	79-80	89-90	99-100	110-111	115-116
<i>Fraxinus angustifolia</i>			1					1	1				
<i>Fraxinus ornus</i>			2		3	1	4	2		2	1	1	6
<i>Cynoglossum</i> type							1			3			
<i>Heliotropium</i>										1			
<i>Myosotis</i> type													
<i>Lappula</i>								1					
<i>Alkanna</i> type						1							
<i>Buglossoides arvensis</i> type								1					
<i>Anchusa arvensis</i> type													
<i>Teucrium</i>													
<i>Scutellaria</i> type							1						
<i>Mentha</i> type	3	1	2	1	3	1	10	2	4	3	1		3
<i>Solanum dulcamara</i>			1				6	3		1			
<i>Solanum nigrum</i> type	1			1			1						
<i>Scrophularia</i> type	1		2				2						
<i>Rhinanthus</i> type										1			
<i>Odontites</i> type										1			
<i>Veronica anagallis-aquatica</i> type													
<i>Pedicularis</i>													1
<i>Galium</i> type	3	1	5	3	6	12	13	1	5	2	3	2	4
<i>Plantago major</i>			3	9	14	16	66	1	1	5	1	3	4
<i>Plantago afra</i>							3						
<i>Plantago lanceolata</i> type	4		8	7	5	9	43	12	10	17	4	6	5
<i>Plantago coronopus</i>	1				4	1	24		2	3			
<i>Plantago bellardii</i>					1		1						
<i>Plantago media</i>			1	3		1	15	2					2
<i>Plantago arenaria</i>													
<i>Plantago argentea</i>					1		4	1		2			
<i>Plantago albicans</i>							1			1			
<i>Plantago atrata</i>					1								
<i>Sambucus nigra</i>			3		1								
<i>Viburnum</i>													
<i>Valeriana officinalis</i> type	1												
<i>Jasione</i>			1			1	15						2
<i>Campanula erinus</i> type							13						
<i>Campanula rotundifolia</i>													
<i>Solidago</i> type		3	4	9	5	14	106	10	5	19	4	5	6
<i>Echinops</i>									1				
<i>Artemisia</i>		2	2	1	3	2	7	4	1		1	1	7
<i>Carlina</i> type							2		2				1
<i>Achillea</i> type		1	2	1		5	3	1	1				1
<i>Centaurea cyanus</i> type					1	1	1						
<i>Centaurea napulifera</i> type										2			
<i>Cirsium</i> type			3	2	2		1		1	1	8	1	4
<i>Centaurea solstitialis</i> type					2		1	1	2		1	1	
<i>Centaurea graeca</i> type									2				
<i>Lactuca</i> type		1	3	2	1		3	2	1	3	3		
<i>Cichorium</i> type							3						
<i>Hieracium</i> type		1	7	12	13	54	72	10	24	20	17	6	10
<i>Taraxacum</i> type		1	2			2	5	1	1	2			2

MONOCOTYLEDONES

<i>Sagittaria sagittifolia</i>													
<i>Damasonium alisma</i>	1												
<i>Hydrocharis morsus-ranae</i>	1						2	2				1	
<i>Stratiotes aloides</i>								1		1		6	
<i>Vallisneria spiralis</i>					1								
<i>Potamogeton crispus</i> type						1							
<i>Narthecium scardicum</i>													
<i>Veratrum</i>							1				1		
<i>Anthericum liliago</i>													
<i>Scilla</i> type		1					1						
<i>Muscari comosum</i>													
<i>Muscari neglectum</i> type			2				13	2					
<i>Narcissus papyraceus</i> type							1						
<i>Sternbergia</i>							1						
<i>Iris pseudacorus</i>		1											
<i>Iris spuria</i> type							1						
<i>Gynandris sisyrinchium</i>											1		
<i>Festuca</i> type	2	4	12	9	12	28	57	9	34	23	8	12	27

Anelia

Depth (cm)

	0-1	9-10	19-20	29-30	39-40	49-50	59-60	69-70	79-80	89-90	99-100	110-111	115-116
<i>Glyceria</i> type	1	4	11	4	11	22	54	20	35	27	19	11	29
<i>Dactylis</i> type	9	6	4	10	27	20	106	10	12	8	3	2	23
<i>Agropyron</i> type									1	3			1
<i>Secale cereale</i>		1		4	2	2		2	3	5	6	1	2
<i>Hordeum</i> type										1			
<i>Avena/Triticum</i> type				1	3				1	6	6	1	3
<i>Phragmites australis</i>	3	3	7	11	27	104	521	4	9	5	2	6	25
<i>Sparganium erectum</i>		1	2	1	2							4	
<i>Sparganium angustifolium</i>								1	1				
<i>Typha angustifolia</i> type													
<i>Typha domingensis</i> type		1						1					
<i>Cyperus michelianus</i>	6		1	2	16	1	5	9					1
<i>Cyperus longus</i> type			8	7	7	3		2	2	3		3	2
<i>Carex hallerana</i> type	5	200	465	244	283	239	240	235	385	333	23	379	178
<i>Carex flacca</i> type	2							1					
<i>Cephalanthera</i>													

PTERIDOPHYTA

<i>Equisetum</i>									92				
<i>Ophioglossum vulgatum</i>													
<i>Botrychium</i>													1
<i>Adiantum capillus-veneris</i>													
<i>Pteridium aquilinum</i>	1	3	12	28	59	56	51	29	31	57	121	44	41
<i>Asplenium</i> type			2	2	2		1	5			14	4	2
<i>Athyrium filix-femina</i>													
<i>Athyrium distentifolium</i>					1								
<i>Dryopteris filix-mas</i> type										1			
<i>Blechnum spicant</i>	1	1	4	7	7		6	3		1	40	10	19
<i>Polypodium</i>		1				1					1		
<i>Salvinia natans</i>		1		1	1								

TOTALS

Indeterminate	5	7	17	6	23	12	75	26	25	15	10	10	10
Unknown					1								
Number of terrestrial types	32	30	60	41	58	51	90	55	60	59	49	45	46
Total wetland pollen & spores	29	213	510	277	371	381	892	290	528	387	50	428	249
Total trees & shrubs	128	377	520	318	285	392	367	320.3	355	346	455.3	335	343

Total terrestrial pollen & spores
(excluding bog & marsh plants,
aquatics, unknown & indeterminate)

	166	414	653	445	497	665	1240	483.3	546	586	722.3	470	536
Total pollen & spores	200	634	1180	728	892	1058	2207	799.3	1099	988	782.3	908	795

CHARCOAL

Charcoal <25 um ²	218	327	763	327	327	1417	1417	2943	327	436	8066	2507	5450
Charcoal 25-50 um ²	0	0	872	327	109	872	763	981	545	327	8502	981	2834
Charcoal 50-100 um ²	0	109	218	327	109	327	545	654	327	218	4687	1090	2180
Charcoal 100-200 um ²	0	109	218	109	0	109	218	109	436	327	1853	981	1090
Charcoal 200-400 um ²	0	0	0	0	109	0	0	218	0	0	654	545	327
Charcoal >400 um ²	0	0	0	0	0	109	109	0	0	109	1744	218	218

Anelia

Depth (cm)

120-121 125-126 130-131 135-136 140-141 145-146 150-151 154-155 160-161 165-166 170-171 175-176 180-181

Absolute counts data

Slide numbers	1	1	1	1	1	1	1&2	1	1	1-7	1	1-4	1
Sample weight (g) (wet)	1.329	1.170	1.254	1.553	1.593	1.520	1.647	1.410	1.910	1.567	1.642	2.045	1.777
<i>Lycopodium</i> suspension added (ml)	0.5	0.2	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	2	0.5
<i>Lycopodium</i> count	827	265	587	363	281	958	985	1096	5454	5328	1106	6510	1005

GYMNOSPERMAE

<i>Abies</i>	14	13	26	23	34	41	44	64	28	38	76	52	49
<i>Pinus</i> subgenus <i>Diploxylon</i>	279	238	177	250	191	200	248	232	92	169	270	175	157
<i>Juniperus</i>	12	9	4	8	15	12	3	12	3	7	6	6	6
<i>Taxus baccata</i>					1								
<i>Ephedra fragilis</i>			1						2				

DICOTYLEDONES

<i>Salix triandra</i>					1								
<i>Salix fragilis</i> type													
<i>Populus</i>													
<i>Juglans regia</i>	1		1			2	1	1	2		2		1
<i>Alnus glutinosa</i>	4					1	3	3	1	3	4	1	6
<i>Betula pendula</i>													
<i>Carpinus</i> type	1		1	1		1	4	1		1	1	2	1
<i>Ostrya</i> type	18	13	8	14	30	9	12	14	20	29	20	18	19
<i>Corylus</i>	1	3	2	2	2	1	7	2			3	1	4
<i>Fagus</i>	76	43	79	56	135	38	30	62	113	46	57	46	55
<i>Castanea sativa</i>		5			3	1		18	1				1
<i>Quercus coccifera</i> type	2	1			3	2					1		
<i>Quercus trojana</i> type	3	1	5	6	5	2	2	6	5	4		2	4
<i>Quercus frainetto</i> type	34	24	21	28	25	35	24	35	30	15	36	20	29
<i>Ulmus glabra</i> type							1		1	1		1	
<i>Humulus lupulus</i>													
<i>Urtica dioica</i>	4			5	2	2			1	2	19	5	5
<i>Urtica urens</i> type		3											1
<i>Urtica pilulifera</i> type													
<i>Parietaria</i>												1	
<i>Viscum album</i>	4												
<i>Arceuthobium oxycedri</i>								1		1	1		
<i>Polygonum aviculare</i> type		1	1		2	2	5	4	5	1		1	1
<i>Oxyria digyna</i>											1		
<i>Rumex acetosella</i> group						1		2		1	1		
<i>Rumex acetosa</i> group	3		3	8	2	10	8	8	5	7	15	5	6
<i>Chenopodiaceae</i> type	1		1	1	5	7		1			4		2
<i>Glinus</i> type			1										
<i>Spergula</i>							1						
<i>Spergularia</i> type				2		3	1						
<i>Herniaria</i> type	1			4	11		4	43	4	7	14		6
<i>Paronychia</i> type													
<i>Dianthus</i> type		2				1		1			1		
<i>Lychnis flos-cuculi</i>	1							1	1				
<i>Agrostemma githago</i>													1
<i>Scleranthus perennis</i>							2	3					
<i>Scleranthus annuus</i> type													
<i>Stellaria holostea</i>											2		
<i>Nuphar lutea</i>		6											
<i>Helleborus</i>			1										1
<i>Nigella</i>													2
<i>Actaea spicata</i>	3										1	1	
<i>Caltha</i> type	5								2		2		
<i>Ranunculus acris</i> group	5				1								1
<i>Ranunculus aquatilis</i> group	1												
<i>Anemone nemorosa</i> group		2											
<i>Ranunculus arvensis</i> type													
<i>Thalictrum aquilegifolium</i>	11	4	1	4	2	3	1	1	4	1	6	1	1
<i>Thalictrum minus</i>					1								
<i>Thalictrum lucidum</i>													
<i>Papaver argemone</i> type													
<i>Hornungia</i> type		3		3	2	3		4	3	1	2	2	3
<i>Arabis</i>	1		1			2	1	1					
<i>Sinapis</i> type		1	2	3	2		2				1		
<i>Chrysosplenium alternifolium</i>										1			
<i>Saxifraga stellaris</i>	2	1							2	1			2

Anelia

Depth (cm)

120-121 125-126 130-131 135-136 140-141 145-146 150-151 154-155 160-161 165-166 170-171 175-176 180-181

<i>Saxifraga oppositifolia</i> type												
<i>Parnassia palustris</i>												
<i>Platanus orientalis</i>		6	2	2	2	2		2	1		1	1
<i>Filipendula</i>		1			1						1	
<i>Rubus</i> type	1											
<i>Sorbus</i> type												
<i>Rosa</i>						1	2	1		1		1
<i>Sanguisorba minor</i>		1		1		1				1		
<i>Geum</i>												
<i>Potentilla</i>	1					1	1	1				
<i>Hedysarum coronarium</i>												
<i>Ononis</i> type				2								
<i>Trifolium dubium</i> type												1
<i>Trifolium repens</i> type												
<i>Lotus</i> type						4		7		1		3
<i>Vicia cracca</i> type						1						1
<i>Galega officinalis</i>	1			2	1							1
<i>Ornithopus compressus</i>												
<i>Dorycnium</i>												
<i>Trifolium montanum</i> type												
<i>Linum austriacum</i> type							1					
<i>Linum catharticum</i>												
<i>Pistacia</i>						2						1
<i>Acer</i>												
<i>Buxus sempervirens</i>	3						1				1	
<i>Frangula</i>												
<i>Rhamnus</i> type		1			1			4				
<i>Vitis vinifera</i>												
<i>Tilia cordata</i> type		1			1		1	1			2	2
<i>Daphne</i>												
<i>Hypericum perforatum</i> type												
<i>Viola hirta</i> type												
<i>Helianthemum</i>									1			
<i>Myricaria germanica</i>	1		1				1					
<i>Tamarix</i>		3			4	1		1	1	2	1	3
<i>Elatine alsinastrum</i>												2
<i>Circaea lutetiana</i>							1					
<i>Epilobium angustifolium</i> type			1						1		5	
<i>Myriophyllum spicatum</i>	1											
<i>Cornus mas</i>	1	1		1								
<i>Hedera helix</i>												
<i>Hydrocotyle vulgaris</i>				1	1			1				1
<i>Bupleurum</i>												
<i>Berula erecta</i>												
<i>Trinia</i>												
<i>Oenanthe aquatica</i> group									2			1
<i>Oenanthe pimpinelloides</i> group												
<i>Chaerophyllum hirsutum</i> type											1	
<i>Chaerophyllum temulentum</i> type												1
<i>Amni</i>												
<i>Pimpinella saxifraga</i>						1						
<i>Torilis arvensis</i>												
<i>Anethum graveolens</i>												
<i>Peucedanum austriacum</i> type					1							
<i>Angelica sylvestris</i>												
<i>Anthriscus sylvestris</i> type												
<i>Eryngium</i>		1										
<i>Scandix</i> type												
<i>Torilis japonica</i> type		1										1
<i>Daucus</i>												
<i>Erica herbacea</i>			2	3		1		1		1	4	
<i>Vaccinium myrtillus</i>							1					
<i>Cyclamen</i>												
<i>Androsace villosa</i>											1	
<i>Primula</i>												
<i>Lysimachia</i>				2								
<i>Anagallis tenella</i> type												
<i>Asterolinon linum-stellatum</i>												
<i>Samolus valerandi</i>						1						
<i>Fraxinus excelsior</i> type						1				2	2	

Anelia

Depth (cm)

120-121 125-126 130-131 135-136 140-141 145-146 150-151 154-155 160-161 165-166 170-171 175-176 180-181

<i>Fraxinus angustifolia</i>					3				1				2
<i>Fraxinus ornus</i>	1	2	1	1	4	1		2	2	3	4	1	3
<i>Cynoglossum</i> type													
<i>Heliotropium</i>											1		
<i>Myosotis</i> type												1	
<i>Lappula</i>													
<i>Alkanna</i> type				1				1					
<i>Buglossoides arvensis</i> type													
<i>Anchusa arvensis</i> type				1									
<i>Teucrium</i>													
<i>Scutellaria</i> type													
<i>Mentha</i> type			1	1	4		3		2	1	1	4	1
<i>Solanum dulcamara</i>	1				1		1					1	2
<i>Solanum nigrum</i> type													
<i>Scrophularia</i> type								1					
<i>Rhinanthus</i> type												1	
<i>Odontites</i> type													
<i>Veronica anagallis-aquatica</i> type		1											
<i>Pedicularis</i>													
<i>Galium</i> type		1		2	5	3	1	2	2	1	3		2
<i>Plantago major</i>	1		4		4	1	5	6	2		1	2	2
<i>Plantago afra</i>													
<i>Plantago lanceolata</i> type	8	4	4	4	6	5	4	6	3	1	4	6	6
<i>Plantago coronopus</i>		1	1				1	1			2	8	
<i>Plantago bellardii</i>												1	
<i>Plantago media</i>	1	1				1						2	
<i>Plantago arenaria</i>													
<i>Plantago argentea</i>	1					2						1	
<i>Plantago albicans</i>	1	1											
<i>Plantago atrata</i>													
<i>Sambucus nigra</i>													
<i>Viburnum</i>					1								
<i>Valeriana officinalis</i> type													
<i>Jasione</i>				1									
<i>Campanula erinus</i> type								2					
<i>Campanula rotundifolia</i>						1							
<i>Solidago</i> type	4	3	6	4	6	6	6	9	5	6	10	3	8
<i>Echinops</i>													
<i>Artemisia</i>	4	6	4	4	3	3	1	3	2	1	5	1	4
<i>Carlina</i> type								1	1				
<i>Achillea</i> type				1		1	2	8	1		1	1	
<i>Centaurea cyanus</i> type													
<i>Centaurea napulifera</i> type													
<i>Cirsium</i> type	4		3	5		5	2	8	4	1	8		1
<i>Centaurea solstitialis</i> type	1		1	1	1		3		1				
<i>Centaurea graeca</i> type		1											
<i>Lactuca</i> type				2		1	1	2	1	1	1		
<i>Cichorium</i> type								8					
<i>Hieracium</i> type	5	7	4	5	4	5	7	7	11	2	9	2	4
<i>Taraxacum</i> type	1												

MONOCOTYLEDONES

<i>Sagittaria sagittifolia</i>												1	
<i>Damasonium alisma</i>													
<i>Hydrocharis morsus-ranae</i>										1			
<i>Stratiotes aloides</i>				1									
<i>Vallisneria spiralis</i>													
<i>Potamogeton crispus</i> type													
<i>Narthecium scardicum</i>												1	
<i>Veratrum</i>													
<i>Anthericum liliago</i>													
<i>Scilla</i> type													
<i>Muscari comosum</i>													
<i>Muscari neglectum</i> type						1	1						
<i>Narcissus papyraceus</i> type								1					
<i>Sternbergia</i>													
<i>Iris pseudacorus</i>													
<i>Iris spuria</i> type													
<i>Gynandriris sisyrinchium</i>													
<i>Festuca</i> type	11	12	18	14	7	10	10	27	5	5	15	14	12

Anelia

Depth (cm)

	120-121	125-126	130-131	135-136	140-141	145-146	150-151	154-155	160-161	165-166	170-171	175-176	180-181
<i>Glyceria</i> type	13	13	19	15	10	21	14	105	20	19	27	16	42
<i>Dactylis</i> type	6	14	8	5	2	13	13	72	15	8	18	6	17
<i>Agropyron</i> type	1	1											
<i>Secale cereale</i>	1	1	1	4		2	4	3	4	2	3	4	6
<i>Hordeum</i> type													
<i>Avena/Triticum</i> type	4	1		1		4		3	5	3		3	6
<i>Phragmites australis</i>	4	5	10	9	6	11	11	14	4	8	10	6	1
<i>Sparganium erectum</i>													
<i>Sparganium angustifolium</i>													
<i>Typha angustifolia</i> type												1	
<i>Typha domingensis</i> type													2
<i>Cyperus michelianus</i>		1				1	33			10		32	
<i>Cyperus longus</i> type	15	10	1	2	1	13	2	20	1	1		5	
<i>Carex hallerana</i> type	351	203	222	178	41	258	177	282	144	137	122	157	69
<i>Carex flacca</i> type										7	1	27	1
<i>Cephalanthera</i>													

PTERIDOPHYTA

<i>Equisetum</i>													
<i>Ophioglossum vulgatum</i>								1					
<i>Botrychium</i>					1						1		
<i>Adiantum capillus-veneris</i>													1
<i>Pteridium aquilinum</i>	42	47	133	85	88	48	46	70	95	67	67	97	99
<i>Asplenium</i> type	2		1		1	1	2	3	4	1	3		
<i>Athyrium filix-femina</i>		1											
<i>Athyrium distentifolium</i>		1											
<i>Dryopteris filix-mas</i> type													
<i>Blechnum spicant</i>	2	6	2	10	4	7	10	13	20	13	22	9	18
<i>Polypodium</i>					1								1
<i>Salvinia natans</i>		1										1	2

TOTALS

Indeterminate	10	6	9	9	6	5	5	2	1	13	13	26	4
Unknown													
Number of terrestrial types	47	44	38	41	45	55	48	56	43	39	52	44	49
Total wetland pollen & spores	399	242	253	211	67	304	240	424	178	186	163	253	123
Total trees & shrubs	456	364	331	395	462	353	384.6	463	303	322.2	491	331.7	341

Total terrestrial pollen & spores
(excluding bog & marsh plants,
aquatics, unknown & indeterminate)

	582	492	533	578	626	515	532.6	796	508	455.2	740	512.7	565
Total pollen & spores	991	740	795	798	699	824	777.6	1222	687	654.2	916	791.7	692

CHARCOAL

Charcoal <25 um ²	2071	2180	4687	10355	8829	4905	5014	7957	46761	13298	19838	13843	14715
Charcoal 25-50 um ²	2071	1635	2398	6322	9265	5777	3379	4251	43709	8393	12971	8611	9701
Charcoal 50-100 um ²	1308	872	1199	3924	3924	2834	3270	3270	32700	6758	6976	5559	5450
Charcoal 100-200 um ²	763	218	1417	2071	2725	1526	1853	3052	14715	2943	4578	1962	3488
Charcoal 200-400 um ²	545	0	436	545	1199	654	872	1635	5886	1962	1853	1090	981
Charcoal >400 um ²	218	109	436	436	654	218	327	436	2834	654	2507	436	654

Anelia

Depth (cm)

185-186 190-191 195-196 200-201 205-206 210-211 215-216 220-221 225-226 230-231 235-236 240-241 245-250

Absolute counts data

Slide numbers	1	1	1-5	1	1	1-3	1	1&2	1&2	1&2	1-3	1	1-3
Sample weight (g) (wet)	1.878	1.922	1.986	1.662	1.637	1.719	1.470	1.314	1.008	1.039	1.184	0.666	1.994
<i>Lycopodium</i> suspension added (ml)	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.2	0.2	0.2	0.5	0.2	0.5
<i>Lycopodium</i> count	1429	3170	1193	1505	953	2472	351	253	528	439	765	400	1469

