ROMANO - BRITISH MORTARS AND PLASTERS

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by

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Preface and acknowledgements

Preface

This study was conceived as an attempt to show that the careful scientific examination of excavated finds has as useful a part to play in the interpretation of a commonly found class of archaeological material as more traditional techniques of study. In considering the writings of ancient experts such as Vitruvius and Pliny it was necessary to produce an extensive analytical data base of the range of materials they discussed, before any comparison could be made with ancient descriptions and modern finds.

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CHAPTER 1 INTRODUCTION

THE COMPARATIVE ANALYSIS OF ROMANO-BRITISH MORTAR AND PLASTER

This thesis is a study into the extent to which the comments of the classical writers regarding plaster, mortar and pigments can be tested by archaeological science applied to a data base from the Roman period in Britain.

My original interest in this project was stimulated by reading Davey and Ling's excellent book on wallpainting in Roman Britain (Davey and Ling 1982), which, although very enlightening, I felt lacked some technical aspects which required proper scientific study. Whilst art historical studies are fairly common, they often contain little technical information. Technological aspects of painting and plastering have been reported on (Weatherhead 1987), but the scientific analysis of the materials is rarely encountered (Ashurst 1984; Davey 1961; Plesters in Rahtz 1963: 337 - 341; Wetzel 1980, have all commented on various selected aspects of mortar and plaster composition). The art historical aspects of wall painting are not discussed here, being detailed elsewhere by recent authors (Davey and Ling 1982; Ling 1985; 1991). Pigment and mortar analyses have been carried out in the past, notably by Sir Humphry Davy in Rome, who carried out perhaps some of the earliest detailed chemical analysis in attempting, with considerable success, to investigate the nature of Egyptian blue and other pigments (Davy 1815), and Buckman in Cirencester, who made useful studies into the composition of plaster and pigments (Buckman 1850). However, a comparative study of Romano - British material currently does not exist, and I saw the need for a systematic study into the scientific aspects as yet only touched upon. Such a study I thought would provide a data base for the comparison of past and future analyses.

The studies of continental Roman material are of particular note (Blake 1947, 1959; ICCROM 1982). The scientific examination of wall plaster and mortar serves several purposes (ICCROM 1982). Archaeologically, the most usual request is for comparative mortar analysis for the phasing of buildings. This is based on the assumption that the composition of mortar should be fairly consistent for any one phase, although in fact the use of locally available materials and continuing tradition may produce similar results over long periods of time. Technologically, analysis can show the methods of manufacture and preparation of the materials, and constructional technique. This last point is particularly important where mortar or plaster preserve impressions of long decayed wood or mud structures. Where complete sections of plaster or mortar survive, weight loadings and quantity surveys may give an idea of wall or ceiling structures and quantities of aggregate and lime used. This in turn can be used as a basis for calculations regarding labour use, transport and local resources. Aggregate analysis can show deliberate selection of various sizes of material or simply the use of ungraded natural deposits, the crushing of rocks or ceramic material to produce suitable material or to improve the quality of the mortar. Examples of such selection include *opus signinum* to improve water resistance, or the use of angular crushed stone to improve the structural quality of plaster or mortar.

The methods and techniques used in this study, fully described in Chapter 3, are as follows:

1) the identification of pigments and painting technique, if any, on the surface of the plaster.

2) the measurement of the physical thickness of the paint layers and the ground on which they occur (*intonaco*), and the quantity of the pigment used to cover a unit area;
3) the analysis of the ground layers for "lime" - to - sand ratios;
4) the analysis of the mortar layers beneath the paint layer (*arriccio*), and of mortars generally for lime to sand ratios and geological identification.

My original aim of only looking at painted plaster neglected the effect that the background plaster has on the technique and alteration of the painting.

This systematic analysis also provided a large amount of information about the distribution of types of aggregate used in mortar manufacture in the Roman period, and, where dated material was available, the occurrence of certain imported pigments such as cinnabar and Egyptian blue, also known as blue frit.

The samples (discussed in Chapter 4) included examples of the following types of building :- military, domestic, public and religious, although the interpretation of purpose or use is sometimes tentative.

Logically mortars might be expected to vary as follows:-

1) Area: with the use of local or transported materials,
2) Structurally: with the purpose of the mortar, for example:- foundation, wall, floor, ceiling, plasters, renders or stucco,
3) Period: from the first to the early fifth centuries A.D., and possibly;
4) the use of the building:- public, military, religious or private,
5) the personnel employed: military, private, public or slave? workers.

The aim in collecting material was to get representative samples relating to the above variations, but, as mentioned above, archaeological uncertainties about dating, use or purpose made safe interpretation very difficult. Before looking at the material, there follows a review of some of the more relevant classical sources. If the classical sources are correct, the results of the analyses should match if the same manufacturing techniques were in fact used in Roman Britain.

Definition of terms

Some of the terms specific to the study of plaster and mortar are defined as follows. Some are of ancient Roman origin, some medieval Italian and others are terms used by specialists.

Aggregate any material mixed with lime as a bulking agent.

Arriccio the medieval Italian term for the plaster layers below the the paint layer on a painted plaster.

Calcined burnt or roasted.

Calcite a common form of crystalline calcium carbonate.

Caldarium the hot room of an under-floor heated bath house.

Curia the council chamber in a basilica.

Encaustic inferring that heat is required in the application of the paint or finishing medium, it often refers to the use of molten wax.

***Fresco* (es)** the medieval Italian term for painting on lime plaster, now in common English usage for wall painting in general.

Giornata(e) di lavoro literally ' day's work', the medieval Italian term for the division of a painting into panels of wet plaster that can be completed before the plaster dries.

Hydraulic in the context of mortar and plaster this term refers to the nature of the lime produced by burning limestone containing quantities of silica and alumina, which can set under water and or have water resisting properties. Hydraulic additives can give similar properties to non hydraulic lime.

Intonaco (i) the medieval Italian term used for the fine plaster layer on which the paint is applied.

Limestone a range of rocks ranging from almost pure calcium carbonate such as white chalk or marble to sand bonded by calcium carbonate which may be highly coloured.

Marble metamorphosed limestone, often very crystalline, but usually distinguishable from other forms of calcite.

Marmoratum the Roman term for plaster containing crushed marble.

Opus signinum the Roman term applied to mortar and plaster containing crushed brick, tile, earthen ware, lava or other volcanic material, which was strong and water resisting. Its use in reference to excavated material is discussed in the text.

Pilae the columns used to support the raised floor of an under-floor heated room.

Plaster slaked lime (calcium hydroxide) used alone or mixed with an aggregate used as a cover layer for walls or ceilings. It sets by absorbing carbon dioxide from the air to form calcium carbonate. To avoid confusion with Plaster of Paris, plaster should be described as either lime plaster or gypsum plaster.

Plaster of Paris partially calcined gypsum. When mixed with water it sets by crystallisation.

Stucco a medieval Italian term generally applied to the finishing layers of lime plaster (or possibly gypsum plaster) for the protection of walls or as a prepared base for painting. It can also mean plaster applied as mouldings or for relief work such as cornices etc..

Tegula (e) the name used for a variety of Roman bricks and tiles. In this work the terms brick or tile are applied to any fired clay fragment other than pottery.

Tessera (e) the Roman term for small usually square pieces of stone brick, tile or pottery used to make tesselated or 'mosaic' pavements.

Trullisato the Roman term for a trowelled on layer.

CHAPTER 2 THE CLASSICAL SOURCES

Of the several classical writers on the more technical aspects of building materials and techniques, Vitruvius appears as the originator of a great deal of useful material. (It is possible that Vitruvius was influenced by even earlier works such as Cato's "On Agriculture".) Marcus Vitruvius Pollio was a Roman architect and engineer, active during the first century B.C. He appears to have had official connections with the works of Augustus, prefacing his Ten Books on Architecture (Morgan 1960) with a dedication to the emperor. The Ten Books were accepted as a basis for the design and construction of public and private buildings until after the medieval period. Little is known about his life, but his laboured literary style suggests that he was primarily a practical man and a writer second. He was followed by Faventius, writing in the early third century AD with his De Diversis Fabricus Architectonicae (Plommer 1973), and Palladius, in the late third century AD with his Opus Agriculturae (Rodgers 1975), who copied to a greater or lesser degree, added to, or 'improved' the original work of Vitruvius.

Far more is known about the other major source of information used in this study, the elder Pliny, than Vitruvius, (Reynold 1986). Pliny was born in A.D. 23 or 24, and died in August A.D. 79, during the eruption of Vesuvius, which his natural curiosity led him to inspect too closely. He came from Novum Comum in Transpadane Gaul, and had Equestrian status, that is, the second order of Roman social hierarchy, his family probably being of the municipal governing class. Tacitus, writing a generation after Pliny, stated that "such men with a municipal background were more conservative, favouring stricter and more antique attitudes than are characteristic of the imperial court and Roman aristocracy" (Tacitus, Annals 16, 5). The younger Pliny, his adopted nephew, made similar comments. Pliny certainly condemned various aspects of luxury and contemporary life, reflecting perhaps his simpler rural upbringing, although he appears to have visited Rome in his youth and during his education, and must have known of urban opulence from a fairly early age. He was an observer and writer, using extensive literary sources from Vitruvius and earlier writers. His lack of understanding of some technical aspects is betrayed by the way he simply quotes earlier sources without criticism. In his medical subjects he has been considered to be a collector of information without understanding, precision or purpose, except that the Natural History (Bostock and Riley 1855-7), perhaps his most well known work, attempts to show nature as a provider to the point of divinity (French & Greenaway 1986, 275), and it is possible that these comments may relate to many of his other topics.

His Natural History contains discussions of many aspects of building construction and painting. He appears, if not actually copying him, to run parallel with Vitruvius with particular references to earlier classical material (Plommer 1979, 99). Both Vitruvius and Pliny appear to have used the same sources on occasion, as their works are very similar. These general comments are therefore often common in principal to all these writers, varying only in detail or where more recent information has been added. There are considerable problems in the interpretation of the various translations of the surviving copies of the original manuscripts, both in philology and technology. Some of these difficulties are discussed by Reynolds, Rottlander and French 1986, and Rodgers 1975. In the following discussion the abbreviations used for Vitruvius's Ten books will be 'Vitruvius' and for Pliny's Natural History 'H.N.' (*Historia Naturalis*). The relevant book and chapter references may also apply to other translations apart from those quoted. (Bostock and Riley 1855-7 for Pliny; Morgan 1960 for Vitruvius; Plommer 1973 for Faventius.)

The Materials

The basic materials for the construction of mortar and plaster works are usually lime and some form of filler or 'aggregate'.

The lime was made by burning with wood (Cato, 4, 16, 1; 4, 38, 4) suitable limestone, chalk or marble (Palladius 1, 10). Vitruvius (Vitruvius 2, 5) said white stone or *silex, silex* generally meaning any hard stone, and Faventius added red stone and dove grey river stone (Faventius 9), but Pliny referred to Cato's insistence that the stone should be "as white and uniform as possible" (Cato,4, 38, 4). Whatever these various rocks and stones were they must have had a substantial calcium carbonate content to be of use. It is possible that gypsum-based stone was used, in which case the result would have been "Plaster of Paris". The harder stones made lime (possibly hydraulic) for concrete (structural mortar), whilst the more porous materials provided lime for stucco (wall plaster).

After burning the lime had to be slaked with water to convert it into calcium hydroxide or 'slaked lime', a process which to be effective took a long time. In recent times slaking took place in pits and the lime was left covered for up to a year to react fully with the water. Pliny referred to ancient laws requiring no building contractors to use slaked lime less than three months old (H.N. 36, 55). Vitruvius (Vitruvius 7, 2) said that the mortar lying in a ditch (pit) was tested by cutting it with an adze or hoe. If it fell cleanly away it was too weak, if it was crumbly or lumpy it was not fully slaked, but if it stuck like glue to the hoe it was ready for use. [Of interest is the recommendation to nineteenth century wallpainters to use slaked lime at least twenty years old if they required the finest surfaces (Hamilton Jackson 1904).]

The aggregate was crushed stone, pounded earthenware (burnt brick or tile) or sand. The stone and earthenware were very varied, according to what was to hand. The sand, however, was divided into types. Pit sand, which was the best and recommended by all the writers, sand from river beds, gravel beds or sea sand. The last three were considered to set very slowly and to have poorer strength. The salt in sea sand also caused the failure of applied stucco layers by efflorescence. Efflorescence is the re-crystallisation of dissolved substances (salts) within the surface structure of a porous material. The forces of re-crystallisation are often sufficient to cause disruption of the surface in the form of powdering or flaking. The problem can be cyclic as the salts can re-dissolve when they become wet again and then re-effloresce, leading to long term damage. Palladius alone recommended the washing out of the salt before use (Palladius 1, 10; Plommer 1973, 36). Pit sand was divided into three groups: black, red and carbunculus (ashen) (plus grey by Vitruvius)(Vitruvius 2, 4). This pit sand had different properties to other sands, being degraded by exposure to the weather, "sun, moon and hoar frost becoming earthy and having no binding power" (Vitruvius 2, 4). The weathering effect suggests that pit sand was in fact of volcanic origin. Recent commentators have argued for and against this (Blake 1947, 1, 44; Plommer 1973, 35). Apart from earthy contamination, there is however no reason for ordinary sand to degrade under normal conditions and it may be that the pit sand if not volcanic at least had a high alumino silicate content. Anhydrous or dehydrated alumino silicate materials would set in the presence of atmospheric water and be little better than ordinary sand after weathering, although they may still have had some residual hydraulic properties.

Pliny said that pit sand was not found overseas and he was presumably unaware of other volcanic deposits (H.N. 36, 54).

Pozzolana or Pozzuolana (*pulvis puteolanus*) was mentioned separately as a useful additive to mortar (H.N. 35, 47; Vitruvius 2, 6). It is an alumino silicate volcanic material, found near present day Pozzuoli (Puteoli) in the Bay of Naples, which produces hydraulic-type mortars when added to lime. Crushed pumice and crushed earthenware (burnt brick, tile and other ceramics) have a similar effect. Their use was recommended particularly for damp areas, sea defences and even under water in some cases. A ratio of 2 parts pozzolana to 1 part of hard lime was used for such work.

Types of mortar

The terms 'concrete', 'mortar' and 'plaster' refer usually to variations of the same basic material for a particular purpose or for reasons of the availability of materials. Concrete is usually used for the basic structure and foundations, mortar refers to bonding and levelling layers, whilst plaster relates to the finishing layers of walls or ceilings.

Structural or massive mortar work was often referred to as concrete or '*opus signinum*', being composed of large stones and lime mortar. Pozzolana or crushed brick was often added to produce hydraulic-type mortars, and to improve water resistance. Vitruvius (Vitruvius 8, 6) gave some recipes for concrete-type material, which he called *opus signinum*, for use in water cisterns. The mortar was composed of 2 parts lime to 5 parts of clean sharp sand. Vitruvius added that the maximum size for the lava was to be not more than one pound in weight, presumably included in the sand portion (Vitruvius 8, 6). (The Roman pound was about 373 grammes.) Lava could be used in place of stones (*caementa*), as an hydraulic additive for "*signinum*" work. Faventius (Faventius 4) added that the mixture could be changed to 1 part of lime to 2 parts sand, which, although it would be more expensive initially, saved on repair costs later. This mixture was to be mixed in a trough by pounding with iron clad wooden 'beetles'. The mixing of mortar in a trough was frequently mentioned by the various writers. Pliny referred to the extensive use of a "*Signine*" composition of crushed earthenware and lime "even for the pavements of houses" (H.N. 3, 9). Bostock and Riley (1885-7) were of the opinion that "*Signine*" derives from the town of Signia in Italy, which Pliny noted for its tiles (H.N. 3, 9). However, Vitruvius (Vitruvius 8, 6) seems to refer to signinum work as being made from lava not earthenware. Signinum may refer to the product and not the materials used in its manufacture: natural or synthetic alumino-silicate mortar. Blake (1947, 323) discusses *opus signinum* at length.

According to most of the sources, floors were of two types, solid and suspended. The solid floors were constructed on (1) a rammed earth surface, followed by (2) pounded rubble and lime, (3) pounded brick and lime (3:1) or (5:2 for re-used aggregate), (4) a nucleus of softer materials, 3 of sand to 2 of lime, spread on and settled by polishing, with a final layer (5) of cut stones or tile etc. also to be polished off. Black floors, "which retain heat and do not show wine spills" (Vitruvius 7, 4), were made as follows: on the prepared surface at a depth of two feet was laid :
(1) rubble or brick, (2) cinders or charcoal, (3) dark sand, ashes and lime of six inches in thickness. Presumably the other layers were lime mixtures as well. Suspended floors were slightly more complex with the use of wooden support structures. On the wooden frame was laid (1) bracken or straw (to stop the lime burning the wood), (2) coarse loose rubble or stones "not smaller than will fill the hand"

(Vitruvius 7, 1), (3) mortar of 1 part lime to 2 parts rubble (reused or new), three quarters of a foot thick, (4) brick mortar, six digits thick, (5) tesserae etc.

Ceilings are mentioned as double vaults, for insulation purposes in bath houses (Vitruvius 5, 10). They were tile vaults suspended from wooden beams by iron rods, with applied stucco. The upper surface of the tile was covered with a layer of clay re-enforced with hair. The under side was covered with an earthenware and lime mixture, which was then whitewashed or plastered. Another description was of reed re-enforced vaulting. The suspended reed vaulting was covered on the upper surface by sand and lime, "rough cast" applied to the under side. Faventius (Faventius 21) here said "pumice applied by hand", which probably would be a hydraulic lime mortar mix, trowelled on, then sand mortar and finally a polished coat of marble plaster.

Wall mortar recipes varied according to whether primary or finishing were being applied. Whilst pit sand was recommended for general mortar work, Vitruvius considered it to be too strong (Vitruvius 2, 4), when mixed with lime and straw, for stucco, (wall plaster) and therefore the weaker river sand was recommended, provided that it was well pounded and polished onto the wall. The general mortar recipe was 3 parts pit sand to 1 part lime. Where pit sand was not available river sand could be substituted in the ratio 2 parts sand to 1 part lime (which was used generally by Faventius and Palladius). River sand mortars could be strengthened by adding a third part of crushed earthenware or burnt brick.

On top of a base render coat, three layers of lime and sand mortar were to be applied, each further coat being added as the previous one was drying (Palladius 22; Vitruvius 7, 3). The use of a trough and beetles was once again recommended for mixing the mortar by pounding. The next coat consisted of large marble grains in mortar and a final finer marble mortar layer polished on (H.N. 36, 55). Vitruvius commented on the various types of marble to be used in plaster work and particularly commended the use of a marble with large transparent grains (Vitruvius 7, 6), which may have been a form of granular crystalline calcite. (Ordinary marble chips or fragments could be crushed and used if the transparent grained variety was not available.) There may have been an intermediate marble mortar top coat, giving three undercoats and three top coats, as Vitruvius recommended (Vitruvius 3, 7), and in damp areas a first layer of mortar made with powdered earthenware was advised (H.N. 36, 55), giving up to seven layers.

Vitruvius's ideal can be tabulated as follows:

On the wall the first layer or process is rough plaster trowelled on (*trullisato*) composed of 2 parts sand : 1 part crushed brick : 1 part lime.

The second process is three layers of plaster of sand mortar (*arenatum*) composed of 2 parts sand : 1 part lime. These layers being called the *arriccio* in Italian.

The third and final process was three layers of plaster containing crushed marble from coarse particles for the first layer to fine dust for the final layer, which was polished on. The final layer or layers were known as the *marmoratum* (referring to the marble) or *intonaco*.

Sun dried bricks called for some care as cracking of applied stucco was likely. Vitruvius mentioned the Utican practice of using five year old mud bricks (Vitruvius 2, 3), whilst Pliny said that mud bricks should be two years old (H.N. 35, 49). 'Utican' probably refers the Roman town of Utica in North Africa.

Where burnt brick walls were to be plastered, it was necessary to apply a coat of lime whitewash, because the extreme dryness or porosity caused flaking (Vitruvius 7, 4). .For wattle and daub walls where the wooden parts caused cracking of the plaster by shrinkage, a protective layer or layers of reeds were to be nailed on (Vitruvius 7, 3). These were to be at right angles to the wooden supports and to each other in the case of two layers. On to the reed layer was added a layer of mud, another layer of reed, layers of mortar and finally marble dust stucco (Vitruvius 7, 3). In damp areas or where there was dampness in walls, a mortar of crushed burnt brick or earthenware with lime was to be applied to a height of three feet, and polished on. For underwater constructions such as harbours, a mortar consisting of 2 parts pozzolana to 1 part lime (the hardest available) was to be used (Vitruvius 7,4).

The medieval Italian term 'stucco' generally applies to finishing layers of lime plaster (or possibly gypsum plaster) for the protection of walls or as a prepared base for painting. It can also mean plaster applied as mouldings or for relief work such as cornices etc.. Particularly in the case of relief work, gypsum mortar may have been used, being very quick setting. Vitruvius gave specific warnings about the inclusion of gypsum (mortar) in lime mortar for stucco work, as it caused cracking (Vitruvius 7, 3). This was due to the different setting or drying times for lime and gypsum. Pliny said that gypsum was useful as a whitewash and for relief work (H.N. 36, 59).

Mortar and plastering equipment and manufacturing evidence

Few tools are mentioned in the written record. These are mainly trowels and polishing devices, although mixing troughs, slaking pits, wooden and iron clad beetles or pounders are noted and various items are shown on contemporary monuments. A now lost wall painting also shows the plastering of a wall (Davey and Ling 1981, 55).

The following is a list of equipment and facilities mentioned in antiquity used in the manufacture of mortar and plaster (Smith 1882);

Lime burning kilns or clamps

Slaking pits

Sieves for aggregate grading

Mixing pits or troughs

Wall preparing tools, such as picks for roughing, rollers for rouletting mud walls or wet plastered undercoats, and trowels

Applying tools, such as trowels, floats and levels; finishing tools such as trowels and burnishers; decorating equipment such as brushes, sponges, compasses and styli.

The slaking of lime in a pit required the use of a hoe (*rutrum*) for mixing and an adze (*ascia)* or hoe for cutting and testing the slaked lime. Both these long handled tools are illustrated in antiquity, the *ascia* on Trajan's column (Lepper and Frere, 1988, 142,3,6). Various other implements are shown on Trajan's column including various axes, pick axes and mattocks. Lepper and Frere refer to the possibility that a shallow mortar mixing trough or *mortarium* is illustrated in scene vcvii, cast 255, on Trajan's column (Lepper and Frere 1988, 146), and that it is more likely to be a stone plaque being prepared for in inscription. (The illustrations in Lepper and Frere are taken from casts made in the Napoleonic era.) The implement shown being used certainly looks more like a hammer pick than an adze or hoe. Most of the building work depicted on Trajan's column appears to be of the construction of turf and timber forts rather than mortared stone structures. The illustration of wall building from a wall painting found in the tomb of Trebius Justus on the Via Latina in Rome, shows the use of an angled hoe or *rutrum*, possibly being used to mix mortar, possibly in a trough or *mortarium* (Blake, 1947, 318) (Fig. 1). The beetle or rammer (*fistuca*) may have been used in breaking up aggregate, mixing the mortar or for pounding the mixed mortar in place.

For wall preparation the masons pick/hammer (*acisculus*) may have been used. Trowels (*trulla*), floats (*liaculum*), and levelling devices such as:- the plumb line (*libella*), straight rule (*regula*), square (*norma*), and the plane device (*amussis*), may all have been used in the plastering work. Trowels and burnishers (*politor*), would have been used to finish the plaster or prepare the surface to receive paint. The paint itself may have been applied by brush (*seta*), stylus (*cestrum*), sponge (*spongea*), or even a float if it was very thick.

Painted plaster

Fresco techniques were noted by Vitruvius, with the comment that "paintings applied to wet plaster would remain forever" (Vitruvius 7, 3). This was the true or '*buon fresco*' method. The pigments were simply mixed with water and applied to the wet plaster, which incorporated them as it set. Timing is critical when painting wet plaster, as the paint must be applied before the plaster hardens. Early twentieth century *fresco* painters were advised that thick *intonaco* layers kept their moisture longer giving five to six hours working time (Hamilton Jackson, 1904, 66). *In tempera* painting, where the pigment was mixed with an organic medium such as white of egg, was also noted, particularly where *buon fresco* was not possible. A variation on the *in tempera* method was the *encaustic* technique, where hot wax was the medium and the resulting pigment and wax mixture was applied with hot tools. The *encaustic* method was used where weathering or exposure could have caused damage to the pigments. The *fresco secco* method of medieval times is not apparently referred to in the classical record. This method, which is occasionally still used by modern painters, uses a technique of mixing lime water with a pigment for application to dry walls, and or to walls soaked in lime water. The chemistry is similar to that of *buon fresco* but the physical bond is not usually so secure.

Pigments

The pigments used in the Roman period (and to some extent earlier) were, according to Pliny, either subdued or vivid (H.N. 35, 12). They were also classed as either natural or made by mixing (manufactured). The vivid pigments included those supplied by the patron (in view of their extreme cost) and were mainly the following:- *Minium* (cinnabar); Armenian stone (azurite); *Cinnabaris* (dragons blood resin); *Chrysocolla* (malachite); Indian blue (indigo); and *Purpurism* (*Murex* colours). Pliny quotes the price of cinnabar as up to 70 sesterces per Roman pound (H.N. 33, 40), which at todays prices (1992) was about £425 per 320 grammes. Pliny reported that cinnabar was mined in Sisapo, the modern Almaden (Arabic for "the mine") in southern Spain, and transported to Rome for refining. Mercury is still mined at Almaden today.

The subdued pigments included both natural and artificial materials: red ochres, brown ochres, yellow ochres, white earths and clays, orpiment, metal ores and metal extraction by-products such as litharge. The individual identification of materials is very difficult from the transcriptions. Very often the same name is applied to chemically different materials simply because they have the same colour (H.N. 33, 36 - 40). Another problem is that in antiquity the materials were rarely pure, pigments often being mixtures with varying amounts of impurities.

The following list attempts to classify the pigments described by Pliny into likely identities:-

Red (H.N. 35, 13 - 16)

Rubrica: generally red earth, more specifically red ochre is likely (Fe_2O_3) haematite). It was also made by burning yellow ochre (*Sil*).

Minium: cinnabar (HgS), artificially produced as vermillion. Modern minium is red lead.

Minium secundarium: red lead (Pb_3O_4) an orange red colour. Often the colour was described as minium when it may have been lead or mercury. It was made by roasting *ceruse*, giving "improved *Sandarac* or *Usta*". Once again there was the use of very different chemicals for materials of the same colour, as *sandarac* is an arsenic compound and not lead.

Sandarach, Sandaraca, (Usta) (H.N. 35, 22 - 24), (modern realgar): red arsenic sulphide (As_2S_2), a red to orange colour.

Sinopis: apparently impure red ochre, giving a range of red / brown colours, perhaps with limonite and goethite as impurities. The mineral Sinopite is a brick red ferruginous clay.

The red colours known as *Sandyx* and *Syricum* were mixtures of red lead and red and brown ochres. The material called Dragons Blood, was probably a variety of natural plant resins, such as that obtained from the Calamnus palm (Bostock and Riley 1857, 6, 121)

Purple and pink

Purpurea : a purple colour, was produced by quenching red hot yellow ochre in red wine vinegar. This would produce a mixture of iron oxides and acetates, probably with some tannin. Another purple colour was made by mixing bilberry juice with milk. A pink or purple colour was produced by dyeing chalk with Madder root *Rubia peregrina*. A red colour was similarly made with the *Hysginum* plant, described by Pliny (H.N. 31, 97) as " the red colour made from the hyacinth". Bostock and Riley (4 , 381), however, reported that no red dye could be made from the plant we now call the hyacinth.

Yellow (H.N. 33, 56)

Ochre *Sil*: yellow ochre ($Fe_2O_3 2H_2O$), limonite.

Orpiment *Arrhenicum, Auripigmentum*: yellow arsenic sulphide (As_2S_3).

Attic yellow was made by pounding chalk with a boiled solution of "violet" flowers, *Viola* spp., perhaps the yellow alpine violet. The yellowish orange pigment Litharge was a by-product of lead extraction. It is mainly lead monoxide (PbO), now called massicot.

Blue (H.N. 33, 57)

Caeruleum was applied to blue pigments generally, both artificial and natural. It may have meant Armenian blue or any other blue pigment, such as burnt blue (Egyptian blue or blue frit) or blue coloured earths.

Burnt blue was manufactured by sintering a mixture of sand, 'natron' (crude naturally occurring sodium carbonate with some limestone) and copper. The actual process consists of rolling the ingredients in the hands into small balls which are placed in a suitable container and heated to about 800 °C. The grains of sand sinter or stick together and are converted into copper calcium silicate [$CaCuSi_4O_{10}$]. The natural blue pigment found at Pozzuoli in Italy may have been cuprorivaite, a natural variety of Egyptian blue (Mineralogical Abstracts, 1940, 225). The coloured earths, often chalk based, were simply made by adding chalk to baths of organic dyes. The best colour was made using the

Murex, Purpura and other shell fish, and was known as *Purpurism* (H.N. 35, 26 - 27). Likewise Indigo, *Indicum* (Indian blue) was used, and more cheaply Woad *Isatis tinctoria*, in imitation of indigo. Another blue was produced from a boiled solution of dried pansies (violets?) with chalk. This particular recipe is virtually identical to that used to produce Attic yellow. It is very probable that the translation of *viola* in each case may point to different coloured plants if not species.

Armenian blue was probably azurite [$2CuCO_3\,Cu(OH)_2$], although the complex mineral lapis lazuli is not an impossible interpretation. Azurite could be dyed to produce the green *Orbitin*.

Black (H.N. 35, 25)

Atramentum: black, usually carbon black from burning resin, but also ground charcoal, burnt wine residues, ivory black, imported Indian black (India ink) and bitumen-like materials were also used. It was, according to Pliny, mixed with glue or size for painting.

Green (H.N. 33, 26 - 27)

Chrysocolla: green, probably malachite [$CuCO_3\,Cu(OH)_2$], but modern chrysocolla is copper silicate [$CuO.SiO_2\,2H_2O$] The name '*Uva*' was sometimes used for green, and may refer to the ovoid egg-like appearance of the surface of malachite.

Creta viridis, green earth. If creta is translated as chalk then this is probably glauconite [$(K,Na)(Fe^{3+}Al,Mg)_2(Si,Al)_4O_{10}(OH)_2$], which is found in veins in chalk, in glauconitic sands and as particles in some limestones. It may however have been cerusite, lead carbonate, stained with copper. Another green earth-like material is celadonite, $K(Mg,Fe^{2+})(Fe^{3+},Al)Si_4O_{10}(OH)_2$, which is usually found in volcanic rocks.

Appian green was thought to be clay coloured with ferrous compounds, but this may also have been glauconite.

Verdigris, basic copper acetate $[CH_3.COO)_2Cu.Cu(OH)_2$, was made by placing copper plates in a sealed pot with wood shavings and vinegar.

Orbitin, Orbitis: a green produced by dying malachite (and azurite) with 'dyers weed', probably the plant Weld, *Reseda luteola.*

White (H.N. 35, 18 - 21)

White pigments were often chalk or lime based, but any white material may have been used. Among those specifically mentioned were: *Creta, Paraetonium,* Eretrian earth, and *Melinium.* These were probably mainly white chalk, but may have included other white minerals.

Ceruse: probably natural lead carbonate cerusite($PbCO_3$). The term was, however, also applied to lead white, produced by reacting lead with wood shavings and vinegar in a sealed vessel. This is basic lead acetate $(3[Pb(CH_3COO)_2.2Pb(OH)_2]$ with some basic carbonate $(2[Pb(OH)_2.2PbCO_3]$ The acetate tends to decompose into the the carbonate with time.

Marble, calcite (calcium carbonate) and gypsum (calcium sulphate) were also used, either burnt to make lime or Plaster of Paris respectively, or crushed for burnishing into the top coats of stucco or plaster.

Annulare was a white material composed of an earth with a glass-like powder. The glass is thought to have been that used on cheap rings, probably a white lead glass (H.N. 35, 30).

Gold (H.N. 33, 20)

As gold was applied as gold leaf some form of adhesive would have been required to stick it onto the wall painting (see below).

In analysing archaeological painted plaster, it must be remembered that most of any original organic pigment and media such as glue egg and natural resins will be lost or at best very degraded during burial. Traces can often only be found by very careful chemical analysis. In this project facilities were not readily available for the analysis of organic traces. Samples of many of the pigments have, however, been taken for possible future analysis.

Painting

The techniques of painting used were *Fresco*, where the pigment was applied directly to the wet plaster, (more correctly called '*Buon Fresco*', to distinguish it from the related method of '*Fresco Secco*'), '*In tempera*', which involved the use of an organic binder with the pigment, and '*Encaustic*', where the pigment was mixed with molten wax.

Pliny said that the following paints were unsuitable for *fresco* work (H.N. 35, 31): Indigo, which turned brown with lime; *Purpurissum*, which being an indigo derivative also turned brown; Orpiment, which turned white; *Cerrusa*, which turned grey; and Appian green, which turned brown. This suggests that Appian Green may not have been glauconite, which does not turn brown with lime. *Melinium*, a white earth, and '*caeruleum*' (possibly organically coloured earths) were also not recommended, possibly due to chemical or physical reasons such as flaking.

In such cases *in tempera* could be used, such as white of egg, glue or gum.

The black pigment, *atramentum*, was mixed with gum as a writing ink (India ink) and glue or size for use as a paint.

Gold leaf was stuck on with white of egg or glue. Where gold was to be applied to wood, a base of a mixture of ochres called '*Leucophorum*' was used (H.N. 35, 17).

The *encaustic* technique (H.N. 35, 41) used pigments mixed with melted wax, which were applied with hot implements. A portable heat source such as a brazier was used to re-melt paints or used in applying wax to large areas. This last method was used to apply wax to outside walls painted with cinnabar. Several writers referred to cinnabar darkening on exposure to sunlight, which could be prevented by applying "hot Punic wax" (Bailey 1929 I: 221).

A few specific methods of painting are described by Pliny (H.N. 35, 26). For example a *minium* -like finish was obtained if a *sandyx* (red lead and red ochre) ground was covered with *purpurissum (Murex)* mixed with white of egg. A purple sheen was obtained if *caeruleum* (blue) was covered with *purpurissum* in egg white. A softer green was given if a white ground was first painted with a thin black layer before the malachite was painted on.

This chapter has summarized the more important classical references relating to this thesis. It is obviously a point of uncertainty that the translators of the various works have correctly interpreted the ideas intended by the ancient writers. The following chapter describes the techniques of analysis used to provide the information needed to relate back to the classical details.

Current analytical methods for use on recent lime mortars are fully described in the relevant British Standard literature: B.S. 812 parts 1, 103, 119, B.S. 890, B.S. 1198, 1199, 1200, B.S. 4551. These were modified for use with archaeological material, but care was taken in identifying the type of aggregate before commencing analysis, in particular the presence of organic and calcareous inclusions. Calcareous aggregates had to be recognised before any analysis was carried out as they caused problems in the measurement of the lime content . In comparative analysis it is important that the same methods are used if true comparisons are to be made. The same methods were used in this work, with the exception that the range of sieves available for particle size grading was modified in the final stages of the project for one site to cope with exceptionally large samples (**Littlechester, Derby**). This did not produce significant changes in the interpretation of the analyses.

Sampling

It was obviously important that standard sampling techniques were used. The following details are somewhat idealistic but a suitable base from which sampling strategy was aimed :- Generally solid mortar samples weighing up to one kilogramme should have been taken from at least three similar places in a structure, for example the wall core, face or bonding layers. In this project only samples specifically requested from current excavations met this requirement. Archived samples were invariably single and of less weight.

Interpretation should be based on three similar results from each sample, but this was obviously not possible where only one sample was available. Problems would occur where walls had been repaired, re-pointed or re-plastered, but such occurrences were not recorded by the keepers of the archived material. Archived plaster samples, usually being finer and fragmentary, rarely provided the minimum one hundred grammes required for sandy mortar analysis. Where walls have had their masonry removed for re-use, or 'robbed out', the remaining mortar or plaster fragments were often contaminated by soil and rubble and also suffered from changes such as the loss of lime by leaching, the mixing of the various layers and the separation of components by the movement of sand and silt by water. The selection on site by eye of recognisable pieces of mortar is unsound practice and probably unrepresentative. In such cases, bulk samples, perhaps five to ten kilogrammes, should have been taken for laboratory separation. Many of the above problems had to be ignored if any results were to be obtained at all. By taking as many samples as possible, from sites where there were sufficient numbers, it was hoped that the problems of limited accuracy associated with small sample weights would be reduced.

ANALYTICAL TECHNIQUE

A preliminary microscopic examination (x10) was carried out on all samples before one or more of the following methods was used:-

1) <u>chemical and physical</u>: dissolution of the sample in dilute hydrochloric acid to remove the lime (and all other acid soluble material), followed by washing, drying and particle size grading. There were problems with hard and resistant high silicate limes as any soft aggregates tended to break up before the lime dissolved. Care was therefore needed in producing accurate results.

2a) <u>physical / mechanical only</u>: samples were crushed by hand in a rubber mortar followed by particle size grading, the finest grade being assumed to be mainly lime. This system was used when calcareous aggregates were present (usually representing the local geology), if the lime was softer than the aggregate.

2b) <u>mechanical and chemical</u>: partial crushing was followed by confirmatory partial dissolution in organic acids, usually dilute acetic acid and aggregate grading as in 1) above.

3) <u>physical / optical only</u>: investigation of polished or thin sections by reflected or transmitted light, when mortars containing calcareous aggregates were too hard. i.e. the lime was at least as hard as the aggregate. This technique was useful in identifying aggregates whether or not they were calcareous. Heavy mineral analysis could also be used for finer aggregate grades, although it was not used in this study. Some polished or broken sections were also examined by scanning electron microscopy, enhanced by the simultaneous use of an analytical probe.

<u>Lime analysis</u>

Both lime and limestone from aggregates or burnt lime may contain identifying materials, for example fossils and related materials such as glauconite from foraminifera and silica fossils. By using organic acids it was sometimes possible to extract identifiable fossils for the sourcing of limestone. (It is also possible that similar materials may have come from the aggregate.) The presence of other elements in limestone such as magnesium and silica may be useful in relating one mortar to another, although preliminary experiments in this project were not encouraging and were not pursued. Even if there was time to carry out this elemental analysis it would have been of limited use as there was often considerable contamination from the aggregate and / or from the burial environment.

Observation of the process of dissolution of lime from mortar often provided useful information. The gas normally evolved is carbon dioxide, but the evolution of hydrogen sulphide pointed to the presence of sulphide inclusions or burial in sulphide deposits. Likewise, the evolution of chlorine pointed to the presence of manganese dioxide either from inclusions or from the nature of the burial environment, for example waterlogging and variations in the water level. The presence of pieces of limestone was often noticed during the acid treatment, sometimes when it had not been seen in the preliminary inspection. Similarly, although not seen in this survey, gypsum particles may be detected during the initial stages of dissolution and may be left as a residue particularly if the dissolution is carried out in cold solutions.

The simple method of dissolving the lime out of a mortar with dilute hydrochloric acid did have inherent problems in that, even when there were no obvious calcareous aggregates, all other acid soluble material could also dissolve. Although not used in this work, the absolute dating of lime plaster involving the use of evolved carbon dioxide for radio carbon dating is often unsafe as there is no way of knowing if all the original C^{14} depleted carbon dioxide was removed during calcination (Ambers 1987). Any residual original calcium carbonate would give an older date, that is a lower level of C^{14}. If required, C^{14} dating could have been more accurately carried out on any residual charcoal surviving from burning of the lime. The measurement of evolved carbon dioxide as a method for calcium carbonate content of mortars was used (Jedrzejewska 1960). The gas evolved included the carbon dioxide from any other carbonate present in the mortar, such as magnesium carbonate in dolomite. Likewise calcium measurement, as an indication of the lime content, would have included calcareous aggregates and neglected magnesium carbonate in dolomitic lime.

Geological examination, both of mortar and subsequent residues, was used to give information on the source of the aggregate and of the lime used.

DETAILED VISUAL INSPECTION OF PLASTER

By identifying the number of layers in plaster, which are often not seen without careful inspection, it was thought that it should be possible to produce a method of practice for plastering used in the Roman period in Britain.

The following is the standard scheme of layering in plaster, found by preliminary observation, with the procedure which was used for analysis:-

layers identified starting from the surface;

a) paint 1st, 2nd, 3rd layer etc. pigment identification, thickness measurement, particle size measurement.

b) paint ground or *intonaco* 1st, 2nd layer etc. plaster analysis, thickness measurement.

c) plaster or *arriccio* 1st, 2nd, 3rd layer etc. plaster analysis, thickness measurement.

d) main wall or other structure:- thickness measurement and analysis as possible.

Paint identification

Qualitative and quantitative techniques of testing.

Paint samples were identified using microchemical methods, by the microscopic observation of the reaction of the pigments with acids or alkalis, followed by X-ray diffraction analysis where confirmation was necessary. X-ray fluorescence was used for the analysis of the Egyptian blue lumps.

Examination of plaster for layering

The section had to be clean. Often this was prepared by simply breaking off a small fragment. The various other methods used were as follows:- sometimes the sample was thin or soft enough to be broken in the hands, other material had to be broken with a hammer, as with geological samples, or a piece sawn off with a diamond or silicon carbide saw.

In friable or dusty material, however, layering was often not be very obvious. In such cases the section was ground flat. This was best done wet, so that abraded particles were removed by flowing water. Very friable samples were consolidated first by solutions of synthetic resin, such as acrylics, or more effectively, but irreversibly, with epoxy or polyester resin systems. Irreversible resins were used when it was required to make a thin section of the sample for petrographic studies. The moisture content can affect the appearance of plaster sections, altering the colours and variations between layers, either enhancing or masking the differences. It was sometimes necessary or advantageous to examine sections both wet and dry. The colour of pigments on plaster is also very moisture dependent, so much so that the use of standard colour charts, such as Munsell (Munsell 1988) had limited use unless the humidity or wetness was also recorded. The quality of the surface (rough, smooth etc) should also be similar to the standard, and the source of illumination may also cause difficulties in description. Colour charts were not used in this project. The apparent colour of mortar and plaster was often due to the fine components (lime, silt, dust) which mask the larger particles, often making up the larger component of the matrix. Only by breaking or cutting were some layers be seen, and polishing or grinding was necessary to differentiate layers. The true components were usually only distinguished by the removal of the lime, although this procedure did sometimes also damage them.

The following chapter is based on the visual observations. The physical and chemical analyses of archaeological evidence generally available to date are presented in Chapter 5. The full results are presented in the appendices. References to specific results will have the site in bold print thus:- **Lullingstone**, fig. xxx, table yyy. General observations will be followed by ***Passim***. The sites are generally arranged alphabetically in the appendices followed by the relevant figures and analytical results. Of the approximately seventy sites represented, ranging in excavated date from the nineteenth century to current excavations, very few produced ideal samples either in identification of structure, date, purpose, size, quality or number. They are, however, all that now survives of some excavations and are generally representative of most of the areas occupied by the Romans in Britain. By accepting the limitations of the material and by careful study it was possible to produce the following initial observations which are followed by a summary of the results, interpretation and conclusion.

Introduction

Samples were collected as far as possible to represent the five main variables discussed in Chapter 1: area, structure, date, use and personnel employed in construction. As mentioned earlier, many aspects of these variables were not precisely known, but the range of material available for examination did cover to some extent most of the variables. In the following discussion, comments and observations can generally be applied across all samples although specific cases are cited. The following chapter is organised from the lower mortar levels through to the upper plaster and finishes.

Inference of building techniques and structures

Careful excavation is obviously vital if as much information as possible is to be recovered from a site. The subsequent examination of mortar and plaster samples can often add to that information. Samples examined in this survey showed a variety of impressions relating directly to the building they had come from. These included: wattle, prepared timber Fig. 2, tied reed bundles Fig. 3, laths Figs 15, 17, keyed mud plaster, roller imprints Fig. 4, stone walls, tile bonding, box tiles, roof tiles Fig. 2, and *tesserae* impressions. Some of the wall plaster from **Lullingstone** (Meates 1979), showed that the building was half timbered, with the impression of a stone built wall on the lower part of the plaster and of a timber structure infilled with clay on the upper part. Plaster which had pecking marks on its surface showed that there may have been another layer of plaster on top, or that it had been prepared to receive another layer (e.g. **Dorchester** Fig. 17). Plaster with pecking casts on its reverse showed there must have been at least one layer of plaster below it (e.g. **Droitwich** Fig. 15). One or more layers of plaster were found still adhering together on occasion (e.g. **Colchester** Fig. 5).

BUILDING TECHNOLOGY

Through careful microscopic examination it becomes apparent that, in Roman Britain, most mortar and plaster can be classified as follows:-

Colour :

paint on mortar / plaster
paint on *intonaco*
paint on paint or over painting, 1st, 2nd, layer etc.
intonaco alone
thick layer on *intonaco*
plaster (self coloured)

Finish :

trowelled
floated
coarse brushed
fine brushed
burnished (after any of the other finishes, including painting)

Basic structure:

'concrete'
brickwork or stonework (tile may show a pattern)
wood frame - shaped lathes etc.
wattle frame - rounded section
reeds - bundles on a framework
mud - mud brick or mud on a wattle base.

TECHNIQUES AND EXAMPLES

Mud

Very few mud structures were seen during the survey but traces of mud backing on plaster from mud walls were examined on samples from **Dover, Leicester (Norfolk St)**.and **Lullingstone.** Mud walls may have been expected to be multi-layered as current primitive practises show. The samples examined had been layered or prepared wet as they showed roller or other keying impressions such as shallow grooves (Fig. 4). If they had been layered dry they may have had pick indentations for keying. A limewash coat should have been present, to help the bonding of the wet plaster onto the dry mud, as instructed by Vitruvius (Vitruvius 7, 4). Whilst this was not seen on the mud samples it was seen in some plaster samples. (See below)

White interfaces and films

When lime mortar sets, water is evolved which rises to the surface. This water contains dissolved slaked lime (calcium hydroxide) which leaves a film of calcium carbonate as it absorbs carbon dioxide and dries. In the application of multiple layers, as in wall plaster, a good bond is only obtained if further mortar is applied before the lower layer dries out. The presence of a calcium carbonate film between layers points to a time delay sufficient to allow drying and carbonation. This period would depend upon the wetness of the mortar, its mass and the weather conditions. These films are usually very thin, in the order of 0.05mm. Occasionally lime films were found at layer interfaces. These were usually white and in the order of 0.1mm - 0.5mm thick. They appear to be deliberate lime wash coatings for the bonding of new plaster layers onto dry surfaces. This may be related to the coating of dry (mud) brick walls with a lime wash before plastering (Vitruvius 7, 4). These thin interfaces did not usually have very flat surfaces and so could be distinguished from surfaces which had been previously finished and coated in white lime as a finish or as an *intonaco*.

(c.f **Verulamium**, **Malton** Fig. 5)

PLASTER AND MORTARS

General comments

When comparing mortars and plasters, note was made of the layering and composition. Plasters in particular can have similar layers (in number and thickness) with differing composition. The colours of layers, void alignment and interfaces, (air bubbles or decayed organic material), and the presence of chalk or other limestone, lime lumps, shell, re-used mortar or plaster, and geological identification are all of importance in making comparisons and analysis in mortars and plasters.

The following comments applied in general to material from many sites.

Visible layering or differences in layers in mortar and wall plaster may be due to various reasons. The layers may be composed of different materials in either aggregate type, aggregate to lime ratio, or varying porosity . Often quite slight variations can be detected by eye. For example, lower lime content will often darken a mortar or plaster, between 5 % and 10 % usually being fairly obvious. Layers may be due to application technique as air is often trapped by the addition of subsequent layers of mortar or plaster.

Air trapped by the addition of mortar is spread into the interfaces as thin air gaps, visible as linear voids. Trapped air bubbles often show dried lime films on their interior surfaces. The analysis of mortars above and below these layers invariably shows very similar composition. If the analysis of laminated layers shows no or little difference between the layers, then this points to air entrapment during the construction of a single layer or the more unusual homogeneity of more than one mortar mix.

Chopped grass or straw was frequently added as a binder to mortar and plaster. When this decays it leaves voids which on first sight may appear to be air bubbles, but not necessarily at interfaces. Such voids often show a typical plant like structures as impressions on the internal plaster surface (**Droitwich** Fig. 2). Very rarely organic inclusions remain as fossilised or calcified structures (**Lullingstone** Fig. 6). More commonly, where the plaster has been burnt before the inclusions rotted, they may survive as charcoal (e.g **Lullingstone**). Such material is useful not only for plant identification but may also may be considered for radio carbon dating. The alkaline nature of slaked lime would have degraded proteinaceous materials such as insects or dung which may have been included in the plaster, but insect casts are occasionally found (**Lullingstone**, Fig. 6). Although hair was recommended as an additive for mud plaster by the ancient writers (e.g.Vitruvius,5, 10) none has been seen in this survey . My research shows that it is commonly found in medieval plaster, however, and a fragment has been found in plaster from a standing Roman building in a dry Mediterranean area.

It was noticed that mortars quite often appeared to be heterogeneous particularly when small samples were analysed.

Time delay between the application of layers can lead to calcite film production which could often be seen as a thin, usually white, layer. This was carefully examined to see whether or not it was accidental or the deliberate lime washing or use of a lime interface between layering. This is discussed in detail below.

Calcareous aggregates

In calcareous areas (Cotswolds, Mendips, Northamptonshire, Yorkshire etc.) calcareous aggregates are often found. It was obviously important that the presence and amount of such material was confirmed before lime to aggregate ratios were determined. The acid soluble components of mortars made with calcareous aggregates were invariably higher than just the lime content. Different techniques were used for the estimation of lime to aggregate ratios. These were discussed in the analytical techniques section above.

(c.f. **Cirencester, Fishbourne, Stanwick, York**)

Marble and calcite filled *intonaco*

Calcareous aggregates such as these would obviously have affected the determination of the lime content of plasters. They tended to be fairly obvious in the section of the *intonaco* , but could have been easily overlooked. There is generally no suitable marble in Britain which could have been used to produce translucent grains for the final layer of plaster. Transparent calcite crystals were used as a very suitable substitute, and may in fact be one of the marble types recommended by Vitruvius (Vitruvius 7, 6). Crystalline calcite is still quarried in Derbyshire and if crushed and added to lime would give a very similar result to some of the samples examined. There were however some examples which did not show much surface damage to the calcite crystals and may not have been produced by the simple crushing of large calcite crystals, but may have come from some form of granular crystalline calcite.

(c.f. **London - Fenchurch St; Fishbourne**).

Very fine marble dust is difficult to see in the *intonaco* layer unless very crystalline, whilst larger pieces (seen in continental samples) have a recognisable translucent marble like appearance. Coarse crystalline calcite was found both in *intonaco* and burnished layers, the grains ranging in length from about 1mm to about 5mm. The glass-like calcite crystals tended to be platelets, aligned with the surface when they were trowelled or floated on. When they were then burnished as well, the surface of the calcite crystal was level with the surface of the plaster. This produced tiny light reflecting and refracting prism-like particles (Davey and Ling 1981, 59). The calcite is so soft, 2 - 3 on the Mohs scale, that it was usually polished completely level with the surface (e.g. **Fishbourne**), whilst quartz grains were usually apparent as being still rounded or angular as in their original state. Where the burnisher used was at least as hard as the quartz grains, they also showed some polishing whilst the calcite was ground flat. A marble burnisher would probably have been too soft for this.

Glass was sometimes used in paint layers and was often very similar in appearance to calcite, being flat and, if decayed, irridescent. It was however much harder and could be distinguished by its resistance to damage by a steel needle under the microscope, or by its failure to dissolve in dilute acid, which completely dissolved any calcite (e.g. **Leicester - Blue Boar Lane** Fig. 9). Extracted particles of calcite tended to be tabular or acicular, reflecting its hexagonal mineral structure, whilst glass has a conchoidal fracture, as does quartz. Quartz may distinguished from glass by X-ray diffraction.

Most of these details could only be seen on clean samples under the microscope, 10 - 20 x, with good low angle lighting. They could possibly be seen with the naked eye, but were usually obscured by dirt and even consolidants. On many examples examined, calcite was not discovered until after the poly vinyl acetate (P.V.A.) consolidant had been completely removed. Where calcite was used in the *intonaco*, the subsequent over-painting of detail often obscured the calcite. The lighting conditions of the original wall painting would have had to have been strong and directional to show the glistening effect, whilst over-painting would probably have obscured quite large areas, although the background may have been apparent.

Burnished surfaces

In order to burnish plaster it is essential that it is partly set. This would be equivalent to the green or leather hard state of pottery before it is burnished. If it is too soft the burnisher would distort the surface, if too hard there would be little effect. The Silchester 'burnisher' has been subjected to recent analysis (Morgan in preparation) and may be recent or recently contaminated with non-Roman pigments or possibly be a pigment crusher or grinder rather than a burnisher (Boon 1974, 211 and n. 3). It is also probably too heavy to be used as a burnisher. The fragment of a fist-sized quartzite stone burnisher found at **Caerleon** (Zienkiewicz 1986, II : 215, No 43, 81.79H), being much smaller, is more likely to have been the sort of tool used. Such a tool would even polish quartz grains to some extent, as mentioned in the paragraph on marble and calcite filled *intonaco* above. A similar polished stone has also been found at **Piddington Roman Villa**. (R. Friendship-Taylor pers com).

A plasterer's float, such as that from Verulamium (Frere 1972 168 - 9), would be of little use in burnishing in view of the marks it would leave (Fig. 8) and the surface area would require very large forces to be effective. The type of finish can be seen on modern plastered walls. A truly burnished surface does not show such float marks providing the surface was dry enough. Where the surface was of correct dryness, the burnishing tends to polish the tops of the ridges left by the plasterer (Fig. 7). It follows that burnished surfaces would be too dry for *buon fresco*. A painting on a burnished surface, unless burnished on, should therefore be in *fresco secco* or *in tempera*. However, Pratt said that "in burnishing, water, containing dissolved lime, rises to the surface of the plaster allowing *buon fresco* painting"

(Pratt 1976, 228). This would be true of the floating process, but not of burnishing, unless the plaster had carbonated but not fully dried. The dryness is obviously critical for burnishing and subsequent painting. In modern burnished plasters, the colour of the layer to be burnished governs to some extent the setting time. Recent experiments in the construction of wall paintings in Italy show that red *intonaci* set more quickly black *intonaci* , due to the "greasy" nature of the black pigment (Cather 1988 pers comm).

PAINT AND PAINTING TECHNOLOGY

General comments

The paint layering may show : the technique of painting (*buon fresco, fresco secco, in tempera, encaustic*), the re-painting of a design, the order of paint application and specific technique, such as the deliberate use of under coats for certain effects. Egyptian blue and cinnabar for example often have similar respective under colours. Details are given under the specific sites below.

Painting technique

Brush marks are commonly shown on painted plaster (c.f. **Dover** Fig. 8, **York**), although damage caused by careless washing can be confused with the original textures. Similarly, thick consolidating layers of synthetic resin can obscure brush marks. Where paint was applied to very wet plaster, the plaster itself may show brush impressions (Davey and Ling 1982, 58). Secondary painting may have impressed lower paint layers if they were still wet enough. Primary paint appears to have been simply a slurry of ground pigment in water, applied to the wet plaster, in the true or *buon fresco* technique. The exudation of lime water and possibly calcium carbonate solutions by the setting plaster bonded the pigment **within** the surface calcite film. Over painting shortly after the primary painting commonly appears to have

been by the *buon fresco* technique. Later over painting without a new *intonaco* layer appears to be of pigments mixed with lime water or lime in the *fresco secco* method. Where painted or coloured *intonaci* were burnished by some hard implement and subsequently over painted, the paint was often poorly bonded, reflecting the necessary harder or more set nature of the plaster needed for burnishing. Such poorly bonded over painting appeared to have been commonly damaged by washing in the field.
(c.f. **Fishbourne**)

The order of paint application did on occasion show standard techniques. Cinnabar was often preceded by a yellow ochre layer and less commonly by a black or red layer. Red ochre preceded by yellow may have been in imitation of cinnabar. Egyptian blue was often preceded by black as was green earth.
(c.f. **London - Southwark; Leicester - Norfolk St**)

The finding of pot sherds with paint or pigment adhering does show that sometimes pigments were mixed with lime either to lighten the colour or for use in *fresco secco* (e.g. **Leicester**). The presence of similar pots with pigments only may show *buon fresco* painting or paint preparation (e.g. **Colchester**). It is possible that some of the sherds with paint deposits were used in preparing the pigment, particularly if the sherd is of a *mortarium* , rather than as a palette as at **Lullingstone** (Meates 1979, 62-3). The discovery of possible *fresco* painter's graves with ranges of paint pots in Germany is of note (Bachmann and Czysz 1977; Bachmann and Pfeffer 1980). Some pigment details are illustrated in Figs 9 and 10.

Whitewash

Apart from white paint layers on internal walls, whitewash or lime wash has on occasion been reported on exterior Roman walls (Crow 1985, Crummy 1988-9, Morgan 1988). Low-powered microscope examination suggested that these were examples of frequently re-whitewashed walls, having many fine layers of lime wash. Chemical dissolution showed them to be mainly calcium carbonate with occasionally thin films of silica. This was in fact a pointer to either the use of hydraulic lime wash or a layer of a completely different origin. Subsequent re-examination of electron micrographs of the material from **Hadrian's Wall, Colchester** town wall and recent stalactites (A.D.1900 to 1955), shows strong similarities. This suggests that the films are in fact natural depositions from rain or ground water containing dissolved minerals. Genuine multi-layered white wash from medieval contexts is shown for comparison in the illustrations, Figs 11 - 13.

<u>Other evidence</u>

Although lime kilns (Jackson, Biek and Dix 1973, and [particularly good examples found in Germany] Borger 1967; Sölter 1970) , slaking pits, often lined with wood (**Verulamium**, Frere 1983, 269 - 70; Chelmsford, Brinson in Pugh 1963: 67) and mixing areas are known from archaeological contexts, few tools are found. Examples of trowels and floats were found at Verulamium (illustrated in Fig. 14 after Frere 1972, 168 - 9), Silchester (now in Reading Museum, Hope and Fox 1896-97, 252) and Caerleon (Fox 1940, 136, No 42, pl vii). Trowels and a hammer-pick from Saalburg,Germany, are also illustrated in Fig. 14. A wooden float from Saalburg is illustrated by Ling (Ling 1976, 215). It is mainly from impressions left in mortar or plaster that the use of equipment such as round and pointed trowels and hammer picks is inferred. Examples of impressions from **Caerleon** and **Dorchester** are illustrated in Figs 15 - 17.

CHAPTER 5 RESULTS : PHYSICAL AND CHEMICAL ANALYSES

This is a summary of the more detailed results which appear in the appendices, where each abbreviated site report contains details of any mortar, plaster or pigments analysed. Many of the comments apply generally across the samples examined; specific cases are noted in bold type.

The analyses are broken down into two main sections: 1) mortar and plaster; and 2) painting and pigments.

Predicted variables

The five main variables from Chapter 1 are used as headings for the group analyses before going on to the more specific results.

Area

Sites in calcareous areas were the ones most obviously showing a relationship with the local geology. The aggregates in particular were usually made of the local limestone of sand or gravel gradings. Where the limestone was oolitic, oolitised or fossiliferous it was particularly easy to identify the aggregate. Conversely, the presence of quartz sand or other non-calcareous material in calcareous areas pointed to the transportation of that material.

(c.f. **Fishbourne** Fig. 18, **Stanwick**, **York**, as examples of calcareous sites; **Caerwent**, **Leicester**, **Silchester**, as examples of non-calcareous sites; and **Bignor** and **Dover** , as examples of sites using transported materials.)

Structure

Examples of structure types examined were: foundations, floors, wall mortars, wall plasters, quarter round mouldings, ceiling plasters, tile torchings and window putty.

(***Passim***)

Period

The lack of precise dating of the samples used in this study meant that only very few closely dated samples, usually with a terminal date fixed by destruction of a building, could be used in comparison of technique with period. Period comparison was not therefore generally attempted. (c.f. **London - Southwark** and **Dover**)

Building use

Examples of all the types of building proposed in Chapter 1 were analysed. These were: military, domestic, public, and religious. It should be noted that many samples were not safely classified as belonging to any one of these types and overall interpretation was therefore limited.

(***Passim***)

Personnel

The personnel used in building could only be assumed to be associated with the site or building use. There was of course no way of being sure that even on military sites, it was the troops who actually built the particular structures sampled. This variable was therefore not pursued further.

GENERAL COMMENTS

Analysis does reflect local geology, but generally the *intonaco* had the highest lime content, averaging about 88% "lime".

The analysis of calcite filled plaster was difficult as it could not be separated by chemical means. It was possible to separate many of the crystals by mechanical methods with the aid of a microscope, where the lime bonding was softer than the calcite.

MORTAR AND PLASTER [Tables of Analyses]

Soluble : Carbonate

The technique of removing lime from mortar by acid does not give the exact amounts of lime and aggregate in the original sample as other material is also dissolved. By using the volume of gas given off as a measure of carbonate content (although even this is an assumption) and comparing it with the acid soluble content, there is commonly an average difference of about 10%. This is due to the solubility of other material such as iron compounds, manganese compounds and alumina. In general acid soluble values and lime estimations were always higher in limestone areas or where calcareous aggregates were used. The presence of calcareous material in the aggregate caused serious problems with the interpretation of the lime to aggregate ratios (Fig. 18).

Table 1 gives examples of acid soluble and carbonate values.

TABLE 1

ACID SOLUBLE AND CARBONATE VALUES

site	acid soluble%	carbonate%	
Baldock	100	100	chalk
	90	70	chalk daub
Bath	55	56	plaster
Cirencester	(45)	67	plaster
Poundbury	15	12	plaster
Droitwich	13	11	plaster
	20	15	plaster
London, Southwark	76	66	*intonaco*
	64	52	yellow ground
Netherwild	90	81	red paint
	93	93	white paint
	(59)	65	*intonaco*

Average 10% difference.

Weight : Volume ratio

There are simple weight ratios between the calcium carbonate content of mortars and plasters determined by analysis and the original calcium hydroxide (slaked lime) used in their manufacture. This ratio however relates to dry material and, as the slaked lime used was almost certainly a wet paste or putty, comparative estimates based on modern material have to be used to compare wet and dry volumes and weights. Gypsum and Plaster of Paris estimations are based on dry materials.

a) Calcium carbonate : slaked lime $CaCO_3 : Ca(OH)_2$. The atomic weights of these materials are 100.09 and 74.09 respectively, giving ratios of 1 : 0.74. The weight of calcium carbonate found by analysis can then be converted to the weight of dry slaked lime used in the mortar or plaster manufacture. Experimental analysis and calculations showed that dry slaked lime had a density of 0.7g/cc and when converted to thick lime putty, a density of 1.3g/cc. The weight of dry slaked lime can then be converted to the weight or volume of wet lime putty. The volume of lime putty was calculated using the following formula:

weight of calcium carbonate ("lime") x 0.74 / 1.3 = volume of slaked lime, or simplified: "lime" weight x 0.6 = volume of lime putty.

b) Sand:

The density of sand and gravel varies considerably with its moisture content. Up to 10% by weight of water may not affect the volume of the sand, depending on its particle size distribution. The coarser the sand the larger the spaces between the grains to hold the water. Actual dry sand densities ranged from 1.5g/cc to 1.6g/cc. Sand and gravel mixtures extracted from plasters and mortars had densities ranging from 1.6g/cc to 1.8g/cc (**Exeter**) and up to 2g/cc for natural sand and gravel from the River Nene near Northampton. Assuming that the sand was not completely dry, (experimentally it was found that up to 10% of added water makes dry fine sand feel just moist to the touch without increasing its volume), the weight of dry aggregate divided by about 1.6 would give an approximation of the volume of damp aggregate. Crushed brick and tile densities varied according to the density or porosity of the original material, the range of particle sizes and the moisture content. Some Roman tile from **Piddington** was crushed and gave densities of 1.3 - 1.5g/cc. Crushed tile extracted from plaster at **York** gave a density of 1.1g/cc.

<u>Composition</u>

The relative quantities of lime (or soluble material) and aggregate in mortars and plasters were measured using the techniques described in Chapter 3, the aggregates were further broken down into gravel, sand and silt or clay components and their geological compositions noted.

MASSIVE MORTARS AND CONCRETE

Evidence from Rome shows that, generally, Roman concrete was made by adding mortar to brick, stone or lava layers rather than being pre-mixed. These layers may have been laid regularly or randomly. Various types of tufa were commonly used in Rome for their lightness, strength or availability (Blake 1947, 324 - 352 et seq). In the Augustan era, the concrete was usually contained by stone walls, but by the Claudian period wooden shuttering was used (Blake 1959).

Little concrete has been recovered from British museum collections. In this study they were mainly represented by foundations and rubble built walls. Often only the footings of walls survived. A fragment from baths in **Chester** suggests that it was pre- mixed, as it was occasionally in Rome (Blake 1947). The thickness of layers may be recorded in the excavation archive but is usually impossible to determine from the fragments supplied for analysis. The **Lincoln aqueduct** (Wacher 1976) is a notable exception. It probably consisted of open channels and sections of a clay pipe line encased in cast concrete *opus signinum* material. It is estimated that this major work had piped sections at least two and a half miles long. Although fairly small in cross section (about 0.117 m^2), its length makes its total bulk enormous, in the order of 200kg/m or 200 tonnes/km, with a volume of about 117m^3/km.

Table 2 gives a summary of lime or acid soluble values to aggregate content and thicknesses of the samples.

TABLE 2

CONCRETE ANALYSIS

site	acid soluble%	gravel : sand	thickness mm
Alcester	12	41 : 59	-
	17	66 : 34	-
Bath	66	73 : 27	-
Chester	12	86 : 14	200+
London forum	28	34 : 66	-
amphitheatre	15	54 : 46	-
Wall	18	32 : 68	.-
Averages	24	55 : 45	-

or expressed as percentage weight values:

24 : 42 : 34 "lime" : gravel : sand

or as volume ratios :

14.4 : 22 : 21 lime : gravel : sand

which approximates to a 1 : 2 : 2 mixture.

MORTARS

Mortars were made with an aggregate and lime. The most common aggregate was sand and gravel or other similar sized stones. Brick or tile was also used with or in place of natural materials and is detailed below. The colour of the mortar was usually governed by the nature of the aggregate, and to a lesser extent by the lime used. The differentiation of mortar and plaster was sometimes difficult as they often had very similar compositions. Once removed from the excavation only obvious features such as painted surfaces could be safely used to distinguish thin mortar or thick plaster. In general mortar was considered to be a more structural material, whilst plaster was regarded as a finishing material. The minimum thickness of any flat layer was obviously determined by the maximum thickness of any aggregate particle used. Table 3 gives summary values for a wide range of mortar types, with; the acid soluble figures approximating to the lime content of the whole sample, the gravel to sand ratios for the whole of the aggregate (gravel being >2mm) and the thicknesses where recorded. Unless stated otherwise the mortar was probably wall mortar.

TABLE 3

MORTAR ANALYSIS

site	context	acid soluble%	gravel : sand	thickness mm
Alcester	-	12	41 : 59	-
Bath	torching	61	21 : 79	-
Bignor	torching	20	1 : 99	-
Caerleon	-	62	3 : 97	-
Caerwent	-	29	28 : 72	80
	floors	25		
Canterbury	-	30	48 : 52	-
Carlisle	floor	15	72 : 28	-
	-	15	26 : 74	-
Caves Inn	torching	45	36 : 64	-
Colchester	-	25	50 : 50	-
Dorchester	-	24	11 : 89	-
	torching	24	11 : 89	-
Dover	-	25	35 : 65	-

site	context	acid soluble%	gravel : sand	thickness mm
Exeter	render	31	26 : 74	28
	pilae	34	5 : 95	12
Feltwell	torching	34	0 : 100	-
	-	45	3 : 97	-
Fishbourne	-	18	60 : 40	-
Hadrian's Wall	-	34	22 : 78	-
Lincoln	-	31	30 : 70	-
Littlechester	-	25	40 : 60	-
	torching	47	7 : 93	-
London - forum		26	20 : 80	-
Lullingstone	torching	52	14 : 86	-
Nether Heyford	-	30	40 : 60	-
Netherwild	floor	31	50 : 50	25
	torching	33	6 : 94	-
Reculver	-	26	41 : 59	-
	-	56	18 : 82	-
Stanton Low	-	51	25 : 75	-
	torching	56	20 : 80	-
	tesserae bedding	80	- -	5
Stanwick	-	25	60 : 40	-
Wall	-	29	35 : 65	-
Wigginton	floor	50	5 : 95	-
York	floor	42	17 : 83	50

The average results for some of these values are given in Table 4, but it can be seen that there are very wide ranges for all the materials.

TABLE 4

MORTAR AVERAGES

mortar type	"lime"%	gravel : sand	gravel% : sand%
wall	32	30 : 70	20 : 48
floor	32	34 : 66	23 : 45
torching	44	10 : 90	6 : 50
pilae	34	5 : 95	3 : 63

volume calculations	lime putty : gravel : sand	
wall	19.2 : 10.5 : 30	(approx 1 : 2)
floor	20.4 : 12 : 28	(approx 1 : 2)
torching	26.4 : 3 : 31	(approx 5 : 7)
pilae	20.4 : 1.5 : 39.4	(approx 1 : 2)

OPUS SIGNINUM AND 'TILE' MORTARS

These were usually reddish or pink in colour, betraying the use of crushed red to orange brick or tile. However, tile or brick can vary from creamy white to yellow, through reds and orange to grey and black. Tile mortar is sometimes only shown by analysis to be actually made with tile. The converse is true in that other red material has been used as aggregate, in particular red marl, which has a similar acid-resisting effect as brick dust during analysis. Mortar will also turn red if it has a high enough iron content and reaches a temperature in excess of 500 °C, as may occur if the building is burnt. The iron compounds in sand and gravel were often found to be red during analysis. Tile mortars are often found in areas affected by damp, such as the lower parts of walls, in bath houses and for floors. They could also have been used purely for decorative effect.

The analysis of tile mortars was often difficult as the tile dust prevented or severely slowed down the acid dissolution of the lime. Petrographic studies of thin sections and electron micrographs often showed lime interaction with the aggregate and the formation of siliceous compounds with both brick and some rocks (**Carlisle, Chester** Fig. 18).

The lime content of tile mortars tended to be higher than the average sand mortar, ranging from 27 % to 76%. The particle-size distribution-curves suggest that the tile was simply crushed and not graded, with a fairly broad range of sizes. The presence of sand in the dissolved mortar may be derived from the tile itself, as sandy clay was often used in brick and tile making. The amount of sand was usually fairly low; large amounts suggested the separate addition of sand to the crushed tile. The particle size distribution curve often showed a distinctive peak for sand amongst the tile grades. Such sand gradings may be of use in identifying or classifying the tile source.

The term *opus signinum* should be perhaps only used where the aggregate is mainly crushed tile without the addition of separate sand or where most of the aggregate is tile (>>50%) The term "mortar with tile" could safely be used to describe other tile-bearing mortars. Only by destructive analysis will the relative proportions become apparent. Fig. 24 shows the particle-size gradings for some crushed tile samples, with typical broad ranges of grade sizes. Table 5 gives a summary of the acid soluble or carbonate values and aggregate contents ("gravel" being >2mm, "sand" being <2mm) for tile based mortars together with their thicknesses. Unless stated otherwise the mortar was probably wall mortar.

TABLE 5

OPUS SIGNINUM MORTAR ANALYSIS

site	context	acid soluble %	"gravel" : "sand"	thickness mm
Baldock	-	61	58 : 42	-
	-	30	17 : 83	-
	-	40	40 : 60	-
Bath	-	71	15 : 85	-
	-	29	89 : 11	60
	torching	61	21 : 79	-
Caerleon				
	-	45	25 : 75	-
	interior putty	76	0 : 100	-
	exterior putty	47	0 : 100	-
Caerwent	floor	45	45 : 54	80
Canterbury	-	45	58 : 42	-
Carlisle	-	30	70 : 30	-
	-	33	30 : 70	45
Chester	-	52	31 : 69	-
Cirencester	-	47	54 : 46	-
Dover	floor	31	84 : 16	-
Lincoln	aqueduct	44	45 : 55	-
Littlechester	-	34	35 : 65	-
London - forum		30	54 : 46	-
	floor	29	75 : 25	70
Piddington	-	23	58 : 42	-
	-	54	24 : 76	-
Silchester	floor	35	18 : 82	37
Stanton Low	-	40	50 : 50	-

floor	27	50 : 50	-

The average results for some of these values are given in Table 6,

TABLE 6

OPUS SIGNINUM MORTAR AVERAGES

mortar type	"lime"%	"gravel" : "sand"	"gravel"% : "sand"%
wall	42	44 : 56	26 : 32
floor	33	80 : 20	54 : 13
volume calculations	lime putty : "gravel" : "sand"		
wall	25.2 : 17.3 : 24.6		(approx 5 : 8)
floor	19.8 : 36 : 10		(approx 5 : 11)

It should be noted that the "sand" size was generally mainly crushed tile.

All of the concrete, mortar and plaster analysed in this survey has been lime-based, with the sole exception of the gypsum based material which is commented on below.

THE USE OF GYPSUM

Even where Roman buildings have been found in areas with known gypsum deposits, no gypsum-based mortar or plaster has been found. (Davey in: Thompson 1951: 8)

The sole occurrence, during this survey, of gypsum plaster was of a grave filling from **Poundbury** (Green 1982). It appeared to have been applied as a calcined re-hydrated mixture which had set *in situ*. If this was the case, the technology to to produce gypsum plaster must have been known but, to date, has not been found in building construction. The more restricted localised deposits of gypsum, its speed of setting, interaction with lime based mortars (efflorescence) and possibly even connotation with burial practice may all have contributed to its general lack of use in Britain (Green 1977, 1982).

The Poundbury sample gave the following general analysis:-

total soluble:	98%wt
insoluble residue:	2%wt
carbonates by CO_2 :	4%wt
sulphates:	94%wt

This analysis may not be typical as it is the average of only two samples.

PLASTER

ARRICCIO ANALYSIS

<u>Layer thickness</u>

The lower layers of plaster or render varied considerably in their preservation. Often there was only one layer, varying from 2mm to 3mm and up to 50mm, with a typical average of about 15mm. This was on occasion composed of more than layer of material with the same or very similar composition, particularly in very thick sections. Layering could be difficult to see in these circumstances, unless the layers were imperfectly applied or there had been a delay in the application of subsequent layers. In areas of possible dampness, such as the lower parts of walls and in bath houses, tile-based plaster was commonly used. The use of tile-based plasters in re-plastering may suggest an attempt to prevent dampness. Table 7 gives the values for the acid soluble or carbonate and aggregate content (gravel being >2mm) together with thicknesses for plaster layers. The context refers to the particular layer analysed. Where no layer is shown the sample was analysed as a whole. Table 9 gives the values for tile-based or *opus signinum* plasters.

TABLE 7

PLASTER ANALYSIS

site	context	acid soluble %	gravel : sand	thickness mm
Alcester	upper	28	15 : 85	12
	lower	25	20 : 80	15
	-		66 : 34	
Baldock	upper	32	53 : 47	15
	-	25	0: 100	
	lower	53	0 : 100	16
Bancroft	upper	60	9 : 91	11
	lower	52	11 : 89	11
Bath	upper	37	74 : 26	20
Beddington	upper	37	10 : 90	12
	lower	32	15 : 85	12
Bignor	upper	30	15 : 85	9
	lower	28	15 : 85	12
	ceiling	53	1 : 99	18
Brean Down	upper	60	1 : 99	8
	lower	52	2 : 98	13
Caerleon				
primary	upper	40	15 : 85	9
	middle	40	16 : 84	10
	lower	88	12 : 88	17
secondary	upper	39	1 : 99	2.5
	lower	36	7 : 93	5
Caerwent	upper	30	8 : 92	13
	lower	26	14 : 86	14
Canterbury	upper	15	11 : 89	8
	lower	14	28 : 72	22
Carlisle	-	32	15 : 85	4
	-	29	10 : 90	25
Castle Copse	upper	30	24 : 76	12
	lower	20	44 : 56	13
Charlton Kings	upper	30	0 : 100	12
	lower	55	40 : 60	14
	single layer	25	40 : 60	30
Chester	upper	25	5 : 95	15
	lower	22	13 : 87	5+
Cirencester	B.P.	45	40 : 60	14
K.C.	upper	30	57 : 43	16
	lower	35	58 : 42	6+
L.G.	-	15	27 : 73	12
Claydon Pike	-	20	35 : 65	15

site	context	acid soluble %	gravel : sand	thickness mm
Dorchester				
	primary upper	26	8 : 92	11
	middle	23	0 : 100	12
	lower	23	8 : 92	12
	secondary upper	22	4 : 96	10
	lower	23	2 : 98	12
Poundbury	upper	19	6 : 94	10
	lower	15	12 : 88	15
Dover	upper	25	15 : 85	12
	lower	20	35 : 65	24
Droitwich	upper	28	0 : 100	11
	lower	30	0 : 100	15
Empingham	upper	43	2 : 98	12
	lower	43	1 : 99	21
Exeter	upper	24	30 : 70	13
	lower	23	30 : 70	19
Fishbourne	upper	30	15 : 85	15
	lower	30	20 : 80	12
Hockwold	-	39	3 : 97	20
	-	24	0 : 100	4
Lincoln	lower	32	8 : 92	25
Littlechester				
	upper	26	2 : 98	11
	lower	22	8 : 92	11
London - Southwark				
	primary upper	24	11 : 89	11
	lower	27	18 : 81	18
	secondary upper	29	13 : 89	9
	lower	28	14 : 86	7
Lullingstone	first	31	10 : 90	13
	second	38	10 : 90	16
	third	35	10 : 90	15
	fourth	-	- -	10
Malton	upper	30	4 : 96	8
	lower	30	3 : 97	11
	third	30	5 : 95	33
Nether Heyford	-	46	30 : 70	22
Netherwild	upper	27	25 : 75	17
	lower	21	20 : 80	10
Norfolk - Caistor				
	upper	25	1 : 99	13
	lower	29	14 : 86	15
Piercebridge				
	primary upper	36	5 : 95	15
	middle	36	15 : 85	16
	lower	35	17 : 83	10

site	context	acid soluble %	gravel : sand	thickness mm
secondary	upper	36	0 : 100	10
	lower	36	1 : 99	8
Pulborough	-	28	8 : 92	22
Munden House	upper	27	25 : 75	7
	middle	27	8 : 92	5
	lower	23	25 : 75	17
Silchester	upper	25	10 : 90	11
	lower	20	16 : 84	13
Staines	upper	26	25 : 75	9
	lower	30	25 : 75	8
Stanwick	-	25	30 : 70	12
Star primary	upper	60	10 : 90	9
	lower	43	10 : 90	19
	secondary	58	- -	12
Thorpe	upper	18	0 : 100	10
	middle	16	0 : 100	25
	lower	16	0 : 100	10
Verulamium				
	1 upper	19	2 : 98	16
	middle	20	45 : 55	16
	lower	12	26 : 74	15
	2 upper	23	5 : 95	14
	middle	19	17 : 83	12
	lower	34	15 : 85	17
Wall	upper	27	20 : 80	13
	middle	22	10 : 90	12
	lower	21	11 : 89	21
	ceiling	89	25 : 75	34
Wigginton	-	51	8 : 92	17
Wyck	upper	44	33 : 67	17
	lower	44	37 : 63	10
York primary	upper	39	15 : 85	14
	middle	40	25 : 75	15
	lower	57	20 : 80	10
	secondary	40	5 : 95	5
	wattle impressed	92	7 : 93	35

Lime interfaces from various sites; thickness in mm:

0.1, 0.5, 0.4, 0.75, 0.2, 0.5, all pure "lime", average 0.4mm.

The average results for some of the plaster values are given in Tables 8, 9 and 10 but it can be seen that there are very wide ranges for all the materials, probably relating to local geologies.

TABLE 8

PLASTER AVERAGES

layer	"lime"%	gravel : sand	thickness mm	gravel% : sand%
primary				
upper	31	14 : 86	12	10 : 60
middle	28	14 : 86	14	10 : 62
lower	32	16 : 84	14	11 : 57
secondary				
upper	37	6 : 94	8	4 : 59
lower	30	8 : 92	10	6 : 64

volume calculations	lime putty : gravel : sand
primary	
upper	18.6 : 5.3 : 37.5
middle	16.8 : 5.3 : 38 7
lower	19.2 : 5.8 : 35.6

volume calculations	lime putty : gravel : sand
secondary	
upper	22.2 : 2.1 : 36 9
lower	18 : 3.2 : 40

TABLE 9

OPUS SIGNINUM PLASTERS

site	context	acid soluble %	gravel : sand	thickness mm
Beauport Park	-	38	50 : 50	11
Bignor	upper	30	50 : 50	9
	lower	46	41 : 59	12
Caerwent	upper	40	40 : 60	13
Cirencester - B.P.				
	lower	54	45 : 55	14
Claydon Pike	-	50	30 : 70	18
Colchester	pointing	52	18 : 82	-
Droitwich	upper	30	25 : 75	24
	lower	30	25 : 75	24
Empingham	middle	50	38 : 62	16
	lower	42	31 : 69	21
Exeter	upper	38	40 : 60	13
	lower	38	35 : 65	19
Feltwell	-	29	62 : 38	15
Littlechester	upper	37	27 : 73	11
	lower	23	16 : 84	11
Netherwild	upper	40	40 : 60	19
	lower	40	50 : 50	16
Norfolk - Caistor				
	upper	42	30 : 70	28
Piercebridge	upper	38	40 : 60	16
	middle	30	40 : 60	10
	lower	38	55 : 45	8
St Albans - Munden House				
	lower	40	51: 49	21
Silchester	ceiling	56	1 : 99	25
Wall	upper	40	55 : 45	15
Wiggington	-	30	32 : 68	11
	-	46	35 : 65	26
York	upper	38	35 : 65	17
	lower	35	32 : 68	35

TABLE 10

OPUS SIGNINUM PLASTER AVERAGES

layer	"lime"%	"gravel" : "sand"	thickness mm	"gravel"% : "sand"%
upper	39	39 : 61	14.5	24 : 37
lower	39	40 : 60	17.8	24 : 37

volume calculations	lime putty : "gravel" : "sand"
upper	23.4 : 16 : 28.4
lower	23.4 : 16 : 28.4

It should be noted that the "sand" size was mainly crushed tile.

Ceiling weight loadings

Samples of ceiling plaster from **Wall** and **Colliton Park** were used to tentatively calculate the weight loadings on ceilings. The surface area and weights were measured on the three samples available and gave very high weights per unit area as follows:

Wall: 89kg/m^2, 71kg/m^2, 46kg/m^2, for thicknesses of; 60, 80 and 30mm respectively.

Colliton Park: 53kg/m^2, for a thickness of 45mm.

By using larger sample sizes and numbers it should be possible to calculate more accurately the actual weights of ceilings and from these the sort of structures needed to hold them up.

INTONACO ANALYSIS

Layer thickness

Layer thicknesses varied from 0.15mm to 1mm and up to 4.5mm, particularly when calcite was included. The very thin layers may have been brushed on rather than being floated or trowelled on. The burnishing of damp plaster would have compacted the surface layer, making it thinner and evening out slight surface variations. In extreme cases polishing removed all traces of the method of application.

c.f **Fishbourne** and **London - Winchester Palace**.

Table 11 gives a summary of the values for the acid soluble or carbonate content, aggregate content and thicknesses. for the *intonaco* layers.

TABLE 11

INTONACO ANALYSIS

site	acid soluble %		thickness mm
Alcester	87		0.5
Baldock	-		0.6
Bancroft	-		0.4
Bath	97		0.9
Beddington	86		0.6
Bignor	-		0.75
Brean Down	89		0.4
Caerleon	89		0.5
Caerwent	-		0.5
Canterbury	50	white	0.5
	79	red	2
Carlisle	86		1.5
	-		0.5
Castle Copse	-	white	0.1
	-	black	0.4
	-	red	0.3
Charlton Kings	99		0.6
Chester	35	with calcite	4.5
Cirencester B.P.	-		0.4
K.C.	-		0.9
LG	-		0.5
Claydon Pike	97		0.5
Dorchester	62		0.3
Poundbury	-		0.5
Dover	87		0.8
Droitwich	75		0.5
Empingham	-		0.2
Exeter white	75		1.0
red	30		0.8
Feltwell	-		0.5
Fishbourne	94	with calcite	1.2
	79	without calcite	0.6
Hockwold	-		0.9
Lincoln	-		0.4
Littlechester	62		0.5
London Southwark	76	white	0.6
	64	yellow	0.4
Lullingstone	89		0.3
Malton	75		0.8
Nether Heyford	65	burnished red	0.15
	52	white	0.5
Netherwild	59		0.8
Norfolk - Caistor	-		0.6
Piercebridge	87		0.6

site	acid soluble %	thickness mm
Pulborough	84 white	0.8
	- red	1
Munden House	89	0.6
Silchester	91	1.5
Staines	80	0.6
Star	90	0.5
Thorpe	75	1
Verulamium 1	-	0.5
2	69	1
Wigginton	66	0.5
Wyck	86	0.5
York	81	1

Average results 78% 0.8mm

volume 46.8 : 13.7 lime putty : sand (approx 7 : 2)

(Many samples showed very little aggregate or sand.)

PAINTING AND PIGMENTS [Tables of analysis]

General comments

Most of the pigments analysed were taken from wall paintings. A few samples were found on pot sherds or as lumps of pigment.

The pigments were identified by combinations of the following techniques : microscopic examination, micro-chemical tests, X-ray diffraction and X-ray fluorescence.

It should be noted that in *fresco* paintings pigments are invariably contaminated with calcite. X-ray diffraction analysis may only show calcite. Iron was also a very common contaminant both in the original pigments and through burial. Micro-chemical tests usually gave a positive response for iron although the intensity of the result was significant.

White

Usually as a white *intonaco* or less commonly as over-painting of bands or stripes. The analysis shows it to be calcium carbonate, presumably applied as a pure lime slurry. Crushed white chalk would give the same reactions although may show fossil micro-structures. Crushed calcite, which was on occasion added to white lime does show up in view of its crystallinity (Fig. 19).

Glass

Glass has been found as an additive to other pigments. Clear glass was used in conjunction with Egyptian blue In **Leicester** (Blue boar Lane).

Black

This was invariably inert carbon. It appeared usually as amorphous soot or lamp black. Less commonly it showed the cellular structure of charcoal. Providing that the substance is not too finely ground, it should be possible to distinguish wood charcoal from bone charcoal under the electron microscope. Chemically, bone charcoal should show a high phosphorous content and possibly even some protein, (Wetzel 1980, Plesters in Rahtz1963), whilst wood or other plant charcoal may show high sodium or potassium levels, (Parr 1981) providing they have not been leached out.

Yellow

Yellow ochre in a range of purities, from pure hydrated haematite, $Fe_2O_3.2H_2O$, limonite or goethite, to mixtures of limonite with earth or haematite, from bright yellow to yellow brown in colour. The yellow orange colour of orpiment / realgar, arsenic sulphide, $As_2 S_3$ / $As_2 S_2$, has not been found on paintings but separately or associated with other pigments (**Caersws**, **Leicester**, **Mancetter**, **Silchester**).

Gold

Gold leaf has been identified on one definitely stratified sample of wallplaster at Colchester, (Colchester Museum 34. 1953, Hull 1958) and on one possibly Roman fragment from **London**, (**Winchester Palace**, Southwark, Mackenna and Ling 1991). Examination showed it to be simply gold leaf, presumably fixed on with some form of glue. Neither sample has been subject to full analysis.

Orange

Usually mixtures of red and yellow ochre or par-burnt yellow ochre. The orange pigment red lead has been found on only two sites in this survey:- **Cave's Inn - Tripontium** and **Silchester**.

Red

Commonly red ochre, haematite (Fe_2O_3) in a variety of purities, ranging in colour from intense red to dark red / brown. Mica was often present, showing the use of micaceous haematite. Burnt yellow ochre may well have been used, giving a good range of colours. Experiments show that it is fairly easy to reproduce various hues. The carefully controlled burning of yellow ochre gave X-ray diffraction data showing the gradual transition from yellow ochre to red ochre (Nayler 1986, Rickerby 1988). Particularly in the case of very thick layers, such as red *intonaco*, it appears that ground earthenware such as brick or pottery was often used as a colourant (Wilson 1984). Less commonly the brilliant red of cinnabar (HgS) was used, probably imported from Spain. In its artificial form cinnabar is known as vermillion.

Green

Occasionally mixtures of yellow ochre and Egyptian blue, but usually green earth, being mainly the mineral glauconite. Usually this appeared to be amorphous, but it was sometimes found in coarse grains which showed a foram-like structure (**Dover**). These point to the origins of the glauconite in fossils and chalk beds. It is also found as the colourant in greensand.

Blue

Manufactured Egyptian blue, also known as blue frit or burnt blue, is copper calcium silicate, $CaCuSi_4O_{10}$, and was probably imported. Pliny reported it as having been made in Italy, at Puteoli (modern Pozzuoli) near Vesuvius. The naturally occurring mineral, cuproriviate, has also been found at Pozzuoli (Mineralogical Abstracts, 1940, 225). It is known from earlier Egyptian contexts: Flinders Petrie excavated large lumps of it from sites dated to 1990 - 1200 B.C. in the 1880s, including pieces of pale turquoise and green colour (Russell 1892). The colour of Egyptian blue depends mainly on two things :- the intensity of the blue produced during manufacture, (it may be paler or darker or be greenish if iron is present), and on the particle-size. The larger the particle the more light is refracted through it, giving a more intense colour. When the pigment is finely crushed, more white light is reflected off its surface than is refracted. This gives a lighter appearance. It was difficult, however, for coarse particles to be fixed to wall paintings by the buon fresco technique, and often some form of compromise seems to have been used or textured surfaces created to retain the particles.

In tempera may have been used but the organic binders would tend not to survive burial, leading to the powdering of the paint layer. Blue was usually found as crushed Egyptian blue on wall paintings, less commonly small spheroidal lumps were found either singly or in clusters. They varied in size from about 8mm to 12mm in diameter, and weighed from 0.6g to 1.3g. Large clusters resembling bunches of grapes have been found on occasion.

Analysis of crude lumps or spheres of Egyptian blue shows that on occasion copper alloys as opposed to pure copper were used in its manufacture. These have been identified by X - ray fluorescence as traces of:- tin, lead and zinc, in variable proportions (**Colchester**,

Dorchester, Leicester, Bancroft). This could be derived from scrap bronze or possibly copper alloy waste such as dross, which could have been easier to powder than metal. Quantitative results are not available yet.

Another blue colour is given by the Rayleigh effect. A film of fine carbon (such as carbon black or fine charcoal) on lime on white lime gives a blue grey tint. It is due to the differential absorbtion and reflection of light by the lime and carbon and is named after the nineteenth century scientist Lord Rayleigh. (Brill 1980: 93 - 4). This blue grey may also have some Egyptian blue mixed with it. It was perhaps used as a cheaper version of blue, at least where the delicate blue grey shade was not deliberately intended.

Other pigments

Apart from lumps of Egyptian blue, the following materials have been found in massive form and could have been used as pigments:-

realgar / orpiment; , **Caersws**, **Leicester**, **Mancetter**, **Silchester.**

madder lake; **London**, **Mancetter.**

white lead; **Mancetter.**

Table 12 gives the acid soluble or carbonate content of the paint layers and measured thicknesses.

TABLE 12

PAINT ANALYSIS

site	acid soluble %	thickness mm
Alcester	97	0.1
Baldock	-	0.15
Bancroft	-	0.1
Bath	96	0.3
Bignor	-	0.05
Brean Down	-	0.05
Caerleon	-	0.1
Caerwent	-	0.2
Canterbury	82	0.2

site	acid soluble %		thickness mm
Carlisle	-		0.05
whitewash	88		1.7
Castle Copse	-		0.1
Charlton Kings	69		0.15
Cirencester B.P.	-		0.075
K.C.	-		0.1
L.G.	-		0.1
Claydon Pike	-		0.075
Dorchester	-		0.1
Poundbury	-		0.3
Dover	-		0.1
Droitwich	-		0.1
Empingham	-		0.07
Exeter	-		0.05
Fishbourne	-		0.3
Hockwold	-		0.2
Lincoln	-		0.1
Littlechester	-		0.09
London Southwark	-	primary	0.2
	-	secondary	0.05
Lullingstone	81		0.1
Malton	-		0.1
Nether Heyford	-		0.05
Netherwild	93		0.2
Norfolk - Caistor	-		0.07
Piercebridge	95		0.15
Munden House	84		0.05
Silchester	88		0.1
Staines	-		0.06
Thorpe	-		0.05
Verulamium 1	-		0.08
2	-		0.25
Wigginton	84 red		0.2
	98 white		0.2
Wyck	-		0.25
York	-		0.1
Averages	88%		0.18mm

OTHER EVIDENCE

The covering power of cinnabar was determined by scraping off a measured surface area, removing the lime consolidant and weighing the residue or determining the chemical content of the particular compound concerned. The calculations have also been used in a attempt to calculate the cost of painting walls related to Pliny's pigment prices (H.N. 33, 40). Pliny quoted the price of 70 sesterces a Roman pound (320 g) for refined cinnabar and analysis shows that a square metre of wall could have about 40 g of cinnabar on it. This would have cost about 8 sesterces in pigment alone, and at current prices (1992) for cinnabar this would be equivalent to £60. It should be remembered that Pliny quoted the prices of materials available in Rome. The price of imported pigments in Britain may have been considerably greater. The very small amounts of pigment used show that they have good covering properties.The results should be considered tentative as only a few small samples have been measured to date.

CHAPTER 6 DISCUSSION AND INTERPRETATION

STRUCTURAL TYPES

From the preceding mortar and plaster analytical results, the following classification may be proposed for distinction by structural purpose:

1) foundations - for walls and floors, being usually mainly aggregate.

2) structurally massive or cast; for aqueducts and arches; resembling modern concrete in use if not composition.

3) levelling and bonding - for bricks, tiles and masonry.

4) rendering - including waterproofing, plasters, stucco, floors, walls, ceilings.

5) finishing - in this group is included: *tesserae* bedding mortars and grouts, *intonaci* and glazing 'putty'.

In view of the generally decreasing thickness of such material, the aggregates used will also be finer with increase in type number. The minimum thickness of any uniform layer of mortar is determined by the maximum thickness of any aggregate particle. The finer mortars often also have a higher lime to aggregate ratio. This is particularly likely in *intonaci* and *tesserae* bedding mortars.

Aggregates

Bearing in mind that present day surface geology may be different from that of Roman times, particularly with respect to worked out or buried deposits and river movements, the following observations were made:

Analysis suggests that aggregates were usually taken from the nearest available deposits. Whatever was to hand seems to have been used. In most cases this information is deduced from current geological maps. In a few cases samples of local sands were compared with the aggregate residues. In areas without sand, crushed or weathered rock of approximate sand size (2mm to 0.1mm) was used, or brought in from the nearest source (**Fishbourne**). The presence of different sands on one site does show importation from more than one source (**York**). However, even sand from one source can vary. Sand deposits will show different grading both horizontally and vertically and river sands can be very varied in quite small areas. The presence of angular material points to crushing or weathering (frost) of larger rocks (**Dover**). If mortar is mixed by pounding, as recommended by the classical writers, all of the particles in the mortar will tend to show damage. If crushed material was added to sand then two distinct aggregate gradings were seen (**York**). Crushed material alone tends to give an ungraded or broad distribution curve (*opus signinum* type material). The material being crushed often has little effect on the curve, unless it is itself composed of a composite material. e.g. sandstone, sandy brick or tile. In this case the hard sandy inclusions often separated to give a peak of their own in the general curve.

Examples of the grading of crushed material and natural sands are given in the Appendices. Natural angular material tends to be close to its source, in particular if weathered, as movement soon begins to round off sharp edges, as is found in water deposited sand. Both natural and artificial crushing and grading will effect the particle shape and size.

The use of crushed earthenware in the form of brick or tile improves mortar resistance considerably, both to decay and wear. Floor samples with tile often show the lime mortar worn away, exposing the resistant aggregate. The hydraulic properties of tile dust, producing calcium alumino silicate type mortars, was very noticeable during analysis. Mortars with high percentages of tile dust, ungraded crushed tile dust or similar siliceous material, were often very resistant to the acids normally used to dissolve the lime matrices. In addition, the angular nature of the larger particles produced a mechanically stronger mortar. The gelling of mortars during the dissolution process was usually caused by the presence of fairly high levels of colloidal or amorphous silica, either from hydraulic lime or from siliceous aggregates such as crushed brick or tile. The presence of very high levels of such siliceous materials often considerably slowed down the dissolution process. Marl and clay had a similar effect.

Blake (Blake 1947, 314) considered that sieves were in use in Rome before the second century A.D. , and Vitruvius (Vitruvius 7, 6) did mention sifting. The use of sieves is suggested by the close particle-size grading in a few cases. However, the lack of comparative samples from local deposits which may have been naturally well graded means that this can be only be a suggestion. The occurrence of coarse tile particles only in a floor surface, and the absence of coarse particles in the lower layer, does mean that some form of grading was available. (Unstratified sample probably from London, Governor's Palace)

Old mortar or plaster was often re-used as a source of aggregate. (c.f. **Caerwent, Castle Copse, Fishbourne, Stanwick**). It was obviously essential that any re-used material was noted before analysis was carried out. When the re-used material was large enough it was extracted physically from the matrix and separate analyses carried out. This related to earlier phases and on occasion gave information about earlier decorative schemes. (c.f. **Leicester - Norfolk St**)

Lime

As with aggregates, lime may have been derived from local sources of limestone, which may in fact have been at some distance, or it may have been brought from even further afield. The presence of amorphous silica, fossils or glauconite particles were useful pointers to the original type and perhaps source of the limestone. The glauconite is often the infill of minute fossils such as foraminifera. By varying the method of dissolution used to separate the aggregate, it may have been possible to isolate the glauconite particle complete with the shell of the fossil, if it had survived. From these it may have been possible to get a good idea of the precise type of the limestone. e.g. lower chalk. It is of course possible that such material may be added to the original aggregate as well as or in place of the lime. The original microscopic observation showed glauconite bearing limestone when it was present. It was not possible to identify accurately glauconite nodules in this project (Fig. 9).

The properties of lime depend very much on the type of limestone, giving variation in strength and colour. The colour is usually not important for mortar, but for the finishing coat or *intonaco* it is often required to be white. Only fairly pure calcium carbonate, such as white chalk, marble or possibly dolomite mixtures could be used. Where white plaster was found in areas without white limestone or dolomite, transportation was indicated (e.g. **London**). The use of crystalline calcite does show deliberate transportation as suitable material is not widely distributed (c.f. **Chester**, **Fishbourne**, **London**).

The presence of charcoal fragments in many mortar and plaster samples shows that wood was used as a fuel to burn the limestone. The use of coal to burn lias limestone at Caerleon is of interest and may reflect the use of a locally available fuel (Boon 1987, 18).

The strength of the lime depends, apart from the basic material, on efficient calcining and slaking. If the limestone is not fired at a high enough temperature for long enough then the calcium carbonate will not be fully converted to calcium oxide (quick lime). Similarly, if the quick lime is not fully slaked, through being treated too quickly or being of too large a lump, allowing neither the proper calcining nor slaking, the resulting slaked lime will produce poor mortar, plaster or *intonaco*.

The analysis of samples from lime slaking pits showed that the composition can be very heterogeneous. This may be due in part to burial processes, but could also be due to variations in the original limestone, particular if the exposed face of a limestone quarry was composed of various geological strata, the quarrying process producing limestone of varying composition (**Wroxeter**, P. Barker 1991).

Where only fairly pure limestone, high in calcium carbonate, was available, and a hydraulic lime was required, the addition of hydraulic additives was employed. Such additives were commonly:- crushed earthenware (brick or tile), occasionally burnt clay and possibly other burnt rocks. There is always the possibility of the accidental burning of any sort of rock during the calcination of limestone, although one might expect that during the extraction of the lime from the kiln or calcination site, or during the slaking process process, that unwanted material would have been removed. If alumino silicate material had been produced by calcination, it may have set by crystallisation during the slaking process (up to three months). This suggests that either calcining temperatures were not high enough for such production or that that lime was not slaked before mortar making, being actually slaked as it was mixed during the mortar making process. It may be suggested that hydraulic additives were added only at the time of mortar mixing, and that they would therefore be calcined separately and not with the limestone. This would be the case with crushed earthenware. The additive effect is greater with dust than larger particles, such material being porous or having a very large surface area, suggests a chemical or possibly physical interaction with the slaked lime. The use of oolitic limestone, either as a source of lime or as an aggregate, sometimes produced small residual silica oolites during the dissolution process. These tended to be suspended in the solution like tiny balloons. Being simply fragile silica structures, they collapsed on drying (**York, General Accident site**).

Research work by the Building Research Establishment (BRE 1985 - 87) indicates the presence of significant quantities of calcium silicate hydrate in core samples taken from Hadrian's Wall. This silicate may well have been formed by chemical action between the slaked lime and the aggregate over a long period of time. The low temperature chemistry of slaked lime has apparently not been studied in any great detail, particularly with respect to long term interactions with building materials. The BRE report did show that there is some form of interaction between slaked lime and certain aggregates, and this may well explain the presence of hydraulic type mortars where earthenware type additives are absent. Comparative analysis of the mortars and local lime deposits does suggest the deliberate and use of hydraulic lime. Also of note was an observed reaction with the basaltic whinsill used as aggregate with the lime in the mortar (**Hadrian's Wall**). Similar work has been carried out on the 'concrete' from various Roman structures on the Continent (ICCROM 1982).

ANALYTICAL PROBLEMS

Re-used material

Material from robber trenches was obviously an unreliable source of samples They may have contained mortar from several phases. Even mortar from surviving walls can be of several phases, varying through the height and from the face to the core, and with the risk of re-pointed or repaired material being present.

The environment

Environmental conditions such as burial or the atmosphere, can seriously affect lime analysis. Lime can be leached out, moved within structures, replaced with other ions and re-deposited within or outside the structure. Areas of high rainfall, varying watertable and waterlogged burial provided extreme examples:

Areas of walling at **Carlisle, Annetwell Street**, showed what was apparently limeless mortar. Closer examination showed traces of silica replaced lime and tiny fragments of lime mortar. The site was frequently waterlogged. Lime was retained in samples of *opus signinum* or hydraulic mortars. This suggests that the presence of silica promotes lime replacement or prevents the loss of adhesion of the particles until the lime is replaced. This points to the ground water being fairly acid and having a high silica content.

At **York, General Accident** site, samples of plaster and mortar were contaminated with iron and sulphides due to burial in anaerobic deposits. This made colour interpretation very difficult, and lime analysis slow.

At **Bignor**, a sample of plaster showed a silica and iron layer parallel to the surfaces, suggesting slow migration of those ions from the outside to the core. The silica layer was much harder and somewhat darker than the plaster, giving the impression of layering and obscuring to some extent the true layers within the plaster. It should be noted that this parallel layer did not show up until the cut surface was polished.

The re-deposition of lime as wash-stone, stalagmite or apparent whitewash or limewash is detailed above. Also of note is the interstitial re-deposition of lime, giving layers or films of white lime within mortar or plaster structures (e.g. **Hadrian's Wall** Fig. 11), and of the formation of tufa-like concretions at ground to wall interfaces (**Hadrian's Wall**).
The presence of large amounts of iron from the burial environment may hinder both lime analysis and colour interpretation. Acid dissolution usually removes any iron but its presence should be noted during the preliminary visual examination.

The historical record suggests that organic binding media may have been used in painting. However, biological decay and leaching during burial, cleaning, conservation treatments and general handling usually make the search for organic traces pointless. Only by very careful excavation and immediate laboratory treatment may organic residues be looked for and their presence determined with any accuracy. No attempt was made to look for organic binding material in this project, although samples have been saved for possible future research work.

Preparative technique

The technique of preparation of the sections for the initial observation of the structure sometimes gave different results, particularly between wet and dry or broken and sawn sections. Hand broken samples often broke around hard aggregate particles when the lime was softer than them. Those broken with a hammer sometimes fractured across hard particles when the lime was as hard as or harder than the aggregate. Sawn samples did not often show variations in hardness, simply cutting across all the components. The appearance of variations in hardness may point to either differences in the lime used or variable preservation. [An example of this was found at **Wall** where a hammer-broken sample showed variations in hardness not shown by the sawn and polished section.] Wet sections did sometimes show layers which were not obvious in the dry state.

CHAPTER 7 CONCLUSION

COMPARISON OF THE CLASSICAL RECORD WITH THE ANALYTICAL RESULTS

The various recipes and building techniques mentioned in antiquity have been compared with the results of the scientific analyses where appropriate. There have been problems in that the original quantification usually cannot be related directly to the results obtained. The original specification for the respective quantities of lime and aggregate usually refers to "parts" of each, which is presumably by volume. In the case of lime, this would refer to lime putty. After carbonation this changes to calcium carbonate which has a different molecular weight and will be drier. The results of the analysis are initially for the weight of dry calcium carbonate. These can however be calculated to give an estimation of the original weight of dry slaked lime used and less accurately to the volume of lime putty. The original water content and volume of the lime putty must be an approximation. The measurement of plaster and mortar layers is less of a problem, assuming the accepted sizes for Roman measurements.

Limestone

Most of the evidence for the selection of limestone is derived from lumps of limestone mixed in with the mortar or plaster. This may be un-burnt lime or simply the limestone used in with the aggregate (Fig. 20). The limestone generally appears to be locally derived, but on occasion deliberate selection seems to have taken place.

Examples of such selection were found at **Hadrian's Wall** where the less easily accessible hydraulic lime had been used instead of the closer non-hydraulic limestone (**Hadrian's Wall 1**), and where the lime used in mortar was discoloured and white lime had been used for *intonaco* layers and paint (**passim**). The deliberate selection of crystalline calcite for use as an additive to the *intonaco* layer is fairly rare (**Chester, Fishbourne, London - Fenchurch St** Fig. 19, **Silchester**). It usually took the form of distinct calcite crystals rather than the more crushed form obtained from translucent powdered marble, seen in some examples from Rome (Courtauld Institute Collection).

The common occurrence of charcoal fragments in mortar samples shows that wood was used to burn limestone, as noted by Cato (Cato 4, 16, 1; 4, 38, 4).

Hydraulic additives

The most common additive was earthen ware in the form of crushed brick or tile. Sometimes pottery was found with this which may useful as dating evidence (**London, forum**).
The use of aggregates which have an hydraulic effect is also of note, but this may be fortuitous rather than deliberate; the whinsill in the aggregate in **Hadrian's Wall** mortar shows considerable interaction with the lime (Figs 18, 20).

Ratios of aggregate to lime

Whilst the original recipes were probably mainly for volume to volume, the initial results of the analyses were weight to weight. These were approximated to volume using the calculations given in Chapter 5 or those of Wetzel (Wetzel 1980).

The ratios given by the ancient writers are generalised in Table 13:

TABLE 13

Ancient ratios for mortar and plaster (vol : vol)

sand : lime	2 : 1
	3 : 1
	3 : 2
lava + sand : lime	5 : 2
brick : sand : lime	1 : 2 : 1
brick or pozzolana : lime	2 : 1

Table 14 gives the results of analysis for mortar and plasters.

TABLE 14

Analytical results of mortar and plaster

intonaci	sand : lime		
	2 : 7 to 1 : 5 or more		
fine plaster	sand : lime	(wt : wt)	(vol : vol)
		7 : 3	2 : 1
opus signinum plaster		3 : 2	2 : 1
bonding mortar	gravel : sand : lime	(wt : wt)	(vol : vol)
		20 : 48 : 32	1 : 3 : 2
opus signinum mortar	tile / sand : lime	(wt : wt)	(vol : vol)
floor		67 : 33	11 : 5
wall		58 : 42	8 : 5
concrete	gravel : sand : lime	(wt : wt)	(vol : vol)
		34 : 42 : 24	3 : 3 : 2

Although the materials used in Roman Britain were different from those used in Rome, it can been seen that the ratios given in antiquity are comparable with those found by experiment.

If mortar was mixed by crushing with a beetle or other heavy implement, aggregate particles would generally be expected to show damage or angularity. This did occur where the aggregate had been prepared from crushed rock rather that sand or gravel. c.f. **Dover**.

Pigments

Many of the pigments described in antiquity have been found during the survey. The absence of some of the more exotic materials such as indigo may be related to poor preservation as much as analytical technique or rarity due to extreme value. By far the most common are the earth colours and charcoal. The addition of burnt material such as brick dust, burnt ochres and, quite commonly, Egyptian blue gives the whole range of colours necessary for wall painting. The single safely stratified example of gold leaf at Colchester perhaps reflects the importance of that town in the Roman period. The rarity of red lead may be due to the lack of use generally of orange or the easier access to yellow and red ochres, although red lead can be manufactured fairly easily. Cinnabar, although considered by the early writers to be expensive and even vulgar, has been found throughout Roman Britain. Table 15 lists the pigments found in the survey and the probable Roman equivalent name.

TABLE 15

PIGMENTS FOUND DURING THE SURVEY

Pigments found	Roman name	occurrence
red ochre - haematite	*usta, rubrica*	very common
siliceous red ochre	*sinopis*	very common
cinnabar	*cinnabaris / minium*	27 identifications
red lead	*cinnabaris / minium seccundum*	2 identifications
madder		3 identifications
realgar	*sandarac*	3 identifications
yellow ochre - limonite	*sil*	very common
green earth - glauconite	*creta viridis*	very common
lime or chalk	*creta*	very common
white lead	*ceruse*	one identification
carbon - soot or charcoal	*atramentum*	very common
Egyptian blue	*caeruleum*	common
glass		1 find
(This was clear glass mixed with Egyptian blue, and therefore probably not the white Roman *annulare.*)		
gold leaf		1 find (safely stratified as Roman)

The comparison of mortars by lime or soluble content can be unreliable. Original mixes are rarely homogeneous and preservation can be very variable even on one site (**Carlisle**). The solubility of lime depends upon the original material and burial conditions. Low silica lime is fairly soluble and acidic ground water or rain water will dissolve it more readily than neutral water or water containing dissolved minerals such as silica. Ion exchange during burial can affect the apparent lime content. The replacement of carbonate by sulphate or silicate for example, would on first sight suggest a lower lime content. Conversely, the use of calcareous aggregates would give a higher lime content, and may even prevent the use of soluble content analysis as a guide to lime content. The use of physical techniques or modified chemical methods would then have to be used.

This study has been made on more than 1,585 samples of mainly fragmentary material. Usually only large scale recovery gave good art historical information and technical detail such as *giornate di lavoro*, literally 'day's work'. (This refers to the practice of dividing the area to be painted in the *fresco* technique into panels small enough to be painted before the wet plaster dried, being visible as joins in the surface of the plaster.) (e.g. **Leicester - Norfolk St**) Although features such as pick marks and impressions on the rear were obtained from fairly large samples (e.g. **Dorchester**), there was obviously less certainty of interpretation than with much larger pieces or assembled groups.

In view of the lack of material from positively identified structures, the original suggestion of classification of mortars and plasters according to building type or use cannot be proven one way or the other, at this stage. Further research on materials from positively identified buildings is needed to prove or disprove possible variation in technology.

The architectural survey of buildings in Rome does show what is possible with well preserved standing structures (Blake 1947).

Despite all the problems mentioned above, this thesis does show to a varying extent that the techniques of Romano - British wallplaster and mortar are comparable with the recommendations of the classical writers (Tables 13 and 14).. It should be noted that studies of material from Rome itself have shown that the ideals of Vitruvius and Pliny are rarely encountered even in imperial structures (Davey and Ling 1982, 55). The analysis of material from Rome showed that even there only three layers of plaster (rough cast, intermediate and '*stucco* ') before the painting were common (Blake 1947, 321), although earlier researchers claimed that Vitruvian seven layer plaster was common except in the humbler rooms of a house (Blake 1947, 321). *Stucco* in the form of moulded plaster was not seen in the survey of the British material but has been reported by other workers (Cunliffe 1971). I have also seen elaborately moulded material from Rome and Nic opolis in Bulgaria. My examination of material from Rome (in the care of the Conservation of Wallpainting Department, Courtauld Institute of Art) showed that crushed calcite was commonly used in place of crushed marble for *intonaco* layers, a view supported by Hamilton Jackson (Hamilton Jackson 1904, 42). The comments of Vitruvius regarding the use of a marble composed of transparent grains for *stucco* work (Vitruvius 7, 6) should be noted here as it may well appear to be very similar to calcite grains when crushed.

The thesis has also demonstrated a number of more specific points. For example that: local materials were used for the manufacture of mortar and plaster; fewer and thinner layers of plaster were found compared with the recommendations of the classical writers (with the notable exception of the superior painted and polished plaster from the Roman Palace at Fishbourne) and, as there were no recent volcanic deposits in Roman Britain,there is an absence of volcanic lava or 'pit sand'. The deliberate selection of white lime for *intonaco* work, with occasionally the use of crushed coarse grained calcite (transported or perhaps even imported) has also been shown. Another finding has been that mainly local earth pigments, with the notable addition of Egyptian blue and more importantly and less often, imported cinnabar, were used for *fresco* painting. This last pigment has been shown by this study to have been far more common than had been previously thought. Of the seventy sites examined, at the time of writing cinnabar has been identified on twenty seven, from the one occurrence noted at York before the project started (Wetzel 1980). This raises the possibility of greater wealth of the inhabitants of Britain in importing what was apparently an expensive colour. The occurrence of rarely found or transported materials (calcite and cinnabar) in apparently low grade buildings, does introduce problems of interpretation, although in the notable case of the building in **Fenchurch Street, London**, the site was in close proximity to a large public structures, suggesting possibly that 'surplus' materials from those buildings may have been used, perhaps even illicitly, or that the building was of far greater importance than was at first apparent. Of interest also was the very limited occurrence of red lead (which could easily have been manufactured in Britain) and the suggestion for the use of realgar / orpiment, white lead and madder lake by their occurrence in connection with other pigment samples and alone on sites in Britain, although they may equally have been used in the decoration of wood, leather or other materials. (**Caersws, Leicester, London, Mancetter, Silchester**)

This study has not proven that Roman exterior or defensive walls were whitewashed, but has shown that very detailed examination is necessary if it is to be identified in the future.

The careful examination and analysis of mortar and wallplaster can assist the archaeologist in the phasing of construction, sourcing and estimation of the quantities of materials used, interpreting methods of construction and even help in dating structures (by radio carbon dating of charcoal found in mortar, the typing of pottery used in the aggregate, the use of imported pigments and by art historical studies of preserved areas of painted plaster). For the conservator, analysis can give a good idea of the stability of the material, composition for restoration purposes and strength, which is vital in the case of consolidation or transfer of wall paintings.

The technological information provided by the examination of ancient mortar and plaster can be of considerable use in the determination of survival rates of various materials, under various conditions. It may also be of use in the re-appraisal of the efficiency of ancient techniques used in burning lime, the selection of specific types of limestone, and the use of alternative sources of aggregate.

To sum up, my principal conclusion in this study is that, bearing in mind Blake's comments that the researcher should not automatically apply the criteria effective for Rome beyond its immediate vicinity (Blake 1947, 352), it has been demonstrated that, within the constraints of local geological material and transportation, the instructions of Vitruvius and observations of Pliny, regarding plaster and mortar, paints and pigments, can be confirmed for Roman Britain, to a greater or lesser degree, by the techniques of archaeological science.

A final interesting point to make is that my investigations show that there was a decline in craftsmanship towards the fourth and fifth centuries, with the use of fewer or less well defined layers of plaster and a poorer quality of finish. This was usually most obvious where there was over-plastering or where old plaster had been re-used. (**Castle Copse, Leicester - Norfolk Street, London - Winchester Palace**) Although there is limited data and not enough material at present to quantify this impression, the investigation corroborates the view of the art historians that there was a decline in painting style, subject and technique in the later years of the Roman occupation, particularly noticeable where secondary paintings have been found (Davey and Ling 1982: 133 - 4; Mackenna and Ling 1991: 159 - 171).

POST SCRIPT: RECOMMENDATIONS

The uses of mortar analysis for comparative and technological purposes would be made easier and more useful with the co-operation of the archaeologist in supplying adequate samples and details of local materials, such as sand, gravel and limestone, which might have been used in mortar making. Ideally, samples of local materials should accompany mortars for analysis. It should be remembered of course that suitable deposits may long have been worked out, and even that materials may have been transported considerable distances.

The thesis has shown that very little material suitable for proper scientific analysis survives in museums or archaeological sites. Foundation, wall and other mortars are still rarely saved, even though they can be of use archaeologically in the phasing of buildings, quite apart from their value for analysis. Painted plaster is more common, but generally only pieces of art historical interest are saved, such pieces of course being unsuitable for full destructive analysis. Plain or undecorated samples saved at the time of excavation would have provided suitable analytical material. Very often samples, unless found *in situ*, did not show the complete structure from the wall to the surface of the plaster. Even in terms of art history and aesthetic consideration it is advisable to save all wallplaster in order to allow reconstruction and calculation of wall areas and room sizes. This of course would require often considerable extra storage and lay out facilities.

Even where samples are taken, they are often inadequate in number or size. The rule of a minimum of three samples for each analysis is rarely appreciated by archaeologists. Likewise sample weights rarely provide even the minimum 100 grammes for sandy mortar or plaster analysis, let alone the several hundred needed for the coarser aggregate analysis in concrete-like mortars (B.S. 4551).

Further problems exist after excavation, as wall painting fragments are commonly over cleaned on site by washing or damaged in transit by incorrect packing. The practice of using consolidants such as poly vinyl acetate (P.V.A.) or poly butyl methacrylate (P.B.M.A.) to strengthen samples will often consolidate dirt as well and make examination inaccurate or impossible until after it has been removed. Whilst consolidation may be advisable for transportation, it will usually interfere with any future organic analysis for oils or waxes on or within the plaster. Ideally separate samples should be taken for destructive analysis, so avoiding the problems of consolidant removal. Traces of some form of wax were actually found on a Roman wall painting from an un-identified source (Evans 1986), although analysis of painted plaster from York showed that the organic material found there was in fact due to contamination by handling (Wetzel 1980).

The validity of the statement that excavation archives or museum collections are representative of sites and suitable for complete or accurate research depends very much on the number and size of samples taken. In this project alone, collections have generally been found to be inadequate in one or both respects. Sampling, at least to date, appears to have been very much dependent on the personal interests of the excavator and curator, each in turn discarding material. Limitations of space may be valid reasons for "rationalising" collections but lack of immediate interests by specialists is not.