GYMNOSPERMAE

<i>Abies</i>	38	47	69	111	105	61	71	51	36	34	48	21	32
<i>Pinus</i> subgenus <i>Diploxylon</i>	167	166	172	207	160	157	203	271	240	131	186	292	128
<i>Juniperus</i>	17	8	6	6	6	1	5	6		7	3	2	
<i>Taxus baccata</i>											1		
<i>Ephedra fragilis</i>		3				1							

DICOTYLEDONES

<i>Salix triandra</i>	1		1				1				1	1	
<i>Salix fragilis</i> type			1										
<i>Populus</i>						1							
<i>Juglans regia</i>		1	1		1			1	1	1	2	1	
<i>Alnus glutinosa</i>	2	2	5	3		6	3	4	1	2		1	1
<i>Betula pendula</i>											1		
<i>Carpinus</i> type	2				2		1			2		1	
<i>Ostrya</i> type	24	27	31	18	10	15	7	9	7	7	2	3	4
<i>Corylus</i>	2	1		1	2	3	2				1	5	1
<i>Fagus</i>	42	49	25	85	57	34	42	42	34	65	37	32	52
<i>Castanea sativa</i>	1	1				2	1		6	6	2	4	
<i>Quercus coccifera</i> type		2	1					1	2	3			1
<i>Quercus trojana</i> type	8	9	1	1	2		4	1	5	1		5	1
<i>Quercus frainetto</i> type	42	48	17	20	25	15	23	19	32	26	16	33	13
<i>Ulmus glabra</i> type	1			1	1	1			2				
<i>Humulus lupulus</i>													
<i>Urtica dioica</i>	2	1	3		1			1	4			2	
<i>Urtica urens</i> type			1				1	2				4	1
<i>Urtica pilulifera</i> type										1			
<i>Parietaria</i>													
<i>Viscum album</i>													
<i>Arceuthobium oxycedri</i>													
<i>Polygonum aviculare</i> type	9	3	3	1	1		2	2	1		1	1	
<i>Oxyria digyna</i>	1												
<i>Rumex acetosella</i> group		1		1	2		1						1
<i>Rumex acetosa</i> group	7	14	8	10	4	5	5	10	13	10	3	9	2
<i>Chenopodiaceae</i> type	3	1	4	5		1	2	4	6	5	7	2	5
<i>Glinus</i> type													
<i>Spergula</i>													
<i>Spergularia</i> type													
<i>Herniaria</i> type	4	5	3	3	1	1	4	5	1	2	1	1	
<i>Paronychia</i> type													
<i>Dianthus</i> type		3		2			1			1	1	2	2
<i>Lychnis flos-cuculi</i>	1								1				
<i>Agrostemma githago</i>			2		2	1							
<i>Scleranthus perennis</i>													
<i>Scleranthus annuus</i> type													
<i>Stellaria holostea</i>													
<i>Nuphar lutea</i>													
<i>Helleborus</i>													
<i>Nigella</i>													
<i>Actaea spicata</i>					1						4		
<i>Caltha</i> type							1		2		4		
<i>Ranunculus acris</i> group							1						1
<i>Ranunculus aquatilis</i> group													
<i>Anemone nemorosa</i> group			1									3	
<i>Ranunculus arvensis</i> type													
<i>Thalictrum aquilegifolium</i>	5	2	3	1	2		3	7	3	5	3	1	1
<i>Thalictrum minus</i>	3							1	3	1			
<i>Thalictrum lucidum</i>													
<i>Papaver argemone</i> type													
<i>Hornungia</i> type	2	8	4	2	1			4	7	7	1	3	1
<i>Arabis</i>		1								2		1	
<i>Sinapis</i> type	1				2		1	3	3	5			
<i>Chrysosplenium alternifolium</i>							2	2	1	1			
<i>Saxifraga stellaris</i>			1		1	1	1	1	1				

Anelia

Depth (cm)

185-186 190-191 195-196 200-201 205-206 210-211 215-216 220-221 225-226 230-231 235-236 240-241 245-250

<i>Saxifraga oppositifolia</i> type										1		
<i>Parnassia palustris</i>												
<i>Platanus orientalis</i>	1	1					2	3	2	4		3
<i>Filipendula</i>											1	
<i>Rubus</i> type												
<i>Sorbus</i> type												
<i>Rosa</i>												
<i>Sanguisorba minor</i>									1			
<i>Geum</i>												
<i>Potentilla</i>								2		1	1	
<i>Hedysarum coronarium</i>												1
<i>Ononis</i> type												
<i>Trifolium dubium</i> type	3	3										1
<i>Trifolium repens</i> type												
<i>Lotus</i> type		1						2				
<i>Vicia cracca</i> type							1	1				
<i>Galega officinalis</i>		1		2	2							1
<i>Ornithopus compressus</i>												
<i>Dorycnium</i>												
<i>Trifolium montanum</i> type		1		1						1		
<i>Linum austriacum</i> type												
<i>Linum catharticum</i>												
<i>Pistacia</i>	1									1		1
<i>Acer</i>			1									
<i>Buxus sempervirens</i>				1		1	1	1				
<i>Frangula</i>												
<i>Rhamnus</i> type					1							
<i>Vitis vinifera</i>								1				
<i>Tilia cordata</i> type	2	2	1	3	2	1	1					
<i>Daphne</i>												
<i>Hypericum perforatum</i> type												
<i>Viola hirta</i> type												
<i>Helianthemum</i>							2					
<i>Myricaria germanica</i>	1		1									
<i>Tamarix</i>		2		1	2	2	2	2	1	5	2	1
<i>Elatine alsinastrum</i>												
<i>Circaea lutetiana</i>												
<i>Epilobium angustifolium</i> type				2	3		1		1			
<i>Myriophyllum spicatum</i>											1	
<i>Cornus mas</i>	1									1		
<i>Hedera helix</i>												
<i>Hydrocotyle vulgaris</i>	1	1				1	1		2	5		3
<i>Bupleurum</i>												
<i>Berula erecta</i>												
<i>Trinia</i>	1											
<i>Oenanthe aquatica</i> group												1
<i>Oenanthe pimpinelloides</i> group												2
<i>Chaerophyllum hirsutum</i> type												
<i>Chaerophyllum temulentum</i> type												
<i>Ammi</i>			1									
<i>Pimpinella saxifraga</i>												
<i>Torilis arvensis</i>												
<i>Anethum graveolens</i>												
<i>Peucedanum austriacum</i> type												
<i>Angelica sylvestris</i>												
<i>Anthriscus sylvestris</i> type												
<i>Eryngium</i>												
<i>Scandix</i> type												
<i>Torilis japonica</i> type	1				1	1		1				1
<i>Daucus</i>												
<i>Erica herbacea</i>		1					2		2			
<i>Vaccinium myrtillus</i>					1							
<i>Cyclamen</i>									1			
<i>Androsace villosa</i>												
<i>Primula</i>										1		1
<i>Lysimachia</i>												
<i>Anagallis tenella</i> type												1
<i>Asterolinon linum-stellatum</i>										1		
<i>Samolus valerandi</i>										1		
<i>Fraxinus excelsior</i> type	1				1		2		1			

Anelia

Depth (cm)

185-186 190-191 195-196 200-201 205-206 210-211 215-216 220-221 225-226 230-231 235-236 240-241 245-250

<i>Fraxinus angustifolia</i>	1	1	1						1		1		1
<i>Fraxinus ornus</i>	2	3	4		1		1	1	1	2	2		1
<i>Cynoglossum</i> type													
<i>Heliotropium</i>													
<i>Myosotis</i> type													
<i>Lappula</i>													
<i>Alkanna</i> type										1			
<i>Buglossoides arvensis</i> type													
<i>Anchusa arvensis</i> type		1	1										
<i>Teucrium</i>										1			
<i>Scutellaria</i> type													
<i>Mentha</i> type	3	1		1		2		2		1			
<i>Solanum dulcamara</i>		1							1				
<i>Solanum nigrum</i> type		1											
<i>Scrophularia</i> type													
<i>Rhinanthus</i> type											1		
<i>Odontites</i> type													
<i>Veronica anagallis-aquatica</i> type													
<i>Pedicularis</i>													
<i>Galium</i> type	2	1	2	1	2	1	1	1	2	2			
<i>Plantago major</i>	5	2	6	2	3	3	2	4	5	4	2		
<i>Plantago afra</i>	1									2			
<i>Plantago lanceolata</i> type	5	10	1	6	8	1	2	4	10	14	6	4	3
<i>Plantago coronopus</i>	1		1				3	1				6	1
<i>Plantago bellardii</i>									1		1		
<i>Plantago media</i>	1	1		2				2	1				
<i>Plantago arenaria</i>	1												
<i>Plantago argentea</i>												1	
<i>Plantago albicans</i>							1						
<i>Plantago atrata</i>													1
<i>Sambucus nigra</i>													
<i>Viburnum</i>													
<i>Valeriana officinalis</i> type													
<i>Jasione</i>													
<i>Campanula erinus</i> type	1												
<i>Campanula rotundifolia</i>													
<i>Solidago</i> type	8	24	4	13	10	4	10	3	9	11	3	6	5
<i>Echinops</i>													
<i>Artemisia</i>	4	3	4	3	2	2	3		6	9		3	4
<i>Carlina</i> type	1			1				2	1				
<i>Achillea</i> type	2	2	1	4	1	1	1	1		4		1	
<i>Centaurea cyanus</i> type						1			1	1			
<i>Centaurea napulifera</i> type													
<i>Cirsium</i> type	7	2	5	4	2	2	3	1	3	5	7	6	2
<i>Centaurea solstitialis</i> type	1					1			2		1	2	
<i>Centaurea graeca</i> type												1	
<i>Lactuca</i> type	2	1	1		1	1	1	1	1				
<i>Cichorium</i> type			1							1			1
<i>Hieracium</i> type	3	4	4	4	3	7	13	4	15	1		6	1
<i>Taraxacum</i> type	2	2										2	

MONOCOTYLEDONES

<i>Sagittaria sagittifolia</i>													
<i>Damasonium alisma</i>													
<i>Hydrocharis morsus-ranae</i>													2
<i>Stratiotes aloides</i>												1	1
<i>Vallisneria spiralis</i>													
<i>Potamogeton crispus</i> type													
<i>Narthecium scardicum</i>					1								
<i>Veratrum</i>						1	2	2	11	8	3	5	3
<i>Anthericum liliago</i>								2					
<i>Scilla</i> type											1		
<i>Muscari comosum</i>					1								
<i>Muscari neglectum</i> type		1					1					1	
<i>Narcissus papyraceus</i> type													
<i>Sternbergia</i>													
<i>Iris pseudacorus</i>													
<i>Iris spuria</i> type													
<i>Gynandriris sisyrinchium</i>													
<i>Festuca</i> type	11	14	6	8	9	2	18	13	19	11	8	9	4

Anelia

Depth (cm)

	185-186	190-191	195-196	200-201	205-206	210-211	215-216	220-221	225-226	230-231	235-236	240-241	245-250
<i>Glyceria</i> type	36	31	36	22	16	24	22	27	34	25	5	12	9
<i>Dactylis</i> type	15	15	9	7	18	2	22	16	15	35	10	38	14
<i>Agropyron</i> type											1	2	1
<i>Secale cereale</i>	5	10	12	5	9	5	8	20	20	29	5	11	5
<i>Hordeum</i> type													
<i>Avena/Triticum</i> type	6	3	1	3	1	2	4	1	4	4	5	11	4
<i>Phragmites australis</i>	4	3	3	2	11	1	12	7	7	20	13	15	4
<i>Sparganium erectum</i>	1	1								4	2	2	
<i>Sparganium angustifolium</i>										1			
<i>Typha angustifolia</i> type													
<i>Typha domingensis</i> type								1			1		
<i>Cyperus michelianus</i>			3							4	9	10	4
<i>Cyperus longus</i> type	1		1			1	1	1		2	1	3	1
<i>Carex hallerana</i> type	159	150	74	206	201	16	200	161	221	95	37	76	30
<i>Carex flacca</i> type			2			2							
<i>Cephalanthera</i>							2						
PTERIDOPHYTA													
<i>Equisetum</i>													
<i>Ophioglossum vulgatum</i>													
<i>Botrychium</i>													
<i>Adiantum capillus-veneris</i>							1						
<i>Pteridium aquilinum</i>	81	101	85	123	135	75	174	244	162	246	160	245	61
<i>Asplenium</i> type	4	2		3	4	1	11	5	8	18	19	8	2
<i>Athyrium filix-femina</i>											2		
<i>Athyrium distentifolium</i>													
<i>Dryopteris filix-mas</i> type													
<i>Blechnum spicant</i>	24	28	31	20	30	23	45	10	10	35	45	13	18
<i>Polypodium</i>	2												
<i>Salvinia natans</i>			1	1				1	1	2	1		1
TOTALS													
Indeterminate	5	12	11	4	7	11	4	5	4	14	8	12	7
Unknown	1								1				
Number of terrestrial types	60	54	45	40	46	39	54	48	52	54	42	49	39
Total wetland pollen & spores	206	188	122	234	232	48	241	203	270	161	75	124	56
Total trees & shrubs	357	374	336.7	458	379	300.7	374	413.4	374	298.3	305.1	406	236.5
Total terrestrial pollen & spores (excluding bog & marsh plants, aquatics, unknown & indeterminate)													
	594	647	544.7	695	639	444.7	728	793.4	725	784.3	603.1	817	382.5
Total pollen & spores	806	847	677.7	933	878	503.7	973	1001.4	1000	959.3	686.1	953	445.5
CHARCOAL													
Charcoal <25 um2	17549	19402	17113	9810	12208	14497	5995	4360	1853	3270	1635	2725	2725
Charcoal 25-50 um2	14715	17004	11881	12971	9265	10028	7848	5777	1962	3052	3052	2289	2289
Charcoal 50-100 um2	8611	12535	8829	7630	7303	9265	6758	3706	981	1199	4796	2071	2071
Charcoal 100-200 um2	3815	5668	3488	5668	4033	4578	3052	2725	436	654	3270	1417	1417
Charcoal 200-400 um2	2180	2289	1308	2943	1853	1853	1417	981	763	545	1199	872	872
Charcoal >400 um2	2180	1526	654	1744	1962	1526	872	763	545	218	1417	763	763

Kellia

Depth (cm)

Absolute counts data

	0-1	5-6	10-11	15-16	20-21	25-26	30-31	35-36	40-41	45-46	50-51	55-56
Slide numbers	1-4	1&2	1	1-5	1&2	1&2	1	1	1&2	1-6	1	1&2
Sample weight (g) (wet)	0.569	1.191	1.121	1.247	1.458	1.582	1.522	1.826	1.992	1.897	1.783	1.695
<i>Lycopodium</i> suspension added (ml)	2.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.5	0.5
<i>Lycopodium</i> count	5833	3531	5762	3376	3653	4624	2303	2926	4214	2241	2650	3668

GYMNOSPERMAE

<i>Abies</i>	19.	3.6	10.	12.4	6.3	5.	3.7	1.	1.4	2.2	4.3	3.3
<i>Cedrus</i>												
<i>Pinus</i> subgenus <i>Diploxylon</i>	136.6	111.6	202.	121.3	79.3	81.7	97.3	62.	44.7	60.4	59.7	76.
<i>Juniperus</i>	22	4	12	11	8	5	4	23	20	20	23	16
<i>Taxus baccata</i>	2											
<i>Ephedra fragilis</i>							2	1				
<i>Ephedra distachya</i> type												

DICOTYLEDONES

<i>Salix triandra</i>	92	121	45	27	5	2	9	10	3	7	5	2
<i>Salix fragilis</i> type	9	3	4	2			1	1				
<i>Juglans regia</i>			1		1	2		2	1			
<i>Alnus glutinosa</i>	3	1		3	1							3
<i>Betula pendula</i>											1	
<i>Carpinus</i> type	2					2			1		1	
<i>Ostrya</i> type	12	7	4	9	14	11	4	3	4	4	15	5
<i>Corylus</i>	5	1		2	3				1	1		1
<i>Fagus</i>	8			1	3	1	4		1		2	
<i>Castanea sativa</i>		4	9	2	2	1		1	13	1	2	1
<i>Quercus coccifera</i> type	5	3	7	1	6	5	11	7	6	3	7	5
<i>Quercus trojana</i> type	25	34	22	6	20	12	11	21	25	22	16	19
<i>Quercus frainetto</i> type	90	49	23	44	66	61	60	67	60	77	106	84
<i>Ulmus minor</i>										1	2	1
<i>Ulmus procera</i>												
<i>Ulmus glabra</i> type												
<i>Morus nigra</i>												
<i>Morus alba</i>												4
<i>Humulus lupulus</i>												
<i>Urtica dioica</i>	2									1		
<i>Urtica urens</i> type												
<i>Urtica pilulifera</i> type			1									
<i>Polygonum bistorta</i> type												
<i>Polygonum aviculare</i> type	17	4	9	10	5	3	6	12	20	9	25	19
<i>Bilderdykia</i>					1				1	1		
<i>Oxyria digyna</i>		1		1				3				
<i>Rumex acetosella</i> group												
<i>Rumex acetosa</i> group	13	7	7	6	1	1		2		5		1
<i>Rumex crispus</i> p.p.												
<i>Rumex conglomeratus</i> group												
<i>Rumex obtusifolius</i> group												
Chenopodiaceae type	16	16	9	8	8	3	2	10	18	6	6	6
<i>Phytolacca americana</i>				1								
<i>Spergula</i>												
<i>Spergularia</i> type												
<i>Herniaria</i> type		1										
<i>Corrigiola litoralis</i>												
<i>Paronychia</i> type												
<i>Dianthus</i> type				1	2			3	1	3		1
<i>Silene alba</i> type												
<i>Lychnis flos-cuculi</i>												
<i>Agrostemma githago</i>												
<i>Scleranthus annuus</i> type						1						
<i>Nymphaea alba</i>												
<i>Nuphar lutea</i>												1
<i>Helleborus</i>	2	1										
<i>Nigella</i>	3		2	1			1					
<i>Trollius europaeus</i>												
<i>Actaea spicata</i>	1					1						
<i>Adonis</i>												
<i>Caltha</i> type	2			2	3		1					1
<i>Ranunculus acris</i> group					1						3	1
<i>Ranunculus aquatilis</i> group		1					1				1	
<i>Anemone nemorosa</i> group	1											

Kellia

Depth (cm)

	0-1	5-6	10-11	15-16	20-21	25-26	30-31	35-36	40-41	45-46	50-51	55-56
<i>Clematis vitalba</i> group									2			
<i>Thalictrum aquilegifolium</i>		1	1	1	2			1	1		1	
<i>Thalictrum minus</i>												
<i>Thalictrum lucidum</i>									1			
<i>Chelidonium majus</i>												
<i>Glaucium</i>							1					
<i>Hornungia</i> type	4	7	4	5	2		1	4				1
<i>Arabis</i>	4	2	6	1	1		1					1
<i>Sinapis</i> type	8	5	4	1	3		1	1			1	2
<i>Chrysosplenium alternifolium</i>	2	2	1		1				2			
<i>Saxifraga stellaris</i>												
<i>Saxifraga oppositifolia</i> type												
<i>Platanus orientalis</i>	9	4	6	6	1	2		2	5	7	15	11
<i>Filipendula</i>												
<i>Rubus</i> type												
<i>Sorbus</i> type												
<i>Cotoneaster</i> type												
<i>Prunus avium</i> type												
<i>Crataegus</i>								1				
<i>Sanguisorba officinalis</i>					1							
<i>Sanguisorba minor</i>					1	1			3	1		2
<i>Geum</i>												
<i>Potentilla</i>	1											
<i>Alchemilla</i> type												
<i>Ononis</i> type							2		1			
<i>Trifolium dubium</i> type												
<i>Trifolium repens</i> type												
<i>Lotus</i> type		1	1									
<i>Lathyrus pratensis</i> type				1								
<i>Vicia sativa</i> type				1								
<i>Vicia cracca</i> type								1			1	
<i>Astragalus</i>				1								
<i>Galega officinalis</i>												
<i>Dorycnium</i>												
<i>Trifolium montanum</i> type												
<i>Lathyrus sativus</i>												1
<i>Oxalis</i>				1								
<i>Geranium robertianum</i> group					1							
<i>Tribulus terrestris</i>												
<i>Radiola linoides</i>												
<i>Linum catharticum</i>												
<i>Linum tenuifolium</i> group												
<i>Euphorbia</i>									1			
<i>Pistacia</i>												
<i>Cotinus coggygria</i>												
<i>Acer</i>												
<i>Ilex aquifolium</i>												
<i>Buxus sempervirens</i>												
<i>Frangula</i>	1								1			
<i>Rhamnus</i> type												2
<i>Vitis vinifera</i>												
<i>Tilia platyphyllos</i>												
<i>Tilia cordata</i> type												
<i>Abutilon</i> type												
<i>Althaea officinalis</i>												
<i>Malva moschata</i>												
<i>Daphne</i>					1							
<i>Elaeagnus angustifolia</i>	1											
<i>Hypericum hircinum</i> type							1			2	1	
<i>Hypericum perforatum</i> type									1	1	1	
<i>Viola hirta</i> type												
<i>Helianthemum</i>			1									
<i>Cistus monspeliensis</i> type												
<i>Myricaria germanica</i>												
<i>Tamarix</i>	3	4	1	2		1	2		1			
<i>Elatine alsinastrum</i>												1
<i>Lythrum salicaria</i> type	4		1									
<i>Lythrum portula</i>	6	4	2	2	2		1				1	
<i>Trapa natans</i>	1											
<i>Myrtus communis</i>		1		1								

Kellia

Depth (cm)

	0-1	5-6	10-11	15-16	20-21	25-26	30-31	35-36	40-41	45-46	50-51	55-56
<i>Ludwigia palustris</i>												
<i>Epilobium angustifolium</i> type						4	1		1			
<i>Epilobium hirsutum</i> type												
<i>Myriophyllum verticillatum</i>												
<i>Myriophyllum spicatum</i>												
<i>Cornus mas</i>	1											
<i>Hydrocotyle vulgaris</i>		1	1						1		5	2
<i>Anthriscus caucalis</i>												
<i>Ligusticum</i>												
<i>Berula erecta</i>	1									1		
<i>Trinia</i>												
<i>Sanicula europaea</i>												
<i>Oenanthe aquatica</i> group		1										
<i>Oenanthe pimpinelloides</i> group	1											
<i>Chaerophyllum hirsutum</i> type		1										
<i>Chaerophyllum temulentum</i> type				1				1	1			
<i>Amni</i>	1					2		1		1		
<i>Pimpinella saxifraga</i>	6	1		1					2	2	1	2
<i>Torilis arvensis</i>												
<i>Peucedanum austriacum</i> type												
<i>Angelica sylvestris</i>	1											
<i>Bunium</i>	3											
<i>Anthriscus sylvestris</i> type												
<i>Pastinaca sativa</i>												
<i>Eryngium</i>	1					1						
<i>Heracleum sphondylium</i>												
<i>Anthriscus cerefolium</i>												
<i>Torilis japonica</i> type	2		1								1	
<i>Daucus</i>	3	1					1		1			2
<i>Coriandrum</i> type	1											
<i>Pyrola</i>					1							
<i>Erica herbacea</i>												
<i>Vaccinium myrtillus</i>						1						
<i>Soldanella</i>									3	1	1	
<i>Androsace villosa</i>		2										
<i>Primula</i>												
<i>Lysimachia</i>												
<i>Anagallis arvensis</i> type												
<i>Anagallis tenella</i> type					1							
<i>Asterolinon linum-stellatum</i>			1	1	1	1			3	1	3	
<i>Samolus valerandi</i>		2				1						1
<i>Ammeria maritima</i> type				1								
<i>Fraxinus excelsior</i> type	1											
<i>Fraxinus angustifolia</i>					1			1			2	1
<i>Fraxinus ornus</i>	6	4	2	2	1	3	5	1	1		2	
<i>Ligustrum vulgare</i>												1
<i>Phillyrea</i>												
<i>Centaurium</i>												
<i>Convolvulus</i>									1			1
<i>Cuscuta epithymum</i> type					2							
<i>Cuscuta europaea</i> type	1				1				1			
<i>Cuscuta monogyna</i>												
<i>Calystegia</i>												
<i>Alkanna</i> type	1	1						1	1			
<i>Borago officinalis</i>												
<i>Buglossoides arvensis</i> type												
<i>Anchusa arvensis</i> type												
<i>Pulmonaria mollis</i>												
<i>Anchusa officinalis</i> type												
<i>Verbena</i>									1			
<i>Callitriche obtusangula</i>	1											
<i>Callitriche stagnalis</i> type						3						
<i>Teucrium</i>												
<i>Stachys sylvatica</i> type												
<i>Prunella</i> type												
<i>Salvia officinalis</i> type												
<i>Mentha</i> type	18	6	6	4			1	2	2	1	4	1
<i>Solanum dulcamara</i>			1	1						1		
<i>Solanum nigrum</i> type	1											1
<i>Scrophularia</i> type		1								1		

Kellia

Depth (cm)

	0-1	5-6	10-11	15-16	20-21	25-26	30-31	35-36	40-41	45-46	50-51	55-56
<i>Odontites</i> type												
<i>Veronica anagallis-aquatica</i> type												
<i>Veronica triphyllos</i> type		1										
<i>Pedicularis</i>												
<i>Putoria calabrica</i>												
<i>Sherardia arvensis</i>										1		
<i>Galium</i> type	39	20	12	9	3	4	4	10	1	9	2	4
<i>Plantago major</i>		2	1		1	2	2	9	3	1	10	13
<i>Plantago afra</i>					3				1	1	3	2
<i>Plantago lanceolata</i> type	18	5	10	11	6	5	7	23	15	12	11	30
<i>Plantago coronopus</i>	1		1									
<i>Plantago bellardii</i>								1				
<i>Plantago media</i>		1	1		2	1			1			92
<i>Plantago argentea</i>				2								
<i>Plantago albicans</i>		1										
<i>Plantago amplexicaulis</i>												
<i>Plantago atrata</i>												
<i>Viburnum</i>												
<i>Valerianella rimosa</i> type												
<i>Valeriana officinalis</i> type		2										
<i>Valerianella locusta</i> type										1		
<i>Succisa pratensis</i>					1			1				
<i>Scabiosa columbaria</i> type												
<i>Dipsacus</i> type						1						
<i>Knautia</i>												
<i>Jasione</i>				1								
<i>Campanula erinus</i> type												
<i>Campanula rotundifolia</i>					1							
<i>Asyneuma</i> type					1							
<i>Solidago</i> type	23	28	13	11	6	8	4	8	8	9	6	5
<i>Echinops</i>				1								
<i>Artemisia</i>			1	1		1		1	1			
<i>Carlina</i> type		2							1			
<i>Picnemon acarna</i>												
<i>Achillea</i> type	2			4	1			2			1	
<i>Centaurea cyanus</i> type	1			1	1		1		1			
<i>Centaurea napulifera</i> type								1				
<i>Cirsium</i> type	67	76	62	213	22	6	12	4	1	4	11	4
<i>Xanthium</i>											1	
<i>Centaurea solstitialis</i> type	6	3		6	2	2		1	2	9	2	4
<i>Centaurea graeca</i> type	1		1	1								
<i>Crepina</i>	1	1				1	1		1	1	2	
<i>Sonchus</i> type						3			3	10		2
<i>Lactuca</i> type		13	7	3	2	6	4	5		7		3
<i>Scolymus</i>												
<i>Cichorium</i> type	1	1	7	3	3	1	1		6	3	5	5
<i>Hieracium</i> type	11	8	12	13	16	12	9	29	39	32	15	20
<i>Taraxacum</i> type	2	3	2	9	5	6	6	15	24	22	21	17

MONOCOTYLEDONES

Alisma

Hydrocharis morsus-ranae

Stratiotes aloides

Vallisneria spiralis

Triglochin bulbosa

Potamogeton crispus type

Potamogeton pectinatus

Colchicum

Narthecium scardicum

Veratrum

Asphodelus fistulosus type

Asphodelus albus

Gagea pratensis

Tulipa sylvestris

Muscari neglectum type

Allium sphaerocephalon type

Asparagus

Gynandris sisyrrinchium

Festuca type

Glyceria type

	7	4	2	2	18	4	4	11	5	5	10	13
	22	32	23	29	21	19	11	38	38	41	10	29

Kellia

Depth (cm)

	0-1	5-6	10-11	15-16	20-21	25-26	30-31	35-36	40-41	45-46	50-51	55-56
<i>Dactylis</i> type	22	5	5	25	18	23	18	49	130	49	49	57
<i>Agropyron</i> type	1	3				1	4	2	3	2	2	8
<i>Triticum</i> type	15	10	2	2	12	4		7		1	2	
<i>Secale cereale</i>	5	4	4	4	5	9	3	7	18	8	6	34
<i>Hordeum</i> type	1			2	3	1		1	3			
<i>Avena</i>	2					4	2	11	28	6	5	23
<i>Phragmites australis</i>	9	3		1	13	1		14	11	15	27	7
<i>Zea mays</i>	6	3		4	2	3	6	3	1	5	3	2
<i>Anum</i>												
<i>Sparganium erectum</i>	129	10	14	32	19	26	6	5	9	1	4	4
<i>Sparganium angustifolium</i>	13	1		3	1	1						
<i>Typha angustifolia</i> type	19	2		1	4	1		5				1
<i>Typha domingensis</i> type								1				
<i>Scirpus</i>					3	3		24	7	10	2	25
<i>Cladium mariscus</i>												
<i>Cyperus michelianus</i>	209	32		2	2	3	1	13	12	1	1	2
<i>Cyperus longus</i> type	902	643	113	189	45	16	25	93	9	4	22	11
<i>Schoenus nigricans</i>	4		3		1		3	11				1
<i>Carex hallerana</i> type	20	14		26	10	6	3	4	18	6	2	9
<i>Carex flacca</i> type	175	26	135	31	1	1		6		2	1	1
<i>Epipactis</i> type												
<i>Cephalanthera</i>				1								
PTERIDOPHYTA												
<i>Equisetum</i>	45	7		6	1		1					1
<i>Ophioglossum vulgatum</i>									1			
<i>Botrychium</i>												
<i>Adiantum capillus-veneris</i>												
<i>Pteridium aquilinum</i>	6	13	8	16	11	4	4	14	11	20	13	18
<i>Thelypteris palustris</i>												
<i>Thelypteris phegopteris</i>												1
<i>Asplenium</i> type			1									
<i>Athyrium filix-femina</i>												
<i>Athyrium distentifolium</i>												
<i>Dryopteris filix-mas</i> type												
<i>Gymnocarpium dryopteris</i>												
<i>Blechnum spicant</i>	3		1						1			
<i>Polypodium</i>			1									
<i>Salvinia natans</i>												
Unidentified monolete spores												
TOTALS												
Indeterminate	28	8	7	4	2	1	2	1	2	7	1	2
Unknown												
Number of terrestrial types	66	55	48	59	55	49	41	49	62	50	48	52
Total wetland pollen & spores	1594	790	303	331	131	84	55	220	110	82	83	99
Total terrestrial trees & shrubs	444	352	344	251	219	196	214	203	191	208	264	235
Total terrestrial pollen & spores (excluding bog & marsh types, aquatics, unknown & indeterminate)	778	614	546	640	395	325	323	457	562	460	485	633
Total pollen & spores	2400	1412	856	975	528	410	380	678	674	549	569	734
CHARCOAL												
Charcoal <25 um2	26596	23217	10246	10137	11772	11663	7085	11336	20274	29430	3924	13734
Charcoal 25-50 um2	21800	25179	12317	8829	13734	12317	5014	8938	17331	16132	2943	10355
Charcoal 50-100 um2	14933	17767	9047	5886	7957	11336	4251	4469	7957	10464	3052	7630
Charcoal 100-200 um2	5014	11445	6976	3706	3161	7194	2398	2398	4033	4251	2507	2507
Charcoal 200-400 um2	2289	3815	2180	2180	1199	4469	1199	1744	1962	1308	763	1526
Charcoal >400 um2	2180	4360	1090	1090	1308	3815	109	1744	2071	1308	436	545

Kellia

Depth (cm)

	60-61	65-66	70-71	75-76	80-81	85-86	90-91	95-96	100-101	105-106	110-111	115-116
Absolute counts data												
Slide numbers	1	1	1&2	1	1	1-3	1	1	1	1	1	1
Sample weight (g) (wet)	1.671	1.718	1.141	1.315	1.802	1.752	1.755	1.701	1.771	1.603	1.868	1.633
<i>Lycopodium</i> suspension added (ml)	0.5	0.5	0.5	0.5	0.5	0.2	0.5	0.5	0.5	0.5	0.5	0.5
<i>Lycopodium</i> count	2190	3299	4396	4381	4392	1242	2373	4829	4664	1779	4294	2635
GYMNOSPERMAE												
<i>Abies</i>	12.3	6.	10.	3.7	5.7	3.3	7.7	4.7	8.	8.3	5.	5.
<i>Cedrus</i>			1.									
<i>Pinus</i> subgenus <i>Diploxylon</i>	99.7	83.3	109.7	107.	95.7	63.	79.	96.7	63.7	78.3	74.7	79.7
<i>Juniperus</i>	15	10	10	5	3	17	9	18	17	19	20	28
<i>Taxus baccata</i>							1				1	
<i>Ephedra fragilis</i>	1							1	1	1		
<i>Ephedra distachya</i> type											1	1
DICOTYLEDONES												
<i>Salix triandra</i>	2	6	4	11	2	2	2	3	2	1	2	1
<i>Salix fragilis</i> type				1								
<i>Juglans regia</i>	1	1		1	2	1		2				
<i>Alnus glutinosa</i>		1		2						1	2	
<i>Betula pendula</i>												
<i>Carpinus</i> type			1					1				1
<i>Ostrya</i> type	3	7	1	2	8	1	6	3	2	3	6	7
<i>Corylus</i>	1							3	1	1	1	
<i>Fagus</i>	1	2	1	1	2	1				1	1	
<i>Castanea sativa</i>	4	1	1	1	2	2	1	1	3			2
<i>Quercus coccifera</i> type	7	5		3	7	4		4	1	8	5	2
<i>Quercus trojana</i> type	10	21	9	13	19	22	22	18	14	16	18	13
<i>Quercus frainetto</i> type	73	99	65	86	136	72	69	115	71	54	61	70
<i>Ulmus minor</i>								3				
<i>Ulmus procera</i>												
<i>Ulmus glabra</i> type												
<i>Morus nigra</i>												
<i>Morus alba</i>												
<i>Humulus lupulus</i>												
<i>Urtica dioica</i>												
<i>Urtica urens</i> type												
<i>Urtica pilulifera</i> type												
<i>Polygonum bistorta</i> type												
<i>Polygonum aviculare</i> type	4	12	17	22	46	59	55	66	30	30	24	12
<i>Bilderdykia</i>			1									
<i>Oxyria digyna</i>												
<i>Rumex acetosella</i> group												
<i>Rumex acetosa</i> group		2	3		1	55		1			1	
<i>Rumex crispus</i> p.p.												
<i>Rumex conglomeratus</i> group												
<i>Rumex obtusifolius</i> group												
Chenopodiaceae type	4	6	8	6	10	5	8	15	11	7	13	11
<i>Phytolacca americana</i>												
<i>Spergula</i>												
<i>Spergularia</i> type												
<i>Hemaria</i> type												1
<i>Corrigiola litoralis</i>												
<i>Paronychia</i> type								1				
<i>Dianthus</i> type		1	1			1				1		1
<i>Silene alba</i> type									2			
<i>Lychnis flos-cuculi</i>												
<i>Agrostemma githago</i>												
<i>Scleranthus annuus</i> type							2					
<i>Nymphaea alba</i>												
<i>Nuphar lutea</i>												
<i>Helleborus</i>												
<i>Nigella</i>												
<i>Trollius europaeus</i>												
<i>Actaea spicata</i>						3						
<i>Adonis</i>						1						
<i>Caltha</i> type		1	1		1	2				1		
<i>Ranunculus acris</i> group												
<i>Ranunculus aquatilis</i> group			2									
<i>Anemone nemorosa</i> group												

Kellia

Depth (cm)

	60-61	65-66	70-71	75-76	80-81	85-86	90-91	95-96	100-101	105-106	110-111	115-116
<i>Clematis vitalba</i> group												
<i>Thalictrum aquilegifolium</i>	1		1			2					3	
<i>Thalictrum minus</i>				1								
<i>Thalictrum lucidum</i>												
<i>Chelidonium majus</i>												
<i>Glaucium</i>												
<i>Hornungia</i> type		1		2		1	1	2	1			
<i>Arabis</i>	3				1	1					1	
<i>Sinapis</i> type	1	2	2	1		1		1	1	3	1	1
<i>Chrysosplenium alternifolium</i>						1						
<i>Saxifraga stellaris</i>	1					1			1		1	
<i>Saxifraga oppositifolia</i> type												
<i>Platanus orientalis</i>	7	15	4	5	2	3	8	2	3		2	4
<i>Filipendula</i>		1										
<i>Rubus</i> type												
<i>Sorbus</i> type												
<i>Cotoneaster</i> type												
<i>Prunus avium</i> type												
<i>Crataegus</i>												
<i>Sanguisorba officinalis</i>												
<i>Sanguisorba minor</i>		1		1	2	1	1		1		2	1
<i>Geum</i>												
<i>Potentilla</i>												
<i>Alchemilla</i> type												
<i>Ononis</i> type		1	1				1		1			
<i>Trifolium dubium</i> type										7		
<i>Trifolium repens</i> type												
<i>Lotus</i> type											2	
<i>Lathyrus pratensis</i> type												
<i>Vicia sativa</i> type												
<i>Vicia cracca</i> type	1											
<i>Astragalus</i>				1								
<i>Galega officinalis</i>												
<i>Dorycnium</i>						1						
<i>Trifolium montanum</i> type	1											
<i>Lathyrus sativus</i>												
<i>Oxalis</i>												
<i>Geranium robertianum</i> group												
<i>Tribulus terrestris</i>												
<i>Radiola linoides</i>												
<i>Linum catharticum</i>												
<i>Linum tenuifolium</i> group												
<i>Euphorbia</i>											1	
<i>Pistacia</i>												
<i>Cotinus coggygria</i>												
<i>Acer</i>												
<i>Ilex aquifolium</i>							1	3		1	2	
<i>Buxus sempervirens</i>												
<i>Frangula</i>												
<i>Rhamnus</i> type												
<i>Vitis vinifera</i>									1			
<i>Tilia platyphyllos</i>												
<i>Tilia cordata</i> type							1					
<i>Abutilon</i> type				1								
<i>Althaea officinalis</i>												
<i>Malva moschata</i>												
<i>Daphne</i>					1		1					
<i>Elaeagnus angustifolia</i>												
<i>Hypericum hircinum</i> type												
<i>Hypericum perforatum</i> type												
<i>Viola hirta</i> type												
<i>Helianthemum</i>												
<i>Cistus monspeliensis</i> type												
<i>Myricaria germanica</i>												
<i>Tamarix</i>		1			2	1			1	1		
<i>Elatine alsinastrum</i>						1						
<i>Lythrum salicaria</i> type												
<i>Lythrum portula</i>								2				
<i>Trapa natans</i>												
<i>Myrtus communis</i>											1	

Kellia

Depth (cm)

	60-61	65-66	70-71	75-76	80-81	85-86	90-91	95-96	100-101	105-106	110-111	115-116
<i>Ludwigia palustris</i>												
<i>Epilobium angustifolium</i> type		1									1	
<i>Epilobium hirsutum</i> type								1		1		
<i>Myriophyllum verticillatum</i>												
<i>Myriophyllum spicatum</i>												
<i>Cornus mas</i>	1		1			2	1	1		2		
<i>Hydrocotyle vulgaris</i>		1		1	1					3		
<i>Anthriscus caucalis</i>						1						
<i>Ligusticum</i>												
<i>Berula erecta</i>						3				1	1	3
<i>Trinia</i>		3							1			
<i>Sanicula europaea</i>												
<i>Oenanthe aquatica</i> group						1						
<i>Oenanthe pimpinelloides</i> group												
<i>Chaerophyllum hirsutum</i> type												
<i>Chaerophyllum temulentum</i> type												
<i>Ammi</i>												
<i>Pimpinella saxifraga</i>		2			4			1	2			
<i>Torilis arvensis</i>												
<i>Peucedanum austriacum</i> type							2					
<i>Angelica sylvestris</i>						1						
<i>Bunium</i>												
<i>Anthriscus sylvestris</i> type												
<i>Pastinaca sativa</i>												
<i>Eryngium</i>								1		1		
<i>Heracleum sphondylium</i>												
<i>Anthriscus cerefolium</i>		2										
<i>Torilis japonica</i> type						1	1	1	1		2	
<i>Daucus</i>			1			1						
<i>Coriandrum</i> type												
<i>Pyrola</i>							1					
<i>Erica herbacea</i>												
<i>Vaccinium myrtillus</i>												
<i>Soldanella</i>				4			1		1	1		
<i>Androsace villosa</i>											1	
<i>Prinula</i>												
<i>Lysimachia</i>												
<i>Anagallis arvensis</i> type							1			1		
<i>Anagallis tenella</i> type							1					
<i>Asterolinon linum-stellatum</i>												
<i>Samolus valerandi</i>						2		1			1	
<i>Ameria maritima</i> type												
<i>Fraxinus excelsior</i> type			1					1				
<i>Fraxinus angustifolia</i>			1	2								
<i>Fraxinus ornus</i>	1	3			2		1				1	
<i>Ligustrum vulgare</i>												
<i>Phillyrea</i>												
<i>Centaurium</i>												
<i>Convolvulus</i>												
<i>Cuscuta epithymum</i> type												
<i>Cuscuta europaea</i> type						1						
<i>Cuscuta monogyna</i>												
<i>Calystegia</i>												
<i>Alkanna</i> type												
<i>Borago officinalis</i>												
<i>Buglossoides arvensis</i> type												
<i>Anchusa arvensis</i> type												
<i>Pulmonaria mollis</i>												
<i>Anchusa officinalis</i> type												
<i>Verbena</i>						1						
<i>Callitriche obtusangula</i>												
<i>Callitriche stagnalis</i> type												
<i>Teucrium</i>												
<i>Stachys sylvatica</i> type												
<i>Prunella</i> type												
<i>Salvia officinalis</i> type												
<i>Mentha</i> type	2	1	4	3	2	3	4				1	1
<i>Solanum dulcamara</i>												1
<i>Solanum nigrum</i> type										1		
<i>Scrophularia</i> type						1						

Kellia

Depth (cm)