APPENDICES

APPENDIX I

LIST OF SITES SAMPLED:

V = visual examination only

P = pigment identification only

A = number of samples examined including paint identification

No = distribution map reference number

S = number of samples fully analysed

1]	Alcester	building	A 77 S 77
2]	Baldock	buildings	A 41 S 35
3]	Bancroft, Buckinghamshire	villa	V 12 S 2
4]	Bath	bath, temple	A 12 S 12
5]	Beddington, Surrey	villa	A 4 S 9
6]	Beauport Park, E. Sussex	bath house	A 3 S 7
7]	Bignor	villa	A 29 S 17
8]	Binchester	fort	V 19
9]	Brean Down, Avon	temple	A 9 S 7
10]	Caerleon	fort	A 41 S 30
11]	Caerwent	villa	A 60 S 70
12]	Caersws	pigment	P 1
13]	Canterbury	buildings	A 18 S 12
14]	Carlisle	buildings	A 87 S 87
15]	Castle Copse - Devizes	villa	A 50 S 15
16]	Cave's Inn, Warwickshire	building	A 2 S 2
Cheltenham			
17]	Charlton Kings	villa	A 23 S 12
18]	Chester	buildings	A 3 S 6
19]	Cirencester:		
	Barnsley Park	building	A 83 S 28
	Kingscote	villa	A 8 S 4
	Leaholm Gdns	building	A 8 S 4
20]	Claydon Pike, Gloucester	villa	A 23 S 27
21]	Colchester, Essex	villa, wall	A 12 S 6
22]	Dorchester, Dorset	villa	A 13 S 20
	Poundbury	building, grave	A 4 S 5
23]	Dover	villa	A 65 S 50
24]	Droitwich	villa	A 16 S 25
25	Empingham	villa	A 30 S 17
26]	Exeter	buildings	A 26 S 44
27]	Feltwell, Norfolk	villa	A 5 S 3
28]	Fishbourne	palace	A 62 S 3

29]	Hadrian's Wall	wall	A 20 S 22
30]	Hockwold, Norfolk	temple	A 19 S 10
31]	Leicester	villas	V 20 P 10
32]	Lincoln	wall	A 23 S 23
		aqueduct	A 2 S 2
		house	A 12 S 3
33]	Littlechester, Derby	fort	A 178 S 98
34	London, Southwark	bath	A 16 S 13
	Fenchurch St	house / shop	V 5 P 5
		forum, amphitheatre	A 11 S 13
35]	Lullingstone	villa	A 27 S 33
36]	Malton	fort	A 22 S 6
37]	Mancetter	pigments	P 13
38]	Netherwild, Herts	bath	A 24 S 22
39]	Nether Heyford, Northants	villa	A 18 S 23
Norfolk, Castle Museum, Norwich:			
40]	Aylsham	building	A 2 S 1
41]	Bergh Apton	building	V 5
42]	Burgh Castle	building	A 1 S 2
43]	Caistor St Edmunds	temple	A 25 S 17
44]	Caister on Sea	building	A 7 S 1
45]	Great Massingham	building	V 1
46]	Grimston	building	V 5
47]	Tivetshall St Mary	building	V 3
47a]	Warham St Mary	building	V 1
47b]	Wicklewood Crown Thorpe	temple	V 3
48]	Piddington, Northants	villa	A 13 S 2
49]	Piercebridge	fort	A 29 S 58
50]	Pulborough	temple	A 12 S 14
51]	Reculver	fort	A 2 S 2
St Albans, Herts			
52]	Munden House	villa	A 9 S 18
53]	Silchester	building	A 20 S 26
54]	Staines	building	A 10 S 7
55]	Stanton Low	villa	A 55 S 63
56]	Stanwick, Redlands Farm	villa	A 40 S 32
57]	Star, Shipham	villa	A 13 S 18
58]	Thorpe by Newark	building	A 20 S 8
59]	Verulamium	building	A 47 S 33
60]	Wall	building	A 33 S 23
61]	Wigginton	villa	A 16 S 21

62]	Wroxeter	building	A 2 V 20
63]	Wyck, Hants.	villa	A 1 S 3
64]	York	building	A 42 S 36

Totals:
A: 1585
S: 1289
V: 92
P: 29

APPENDIX I contd

LIST OF CINNABAR FINDS

These are the sites where cinnabar, mercury sulphide, used as a bright red pigment has been identified. They are on painted plaster unless stated otherwise. Laboratory confirmation was by X-ray diffraction. The number preceding the site name is the distribution map reference. The colour noted by the sites is the colour of the underlying ground or lower paint layer.

41) Bergh Apton, building: grey on white *intonaco.*
7) Bignor, Roman villa: yellow on white on white *intonaco.*
43) Caistor St Edmunds, Roman town: yellow on pink on white *intonaco.*
10) Caerleon, Roman town: pigment only.
11) Caerwent, Roman town: brown on white *intonaco.*
13) Canterbury, Roman town: yellow on white *intonaco.*
18) Chester Museum collections - visual identification only
19) Cirencester, Kingscote, Roman "villa": white on red on white on cream *intonaco.*
21) Colchester, Roman town: on white *intonaco,* and pigment.
15) Devizes, Castle Copse, Roman villa: pink on grey *intonaco,* yellow on white *intonaco.*
22) Dorchester, Roman town: red on white *intonaco*, and brown on white *intonaco.*
23) Dover, The Painted House: on pink *intonaco.*, and on pink on white *intonaco.*
25) Empingham, Roman villa: on white *intonaco.*
28) Fishbourne, Roman Palace: yellow on pink on white *intonaco,* all with crystalline calcite.
46) Grimston, building: on white *intonaco.*

30) Hockwold, Roman villa ?: orange / brown on white *intonaco* and pink on white *intonaco.*

31) Leicester, various sites: yellow on black on white *intonaco* and yellow on red *intonaco.*

32) Lincoln, various sites: pink on white *intonaco* and yellow / brown on white *intonaco.*

34) London, various sites: on white *intonaco* and yellow on white *intonaco.*

36) Malton, Roman fort: on white *intonaco.*

48) Piddington, Roman villa: red with calcite on white *intonaco.*

49) Piercebridge, Roman fort: yellow on white *intonaco.*

52) St Albans, Munden House, Roman villa: yellow on white *intonaco.*

58) Thorpe by Newark, Roman town: yellow on white *intonaco* and on white *intonaco.*

59) Verulamium, museum collections - visual identification only

62) Wroxeter, Roman town: orange / brown on white *intonaco.*

64) York, various sites: pink on white *intonaco.*

Total: 27 sites

APPENDIX II

FIGURES

DISTRIBUTION MAPS:

1) SITES SAMPLED:
Fig No 21

2) CINNABAR FINDS:
Fig No 22

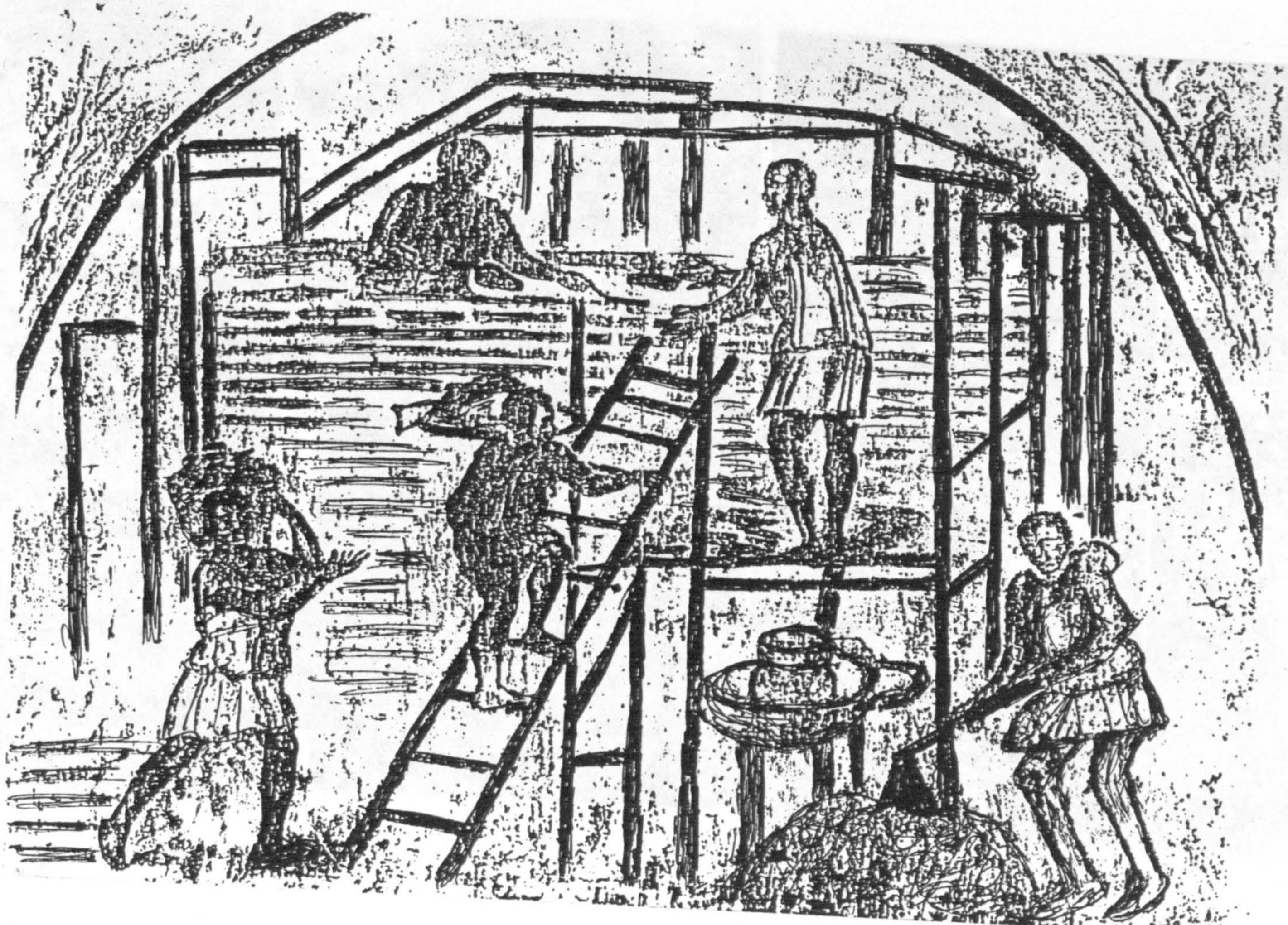
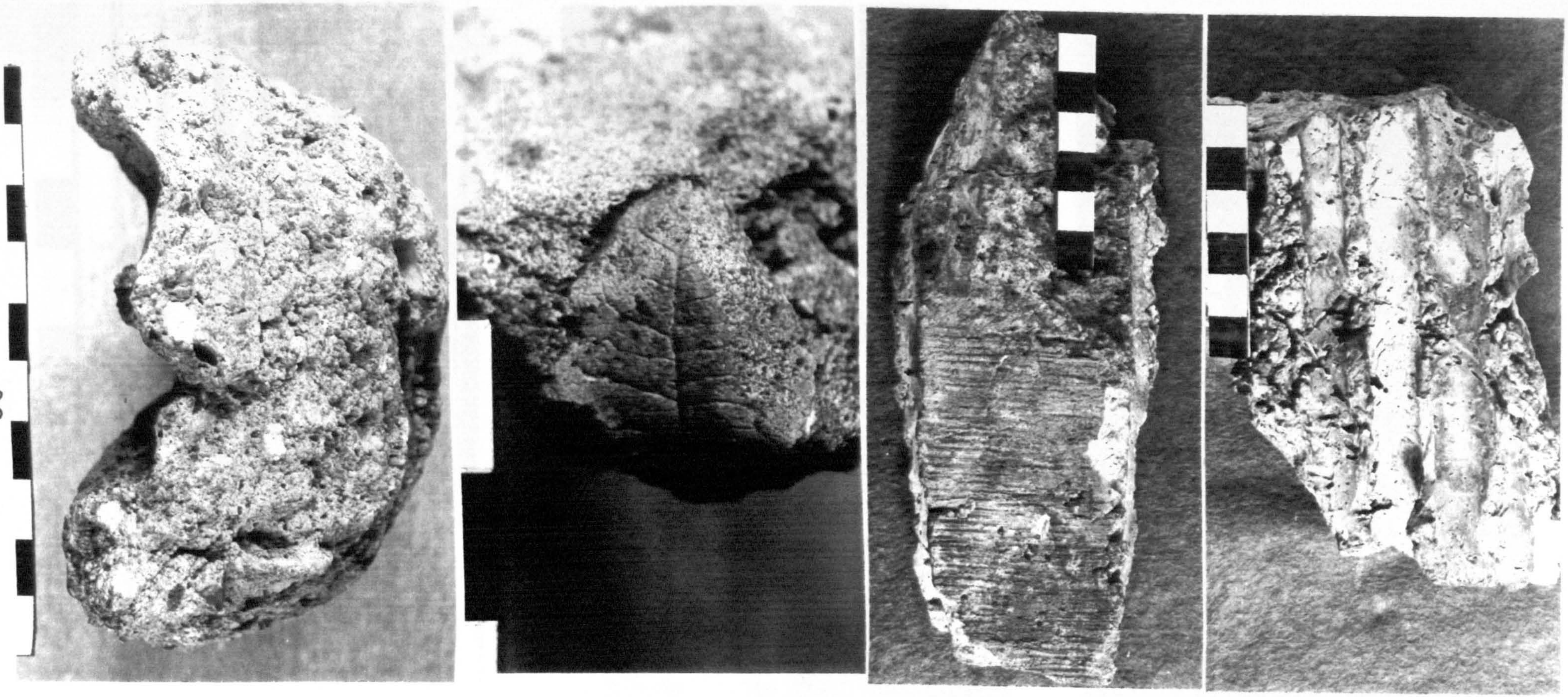


Fig. 1: Wall painting from the tomb of Trebius Justus, Via Latina, Rome, showing mortar mixing and brick laying. (Tentative reconstruction after Blake 1947: 318)



4 3 2 1

Fig. 2: Wattle impressions (1): York; Timber and wattle impressions (2): York; Leaf impression (3): Droitwich; *Imbrex* torching mortar (4): Caerleon Fortress baths.

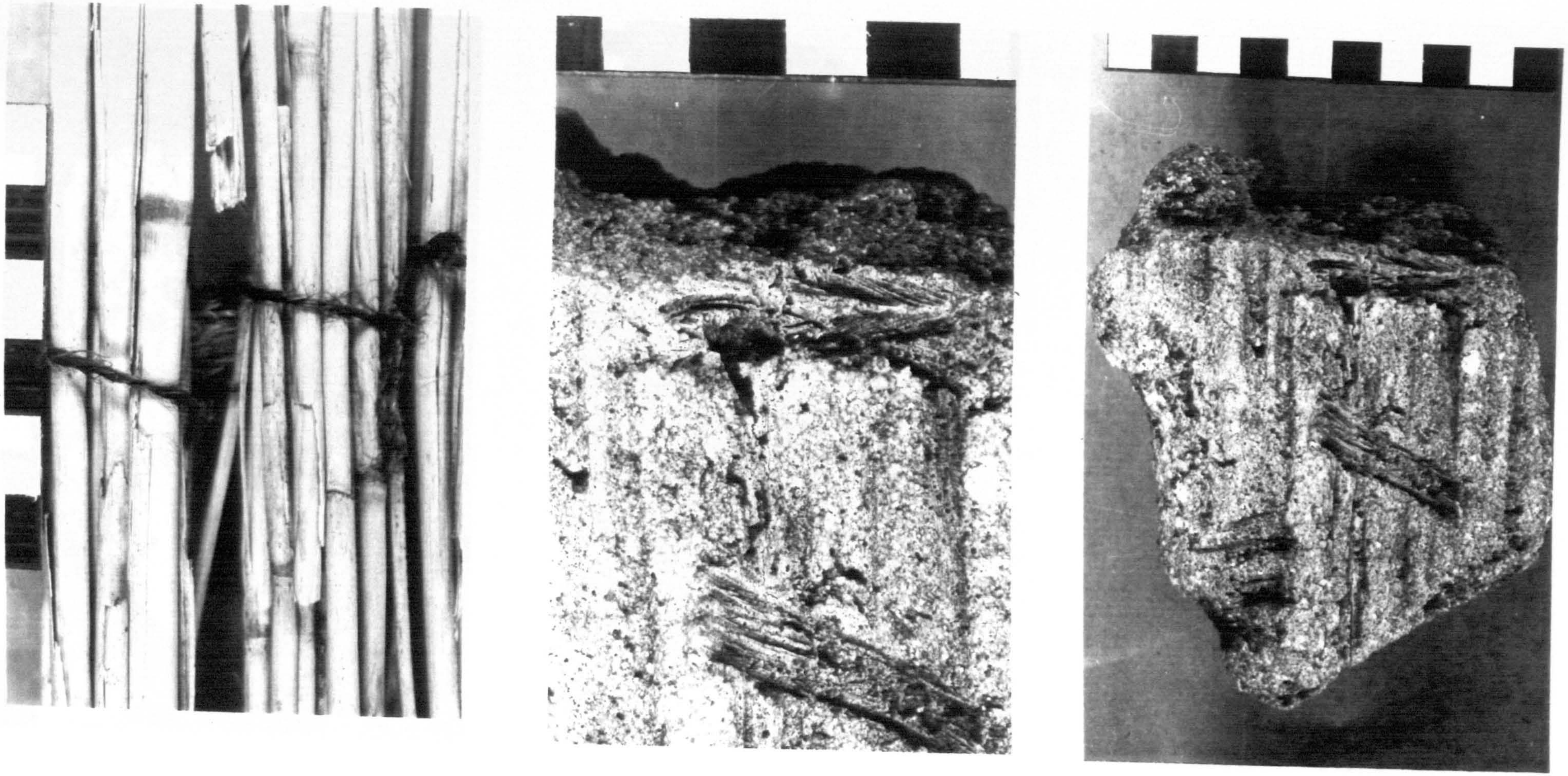


Fig. 3: Tied reed bundle impressions: Colliton Park, Dorchester; reconstruction of reed bundle.

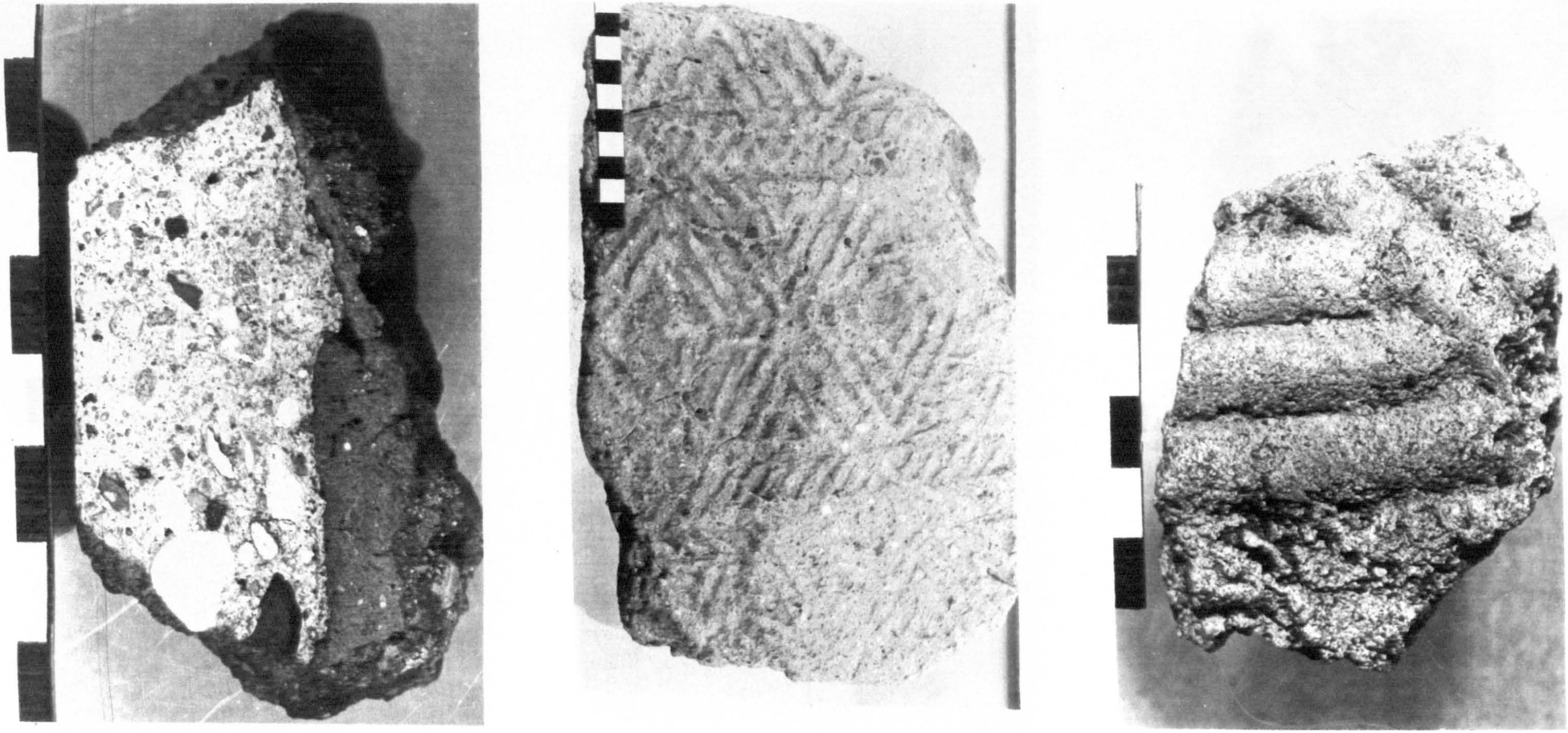


Fig. 4: Broad keying marks (right): Binchester; Roller key impressions (centre): Leicester, Norfolk Street; Section of plaster on keyed mud: Lullingstone (burnt sample) (left).

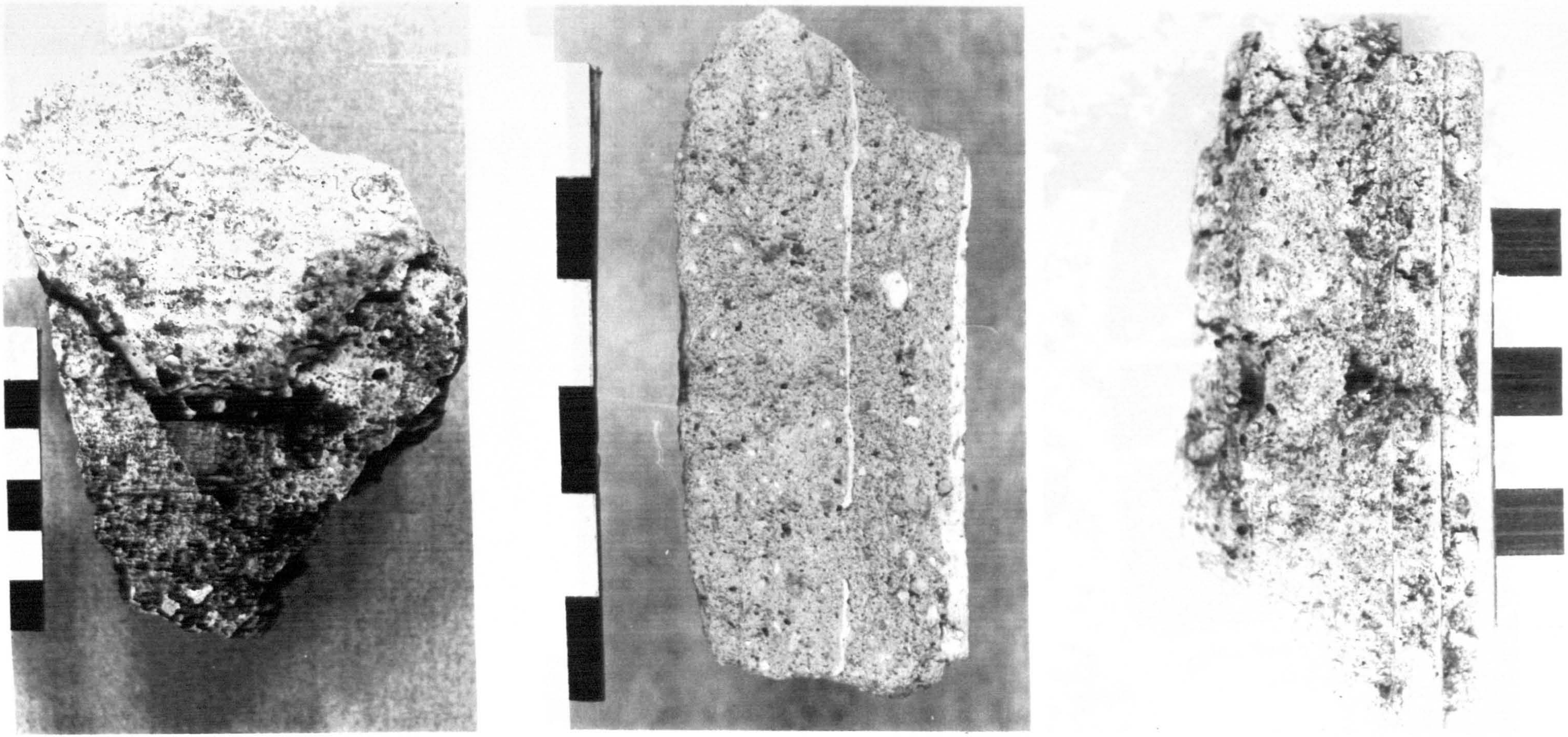


Fig. 5: Multi-phase [3] painted plaster from Colchester (right; Lime inter-face (centre): Malton; Thick lime wash or fine plaster (left): Carlisle Cathedral site.

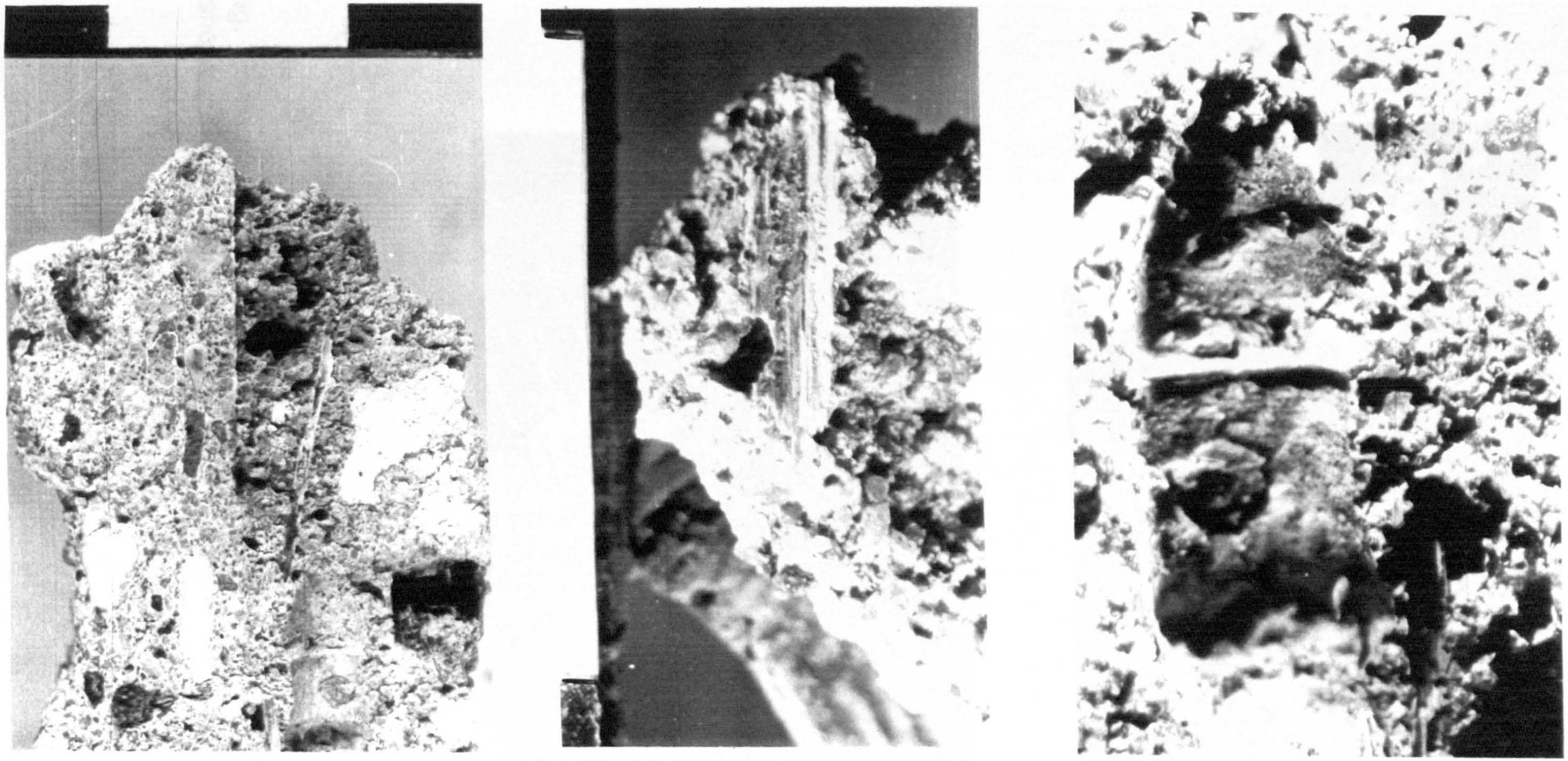


Fig. 6: Over-plastered sample from Lullingstone with organic traces; detail of calcified grass (centre), detail of pupa or caterpillar (right).

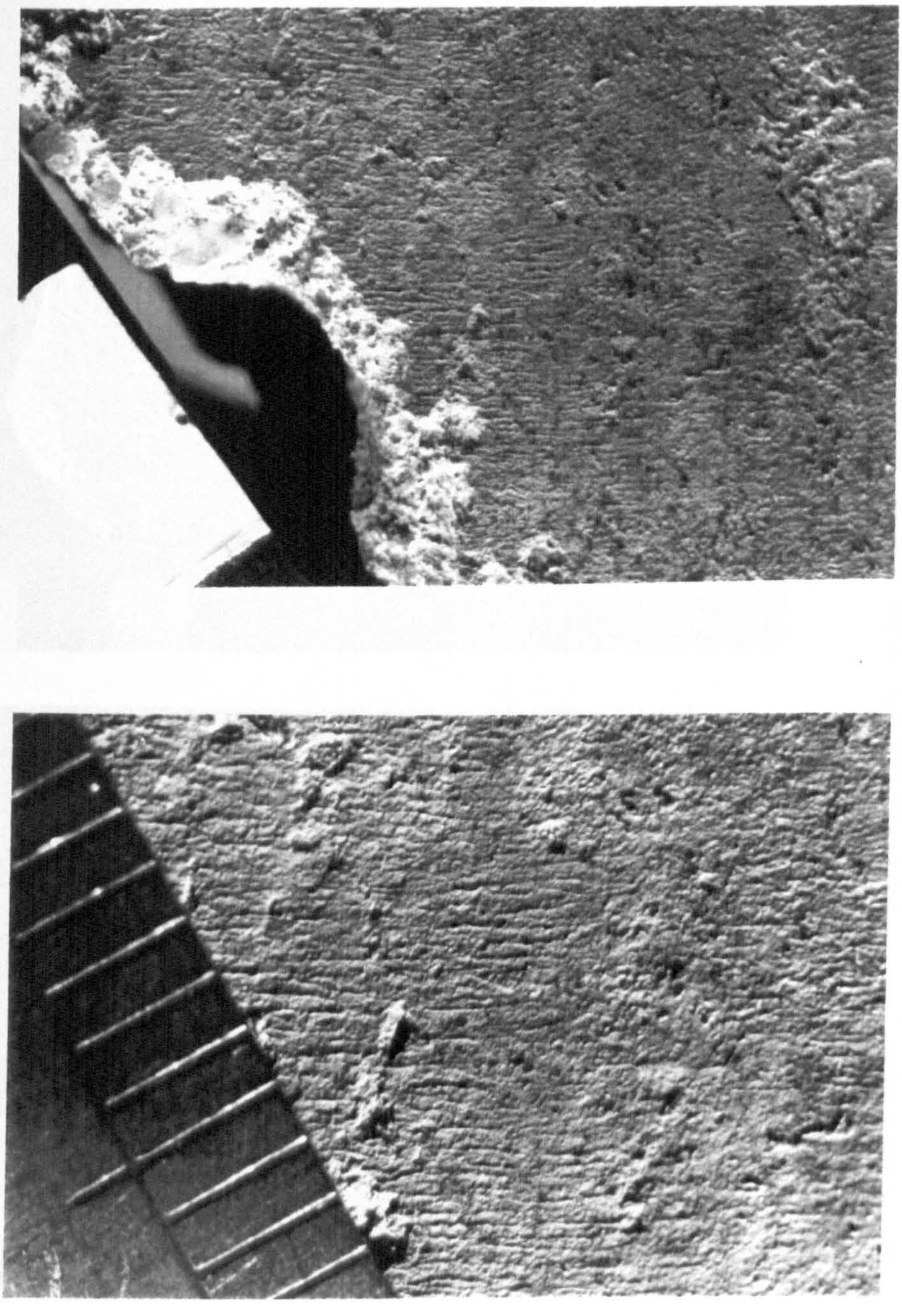


Fig. 7: Burnished plaster from Dover (bottom) and Colchester (top) showing the polished ridges. 1mm and 1cm scale.

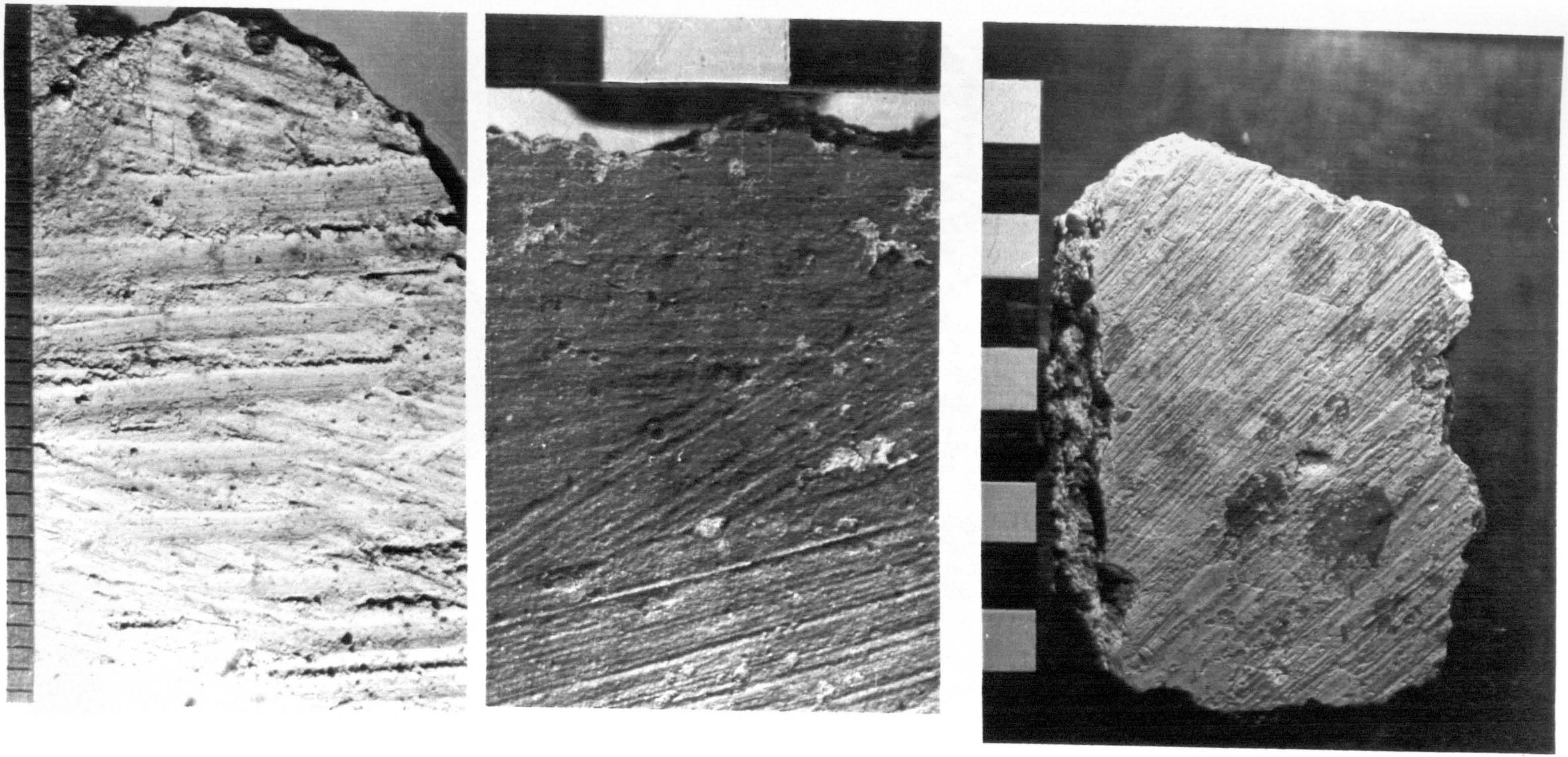


Fig. 8: Brush marks (centre) and float marks (left) with paint splashes over the brush marks (right) all from Dover. 1mm and 1cm scales.

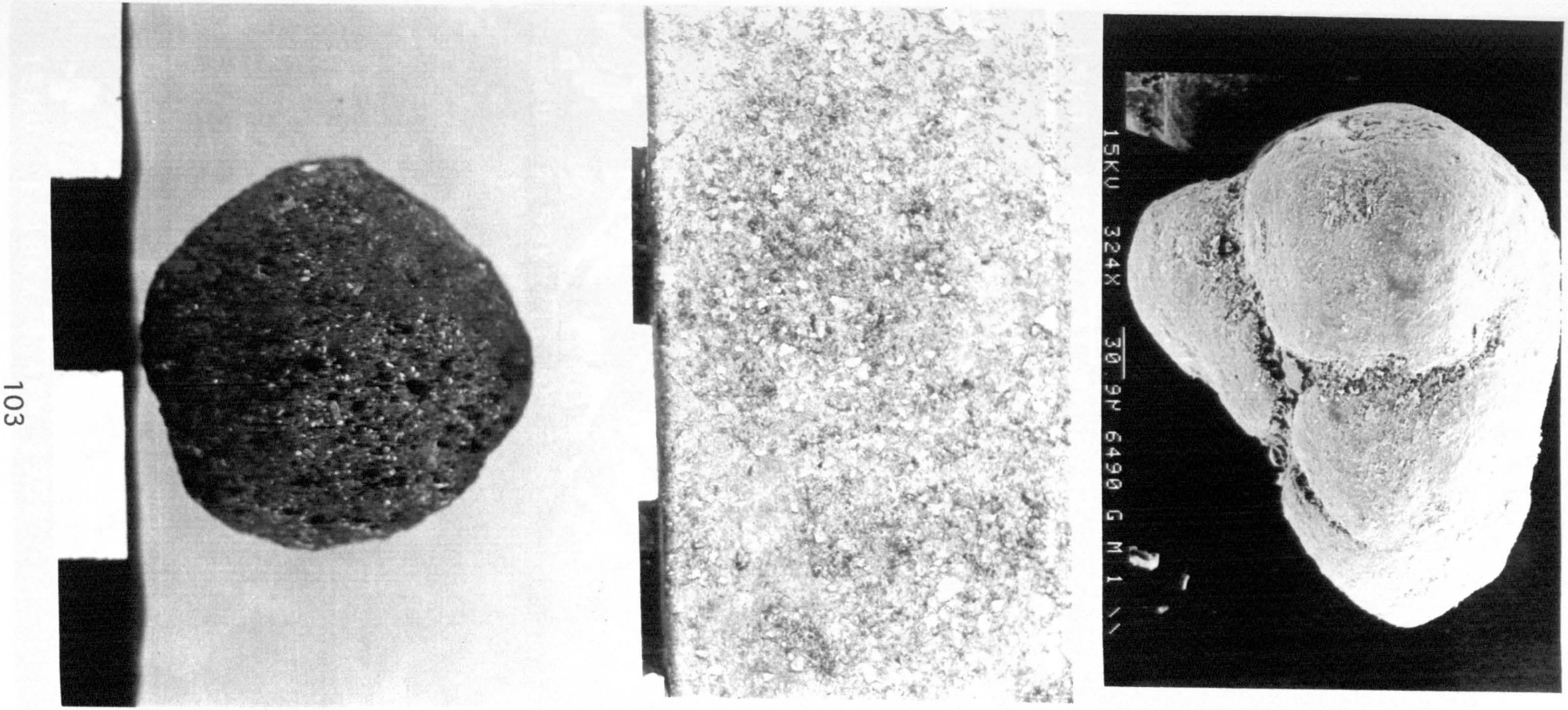


Fig. 9: Glauconitic foram: Dover; Particles of clear glass: Leicester, Blue Boar Lane; Ball of Egyptian blue: Colchester.

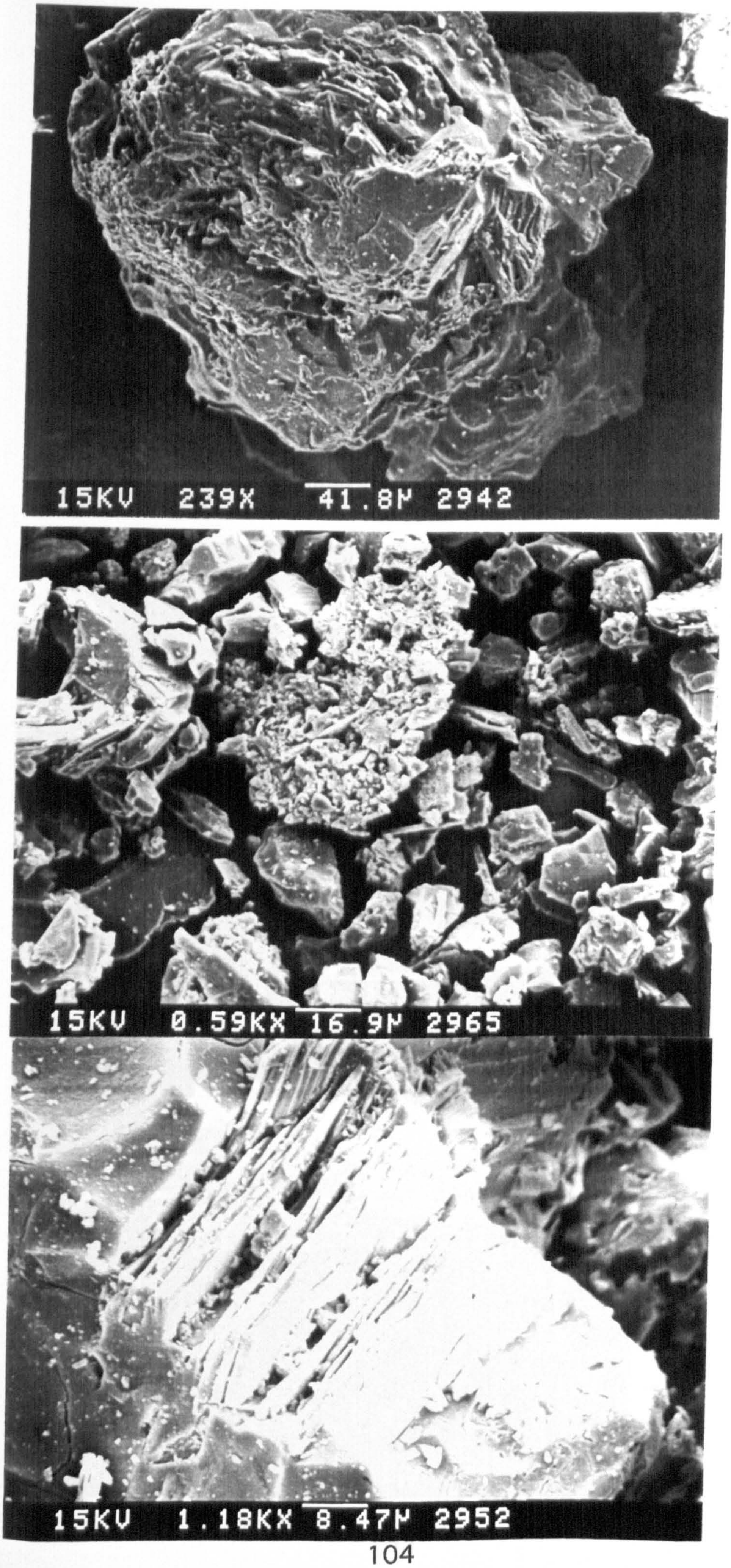


Fig. 10: Details of crushed Egyptian blue from Colchester. Scale bar is in micrometers - μm.

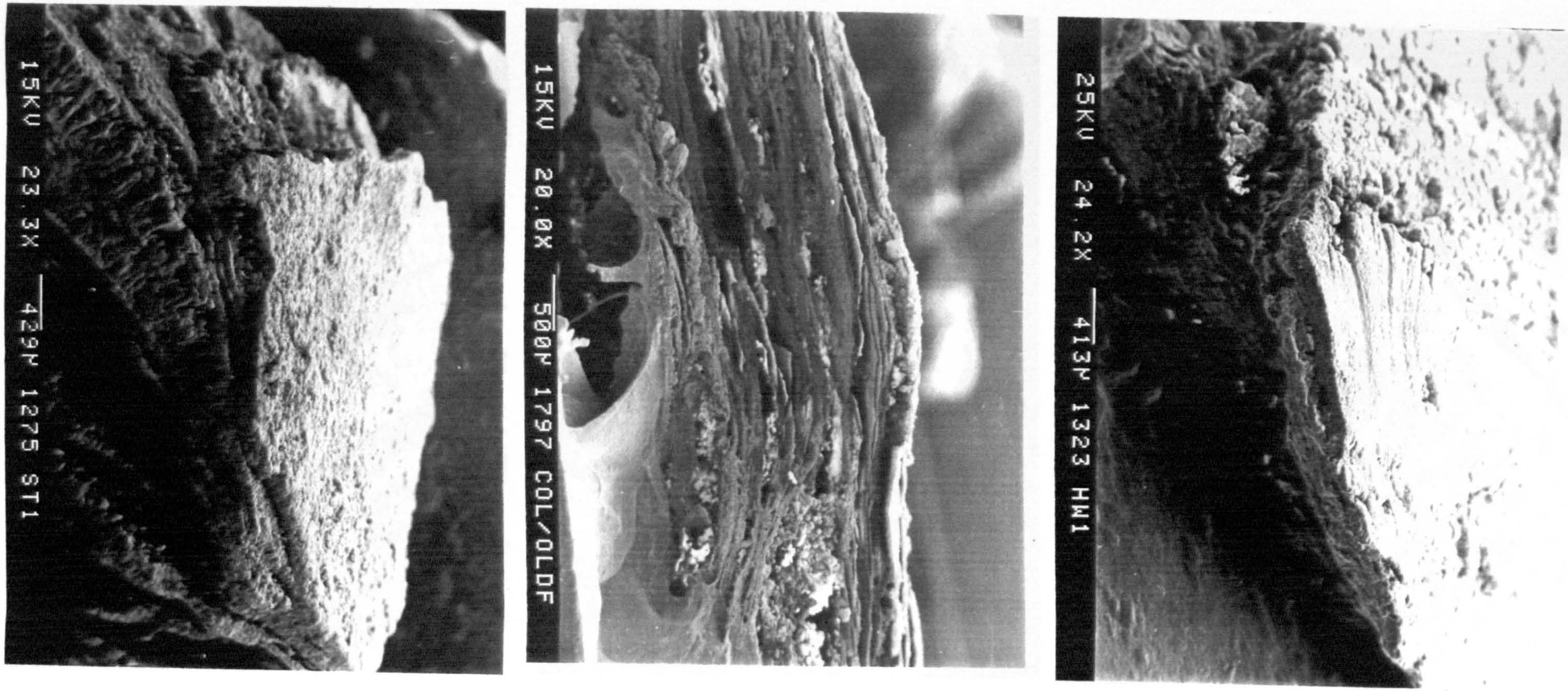


Fig. 11: White films from Hadrian's Wall (HW1) and Colchester Town Wall (COL); Natural stalactite (ST1) (about 50 years old).

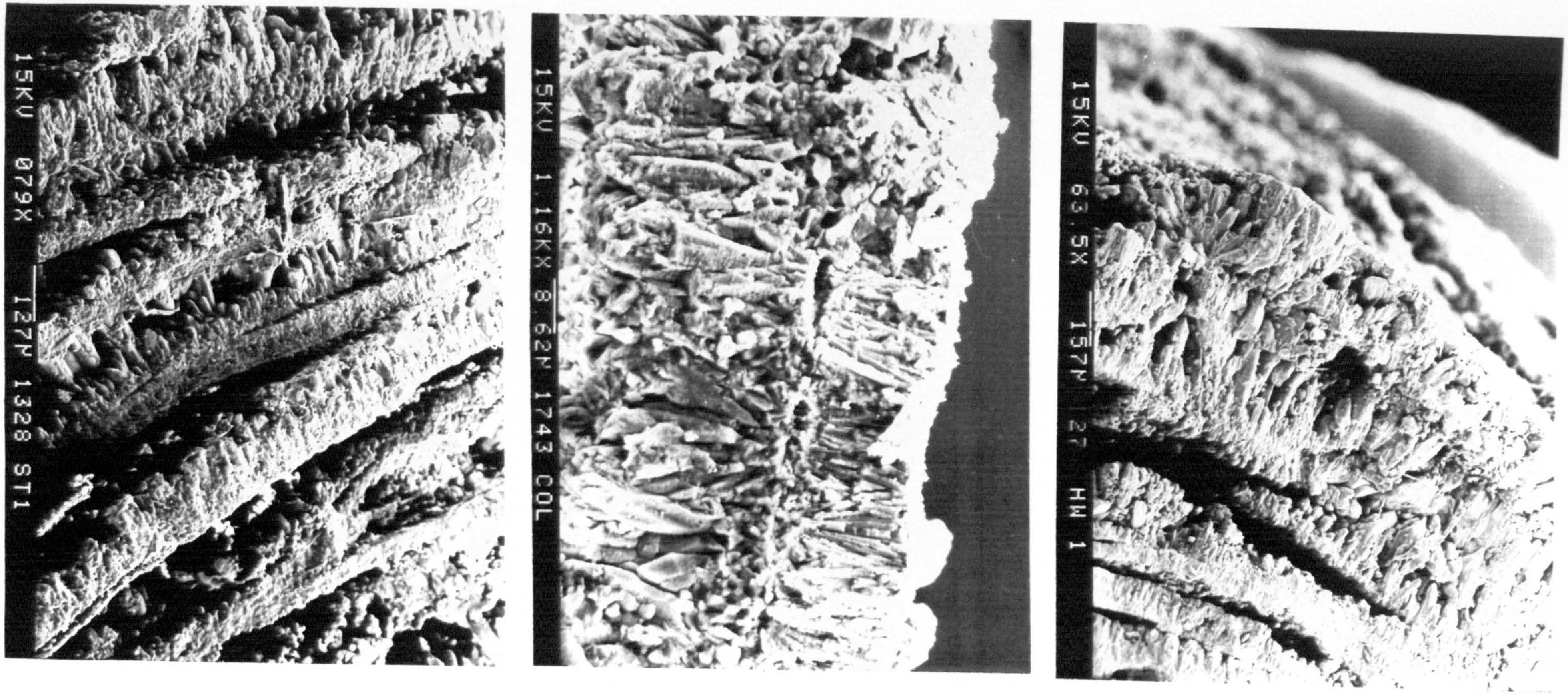


Fig. 12: Details of the white films and stalactite in Fig. 11 showing columnar crystals. Scale bar is in micrometers - µm.

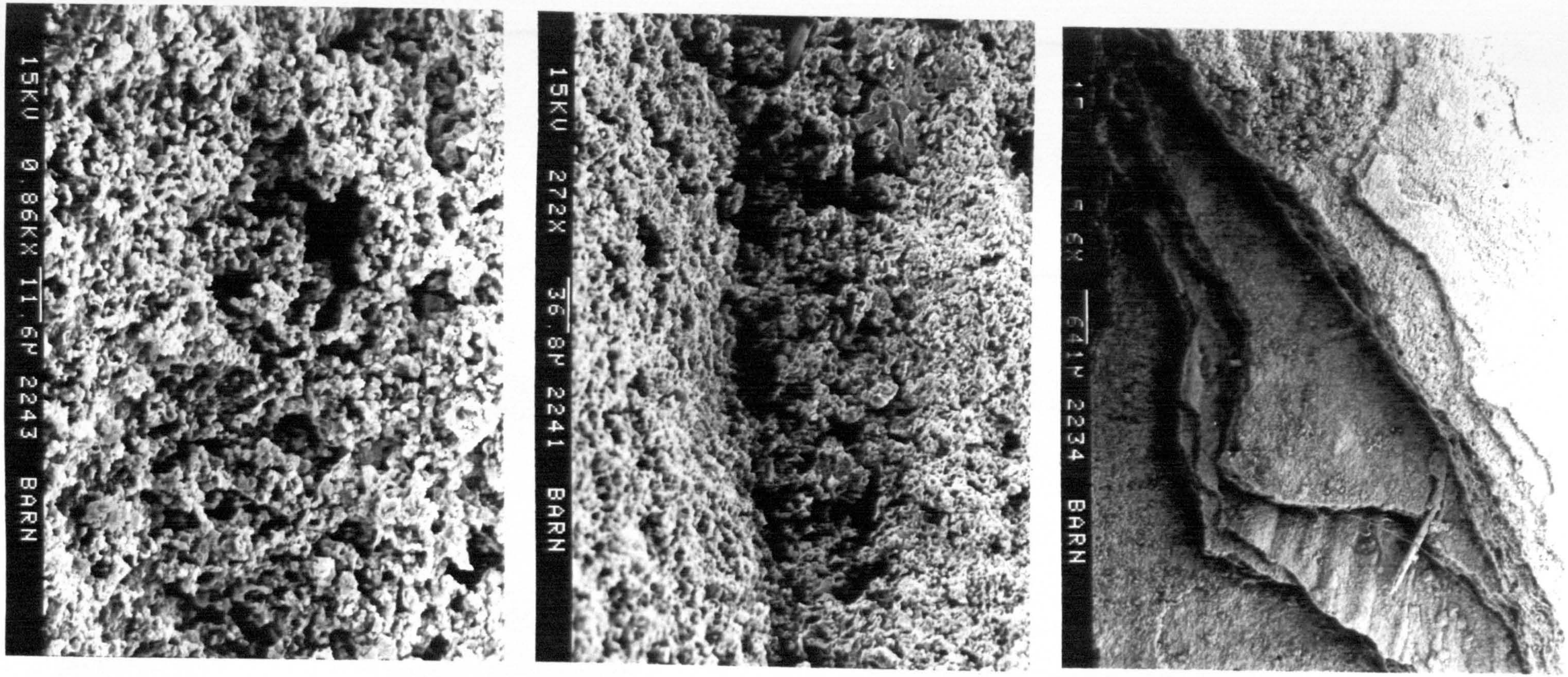


Fig. 13: White wash from a medieval barn showing particulate structures. Scale bar is in micrometers - µm.

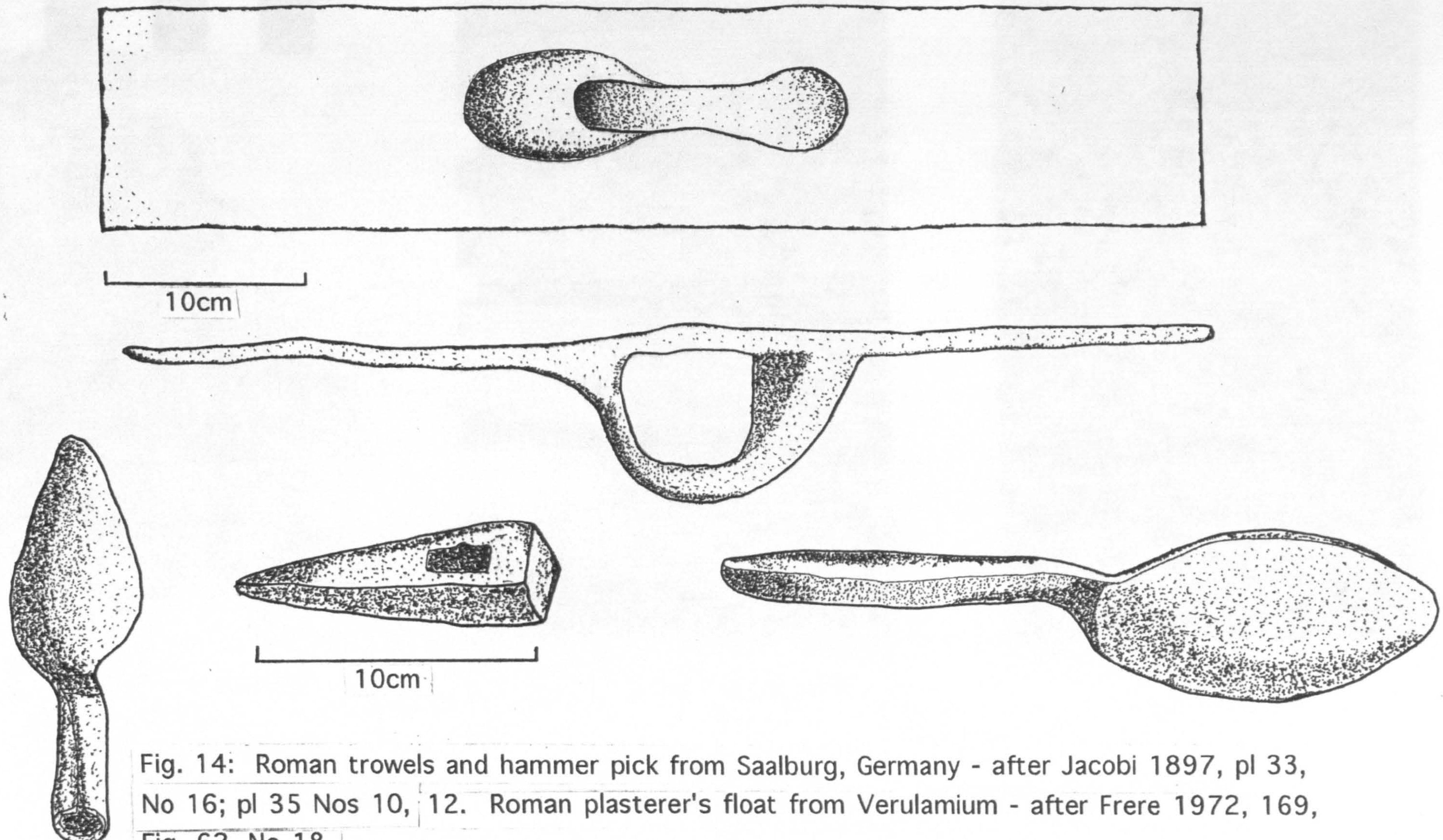


Fig. 14: Roman trowels and hammer pick from Saalburg, Germany - after Jacobi 1897, pl 33, No 16; pl 35 Nos 10, 12. Roman plasterer's float from Verulamium - after Frere 1972, 169, Fig. 62, No 18.

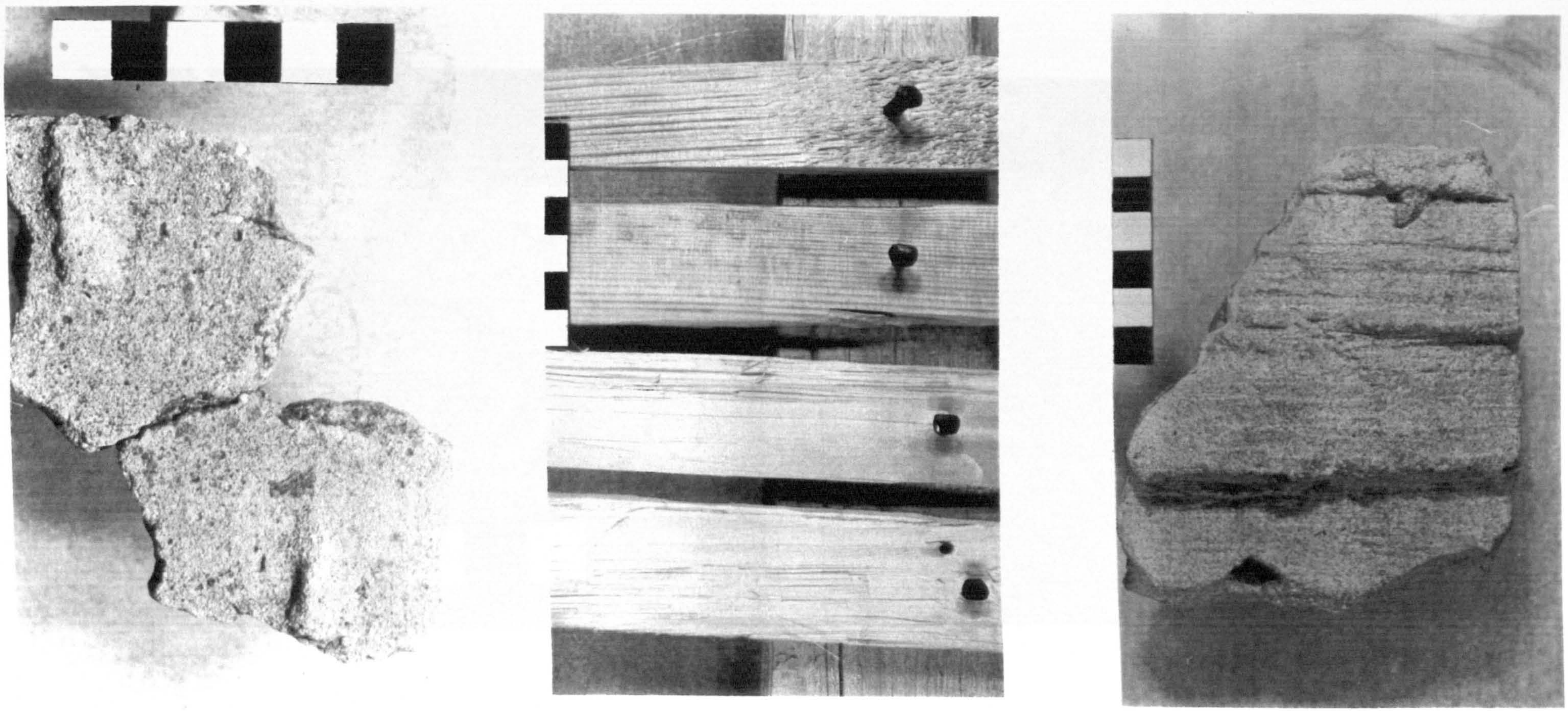


Fig. 15: Lath impressions: Bignor, lath reconstruction; pick mark casts: Droitwich (left).

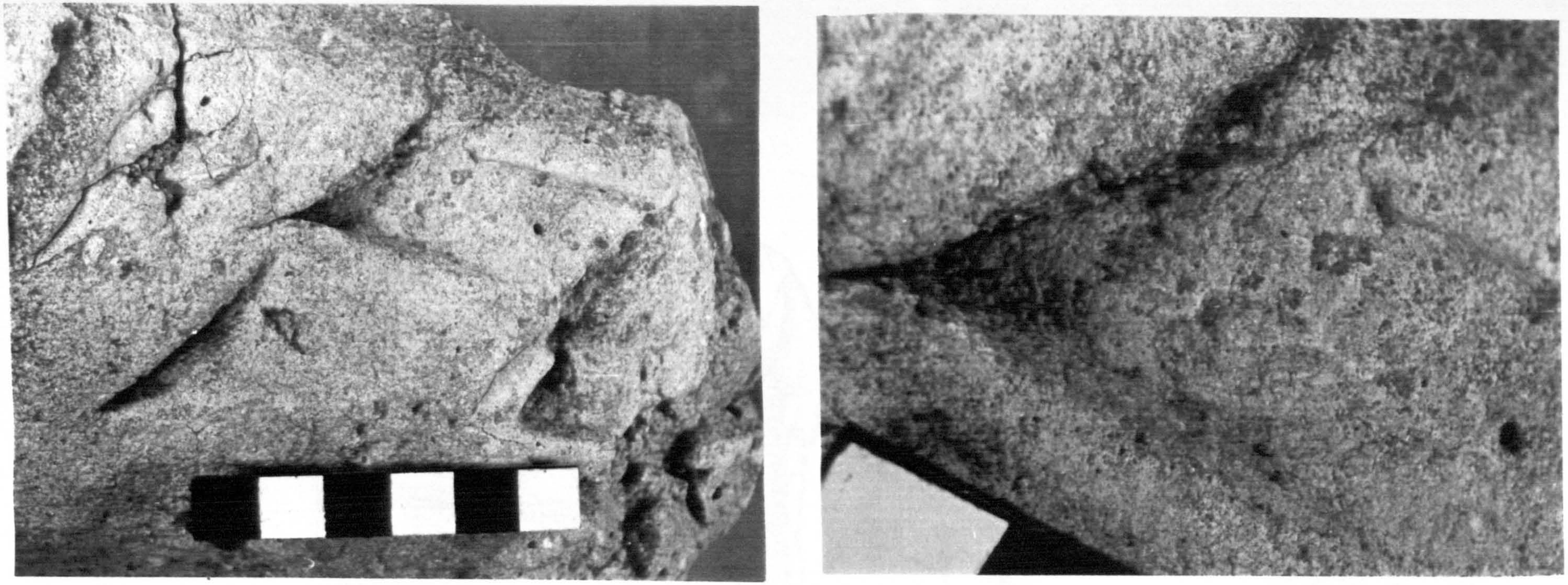


Fig. 16: Pointing trowel impressions; Caerleon Fortress Baths.

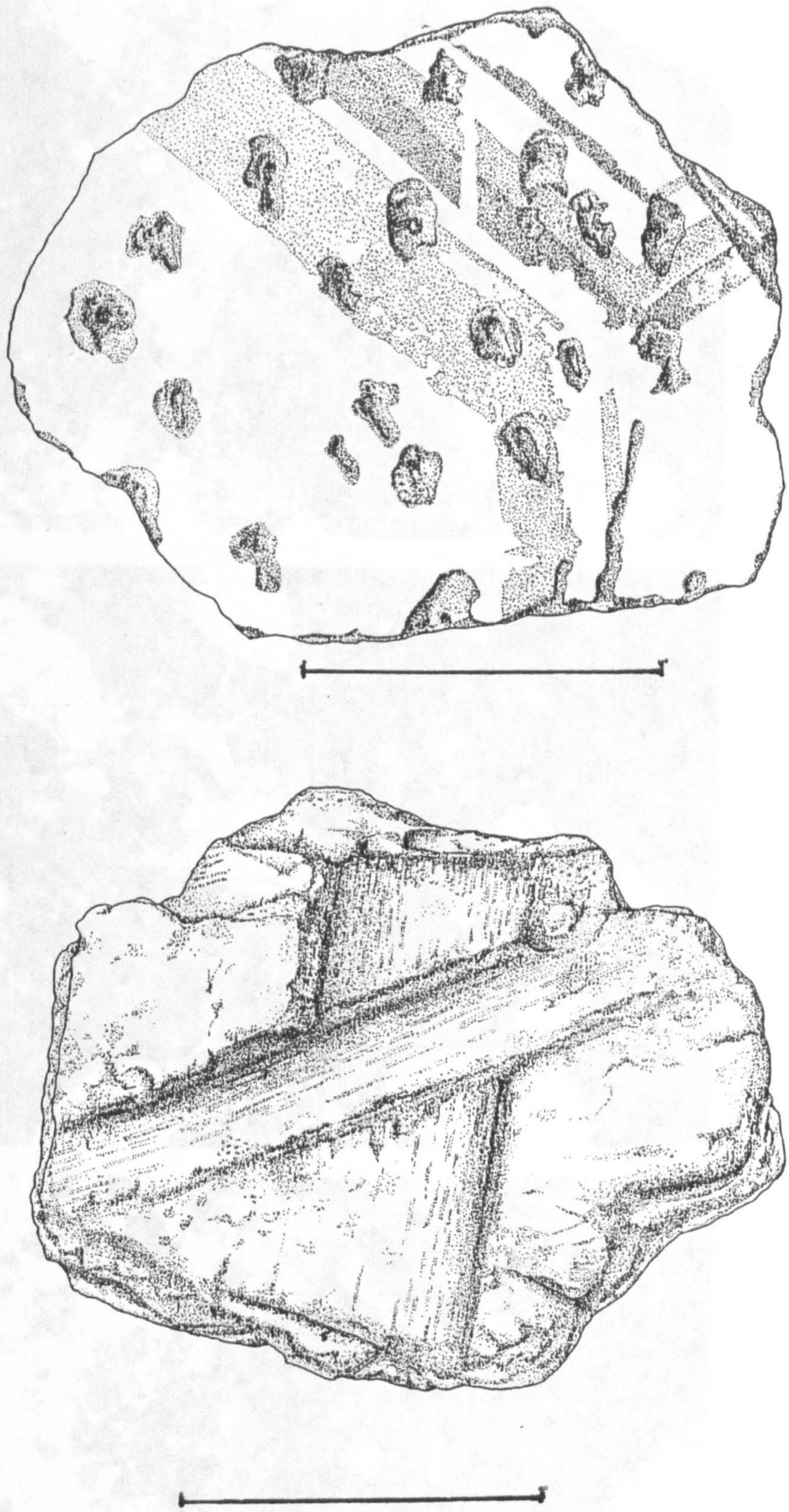


Fig. 17: Pick marked and lath impressed ceiling plaster from Colliton Park, Dorchester (10cm scale).

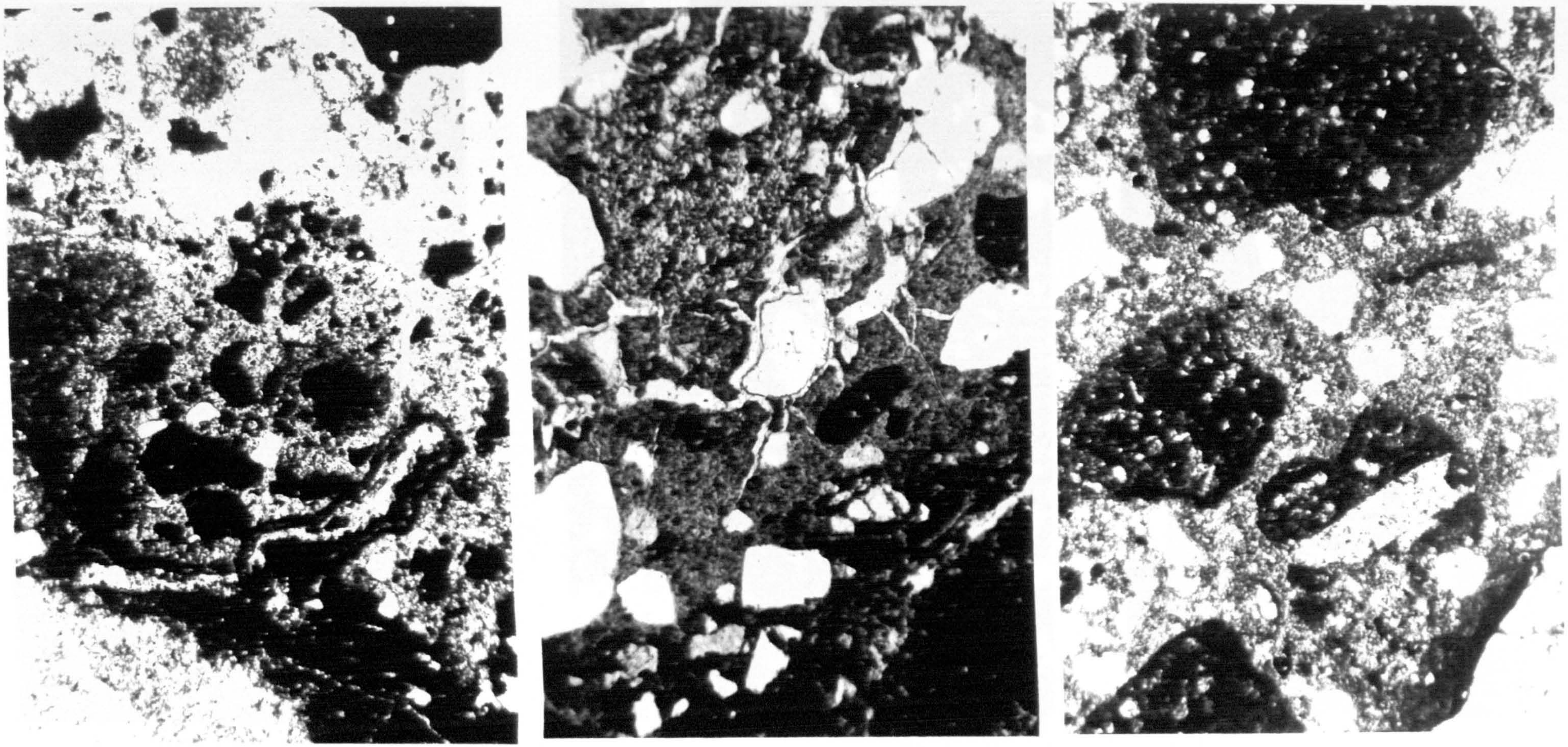


Fig. 18: Thin sections x100 of: plaster with chalk aggregate (right) Fishbourne, Lime / Aggregate interaction (centre) Chester Baths, Lime / tile interaction (left) Carlisle.

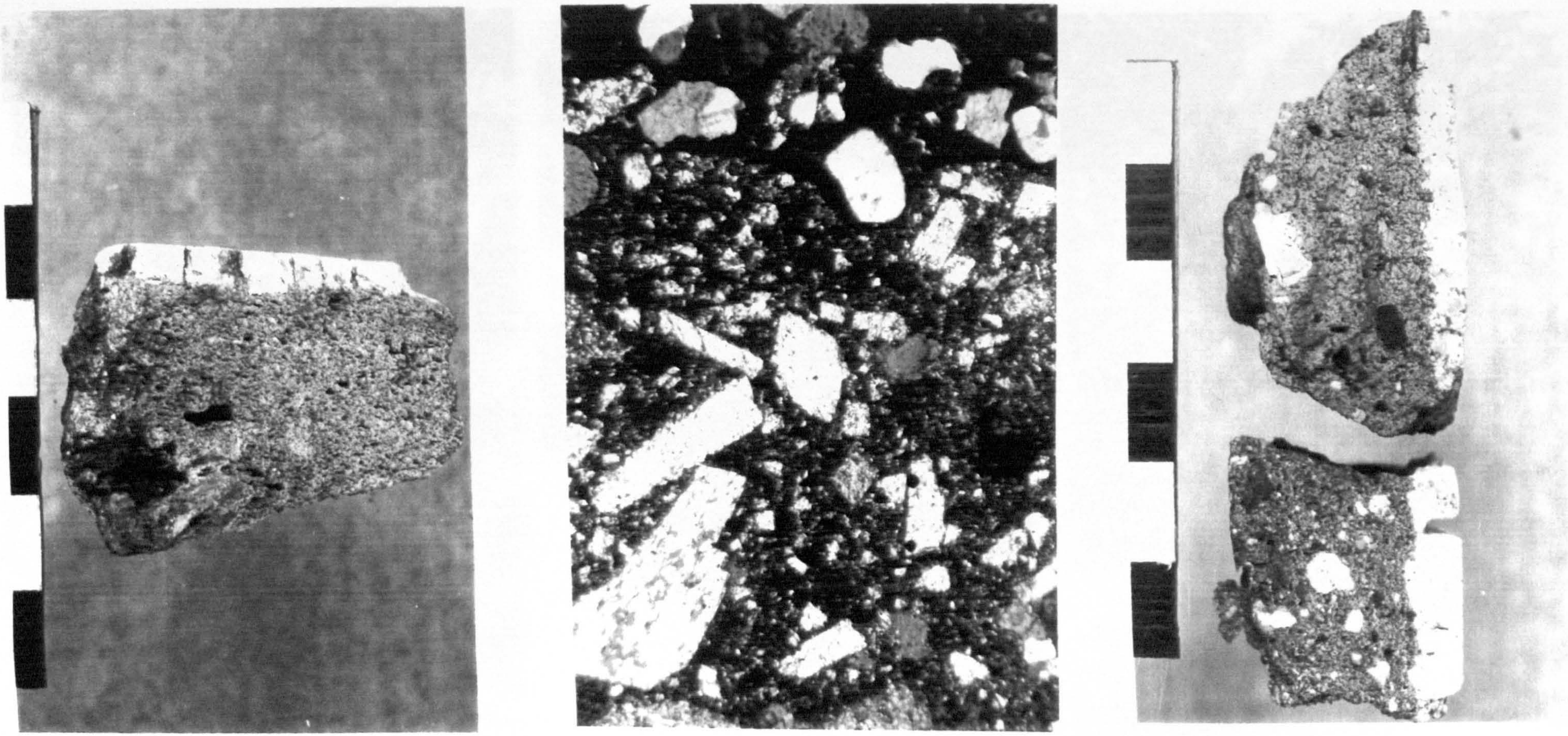


Fig. 19: Thick *intonaco* with crystalline calcite: Fenchurch Street, London and Chester (right); Thin section of the Chester sample x100; Thick *intonaco* without added calcite (left): Binchester.

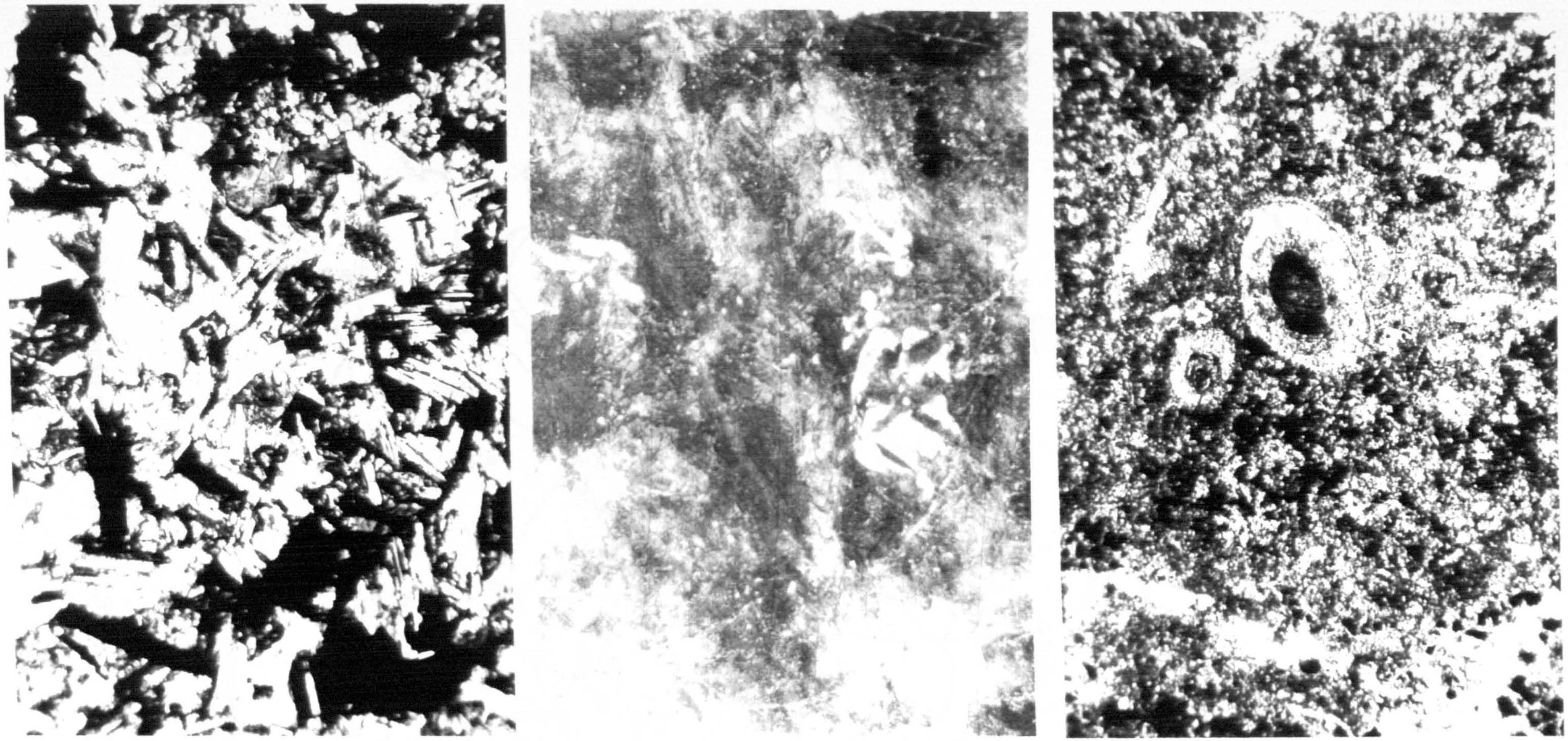


Fig. 20: Thin sections: Limestone with fossils x25 (right) Hadrian's Wall mortar; Degraded Whinsill x100 (centre) Hadrian's Wall mortar; Fresh Whinsill (basalt) x100 (left) (collections of Prof. A. Dunham).

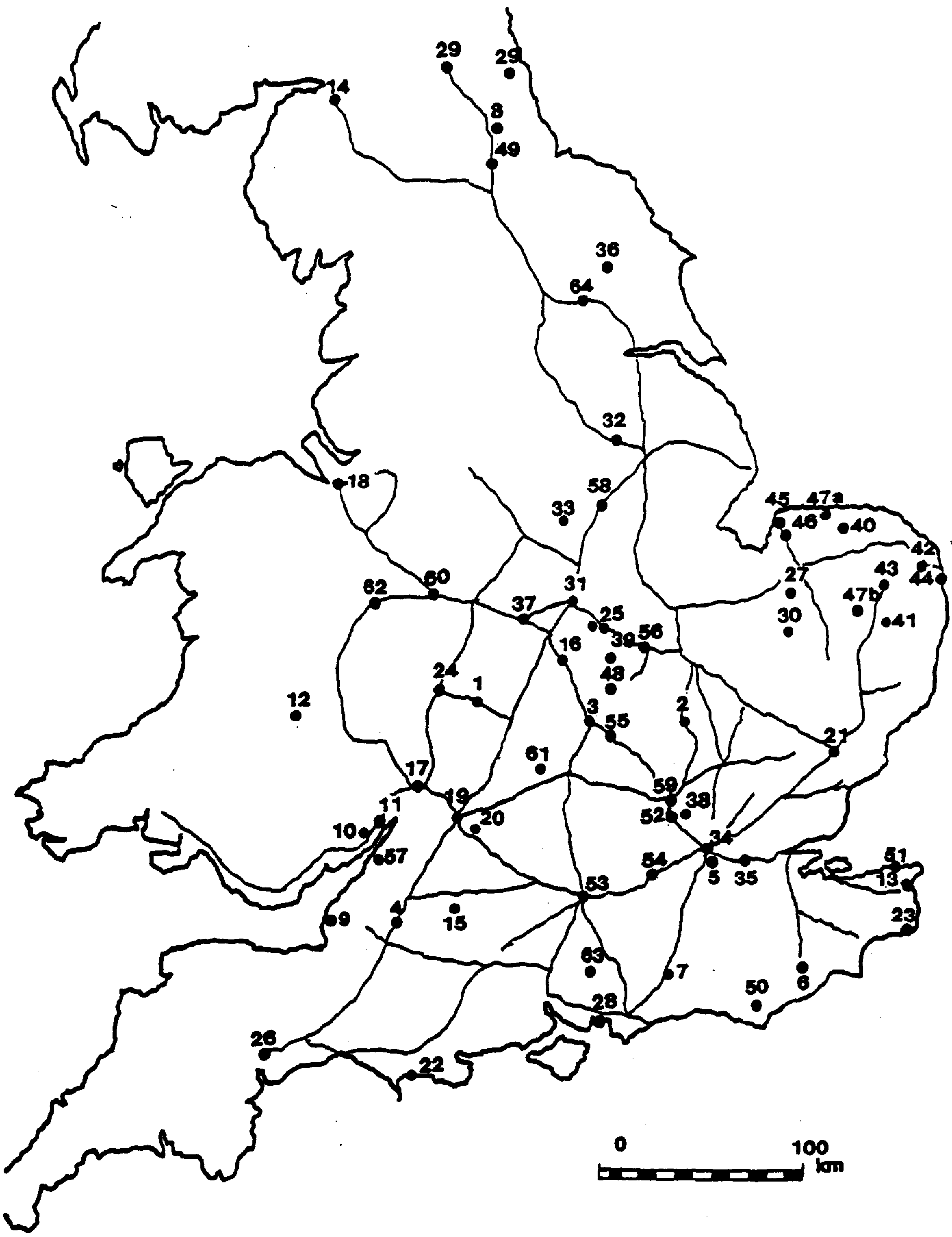


Fig. 21: **Sample distribution map**

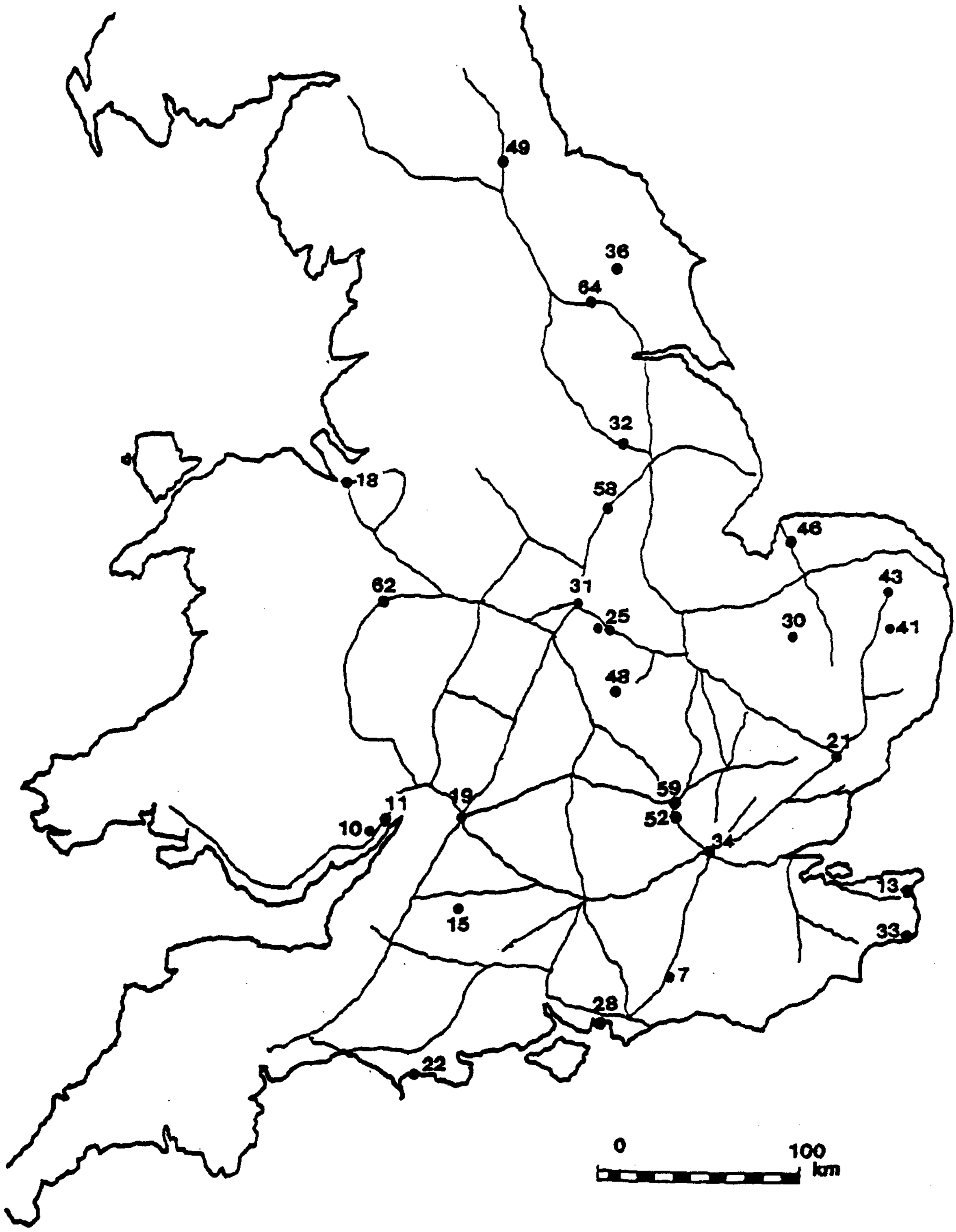


Fig. 22: **Cinnabar distribution map**

IV RESULTS OF ANALYSIS AND OBSERVATIONS:

a) GRADING ANALYSIS:

1) crushed materials and 2) natural sands and gravel.

Various rocks, tiles or bricks were experimentally crushed to examine the particle size distribution curves. These were compared with natural sands from rivers, beaches, sand dunes and other sand deposits. The results showed that many natural deposits could be very closely graded, whilst crushed materials tended to show a broader spectrum of sizes, varying mainly in particle size with the amount of crushing carried out. In the case of brick and tile, a secondary peak often occured with the separation of included sand from the fired clay. The density values are the apparent densities for the gross volume of a given weight of material including air spaces.

1) CRUSHED MATERIALS

ROCK:

a) Carboniferous limestone from Brean Down, Somerset. This red to brown crystalline limestone outcrops at Brean Down where it is being eroded by the sea. Samples were crushed by hand using hammers to approximately gravel size. The graph shows a broad range of sizes, perhaps reflecting the softness of the rock.

Percentage weight for the gravel, sand and silt sizes:

gravel >2mm	sand 0.15 - 2mm	silt <0.15mm
58	32	10

density 1.8 - 1.9g/cc
Graph Fig. No. 23

b) Granite / diorite, unlocated. A fine grained grey "granite" type rock was crushed by hand with hammers to approximately gravel size. The graph shows a sharp peak for the larger particles, reflecting the hardness of the rock.

Percentage weight for the gravel, sand and silt sizes:

gravel >2mm	sand 0.15 - 2mm	silt <0.15mm
67	25	8

density 1.8g/cc
Graph Fig. No. 23

ROMAN BRICK / TILE

Fragments of a fine clay Roman *tegulae*, from Piddington Roman villa, were crushed by hand using hammers to a visual approximation of gravel size. The result was graded and its density measured. Only one type of tile was used. Other tile fabrics would give variations in density at least, and various fillers used in the clay would give different peaks in the particle size distribution analysis graphs. Fig No 24 shows the grading of the crushed tile.

Percentage weight for the gravel, sand and silt sizes:

gravel >2mm	sand 0.15 - 2mm	silt <0.15mm
43%	39%	18%

dry density 1.3 - 1.5g/cc
Graph Fig. No. 24

2) Sands and gravel

SAND AND GRAVEL

a) Shingle from the top of the beach at Sheringham, Norfolk. This material was mainly round to sub-angular flint pebbles with traces of quartzite and quartz. The graph shows that the material is closely graded and virtually free of sand.

Percentage weight for the gravel, sand and silt sizes:

gravel >2mm	sand 0.15 - 2mm	silt <0.15mm
99	trace	trace

density 1.6g/cc
Graph - Fig. No. 25

b) Gravel with sand from the flood plain of the River Nene, near Irchester, Northamptonshire. This was simply shovelled up from the surface of the deposit after the top soil had been removed. It was composed of pebbles of: quartzite, flint, quartz, ferruginous sandstone and fragments of limestone with fossil. The sand size was mainly round to sub-angular quartz.. The sample was removed from the excavtions of an Iron age complex, showing that the deposit had not been altered since that time, and may have been glacial in origin. The graph shows that there are peaks in both gravel and sand sizes.

Percentage weight for the gravel, sand and silt sizes:

gravel >2mm	sand 0.15 - 2mm	silt <0.15mm
59	38	3

density 2g/cc

Graph - Fig. No. 26

c) Gravel and sand from the upper reaches of the Avon Clywedog in mid Wales. This material was collected from the small rivers edge. It was mainly composed of fine black schists, quartzite, quartz and felspars, and generallly appeared to represent fragments of laminar rock.

Percentage weight for the gravel, sand and silt sizes:

gravel >2mm	sand 0.15 - 2mm	silt <0.15mm
66	32	2

density 1.9g/cc

Graph - Fig. No. 27

<u>SAND</u>

Surface sand samples from beaches, sand dunes and glacial deposits were graded and compared. They generally show very close grading, with a range of sizes depending on the method of deposition. The upper estuary sample, Dysynni 16, shows that the finer sand has been washed away by the river. There is supprisingly little difference between the sand from beaches and sand dunes.

Percentage weight for the gravel, sand and silt sizes:

	gravel >2mm	sand 0.15 - 2mm	silt <0.15mm	
West Wales, Aberdyfi 6 - top beach; quartz, quartzite, schist and mica.	0	97	3	density 1.6g/cc
West Wales, Aberdyfi 8 - dune; as above.	0	96	4	density 1.6g/cc

Brean, Avon, top beach; round to sub-angular quartz.

0	18	82	density 1.4g/cc

Brean Down, Avon, surface sand from the cliff face; as above.

0	86	14	density 1.6g/cc

Brean Down, Avon, deposit under Bronze Age site; as above.

0	78	22	density 1.5g/cc

Colchester - natural sand from under Roman buildings in the High Street; round to sub-angular quartz, flint and ferruginous sandstone.

2	84	14	density 1.6g/cc

Afon Dysynni 15 - top beach; quartz, quartzite, schist and shell.

3	93	4	density 1.6g/cc

Afon Dysynni 16 - upper estuary (gravel); quartz, quartzite, schist, felspars, slate and shell.

35	65	0	density 1.7g/cc

Graphs - Fig. Nos. 28 - 30

The graphs show that the sands and gravels are well graded.

Fig. 23 Crushed Rock

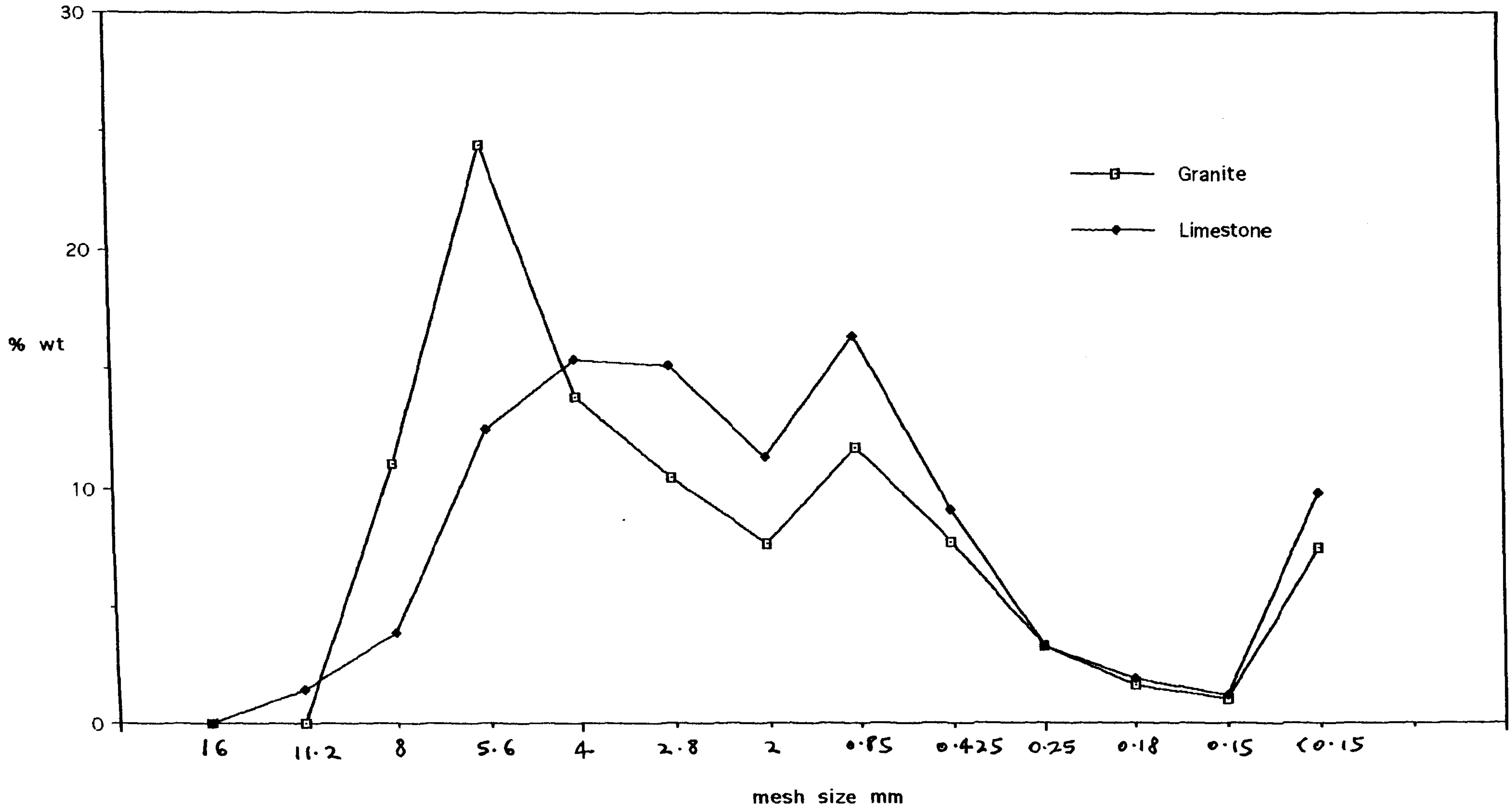


Fig. 24 Piddington - crushed tile

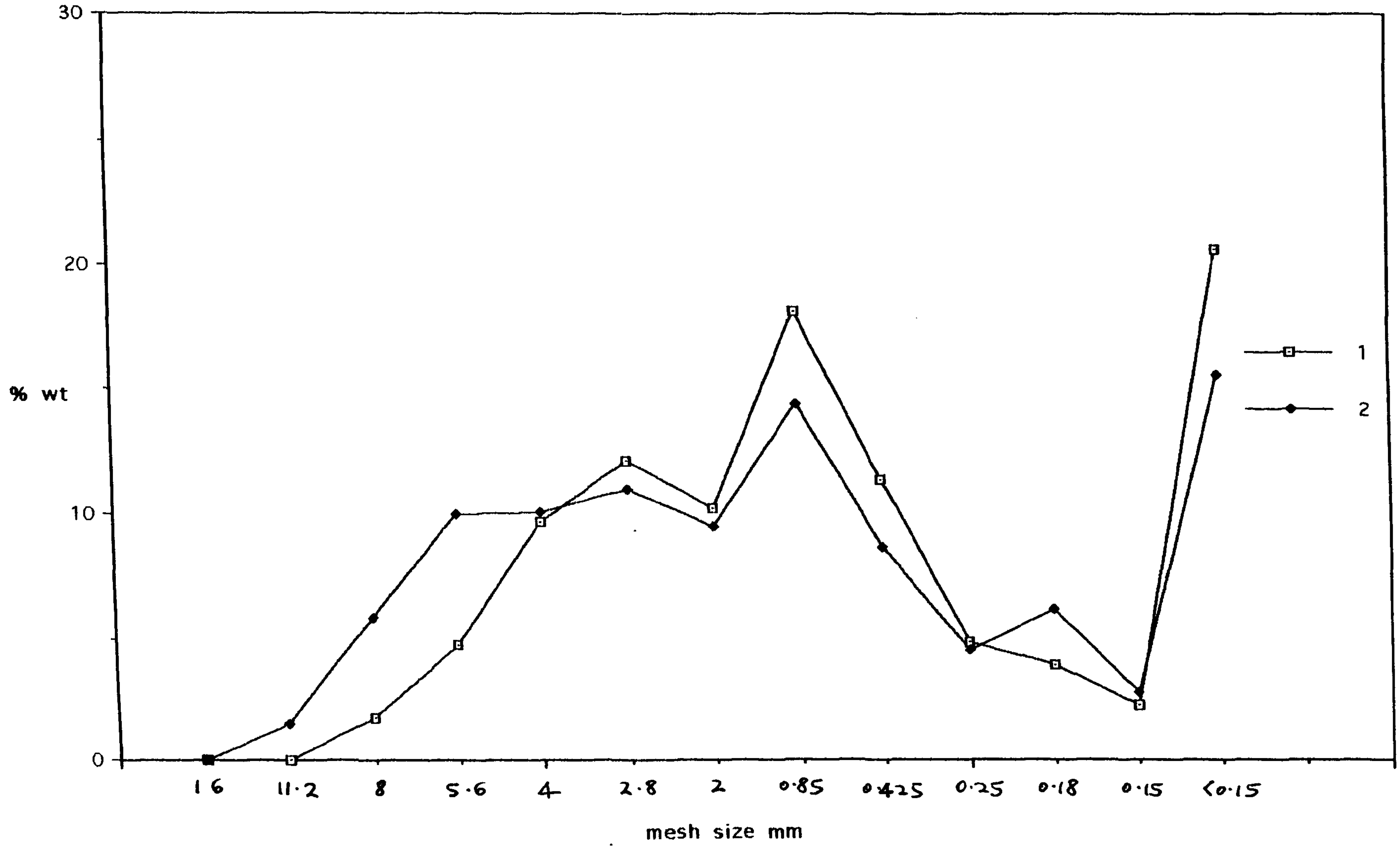


Fig. 25 Shingle

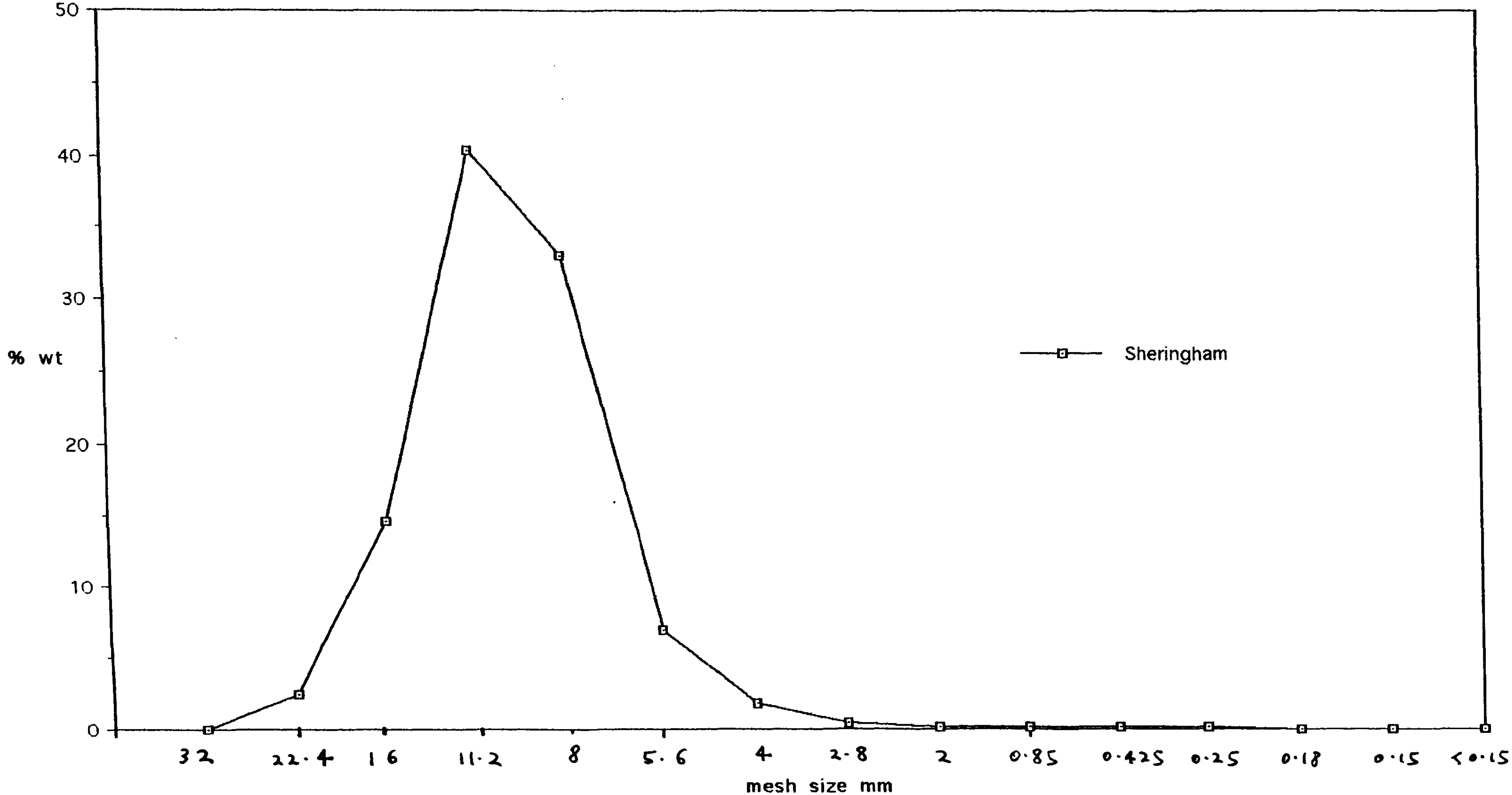


Fig. 26 Northants - gravel and sand

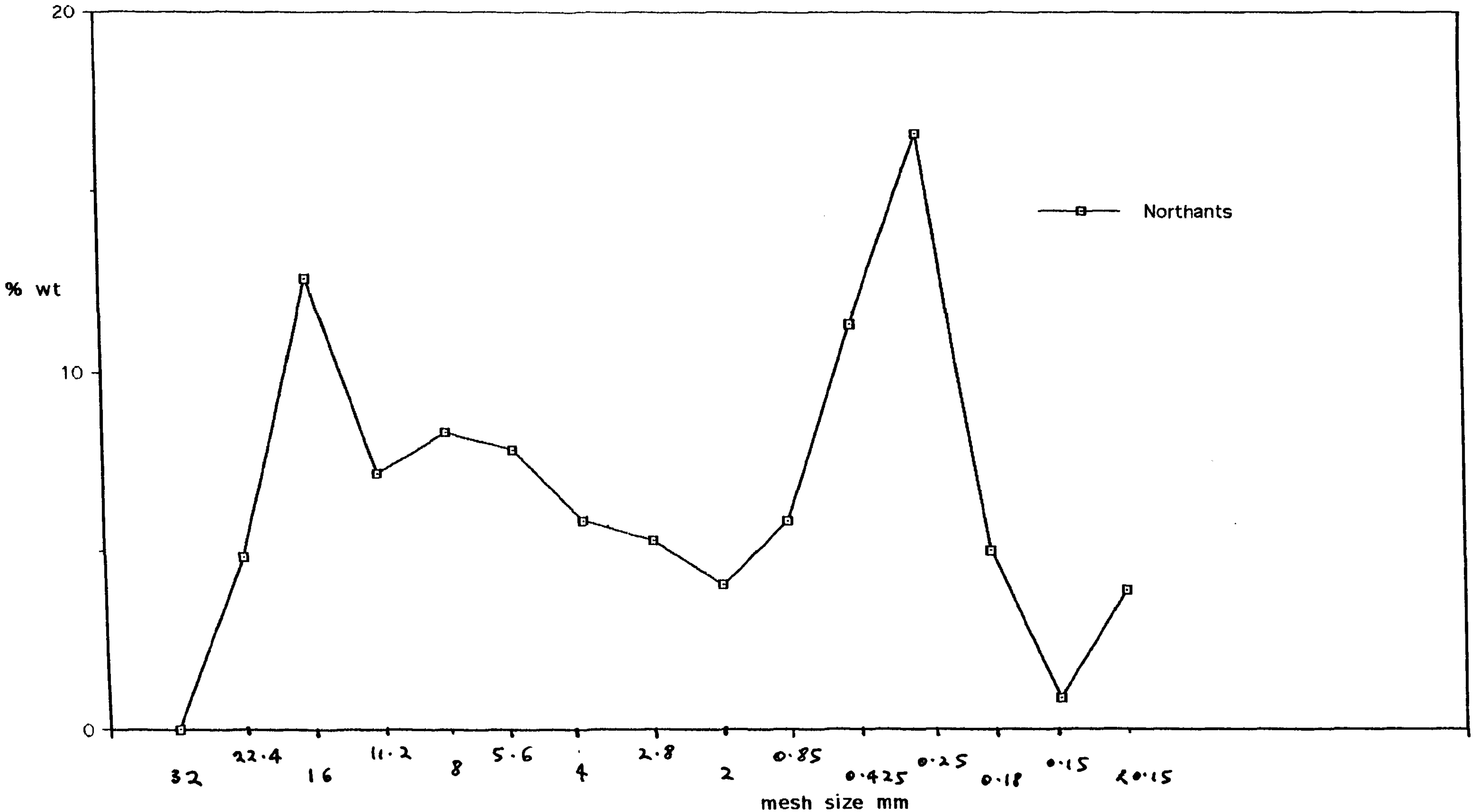


Fig. 27 Afon Clywedog

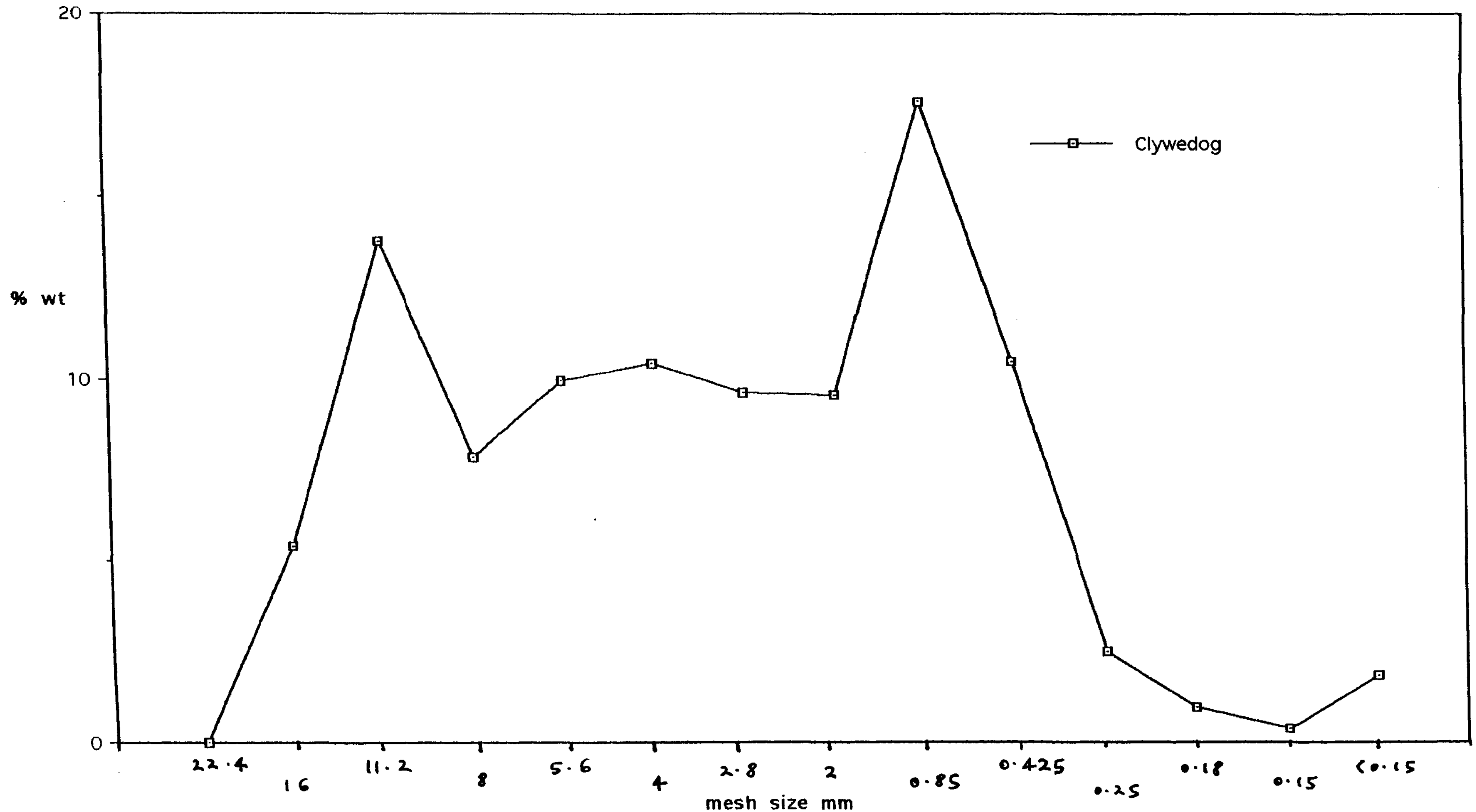


Fig. 28 Estuary and beach - sands and gravel

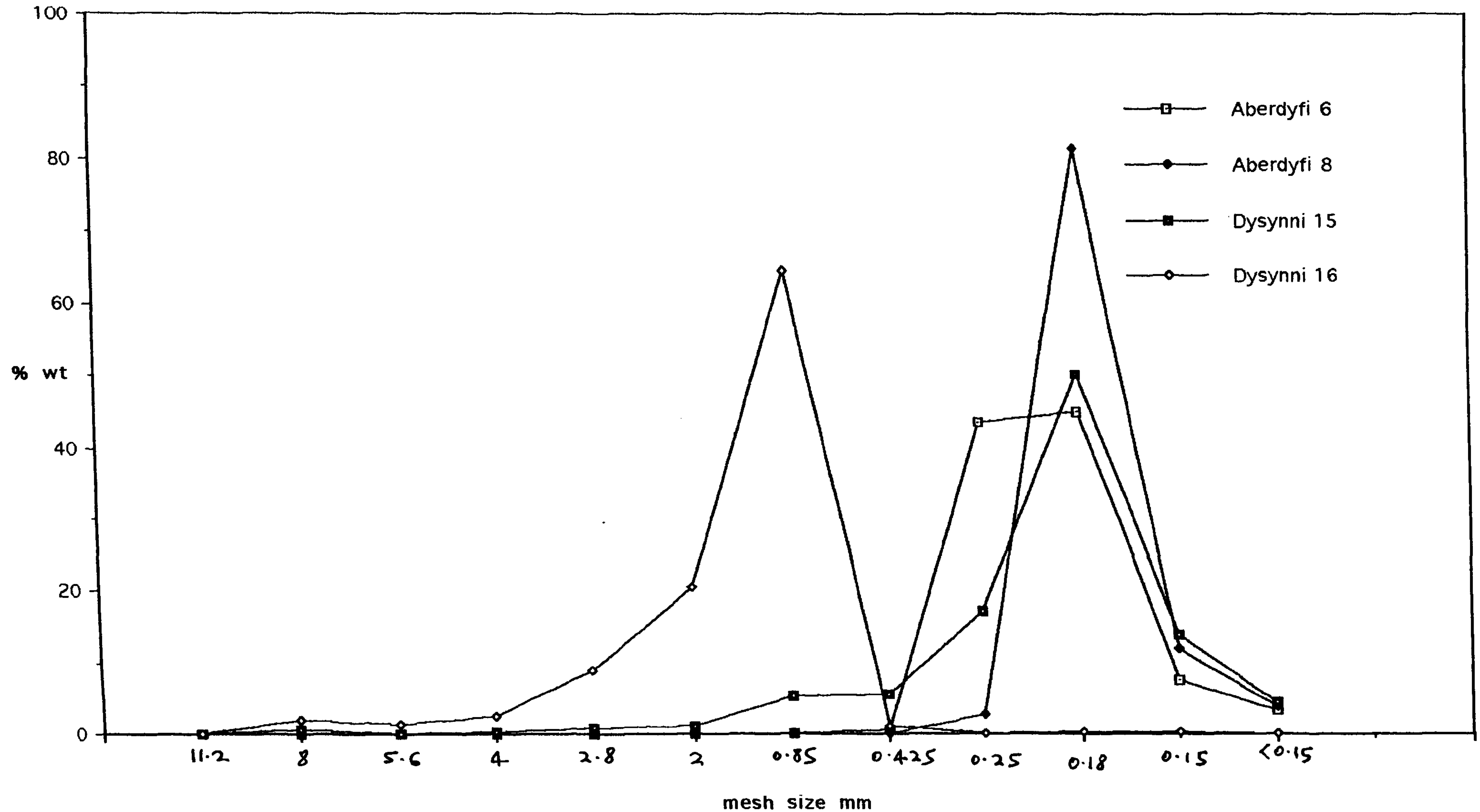


Fig. 29 Brean Down sands

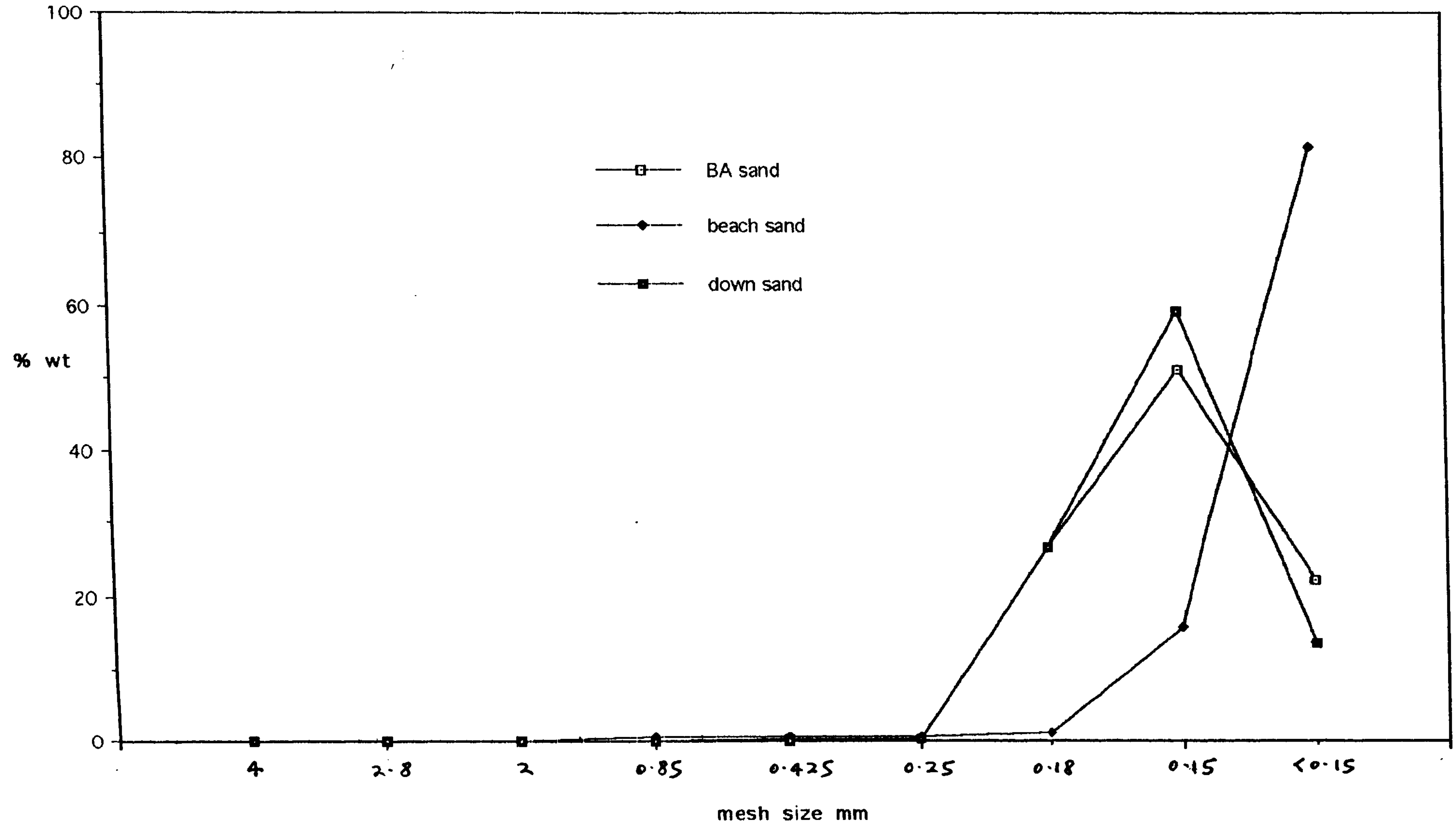
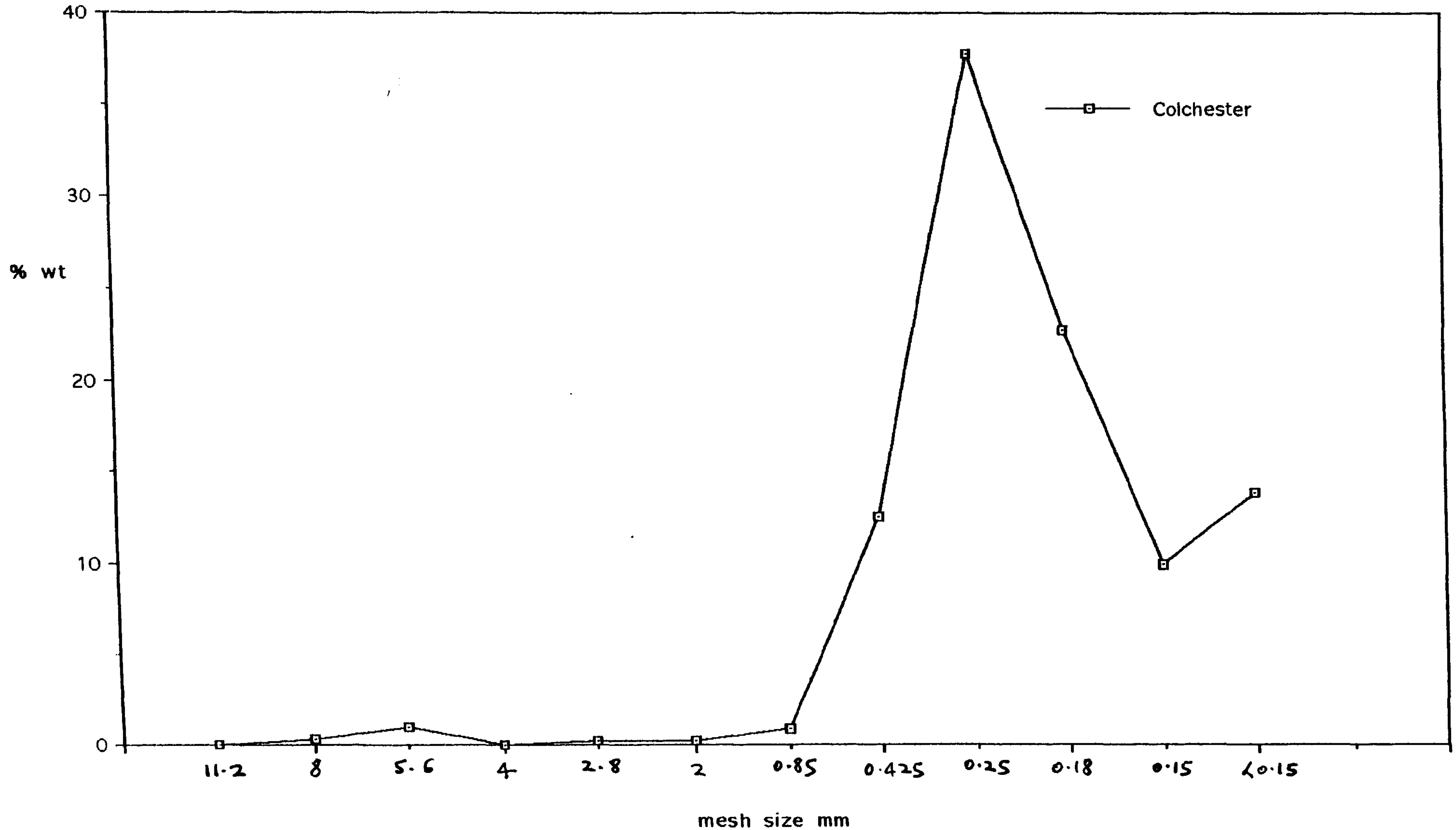


Fig. 30 Colchester sand



III Results of analysis and observations:

b) Site, References, Observations:

Being the typical results for that site as:

1) The type, number and thickness of plaster layers (wall plaster unless stated otherwise).