	60-61	65-66	70-71	75-76	80-81	85-86	90-91	95-96	100-101	105-106	110-111	115-116
<i>Odontites</i> type												
<i>Veronica anagallis-aquatica</i> type							1					
<i>Veronica triphyllos</i> type												
<i>Pedicularis</i>				1								
<i>Putoria calabrica</i>												
<i>Sherardia arvensis</i>												
<i>Galium</i> type	2	10	4	7	4	10	4	8	2	7	7	1
<i>Plantago major</i>	13	11		9	7	1	4	2	3	3	8	4
<i>Plantago afra</i>	1		1		1					1		
<i>Plantago lanceolata</i> type	1	10	7	6	15	14	19	28	20	24	8	8
<i>Plantago coronopus</i>			1	1						1		
<i>Plantago bellardii</i>												2
<i>Plantago media</i>												
<i>Plantago argentea</i>						1		1				
<i>Plantago albicans</i>			1	1								
<i>Plantago amplexicaulis</i>												
<i>Plantago atrata</i>	1										1	
<i>Viburnum</i>												
<i>Valerianella rimosa</i> type												
<i>Valeriana officinalis</i> type												
<i>Valerianella locusta</i> type												
<i>Succisa pratensis</i>												
<i>Scabiosa columbaria</i> type												
<i>Dipsacus</i> type												
<i>Knautia</i>					1							
<i>Jasione</i>			1									
<i>Campanula erinus</i> type												
<i>Campanula rotundifolia</i>												
<i>Asyneuma</i> type												
<i>Solidago</i> type	5	5	3	5	9	11	6	9	4	5	7	8
<i>Echinops</i>												
<i>Artemisia</i>	1		2	1	2	2		2	1	1	1	1
<i>Carlina</i> type					2				1			
<i>Picnomon acarna</i>												
<i>Achillea</i> type	1				1	1						
<i>Centaurea cyanus</i> type					1							
<i>Centaurea napulifera</i> type					1							
<i>Cirsium</i> type	2	8	31	18	10	1	1	3	1	2	2	4
<i>Xanthium</i>												
<i>Centaurea solstitialis</i> type	4	3	2	5	8	10	5	5	12	5	1	15
<i>Centaurea graeca</i> type				1								
<i>Crupina</i>	1	2		2	3			2		1	1	
<i>Sonchus</i> type						7						
<i>Lactuca</i> type	4	5	6	3	9	22	8	7	5	8	10	9
<i>Scolymus</i>								2				
<i>Cichorium</i> type		11	1	4	12	7	15	15	12	12	14	9
<i>Hieracium</i> type	5	21	8	18	34	42	29	36	33	27	29	23
<i>Taraxacum</i> type	18	37	6	23	22	22	26	21	22	20	10	6
MONOCOTYLEDONES												
<i>Alisma</i>												
<i>Hydrocharis morsus-ranae</i>	1					1	1					
<i>Stratiotes aloides</i>												
<i>Vallisneria spiralis</i>												
<i>Triglochin bulbosa</i>												
<i>Potamogeton crispus</i> type												
<i>Potamogeton pectinatus</i>												
<i>Colchicum</i>												
<i>Narthecium scardicum</i>												
<i>Veratrum</i>												
<i>Asphodelus fistulosus</i> type			1									
<i>Asphodelus albus</i>												
<i>Gagea pratensis</i>												
<i>Tulipa sylvestris</i>											1	
<i>Muscari neglectum</i> type					1							
<i>Allium sphaerocephalon</i> type												
<i>Asparagus</i>												1
<i>Gynandris sisyrinchium</i>	1											
<i>Festuca</i> type	1	3	4	3	10	1	13	14	9	12	9	17
<i>Glyceria</i> type	10	10	11	11	24	14	21	13	16	24	19	7

Kellia

Depth (cm)

	60-61	65-66	70-71	75-76	80-81	85-86	90-91	95-96	100-101	105-106	110-111	115-116
<i>Dactylis</i> type	7	4	6	3	22	16	13	19	20	16	10	16
<i>Agropyron</i> type			1	2						6	3	7
<i>Triticum</i> type			3		1	1		5		2	1	
<i>Secale cereale</i>	8	6	2		1	2	4	9	6	3	5	8
<i>Hordeum</i> type		1	2		6	2	2	3	1	3	1	7
<i>Avena</i>	1	1	2	1	5	1	3	10	6	7	4	
<i>Phragmites australis</i>	2		2	4	8	5	1	1	3	10	6	8
<i>Zea mays</i>	2	2	2	2	3	4	2	3		2		
<i>Anum</i>												
<i>Sparganium erectum</i>	3		38	154	6	1	9	43	14	14	8	26
<i>Sparganium angustifolium</i>			5	5			4	35	10	11	3	8
<i>Typha angustifolia</i> type	1		1	1			5			5	1	7
<i>Typha domingensis</i> type		2		10			8	5	4		2	5
<i>Scirpus</i>	13	4	6	12	10	6	4	11	7	6	7	8
<i>Cladium mariscus</i>												
<i>Cyperus michelianus</i>	1	9	3	2		1		1			1	2
<i>Cyperus longus</i> type	17	21	25	53	28	12	20	25	20	15	9	10
<i>Schoenus nigricans</i>												6
<i>Carex hallerana</i> type	2	5	3			7			2	1		
<i>Carex flacca</i> type	2	2	5	9	2		4	1	1			1
<i>Epipactis</i> type												
<i>Cephalanthera</i>												
PTERIDOPHYTA												
<i>Equisetum</i>			1	1				1	1	1		
<i>Ophioglossum vulgatum</i>												
<i>Botrychium</i>												
<i>Adiantum capillus-veneris</i>								1				
<i>Pteridium aquilinum</i>	11	11	4	14	41	22	23	41	39	20	38	36
<i>Thelypteris palustris</i>												
<i>Thelypteris phegopteris</i>												
<i>Asplenium</i> type												
<i>Athyrium filix-femina</i>												
<i>Athyrium distentifolium</i>												1
<i>Dryopteris filix-mas</i> type												
<i>Gymnocarpium dryopteris</i>												
<i>Blechnum spicant</i>						1	4	2			1	2
<i>Polypodium</i>												
<i>Salvinia natans</i>						1	1					
Unidentified monolete spores												
TOTALS												
Indeterminate	1	5	4	3	4	18	2	6	1	3	1	2
Unknown										1		
Number of terrestrial types	43	45	48	45	48	55	44	51	43	51	48	40
Total wetland pollen & spores	55	57	107	267	82	63	84	140	79	93	60	92
Total terrestrial trees & shrubs	238	259	222	243	289	194	210	280	189	197	203	214
Total terrestrial pollen & spores (excluding bog & marsh types, aquatics, unknown & indeterminate)	343	444	359	412	585	532	465	617	438	440	424	427
Total pollen & spores	399	506	470	682	671	613	551	763	518	537	485	521
CHARCOAL												
Charcoal <25 um2	5341	16459	6976	11336	10246	15260	12753	9810	13080	6758	9810	3597
Charcoal 25-50 um2	5014	14606	4251	15260	14061	9483	9701	12753	14279	9047	10573	6758
Charcoal 50-100 um2	3924	10573	2398	9810	11445	6540	8175	13516	11445	6758	6540	5341
Charcoal 100-200 um2	2398	6104	654	5341	5559	4687	4796	5450	8611	2725	3815	2180
Charcoal 200-400 um2	1308	2725	218	1417	2507	2289	1526	2507	2834	436	1090	763
Charcoal >400 um2	436	327	109	327	2180	981	872	872	1090	218	436	218

Kellia

Depth (cm)

120-121 124-125 130-131 132-133 135-136 140-141 145-146 150-151 155-156 160-161 162-163 165-166

Absolute counts data

Slide numbers	1	1-6	1	1	1&2	1	1	1	1&2	1-3	1	1
Sample weight (g) (wet)	1.592	1.922	1.803	1.781	1.925	1.811	1.718	1.708	1.765	1.525	1.621	1.486
<i>Lycopodium</i> suspension added (ml)	0.5	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.5	0.5
<i>Lycopodium</i> count	2421	2412	3652	3217	8934	5633	4022	2824	5933	1080	2090	1952

GYMNOSPERMAE

<i>Abies</i>	4.7	.9	5.7	2.7	4.3	2.7	7.3	6.3	3.3	7.3	4.7	1.7
<i>Cedrus</i>												
<i>Pinus</i> subgenus <i>Diploxylon</i>	112.	56.6	54.7	50.	64.3	54.3	92.3	118.7	53.6	93.	115.7	117.3
<i>Juniperus</i>	50	32	17	22	28	31	49	32	32	22	26	29
<i>Taxus baccata</i>								1				
<i>Ephedra fragilis</i>						1				1		
<i>Ephedra distachya</i> type												

DICOTYLEDONES

<i>Salix triandra</i>		1	1	2		2	2	4	1	6	3	7
<i>Salix fragilis</i> type								1				
<i>Juglans regia</i>										1	2	1
<i>Alnus glutinosa</i>	1		1									
<i>Betula pendula</i>												
<i>Carpinus</i> type	2	1							1			
<i>Ostrya</i> type	8	6	5		9	5	4	7	10	7	8	4
<i>Corylus</i>							1		1			1
<i>Fagus</i>	8		1	4	1	1	2	1			2	
<i>Castanea sativa</i>	1	4	3	1					3	7	3	
<i>Quercus coccifera</i> type	16	2	15	7	2	10		4		2	1	2
<i>Quercus trojana</i> type	30	30	32	19	20	15	8	7	26	16	10	6
<i>Quercus frainetto</i> type	129	78	90	101	77	69	90	109	77	75	67	90
<i>Ulmus minor</i>			4	1								
<i>Ulmus procera</i>												
<i>Ulmus glabra</i> type												
<i>Morus nigra</i>												2
<i>Morus alba</i>												
<i>Humulus lupulus</i>												
<i>Urtica dioica</i>							2	1		2		1
<i>Urtica urens</i> type												
<i>Urtica pilulifera</i> type												
<i>Polygonum bistorta</i> type												
<i>Polygonum aviculare</i> type	34	15	33	23	12	22	387	167	63	28	45	26
<i>Bilderdykia</i>	4	1	7	14	4	3					2	2
<i>Oxyria digyna</i>												
<i>Rumex acetosella</i> group							1					
<i>Rumex acetosa</i> group	2	12	2	3	5	1	1		3	7		1
<i>Rumex crispus</i> p.p.												
<i>Rumex conglomeratus</i> group												
<i>Rumex obtusifolius</i> group	1											
Chenopodiaceae type	15	4	5	8	9	11	13	12	9	10	6	10
<i>Phytolacca americana</i>												
<i>Spergula</i>												
<i>Spergularia</i> type				1		1					1	
<i>Herniaria</i> type			1					1		1		
<i>Corrigiola litoralis</i>												
<i>Paronychia</i> type												
<i>Dianthus</i> type	1	1		1				2		1		
<i>Silene alba</i> type												
<i>Lychnis flos-cuculi</i>												
<i>Agrostemma githago</i>					2							
<i>Scleranthus annuus</i> type								1				
<i>Nymphaea alba</i>												
<i>Nuphar lutea</i>										1		
<i>Helleborus</i>												
<i>Nigella</i>							1	6				1
<i>Trollius europaeus</i>												
<i>Actaea spicata</i>								4	1			
<i>Adonis</i>				1			2	3				
<i>Caltha</i> type	2			1				1	1	1		
<i>Ranunculus acris</i> group												
<i>Ranunculus aquatilis</i> group												
<i>Anemone nemorosa</i> group												

Kellia

Depth (cm)

120-121 124-125 130-131 132-133 135-136 140-141 145-146 150-151 155-156 160-161 162-163 165-166

<i>Clematis vitalba</i> group												
<i>Thalictrum aquilegifolium</i>	2								1	1	1	
<i>Thalictrum minus</i>												
<i>Thalictrum lucidum</i>			2				1	1				
<i>Chelidonium majus</i>												
<i>Glaucium</i>												
<i>Hornungia</i> type	1	3	2				1	4		2	1	1
<i>Arabis</i>	1	2	1					1				
<i>Sinapis</i> type		1		1						4	1	1
<i>Chrysosplenium alternifolium</i>	2	2	2	1	1		7	3	3	2		
<i>Saxifraga stellaris</i>						1		2	1	2		
<i>Saxifraga oppositifolia</i> type												
<i>Platanus orientalis</i>	8	5	5	6	8	3	12	5	1	10		
<i>Filipendula</i>								2		1		
<i>Rubus</i> type												
<i>Sorbus</i> type												
<i>Cotoneaster</i> type								1				
<i>Prunus avium</i> type		2										
<i>Crataegus</i>												
<i>Sanguisorba officinalis</i>												
<i>Sanguisorba minor</i>	4		2	1	4	3		7	7	2	1	1
<i>Geum</i>												
<i>Potentilla</i>								1		1		1
<i>Alchemilla</i> type	6											
<i>Ononis</i> type	1			1								1
<i>Trifolium dubium</i> type										1	2	
<i>Trifolium repens</i> type												
<i>Lotus</i> type	1						3	1		1	1	
<i>Lathyrus pratensis</i> type												
<i>Vicia sativa</i> type												
<i>Vicia cracca</i> type										3		
<i>Astragalus</i>												
<i>Galega officinalis</i>												
<i>Dorycnium</i>												
<i>Trifolium montanum</i> type												
<i>Lathyrus sativus</i>												
<i>Oxalis</i>												
<i>Geranium robertianum</i> group												
<i>Tribulus terrestris</i>												
<i>Radiola linoides</i>											1	
<i>Linum catharticum</i>												
<i>Linum tenuifolium</i> group										1		
<i>Euphorbia</i>												
<i>Pistacia</i>												
<i>Cotinus coggygria</i>												
<i>Acer</i>												
<i>Ilex aquifolium</i>												
<i>Buxus sempervirens</i>												
<i>Frangula</i>												
<i>Rhamnus</i> type		1	1			1		1		3		
<i>Vitis vinifera</i>												
<i>Tilia platyphyllos</i>												
<i>Tilia cordata</i> type							1					
<i>Abutilon</i> type												
<i>Althaea officinalis</i>												
<i>Malva moschata</i>												
<i>Daphne</i>												
<i>Elaeagnus angustifolia</i>												
<i>Hypericum hircinum</i> type							1					2
<i>Hypericum perforatum</i> type	1	1										
<i>Viola hirta</i> type												
<i>Helianthemum</i>												
<i>Cistus monspeliensis</i> type	1											
<i>Myricaria germanica</i>												
<i>Tamarix</i>		1					1	3	2			
<i>Elatine alsinastrium</i>							2	1		1	1	
<i>Lythrum salicaria</i> type												
<i>Lythrum portula</i>												
<i>Trapa natans</i>												
<i>Myrtus communis</i>												

Kellia

Depth (cm)

120-121 124-125 130-131 132-133 135-136 140-141 145-146 150-151 155-156 160-161 162-163 165-166

<i>Ludwigia palustris</i>											1	
<i>Epilobium angustifolium</i> type												
<i>Epilobium hirsutum</i> type												
<i>Myriophyllum verticillatum</i>								1				
<i>Myriophyllum spicatum</i>				3								
<i>Cornus mas</i>				2	3	1	2	1				
<i>Hydrocotyle vulgaris</i>		3	1	1	1	2	1	2		1	2	
<i>Anthriscus caucalis</i>												
<i>Ligusticum</i>												
<i>Berula erecta</i>		1	3	5	1	2	1	1		5	1	1
<i>Trinia</i>		1										
<i>Sanicula europaea</i>												
<i>Oenanthe aquatica</i> group												
<i>Oenanthe pimpinelloides</i> group												
<i>Chaerophyllum hirsutum</i> type												
<i>Chaerophyllum temulentum</i> type												
<i>Ammi</i>												
<i>Pimpinella saxifraga</i>	1			2		1	1	3	1	2	1	
<i>Torilis arvensis</i>										1		
<i>Peucedanum austriacum</i> type												
<i>Angelica sylvestris</i>					1							
<i>Bunium</i>												
<i>Anthriscus sylvestris</i> type												
<i>Pastinaca sativa</i>				1								
<i>Eryngium</i>										1		1
<i>Heracleum sphondylium</i>												
<i>Anthriscus cerefolium</i>										1		
<i>Torilis japonica</i> type	1			1				1				
<i>Daucus</i>					1		1		2	4	16	1
<i>Coriandrum</i> type												
<i>Pyrola</i>										2		
<i>Erica herbacea</i>										1		
<i>Vaccinium myrtillus</i>	1		1									1
<i>Soldanella</i>		3	5	2					3	1	3	
<i>Androsace villosa</i>				1								
<i>Primula</i>												
<i>Lysimachia</i>												
<i>Anagallis arvensis</i> type						1				2		
<i>Anagallis tenella</i> type	1											
<i>Asterolinon linum-stellatum</i>	3	1			1					4		1
<i>Samolus valerandi</i>		2			1							2
<i>Ammeria maritima</i> type												
<i>Fraxinus excelsior</i> type					1							
<i>Fraxinus angustifolia</i>					2					1		
<i>Fraxinus ornus</i>	2		2	1		1	3			4		3
<i>Ligustrum vulgare</i>										3		
<i>Phillyrea</i>												
<i>Centaureum</i>												
<i>Convolvulus</i>												
<i>Cuscuta epithymum</i> type							3	4	1	4	1	1
<i>Cuscuta europaea</i> type					1		1		1	2	1	
<i>Cuscuta monogyna</i>									1			
<i>Calystegia</i>												
<i>Alkanna</i> type												
<i>Borago officinalis</i>												
<i>Buglossoides arvensis</i> type									1			
<i>Anchusa arvensis</i> type												
<i>Pulmonaria mollis</i>						1						
<i>Anchusa officinalis</i> type												
<i>Verbena</i>												
<i>Callitriche obtusangula</i>												
<i>Callitriche stagnalis</i> type												
<i>Teucrium</i>					1							
<i>Stachys sylvatica</i> type												
<i>Prunella</i> type	1											
<i>Salvia officinalis</i> type												
<i>Mentha</i> type	1	3	3	2		4	1	6	1	3	1	1
<i>Solanum dulcamara</i>			1									
<i>Solanum nigrum</i> type	1					1						
<i>Scrophularia</i> type									1	1		

Kellia

Depth (cm)

120-121 124-125 130-131 132-133 135-136 140-141 145-146 150-151 155-156 160-161 162-163 165-166

<i>Odontites</i> type										1		
<i>Veronica anagallis-aquatica</i> type												
<i>Veronica triphyllos</i> type												
<i>Pedicularis</i>												
<i>Putoria calabrica</i>												
<i>Sherardia arvensis</i>												
<i>Galium</i> type	3	7	8	5	8	4	6	10	16	9	3	1
<i>Plantago major</i>	6	5	5	9				10	2	10	4	2
<i>Plantago afra</i>	1			1					3	1		
<i>Plantago lanceolata</i> type	12	14	14	8	11	9	14	35	20	29	9	6
<i>Plantago coronopus</i>												
<i>Plantago bellardii</i>								1				
<i>Plantago media</i>		1			1		4	3		4		2
<i>Plantago argentea</i>						1	1	1				
<i>Plantago albicans</i>							1	1		3		
<i>Plantago amplexicaulis</i>							4					
<i>Plantago atrata</i>												
<i>Viburnum</i>						1						
<i>Valerianella rimosa</i> type												
<i>Valeriana officinalis</i> type												
<i>Valerianella locusta</i> type												
<i>Succisa pratensis</i>				1		1						
<i>Scabiosa columbaria</i> type												
<i>Dipsacus</i> type	1											
<i>Knautia</i>								2				
<i>Jasione</i>												
<i>Campanula erinus</i> type												
<i>Campanula rotundifolia</i>												
<i>Asyneuma</i> type												
<i>Solidago</i> type	11	13	26	11	10	5	16	13	46	9	9	2
<i>Echinops</i>												
<i>Artemisia</i>	4			3		1				4	1	2
<i>Carlina</i> type					2	1						2
<i>Picnemon acarna</i>												
<i>Achillea</i> type								1	7	1		
<i>Centaurea cyanus</i> type		10						1	1			
<i>Centaurea napulifera</i> type												
<i>Cirsium</i> type	9	7	6	9	3	2	5	18	9	25	7	34
<i>Xanthium</i>												
<i>Centaurea solstitialis</i> type	10	4	7	11	14	12	8	14	24	15	8	10
<i>Centaurea graeca</i> type				1	1		1					1
<i>Crepina</i>	1				2			1		1		1
<i>Sonchus</i> type		8			7		20	24	21	11	11	5
<i>Lactuca</i> type	4	2	12	12	8	11	13	14	19	5	3	10
<i>Scolymus</i>		1										
<i>Cichorium</i> type	10	9	14	15	5	17	8	19	15	7	15	11
<i>Hieracium</i> type	23	32	18	33	39	23	15	27	54	25	15	6
<i>Taraxacum</i> type	21	17	22	18	26	24	23	24	8	12	14	7

MONOCOTYLEDONES

<i>Alisma</i>	1											
<i>Hydrocharis morsus-ranae</i>				2								
<i>Stratiotes aloides</i>						1						
<i>Vallisneria spiralis</i>												
<i>Triglochin bulbosa</i>												
<i>Potamogeton crispus</i> type												
<i>Potamogeton pectinatus</i>												
<i>Colchicum</i>												
<i>Narthecium scardicum</i>												
<i>Veratrum</i>												
<i>Asphodelus fistulosus</i> type												
<i>Asphodelus albus</i>												
<i>Gagea pratensis</i>												
<i>Tulipa sylvestris</i>									1			
<i>Muscari neglectum</i> type												
<i>Allium sphaerocephalon</i> type					1							
<i>Asparagus</i>												
<i>Gynandrisis sisyrinchium</i>												
<i>Festuca</i> type	21	1	17	14	17	11	13	11	8	6	10	6
<i>Glyceria</i> type	28	55	33	35	37	38	48	25	35	55	22	34

Kellia

Depth (cm)

	120-121	124-125	130-131	132-133	135-136	140-141	145-146	150-151	155-156	160-161	162-163	165-166
<i>Dactylis</i> type	22	45	18	18	15	2	33	17	36	49	9	11
<i>Agropyron</i> type	3		7	8	5	3	2	8	1	2	4	1
<i>Triticum</i> type					1				1			
<i>Secale cereale</i>	11	4	8	5	1	2	5	8	2	1	6	1
<i>Hordeum</i> type	4	1	13	3	3	7	4	6	1	1	6	3
<i>Avena</i>	5	12	5		3	1	4	3	4	1	4	4
<i>Phragmites australis</i>	5	7	3	22	4	4	9	3	4	8	2	2
<i>Zea mays</i>	3	1	5	4		1	3	5		1	1	1
<i>Anon</i>												
<i>Sparganium erectum</i>	8	11	1	2	4		15	2	3	17		6
<i>Sparganium angustifolium</i>	1	1								2	1	
<i>Typha angustifolia</i> type							1			41		
<i>Typha domingensis</i> type							2	1		1		
<i>Scirpus</i>	11	12	14	15	15	7	7	7	18	35	34	170
<i>Cladium mariscus</i>		1										
<i>Cyperus michelianus</i>		12		1		1		2	1	6		2
<i>Cyperus longus</i> type	13	20	11	10	4	6	1	1	3	5	4	5
<i>Schoenus nigricans</i>	1	2					18	10	6	14	7	60
<i>Carex hallerana</i> type		7			7	2	1	13	13	37	15	4
<i>Carex flacca</i> type	9	22	1	2	1				3	12	3	2
<i>Epipactis</i> type												
<i>Cephalanthera</i>												
PTERIDOPHYTA												
<i>Equisetum</i>			1	6	2	2			4			2
<i>Ophioglossum vulgatum</i>												
<i>Botrychium</i>												
<i>Adiantum capillus-veneris</i>												
<i>Pteridium aquilinum</i>	42	14	23	24	37	29	42	16	23	36	13	9
<i>Thelypteris palustris</i>												
<i>Thelypteris phegopteris</i>												
<i>Asplenium</i> type												
<i>Athyrium filix-femina</i>												
<i>Athyrium distentifolium</i>												
<i>Dryopteris filix-mas</i> type												
<i>Gymnocarpium dryopteris</i>				1								
<i>Blechnum spicant</i>	1			2		1		1	2	2	1	
<i>Polypodium</i>											1	
<i>Salvinia natans</i>												
Unidentified monolete spores												
TOTALS												
Indeterminate	1	20	2	7	6	4	8	12	8	22	4	2
Unknown												
Number of terrestrial types	56	47	45	50	45	46	52	61	50	71	48	53
Total wetland pollen & spores	84	161	73	109	79	71	114	86	96	250	95	291
Total terrestrial trees & shrubs	374	221	238	219	220	198	276	301	211	259	242	267
Total terrestrial pollen & spores (excluding bog & marsh types, aquatics, unknown & indeterminate)	682	474	527	495	480	410	939	815	630	620	479	455
Total pollen & spores	767	655	602	611	565	485	1061	913	734	892	578	748
CHARCOAL												
Charcoal <25 um2	8611	25179	10791	7412	18421	10791	23871	14606	18530	13298	8502	7630
Charcoal 25-50 um2	10246	15914	15478	10355	22345	12099	17876	11227	21909	7848	9265	10028
Charcoal 50-100 um2	6104	8284	8720	10028	13734	9592	10355	9047	15260	6976	6431	5014
Charcoal 100-200 um2	3052	4251	5450	7630	5450	5450	6867	4142	8611	2071	3270	2507
Charcoal 200-400 um2	981	1308	1635	3815	2180	2180	3270	1744	4033	981	1199	545
Charcoal >400 um2	436	981	1417	1744	1962	1635	872	1199	1853	545		218

Kellia

Depth (cm)

170-171 175-176 180-181 185-186 190-191 195-196 197-198 200-201 205-206 210-211 214-215 220-221

Absolute counts data

Slide numbers	1&2	1	1	1	1	1	1	1	1	1	1	1
Sample weight (g) (wet)	1.620	1.396	1.519	1.655	1.667	1.659	1.665	1.554	1.780	1.651	1.774	1.506
<i>Lycopodium</i> suspension added (ml)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
<i>Lycopodium</i> count	4793	2475	2623	2379	1785	2080	1935	2666	2862	2073	2611	3316

GYMNOSPERMAE

<i>Abies</i>	4.	3.7	3.7	4.7	4.7	3.3	7.	6.7	1.3	1.7	1.3	6.3
<i>Cedrus</i>												
<i>Pinus</i> subgenus <i>Diploxylon</i>	93.7	128.3	123.3	132.	112.	124.3	122.3	104.7	132.3	107.	79.7	126.3
<i>Juniperus</i>	27	16	20	33	16	15	21	14	7	16	9	6
<i>Taxus baccata</i>								1				
<i>Ephedra fragilis</i>			1		2	2	1	1				
<i>Ephedra distachya</i> type												

DICOTYLEDONES

<i>Salix triandra</i>	4	1		1	2	8	2		2	1	3	3
<i>Salix fragilis</i> type												
<i>Juglans regia</i>												1
<i>Alnus glutinosa</i>	2								1		1	
<i>Betula pendula</i>												
<i>Carpinus</i> type	2								1			
<i>Ostrya</i> type	2	3	4		8	2	5	4	1	4	2	3
<i>Corylus</i>		1	1					1				
<i>Fagus</i>	2	1		4	1		1					1
<i>Castanea sativa</i>	3	2	2	4		5	1	2	1	3	2	2
<i>Quercus coccifera</i> type			2			3	3	1	1		4	
<i>Quercus trojana</i> type	11	15	11	9	14	9	15	7	39	31	41	53
<i>Quercus frainetto</i> type	67	74	44	29	40	61	41	46	49	53	64	110
<i>Ulmus minor</i>	1											
<i>Ulmus procera</i>												1
<i>Ulmus glabra</i> type												
<i>Morus nigra</i>	3									1		
<i>Morus alba</i>												
<i>Humulus lupulus</i>			1									
<i>Urtica dioica</i>									1	2	1	2
<i>Urtica urens</i> type												
<i>Urtica pilulifera</i> type												
<i>Polygonum bistorta</i> type												1
<i>Polygonum aviculare</i> type	60	9	18	24	17	18	24	33	29	21	33	70
<i>Bilderdykia</i>	6	5	3	9	3	4		10		2	10	5
<i>Oxyria digyna</i>												
<i>Rumex acetosella</i> group												
<i>Rumex acetosa</i> group		1	5	1	1	1		1	2	1	2	1
<i>Rumex crispus</i> p.p.		1	1									
<i>Rumex conglomeratus</i> group			1		1							
<i>Rumex obtusifolius</i> group												
Chenopodiaceae type	13	26	71	126	49	46	25	6	9	7	9	13
<i>Phytolacca americana</i>												
<i>Spergula</i>												
<i>Spergularia</i> type											1	
<i>Herniaria</i> type												
<i>Corrigiola litoralis</i>												
<i>Paronychia</i> type		1						1				
<i>Dianthus</i> type	3		2	1			1					2
<i>Silene alba</i> type												
<i>Lychnis flos-cuculi</i>												
<i>Agrostemma githago</i>						1						
<i>Scleranthus annuus</i> type	1											
<i>Nymphaea alba</i>												
<i>Nuphar lutea</i>												
<i>Helleborus</i>		4										
<i>Nigella</i>					1		1					
<i>Trollius europaeus</i>			1									
<i>Actaea spicata</i>		2										1
<i>Adonis</i>						1						
<i>Caltha</i> type	2						1					3
<i>Ranunculus acris</i> group												1
<i>Ranunculus aquatilis</i> group										2	3	3
<i>Anemone nemorosa</i> group												

Kellia

Depth (cm)

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<i>Clematis vitalba</i> group											
<i>Thalictrum aquilegifolium</i>	1	1	2	2	1	2		1	1	2	
<i>Thalictrum minus</i>											
<i>Thalictrum lucidum</i>	1									1	
<i>Chelidonium majus</i>											1
<i>Glaucium</i>											
<i>Homungia</i> type		2	2	1		1	1			2	
<i>Arabis</i>						1	1			1	
<i>Sinapis</i> type	1					3	2	1	4	4	2
<i>Chrysosplenium alternifolium</i>			3		1	5				2	7
<i>Saxifraga stellaris</i>		1	1			1	2				
<i>Saxifraga oppositifolia</i> type											
<i>Platanus orientalis</i>	1		5	1	2	3	2	1	2	2	5
<i>Filipendula</i>											
<i>Rubus</i> type											
<i>Sorbus</i> type											1
<i>Cotoneaster</i> type											
<i>Prunus avium</i> type											
<i>Crataegus</i>			1								
<i>Sanguisorba officinalis</i>											
<i>Sanguisorba minor</i>	1		1		4	3	1		3	1	4
<i>Geum</i>											
<i>Potentilla</i>							8				
<i>Alchemilla</i> type											
<i>Ononis</i> type		1		1	1		1				
<i>Trifolium dubium</i> type			1					2	3	1	2
<i>Trifolium repens</i> type											
<i>Lotus</i> type	1						1			1	
<i>Lathyrus pratensis</i> type											
<i>Vicia sativa</i> type							1				
<i>Vicia cracca</i> type										1	1
<i>Astragalus</i>											
<i>Galega officinalis</i>				1							
<i>Dorycnium</i>											
<i>Trifolium montanum</i> type											
<i>Lathyrus sativus</i>											
<i>Oxalis</i>											
<i>Geranium robertianum</i> group											6
<i>Tribulus terrestris</i>											
<i>Radiola linoides</i>											
<i>Linum catharticum</i>			1								
<i>Linum tenuifolium</i> group											
<i>Euphorbia</i>											
<i>Pistacia</i>											
<i>Cotinus coggygria</i>			1								
<i>Acer</i>											
<i>Ilex aquifolium</i>											1
<i>Buxus sempervirens</i>											
<i>Frangula</i>							1				
<i>Rhamnus</i> type											1
<i>Vitis vinifera</i>											
<i>Tilia platyphyllos</i>		1									
<i>Tilia cordata</i> type											
<i>Abutilon</i> type											
<i>Althaea officinalis</i>											
<i>Malva moschata</i>											
<i>Daphne</i>											
<i>Elaeagnus angustifolia</i>											
<i>Hypericum hircinum</i> type							1				
<i>Hypericum perforatum</i> type			1			1	2			1	
<i>Viola hirta</i> type											
<i>Helianthemum</i>											
<i>Cistus monspeliensis</i> type											
<i>Myricaria germanica</i>											
<i>Tanarix</i>	1					1	1	1	5	1	4
<i>Elatine alsinastrum</i>			1	1	2	1					1
<i>Lythrum salicaria</i> type											
<i>Lythrum portula</i>					1						
<i>Trapa natans</i>											
<i>Myrtus communis</i>											

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Depth (cm)

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<i>Ludwigia palustris</i>					1							
<i>Epilobium angustifolium</i> type												
<i>Epilobium hirsutum</i> type												
<i>Myriophyllum verticillatum</i>												
<i>Myriophyllum spicatum</i>												
<i>Cornus mas</i>	1	1		1								
<i>Hydrocotyle vulgaris</i>		1					1	1	1			1
<i>Anthriscus caucalis</i>												
<i>Ligusticum</i>												
<i>Berula erecta</i>	3		1	1	3		4	1	2	1		
<i>Trinia</i>												
<i>Sanicula europaea</i>							1					
<i>Oenanthe aquatica</i> group												
<i>Oenanthe pimpinelloides</i> group												
<i>Chaerophyllum hirsutum</i> type							1					
<i>Chaerophyllum temulentum</i> type												
<i>Ammi</i>							2					
<i>Pimpinella saxifraga</i>							2					
<i>Torilis arvensis</i>												
<i>Peucedanum austriacum</i> type							1					
<i>Angelica sylvestris</i>												
<i>Bunium</i>												
<i>Anthriscus sylvestris</i> type												
<i>Pastinaca sativa</i>												
<i>Eryngium</i>			1					1				
<i>Heracleum sphondylium</i>				2								
<i>Anthriscus cerefolium</i>		1					1					
<i>Torilis japonica</i> type				1			1					
<i>Daucus</i>	1		1	4	3	1				1	1	2
<i>Coriandrum</i> type												
<i>Pyrola</i>												
<i>Erica herbacea</i>												
<i>Vaccinium myrtillus</i>												
<i>Soldanella</i>			1	2	2	1		3		1		
<i>Androsace villosa</i>												
<i>Primula</i>											1	
<i>Lysimachia</i>												
<i>Anagallis arvensis</i> type			1					1	1		1	
<i>Anagallis tenella</i> type												
<i>Asterolinon linum-stellatum</i>			1					1	2		2	1
<i>Samolus valerandi</i>	1			1	2	1	2					
<i>Armeria maritima</i> type												
<i>Fraxinus excelsior</i> type						1						
<i>Fraxinus angustifolia</i>			1				2	1			1	1
<i>Fraxinus ornus</i>		3	2			2	2	1	2			7
<i>Ligustrum vulgare</i>												
<i>Phillyrea</i>		1										
<i>Centaureum</i>												
<i>Convolvulus</i>		1										
<i>Cuscuta epithymum</i> type		3									3	1
<i>Cuscuta europaea</i> type	1	2					2			1	1	6
<i>Cuscuta monogyna</i>												
<i>Calystegia</i>												
<i>Alkanna</i> type					1							
<i>Borago officinalis</i>												
<i>Buglossoides arvensis</i> type												
<i>Anchusa arvensis</i> type				1								
<i>Pulmonaria mollis</i>												2
<i>Anchusa officinalis</i> type												2
<i>Verbena</i>										1		1
<i>Callitriche obtusangula</i>						1						
<i>Callitriche stagnalis</i> type												
<i>Teucrium</i>			1									
<i>Stachys sylvatica</i> type												
<i>Prunella</i> type		1										
<i>Salvia officinalis</i> type										2		
<i>Mentha</i> type	2	2		1	2	4	4	3	25	5	7	
<i>Solanum dulcamara</i>						1						
<i>Solanum nigrum</i> type												
<i>Scrophularia</i> type	1	1	2	1	2			1		4	1	

Kellia

Depth (cm)

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<i>Odontites</i> type												
<i>Veronica anagallis-aquatica</i> type												
<i>Veronica triphyllos</i> type												
<i>Pedicularis</i>										1		
<i>Putoria calabrica</i>				1								
<i>Sherardia arvensis</i>				2								2
<i>Galium</i> type	5	7	7	8		11	4	1	1	2	3	5
<i>Plantago major</i>	4	2	1			3	1	1	2		1	1
<i>Plantago afra</i>							2		1	1	2	
<i>Plantago lanceolata</i> type	10	3	12	14	7	1	9	6	8	8	9	10
<i>Plantago coronopus</i>	1		2					1				
<i>Plantago bellardii</i>												
<i>Plantago media</i>	1							1	1	1		2
<i>Plantago argentea</i>		1	2									
<i>Plantago albicans</i>								1				
<i>Plantago amplexicaulis</i>												
<i>Plantago atrata</i>												
<i>Viburnum</i>												
<i>Valerianella rimosa</i> type								1				
<i>Valeriana officinalis</i> type												
<i>Valerianella locusta</i> type												
<i>Succisa pratensis</i>	2								1	1		
<i>Scabiosa columbaria</i> type												
<i>Dipsacus</i> type												
<i>Knautia</i>												
<i>Jasione</i>									1	1		
<i>Campanula erinus</i> type												
<i>Campanula rotundifolia</i>												
<i>Asyneuma</i> type												
<i>Solidago</i> type	9	11	11	22		8	12	11	12	9	15	7
<i>Echinops</i>												
<i>Artemisia</i>			1		1		1	1	1			
<i>Carlina</i> type			1	1	1							
<i>Picnemon acarna</i>	2											
<i>Achillea</i> type	1			1						1		
<i>Centaurea cyanus</i> type	1			1					1		1	
<i>Centaurea napulifera</i> type												
<i>Cirsium</i> type	2	4	9	15	8	8	17	25	11	13	14	7
<i>Xanthium</i>												
<i>Centaurea solstitialis</i> type	6	7	8	9	6	7	14	6	8	15	23	19
<i>Centaurea graeca</i> type	2		3		2		1			2	5	
<i>Crupina</i>		1	1	1	1		2	8				
<i>Sonchus</i> type	13	6	15	22	20	21	19	15	7	13	2	4
<i>Lactuca</i> type	14	12	21	33	37	24	13	22	8	10	17	9
<i>Scolymus</i>			1									
<i>Cichorium</i> type	16	18	24	16	17	10	30	8	6	2	5	5
<i>Hieracium</i> type	23	19	27	35	26	38	36	21	42	47	68	54
<i>Taraxacum</i> type	11	17	26	44	21	19	20	18	20	15	10	13

MONOCOTYLEDONES

<i>Alisma</i>												
<i>Hydrocharis morsus-ranae</i>	1	1						1				
<i>Stratiotes aloides</i>	7											2
<i>Vallisneria spiralis</i>												
<i>Triglochin bulbosa</i>												
<i>Potamogeton crispus</i> type												
<i>Potamogeton pectinatus</i>												
<i>Colchicum</i>												
<i>Nartheicum scardicum</i>												
<i>Veratrum</i>												
<i>Asphodelus fistulosus</i> type												
<i>Asphodelus albus</i>						1						
<i>Gagea pratensis</i>												
<i>Tulipa sylvestris</i>												
<i>Muscari neglectum</i> type												
<i>Allium sphaerocephalon</i> type												
<i>Asparagus</i>						2						4
<i>Gynandriris sisyrinchium</i>												
<i>Festuca</i> type	31	12	8	6	5	11	11	11	6	8	12	15
<i>Glyceria</i> type	78	43	72	58	41	54	57	65	30	32	37	14

Kellia

Depth (cm)

	170-171	175-176	180-181	185-186	190-191	195-196	197-198	200-201	205-206	210-211	214-215	220-221
<i>Dactylis</i> type	57	29	36	17	9	11	12	21	29	22	18	21
<i>Agropyron</i> type	9	7	8	9	12	7	13	4		1	1	3
<i>Triticum</i> type							1					
<i>Secale cereale</i>	9	10	12	13	17	22	19	8	6	6	4	5
<i>Hordeum</i> type	2	4	4	14	15	17	10	12		2		2
<i>Avena</i>	5	3	6	12	12	15	12	8	3	6	1	5
<i>Phragmites australis</i>	38	5	9	15	12	2	13	4	2	1	3	4
<i>Zea mays</i>	1		3	9	8	4	6	5	1			
<i>Arum</i>												
<i>Sparganium erectum</i>	6	4	5	20	14	25	9	20	3	2	1	6
<i>Sparganium angustifolium</i>		3		2		1	3					
<i>Typha angustifolia</i> type	1						4		4			
<i>Typha domingensis</i> type												
<i>Scirpus</i>	82	168	136	128	88	113	100	129	118	140	58	415
<i>Cladium mariscus</i>												
<i>Cyperus michelianus</i>	6	1		8	4	2	4		14	18	7	32
<i>Cyperus longus</i> type	2	4	23	19	17	25	16	32				
<i>Schoenus nigricans</i>	36	56	34	33	38	13	34	22				
<i>Carex hallerana</i> type	8		2	1	3	4	7	5	73	74	53	176
<i>Carex flacca</i> type	3	5	11	10	14	13	3	9				
<i>Epipactis</i> type												
<i>Cephalanthera</i>												
PTERIDOPHYTA												
<i>Equisetum</i>	3	9	8	19	13	22	12	34	56	8	5	2
<i>Ophioglossum vulgatum</i>											1	
<i>Botrychium</i>												
<i>Adiantum capillus-veneris</i>												
<i>Pteridium aquilinum</i>	11	9	22	34	22	23	29	14	13	16	13	10
<i>Thelypteris palustris</i>												
<i>Thelypteris phegopteris</i>												
<i>Asplenium</i> type												
<i>Athyrium filix-femina</i>											1	
<i>Athyrium distentifolium</i>												
<i>Dryopteris filix-mas</i> type												
<i>Gymnocarpium dryopteris</i>												
<i>Blechnum spicant</i>	1		1	1	1		2		2		1	1
<i>Polypodium</i>												
<i>Salvinia natans</i>												
Unidentified monoete spores												
TOTALS												
Indeterminate	7	3	4	4	3	4	7	7	4	3	2	9
Unknown												
Number of terrestrial types	53	52	62	49	44	45	62	57	46	48	58	62
Total wetland pollen & spores	279	303	306	320	254	279	281	329	307	304	175	674
Total terrestrial trees & shrubs	225	251	222	220	202	239	226	194	241	225	214	333
Total terrestrial pollen & spores (excluding bog & marsh types, aquatics, unknown & indeterminate)	561	496	609	736	536	581	604	489	479	477	524	664
Total pollen & spores	847	802	919	1060	793	864	892	825	790	784	701	1347
CHARCOAL												
Charcoal <25 um2	21691	7630	15805	15805	8720	12317	13625	10682	9701	7194	8175	12644
Charcoal 25-50 um2	21364	8502	17658	17658	13843	20274	18312	14061	16241	17876	15914	19184
Charcoal 50-100 um2	9919	5232	9483	9483	7848	8175	8611	7303	11445	10355	10137	10246
Charcoal 100-200 um2	4033	1962	2725	2725	4469	4033	3488	3379	4033	2289	3270	3815
Charcoal 200-400 um2	654	109	436	436	981	872	981	545	981	1090	327	654
Charcoal >400 um2	109	327	109	109	218	218	545	218	327	218	109	327

Kellia

Depth (cm)

225-226 230-231 235-236 240-241 245-246 250-251 255-256 260-261 265-266 270-271 275-276 280-281

Absolute counts data

Slide numbers	1	1	1	1-3	1-3	1&2	1-3	1-5	1&2	1-5	1	1&2
Sample weight (g) (wet)	1.601	1.536	1.672	1.758	1.774	1.806	1.789	1.834	1.666	1.918	1.787	1.762
<i>Lycopodium</i> suspension added (ml)	0.5	0.5	0.5	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
<i>Lycopodium</i> count	2422	1445	1634	1266	11681	7419	8113	18673	6713	19845	3836	3359

GYMNOSPERMAE

<i>Abies</i>	5.3		1.3	.3	2.4	.3	1.3	2.	2.3	3.2	3.	2.4
<i>Cedrus</i>												
<i>Pinus</i> subgenus <i>Diploxylon</i>	81.7	69.7	57.7	78.4	59.6	38.3	53.	56.4	77.6	51.3	49.7	78.
<i>Juniperus</i>	10	4	5	5	2	2	12	4	2	6	1	8
<i>Taxus baccata</i>				1								
<i>Ephedra fragilis</i>	1	1			1			2	1			1
<i>Ephedra distachya</i> type			1									