2) The general composition of the mortar and plaster as the breakdown of the aggregate sizes and "lime" or acid soluble content.
The aggregate is shown as:- gravel - > 2mm, sand 2mm - 0.15mm, silt and clay - < 0.15mm, totalling 100%. The range of sieves used included standard soil sieves with a range of 0.15mm to 2mm, augmented with the use of coarser and finer sieves when necessary.
The lime or acid soluble component is given as a percentage of the weight of the original sample. Where given, the carbonate (carbonated lime) content, as opposed to the acid soluble content, was determined by measuring the volume of carbon dioxide gas evolved by adding acid to a small sample of fine plaster or lime. In the case of calcareous mixtures, the approximate aggregate content was determined by physical methods or by the partial dissolution of the lime by acetic acid.
The references given are for the last known publication or where the results have not been published, of articles relating in general to that site. These are commonly in the popular magazine Current Archaeology and Britannia, the Journal of The Society for the Promotion of Roman Studies. Many of the results may be used in forthcoming site publications.
Whilst it is recognised that the acid soluble component is only approximately equivalent to the calcium carbonate content, it does usefully reflect the probable carbonated lime now present which was originally added as slaked lime in the mortar mix. The weight of the original slaked lime content can be estimated by multiplying the value for the acid soluble content by 0.74. The result is the value for dry slaked lime. The volume of lime putty can be estimated by multiplying the acid soluble weight or "lime" value by 0.6.
The pigments shown are the basic materials not the particular mixtures used.
The geology of the aggregate and lime is generalised, giving the typical materials found.

Alcester, Warwickshire
Cracknell, S. 1985

Mortars and painted plasters mainly of the third to fourth centuries from excavations in Roman Alcester.

AL 20, 22, 23, ALC 73, AES 76, a total of seventy seven samples were analysed.

COMPOSITION

number	gravel	sand	silt	"lime"	comments
AL 20					
69/0/1	41	45	14	12	concrete like lump
17/0/1	-	-	-	97	*intonaco* 0.5mm
	15	69	16	29	upper plaster, 18mm, sand+
	28	56	16	23	lower plaster, 10mm, sand+
17/0/2	31	54	15	30	upper plaster, 7mm, sand+
	44	43	13	25	lower plaster, 6+mm, sand+
AL 22					
[1]	27	52	21	39	window? moulding, 25mm tile, sand and gravel
[3]	11	58	31	49	upper plaster, 13mm, tile
	36	47	17	32	lower plaster 1, 22mm, sand+
	25	58	17	25	lower plaster 2, 25mm, sand+
x	0	91	9	76	lime waste with tile
[2]	-	-	-	79	*intonaco* , 0.5mm
	20	58	22	39	upper plaster, 12mm, tile
	22	58	20	36	lower plaster, 18mm, sand+
[4]	34	48	18	33	upper plaster, 11mm, tile
	66	26	8	17	lower "plaster", 55mm, gravel+, approx 2:1 gravel:sand
ALC 73					
154	-	-	-	94	white, 0.1mm, on *intonaco* ,1mm
	3	74	23	14	upper plaster, 7mm, sand
	1	83	16	14	lower plaster, 20mm, sand
167	10	68	22	15	upper plaster, 14mm, sand + lime interface
	3	79	8	15	lower plaster, 4mm, sand

38	-	-	-	99	white paint, 0.1-0.2mm, lime
	-	-	-	91	intonaco, 0.5-1mm, lime
	1	87	12	21	plaster, 16mm, sand
AES 76					
I 120		2	59	39	23 upper plaster, 35mm, sand
	31	56	13	15	lower plaster, 12mm, sand+
I 86	-	-	-	79	*intonaco* , 0.5-0.75mm, lime
	34	49	17	18	upper plaster, 12mm, sand+
	26	58	16	27	lower plaster, 13mm, sand+
AL 23					
7/7028	11	81	8	32	upper plaster, 5mm, sand+
	18	75	7	30	lower plaster, 18mm, sand+
7(N)7028	31	49	20	31	upper plaster, 10mm, tile+
	47	33	20	30	lower plaster, 35mm, tile+
7(N)7028	13	79	8	31	upper plaster, 11mm, sand+
	31	59	10	28	lower plaster, 20mm, sand+ limestone pebbles
2087/1	9	74	17	16	plaster, 12mm, siliceous

(AL 20). A white lime interface was shown in one sample (ALC 23). The lime used was slightly siliceous, suggesting the use of lower chalk. The aggregate used was mainly alluvial sand and gravel with some limestone pebbles.

PIGMENTS

The pigments used were: red, yellow and brown ochres, green earth, carbon black, white lime, Egyptian blue and Rayleigh effect blue

Average results

	Thicknesses		"Lime"	
paint	(< 0.05 - 0.4)	0.1mm	97%	white
intonaco	(0.2 - 0.75mm)	0.5mm	87%	
upper plaster	(7 - 35)	12mm	28%	
lime interface		0.1mm	-	
lower plaster	(6 - 35)	15mm	25%	
(Also one very coarse layer 55mm thick. This may have been structural)				
third layer		25mm	39%	window moulding
single layers		13 - 40mm	25%	)the thinner layers
		probably being split multi-layer plasters)		
concrete type lump			12%	

Samples illustrated in the aggregate particle size distribution graphs

(showing well graded sand sizes) Fig No. 32

1) AL 23 - 7/7028 lower plaster

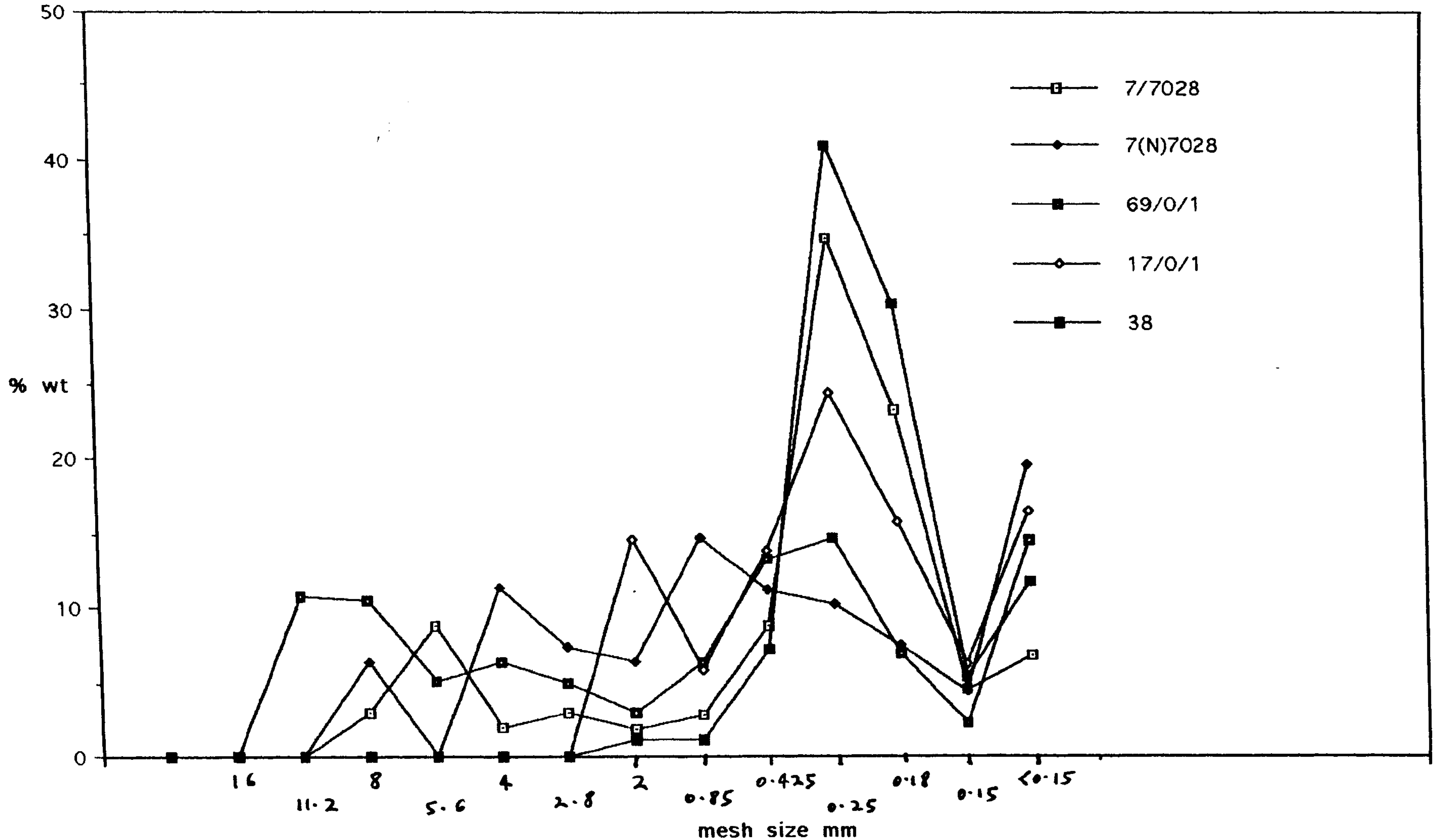
2) AL 23 - 7(N)7028 upper plaster

3) AL 20 - 69/0/1 concrete like lump

4) AL 20 - 17/0/1 upper plaster

5) ALC 73 - 38 plaster

Fig. 31 Alcester



Baldock, Hertfordshire.
Britannia 1986 17: 401 - 2
Stead and Rigby 1986

Mortars and painted plaster from various excavations in Baldock, ranging in date from the first to the fourth centuries. Samples of local sand and limestone were also analysed.

The material strongly reflected the geological nature of the sites, being mainly chalk with sands and gravel. Of interest was the deliberate use of the sand and gravel for some of the mortars and plasters as well as the more likely calcareous material. This implied some effort in bringing sand and gravel to the site, assuming that is was not as common as the chalk even in the Roman period, although the local chalk bed rock was also used. The use of calcareous mud for building was shown by the presence of quantities of burnt daub. There must have been considerable deposits of weathered chalk available for such use. Other samples of burnt daub had a much higher clay content, giving a typical red colour when burnt. The presence of some burnt red daub with a pale cream surface suggested that there was a lime rich coating at the time of burning. This appears to inhibit the formation of the red colour in the clay. The lime rich coating may have been calcareous mud, or a chalk white wash like suspension. Good wattle impressions were shown by some of the daub fragments. The lime and calcite values are approximate in view ofthe calcareous nature of the aggregates. Forty one samples were examined and thirty five analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime'	comments
1	17	46	32	30	op sig TW/DJ
2	2	89	9	40	A18 corner B of well, op sig
3	58	23	19	61	A18 corner B of well, op sig
4	43	36	21	36	A18 F802 3, op sig
5	2	79	19	34	A18 F800 1, coarse op sig
6	57	20	23	40	A18 F800, finer op sig
7	34	38	28	41	A18 F802 1st house, op sig
8	2	53	45	54	A1 F604 L(1) 80/100 lime mortar
9	-	66	44	90	A18 F802 3, lime with clay
10	47	28	25	34	A18 F804 7030, op sig
11	39	34	27	47	TB/GT (8)26, op sig
12	45	34	21	45	A18 F802 G/H

13	12	58	30	64	A18 SE/NW wall
14	-	52	48	85	A18 F802 3, chalk daub
15	5	74	21	30	TM/DM
16	11	13	76	47	TV/QM S F vi
17	8	71	21	45	TY/Q
18	-	26	74	74	A1 F536 90/110 5008, daub
19	-	85	15	47	TVQD F iv 5
20a	-	85	15	25	TV/QD F iv 5 upper layer
20b	-	88	12	54	TV/QD F iv 5 lower layer
21	9	77	14	27	TY/PM
22a	9	75	17	40	TP/CA
22b	10	70	20	30	TP/CA
23a	-	90	10	27	TO?, TO/DZ and TO
23b	-	86	14	49	TO?, TO/DZ and TO
24a	15	70	15	34	TY/PF upper layer
24b	9	76	15	58	TY/PF lower layer
25a	8	67	25	54	A18 866 painted surface
25b	24	46	30	73	A18 866 lower layer

Comparison of the acid soluble % with the carbonate % (calcite)

number	carbonate	soluble	comments
A18	100	100	natural chalk sample
C4ph26	64	72	clunch
A18 865	85	91	clunch
A6 P3	33	46	clunch
A18 F802 3	70	90	sample 9

EXAMPLES OF MORTAR AND PLASTER DESCRIPTIONS

Sand, chalk and other limestone fragments were commonly found in the aggregates

Mortars

1) TW/DJ:
Opus signinum, with traces of white mortar on the top and bottom faces. The pink colour was due to tile dust. 40mm thick.
2) A18 Corner 'B' of well to 2nd & 3rd house B-C:
Opus signinum. One flat surface.
3) A18 Corner 'B' of well to 2nd & 3rd house B-C:
Opus signinum. Impressions of a wooden beam, possibly the corner of a room. Light pink.

4) A18 F802 3:

Opus signinum. Top face smooth. Bottom face pitted as if made on a sandy surface. Light pink.

5) A18 F800 I:

Coarse *opus signinum*, with flint inclusions. Two flattish and pitted surfaces. Light pink.

6) A18 F800 I:

Fine *opus signinum*, with possibly an impression of wood. Light pink.

7) A18 F802 1st house, floor level:

Opus signinum, with small pebble inclusions. Light pink.

8) A1 F604 L(1) 80/100 st65:

Lime mortar? Light orange and light brown.

9) A18 F802 3:

Brown sandy clay on top of a limestone infill. Grey and white silica. 13mm thick.

10) A18 F804 7030:

Opus signinum, with straw or grass impressions. Light pink

11) TB/GT (8)26:
Opus signinum. Dark pink.

Plasters

A18 F802 G/H 1ST HOUSE FLOOR:
Pink (brick dust or siliceous red ochre with lime), 0.3mm, on off white *intonaco*, 0.3 - 0.6 mm, on pinkish sandy mortar with chalk/lime lumps and flint in two layers,14mm and 10mm thick.
A18 SE/NW WALL:
Top surface shows parallel trowel or float marks. Pink on yellow, 0.1mm, on sandy white *intonaco*, 0.5mm, on cream to buff sand plaster with chalk, possibly one layer 30mm, containing about10-20% chalk.
A18 F802 3:
Top surface is not painted but discoloured on fine decayed chalk with chalk, lime and sand,1mm, on coarser decayed chalk with chalk, lime and sand,18mm,. Possibly burnt chalk clay plaster.
TM/DM:
Red, 0.2mm, on off white sandy plaster, possibly burnt red, 0.5mm.
TV/QM S F VI:
Yellow, <0.05mm, on sandy white.*intonaco*, 0.2mm, on sandy off white plaster, including hard chalk with grass or straw inclusions, 20mm.
TY/Q:
Red on creamy yellow, 0.2mm, on white *intonaco*, 0.1 - 0.8mm, on sandy buff plaster with chalk and flint, 23mm.
A1 5008 F536 90/110:
Wattle impression in daub/clay; buff coloured calcareous mud, 0.5mm, on light orange/buff calcareous mud, 0.5mm, on lime and sand, 23mm thick. Possibly burnt chalk clay plaster with straw impressions.
TV/QD F IV 5:
1) Pseudo marbleing; very coarse plaster work with red and yellow splashes on coarsely trowelled/floated white *intonaco*, 0.5 - 1mm. The *intonaco* appears to be a separate pale grey layer (white and charcoal) on off white to cream sandy plaster with chalk and flint, 10mm.
2) Brushed white paint on flat sandy white *intonaco*, 0.5mm total thickness, on pale buff plaster, 10mm, on creamy white plaster with chalk lumps.
TY/PM:
1) Brushed white, 0.1mm, on sandy white.*intonaco*, 1mm, on pale buff sandy plaster with flint, 12mm thick.
2) As above.with plaster 15mm thick.

TP/CA:

1) Bands of dark yellow, yellow and red ochre.on sandy white *intonaco*, 1 - 1.5mm total thicknes, on light buff/beige sandy plaster, 10mm thick.

2) Several samples the same except for painted surface.

a) Green and red on white *intonaco*, on sandy plaster, 15 - 20mm thick.

b) Green on white; same as above.

c) Plain trowelled/floated white surface. Same as above. 20mm total thickness.

TO?:

Orange/brown (yellow ochre and brick dust),0.05 - 0.1mm, possibly burnt, on sandy.white *intonaco*, 0.75mm, on brown sandy plaster,18mm, on beige sandy plaster with chalk and straw, 30+mm.

The sample taken from this was mixed with the equivalent layers from TO/DZ and TO.

TO/DZ:

Same as TO? and TO.

1) This sample appears to have been burnt, with the same red/brown ochre. Bands of dark red, orange-red, and grey-blue paint. Orange-red and red-brown probably originally yellow ochre before being burnt. Pale grey-blue paint shows traces off Egyptian blue.

2) Same as above. except there was a much wider band of the pale grey-blue paint.

TO:

Same as TO? and TO/DZ.

a) The red surface is burnished.

b)Two bands of red ochre and pale blue over dark grey/black.

TY/PF:

Several pieces which are all the same except for different paint on the top surface.

1) Yellow (0.25mm - 0.4mm) on white *intonaco*, 0.5 - 0.75mm, on sandy plaster,11mm, (1 piece was 25mm thick), on light buff sandy plaster with chalk lumps,12mm thick.

2) Plain white, 0.2mm, on white *intonaco*.

3) Black stripe (11mm wide) on yellow, on white *intonaco*.

4) Orange on yellow on white *intonaco*. The orange was brick dust.

5) Red on yellow on white *intonaco*.

A1 F20 L1:

Burnt clay, straw impressions, presumably burnt daub. Dark orange to red and slightly calcareous,18mm thick. The top surface was pale green to buff and of varying thickness.

A1 F505 N/E QUAD 100:110 5138:

Burnt clay with a flat surface on top and bottom, with grass or straw impressions and slightly calcareous, 15mm thick. The top surface was pale green in colour.

A18 866 N/E & S/W WALLS:

Yellow, 0.05mm, on cream *intonaco*, 0.5mm, on coarse sandy plaster with chalk, 20mm, on very coarse sandy plaster with chalk.

PAINTING TECHNIQUE

The paint appeared to be in the buon fresco method with the following schemes: light and dark red, light and dark yellow, red and yellow splashes on white (pseudo marbling), orange to brown, grey, blue on black and black on yellow.

PIGMENTS

The colours present were ochres (red through yellow to brown), white lime carbon black (charcoal or soot), green earth (glauconite), crushed brick or tile dust, Egyptian blue, together with mixtures of these colours.

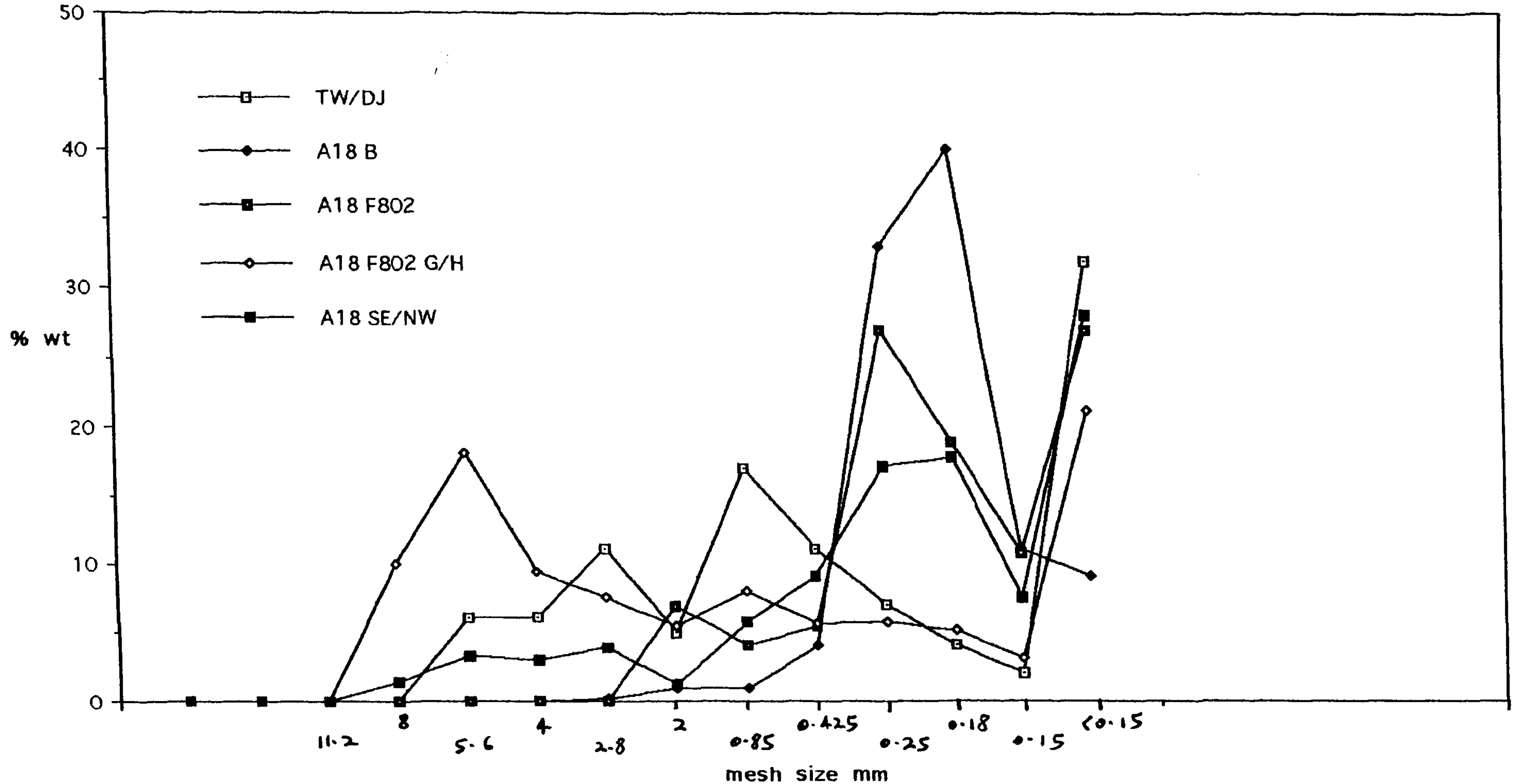
Amongst the material examined was a fragmentary pot base containing tiny grains of Egyptian blue. X-ray flourescence analysis detected the presence of traces of other metals, in particular tin, lead and zinc. This particular blue sample did not contain any lime and could well have been used for *buon fresco* painting.

Average results

	Thicknesses		"Lime"	
paint	(0.05 - 0.4)	0.15mm	-	
intonaco	(0.2 - 1)	0.6mm	-	
plaster	(10 - 20)	15mm	32%	upper layer
plaster	(10 - 30)	16mm	53%	lower layer
plaster	(10 - 30)	18mm	42%	single layer
lime mortar			54%	
opus signinum			40%	
daub	(15 - 18)	17mm	83%	

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 33
TW/DJ (op sig), A18 B, A18 F802, A18 F802 G/H, A18 SE/NW.

Fig. 32 Baldock



Bancroft Villa, Milton Keynes, Buckinghamshire.
Britannia 1979 10: 303 - 4, 1984 15: 303, 4, 6, 1985 16: 290 - 293
Current Archaeology (1984) 90: 198 - 208.

Fragments of painted plaster from the pool area of the villa, dated to the mid fourth century. Only visual examination and pigment identification was possible on most of this material. The aggregates were composed of: flint, ferruginous sandstone, round to angular quartz sand and traces of crushed brick or tile. Twelve samples were examined and two analyses carried out.

COMPOSITION

No.	gravel	sand	silt	"lime"	comments
8)	9	64	27	60%	upper layer
	11	69	20	52%	lower layer

EXAMPLES OF PLASTER DESCRIPTIONS

83 MK 105 / 42

1) Moulded plaster - red on white *intonaco*, 0.3mm, on sandy plaster, 6+mm thick.

2) maroon on white *intonaco*, 0.3 - 0.4mm, on sandy plaster, 7+mm thick.

3) pale grey on white *intonaco*, 0.4mm, on sandy plaster, 16mm thick.

4) grey on white *intonaco*, 0.25 - 0.5mm, on sandy plaster, 8+mm thick.

5) coarse green on white *intonaco*, 0.4mm, on sandy plaster, 4+mm thick.

6) coarse green on white *intonaco*, 0.4mm, on sandy plaster, 8+mm thick.

83 MK 105 / 44

7) maroon on white *intonaco*, 0.1mm, on off white *intonaco*, 0.4mm, on sandy plaster 11mm thick.

8) yellow on white, 0.05mm, on off white *intonaco*, 0.3mm, on sandy plaster, 11mm, on sandy plaster, 11mm thick.

9) red and drab yellow on white, 0.1mm, on off white *intonaco*, 0.5mm, on sandy plaster, 12mm thick.

83 MK 105 / 66

10) grey on white *intonaco*, 0.4 - 0.5mm, on sandy plaster, 25mm thick, with reed bundle impressions on the rear.

11) black spot on grey on white *intonaco*, 0.5mm, on sandy plaster, 20mm, on plaster traces.

12) red on white *intonaco*, 0.4mm, on buff sandy plaster, 4.5mm, on pale pink plaster, 24.5mm thick to the centre of the reed bundle impression.

PAINTING TECHNIQUE

The paint was applied in the buon fresco method, partly in a fairly complex style, probably representing a decorative scene.

PIGMENTS

The colours were all natural: red ochres (haematite), yellow ochre (limonite), white lime, carbon as soot or charcoal and green earth (glauconite). The glauconite was very coarse. The apparently un-crushed grains could have been extracted from green sand or chalk by panning or some similar process.

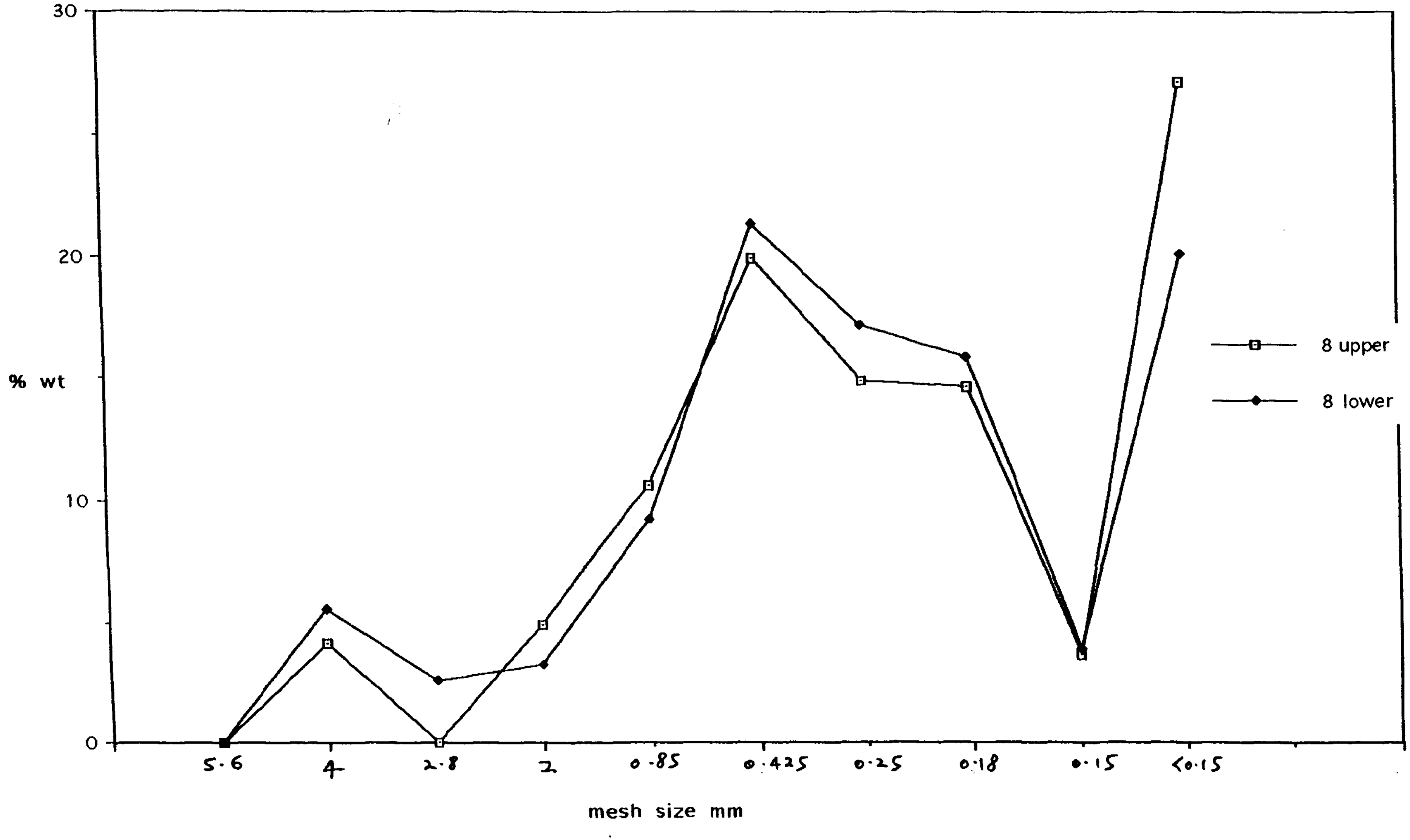
Average results

	Thicknesses		"lime"	
paint	(0.05 - 0.1)	0.1mm	-	
intonaco	(0.3 - 0.5)	0.4mm	-	
plaster	(4+ - 20)	11mm	60%	upper layer
		11mm	52%	lower layer
		25mm	-	reed impressed layer

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 33

8) upper and lower layers. The graphs show that the upper and lower layers are made from the same type of sand.

Fig. 33 Bancroft



Bath, Avon.
The Roman Bath complex
Cunliffe 1969
Lewis 1966: **passim** (second to fourth centutries)

A few examples of mortars and painted plaster from the Roman Bath museum store, from the main bath area and the temple precinct were examined and analysed. The mortar aggregates were mainly river sands and gravels, with fragments of limestone. Crushed brick or tile was also used, presumably to combat the very damp conditions. These samples were very resistant to dissolution in acid during the analysis process. Some samples were coated in "lime" concretions due to burial in the mineral rich wet soil of the bath area. Analysis of modern efflorescences from the exposed wall plaster showed high levels of sulphates (>10%) and chlorides (water soluble salts were about 80% chloride) which were causing serious conservation problems. Twelve samples were examined and twelve analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1)	73	12	15	66%	"concrete"
2)	21	66	13	61%	"torching"
3)	89	3	8	29%	coarse *opus signinum*
4) (13a)	40	40	20	67%	fine *opus signinum* above 3)
5)	41	35	24	52%	lower *opus signinum*
6) (19a)	8	62	30	72%	upper dark *opus signinum*
7)	74	10	16	37%	coarse upper render
8)	20	30	50	39%	fine lower render, *opus signinum*
9)	15	51	34	71%	bonding mortar
10) painted plaster					
				96%	dark pink paint
				97%	*intonaco*
	21	38	41	55%	(56% calcium carbonate)

EXAMPLES OF PLASTER DESCRIPTIONS

1) Concrete like grey mortar lump; unlocated:
a grey amorphous coarse mortar with gravel and charcoal.
2) Tile bonding mortar from the inside of an *imbrex*, with impressions of a box flue tile combing on the lower side:
an *opus signinum* mortar (this sample was heavily concreted).

3) RB 81 TR 105 (13):
a coarse tile based mortar or plaster with lime stone pebbles, about 60mm thick.
4) (13a) A fine tile based plaster? layer on the above sample, about 10mm thick.
5) RB 81 TR 105 (19):
a pink tile mortar 18mm thick.
6) (19a) A dark tile based mortar on the above sample, about 15mm thick.
7) Great Bath rendering; north side, west alcove by stalls:
a coarse white plaster with tile, 15 - 20mm thick, over a fine plaster:
8) Fine pink tile plaster under the above sample, about 10mm thick.
9) Bonding mortar from the outer wall of the east end of the Great Bath (forming the wall of the museum stone store):
a buff mortar with gravel including some limestone.
10) Painted plaster from the "Sacrificial Altar".
Many small fragments of painted plaster were recovered from under an area of paving to the west of the altar in 1983. This plaster was presumably removed from some previous construction and used as hardcore. The fragments were all of the same basic sandy plaster construction:
paint on, 0.05 - 0.1mm, on white *intonaco*, 0.5mm, on sandy plaster with tile traces, 8 - 12mm thick. One sample showed an over layer of pink, 0.05mm, on white *intonaco*, 0.75 - 1mm, on white, <0.05mm, on white *intonaco*, 0.5mm, on the plaster as above. This may have been a *giornata* join.

PAINTING TECHNIQUE
The paint appeared to have been applied in the buon fresco method, in the following schemes: red, red and white spots on dark pink, white stripe on dark pink, dark yellow, grey and white over dark yellow (perhaps over painting).

PIGMENTS
The pigments were all natural materials: red ochre (haematite), yellow ochre (limonite), white lime, grey - lime with carbon (as soot or charcoal).

Average results

	Thicknesses	"Lime"	
concrete	-	66%	
torching	-	61%	
coarse plaster	-	29%	*opus signinum* / tile
fine plaster	(10 -18) 14mm	64%	*opus signinum* / tile
coarse plaster	20mm	38%	
bonding mortar	-	71%	
painted plaster	10mm	55%	
red paint	(0.05 - 0.1) 0.3mm	96%	
intonaco	(0.5 - 1) 0.9mm	97%	

Samples illustrated in the aggregate particle size distribution graphs:

Fig Nos 34 - 36

1, 7, 9, 2, 3, 8, 4, 6, 10.

The graphs show the well graded sand and poorly graded crushed tile or brick, together with mixtures of these two.

Fig. 34 Bath 1 - sand and gravel

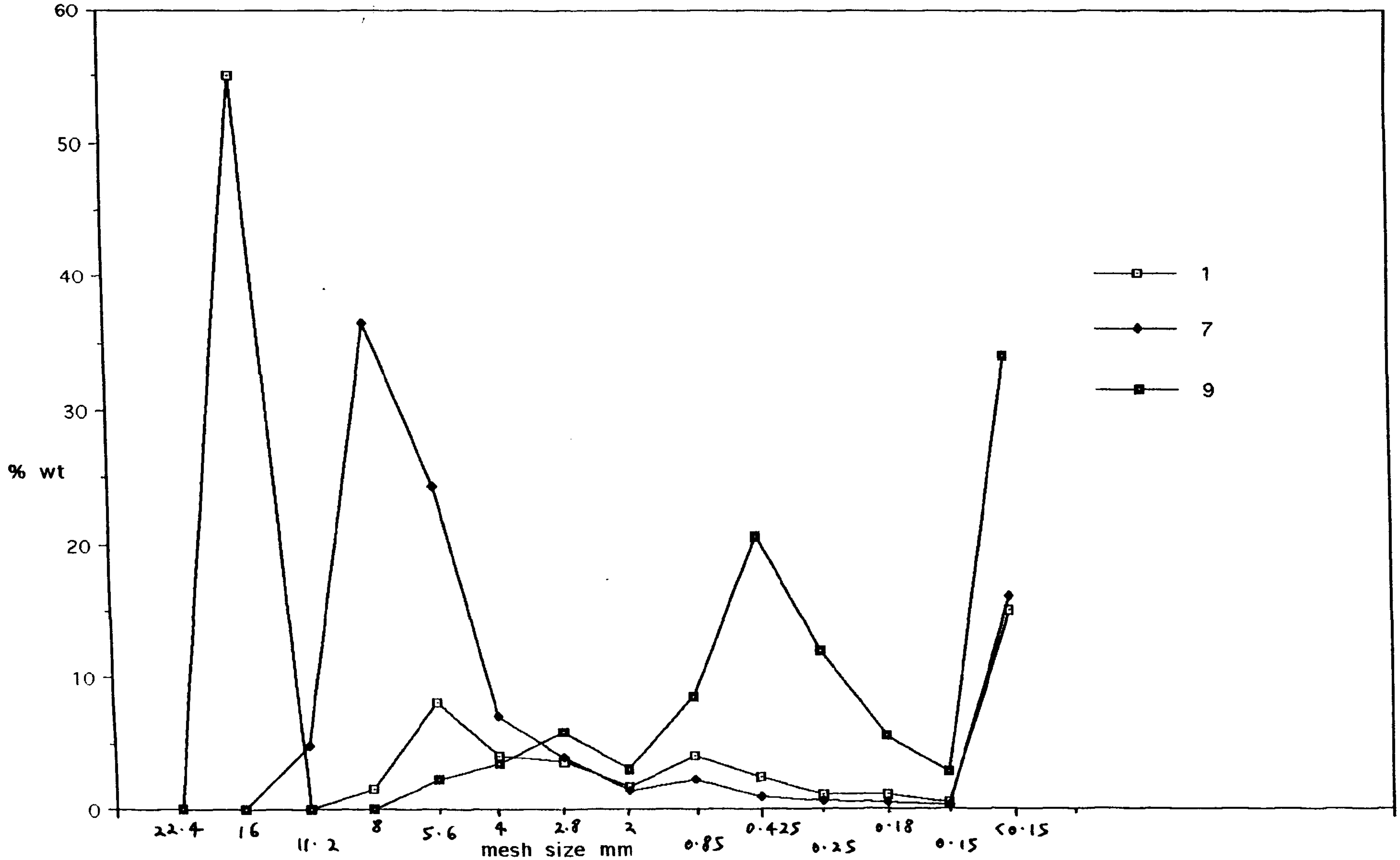


Fig. 35 Bath 2 - tile / opus signinum

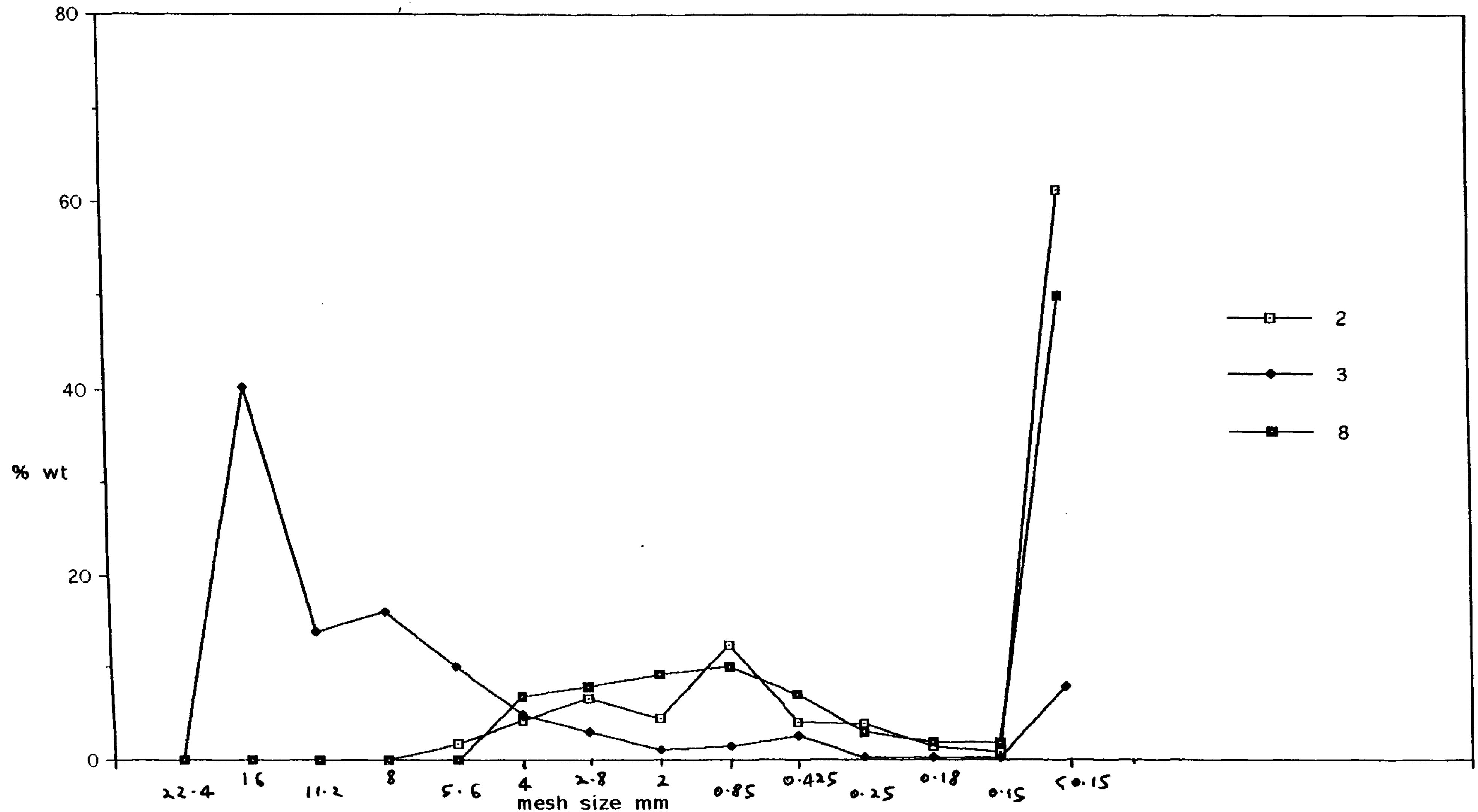
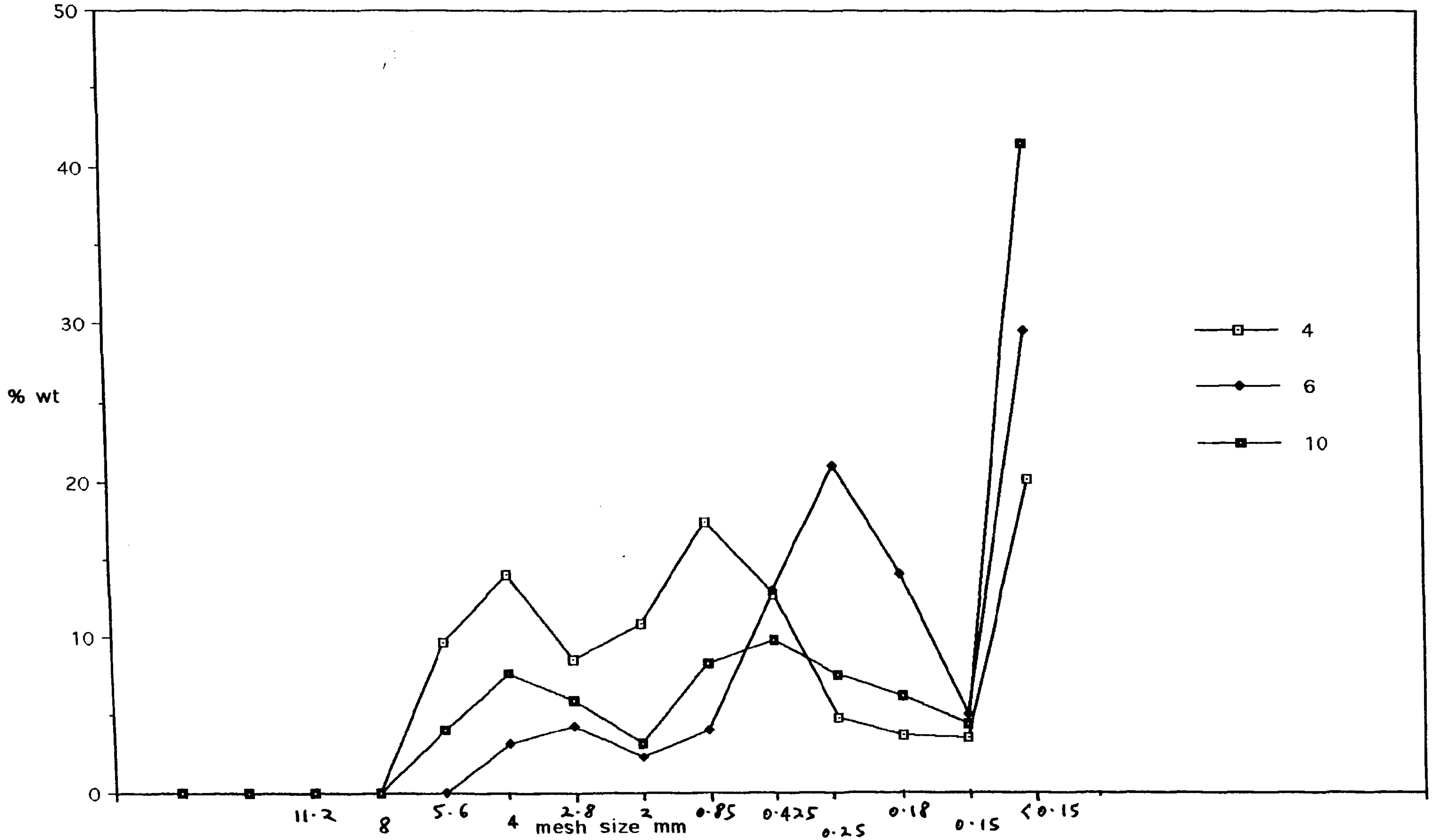


Fig. 36 Bath 3 - sand and tile



Beauport Park, East Sussex
Brodribb and Cleere 1988

The Roman site at Beauport Park, was associated with very extensive iron working. The buildings were almost buried in iron slag. The Bath house survived to a considerable height and the interior still had much wallplaster *in situ.* Most of the plaster was tile based or *opus signinum*, with lesser amounts of: flint, quartzite, quartz and ferruginous sandstones. Problems with rising damp were causing the plaster to crumble and fall off. Analysis showed that this was in part due to the loss of lime. Only three samples were examined (flaked fragments from the main entrance room) and five analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1	50	35	15	40%	mainly tile with some gravel
2a	51	27	22	13%	mainly tile
2b	49	34	16	37%	mainly tile with some gravel
3a	49	29	22	35%	mainly tile
3b	40	42	18	38%	

PLASTER DESCRIPTIONS

1: pink tile plaster, 10mm thick, in a single layer
2: dark pink (a) and light pink (b) plaster fragments. These were originally layered. The residue contained quantities of haematite and other ferruginous material.
3: coarse pink plaster (a), 12mm, on fine pink plaster (b), 12mm thick. The residues also contained ferruginous material.

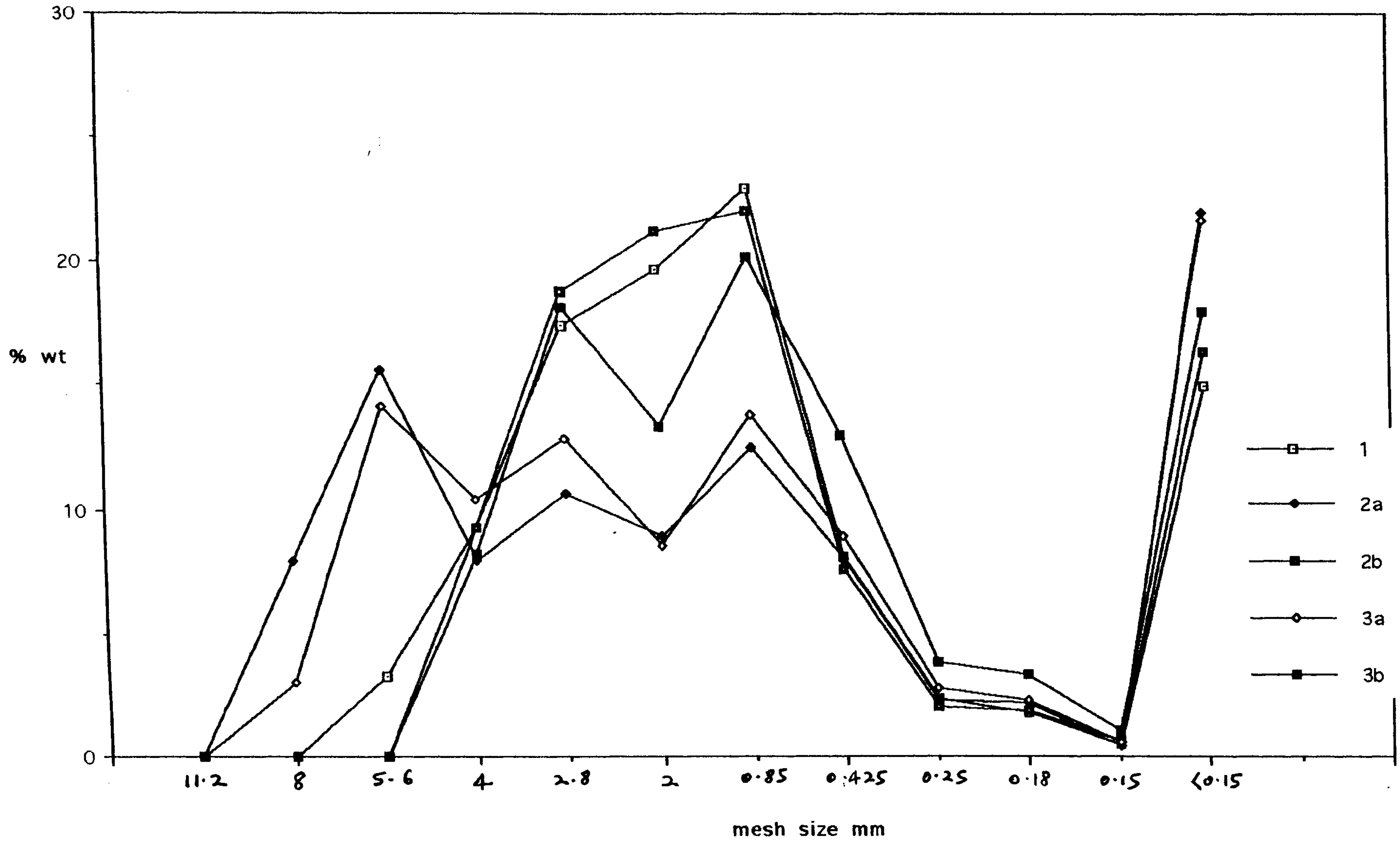
<u>Average results</u>

	<u>Thicknesses</u>	<u>"Lime"</u>
	11mm	38%

One sample, not included in the averages, had a "lime" content of just 13%, which is very low for wall plaster, suggesting loss of lime.

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig No. 37
1, 2a, 2b, 3a, 3b.

Fig. 37 Beauport Park - opus signinum



The graphs show that the (a) layers are very similar, and that sample 1 is the same as the (b) layers. The variation in lime content did not affect the grading.

Beddington, Surrey.
Beddington Roman villa.
Adkins and Adkins 1986

Samples of painted ceiling plaster, probably from a clay cob and wood structure in use between the second and fourth centuries. The plaster was all lime based with aggregates of rounded quartz sand, angular flint and traces of tile or brick. The sand was in approximately the same proportion as the crushed flint. Only four samples were examined and nine analyses carried.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1)	-	-	-	92%	top of *intonaco*
plaster	11	65	24	35%	both layers
2)	-	-	-	84%	*intonaco*
plaster	11	64	25	36%	upper layer
plaster	16	61	23	31%	lower layer
3)	-	-	-	92%	upper *intonaco*
	-	-	-	75%	lower *intonaco*
plaster	9	63	28	38%	upper layer
	14	60	26	33%	lower layer

EXAMPLES OF PLASTER DESCRIPTIONS

81 BSF /85\

1) 8 [B3] / [C3] AND [E1] 103 (1):

Red stripe on trowelled white *intonaco*, 0.75mm, on coarse light sandy plaster with lime lumps and straw impressions in two probably equal layers, 17mm total thickness. Also a second sample with a yellow stripe.

2) 12 A1 II 103 (1):

Red and yellow stripes on white *intonaco*, 0.75 - 1.5mm, on light sandy plaster in two equal layers with more straw impressions in the lower layer, 11mm + 11mm thick. This unusually thick intonaco was apparently made with a very fine sandy lime.

3) [D2] 103 (1)

Red and yellow stripes on white *intonaco* in two layers, white , 0.05m, on sandy white, 0.5 - 0.75mm, on light sandy plaster in two equal layers, 26mm total thickness.

PAINTING TECHNIQUE

The painting technique appeared to be in the *buon fresco* method, with colour schemes of red and yellow stripes on white.

PIGMENTS

Only red and yellow ochres were found on the samples examined.

Average results

	Thicknesses		"Lime"
intonaco	(0.05 1.5)	0.6mm	86%
upper plaster	(11 - 13)	12mm	37%
lower plaster	(11 -13)	12mm	32%
combined layers		17mm	35%

Samples illustrated in the aggregate particle size distribution graphs:

Fig Nos 38, 39

3), 4) 5), 6).

The graphs show the poorly graded nature of the aggregate and one sample obviously from a different source. It was probably derived from sandy limestone used as a source for the lime for the *intonaco*. A second set of sieves was used to extend the range of mesh sizes down to 45µm. This showed that the peak of the fine sizes (which was fine rounded sand not silt) occurred at about 0.15mm.

Fig. 38 Beddington 1

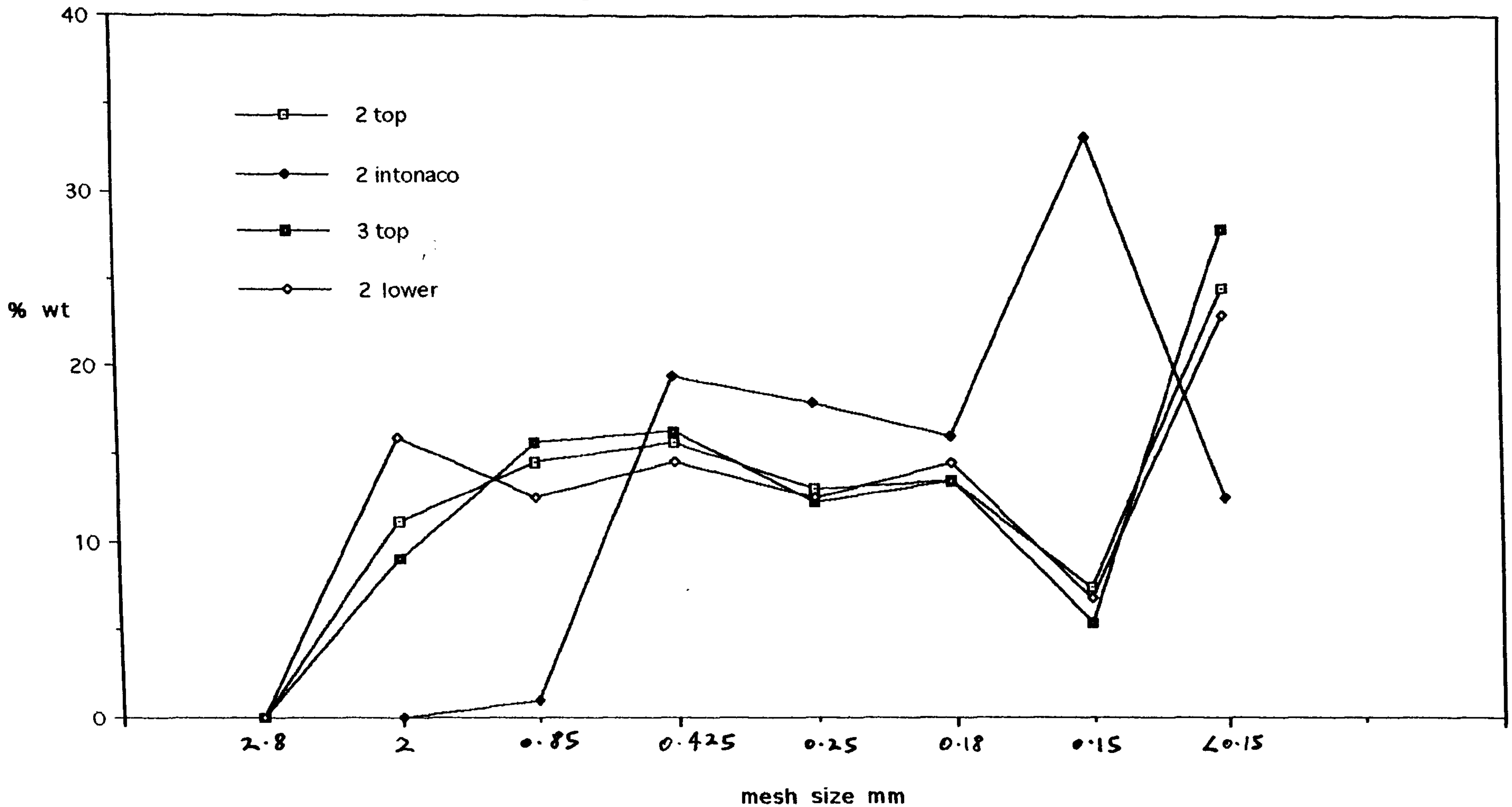
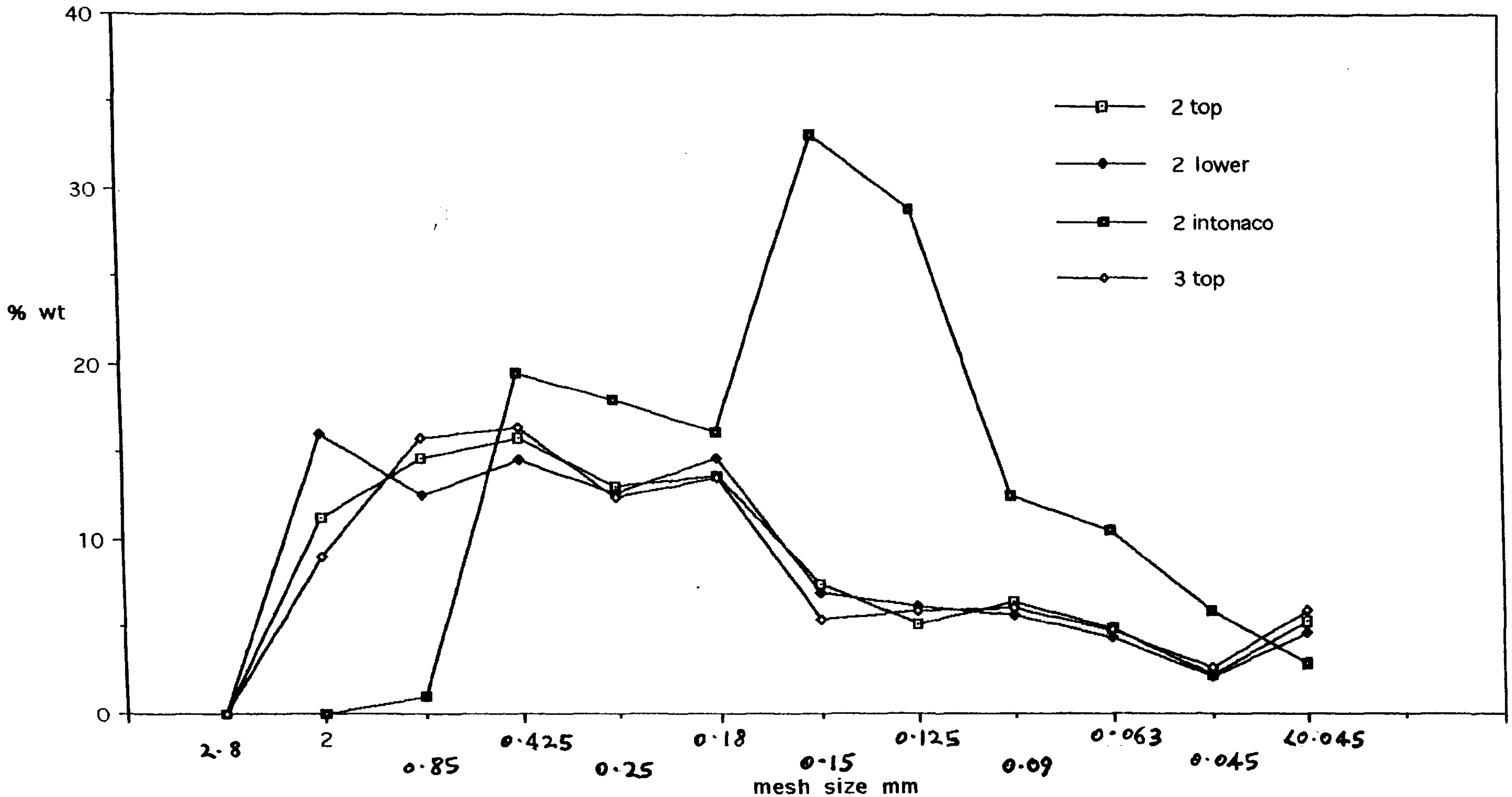


Fig. 39 Beddington 1 - extended range



Bignor Roman Villa, West Sussex.
Aldsworth 1983, Frere 1982

Mortar and painted plaster from from various parts of the villa complex dated to the third and fourth centuries. The geology of the area is mainly chalk with fossils and flint. Under the chalk there are various layers of greensand, gault clay and calcareous sandstone. The presence of red sand in some of the mortars is of note as it may have been brought some distance from the outcrops of red sandstone. The aggregates generally reflect the local geology, being mainly composed of: weathered limestone fragments, chalk, rounded quartz sand and flint, with the addition of crushed red brick or tile. Twenty nine painted plaster samples were examined and seventeen mortar or plaster analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1)	1	80	19	53%	lath impressed, upper layer
	1	83	17	53%	lath impressed layer
2)	1	85	14	20%	tile torching mortar
3)	0	93	7	20%	red sandy plaster or mortar
4)	12	62	26	31%	plaster, upper layer
	10	61	29	30%	plaster lower layer
5)	30	60	10	27%	plaster upper layer
	10	76	14	24%	plaster lower two layers
6)	9	49	42	50%	waste? mortar lump
opus signinum types:					
1)	43	45	12	40%	plaster
2)	70	14	16	40%	plaster
3)	50	38	12	38%	plaster or mortar
4)	57	28	15	26%	upper plaster
4)	48	31	21	44%	lower plaster
5)	65	19	16	38%	plaster or mortar
6)	61	26	13	40%	plaster or mortar
7)	51	40	9	33%	upper plaster
8)	34	56	10	48%	lower plaster

EXAMPLES OF PLASTER DESCRIPTIONS

1) B / 84 /49 lath impressed wall or ceiling plaster:
This sample of light buff sandy plaster showed parallel lath impressions with wood graining on the rear. The tapering sample had a lime wash or lime surface film on buff to off white sandy plaster in two layers about 18mm + 19mm in maximum thickness. The lath impressions were about 30mm wide. A similar example on display in the site museum (not analysed) showed lath impressions and had a lath fixing nail still embedded in the plaster. The layering in the sample was masked by an apparent ion migration, giving an iron pan like film parallel to the surface. The sample was separated along the probable plaster layers for analysis, which showed the two layers to be very similar.

2) Tile bonding mortar "torching"; unlocated
3) Red sandy plaster or mortar lump; unlocated.
4) Winter Room - blue:
Blue green on buff sandy plaster in two layers, 10mm + 8mm thick.

5) 61 II [40] (35)
Blue on dark green on black on pale green on white, total 0.05mm, on creamy white *intonaco*, 0.75mm, on buff sandy plaster, 8mm, on chalky mortar, 15mm thick.

6) Various *opus signinum* samples, composed of crushed red to orange red to grey brick or tile, with varying amounts of flint and quartz sand. The following paint types were all on the same layered cream to buff sandy plaster with a white *intonaco*:
a) Winter Room white: Red, pink and green on a combed white surface.
b) 61 II [40] (35): White with blue specks on red, black on red, pale blue on red and red (cinnabar) on yellow, 0.05mm, on white 0.05mm, on a white *intonaco*, 0.75mm thick.
Wall plaster from covered yard No 1:
c) Plain purple: blue on purple on red.
d) Red: red on pink on white.
e) Green: plain green on white.
f) Green and red: green on red on white.
g) White on purple with green edging: white on green on purple on red.

h) Green background with white and green stripe: light green on white with dark green edging and a white stripe on the light green.

i) White line on black with green edging: green on black and white on black.

Unmarked plaster from the Venus Room:

j) Blue: plain blue with black flecks.

k) Pink: burnished red on pink.

l) Purple and white: purple on white (on three layered coarser plaster).

PAINTING TECHNIQUE

The painting appeared to be in the *buon fresco* method with the following colour schemes which were mainly bands of colour, suggesting borders: red, red (cinnabar) on yellow, red on pink, pink, burnished pink, pink on yellow, purple on white, light and dark green, green on red, green on black, green on yellow, blue with black, blue with green, blue on green on black, blue on purple on red, white with blue on red, white on green,

PIGMENTS

The natural pigments were earth colours; red ochre (haematite), yellow ochre (limonite), green earth (glauconite), white lime and carbon as soot or charcoal. The other red colour present was cinnabar (mercury sulphide). The artificial colour was Egyptian blue.

<u>Average results</u>

		Thicknesses	"Lime"	
paint		0.05mm	-	
intonaco		0.75mm	-	
plaster	(8 - 10)	9mm	29%	upper layer
	(8 - 15)	12mm	27%	lower layer
lath impressed		19mm	53%	ceiling
red sandy type		-	20%	
opus signinum			30%	upper layer
			46%	lower layer
			39%	single layer
torching mortar			20%	

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 40 - 42

1: 1) upper and lower layers, 2) torching, 3) red sandy plaster.
2: 4) upper and lower, 5) upper and lower layers, 61 II [40].
3: *opus signinum* types; 1, 2, 3, 4 upper and lower layers.

The three types of distribution curve show the red sandy mortar, the buff plaster and the *opus signinum* types.

Fig. 40 Bignor 1

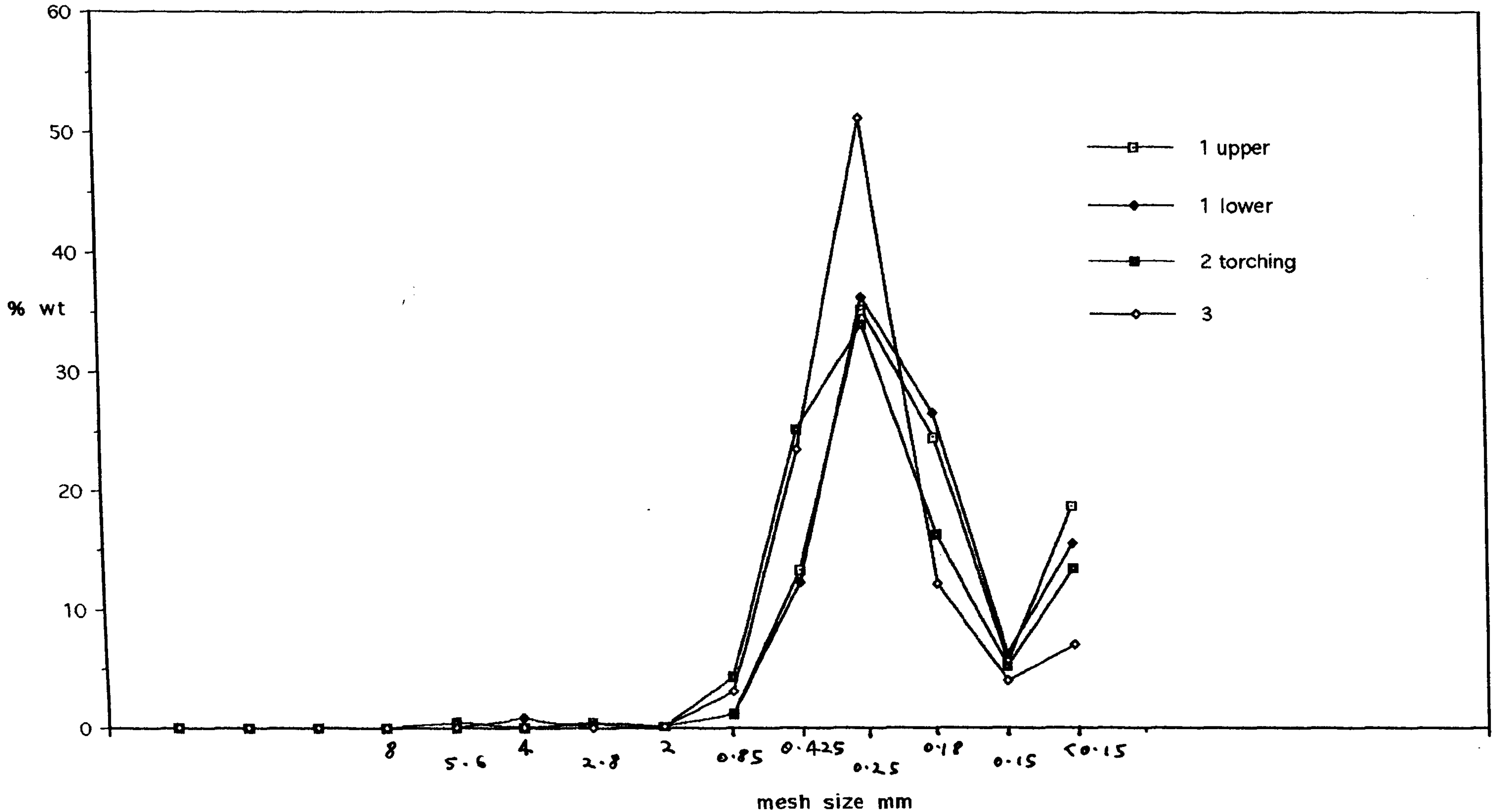


Fig. 41 Bignor 2

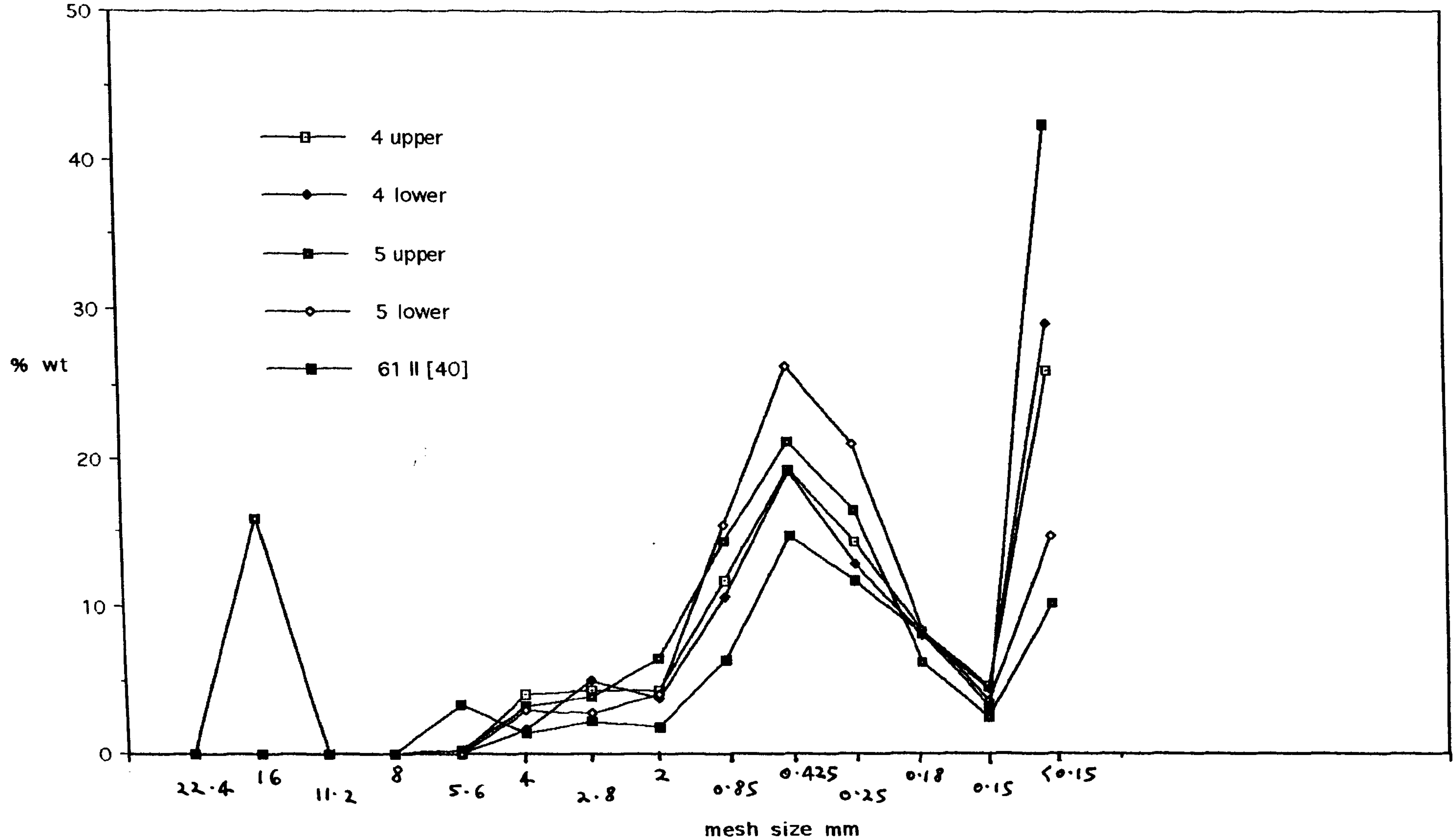
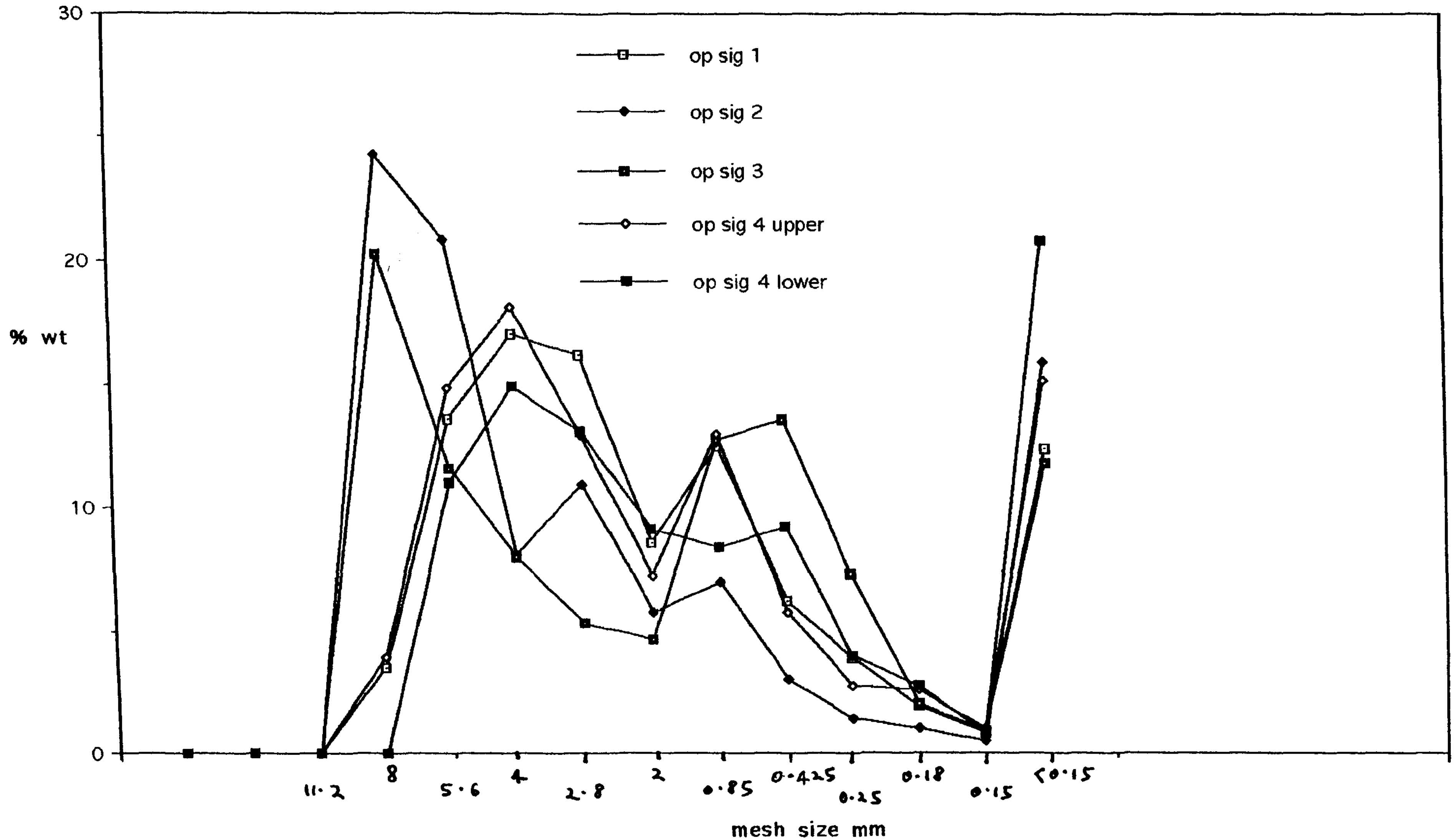


Fig. 42 Bignor 3 - opus signinum



Binchester, County Durham
Britannia 1978, 9: 425 - 6; 1979, 10: 284; 1980, 11: 361 - 2.

Finds from the excavation of the Roman fort at Binchester from 1976 to 1978 were deposited in the collections of the Bowes Museum, Barnard Castle. They were not analysed but detailed visual examination was carried out on many of the samples. The aggregate appeared to be mainly coarse sand with traces of red brick or tile and coal. Many of the samples were stained a buff colour and were very friable. This was probably due to the burial conditions. Of particular interest were impressions of tied reed bundles and keying marks. Nineteen samples were examined. These results are unpublished.

DESCRIPTIONS

Bin A6:
white edge on pink and white splashes on light green, 0.05 - 0.1mm, on white *intonaco*, 0.5mm, on light grey to buff coarse sandy plaster with traces of tile and coal, 7mm thick.
Also a sample with pink and red splashes on orange to pink, <0.05mm, on white *intonaco*, 0.6mm, on grey sandy plaster, 11mm, on buff plaster, 10mm thick.

Bin 76 A15.1:
plain off white, 0.75mm, on light grey to buff sandy plaster, 10mm, on light buff sandy plaster 45mm thick, probably a levelling plaster from a rough stone wall.

Bin 76 A15.2:
white over-paint with blue traces, 0.5mm, on red on off white *intonaco*, 0.5mm, on buff to yellow sandy plaster, possibly in two layers, 5mm + 15 - 20mm thick. Also a sample with white lime with sand on red on white as above.

Bin 76 A6 /71\:
coarse grey sandy plaster with red tile traces, 12 - 14mm with semi-circular raised keying marks, on grey sandy plaster with tile traces, 9mm thick. The keying ridges were about 12.5mm across and about 3mm high.

Bin 76 A81:
rough white lime with sand, 2.5mm, on red on white *intonaco*, 0.1 - 1mm, on buff plaster with sand, 6mm, on light grey sandy plaster with cola, 6mm, on white *intonaco*, 1mm, on light grey sandy plaster, 10mm thick.
Also a sample with plain white, 0.4mm, on light sandy plaster, 6mm, on white, 0.05mm, on buff sandy plaster with coal traces in two layers, 5mm + 7mm, on white traces, 0.1mm thick. These were both examples of three phase plasters.

Bin 76 A6 /110\:
1) light green with blue traces, 0.05mm, on white *intonaco*, 0.5 - 0.75mm, on light grey sandy plaster, 9mm, on buff sandy plaster, 9mm, on light grey sandy plaster, 10+mm thick.
2) lime with red tile traces, 2mm, on coarse gravel / cobble mortar, 25+mm thick, possibly a floor.

Bin 76 A81.1:
plain white, 0.75mm, on buff lime with sand, 2.5mm, on light grey sandy plaster with reed bundle impressions, possibly tied, max 20mm, min 10mm thick.

Bin 76 A81.2:
white splashes? on red on white *intonaco*, 2 - 2.5mm, on light grey sandy plaster, 6mm, on light grey sandy plaster with tied reed bundle impressions, max 25mm, min 10mm thick. The reed bundles were between 25mm and 30mm in diameter. The string used to tie the bundles appeared to be of twisted twine. It may have been ceiling plaster.

Bin 77 A771:
yellow on rough white *intonaco*, 0.2 - 0.5mm, on coarse light grey sandy plaster, 7 - 10mm, on light buff sandy plaster, 10mm thick. Also a sample with dark red on rough white as above.

Bin 78 A458:
light green, 0.1mm, on white *intonaco*, 0.4mm, on light grey to buff sandy plaster, 10mm thick.
Also a sample with red, <0.05mm, on rough white *intonaco*, 0.2mm, on light grey sandy plaster, 12mm, on buff sandy plaster, 12mm thick.

Bin 78 A1361 /1774\:

1) plaster? lump of light buff lime with sand, 53mm thick with traces of an upper layer.

2) grey, <0.05mm, on white, 0.05mm, on white *intonaco*, 3 - 4mm, on light grey sandy plaster, 25mm thick.

Also a sample with buff lime traces on red, <0.05mm, on white *intonaco*, 1.5mm, on light grey sandy plaster, 10mm thick.

The paint appeared to have been applied in the *buon fresco* method, with over painting probably in *fresco secco*.

The pigments were the natural colours: red ochre (haematite), yellow ochre (limonite), white lime, green earth (glauconite) and crushed Egyptian blue.

Brean Down, Avon.
ApSimon 1965
Lewis 1966 : **passim** (mid fourth century)

The Roman temple on Brean down provided samples of painted plaster from one of the few safely classified religious buildings examined in the survey. The material, from the collections of the Woodspring Museum, Weston super Mare, was very fragmentary and partly decayed. The site is on a carboniferous limestone promentary, partly reflected by the composition of the plaster which included some limestone material. The aggregates consisted mainly of round to sub-angular quartz sand with small brown sand and mud concretions. The carboniferous limestone appeared as brownish crystalline fragments. In view of the presence of limestone, the "lime" values must be considered to be somewhat high. Samples of sand from the beach and down (including a sample from underneath a Bronze Age deposit) were also graded for comparison. Nine samples were examined and seven analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1)	-	-	-	86%	*intonaco*
	1	54	45	59%	upper plaster layer
	2	68	30	49%	lower plaster layer
1.1)	-	-	-	92%	*intonaco*
	3	58	39	64%	upper layer
	2	69	29	55%	lower layer
2)	1	59	40	57%	upper layer
	1	57	42	53%	lower layer

EXAMPLES OF PLASTER DESCRIPTIONS

1) BD 58 E10 2C 183p; Portico:
yellow, <0.05mm, on white *intonaco*, 1 - 2mm, on sandy brown plaster with lime and limestone in two layers, 8mm + 17mm thick. (Repeated as 1.1)

2) BD 58 E10 Cella (2):
red on pink on white traces; red over yellow to white interface; pink over yellow; dark red on pink, and light green on pink on white *intonaco* traces, 0.1 - 0.4mm, on brown plaster in two layers, 10mm + 12mm thick.

Also green on white, 0.5mm, on brown plaster in two layers, 5mm + 10mm thick.

3) BD 58 Cella:

red and green on yellow; red on white; plain white with traces of blue; pink 0.05mm, on white *intonaco*, 0.5mm, on brown plaster in two layers, 9mm + 13mm thick.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* method. Although only small samples were examined, the scenes were probably fairly complex.

PIGMENTS

The pigments identified were the usual earth colours; red ochre (haematite), yellow ochre (limonite), green earth (glauconite), white lime with traces of crushed Egyptian blue.

Average results

	Thicknesses		"Lime"
paint		0.05mm	-
intonaco	(0.3 - 1.5)	0.4mm	89%
upper plaster	(5 - 10)	8mm	60%
lower plaster	(10 - 17)	13mm	52%

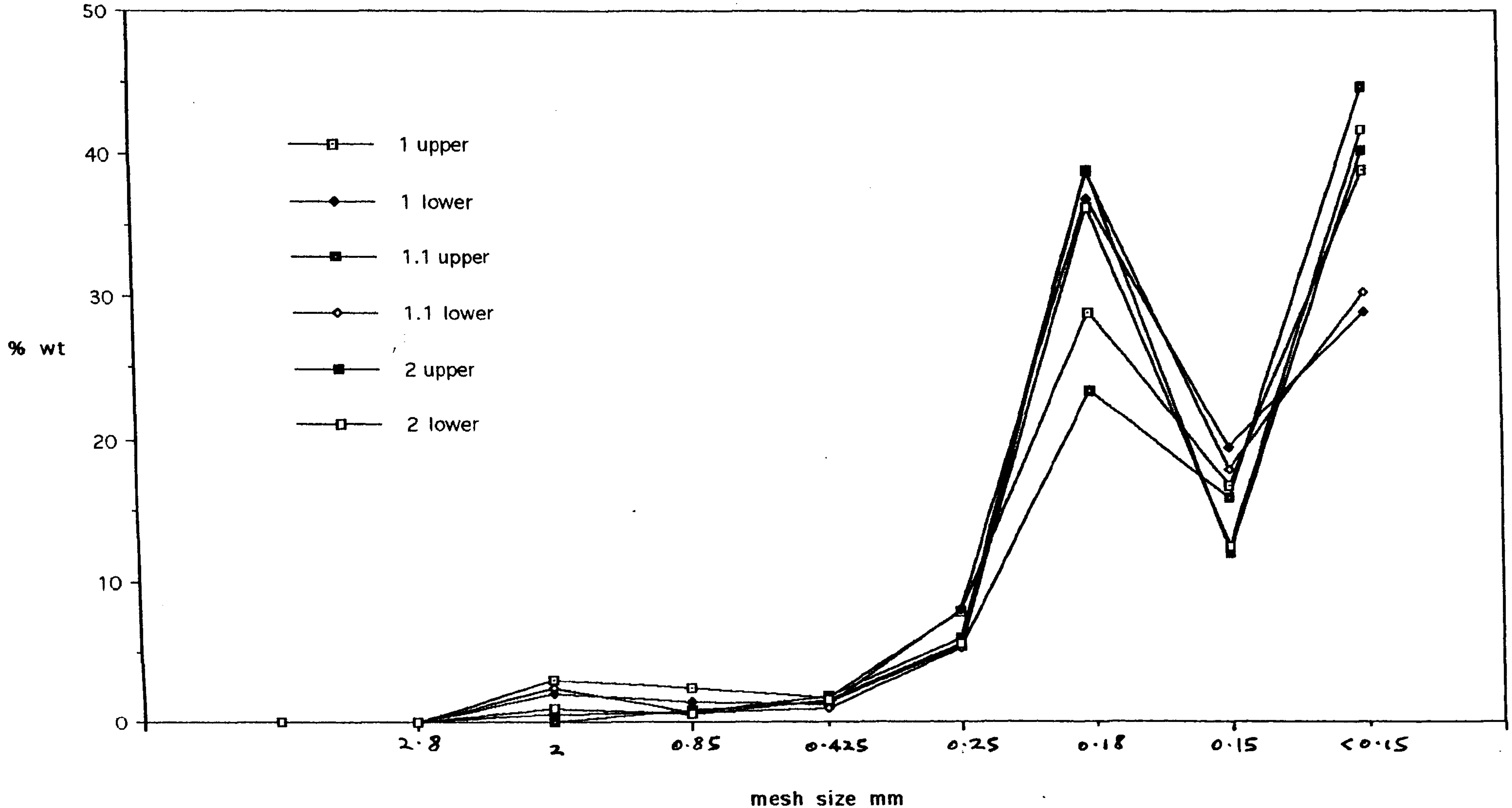
Samples illustrated in the aggregate particle size distribution graphs:

Fig No. 43 (and natural sands; Fig No. 29)

1, 1.1 (duplicate of 1), 2.

The graphs show that neither the current beach nor the down sand was used as a aggregate in the Roman plaster.

Fig. 43 Brean Down Temple



Caerleon, Gwent
Legionary Fortress Baths
Zienkiewicz 1986

Plaster, pigments and mortar from various parts of the site, dated to between the second and third centuries, were examined and analysed. The site lies on alluvial sands and gravels as is shown by the aggregate analyses, whilst much of the lime was apparently derived from high silica Liassic limestone which outcrops a few mile from the site. The aggregates consisted mainly of: fragments of red micaceous sandstone, sands, gravel, ferruginous sandstone, quartzite, siliceous limestone, brick or tile and coal traces, most of which, apart from the tile, was probably extracted from the river gravels. Forty one samples were examined and identified and 30 analyses carried out.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1a	-	-	-	90%	*intonaco*
1	15	73	12	43%	plaster, upper layer
2	16	72	12	40%	middle layer
3	10	34	56	88%	lower layer with tile
4a	-	-	-	86%	*intonaco*
4	3	55	42	39%	plaster, upper layer
5	4	29	67	89%	lower layer, siliceous
6a	-	-	-	83%	*intonaco*
6	3	59	38	35%	plaster, upper layer
7	4	54	42	35%	middle layer
8	12	51	37	45%	lower layer
9	11	43	47	29%	plaster, upper layer with tile
10	11	41	48	35%	lower layer with tile
11	-	42	58	76%	white window "putty", some tile
12	1	66	33	47%	pink window "putty" with tile
13	27	43	30	51%	*opus signinum*
14	29	63	8	37%	ceiling plaster
15a	-	-	-	95%	*intonaco*
15	9	81	10	42%	plaster
16	21	51	28	39%	*opus signinum*
17	1	82	17	39%	secondary plaster, upper layer
18	7	65	28	36%	lower layer with tile
19	9	81	10	45%	primary plaster, upper layer

20	11	79	10	43%	middle layer
21	-	-	-	86%	lower layer, lath impressed
22	4	60	36	39%	plaster
23	9	61	30	22%	secondary plaster
24	13	44	43	37%	primary plaster, upper layer
25	4	46	50	19%	lower layer
26	3	59	38	62%	roof tile "torching" mortar

EXAMPLES OF PLASTER AND MORTAR DESCRIPTIONS

1] CFB I p 282, coffered ceiling:
White lime, 0.05mm, on white *intonaco*, 0.4mm, on cream sandy plaster, 8mm (1) on off white sandy plaster, 10mm (2), on white plaster with grass or straw impressions, 17mm (3), with lath impressions (6mm thick x 25+mm wide) on the rear.
2] CFB I fig 90 pl XVCI, lath impressed ceiling plaster:
Thick brushed whitewash, 1 - 2mm, on grey to buff sandy plaster, 8 - 10mm (4), on lightweight white plaster with straw impressions, 15 - 20mm thick (5).
3] CFB I fig 90, wall plaster:
Off white to pink (tile dust), 0.25 - 0.5mm, on white, 1mm, on grey to buff plaster, 12 - 14mm (6), on lighter grey to buff plaster, 13mm (7), on grey to buff mortar, 14 - 15mm (8), all with grass or straw impressions, total thickness 40mm.
4] CFB I fig 94 65.170, wattle impressed plaster:
Traces of pale sandy plaster, 1mm, on pink tile plaster with straw impressions in two layers, 5mm (9), and up to 40mm thick (10) around wattle impressions. The wattle diameters were between 10mm and 15mm in diameter.
5] CFB I 1979 (1188), CFB I p 327 fig 112, window putty:
Approximately triangular section plaster fragments in white (11) and pink (12) plasters. Glazing putty was also found at Godmanchester (Green 1959 229).
6] CFB 616, painted plaster:
Green and red on white, 0.4mm, on pink tile plaster, 30mm (13).
7] CFB 1084 / 1091, painted ceiling? plaster:
Red to dark red and grey, 0.1mm, on white on off white, 0.2mm, on cream (*intonaco*?) 0.3mm, on creamy white sandy plaster in two layers, 7mm + 5mm (14), on white plaster with lath impressions, 13+mm thick.
8] CFB 1084 / 1091:

Secondary plaster traces over pick marks on red to dark red and grey on off white, 0.1mm, on white *intonaco*, 0.5 - 0.6mm, on white sandy plaster in two layers, 9mm + 11mm (15).

9] CFB 1084 / 1091

Green bands or leaves on white, 0.1mm, on tile mortar in two layers, 9mm + 9mm (16).

10] CFB 1084 / 1091, over-plastered:

Coarsely floated or combed samples. Light blue on white, 0.1mm, on coarsely floated white sandy plaster, 25mm (17), on pink sandy plaster, 4 - 5mm (18), on red to dark red and grey and grey green on white, 0.25mm, on cream, o.6mm, on off white to cream sandy plaster in two layers, 10mm + 10mm (19), (20), on white lime plaster, 5+mm (21) with grass impressions and lath impressions on the rear.

11] CFB 1040 / 1050, ceiling / wallplaster:

The shape of this sample suggested a wall to ceiling junction. Dark red on white on sandy white (*intonaco*?), 0.5 - 0.75mm, on pale sandy plaster with lime lumps, 30 - 35mm thick (22).

12] CFB (28) plaster from the apse of the fountain house:
Green on black on pink, 0.1 - 0.2mm, on pink sandy plaster with red sandstone and re-used plaster in two layers, 7mm + 9mm (23), on white, 0.5mm, on white, 0.2mm, on white, 0.2mm, on pink sandy plaster with lime lumps, 7mm (24), on darker pink sandy plaster with large sandstone pebbles (partly red sandstone), 25mm thick (25). This pink sandy mortar was unique.
13] CFB roof tile bonding mortar "torching":
White lime with crushed limestone (26).

PAINTING TECHNIQUE
The painting technique appeared to be in the *buon fresco* method with the following colour schemes:
light and dark green, green on black, black on white, light and dark red, red to brown, dark pink to orange, pink, white, grey, light blue, yellow and green on pink, blue green on black and green with blue on pink.

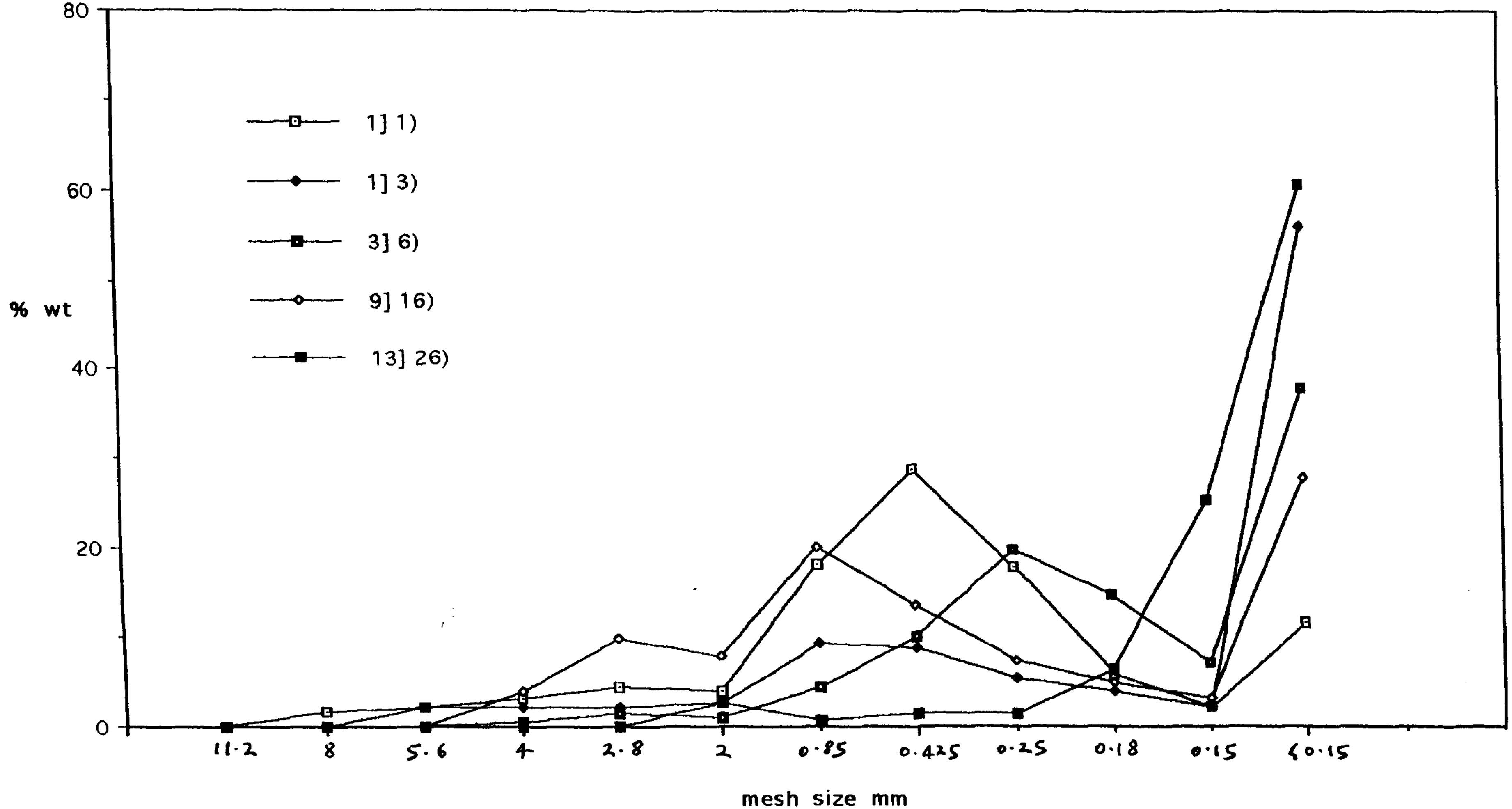
PIGMENTS
The pigments found on the painted plaster were mainly natural earths and ochres: red to brown ochres (haematite), yellow ochre (limonite), green earth (glauconite), carbon as soot or charcoal, white lime with the addition of orange / red brick or tile dust and Egyptian blue.
Pigments were also found on pot sherds, as a pigment lump, and on a possible burnisher as detailed below:
CFB 79 1125 N 5, a grey pot sherd with red on pink traces. Both colours were due to cinnabar (mercury sulphide) and it is possible that the sherd had been used as a palette.
CFB 79 939 3, pot group 17, drain group (4): Red, white and green traces on a brown pot sherd, being green earth, red ochre and white lime, once again probably a palette.
SF 1928 35 - 118, pieces of red and yellow ochre.
62.265c, vicus bear house field: dark red ochre.
CFB II p215, No 43 81.79H drain group 4, stone rubber: a fragment of a hand sized polished quartzite pebble with red pigment traces. The red was red ochre and cinnabar. This would have made an ideal burnisher for wallplaster.
87 - 2699 civil settlement stone object No 9 62.265c F2: a flattened sphere of Egyptian blue, weighing 4.4633g.

Average results

	Thicknesses		"Lime"
paint	(0.05 - 0.4)	0.1mm	-
intonaco	(0.1 - 1.5)	0.5mm	89%
primary plaster			
upper layer	(7 - 13)	9mm	40%
middle layer	(5 - 13)	10mm	40%
lower layer	(6 - 25)	17mm	88%
secondary plaster			
upper layer		2.5mm	39%
lower layer		5mm	36%
opus signinum			38%
glazing "putty"			
white - interior (*opus signinum*)			76%
pink - exterior (*opus signinum*)			47%

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 44
1] 1) (upper layer), 3) (lower layer), 3] 6) (upper layer), 9] 16) (*opus signinum*), 13] 26) (torching).

Fig. 44 Caerleon



Caerwent, Gwent

1) The Courtyard house, Insula 1, Caerwent - Venta Silurum
Britannia 1984 15: 270, 1988 19: 422 - 3, 1989 20: 264

Excavations in 1987 on the above site of a courtyard house of the late third to fourth centuries, produced mortar and some re-used painted plaster.
The mortar was all very similar, being buff coloured with varying amounts of river sand and gravel with crushed brick or tile in some samples. The aggregate was geologically identified as: round to sub-angular quartz, quartzite, flint, coarse and fine sandstones (including very fine micaceous material), ferruginous sandstones and a ferruginous - siliceous material. Yellow ochre nodules (limonite with some haematite) were found in most of the samples and traces of igneous material such as basalt or decayed granite were also noted. Of particular note was the presence of buff, grey, green and red marl or silt stone. This with lias limestone also found caused great difficulties in the dissolution of the samples in acid. Considerable quantities of amorphous silica were left in the residues after the lime had been removed. Analysis of the lias limestone found suggested that it was not the source of the lime used in the mortars as it had higher calcium carbonate and lower silica contents. Sixty samples were examined and seventy analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
Mortars:					
1)	24	52	24	21%	
4)	12	68	20	26%	
15)	30	56	14	30%	
18)	47	24	29	19%	
24)	25	36	39	32%	
30)	22	48	30	33%	
32)	21	58	21	23%	some tile
33)	18	60	22	44%	some tile and re-used plaster
35)	32	49	19	33%	multi layer / re-used plaster
38)	8	72	20	39%	some tile
40)	6	46	48	73%	lime and tile
44)	45	29	26	20%	with tile
45)	11	55	34	16%	

47)	19	64	17	26%	
48)	29	44	27	50%	upper layer, *opus signinum*
	16	49	35	28%	lower layer, some tile
52)	21	58	21	32%	
55)	41	34	25	40%	upper layer, *opus signinum*
	39	45	16	29%	lower layer 1, some tile
	55	31	14	23%	lower layer 2, some tile
56)	52	31	17	34%	upper layer, *opus signinum*
57)	15	77	8	19%	some tile
Re-used plasters					
35a1)	11	75	14	24%	
35a2)	4	84	12	26%	
35a3)	9	77	14	32%	
35b)	15	68	17	30%	re-used or lower mortar
38a)	8	72	20	39%	upper layer
38b)	14	72	14	36%	lower layer
38c)	16	69	15	24%	

EXAMPLES OF MORTAR AND PLASTER DESCRIPTIONS

33) phase III wall "bench": off white to light buff sandy mortar with lime and tile traces and re-used painted plaster;

33a) sandy pink tile plaster on dark green, <0.05mm, on white *intonaco*, 0.5mm, on sandy plaster to 20mm thick. Another sample showed a dark red to maroon colour on white but without the tile plaster covering. This suggested that a green painted wall was over-plastered with an opus signinum type plaster and subsequently demolished or had its plaster removed. This material was then used as aggregate for the later mortar. The dark red sample was not over-plastered before re-use.

35) phase III "bench" hypocaust: a light buff sandy mortar with large lias limestone pebbles and re-used painted plaster on brown mortar.

35a) the plaster was: dark red traces on pale green on white *intonaco*, 0.5mm, on sandy plaster, 5 - 7mm (35a1), on a white interface, 0.25 - 0.4mm, on sandy plaster, 10mm thick (35a2). Also present was a sample with dark red to brown with a blue speck, on pale green on white, on sandy plaster to 15mm without the white interface (35a3).

38) phase III wall: light buff mortar with large lias limestone pebbles and re-used plaster;

white, 0.4mm, on white *intonaco* ?, 0 - 0.5mm, on sandy plaster, 7 - 8mm (38a) on a white interface, c.f. 35a), on sandy plaster to 17mm (38b). Also present was a with dark red to brown on pale green on white *intonaco*, 0.5mm, on sandy plaster to 18mm thick which did not show the white interface. Similar samples had dark pink and dark red to maroon colours.

PAINTING TECHNIQUE

The painting appeared to be in the *buon fresco* method. The fragments were too small to show the decorative scheme clearly, but linear panels possibly with some more intricate detail seemed to be represented. The presence of the white lime interface in some samples pointed to a delay in the plastering process.

PIGMENTS

The pigments present were: red ochre (haematite), green earth (glauconite), white lime and traces of Egyptian blue.

Average results

		Thicknesses	"Lime"
mortars (mainly floors)	(56 - 140)	80mm	29% (25% floors)
(mainly floors)			45% *opus signinum*
re-used plasters			
paint		0.2mm	-
intonaco		0.5mm	-
upper layer	(6 - 20)	13mm	30%
interface		0.4mm	-
lower layer	(10 - 17)	14mm	26%
lias lime			88% calcium carbonate.

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 45 - 49
1), 4), 18), 30), 33), 40), 45), 47), 57), 48), 55), 56), 35), 38).
The mortar graphs show little variation except where tile was used.
The plaster graphs show that the sand used was finely graded.

Other Caerwent results
Brewer 1983

Excavations from 1981 - 1984 in the north-western area of the Roman town, known as the "Orchard site", produced evidence of Roman buildings from the late second to the early fourth centuries. The mortar and plaster and plaster was analysed under my direction by post-graduate students at the University of Leicester and is as yet unpublished. Some particular points are worth noting at this stage.

2) V.S. 83 (023) "paint pot" sherd see (024):
A rim sherd with traces of red ochre (haematite) and white lime. The patches were separate and not mixed. The red ochre alone could have been used for *buon fresco* painting. If mixed with the white lime it could have been used for *fresco secco* or for a red *intonaco*.

3) The orchard site; V.S. 82, produced several cinnabar identifications:
[2] 1063, [4] 1080, [3] 1517, [3] 1520 (peacock).
VS 82 [3] 1517 M is described in detail:
brushed red (bright red cinnabar on red brown ochre), total <0.05mm, on white *intonaco*, 0.5 - 1mm, on coarse sandy plaster possibly in two layers, 25mm + 20mm thick, with a "lime" content of about 23%.

Fig. 45 Caerwent 1

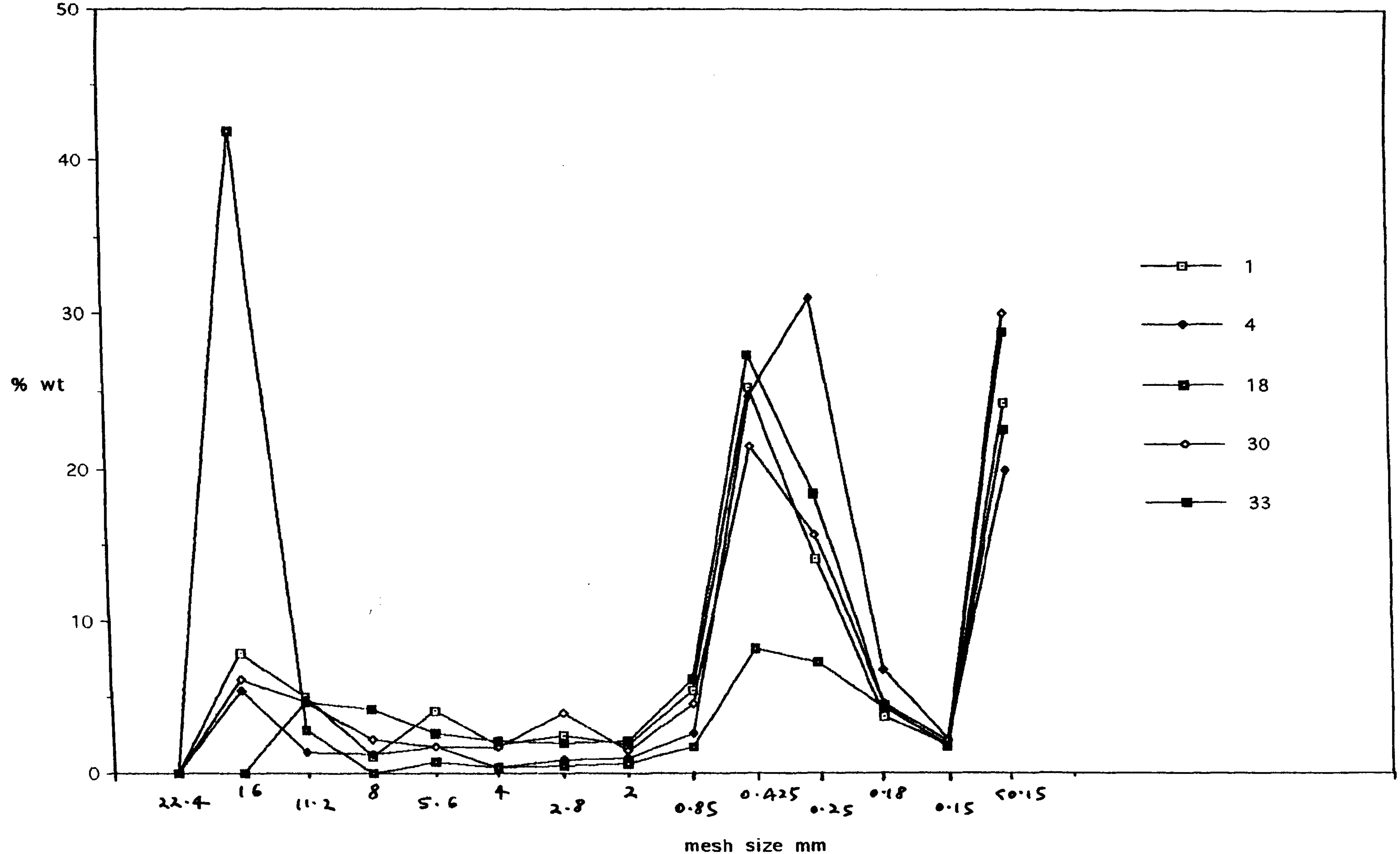


Fig. 46 Caerwent 2

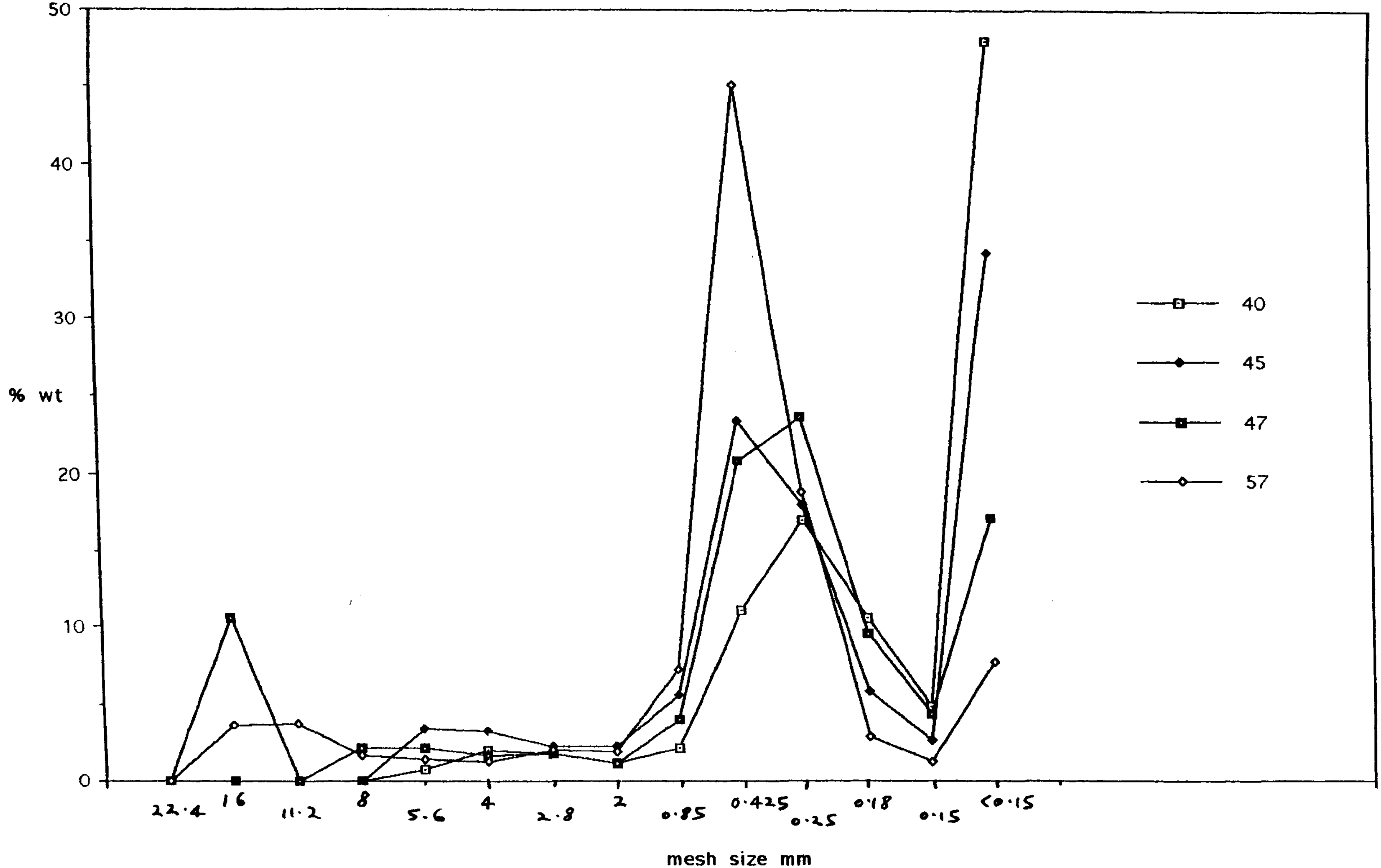


Fig. 47 Caerwent 3

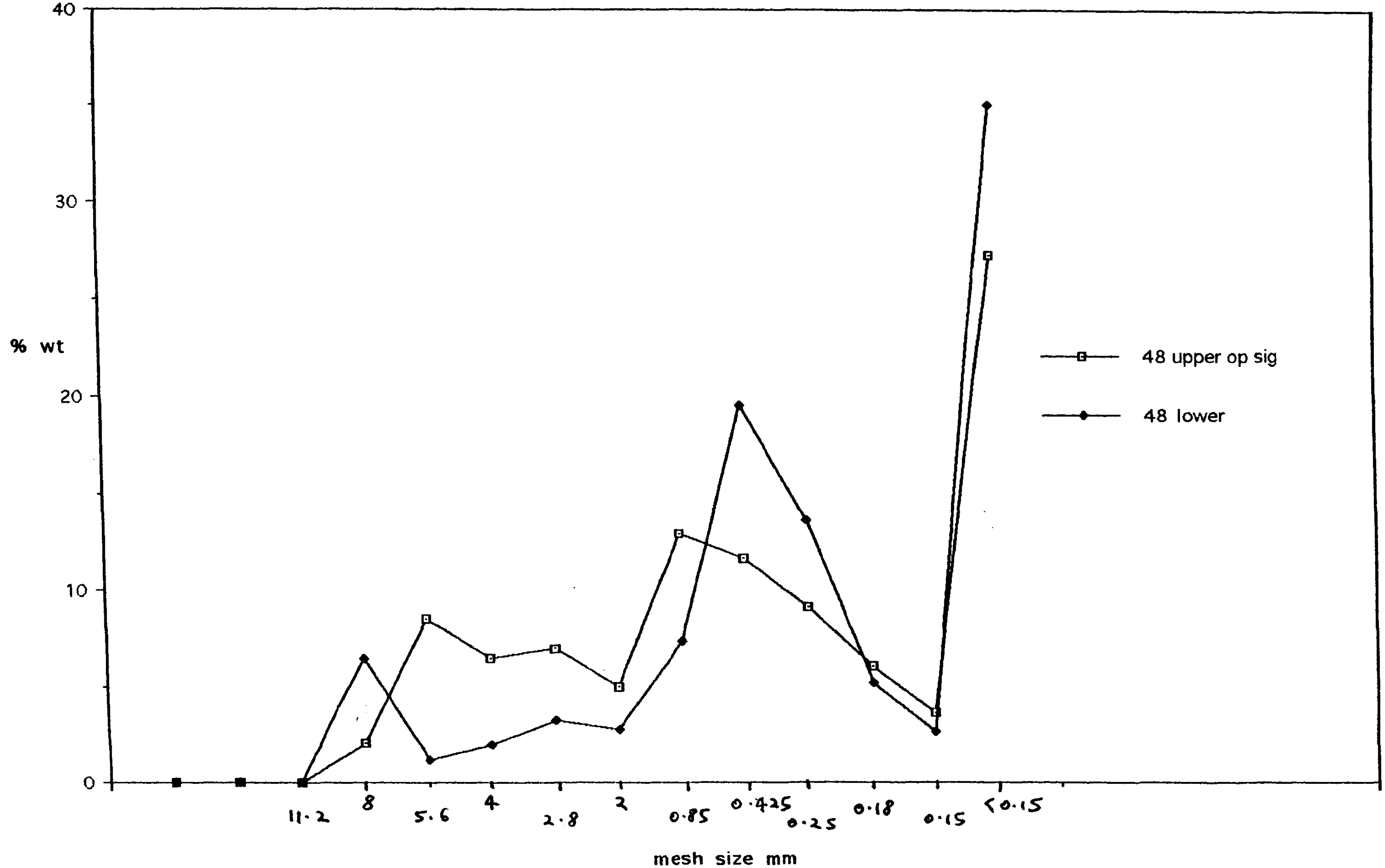


Fig. 48 Caerwent 4

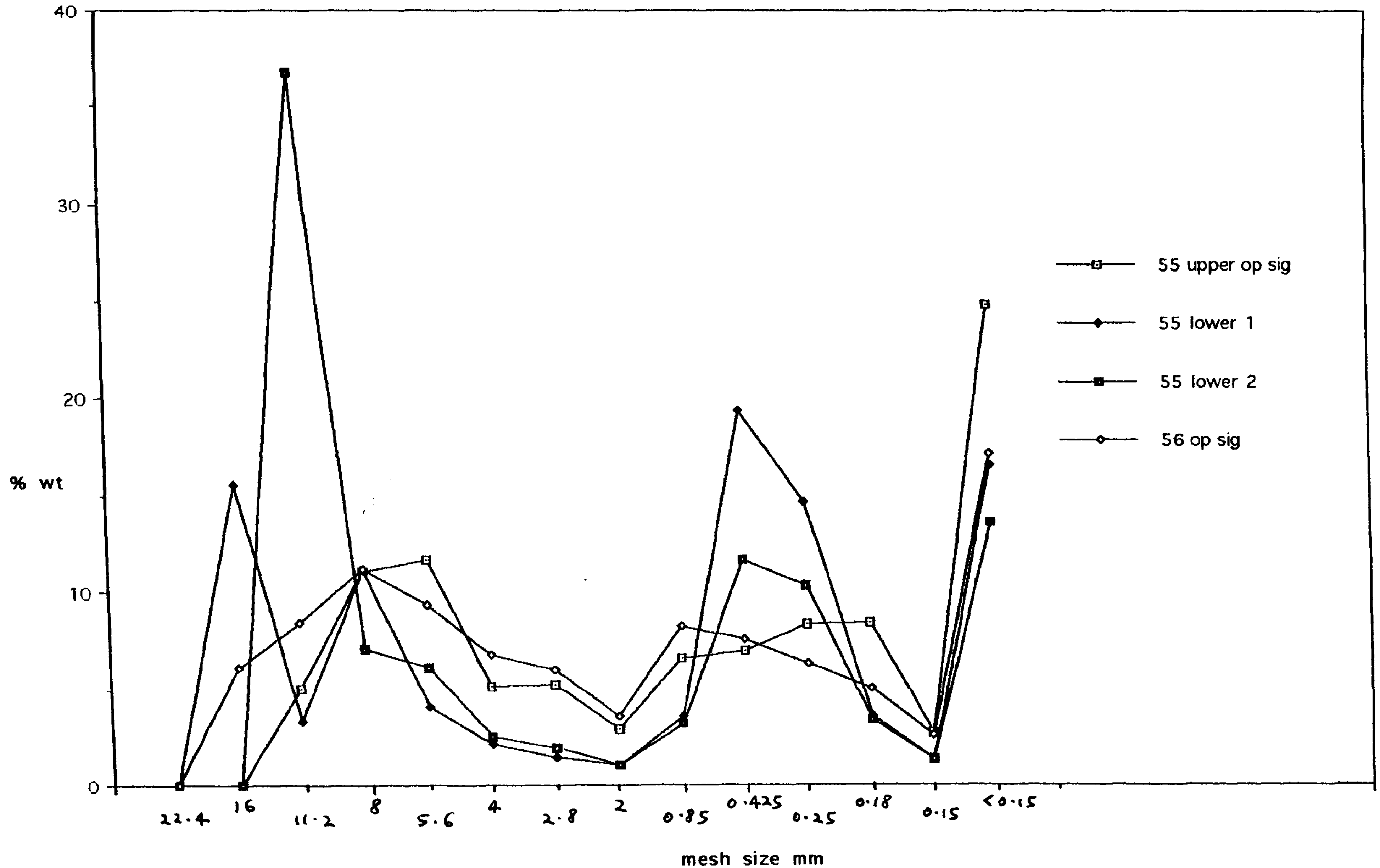
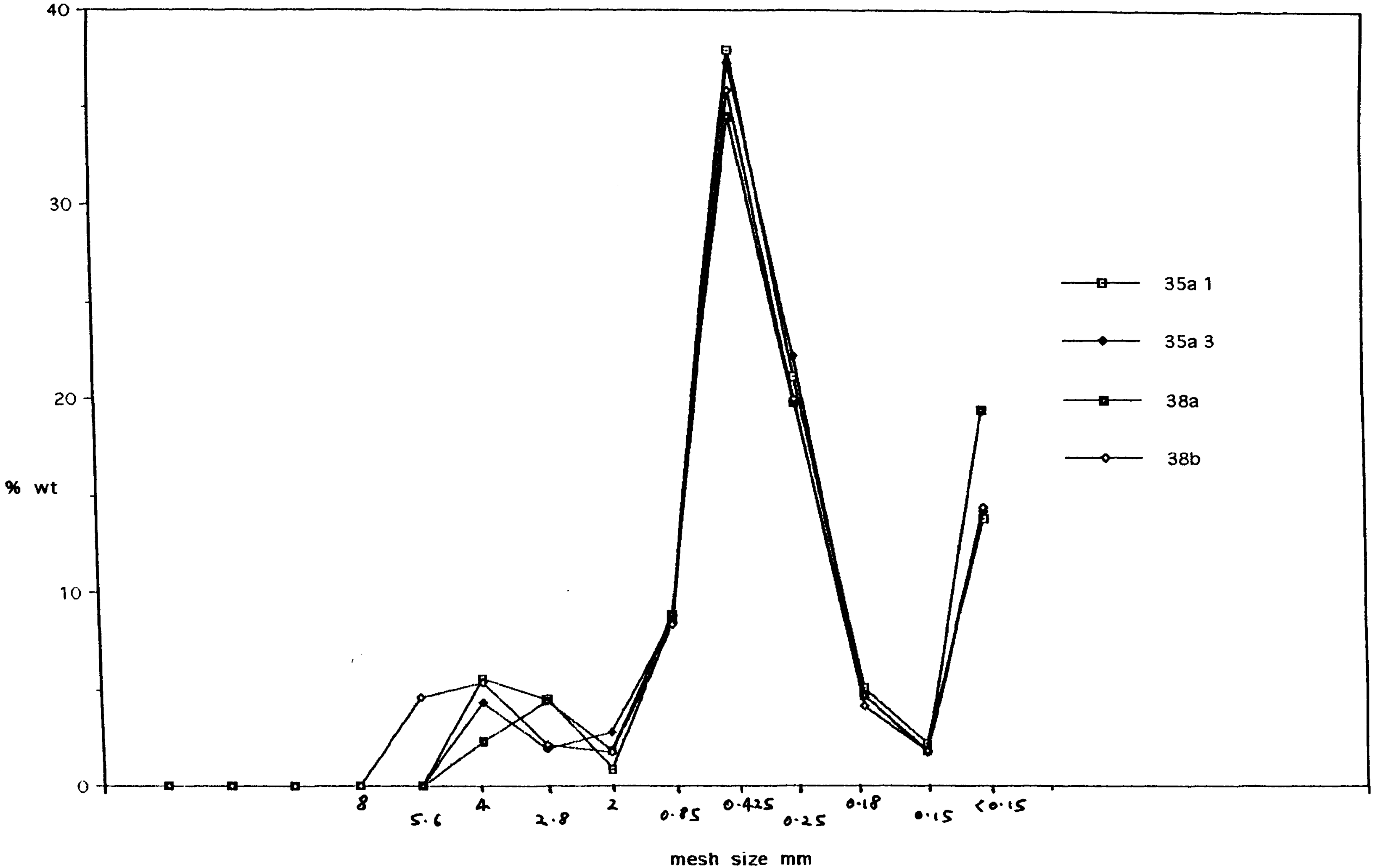


Fig. 49 Caerwent 5



Caersŵs, Powys
Britnell 1989, 133

Excavation of the first century fort at Caersws did not produce any painted plaster but some realgar (which could have been used as a pigment) was found.