DICOTYLEDONES

<i>Salix triandra</i>	2	2		1	2		2	2	1			
<i>Salix fragilis</i> type												
<i>Juglans regia</i>	3	1	1	1	1		2	1		1	2	
<i>Alnus glutinosa</i>			2		2	2		1	2	2		
<i>Betula pendula</i>												
<i>Carpinus</i> type	1							2	1			
<i>Ostrya</i> type	3	2	8	11	7	14	7	9	15	8	2	2
<i>Corylus</i>		1	1	2	4	1		1		1	6	1
<i>Fagus</i>			1				2		1			1
<i>Castanea sativa</i>	1	2		5	2	1	3	2	4	1	3	
<i>Quercus coccifera</i> type	2			2		8	3	2	2	2	1	4
<i>Quercus trojana</i> type	34	35	41	46	61	56	47	45	23	46	88	88
<i>Quercus frainetto</i> type	64	85	75	68	82	66	72	81	65	79	65	69
<i>Ulmus minor</i>					1							
<i>Ulmus procera</i>												
<i>Ulmus glabra</i> type												
<i>Morus nigra</i>											1	
<i>Morus alba</i>												
<i>Humulus lupulus</i>												
<i>Urtica dioica</i>	1	1	3		1		1	3	2	2		
<i>Urtica urens</i> type					1							
<i>Urtica pilulifera</i> type										1		
<i>Polygonum bistorta</i> type												
<i>Polygonum aviculare</i> type	41	53	27	38	22	16	26	16	22	14	49	32
<i>Bilderdykia</i>	11	5	10	2	9		2			5	8	2
<i>Oxyria digyna</i>			1									
<i>Rumex acetosella</i> group					1							
<i>Rumex acetosa</i> group	1	1	4	4	3		2	11	2	2	3	4
<i>Rumex crispus</i> p.p.												
<i>Rumex conglomeratus</i> group												
<i>Rumex obtusifolius</i> group												
Chenopodiaceae type	9	8	45	8	10	10	10	8	4	11	6	2
<i>Phytolacca americana</i>												
<i>Spergula</i>												
<i>Spergularia</i> type								1				
<i>Hemiaria</i> type												
<i>Corrigiola litoralis</i>									1			
<i>Paronychia</i> type												
<i>Dianthus</i> type	4		1						2	2	1	2
<i>Silene alba</i> type					1							
<i>Lychnis flos-cuculi</i>												
<i>Agrostemma githago</i>					1							
<i>Scleranthus annuus</i> type												
<i>Nymphaea alba</i>												
<i>Nuphar lutea</i>			1									
<i>Helleborus</i>												
<i>Nigella</i>	1				2				1			
<i>Trollius europaeus</i>												
<i>Actaea spicata</i>					1			1				
<i>Adonis</i>												
<i>Caltha</i> type		1								1		2
<i>Ranunculus acris</i> group		3										
<i>Ranunculus aquatilis</i> group	1	4	2		1		2	1	2			
<i>Anemone nemorosa</i> group												

Kellia

Depth (cm)

225-226 230-231 235-236 240-241 245-246 250-251 255-256 260-261 265-266 270-271 275-276 280-281

<i>Clematis vitalba</i> group												
<i>Thalictrum aquilegifolium</i>			2		2				1		1	
<i>Thalictrum minus</i>		1										
<i>Thalictrum lucidum</i>					2	2			1			
<i>Chelidonium majus</i>												
<i>Glaucium</i>												
<i>Hornungia</i> type	2	4	1	3	1		2	2				3
<i>Arabis</i>	2	1		4	1		1		1			2
<i>Sinapis</i> type	2		1	4	1	2						2
<i>Chrysosplenium alternifolium</i>	3		1	4	1	3			2	1		3
<i>Saxifraga stellaris</i>		1					1	2				1
<i>Saxifraga oppositifolia</i> type												
<i>Platanus orientalis</i>	8	3		3	1	3	3	3	2	3		3
<i>Filipendula</i>												
<i>Rubus</i> type									1			
<i>Sorbus</i> type												
<i>Cotoneaster</i> type												
<i>Prunus avium</i> type												
<i>Crataegus</i>												
<i>Sanguisorba officinalis</i>												
<i>Sanguisorba minor</i>	4	6	2	3	2	2		2	3	2	3	4
<i>Geum</i>												
<i>Potentilla</i>			3									
<i>Alchemilla</i> type												1
<i>Ononis</i> type						1			1	1		
<i>Trifolium dubium</i> type	4	4	2		2		4	12	1		1	1
<i>Trifolium repens</i> type										1		
<i>Lotus</i> type	1	1			2	4	1		1		1	1
<i>Lathyrus pratensis</i> type												
<i>Vicia sativa</i> type												
<i>Vicia cracca</i> type	2							1	1			
<i>Astragalus</i>				2								
<i>Galega officinalis</i>						1						1
<i>Dorycnium</i>												
<i>Trifolium montanum</i> type												
<i>Lathyrus sativus</i>												
<i>Oxalis</i>												
<i>Geranium robertianum</i> group	1	1										
<i>Tribulus terrestris</i>		1										
<i>Radiola linoides</i>												
<i>Linum catharticum</i>												
<i>Linum tenuifolium</i> group												
<i>Euphorbia</i>												
<i>Pistacia</i>												1
<i>Cotinus coggygria</i>												
<i>Acer</i>					1							
<i>Ilex aquifolium</i>						1						
<i>Buxus sempervirens</i>		2						1				
<i>Frangula</i>								1				
<i>Rhamnus</i> type		1							1			
<i>Vitis vinifera</i>	3			1			1	1				
<i>Tilia platyphyllos</i>												
<i>Tilia cordata</i> type							1					
<i>Abutilon</i> type												
<i>Althaea officinalis</i>												
<i>Malva moschata</i>								1				
<i>Daphne</i>												
<i>Elaeagnus angustifolia</i>												
<i>Hypericum hircinum</i> type									1			
<i>Hypericum perforatum</i> type								2				
<i>Viola hirta</i> type												1
<i>Helianthemum</i>					1							
<i>Cistus monspeliensis</i> type												
<i>Myricaria germanica</i>				1			1					2
<i>Tamarix</i>	5	1		1		1		2		1		4
<i>Elatine alsinistrum</i>		3	2	6							1	
<i>Lythrum salicaria</i> type												
<i>Lythrum portula</i>												
<i>Trapa natans</i>												
<i>Myrtus communis</i>												

Kellia

Depth (cm)

225-226 230-231 235-236 240-241 245-246 250-251 255-256 260-261 265-266 270-271 275-276 280-281

<i>Ludwigia palustris</i>												
<i>Epilobium angustifolium</i> type												
<i>Epilobium hirsutum</i> type												
<i>Myriophyllum verticillatum</i>												
<i>Myriophyllum spicatum</i>												
<i>Cornus mas</i>				1					1			
<i>Hydrocotyle vulgaris</i>		1	2	7	2	2		2	1	4		2
<i>Anthriscus caucalis</i>												
<i>Ligusticum</i>												
<i>Berula erecta</i>					3			1	2		3	3
<i>Trinia</i>					1							
<i>Sanicula europaea</i>												
<i>Oenanthe aquatica</i> group					1							
<i>Oenanthe pimpinelloides</i> group												
<i>Chaerophyllum hirsutum</i> type				1								
<i>Chaerophyllum temulentum</i> type												
<i>Ammi</i>			1	1	1	1						
<i>Pimpinella saxifraga</i>	1			2		1	1		2	1	3	
<i>Torilis arvensis</i>						1					1	
<i>Peucedanum austriacum</i> type												
<i>Angelica sylvestris</i>										1		
<i>Bunium</i>												
<i>Anthriscus sylvestris</i> type												
<i>Pastinaca sativa</i>												
<i>Eryngium</i>						1			1			
<i>Heracleum sphondylium</i>												
<i>Anthriscus cerefolium</i>												
<i>Torilis japonica</i> type												
<i>Daucus</i>	4	2	1	3	1		3	2	5	1		1
<i>Coriandrum</i> type												
<i>Pyrola</i>												
<i>Erica herbacea</i>												
<i>Vaccinium myrtillus</i>												
<i>Soldanella</i>	1							1				
<i>Androsace villosa</i>												
<i>Primula</i>		1										1
<i>Lysimachia</i>												
<i>Anagallis arvensis</i> type									1			
<i>Anagallis tenella</i> type											2	
<i>Asterolinon linum-stellatum</i>		7	4	2	2							
<i>Samolus valerandi</i>								1				
<i>Armeria maritima</i> type												
<i>Fraxinus excelsior</i> type				2								
<i>Fraxinus angustifolia</i>			1				1		1			
<i>Fraxinus ornus</i>	5		14					2	1	1		
<i>Ligustrum vulgare</i>												
<i>Phillyrea</i>								1				
<i>Centaureum</i>					1							
<i>Convolvulus</i>												
<i>Cuscuta epithymum</i> type					2							
<i>Cuscuta europaea</i> type				4	2			1				5
<i>Cuscuta monogyna</i>												
<i>Calystegia</i>												
<i>Alkanna</i> type												
<i>Borago officinalis</i>				1								
<i>Buglossoides arvensis</i> type						1						
<i>Anchusa arvensis</i> type								1				
<i>Pulmonaria mollis</i>												
<i>Anchusa officinalis</i> type												
<i>Verbena</i>	1											
<i>Callitriche obtusangula</i>												
<i>Callitriche stagnalis</i> type												
<i>Teucrium</i>												
<i>Stachys sylvatica</i> type												
<i>Prunella</i> type												
<i>Salvia officinalis</i> type												
<i>Mentha</i> type	7	1	4	38	5	19	1	5	8		1	1
<i>Solanum dulcamara</i>			2									
<i>Solanum nigrum</i> type				1	1							
<i>Scrophularia</i> type		2		4	3			2	1			

Kellia

Depth (cm)

225-226 230-231 235-236 240-241 245-246 250-251 255-256 260-261 265-266 270-271 275-276 290-281

Odontites type

Veronica anagallis-aquatica type

Veronica triphyllos type

Pedicularis

Putoria calabrica

Sherardia arvensis

Galium type

Plantago major

Plantago afra

Plantago lanceolata type

Plantago coronopus

Plantago bellardii

Plantago media

Plantago argentea

Plantago albicans

Plantago amplexicaulis

Plantago atrata

Viburnum

Valerianella rimosa type

Valeriana officinalis type

Valerianella locusta type

Succisa pratensis

Scabiosa columbaria type

Dipsacus type

Knautia

Jasione

Campanula erinus type

Campanula rotundifolia

Asyneuma type

Solidago type

Echinops

Artemisia

Carlina type

Picnemon acarna

Achillea type

Centaurea cyanus type

Centaurea napulifera type

Cirsium type

Xanthium

Centaurea solstitialis type

Centaurea graeca type

Crupina

Sonchus type

Lactuca type

Scolymus

Cichorium type

Hieracium type

Taraxacum type

MONOCOTYLEDONES

Alisma

Hydrocharis morsus-ranae

Stratiotes aloides

Vallisneria spiralis

Triglochin bulbosa

Potamogeton crispus type

Potamogeton pectinatus

Colchicum

Narthecium scardicum

Veratrum

Asphodelus fistulosus type

Asphodelus albus

Gagea pratensis

Tulipa sylvestris

Muscari neglectum type

Allium sphaerocephalon type

Asparagus

Gynandris sisyrinchium

Festuca type

Glyceria type

Kellia

Depth (cm)

	225-226	230-231	235-236	240-241	245-246	250-251	255-256	260-261	265-266	270-271	275-276	280-281
<i>Dactylis</i> type	27	50	30	54	80	34	32	48	41	47	32	29
<i>Agropyron</i> type	6	3	1	4	4			1	2	4	3	3
<i>Triticum</i> type												
<i>Secale cereale</i>	4	19	6	10	13	11	3	1	5	6	13	8
<i>Hordeum</i> type	4	6	7		3	1	3		1	2	1	4
<i>Avena</i>	4	12	3	5	7	4	3	7	5	5	2	3
<i>Phragmites australis</i>	6	2	7	5	17	2		4	3	3	8	1
<i>Zea mays</i>		1	1		2	1	4				1	
<i>Arum</i>												
<i>Sparganium erectum</i>			4	14	51	82	35	53	58	20	5	9
<i>Sparganium angustifolium</i>												
<i>Typha angustifolia</i> type						1						
<i>Typha domingensis</i> type	2			1	2		1	1	2	2	2	1
<i>Scirpus</i>	179	930	290	63	56	39	154	111	164	65	42	77
<i>Cladium mariscus</i>												
<i>Cyperus michelianus</i>	62	63	20	5	10	8	15	31	39	95	16	59
<i>Cyperus longus</i> type		2	3	1		1		4	1	1	1	
<i>Schoenus nigricans</i>	3	2	3	2	1		10	2	1	3	2	7
<i>Carex hallerana</i> type	78	309	37	42	32	33	18	17	59	19	28	120
<i>Carex flacca</i> type				5		2						
<i>Epipactis</i> type												
<i>Cephalanthera</i>												
PTERIDOPHYTA												
<i>Equisetum</i>		2	11	5	15	2	39	19	84	1		
<i>Ophioglossum vulgatum</i>												
<i>Botrychium</i>											1	1
<i>Adiantum capillus-veneris</i>												
<i>Pteridium aquilinum</i>	15	9	13	23	22	20	18	15	13	21	16	11
<i>Thelypteris palustris</i>												
<i>Thelypteris phegopteris</i>												
<i>Asplenium</i> type				1							1	
<i>Athyrium filix-femina</i>												
<i>Athyrium distentifolium</i>												
<i>Dryopteris filix-mas</i> type												
<i>Gymnocarpium dryopteris</i>												
<i>Blechnum spicant</i>	1				1							
<i>Polypodium</i>								1	2			
<i>Salvinia natans</i>										1		
Unidentified monoete spores												1
TOTALS												
Indeterminate	6	2	1	18	10	6	4	15	14	15	3	11
Unknown				1								
Number of terrestrial types	62	57	52	62	75	46	52	64	56	51	46	52
Total wetland pollen & spores	373	1368	430	245	298	220	308	291	468	280	142	312
Total terrestrial trees & shrubs	229	210	209	230	229	194	211	221	204	206	223	264
Total terrestrial pollen & spores (excluding bog & marsh types, aquatics, unknown & indeterminate)												
	526	546	500	550	610	415	444	624	471	557	512	563
Total pollen & spores	905	1916	931	814	918	641	756	930	953	852	657	886
CHARCOAL												
Charcoal <25 um2	11336	9919	10137	17004	16023	9374	10682	25724	12426	35098	8829	7957
Charcoal 25-50 um2	15151	18203	15696	10355	17876	16241	11663	33790	15587	44581	12208	12317
Charcoal 50-100 um2	8938	9483	8066	6213	14824	15260	8720	26269	13625	36079	9701	8829
Charcoal 100-200 um2	2507	3379	2834	2398	10464	9374	4687	15260	5995	21146	4033	3815
Charcoal 200-400 um2	436	654	872	1853	3379	4469	1853	4687	1635	8066	872	1635
Charcoal >400 um2	545	109	109	654	1417	1853	1744	1962		2616	218	545

Kellia

Depth (cm)

285-286 290-291 295-296 305-306 310-311 315-316 320-321 325-326 330-331 335-336 340-341 345-346

Absolute counts data

Slide numbers	1	1	1	1	1	1&2	1&2	1&2	1&2	1	1	1
Sample weight (g) (wet)	1.696	1.440	1.466	1.550	1.547	1.828	1.862	1.685	1.760	1.884	1.927	1.857
<i>Lycopodium</i> suspension added (ml)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
<i>Lycopodium</i> count	2265	1880	2325	1898	1594	3893	4514	4018	6198	3469	3560	3135

GYMNOSPERMAE

<i>Abies</i>	2.7	2.7	3.	1.3	2.		.7	2.4		2.	2.	2.3
<i>Cedrus</i>												
<i>Pinus</i> subgenus <i>Diploxylon</i>	66.3	95.3	93.7	81.7	74.7	52.	54.	74.	62.4	41.3	44.7	49.3
<i>Juniperus</i>	3	3	1	4	4	4	1		1	5	1	3
<i>Taxus baccata</i>					2							
<i>Ephedra fragilis</i>	1			1					1	2	1	
<i>Ephedra distachya</i> type												

DICOTYLEDONES

<i>Salix triandra</i>	13	2	1	4	4	1	2		1	2	1	1
<i>Salix fragilis</i> type												
<i>Juglans regia</i>	1	1	1	3			1	1	1	1		
<i>Alnus glutinosa</i>						3	2				1	2
<i>Betula pendula</i>												
<i>Carpinus</i> type												
<i>Ostrya</i> type	2	3	8	6	2	7	11	3	8	7	11	4
<i>Corylus</i>						2	2		1	1	4	3
<i>Fagus</i>	1									2	1	
<i>Castanea sativa</i>	1	2	1	4	1			1	2			
<i>Quercus coccifera</i> type	1		1			6	2	3	1	4	7	3
<i>Quercus trojana</i> type	75	38	60	35	54	67	77	86	66	57	75	53
<i>Quercus frainetto</i> type	37	77	79	93	93	71	57	62	65	66	109	74
<i>Ulmus minor</i>												
<i>Ulmus procera</i>												
<i>Ulmus glabra</i> type												
<i>Morus nigra</i>												
<i>Morus alba</i>												
<i>Humulus lupulus</i>												
<i>Urtica dioica</i>						3	2	1		1	1	2
<i>Urtica urens</i> type												
<i>Urtica pilulifera</i> type												
<i>Polygonum bistorta</i> type												
<i>Polygonum aviculare</i> type	31	20	25	18	22	20	15	30	24	13	6	7
<i>Bilderdykia</i>	2			1								
<i>Oxyria digyna</i>												
<i>Rumex acetosella</i> group												
<i>Rumex acetosa</i> group	1	3		7	2	6						
<i>Rumex crispus</i> p.p.												
<i>Rumex conglomeratus</i> group												
<i>Rumex obtusifolius</i> group												
Chenopodiaceae type	12	7	5	12	4	14	13	20	19	8	14	11
<i>Phytolacca americana</i>												
<i>Spergula</i>				1				1				
<i>Spergularia</i> type												
<i>Herniaria</i> type												
<i>Corrigiola litoralis</i>												
<i>Paronychia</i> type												
<i>Dianthus</i> type			1						3	2	1	2
<i>Silene alba</i> type												
<i>Lychnis flos-cuculi</i>												
<i>Agrostemma githago</i>												
<i>Scleranthus annuus</i> type												
<i>Nymphaea alba</i>												
<i>Nuphar lutea</i>												
<i>Helleborus</i>												
<i>Nigella</i>												
<i>Trollius europaeus</i>												
<i>Actaea spicata</i>				1								
<i>Adonis</i>												
<i>Caltha</i> type				1	2			1	1	2	1	1
<i>Ranunculus acris</i> group												
<i>Ranunculus aquatilis</i> group							1					
<i>Anemone nemorosa</i> group		2		3								

Kellia

Depth (cm)

285-286 290-291 295-296 305-306 310-311 315-316 320-321 325-326 330-331 335-336 340-341 345-346

<i>Clematis vitalba</i> group											
<i>Thalictrum aquilegifolium</i>		1	2			1	1	2	1		1
<i>Thalictrum minus</i>				1				1			
<i>Thalictrum lucidum</i>				1		2	2				
<i>Chelidonium majus</i>											
<i>Glaucium</i>											
<i>Hornungia</i> type	5		1	8	1	1	2	1			1
<i>Arabis</i>	1	3		1	1		1			2	1
<i>Sinapis</i> type	1				2	2	1				
<i>Chrysosplenium alternifolium</i>		1			1	4	1		2	3	1
<i>Saxifraga stellaris</i>					1						
<i>Saxifraga oppositifolia</i> type											1
<i>Platanus orientalis</i>	2			1	1	4	5	9	6	1	2
<i>Filipendula</i>											
<i>Rubus</i> type											
<i>Sorbus</i> type		1									
<i>Cotoneaster</i> type											
<i>Prunus avium</i> type											
<i>Crataegus</i>											
<i>Sanguisorba officinalis</i>											
<i>Sanguisorba minor</i>		4		1		1				2	1
<i>Geum</i>							1				
<i>Potentilla</i>											
<i>Alchemilla</i> type											
<i>Ononis</i> type											
<i>Trifolium dubium</i> type		3	2	5	1	2	1			1	1
<i>Trifolium repens</i> type											
<i>Lotus</i> type	1										
<i>Lathyrus pratensis</i> type											
<i>Vicia sativa</i> type											
<i>Vicia cracca</i> type				2	1						
<i>Astragalus</i>											
<i>Galega officinalis</i>											
<i>Dorycnium</i>											
<i>Trifolium montanum</i> type											
<i>Lathyrus sativus</i>											
<i>Oxalis</i>											
<i>Geranium robertianum</i> group											
<i>Tribulus terrestris</i>											
<i>Radiola linoides</i>											
<i>Linum catharticum</i>											
<i>Linum tenuifolium</i> group											
<i>Euphorbia</i>											
<i>Pistacia</i>											
<i>Cotinus coggygria</i>											
<i>Acer</i>											2
<i>Ilex aquifolium</i>											
<i>Buxus sempervirens</i>											
<i>Frangula</i>	1										
<i>Rhamnus</i> type											
<i>Vitis vinifera</i>											
<i>Tilia platyphyllos</i>							1				
<i>Abutilon</i> type											
<i>Althaea officinalis</i>					1						
<i>Malva moschata</i>											
<i>Daphne</i>											
<i>Elaeagnus angustifolia</i>											
<i>Hypericum hircinum</i> type											
<i>Hypericum perforatum</i> type											
<i>Viola hirta</i> type							1				
<i>Helianthemum</i>											
<i>Cistus monspeliensis</i> type											
<i>Myricaria germanica</i>	1										
<i>Tamarix</i>	2										
<i>Elatine alsinistrum</i>	2				1			1			
<i>Lythrum salicaria</i> type											
<i>Lythrum portula</i>											
<i>Trapa natans</i>											
<i>Myrtus communis</i>											

Kellia

Depth (cm)

285-286 290-291 295-296 305-306 310-311 315-316 320-321 325-326 330-331 335-336 340-341 345-346

<i>Ludwigia palustris</i>												
<i>Epilobium angustifolium</i> type												
<i>Epilobium hirsutum</i> type												
<i>Myriophyllum verticillatum</i>	1					1						
<i>Myriophyllum spicatum</i>												
<i>Cornus mas</i>										2		
<i>Hydrocotyle vulgaris</i>				1		1						
<i>Anthriscus caucalis</i>												
<i>Ligusticum</i>												
<i>Berula erecta</i>				1						1		1
<i>Trinia</i>												
<i>Sanicula europaea</i>												
<i>Oenanthe aquatica</i> group												
<i>Oenanthe pimpinelloides</i> group												
<i>Chaerophyllum hirsutum</i> type												
<i>Chaerophyllum temulentum</i> type												
<i>Ammi</i>												
<i>Pimpinella saxifraga</i>				2		2				1	1	1
<i>Torilis arvensis</i>												
<i>Peucedanum austriacum</i> type												
<i>Angelica sylvestris</i>												
<i>Bunium</i>												
<i>Anthriscus sylvestris</i> type												1
<i>Pastinaca sativa</i>												
<i>Eryngium</i>												
<i>Heracleum sphondylium</i>												
<i>Anthriscus cerefolium</i>						1						
<i>Torilis japonica</i> type												
<i>Daucus</i>	2			1			2	1	1	2	2	5
<i>Coriandrum</i> type												
<i>Pyrola</i>												
<i>Erica herbacea</i>												
<i>Vaccinium myrtillus</i>												
<i>Soldanella</i>											1	
<i>Androsace villosa</i>												
<i>Primula</i>												
<i>Lysimachia</i>				2		1						
<i>Anagallis arvensis</i> type									1			
<i>Anagallis tenella</i> type												
<i>Asterolinon linum-stellatum</i>						2						
<i>Samolus valerandi</i>												
<i>Ammeria maritima</i> type												
<i>Fraxinus excelsior</i> type												
<i>Fraxinus angustifolia</i>												
<i>Fraxinus ornus</i>	4											
<i>Ligustrum vulgare</i>												
<i>Phillyrea</i>												
<i>Centaurium</i>												
<i>Convolvulus</i>	1											
<i>Cuscuta epithymum</i> type												
<i>Cuscuta europaea</i> type												
<i>Cuscuta monogyna</i>												
<i>Calystegia</i>	2											
<i>Alkanna</i> type												
<i>Borago officinalis</i>	1						1					
<i>Buglossoides arvensis</i> type												
<i>Anchusa arvensis</i> type												
<i>Pulmonaria mollis</i>												
<i>Anchusa officinalis</i> type						1						
<i>Verbena</i>												
<i>Callitriche obtusangula</i>												
<i>Callitriche stagnalis</i> type									2			
<i>Teucrium</i>												
<i>Stachys sylvatica</i> type												
<i>Prunella</i> type	1											
<i>Salvia officinalis</i> type												
<i>Mentha</i> type	3					2	1	9	6	5	1	1
<i>Solanum dulcamara</i>												
<i>Solanum nigrum</i> type						1		1				
<i>Scrophularia</i> type												

Kellia

Depth (cm)

285-286 290-291 295-296 305-306 310-311 315-316 320-321 325-326 330-331 335-336 340-341 345-346

<i>Odontites</i> type						1						
<i>Veronica anagallis-aquatica</i> type												
<i>Veronica triphyllos</i> type												
<i>Pedicularis</i>												
<i>Putoria calabrica</i>												
<i>Sherardia arvensis</i>												
<i>Galium</i> type	10	2		2	2	7	8	8	5	9	5	6
<i>Plantago major</i>												
<i>Plantago afra</i>						1						1
<i>Plantago lanceolata</i> type	10	10	6	10	6	4	4	2	5	7	5	7
<i>Plantago coronopus</i>												
<i>Plantago bellardii</i>												
<i>Plantago media</i>	2			4	1		1					
<i>Plantago argentea</i>	1				1							
<i>Plantago albicans</i>			2									
<i>Plantago amplexicaulis</i>												
<i>Plantago atrata</i>									1			
<i>Viburnum</i>												
<i>Valerianella rimosa</i> type												
<i>Valeriana officinalis</i> type												
<i>Valerianella locusta</i> type												
<i>Succisa pratensis</i>	2				1		1	1				
<i>Scabiosa columbaria</i> type												
<i>Dipsacus</i> type												
<i>Knautia</i>												
<i>Jasione</i>						1		1				
<i>Campanula erinus</i> type												1
<i>Campanula rotundifolia</i>												
<i>Asyneuma</i> type												
<i>Solidago</i> type	15	11	7	24	20	13	16	17	21	10	3	9
<i>Echinops</i>												
<i>Artemisia</i>		1		1	2	1						
<i>Carlina</i> type							2	1	2			
<i>Picnemon acarna</i>												
<i>Achillea</i> type					1		1	1				
<i>Centaurea cyanus</i> type						1						
<i>Centaurea napulifera</i> type							1					
<i>Cirsium</i> type	3	10	12	19	13	23	8	15	20	4	1	4
<i>Xanthium</i>												
<i>Centaurea solstitialis</i> type	21	6	14	25	19	25	37	25	18	24	25	22
<i>Centaurea graeca</i> type	5		2	9								
<i>Crupina</i>					2	3			1	1	4	
<i>Sonchus</i> type	23	11	15	30	36	17	13	14	21	10	8	12
<i>Lactuca</i> type	13	15	19	10	14	20	17	35	34	15	15	5
<i>Scolymus</i>						1						
<i>Cichorium</i> type	14	5	45	13	12	7	6	21	23	9	4	11
<i>Hieracium</i> type	22	12	23	49	32	69	25	65	53	21	29	20
<i>Taraxacum</i> type	23	6	15	24	22	13	13	20	26	10	9	9

MONOCOTYLEDONES

<i>Alisma</i>												
<i>Hydrocharis morsus-ranae</i>				1		3						
<i>Stratiotes aloides</i>												
<i>Vallisneria spiralis</i>												
<i>Triglochin bulbosa</i>									1			
<i>Potamogeton crispus</i> type			1									
<i>Potamogeton pectinatus</i>					1							
<i>Colchicum</i>												
<i>Narthecium scardicum</i>			1									
<i>Veratrum</i>												
<i>Asphodelus fistulosus</i> type												
<i>Asphodelus albus</i>												
<i>Gagea pratensis</i>						1						
<i>Tulipa sylvestris</i>												
<i>Muscari neglectum</i> type												
<i>Allium sphaerocephalon</i> type												
<i>Asparagus</i>												
<i>Gynandris sisyrinchium</i>												
<i>Festuca</i> type	5	10	10	3	4	9	4	3	8	10	6	6
<i>Glyceria</i> type	35	14	12	39	20	32	30	21	29	34	25	34

Kellia

Depth (cm)

	285-286	290-291	295-296	305-306	310-311	315-316	320-321	325-326	330-331	335-336	340-341	345-346
<i>Dactylis</i> type	22	4	10	12	25	25	35	27	19	38	33	34
<i>Agropyron</i> type	5	1	1	3	2	4	2	5	8	6	6	5
<i>Triticum</i> type												
<i>Secale cereale</i>	5	1	3	10	7	2	3	9	3	3	4	2
<i>Hordeum</i> type	2			2	5	3	1	2	1		2	2
<i>Avena</i>	2	1	1	3	3	3	5	12	1	3		1
<i>Phragmites australis</i>			1	1		2	1				1	1
<i>Zea mays</i>			2	3	2				2			
<i>Anon</i>												
<i>Sparganium erectum</i>	4	1	7	9	20	131	272	10	104	77	69	62
<i>Sparganium angustifolium</i>						1			1	5		
<i>Typha angustifolia</i> type										1		
<i>Typha domingensis</i> type	4					2	2		1	7	2	
<i>Scirpus</i>	128	430	285	661	845	125	76	177	53	205	59	76
<i>Cladium mariscus</i>												
<i>Cyperus michelianus</i>	65	58	235	268	63	5	1	1	6	2		
<i>Cyperus longus</i> type	1					6	3	21	4	2	2	
<i>Schoenus nigricans</i>	14	18	15	38	27	2						
<i>Carex hallerana</i> type	214	682	914	877	311	11	14	28	24	28	6	5
<i>Carex flacca</i> type						1		3	1			
<i>Epipactis</i> type												
<i>Cephalanthera</i>												
PTERIDOPHYTA												
<i>Equisetum</i>	1	1	1	10	1	3						
<i>Ophioglossum vulgatum</i>												
<i>Botrychium</i>												
<i>Adiantum capillus-veneris</i>												
<i>Pteridium aquilinum</i>	14	13	11	18	24	58	43	75	77	53	48	40
<i>Thelypteris palustris</i>								1				
<i>Thelypteris phegopteris</i>												
<i>Asplenium</i> type												
<i>Athyrium filix-femina</i>												
<i>Athyrium distentifolium</i>												
<i>Dryopteris filix-mas</i> type												
<i>Gymnocarpium dryopteris</i>												
<i>Blechnum spicant</i>					1	1	1				2	2
<i>Polypodium</i>					1							
<i>Salvinia natans</i>						1						
Unidentified monolete spores								1				
TOTALS												
Indeterminate	8	2	2	7	4	6	10	4	3	5		3
Unknown												
Number of terrestrial types	50	35	36	47	46	50	46	38	38	39	44	38
Total wetland pollen & spores	473	1206	1473	1912	1294	333	412	274	232	365	166	182
Total terrestrial trees & shrubs	214	225	249	234	238	218	215	241	215	191	264	195
Total terrestrial pollen & spores (excluding bog & marsh types, aquatics, unknown & indeterminate)	492	387	485	572	533	587	503	660	611	455	504	423
Total pollen & spores	973	1595	1960	2491	1831	926	925	938	846	825	670	608
CHARCOAL												
Charcoal <25 um2	10464	1308	1417	3597	1308	22890	29975	31392	43491	22672	22454	18203
Charcoal 25-50 um2	11772	3488	2616	4251	2507	28994	31392	50794	81096	28122	30411	21582
Charcoal 50-100 um2	7957	1526	2725	3488	2071	21037	23871	30302	51121	12753	17222	14497
Charcoal 100-200 um2	3270	1853	545	1199	763	10900	10791	9265	17113	5995	6104	4469
Charcoal 200-400 um2	1308	436	436	109	218	4251	2834	2507	4905	1308	981	981
Charcoal >400 um2	545	218	436		109	2725	1744	654	436	436	327	218

Kellia

Depth (cm)

350-351 355-356 360-361 365-366 370-371 375-376 380-381 385-386 390-391 395-396

Absolute counts data

Slide numbers	1-3	1	1	1	1	1&2	1&2	1	1	1&2
Sample weight (g) (wet)	1.868	1.877	1.918	1.829	1.826	1.879	1.893	1.902	1.936	1.490
<i>Lycopodium</i> suspension added (ml)	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
<i>Lycopodium</i> count	1139	1858	1610	3568	2683	2354	3198	4140	3643	3188

GYMNOSPERMAE

<i>Abies</i>	.7	3.		3.	.7	1.3	2.4	6.	3.	
<i>Cedrus</i>										
<i>Pinus</i> subgenus <i>Diploxylon</i>	29.	38.7	40.7	97.	66.7	62.	45.4	73.	71.	53.
<i>Juniperus</i>	2	2	4	4	1	2				1
<i>Taxus baccata</i>										
<i>Ephedra fragilis</i>	1					1				1
<i>Ephedra distachya</i> type										

DICOTYLEDONES

<i>Salix triandra</i>	1				1	1		3		1
<i>Salix fragilis</i> type										
<i>Juglans regia</i>	1		1	1				1		
<i>Alnus glutinosa</i>	3	2		2	4	1	1	1		4
<i>Betula pendula</i>	1									
<i>Carpinus</i> type										1
<i>Ostrya</i> type	7	12	3	8	7	9	13	10	14	18
<i>Corylus</i>	4	2	2	3	2	1	1	1	3	
<i>Fagus</i>			1	2				1		
<i>Castanea sativa</i>		1		1	1		1			1
<i>Quercus coccifera</i> type		4	3	5	6	13	2	10	12	7
<i>Quercus trojana</i> type	72	55	69	84	76	79	75	98	60	80
<i>Quercus frainetto</i> type	81	66	57	94	62	45	49	71	33	35
<i>Ulmus minor</i>										
<i>Ulmus procera</i>										
<i>Ulmus glabra</i> type					2					
<i>Morus nigra</i>										
<i>Morus alba</i>										
<i>Humulus lupulus</i>										
<i>Urtica dioica</i>	1	1	1		1					
<i>Urtica urens</i> type								1	1	1
<i>Urtica pilulifera</i> type										
<i>Polygonum bistorta</i> type										
<i>Polygonum aviculare</i> type	5	5	13	7	3	2	3	1	1	2
<i>Bilderdykia</i>										
<i>Oxyria digyna</i>										
<i>Rumex acetosella</i> group										
<i>Rumex acetosa</i> group	1	1	2	2	5		3	2		2
<i>Rumex crispus</i> p.p.										
<i>Rumex conglomeratus</i> group										
<i>Rumex obtusifolius</i> group										
Chenopodiaceae type	7	8	15	8	10	11	12	14	9	11
<i>Phytolacca americana</i>										
<i>Spergula</i>										
<i>Spergularia</i> type										
<i>Herniaria</i> type										1
<i>Corrigiola litoralis</i>						1				
<i>Paronychia</i> type										
<i>Dianthus</i> type			1	1	2	1	3	1	2	1
<i>Silene alba</i> type										
<i>Lychnis flos-cuculi</i>								2		
<i>Agrostemma githago</i>							1	1		
<i>Scleranthus annuus</i> type			1							
<i>Nymphaea alba</i>						1				
<i>Nuphar lutea</i>										
<i>Helleborus</i>										
<i>Nigella</i>	1									
<i>Trollius europaeus</i>										
<i>Actaea spicata</i>										1
<i>Adonis</i>										
<i>Caltha</i> type		1		2		1				1
<i>Ranunculus acris</i> group										
<i>Ranunculus aquatilis</i> group										
<i>Anemone nemorosa</i> group										

Kellia

Depth (cm)

350-351 355-356 360-361 365-366 370-371 375-376 380-381 385-386 390-391 395-396

<i>Clematis vitalba</i> group				1	1				
<i>Thalictrum aquilegifolium</i>									
<i>Thalictrum minus</i>	1								
<i>Thalictrum lucidum</i>									1
<i>Chelidonium majus</i>									
<i>Glaucium</i>									
<i>Hornungia</i> type		2			2		3	3	1 4
<i>Arabis</i>			1		1			2	
<i>Sinapis</i> type						1			1
<i>Chrysosplenium alternifolium</i>	1	2		1			1		
<i>Saxifraga stellaris</i>							1	3	
<i>Saxifraga oppositifolia</i> type									
<i>Platanus orientalis</i>		3	1		1		1	2	3
<i>Filipendula</i>									
<i>Rubus</i> type									
<i>Sorbus</i> type									
<i>Cotoneaster</i> type									
<i>Prunus avium</i> type									
<i>Crataegus</i>									
<i>Sanguisorba officinalis</i>						1			
<i>Sanguisorba minor</i>	1	1							
<i>Geum</i>									
<i>Potentilla</i>									
<i>Alchemilla</i> type									
<i>Ononis</i> type									
<i>Trifolium dubium</i> type	1	1	2	4					
<i>Trifolium repens</i> type									
<i>Lotus</i> type									
<i>Lathyrus pratensis</i> type									
<i>Vicia sativa</i> type							2		
<i>Vicia cracca</i> type						1			
<i>Astragalus</i>									
<i>Galega officinalis</i>						1			
<i>Dorycnium</i>									
<i>Trifolium montanum</i> type									
<i>Lathyrus sativus</i>									
<i>Oxalis</i>									
<i>Geranium robertianum</i> group									
<i>Tribulus terrestris</i>									
<i>Radiola linoides</i>									
<i>Linum catharticum</i>									
<i>Linum tenuifolium</i> group									
<i>Euphorbia</i>									
<i>Pistacia</i>									
<i>Cotinus coggygria</i>									
<i>Acer</i>									
<i>Ilex aquifolium</i>						2			
<i>Buxus sempervirens</i>									
<i>Frangula</i>									
<i>Rhamnus</i> type									
<i>Vitis vinifera</i>									
<i>Tilia platyphyllos</i>									
<i>Tilia cordata</i> type									
<i>Abutilon</i> type									
<i>Althaea officinalis</i>									
<i>Malva moschata</i>									
<i>Daphne</i>									
<i>Elaeagnus angustifolia</i>									
<i>Hypericum hircinum</i> type					1	2			
<i>Hypericum perforatum</i> type						1			
<i>Viola hirta</i> type									
<i>Helianthemum</i>									
<i>Cistus monspeliensis</i> type									
<i>Myricaria germanica</i>									
<i>Tamarix</i>						2	1	1	6
<i>Elatine alsinastrum</i>						1			
<i>Lythrum salicaria</i> type									
<i>Lythrum portula</i>									
<i>Trapa natans</i>									
<i>Myrtus communis</i>									1

Kellia

Depth (cm)

350-351 355-356 360-361 365-366 370-371 375-376 380-381 385-386 390-391 395-396

<i>Ludwigia palustris</i>									
<i>Epilobium angustifolium</i> type									
<i>Epilobium hirsutum</i> type									
<i>Myriophyllum verticillatum</i>									
<i>Myriophyllum spicatum</i>							1		
<i>Cornus mas</i>	2		1						
<i>Hydrocotyle vulgaris</i>		1		1	1	1		2	2
<i>Anthriscus caucalis</i>									1
<i>Ligusticum</i>							1		
<i>Berula erecta</i>			1						
<i>Trinia</i>									1
<i>Sanicula europaea</i>									
<i>Oenanthe aquatica</i> group							1		2
<i>Oenanthe pimpinelloides</i> group									
<i>Chaerophyllum hirsutum</i> type						1			
<i>Chaerophyllum temulentum</i> type									
<i>Ammi</i>						1			
<i>Pimpinella saxifraga</i>	1		2			2	2	2	1
<i>Torilis arvensis</i>									
<i>Peucedanum austriacum</i> type									
<i>Angelica sylvestris</i>									
<i>Bunium</i>									
<i>Anthriscus sylvestris</i> type	1								1
<i>Pastinaca sativa</i>									
<i>Eryngium</i>									
<i>Heracleum sphondylium</i>									
<i>Anthriscus cerefolium</i>		1							
<i>Torilis japonica</i> type	1							1	1
<i>Daucus</i>			1	2	4	1			
<i>Coriandrum</i> type									
<i>Pyrola</i>									
<i>Erica herbacea</i>									
<i>Vaccinium myrtillus</i>									
<i>Soldanella</i>									
<i>Androsace villosa</i>									
<i>Primula</i>			1					1	1
<i>Lysimachia</i>									
<i>Anagallis arvensis</i> type									
<i>Anagallis tenella</i> type									
<i>Asterolimon linum-stellatum</i>									
<i>Samolus valerandi</i>									
<i>Anneria maritima</i> type									
<i>Fraxinus excelsior</i> type									1
<i>Fraxinus angustifolia</i>					1				
<i>Fraxinus ornus</i>									
<i>Ligustrum vulgare</i>									
<i>Phillyrea</i>									
<i>Centaurium</i>									
<i>Convolvulus</i>									
<i>Cuscuta epithymum</i> type									
<i>Cuscuta europaea</i> type									
<i>Cuscuta monogyna</i>									
<i>Calystegia</i>									
<i>Alkanna</i> type									
<i>Borago officinalis</i>									
<i>Buglossoides arvensis</i> type						1			
<i>Anchusa arvensis</i> type									
<i>Pulmonaria mollis</i>									
<i>Anchusa officinalis</i> type									
<i>Verbena</i>									
<i>Callitriche obtusangula</i>									
<i>Callitriche stagnalis</i> type									
<i>Teucrium</i>			1						
<i>Stachys sylvatica</i> type						1			
<i>Prunella</i> type									
<i>Salvia officinalis</i> type									
<i>Mentha</i> type	3	3	11	21	8	2	8	15	1
<i>Solanum dulcamara</i>					2		1		
<i>Solanum nigrum</i> type									
<i>Scrophularia</i> type					2	1	1		

Kellia

Depth (cm)

350-351 355-356 360-361 365-366 370-371 375-376 380-381 385-386 390-391 395-396

<i>Odontites</i> type										
<i>Veronica anagallis-aquatica</i> type										
<i>Veronica triphyllos</i> type										
<i>Pedicularis</i>	1									
<i>Putoria calabrica</i>										
<i>Sherardia arvensis</i>										
<i>Galium</i> type	9	5	13	6	8	6	16	13	4	18
<i>Plantago major</i>						3	1		1	1
<i>Plantago afra</i>						1	2			
<i>Plantago lanceolata</i> type	6	5	7	5	4	14	19	5	4	9
<i>Plantago coronopus</i>						1				
<i>Plantago bellardii</i>										
<i>Plantago media</i>	1									2
<i>Plantago argentea</i>					1					2
<i>Plantago albicans</i>										
<i>Plantago amplexicaulis</i>										
<i>Plantago atrata</i>										
<i>Viburnum</i>										
<i>Valerianella rimosa</i> type										
<i>Valeriana officinalis</i> type										
<i>Valerianella locusta</i> type										
<i>Succisa pratensis</i>		1			1	1				
<i>Scabiosa columbaria</i> type										
<i>Dipsacus</i> type										
<i>Knautia</i>							1			
<i>Jasione</i>										
<i>Campanula erinus</i> type										
<i>Campanula rotundifolia</i>										
<i>Asyneuma</i> type										
<i>Solidago</i> type	16	6	8	13	11	21	21	30	10	22
<i>Echinops</i>										
<i>Artemisia</i>	1									
<i>Carlina</i> type									1	2
<i>Picnomon acarna</i>										
<i>Achillea</i> type										
<i>Centaurea cyanus</i> type	1									1
<i>Centaurea napulifera</i> type										
<i>Cirsium</i> type	1	2	8	2	1	4	3	5		6
<i>Xanthium</i>										
<i>Centaurea solstitialis</i> type	27	12	36	39	29	30	45	30	26	32
<i>Centaurea graeca</i> type						3		1		
<i>Crupina</i>			3	1	4	1	3			
<i>Sonchus</i> type	8	11	33	28	40	33	38			62
<i>Lactuca</i> type	5	10	12	8	11	11	21	27	22	22
<i>Scolymus</i>										
<i>Cichorium</i> type	11	3	14	8	11	16	30	44	26	12
<i>Hieracium</i> type	20	16	38	32	26	102	76	221	235	79
<i>Taraxacum</i> type	14	13	20	7	13	15	27	7	5	1