Caersws 10 (779) ucc 4211; "red crystalline material":
was red realgar with traces of yellow orpiment. Both substances are varieties of arsenic sulphide and, commonly, the red changes to yellow on exposure to light and air. Although the sample was small, 0.317g, it was geologically "massive". Realgar is found in Britain but usually only as traces, suggesting that the sample may have been imported. Realgar was also found at Leicester and Mancetter. Realgar may be used as a pigment for painting walls, wood or leather, or for metallurgical purposes. The site did not produce evidence for any of these uses.

Canterbury, Kent.

Reference collections from various sites excavated by the Canterbury Archaeological Trust. (Unpublished results.)
This collection reflects the local geology with the presence of quantities flint, sand and chalk. The glauconite grains seen in the aggregates may have come from the lime or from calcareous aggregates. The very fine sand probably came from sandy limestone used as a lime source. Eighteen samples were examined and identified, twelve samples were fully analysed.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
St Johns Lane					
289	-	-	-	82%	burnished red
	-	-	-	50%	*intonaco*
	11	67	22	15%	upper layer
	28	60	12	14%	lower layer
294	23	64	13	14%	whole sample
295 1	0	50	50	79%	pink layer - tile
2	90	5	5	48%	middle layer with tile
3	47	36	17	44%	bottom layer - tile
Miscellaneous					
1)	48	41	11	30%	mortar with flint
2)	58	29	13	45%	tile mortar
3)	0	2	98	31%	fine sand

EXAMPLES OF PLASTER DESCRIPTIONS

St Johns Lane, 1986.
A first to second century building with painted plaster on clay walls.
SJ 86 289:
Burnished red with crystalline calcite, 0.2mm, on white sandy *intonaco*, 0.5mm, on sandy plaster, 6 - 8mm, on coarse sandy plaster 22mm thick.
SJ 86 U/S blue:
Light blue, 0.05 - 0.1mm, on grey, 0.1 - 0.2mm, on white *intonaco*, 0.5mm, on pale pink plaster with large tile pieces, 18mm thick.
SJ 86 294 red and yellow on white:

1) Grey on white *intonaco*, 0.75mm, on layered sandy plaster, 20mm thick.

2) Burnished red with calcite, 0.1mm, on white *intonaco*, 0.6mm, on sandy plaster, also a fragment of burnished red with a yellow stripe as above.

3) Brushed red on white *intonaco*, 0.5mm, as above.

SJ 86 294 two red one white:

1) Pink, 0.05mm, on white *intonaco*, 0.3mm, on sandy plaster.

2) Yellow and green on white *intonaco*, 0.5mm, on sandy plaster.

SJ 86 316 white:

White, 0.5 - 0.75mm, on sandy plaster.

SJ 86 316 red:

Burnished red with calcite, 0.1mm, on white *intonaco*, 0.6mm, on sandy plaster.

SJ 86 295 plaster sample:

Pale pink (*intonaco*?), 2mm, on white lime mortar with tile, 46mm, on pink mortar with tile, 11mm thick. The tile had a variety of colours, ranging from yellow to buff, orange to red and even black. The coarser aggregate was entirely tile, but the finer grades also contained some quartz sand, probably from the tile. There was also a small amount of furnace residue of vitrified clay and fuel ash slag, probably from the lime burning.

<u>Miscellaneous sites</u>

Mortars

1) 16 Pound Lane, tr II (5) Roman wall:

Coarse mortar with sand and flint.

2) RG 86 (14):

Opus signinum type composed of crushed brick or tile with traces of quartz and flint.

3) Lin / G 79 (93) sample from brick floor:

Cream mortar composed of very fine sand with tile traces.

4) Lin / G 79 drain mortar from second phase east wall:

Pale yellow fine sandy lime with traces of tile and white and yellow sandy limestone.

Painted plasters

MI (523) 6 iv:

White band, 5mm wide, on burnished red with rounded quartz sand and mica (*intonaco*?), 0.05 - 0.25mm, on dirty white to buff coarse sandy plaster, 12.5mm thick.

ST / R / 77:

Burnished red, 0.05mm, on yellow, 0.3mm, on sandy white *intonaco*, 1mm, on coarse sand and gravel plaster, 15mm thick. The red was cinnabar.

Gas Street:

Burnished red on yellow on sandy white *intonaco*, 1 - 1.5mm, on coarse sand and gravel plaster, 14mm thick. The red was cinnabar. This sample was virtually identical to ST / R 77.

Cant 80 M III (813):

White spot on sandy burnished red with rounded quartz sand, 0.2mm, on white *intonaco*, 0.5mm, on coarse sand and gravel plaster, 14mm thick. Also another sample with pale blue on sandy burnished dark pink, 0.2 - 0.5mm, on white *intonaco*, 0.5mm, on coarse white sandy plaster, 11mm thick.

PAINTING TECHNIQUE

The painting technique was in the *buon fresco* method with the following schemes: white on burnished red, burnished red on yellow, pale blue on burnished dark pink, blue on grey, grey on white, yellow on red and green and yellow.

PIGMENTS

Red and yellow ochres (haematite / limonite), crushed brick or tile, cinnabar (not at St Johns Lane), crushed calcite (with red), Egyptian blue, white lime, green earth (glauconite) and carbon as soot or charcoal.

Another site (Longmarket) produced samples of pigments:

LM 90 (1990 - 11);

(4184) trace of red (haematite and cinnabar) on three fragments of pottery.

/3770\ (3702) red ochre lump

/4195\ (4484) Egyptian blue balls, containing tin as well as copper.

<u>Average results</u>

	Thicknesses		"Lime"
St Johns			
paint	(0.05 - 0.2)	0.15mm	82%
intonaco	(0.3 - 0.75)	0.5mm	50%
tile *intonaco*		2mm	79%
plaster		16mm	14%
tile plaster - upper		46mm	48%
tile plaster - lower		11mm	44%
miscellaneous			
paint	(0.05 - 0.35mm)	0.2mm	
intonaco	(0.05 - 1.5)	0.6mm	
plaster	(11 - 15)	13mm	
mortar			31%
tile mortar			45%

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:

Fig Nos 50, 51

294, 295 ; 2, 3, 4, 5.

The graphs show both ungraded tile and sorted sand curves The very fine sand may be derived from a sandy limestone used as a lime source.

Fig. 50 Canterbury 1

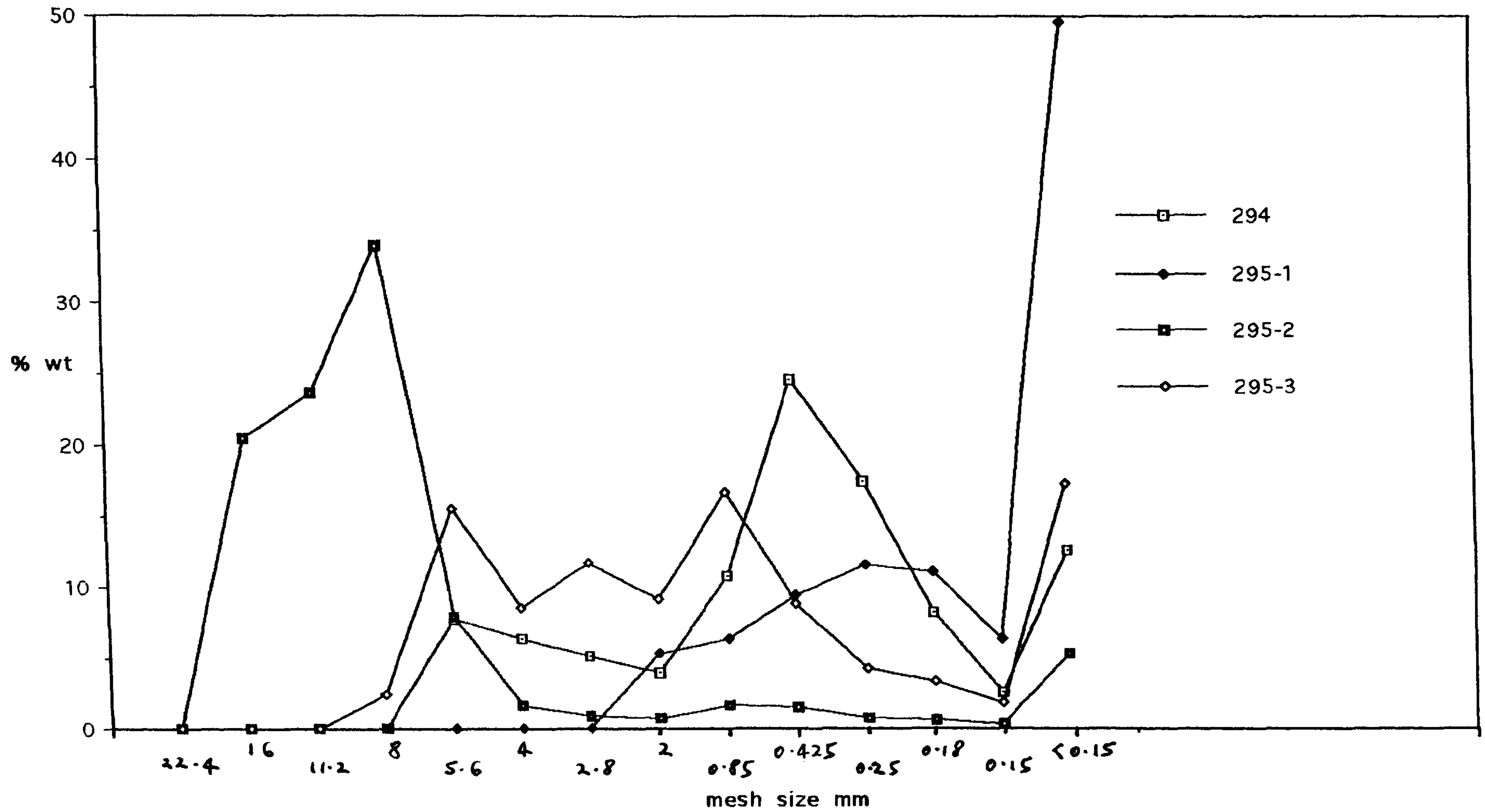
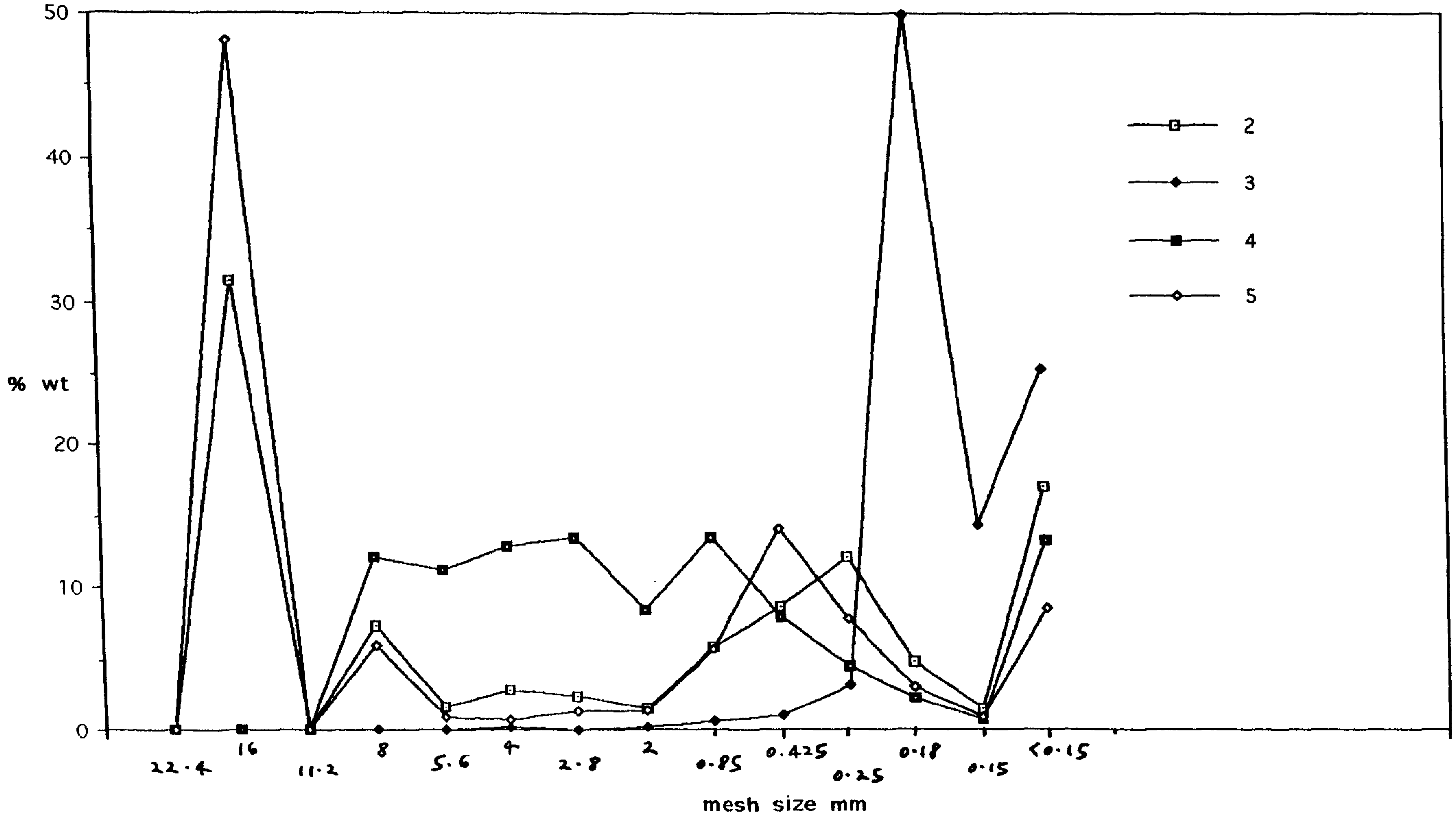


Fig. 51 Canterbury 2



Carlisle, Cumbria.
1) Roman Fort, Annetwell Street.site
Caruana 1986;1991
Mc Carthy, Caruana and Keevil 1989
Britannia 1985 16: 275

2) Carlisle Cathedral site
Keevil 1989

1) Excavations on the site of the Roman fort produced both mortar and plaster samples dated to the first or second century. There were considerable problems in the analysis of this material as most of the samples had been affected by water leaching and ion movement, probably due to water table fluctuations. Comparison of the mortars was by aggregate grading alone as the residual lime content was very variable. The aggregates generally reflected the alluvial nature of the area, with quantities of river sand and gravel. Geological identification showed the aggregate to be mainly rounded: red sandstone, other types of sandstone, quartz, quartzite and various types of granite and diorite type rocks. Crushed red brick or tile was also used. The "lime" values were generally very low, some too low to have actually have made a coherent mortar, this being the result of water leaching. Some samples appeared to be lime plasters, but on analysis the white lime turned out to be mainly siliceous replacements. White silica was found in many samples. This may have been water deposited or from siliceous lime or from the crushed brick or tile aggregates. In other samples very small pieces of lime bonded material were found amongst the loose gravel. Seventy two samples were analysed.

2) The Cathedral site excavations in 1988 produced evidence of Roman buildings dated to the third or fourth centuries and examples of the re-use of Roman building material in the medieval period. The Roman building remains were basically traces of a wattle? type partition wall with plaster on both faces sitting on a mortar floor. The aggregate was mainly sandstone fragments, with volcanic material such as rhyolytic tuffs, diorite and metamorphosed slates and other rocks relating to the local geology, being found in the river gravels. Fifteen samples were analysed.

COMPOSITIONS
1) Annetwell Street.site

No	gravel	sand	silt	"lime"	comments
036	42	34	24	83%	waste lime?
040	26	55	19	16%	mortar
042	72	14	14	16%	floor
043	47	41	12	4%	floor, *opus signinum*
066	49	46	5	4%	mortar
097	32	62	6	11%	mortar
299	7	90	3	24%	painted plaster or render
54	39	44	17	19%	*opus signinum*
60b	35	43	22	34%	*opus signinum*
81	69	21	10	27%	*opus signinum*
83b	17	61	22	28%	*opus signinum*
121a	14	78	8	41%	plaster
121b	10	85	5	34%	plaster
121c	20	75	5	30%	plaster
126	35	64	1	17%	*opus signinum*
160	15	77	8	31%	plaster
	-	-	-	63%	*intonaco*
176	4	89	7	46%	plaster
178	9	88	3	24%	plaster
	-	-	-	96%	*intonaco*
A64	19	74	7	25%	plaster
	-	-	-	98%	*intonaco*
A58a	32	46	22	31%	upper layer, *opus signinum*
A58b	26	62	12	32%	lower layer, some tile dust

2) Cathedral site

2/D (26)/3\	41	43	16	33%	*opus signinum*
2/cat G	12	72	16	28%	plaster
	-	-	-	88%	*intonaco*

EXAMPLES OF MORTAR AND PLASTER DESCRIPTIONS

1)

036: a very calcareous sample, high in gravel and lime, possibly waste.

040: river gravel and sand mortar.

042: a pink coarse gravel floor mortar

043: a coarse *opus signinum* floor mortar.

066: river gravel and sand mortar.

097: river gravel and sand mortar.

299: red ochre on sandy plaster, 17mm thick.

54: a leached *opus signinum.* mortar.

60b: an *opus signinum.* mortar.

81: coarse *opus signinum.* mortar, perhaps floor.

83b. *opus signinum.* plaster, the middle of three similar layers.totalling 40mm thick.

121a. buff or stained *intonaco*, 0.75 - 1mm, on layered coarse sandy plaster with straw impressions, 9 - 12mm thick.

121b: as 121a.

121c: as 121a.

126: *opus signinum.* mortar or plaster, 28mm thick.

160: sandy plaster.

176: white *intonaco*, 0.5mm, on sandy plaster, 13mm thick.

178: sandy plaster.

A64: brushed white lime, 0.05mm, on a hard white *intonaco*, 3mm (this is exceptionally thick), on coarse sandy plaster, 18 - 20mm thick, with a dried calcite film.

A58a: traces of white sandy plaster, 2mm, on *opus signinum.* plaster, 20mm, on:

A58b: variable coarse sandy plaster with some tile, about 10mm thick.

2)

2/D26/3\: *opus signinum* plaster, 45mm thick with a natural? calcite deposit on its surface.

2/cat G: white lime, 0.5 - 1.5mm, on white lime, 1 - 3.5mm, on a grey stripe, 5mm wide, or a red band about 30mm wide, on a white lime *intonaco*, 0.5mm, on a whitish sandy plaster up to 25mm thick. The plaster appeared to have been applied in two or three similar layers. The secondary lime coating was unusually thick, up to 5mm, and crudely applied. The red colour was red ochre and the grey; lime with charcoal or soot.

PAINTING TECHNIQUE

The few traces of paint were all apparently applied in the *buon fresco* method. The thick layers of white lime noted may be white wash applied as a slurry and therefore would be *fresco secco*.

PIGMENTS

The red paint was red ochre (haematite), the grey was carbon (soot or charcoal) with lime.

Average results

	Thicknesses		"Lime"
1)			
opus signinum plaster	(20 - 28)	24mm	30%
opus signinum mortar		-	30%
gravel mortar		-	15% (low)
sand and gravel plaster	(10 - 19)	4mm	32%
intonaco	(0.75 - 3)	1.5mm	86%
paint		0.05mm	-
2)			
opus signinum mortar		45mm	33%
sandy plaster		25mm	29%
intonaco		0.5mm	-
whitewash or lime	(0.5 - 3.5)	1.7mm	88%

Samples illustrated in the aggregate particle size distribution graphs:

Fig Nos 52 - 54

040, 60b, 81, 83b, 121b, 160, 176, 299, A58a, A58b, 299. G4, 26/3.

The graphs show both the well graded sand and poorly graded gravels and crushed brick or tile.

Fig. 52 Carlisle 1

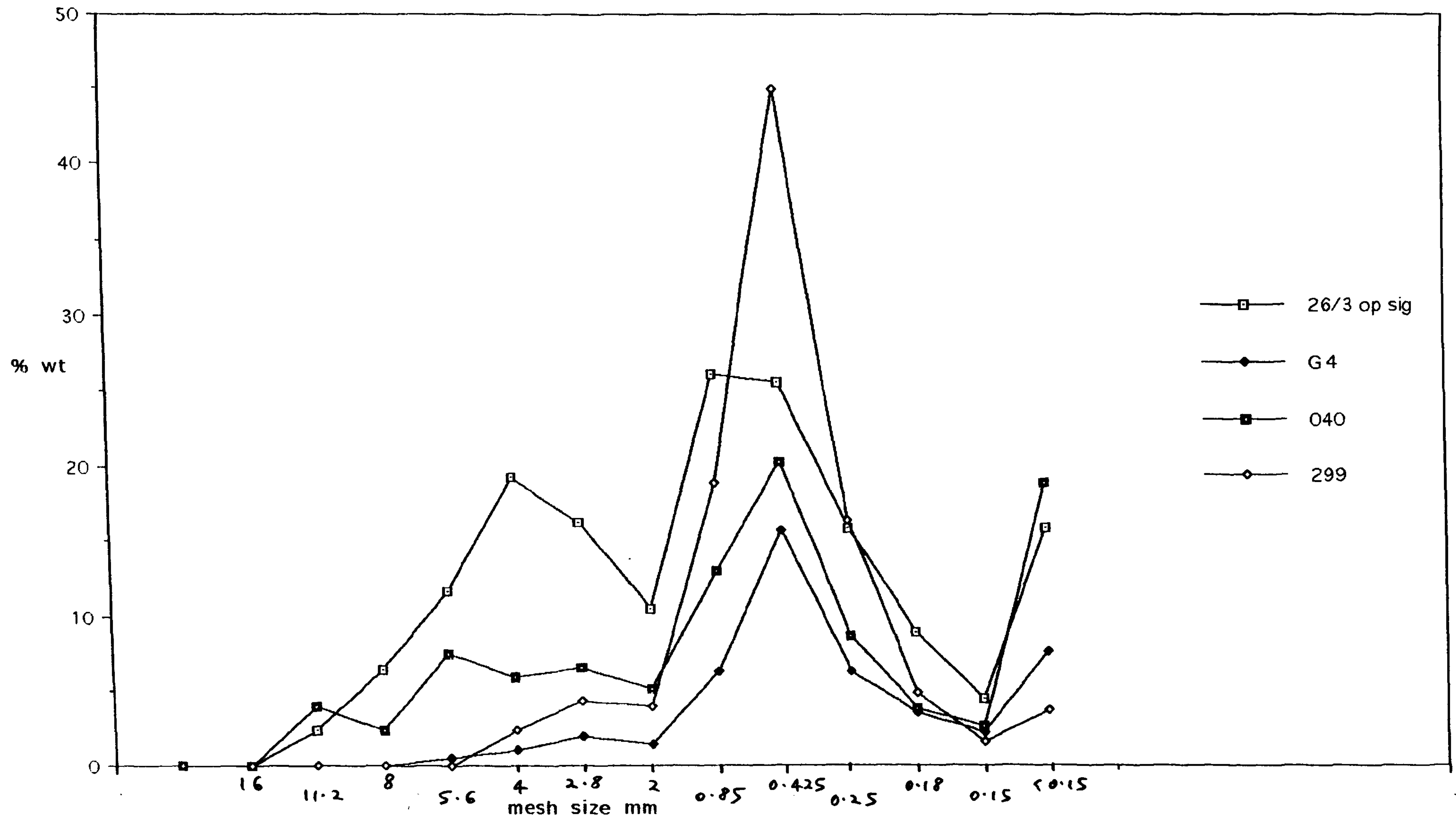


Fig. 53 Carlisle 2

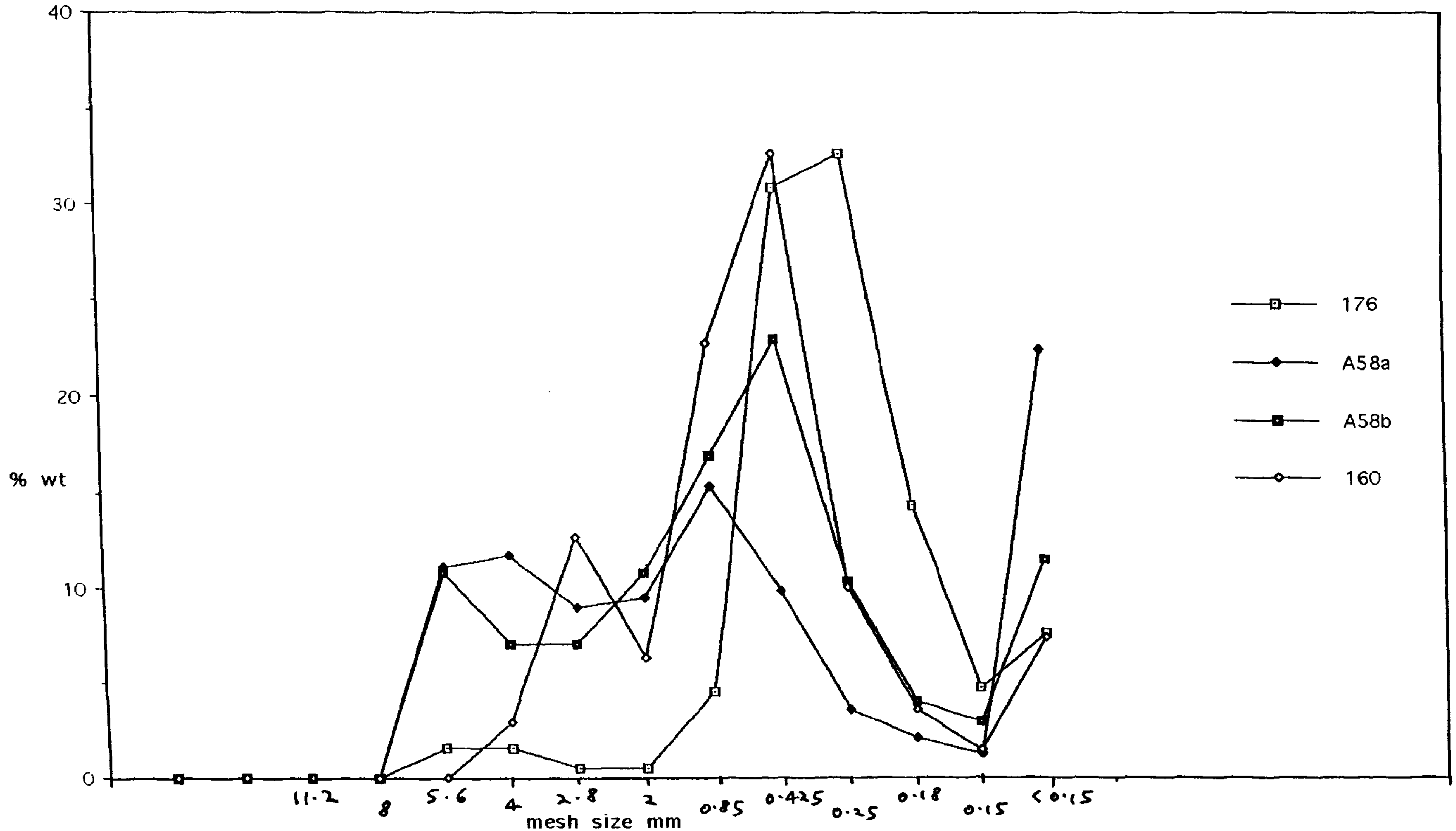
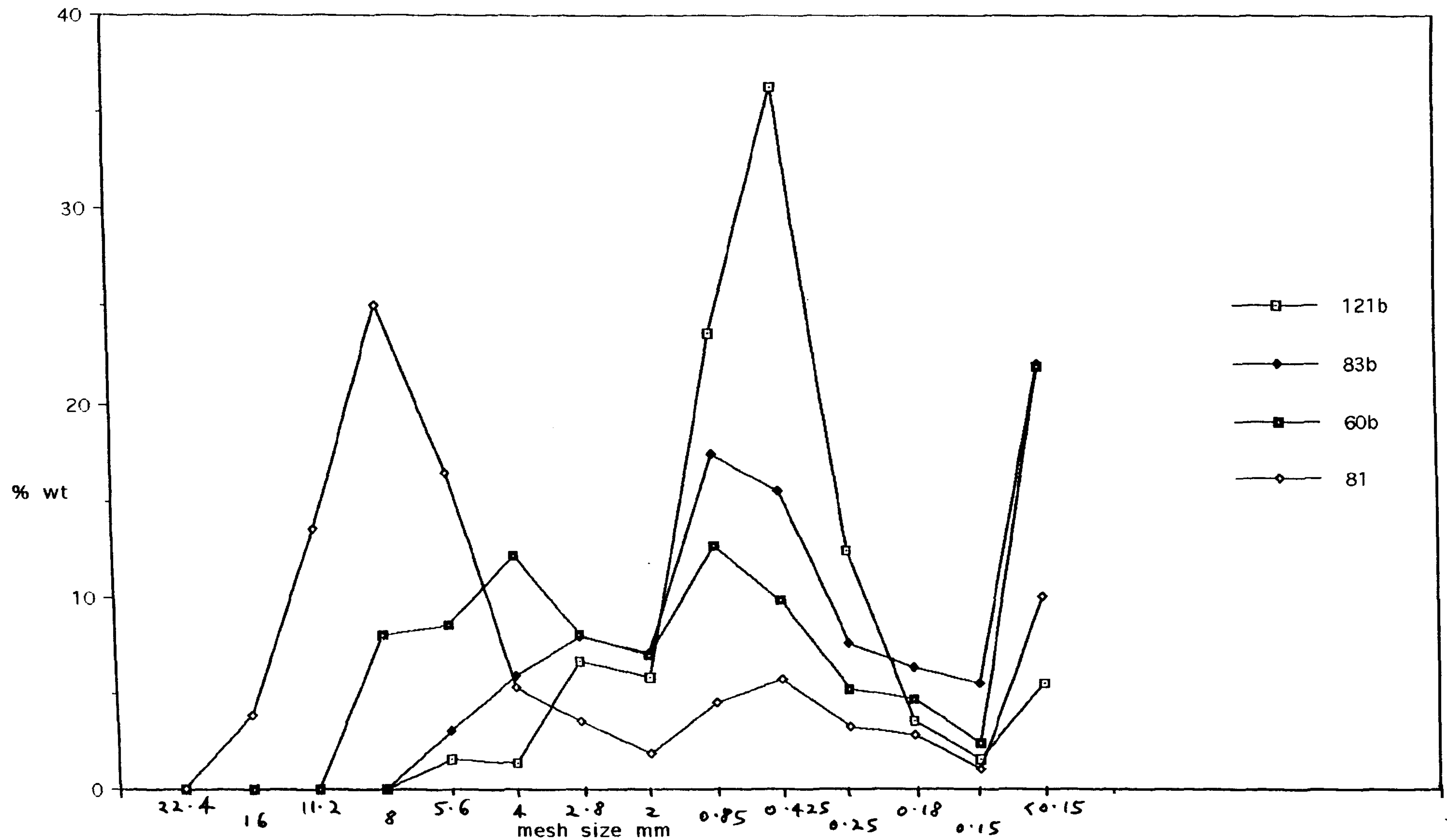


Fig. 54 Carlisle 3



Castle Copse, Great Bedwyn, Wiltshire.
Britannia 1985 16: 308 - 9.

Mortars and plasters dated to the third and fourth centuries, from the extensive villa complex still being excavated.
The aggregates were mainly limestone (hard chalk) and flint fragments, with smaller quantities of rounded quartz sand. In view of the calcareous aggregates, the samples were hand crushed and / or partially dissolved in acetic acid. The "lime" content is therefore only approximate. More than fifty samples were examined and fifteen plaster analyses carried out. These results are unpublished.

COMPOSITIONS

number	gravel	sand	silt	"lime"	comments
CCA 7/1	24	43	33	32%	top layer 14mm
	54	21	25	25%	lower layer 19mm
7/3	38	25	37	26%	upper layer 15-18mm with tile
	44	34	22	15%	lower layer 50-55mm with tile
CCA 85	27	36	37	14%	
CCA 198	38	23	38	15%	

EXAMPLES OF PLASTER DESCRIPTIONS

CCA

35) Red / brown, 0.1mm, on white *intonaco*, 0.05 - 0.1mm, on buff plaster with chalk, 16mm thick.

85) Blue with lime, 0.25mm, on black, 0.5mm, on buff plaster with chalk with flint. Estimated to about 20% by volume chalk.

189) Fine buff plaster with chalk, 4mm, on green with blue particles, 0.1mm, on black, 0.4mm, on buff plaster with flint, 12mm thick. This appeared to be an over-plastered sample.

198) Coarse green, 0.1 - 0.2mm, on yellow, 0.2 - 0.4mm, on buff plaster with chalk, 13mm thick. Also a sample with red, 0.05 - 0.1mm, on buff plaster with flint, 10mm thick (as opposed to chalk in the other samples), and a flake of re-used plaster with pale blue on pale green. This sample appeared to be different from the rest of 198).

224) Coarse blue, 0.2mm, on black, 0.25mm, on traces of white, 0.1mm, (possibly *intonaco*), on buff plaster with flint, 15mm thick. Also other samples with orange / red* with mica on pink, 0.2mm, on grey, 0.1mm, on buff plaster as above (the red* was crude cinnabar or cinnabar mixed with red ochre and clay or possibly brick dust), and pieces of buff mortar containing flakes of re-used plaster with bright red*, 0.05mm, on yellow, 0.05mm, and fine blue, 0.05mm, on grey, 0.25mm thick.

CCB

10) Red, 0.05mm, on white *intonaco*, 0.2mm, on buff plaster with flint, 15mm thick. This sample contained a fragment of re-used plaster; white, 0.05mm, on pink, on white *intonaco*, 0.25mm thick.

58) White stripe on red with calcite grains, 0.25mm, and pink on black to yellow, total 0.05mm, on white plaster with calcite and flint, 3mm (*intonaco*)?, on buff plaster with flint, > 2mm thick.

61) White stripe on orange red, 0.05mm, and grey to black on orange red on an irregular buff *intonaco*, 0 - 0.4mm, on buff plaster with flint, 10mm, on buff plaster with less flint, > 8mm thick.

PAINTING TECHNIQUE

The following schemes of painting were found and all appeared to have been applied in the *buon fresco* technique :

Red to brown, bright red on yellow, red with calcite, orange red, pink on black, dark pink to purple or maroon, yellow on brown, blue on black, green with blue on black, green on grey, green on yellow, black with blue, grey to blue. The absence of *intonaco* layers in many samples suggested poor quality, but the presence of calcite grains in some samples and the use of cinnabar did however point to the use expensive pigments and higher standards.

PIGMENTS

The following pigments were identified:
Red, yellow and brown ochres (haematite / limonite, some being micaceous), crushed brick or tile dust, red* cinnabar, white lime, green earth / glauconite, Egyptian blue, carbon as charcoal or soot.

Average results

	Thicknesses		"Lime"
paint layer	(0.05 - 0.4)	0.1mm	-
white *intonaco*	(0.05 - 0.1)	0.1mm	-
black *intonaco*	(0.25 - 0.5)	0.4mm	-
red *intonaco*	(0.25 - 0.4)	0.3mm	-
upper plaster	(8 - 18)	12mm	30%
lower plaster	(6 - 19)	13mm	20%
single layers	(10 - 20)	10mm	15%

Samples illustrated in the aggregate particle size distribution graphs

Fig Nos 55, 56

7/1 upper layer, 7/1 lower layer, 7/2 single layer, 7/3 lower layer, 85 single layer, 198 single layer, 200 single layer.

The graphs generally show the poor grading of the aggregates.

Fig. 55 Castle Copse 1

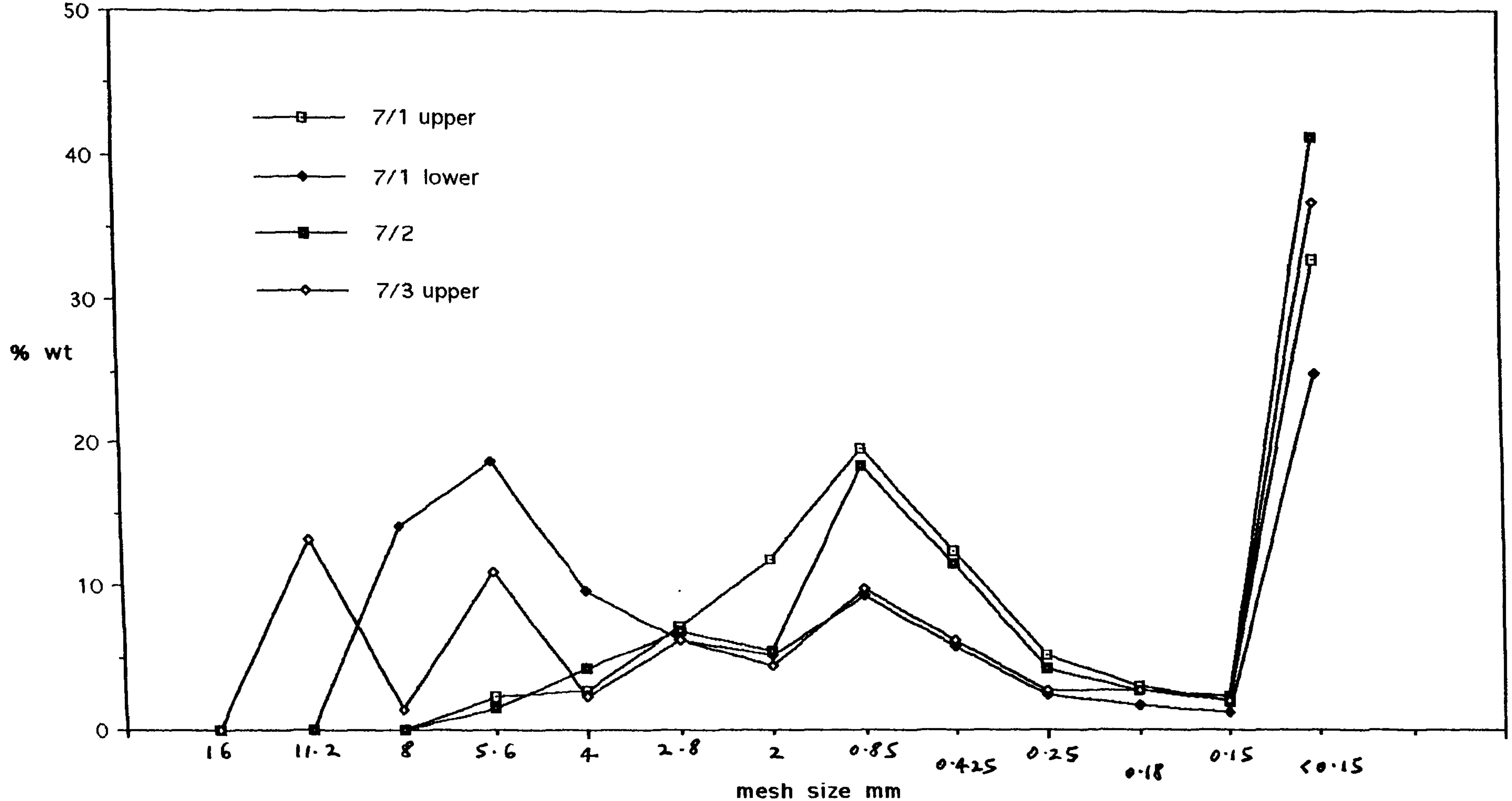
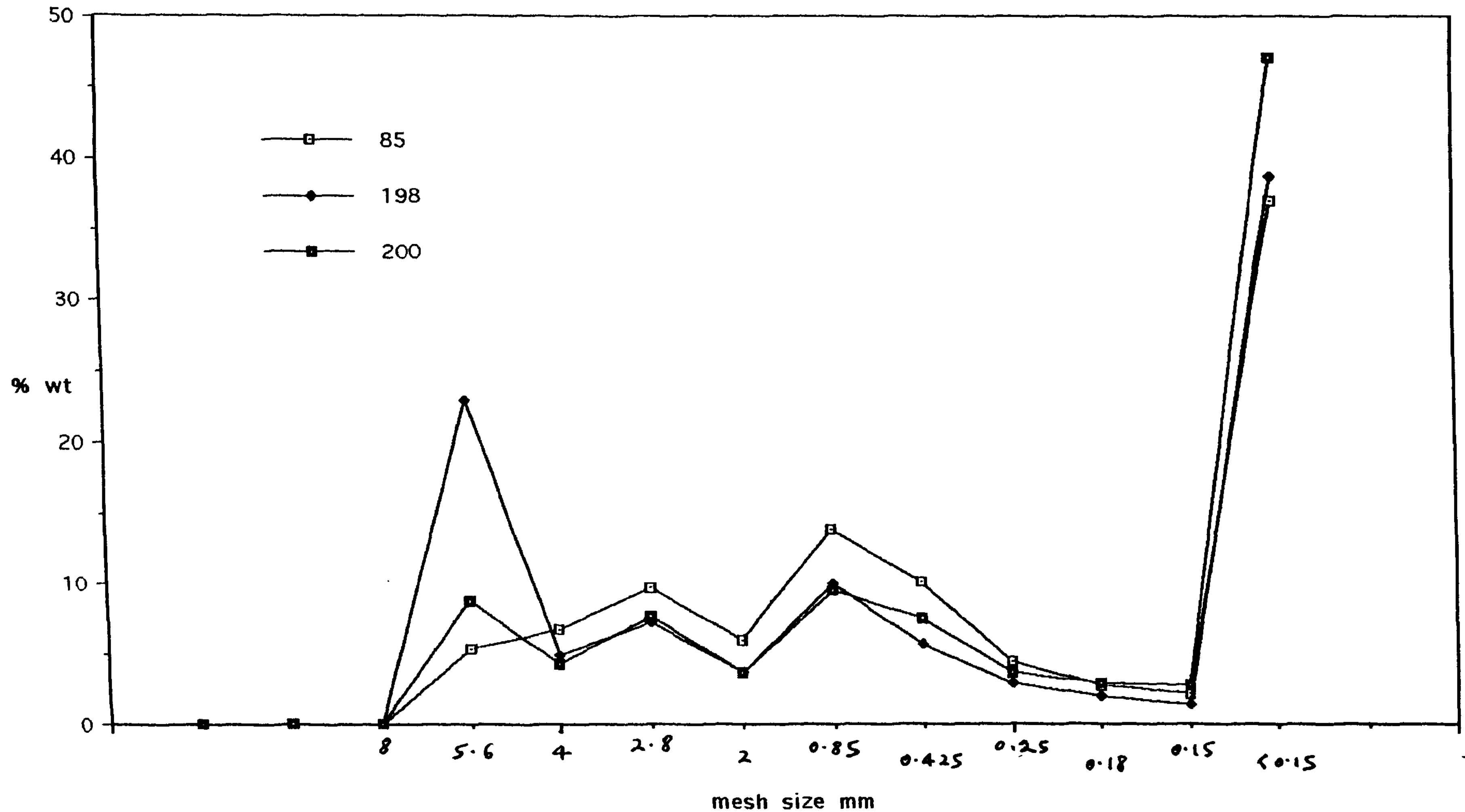


Fig. 56 Castle Copse 2



Cave's Inn, Warwickshire.

Britannia 1971 2: 263; 1973 4: 288, 290 - 1; 1974 5: 431

The site of the Roman town of Tripontium near Rugby has produced many finds, some of which are in the Warwickshire Museum, others are in private hands, produced by field walking surveys. The examples examined came from both sources which were without specific location and are unpublished. The Museum has quantities of painted plaster from Tripontium which was only examined visually. Field walking produced mortar and plaster samples of which only one piece has currently been analysed. The analysis shows the use of local sand and gravel, composed of: flint, quartz, quartzite, sandstones, (including ferruginous types), oolitic and fossiliferous limestones, together with such fossils fragments as belemnites. Crushed brick or tile was also used. Two samples were examined and two analyses carried out.

COMPOSITION

type	gravel	sand	silt	lime"	comments
torching	36	50	14	45%	gravel with limestone

EXAMPLES OF PLASTER AND MORTAR DESCRIPTION

1) tile torching mortar:

this was an example of tile bonding mortar, apparently from the inside of a half round tile or *imbrex*. The mortar also showed the impressions of two more *imbrices* on the rear suggesting that one tile had been used to cover the join between two inverted tiles. The radius of the mortar cast was about 50mm. The presence of limestone in the aggregate meant that the "lime" content is probably slightly high, although some larger pieces were extracted before the acid dissolution.

2) painted plaster:

The plaster examined in the Warwick Museum store was apparently of typical Roman type. One example was of particular interest in having bright orange paint, which on analysis proved to be red lead. The plaster was probably a fragment of a border decoration with lines and small semi-circles. The colour order was: a white band on orange, dark red and light green all on yellow on a white *intonaco*, 0.5mm, on buff sandy plaster, 4mm, on coarse sand and gravel plaster in two layers, 16mm + 14mm. Although not analysed the aggregate appeared to be composed of quartz sand with flint and limestone.

PAINTING TECHNIQUE

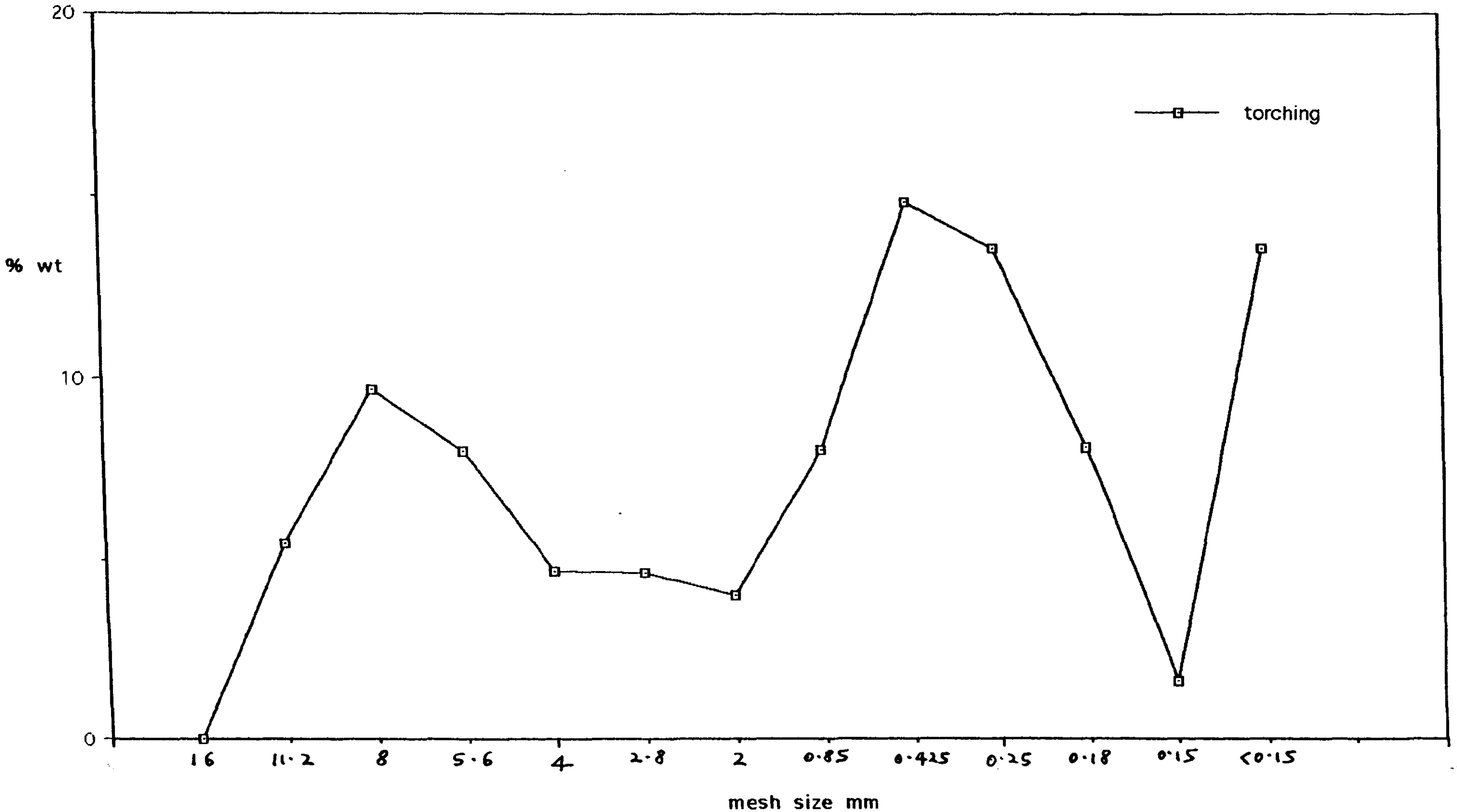
The paint was probably applied in the *buon fresco* method. The orange band appeared to have been completely over painted in dull white, but this could have been conversion of the red lead oxide (orange) to white lead carbonate. It could possible have been a marking out line which was subsequently over-painted in white.

PIGMENTS

The pigments used were the usual colours: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), white lime with the exceptional use of red lead for the orange pigment.

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig No. 57
Torching: the graph shows fairly good grading of both the sand and gravel sizes.

Fig. 57 Cave's Inn



Charlton Kings, Cheltenham.
Vineyards Farm Roman Villa
Rawes 1991

A collection of painted plasters from a villa in use from the first to the third? centuries. The earliest structure appeared to have been wooden. The plaster reflects both the local oolitic geology and alluvial sands, deliberate selection of material having taken place. Both oolitic limestone and chalk appear to have been used as lime sources. The plasters all contained calcareous aggregates and the "lime" contents are therefore approximate. Lime to aggregate ratios were determined partly by simply crushing and sieving the plasters, and partly by dissolving the samples in dilute acetic acid. Twenty three samples were examined and identified and twelve analyses carried out.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
6	41	27	32	69	ceiling? plaster
10	-	-	-	96	paint
10	-	-	-	99	*intonaco*
10	47	38	15	22	plaster
11a	24	56	20	(20)	plaster crushed
11b	20	52	28	(28)	plaster 11a crushed
11c	37	52	11	11	plaster 11 partially dissolved
12	1	90	9	31	plaster upper, sandy
13	0	92	8	29	plaster upper, sandy
14	31	43	26	23	plaster upper, limestone
15	50	37	13	24	single layer, limestone
17	39	46	15	29	single layer, limestone
18c	46	37	17	67	over plaster, limestone

EXAMPLES OF PLASTER DESCRIPTIONS

1) room B:
a) Red on white, 0.05mm, on off white *intonaco*, 0.5mm, on sandy plaster, 10m, on buff limestone plaster with lime lumps, 12+mm thick.
2) L18 / 19:
a) Green with blue traces, 0.1mm, on black on yellow, on off white sandy *intonaco*, 0.5mm, on sandy plaster, 10mm, on limestone plaster, 20mm thick.

b) Spots of dark grey, red and yellow on light blue grey (Rayleigh Effect) *intonaco*, 0.25mm, on sandy plaster, 12mm, on limestone plaster traces.

3) M18 / 19:

White stripe on red stripe on yellow, 0.05mm, and green on yellow, both on off white *intonaco*, 0.5mm, on limestone plaster, 11mm thick.

4) room A wall 14 P18 / 19:

a) red on white stripe or border, 0.05mm, on off white *intonaco*, 0.2mm, on limestone plaster, 7mm, on limestone plaster, 18mm thick.

b) Off white lime traces on limestone plaster, 4mm, on a lime wash or , lime interface, 0.5mm, on light buff lime, 1mm, on dark buff limestone and lime plaster, 0.5 - 3mm, on dark red on dirty yellow, 0.05mm, on off white *intonaco*, 1mm, on limestone plaster, 19mm thick. This was probably the surviving lower layer of an over-plaster.

5) room A wall 2B:

a) White stripe or border on red, 0.05mm, on yellow to buff, 0.05mm, on white, 0.1mm, on off white *intonaco*, 0.25mm, on brownish limestone plaster, 18mm, on light limestone plaster traces, 14+mm thick.

6) room D 2A "ceiling":

a) Red on pink on green on black on white, 0.5mm, on white, 0.25mm, on white, 0.4mm, on off white *intonaco*, 0.75mm, on limestone plaster, 11 - 13mm, with traces of fine grey micaceous mortar on the rear.

7) L19:

White stripe on grey on yellow, 0.05mm, on off white *intonaco*, 0.5mm, on limestone plaster, 9mm thick.

8) L19:

White, dark red and dark grey spots on light grey, 0.1mm, on off white *intonaco*, 0 -0.2mm, on sandy plaster, 10 - 15mm, on limestone plaster, 10+mm thick.

9) K20 L20:

Dark red spots on light grey, 0.1 - 0.2mm, on yellow, 0.1mm, on white to off white *intonaco*, 0.5mm, on limestone plaster, 19mm thick.

10) G20:

Grey to blue on buff to yellow, 0.1 - 0.2mm, on off white *intonaco*, 0.5 - 0.75mm, on limestone plaster, 27mm thick.

11) L20 M20 wall 10 NE side:

Red on white, 0.2mm, on off white *intonaco*, 0.5mm, on limestone plaster, 32mm thick.

12) L19 walls 8 - 9:

Brown stripes on yellow on white, 0.05mm, on sandy plaster with lime lumps, 7 - 12mm, on limestone plaster, 15mm thick.

13) Room B wall 6 - 7 Purple and red stripe:
Grey to translucent white, 0.1mm, on cream to off white *intonaco*, 0.4mm, on sandy plaster, 12mm, on limestone plaster, 13mm thick.
14) Room A wall 13:
Dark red stripe on white, 0.5mm, on off white *intonaco*, 0.4mm, on limestone plaster with mud? lumps and lime lumps, 27mm thick.
15) Room A "overplastered":
White, 0.1mm, on off white *intonaco*, 1mm, on limestone plaster, 33mm thick.
16) Room B "blue":
Blue on black, 0.25mm, on white *intonaco*, 0.5mm, and red to brown on buff to yellow on white intonaco, 0.5mm, (with white over the blue to buff interface) on sandy plaster with lime lumps, 6 - 8mm, on limestone plaster, 7 - 10mm thick. The back of the sample showed a particularly flat surface some 50mm wide, possibly from a lath or similar strip.
17) Room C "pink and black":
Pink on yellow on off white *intonaco*, 0.1mm, and black to grey on off white *intonaco*, on limestone plaster with lime and mud lumps, 0.5mm, on limestone plaster.
18) Wall 10 fallen wall L20 K20 "red over plaster":
a) Red on white, 0.1 - 0.5mm, on off white *intonaco*, 0.25mm, on limestone plaster, 30mm thick.

PAINTING TECHNIQUE

The painting technique appeared to be in the *buon fresco* method with the following paint schemes: red on white, purple to dark red, red on pink on green on black on white, red on yellow, pink on yellow, green on yellow, green with blue on black on yellow, black on red, white on grey on yellow, blue on black, grey / blue on yellow and pseudo marbling; white, dark red and dark grey spots on light grey.

PIGMENTS

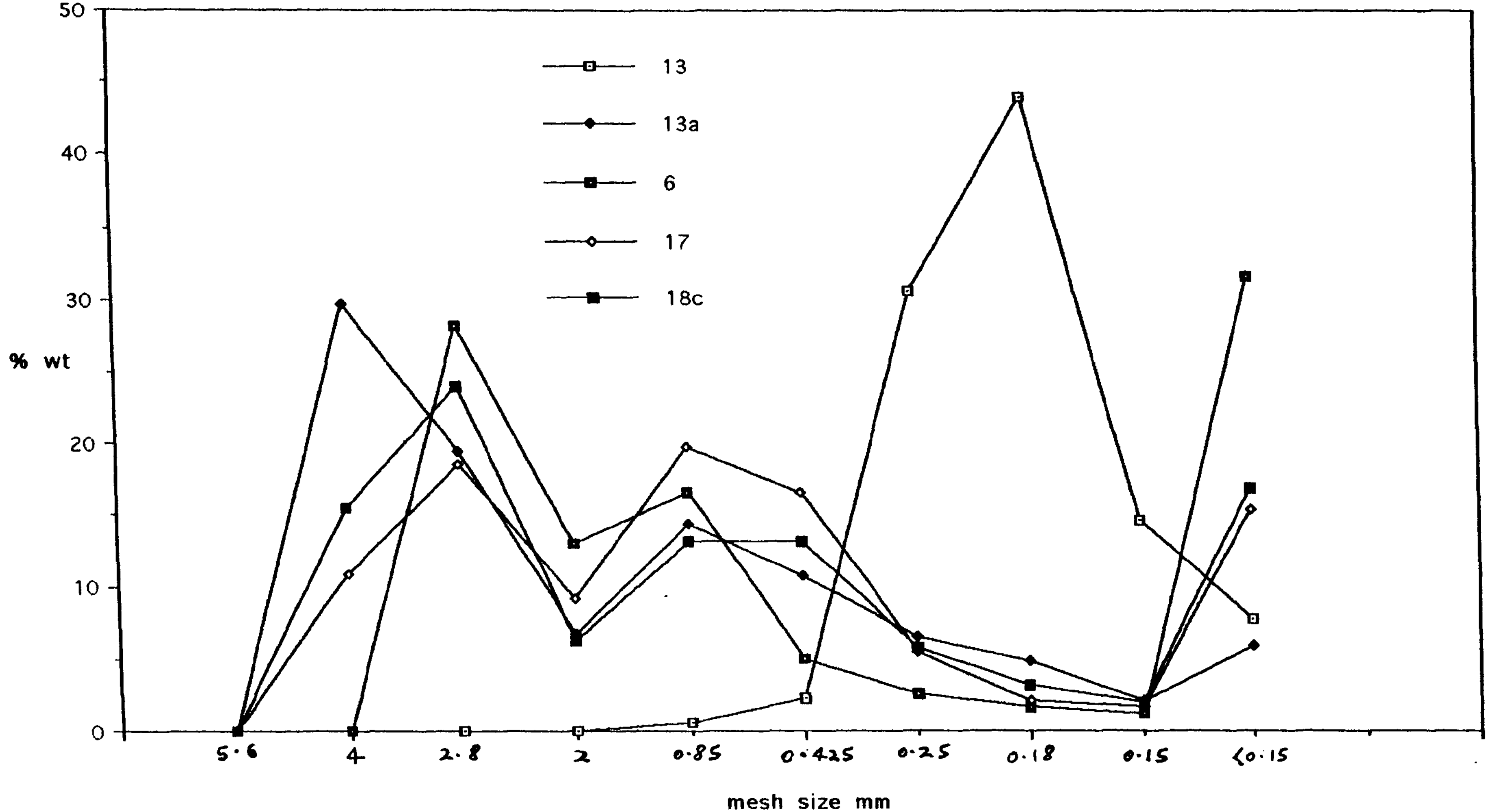
Red to purple ochres (haematite), yellow to brown ochres (limonite), green earth (glauconite), white lime, Egyptian blue.

Average results

	Thicknesses		"Lime"
paint	(0.05 - 0.5)	0.15mm	69%
intonaco	(0.2 - 1)	0.6mm	99%
upper plaster	(8 - 19)	12mm	30% sandy
			23% limestone
lower plaster	(10 - 20)	14mm	55% limestone
single layer	(22 - 40)	30mm	27% limestone
lime interface		0.75mm	
over plaster		4mm	67% limestone

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 58
6 ("ceiling"), 13 (sandy), 13a (limestone), 17 (single layer, limestone), 18c (limestone over-plaster).

Fig. 58 Vineyards Farm



Chester, Cheshire.
Undated Roman material from the collections of the Grosvenor Museum.

The material was from the Roman Baths and an unspecified Roman villa. The local geology consists of Bunter pebble beds, pebble sandstone and lower mottled sand stone. The aggregates found in the samples reflected the geology, particularly with micaceous red and green sandstone. Crushed brick or tile was also used. The presence of grey limestone and various fossil fragments pointed to a fossiliferous limestone source for lime making. An unlocated painted plaster sample appeared to have cinnabar on it.
Only three samples were examined and six analyses carried out. These results are unpublished.

COMPOSITIONS

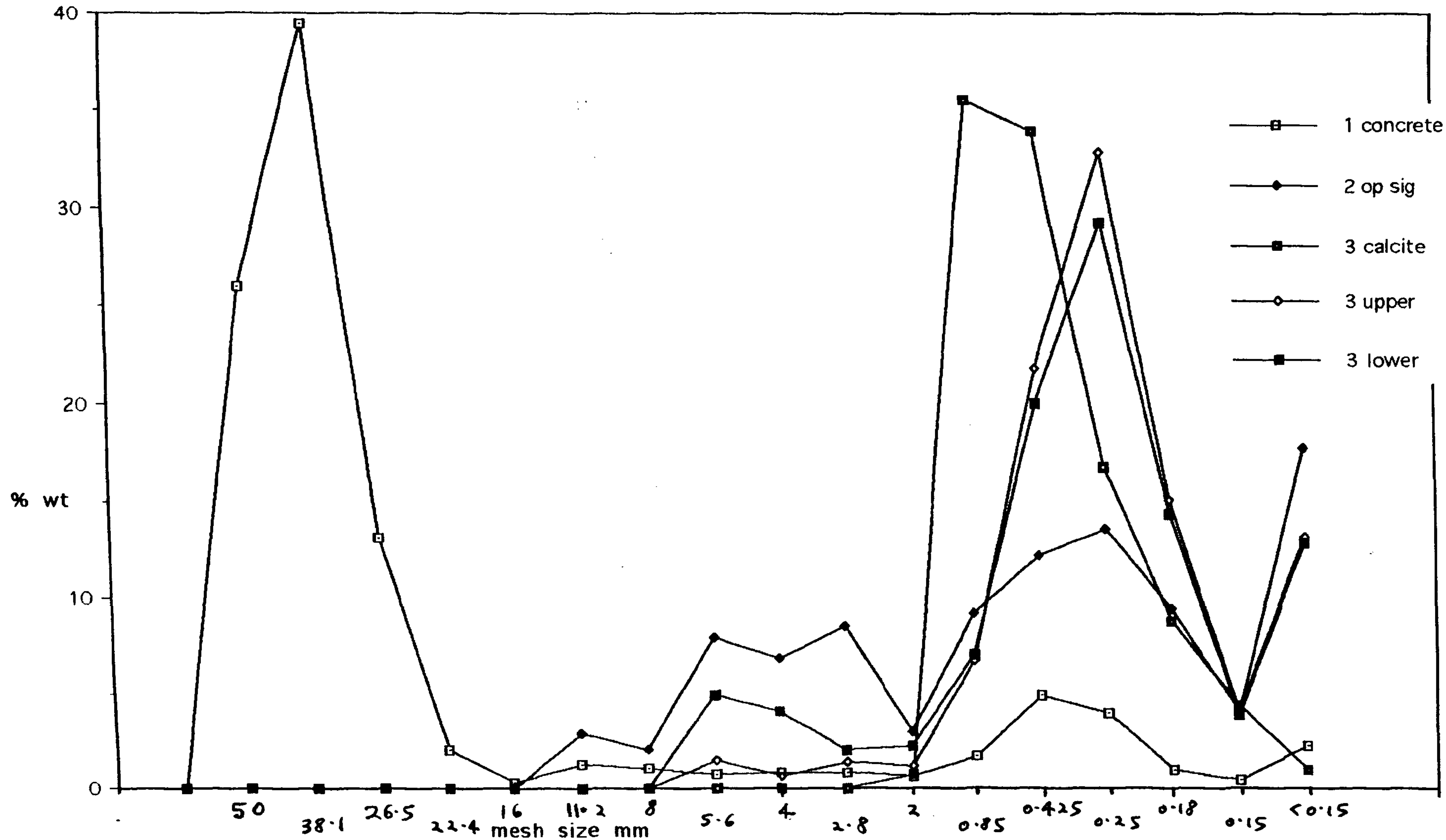
No	gravel	sand	silt	"lime"	comments
Chester Baths					
11 (UD)	31	51	18	52%	opus signinum
"concrete"	86	12	2	12%	S. E. corner foundation
Wall plaster					
1 [326] GFC 77	-	-	-	≈ 35%	calcite filled *intonaco*
	5	82	13	25%	upper layer
	13	74	13	22%	lower layer

EXAMPLES OF PLASTER DESCRIPTIONS
1) Chester Baths; 11 (UD): tile mortar or plaster in two layers, about 10mm and 13mm thick, with cross hatch marks or box flue tile impressions on one surface. The layer without the marked surface appeared to contain slightly more tile than the other layer. The layers could not be separated and were analysed together. The finer component of the aggregate contained quantities of quartz sand as well as tile.
2) Chester Baths; concrete from the foundation of the S. E. corner: a piece from a massive sample made of very hard gravel mortar. Even though the sample weighed 2.2kg this was insufficient for a truly accurate analysis. The aggregate was mainly coarse and fine red and green sandstone and rounded cobbles, with lesser amounts of lime / chalk, sand, limestone and brick or tile.
3) "Wall plaster" 1 [326] GFC 77: white lime, 0.5mm, on thick white *intonaco* with large calcite grains, 4.5mm, on two layered light brown plaster, 13 - 18mm and 5+mm thick. The exceptional *intonaco* layer was analysed by separating the calcite crystals by hand after gently

crushing the sample, giving about 65% crystalline calcite in a lime matrix. The very fine residue from the sieving consisted mainly of lime with some crushed calcite crystals. The *intonaco* layer showed considerable cracking, perhaps due to poor slaking of the lime.

Samples illustrated in the aggregate particle size distribution graphs:
Fig. No. 59
1), 2), 3).
The graphs show the well graded nature of both the gravel and sand. The calcite particle size distribution also appears to be fairly well graded but this was from a crushed sample and may be partially artificial.

Fig. 59 Chester



Cirencester, Gloucestershire.
Roman material from sites in the vicinity of Cirencester in the collections of the Corinium Museum.
The three sites included here are: Barnsley Park, Kingscote Roman Villa complex and the Leaholm Gardens site.

The calcareous geology of the Cirencester area (mainly oolitic and fossiliferous limestones with some quartz sand and flint) made mortar and plaster analysis difficult, particularly with respect to the estimation of the lime content. When limestone was dissolved, a very fine sand residue was left. Tile based material was analysed by acid dissolution, whilst the calcareous material was crushed by hand and sieved. Although most of the aggregates were of buff or cream calcareous sand and gravel, some quartz sand was also found. The values for the "lime" content are generally based on the finest residues from the grading of hand crushed samples, being assumed to be mainly lime, although some silt was also present. Some of the analyses were duplicated using both micro and macro techniques, giving estimations of the actual lime content and total carbonate. These results are unpublished.

1) Barnsley Park, near Cirencester.
Webster 1980
Britannia 1980 11: 382 - 4.

A collection of Roman buildings possibly associated with a villa or similar complex dated to about the fourth century. Various types of calcareous plaster were identified based on the different compositions of the aggregates. The most obvious variations was the presence or absence of crushed brick or tile. Eighty three samples were examined and 28 analyses carried out.

COMPOSITIONS

No	gravel	sand	silt	lime"	comments
1] BP (24) 8	28	72	-	30%	limestone
2] BP (23) 3	36	64	-	17%	limestone
3] BP (17) 3	7	93	20	80%	limestone and fine sand
			60	40%	micro sample

(17) 3 2	-	-	67	33%	micro sample
4] BP (24) 7	40	60	-	30%	limestone
	-	-	15	85%	micro sample
	-	-	30	70%	micro sample
5] BP (28)/2454\	-	-	15	85%	micro sample - upper layer
	-	-	7	93%	soluble - sand
	-	-	19	81%	micro sample - lower layer
	-	-	11	89%	soluble - sand
6] hypocaust	49	23	28	59%	*opus signinum*
7] BP (3) 4	54	28	18	40%	*opus signinum*
8] BP (23) 2	48	31	21	40%	*opus signinum*
9] BP 1961 TT3	54	25	21	53%	*opus signinum*
	-	-	49	51%	micro sample, tile with sand
10] BP(171)13?	45	25	30	54%	*opus signinum*
upper layer	-	-	14	86%	*opus signinum*, with fine sand
	-	-	25	75%	micro sample tile with fine sand, upper layer
11] BP (6) 5 2)	-	-	34	66%	fine sand and tile traces
	-	-	49	51%	micro sample, fine sand
12] BP (4) 1961	-	-	72	28%	micro sample, fine sand

EXAMPLES OF PLASTER DESCRIPTIONS

BP (24) 8

1) Red to orange on white *intonaco*, 0.2mm, on pale buff calcareous plaster with straw impressions, 10mm thick.
2) Red on white *intonaco*, 0.2 - 0.4mm, on cream calcareous plaster with charcoal, 20mm, possibly in two equal layers.
3) Grey to black, 0.1mm, on white *intonaco*, 0.2mm, on cream to pale buff calcareous gravel plaster with traces of tile, 25mm thick.
4) Maroon or dark red, 0.05mm, on white *intonaco*, 0.2mm, on buff calcareous plaster, 11mm thick.
5) White stripe on a maroon band on a white to cream *intonaco*, 0.2mm, on pale buff to cream plaster?, 1mm, on pale buff calcareous plaster with tile traces, 13mm thick.
6) Grey to black band, 0.1 - 0.2mm, on plaster with a straight edge (a doorway?) as sample 3): *intonaco*, 0.4mm, on calcareous plaster with tile traces, 22mm, on calcareous plaster with tile traces, 8mm thick.
7) White, 0.1mm, on floated / trowelled / combed cream *intonaco*, 0.8mm, on pale buff calcareous plaster, 18mm thick.

8) Dark red to brown streak on a pink band, 0.05mm, on white *intonaco*, 0.1mm, on pale buff calcareous plaster, 25 - 34mm thick.
9) Red and white splashes on pink, 0.05mm, on white *intonaco*, 0.2mm, on pale buff calcareous plaster with tile traces, 12mm thick.
10) Black stripe on yellow, 0.05mm, on white to cream *intonaco*, 0.1mm, on buff calcareous plaster with some tile, 10mm thick.
11) Grey to black, 0.05mm, on white *intonaco*, 0.2 - 0.4mm, on buff calcareous plaster with tile traces, 8mm thick. [c.f. 12)]
12) Yellow stripe on black stripes, 0.05mm, on off white *intonaco*, 0.5mm, on buff calcareous plaster with tile traces, 7mm, on pink to buff calcareous plaster with tile, 9mm, on coarse calcareous gravel plaster with tile traces, 8+mm thick.
13) Green leaf?, red to brown stripe and red to brown on ridged yellow on white to cream *intonaco*, 0.4mm, on pale buff coarse calcareous plaster, 22mm, on traces of calcified mud daub. Also a sample with a grey band on the white *intonaco* on plaster as above but in two layers, 9mm + 20mm, which was analysed as a single layer, analysis [1].

BP 1963 (16) 4:

Black stripe on pale blue and white on grey, 0.1mm, on white to cream *intonaco*, 0.4mm, on pale buff coarse calcareous plaster with tile traces to 23mm thick. c.f. BP (26) 1

BP (17) 3:

Dark pink, 0.05mm, on off white cream *intonaco*, 0.1 - 0.2mm, on buff calcareous and sand plaster, 10mm thick. Analysis [3]. c.f. BP (24) 30 part II.

BP (24) 7:

Dark red band, on combed or brushed white *intonaco*, 0.2mm, on buff calcareous plaster with tile traces, 12 - 19mm, on a dirty yellow to green band, 0.1mm, on white *intonaco*, 0.3mm, pale buff coarse calcareous plaster, 12mm thick. The top layer only was analysed [4]. This is an over plastered and painted sample.

BP (28) 26 /2454\:

Orange to red , 0.05mm, on white *intonaco*, 0.5mm, on pale buff coarse calcareous plaster, 5 - 7mm, on buff coarse calcareous and sand plaster, 20mm thick. Analysis [5]. Also a sample with black to grey on white and blue to grey or green on white *intonaco* on plaster as above.

BP (28) 15 /2455\:

1) c.f. (24) 8 - 1, 2; red bands, 0.05 - 0.1mm, on white *intonaco*, 0.5mm, on coarse calcareous plaster, 10mm thick. Also with maroon or dark pink.

2) c.f. (24) 8 - 5 but without the cream to buff plaster under the white; dark red stripe on yellow on white *intonaco*, 0.5mm, on pink to cream calcareous plaster with tile traces, 6mm, on buff coarse calcareous plaster with tile traces, 15mm thick. Also with grey on white as above.

3) c.f. (17) 3 : dark red stripe on white *intonaco*, 0.1mm, on buff calcareous plaster with sand, 5mm thick. Also orange red on white to off white *intonaco* in two layers, 0.75mm + 0.25mm, as above.

BP (28) 28 /2456\ :

Grey, 0.1mm, on white *intonaco*, 0 - 0.1mm (edge sample), on buff to pink coarse calcareous (oolitic limestone with fossil shell) plaster with tile traces to 13mm thick. c.f. /2445\ 2) top layer only.

BP (28) 2 :

White on combed pale buff to white *intonaco*, 0.5mm, on off white to pale buff coarse calcareous plaster with tile traces in two layers, 10mm + 10mm thick. c.f. (24) 8 1), 2).

From hypocaust in debris:

Pale pink *opus signinum* with lime lumps and straw. Analysis [6].

(3) 4 :

Flattened quarter round type moulding in *opus signinum* with some calcareous gravel and traces of pale buff calcareous gravel and sand mortar on one flat face. Analysis [7].

(23) 2 :

Quarter round moulding in *opus signinum* with some of calcareous gravel and traces of buff to yellow coarse calcareous gravel mortar on one flat face. Analysis [8].

BP (157) 20 1971 :

Par burnt clay.

BP (158) 131 :

Traces of orange to red brick dust, possibly a pigment layer from painted plaster.

BP 171 1974 Mortar from the foundation of the N - S wall (F3) :

Yellow to buff calcareous mortar, c.f. BP (24) 8 1), 2).

BP 171 1974 Mortar from doorway at E end of beam slot at junction with wall (F3) :

Mixed yellow to buff calcareous mortar with clay and burnt clay or tile. This could be a burnt sample or mixtures of mortars.

BP 1961 (4) 4 Painted plaster :

Orange red, 0.05mm, on off white sandy *intonaco*, 0.5mm, on buff sandy plaster, 16mm thick. c.f. BP 1963 (17) 3. Also a sample with pink and light grey as above. Analysis [ ].

BP 1961 Plaster TT3 :

Red, 0.1mm, on white *intonaco* traces, 0 - 0.1mm, on pink tile plaster with limestone to 30mm thick. Analysis [9].

BP 1961 (5) 1 Plaster :

Brushed white, 0.05mm, on off white *intonaco*, 0.5mm, on grey to pink (burnt?) calcareous sand and gravel plaster, 11 - 13mm thick. c.f. BP (24) 8 1), 2).

BP 1961 (7) + :

Very hard plaster with a leached surface. White and red splashes on pink, 0.1mm, on off white to cream calcareous sand and gravel plaster with tile traces to 23mm thick. c.f. BP (24) 8 1), 2), 9) but with no sign of an *intonaco*. It is possible that the top of the plaster is a fine calcareous *intonaco*.

BP 1961 (3) 3 : A sample of calcareous tufa and plaster:

Off white to buff calcareous sandy *intonaco* ?, 0.5mm, with a marking out line, on buff calcareous sandy plaster with tile traces possibly layered to 26mm thick. c.f. ? BP (24) 8 1) 2) but more buff and without paint.

BP (171) 3 1972 Several plaster types :

1) Leached plaster with a pink stripe on white *intonaco*, 0.1 - 0.2mm, on coarse calcareous plaster with tile, 4mm, on coarse calcareous plaster, 13mm thick. c.f. BP (28) 15 /2455\ 2).

2) Light green on black on buff to cream *intonaco*, 0.3mm, on pale buff calcareous plaster with burnt red sandy clay or red sandstone, 15mm thick. Some of the aggregate was burnt or red oolitic limestone. The rear of the sample showed impressions of split wood laths, perhaps from a ceiling or wall.

3) (the bulk of the sample) Grey, red, green, light and dark yellow, pink and maroon stripes and bands, 0.05, on white, 0.1 - 0.2mm, on pale buff, 0.2 - 0.3mm, on pale buff coarse calcareous plaster, possibly layered, 23 - 26mm thick. The samples show lath impressions on the rear. c.f. Bignor ceiling plaster.

3a) An edge sample with lath impressions (wall or ceiling junction). Black, 0.1mm, on off white *intonaco*, 0.5mm, on pale buff coarse calcareous plaster, 12mm, on buff calcareous plaster, 10+mm thick. One sample from this group had some pink tile plaster mixed in on the rear. This may have been poor mixing or contact with an *opus signinum* layer.

4) Yellow and dark red or maroon, 0.05 - 0.1mm, and grey on white, 0.05 - 0.1mm, on cream *intonaco*, 0.5mm, on buff coarse calcareous plaster, 11mm, on buff calcareous plaster traces with

possible lath impressions 5+mm thick. Apart from the buff plaster this is fairly similar to 3) above.

5) Window type edge moulding; dark green to black on off white *intonaco*, 0.5 - 0.8mm, on coarse buff calcareous plaster to 23mm thick. c.f. 3).

6) Red to orange tile mortar, 4mm, on very coarse limestone gravel mortar to 33mm, probably a wall or floor sample.

BP 1961 (3) 3 bag 2 :

Pink, 0.05mm, on yellow, 0.1mm, on white *intonaco*?, 0.1mm, on pale buff calcareous plaster to 23mm thick. Also samples with: white on grey to green on yellow on white *intonaco* as above with a tapering plaster layer, flattened on the rear, perhaps with wood impressions; and brushed cream on white as above with the plaster tapering from 15 - 22mm, also with a wood? impressed surface. The plaster is the same as (3) 3 bag 1.

BP (171) 19 :

Green on grey, 0.05mm, and orange brown , 0.05mm, on white, 0.1mm, on floated white to cream *intonaco*, 0.5mm, on pale buff coarse calcareous plaster with a flat rear, 17mm thick, perhaps an upper layer of secondary plaster. c.f. (3) 3 except for the *intonaco*.

BP (171) 19? :

As above; green, black, dark red and yellow on white on floated white. The rear of the plaster showed traces of a lower buff plaster layer. c.f. BP (171) 3 1972, although the *intonaco* is different; also red on pink and white on green on white on white on floated cream *intonaco* as above, with a possible lath impression on the rear.

BP (171) 8 bag 1 :

Grey, yellow, 0.05 - 0.1mm, and dark pink on grooved or coarsely brushed white, 0.05 - 0.1mm, on buff to cream *intonaco*, 0.1 - 0.2mm, on sandy calcareous plaster with tile? traces, 18mm, on buff calcareous plaster with lath-like impressions (ceiling or wall edge?) to 18mm thick. c.f. BP (171) 3 1972. Also a sample with grey to yellow and yellow as above on plaster to 28mm thick, with buff plaster traces and possible lath impressions.

BP (171) 8 bag 2 :

As bag 1 plus a fragment of edge moulding c.f. BP (171) 3 1971 5).

BP (171) 13? :

1) yellow on white, 0.05mm, on grooved cream to buff *intonaco*, 0.5mm, on pale calcareous plaster, 10mm, on buff calcareous plaster with lath impressions to 15mm, the lath impression being 3mm thick and 35mm wide. c.f. BP (171) 3 1972 3). Also fragments with yellow,

dark red, grey, pink and dark red to black, and a sample with a brushed surface with red and pink stripes, 0.05mm, on white 0.1mm, on cream *intonaco* ?, 0.4mm, on pale plaster with straw impressions, 20mm, on buff plaster, 8+mm thick. c.f. BP (171) 3 1972 3).

2) Light green, 0.1mm, and green, 0.1mm, on black, 0.05mm, on pink on white, 0.1mm, on pale buff calcareous plaster, 6mm, on tile plaster to 23mm thick. Analysis [10].

BP (171) 13 :

White on dark pink on yellow, 0.05 - 0.1mm, on white *intonaco*, 0.5mm, on pale buff sandy calcareous plaster with brown clay? lumps to 20mm thick. Possibly c.f. BP (171) 3 4) but with a different *intonaco*.

BP (171) 16:

Green on grey and orange red on white on grooved white to cream on pale buff calcareous plaster to 18mm thick, with traces of buff plaster and possible lath impressions. c.f. BP (171) 3 1072 3)a.

Also yellow on smooth white; dark red or maroon, 0.05 - 0.1mm, on white, 0.1 - 0.2mm, on sandy calcareous plaster to 18mm thick. c.f BP (171) 13.

BP (171) 5 1971:

Blue with grey, 0.1mm, on white, 0.1 - 0.2mm, on pale buff calcareous plaster, 18mm thick. c.f. BP (171) 13? or BP (24) 8 1), 2).

BP 1961 (6) 5:

1) Dark red to maroon, 0.05mm, on yellow, 0.05mm, on white, 0.2mm, on pale fine calcareous sandy plaster, 5mm, on buff fine calcareous sandy plaster, 8mm thick. c.f. BP 1963 (17) 3 pale (grey) and BP 1961 (4) 4 buff (red).

2) Brushed orange red on rough white with a bubbled surface (applied by brush as a frothy mix?) on pale buff calcareous plaster, possibly a wall to ceiling interface. c.f BP 1963 (17) 3 (grey). Analysis [12].

BP (171) 57 :

1) White stripe on a yellow and grey to yellow interface, 0.05mm, on white *intonaco*, 0.3mm, on coarse pale buff calcareous plaster, 17mm, on buff calcareous sandy plaster traces, 5+mm thick. c.f. BP (171) 3 1972 3a).

2) White on pink, 0.1mm, on white to cream *intonaco*, 0.6mm, on coarse and sandy calcareous plaster, 17mm thick. c.f. BP (171) 13.

BP (171) + :

1) Red and dark green on white on white, 0.1 - 0.2mm, on cream *intonaco*?, 0.4mm, on coarse calcareous plaster possibly layered to 21mm thick. Also samples with yellow on grey and red on white; and

yellow and dark red or maroon on white as above. c.f. BP (171) 3 1972 3).

2) Dark red or maroon on a very rough surface (edge of wall - ceiling or door frame) on buff coarse calcareous plaster with calcareous sand and tile traces. c.f. BP 1961 (7) +.

3) Red and yellow, <0.05mm, on rough white *intonaco* ?, 0.4mm, on pale buff coarse calcareous plaster, 5mm, on buff calcareous plaster, 10mm thick. c.f. BP (28) 15 /2455\ 2) but without the tile.

BP (172) 16 :
White over the interface of red and grey blue, 0.05mm, on white *intonaco*, 0.3 - 0.4mm, on coarse calcareous and sandy pale plaster to 15mm thick. c.f. BP (171) 3 1972 3a).

PAINTING TECHNIQUE

The painting appeared to be in the buon fresco method, being mainly border fragments.

PIGMENTS

The pigments were those commonly found: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), carbon (as soot or charcoal), white lime and Egyptian blue. Crushed brick or tile was also used to augment the red to orange colours and as a colourant in the pink *intonaco*.

Average results

	Thicknesses		"Lime"	
paint	(0.05 - 0.15)	0.075mm	-	
intonaco	(0.1 - 1)).	0.4mm	-	
plaster upper	(5 - 37)	14mm	45% (67% soluble)	
plaster lower	(5 - 30)	12mm	-	
plaster upper	(5 - 30)	16mm	57%	op. sig.
plaster lower	(14 - 23)	19mm	54%	op. sig.
mortar		-	47%	op. sig.

Samples illustrated in the aggregate particle size distribution graphs:
Fig. No. 60, 61

Fig. 60 Barnsley park - limestone plasters

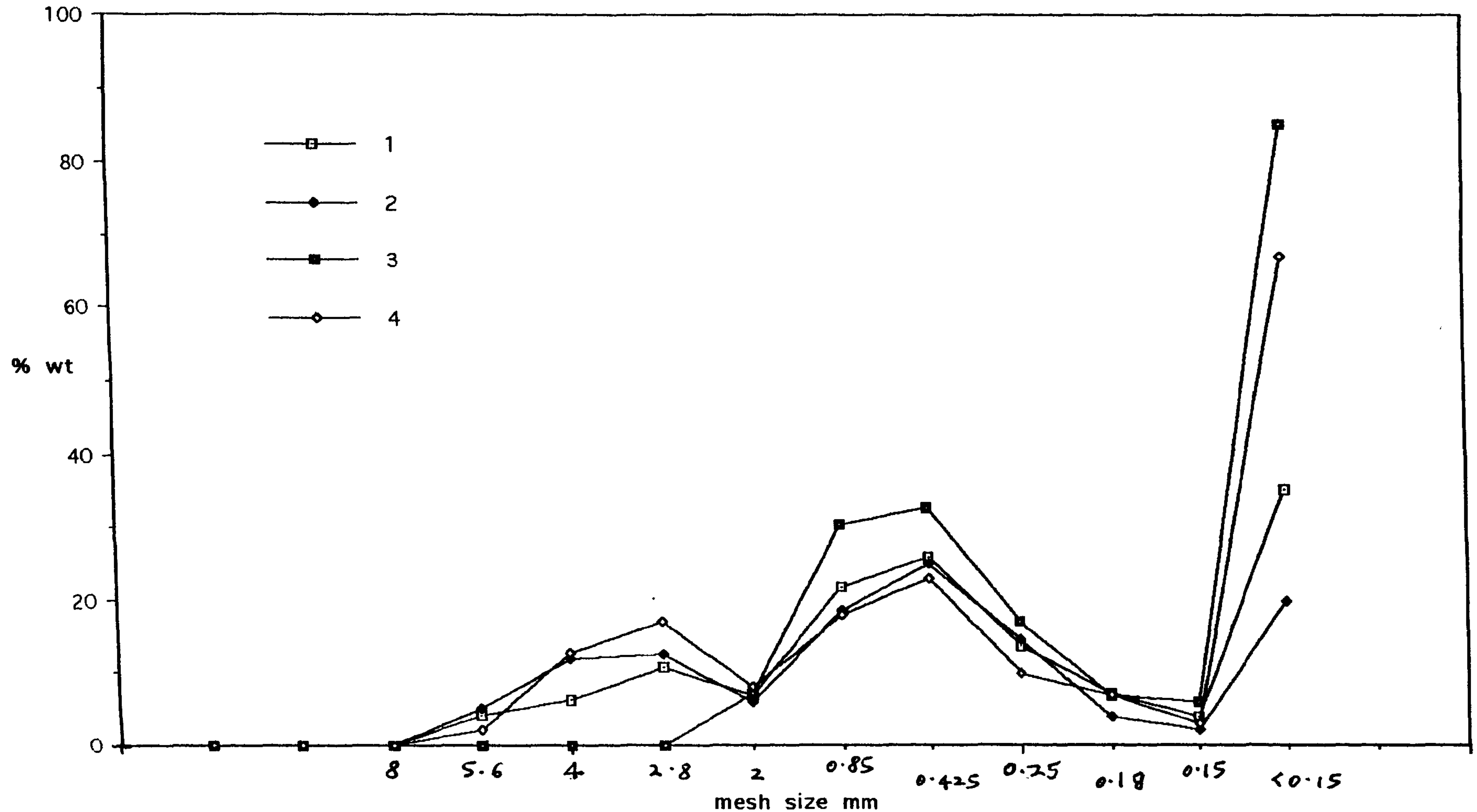
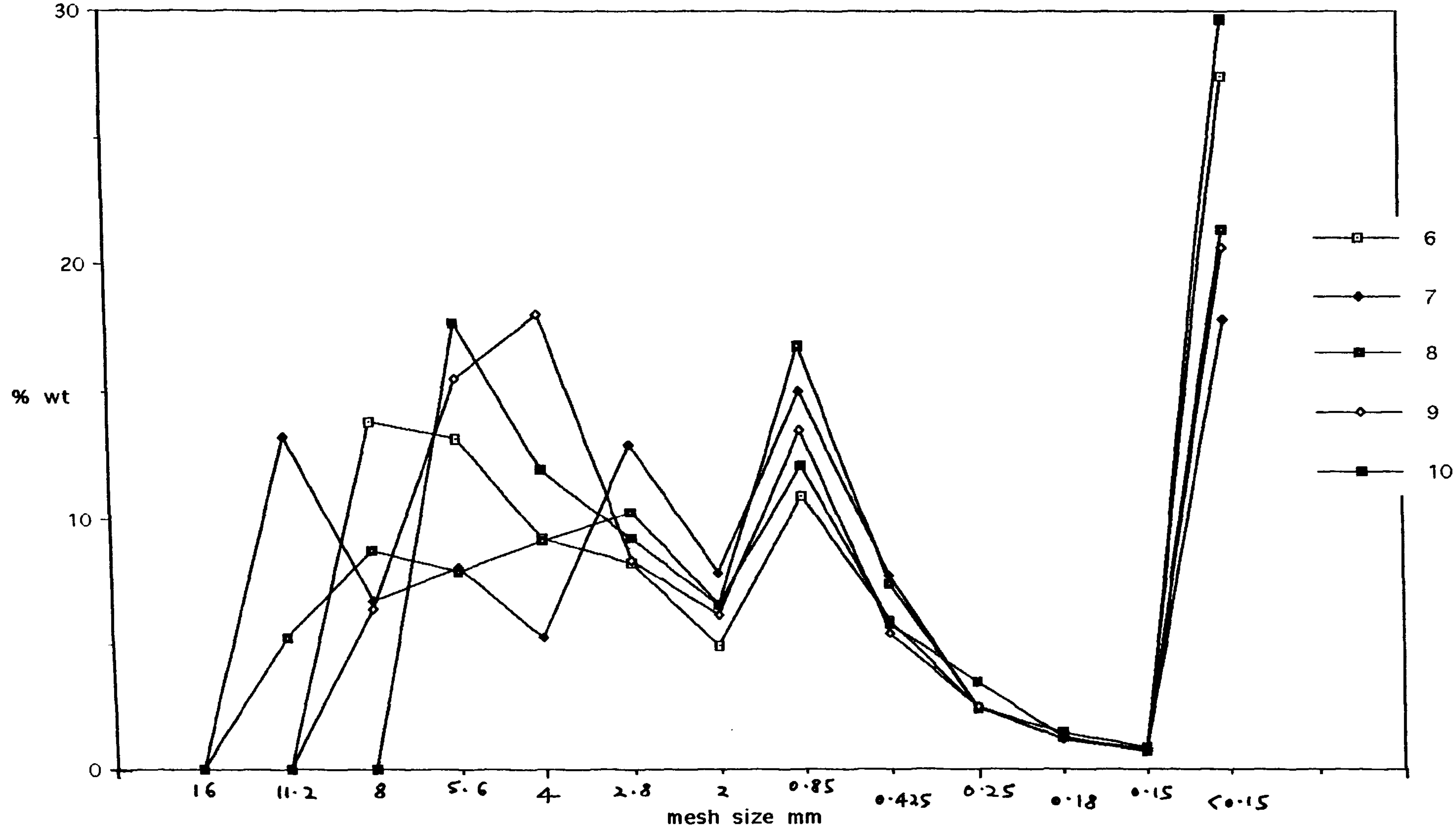


Fig. 61 Barnsley Park - opus signinum plasters



Kingscote Roman Villa, Gloucestershire.
Current Archaeology (1979) 69: 294 - 299
Swain and Ling 1981

Samples from the Corinium Museum. This is not strictly a Roman villa but perhaps a small 'town', it being so large and complex, probably of mainly third century date. The painted plaster was of very good quality. Eight samples were examined and two analyses carried out. These results are unpublished.

COMPOSITION

	gravel	sand	silt	"lime"	
plaster [1]	57	43	-	≈30%	upper layer
plaster [2]	58	42	-	≈40%	lower layer

EXAMPLES OF PLASTER DESCRIPTIONS
Tray 1 Red:
Red on pink on white, 0.05mm total, on off white *intonaco*, 0.4mm, on cream calcareous gravel plaster, 25mm thick.
Tray 2 Blue and yellow:
Brown to dark yellow and dark red traces on light yellow stripes, 0.05mm, on pale blue and light green, 0.3mm, on grooved off white *intonaco*, 1mm, on cream coarse calcareous gravel plaster, 15mm thick.
Tray 3
1) Brushed grey with blue particles, 0.1mm, on white, 0.2mm, on cream *intonaco*, 1.2mm, on cream coarse calcareous plaster, 14mm, on traces of cream coarse calcareous plaster, 5+mm thick.
2) Pale green on black on dark micaceous red, 0.05mm, on white, 0.15mm, on cream *intonaco*, 0.6mm, on cream coarse calcareous plaster, 16mm, on cream coarse calcareous plaster, 8+mm thick. The *intonaco* showed an incised marking out line.
3) Pale green on black and micaceous red, 0.1mm, and bright red (cinnabar) on white on micaceous red, 0.1mm, on white, 0.2 - 0.4mm, on cream *intonaco*, 1mm, on cream coarse cream calcareous plaster, 16mm, on darker cream coarse calcareous plaster, 6+mm thick. The colour scheme was basically a white stripe over a black / green to red interface.
Plaster analyses [1] and [2]. The aggregate was mainly oolitic limestone with some ferruginous sandstone, quartz, flint and fossil traces.

This tray also contained a sample with the same colours but with combing after the application of the white band on the *intonaco*, in the same position as the white band on the interface.

4) Red on pink on black and pale green on a black to red interface, 0.05mm, and red on white, 0.05mm, on cream to white *intonaco*, 1mm, on cream coarse calcareous plaster, 20mm thick.

PAINTING TECHNIQUE

The painting appeared to be in the *buon fresco* method with over painting in *fresco secco.* The fragments appeared to be of both detailed paintings and borders.

PIGMENTS

The pigments showed the use of the expensive red pigment cinnabar and the usual earth colours; red ochre (haematite), yellow ochre (limonite), green earth (glauconite), white lime and carbon as soot or charcoal. The blue colour was Egyptian blue with lime.

Average results

	Thicknesses		"Lime"
paint	(0.05 - 0.4)	0.1mm	-
intonaco	(0.4 - 1.2)	0.9mm	-
plaster upper	(14 - 25)	18mm	≈30%
plaster lower	(5+ - 8+)	7mm	≈35%

Samples illustrated in the aggregate particle size distribution graphs:

Fig. No. 62

1), 2)

Leaholm Gardens, Cirencester
Wacher 1962

A shop or town house in the Roman town of Cirencester. Loose fragments from the edge of a reconstructed wall painting in the museum store. Ten samples were examined and four analyses carried out.

COMPOSITION

	gravel	sand	silt	"lime"
1) plaster layer	27	73	-	≈15%

EXAMPLES OF PLASTER DESCRIPTIONS

1) Burnished green and blue with calcareous sand, 0.1mm, on pink *intonaco*, 0.6mm, on pale yellow to cream plaster, 14mm thick.
2) Burnished calcareous sandy pink *intonaco*, 0.5mm, on calcareous plaster, 10mm thick.
3) Traces of yellow on burnished pink *intonaco*, as above.

The plaster aggregate was mainly oolitic and fossiliferous limestone sand and gravel with some round to sub-angular quartz sand. The pink *intonaco* was lime with crushed brick or tile.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* method.

PIGMENTS

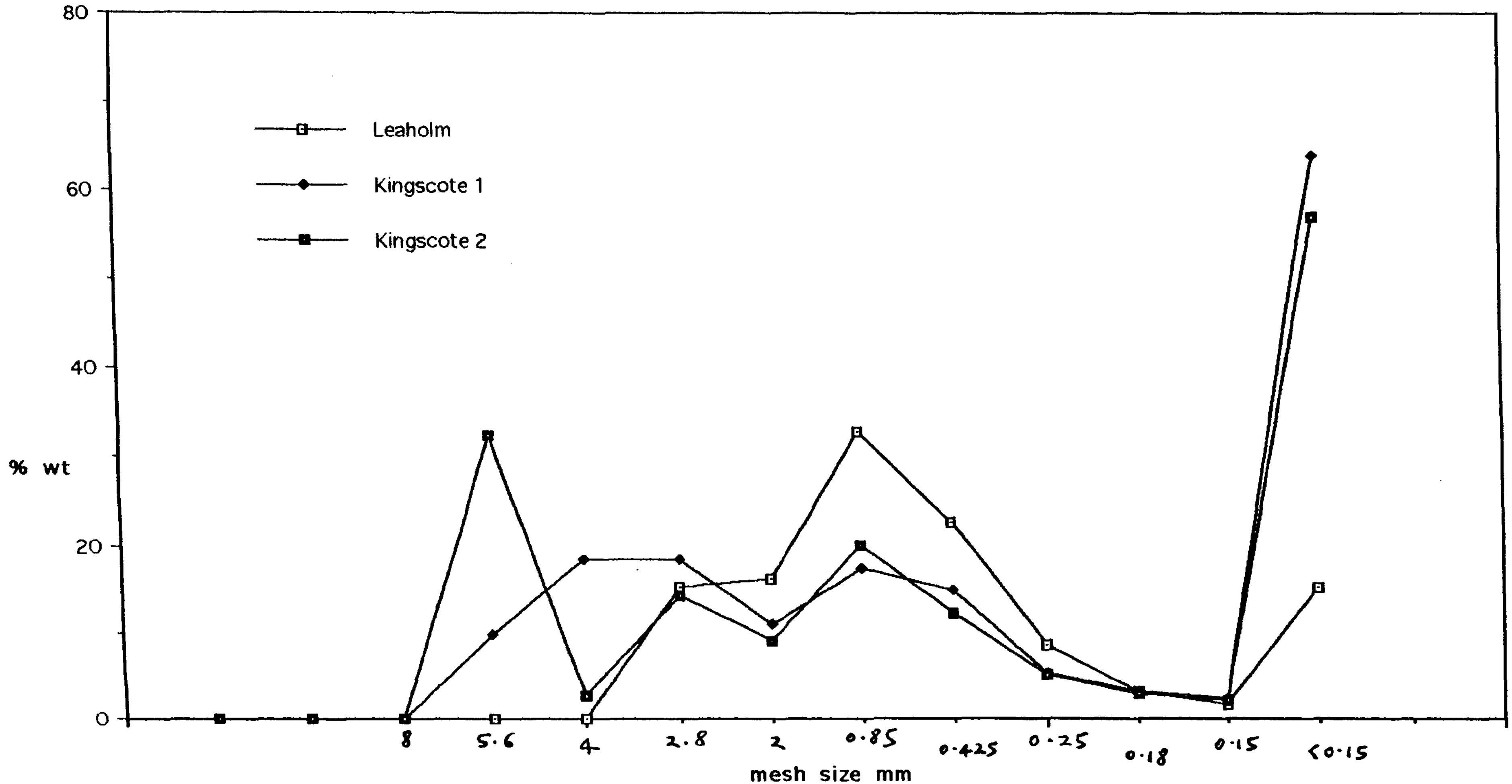
The green was green earth (glauconite), blue was Egyptian blue, yellow was yellow ochre (limonite).

Average results

	Thicknesses		"Lime"
paint		0.1mm	-
intonaco	(0.5 - 0.6)	0.5mm	-
plaster	(10 - 14)	12mm	≈15%

Samples illustrated in the aggregate particle size distribution graphs:
fig No. 62
1)

Fig. 62 Leaholm & Kingscote



Claydon Pike, Fairford, Gloucestershire.
Britannia 1984 15: 312 - 4.

The painted plaster examined came from the site of a later Romano-British building with under floor heating built over an earlier depot or estate centre. The presence of quantities of limestone sand and gravel in the aggregate made "lime" content analysis almost impossible. Estimations were made on some hand crushed samples and those made with crushed brick or tile rather than limestone, even so, the "lime" values are probably high. Twenty three samples were examined and twenty seven analyses carried out. These results are unpublished.

COMPOSITIONS

Due to their calcareous nature, few of the samples could be accurately analysed for their "lime" to aggregate ratios.

No	gravel	sand	silt	"lime"	comments
3155	28	21	51	54%	*opus signinum*
3158	24	24	52	53%	*opus signinum*
3163	47	30	23	36%	*opus signinum*
3165	-	-	-	97%	*intonaco*
3166	31	53	≈16	≈16%	crushed, limestone gravel
3167	40	21	39	49%	*opus signinum*
3171	29	25	46	75%	*opus signinum*
3193	34	16	50	58%	*opus signinum*
3201	39	27	34	56%	*opus signinum*
3202	29	24	47	53%	*opus signinum*
3204	-	-	-	97%	*intonaco*
	37	43	≈20	≈20%	crushed, limestone gravel
3206	31	54	≈15	≈15%	crushed, limestone gravel
3208	12	23	≈65	≈65%	crushed, limestone gravel.

EXAMPLES OF PLASTER DESCRIPTIONS

Type 1; fine plaster with little aggregate:
3208; red, 0.05mm, on white *intonaco*, 0.25 - 0.5mm, on fine off white plaster, 9mm thick. Also a sample of green on pale yellow. c.f. 3207.
Type 2; coarse wall plaster with gravel:
3138; two layers of fine gravel plaster separated by a white lime interface, respective thicknesses: 5mm, 1mm, 24mm.
3157; plaster or mortar with tile and coarse gravel.
3165; white *intonaco*, 0.5mm, on fine gravel plaster on coarse gravel plaster, total thickness, 20mm.

3166; fine gravel mortar.
3204; yellow, 0.1mm, on white *intonaco*, 0.75mm, on buff coarse plaster in three layers, 12mm + 12mm + 20mm.
3206; red on white *intonaco*, 0.5mm, on off white plaster, 12mm thick. Also fragments with green (black and green) spots on orange.
3207; white on green on pale yellow on dark yellow on white *intonaco*, 0.5mm, on whitish plaster, 7mm thick. Also a fragment with red on white *intonaco* on plaster 11mm thick.
Type 3; very coarse floor or wall mortar:
3160 (circular shrine), 3183, 5471, 5472-1, 5474, 5486; these were all calcareous and too hard to crush by hand without breaking the aggregate. They contained gravel up to 40mm mesh.
Type 4; crushed brick or tile plasters or mortars (*opus signinum*):
3155, 3157, 3158, 3163, 3167, 3171, 3193, all being lower plaster layers or mortar-like, and the following plasters:
3200; white *intonaco*, 0.25mm, on tile plaster, 11mm thick.
3201; white *intonaco*, 0.5mm, on tile plaster, 17mm thick.
3202; white *intonaco* on tile plaster, 25mm thick.
Type 5; unused or waste lime:
3154, 3170.

PAINTING TECHNIQUE
The paint all appeared to have been applied in the *buon fresco* method.

PIGMENTS
The pigments were natural types: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), carbon as soot or charcoal and white lime.

<u>Average results</u>

	Thicknesses		"Lime"	
paint	(0.05 - 0.1)	0.075mm	-	
intonaco	(0.25 - 0.75)	0.5mm	≈97%	
mortar / plaster	(5 - 12)	9mm	≈20%	upper
		1mm	-	interface
	(10 - 24)	15mm	≈20%	middle
		20mm	≈20%	lower
opus signinum	(11 - 25)	18mm	≈54%	

limestone gravel density - 1.7g/cc.

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 63 - 65
Crushed - limestone: 3166, 3204, 3206.
Opus signinum: 3158, 3155, 3157, 3171, 3163, 3167, 3193, 3210, 3202.

The sand and gravel graphs must be assumed to be approximate in view of possible damage caused by the hand crushing process and loss of calcareous aggregate by acid dissolution, but they do show a broad grading. The *opus signinum* graphs are probably more accurate and show poor grading.

Fig. 63 Claydon Pike 1 - limestone

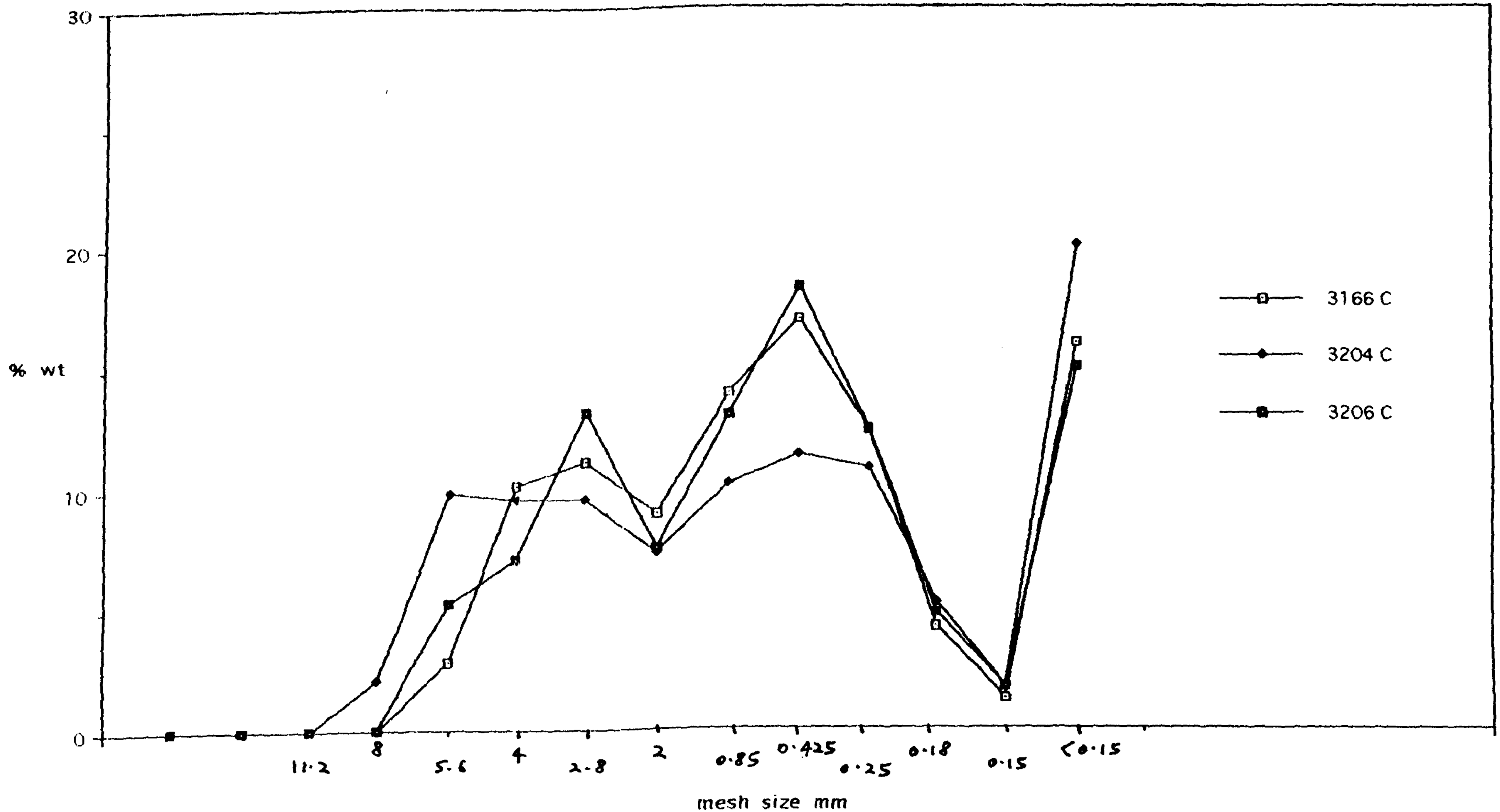


Fig. 64 Claydon Pike 2 - opus signinum

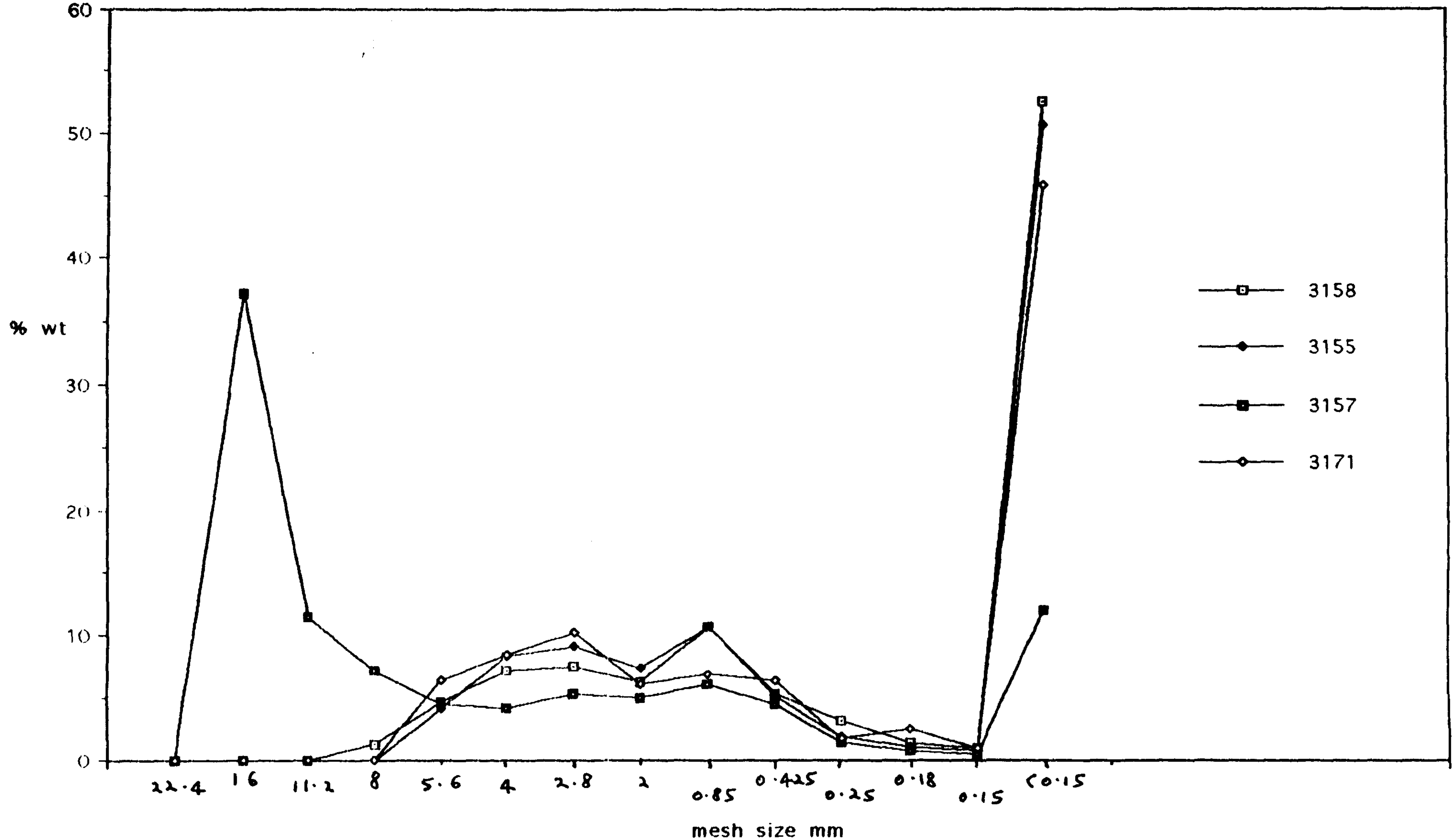
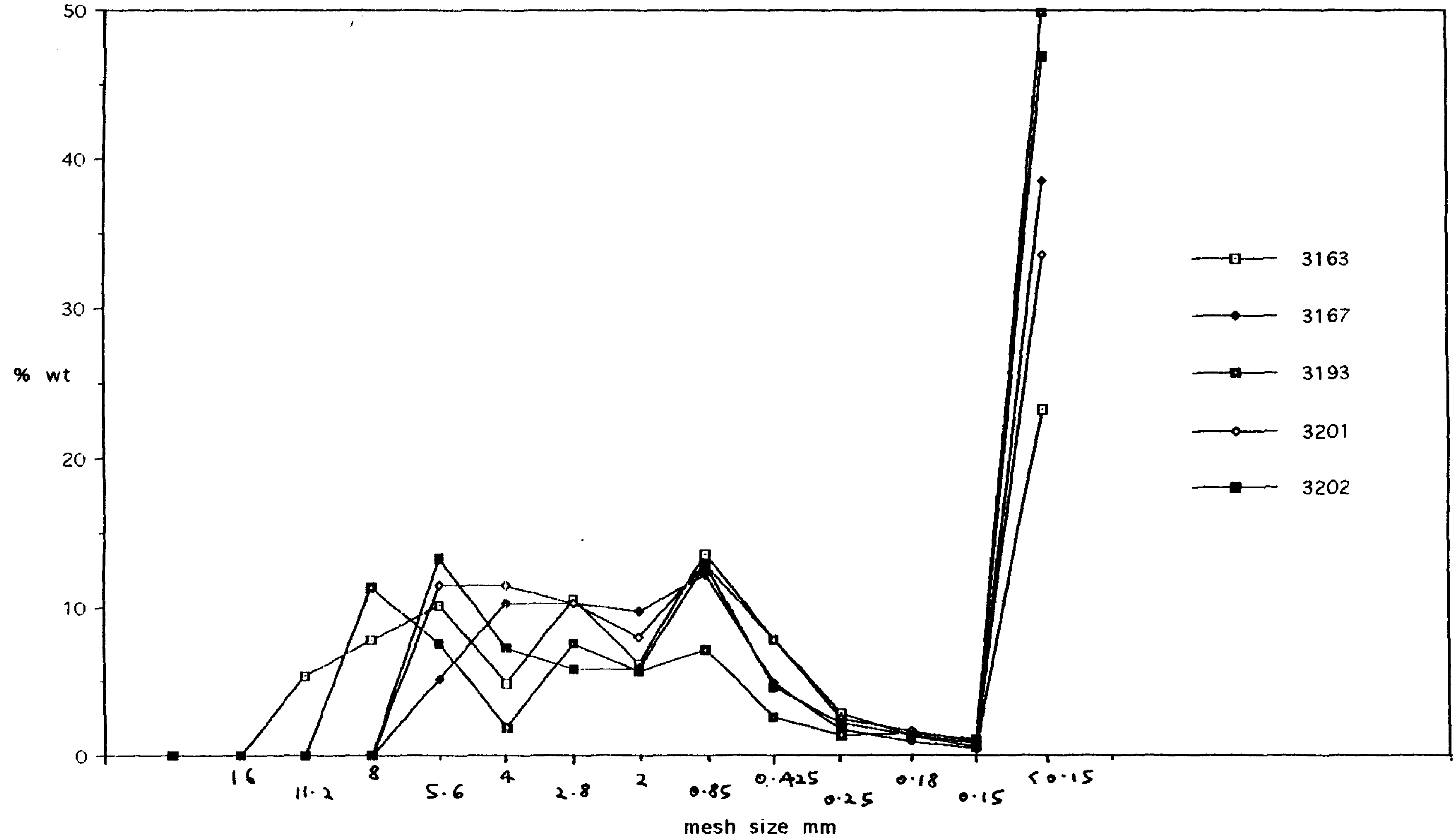


Fig. 65 Claydon Pike 3 - opus signinum



Colchester, Essex
Britannia 1985 16: 295 - 6, 1988 19: 458
Crummy 1987, 16 - 17; 1988, 6 - 7
Davey and Ling 1981, 29, 34, 99 - 101
Morgan 1988

The important Claudian capital of Roman Britain has produced vast amounts of mortar and plaster. Very little has yet been examined scientifically but a programme of analysis has recently been started on material from the Culver Street and Gilberd School sites at the School of Archaeological Studies, University of Leicester . No full results are available but the following observations give an idea of the range of material being studied. The samples were provided by the Colchester Archaeological Trust and The Colchester and Essex Museum.

1) The Town Wall.
The Roman town walls of Colchester are among the best surviving in Britain. Samples of mortar and render from the excavation in Culver Street were analysed. The wall was made from local septarian nodules, a hard calcareous clay-like stone, with bonding layers of large Roman bricks or tiles. The mortar was of lime and gravel and *opus signinum* types.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1	61	31	8	21%	wall core, gravel and sand
2	44	44	12	31%	bonding mortar with some tile
3	18	67	15	52%	render or pointing, opus signinum
4	-	-	-	95%	"whitewash"
5	-	-	-	48%	septaria

DESCRIPTIONS
1) The wall core was composed of white lime mortar with an aggregate of flint, quartz and quartzite pebbles, with sand. The presence of amorphous silica in the finest residue suggested the use of hydraulic lime.
2) The outer or bonding mortar was described by the excavator as *opus signinum*, but proved to be sand and gravel mortar with the addition of crushed brick or tile, giving the typical pink colour of tile based mortar.
3) A possible render coat from the surface of the wall, which also had a thick white coating on it. The mortar was a mixture of sand and tile.

The white coating appeared to be multi-layer whitewash, of about forty five layers and totalling 4mm in thickness, but subsequent microscopic analysis showed it to be a natural deposit of calcite. Similar material from other sites, including Hadrian's Wall, was analysed together with genuine whitewash for comparison. The amorphous nature of whitewash slurries and columnar crystals of natural calcite were readily distinguishable at high powered magnification. Analysis of the septaria showed that they could possibly have been used as a source for hydraulic lime.

PAINTED PLASTER

Vast amounts of painted plaster await scientific analysis. Much of it is of high quality. Only a few descriptions are given here.

1) Culver Street (1.81) site M, find No. 71 (layer 11) red painted plaster: red cinnabar, <0.05mm, on pink on yellow, 0.1mm, on white *intonaco*, 0.2 - 0.4mm, on coarse sandy plaster with straw impressions, 15mm thick.

2) 18 North road;

This sample from old excavations in the Colchester Museum collections was of particular use in demonstrating over plastering. Three separate painted plaster layers could be seen and traces of wattle and daub:

3rd phase / top layer; dark blue spots and band on pale pink and a light blue band over the light pink to dark pink / red interface all on white *intonaco*, 0.2mm, on

2nd phase / middle layer; white lime with blue specks, 0.3mm, possibly a bonding interface, on maroon and green on black all on a white *intonaco*, 0.75mm, on sandy plaster, 7mm, on

1st phase / first layer; dark yellow, 0.05mm, on pink *intonaco*, 0.4mm, on pink sandy plaster with tile, 6mm, on buff sand and clay? plaster, 14mm, on buff calcareous clay with lath? impressions to 15mm thick.

The pigments used were: red ochre (haematite), red cinnabar with lime for the dark pink, yellow ochre (limonite), green earth (glauconite), Egyptian blue, black soot or charcoal and white lime.

The Colchester Museum has on display in its collections the only safely stratified piece of Romano-British painted plaster with traces of gold leaf. It is only a small piece, about 80mm x 100mm, with gold leaf applied as a narrow band and two small spots. The order of application was: gold leaf on green earth on black on a grey *intonaco*, 1mm, on sandy plaster in two layers, 6mm + 11mm thick. (Colchester Museum ref No 34.1953; Hull 1958).

PIGMENTS

Several Egyptian blue spheroids and traces of Egyptian blue were found at the Gilberd School site. They were mainly flattened or irregular spheres with the following approximate measurements:

No	size	weight g
GBS 84		
/434\	18mm dia	3.5562
/748\	16 - 22mm dia x 16mm thick	3.459
/770\	18mm dia	3.2454
GBS 85		
/1265\	18mm dia x 14mm thick	3.02
/1266\	18 - 20mm dia x 15mm thick	3.0967

Various pottery sherds also had traces of pigments, either from their use as palettes or as paint pots.

1) GBS 84 A (318) /372\ pink on mortarium fragment:
this was in fact red cinnabar which appeared to have been absorbed by the light buff pot fabric giving a pink colour. There was no trace of lime, suggesting that the pigment had been prepared for use in *buon fresco* work.

2) GBS 84 A (1321) L 81 /680\ red on pot rim:
red ochre without lime; pot about 110mm dia.

3) GBS 84 (1341) L 81 /688\ blue on the outside of pot rim:
Egyptian blue; pot rim about 180mm dia.

4) GBS 84 A (1395) L 81 /697\ grey blue on pot sherd:
was green with traces of Egyptian blue. This may have been altered by burial, or an impure blue.

5) 1/81 K (96) F 66 yellow on pot rim:
yellow ochre with traces of lime; pot about 120mm dia.

6) GBS 84 A (1774) L 139 /798\ sherds with blue and red:
these sherds showed traces of several pigment colours, suggesting re-use. The colours represented were: red ochre, red cinnabar, Egyptian blue, green earth and mixtures of these pigments.

7) BKC 76 N (525) L 82 /4870\:
this was a soil sample containing quantities of crushed Egyptian blue, charcoal (oak and ash), fragments of red cinnabar and lime. It may have a painters waste. It was possible to extract lumps of the crushed blue and grade it. The bulk of the sample (90%) was finer than 0.15mm, and 49% was finer than 0.045mm, giving a pale blue colour. The presence of 35% lime suggested that it was probably used for painting.

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig Nos 66, 67

1) Wall mortars 1, 2, 3,

2) The blue pigment from BKC 76 N, which was graded with an extended range of sieves.

The graphs show that the same sand source was used in the mortars, which appeared to differ only in their coarser components. The crushed Egyptian blue sample had a very fine composition.

Fig. 66 Colchester mortar

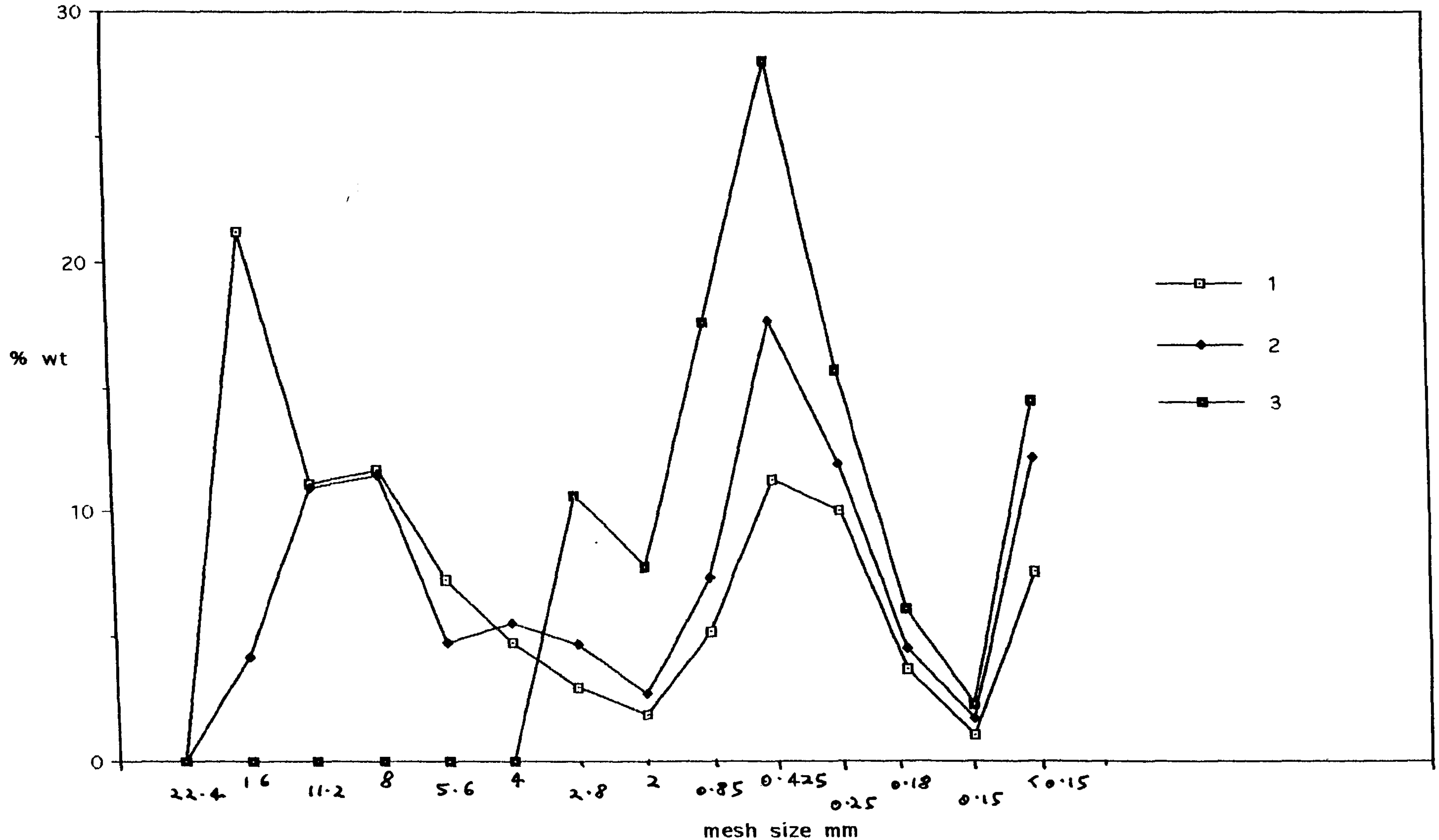
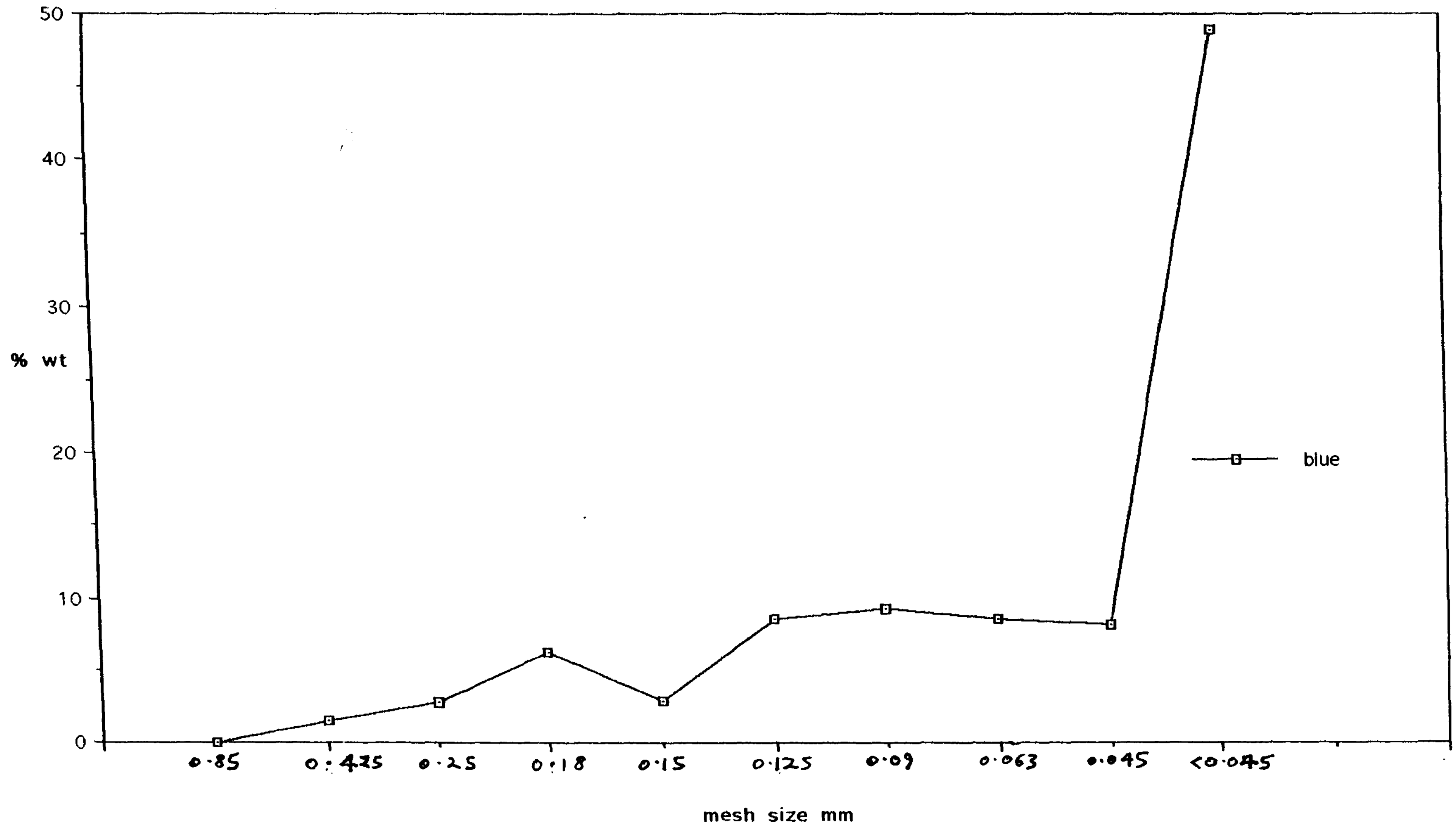


Fig. 67 Colchester - Egyptian blue



Dorchester, Dorset.
Colliton Park, Roman Town House.
Drew and Collingwood Selby 1937, 1938

Mortar, painted plaster and pigments from Colliton Park Roman Villa, excavated around 1937 and currently in the Dorset County Museum collections. Analysis showed that the aggregate in many samples was poorly sorted sub-angular quartz sand with flint, perhaps derived from a crushed or weathered deposit. The lime content was fairly constant in both mortars and plasters, ranging from 21 - 29%. Among the samples examined were fragments of pink tile mortar or opus signinum, this may have been from damp areas, such as the lower parts of walls, or possibly from a bath house structure. The presence of quantities of lattice work lath impressed plaster suggested a ceiling. Thirteen samples were examined and identified, twenty samples were fully analysed.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1	3	92	5	28	torching
2	11	73	16	24	wall mortar
4	8	80	12	27	lower layer with tile
5	-	-	-	62	*intonaco*
5	8	81	11	27	upper layer with tile
6	2	87	11	21	lower layer
10	0	92	8	25	pecked plaster - ceiling
11	0	94	6	23	middle layer
12	2	94	4	23	lower layer - lath impressed
13	4	75	21	22	upper layer - secondary
14	2	78	20	23	lower layer - secondary
15	1	92	7	32	pecked - primary layer
16	1	88	11	24	pecked plaster - wall
17	4	88	8	22	middle layer
18	0	94	6	20	lower layer
19	19	70	11	35	upper layer - ceiling
20	1	84	15	35	lower layer - reed impressed

EXAMPLES OF PLASTER DESCRIPTIONS

1) C.P. pit 1, 26N, level ?, mortar 1:

Tile bonding mortar or "torching" from *imbrex*; grey sandy mortar with flint and grass or straw impressions.

2) C.P. mortar B1, from wall of stoke hole xvii A ?:

Fragment of coarse sandy yellow mortar with flint and chalk.

3), 4) C.P. unknown section (15):

Yellow to buff sandy plaster with red tile or brick traces, in two or three layers, 23 and 15mm (8 + 7mm) thick. The lower layers contained more tile. This sample also contained some painted plaster: brushed dark red (cinnabar) on brown, 0.5mm, on white, 0.05mm, on sandy off white *intonaco,* 0.5mm, on buff to yellow sandy plaster in two layers, 8 + 7mm, with tile traces mainly in the lower layer.

5), 6) C.P. mortar (1), S2N, (3) debris 11.10.37:
Orange to red on off white / cream *intonaco*, 0.5mm, on buff sandy plaster with tile, 10mm, on buff sandy plaster possibly in two layers totalling 35mm.
7) C.P. site C, section 3N, room 15, (4) layer on floor:
Pink stripe on orange red to white interface on white on white, total thickness 0.1mm, on buff sandy plaster with tile, 16mm possibly in two layers (10 + 6mm).
8), 9) C.P. mortar box 10, S 101, TTA (2), black earth debris 11.9.37:
Red band over white to yellow interface and red on white on sandy plaster, 0 - 1.5mm, on yellow on white on sandy plaster, 11mm, on very coarse sand to gravel plaster traces, 8mm thick. This was probably a *giornata di lavoro* join.
10), 11), 12) C.P. unknown section (15):
Lath impressed painted plaster with a geometric design of octagons or hexagons in two different colour schemes: blue and green and red on pink. Further work might show that it represents a typical geometric design surrounded by a border. The red was cinnabar. The structure was: red on red, 0.05mm, on white *intonaco*, 0.1mm, on sandy plaster, 8mm, on sandy plaster, 13mm, on sandy plaster with lath impressions, 10 - 15mm thick. A similar plaster structure was found in ceiling plaster from Wall, Staffordshire. The weight loading of this sample was calculated to be about 53kg/m^2.
13), 14), 15) C.P.layer 3, room 17:
White stripe on pink on white and green on white *intonaco* on buff sandy plaster in two layers, 10 + 12mm, on pecked white painted sandy plaster traces, 8mm thick. The lower layer appeared to be layered, with a possibly a pale grey limewash bonding coat prior to re-plastering. Aggregate analysis suggested that this fragment of over-plastering was originally attached to the peck marked wall or ceiling plaster.
16), 17), 18) C.P. site C, section 11 + 14, layer 1, room 17:
Pecked plaster with a drab green band and a blue on black band on white, 0.1mm, on pale buff *intonaco*, 0.1 - 0.5mm, on sandy plaster, 8mm, on variable sandy plaster, 18 - 30mm (10 + 8 - 20mm), with stone? impressions and traces of yellow sand and gravel mortar. The blue band masked an *intonaco* overlap possibly a *giornata di lavoro* division; blue on black, blue on white on sandy plaster, 0.15mm, on white *intonaco*.
19), 20) C.P. 1936 - 50, on floor 1:
Pink on white on red on a combed off white *intonaco*, 0.1 - 0.2mm, on buff sandy plaster, 12mm, on buff sandy plaster, possibly in two layers with tied reed bundle impressions on the rear, 10 + 2 - 10mm (12 -

20mm total). The combing grooves on the surface were about 0.1 - 0.2mm deep.

PAINTING TECHNIQUE

The main painting technique appeared to be in the *buon fresco* method, and over-painting in *fresco secco* with the following schemes: dark red on brown, red on pink, orange red on cream, red on yellow, green on blue on black.

PIGMENTS

The pigments were: red to brown ochres (haematite), brick or tile dust, cinnabar, yellow ochre (limonite), green earth (glauconite) Egyptian blue, white lime and carbon as soot or charcoal. Of note was a collection of Egyptian blue spherical lumps :

[2955] S 88 SE pit M (1) black earth "blue metallic substance" 29.4.38. These were crude balls of Egyptian blue as manufactured, being a cluster of eleven balls each about 8mm in diameter, weighing a total of 7.2105g. X-ray fluorescence analysis of these balls showed them to contain copper, tin, lead and zinc, being the elements of copper alloys and not pure copper as in the recipes of the ancient writers.

<u>Average results</u>

	Thicknesses		"Lime"	
tile torching	-		28%	
wall mortar	-		24%	
paint	(0.05 - 0.35)	0.1mm		
intonaco	(0.1 - 0.5)	0.3mm	62%	
upper layer	(8 - 23)	11mm	26%	primary plaster
middle layer	(8 - 17)	12mm	23%	
lower layer	(7 - 17)	12mm	23%	
upper layer		10mm	22%	secondary plaster
lower layer		12mm	23%	

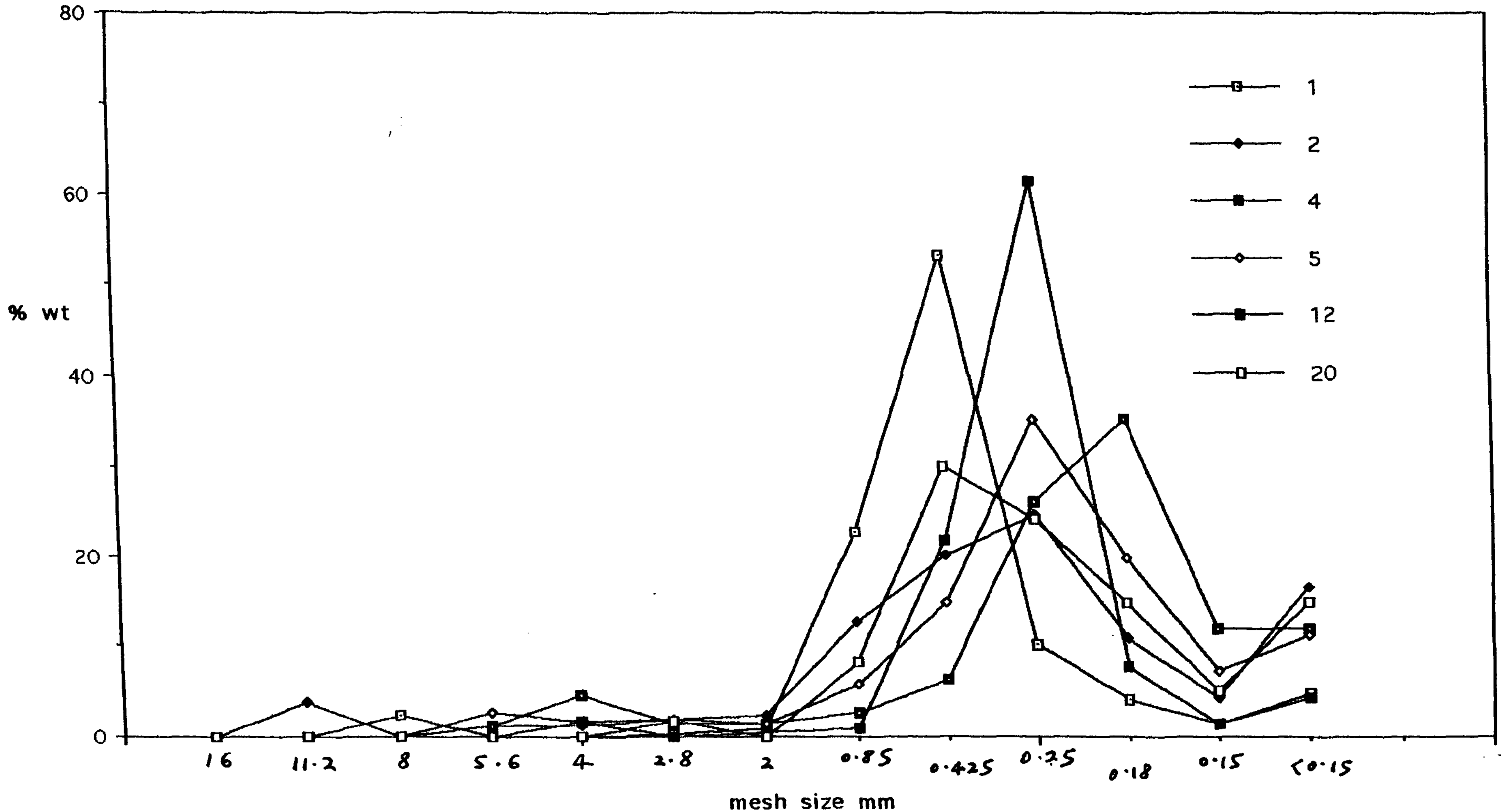
<u>Samples illustrated in the aggregate particle size distribution graphs</u>:

Fig No. 68

1), 2), 4), 5),12), 20)

The pecked plaster sample(10, 11, 12) shows a more closely graded sand component, perhaps reflecting a different sand source.

Fig. 68 Colliton Park



Dorchester, Dorset.
Poundbury Camp
Green 1974, 1982

Samples of plaster from Poundbury Camp in the Dorset County Museum collection were examined. The painted plaster showed reed bundle impressions on the rear, suggesting that it was ceiling plaster. It was particularly friable. The aggregate was composed of poorly sorted round to sub-angular quartz sand, fairly similar to that from only one sample from the nearby site of Colliton Park. Of particular note were samples of gypsum plaster from the burials, being the only examples of Roman gypsum plaster seen in this survey. Four samples were examined and five analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1	6	87	7	19%	upper layer (ceiling)
2	12	77	11	15%	lower layer, reed impressed
				12% carbonate	
3) gypsum plaster				4% carbonate, 94% sulphate.	

EXAMPLES OF PLASTER DESCRIPTIONS
1) PC 70 B box 261, E end of building; ceiling plaster, WP 100:
coarse blue, 0.05 - 0.1mm grains, with black, 0.5mm, on white *intonaco*, 0.5mm, on yellow sandy plaster, 8 - 11mm, on yellow sandy plaster with reed bundle impressions, 10 - 20mm thick. Also a sample with white overpainting on red on white on white *intonaco* on reed impressed plaster as above, and; dark red to maroon with blue patches, 0.25mm, on white on white *intonaco*, 0.5mm, as above.
2) PC 70 B box 1197, 200 / 72, WP 98 /7\ + /11\ J9; middle of E end of interior:
coarse blue on green on white intonaco, on yellow sandy plaster, on yellow sandy plaster with reed bundle impressions. c.f 1).
3) Context 72E, grave 529, gypsum box No 205:
The plaster was a mixture of "micro-crystalline" white crystals with pieces of translucent gypsum and sand traces. It was probably only partly calcined or calcined in large pieces, the inner part being unaffected by the heat. This would have been equivalent to crude Plaster of Paris. The smoothed surface showed that it must have been applied in much the same way as lime plaster. The residue left after the treatment with acid was angular quartz with traces of fired clay or

brick dust. Partial dissolution left quantities of gypsum crystals which appeared not to have been calcined.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* method.

PIGMENTS

The pigments used were: red ochre (haematite), white lime, green earth (glauconite), carbon as soot or charcoal and crushed Egyptian blue.

<u>Average results</u>

	Thicknesses		"Lime"
paint	(0.05 - 0.5)	0.3mm	-
intonaco.		0.5mm	-
plaster	(8 - 11)	10mm	19% upper layer
	(10 - 20)	15mm	15% lower layer

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:

Fig. No. 69

1), 2)

The graphs show that the sands for the upper and lower layers are very similar and not particularly well graded. The graph is similar to one sample from nearby Dorchester (20).

brick dust. Partial dissolution left quantities of gypsum crystals which appeared not to have been calcined.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* method.

PIGMENTS

The pigments used were: red ochre (haematite), white lime, green earth (glauconite), carbon as soot or charcoal and crushed Egyptian blue.

Average results

	Thicknesses		"Lime"
paint	(0.05 - 0.5)	0.3mm	-
intonaco.		0.5mm	-
plaster	(8 - 11)	10mm	19% upper layer
	(10 - 20)	15mm	15% lower layer

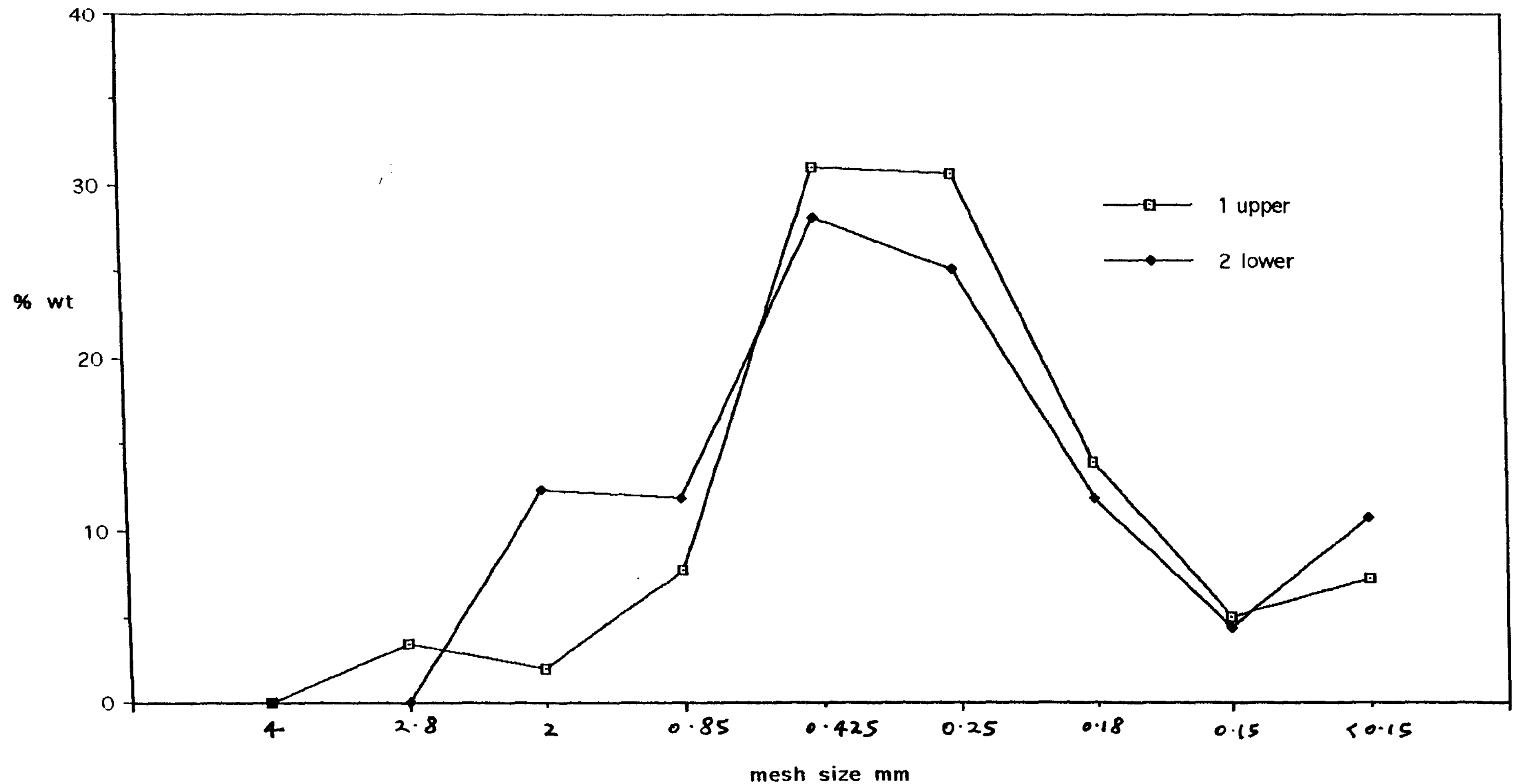
Samples illustrated in the aggregate particle size distribution graphs:

Fig. No. 69

1), 2)

The graphs show that the sands for the upper and lower layers are very similar and not particularly well graded. The graph is similar to one sample from nearby Dorchester (20).

Fig. 69 Poundbury



Dover, Kent.
Philp 1989
Davey and Ling 1981, 111 - 113.

Mortars and painted plasters from the "Roman Painted House" in Dover and its environs, dated to the second and third centuries. Samples of local sand and limestone (upper chalk) were also analysed. The plaster aggregates were almost entirely crushed hard chalk and flint, with only small amounts of: rounded quartz sand, opaque white chert, yellow mudstone, magnetite, micaceous grey green sandstone, red sandstone and crushed brick or tile. Many samples showed grass or straw impressions and traces of a mud and straw plaster on the rear. Shallow grooved impressions on the rear were probably keying marks from mud plaster The presence of grains of glauconite suggested the use of lower chalk for the aggregate or as a lime source. The presence of calcareous aggregates meant that the estimation of the lime content was tentative and based partly on visual estimations. Sixty five specimens were examined and fifty samples analysed.

COMPOSITIONS
Painted House site

number	gravel	sand	silt	"lime"	comments
mortar	35	28	37	25%	wall mortar
floor	84	11	5	31%	*opus signinum* type tile mortar
A) DV 1167	-	-	19	81%	white *intonaco*
cat 304	17	63	20	20%	upper layer
	35	62	3	15%	lower layer
B) cat 307	-	-	10	90%	white *intonaco*
	15	47	38	30%	upper layer
	33	42	25	20%	lower layer
D1) DV 2306	-	-	4	96%	white *intonaco*
	0	38	62	38%	upper layer
	1	7	92	25%	lower layer, tile traces
J) DV 9605					*intonaco* traces not analysed
	11	64	25	25%	upper layer with tile
	36	42	22	30%	lower layer with tile

Bingo Hall site number	gravel	sand	silt	"lime"	comments
2) DV 3062					
	15	41	44	40%	chalky plaster
7) DV 9938					
	-	-	8	92%	white *intonaco*
	0	60	40	25%	single layer
8) DV 9890					
	-	-	10	90%	*intonaco*
	26	59	15	33%	upper layer
	47	40	13	15%	lower layer

The upper chalk sample had a "lime" content of 97% weight (as acid soluble)

EXAMPLES OF PLASTER DESCRIPTIONS

Painted house

A) DV 1167 cat 304 Red on yellow on white *intonaco*, 0.5 - 0.75mm, on off white plaster, 8mm, on coarse white plaster, 38mm thick.
B) cat 307 Burnished red on white *intonaco*, 0.75 - 1mm, on white plaster, 12mm, on buff plaster with straw impressions, 15mm thick.
D) DV 2306 cat 334 Red on white *intonaco*, 0.5 - 0.75mm, on off white plaster, 1.5 - 3mm, on buff plaster with chalk, 25mm thick.
F) DV 2373 cat 239 Red, yellow and white on white *intonaco*, 1mm, on off white plaster, 16mm, on buff plaster with chalk, 18mm, on a mud layer. Shallow grooves, 3mm deep and 17 - 20mm wide, on the rear were probably keying marks from a lower mud plaster.
I) DV 1184 cat 247 Red / brown and yellow on white *intonaco*, 0.75mm, on off white plaster, 4mm, on pink tile plaster, 24mm thick.
This was similar to J) DV 9605 cat 336.
DV 2308 Blue on grey on white *intonaco*, 0.75mm, on white plaster, 9mm thick.
DV 4381 62 Red, 0.1mm, on pink *intonaco*?, 0.3mm, on white / grey plaster with straw traces, 18mm thick. The red was cinnabar.

Bingo hall site

2) DV 3062 Green on orange on white *intonaco*, 1- 1.5mm, on white plaster in two layers, 11mm total, on white plaster, 18mm thick, all with traces of straw and chalk.
5) DV 9869 Red on yellow on white *intonaco*, 0.75mm, on white plaster, 10mm, on buff plaster, 5+mm thick.

7) DV 9938 White on sandy white *intonaco*, 0.5 - 0.75mm, on sandy plaster with chalk, 33mm thick. This was the only sample containing sand.

8) DV 9890 Pink on dark red, 0.05mm, on white *intonaco*, 0.5 - 0.75mm, on white plaster, 11mm, on white plaster, 13mm thick.

10) DV 9890 Burnished pink / brown on red on pink, 0.1mm, on white *intonaco*, 0.25 - 0.5mm, on white plaster, 9mm thick. The burnished layer contained cinnabar.

PAINTING TECHNIQUE

The painting technique appeared to be entirely in the *buon fresco* method, with the following colour schemes:
burnished pink, pink, light and dark red, burnished red, blue, orange, light and dark green, burnished yellow, yellow, black, grey, white, cream; red on pink, blue on grey, green on black; yellow, brown and grey on cream with blue specks on pink; green on red, dark red on yellow; black on yellow.

PIGMENTS

With the exception of small amounts of Egyptian blue, from the Painted House site, the pigments were mainly natural minerals : red, yellow and brown ochres (haematite / limonite), brick or tile dust, cinnabar, green earth (glauconite), white lime and carbon as soot or charcoal.

Average results

	Thicknesses		"Lime"
paint	(0.05 - 0.40)	0.1mm	-
intonaco	(0.5 - 1)	0.8mm	87%
upper plaster	(3 - 33)	12mm	25%
lower plaster	(10 - 55)	24mm	20%

Samples illustrated in the aggregate particle size distribution graphs

Fig Nos 70 - 73

Painted house

A) DV 1167 cat 304

B) cat 307

D1) DV 2306 cat 334

J) DV 9605 cat 336

floor mortar (*opus signinum*)

wall mortar

Bingo hall site

2) DV 3049

5) DV 9869

7) DV 9938 gp1

8) DV 9890

Current beach sand and gravel; high tide and low tide. This was almost entirely composed of flint fragments, from rounded pebbles to angular particles.

The graphs show that the plaster gradings are all similar with the exception of the one sandy sample 7), which appears to be made from fine sandy limestone. The tile containing plasters are only slightly different from them rest. The beach sand gradings do not appear to be similar to the plaster aggregates.

Fig. 70 Dover - Painted House 1

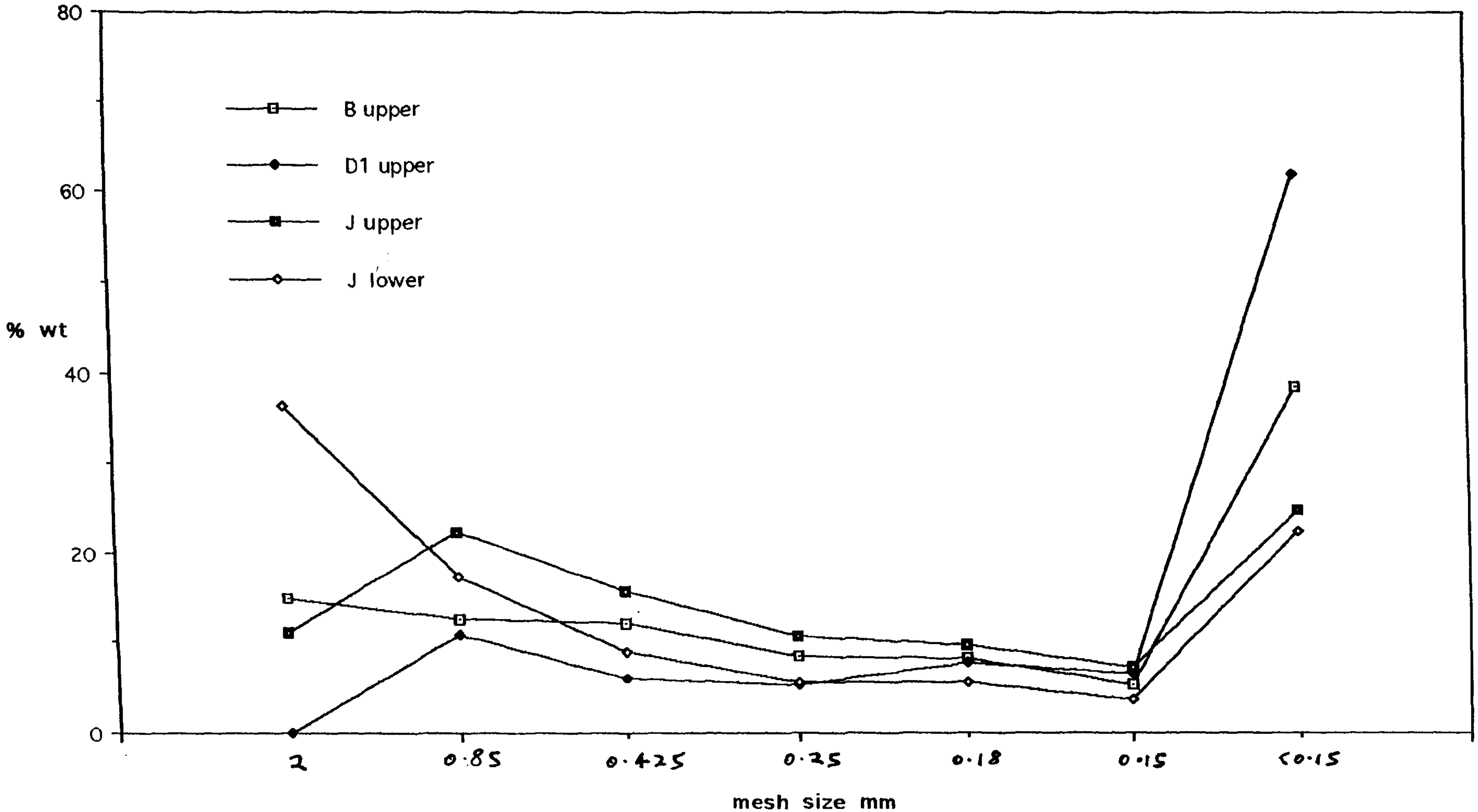


Fig. 71 Dover - Painted House 2

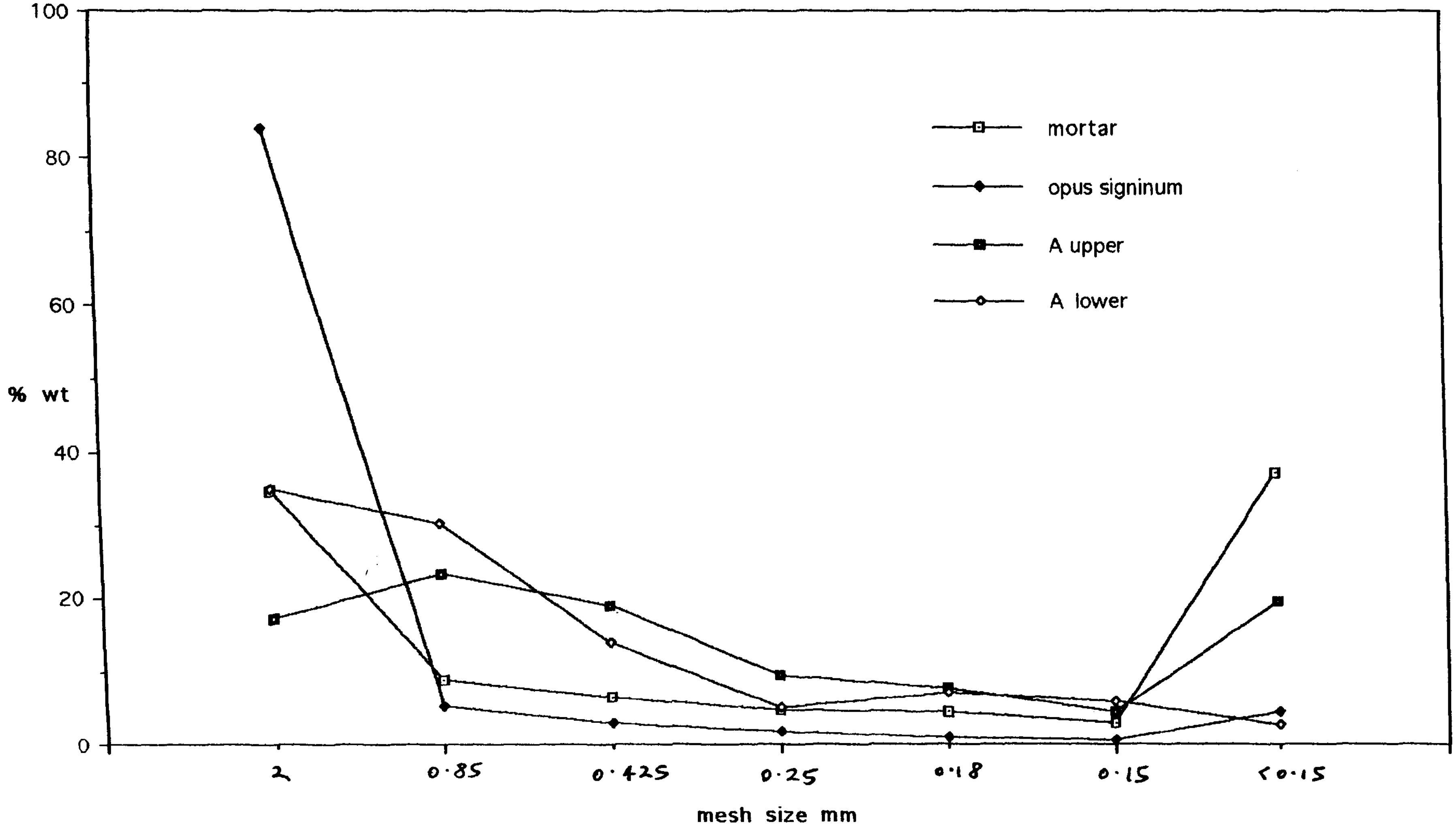


Fig. 72 Dover - Bingo hall & Beach 1

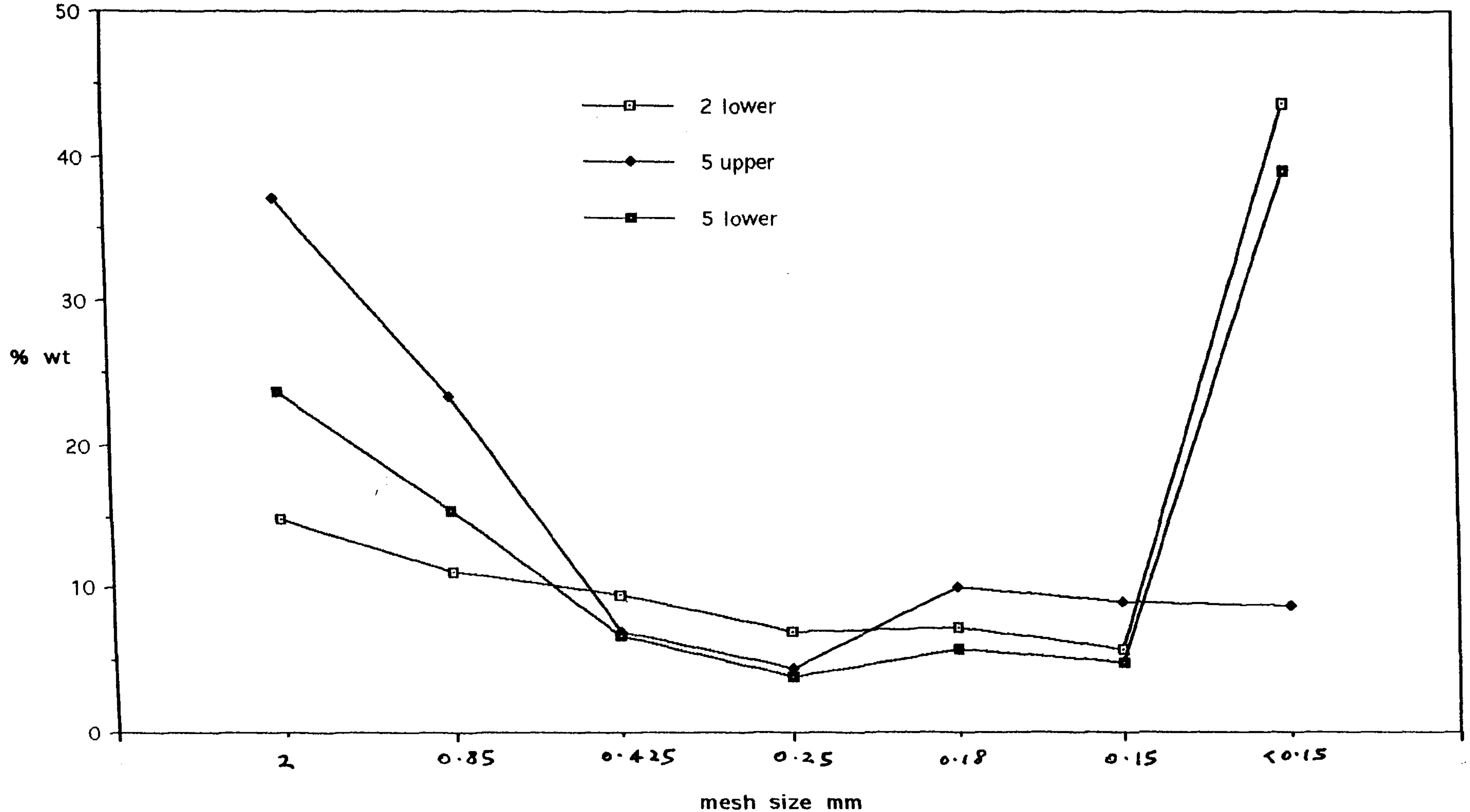
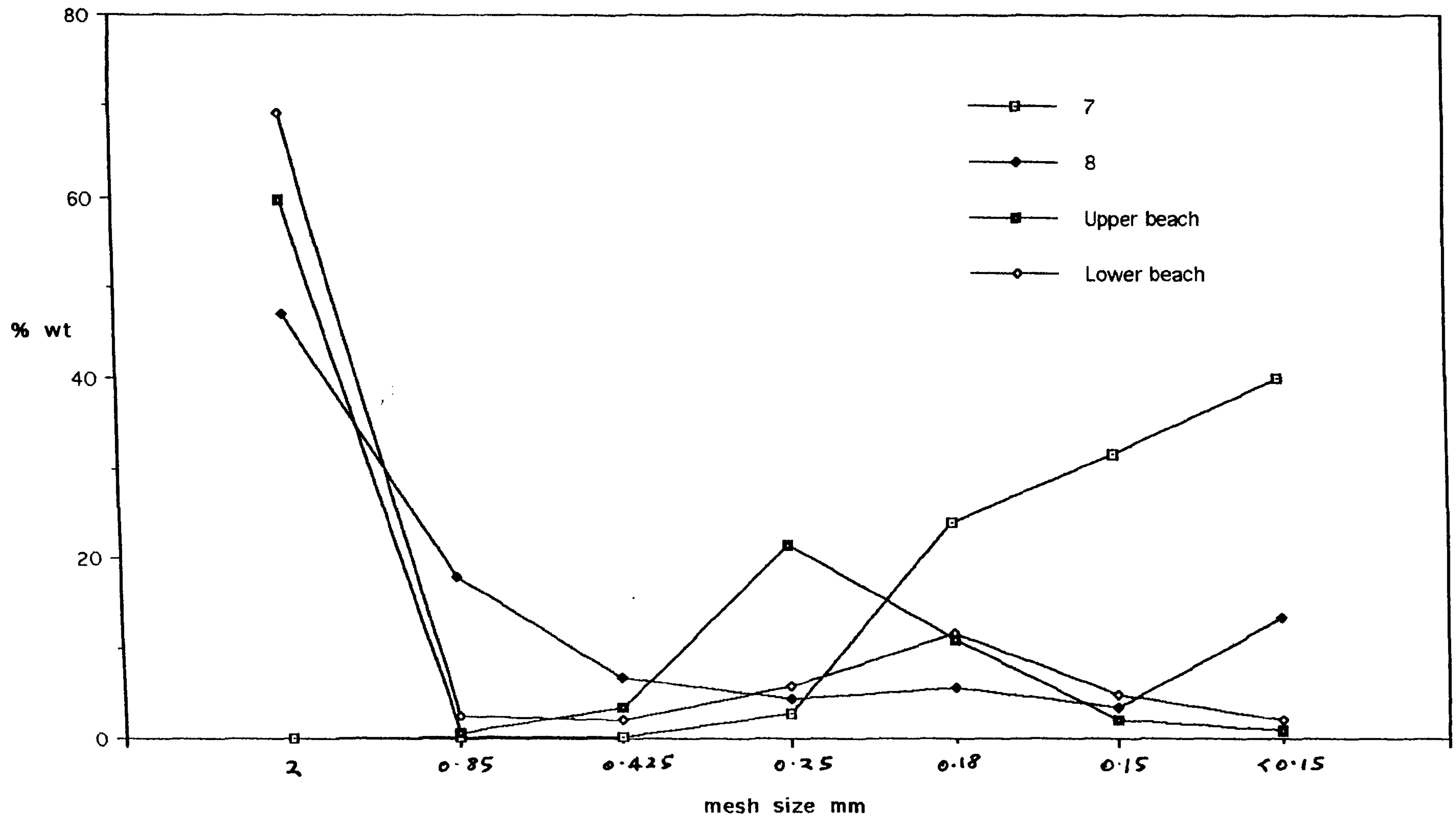


Fig. 73 Dover - Bingo hall & Beach 2



Droitwich, Worcestershire.
Bays Meadow Roman Villa.
Barfield and Tomlinson 1971, 1973, 1974.
Davey and Ling 1981, 114-115.

A collection of painted plaster from recent excavations on the site of the Roman villa complex near Droitwich.
The material was all fairly similar, being mainly light grey or brown sandy plaster, with some tile mortars. The aggregates reflected the local alluvial geology with the bulk of the material being sand and gravel. This included: round to sub-angular quartz sand, quartzite, micaceous sandstones, fine micaceous schist and fragments of brick or tile, red marl and kiln residues (fuel ash slag and vesicular cinder). Fragments of both shelly limestone and chalk were found. The source of the lime appeared to be the chalk. Sixteen samples were examined and identified, 25 samples were fully analysed. These results are unpublished.

COMPOSITIONS
The bracketed figures after the "lime" content are for measured carbonate values.

No	gravel	sand	silt	"lime"	comments
Group 1					
6)	0	59	41	31	upper layer
7)	1	57	42	31	lower layer
Group 2					
4)	1	58	41	28	upper layer with tile
5)	23	46	31	32	tile - *opus signinum*
Group 3					
8)	0	60	40	16	upper layer
9)	5	58	37	42	lower layer
Group 4					
10)	-	-	-	73	*intonaco*
10)	23	50	27	33	upper layer - *opus signinum*
11)	25	51	24	31	lower layer - *opus signinum*
Group 5					
1)	0	57	43	32	upper layer
2)	0	58	42	28	lower layer
3)	0	55	45	31	whole sample - pick mark casts

Group 6					
12)	-	-	-	77	*intonaco* - yellow
12)	2	78	20	42	whole sample
Group 7					
13)	0	59	41	28	upper layer
14)	0	57	43	32	lower layer with tile
7a 15	0	59	41	38	upper layer
16	1	60	39	28	lower layer with tile
7b 17	3	77	20	41	whole sample
7c 18	26	50	24	32	whole sample - *opus signinum*
7d 19	0	65	35	13 (11)	upper layer
20	0	63	37	20 (15)	lower layer
West hypocaust room					
21	0	59	41	34	upper layer
22	9	55	36	27	lower layer with tile
DBM 71 kiln	-	-	-	(78)	shelly limestone
DBM 73 viii (84)	-	-	-	(86)	chalky stone
DBM 76 x (18)	-	-	-	(96)	chalk

EXAMPLES OF PLASTER DESCRIPTIONS

Group 1

6), 7) Red on pink spots and traces of red on white, <0.05mm, on white *intonaco*, 0.5mm, on brownish sandy plaster, 11mm, on brownish sandy plaster, 15mm thick. The impression of a leaf on the rear of this sample showed the inclusion of organic material.

Group 2

4), 5) Patchy maroon to grey, 0.1mm, on white *intonaco*, 0.2mm, on sandy plaster, 10mm, on tile mortar, 1 - 14mm thick.

Group 3

8), 9) Red splashes on a maroon to dark red band, 0.1mm, on white *intonaco*, 0.5mm, on brown sandy plaster, 11mm, on a white lime interface, 0.5mm, on pale grey to buff sandy plaster, 11mm thick. The white interface was probably a bonding layer for over plastering.

Group 4

10), 11) Light green on red to brown on burnished or very flat white *intonaco* with red tile dust traces, 0.5 - 1mm, on tile mortar, 12mm, on tile mortar, 24mm thick.

Group 5

1), 2), 3)

a] Red on white, 0.1mm, on white *intonaco*, 0.6mm, on sandy plaster, 10 - 18mm, on sandy plaster, 8 - 15mm, total thickness 25mm .

b] As above but: dark pink to light maroon bands and red to orange traces on white on sandy plaster with pick impression casts on the rear, total thickness 16mm. The casts were about 4mm high. This was an over plaster from a pick prepared wall.

Group 6

12) Yellow, <0.05mm, on thin and variable burnished or very flat white *intonaco*, 0.4 - <0.1mm, on brownish sandy plaster, 15mm thick. This was a particularly hard sample and may have been modified by burial or by the use of hydraulic lime.

Group 7

13), 14) Rough micaceous red on white on brownish sandy plaster, 5 - 8mm, on traces of pink tile plaster.

7a: 15), 16) Rough red on pink, <0.05mm, on white *intonaco*, 0.3 - 0.4mm, on light brown sandy plaster, 3mm, on brownish sandy plaster, 15mm, thick.

7b: 17) Rough red with traces of yellow under, 0.05mm, on off white *intonaco*, 0.2 - 0.5mm, on brownish sandy plaster to 23mm, possibly layered. Also a fragment with a green spot on white.

7c: 18) Rough red on white, 0.5mm, on pink tile plaster to 25mm thick. This piece was an edge sample, possibly from a window or door.

7d: 19), 20) Green on black, 0.05mm, on white, 0.05mm, on cream *intonaco*, 0.7- 0.8mm, on light grey sandy plaster, 6mm, on white, 0.2 - 0.5mm, on light grey sandy plaster traces, 1+mm. This may have been a *giornata di lavoro* join although the lower white layer was not very flat.

West hypocaust room

21), 22) Red brown to dark maroon, <0.05mm, on grey, <0.05mm, on white, 0.05mm, on grey *intonaco*, 0.4mm, on grey sandy plaster, 9mm, on brown plaster with tile, 14mm thick.

PAINTING TECHNIQUE

The painting technique appeared all to be *buon fresco*, with the following colour arrangements: red on pink, red on white, maroon on grey, red on maroon, light green on red to brown, green on black, yellow, red on yellow.

PIGMENTS

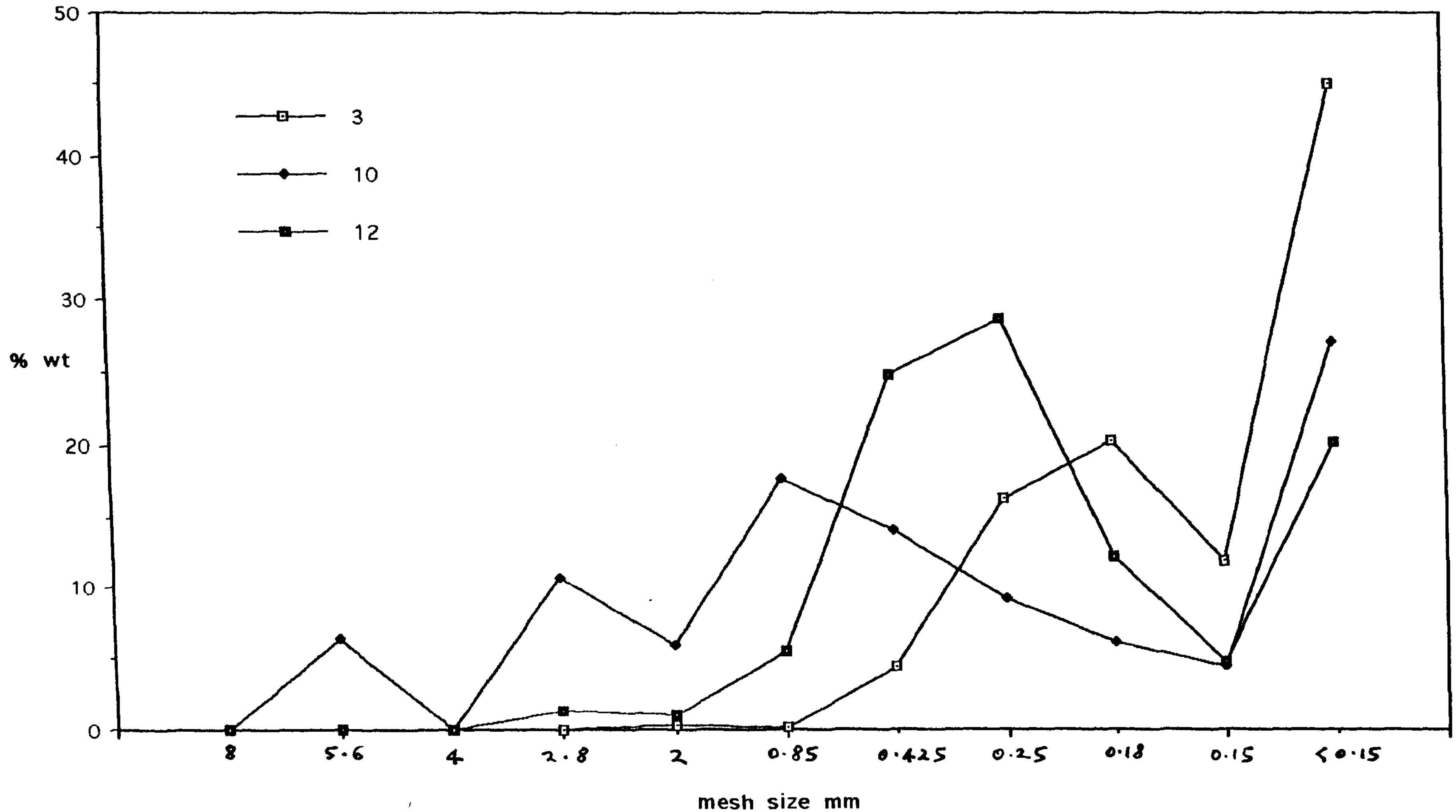
The pigments were earth colours: red to brown ochres (haematite), yellow ochre (limonite), green earth (glauconite)and carbon (soot or charcoal).

Average results

	Thicknesses		"Lime"
paint	(0.05 - 0.1)	0.1mm	-
intonaco	(0.2 - 0.75)	0.5mm	75%
upper plaster	(3 - 15)	11mm	28%
lower plaster	(11 - 15)	15mm	30%
single layer		16mm	37%

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 74
3), 10), 12)
No 10) is an *opus signinum* type plaster, the others are sandy plasters.

Fig. 74 Droitwich



Empingham, Rutland (Leicestershire)
Britannia 1970 1: 286; 1971 2: 258 - 9; 1975 6:246

Work on the report for the excavations at Empingham is currently being completed in the School of Archaeological Studies, University of Leicester.
The site is in the general area of Rutland Water, the large man-made reservoir, where both Roman and later sites were excavated in advance of the reservoir construction. The area is rich in various forms of ironstone, which was utilised as an iron source. Plasters and mortars from various areas were examined, showing a variety of different aggregate types. Ironstones, ranging from ferruginous sandstones to fossiliferous haematite and ferruginous limestones were commonly present in the aggregates. Fossiliferous and oolitic limestones were also found, together with round to sub-angular quartz sand, crushed brick or tile and small amounts of flint and quartzite. Thirty samples were examined and seventeen analyses carried out. These results are currently unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
EPR 69	0	2	98	29%	mainly silt
EPN PL 1 middle	42	30	28	44%	tile
PL 1 lower	34	40	26	46%	tile
PL 2	1	65	34	42%	coarse sand
QQ 1	29	49	22	50%	tile and sand
QQ 2 upper	2	63	35	44%	coarse sand
QQ 2 lower	1	70	29	43%	coarse sand
EPN QV 1	29	46	25	48%	tile and sand
QV 2	29	45	26	48%	tile and sand
QV 3	3	64	33	42%	coarse sand
RK 3	1	66	33	43%	coarse sand
RL 1	58	29	13	42%	tile
RL 2	28	53	19	48%	tile and sand
RS middle	38	30	32	50%	tile
RS lower	31	43	26	42%	tile
RZ 1	63	19	18	36%	tile
RZ 2	2	58	40	45%	coarse sand

The calcareous oolitic limestone sand plaster was not analysed.

EXAMPLES OF PLASTER DESCRIPTIONS

EMP 67; cutting 3 F 15:

mixed fine sandy plaster and tile plaster fragment.

EPR 69; from gulley to north of re-enforcement footings:

1) micaceous yellow brown, 0.1mm, on pink on off white, 0.15mm, on black, 0.2mm, on white traces, 0.1mm, on pale yellow fine sandy plaster, 16mm thick. The residue was mainly very fine yellow sand and silt with some coarse ironstone. This was plaster type [1].

2) red (cinnabar), red, light blue all on white *intonaco*, 0.5mm, on oolitic sand plaster, 13mm thick. This was plaster type [5].

Also buff silty plaster type[1] with black paint.

EPN 71 MT: tile not plaster.

EPN 71 NE: *opus signinum* plaster or mortar, 25mm thick.

EPN 71 NP:

red on white, 0.1mm, on white *intonaco*, 0.1mm, on sandy plaster with tile, 10mm thick.

EPN 71 NY: calcareous tufa.

EPN 71 OJ: smoothed opus signinum, 20mm+ thick. c.f. RZ.

EPN 71 OR:

pale yellow, 0.05mm, on grey, 0.05mm, on white, 0.2mm, on coarse sandy plaster with limestone, 11mm thick.

EPN 71 OS: micaceous red, 0.05mm, on pink, 0.05mm, on white *intonaco*, 0.4mm, on oolitic plaster, 12mm thick.

EPN 71 OX: micaceous red, <0.05mm, on rough white, 0.6mm, on buff silty plaster, 10mm thick.

EPN 71 PL (some samples marked EPN 71 RB):

1) white, 0.05mm, on *opus signinum*, 10mm, on red, 0.1mm, on white *intonaco*, 0.4mm, on *opus signinum*, 15mm thick. An over-plastered sample. c.f RS lower layer. This was typical *opus signinum* - plaster type [4].

2) white on maroon; black and red; white on red; red and black stripes and a yellow circle? on black to dark grey; all on white *intonaco*, 0.1mm, on coarse sandy plaster, 12 - 15mm thick with a smooth reverse and traces of over plaster. This was probably a flaked secondary layer perhaps also over-plastered. This was plaster type [2].

EPN 71 PM:

red on grey, 0.05mm, on white, 0.2mm, on coarse sandy plaster, 11mm thick.

EPN 71 PP:

1) coarse buff mortar with tile.

2) pink, 0.1mm, on smooth *opus signinum*. c.f. RZ?

3) maroon, 0.05mm, on white, 0.1mm, on coarse sandy plaster, 14mm thick.

EPN 71 PW: micaceous orange red, <0.05mm, on white *intonaco*, 0.2mm, on sandy plaster, 9mm thick.

EPN 71 PX: calcareous tufa.

EPN 71 QA:

1) maroon, <0.05mm, on white, 0.05mm, on coarse sandy plaster, 8mm thick.

2) traces of red and black on white, 0.05mm, on burnt? coarse red sandy plaster to 25mm thick. Also a sample of vitrified clay / fuel ash slag.

EPN 71 QE: tile with plaster traces.

EPN 71 QL:

1) red; dark red; maroon; yellow; brown; all on white *intonaco*, 0.3mm, on fine buff to yellow plaster in two layers, 8mm + 12mm thick.

2) green on red, 0.05mm; white on red; plain green; all on pink on white layered *intonaco*, total 0.4mm, on coarse white oolitic limestone sand plaster up to 15mm thick. The use of pink under the red may be in imitation of cinnabar, and the painting technique was of good quality.

3) pink, < 0.05mm, on white *intonaco*, 0.1mm, on coarse sandy plaster, 10mm thick. This was plaster type [5].

EPN 71 QQ:

1) coarse sandy plaster or mortar with tile, 40mm thick. This was plaster type [3].

2) red on pink; black and dark red, <0.05mm, on white *intonaco*, 0.05 - 0.1mm, on coarse sandy plaster, 5mm, on coarse sandy plaster to 30mm thick in a single? layer.

EPN 71 QV:

1) coarse cream sandy mortar with gravel and tile, 50mm thick.

2) coarse pink to cream sandy mortar with gravel and tile, 30mm thick.

3) maroon on white, 0.05mm; black and maroon on white; 0.1mm, red on white, 0.1mm; all on coarse sandy plaster in two layers, 6mm + 12mm thick. There was also a sample of pink tile plaster without paint.

EPN 71 RA:

green on yellow to red areas, 0.05mm total, and a white band over yellow red to red areas all on pink, 0.2mm, on white, 0.2mm, combined *intonaco* layer, on oolitic sand plaster, 20mm thick. c.f. QL.

EPN 71 RK:

3) lower layer, sandy plaster, 30mm thick

EPN 71 RL:

1) tile plaster - *opus signinum*, 23mm, with red to black tile.

2) buff mortar with tile, 40mm thick.

EPN 71 RN:
coarse sand and tile mortar or plaster 35mm thick. c.f. QQ. Also a sample of painted plaster: dark red on red / pink and red on white on coarse sandy plaster, 10mm thick. c.f. QQ.
EPN 71 RP:
white on micaceous red, 0.05mm, on white traces, 0.05mm, on coarse sandy plaster in two layers, 6mm + 8mm thick.
EPN 71 RQ:
coarse sandy plaster or mortar with tile, 27mm thick. c.f. QQ.
EPN 71 RS:
a multi-layer plaster showing three phases; coarse *opus signinum*, 7mm, on black, 0.05mm, on *opus signinum*, 17mm, on red, 0.1mm, on white *intonaco*, 0.4mm, on *opus signinum*, 13mm thick.
EPN 71 RV:
1) white over-paint or over-plaster, 0.6mm, on red, yellow and pink, on white *intonaco*, 0.6mm, on fine buff sandy plaster, 8mm, on coarse sandy plaster with tile, 8+mm thick. c.f. QL / QQ.
2) white line over red; green on yellow; white on red, on pink, 0.1, on white, 0.1mm, combined *intonaco* layer, on oolitic sand plaster, 14mm thick. c.f. QQ / QL.
EPN 71 RY:
1) burnt shelly clay - daub?
2) coarse sandy mortar with tile.
3) black; dark red; maroon; white, on white *intonaco*, 0.2 - 0.4mm, on coarse sandy plaster in two layers, 6mm + 10 - 20mm thick.
EPN 71 RZ:
1) coarse tile mortar or plaster, 36mm thick, with one smooth face, possibly floor or wall plaster. The aggregate was almost entirely crushed red to black brick or tile, being a good example of *opus signinum*.
2) coarse sandy mortar, 50mm thick.
EPN 71 SG; stoke hole east of room vii:
fine buff plaster? with tile.
EPN 71 well 2 (N):
1) coarse mortar with some tile.
2) fine *opus signinum* mortar.
3) off white on off white to buff *intonaco*, 0.4mm, on fine buff sandy plaster, 9mm thick.
4) orange; red; grey on white; white with blue traces on grey on white, on white *intonaco*, 0.2mm, on sandy plaster, 5mm, on coarse sandy plaster, 15mm thick.

5) white on red on white *intonaco*, 0.2mm, on pink tile plaster, 10mm, thick.

Numbered samples; EPN 71:

505: red on pink on white on oolitic plaster.

514: red on fine *opus signinum*, 2.5mm, on coarse *opus signinum*, 18mm thick.

520: red on white on buff silty plaster and a sample of *opus signinum* mortar or plaster.

523: burnished red; black on pink, all on white on oolitic plaster. Also a sample of *opus signinum* mortar or plaster.

524: micaceous red on white on sandy plaster.

526: burnished red; black on pink; green on red on pink; white band, 5mm wide) on red, all on white on oolitic plaster. Some pieces had a lime covering, 0.5mm thick, which could have been over-plastering or over-painting.

527: light blue, 0.1mm, on white traces, 0.05mm, on sand plaster, 14mm thick.

529: maroon on rough white on sandy plaster.

532: light *opus signinum* traces on red, black, white on white traces on dark *opus signinum*, 13mm thick. This was an over-plastered sample. Also a sample of dark red on white on white *intonaco* on sandy plaster.

543: light blue on white traces on sandy plaster.

549: light blue, 0.075, on white *intonaco*, 0.1mm, on sandy plaster, 7mm thick.

550: red to pink on white on sandy plaster.

554: red on pinkmon white on oolitic plaster.

558: red and plain white on white on buff silt and limestone sand and gravel, 15mm thick. This was probably the same as the fine buff silty plaster with added limestone gravel.

560: grey to black on white traces on sandy plaster.

Five types of plaster or mortar were present:

[1] fine buff plaster, containing quantities of micaceous clay or silt.

[2] coarse sand plaster.

[3] tile and sand or gravel plaster.

[4] tile only - *opus signinum* type.

[5] oolitic limestone sand plaster.

PAINTING TECHNIQUE

The paint appeared to have been generally applied in the *buon fresco* method, although some of the over-painting may have been in *fresco secco*. The use of pink on white *intonaco* is of note as it was used as an ground layer for cinnabar on occasion. The cinnabar found was however on a white ground.

PIGMENTS

The pigments used were those commonly found in Roman Britain: red ochre (haematite) or brick dust, yellow ochre (limonite), green earth (glauconite), white lime, black soot or charcoal and crushed Egyptian blue, this being manufactured and probably imported. The imported red, cinnabar, was only found in painting on the oolitic plasters.

<u>Average results</u>

	Thicknesses		"Lime"
paint	(0.05 - 0.2)	0.07mm	-
intonaco	(0.1 - 0.6)	0.2mm	-
upper	(5 - 28)	12mm	43% sand 49% sand and tile
middle	(15 - 30)	16mm	-
lower	(13 - 30)	21mm	43%
single layer	(23 - 40)	33mm	43% tile
single layer	(30 - 50)	41mm	43% sand

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:

Fig Nos 75 - 77

[1] was mainly silt and not therefore illustrated.

[2] coarse sand: QV 3, RK 3, PL 2, QQ 2 upper.

[3] tile and sand: RL 2, QV 1, QV 2, QQ 1.

[4] tile only: RZ 1, RL 1, RS middle, PL 1 middle.

The graphs are quite distinctive, clearly showing the variations in composition.

Fig. 75 Empingham - type 2 - coarse sand

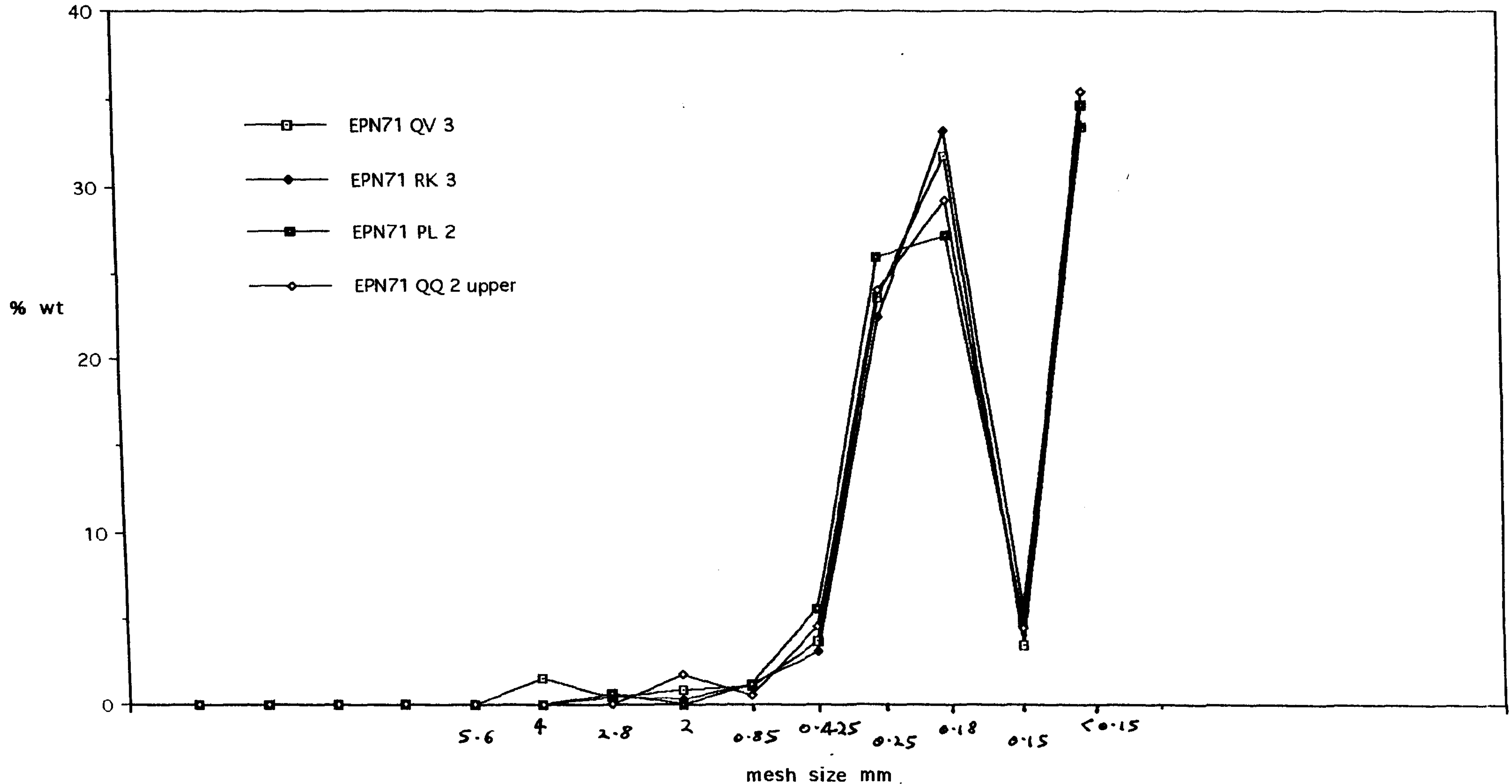


Fig. 76 Empingham - type 3 - tile and sand

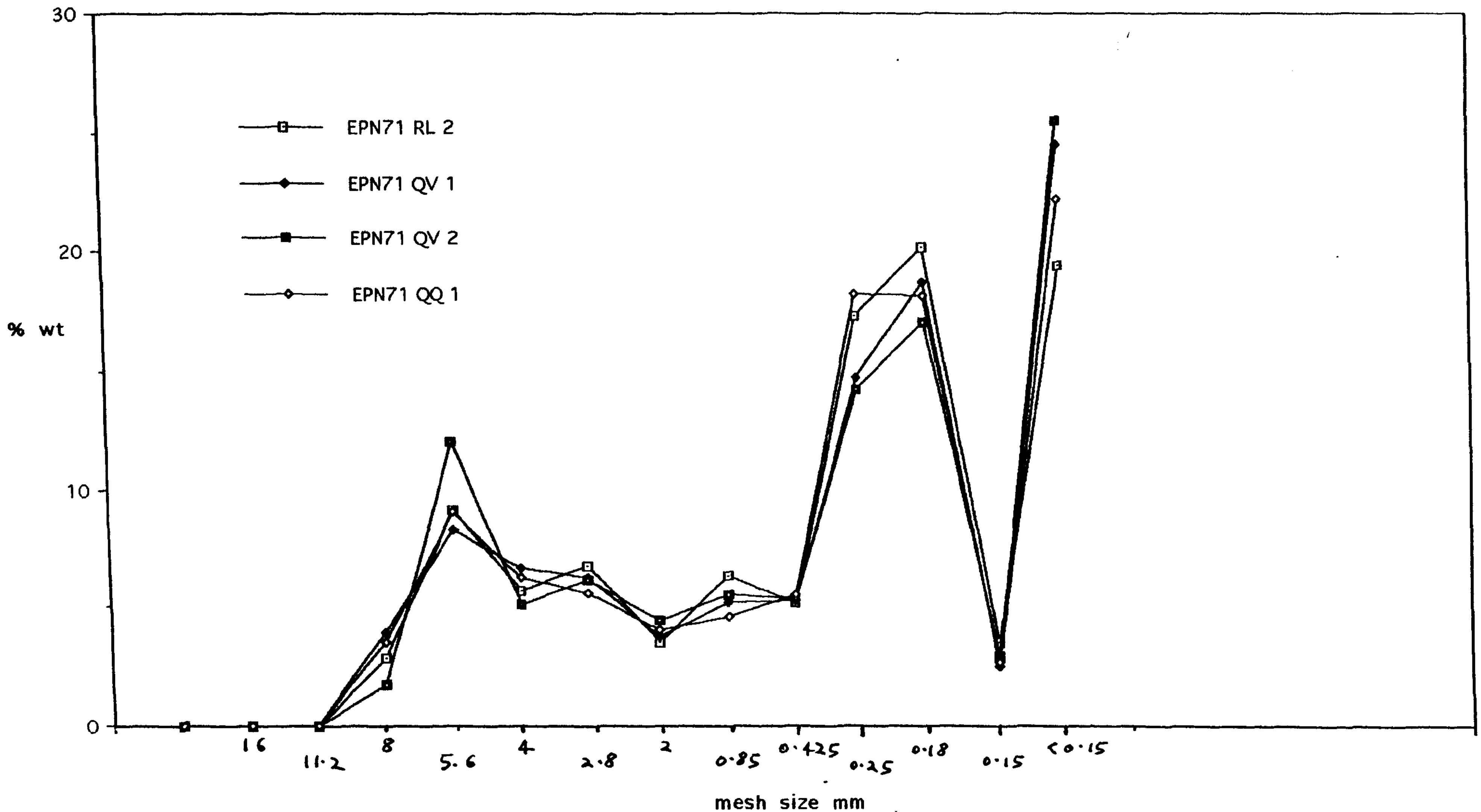
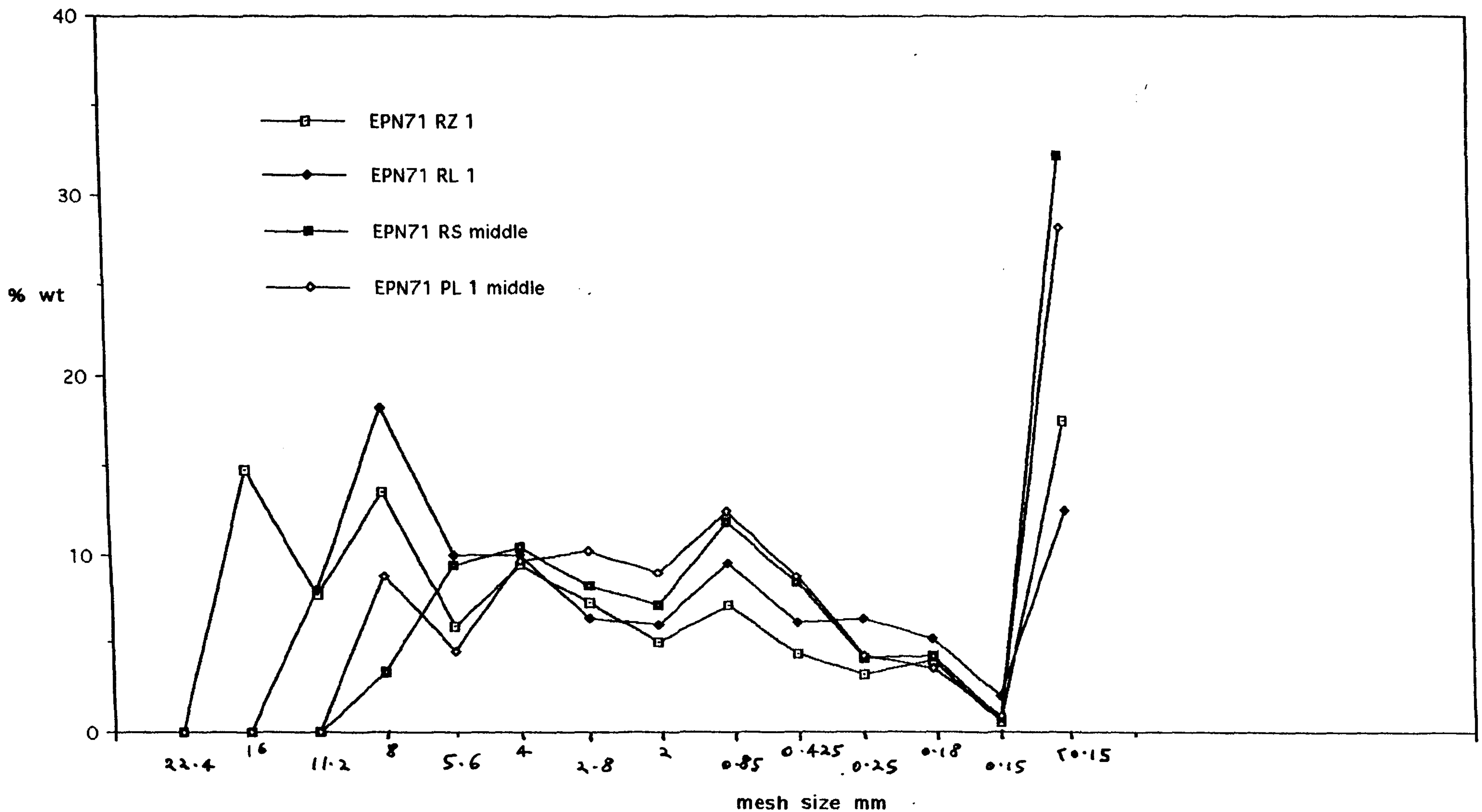


Fig. 77 Empingham - type 4 - tile / opus signinum



Exeter, Devon
Bidwell 1979

Excavations in Exeter revealed remains of the Roman Basilica ranging in date from the first to the fourth centuries, and many other buildings. The mortar and painted plaster was deposited in the Royal Albert Memorial Museum in Exeter. Examination of samples showed that many pieces had come from over-plastered walls. The aggregates contained quantities of the local red sandstone, giving a distinctive reddish colour to plaster. The aggregate was identified as mainly river sands and gravel, being composed: of round to angular quartz, feldspars, micaceous siltstones, "granite", haematite, micaceous schists, red, green and other sandstones and crushed brick or tile. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
E2 1 (1)	-	-	-	15%	polished red
	-	-	-	33%	red *intonaco*
	43	50	7	27%	secondary plaster
F2 1	-	-	-	90%	white *intonaco*
	25	65	10	24%	primary plaster, upper layer
	35	50	15	38%	lower layer, *opus signinum*
F3 1 (1)	-	-	-	90%	white *intonaco*
	32	60	8	24%	upper layer
	37	54	9	28%	lower layer, with tile
F3 1 (2)	33	59	8	30%	secondary plaster
	-	-	-	86%	primary *intonaco*
	29	61	10	27%	primary plaster
F3 1 (3)	-	-	-	93%	white *intonaco*
	47	46	7	26%	upper layer
	26	64	10	26%	lower layer with tile
G2 3	-	-	-	26%	polished red and *intonaco*
	36	58	6	29%	secondary plaster
	36	56	8	26%	primary plaster with tile
G2 4	-	-	-	63%	upper *intonaco* with quartz
	-	-	-	82%	lower *intonaco*
	33	58	9	26%	plaster
G3 1 (1)	-	-	-	25%	polished red and *intonaco*
	37	57	6	31%	upper, secondary layer
	41	49	10	45%	primary, *opus signinum*

Bath 1)	26	66	8	31%	*caldarium* mortar
Bath 2)	5	94	1	34%	*pilae* mortar
PS 85 3079	65	31	4	7%	city wall mortar (leached)
BSE 1980 395					
1)	44	44	12	24%	plaster, upper lower
	45	46	9	19%	plaster, lower layer
2)	39	48	13	27%	plaster
3)	32	54	14	19%	plaster, upper layer
	35	51	14	19%	plaster, lower layer
WM72					
2)	18	73	9	24%	plaster
3)	22	69	9	25%	plaster, upper layer
	19	71	10	25%	plaster, lower layer
4)	-	14	-	80%	carbonate, *intonaco*
	41	47	12	23%	plaster, upper layer
	41	46	13	22%	plaster, lower layer
5)	-	18	-	74%	carbonate, secondary *intonaco*
	33	51	16	51%	plaster, secondary upper layer
	21	58	21	25%	plaster, secondary lower layer
	-	17	-	77%	carbonate, primary *intonaco*
	32	52	16	18%	plaster, primary upper layer
	46	42	12	20%	plaster, primary lower layer

EXAMPLES OF PLASTER DESCRIPTIONS

BASILICA

WN 1972 Cathedral Close "context 2"

E2 1:

part 1) polished red on pink paint? on orange red *intonaco* with tile, 0.5mm, on off white plaster with pebble, 10mm, on on dirty white lime *intonaco*. This was a flaked secondary plaster.

part 2) polished red, 0.5mm, on red *intonaco*, 1mm, on off white plaster with pebbles with a tapering section, 0.5 - 6mm, on black on light and dark green and red on white *intonaco*, 1.5mm, on off white plaster with pebbles possibly in two layers, 10 + 5mm thick. This was an over-plastered sample.

F2 1; Basilica steps context, c 80 A.D.:

black on light and dark green on white *intonaco* in two layers, upper; lime with quartz, 0.5mm, lower; pure lime, 1 - 1.5mm, on grey to off white plaster with pebbles possibly in two layers, 11 - 18mm, on pink tile plaster, 8 - 14mm thick. This was very similar to the lower part of E2 1 part 2).

F3 1; period 3 wall foundation context, c 340 - 350 A.D. No 1:
grey on white *intonaco*, 1mm, on off white plaster with pebbles in two layers with tile traces, 10mm and 14+mm thick.
F3 1 No 2:
polished red on red *intonaco*, 0.5mm, on off white pebble plaster, 10mm, on white *intonaco* with a red line, 1 - 2mm, on off white to pink plaster with pebbles, 12mm thick. Also a sample with green on white *intonaco* on two layer off white plaster with pebbles.
F3 1 No 3:
trace of a black line, 8mm wide, on white *intonaco*, 1 - 1.5mm, on two layer plaster with pebbles and tile traces, 9 - 12mm and 17+mm thick.
Stone drain with mortared sides and floor context, c 80 A.D.:
G2 3:
polished micaceous red on orange red *intonaco* with tile on off white plaster with pebble, 15mm, on off white to pink plaster with tile, 20mm thick. c.f. G2 4, F3 1.
G2 4:
red on white *intonaco*, 2.5mm, in two equal layers; upper layer of lime with quartz, lower layer of pure lime, on two layers of off white plaster with pebbles and tile traces, 14mm and 11+mm thick. Also a sample with green on white *intonaco*, 2.5mm, on two layer plaster, 13mm and 17+mm thick.
G3 1 No 1:
green on white on polished micaceous red on orange *intonaco* with tile, 0.5mm, on off white plaster, 9mm, on traces of white on orange *intonaco* with tile, 0.5mm, on pink tile plaster, 25 - 35mm thick. c.f F2 1.
G3 1 No 2:
red on white *intonaco*, 0.5 - 1.5mm, on two layer plaster with pebbles and tile traces, 2 - 7mm and 1 - 18mm thick. Also a sample with black on green on white *intonaco* possibly in two layers, 2 - 5mm, on off white plaster in two layers, 5mm and 25mm thick.
Bath house
1) coarse gravel and sand mortar with some brick or tile, 18 - 28mm thick, from the east apse of the *caldarium*, period 1a,c 60 A.D.:
2) porous buff to light grey sandy mortar with grass or straw impressions and traces of brick or tile, 12mm thick, from the *hypocaust pilae* in the *caldarium*, period 1a, c 60 A.D.:
Wall
PS 85 3079; leached? red to brown gravel with buff mortar traces from the Roman town wall, c 180 200 A.D.:

BSE 1980 395; demolition of late Roman town house, c third to fourth century; these samples were all darkened apparently due to burial in sulphide rich deposits:

1) orange on white, 0.05 - 0.1mm, on grey? *intonaco*, 0.5mm, on coarse pink plaster, 15mm, on coarse pink plaster, 15mm thick. The pink colour was due mainly to the red sandstone and clay. Also a sample with white on off white on grey *intonaco* on coarse pink plaster as above.

2) yellow brown? on white?, 0.05mm, on grey? *intonaco*, 0.5mm, on coarse light grey plaster in one? layer, 20mm thick. Also a sample with brown? on grey *intonaco* on coarse pale grey plaster as above.

3) dark red, 0.25mm, on white *intonaco*, 0.5mm, on coarse pink plaster, 24mm, on coarse pink plaster 15mm thick, all with straw impressions. The pink colour was due mainly to the red sandstone and clay.

War Memorial site, WM 72, WX 5A 1100 trench 8:

1) red band on polished white, 0.05mm, on white *intonaco*, 1mm, on coarse off white to pink plaster, 3.5mm, on red sand and gravel plaster, 4mm thick. This was a flaked secondary layer.

2) brushed black on rough white, 0.75mm, on coarse off white sandy plaster with straw impressions in one? layer, 23mm thick.

3) brushed black on rough white *intonaco*, 0.75mm, on off white coarse plaster in two layers, 11mm + 11mm thick.

4) brushed dark red, <0.05mm, on white *intonaco*, , 1 - 1.5mm, on coarse buff plaster with straw impressions, 18mm, on coarse red sand and gravel plaster, 24mm thick. Both plaster layers were very heterogeneous.

5) black stripe, 5mm wide, on burnished white *intonaco*, 0.5 - 1mm, on off white to pink plaster, 3 - 4mm, on pink to red plaster, 3 - 4mm, on red stripe on white *intonaco*, 2mm, on coarse buff to red plaster in two layers, 10mm + 25mm thick. The secondary black stripe was on almost the same alignment as the primary red stripe. This sample was very similar to WM 1), which was too small to be analysed.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* method, although the black stripe on the burnished sample may have been applied by the *fresco secco* technique.

PIGMENTS

The pigments were the usual natural colours: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), carbon as soot or charcoal and white lime.

<u>Average results</u>

	Thicknesses	"Lime"
mortar / render	23mm	33%
pilae mortar	12mm	33%
secondary plaster		
paint	0.05mm	_
polished red	0.5mm	15%
red *intonaco*	(0.5 - 1) 0.8mm	33%
red and *intonaco*	-	25%
white *intonaco*		74% carbonate
upper plaster	(3.5 - 10) 7mm	29%
divided layer	4mm	51% upper, 29% lower
primary plaster		
paint	(0.05 - 0.25) 0.1mm	-
white with quartz	0.75mm	63%
intonaco	(0.5 - 3) 1.3mm	88%
		77% carbonate
upper plaster	(10- 24) 13mm	24%
lower plaster	(5 - 25) 19mm	23%
opus signinum	14mm	38%

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig. Nos 78 - 84
E2 1 (1), F2 (1) upper and lower, F3 1 (1) upper and lower;
F3 1 (2) upper and lower, F3 1 (3) upper and lower;
G2 3 secondary and primary, G2 4, G3 1 (1) secondary, and primary;
bath 1 apse, bath 2 *pilae*, city wall, G3 1 (2) upper and lower;
BSE 395 (1) upper and lower, (2), (3) upper and lower;
WM 72 (2), (3) upper and lower, (4) upper and lower;
WM 72 (5) secondary 1 and 2, primary 1 and 2.

The graphs show a wide range of generally poorly graded sands and gravels.

Fig. 78 Exeter 1

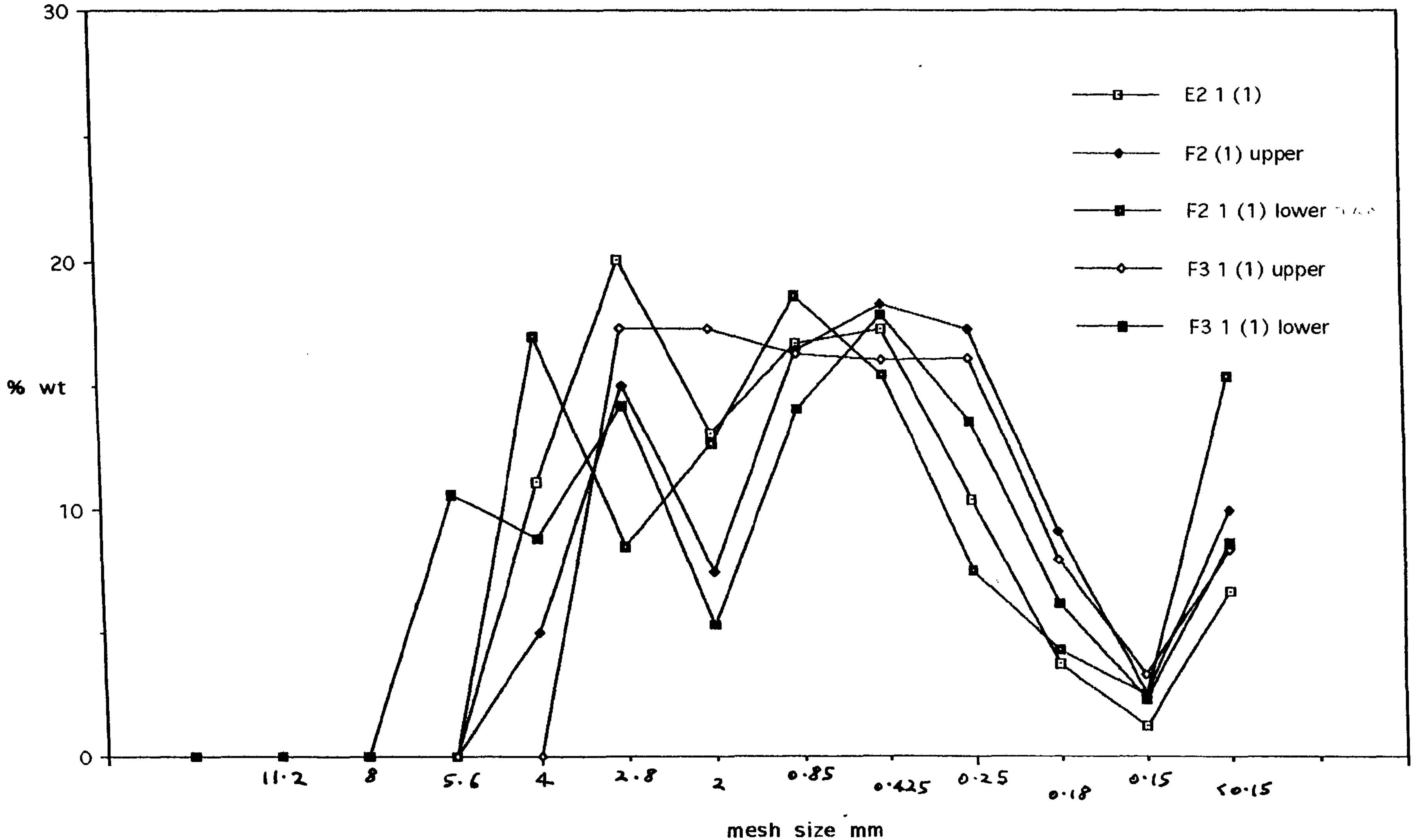


Fig. 79 Exeter 2

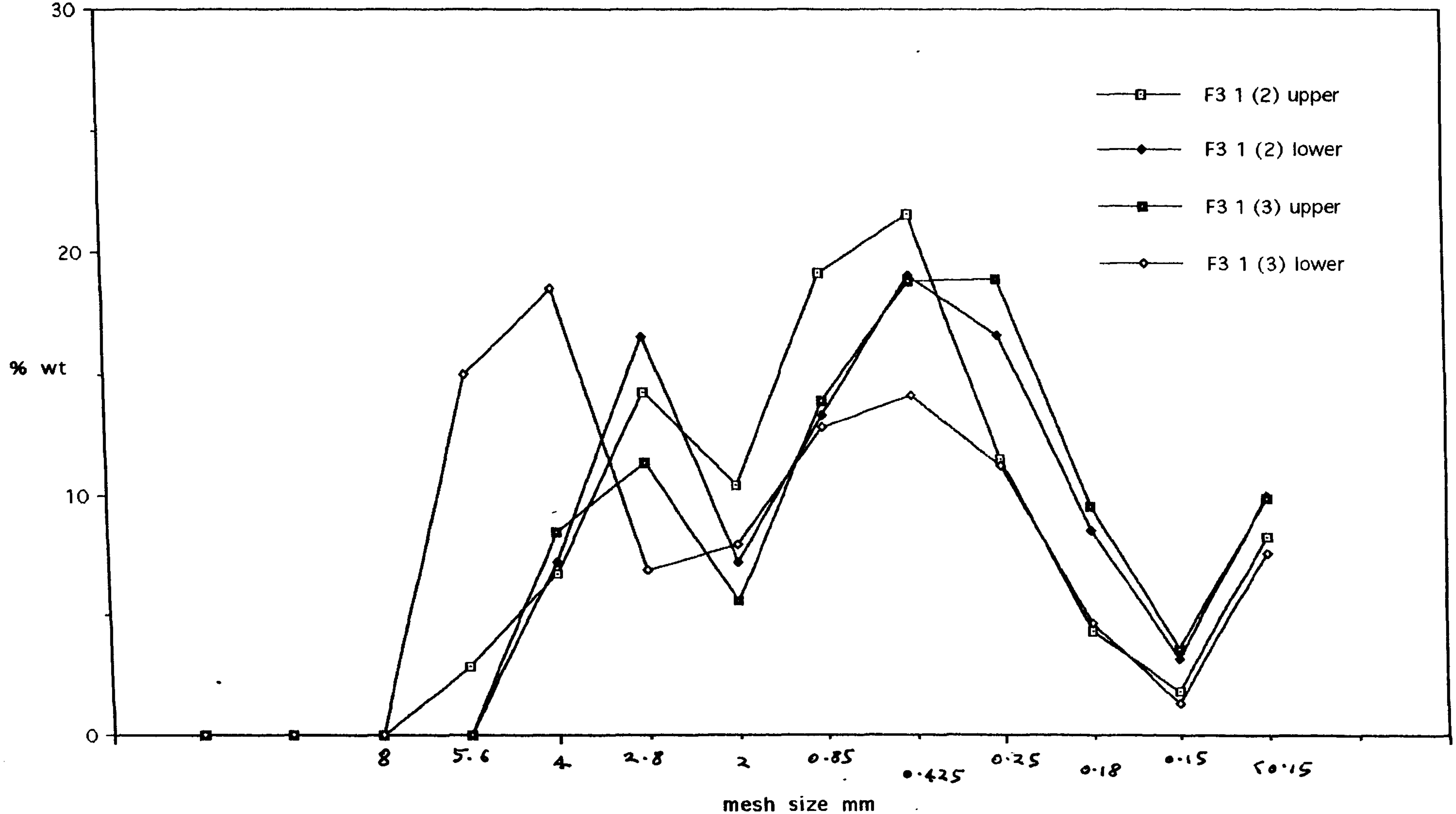


Fig. 80 Exeter 3

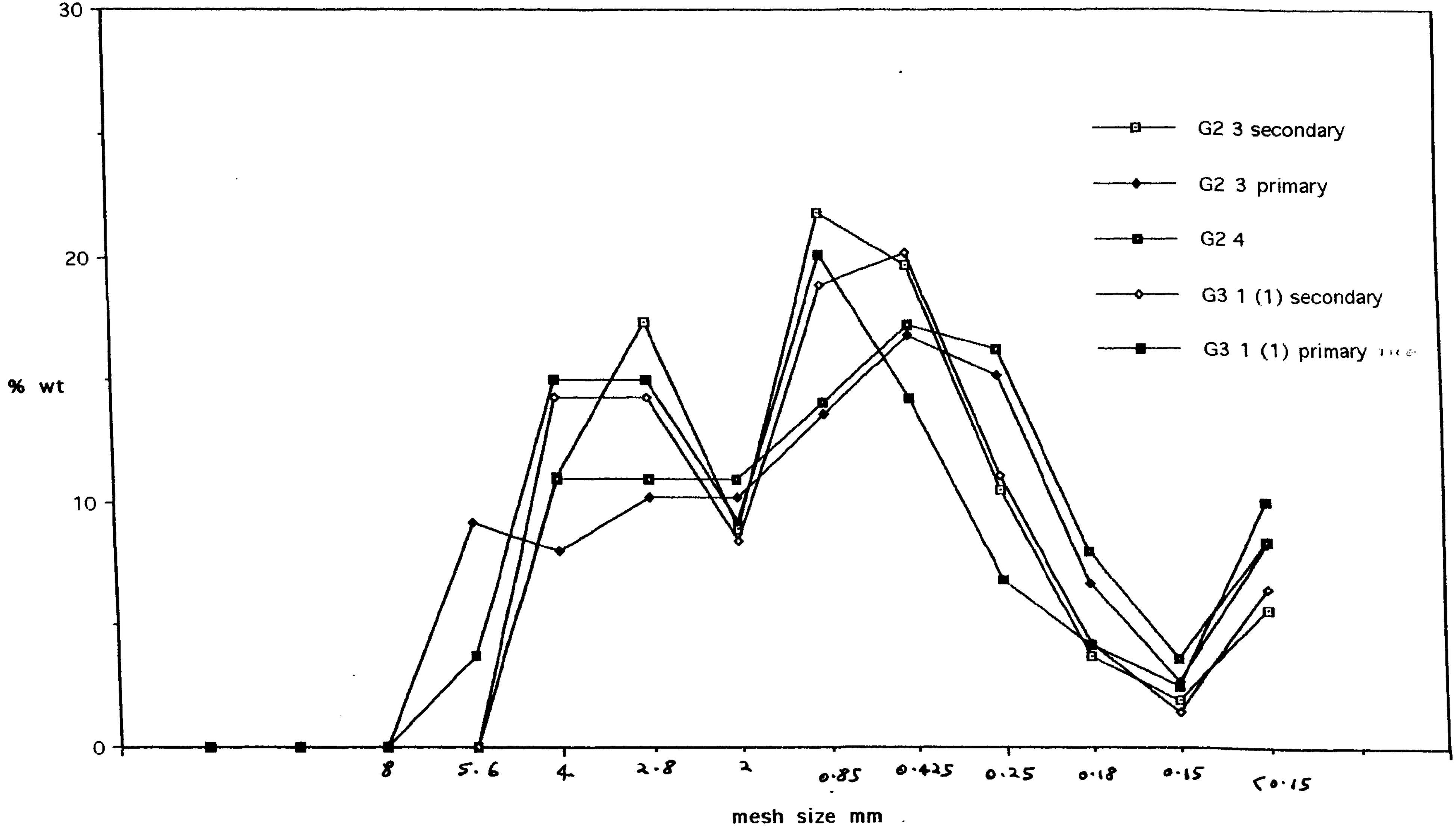


Fig. 81 Exeter 4

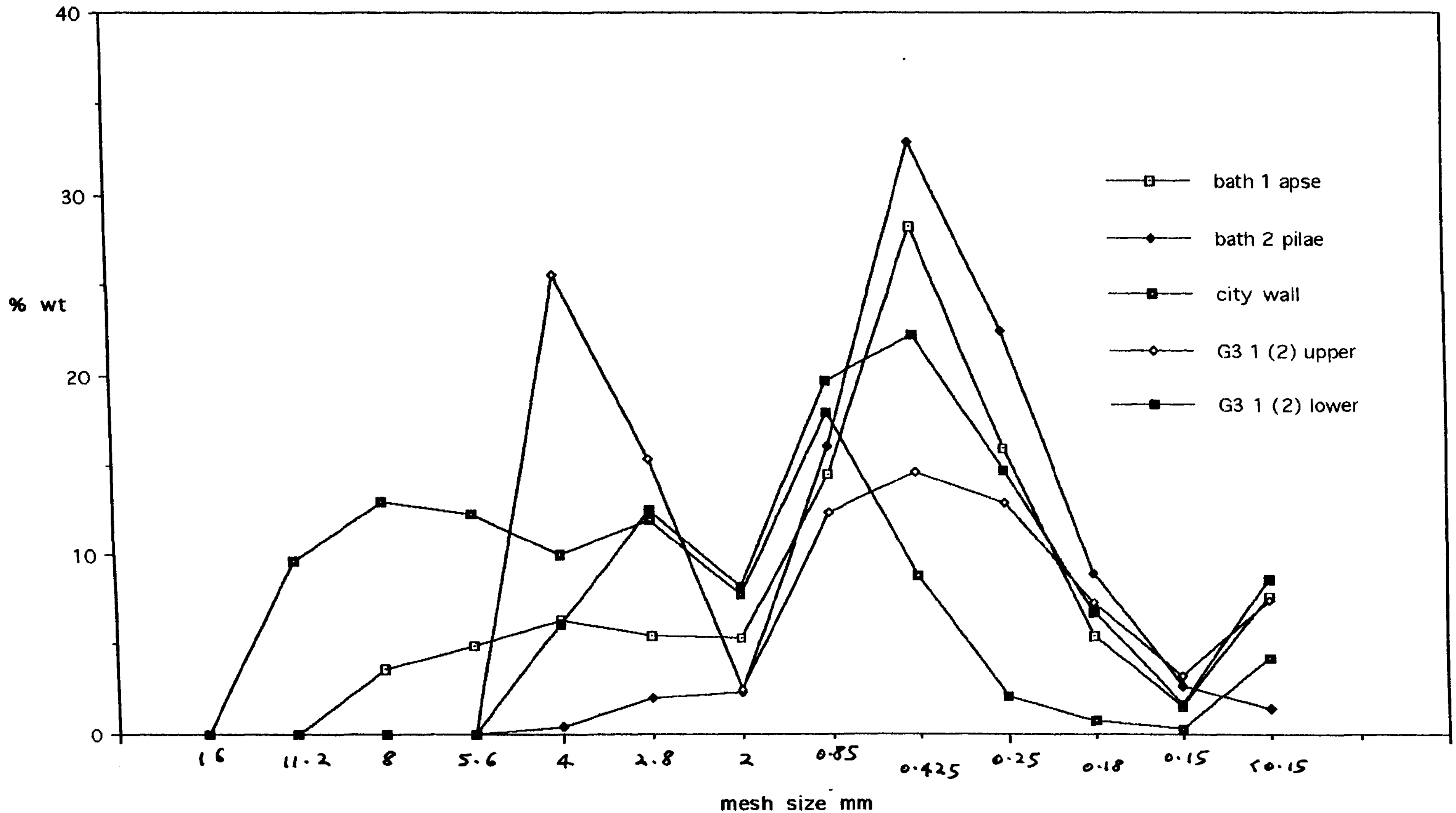


Fig. 82 Exeter 5

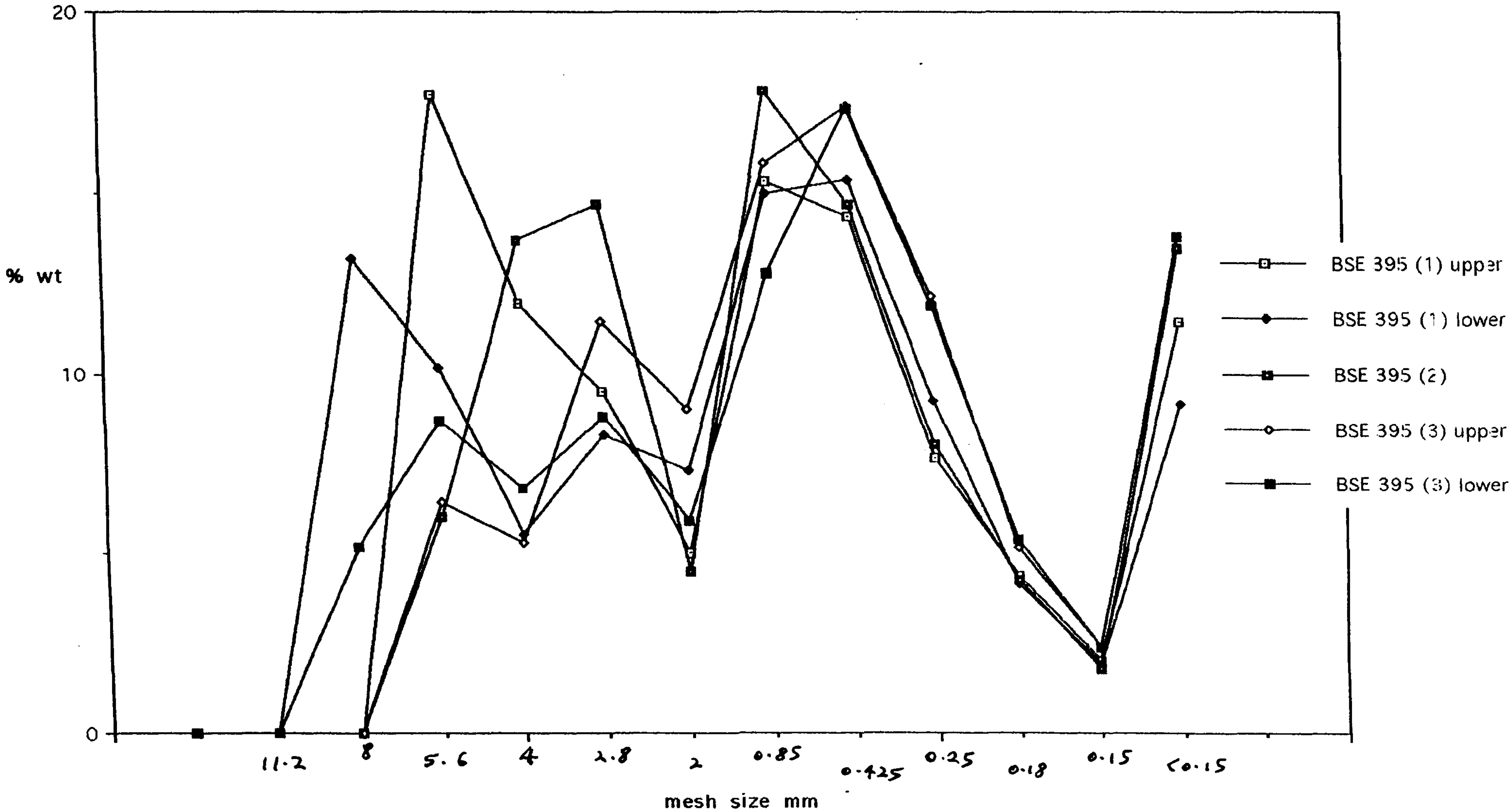


Fig. 83 Exeter 6

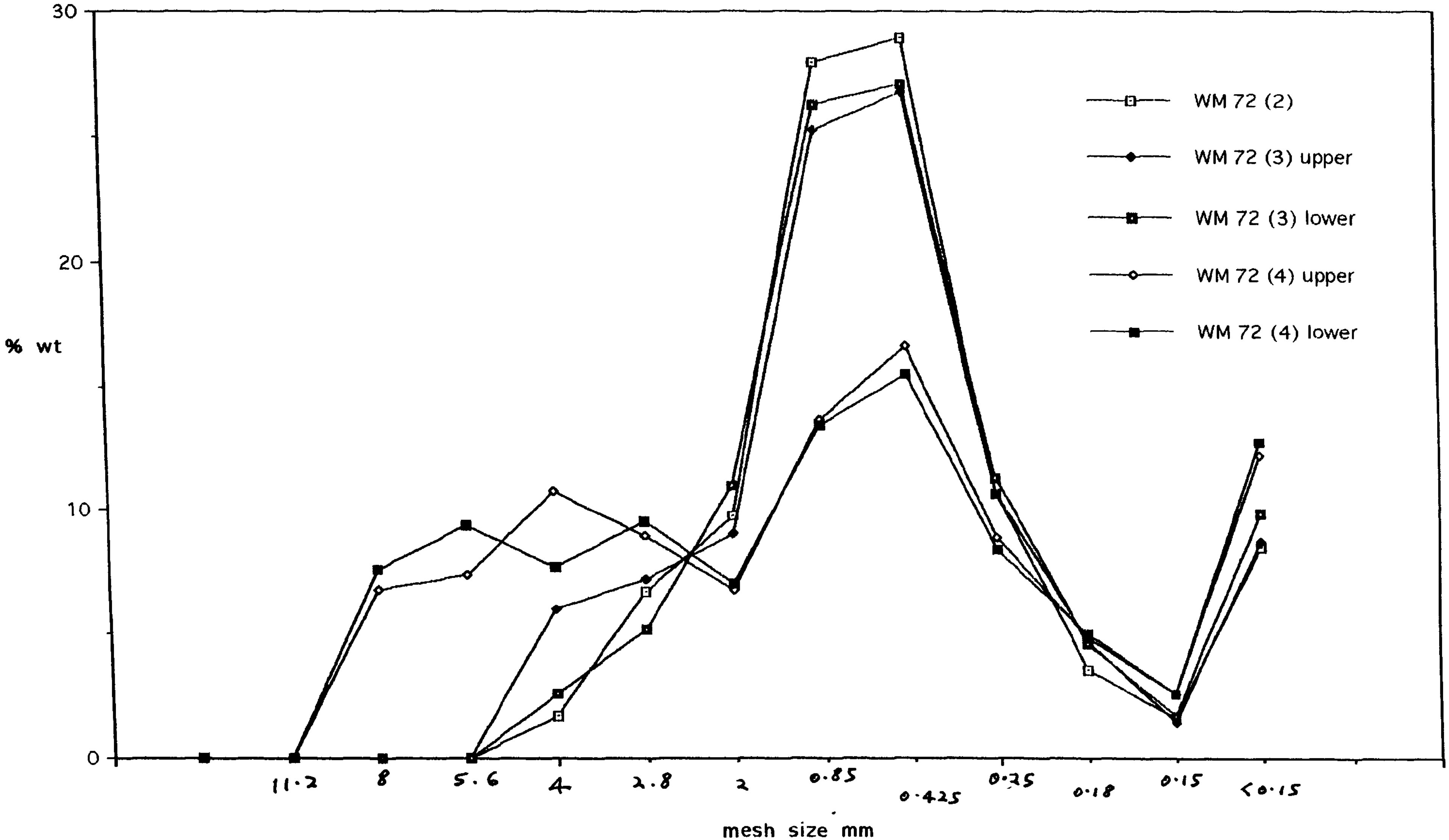
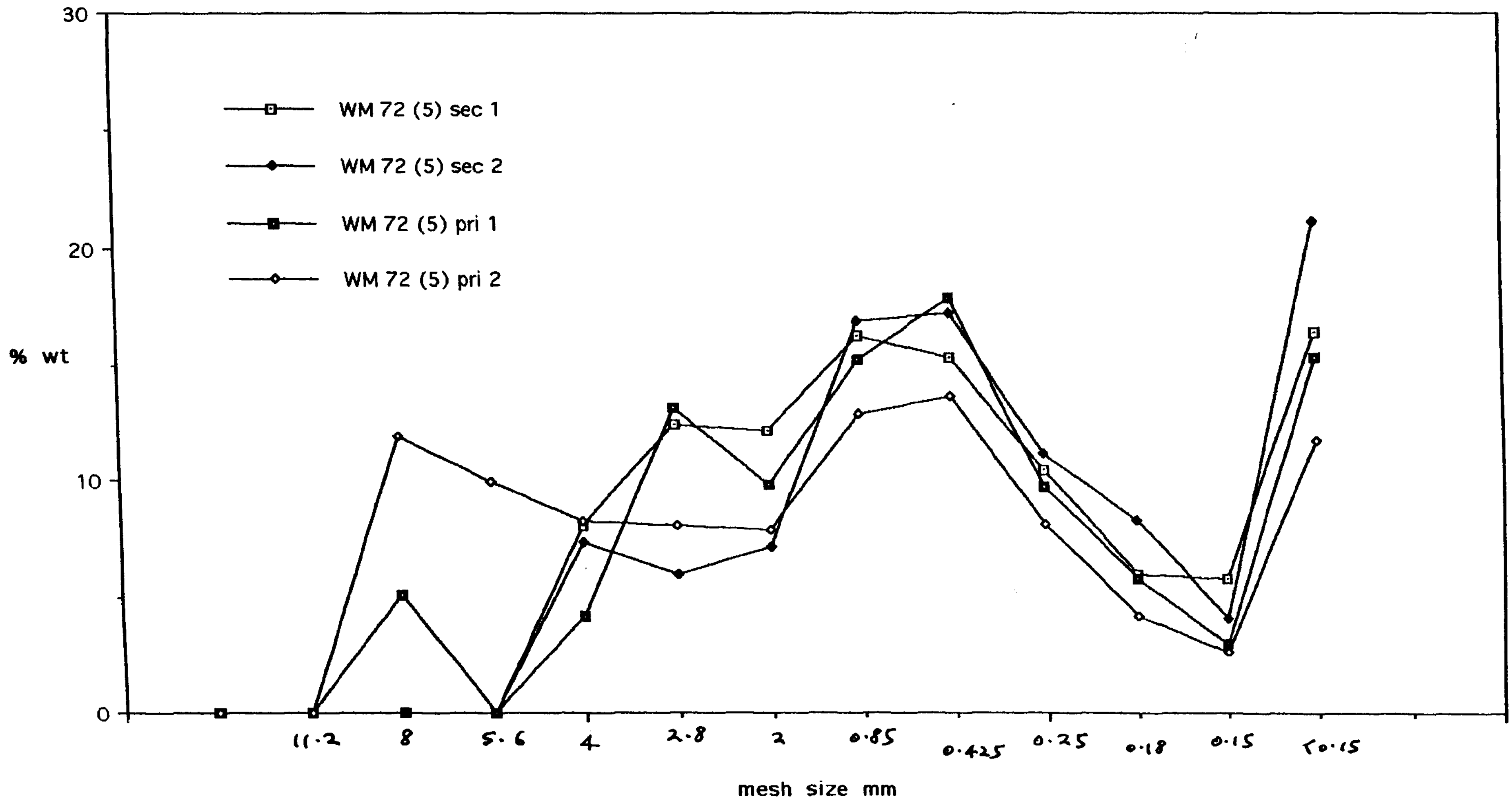


Fig. 84 Exeter 7



Feltwell, Norfolk
Gurney 1986: 29 - 30, 43

A Roman villa site dating up to at least the late fourth century.