MONOCOTYLEDONES

<i>Alisma</i>							2			
<i>Hydrocharis morsus-ranae</i>										
<i>Stratiotes aloides</i>										
<i>Vallisneria spiralis</i>										
<i>Triglochin bulbosa</i>										
<i>Potamogeton crispus</i> type						1				
<i>Potamogeton pectinatus</i>										
<i>Colchicum</i>										
<i>Narhecium scardicum</i>						1				
<i>Veratrum</i>						1				
<i>Asphodelus fistulosus</i> type						1				
<i>Asphodelus albus</i>										
<i>Gagea pratensis</i>										
<i>Tulipa sylvestris</i>										
<i>Muscari neglectum</i> type					1					
<i>Allium sphaerocephalon</i> type										
<i>Asparagus</i>				1		1				
<i>Gynandris sisyrinchium</i>										
<i>Festuca</i> type	6	4	4	9	6	15	9	14	18	20
<i>Glyceria</i> type	38	23	38	77	74	89	92	67	56	40

Kellia

Depth (cm)

	350-351	355-356	360-361	365-366	370-371	375-376	380-381	385-386	390-391	395-396
<i>Dactylis</i> type	26	21	21	46	42	37	12	46	41	77
<i>Agropyron</i> type	2	7	11	10	4	1	2			3
<i>Triticum</i> type						1	12	9	6	1
<i>Secale cereale</i>		4	3	13	1	5	23	15	12	4
<i>Hordeum</i> type	3	5	5	2	3	1	1			1
<i>Avena</i>		1		2	1	1		1	3	
<i>Phragmites australis</i>		4				4	1		1	5
<i>Zea mays</i>										
<i>Arum</i>					1					
<i>Sparganium erectum</i>	15		2	1	10	11	4	1		
<i>Sparganium angustifolium</i>			1	2	1	2				
<i>Typha angustifolia</i> type							1			
<i>Typha domingensis</i> type					2					
<i>Scirpus</i>	36	98	33	82	73	5	3			
<i>Cladium mariscus</i>										
<i>Cyperus michelianus</i>	1			1		1		2	1	1
<i>Cyperus longus</i> type	2	1	1	1	2	1	2			6
<i>Schoenus nigricans</i>				1	5					
<i>Carex hallerana</i> type	2	3	3	6	17	4	11	2	1	6
<i>Carex flacca</i> type	14					13		54	20	16
<i>Epipactis</i> type						1				
<i>Cephalanthera</i>										
PTERIDOPHYTA										
<i>Equisetum</i>							5			
<i>Ophioglossum vulgatum</i>										
<i>Botrychium</i>										
<i>Adiantum capillus-veneris</i>										
<i>Pteridium aquilinum</i>	26	21	31	35	49	80	63	218	174	57
<i>Thelypteris palustris</i>					1		1			
<i>Thelypteris phegopteris</i>										
<i>Asplenium</i> type										
<i>Athyrium filix-femina</i>										
<i>Athyrium distentifolium</i>										
<i>Dryopteris filix-mas</i> type	1									
<i>Gymnocarpium dryopteris</i>										
<i>Blechnum spicant</i>		1	3	2	1	1	1	3	2	1
<i>Polypodium</i>		1			2		1			1
<i>Salvinia natans</i>										
Unidentified monolete spores										1
TOTALS										
Indeterminate	9	2	7	4	4	13	8	16	25	19
Unknown								1		1
Number of terrestrial types	44	38	42	41	49	53	46	40	33	53
Total wetland pollen & spores	112	137	90	196	197	139	134	148	82	82
Total terrestrial trees & shrubs	205	189	183	306	232	219	192	278	196	213
Total terrestrial pollen & spores (excluding bog & marsh types, aquatics, unknown & indeterminate)										
	411	357	495	600	536	650	651	995	804	679
Total pollen & spores	532	496	592	800	737	802	793	1160	911	781
CHARCOAL										
Charcoal <25 um2	46107	34444	25615	20383	17331	45017	82840	63874	23871	42837
Charcoal 25-50 um2	29648	34771	26051	28994	20274	38695	78044	69978	43055	65836
Charcoal 50-100 um2	18748	20383	15478	18094	14170	21909	39676	50249	28885	34662
Charcoal 100-200 um2	7739	6649	5886	7303	5123	7303	12426	17113	14388	13298
Charcoal 200-400 um2	3379	2180	2071	1526	1417	2398	3815	3924	4905	4142
Charcoal >400 um2	1090	436	545	872	218	763	1744	981	981	1090

Appendix XIV

Stratigraphy of exploratory boreholes in Anelia & Kellia wetlands

Anelia

Depth below ground surface (cm) Description of stratigraphy

Hiller exploratory core a:

0- 94	wet fibrous peat; medium brown, oxidises very dark brown; paler at base, grading into grey clay
94-102	light-medium grey (slightly yellow) clay
102-110	same clay as above with angular pebbles >1 cm size (?colluvium)

Hiller exploratory core b:

0- 95	wet fibrous peat; medium brown, oxidises very dark brown; paler at base, grading into grey clay
95-112	light-medium grey (slightly yellow) clay with some plant stems
112-125	medium brownish grey clay, more plant material
125-128	medium brown ? <i>Detritus herbosus</i>
128-138	medium brownish grey silt, much fibrous plant material
138-150?	medium greyish brown clay with more fibrous plant material than above unit
150?-161	sloppy clay with wood fragments (twigs, ?bark to 2 cm size) - medium to dark brown
161-167	medium brown clay with some fibrous plant material
167-175	grey clay, rare plant fibres
175-181	laminated medium brown & dark grey silt
181-225	pebbly greenish-grey clay; dark grey at top, medium grey at bottom; angular pebbles to 1 cm (?colluvium)

Hiller exploratory core c:

0- 45	wet fibrous peat; medium brown; oxidises very dark brown
45- 60	grey-brown clay with abundant plant fibre
60- 66	fibrous peat ? <i>Detritus herbosus</i>
66- 68	brownish grey clay with some plant fibre
68- 71	same as 60-66 cm
71- 84	light-medium grey clay; some fibrous material
84- 86	dark brown detritus
86-165	pebbly gritty medium grey clay, darker in top 4 cm

Hiller exploratory core d:

0- 84	wet fibrous peat (wetter below 50 cm);
84- 92	medium greyish brown clay with abundant plant material
92-107	medium grey clay with common fibrous plant material
107-115	medium brown clayey <i>Detritus herbosus</i>
115-132	grey clay with some plant fragments & silt, minor sand
132-145	dark greyish brown clayey detritus with some woody material
145-200	gritty medium grey clay

Hiller exploratory core e:

0-110	wet fibrous peat; slightly silty between 95-110 cm
110-116	grey clay
116-119	medium brown clayey detritus
119-120	grey clay

120-125	medium brown clayey detritus
125-135	clayey grey grit
135-160	grey clay with some plant material
160-165	muddy grey gravel, angular fragments to 1 cm
165-190	slightly laminated medium brownish grey to medium greyish brown clay & silt with some fibrous material
190-215	medium dark grey clay with roots & occasional grit
215-240	blue/grey clay with grit

Hiller exploratory core f:

0- 82	wet fibrous peat; some grey silt below 70 cm
82- 88	fine grey gravel with some fibrous plant material, clay matrix
88-110	grey gritty clay
110-125	brownish grey-greyish brown silt & clay with detritus
125-137	grey silty fine gravel
137-165	brownish grey mud with some fibrous plant material
165-170	medium brownish grey <i>Detritus herbosus</i> with pebbles
170-185	medium brownish grey muddy fine gravel with some detritus
185-225	brownish grey silt with some detritus
225-280	pebbly blueish grey clay

Hiller exploratory core g:

0- 57	wet fibrous peat; 7.5YR 3/3 dark brown
57- 80	mud & muddy sand with plant fibres; 5GY 4/1 dark olive grey
80- 95	mud & fine sand with some plant fibre, some grit; 10YR 5/8 yellowish brown - 10YR 4/2 greyish yellow brown
95-125	muddy grit, average 3-4 mm particle size; also sand; 10YR 4/4 brown; bottomed on pebble

Hiller exploratory core h:

0- 87	wet fibrous peat as elsewhere
87-105	mud with some fibrous plant material; 5Y 4/2 greyish olive
105-	gravel; unrecovered

Hiller exploratory core i:

0- 89	wet fibrous peat as elsewhere; silty in last 5 cm
89-105	mud with some fibrous material; 10YR 4/2 greyish yellow brown
105-150	muddy sand & fine gravel (alluvium); 5GY 5/1 olive grey

Hiller exploratory core j:

0- 71	wet fibrous peat as elsewhere
71- 85	sandy fine gravel; admixture of organic muck; same colour as above
85- 94	silt; 10YR 2/2 brownish black
94-126	clay; 2.5GY 5/1 olive grey
126-170	grit & clay; same colour as above

Hiller exploratory core k:

0- 22	wet fibrous peat as elsewhere
22- 45	mucky gravel, sandy gravel with organic muck; same colour as peat
45- 65	silt with fine organic material; 7.5YR 3/1 brownish black
65-100	muddy sand & fine gravel; 2.5GY 5/1 olive grey

Hiller exploratory core l:

0- 33	wet fibrous peat as elsewhere
33- 61	interbedded detritus, and clay with detritus; colour varies from brown to grey, 7.5YR 4/2 greyish brown
61- 66	<i>Detritus herbosus</i> ; same colour as 0-33 cm
66- 90	mud with detritus; 5GY 5/1 olive grey
90- 98	muddy fine gravel; same colour as horizon above
98-157	silt & fine sand with gravel layers; 5GY 5/1 olive grey
157-	bottomed on gravel

Hiller exploratory core m:

0- 10	wet fibrous peat as elsewhere, with occasional grit
10- 25	peaty clay with pebbles; 10YR 3/1 brownish black
25- 36	wet fibrous peat as elsewhere
36- 41	clayey detritus; 10YR 3/3 dark brown
41-112	mud with detritus; 10YR 4/2 greyish yellow brown
112-	bottomed on gravel

Hiller exploratory core n:

0- 20	wet fibrous peat as elsewhere
20- 30	clayey detritus; 10YR 3/3 dark brown
30- 37	clay with some detritus
37- 95	pebbly sandy mud; 2.5Y 3/1 brownish black, greenish below 80 cm
95-	bottomed on gravel

Hiller exploratory core o:

0- 95	wet fibrous peat as elsewhere
95-115	gravel; 5Y 5/1 grey
115-124	clay with plant fibres; 2.5Y 5/2 dark greyish yellow
124-125.5	clayey peat; 10YR 3/2 brownish black
125.5-131	same as 115-124 cm
131-132.5	clayey peat with fine gravel
132.5-182	clay & silt with some plant material
182-186	clay but more peaty than above horizon; 5Y 3/1 olive black
186-190	sand with silt to very fine sand; 2.5GY 4/1 dark olive grey
190-220	grey clay
220-232	brown peat
232-240	grey clay
240-245	peaty
245-250	gravelly

Kellia

Depth below
ground surface
(cm)

Description

Hiller exploratory core a:

0- 25	stiff mud; 10YR 4/2, greyish yellow brown
25- 60	stiff mud with some plant material; 5Y 5/1-2, grey to greyish olive
continued with soil auger:	
60-100	stiff greyish olive mud as above with calcareous grit & plant material
100-135	same as above, but more gritty & more plant material
135-140	same but sandy
140-170	same as 60-100 cm
170-175	peaty material mixed with same mud with calcareous grit
175-205	as 60-170 cm
205-235	same mud, but less calcareous grit, much plant material
235-340	same mud, but much firmer & less plant material, less calcareous grit
340-415	softer silt-rich mud, with fine calcareous grit and no plant material
415-445	same as 60-100 cm
445-470	same mud with some orange mottling; quartz pebble at 467 cm
470-480	sand; 2.5Y 5/3, yellowish brown
480-490	gravel

Hiller exploratory core b:

0- 18	stiff mud; 10YR 4/2, greyish yellow brown
18- 20	sand; 2.5Y 6/3 dull yellow
20- 22	same as top horizon
22- 25	sand as at 18-20 cm
25- 97	stiff greyish olive mud with some plant material as in section 'a' from 25-60 cm, sandy below 85 cm
97-100	grey muddy sand

Hiller exploratory core c:

0- 20	stiff mud; 10YR 4/2, greyish yellow brown
20- 25	sand as in exploratory core b
25-133	stiff greyish olive mud with occasional plant material; sandy at 75-82, 108-112, 119-121, 126-131 cm
133-138	greyish olive muddy sand with grit at base
138-273	greyish olive mud as above, slightly sandy in places; noticeable sandy layers at 182-185, 186-190, 194-195 cm
160-165,	
273-290	peaty silt; 10YR 2/3 brownish black
290-350	same as 25-133 cm
continued with soil auger:	
350-410	same as 25-133 cm
410-430	greyish olive silty mud, very little or no plant material; stiffer
430-435	greyish olive mud with brown-orange mottles
435-470	brown clay with orange mottles & grit to 3 mm

Hiller exploratory core d:

0- 15	mud; 10YR 4/2, greyish yellow brown
15- 17	sand as in 'b'
17-150	stiff greyish olive mud with plant fragments & sandy layers (sand minor); calcareous grit; sandy layers at 35-48 cm and 132-140 cm; fruit at 65 cm; concentration of coarse plant material at 90-110 cm; 5Y 5/2 greyish olive

continued with soil auger:

- 150-180 same as above
- 180-200 change in colour at 180 to 5Y 5/1 grey; mud stiffer from 180 cm
- 200-225 no sample retrieved

continued with D-section corer:

- 225-240 browner more organic matter, 10YR 3/2 brownish black
- 240-260 mud, slightly darker 5Y 4/1 grey
- 260-280 no sample retrieved

continued with soil auger:

- 280-300 mud, very stiff with less plant material
- 300-305 mud, 5Y 5/1 grey; no plant material
- 305-310 intermixed grey and 2.5Y 6/3 dull yellow mud, no plant material
- 310-360 mud with occasional mottles of 10YR 5/8 yellowish brown; minor plant material; carbonate nodules 2 mm rare; darker from 340 cm i.e. 2.5Y 5/3 yellowish brown;
- 350-360 sandy with carbonate and quartz
- 360-373 no sample retrieved
- 373-395 muddy sand, orange mottles and ?charcoal also manganese mottles
- 395-408 mud with orange mottles and quartz grit at top, sand fines upwards from coarse sand at base
- 408-500 muddy fine sand and silt, orange and black mottles and some carbonate grit, these increasing with depth

Soil auger exploratory core e:

- 0- 15 stiff clay with some silt; 10YR 4/2, greyish yellow brown
- 15-110 stiff greyish olive clay with calcareous grit; sand layers at 25-28, 45-47 cm; quite peaty at 100 cm; charcoal and peaty at 110 cm

continued with soil auger:

- 110-300 mud as above; 130-136 cm - grey clay with much plant material as elsewhere; sample between 160-180 cm not retrieved (prob. too soft); 180-200 cm - less plant material and with calcareous grit; 220-240 cm - some brown mottling of peaty material; at 275 cm less plant material & firmer; calcareous grit; 280-300 cm stiff grey clay with some plant material & calcareous grit
- 300-360 muddy sand; 300-320 cm - 5Y 5/3 greyish olive; 320-340 cm - more orange than above; 10YR 5/6, yellowish brown with iron staining; 340-360 cm - same as above with more iron staining

Soil auger exploratory core f:

- 0- 10 peaty mud; 7.5YR 4/2 greyish brown; grades into horizon below
- 10- 24 mud with calcareous grit; 2.5Y 6/3 dull yellow
- 24- 32 sand medium to coarse (up to 4 mm); orange mottled especially at base; some plant material
- 32- 64 same stiff olive greyish clay (5Y 5/1) with plant fragments and calcareous "sand" layers 1-2 cm
- 64- 68 medium sand
- 68-170 same stiff grey clay with plant material & calcareous grit
- 170-172 iron stained gravel
- 172-183 same clay as above
- 183-198 sandy layer with abundant calcareous grit
- 198-200 same clay as above
- 200-260 mud much softer with more abundant plant material; not much material retrieved
- 260-290 mud remains soft, some plant material
- 290-317 same mud, but firmer from 290 cm with some calcareous grit
- 317-320 grey mud with large orange/yellow mottles
- 320-355 firm grey mud with calcareous grit & little plant material
- 355-380 yellow sand with orange mottles

Soil auger exploratory core g:

- 0- 10 friable brown soil with roots and some peaty mud same as previously but drier
10- 45 stiff greyish olive mud with calcareous grit, some small orange mottles, 2 mm at
10-20 cm; 2.5Y 6/3-5/3 dull yellow-yellowish brown; drier than previously; at 30 cm small (grit
size) pottery fragment; more calcareous 30-35 cm; less gritty 35-40 cm
45- 73 laminated silt & clay; 2.5Y 5/2-7/4 dark greyish yellow-light yellow, general
appearance 2.5Y 6/3 dull yellow; calcareous and with occasion plant material e.g.
3 cm of *Equisetum* rhizome at 70 cm
73- 80 medium grained sand with orange mottles and some plant material
80-110 olive grey (2.5GY 5/1, olive grey) calcareous clay and silt with orange mottles some
plant material; soft and slightly moist at bottom; *Equisetum* fragments

Soil auger exploratory core h:

- 0- 15 peaty silt with some orange mottles; 7.5YR 3/2 brownish black; more peaty at bottom
15- 25 peat with greyish olive silt and clay; peat is 7.5YR 1.7/1 black
25-115 greyish olive clay carbonate rich with plant material; very wet from 40 cm below
ground surface level; peaty layer at 100 cm as in exploratory core 'e'

Soil auger exploratory core i:

- 0- 15 silty peat; 7.5Y 3/2 olive black
15- 20 peat with clay and silt; 5Y 7/2 light grey
20-296 stiff olive greyish mud as elsewhere, carbonate rich with coarse plant material; very
wet from 80 cm; 75-95 cm very peaty, 7.5Y 3/2 olive black
296-307 *Detritus*
307-376 soft olive greyish mud with very little plant material; gastropod collected while
cleaning hole, ?from 370 cm
376-386 mixed grey and brown clay
386-406 brown clay

Soil auger exploratory core j:

- 0- 7 peaty silt; moist at top; 10YR 3/4 dark brown
7- 12 peaty silt and clay 7.5Y 3/2 olive black
12- 14 peaty silt and clay 5Y 7/2 light grey
14-100 stiff olive greyish mud with coarse plant material as elsewhere; rich in plant material
20-30 cm; calcareous from 35-50 cm; less calcareous and more plant material below
50 cm; very moist from 60 cm; fine grained with much plant material as from 50 cm;
peaty material from 80-100 cm

Soil auger exploratory core k:

- 0- 20 peaty silt and clay; 7.5Y 3/2 olive black
20-160 stiff olive greyish mud with plant fragments and calcareous grit; carbonate rich at
40-50 cm; stiff between 80-115 cm with less organic material
160-180 same mud, but less plant material; carbonate rich
180-280 same mud, but no plant matter; very carbonate rich
280-300 silty olive greyish mud; no plant material; little carbonate material

Soil auger exploratory core l:

- 0- 10 peaty silt; 10YR 4/2 greyish yellow brown
10- 20 peaty silt and clay 10YR 2/1 black
20- 35 peaty silt and clay - clayey peat; 10YR 4/1 brownish grey
35-100 stiff calcareous olive greyish clay with plant fragments as before; bivalve at 50 cm

Soil auger exploratory core m:

- 0- 20 crumbly silt and clay with fresh roots, carbonate; some peat; slightly moist; worm at
20 cm; 10YR 5/3 dull yellowish brown, paler at base (all material this colour is

- probably disturbed after drainage)
- 20- 57 clay and silt, with carbonate and some plant material laminated; small orange mottles; 10YR 6/3 dull yellow orange
- 57- 67 stiff olive greyish clay with orange mottles
- 67-100 stiff olive greyish clay with plant fragments and carbonate; gastropod at 90 cm

Soil auger exploratory core n:

- 0- 50 crumbly very slightly moist; top same as for 'm'; remnant lamination in places; paler at base; gastropods at c. 38 cm; carbonate; minor organic fragments
- 50- 65 carbonate-quartz grit plus ?black nodules of same size; muddy matrix; concentration of soil nodules i.e. concentrated with water washing
- 65- 97 as 0-50 cm with rare small orange mottles
- 97-100 olive grey clay with orange mottles
- 100-120 firm grey clay with much plant material
- 120-140 stiff grey clay with plant material & calcareous grit as elsewhere
- 140-180 stiff clay with ?charcoal & calcareous material; 7.5GY 5/1 greenish grey (sample collected)
- 180-220 more organic; darker shade, 2.5GY 4/1 dark olive grey
- 220-280 very stiff with plant material & calcareous material
- 280-290 small orange mottles
- 290-307 more calcareous & less plant material & more mottles
- 307-330 much calcareous material with small orange mottles; 2.5Y 6/3 dull yellow

Soil auger exploratory core o:

- 0- 20 slightly moist, crumbly clay as at 'n'
- 20- 25 carbonate nodule grit, minor quartz grit
- 25- 60 slightly laminated brown clay and silt with small orange mottles; carbonate
- 60-100 stiff clay with carbonate and plant fragments; darker than above, 10YR 5/2 greyish yellow brown; *Equisetum* at 75 cm; much *Equisetum* from 80-100 cm

Soil auger exploratory core p:

- 0- 15 silty peat with living roots
- 15- 30 peaty clay lighter in colour slightly laminated with orange mottles
- 30- 40 medium sand with abundant carbonate
- 40- 75 stiff olive-grey clay with coarse plant fragments; carbonate and sandy layers
- 75- 79 olive-grey sand with abundant carbonate and abundant plant material
- 79-100 as for 40-75 cm

Soil auger exploratory core q:

- 0- 10 peaty mud with roots; 10YR 3/2 brownish black
- 10- 20 mud with coarse plant material (oxidised material); 2.5Y 5/3 yellowish brown
- 20-100 stiff olive-grey mud with scattered coarse plant material; sandy and peaty and carbonate rich at 32-45 and 65-67 cm; concentration of coarse plant material at: 85-87 and 95-97 cm; small corms or fruit at c. 50 cm