Examples of painted plaster from the bath house. The three samples come from two different bath house excavations, one by Curtis and the other by Greenfield, both dug (on the same site?) in 1964. Only the Greenfield site has been reported on. The analysis of the Curtis sample compares with material from the temple? complex at nearby Hockwold. Five samples were examined and three analyses carried out. The values for the wall and buttress mortars are estimated from previously analysed samples.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
WP 1	62	27	11	29%	*opus signinum*
WP 2	38	42	20	52%	*opus signinum*
C 4921	-	66	34	34%	torching
M 1	3	57	41	42%	wall, approximate values
M 2	2	66	32	49%	buttress, approximate values.

PLASTER DESCRIPTIONS
FL 280 WP 1:
a crushed sample but showing traces of: off white with pink tile and sand, 0.5mm, on *opus signinum* tile plaster, 15mm thick. Other fragments showed: white in three layers totalling 0.5mm and black on white, 0.25mm thick, all on tile plaster a above.
FL 281 WP 2:
dark green on dark red on white sandy plaster on red to purple, 1mm, on *opus signinum* , 32mm + 25mm thick. The original dark red to purple painted plaster was partially over plastered and re-painted in green on red. This irregular sample may have come from a wall edge or possibly some form of moulding.
Curtis: C No. 4921, 203 967, 82.9823:
Bath house: a tile bonding mortar or "torching" of white sandy mortar. The aggregate consisted mainly of flint and sand with tile traces. c.f. Hockwold B 22.

PAINTING TECHNIQUE
Probably *buon fresco.*

PIGMENTS

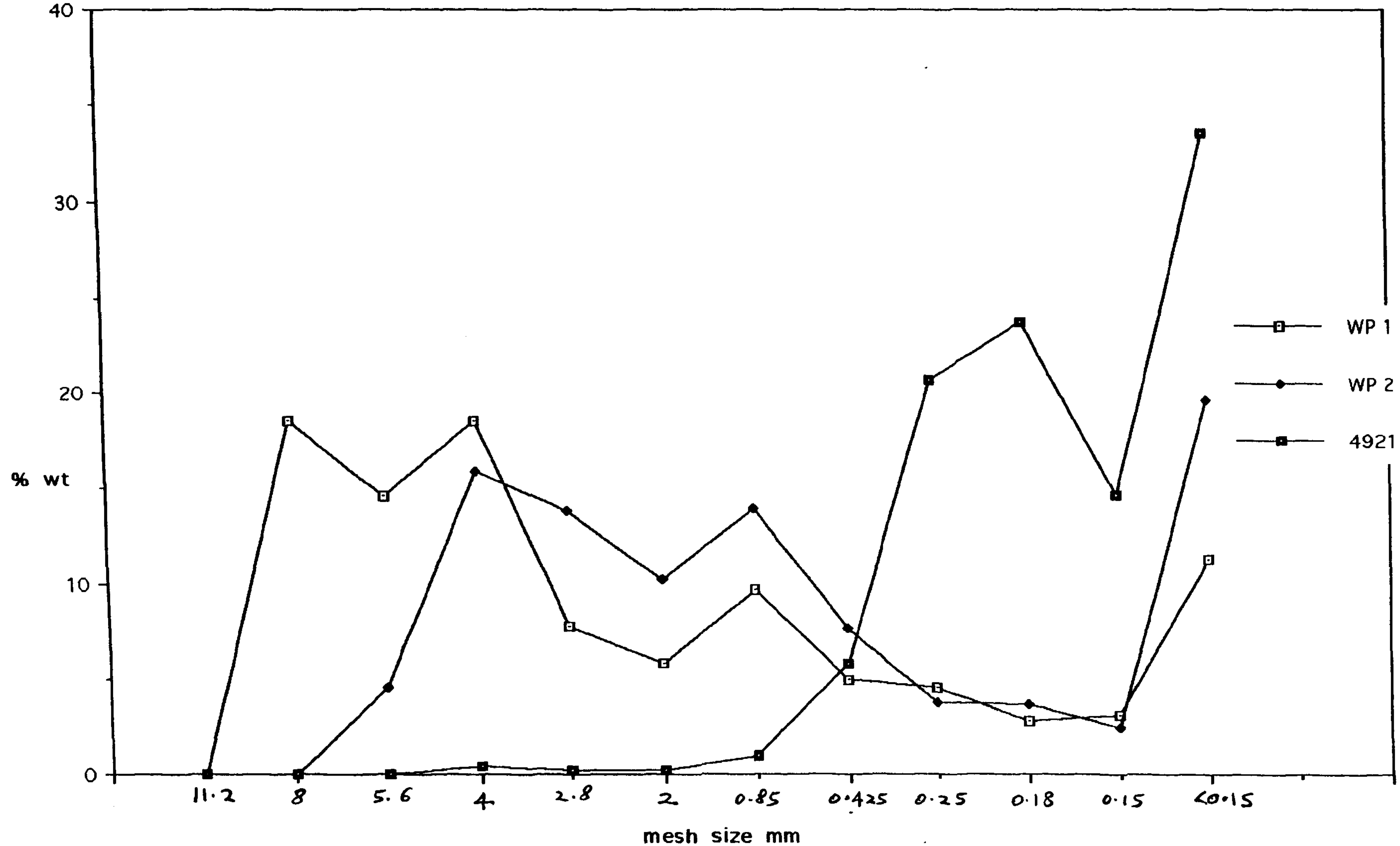
White lime, red ochre (haematite), green earth (glauconite) and carbon as soot or charcoal.

Results

	Thicknesses	"Lime"	
intonaco	0.5mm	-	
plaster	15mm	29%	*opus signinum*
torching	-	34%	
mortar	-	42%	wall
mortar	-	49%	buttress

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 85
FL 281, FI 280, C 4921. The tile curves are quite different to the sand curve, although even that is not closely graded.

Fig. 85 Feltwell



Fishbourne Roman Palace, West Sussex.
Cunliffe 1971
Rudkin (forthcoming - 1992)

Material from excavations to the south of the main palace (first to third centuries) in 1987 - 88 revealed structures including a "Hippodromos". This material was examined and forms the bulk of this report. Three fragments of painted plaster from the main palace excavations from 1965 - 67 were also examined.
The mortar and plaster from Fishbourne was based almost entirely on chalk gravel and sand with flint and smaller amounts of quartz sand. Crushed brick or tile was also used. The resulting white mortar and plaster was often very hard and subsequent analysis difficult. Some samples were simply crushed and sieved, others were partially crushed and partially dissolved in dilute acetic or hydrochloric acid. The presence of silica fossils, chert and flint in the chalk probably led to the formation of partially hydraulic lime or hydraulic type aggregates. The estimations of "lime" content is approximate. Many mortar samples contained re-used plaster from earlier structures. Sixty two samples were examined and thirty three fully analysed.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
A 75 6	64	28	8	12%	flint and chalk
A 100 2	53	35	12	4%	‖
A 100 7	62	33	5	17%	‖
A 100 8	84	13	2	9%	‖
A 102 1	87	11	2	6%	‖
A 105 5	74	21	5	9%	‖
A 105 5a	81	15	4	16%	‖
B 31	51	30	19	15%	‖
B 57 3	61	31	8	12%	‖
B 66 4	57	31	12	5%	‖
B 66 4a	60	30	10	12%	‖
B 67 9	62	33	5	12%	‖
D 36 1	11	60	29	33%	plaster type 2) top layer
D 36 1	15	64	21	23%	plaster lower layer
D 37	33	21	46	36%	mortar, top layer
D 37	35	28	37	68%	plaster type 3
D 37	7	63	30	33%	plaster type 2
D 37	46	23	31	38%	mortar, Flavian palace wall

D 37	20	50	30	66%	mortar, with plaster type 2
D 38	72	14	14	25%	mortar and plaster
D 39	52	30	18	27%	mortar
D 42 2	16	54	30	≈30%	plaster type 2 (crushed)
D 42 2	20	64	16	23%	plaster type 2 (acid)
D 42 2	19	59	22	≈22%	plaster type 3 (crushed)
D 42 2	27	60	13	39%	plaster type 3 (acid)
D 43 1	83	9	8	30%	chalk and flint mortar
D 43 1	74	12	13	36%	re-dissolved
D 43 2	74	16	10	57%	(HCl)
D 55	42	26	32	50%	mortar
F 3	82	11	7	23%	mortar
"H 90"					
S. Hippodromos	-	-	-	79%	*intonaco*
	22	66	12	35%	upper plaster (HCl)
	19	69	12	33%	lower plaster (HCl)

The mortars were all very similar and composed of hard off white; flint, hard chalk and buff to white lime. Many contained fragments of various types of re-used painted plaster described below.

EXAMPLES OF PLASTER DESCRIPTIONS

Four main types of plaster were noted and are generalised as follows:
1) Burnished colour with crushed calcite, 0.05mm, on white *intonaco* with crushed calcite, 1 - 1.5mm, on pale pink plaster with chalk, flint and orange to brown ochre, 13mm thick.
2) Colour, 0.05mm, on white *intonaco*, 0.75mm, on off white chalky plaster with crushed flint (some may be burnt), 20mm thick, possibly in two equal layers.
3) Burnished white with calcite, 1mm, on fine chalky plaster, 1.5mm, on coarse off white chalk gravel plaster, 17mm thick.
4) Mortar or plaster with red to orange brick or tile fragments.

SPECIFIC CASES:
D 26: re-used plaster; plain white and pale grey on white plaster type 3) 20mm thick, and a fragment of type 4) with tile.
D 36 1: type 2) plasters; plain burnished white with calcite, plain white over-painted with streaks of pale pink (with traces of Egyptian blue), white on dark pink on white *intonaco*, burnished black with calcite on white and burnished red with calcite on white. These last two were

very similar to the red burnished type 1). It may be that type 1) is a discoloured variation of type 3).

D 37 Flavian palace wall (E. Wall of hippodrome) D[37]: coarse off white to cream or buff chalky mortar with flint and re-used plaster type 2); pink to dark pink plaster with splashes or streaks of red, also black on pink and plain white, all with white *intonaco*.

D 41: plaster (type 1) sample); burnished red with calcite, 0.05mm, on off white *intonaco* with calcite, 1 - 1.5mm, on pale buff to pink plaster with chalk, flint and fragments of calcite and orange to brown ochre.

D 42 1: plaster (type 2) sample); pink, 0.1 - 0.2mm, on dark red, <0.05mm, with a black line 8mm wide over the interface, on white *intonaco*, 0.75mm, on off white chalky plaster with crushed flint, possibly partly calcined red in two equal layers totalling about 20mm thick. The plaster had straw or grass impressions. Other examples showed: splashes of black, white and yellow to brown paint, in a pseudo marbled effect, plain white 1mm thick, a green (with some Egyptian blue) stripe 15mm wide on white, 0.75mm thick.

D 42 2: plaster (type 3) sample); burnished white with crushed calcite crystals, 1mm, on fine white chalky plaster, 1.5mm, on coarse off white chalk gravel plaster, 17mm thick. One example showed: pink on yellow on white with calcite traces, 0.5 - 1mm thick, on fine white chalky plaster, 3mm, on coarse chalky plaster to 17mm thick as above. One sample appeared to have burnt or pink plaster. Other samples of this type 3) plaster included: red to dark pink on white *intonaco* and a blue stripe 15mm wide over red to dark pink on a yellow interface on a white *intonaco*. The blue grey was carbon with lime and Egyptian blue traces.

With the bulk sample D 42 2 were fragments of other types of plaster: 2) : green on white, speckled pink and dark red on white, burnished red with calcite on pink or burnt plaster with calcite as in type 1), and a fragment of pink painted plaster with tile, being type 4).

"H 90" 1987 deposit further south in the Hippodromos:

splashes of red and yellow, 0.5 - 0.7mm, on blue grey (Rayleigh effect), 0.1 - 0.3mm, on off white to cream *intonaco*, 0.5 0.7mm, on white plaster with chalk, flint and round to sub-angular quartz sand, 11mm, on white plaster with chalk, flint and sand, 12mm thick. The rear showed the impression of a plank? >40mm wide. This sample was not directly comparable to the others but showed similarities to D 36 plaster type 2).

PAINTING TECHNIQUE

The painting appeared to be in the *buon fresco* method with over painting possibly in *fresco secco.* The use of burnishing and calcite crystals is of note.

PIGMENTS

The pigments were mainly natural colours: red ochres (haematite), crushed red to orange brick or tile, yellow ochres (limonite), green earth (glauconite), carbon as soot or charcoal and white lime. The blue was Egyptian blue.

<u>1965 - 67 main Palace excavation samples</u>

It was not possible to carry out destructive analysis on these samples.

FB 65 259 (16) /995\ "stucco":

traces of light blue on pale green, <0.05mm, on burnished yellow with calcite, 0.05mm, on pink with calcite, 0.5mm, on white with calcite, 2.25mm, on cream fine chalk gravel plaster to 8mm thick.

FB 67 398 ditch courtyard 7 "white lines on yellow":

traces of red and white lines on yellow, 0.05mm, on burnished pink with calcite, 0.5mm, on white with calcite, 1.5mm, partly on 0 - 2mm, pink with calcite and partly on cream chalk gravel plaster with flint and tile traces in two layers, 10 - 12mm and 25mm thick. The pink to white interface on the plaster may have been a *giornate di lavoro* join.

FB 398 / 399:

burnished? red*, <0.05mm, on burnished yellow with calcite, <0.05mm, on pink with calcite, 0.5 - 1mm, on white with calcite, 2.5 - 3.5mm, on cream chalk gravel plaster with flint and tile traces to 15mm thick.

PAINTING TECHNIQUE

The painting technique was presumably in the buon fresco method but the surfaces were so heavily polished that it was difficult to see any marks at all. The layers were exceptionally smooth and flat, with large clear calcite crystals within the paint and plaster layers. If these were all separate layers they would almost approach the Vitruvian ideal of six or seven layers. The technology of these samples is probably the best seen in Britain during the survey.

PIGMENTS

The pigments included the usual earth colours and Egyptian blue seen in the other Fishbourne material above, with the addition of red* cinnabar.

Average results

	Thicknesses	"Lime"
mortar	-	18%
paint	(0.05 - 1) 0.3mm	-
intonaco	(0.75 - 2) 1.2mm	94% including calcite
intonaco	(0.5 - 0.7) 0.6mm	79% without calcite
plaster upper	(10 - 20) 15mm	30%
plaster lower	(10 - 13) 12mm	30%

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 86, 87
Mortars: D 38, D 39, F 3; Plasters: D 37 top layer (3), D 42 2 (2), D42 2 (2), "H 90" (south in Hippodromos)
The graphs show the generally poorly graded nature of the aggregates in the mortars and the occurrence of some graded sand in the plasters.

Fig. 86 Fishbourne mortars

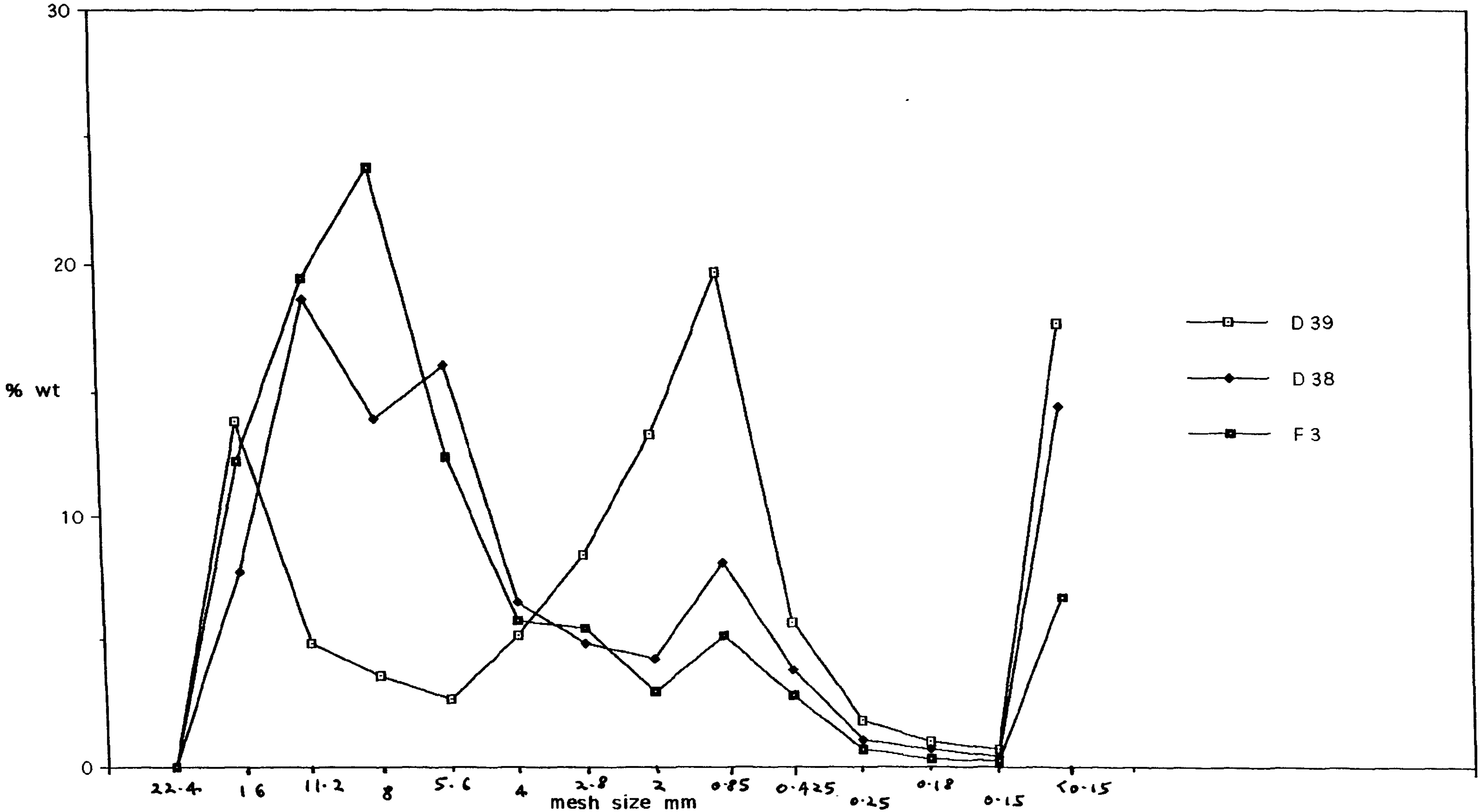
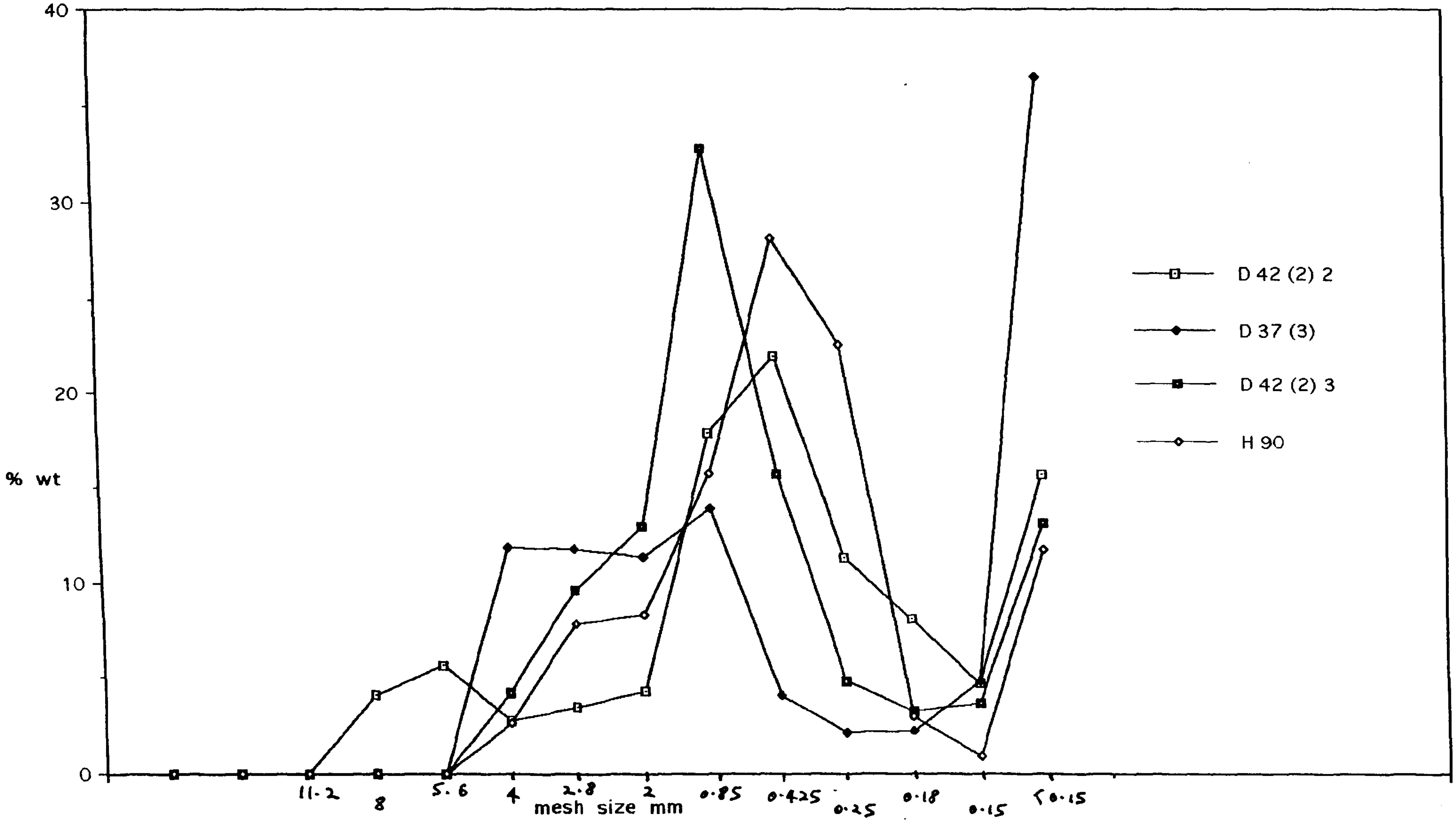


Fig. 87 Fishbourne plasters



Hadrian's Wall

1) Hadrian's Wall in the vicinity of Housteads Roman Fort.
Crow 1991

Samples from various parts of Hadrian's Wall were compared analytically. The most noticeable feature was the amount of leaching and re-deposition of lime, either as a whitewash-like film on the wall surface, or calcareous tufa-like concretions at lower levels. The aggregates were composed of local sandstone and basalt, the Whinsill, together with smaller amounts of: brick, tile or other burnt clay, clinker, micaceous schist, dense brown fossiliferous limestone, quartzite, round to angular quartz grains and traces of coal and charcoal. The Whinsill was generally weathered with a rusty appearance, probably due to interaction with the lime. The sandstone was variable from coarse to fine, often with mica and iron corrosion products. The presence of fine amorphous silica in the residues pointed to the use of hydraulic lime, although it appeared that some silica could have come from the brick or tile or the Whinsill. The brown limestone found in the aggregate had a very high acid soluble level (about 99%), but examples of the siliceous local four fathom limestone compared very favourably with the analysis of some of the mortars. Fifteen samples were examined and seventeen analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	'lime"	comments
S 63	23	45	32	32%	
S 64	12	44	44	45%	
S 68	26	32	42	51%	some limestone
limestone	-	-	-	99%	brown limestone
S 157	16	42	42	40%	
S 176	12	76	12	32%	
S 177	13	63	24	36%	
S 178	17	43	40	31%	
S 180	5	65	30	64%	tufa
S 182	19	68	13	35%	
S 183	0	99	1	27%	
S 184	16	60	24	34%	
S 186	18	61	21	40%	

M 37	41	42	17	40%
BH 1	54	38	8	15%
BH 2	43	48	8	12%
Limestone	-	-	-	83% (76% carbonate) "four fathom"

EXAMPLES OF AND MORTAR DESCRIPTIONS

S 63 383 - 47 (11); decayed core west of Sycamore Gap:
soil and buff mortar containing a sherd of black faced grey pottery.

S 64 383 - 53 (4); "t" of milecastle 39:
buff lightweight vesicular mortar, a lime and soil mix with re-deposited lime.

S 68 383 - 52; "Mons Fabricus":
a dense coarse mortar with re-deposited lime and hard brown limestone lumps.

S 157 392 - 35 (8); Peel Gap, Severan wall:
a fine uniform buff mortar with stone fragments and brick or tile.

S 176 3700 G (6); Milecastle 37:
buff mortar with re-deposited lime.

S 178 383 - 57 (21); "Mons Fabricus", mortar from the core of the north of the east end of Shieling 'A':
uniform buff mortar with brick or tile.

S 180 383 - 40; encrustation on the lower face of the north side of the wall:
calcareous tufa with: root casts, snail shells and general plant-like impressions.

S 181 383 - 40; leached lime or whitewash, Highshield:
re-deposited crystalline lime layers on buff sandy mortar with brick or burnt shale and mica.

S 182 H 20 (10) 21; Housteads Fort, north wall:
hard grey mortar with re-deposited lime.

S 183 H 20 (10) 9; Housteads Fort, north wall:
off white vesicular sandy mortar with re-deposited lime.

S 184 383 - 42; Highshield - RTAS area:
weathered surface sample of buff mortar with large sandstone lumps, brick or tile and re-deposited lime.

S 185 383 - 40; lime or whitewash:
layers of re-deposited lime.

S 186 383 - 40; Wall core, Highshield:
weathered buff sandy mortar with re-deposited lime.

392 - 34 (101); plaster? from Peel Gap:
lightweight fossiliferous clay, a leached mudstone.

392 - 35 (8); plaster? from Peel Gap tower:
lightweight fossiliferous clay, a leached mudstone.
Milecastle 37 S 197; Hadrianic mortar:
off white to pale grey mortar with white and yellow sandstone.
Burtholme Beck 1, NGR 548 643; pale grey mortar with pale buff silica lumps, sand and gravel, red sandstone, brick or tile and grass or straw impressions. This sample had a "limewash" coating of re-deposited lime.
Burtholme Beck 2; as above without the red sandstone.

<u>Average results</u>

<u>gravel : sand</u>	<u>"Lime"</u>
22 : 78	34%

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig Nos 88 - 90
S - 63, 64, 68, 177, 178.
S - 157, 176, 180, 182.
S - 183, 184, 186, M 37, BH 1, BH 2.
The graphs show that the gravel sizes are poorly graded whilst the sand sizes are fairly well grade, perhaps reflecting weathered rather than alluvial material.

Fig. 88 Hadrian's Wall 1

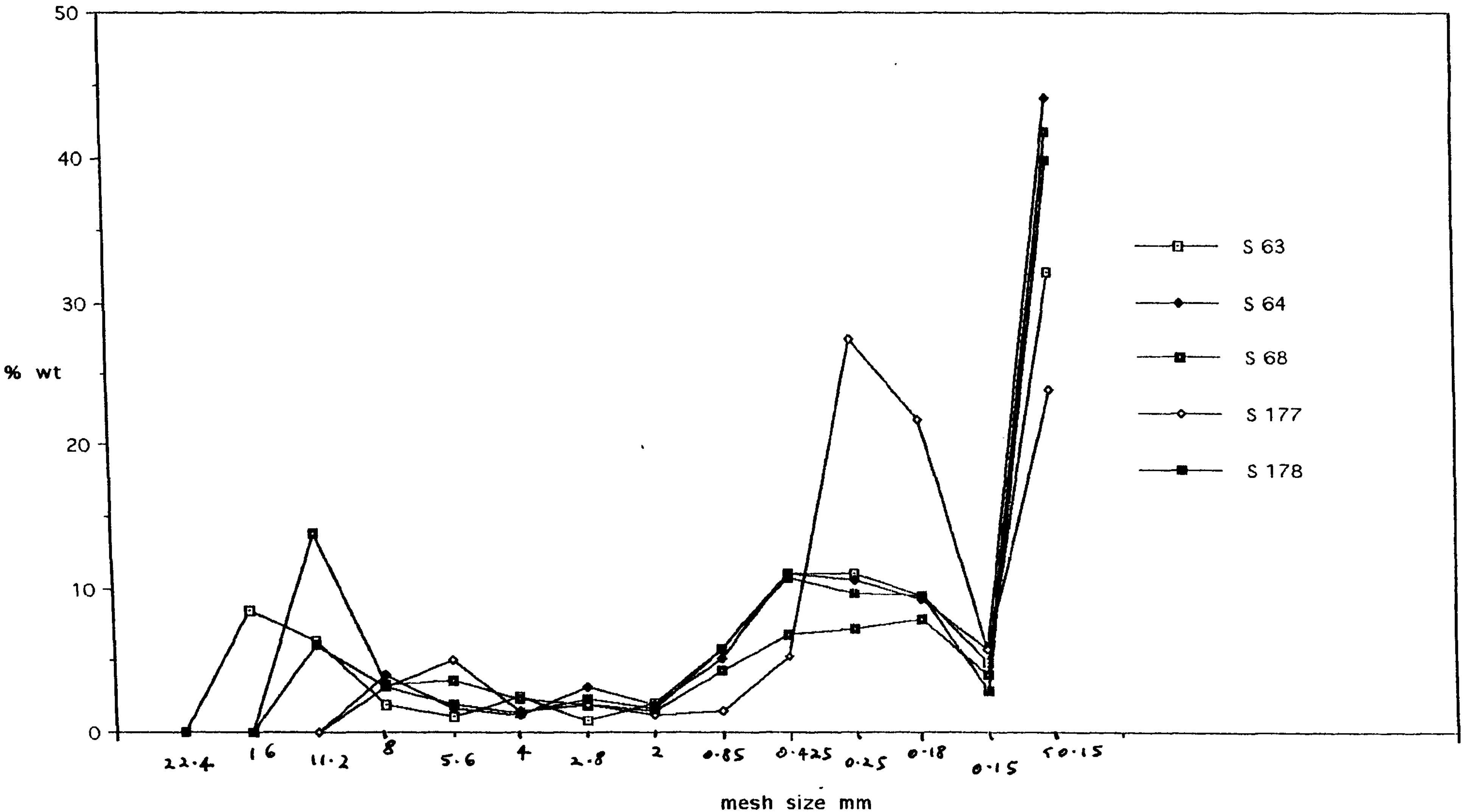


Fig. 89 Hadrian's Wall 2

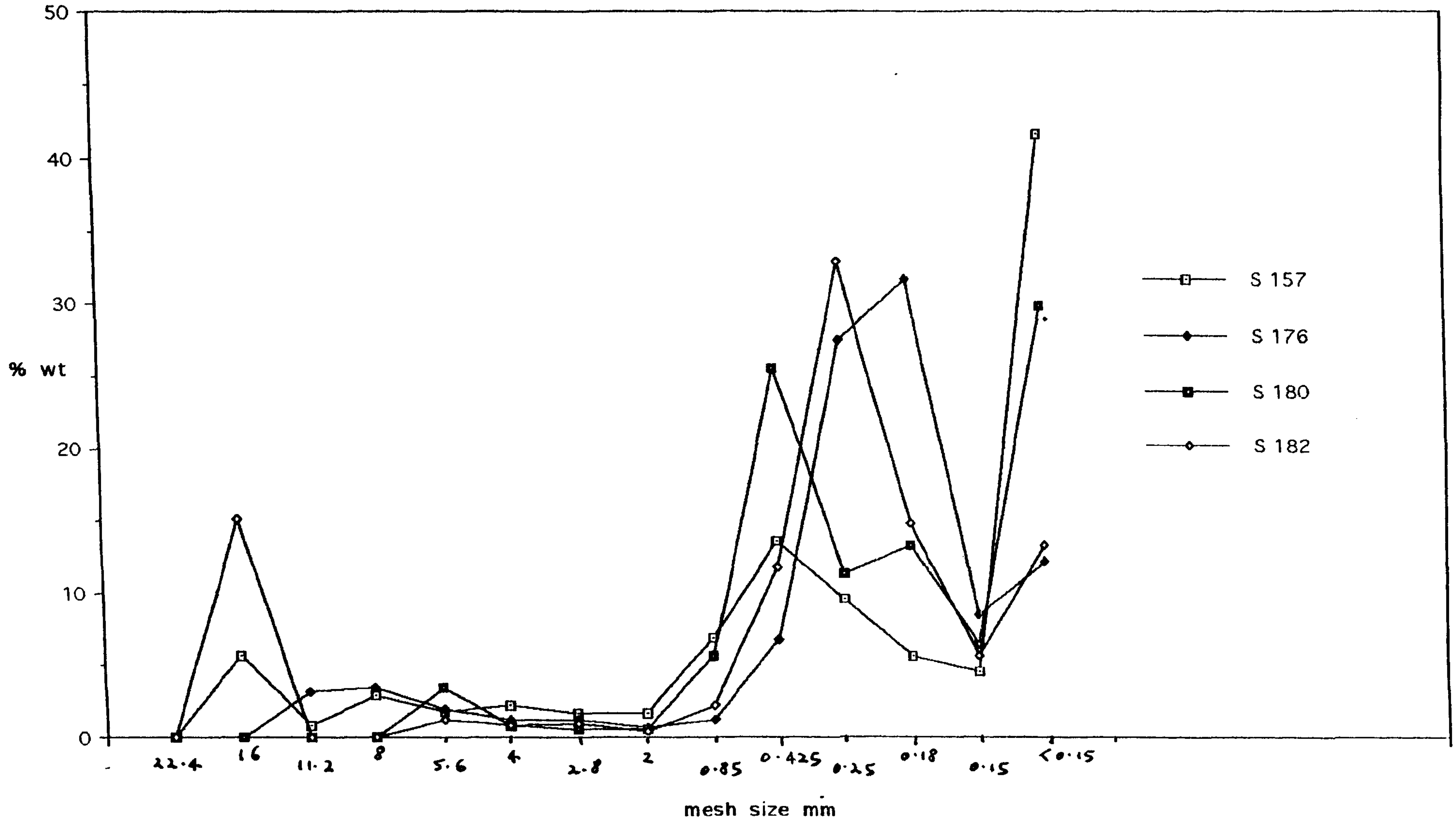
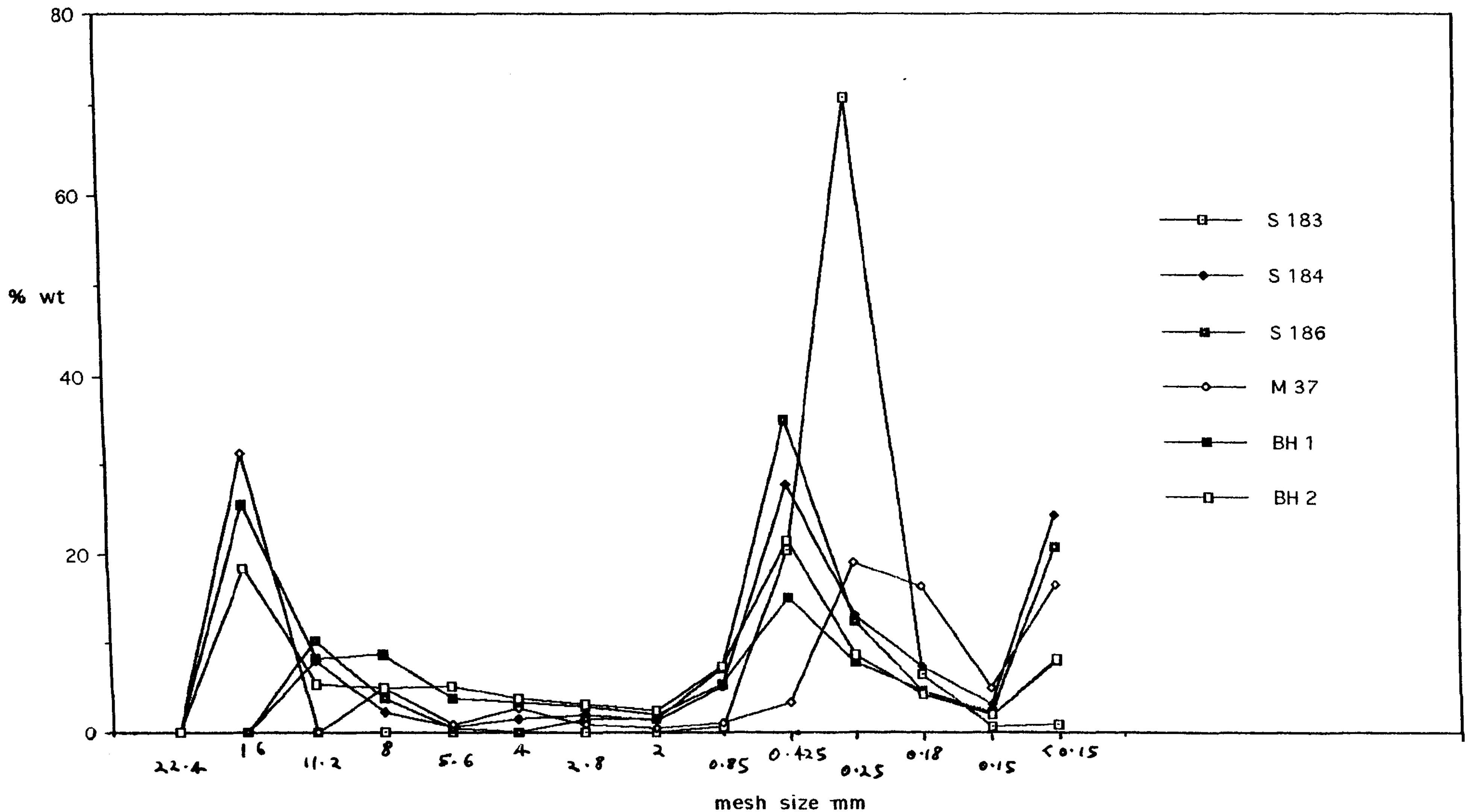


Fig. 90 Hadrian's Wall 3



2) Hadrian's Wall in the vicinity of Newcastle

West Denton 1988
Britannia 1988 19: 433, 1989 20: 273 - 4

The construction of a by-pass in 1988 - 9 led to the destruction of a length of the Wall and Vallum at Denton Burn. Excavation in advance of the road works revealed details of the Walls construction, including a length of fallen wall which had preserved the face and original "plaster" rendering. Five samples were examined and analysed. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
29	11	55	34	68	cream render
29A	24	61	15	31	grey mortar
29B	0	87	13	16	grey mortar residue
100	35	35	30	31	tufa concretion
436	19	40	41	62	tufa concretion

EXAMPLES OF PLASTER AND MORTAR DESCRIPTIONS

29) fragment of fallen wallplaster / rendering;
Cream coloured lightweight mortar with fine angular aggregate, about 35 mm thick. This mortar appeared to have been made with hydraulic lime derived from a siliceous limestone. The aggregate was mainly crushed or weathered micaceous sandstone, with smaller amounts of rounded quartz, amorphous silica, traces of slate or shale, bituminous coal and the more common charcoal. The particle size distribution curve shows a peak around 0.18 mm. The coal may possibly have been used in the lime burning or simply found with the aggregate.

29 A, 29 B, grey mortar attached to the rendering;
Only small fragments of the grey mortar could be extracted by wet sieving from the sample supplied. Larger pieces numbered 29 A, and 0.2 - 0.15 mm numbered 29 B. Both had the same type of aggregate, being mainly micaceous sandstone with rounded to angular quartz, amorphous silica, fossil fragments, slate or shale, igneous fragments, red brick or tile, charcoal and iron concretions. The particle size analysis for these two samples shows a peak at 0.425 mm, being quite different to 29).

100) from fill of robber trench, outer face of the wall, area F; This appears to be a concreted mixture of coarse cream mortar with soil, grey mortar and lime. It is very tufa like, with "grass" impressions or replicas. The aggregate is mainly micaceous sandstone, with smaller amounts of round to angular quartz, red brick or tile, bituminous coal, charcoal and slate or shale. The micaceous sandstone varies in nature from fine to coarse.

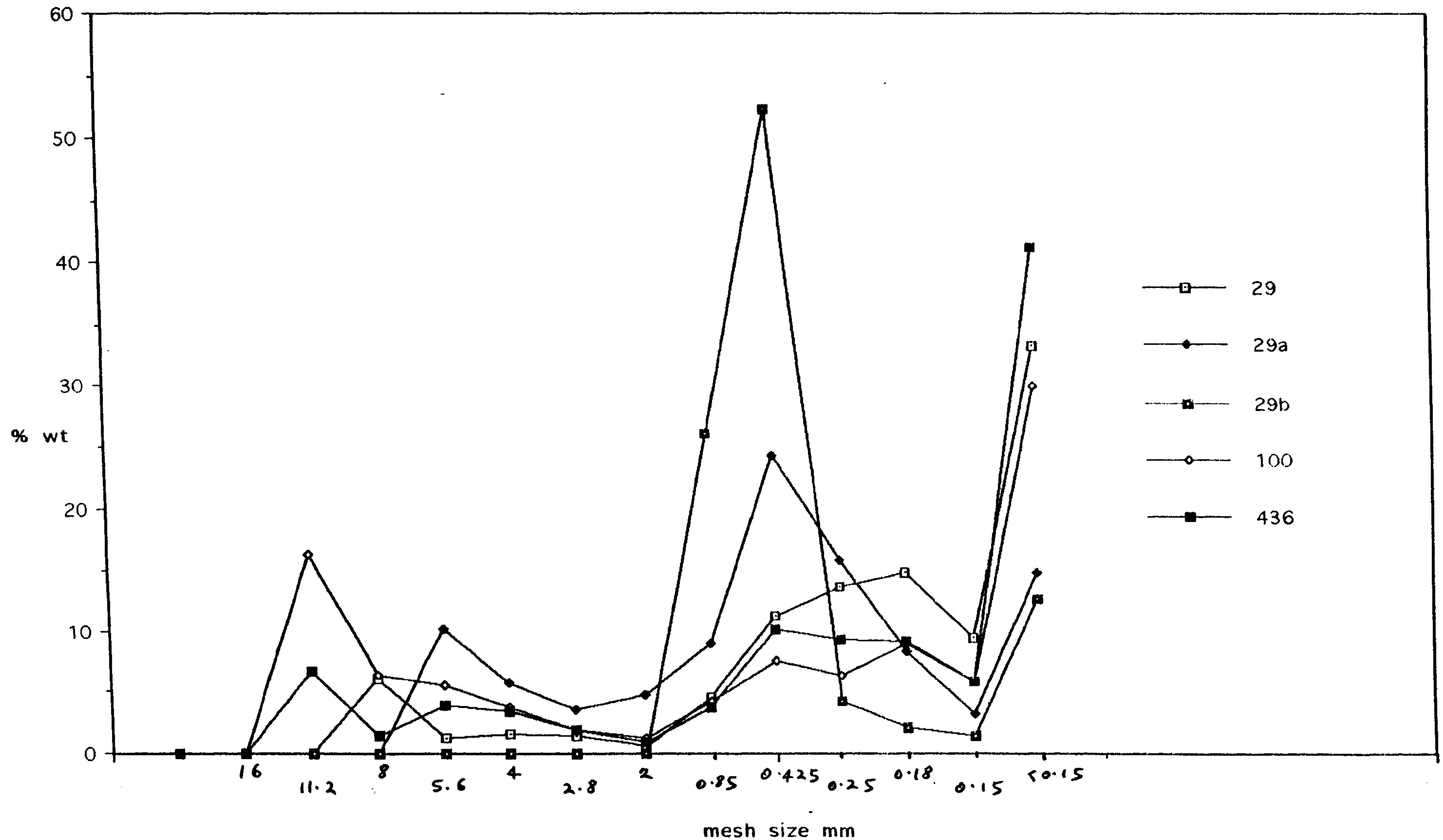
436) material from between foundation stones and rubble layers, area A; This is very similar in appearance to 100). It was also a tufa like concretion. The aggregate contained quantities of amorphous silica together with micaceous sandstone, flint, fossil fragments, tile, fuel ash slag / kiln residue, slate / shale and charcoal. The large size of the amorphous silica and high lime content suggested that this possibly included some waste lime.

Particle size distribution analysis of the last two samples showed a similarity between both the grey and cream mortars. Together with the concreted nature of the samples this pointed to the the accretion of fragments of both types of mortar and subsequent consolidation by lime leached from the mortar and re-deposited to form the tufa like material. (c.f. Housteads above.)
Presumably the micaceous sandstones were local, and the lime derived from siliceous limestone, examples of existing limestone deposits should have been supplied for comparison to see if in fact they could have been used as a source of lime for the wall mortar. (c.f. four fathom limestone from quarries near Housteads.)

<u>Average results</u>
The results are too few and various for any safe averages to be made.

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig No. 91
29, 29a, 29b, 100, 436.
The graph shows that there are various grades of sand and gravel present.

Fig. 91 Hadrian's Wall 4



Hockwold cum Wilton, Norfolk

Gurney 1986: 84

Lewis 1966: **passim**

A possible temple complex, mainly of the later fourth century, on the Roman Fen-edge, near Feltwell.

This collection of painted plaster fragments probably represented in part a complex scene or portrait. The aggregates were mainly sands and flint with some ferruginous sandstone fragments and lime or chalk lumps. Nineteen samples were examined and ten analysed.

COMPOSITIONS

No.	gravel	sand	silt	"lime"
B 14	4	88	8	53%
B 16	3	88	9	53%
B 17	15	66	19	43%
B 22	-	86	14	24%
B 29	30	56	14	36%
B 30	12	61	17	40%
B 70	-	85	15	27%

EXAMPLES OF PLASTER DESCRIPTIONS

B 16:

black, on blue on grey, on white *intonaco*, 1mm, on sandy plaster, 20 - 35mm thick, also pale blue on red brown on green on yellow on white *intonaco* as above.

B 22:

pink, 0.25mm, on white *intonaco*, 0.5mm, on sandy plaster to 12mm thick. This sample had a rounded section and may have been moulded.

B 29:

dark red and pale orange on sandy white *intonaco*, 1mm, on sandy plaster, 18mm thick.

B 70:

Sandy plaster with lime or chalk, 15mm thick.

H XXVII:

1: dark red on white, 0.1mm, on yellow on white sandy *intonaco*, 0.5 - 1mm, on sandy plaster, 4mm thick. c.f. B 22.

2: red on white *intonaco*, 0.5 - 1mm, as above.

3: white on red* on orange brown on white *intonaco*.

4: red* and white traces on pink on white *intonaco*.

5: red* on white on black on red on pale green on yellow on white *intonaco*.

6: blue on black as above.

7: white on blue on black on red* on yellow on white *intonaco*.

8: red* on black on pale green on yellow on white *intonaco*.

9: white and pale blue on dark red on white on yellow on white *intonaco*.

PAINTING TECHNIQUE

This complex series of colours must have used both *buon fresco* and *fresco secco*. The fragments were all too small for any constructive idea of the whole the may have come from, but presumably some detail from a decorative scheme rather than plain borders.

PIGMENTS

The pigments were the usual natural colours: red ochre - ranging from red to brown or maroon (haematite), yellow ochre (limonite) green earth (glauconite) white lime, carbon as soot or charcoal, with the notable addition of the red* cinnabar. The blue was crushed Egyptian blue.

Average results

	Thicknesses		"Lime"	
paint	(0.25 - 0.1)	0.2mm	-	
intonaco	(0.5 - 1)	0.9mm	-	
plaster	(15 35)	20mm	39%	thick samples
plaster	(3 - 4)	4mm	-	thin samples

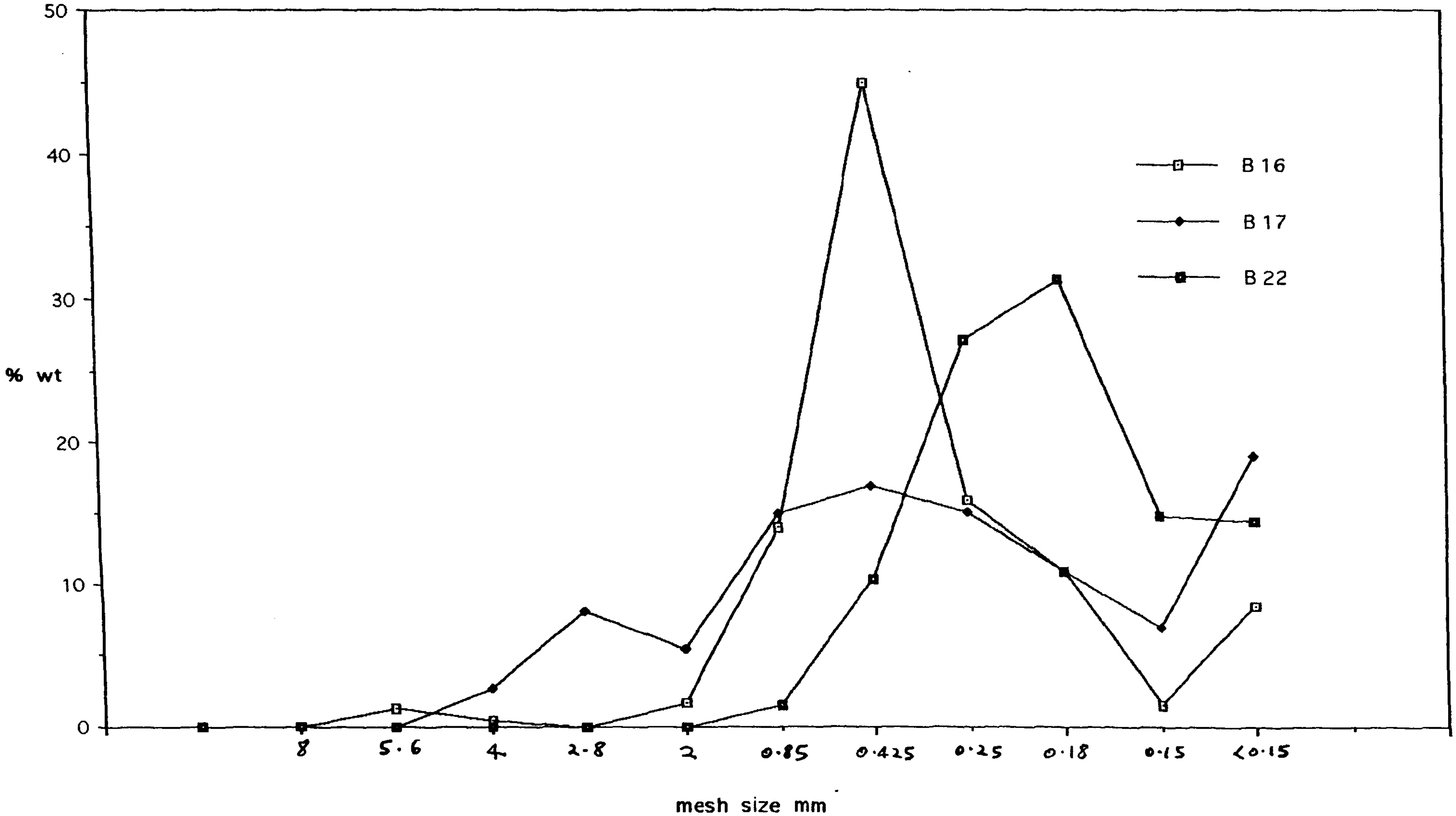
Samples illustrated in the aggregate particle size distribution graphs:

Fig No. 92

B 16, B 17, B 22.

The graphs show three very different gradings which coincide with the three different lime content groups of the samples. They obviously relate to differently graded deposits of fairly similar materials. The graph for B 22 and B 70 is very similar to the aggregate curve for C 4921 at nearby Feltwell. Fig No. 85

Fig. 92 Hockwold



Leicester, Leicestershire
Britannia 1980 11: 367, 1981 12: 337 - 8
Davey and Ling 1981 123 - 134
Mellor 1981

Various Roman sites in and around Leicester have produced material for analysis. Work is still in progress on finds from many sites but some preliminary results are presented hear. These results are unpublished

1) Blue Boar Lane, Leicester, the Roman town of Ratae Corieltavorum. A first to second century building, partly of mud brick produced a fine series of wall-paintings, some on display in the Jewry Wall Museum in Leicester. The painting style is described in detail by Ling (op. cit.) but the pigments and plaster had not been analysed until recently. Only visual description are given here.

EXAMPLES OF PLASTER DESCRIPTIONS
LEI 58:
A(V)(7):
red* on yellow on black, 0.05mm, on white *intonaco* with calcite, 0.5mm, on sandy plaster, 10mm thick.
A(I)(16):
white on pale green, dark red on cream, white on cream with blue specks, on red*, <0.05mm, on yellow, 0.1mm, on burnished black on grey, 0.2mm, on sandy white *intonaco*, 0.5mm, on sandy plaster, 10mm thick.
BL64 2, 3:
brushed white with blue specks on dark red on red* on yellow on burnished black, total <0.05mm, on grey with calcite grains, 0.4mm, on sandy white *intonaco*, 0.5 - 0.6mm, on sandy plaster, 10mm thick.
A(I)(16):
burnished red* on a coarse red stripe on blue green with calcite, 0.25mm, on yellow traces on red (crushed tile) *intonaco*, 0.5mm, on sandy plaster in two layers, 7mm + 20mm thick.
A(II)(5) 99:
pale blue green on coarse; blue, green, charcoal and clear glass, 0.6mm, on grey to buff sandy plaster in two layers, 7mm + 35mm thick.
The glass layer was completely obscured by the blue green surface.

PAINTING TECHNIQUE

The use of cinnabar and calcite, the quality and nature of the paintings show that a very high standard of workmanship was available in Roman Leicester. The use of crushed clear glass in an under layer was of particular note. The main painting was almost certainly in *buon fresco* with the over-painting probably in *fresco secco* or possibly, in part, *in tempera*.

PIGMENTS

The pigments included: red ochre (haematite), red* cinnabar, red brick or tile dust, yellow ochre (limonite), green earth (glauconite), white lime, black soot or charcoal and crushed Egyptian blue.

2) Norfolk Street Roman villa was on the outskirts of Roman Leicester. Of particular interest was a mud brick wall with two phases of painting which had fallen into a cellar and been preserved. These paintings were lifted and one is now on display in the Jewry Wall Museum, Leicester. The painting is described by Ling (op. cit.). The mud brick had been plastered with mud which had then been impressed with a patterned roller. The lime plaster layers had then been applied to the mud plaster, forming a good key with the ridged mud. The Roller pattern was of "herring-bone" style and appeared to be very similar to the roller impression found on some box flue tiles. The lime plaster produced a very good cast of the impressed mud.

3) Red Cross Street; A316 1962, VII 14(MR):

Excavations in the Forum area produced a lump of crystalline orange red material. This was shown to be realgar with traces of yellow orpiment, both forms of arsenic sulphide.. The weight of the sample was 3.5g. Such a large sample was probably imported. The context was thought to be first century. Similar samples of similar date were found at Caersws and Mancetter. No examples of its use as a pigment were found.

Lincoln, Lincolnshire

1) The Town Walls
Jones forthcoming
Current Archaeology 1992 129: **passim**

Various fragments from the defensive walls and towers at Lincoln were comparatively examined.in an attempt to show phasing. The aggregates were all fairly similar, containing: river sands and gravels of; quartz, quartzite, ferruginous sandstones, flint, fossiliferous and oolitic (or peloidal) limestone and crushed brick or tile. The presence of limestone affected the accuracy of the "lime" measurement. The mortars were all buff to brown in colour with silica and silt in the residues possibly derived from the included limestone or from the lime. Twenty three samples were examined and analysed. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
The Park:					
27	3	30	67	16%	
28	29	60	11	24%	
29	15	54	31	30%	
31	41	48	11	29%	
32	21	73	6	19%	
33	33	61	6	11%	
	9	73	18	33%	lower part
96	44	36	20	28%	
97	28	52	20	30%	
99	0	4	96	80%	limestone, not mortar
104	31	57	12	31%	
111	15	66	19	44%	
115	28	61	11	31%	
116	20	52	28	31%	
156	27	62	11	27%	
West Parade					
31	8	64	28	37%	
32	6	67	27	36%	
33	18	66	16	34%	
34	54	43	3	11%	
35	17	56	27	41%	
36	11	73	16	51%	

Average "lime" content: 31%

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 93 - 98

1) P32, P33, P156.
2) P33A, P70, P111, P31.
3) P104, P115, P28.
4) P97, P29, P116, P96, P97.
5) W33, W34, W36.
6) W31, W32, W35.

The graphs show four apparent groups, the early wall and tower samples being particularly distinctive, 5) and 3) and 2) and 6) being similar.

Fig. 93 Lincoln 1

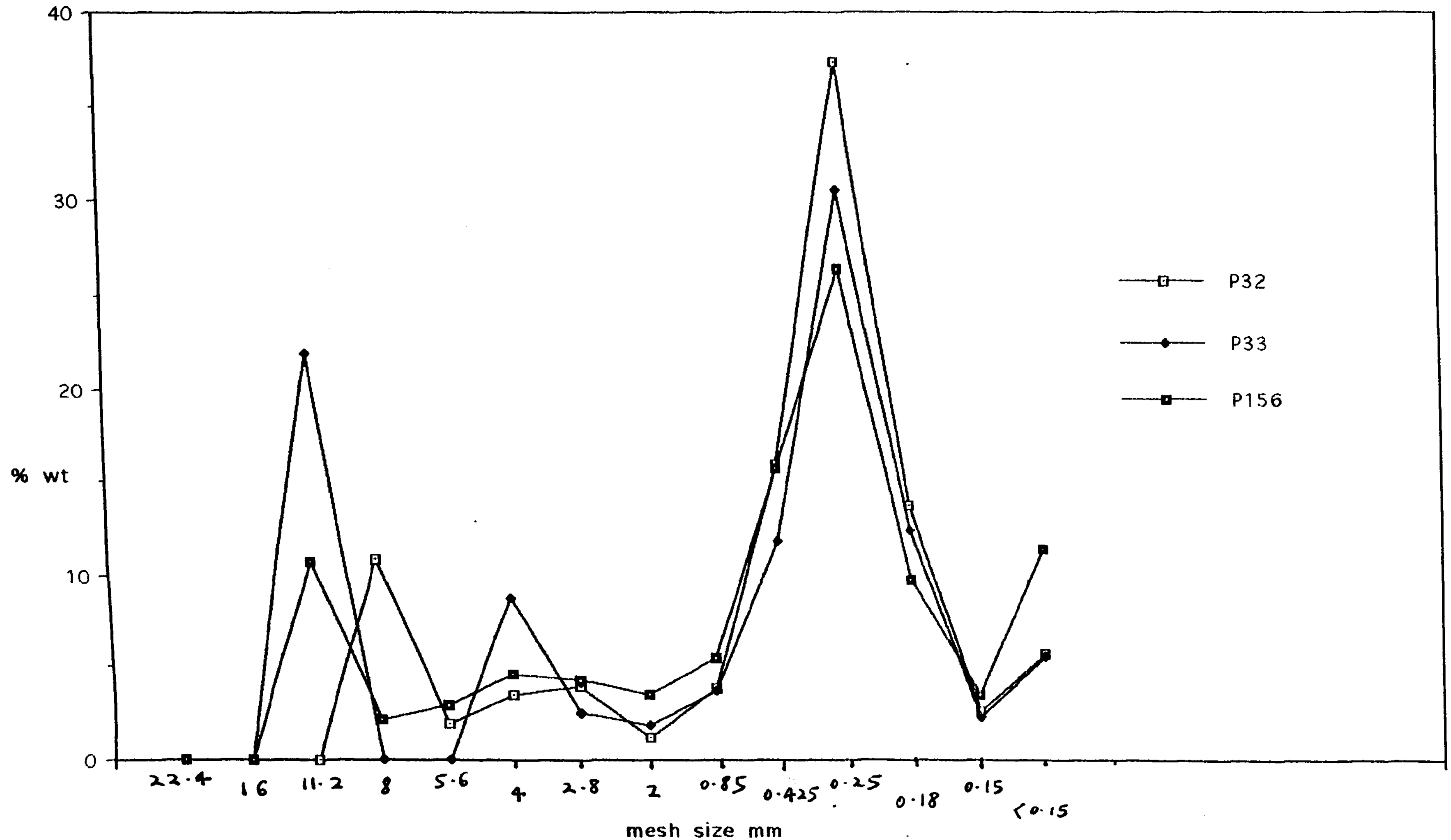


Fig. 94 Lincoln 2

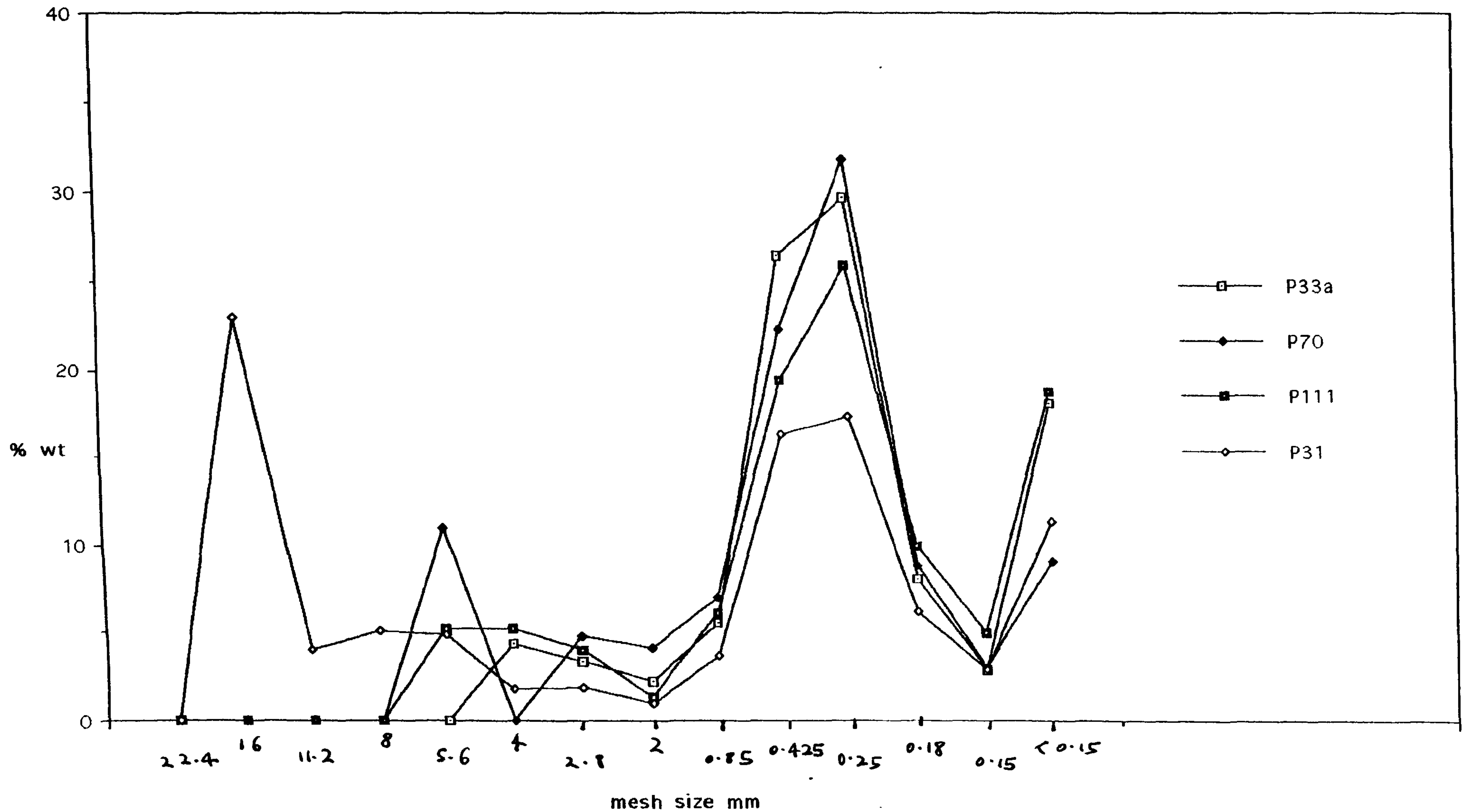


Fig. 95 Lincoln 3

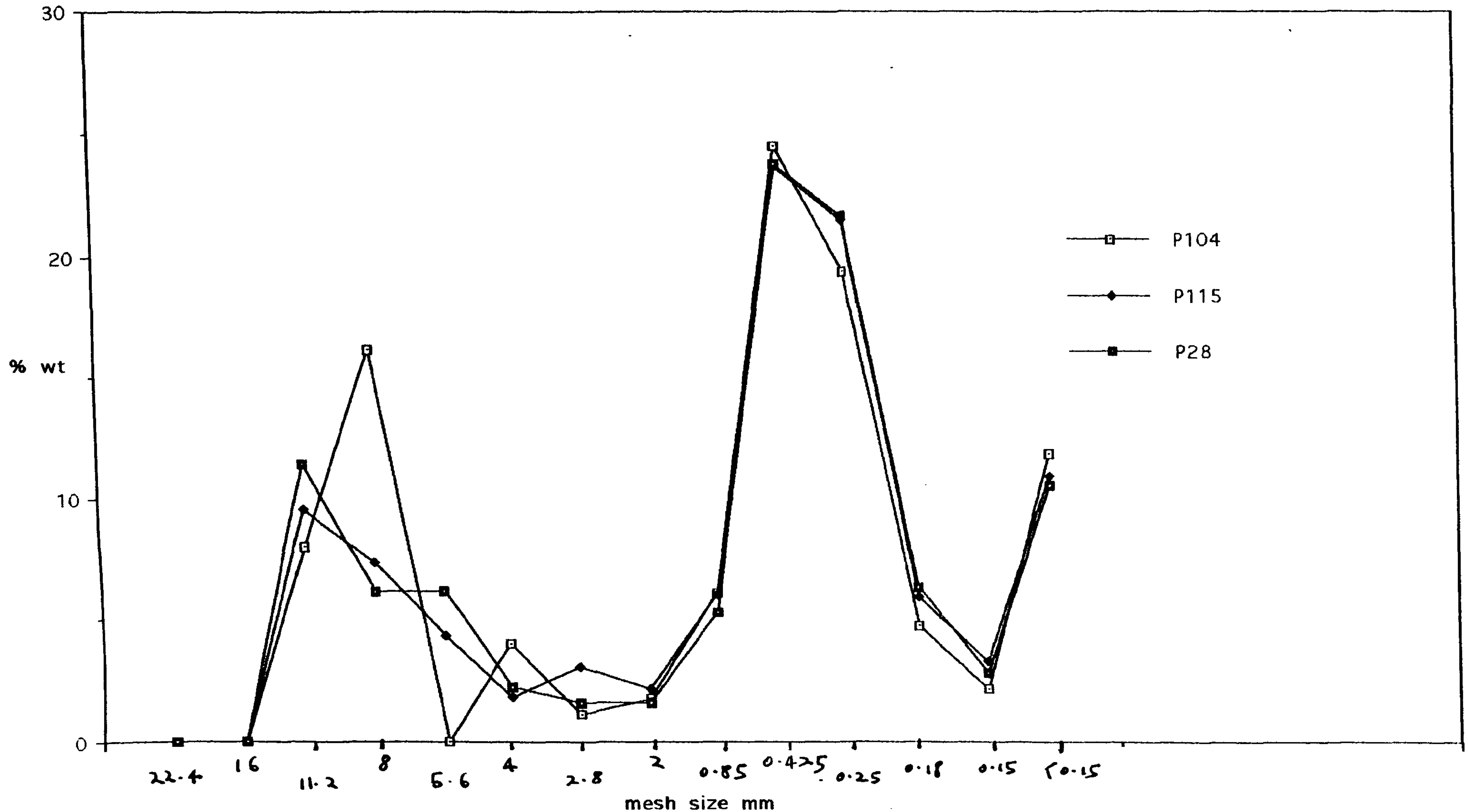


Fig. 96 Lincoln 4

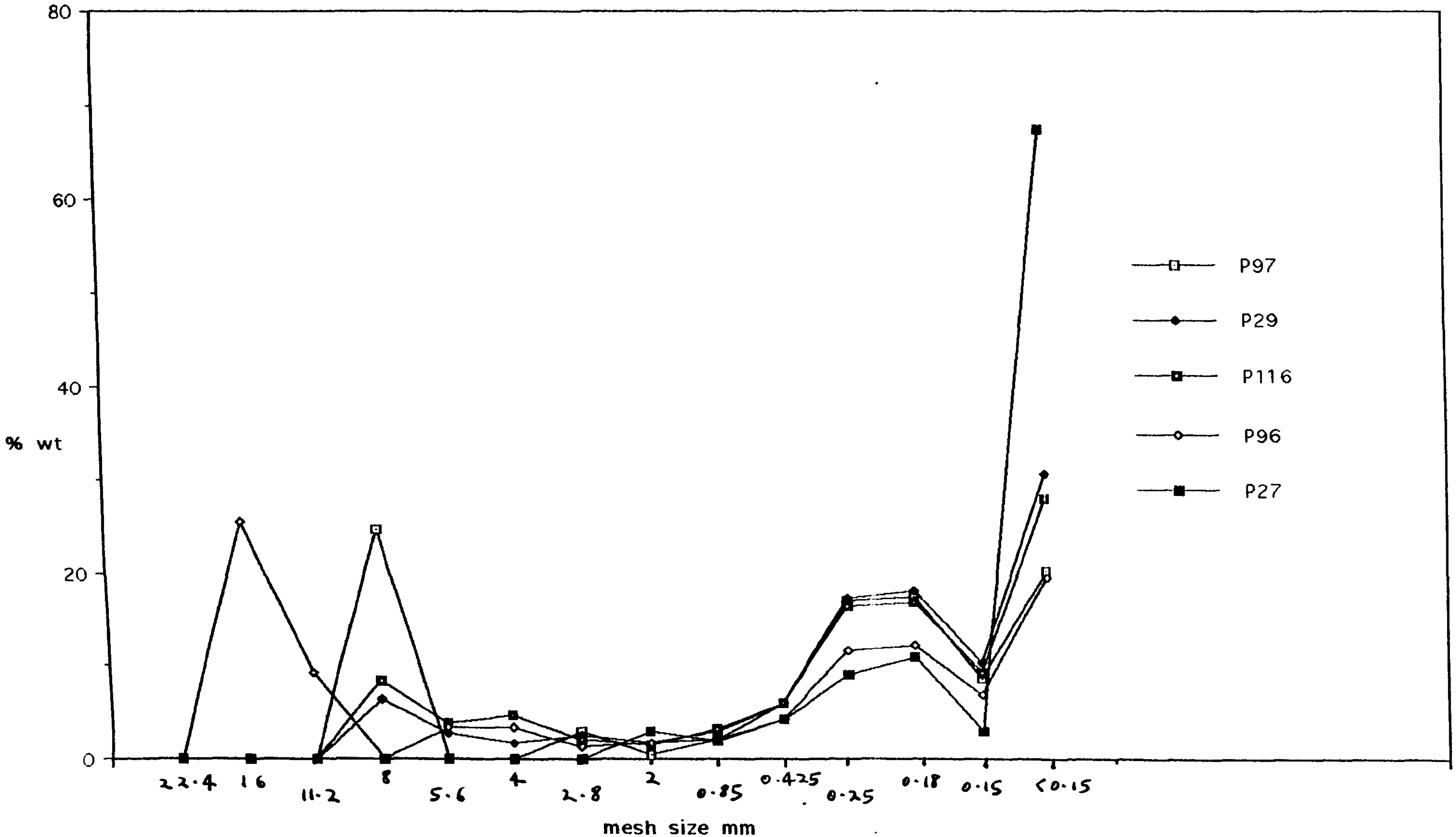


Fig. 97 Lincoln 5

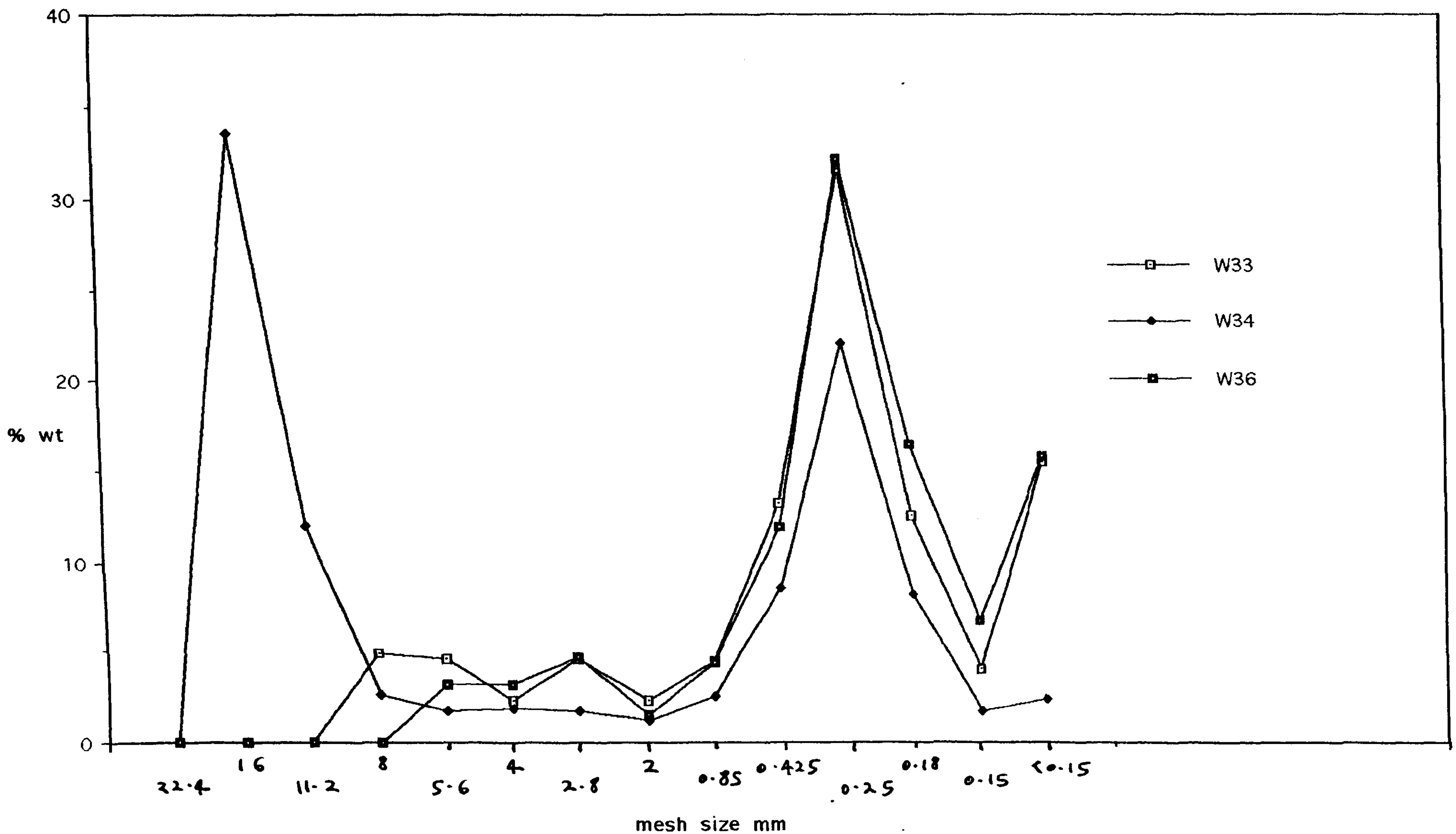
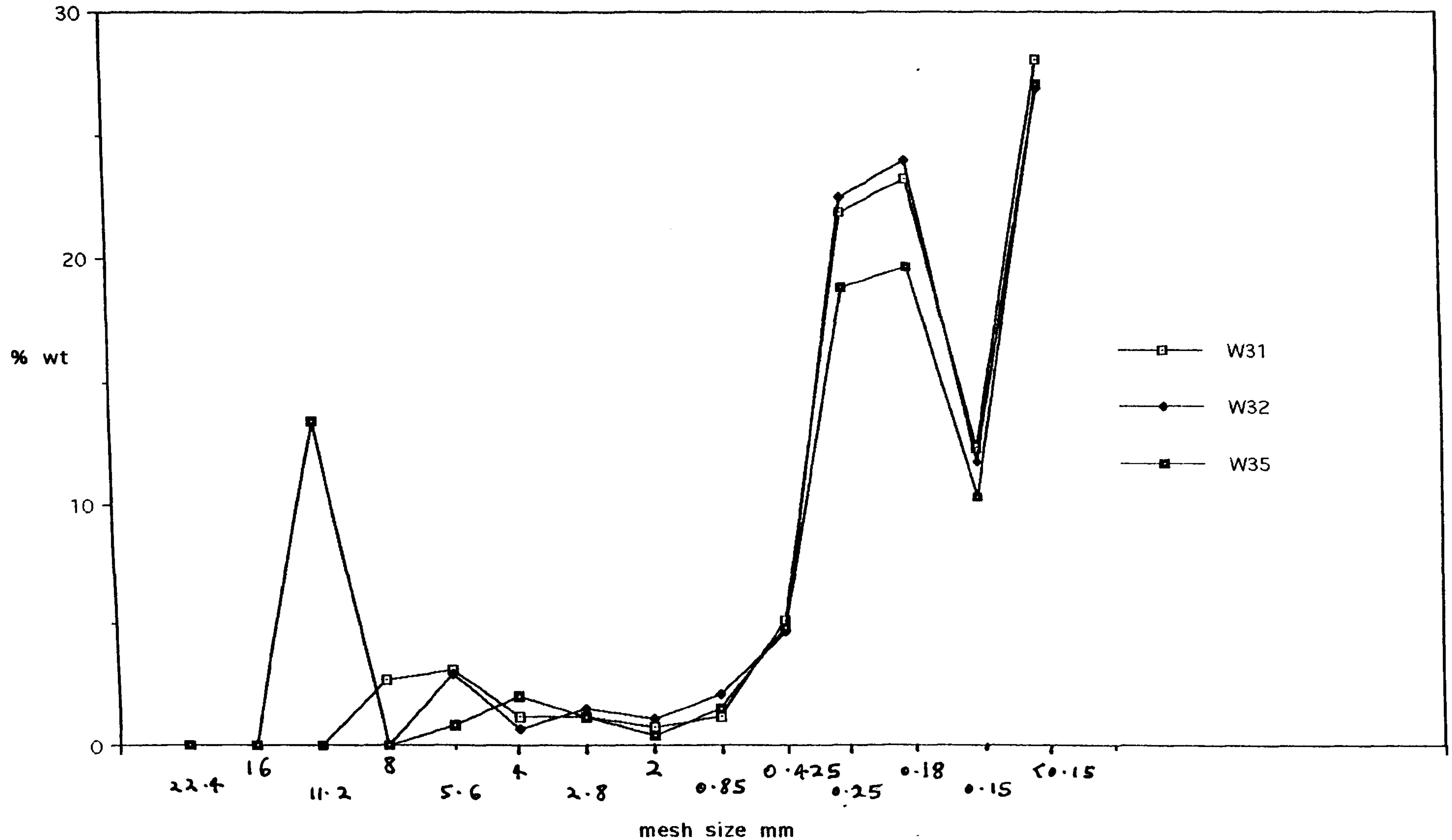


Fig. 98 Lincoln 6



2) The aqueduct
(Wacher) Current Archaeology (1976) 54: 205

Other material examined from the Lincoln area included fragments of the piped aqueduct into the city. This was a fired clay pipeline encased in cast *opus signinum* concrete. It appeared to have been constructed by a trench being dug in the ground, a layer of concrete poured in, the pipe (made from a single piece of clay wrapped around a former, with male to female joints) was set in or on the bedding layer and then encased in more similar concrete to form a more or less oblong section block with slightly convex upper and lower surfaces. It was approximately 300mm (up to 345mm) x 390mm, with the pipe (145mm bore and 25mm thick wall) set in the centre.
A 100mm slice of the aqueduct weighed about 20kg, including the pipe. From this it was calculated that a metre length would have a volume of 0.117m^3 and a weight of 200kg. A kilometre length would weigh 200 tonnes and have a volume of 117m^3, whilst a mile would weigh about 320 tonnes.
These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	
upper part	46	40	14	40%	density: 1.4g/cc
lower part	45	39	16	48%	density: 1.5g/cc

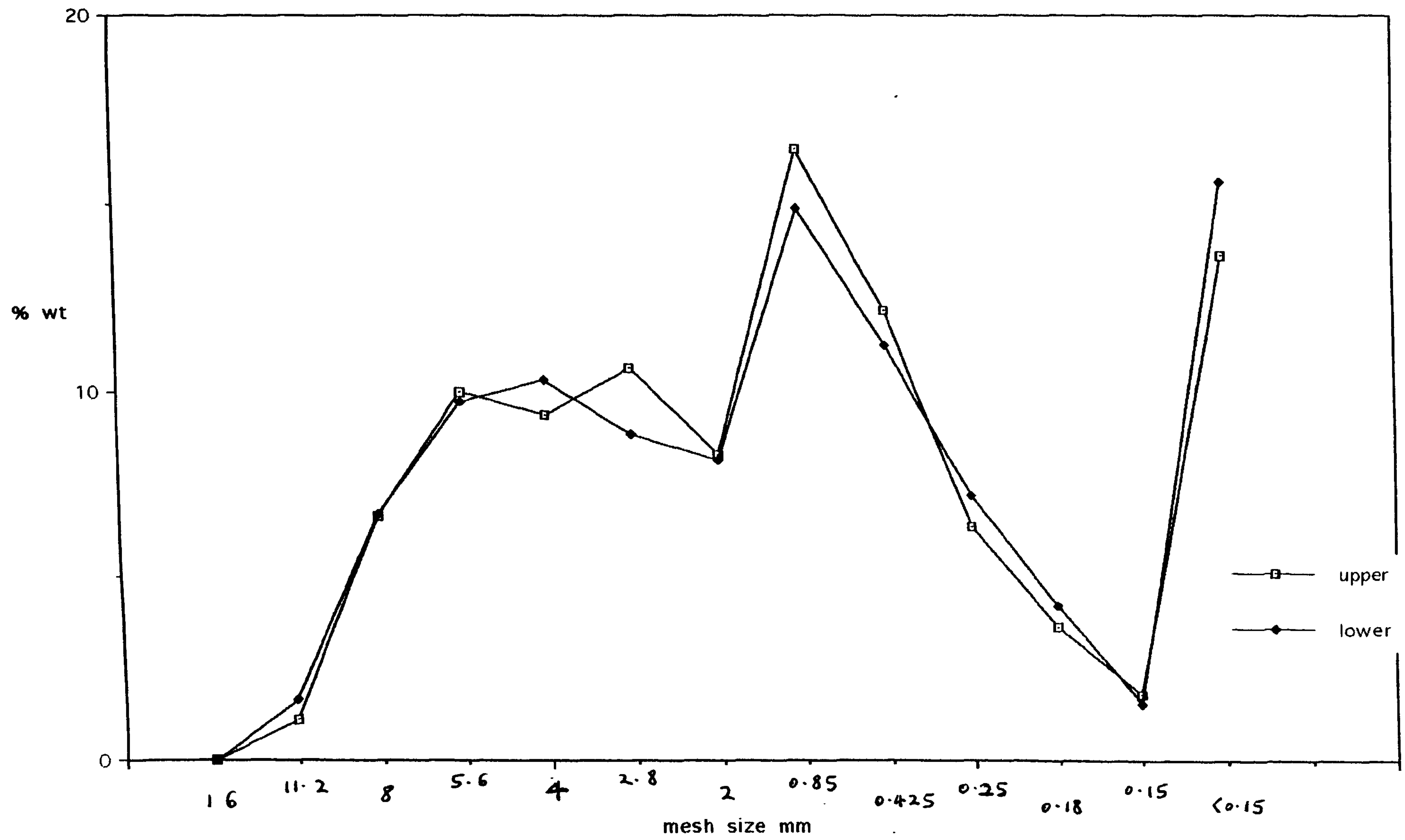
DESCRIPTIONS
Both upper and lower layers were composed almost entirely of crushed brick or tile, and as such would ideally suit the description of *opus signinum*. The tile ranged in colour from black through red, pink and buff to pale yellow in colour. Small amounts of round to sub-angular quartz sand were present in the sand size gradings, almost certainly derived from the sandy clay used to make the tile or brick. The silt size was almost entirely composed of amorphous silica and tile dust. The surface of much of the tile showed a coating of white silica, presumably due to reaction with the slaked lime when it was mixed. The material was in general extremely resistant to dissolution. It was necessary to heat the acid and use mechanical action over some three weeks to remove the "lime". The upper layer, with its slightly lower "lime" content, was

even more resistant to dissolution. The results show that the only difference between the layers was in the "lime" content.

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig. No. 99

Both layers are illustrated, and show that the crushed tile was almost certainly from the same source.

Fig. 99 Lincoln - aqueduct



Lincoln

3) Roman House.
Britannia 1974 5: 421 - 425
Davey and Ling 1982 134 - 136

Excavations at sites in Silver Street and Saltergate in Lincoln in 1973 revealed remains including a second century house beneath the western defences of the Roman town. The painted plaster is described in detail by Ling (op. cit.). The plaster has been examined and partly analysed. They were all lime plasters with aggregates of: ferruginous sandstones, quartzite, quartz, flint and some fossiliferous limestone   The quality of some of the samples was very good, and the presence of cinnabar of note. Only three plaster analyses are given here and twelve samples described. The results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
Lin 73 C I					
(63)[632]	6	58	36	32%	lower layer only
(63)[778]	8	57	35	27%	lower layer only
(89)[780]	8	25	67	34%	lower two layers

EXAMPLES OF PLASTER DESCRIPTIONS
Lin 73
B I (27)[278] 7310276:
red* on pink, <0.05mm, on white *intonaco*, 0.5 - 1mm, on light sandy plaster, 5mm thick.

C I (63)[632] 7310287:
a complex painting summarised as follows; black and white on yellow to brown on green on yellow to brown, 0.05mm, on white *intonaco*, 0.5mm, on sandy plaster, 5mm, on sandy plaster, 25mm thick.

C.I (63)[778] 7310293:
cream on white on light green on burnished black, 0.05mm, on sandy white, 0.04mm, on sandy plaster, 5mm, on sandy plaster to 35mm thick, apparently in one layer.

C I (84)[779] 7310294:
light green band? with a white edge on polished sandy red, 0.2mm, on sandy white *intonaco*, 0.4mm, on coarse sandy plaster, 6mm, on fine sandy plaster, 22mm thick.

C I (89)[780] 7310295:
red with a black edge, 0.05mm, on white *intonaco*, 0.6mm, on sandy plaster, 6mm, on sandy plaster in two layers, 23mm + 15mm thick.

E I (200)[4364]:
1) blue on maroon, 0.05mm, on white *intonaco*, 0.75mm, on sandy plaster, 14mm, on finer sandy plaster, 25mm thick.
2) burnished red* on brown to yellow, <0.05mm, on white *intonaco*, 0.5mm, on sandy plaster in two layers, 6mm + 9mm thick.

E I (200)[4365]:
1) polished red* on brown to yellow, 0.1mm total, on white *intonaco*, 0.4mm, on light sandy plaster, 9mm thick.
2) green with blue traces, 0.05mm, on white *intonaco*, 0.3mm, on light sandy plaster, 12mm thick.
3) red band? on white *intonaco*, 0.5mm, on coarse sandy plaster, 9mm, on finer sandy plaster, 25mm thick.

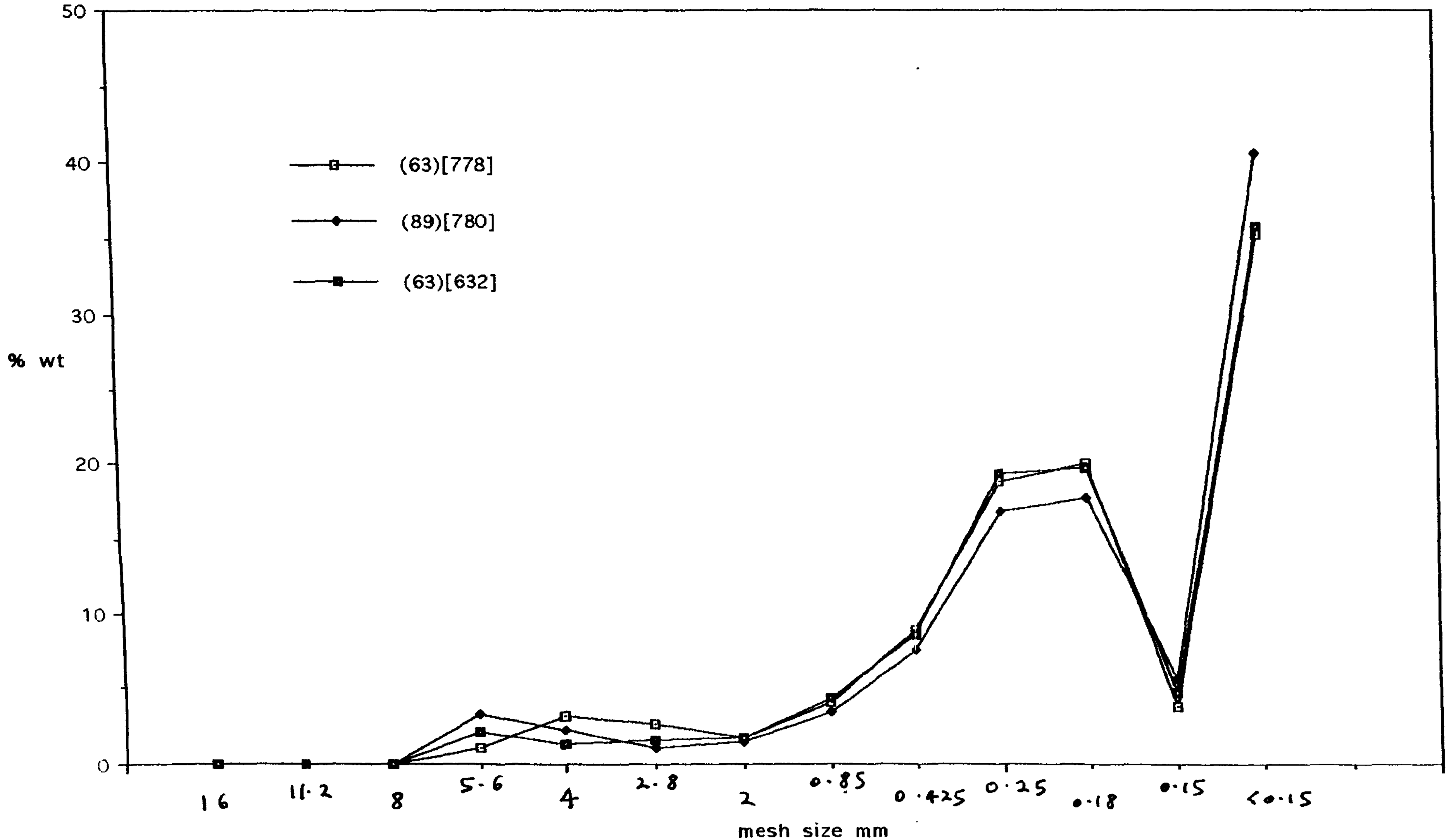
E I (200a)[4366]:
1) red on burnished white, 0.4mm, on sandy plaster, 12mm thick.

PAINTING TECHNIQUE
The paint appears to have been generally applied in the *buon fresco* method, with over-painting probably in *fresco secco*. Some of the more complex detail may have been added *in tempera*. The quality of the polishing and burnishing was particularly good.

PIGMENTS
The colours identified were as follows: red ochre (haematite), red* cinnabar, yellow ochre (limonite), green earth (glauconite), white lime, black soot or charcoal and crushed Egyptian blue.

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig No. 100
All three of the analysed samples are illustrated. The graphs show that the aggregates are virtually identical.

Fig. 100 Lincoln 7



Littlechester, Roman Fort, Derbyshire
Britannia 1988 19: 445 - 6, 1989 20: 283 - 6

Samples of mortar and plaster from the above site were analysed both chemically and physically in an attempt to show phasing differences. The nature of the local geology and in particular the presence of various limestones and red and green marl caused problems with the use of standard methods of lime removal using dilute hydrochloric acid. The smaller pieces of limestone tended to dissolve in the acid and the marl serious slowed up the dissolution process. The results however represent to a greater degree the apparent composition of the material.

The material was all lime based mortar or plaster with gravel, sand and silt or clay in variable proportions. The use of the marls in the aggregates gave the mortars distinctive colours, red or grey to green. The main components of the aggregates were; various sandstones, including coarse millstone grit and calcareous sandstone, quartz, quartzite, flint, chert, ferruginous sandstones and ochres, fine limestone and fossiliferous limestones in a range of colours from dark brown or black to cream, red and green marl, and crushed red brick or tile. There were occasional fragments of lime or tile kiln residues, slate or shale, glauconite nodules and fine micaceous schist. The sand component was mainly rounded to angular quartz with felspars, mica and fragments of the other rocks. The silt and clay fraction was frequently composed of marl dust with sand, giving it a distinctive colour. The colour of the silt fraction was often the most obvious difference between the mortar samples, and they are not therefore described individually. This site produced the largest number of samples seen in the survey. As specific requirements were given to the excavator, the correct sample weight for mortar analysis was generally adhered to. This produced large residues for aggregate analysis, necessitating physically larger sieves for the grading. This meant that the exact mesh sizes used in the other analyses could not be exactly matched. One hundred and six plaster samples were examined and twenty six analysed. Seventy two mortar samples were examined and analysed. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
mortar - type 1					
010	23	66	11	26%	
012	47	36	17	25%	
020	80	16	4	3%	mainly gravel without lime
106	51	35	14	28%	
118 - 033	23	63	14	24%	
008 - 025	32	46	22	45%	lime with red marl
080 - 026	19	61	20	30%	
mortar - type 1+					
046A	41	33	26	43%	mainly tile
003	34	55	11	31%	
046B	43	35	22	40%	mainly tile
071 - 026	27	37	36	31%	tile
005A - 026	44	34	22	44%	mainly tile
040[2] - 026	35	28	37	33%	mainly tile
mortar - type 2					
129	20	62	18	21%	some tile
117 - 028	56	33	11	23%	
044	53	36	11	22%	
mortar - type 3					
006A1 - 026	9	66	25	23%	some tile
045A - 026	27	47	26	38%	mainly tile
042A - 026	3	82	16	20%	some tile
014 - 026	1	86	13	27%	
mortar - type 4					
008 - 026	7	62	31	47%	tile bonding mortar
plaster					
type 1					
539E - 026	6	78	16	25%	
type 2					
784 - 028	2	76	22	23%	
555.1 - 026	5	76	19	21%	
102.1 - 026 upper	2	66	32	20%	
733G3 - 028 top	10	70	20	28%	
type 3					
006A - 026	1	81	18	21%	
014 - 026	2	82	16	29%	
725A+B - 028	1	83	17	27%	upper layer

082C bottom	16	60	24	23%	mainly tile
type 5 - plasters only					
042A I3	0	76	24	34%	upper layer
075G lower	8	73	19	22%	
075 - 026	2	73	25	28%	
040G3 - 026	7	73	20	20%	
type 6 - plaster only					
082C top	27	55	18	37%	some tile

EXAMPLES OF PLASTER DESCRIPTIONS

DLC 026:

005 C: dark yellow on white *intonaco*, 0.1mm, on a combed or floated sandy plaster with tile, 12 - 15mm thick.

005 C+D: as 005 C with traces of tile plaster on the rear.

006 A: traces of red, green and yellow on burnished white *intonaco*, 0.05 - 0.1mm, on sandy plaster possibly in two layers, 10mm + 25mm thick.

009? I: burnished micaceous red, <0.05mm, on white *intonaco*, 0.5mm, on coarser sandy plaster, 8mm thick.

014 G 1: pink on off white, 0.1mm, on white *intonaco*, 0.75mm, on coarser sandy plaster, 8mm thick.

014 G 2: as 014 G 1: pink on white.

014 : white *intonaco*?, 0.5 - 0.75mm, on sandy plaster, 13mm thick.

040 : burnished micaceous red on white on sandy plaster as 009.

040 G 1: burnished green on black, <0.05mm, on red traces on white *intonaco*, 0.75mm, on sandy plaster, 7mm thick.

040 G 2: white stripe on green on red on white as 040 G 1.

040 G 3: brushed white, <0.05mm, on white *intonaco*, 0.5 - 1mm, on sandy plaster to 23mm thick.

040? G+J: burnished white on white sandy plaster, 13mm, on buff sandy plaster, 8+mm thick.

042 A I 1: brushed white *intonaco*, 0.05 - 0.1mm, on sandy plaster, 6mm thick.

2: pink, <0.05mm, on white *intonaco*, 0.5 - 1mm, on coarse sandy plaster, 9mm thick.

3: pink on white on coarse sandy plaster, 5 - 10mm, (with a re-used fragment of; dark green on black on dark red), on green on black, 0.1mm, on white *intonaco*, 0.5mm, on sandy plaster traces.

045 A H: pink, <0.05mm, on hard lime plaster, 12mm thick, and a sample of "pure" lime.

061 A I: white, 0.5mm, on sandy plaster, 7mm thick.

066 G 1: rough yellow, <0.05mm, on white *intonaco*, 0.5mm, on sandy plaster, 6mm, on black on dark pink, 0.05mm, on white *intonaco*, 0.2mm, on sandy plaster traces 2+mm thick.

2: dark red on white *intonaco* ?, <0.1mm, on sandy plaster, 10mm thick.

042 A I 3: over plastering on an under cut lower layer? Green on black c.f. 040 G 1.

066 G 1: over plastering on black lines on dark red to dark pink, possibly as 042 A I 3.
075: cream sandy plaster, 13mm thick with traces of a pink lime wash or *intonaco* on both faces. This was possibly an over-plastering on pink lower plaster. Also samples showing the lower dark pink on white *intonaco* on coarser white plaster, and one fragment showing grey paint on the upper layer.
074 G: white, <0.05mm, on yellow, <0.05mm, on red *intonaco* ?, <0.05mm, on sandy plaster, 7mm thick.
075 G 1: brushed white, <0.05mm, on white *intonaco*, 0.5mm, on sandy plaster, 15mm thick.
2: as 009? I: burnished micaceous red, <0.05mm, on white *intonaco*, 0.5 - 0.75mm, on sandy plaster, 10mm, on sandy plaster, 10mm thick.
075 G 4: off white stripe on yellow, 0.05mm, on red on white *intonaco*, 0.75mm, on sandy plaster, 7 - 15mm thick.
075 G: brushed pink, 0.1mm, on brushed white, 0.1mm, on white *intonaco*, 0.5mm, on sandy plaster, 6mm, on pink, <0.05mm, on white *intonaco*, on sandy plaster to 16mm thick, possibly 7mm + 9mm, c.f. 066 G 1.
075 I: pink, <0.05mm, on white *intonaco*, 0.1mm, on sandy plaster to 23mm thick.
077 A: yellow on floated or combed white *intonaco* on sandy plaster with tile traces, c.f. 005.
077 G: burnished micaceous red, <0.05mm, on white *intonaco*, 0.75mm, on sandy plaster, 11mm thick as 009?.
2: white on burnished micaceous red on sandy plaster, 8mm, as 074 G.
3: white on yellow on burnished micaceous red on white on sandy plaster, 8mm, similar to 074 G.
080 A+B: yellow on white on sandy plaster on buff sandy plaster; c.f. 040? G+J.
080? A+F: white on sandy plaster, 12mm thick.
080 G+I: burnished white, 0.5mm, on sandy plaster, 8mm, on buff sandy plaster, 7mm thick, as 040? G+J.
080 I: burnished red on white (as 077 G 3 009) on sandy plaster, 6mm, on dark red on white on sandy plaster; c.f. 066 G1, 075 G.
082 C: orange, <0.05mm, on sandy plaster, 17mm thick.
orange on pink plaster, 3.5mm, on sandy plaster, 8 - 15mm thick.
082 C+D: orange red stripe on white *intonaco* ?, 0.2mm total, on white sandy plaster, 5.5mm, on pink plaster, 8mm thick.
087 A+B:
1:pink and green bands on white, 0.05mm, on burnished white *intonaco*, 0.5mm, on sandy plaster with tile traces, 10 - 12mm, on buff plaster, 10mm thick; c.f. 080 G+I.
2: as above; yellow (7+) red (13) white (15) green (10+) bands (mm)

3: yellow and red spots, yellow, white and red bands on white on sandy plaster, 25mm, on buff plaster with straw impressions, 10+mm thick.

4: plain white.

087 I: over plaster; grey to black, 0.05mm, on white *intonaco* ?, 0.1 - 0.5mm, on sandy plaster, 4mm, on red, 0.05mm, on white *intonaco* ?, 0.2mm, on sandy plaster, 5mm thick. c.f. 042 A I 3, 066 G 1.

089 I: yellow on burnished micaceous red< <0.05mm, on sandy white traces, 0.75mm, on sandy plaster, 13mm thick.

026 / 102:

1: coarse dark pink, 0.05mm, on white traces, 0.1mm, on sandy plaster to 9mm thick with a flat rear, suggesting that this was an upper layer. Also a sample with dark pink, 0.05mm, on white *intonaco* ?traces, 0.5mm, on sandy plaster, 15mm thick, a flaked lower layer?. c.f. 087 I ?.

102 G: yellow on red to brown, 0.05mm, on yellow on white *intonaco* ? traces, 0.5mm, on sandy plaster, 10mm.

G 2: yellow to red on white traces on sandy plaster to 14mm thick.

G 3: grey on burnished yellow, 0.05mm, on white *intonaco* , 0.5mm, on sandy plaster, 8mm thick.

white on burnished micaceous red, 0.05mm, on sandy white *intonaco* traces, 0.75mm, on sandy plaster, 17mm thick.

G 4: burnished micaceous red on white *intonaco* , 1mm, on sandy plaster to 17mm thick, composed of white and buff plaster in two layers, 10+7mm.

also; red, 0.05 - 0.1mm, on white *intonaco* , 0.75mm, on sandy plaster, 8mm thick. c.f. 077 G ?.

102 G+J: black, 0.05mm, on white *intonaco* , 0.5mm, on sandy plaster, 7mm, on red, <0.05mm, on white *intonaco* , 0.1mm, on sandy plaster, 10+mm thick. c.f. 087 I.

102 I: pink, <0.05mm, on white *intonaco* , 0.5mm, on sandy plaster, 6mm, on buff plaster traces, 2+mm.

118 E+?I: white *intonaco* ?, 0.5mm, on coarse sandy plaster, 12mm, on coarse buff plaster, 12mm thick.

539 E: white *intonaco* ?, 1 - 1.5mm, on very coarse sandy plaster, 15mm, on sandy plaster, 8+mm thick.

1: red, <0.05mm, on white *intonaco* , 0.75mm, on coarse sandy plaster, 12mm, on sandy plaster, 7+mm thick. c.f. 118 E+?I.

555: white, <0.05mm, on white *intonaco* , 0.75mm, on coarse sandy plaster, 14mm, on sandy plaster, 10mm thick. c.f. 118 E+?I.

555 I: burnished micaceous red on white on sandy plaster, 5+6mm thick, c.f. 077 G 2 ?.

713 I: red, 0.05mm, on white *intonaco* , 0.75mm, on sandy plaster to 20mm thick.

u/s ?E: rough white *intonaco* , 0.75 - 1mm, on sandy plaster, 10mm thick.

DLC 028

725 A+B: white on sandy plaster, 16mm, on buff plaster, 8mm thick.

727 A+B: red and yellow, 0.05mm, on sandy white *intonaco* , 0.5mm, on sandy plaster, 6mm, on buff plaster traces, 7+mm thick.

A+F: as above - plain white.

B: as above - plain white.

C+D: pink on sandy white *intonaco* ? traces, on sandy plaster with tile traces, 10mm, on pink plaster, 13mm, on coarser pink plaster, 11mm thick.

E: white *intonaco* ?, 0.4mm on coarse sandy plaster to 18mm thick. c.f. 026 539 E.

733 G: yellow splashes on micaceous red on white sandy plaster, 1mm, on sandy plaster, 6mm thick with a flat rear - an upper plaster layer. c.f. 026 102 G 4.

1: traces of blue in white and a red stripe on burnished black on white on sandy plaster to 17mm (9+8?).

2: burnished micaceous and siliceous red, <0.05mm, on white *intonaco* , 0.75mm, on sandy plaster, 9mm thick. c.f. 026 077 G. Another sample with 7mm of plaster had lime on the rear suggesting an over plaster.

3: micaceous red, <0.05mm, on sandy white *intonaco* ? traces, 0.5mm, on hard sandy plaster, 7mm, green with blue traces, 0.1mm, on white *intonaco* , 0.5mm, on sandy plaster, 8mm + 6mm thick.

734 A+B: plain white *intonaco* ?, 0.5mm, on sandy plaster, 10mm, on buff plaster, 8 - 12mm thick.

B: plain white as above.

?A+F: plain white as above.

I: burnished micaceous red, <0.05mm, on white *intonaco* , 0.75mm, on sandy plaster, 10mm thick.

745 I: burnished micaceous red, 0.1mm, on white *intonaco* , 0.5mm, on sandy plaster with a tapering section, 8 - 18mm thick.

762 ?A+F: plain white *intonaco* ?, 0.5mm, on sandy plaster, 4mm, on buff plaster, 4mm thick.

766 H+?I: dark red, 0.05mm, on thick white *intonaco* , 5mm, on sandy plaster, 15mm thick.

I: burnished micaceous red, <0.05mm, on sandy white *intonaco* , 0.5mm, on sandy plaster, 6mm, on buff plaster, 8mm thick.

773 I: burnished micaceous red, <0.05mm, on sandy white *intonaco* , 0.5mm, on sandy plaster to 11mm (6mm + 5mm).

776 I: Dark sandy red on sandy white traces on sandy plaster, 9mm + 8mm.

783 I: traces of green on yellow on pink on sandy plaster to 15mm thick.

783 I 1: yellow splash (marbling?) on burnished red, 0.2mm, on sandy white *intonaco*, 0.5mm, on sandy plaster, 10mm thick; and: yellow and red, 0.1mm, on pink *intonaco* ?, 0.75mm, on sandy plaster in two layers, 6mm + 9mm.

2: burnished red, 0.2mm, on sandy white *intonaco*, 0.5mm, on sandy plaster, 12mm thick.

3: grey , 0.1mm, on pink *intonaco*, 0.2mm, on sandy plaster in two layers, 5mm + 7mm.

E: plain white fragments as above.

784 : burnished red, 0.1 - 0.2mm, on sandy white *intonaco*, 0.5mm, on sandy plaster to 17mm thick.
784 I 1: white on black, 0.05mm, on pink *intonaco*, 0.5mm, on sandy plaster, 15mm thick. c.f. 783 I 1. Also; white stripes on green on black on pink and; green on yellow on pink as above.
2: plain white *intonaco* ?, 0.6mm, on sandy plaster to 24mm thick.
3: grey to black, 0.1mm, on pink *intonaco*, 0.4mm, on sandy plaster to 13mm thick. c.f. 783 I 3.
4: black stripe and red on burnished white *intonaco*, 0.5mm, on sandy plaster, 11mm, on buff plaster, 10+mm thick. A border or panel.
5: burnished black on pink on sandy plaster to 15mm thick (10mm + 5mm), c.f. 783 I 1.
6: burnished yellow, 0.05mm, on pink *intonaco*, 1mm, (c.f. 783 I 1) on plaster to 18mm thick.
7: yellow splashes on burnished red, 0.1mm, on sandy white *intonaco*, 0.5mm, on sandy plaster to 20mm thick. c.f. 783 I 1
8: black stripe on white c.f. 784 I 4.
9: red on white *intonaco*, 1mm, on sandy plaster, 17mm thick. The uneven surface suggested a room edge.
785: red, 0.1mm, on sandy white *intonaco*, 0.75mm, on sandy white plaster, 11m thick.
799: rough red on thick white lime only, 11mm thick.
1: burnished red, 0.2mm, on white *intonaco*, 0.5mm, on sandy plaster, 12mm thick.
2: burnished white as above.
3: black on grey on pink *intonaco*, on sandy plaster, 12mm thick. c.f. 783 I 1.
800 I: rough yellow on sandy plaster fragment.
808 A: plain white on sandy plaster to 15mm thick.
808 ?A+F: plain white *intonaco*, 0.5mm, on sandy plaster, 12mm, on buff plaster traces.
820 I: burnished red <0.05mm, on sandy white *intonaco*, 0.5mm, on sandy plaster, 13mm thick.
861 I: burnished red, 0.2mm, on sandy white *intonaco*, 0.5mm, on sandy plaster, 10mm thick.
862: yellow on red on pink *intonaco* on sandy plaster fragment. c.f. 783 I 3.
and: sandy red, 0.5mm, on sandy white *intonaco*, 0.5mm, on sandy plaster, 8mm thick.
1104: white, <0.05mm, on white *intonaco*, 0.5mm, on sandy plaster to 14mm thick.

DLC 029
301 E: red, 0.05mm, on white *intonaco*, 0.5mm, on coarse sandy plaster, 18mm thick.

DLC 0361500 unstrat.: burnished yellow on pink *intonaco*, 0.5mm, on coarse sandy plaster, 7mm, on a lime rich sandy plaster, 7mm thick. The flat rear suggested an over plaster.

1552 E 1: burnished red brown to yellow brown, 0.05mm, on sandy plaster, 5 - 7mm, on lime and sand plaster, 5 - 12mm, with flat rear as above.
2: over plastered? plain burnished sandy white *intonaco*, on sandy plaster, 10mm thick. The over plastering has masked any colour on the white.
1553 E: brushed red, 0.1mm, on sandy white *intonaco*, 0.5mm, on coarse sandy plaster, 4mm + 7mm, on (burnt?) sandy orange clay traces. c.f. 1552 E 1.

The plasters appear to fall into about ten groups based on their layered structures and compositions:

PAINTING TECHNIQUE

The painting technique was mainly *buon fresco*, with over painting possibly in *fresco secco*. The micaceous red was frequently burnished.

PIGMENTS

The pigments used were the usual natural colours: red ochre (haematite), yellow ochre (limonite), white lime, green earth (glauconite), black soot or charcoal and crushed Egyptian blue. Much of the red was micaceous.

Average results

	Thicknesses		"Lime"
lime lump	-		86%
mortar	-		25%
torching	-		47%
opus signinum:			
mortar	-		34%
tile bonding or plasters	(15 -35)	20mm	42%
plasters:			
paint	(<0.05 - 0.5)	0.09mm	42% carbonate
intonaco	(0.05 - 1)	0.5mm	62% carbonate
upper layer	(4 - 25)	11mm	26% (28% carbonate)
lower layer	(5 - 25)	9mm	24%
third layer		11mm	22%
single layers	(20 - 24)	22mm	24%

secondary plaster:

paint	(<0.05 - 0.1)	0.06mm	-
intonaco	(0.1 - 0.5)	0.5mm	-
upper layer	(4 - 9)	6mm	34%
lower layer	(7 - 9)	8mm	34%

opus signinum:

upper layer	-	37%
lower layer	-	23%

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig Nos 101 - 110
type 1: 012, 010, 020, 106, 118 - 033, 008 - 025, 080 - 026, 539E - 026 (plaster).
type 1+: 046A, 046B, 071 - 026, 005A - 026, 040[2] - 026.
type 2: 129, 117 - 028; plasters: 784 - 028, 555.1 - 026, 102.1 - 026 upper, 733G.3 - 028 top.
type 3: 006A.1 - 026, 045A - 026, 042A - 026, 014 - 026; plasters: 006A - 026, 014 - 026, 725 A+B - 028 upper, 082C bottom.
type 4: 008 - 026
type 5: plasters only; 042A I3, 075G lower, 075 - 026, 040G3 - 026.
type 6: plaster; 082C top.

The graphs show six main types of particle distribution. Some of the differences are however only slight. In view of the very large sample weights used for the mortars, a different set of sieves was used for the gradings. The results can not therefore be used for direct comparison with other gradings in the survey.

Fig.101 Littlechester - type 1.1

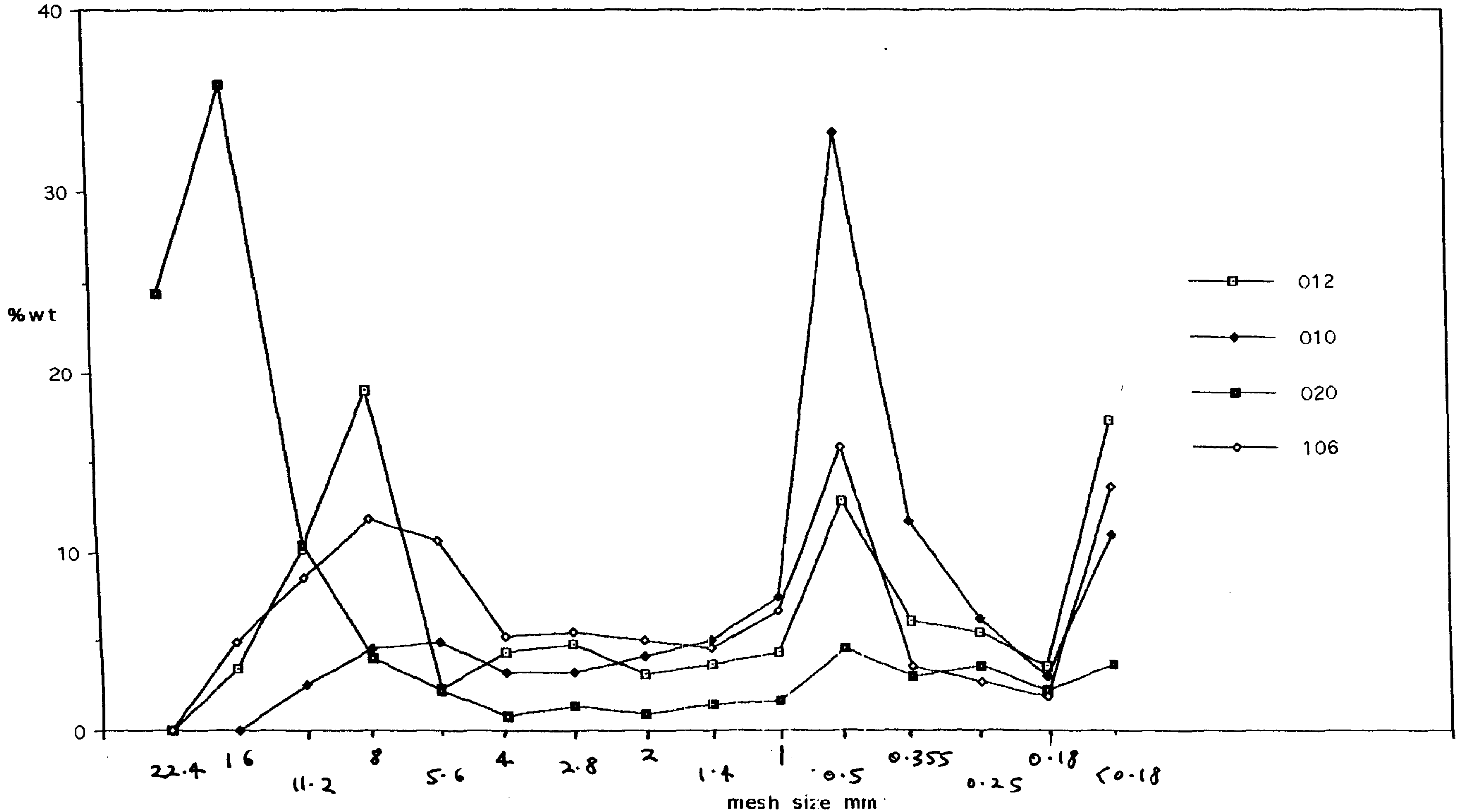


Fig. 102 Littlechester - type 1.2

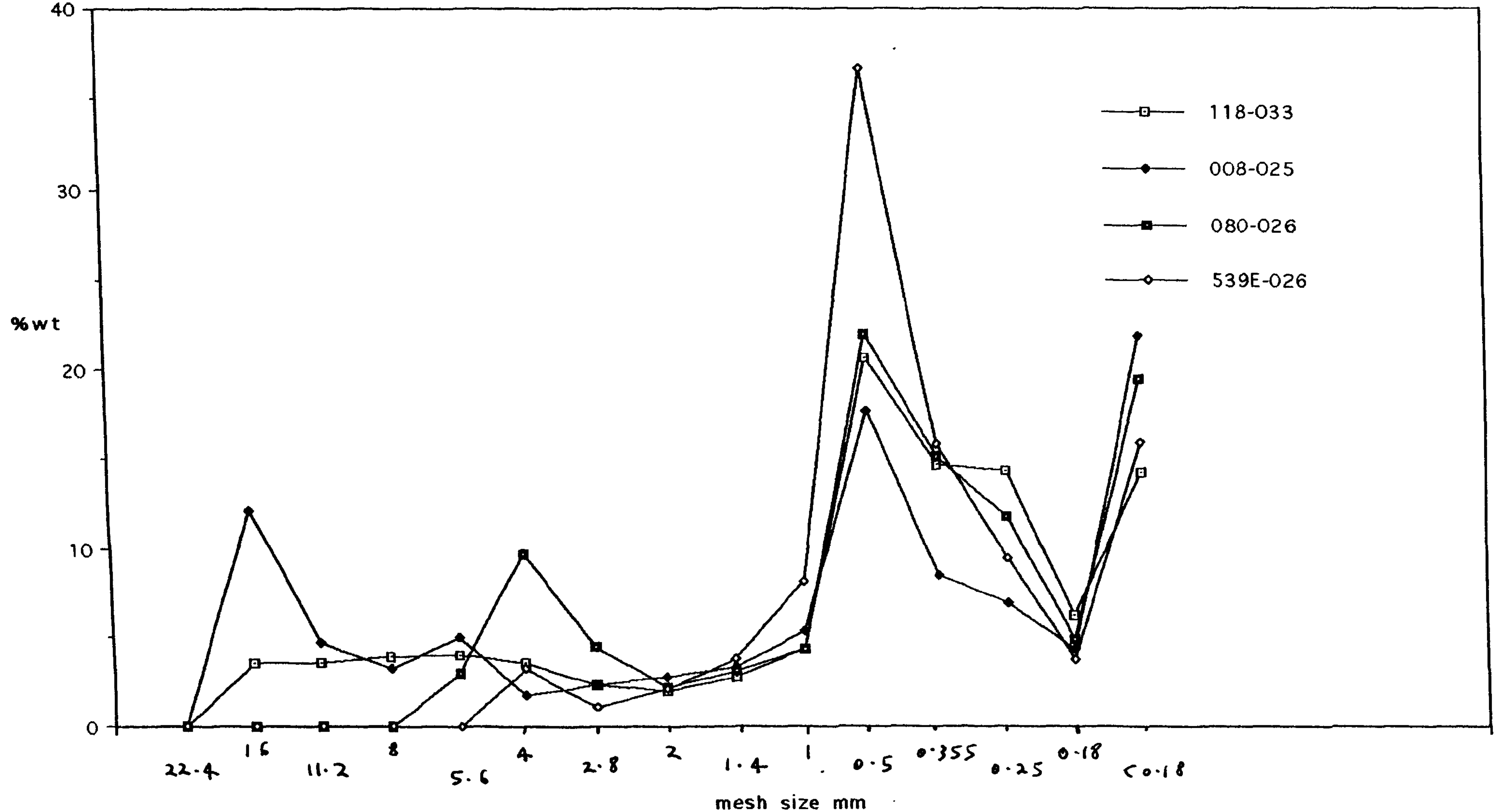


Fig. 103 Littlechester - type 1+

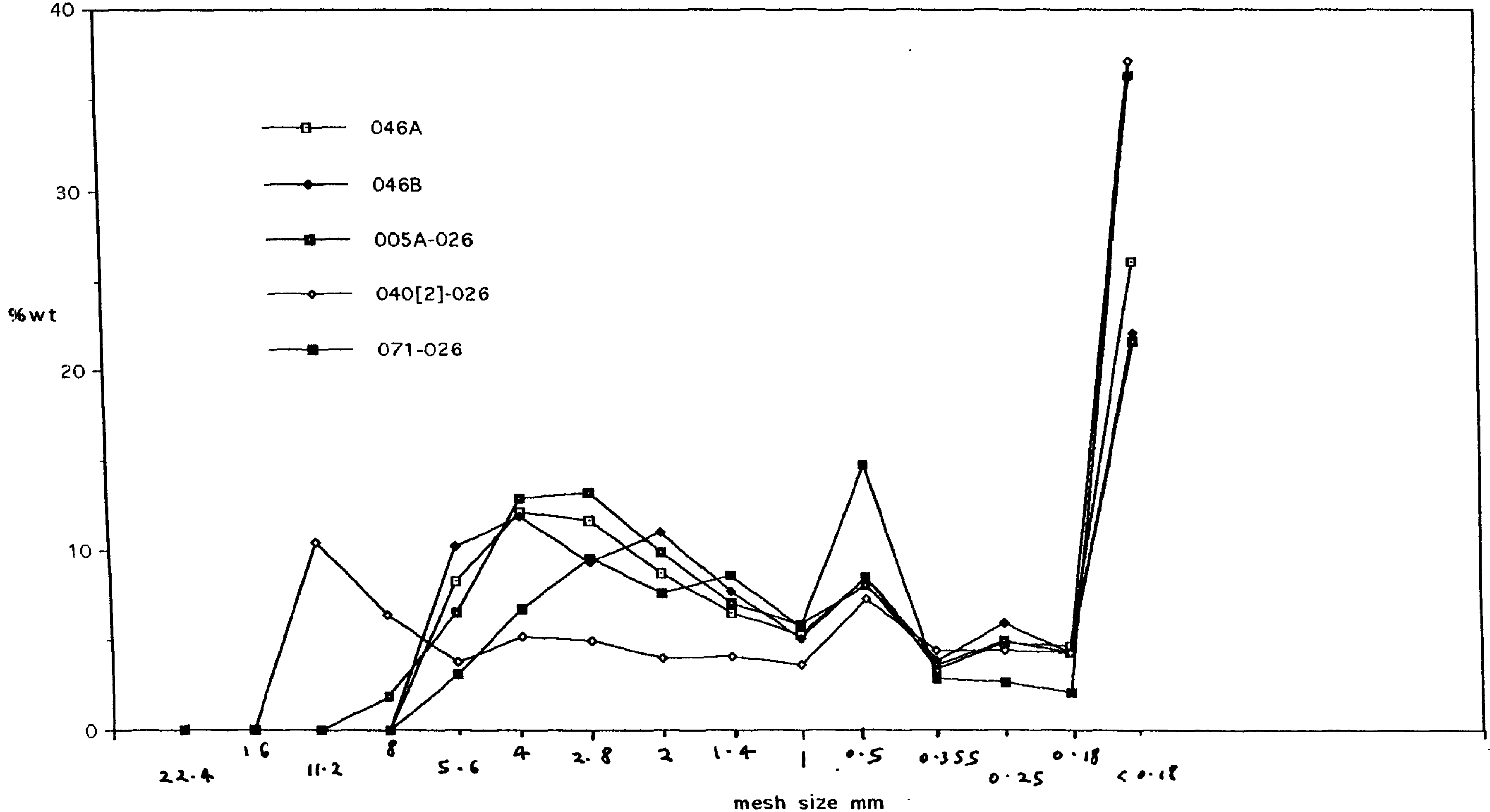


Fig. 104 Littlechester - type 2

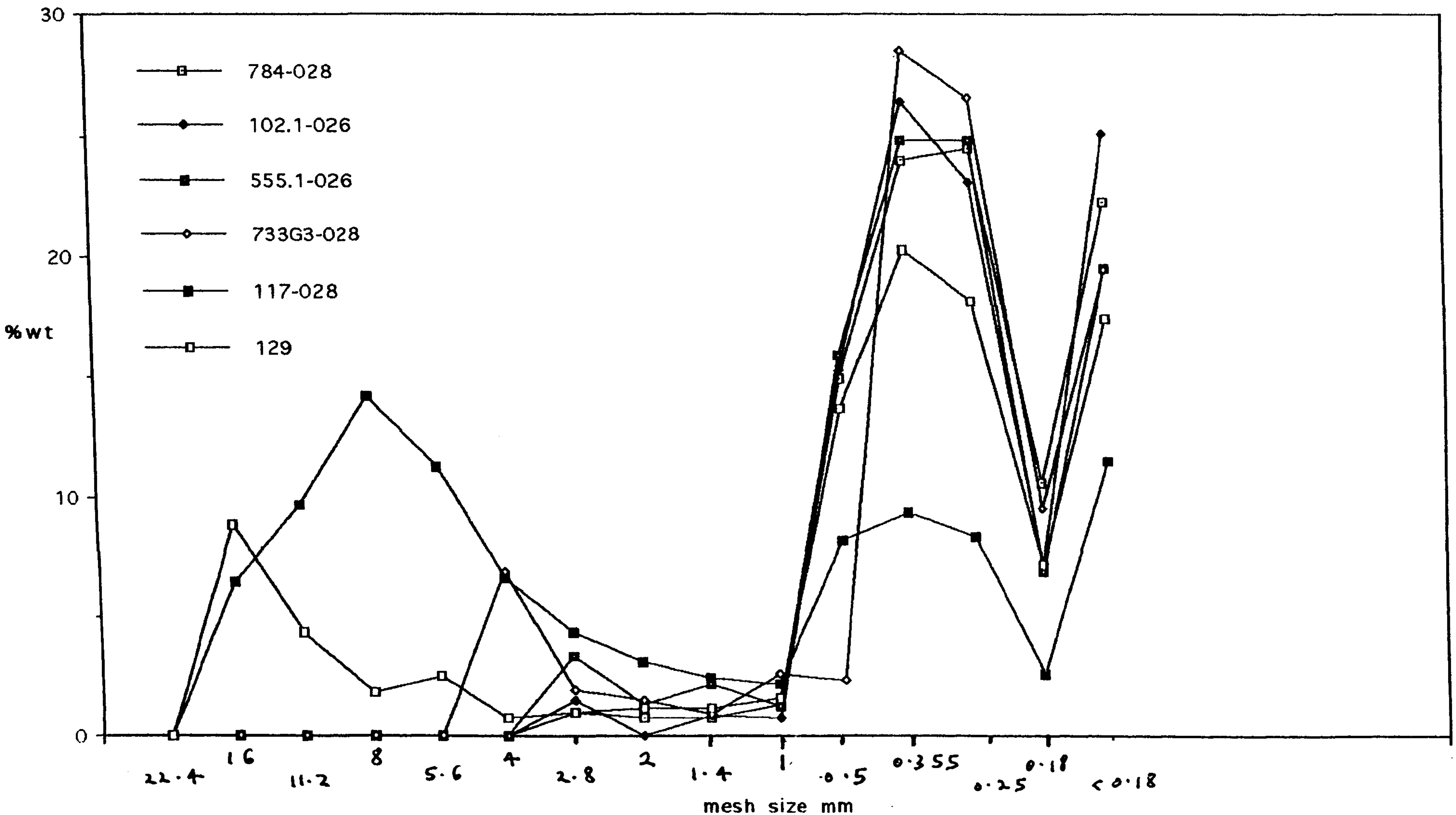


Fig. 105 Littlechester - type 3.1

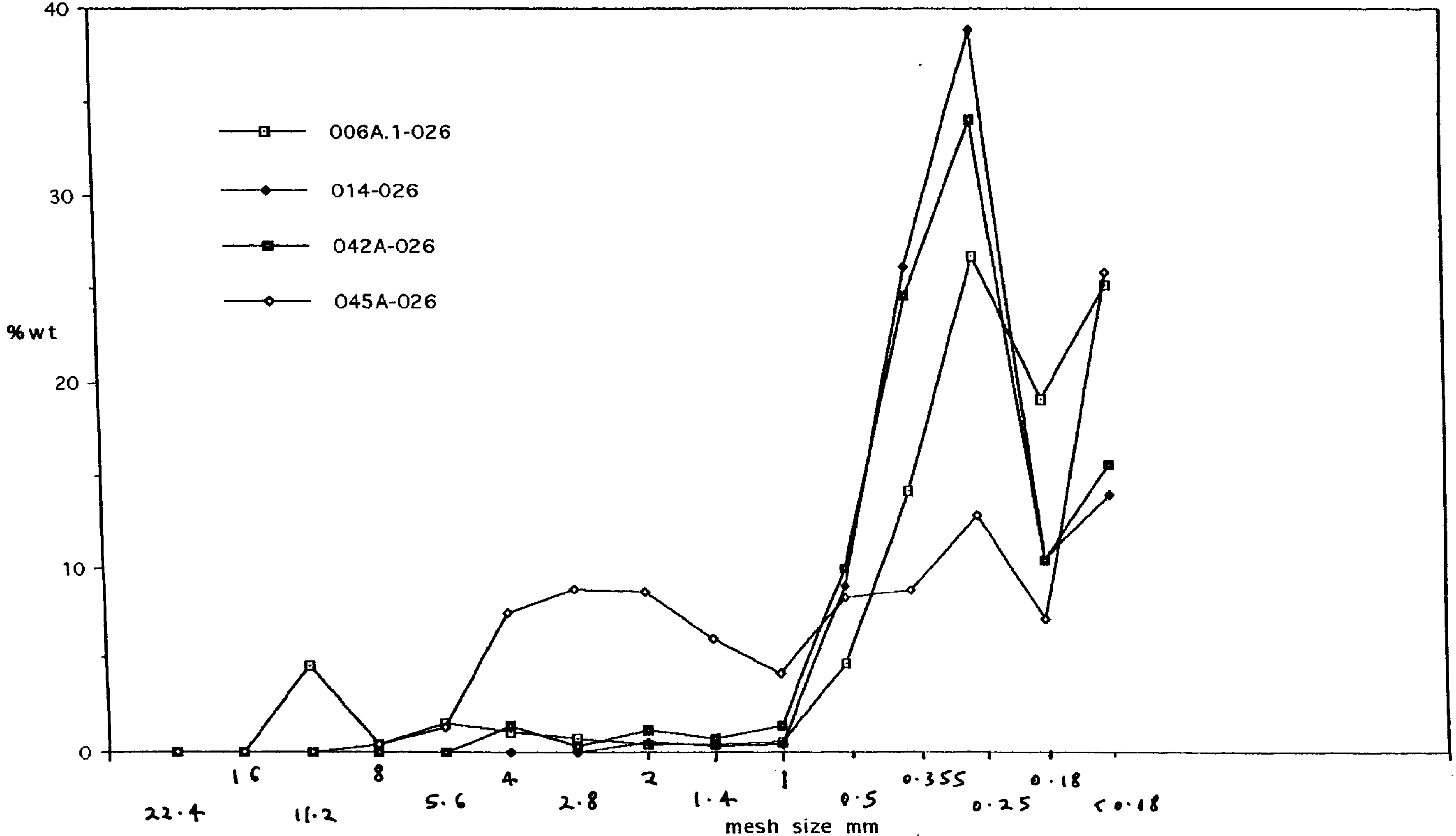


Fig. 106 Littlechester - type 3.2

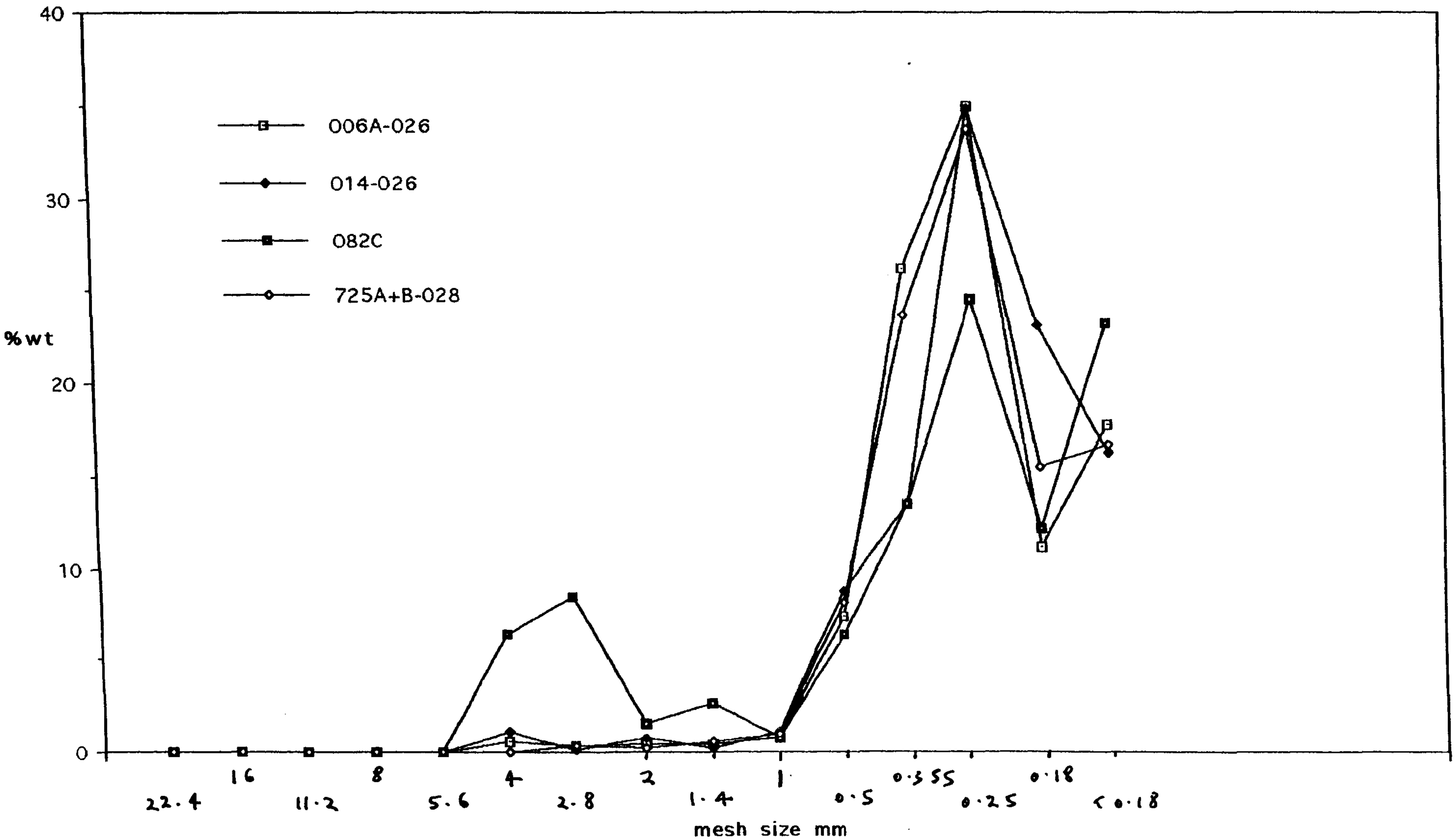


Fig. 107 Littlechester - type 5

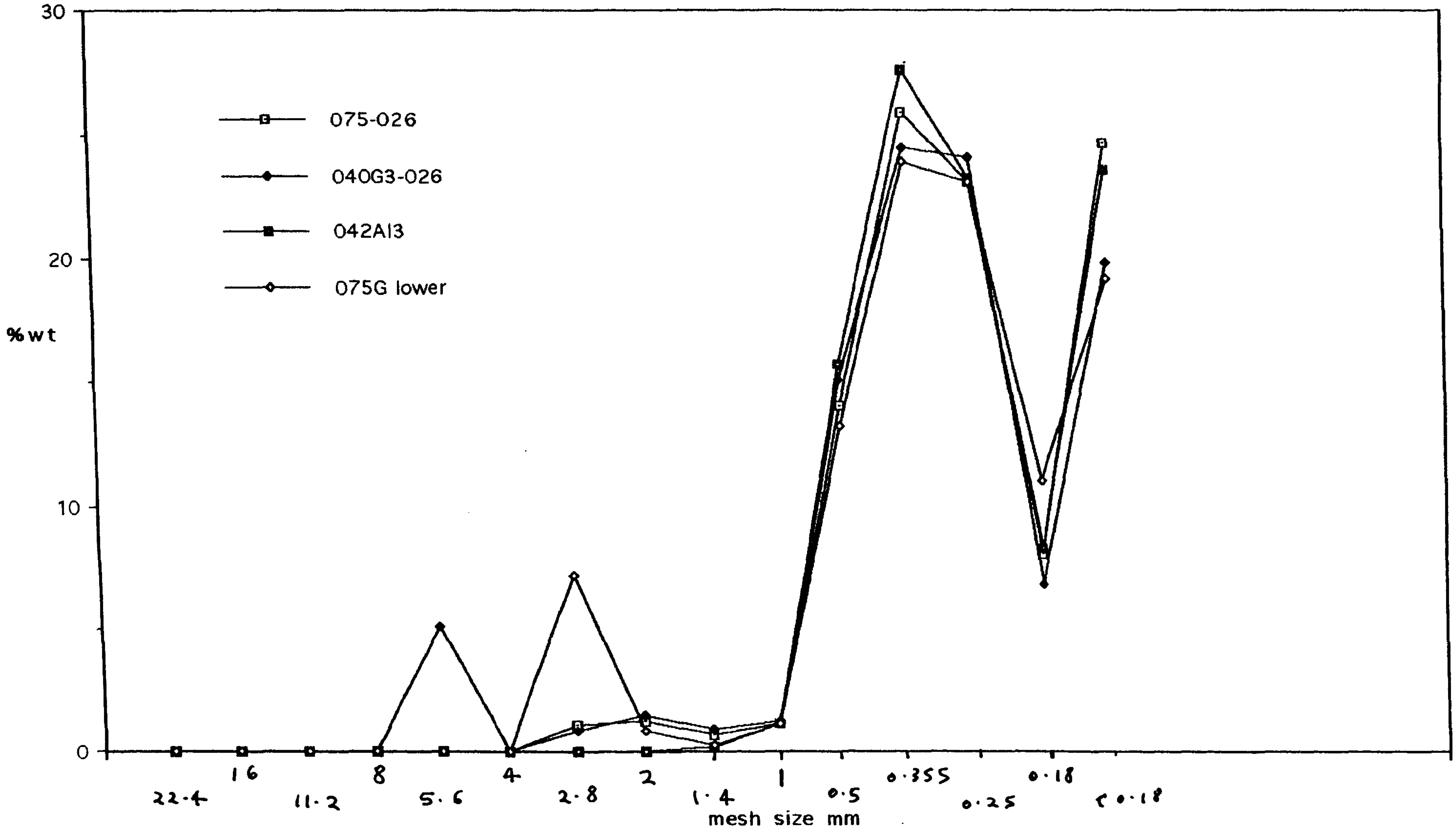


Fig. 108 Littlechester - types 4, 6

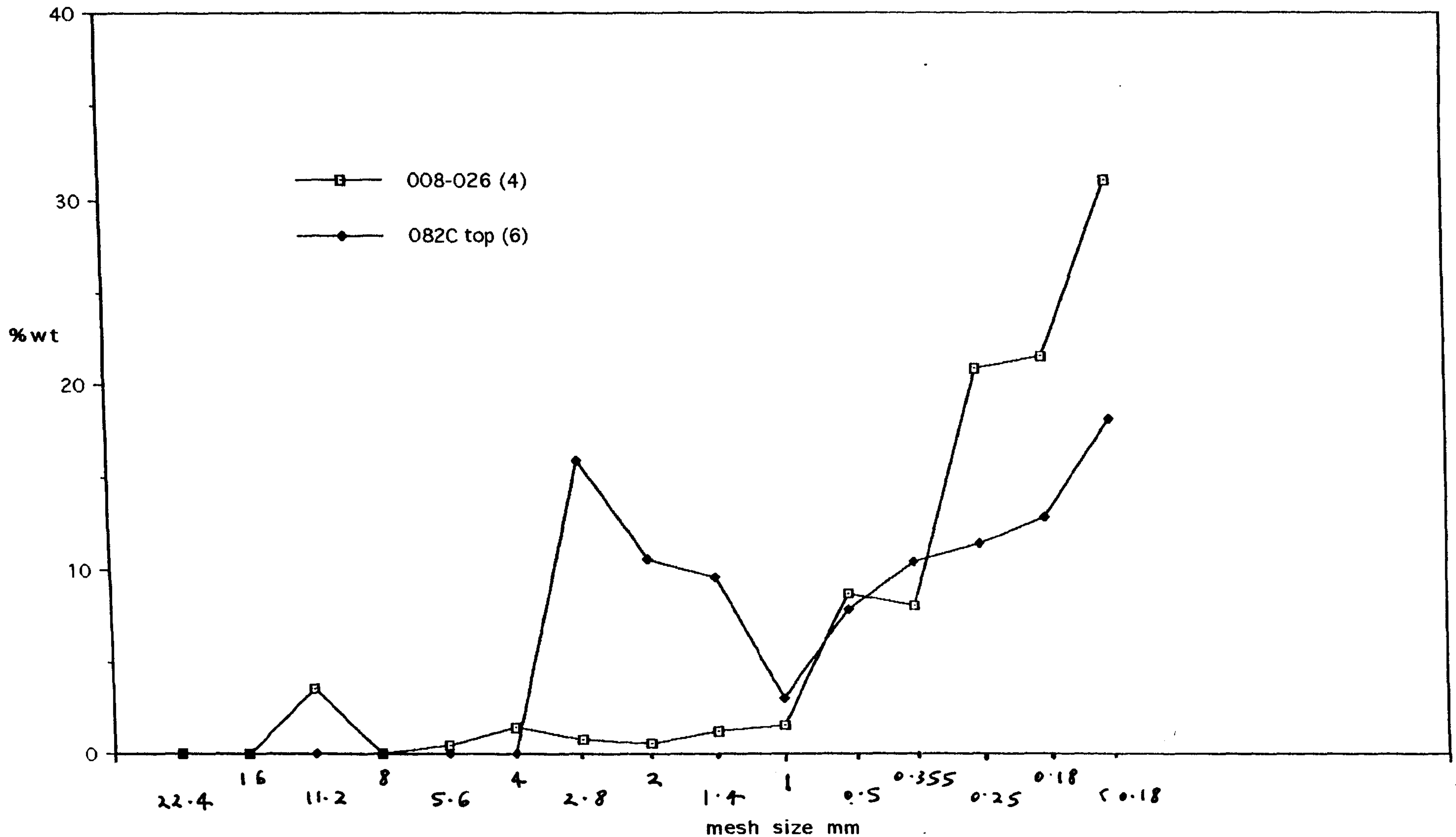


Fig. 109 Littlechester - opus signinum 1

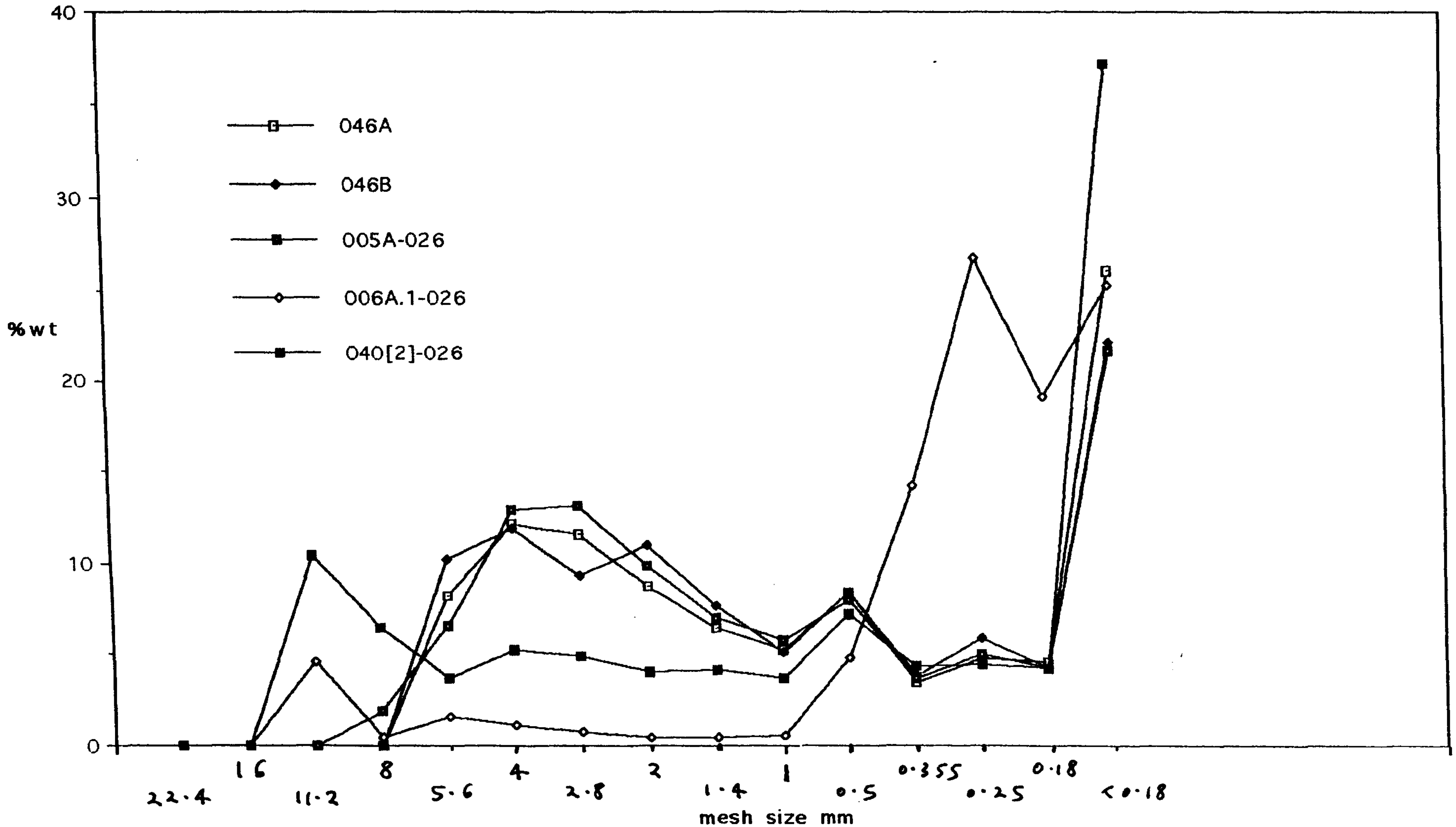
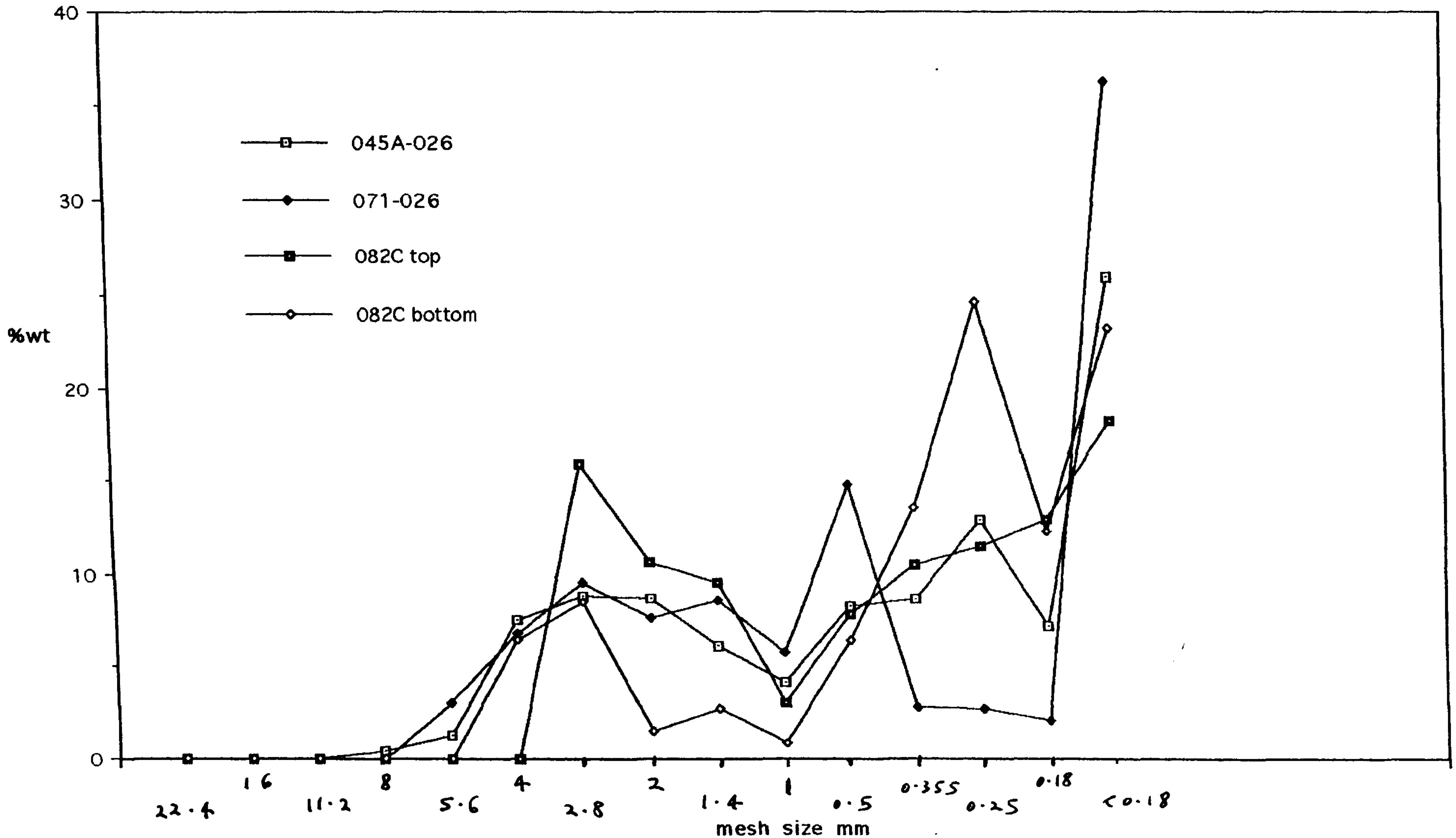


Fig. 110 Littlechester - opus signinum 2



London
Amphitheatre and Forum
Philp 1970
Current Archaeology (1988)109: 49 - 50: (1977) 59: 370 - 1.

Samples of mortar from the walls of the Amphitheatre (only one sample) and the Forum / Basilica were supplied by the Museum of London for analysis. The material came from several sites on the presumed walls of the Forum. The aggregates were mainly river gravels and sand, being composed of: quartz, quartzite, flint and ferruginous sandstones. The presence of quantities of glauconite grains and amorphous silica in the acid soluble residues pointed to the use of a siliceous and glauconitic limestone, such as lower chalk or Reigate sandstone, as a possible source for the lime. Eleven samples were examined and thirteen analyses carried out. These results are unpublished.

COMPOSITIONS

No		gravel	sand	silt	"lime"	comments
Amphitheatre		54	39	7	15%	some chalk and lime lumps
Basilica walls						
A:	9224	36	53	11	22%	wall
	9224	20	68	12	25%	tile course
	9267	34	58	8	24%	foundation
B:	9587	34	54	12	54%	wall rebuild
	9588	35	57	8	35%	wall
	9588	29	60	11	24%	tile course
	9267	28	60	12	28%	foundation
669 <135>		56	28	16	33%	upper layer, *opus signinum*
		51	29	20	29%	lower layer, *opus signinum*
479 <127>		32	58	10	21%	wall
83 [247]		75	15	10	29%	"floor"
		83	13	4	18%	second sample from 83 [247]

EXAMPLES OF MORTAR DESCRIPTIONS

Amphitheatre:

stone retaining wall of arena; very coarse gravel and sand mortar with hard chalk and lime, estimated at <5% volume. This mortar appeared to be more like concrete than bonding mortar with pebbles up to 35mm across. The very fine residue was mainly amorphous silica.

Basilica Walls, Leadenhall Court, (LCT 84)

A: [9224] stone wall: pale buff sandy mortar with fine and medium to coarse pebbles.

[9224] tile course: pale buff sandy mortar with fine and medium to coarse pebbles and about 10% by volume hard chalk or lime.

[9267] stone foundation: yellow to buff sandy mortar with fine and medium to coarse pebbles and about 5% by volume hard chalk or lime.

B: [9587] stone wall rebuild: pale buff sandy mortar with fine pebbles.

[9588] stone wall: yellow to pale buff sandy mortar with fine and medium to coarse pebbles and 5 - 10% by volume hard chalk or lime.

[9588] tile course: pale buff sandy mortar with fine to medium pebbles, a few coarse pebbles and 5 - 10% by volume hard chalk or lime. The sample was 100mm thick with a red ochre or brick dust coated surface. This was probably due to contact with a large piece of brick or tile rather than being a painted surface.

[9627] stone foundation: yellow to pale buff sandy mortar with fine to medium pebbles and about 5% by volume of hard chalk or lime.

Lime Street, (LIM 83) mortar from period V '7' "large masonry walls"

[669] <135>: pink crushed brick or tile mortar with fragments of charcoal, lime or chalk and grass or straw impressions. This sampled showed two layers which were analysed separately. They probably represented two batches of mortar.

[479 <127>: pale buff sandy mortar with medium to coarse pebbles, lime or chalk to about 5% by volume, a fragment of black pottery and a large piece of Kentish ragstone.

IME 83 [247] <158>: mortar sample from "*opus signinum* floor": buff medium to coarse pebble mortar, 70mm thick, with large pieces of lime, about 10% by volume. This was a very heterogeneous sample and two samples were taken for analysis. This may have been two batches or poor mixing. There was only a small amount of tile in the aggregate, not enough to describe this sample as *opus signinum*.

Average results

		"Lime"	
Amphitheatre		15%	foundation
Forum:			
rebuild		54%	
mortars	(18 - 35)	26%	walls and foundations

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig No. 113, 114
Amphitheatre, Forum; 247, 479, 669 (op. sig), 9224 A, 9267 B. The sand size grade of the Amphitheatre sample was very similar to those from the Forum, suggesting a similar source.

Fig. 113 London - Forum

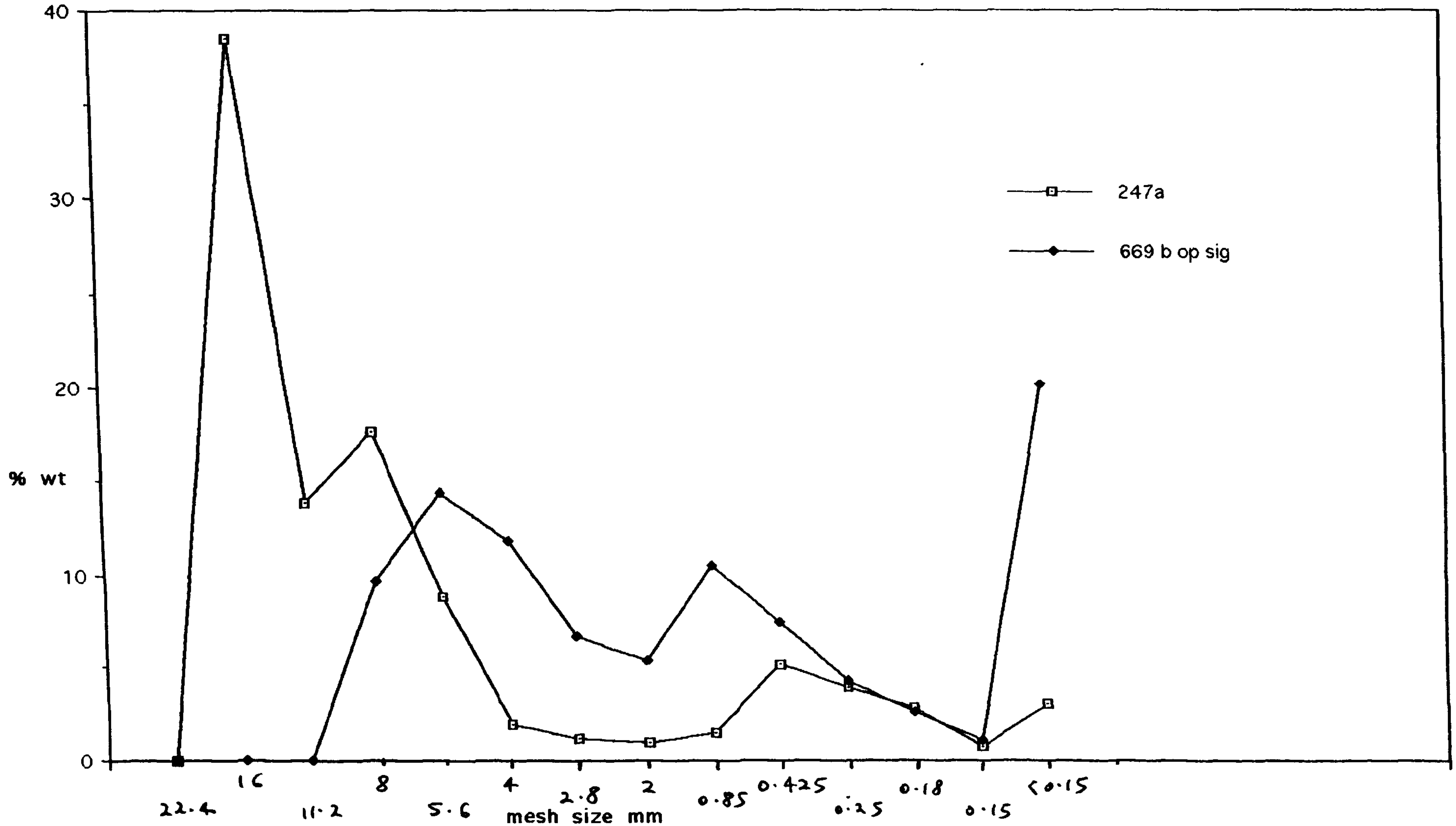
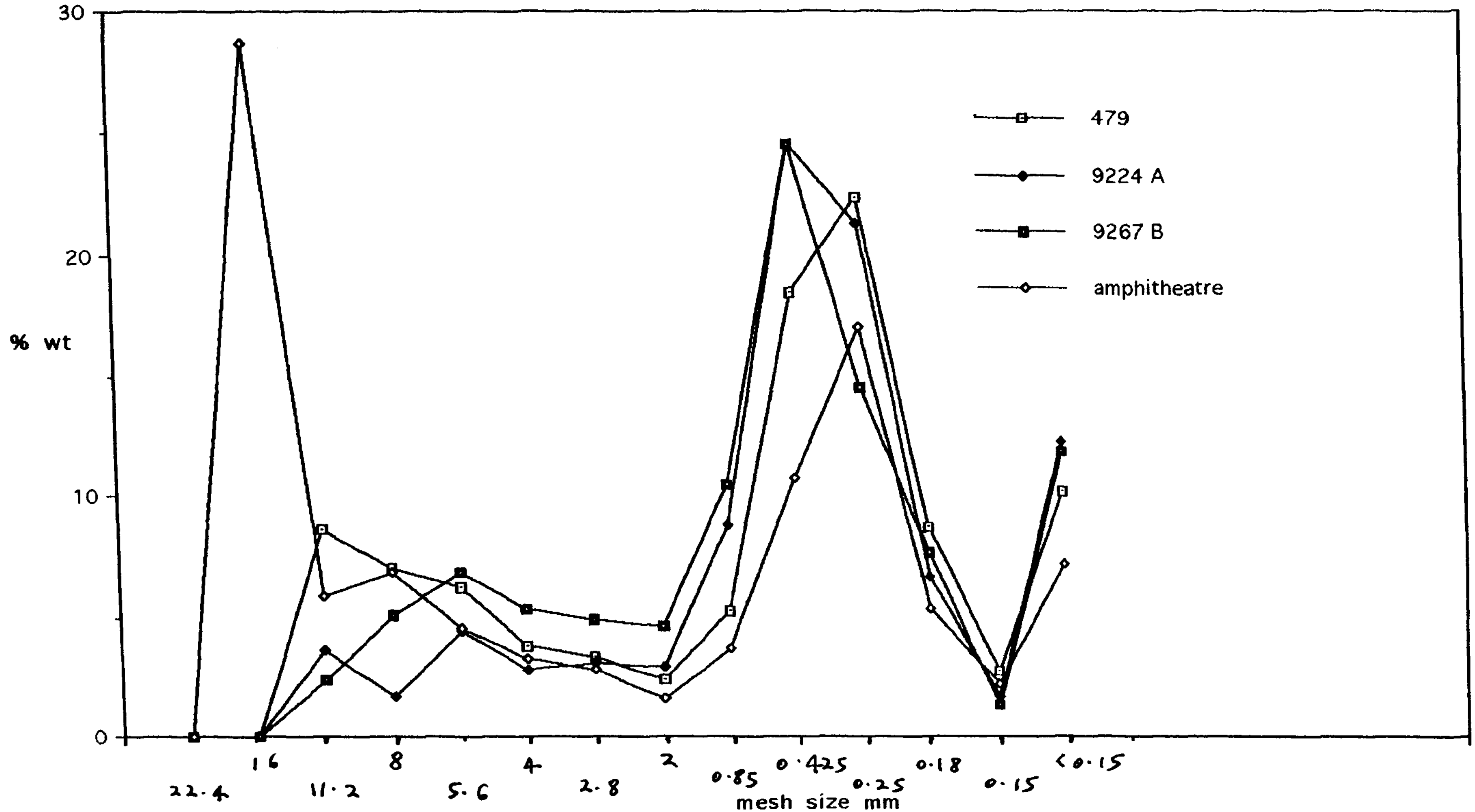


Fig. 114 London - Amphitheatre and Forum



London
Fenchurch Street
Rhodes 1987

Excavations at 6 - 12 Fenchurch Street, London, (a site across the Roman road from the Forum) in 1983 produced remains of a Roman shop or house. The wall plaster showed that the building had, at least in part, been destroyed by fire. The aggregates were mainly river sands, similar in composition to material from Southwark, Winchester Palace site and other sites in the area. The presence of calcite grains in the *intonaco* layers is of note. This crystalline material has been more commonly seen in official or public buildings, similarly, cinnabar was considered to be very expensive, both occurrences pointing to a special building or a wealthy patron. The presence of the Forum over the road from the site may however point to perhaps the illicit use of such expensive materials in an apparently lowly structure, although the particular use may reflect a rather special room in an otherwise ordinary building. This is to some extent confirmed by the painting described by Rhodes (op.cit.). Work is continuing on the analysis of the plaster from the site. Preliminary observations only are given here.

EXAMPLES OF PLASTER DESCRIPTIONS
FEN 83:
2458)
a) yellow on blue on white *intonaco*, 0.5mm thick.
b) blue green on red on white *intonaco* with calcite traces, 1mm thick.
1) white, green, green to yellow (burnt) and red on white *intonaco* with calcite traces, 0.8 - 1mm, on burnt plaster, 20+mm thick.
2) pale grey on blue with black and off white on white *intonaco*, 1mm, on burnt plaster.
3) dark grey on blue with black on white *intonaco* on burnt plaster.
2288)
1) thick red on traces of white with calcite, total 0.5mm, on burnt plaster, 30mm thick.
2) bright red*, 0.05 - 0.1mm, on white to grey (burnt) *intonaco*, 0.5 - 1mm, on sandy plaster, 9mm, on sandy plaster, 17mm thick. c.f. 2461.
3) white on green on red. c.f. 2458, 2463.

PAINTING TECHNIQUE

The painting technique appeared to be *buon fresco*. The use of quantities of crystalline calcite in the *intonaco* layers and the use of cinnabar was of note.

PIGMENTS

The pigments used were: red ochre (haematite), red* cinnabar, yellow ochre (limonite), green earth (glauconite), carbon as soot or charcoal, white lime and crushed Egyptian blue. The burning had altered many of the colours, reddening any plaster or pigment containing iron.

London, Southwark
Winchester Palace Site.
Mackenna and Ling 1991
Britannia 1984 15: 310 - 11

Excavations on the site of the palace of the medieval Bishops of Winchester near the southern end of London Bridge uncovered remains of Roman buildings dating from the first to the fourth centuries. This report was based on painted plaster from the bath house complex and represents two phases; the first probably of the mid second century and the second probably of the third century. The painting is described in great detail by Mackenna and Ling (op cit). The painted plaster came from a clay wall with the first layer of sandy lime plaster with straw or grass some 60mm thick. Traces of the lower plaster were seen on the samples examined, together with the upper layer of sandy plaster with tile traces, about 10mm thick, with a white *intonaco* and burnished yellow ochre (or lime) ground for the applied paint. On top of the lower painting was applied a secondary more crudely applied layer of sandy plaster and painting. Sixteen samples were examined and thirteen analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
WP 522 1	-	35	-	52%	carbonate, yellow layer
	-	24	-	66%	carbonate, *intonaco*
	14	70	16	24%	upper layer
WP 522 3	18	70	12	25%	lower layer
WP 522 1a	-	30	-	57%	carbonate, secondary *intonaco*
WP 522 4a	13	73	14	29%	upper layer
WP 83.935	10	77	13	29%	lower layer
WP 83 (140)/102\					
	0	76	24	32%	gilt plaster matrix

EXAMPLES OF PLASTER DESCRIPTIONS
Primary painting:
WP 522
1) burnished red*, 0.3mm, on burnished yellow with white flint or chert, 0.2mm, on white *intonaco* with white flint or chert, 0.4mm, on sandy plaster with traces of grass, chalk and tile, 13mm thick.
2) black with blue on burnished yellow with white flint or chert, 0.3 - 0.4mm, on white *intonaco* with white flint or chert, 0.4 - 0.5mm, on

sandy plaster with tile traces, 10mm, on coarse sandy plaster with grass or straw impressions, 24mm thick.

3) light blue on dark green on burnished yellow, 0.4mm, on white *intonaco* with white flint or chert, 0.75 - 1mm, on sandy plaster with tile traces, 13mm, on sandy plaster with chalk traces, 20mm thick.

WP 83 935

Other colour schemes included: green (yellow + blue) on red*, white and green on red* and plain yellow on white.

light blue patches on dark red, <0.05mm, on burnished yellow, 0.2mm, on sandy white *intonaco*, 0.4mm, on sandy plaster with tile traces, 12mm, on sandy plaster with grass impressions, 14mm thick.

3349:

1) light green with blue on traces of yellow on grey to white *intonaco*, 1mm, on coarse sandy plaster with grass in a single? layer, 17mm thick.

2) white leaves and spots (flowers?) on burnished red ochre, 0.1mm, on grey to white sandy *intonaco*, 0.75mm, on coarse sandy plaster, 6mm, on coarse sandy plaster, 10+mm thick.

Secondary painting:

WP 522. This all had a fairly rough trowelled or floated surface under the paint;

1a) red brown stripe, 7mm wide, on a pink stripe 23mm wide, on white *intonaco*, 0.5mm, on sandy plaster, 5.5mm, on sandy plaster, 8.5mm thick, all with grass or straw impressions.

2a) red stripe, 9mm wide, on yellow band, 35mm wide, on white *intonaco*, 0.5mm, on sandy plaster with chalk and straw, 7mm, on sandy plaster with straw impressions, 7mm thick.

3a) brown stripe, 12+mm wide, and red stripe, 31+mm wide, on white *intonaco*, 0.25mm, on sandy plaster, 8mm, on sandy plaster with straw, 16mm thick.

4a) dark red to maroon stripe, 10mm wide, on sandy white *intonaco*, 1 - 2mm, on coarse sandy plaster with straw impressions, 16mm thick.

Gilded fragment: (This sample came from a later deposit cut through the Roman levels and may not therefore be Roman but medieval)

WP 83 (140) /102\

This was gold leaf on sandy plaster. Examination of a sample taken from the plaster revealed a piece of re-used painted plaster. This was dark red ochre on fine white *intonaco* 1mm thick. The nearest comparative plaster was the secondary painting 3), which also had a thick white *intonaco*. If this was the source of the re-used plaster it implied that the gilding was of later date than the over-painting. The analysis of the bulk backing matrix showed it to be fairly similar to the other samples but with finer aggregate.

PAINTING TECHNIQUE

The painting was applied mainly in the *buon fresco* method, with some grounds and pigments being burnished on.

PIGMENTS

The pigments used were: red ochre (haematite), red* cinnabar, yellow ochre (limonite), green earth (glauconite), carbon as soot or charcoal, crushed Egyptian blue and gold leaf. (This gold could equally have come from medieval church paintings) The primary painting was of very high quality on finely prepared plaster. The use of white chert or flint in the burnished yellow and *intonaco* layers (which visually may easily have been mistaken for calcite) is of interest. It was also used in the Painted House at Dover. The secondary painting was very poorly made in comparison.

Sample 28 PS 84 II (2065)/89\ was a Roman pottery bowl rim, found near the above site, with red pigment on the inside. This was found by analysis to be very pure cinnabar without lime. Such pigment could have been used directly for *buon fresco* painting.

<u>Average results</u>

	Thicknesses		"Lime"	
paint	(0.1 - 0.3)	0.2mm	-	
coloured ground		0.4mm	64%	52% carbonate
intonaco	(0.4 - 1)	0.6mm	76%	66% carbonate
plaster	(6 - 17)	11mm	24%	upper layer
	(11 - 24)	18mm	27%	partial lower layer
secondary layer				
paint		0.05mm	-	
intonaco	(0.25 - 1.5)	0.6mm	-	
plaster	(5.5 - 16)	9mm	29%	upper layer
	(6 - 8.5)	7mm	28%	lower layer

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 111, 112
83.140, 3349.1, 522.4a(3a), 83.935, 522.1, 522.1a.
The graphs show that the aggregates are in general very similar. Both samples from the 83 site are slightly different and the secondary plaster 522.4a(3a) also varies from the others. The number of samples was however too small for safe distinctions.

Fig. 111 London, Winchester Palace 1

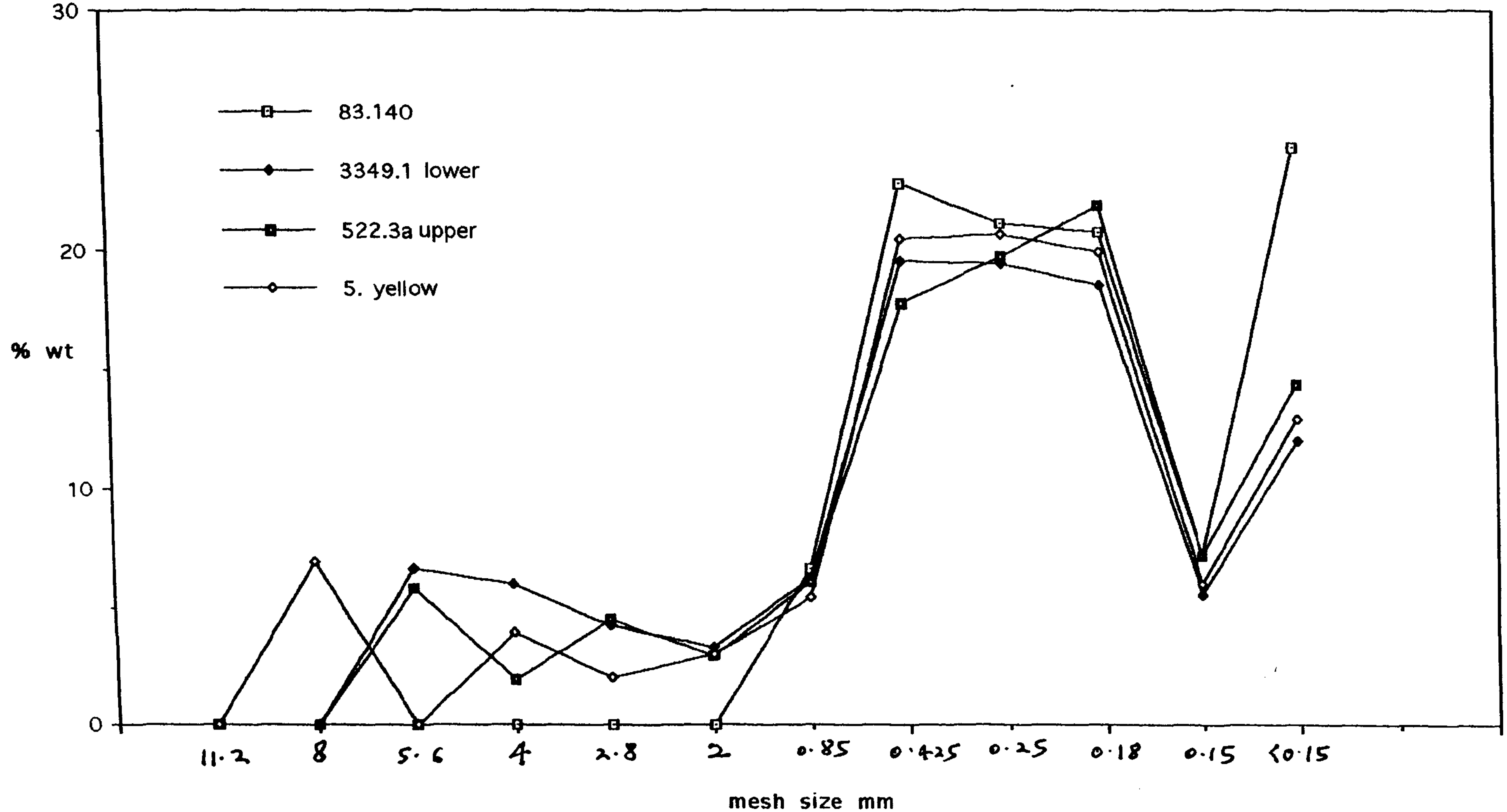
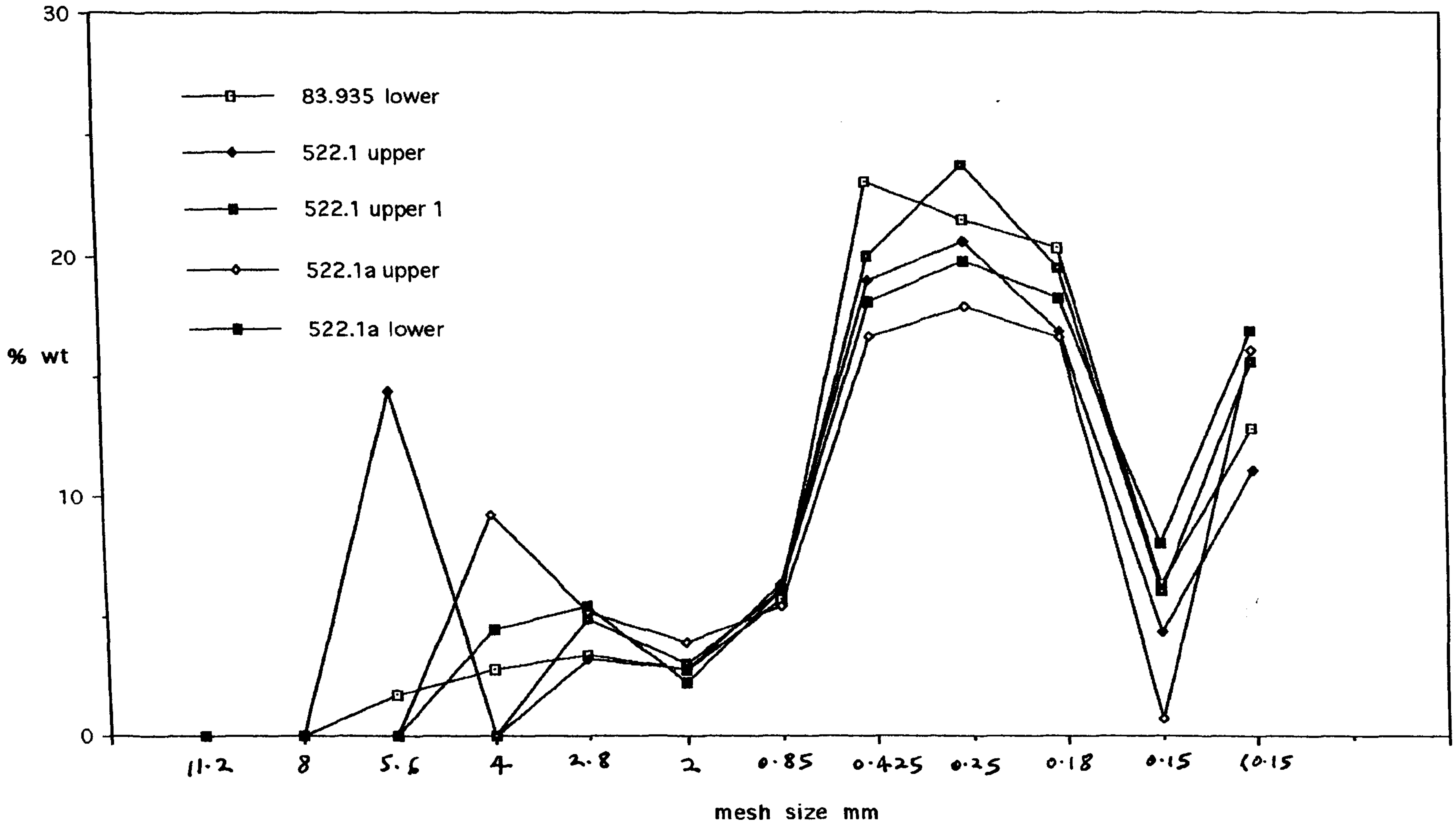


Fig. 112 London, Winchester Palace 2



Lullingstone Roman Villa, Kent.
Meates 1979, 1987

This report is based on painted plaster in the care of the British Museum. The geology of the area is river sand and gravel with chalk and is generally reflected in the aggregates, which in detail contained: flint, quartz (including well rounded and polished sand) and a variety of sandstones (quartzitic, glauconitic, ferruginous, fossiliferous and calcified calcareous types) with brick or tile and furnace residues. The villa was partly a wooden structure and partly stone built. The wood and wattle framework was covered in mud or clay (and in some places given keying impressions by means of roller of the same type used to impress box flue tiles (Meates 1987; 46)) and then plastered with lime plaster as was the stone structure. Much of the building was destroyed by fire in the early fifth century giving burnt plasters and fired clay daub. The building was mainly dated from the second to the fourth centuries. Twenty seven samples were examined and thirty three analyses carried out. The presence of chalk and other limestones in the aggregates means that the "lime" values for the plasters may be up to 10% high. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
8	9	83	8	40%	upper layer
	8	80	12	48%	middle layer
	6	84	10	37%	lower
17	30	55	15	35%	upper
	24	59	17	35%	lower
50	26	59	15	39%	whole sample
65	56	30	14	45%	whole sample, *opus signinum* type
95	-	94	6	39%	white over plaster
	-	66	34	28%	brown over plaster
	6	82	12	38%	lower plaster
108	24	60	16	36%	whole sample
123	8	83	9	33%	top, yellow on white
	5	83	12	36%	middle layer
	8	79	13	33%	lower layer
123	14	34	52	52%	torching, with brick
160	1	85	14	32%	over plaster
	9	80	11	41%	lower plaster
451	2	75	23	37%	*intonaco*, quartz or chert

	2	80	18	29%	upper layer
	8	76	16	30%	middle layer
	9	76	15	33%	lower layer
468	36	53	11	32%	brick with sand
481	10	63	27	28%	whole sample
EV1	-	-	-	81%	Egyptian blue paint
	-	-	-	89%	*intonaco*
	24	58	18	34%	plaster
D111	18	64	18	44%	dado
C1	22	63	15	39%	ceiling
C111	24	60	16	36%	upper layer
	32	53	15	33%	lower layer
un-numbered					
	6	75	19	35%	upper layer
	20	62	18	41%	middle layer
	-	-	-	5%	soluble, lower burnt clay layer.

EXAMPLES OF PLASTER DESCRIPTIONS

(8) R/2:

Plain white; white on off white sandy *intonaco*, 1mm, on buff sandy plaster, 6mm, on buff sandy plaster, 20mm, on white sandy plaster with flint and chalk,14mm thick.

Plain red; [burnt sample] brushed sandy red on traces of white, total 0.1mm, on sandy plaster as above to a total of 34mm with no sign of layering.

Floor; coarse hard chalk and tile (10mm x 20mm) in a tile mortar matrix, total 28mm thick.

(16)

Grey on white; flaked blue on pink, 0.1mm, on white, 0.05mm, on sandy plaster with flint and chalk, 20mm thick. Not analysed but c.f. (123)

(17) R/2:

Plain red; [burnt sample] sandy red, 0.1mm, on sandy white *intonaco*, 0.2mm, on sandy plaster, 39mm, possibly in two layers; 25mm + 14mm. The reverse showed trowel or other keying marks.

(19)

Plain white; [burnt sample] possibly white on sandy white *intonaco*, 0.2 - 0.5mm, on sandy plaster with charcoal, flint and sandstone to 45mm thick with no obvious layering.

(50)

Dark red on grey; [burnt sample] orange to red, 0.1mm, on white, 0.1mm, on off white *intonaco*, 0.1 - 0.2mm, on sandy plaster, 20mm, on sandy plaster traces, 5+mm thick.

(65)

Floor; tile and chalk fragments in a coarse sandy mortar with some tile dust to 28mm thick.

(95)

Plaster lump; white concretion on off white sandy plaster, 12mm, on red to brown friable sandy plaster with straw impressions, 7mm, on, pick marked; red stripe on white, 0.5mm, on off white sandy plaster, 10mm thick. The upper surface was covered with a lime concretion c.f. (160) and (167). This was an overplastered sample.

(108)

Yellow on white; blue on grey on yellow, 0.05mm, on white, 0.1mm, on off white sandy *intonaco*, 0.5mm, on pale buff sandy plaster with chalk, 30mm thick. c.f. (123).

(123)

Yellow on white; micaceous yellow on white on white on off white sandy plaster with chalk and glauconite, 34mm thick in four layers; 2 - 3mm, 7 - 8mm, 15mm and 10mm thick. The surface of the plaster suggested that it had dried before the first white coat was applied.

Shaped mortar lump, probably torching with *tegula* impressions; the mortar was buff with chalk and some tile and sand. Within the mortar structure were patches of white mortar with sand and pink mortar with tile. This did not look like re-used mortar but contamination from a previous mortar mix.

(160)

Over plastered sample; buff coarse sandy plaster with straw or grass and insect impressions, 12mm, on green, dark red and orange red on white, with a pecked surface, on off white sandy plaster, 7mm thick.

(167)

As (160) an over plastered pecked painted plaster; coarse friable sandy plaster with straw and insect casts on orange to red stripes (5mm wide), 0.05mm, on white on white (*intonaco* ?), 0.25mm total, on off white sandy plaster with glauconite, 7mm, on off white sandy plaster, 17+mm thick. This plaster appeared to have dried before it was painted.

(304)

Red on white [burnt sample]; coarse brushed red on white, 0.4mm, on coarse sandy plaster, 28mm thick. c.f. (123) - not analysed.

(451)

Blue; coarse (0.2mm) blue with white, 0.25mm, on off white with white quartz or chert (*intonaco* ?), 2mm, on coarse sandy plaster in three layers; 10mm, 10mm and 5+mm thick.

(467)

Green on white; green, <0.05mm, on white, 0.1mm, on sandy plaster, 5mm thick. This small sample had plaster traces all over it, suggesting re-use or a burial deposition.

(468)

Quarter round moulding; red, 0.05mm, on pink tile and sand mortar of about 50mm radius.

(481)

"Brown"; an inverted sample - white, 0.1mm, on sandy plaster, 30mm thick, possibly in three layers with brown underneath.

Box 268 North wall PV ?:

Brushed white on off white, 0.25mm total, on sandy plaster, 34mm thick, with no obvious layering. c.f. (123).

EV1 East wall:

[burnt sample] Coarsely brushed blue with grey, 0.1mm, on grey on white, 0.1mm, on off white (*intonaco* ?), 0.2mm, on coarse sandy plaster, 15mm + 25mm thick. The sample showed keying grooves on the rear.

D111 Dado North wall?:

[burnt sample] Dark red to light red, <0.05mm, and purple on white, 0.2mm, on coarse sandy plaster, 25mm, on burnt clay or mud with straw, 10mm thick. The mortar to clay interface was a thin black layer. This was apparently a charred organic layer. It may have been formed by the alkaline lime plaster leaching and concentrating dung? or other proteinaceous material from the clay, and its subsequent burning.

C1 Ceiling roundel:

Very similar to D111 except that there was no black layer on the clay to plaster interface. [burnt sample] Dark red to red orange, 0.1mm on pink on white, 0.1mm, on sandy plaster, 18mm, on dark brown clay or mud, 9mm thick.

C111 Ceiling roundel:

Dark to light purple, 0.1 - 0.2mm, on orange to pink, 0.1 - 0.2mm, on sandy plaster in three layers; 10 - 15mm, 10 - 15mm, 25 - 30mm, totalling 48mm. The reverse showed keying marks from a lower mud or plaster layer.

"Un-numbered material tray":

[burnt sample] Dark red brown to purple on lighter red brown on white on sandy plaster, 2mm, on white traces, 0.1 - 0.5mm, possibly a lime smear, on sandy plaster, 15mm, on brown clay or mud with a black lime to mud interface as in D111 dado, and with trowel or key marks on the rear. This sample showed re-deposited lime on the paint surface and on the plaster to mud interface.

"Odd pieces collected from several boxes":

[burnt samples] Orange stripe on white, 0.1mm, on sandy plaster in two layers, 7mm + 32mm, c.f. (160), (167). There were traces of pick marks and over plastering with coarse sandy plaster on the surface.

Burnt daub with wattle traces. A sandy clay, mud or soil with bark impressions and traces of other burnt organic material.

Two main type of plaster were represented, those with a daub backing and those without, although this may have been due to poor preservation. A sub-group was those samples showing over plastering. Many of the samples showed calcified plant remains, such as grass or straw, and insect impressions. The alkaline plaster appears to have aided the preservation of the cellulosic material and the loss of the protein based insect remains.

PAINTING TECHNIQUE

The technique of painting appeared to be *buon fresco*, but the presence of surface films of lime under some of the paint layers suggested that *fresco secco* may have been used or that lime was mixed with the pigments. The *intonaco* layers were generally thin and appeared to be just lime wash in may cases.

PIGMENTS

The pigments were the natural colours: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), white lime, carbon as soot or charcoal and Egyptian blue.

A red colour coated mortarium repaired with rivets, room 10a , dated to the second half of the fourth century ≈ 350 AD, contained crushed Egyptian blue with lime. The analysis of this material showed, among the usual elements for Egyptian blue, some tin, pointing to the use of a copper alloy in its manufacture. (Meates 1987: 45 - 46).

Average results

	Thicknesses		"Lime"	
paint	(0.05 - 0.25)	0.1mm	81%	(blue)
intonaco	(0.05 - 2)	0.3mm	89%	
over plaster	(2 - 12)	8mm	33%	
plaster	(2.5 - 25)	13mm	31%	upper layer
	(5 - 32)	16mm	38%	middle layer
	(6 - 28)	15mm	35%	lower layer
fourth layer		10mm	-	
mud layer		10mm	5%	(soluble content)
single layer	(28 - 45)	34mm	37%	
tile plaster		28mm	43%	

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 115, 116
(65) *opus signinum*, (95) off white sandy plaster, (123) torching - *opus signinum*, (451) *intonaco*, (468) *opus signinum*, (481), EV1 top layer. The graphs show the poorly graded *opus signinum* components and the well graded sands.

Fig. 115 Lullingstone 1 - opus signinum

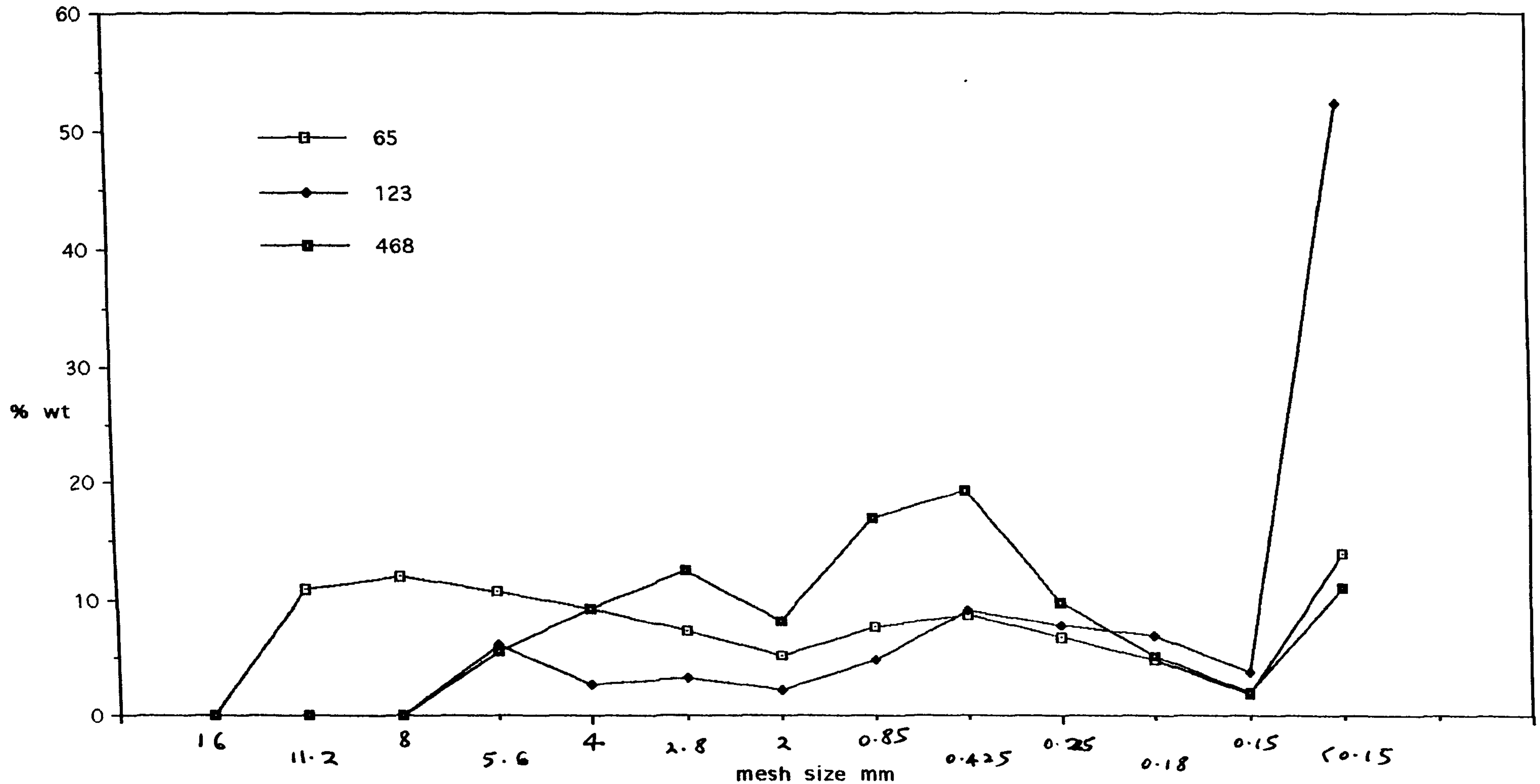
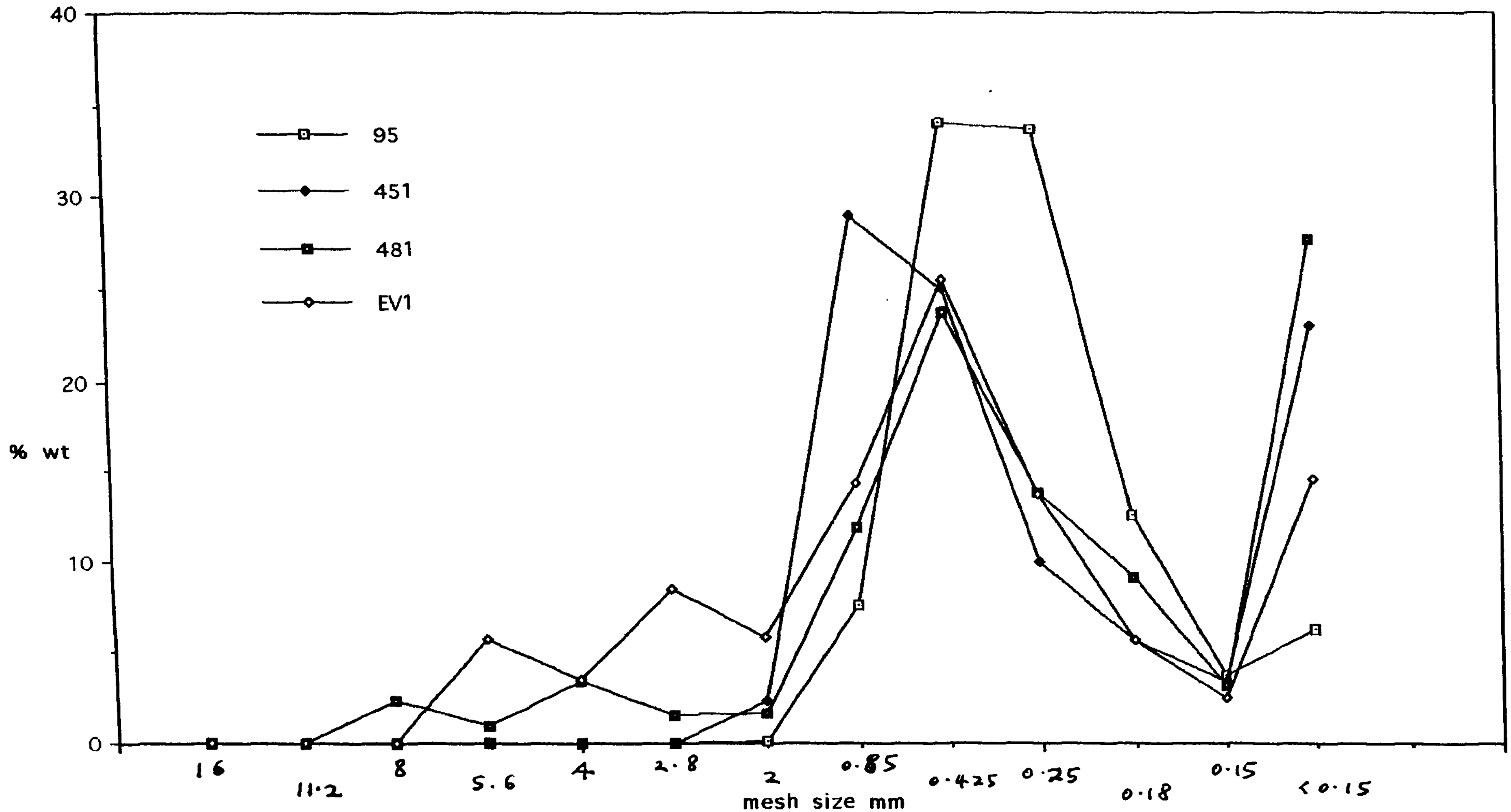


Fig. 116 Lullingstone 2



Malton, Yorkshire.
Derventio NEEB 91
Samples from Paula Ware, MAP Archaeological Consultancy Ltd.
These results are as yet unpublished

A collection of painted plaster fragments recovered from a cable trench on the site of the Roman fort at Derventio in 1991.
The material was generally paint on white *intonaco* layers on very similar grey to buff calcareous plaster, being composed mainly of oolitic limestone fragments, with traces of red fired sandy clay and angular to sub-angular quartz sand. Twenty samples were examined and twenty two identifications carried out. Only one sample was fully analysed as it was considered that the material represented a single type. In view of the calcareous aggregate the "lime" values must be regarded as approximate.

COMPOSITIONS
sample 13)

	gravel	sand	silt	"lime"	thickness	comments
intonaco	-	-	21	(75)	1.4mm	white lime with sand traces
2) plaster	4	57	39	(30)	9mm	upper sandy plaster
3) plaster	3	59	39	(30)	8mm	lower sandy plaster
4) plaster	5	55	40	(30)	33mm	third layer

EXAMPLES OF PLASTER DESCRIPTIONS

1) Bright red* on pink, <0.05mm thick, on white *intonaco* , 0.5mm, on grey to buff sandy plaster in two similar layers, 9mm + 9mm thick. There were traces of burnt red clay (probably brick or tile) in the upper plaster layer. Fragments of oolitic limestone were noticed throughout the plaster. The bright red* was cinnabar which is commented on with the other pigments below. Other samples with cinnabar were: a black stripe over the interface of blue grey and red areas; and a white stripe over the interface of black and red areas.

2) Pink spots on maroon, <0.05mm, on white *intonaco*, 0.8mm, on grey to buff sandy plaster in two layers, 7mm + 11mm. The pink spots were very fine and appear to have been sprayed or flicked on by some means. This may have been pseudo marbling although the spots were very small.

3) Red on yellow over painting, on pink on white *intonaco*,0.75mm, on grey to buff sandy plaster in two layers, 8mm + 14mm. The red on yellow completely obscured the pink band underneath, hence the suggestion of secondary over painting.

4) A narrow white line over the interface of light to dark pink and light green areas, <0.05mm thick, on white *intonaco*, 0.75mm, on grey to buff sandy plaster, 9mm thick, and other fragments showing the two layered structure, 5mm + 15mm thick.

5) Black and white lines over the interface of dark red and light green areas, <0.05mm thick, on white *intonaco*, 0.75mm, on grey to buff sandy plaster in two layers, 7mm + 13mm thick. Another fragment showed red on light blue / green without the black and white lines. c.f. type 10).

6) Pink on orange to red, 0.1mm, on white *intonaco,* 1.2mm, on grey to buff sandy plaster, 8mm thick and two layer fragments at 7mm + 5mm and 8mm + 10mm thick. This could possibly be a flesh tint. c.f.8).

7) Maroon to dark pink streaks on light pink, 0.5mm, on white *intonaco,* 0.75mm, on grey to buff sandy plaster in two layers, 8mm + 12mm thick. This may possibly be a representation of textile or a costume, e.g. the highlighted folds on a purple or maroon toga or similar garment.

8) Pink to orange, 0.3mm, on light blue / green with a trace of a dark red band on one edge, on white *intonaco,* 0.75mm, on grey to buff sandy plaster in two layers, 5mm + 15mm, and 5mm + 15mm. On one sample the light green was completely covered. On the other sample the green and pink areas were distinct and there was a white spot in one corner.

9) Black and light green traces on orange pink, 0.05mm, on white *intonaco,* 0.75mm, on grey to buff sandy plaster up to 13mm thick.

10) White band over red and dark green over light green, 0.1mm total thickness, on white *intonaco,* 1.2 - 1.4mm, on grey to buff sandy plaster in two layers, 6mm + 12mm.

11) White band over the interface of dark green and black areas, <0.05mm, on white *intonaco*,0.75mm, on grey to buff sandy plaster with

traces of red sandy fired clay, 10mm, on a white interface, <0.05mm to 0.4mm thick, on grey to buff sandy plaster, 11 - 16mm thick. The interface was the result of a delay in the plastering process. It may have been a deliberate lime wash coating to improve the adhesion of the upper layer of plaster after the lower layer had dried. A similar film may have developed if the wet plaster had simply been allowed to dry. Normally upper layers of plaster were applied whilst the lower one was still wet.

12) White band over the interface of dark green (with blue and black traces) and light blue on grey areas, 0.05mm, on white *intonaco,* 1.4mm, on grey to buff sandy plaster in two layers, 7mm + 7mm, on a white interface, <0.05mm, on grey to buff sandy plaster, 14mm thick. Another sample of blue on grey only was 34mm thick. The blue colour was a mixture of Egyptian blue and lime.

13) Light green, 0.05mm, on white *intonaco,* 0.75mm, on grey to buff sandy plaster in three layers, 9mm + 8mm + 33mm, the lower layer with traces of red brick or tile.

14) White band? on light blue / green, 0.1mm, on white *intonaco,* 0.4mm, on grey to buff sandy plaster in two layers, 7mm + 4mm.

15) Very light blue / green (lighter than 14)), <0.05mm, on white *intonaco,* 0.75mm, on grey to buff sandy plaster in two layers, 8mm + 8mm.

16) Maroon on light pink, <0.05mm, on white *intonaco,* 1mm, on grey to buff sandy plaster in two layers, 6mm + 15mm.

17) Red line on white band over the interface of a dark red on grey green and dark orange on yellow areas, <0.05mm, on white *intonaco,* 0.75mm, on grey to buff sandy plaster in two layers, 8mm + 12mm. The green was completely over-painted and may be similar to sample 5).

The plaster was all very similar technically. It seemed to be entirely of one type of manufacture. The layers were similar in thickness and numbers. The fact that most of the samples had only two plaster layers pointed to the fact that this was only the surface part of a plastered wall. It is possible that it was the waste from a re-decoration process, as often the top layer of plaster was removed and replaced by new plaster before re-painting.

PAINTING TECHNIQUE

The paint appeared to be in the *buon fresco* method, with the following colour schemes:

The style of painting suggests that fragments of panel borders are mainly represented here. Samples 6), 7) and 8) may possible be part of some pictorial scene, with textile and flesh tones possibly being shown.It would, however, be unwise to interpret too much on such slight evidence

PIGMENTS

The following pigments were identified:

Red and yellow ochres (haematite / limonite), cinnabar, crushed brick or tile, white lime, green earth (glauconite), Egyptian blue and carbon as charcoal or soot.

Average results

	Thicknesses		"Lime"
paint	0.1mm		-
intonaco	0.8mm	white lime with sand traces	75%
plaster	8mm	upper layer	30%
interface	0.2mm	white lime	-
plaster	11mm	lower layer	30%
plaster	33mm	third layer (one example only)	30%

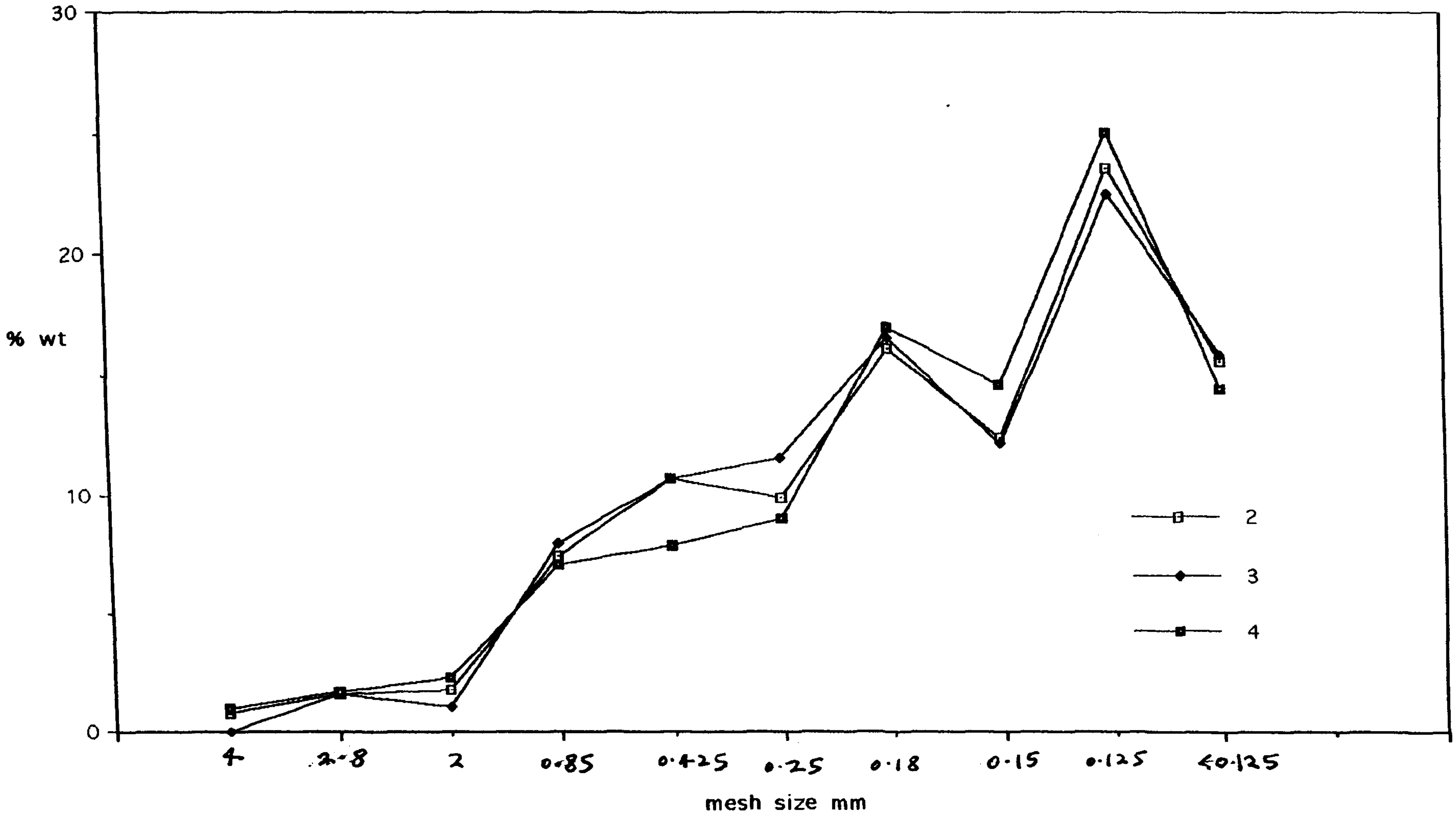
Samples illustrated in the aggregate particle size distribution graphs:

Fig. No. 117

The three plaster layers from sample 13 only.

The particle size distribution graphs show that the aggregate is very poorly graded, being composed of limestone fragments with small quantities of angular to sub-angular quartz sand (0.425mm - 0.15mm) and fragments of red fired clay (brick or tile?). The finest grades (<0.15mm) are mainly very fine quartz sand, probably derived from the limestone.

Fig. 117 Malton



Mancetter, Warwickshire.
Parr 1981
Britannia 1982 13: 361
Current Archaeology (1991)125: 210 - 214

Excavations of the first century levels at the fort site at Mancetter Farm, produced several samples of pigment and pigment-like materials. The whole collection was contaminated with clay minerals, sulphates, phosphates and lead. There was no evidence that these materials were used for wall painting, but they could have been raw materials for painting on walls, wood or leather. They are of particular interest in containing a sample of the rarely found pigment; orpiment and realgar. This collection was borrowed from the Warwick Museum and the reference numbers no longer relate exactly to those given by the excavator. Thirteen samples were examined and analysed. The samples were all analysed using wet chemistry, X-ray diffraction and electron probe analysis.

DESCRIPTIONS AND ANALYSES

MF IF 3

A) a pink powdery lump, with clay minerals and alumina; probably madder lake.

B) pale grey, clay minerals only; probably white clay.

C) pink powdery lump, probably madder lake.

D) pale green lump, glauconite and clay minerals; probably green earth with white clay.

E) crystalline orange and red, orpiment and realgar. Such a large piece, 5g, was probably imported.

F) buff to off white lump, some carbonate, phosphate and lead present; probably lead white with sand and traces of white clay.

G) dark red, haematite; red ochre with soil traces.

H) black glass-like material, amorphous material with sulphur, burning with a bituminous smell; mainly pitch or bitumen.

J) blue granular moulded lump; Egyptian blue.

MF IF 3 pale green on pot: this was in fact pale grey with crushed Egyptian blue. Analysis also showed the presence of lead and clay minerals.

M 49 F latrine channel?: a pale grey muddy lump, highly calcareous with phosphates, clay minerals and some lead. Possibly a latrine deposit or chalk.

Unstratified: white on pot: high phosphate levels with calcite and lead; mainly lime with lead white.
Unstratified: white to pink on pot: traces of lime, lead, phosphate, alumina and clay minerals; probably madder lake with clay.

Netherwild, Hertfordshire
Britannia 1970 1: 289
Rawlins 1966, 1979

Examples of the mortar and plaster finds from the unpublished Roman Villa site at Netherwild (Netherwylde) Farm were borrowed from the Watford Museum. They represent material from the fourth century bath house. The material was mainly tile based plaster and mortar - *opus signinum* , perhaps reflecting the use of waste material from the tile kiln excavated nearby (Rawlins op. cit.). Some presumably local sand and gravel was also used. This was mainly round to sub-angular quartz sand or pebbles with flint and ferruginous sandstone fragments. The presence of glauconite grains in the analysed residues suggested the use of lower chalk or similar limestone as a source for the lime. Twenty four samples were examined and twenty four analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1)	49	36	15	40%	moulding, *opus signinum.*
2)	52	36	12	31%	bath side, *opus signinum.*
3)	52	35	13	45%	painted plaster, *opus signinum.*
4)	53	35	12	39%	moulding, *opus signinum.*
5)	47	31	22	48%	upper plaster, *opus signinum.*
	52	36	12	45%	lower plaster, *opus signinum.*
6)	50	35	17	31%	floor, *opus signinum.*
7)	9	81	10	26%	painted plaster
8)	42	44	14	42%	plaster edge, *opus signinum.*
9)	46	43	11	34%	painted plaster, *opus signinum.*
10)	6	72	22	33%	torching mortar
11)	26	66	8	22%	painted plaster
12)	47	39	14	32%	painted plaster, *opus signinum.*
13)	51	36	13	56%	upper plaster, *opus signinum.*
	48	38	14	46%	lower plaster, *opus signinum.*
14)	49	33	18	40%	upper plaster, *opus signinum.*
	44	44	12	44%	lower plaster, *opus signinum.*
15)	48	38	14	40%	painted plaster, *opus signinum.*
16)	-	-	10	81%	carbonate, red + upper *opus signinum.*
	-	-	7	93%	carbonate, white paint.
	-	-	35	59%	carbonate, *intonaco.*
	47	38	14	35%	lower *opus signinum.*

17)	11	73	16	36%	painted plaster
18)	31	63	6	21%	painted plaster, upper layer
19)	18	73	9	21%	lower layer
20)	23	70	7	25%	upper layer
21)	31	59	10	30%	upper layer
22)	40	42	18	48%	painted plaster, *opus signinum*.

EXAMPLES OF PLASTER DESCRIPTIONS

[C3] (3SE)

1) quarter round moulding from the bath in *opus signinum*, about 35mm high and 50mm wide.

2) red painted side of hot bath in *opus signinum*; dark red on dark pink plaster possibly in two layers, 5mm + 25mm thick.

3) red on white plaster; red, <0.05mm, on white, 0.2mm, on white *intonaco*, 0.6mm, on light pink plaster, 8mm, on dark pink plaster, 13mm thick. The irregular section suggested a wall edge. The plaster was all tile based.

[C3] (3S)

4) quarter round moulding from bath; red on tile based mortar with sand and gravel; about 47mm high and 55mm wide.

[C3] (3S)

5) *opus signinum* side of hot bath; red on *opus signinum*, 30 - 35mm, on *opus signinum*, 45mm thick.

[C4] (6S)

6) *opus signinum* floor, 25mm thick.

8) plaster including door jamb? and quarter round moulding;

a) edge of wall (door or window); white on white, 1mm, on *opus signinum*, 25mm thick, in one layer.

b) quarter round moulding; 45mm high and 50mm wide, red on *opus signinum*, with traces of a lighter pink plaster attached to the back of the sample.

c) plaster; red traces on white, 0.5mm, on white *intonaco* ?, 1.5mm, on *opus signinum*, 17mm thick.

[C4] (CW)

painted plaster:

7) / a) traces of orange on white, <0.05mm, on white *intonaco*, 0.7mm, on cream sandy plaster, 11 - 14mm thick. The surface was very flat but not apparently burnished.

b) red on white, <0.05mm, on white *intonaco*, 1mm, on light pink *opus signinum*, 20mm thick in a single layer. This was an edge sample, c.f. [C3] (3SE).

c) white *intonaco* ?(with some tile) 0.7 - 1mm, on *opus signinum*, 25mm thick.

d) red band, 3.5mm wide, on white, 0.1mm, on white *intonaco*, 1.5mm, on light *opus signinum*, 17mm thick.

[D2] (3E) painted plaster:

9) white, 0.5mm, on white, 0.5 - 1mm, on white with tile, 0.5mm, on *opus signinum*, 20mm thick. c.f. [C4] (6W), [D3] (CSE).

[D3] (3E) torching:

10) mortar from *imbrices*; shaped cream coarse sand and flint mortar with chalk and grass or straw impressions, from 28mm to 35mm thick.

[D4] (2W)

11) painted plaster:

white, 0.5mm, on white, 1mm, on cream coarse sand and gravel plaster, 25mm thick.

"Unlabelled" painted plaster:

12) red on *opus signinum*, 25mm thick. c.f. hot bath.

13) white, 0.2mm, on white with some tile, 0.7mm, on *opus signinum*, 20mm, on friable *opus signinum*, 10+mm thick.

[D5] (3SW)

parts of cold bath seat:

14) red on *opus signinum*, 15mm, on *opus signinum*, 20+mm thick. This was the rounded edge of the seat.

[D3] (3SE)

15) painted plaster: white, 0.2mm, on white *intonaco* ?, 1mm, on *opus signinum*, 25mm thick. c.f. 13), 9).

[D3] (3W)

16) parts of the sides of the hot bath: red on pink *opus signinum* , 1.9mm, on white, 0.4mm, on white *intonaco* with tile traces, 1.5 - 2mm, on *opus signinum*, 35mm thick. This was an over-plastered sample.

[D3] (3)

17) painted plaster: burnished green with blue, 0.1mm, on sandy black, 0.2mm, on white, 0.2mm, on pale buff sand and gravel plaster, 13mm thick.

[D3] (3S&E)

painted plasters:

18), 19) red stripe, 3mm wide, on white, 0.25mm, on white, 0.7mm, on cream sand and gravel plaster in two layers, 14mm + 10mm thick.

20) as above but the upper layer only, 18mm thick.

21) as above but with tile traces in the coarse sandy plaster, 18mm thick.

22) white, 0.05mm, on white with tile *intonaco* ?, 0.3mm, on *opus signinum*, 12mm thick.
Also a sample as above with a red to brown stripe 6mm wide.
Baulk C3 / C4 (3); not analysed but similar to [D3] (3S&E) and [D3] (3W).

PAINTING TECHNIQUE
The painting technique was *buon fresco*. Too little was examined to suggest any particular painting scheme, although the stripes suggested borders or panels.

PIGMENTS
The pigments were: red ochre (haematite), crushed red brick or tile dust, white lime, green earth (glauconite), carbon as soot or charcoal and crushed Egyptian blue traces (with the green).

<u>Average results</u>

	Thicknesses		"Lime"	
paint	(0.05 - 0.5)	0.2mm	93%	
intonaco	(0.2 - 1.5)	0.8mm	59%	
plaster (sand)	(12.5 - 25)	17mm	27%	upper layer
		10mm	21%	lower layer
plaster (tile)	(5 - 25)	19mm	40%	upper layer
	(11 - 25)	16mm	40%	lower layer

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig Nos 119, 120
Sand and gravel plasters: 7, 10, 18 / upper, 19 / lower, 20.
Opus signinum plasters: 2, 6, 14 upper, 14 lower.

Fig. 119 Netherwild - sand

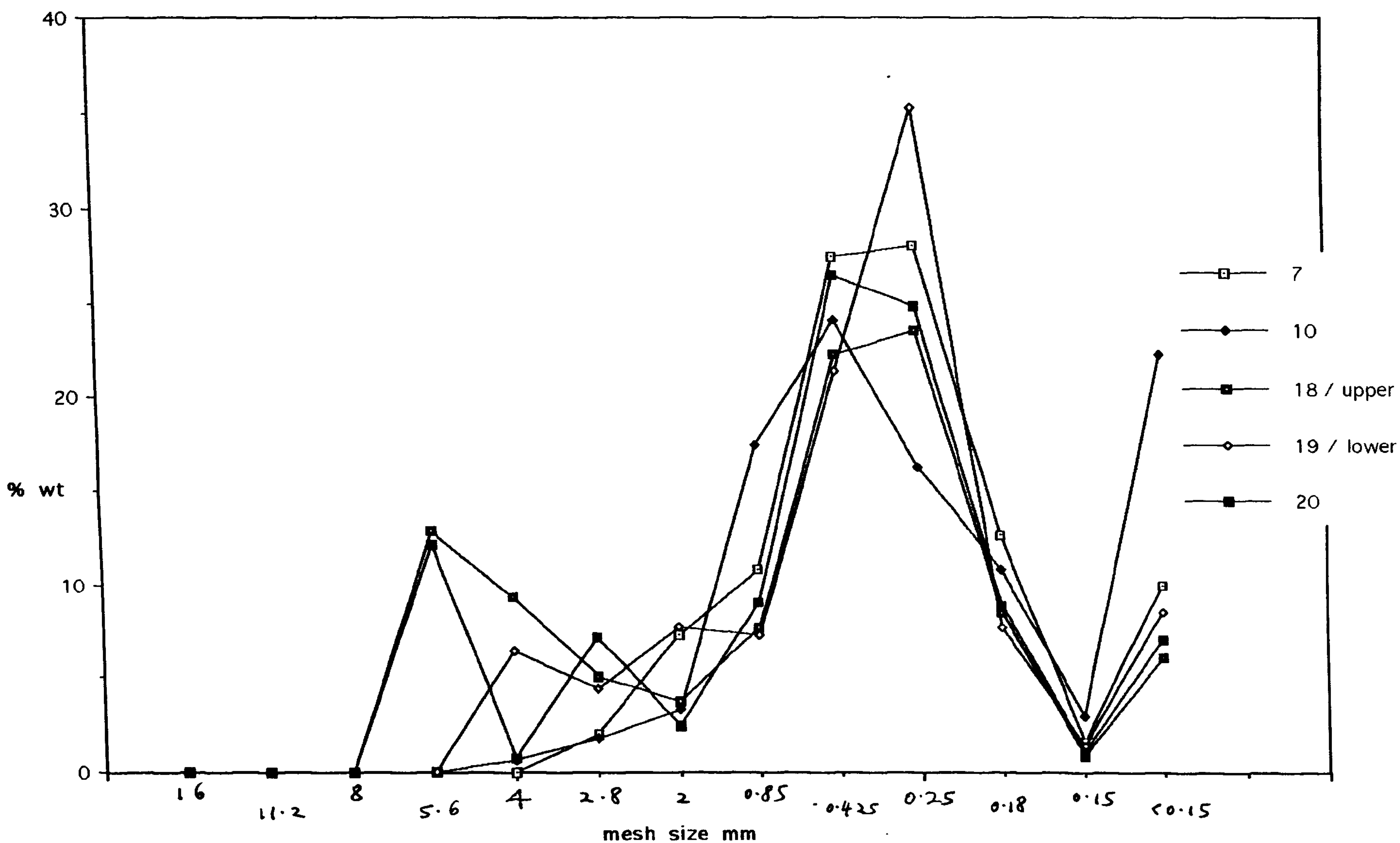
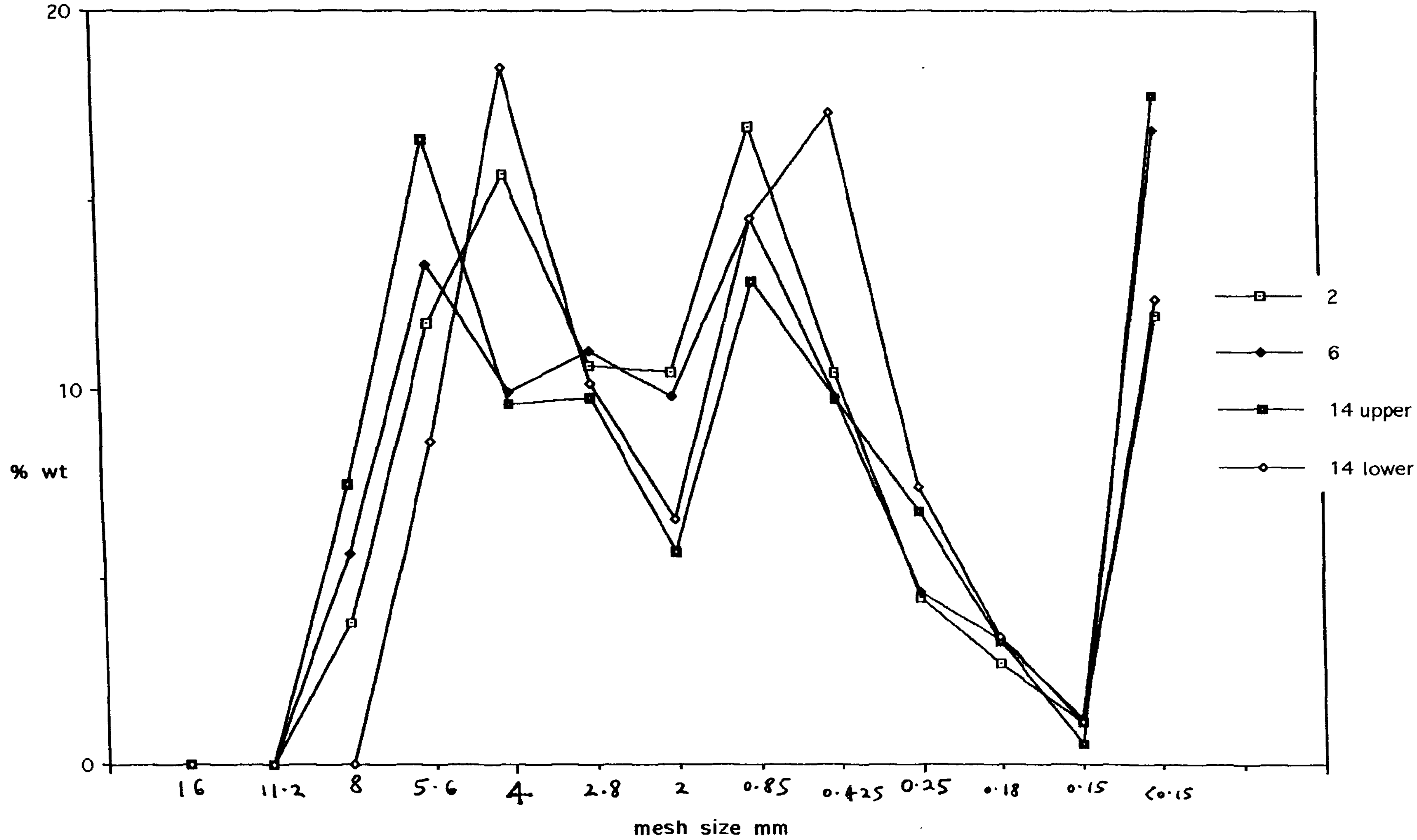


Fig. 120 Netherwild - opus signinum



Nether Heyford, Northamptonshire
Excavated by S. Young
Unpublished

The "villa" at this site was first discovered in 1699 and has been lost and found on several occasions since. The material reported on here was recovered by trial trenching on the probable site of the villa.
The vicinity of the site to the River Nene is reflected in the aggregates which consisted mainly of: river sands and gravel of quartz and flint, sandstone / ferruginous sandstones and fossiliferous limestone.
Crushed brick or tile was also used. The presence of hard chalk (estimated visually to between 10% and 20%) probably from the lime, in the plasters and mortars means that the analysed values for the "lime" content are approximate. Eighteen samples were examined and twenty three fully analysed. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1)	40	41	19	59%	
2)	52	30	18	46%	with brick or tile
3)	29	58	13	49%	
4)	25	60	14	50%	
5)	-	-	-	65%	red layer
	-	-	-	52%	*intonaco*
	11	73	16	46%	plaster, both layers.

EXAMPLES OF PLASTER DESCRIPTIONS
Mortars:
1) trench B feature 2 the wall:
gravel (sandstone, quartz, flint and ferruginous sandstone) mortar with some hard chalk and fossiliferous limestone.
2) corn dryer fill /11\:
coarse gravel mortar with brick or tile.
3) trench 1a layer 2 /12\:
buff gravel mortar.
4) 10/20 6.3 20/20 6.1 20/30 8.1:
heterogeneous coarse buff mortar, possibly waste.
Plasters:
5) trench 1a layer 2:
hard burnished red with traces of calcite, 0.1 - 0.2mm, on pale sandy *intonaco,* 0.5mm, on buff sandy plaster in two layers, 9mm and 13mm

thick. The aggregate is geologically the same as 1) but finer in size. Also a sample with green (with some blue) on yellow on black on the burnished red as above.

The following plasters all had the same plaster layers as 5):

1a: brushed grey, 0.5mm, on sandy white *intonaco,* 0.5mm thick.

feature 1: brushed white line on a brushed grey to red interface on white sandy *intonaco*, also a white line on a yellow to grey interface and; white, 0.05mm, on pale green on buff to yellow on burnished red, 0.1 - 0.2mm, on sandy *intonaco*, 0.1mm thick.

(1) 1a layer 2: black, pale green, red to pink and white spots on brushed buff to yellow on sandy white *intonaco*, pseudo marbling.

/1.2\ layer 2 trench 1a N ext F.11: burnished red with traces of calcite on slight grey *intonaco* ? on sandy plaster.

T.1a sect B to N of trench, curved wall layer 2 /1.2\: burnished red with calcite traces, 0.1mm, on white *intonaco*, 0.5mm, and; white stripe on a.yellow (with calcite traces) to black interface on grey *intonaco*,, total 0.2mm thick.

/1.2\ T.1a layer II: burnished red with calcite traces and quartz sand, 0.15mm, on pink *intonaco* (with tile dust), 0.4mm, also; burnished pink with quartz sand, 0.2mm, on off white *intonaco* traces to 0.2mm thick.

/3.2\ F.1 T 1C courtyard surface: pink, 0.05mm, on patchy white on off white *intonaco*, 1mm thick.

/10\ B20 T A, N of trench 2B F1: white stripe? on green, 0.05mm, on white *intonaco*, 0.75mm thick.

/2.2\ F1: burnished red with calcite, 0.1mm, on pink *intonaco*, 0.3mm.

/1.2\ L2 T1A feature 2 retaining wall for the apse: pale green on burnished black, 0.05mm, on off white *intonaco*, 0.5mm thick.

/13.4\ B10 T.B, east of TA feature ST wall F.2: pink on sandy off white *intonaco*, 0.5mm, on dark red, 0.05mm, on white *intonaco*, 0.75mm, on sandy plaster. This may be over plastering.

PAINTING TECHNIQUE

The painting appeared to be in the buon fresco method. The use of burnishing and calcite in the paint and *intonaco* layer is of note. In these samples the calcite appeared to be more usually associated with the pink *intonaco* samples.

PIGMENTS

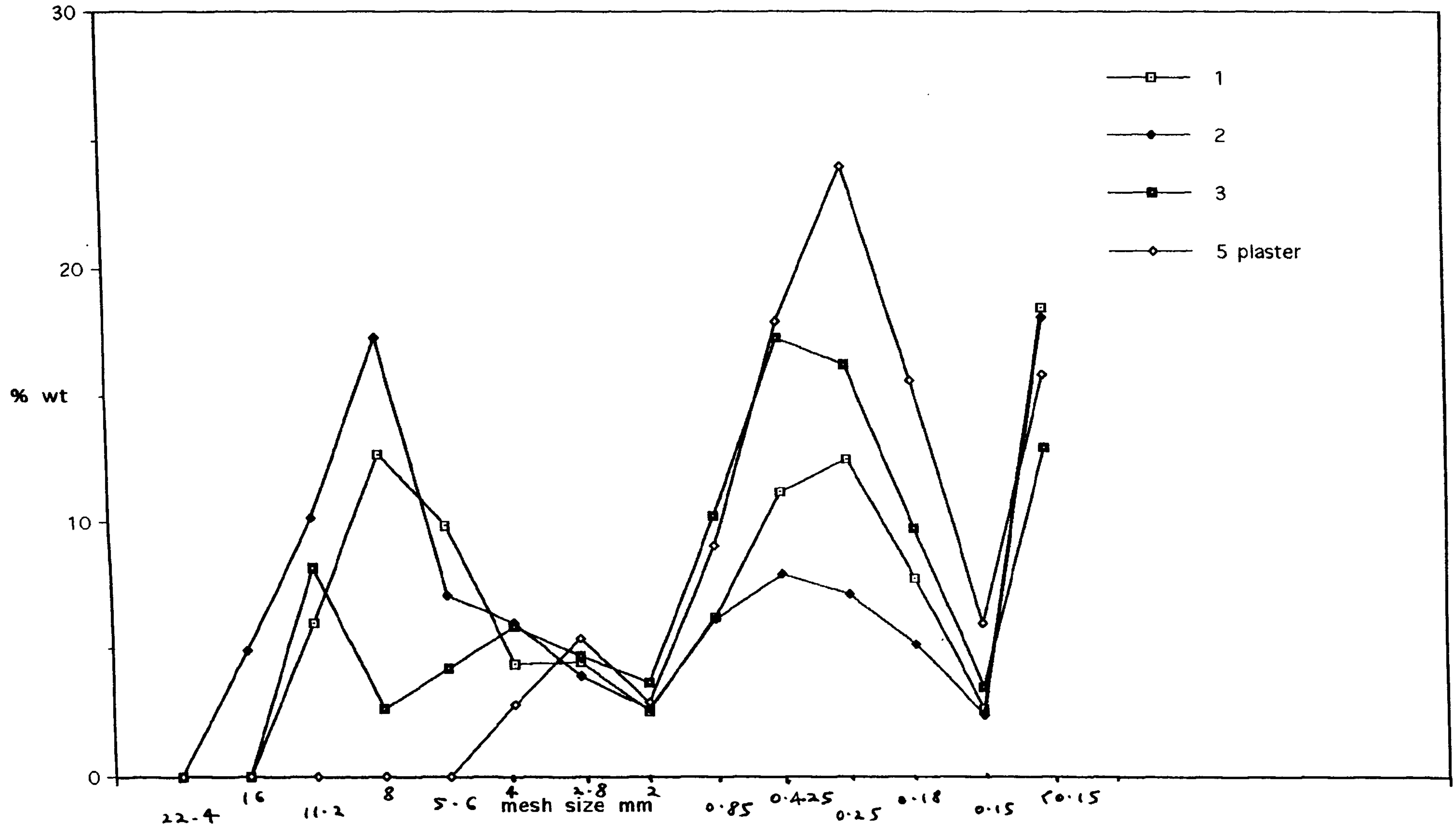
The pigments used were; red ochre (haematite), crushed red brick dust, yellow ochre (limonite), green earth (glauconite), carbon as soot or charcoal, white lime and Egyptian blue.

Average results

	Thicknesses	"Lime"	
mortar	-	51%	probably about 30% lime
paint	0.05mm	-	
burnished red	(0.1 - 0.2) 0.15mm	65%	
intonaco	(0.3 - 0.75) 0.5mm	52%	
plaster	(9mm + 13mm) 22mm total	46%	

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 118
1), 2), 3), 5).
The graphs show that the aggregate is poorly graded, perhaps indicating the use of weathered rock as well as the river gravels.

Fig. 118 Nether Heyford



Norfolk, Castle Museum, Norwich:

Examples of Roman plaster and mortar from many sites in Norfolk were borrowed from the collections of the Castle Museum, Norwich. Analysis has been carried out on a few samples only, although they were all microscopically examined. None of the results have been published.

Aylsham
Bergh Apton
Burgh Castle
Caistor St Edmunds (Caistor by Norwich)
Caister on Sea (Caister by Yarmouth)
Feltwell (reported on separately with another excavated site at Feltwell)
Great Massingham
Grimston
Tivetshall St Mary
Warham St Mary
Wicklewood, Crown Thorpe

COMPOSITIONS

Caistor St Edmunds 19.957

[Lewis 1966: **passim** second to third or fourth centuries]

No	gravel	sand	silt	"lime"	comments
1) /67\	15	62	23	42%	tile plaster
4) /108\	39	54	7	18%	mortar/plaster
4a) /108\	20	70	10	31%	mortar/plaster
5) T1/83\	51	32	17	35%	tile plaster/mortar
6) /141\	35	61	4	20%	mortar floor?
8) /62\	15	56	29	40%	tile mortar/plaster
9) /27\	1	89	10	25%	upper plaster
9a)	14	74	12	40%	lower plaster
10) T1/28\	7	90	3	51%	
11) /26\	2	87	11	22%	
12) /63\	11	86	3	24%	
14) /95\	57	30	13	37%	tile plaster
16) /37\	34	51	15	42%	secondary tile plaster
21) /137\	13	84	3	18%	lower layer
23) /134\	36	50	14	39%	tile plaster
25) /64\	37	45	18	49%	tile plaster/mortar
26) /49\	28	66	6	45%	

Caister on Sea 193.961

13) SF 1581	28	22	50	92%	waste lime?

Aylsham

19)	4	84	12	27%	some tile

Burgh Castle 584.v64

17) BC 133 AB	12	63	25	34%	burnt mud - lower layer
18)	20	72	8	42%	burnt plaster - upper layer

EXAMPLES OF PLASTER DESCRIPTIONS

Caistor St Edmunds 19.957

1) pink *opus signinum*, 27mm thick.

4) coarse sand and gravel mortar or plaster.

4a) as 4) but slightly finer and with more lime.

5) *opus signinum* mortar or plaster.

6) T4 from outside inner wall: coarse gravel and chalk mortar floor?

8) *opus signinum* plaster or mortar.

9) plain white, 0.5 - 0.75mm, on sandy plaster, 10mm, on coarse sand and tile plaster, 25mm thick (9a).

10) cream mortar with sand, 25mm thick. Also samples of plain white plaster c.f. (9).

11) coarse sandy mortar or plaster, 40mm thick.

12) coarse cream mortar or plaster, 40mm thick.

14) red on pink *opus signinum*, 30mm thick. Also samples of red on white, 0.4mm, on sandy plaster, 11mm thick.

16) rough *opus signinum* with coarse sand, 18mm thick with a flat rear - probably a secondary layer.

21) white and yellow traces on burnished or polished red, 0.05mm, on white *intonaco*, 0.5mm, on sandy plaster, 5 - 8mm, on coarse sandy plaster, 15mm thick. Also samples with: dark red on yellow on white on sandy plaster, 5mm thick; black and orange on white; dark red on pink.

23) N end outside outer wall: dark red on pink, 0.05mm, on white *intonaco*, 0.1mm, on *opus signinum*, 28mm thick. Also samples with: polished or burnished red on white *intonaco*, 0.75mm, on sandy plaster, 11mm thick; black, 0.05mm, on white *intonaco*, 0.75mm, on sandy plaster, 5mm thick.

25) light pink *opus signinum* mortar or plaster.

26) coarse gravel mortar.

Other samples examined included material from earlier excavations;
Caister by Norwich 1933, 152.929:
Bag 1) red on white *intonaco*, 0.4mm, on sandy plaster with chalk or lime to 18mm thick.
Bag 2):
(1) green on polished red, 0.05mm, on burnt (pink) white *intonaco*, 0.4mm, on sandy plaster in two layers, 27mm + 16mm thick.
2) white on polished black on white *intonaco*, 0.4mm, on sandy plaster, 13mm, on coarse plaster with quantities of straw or grass, 11mm thick.
(3) white and pink on polished black on white *intonaco*, 0.5mm, on burnt coarse sandy plaster, 27mm thick.
(4) polished red, 0.1mm, on white *intonaco*, 0.75mm, on cream sandy plaster, 9mm thick.
(5) polished red* on yellow on pink, total 0.1mm, on white *intonaco*, 0.4mm, on fine sandy plaster in two layers, 8mm + 10mm thick, with straw or grass in the lower layer.
Caister St Edmunds, Roman Town Site, [9786] pit 13:
polished red* on yellow on pink on white *intonaco* on sandy plaster to 15mm thick.

Caister on Sea 193.961:
13) SF 1581: waste lime lump.
Other samples examined included:
(1) V SF 1200; black, 0.05mm, on white *intonaco*, 0.3mm, on sandy plaster, 9mm thick.
(2) ?bag 1038.57 layer 3; red lines on a yellow band on white; black line on white; black line on red band on pink all on white *intonaco*, 0.2mm, on sandy plaster in two layers, 12mm + 10 - 12mm thick.
(3) ?bag 2095 plain, room 4, D ix 4 2095;
(1) white on burnt sandy plaster possibly in two layers, 9mm + 16mm thick, on burnt mud traces.
(2) black, 0.2mm, and green, 0.5mm, on white *intonaco*, 0.2mm, on sandy plaster, 7mm thick.
(3) lime over-plaster? on red and yellow on white *intonaco*, 0.3mm, on sandy plaster in two layers, 17mm + 15mm thick.

Aylsham:
19) traces of sandy over-plaster on red on white *intonaco*, 0.3mm, on sandy plaster, 11mm, on sandy plaster with tile, 11mm thick. Only the lower layer was analysed. Also samples with: red, yellow, black and

green on white *intonaco* on sandy plaster in three layers, 11mm + 11mm + 18mm thick, the lower layer containing some tile as well; and a sample with the second layer being pink with tile.

Burgh Castle 584.v64
17) BC 133 AB iv layer 4: black and red; dark red; plain red all on white? *intonaco*, 0.3mm, on coarse burnt plaster (18), 8 - 11mm, on burnt mud plaster with straw, 14mm thick.

Bergh Apton:
(1) probably burnt calcareous clay daub with grass and wattle impressions and keying marks.
(2) red on white *intonaco*, 0.2mm, on sandy plaster, 3.5mm, on a possible white interface, 0.2mm, on sandy plaster, 14mm thick.
(3) light grey over grey brown on white *intonaco*, 0.4mm, on sandy plaster to 20mm thick.
(4) dark red on white *intonaco*, 0.4mm, on sandy plaster, 9mm thick.
(5) dark red on orange pink and red*, 0.05 - 0.1mm, on grey, 0.2mm, on white *intonaco*, 0.3mm, on sandy plaster in two layers, 5mm + 8mm thick.

Great Massingham:
over-plaster traces and pick markings on brushed red on white, 0.1mm, on white *intonaco*, 0.3mm, on pink *opus signinum* in two layers, 15mm + 35mm thick.

Grimston:
211.954: window moulding or similar feature; red on white, <0.05mm, on white / cream *intonaco*, 0.3mm, on coarse sandy plaster with tile, 12mm, on pink tile plaster, 12mm thick.
426.973; white line on red* on pink*, total 0.1mm, on white *intonaco*, 0.75mm, on sandy plaster, 7mm, on sandy plaster, 18mm thick.
(1) yellow on white *intonaco*, 0.5mm, on sandy plaster possibly in two layers, 7mm + 8mm thick.
(2) black line on white *intonaco*, 0.75mm, on sandy plaster, 9mm thick.
(3) coarse blue on maroon to black on red* on yellow, total 0.5 - 0.75mm, on white *intonaco*, 0.5mm, on sandy plaster in two layers, 4mm + 8mm thick.

Wicklewood - Crownthorpe
8897 WCK: white; yellow red; black line all on white *intonaco*, 0.5 - 0.75mm, on sandy plaster, 9mm, on coarse sandy plaster, 17mm thick.

Tivetshall St Mary 668.964
(1) red splashes on white *intonaco*, 0.4mm, on sandy plaster with tile, 6.5mm, on pink tile plaster, 8mm thick.
(2) mixed red and yellow, 0.05mm, on rough white *intonaco*, 1mm, on coarse sandy plaster with tile, 15mm thick.
(3) red and yellow line on white *intonaco*, 0.5mm, on coarse sandy plaster with tile, 12mm, on pink tile plaster, 25mm thick.

Warham St Mary: yellow line on pink, 0.05mm, on white *intonaco*, 0.25mm, on coarse sandy plaster in two layers, 10mm + 10mm thick.

PAINTING TECHNIQUE
The painting technique appeared to have been in the *buon fresco* method. The presence of polished and burnished samples and the use of cinnabar was of note.

PIGMENTS
The pigments included: red ochre (haematite), red* cinnabar, pink* cinnabar with lime, yellow ochre (limonite), green earth (glauconite), black soot or charcoal, white lime and crushed Egyptian blue.

Average results - Caistor St Edmunds only

	Thicknesses		"Lime"
paint	(0.05 - 0.1)	0.07mm	-
intonaco	(0.1 - 0.75)	0.6mm	-
upper plaster layer	(5 - 27)	13mm	25%
lower plaster layer	(10 - 25)	15mm	29%
single layers of plaster or mortar	(25 - 40)	35mm	33%
floor		40mm	20%
opus signinum types:			
upper plaster layer	(27 - 30)	28mm	42%
single layers of plaster or mortar		-	40%
secondary plaster		18mm	42%

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 121 - 126
Caistor - sand and gravel 1: 4, 4a, 6, 9, 9a.
Caistor - sand and gravel 2: 10, 11, 12, 21, 26.
Caistor - opus signinum 1: 1, 5, 8, 14.
Caistor - opus signinum 2: 16, 23, 25.
Burgh Castle - 17, 18.
Caister and Aylsham - 13, 19.

Although the sites represented are from a large area there are similarities in some aggregate gradings. This may suggest similar geological sources or deposition methods. The identified aggregates were mainly flint pebbles or gravel with: quartz, quartzite and ferruginous concretions. Crushed brick or tile was also commonly present.

Fig. 121 Caistor St Edmunds - sand and gravel 1

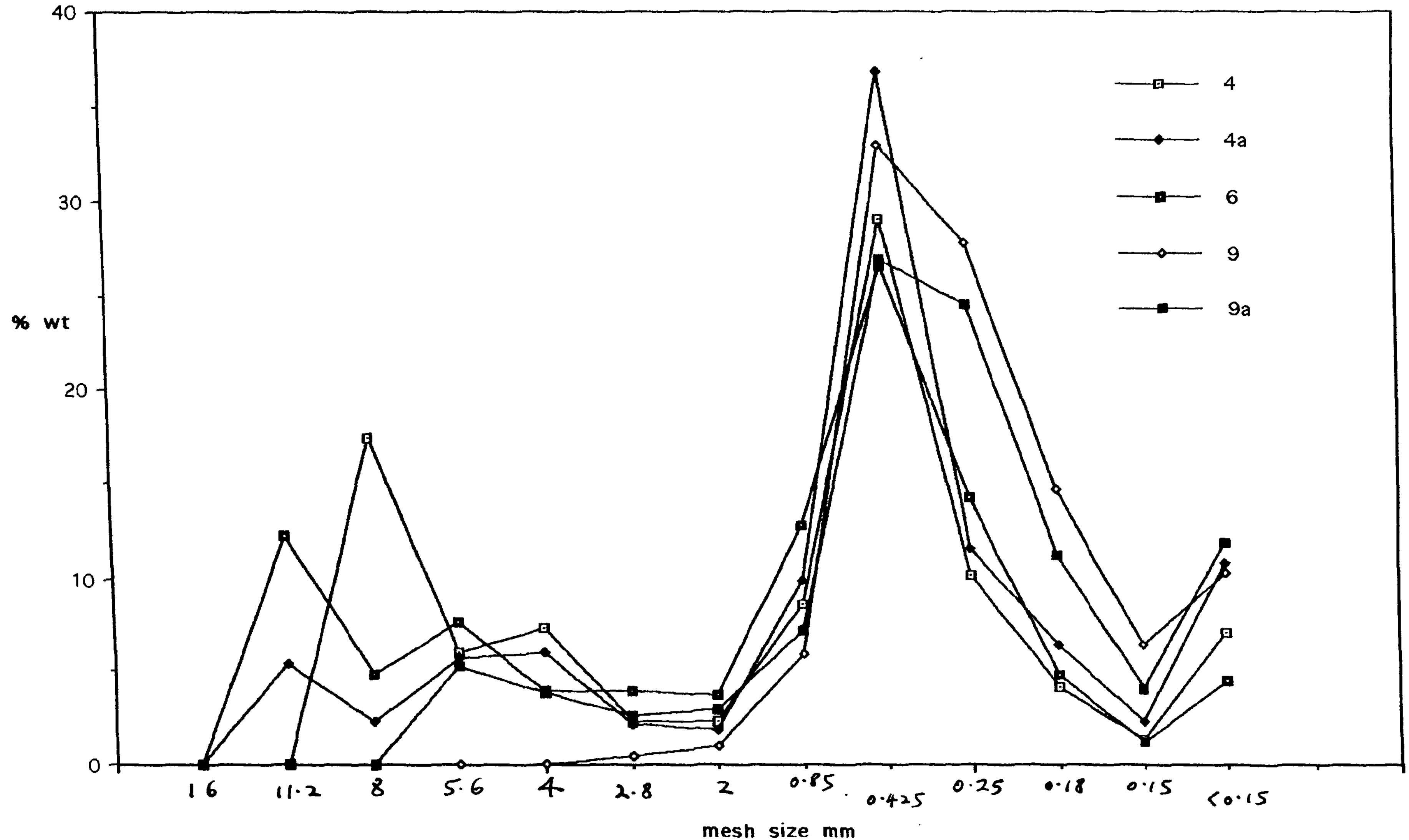


Fig. 122 Caistor St Edmunds - sand and gravel 2

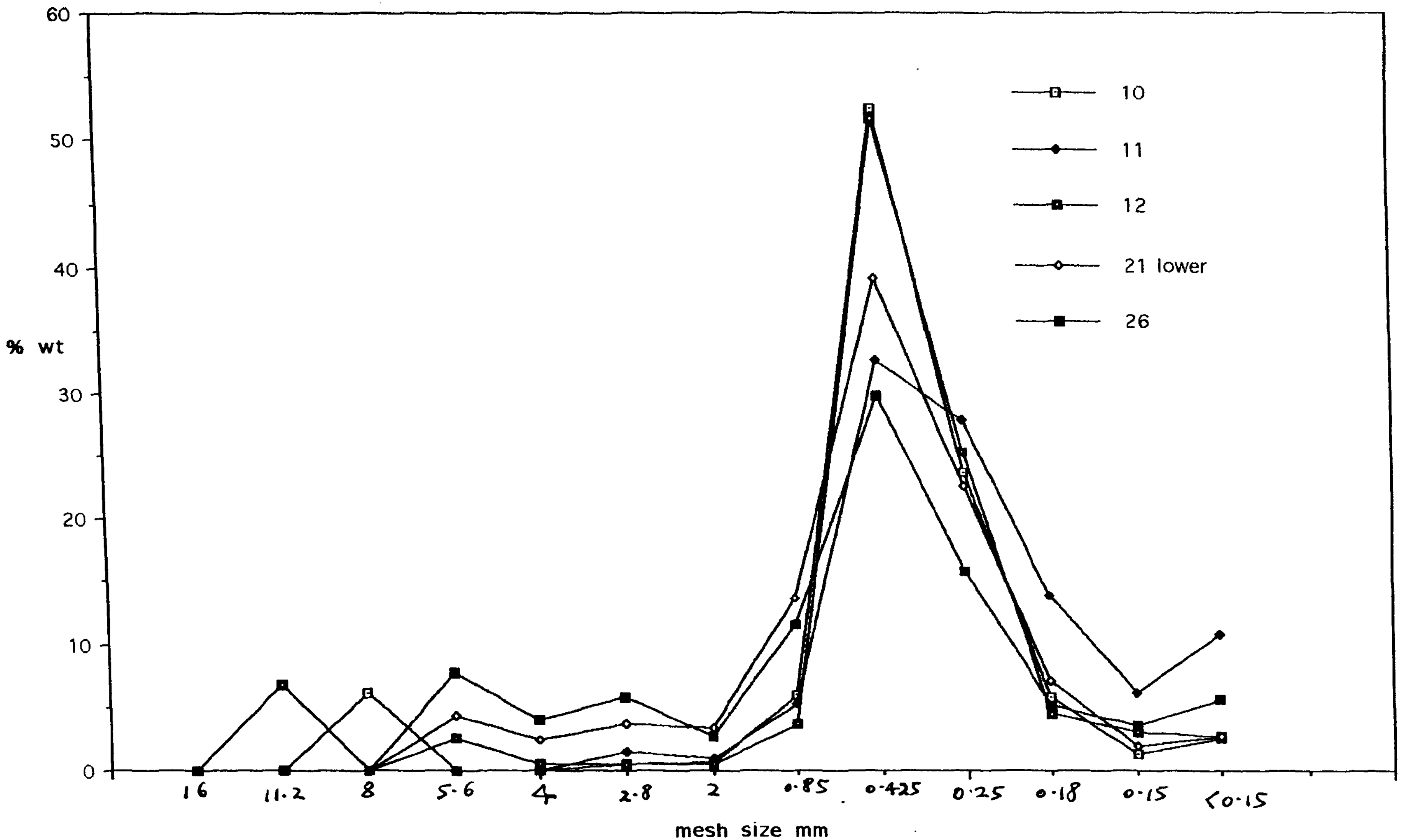


Fig. 123 Caistor St Edmunds - opus signinum 1

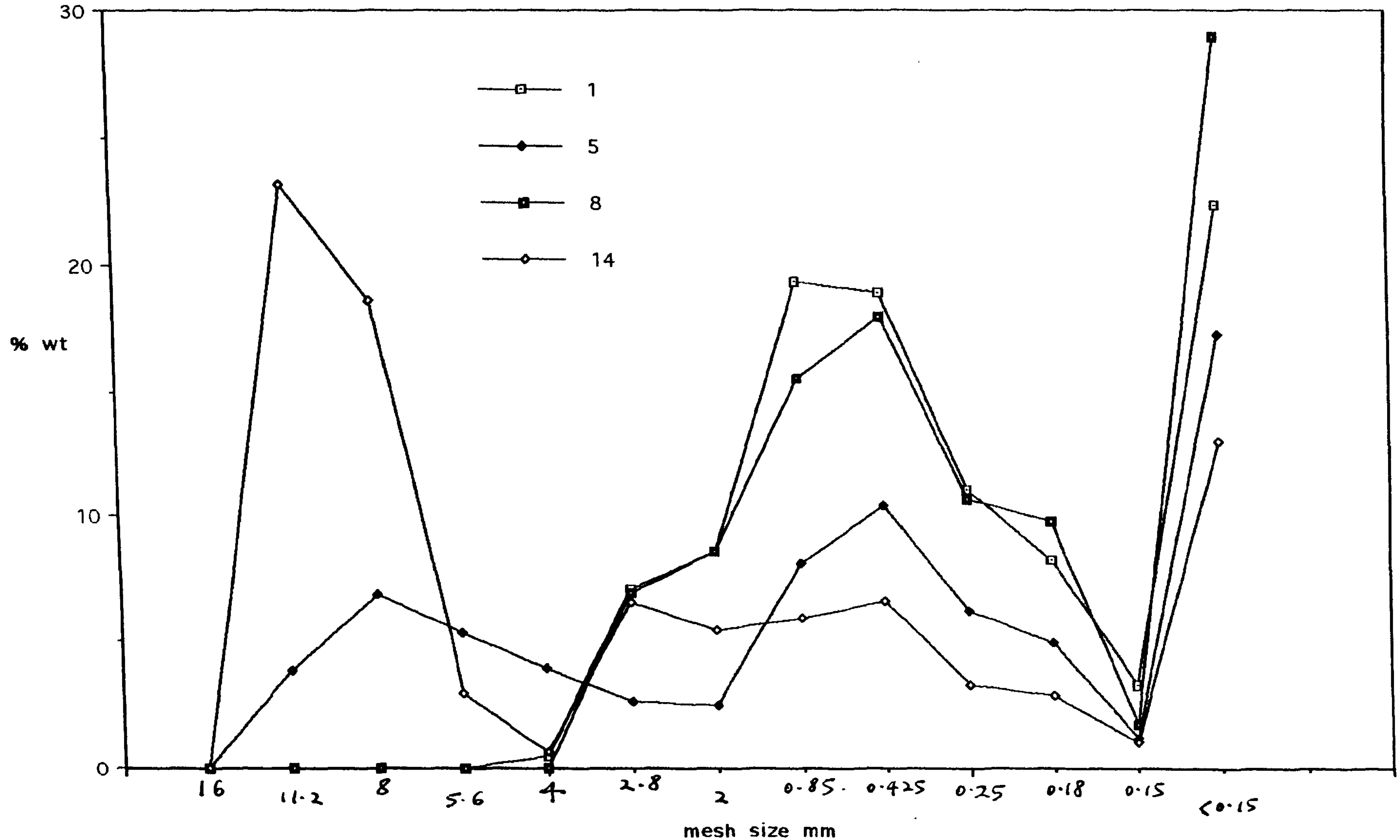


Fig. 124 Caistor St Edmunds - opus signinum 2

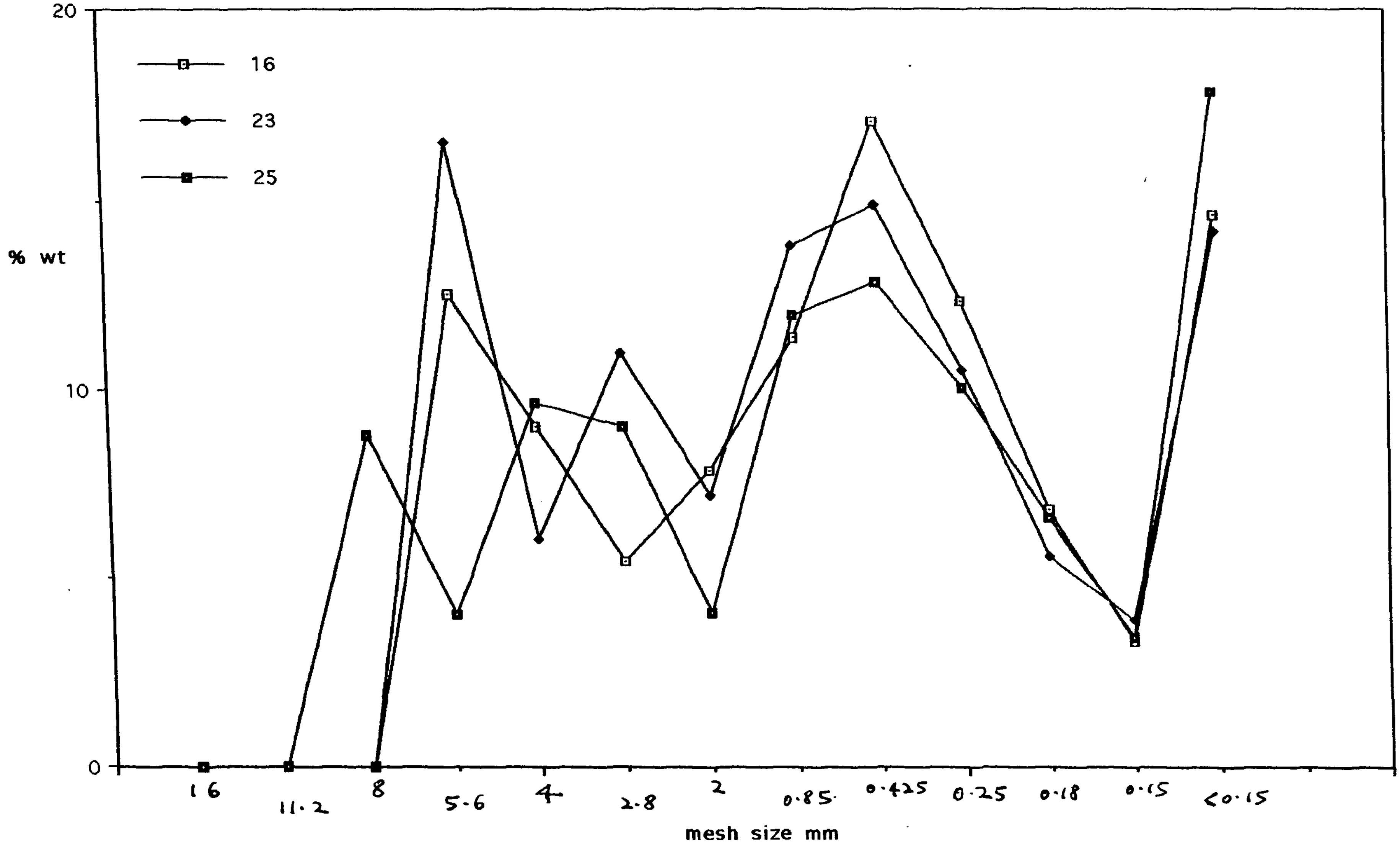


Fig. 125 Caister on Sea and Aylsham

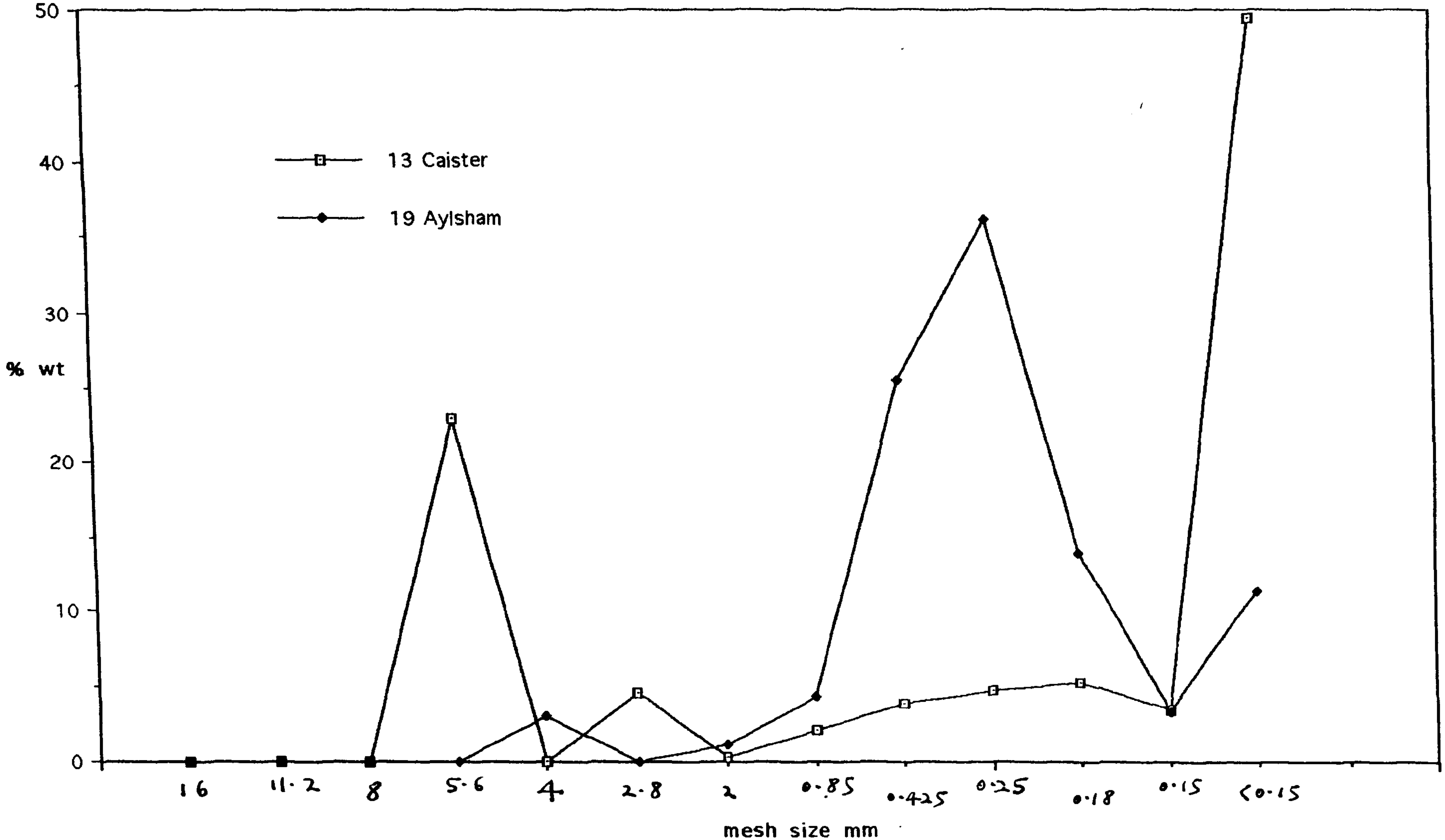
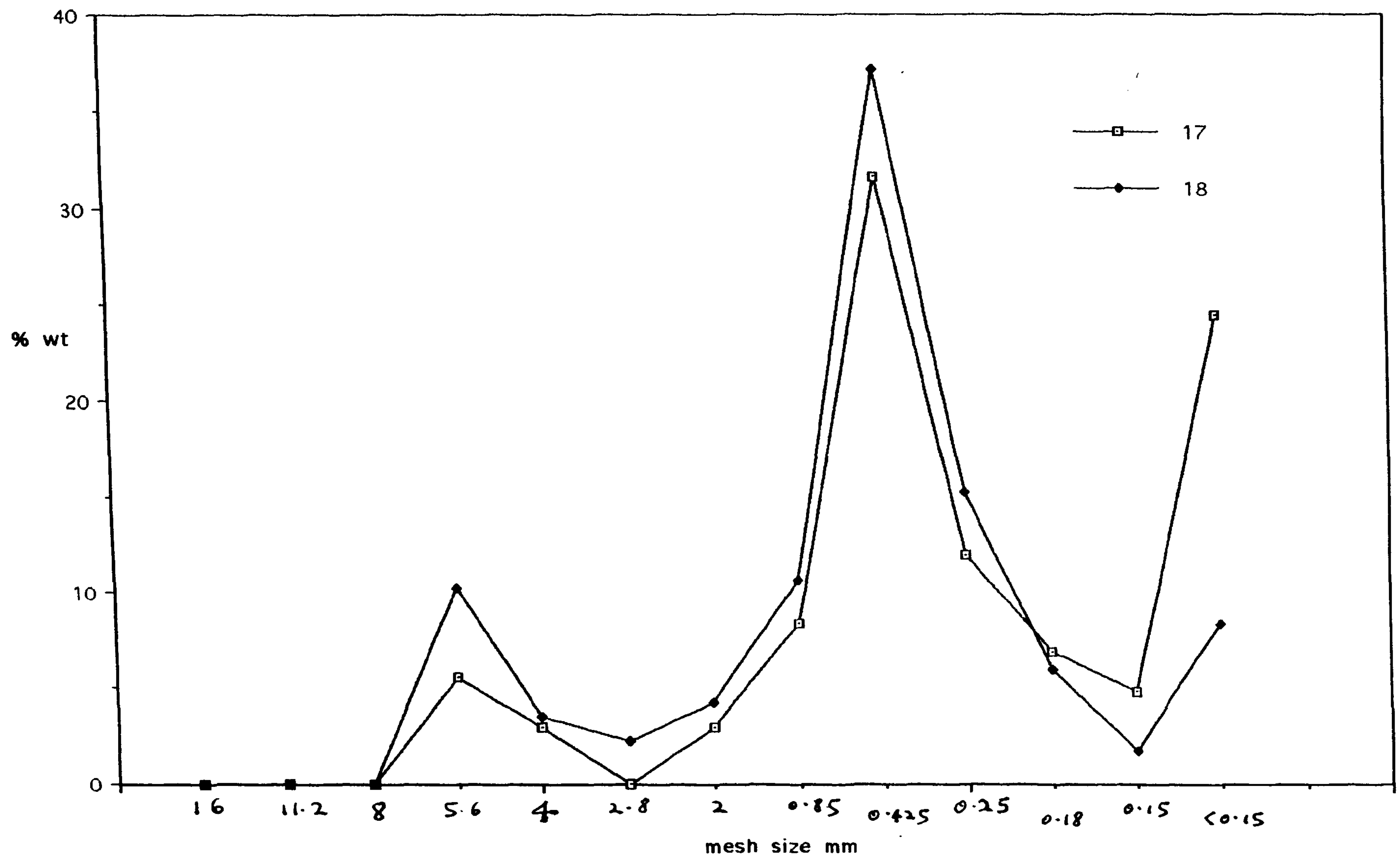


Fig. 126 Burgh Castle



Piddington, Northamptonshire
Britannia 1981 12: 432 - 3; 1988 19: 452; 1989 20: 290 - 2.
Current Archaeology 1982 82: 348 - 9; 1989 117: 316 - 321

The large villa complex at Piddington is still being excavated. Results so far suggest that the site is very large. Small numbers of painted plaster samples have been examined and analysed. The quality was very good and the use of crystalline calcite and cinnabar of note. The aggregates reflected the local Nene valley gravels, being quartzite, quartz, flint, ferruginous sandstones and fossiliferous limestone. Crushed brick and tile was also used. Crushed samples of the Roman brick or tile were used for experimentally determining particle size distribution curves. Thirteen samples were examined and two fully analysed. These results are unpublished.

COMPOSITIONS

No	gravel	sand	slit	"lime"	comments
1)	58	29	13	23%	pink *opus signinum*
2)	24	50	26	54%	buff *opus signinum*

EXAMPLES OF MORTAR AND PLASTER DESCRIPTIONS

mortar

1) Room 1, area B, pink mortar:
pink to buff slightly sandy tile and lime mortar.
2) Room 1, area B, buff tile mortar:
pink to buff, red and black slightly sandy tile and lime mortar.

painted plaster

1) WP 9, N12, G, L2, a burnt sample:
white band over red* to pink on burnished? red with calcite crystals, 0.05 - 1mm, on white *intonaco*, 0.2mm, on sandy plaster, 10mm thick.
2) S7, L2, A6:
maroon on light blue on burnished? black on green, 0.05mm, on white *intonaco*, 0.5mm, on coarse sandy plaster, 8mm, on sand and gravel plaster, 10mm thick.
3) R2, 21, room 7/9, area F:
purple (red with blue) on white with blue on grey and light green on white, 0.05mm, on white *intonaco*, 0.5 - 1mm, on coarse sand and gravel plaster in two layers, 9mm + 12mm thick.

4) B9, room 5, L5, area B, a burnt sample:
burnished? black, 0.2mm, on burnt white *intonaco*, 0.2mm, on coarse sandy plaster, 7mm thick.
Also a sample with a white line on burnished black, 0.05mm, on white *intonaco* traces, 0.4mm, on coarse sandy plaster in two layers, 10mm + 18mm thick.
5) area F:
green on black, <0.05mm, on burnished white *intonaco*, 0.75mm, on coarse sand and gravel plaster, 8mm thick.
6) F21, area E, burnt sample:
polished red, 0.1mm, on white *intonaco*, 0.1mm, on sandy plaster, 8mm thick.
7) P2, L6, area F:
yellow line? on dark green with blue, on yellow brown, <0.05mm, on white *intonaco*, 0.5mm, on coarse sand and gravel plaster in two layers, 9mm + 8mm thick.
8) area F:
white? with blue traces on dark red on light maroon to pink, 0.05mm, on burnished white *intonaco* with tile traces, 0.75mm, on buff sand, tile and gravel plaster, 12mm thick.
9) Y/Z, 5/6, L2, area A, external wall plaster:
burnished? red, <0.05mm, on white *intonaco*, 0.4mm, on coarse sandy plaster, 12mm, on coarse sand, tile and gravel plaster, 18mm thick.
10) area F:
white with a blue line and a yellow line on red* on yellow, a white band with blue specks over the black to red* interface all on white *intonaco*, 0.4mm, on coarse sand and gravel plaster to 20mm thick, possibly in two equal layers.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* method. The over painting, particularly on the burnished or polished surfaces, may have been applied in the *fresco secco* method. The use of crystalline calcite, cinnabar and the quality of the polishing point to high quality workmanship.

PIGMENTS

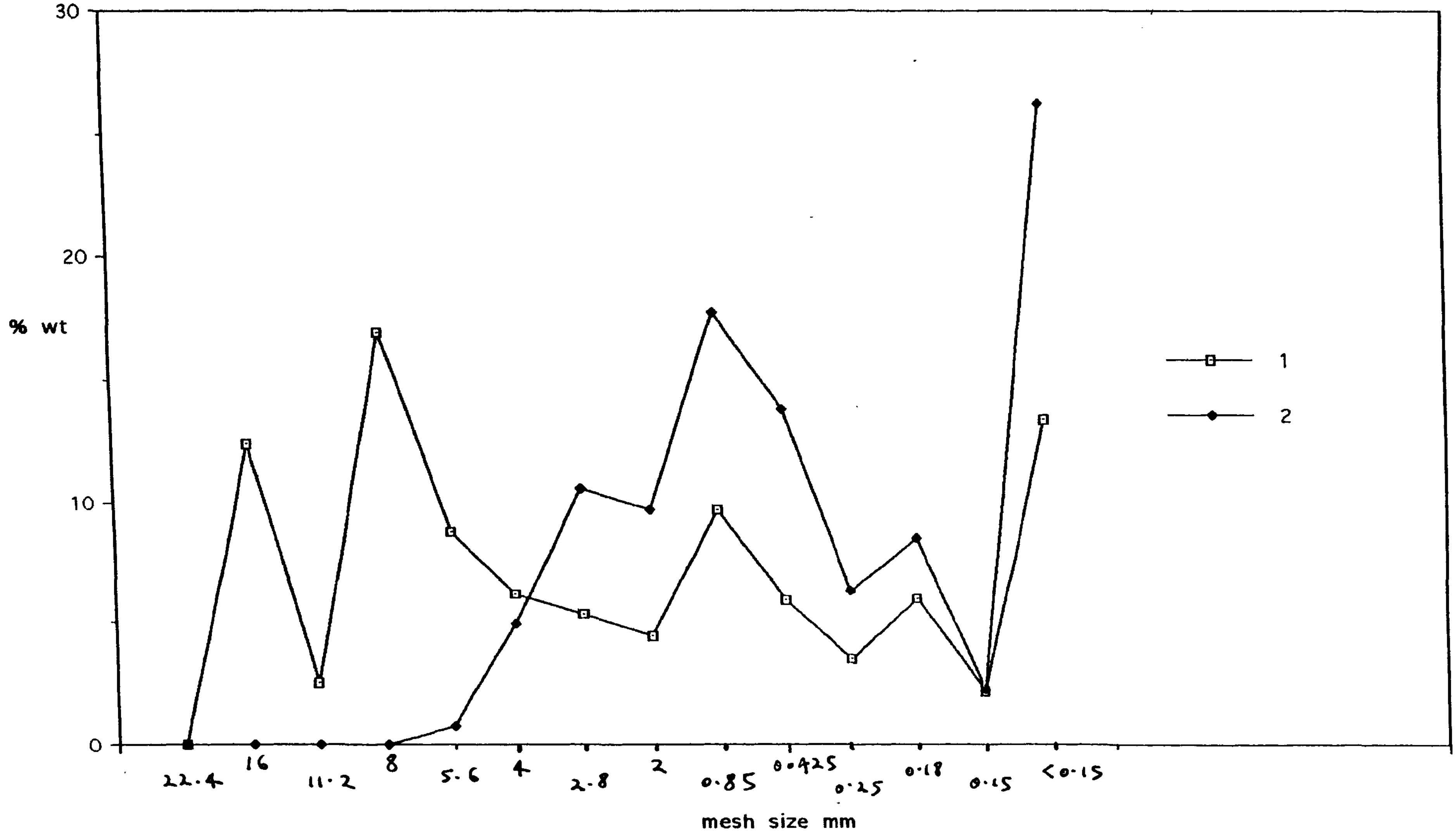
The pigments included with the crushed Egyptian blue and red* cinnabar the usual range of natural colours: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), white lime and black soot or charcoal.

Average results

	Thicknesses
paint	<0.05 - 0.05mm
intonaco	(0.4 - 1) 0.5mm
upper plaster	(8 - 12) 10mm
lower plaster	(10 - 18) 13mm

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 127 and recently crushed tile Fig No. 24
Tile mortar samples 1) and 2). The pink sample 1) was coarser than the buff sample but both showed the same peaks for the included sand from the tile.

Fig. 127 Piddington - opus signinum



Piercebridge, Co. Durham
Britannia 1979 10: 285 - 6

This material was borrowed from the collections in the care of the Bowes Museum, Barnard Castle. It represents various areas excavated at the Roman fort site at Piercebridge from 1969 - 1980. The site references are: HH 69 - the Villa, TF 75 and HS 76 - features outside the east wall of the fort, mainly 'vicus', GV 76, 77 - bath house, BG 76, 77 and BB 77 - courtyard building.
The painted plasters were made with lime and the local river gravels with the addition of crushed brick or tile for some aggregates. Geologically they contained: quartz, quartzite, ferruginous, micaceous and other sandstones, dolerite and fine grained greenish "granite". Small quantities of coal were also found, either derived from the aggregate or from its use as a fuel in the lime manufacture. Twenty nine samples were examined and fifty eight analyses carried out.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
GV 76 2A 2B					
a)	-	-	-	96%	*intonaco.*
	11	71	18	23%	upper layer
	66	31	3	8%	lower layer
b)	-	-	-	90%	*intonaco*, upper
	1	89	10	23%	secondary plaster
	-	-	-	89%	*intonaco*, lower
	7	76	17	23%	upper primary plaster
	25	62	13	33%	lower plaster
c)	-	-	-	85%	*intonaco*
	2	75	23	26%	upper layer
	41	43	16	22%	middle layer with tile
	12	59	29	26%	lower layer, *opus signinum*
GV 76 (5) A	0	63	37	88%	upper layer with coal
	0	77	23	54%	lower layer with coal
GV 76 (33) 2A:					
a)	27	41	32	42%	*opus signinum.*
b)	25	51	24	41%	upper layer, *opus signinum.*
	36	40	24	38%	lower layer, *opus signinum.*
HS 76 area A room 4(W):					
	4	87	9	26%	upper layer
	4	66	30	34%	lower layer

TF 75 temple 2	23	61	16	18%	combined layers
TF 75 room 1 (4):					
	30	57	13	17%	combined layers
BG 77 22 trench IV (2):					
	5	90	5	23%	upper layer
	12	84	4	21%	middle layer
	8	70	22	67%	third layer, on daub?
BB 77 W/W:					
a)	-	-	-	93%	*intonaco*
	5	84	11	26%	upper layer
	15	78	7	22%	middle layer
	17	74	9	24%	lower layer
b)	7	87	6	22%	upper layer
	3	91	6	18%	middle layer
	18	75	7	20%	lower layer
BB 77 (W) 145.5 149:					
	8	82	10	30%	upper layer
	8	73	19	19%	lower layer
barracks room 2 2A:					
	-	-	-	98%	*intonaco*
	23	58	19	35%	upper layer, some tile
	41	42	17	32%	second layer, *opus signinum*
	30	46	24	38%	third layer, *opus signinum*
	34	49	27	35%	fourth layer, *opus signinum*
BB 77 WW 444.5 / 150 IV:					
	-	-	-	98%	white
	-	-	-	73%	*intonaco*
	9	84	7	27%	upper layer
	18	66	16	26%	lower layer
BB 77 room 11 drain 127:					
	12	79	9	27%	single? layer
(BB) room 2 box D:					
	39	41	20	45%	upper layer, *opus signinum*
	27	47	26	44%	middle layer, *opus signinum*
	71	15	14	44%	lower layer, *opus signinum*
(BB) Yellow, box 2:					
	4	90	6	27%	upper layer
	9	80	11	25%	lower layer

HH 69:

a)	0	50	50	61%	secondary, upper layer
	1	50	49	61%	secondary, lower layer
	4	51	45	63%	primary plaster
b)	1	52	47	62%	combined upper layers
	2	58	40	63%	lower layer
c)	-	-	-	92%	yellow
	-	-	-	87%	*intonaco*
	0	52	48	63%	upper layer
	8	42	50	68%	lower layer

EXAMPLES OF PLASTER DESCRIPTIONS

GV 76 2A 2B:

a) dark red, 0.05 - 0.1mm, on white *intonaco*, 0.75mm, on pale grey to buff sandy plaster, 15 - 20mm, on traces of fine gravel plaster with some tile.

b) dark red to red stripes? on white *intonaco*, 0.5mm, on sandy plaster, 3.5mm, on orange red on white with pick marks, 0.05mm, on white *intonaco*, 0.5mm, on pale buff plaster, 4mm, on sandy plaster with straw impressions, 10mm thick. The primary and secondary plasters were very similar, suggesting re-plastering within a short period of time.

c) black and red on white on white *intonaco*, 0.4mm, on sandy plaster, 13mm, on sandy plaster with tile (*opus signinum*), 16mm, on tile plaster with sand, 12mm thick.

GV 76 (5)A:

light weight lime plaster with wattle and plank impressions, 25mm, on light grey sandy plaster also with wattle impressions, 15mm thick. This sample contained coal and par-burnt coal. Its analysis was quite different from all the other material seen. Unless it was safely stratified it would appear to be possibly medieval or later.

GV 76 (33) 2A:

a) red, 0.05mm, on pink tile plaster, 35mm thick. (*opus signinum*)

b) red on white *intonaco*, 3mm, on buff plaster, 10mm, on pink plaster, 17mm thick.

HS 76 area A room 4 (W):

green on yellow on white *intonaco*, 0.5mm, on whitish sandy plaster with wattle impressions up to 60mm thick possibly in two equal layers. The wattles were about 12mm in diameter.

TF 75 temple 2:
orange on white *intonaco*, 0.5mm, on very friable and muddy sandy plaster with straw impressions, 30mm, possibly in two layers 10mm + 20mm thick. Also a sample with white spots on orange as above.
TF 75 room 1 (4):
traces or red orange and yellow on white *intonaco*, 0.6mm, or possibly white on off white *intonaco*, on muddy friable sandy plaster in two layers, 10mm + 30mm thick.
BG 77 22 trench IV (2):
white *intonaco*, 0.5mm, on very friable pale grey sandy plaster, 18mm, on buff sandy plaster, 25mm, on buff mortar traces, 5mm, on soil or daub?, 3+mm thick.
BB 77 W/W:
a) green strip on white, 0.1mm, on white *intonaco*, 0.75mm, on grey sandy plaster, 14mm, on coarser sandy plaster, 22mm thick. Also as above with green 'leaves' on white.
b) red stripes on white *intonaco*, 0.5mm, on pale grey sandy plaster, 14mm, on pale grey sandy plaster, 14mm, on buff plaster, 8mm thick.
Both these samples were described as ceiling plasters.
BB 77 (W) 145.5 149:
7mm wide red stripe on white as a) above;
red on white as above;
brushed dark green on light green on white *intonaco*, 0.75mm, as above on sandy plaster, 10+mm thick;
white stripe on light grey on dark grey on pink on burnished white *intonaco*, on pale grey sandy plaster, 20mm, on dark grey to buff sandy plaster, 10+mm thick.
(BB) barracks room 2 2A:
streaky grey on white *intonaco*, 0.75mm, on sandy plaster, 7mm, on tile plaster with sand, 14 - 20mm, on tile plaster with sand, 7 - 14mm, on tile plaster, 11 - 13mm thick.
(BB) barracks 8 - 9 WW:
white *intonaco* on three layers of sandy plaster, totalling 50mm, as BB 77 W/W. The formation of a lime interface on the second layer, 12mm from the surface, suggested a time delay or partial drying between plaster applications. A fragment of coal was also found in this sample.
BB 77 WW 444.5 / 150 IV:
white on buff *intonaco* on yellow sandy plaster possibly in two layers, 34mm, on yellow sandy plaster, 6mm thick. The whole sample may be iron stained.

BB 77 room 11 drain 127:
orange red* stripe on dark green stripe on off white *intonaco*, 0.5mm, on pale yellow to buff sandy plaster, 38mm thick, apparently a single layer.
(BB?) room 2 box D:
white plaster with tile, 25mm, on pink tile plaster, 15mm, on paler tile plaster, 10mm thick. The top layer was lighter because there was less tile dust in it, suggesting sieving or some other form of grading. This was a unique sample.
(BB?) yellow box 2:
yellow on red on white *intonaco*, 0.5mm, on pale sandy plaster, 17mm, on pale sandy plaster, 17mm thick. Both layers showed iron staining. The red was a drip, perhaps from another painted area higher up on the wall.
HH 69:
a) blue (0.2mm particles) on black on white on combed white *intonaco*, 1.2 - 1.5mm, on buff to yellow sandy plaster, 11mm, on greyer sandy plaster, 8mm, on a red to brown stripe on green on black on white *intonaco*, 0.25mm, on greyish sandy plaster, 7+mm thick. The primary and secondary plaster layers were very similar. The combing was most obvious under the blue area, suggesting deliberate grooving to retain the coarse Egyptian blue particles. Also a sample with a white stripe on green on orange to brown on blue (0.15mm particles) on white *intonaco* on sandy plaster, 20mm, on red on green on white *intonaco* on sandy plaster as above.; and:
white on yellow on pale green on black on pink on white *intonaco* on sandy plaster, 14mm + 6mm, on dark green on white *intonaco* on sandy plaster, 18mm thick as above.
b) white on blue on red* on pale buff to yellow on white *intonaco*, 0.1mm, on buff plaster, 4mm + 10mm, on pale grey plaster traces, 4+mm thick. The *intonaco* is deeply combed under the blue only.
c) red* on yellow to pale buff, on white *intonaco*, 0.2mm, on whitish sandy plaster with straw impressions, 20mm, on buff sandy plaster, 7+mm thick. Also a sample with pink on off white on grey and dark purple on green on brown, total 0.2mm, on grey, 0.4mm, on white *intonaco*, 0.6mm, on pale sandy plaster, 17mm, on buff sandy plaster, 8mm as above.

PAINTING TECHNIQUE

The painting appeared to be in the *buon fresco* method with over painting in *fresco secco*. The style of painting suggested both borders and complex freehand painting. The ceiling plasters were painted in geometrical styles seen in other ceiling paintings. The colour schemes used were: red, orange red, red* on yellow, orange red* on dark green, red brown on green, orange, black and red, dark green on light green, green on yellow, green, white on light grey on dark grey on pink, blue on black, white on yellow on pale green on black on pink, white on blue on red* on pale buff to yellow, pink on off white on grey and dark purple on dark green on brown.

PIGMENTS

The pigments were the usual natural colours: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), white lime, carbon as soot or charcoal with red* cinnabar and crushed Egyptian blue.

Average results

	Thicknesses		"Lime"	
paint	(0.05 - 0.4)	0.15mm	95%	
intonaco	(0.1 - 3)	0.6mm	87%	
secondary plaster	(3 - 14)	10mm	36%	upper layer
	(6 - 10)	8mm	36%	lower layer
primary plaster	(4 - 35)	15mm	36%	upper layer
	(8 - 30)	16mm	36%	second layer
	(5 - 22)	10mm	35%	third layer
	(4 - 12)	8mm	35%	fourth layer

the opus signinum plasters averaged 38% "lime".

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 128 - 130

The graph references are in **bold**: HS 76 area A room 4 (W) upper layer **14**, GV 76 2A 2B a) upper layer **1**, lower layer **2**, c) middle layer **7**, lower layer **8**, BG 77 22 trench IV (2) third layer **20**, GV 76 (5)A lower layer **10**, GV 76 (33) 2A b) upper layer **12**, Barracks room 2 2A first **29** and fourth **32** layers, HH 69 a) upper layer **36**, (BB) room 2 box D upper **43** and middle **44** layers.

The graphs show the main groups of gradings of fairly coarse or coarsely graded sand, and poorly graded crushed brick or tile, together with mixed aggregates.

Fig. 128 Piercebridge - sand and gravel

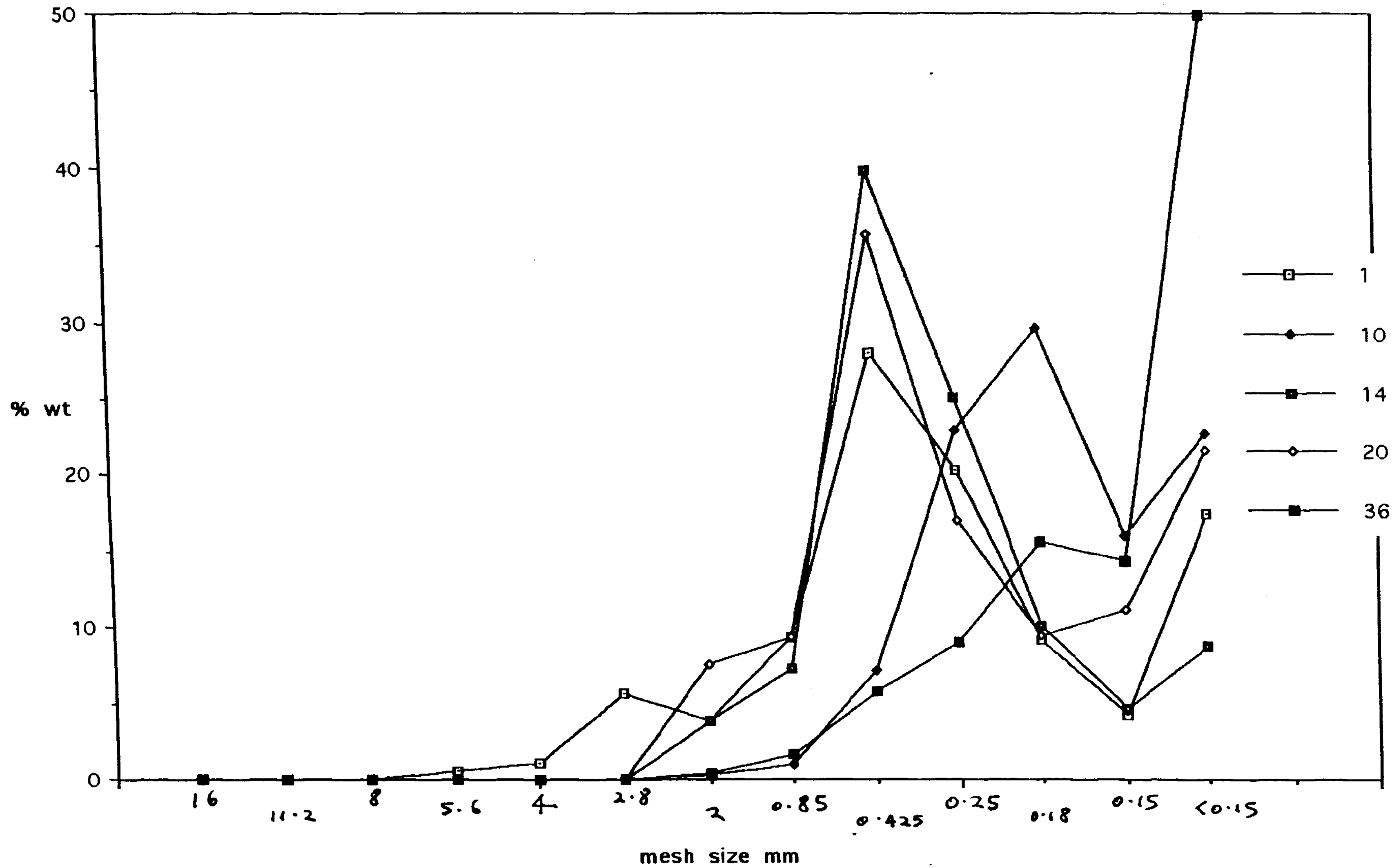


Fig. 129 Piercebridge - sand and tile

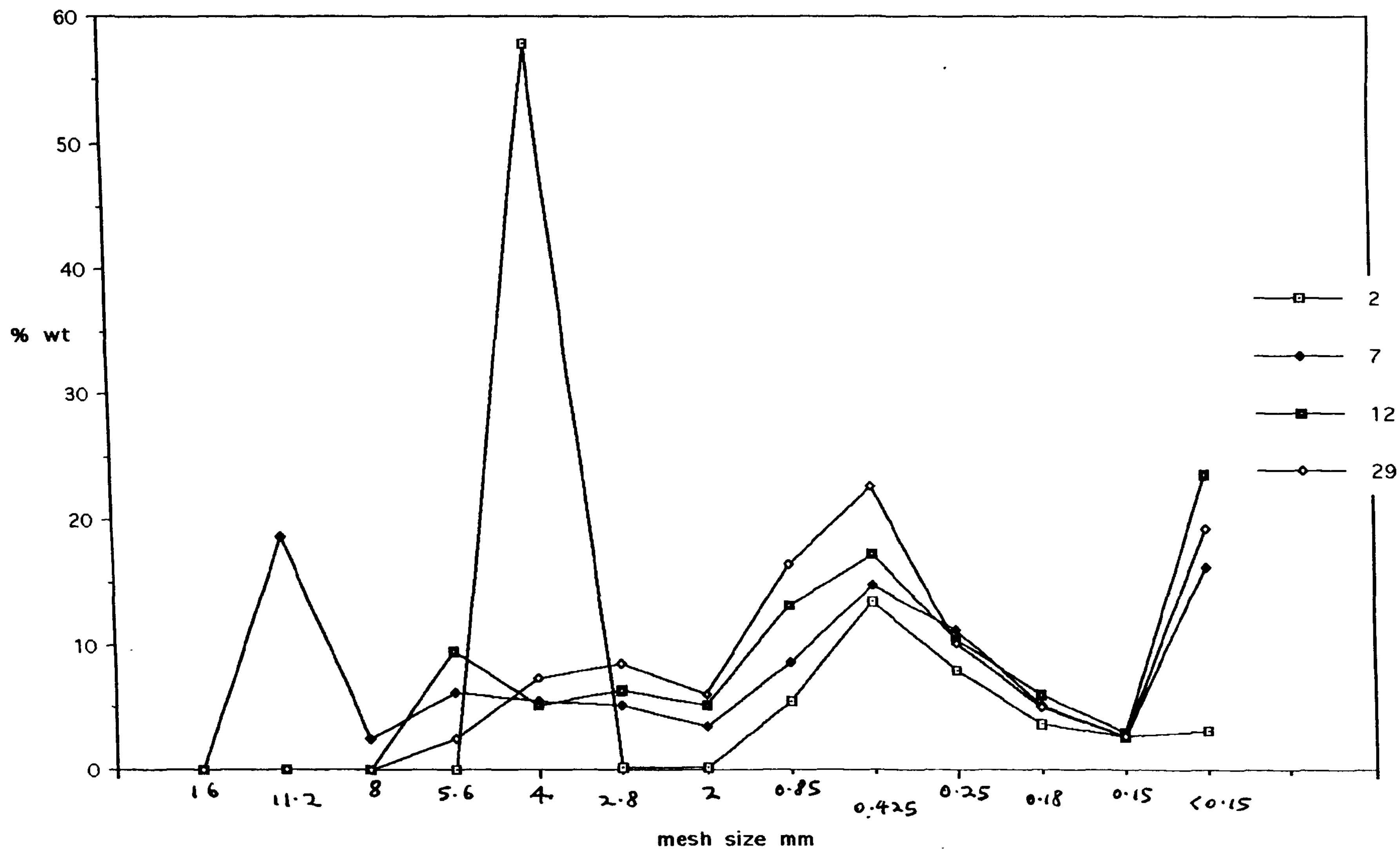
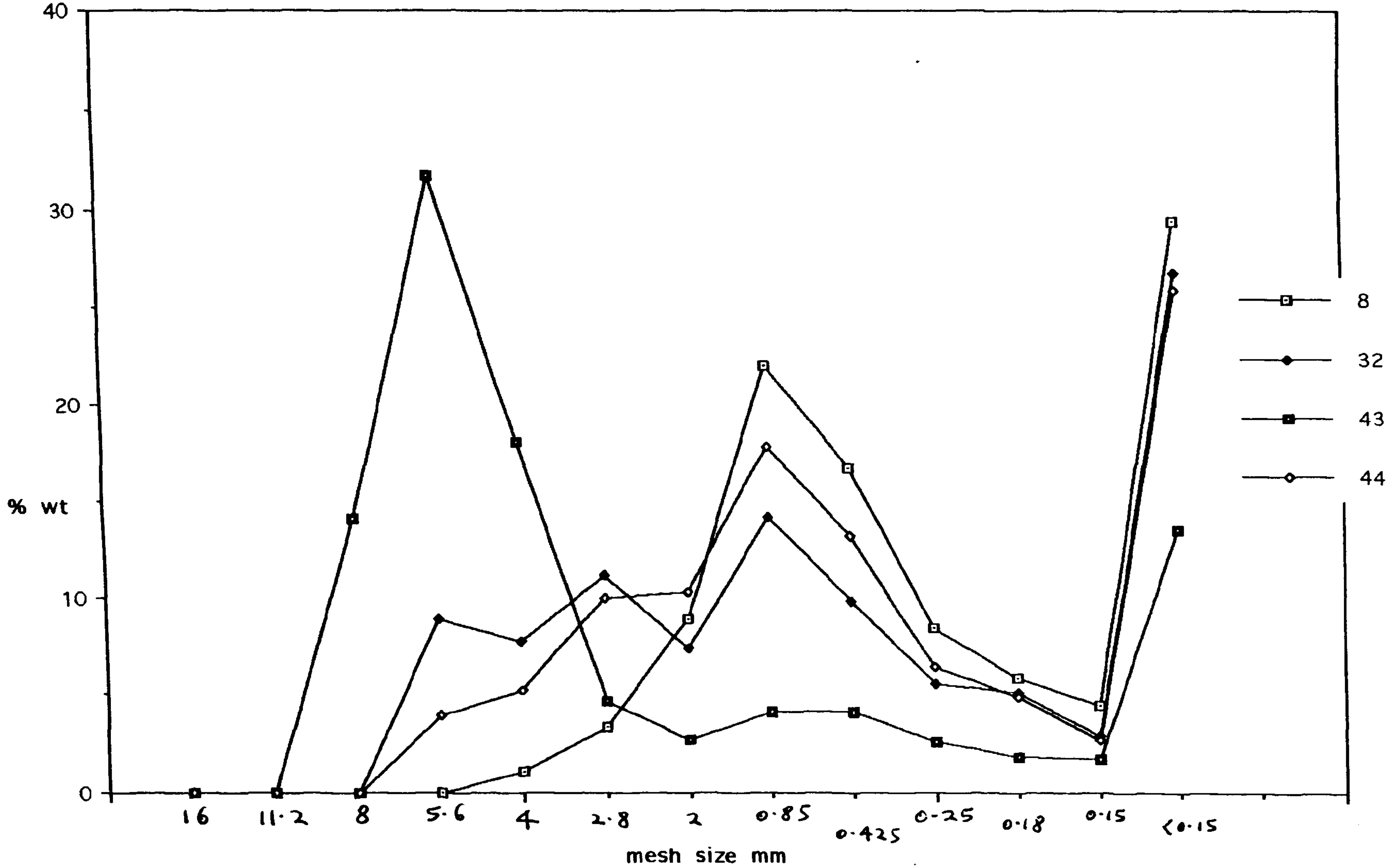


Fig. 130 Piercebridge - opus signinum



Pulborough, West Sussex.
Mares Hill, Roman temple.
Lewis 1966: 56

These wall plaster fragments were from the collections of Worthing Museum. They were all lime plasters with quartz sand, flint and ferruginous sandstones as the aggregate. Some of the sandstone appeared to be burnt. Chalk was present in many samples, estimated at up to 10% by volume. Twelve samples were examined and fourteen analyses carried out. These results are un-published.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1a	5	79	16	28%	
1b	1	81	18	28%	
	-	-	-	91%	*intonaco*
2	7	80	13	27%	lower plaster ?
3	5	80	15	25%	
	-	-	-	86%	*intonaco*
4	28	57	15	26%	
	-	-	-	70%	*intonaco*
5	7	79	14	26%	
	-	-	-	93%	red with calcite
6	4	76	20	32%	
7	7	79	14	28%	
8	4	84	12	30%	
	-	-	-	82%	*intonaco*

EXAMPLES OF PLASTER DESCRIPTIONS

1) Polished white *intonaco*, 0.2 - 0.5mm, on light coarse sand plaster with grass or straw impressions, 18mm thick.
2) Intermediate plaster layer, probably a backing, being coarser than 1): buff sand and gravel with straw impressions, 25mm thick.
3) Traces of red on polished or trowelled white *intonaco*, 0.5 - 0.8mm, on plaster with straw impressions, 25mm thick, as 2).
4) Yellow on black on buff *intonaco*, 0.5mm, on buff plaster with some grass, 30mm thick.
5) Polished red with calcite grains, 1mm, on white *intonaco*, 0.6 - 0.8mm, on buff sandy plaster, 10mm thick.
6) Red on yellow on black, 0.2mm, on white *intonaco*, 1mm, on buff plaster, 18mm thick, with some chalk.

7) Dark red on red on yellow on black, 0.4mm total, on white *intonaco* with some calcite, 1.5mm, on buff plaster in two layers to 12mm thick.
8) Black on white *intonaco*, 1.5 - 2mm, buff sandy plaster, 14mm thick.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* method. It probably represented both panel borders and decorative detail. The use of crushed crystalline calcite in the burnished red is of particular note.

PIGMENTS

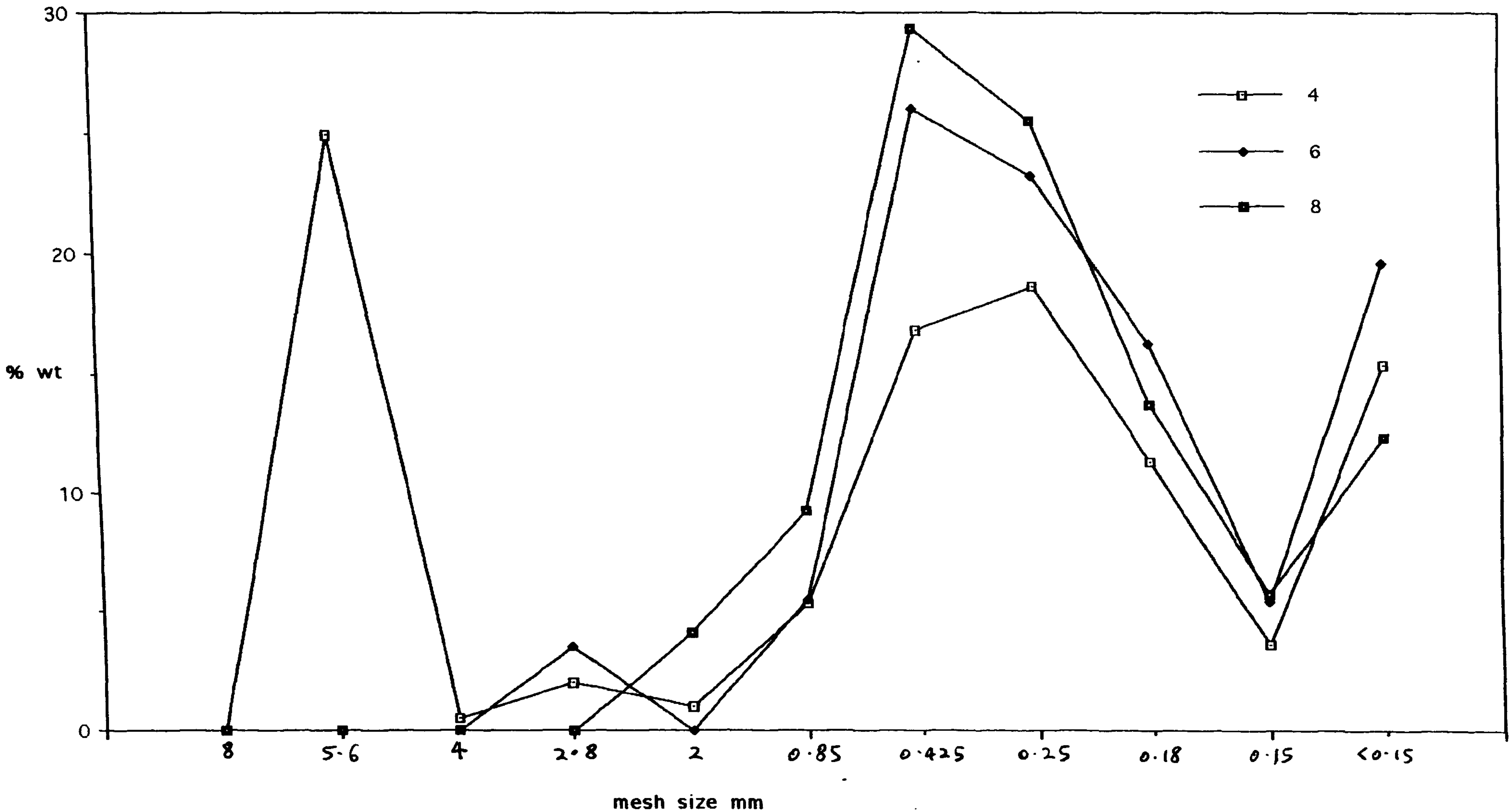
The paints used were the usual natural colours: red ochre (haematite), yellow ochre (limonite), white lime and carbon as soot or charcoal.

Average results

	Thicknesses	"Lime"
burnished red	1mm	-
intonaco	(0.2 - 2) 0.8mm	84%
plaster	(10 - 30) 22mm	28%

Samples illustrated in the aggregate particle size distribution graphs:
Fig. No. 131
4), 6), 8). The curves are all very similar, showing fairly well graded sand. No 4) is slightly different due to the presence of a single large flint nodule.

Fig. 131 Pulborough



Reculver, Kent.
Kent Archaeological Rescue Unit

Two fragments from the walls of the Roman and Saxon shore fort at Reculver were analysed. One sample was described as a fourth century repair, the other as wall mortar, dated to the mid third century. These results are unpublished.

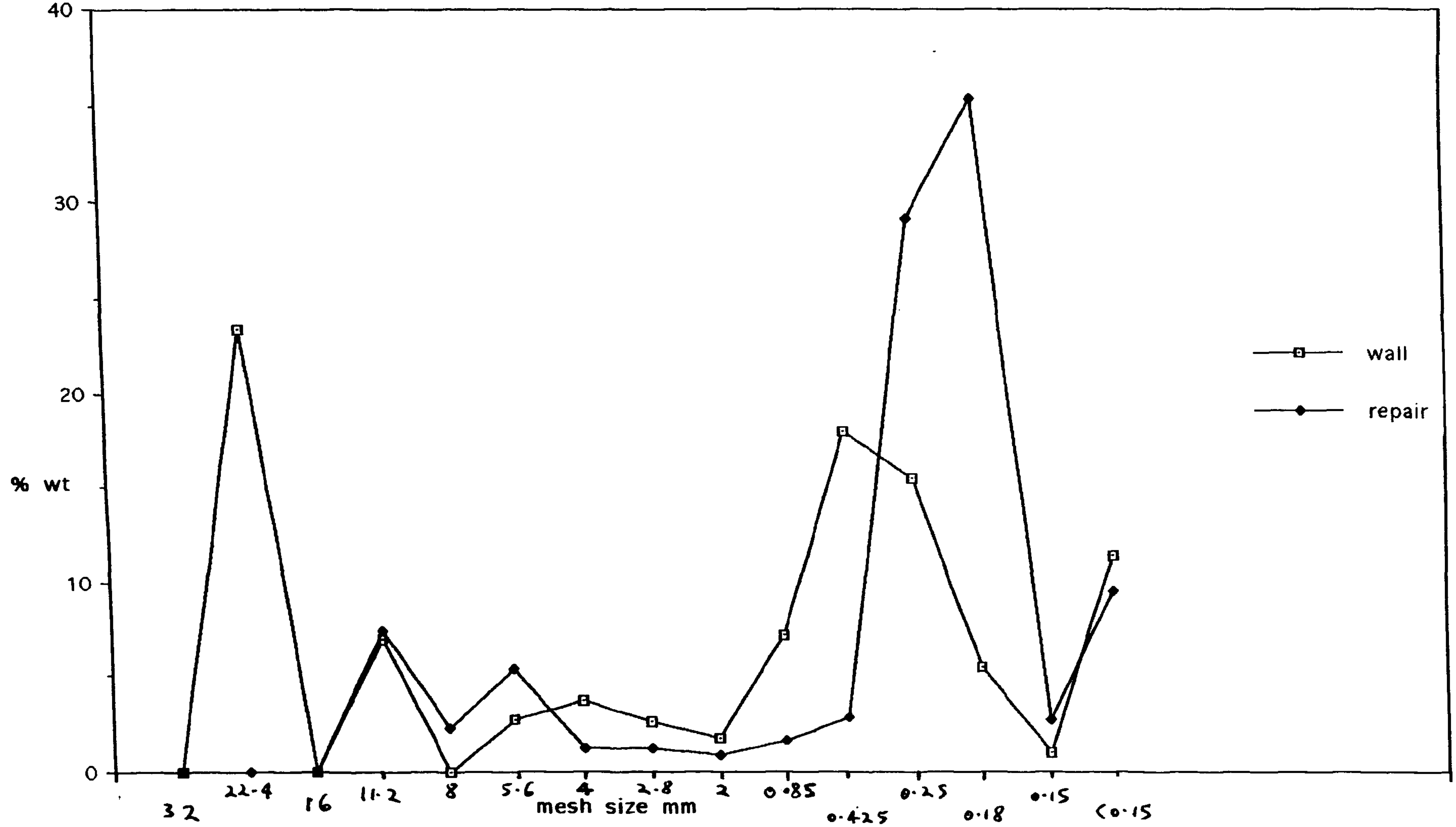
The wall material was a pale sandy mortar with flints.
The repair was pale sandy mortar with flint pebbles and quantities of sea shells such as winkles and bi-valves, estimated at about 30% by volume. This was unusual, suggesting perhaps a very hasty repair using un-sorted beach shingle.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
wall	41	48	11	26%	
repair	18	72	10	57%	with shells

The particle size distribution curves are quite distinct, pointing to different aggregate sources. The repair has a more closely graded sand peak, presumably relating to the beach sand.
Fig No. 132

Fig. 132 Reculver



St Albans, Herts
Munden House site

Excavations in the grounds of Munden House near St Albans revealed traces of a Roman villa. The finds were deposited in the Verulamium Museum. Typical examples of the various types of painted plaster found were examined. The aggregates were mainly river sand and gravel, being composed of: round to sub-angular quartz, angular to sub-angular flint, quartzite, ferruginous sandstone, crushed brick or tile and traces of glauconite. The glauconite grains may have come from the limestone used to make the lime, perhaps the lower chalk. Nine samples were examined and eighteen analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1	22	65	13	23%	upper layer
	8	64	28	27%	middle layer
	11	79	10	24%	lower layer
2	2	89	9	31%	whole sample
3	30	56	14	22%	upper layer
	18	73	9	25%	lower layer
4	33	38	29	21%	whole sample
5	23	41	36	49%	upper layer
	34	48	18	24%	lower layer
6	34	59	7	29%	upper layer
7	15	55	30	14%	upper layer
	36	50	14	18%	lower layer
8	24	52	24	16%	upper layer
	-	-	-	77%	interface
	31	55	14	18%	lower layer
9	-	-	-	89%	*intonaco*
	13	74	13	38%	upper layer, some tile
	51	34	15	40%	lower layer, *opus signinum*

EXAMPLES OF PLASTER DESCRIPTIONS

1) [B1] (6); white to pale blue on pale blue, <0.05mm, on red*, on yellow, <0.05mm, total paint about 0.1mm, on white *intonaco* with crushed white quartz traces, 0.8 - 0.9mm, on buff sandy plaster, 6mm, on light buff muddy plaster, 4mm, on sandy plaster, 10mm thick.

2) [B1] unlocated; coarse dark red on orange (possibly an *opus signinum* concretion) on off white *intonaco*, total paint and *intonaco*, 0.1mm, on dense sandy buff plaster, 18mm thick. This was a flaked upper layer.

3) [B1] (6); blue, 0.1 - 0.2mm, on dark grey, <0.05mm, on white *intonaco* with crushed quartz traces, 5.5mm, on buff sandy plaster, 10mm, on light buff sandy plaster traces, 3+mm thick. c.f. 1).

4) dark red spots on yellow and dark red line, 8mm wide, over a yellow to yellow green interface on white *intonaco*, 1mm, on buff muddy plaster, 15mm thick.

5) [B1] (6) East corner /6B\; splashes of green, red orange, black and white on coarsely brushed grey on white on buff to white plaster in two layers, 11mm total, on a white interface, 0.5mm, on buff sandy plaster, 15mm, with a possible wooden plank impression on the rear.

6) South corner of in fill /33\; unpainted floated yellow sand and pebble plaster, 6 - 12mm, on coarse white chalk and lime plaster with some burnt clay or brick and flint, 33mm thick. This may have been a wall top as the section tapered.

7) bottom layer in North West entrance; floated or burnished white on off white *intonaco* on buff sandy or muddy plaster on light buff sandy plaster.

8) [B1] (6); brushed dark red, <0.05mm, on sandy white *intonaco*, 0.3 - 0.5mm, on sand, grave and mud plaster, 9 - 10mm, on coarsely brushed white interface, 0.5 - 1mm, on buff sand and gravel plaster up to 20mm thick.

9) [B1] (6); white (*intonaco* ?), 0.8mm, on pink sandy plaster, 4.5mm, on pink tile plaster, 21mm thick.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* technique. The fragments examined were too small to show any particular style, but the lines may depict borders and the spotted sample pseudo marbling.

PIGMENTS

The pigments used were: red ochre (haematite), red* cinnabar, orange brick or tile dust, yellow ochre (limonite), green earth (glauconite), carbon as soot or charcoal, white lime and crushed Egyptian blue. The cinnabar is of note as an expensive pigment.

Average results

	Thicknesses		"Lime"	
paint		0.05mm	-	
intonaco	(0.1 - 5.5)	0.6mm	89%	
plaster	(4.5 - 10)	7mm	27%	upper layer
	(4 - 6)	5mm	27%	middle layer
	(10 - 21)	17mm	23%	lower layer
			40%	*opus signinum*
single layer	(15 - 33)	17mm	26%	

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 133 - 136

All the samples are illustrated. The graphs show that there are similarities and differences between the various samples. This was probably due to local variations within the sand deposits used.

Fig. 133 Munden House 1

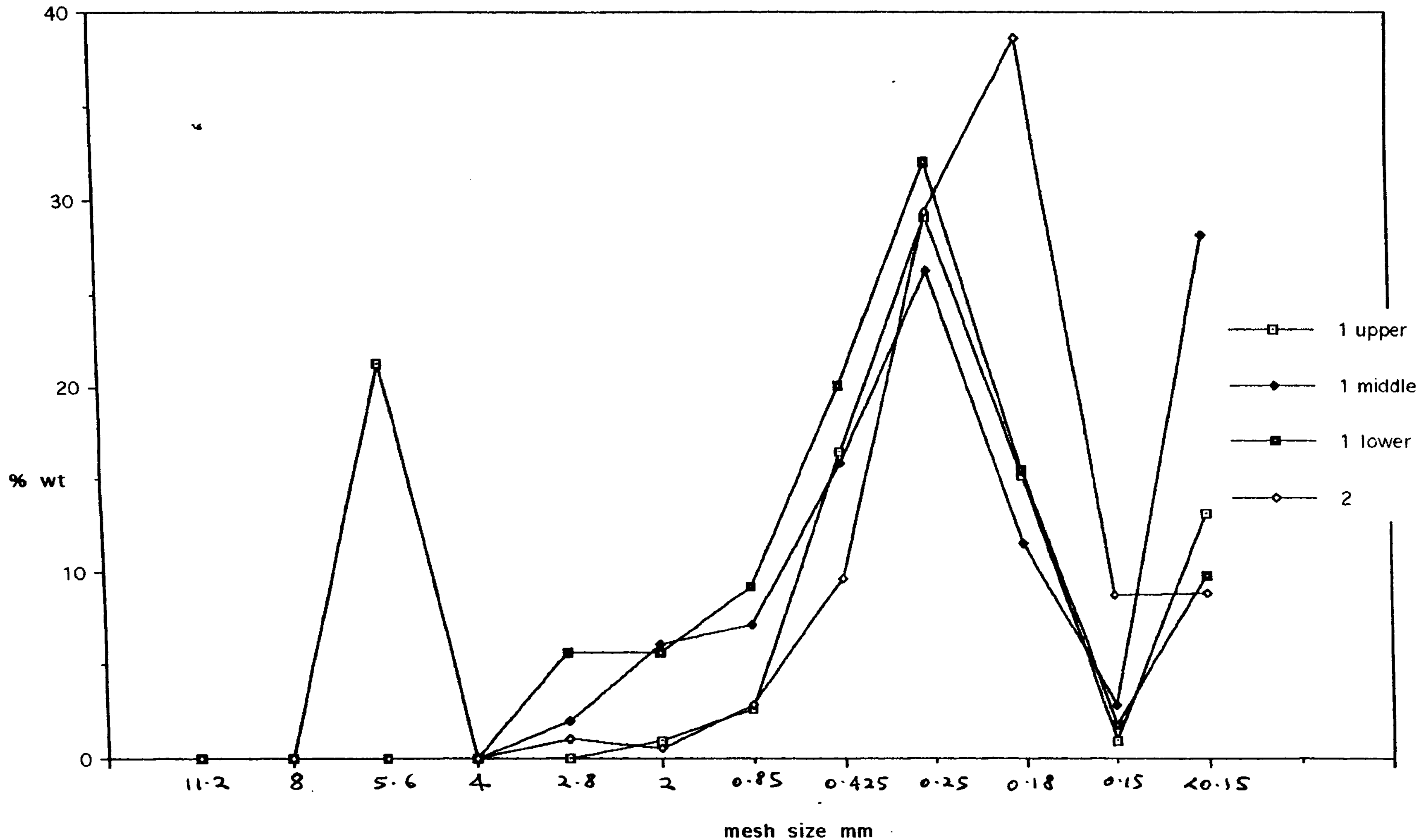


Fig. 134 Munden House 2

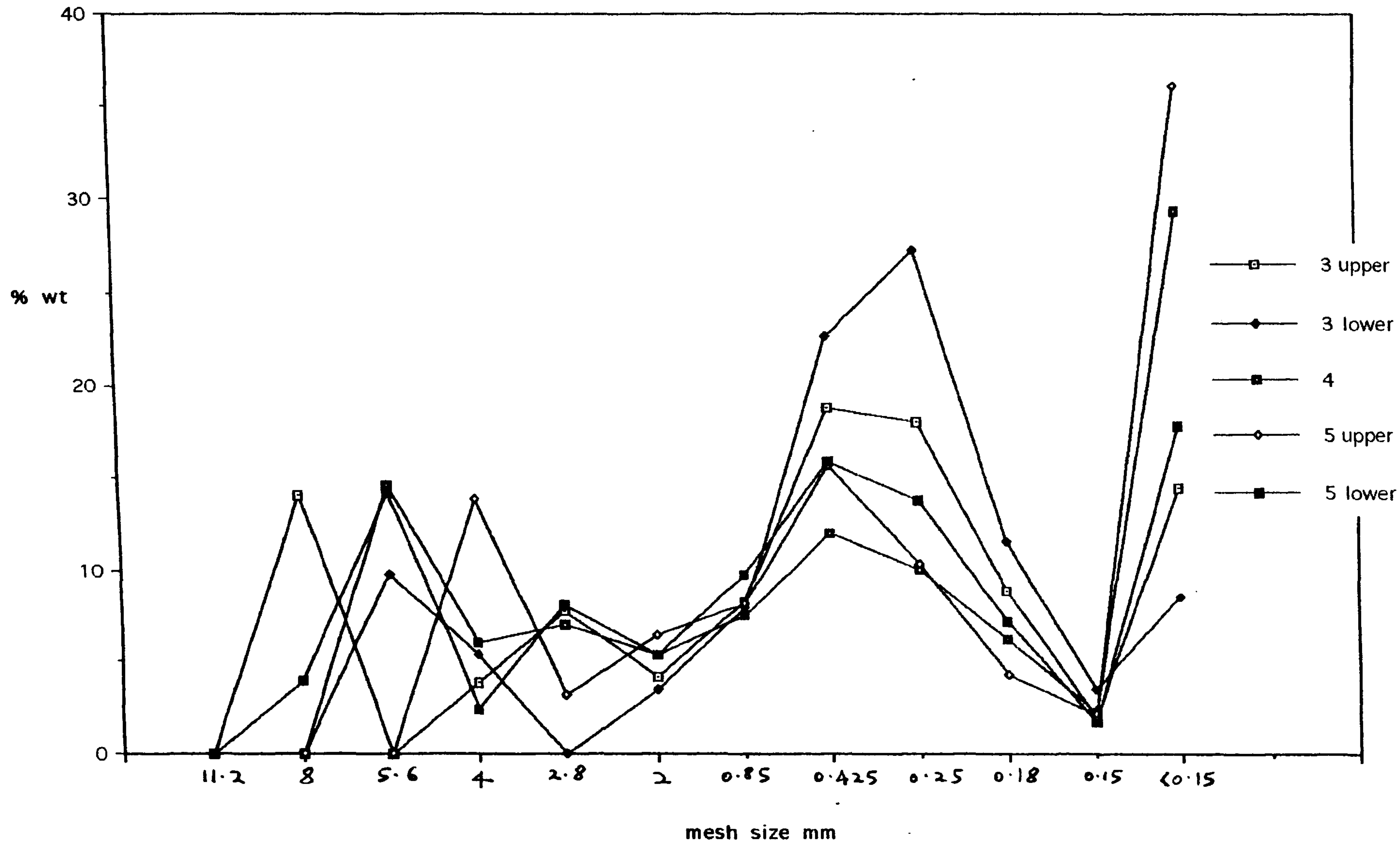


Fig. 135 Munden House 3

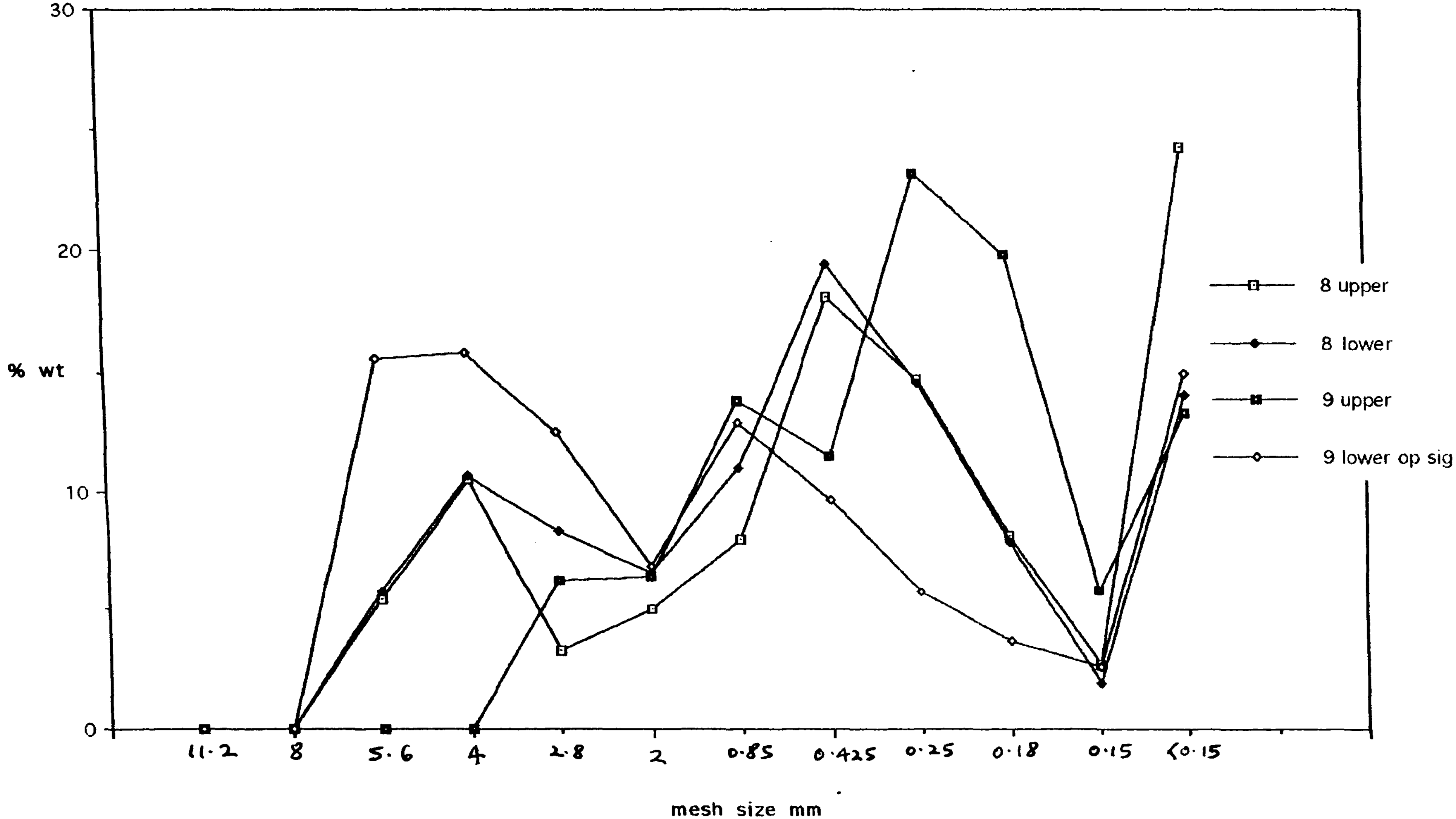
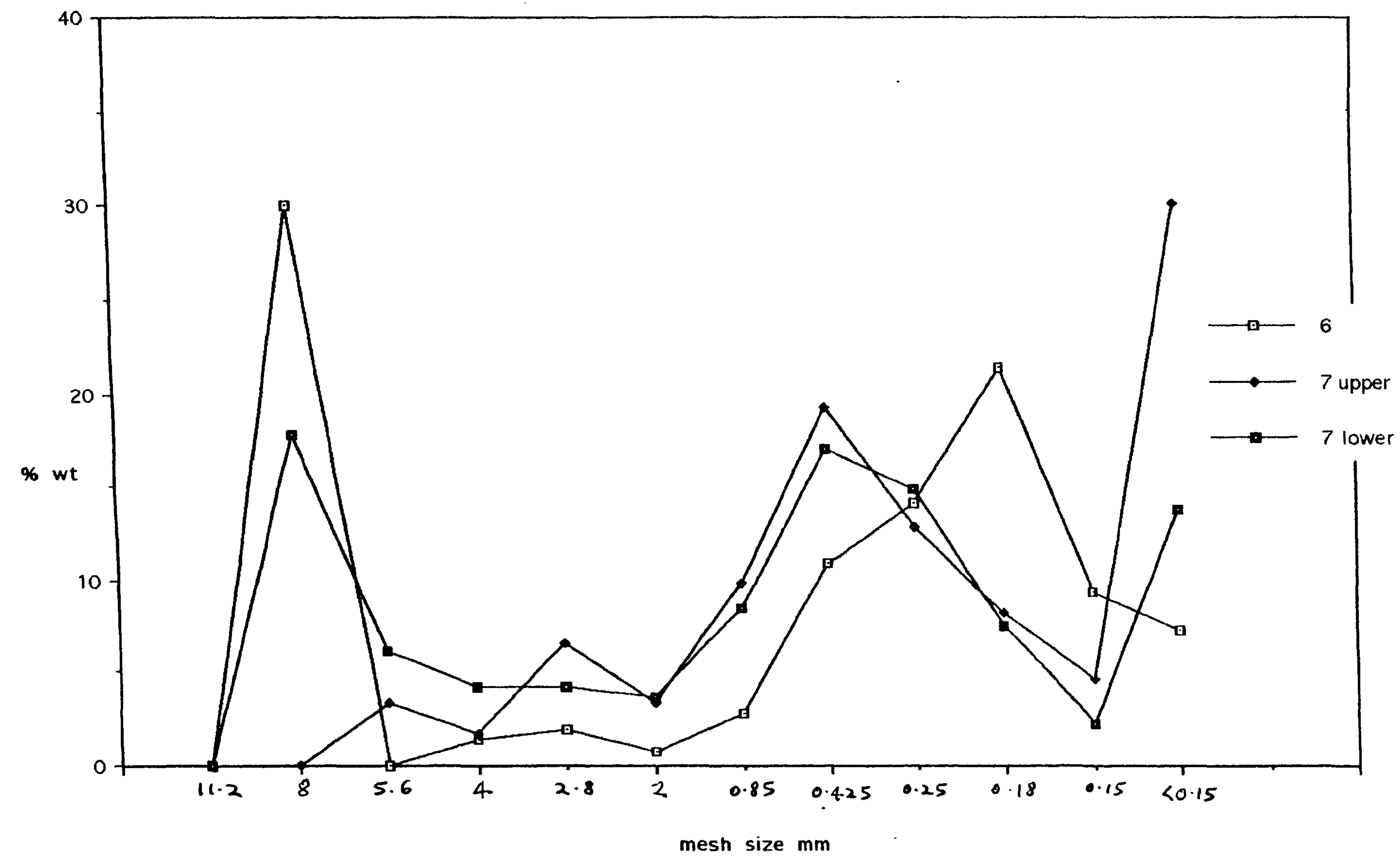


Fig. 136 Munden House 4



Silchester, Berkshire.
Fulford 1982
Britannia 1987 18: 348 - 50

Excavations on the site of the Flavian Basilica at Silchester from 1980 - 86, produced various types of painted plaster and mortar. The use of crushed calcite was of particular note, as was the finding of red lead used as a pigment. Finds from previous excavations in the care of the Reading Museum were also examined, including pigments and tools. The tools included plasterers iron trowels, one with a solid handle and a rounded end, the other a pointing trowel with blade about 14cm long. These were only seen in the museum display case and not handled. A marble "burnisher", measuring; 10.5 x 17.3 x 3.2 cm, was examined closely. This object of coarse crystalline marble had a thin strip iron handle grouted into the rear with lead. Both the lead and the handle showed relatively slight corrosion for a supposedly Roman object. The lower face was polished flat and there were traces of various pigments around the edges and on the upper surface. Further analysis is still in progress and suggests that the pigments may be of more recent manufacture than the Roman period. The "burnisher" would probably be too heavy to be of practical use for burnishing walls and may have been used for grinding pigments. The more recent? pigments may be the result of experimental use of the object. The quartzite pebble burnisher found at Caerleon would have been far easier to use (Zienkiewicz 1986 II: 215, No 43 81.79H)
The aggregates used in the mortars and plasters reflect the local sand and gravel geology, with quartz, quartzite, flint and chert, limestone and fossil fragments with the addition of crushed brick or tile. The presence of glauconite grains suggested a lias limestone source for some of the lime. Most of the plaster aggregates were composed of crushed flint with smaller amounts of rounded quartz. The fine silt size residue contained very fine quartz sand, possibly derived from sandy lime. Finer grade sieves were used to extend the range of the silt particle gradings to show the very fine sand content. Twenty samples were examined and twenty six analyses carried out.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
pot fill	53	29	18	25%	*opus signinum*
226	1	50	49	56%	ceiling?, *opus signinum*
1959	18	49	33	35%	floor, *opus signinum*
226 - 57/125	-	-	-	93%	red
	-	-	-	91%	*intonaco*, pink,tile dust
	8	63	29	26%	upper layer, crushed flint
	16	58	26	24%	lower layer, crushed flint
595 - 6/8	-	-	-	84%	burnished red
	-	10	-	40%	lime, 50% calcite *intonaco.*
	15	56	28	20%	upper layer, crushed flint
	11	64	25	11%	lower layer, crushed flint
226	-	-	-	88%	yellow with calcite
	-	-	-	87%	*intonaco*, pink tile and calcite
	14	57	290	21%	upper layer, crushed flint
	13	59	28	19%	lower layer, crushed flint
002 - 80/30 (a)	27	55	18	35%	crushed flint and tile
(b)	21	60	19	35%	upper layer, flint and tile
	50	39	11	26%	lower layer, flint and tile
80/30 A + 18 226 - 57/125					
	13	57	30	24%	crushed flint
226 - 57/126	13	59	28	24%	no *intonaco*, crushed flint
595	-	-	-	95%	*intonaco*
	17	58	25	15%	upper layer, crushed flint
	16	59	25	21%	lower layer, crushed flint

EXAMPLES OF MORTAR AND PLASTER DESCRIPTIONS

Reading Museum collections:

Pot with filling of pink mortar:

crushed tile mortar or plaster with sand, flint and furnace residues, an example of *opus signinum.*

1980 - 86 excavations:

Mortar

226: lightweight pink tile mortar with grass or straw impressions, 25mm thick, possibly from a ceiling as there were traces of lath-like impressions on the rear.

1959: floor; tile mortar, 37mm thick.

Painted plaster

226 57/125: pale orange red or pink, 0.05mm, on white to pink *intonaco*, 1 - 1.5mm, on pale sandy plaster, 9mm, on pale sandy plaster, 18mm thick.

595 6/8: finely burnished red with a few calcite crystals (up to 1.5 x 1 x 1mm), 1mm, on white *intonaco* with calcite, 1 - 1.5mm, on pale sandy plaster, 7mm, on buff sandy plaster, 18mm thick. The *intonaco* contained about 50% by weight of calcite crystals.

226: red spot on burnished yellow with calcite, 0.1 - 0.2mm, on pink *intonaco* with calcite, 1mm, on sandy plaster, 9mm, on sandy plaster, 14mm thick. The *intonaco* contained about 15% of calcite crystals with tile dust.

002 80/30:

a) burnished red with calcite, 0.1mm, on white *intonaco* with some calcite, 0.75mm, on sandy plaster with tile.

b) burnished red with calcite, 0.1mm, on white *intonaco* with patches of yellow *intonaco* both with some calcite, 1mm, on sandy plaster with tile, 12mm, on pink sandy plaster with tile, 10mm thick. Both these samples were very hard, possibly due to the tile dust addition.

80/30 A + 18 226 57/125: yellow traces on green patches with traces of blue on burnished white *intonaco* with at least 50% calcite crystals, 1 - 1.5mm, on pale sandy plaster, 12mm thick. This sample was of exceptional quality, comparable with material from Fishbourne Roman Palace. (FB 67 398 ditch courtyard 7 "white lines on yellow", see Fishbourne above)

226 57/126: thick white lime stripes 5mm wide and 30mm apart, 0.5 - 0.75mm thick, on pale sandy plaster, 15mm thick.

595: roughly floated or brushed white *intonaco* ?, 0.5 - 1.5mm, on coarse pale sandy plaster with grass or straw impressions, 22mm, perhaps in two equal layers, with ridging? on the rear, possibly from keying from a mud wall.

776: traces of red ochre and yellow iron staining on white *intonaco* without calcite crystals, 0.5mm, on pale sandy plaster. c.f. 595).

507: white, 0.05mm, on blue, 0.15mm, on red, 0.05mm, on thick white *intonaco* with calcite, 4.5mm, on pale sandy plaster. Also samples with: white, 0.05 - 0.1mm, on blue, 0.15mm, on black, 0.05mm, on white *intonaco*, 3.5mm thick.

80/30 2031 pwp 38: brushed orange, 0.05mm, on burnished? white *intonaco* with calcite, 1.5 - 2mm, on pale sandy plaster. The orange was red lead.

80/30 2079 over painted red: black on yellow on brushed white, 0.05mm, on red to pink on white *intonaco* with calcite traces, 1mm, on buff sandy plaster, 9mm thick. c.f 507).
80/30 226 57/126: white on dark yellow on yellow, 0.1mm, on green with blue traces, on orange pink on white *intonaco* with some calcite, 0.6 0.75mm, on pale sandy plaster, 14mm thick.
80/30 226 58/126: white, 0.1mm, on green with traces of blue, 0.4mm, and white with blue traces on green, 0.1mm, on orange pink on pale pink to white *intonaco* with some calcite, 1 - 0.75mm, on pale sandy plaster, 8mm, on pale sandy plaster, 12mm thick.

PAINTING TECHNIQUE

The paint appeared to be in the *buon fresco* method, with the over painting possibly in *fresco secco*. The presence of calcite crystals both in the paint layers and the *intonaco* is particular note. This pointed to high class workmanship.

PIGMENTS

The pigments included the usual natural colours: red ochre (haematite) brick or tile dust, yellow ochre (limonite), green earth (glauconite), carbon as soot or charcoal and white lime with the addition of crushed Egyptian blue and notably the orange colour of red lead. This find of red lead is currently the only safely stratified example seen in this survey. The other find was on painted plaster probably from Caves Inn (Tripontium) near Rugby.
Material in the Reading Museum collections included a collection of Egyptian blue spheroids, some of which were still fused together. The total weight of these was 18.82g. The individual weights were: 4.32g, 2.25g, 1.89g, 1.44g, 1.2g, 1.15g, three fused 3.48g, 5 fused 3.26g. X-ray fluorescence analysis of some of the lumps showed the presence of tin, lead and zinc in with the usual elements for Egyptian blue. This was probably caused by the use of bronze instead of copper in its manufacture. A lump of crystalline orpiment / realgar weighing about 1g was also examined. The source of the crystalline calcite may have been veins of calcite seen in the Bath stone used for building, and balls of crystalline calcite were recovered according to the excavator (pers com).

Average results

	Thicknesses		"Lime"
paint	(0.05 - 0.4)	0.1mm	88%
intonaco	(0.05 - 4.5)	1.5mm	91%
plaster - upper	(7 - 15)	11mm	25%
plaster - lower	(10 - 18)	13mm	20%
opus signinum :			
floor		37mm	35%
ceiling		25mm	56%
pot fill		-	25%

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 137 - 139
002 - 80/30 a, b, 226, 226 - 57/125 upper, 595; *opus signinum* : 226, 1959, pot fill.
The graphs show the poor grading of the aggregates, perhaps reflecting the use of crushed material. The use of finer sieves shows the peak around 0.09mm for the lime? derived fine sand.

Fig. 137 Silchester - opus signinum

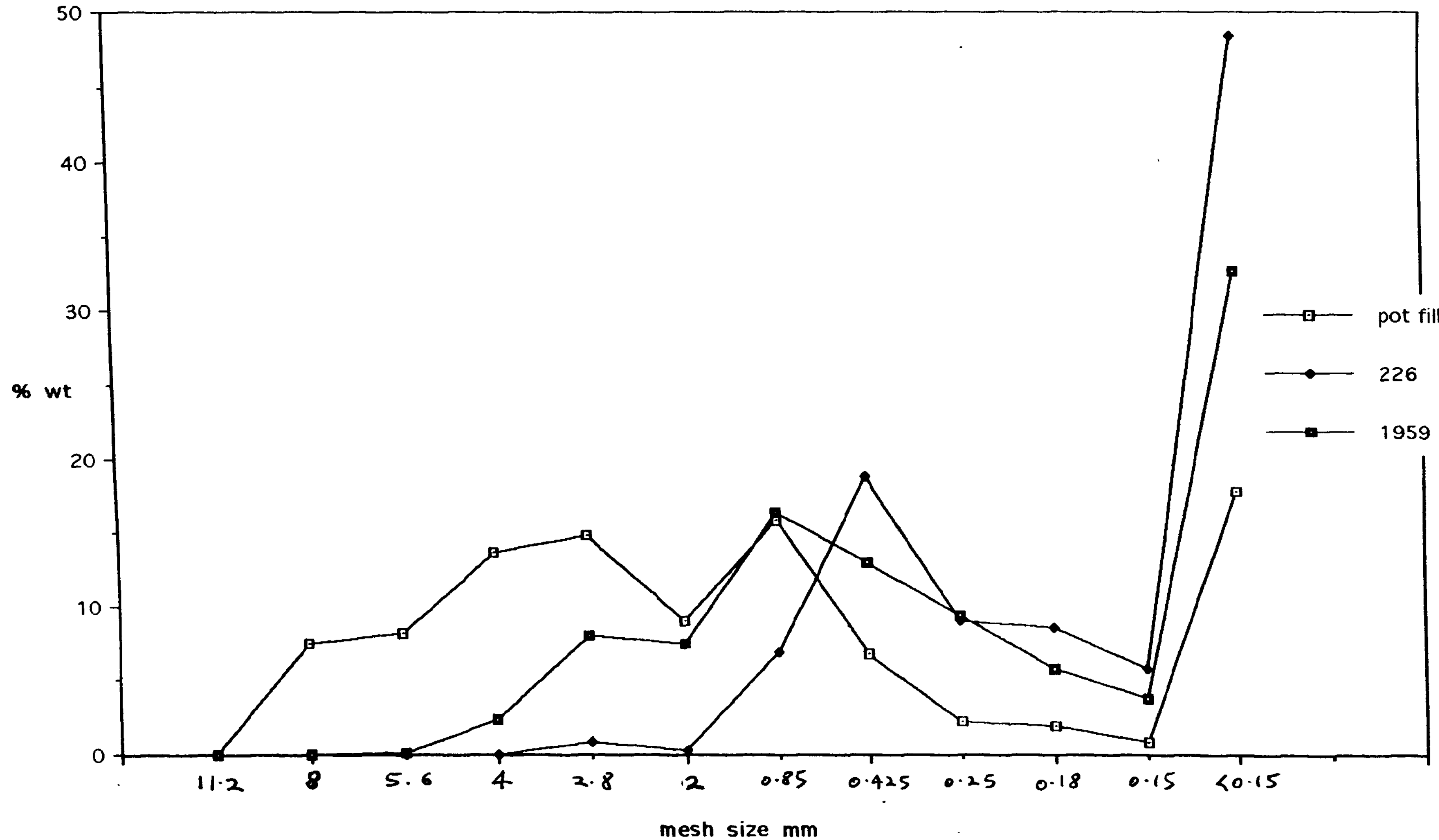


Fig. 138 Silchester 1

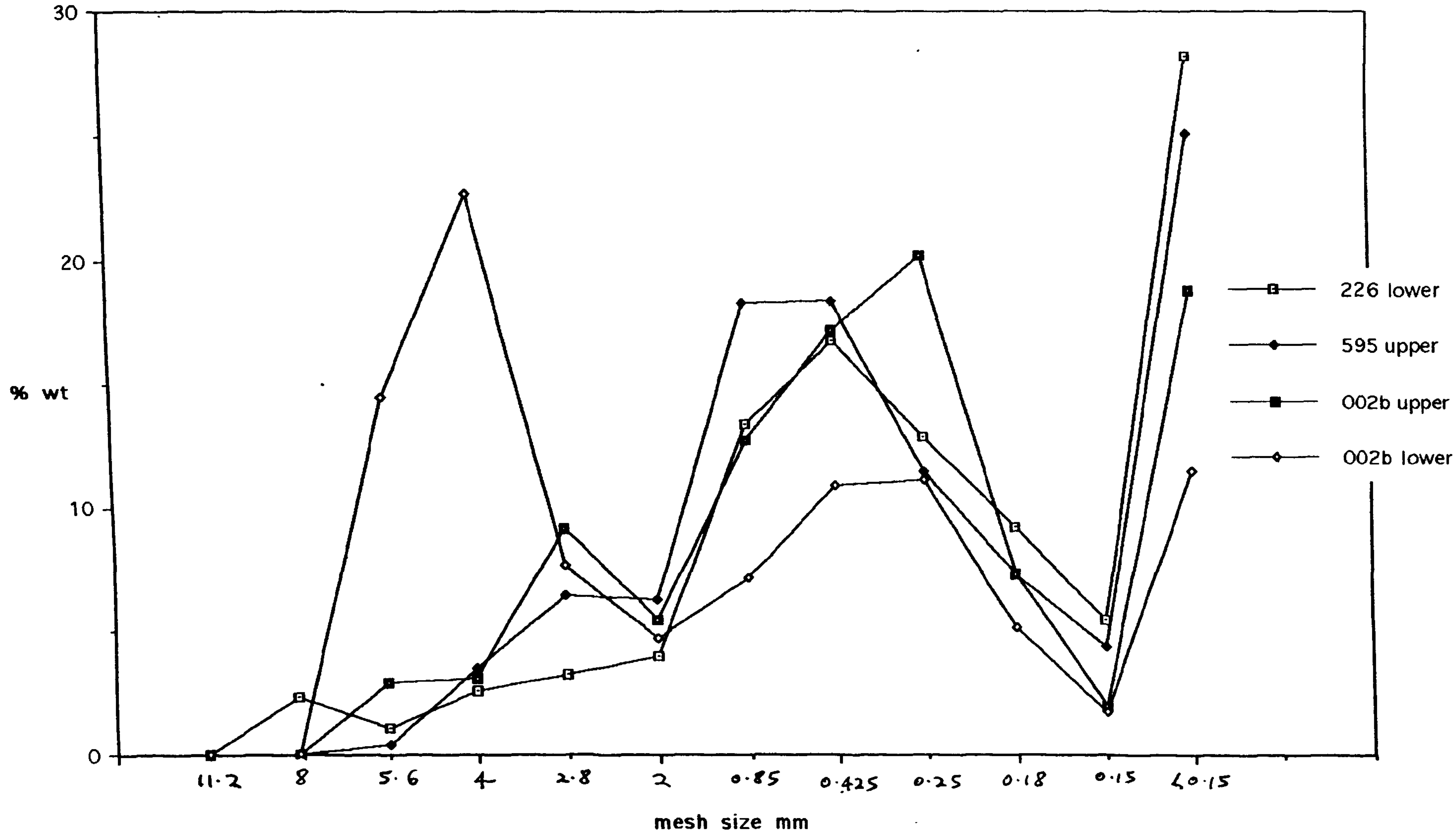


Fig. 139 Silchester 3 - extended range

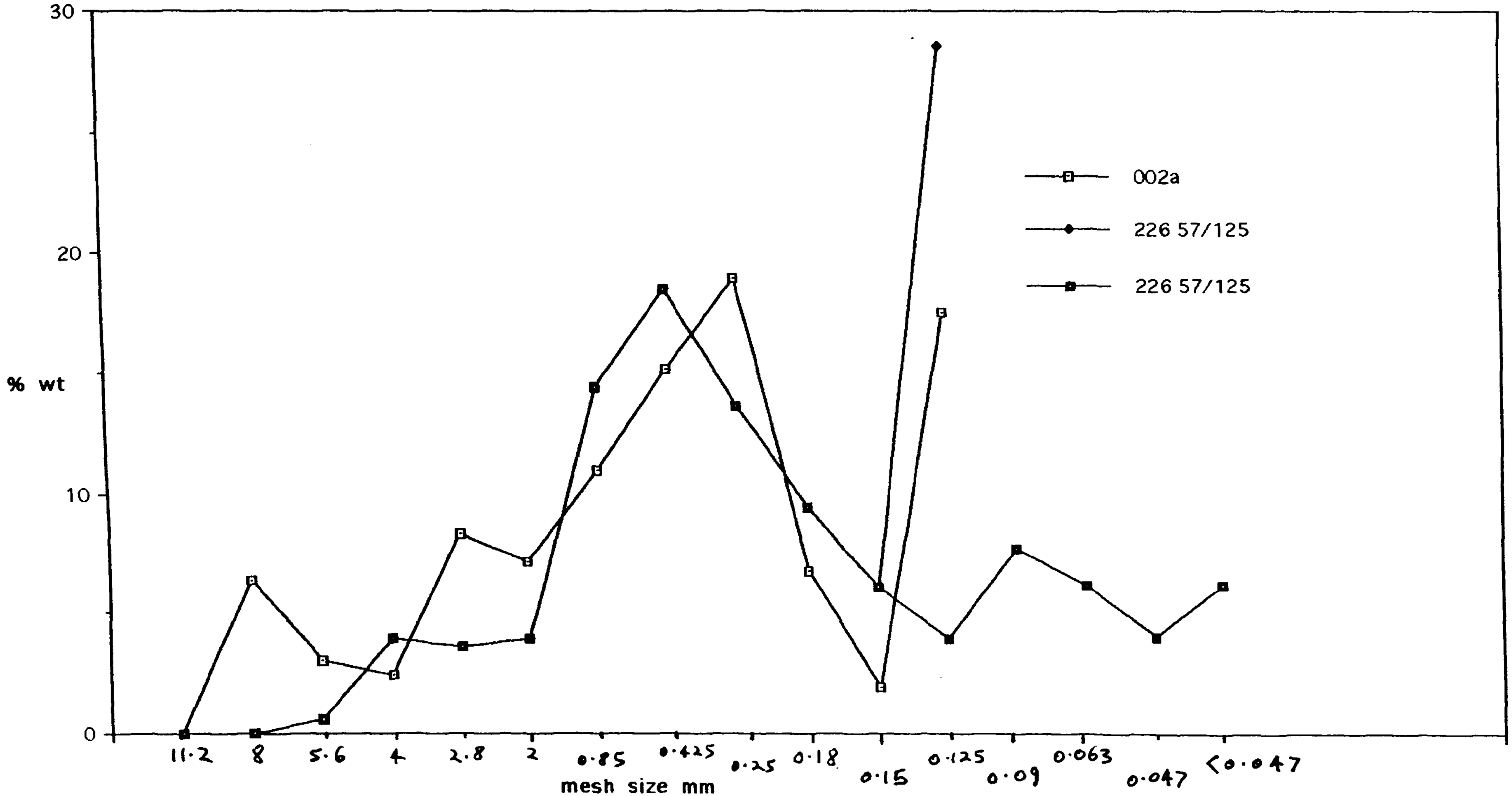
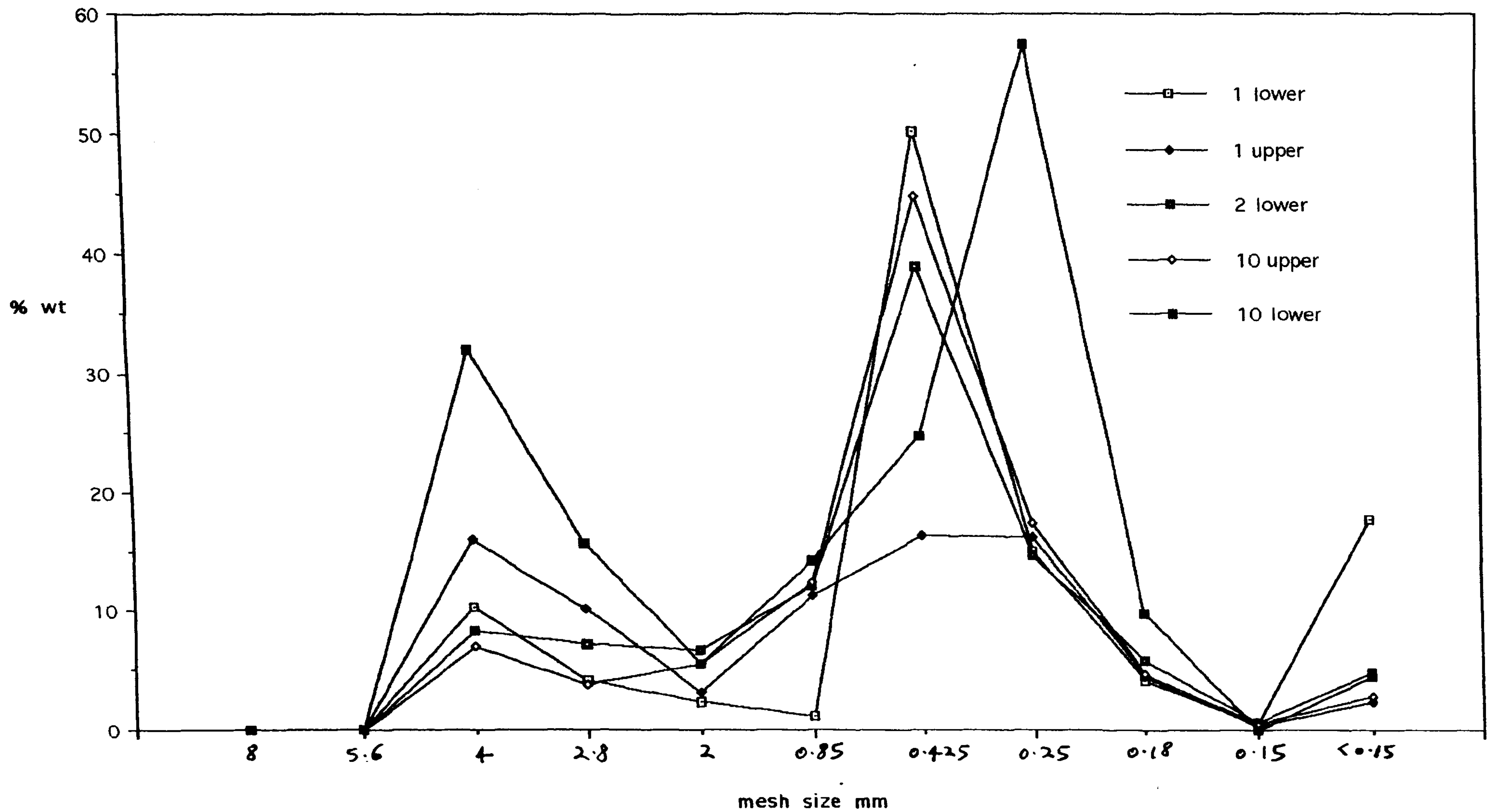


Fig. 140 Staines



Staines, Middlesex
Crouch 1976
Crouch and Shanks 1984

Excavations in Staines (the Roman town of Pontes) on the site of Barclays Bank in 1969, produced remains of a Roman building. The site was on the bank of the Thames, and the plaster aggregates were all of river sand and gravel, being composed of round to angular: flint, quartz, quartzite, ferruginous sandstones, brick or tile, fragments of chalk or lime and traces of glauconite (possibly from the lime). Many of the samples showed signs of having been burnt. Ten samples were examined and seven analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
BBS 69 1	-	-	-	77%	*intonaco*
	30	68	2	22%	upper plaster layer
	17	65	18	18%	lower layer
BBS 69 2	-	-	-	82%	*intonaco*
	22	73	5	25%	lower plaster layer
BBS 69 10	16	81	3	29%	*intonaco* and upper plaster
	54	42	4	46%	lower plaster layer

EXAMPLES OF PLASTER DESCRIPTIONS
BBS 69:
1) blue lines on black on grey, 0.05mm, on white *intonaco*, 0.5 - 0.75mm, on light sandy plaster in two layers, 7mm + 8mm thick.
2) traces of lime on red traces, 0.05mm, on white *intonaco*, 0.5mm, on sandy plaster, 11mm thick.
3) black, 0.05mm, on white *intonaco*, 0.1mm, on burnt sandy plaster in two layers, 13mm + 6mm thick, with keying? grooves on the rear.
4) black on red on white, 0.05mm, on white *intonaco*, 0.5mm, on burnt sandy plaster, 9mm thick.
5) grey and lilac lines on red, 0.05mm, on *intonaco*, 1.6mm, on light sandy plaster, 7mm thick.
6) green, 0.05mm, on *intonaco*, 1mm, on white sandy plaster, 7mm thick.
7) blue over black and red, <0.05mm, on white *intonaco*, 0.5mm, on burnt sandy plaster in two layers, 8mm + 10mm thick.

8) dark green, <0.05mm, on white *intonaco*, 0.5mm, on sandy plaster traces, 1mm, on white *intonaco*, 0.5mm, on buff sandy plaster, 10mm thick. This may have been over-plastering or an overlap between two panels.
9) yellow and red, <0.05mm, on white *intonaco*, 0.5mm, on burnt sandy plaster in two layers, 9mm + 2+mm thick.
10) burnished red, 0.05 - 0.075mm, on white *intonaco*, 0.5mm, on burnt sandy plaster in two layers, 11mm + 5mm thick.

PAINTING TECHNIQUE
The paint was probably applied in the *buon fresco* method.

PIGMENTS
The colours were mainly natural: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), white lime, black soot or charcoal and crushed Egyptian blue. The burning may have reddened some of the colours.

Average results

	Thicknesses		"Lime"
paint	(0.05 - 0.75)	0.6mm	-
intonaco	(0.5 - 1.5)	0.6mm	80%
upper plaster	(7 - 11)	9mm	26%
lower plaster	(5 - 10)	8mm	30%

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 140
1 upper and lower, 2 lower, 10 upper and lower layers.
The graphs were fairly similar with the exception of the lower layer of 10), which was slightly finer.

Stanton Low, Buckinghamshire.
Woodfield 1989

The Roman villa site at Stanton Low was on river sands and gravels, ranging in date from the first to the fourth centuries. Most of the samples were mortars. The painted wall plaster samples were not scientifically examined during the survey but are commented on in the main report. The aggregates were mainly sand and gravel: quartz, quartzite, flint, various igneous fragments such as basalt and rhyolite, green siltstone, quartz conglomerates and ferruginous sandstones. Some limestone was also found, which will have affected the "lime" estimations, together with brick and tile which was used in the manufacture of *opus signinum*. Fifty five samples were examined and sixty three analyses carried out. These results apparently remain in the level three archive.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
wall 1	28	61	11	47%	mortar
wall 5	48	43	9	38%	mortar
wall 6	25	64	11	50%	mortar
wall 13	27	60	13	40%	mortar
14 box K	22	57	21	52%	torching
15 ii - iii	10	68	22	61%	torching
17 box H	24	53	23	52%	torching
20 8547 room 5	2	48	50	56%	mortar from flue
22 8546	38	42	20	53%	mortar from stoke hole
27 ii - iii	43	47	10	51%	*opus signinum*
35 II 41 box I	50	35	15	27%	*opus signinum* floor
38 6566	-	-	-	80%	5mm, *tesserae* bedding
39 6556	48	35	17	45%	20mm, *opus signinum*
45	54	30	16	39%	40mm, *opus signinum*
48	43	29	28	68%	50mm, *opus signinum* moulding
50 6560 (22) II	17	74	9	47%	25mm pale yellow mortar

EXAMPLES OF MORTAR DESCRIPTIONS

The majority of the wall mortars were simply coarse sand or gravel with lime. Only those which had a different purpose or composition are described here.

14 box k: *imbrex* torching mortar, buff with pebbles.
15 ii - iii: *tegula* torching mortar, buff with pebbles.
16: *tegula* torching mortar, buff with pebbles.
27 ii - iii shaped: *opus signinum*, perhaps a wall edge.
35 II 41 box I smoothed floor foundation.
36 box I floor with marks of alteration, two type of mortar; *opus signinum* and coarse pebble mortar, possibly a wall or ceiling junction.
38 6566: white mortar on tile mortar on sandy mortar, probably a *tesserae* base.
46: tile mortar with straw and flue tile impressions.
51 6561 (21) II: fine buff limestone.

Samples of tesselated pavement were visually examined but not analysed. The use of a pink grout made of crushed tile and lime to seal the *tesserae* was noted.

PIGMENTS

The only pigments examined from this site were from pot sherds, red and yellow ochres, and a spheroidal lump of Egyptian blue, weighing 1.9263g (SLB 58 iii 63).

<u>Average results</u>

	<u>"Lime"</u>
sand and gravel mortar	51%
opus signinum	45%

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:

Fig No. 141 - 144

Walls: 1, 5, 6, 13; 14, 15, 17, 20, 22, 50, all being sand and gravel types; 27, 35, 45, 48, representing the *opus signinum* types. The sand size grades are different in the tile mortars, probably coming from the sandy clay used in the tile making.

Fig. 141 Stanton Low - opus signinum

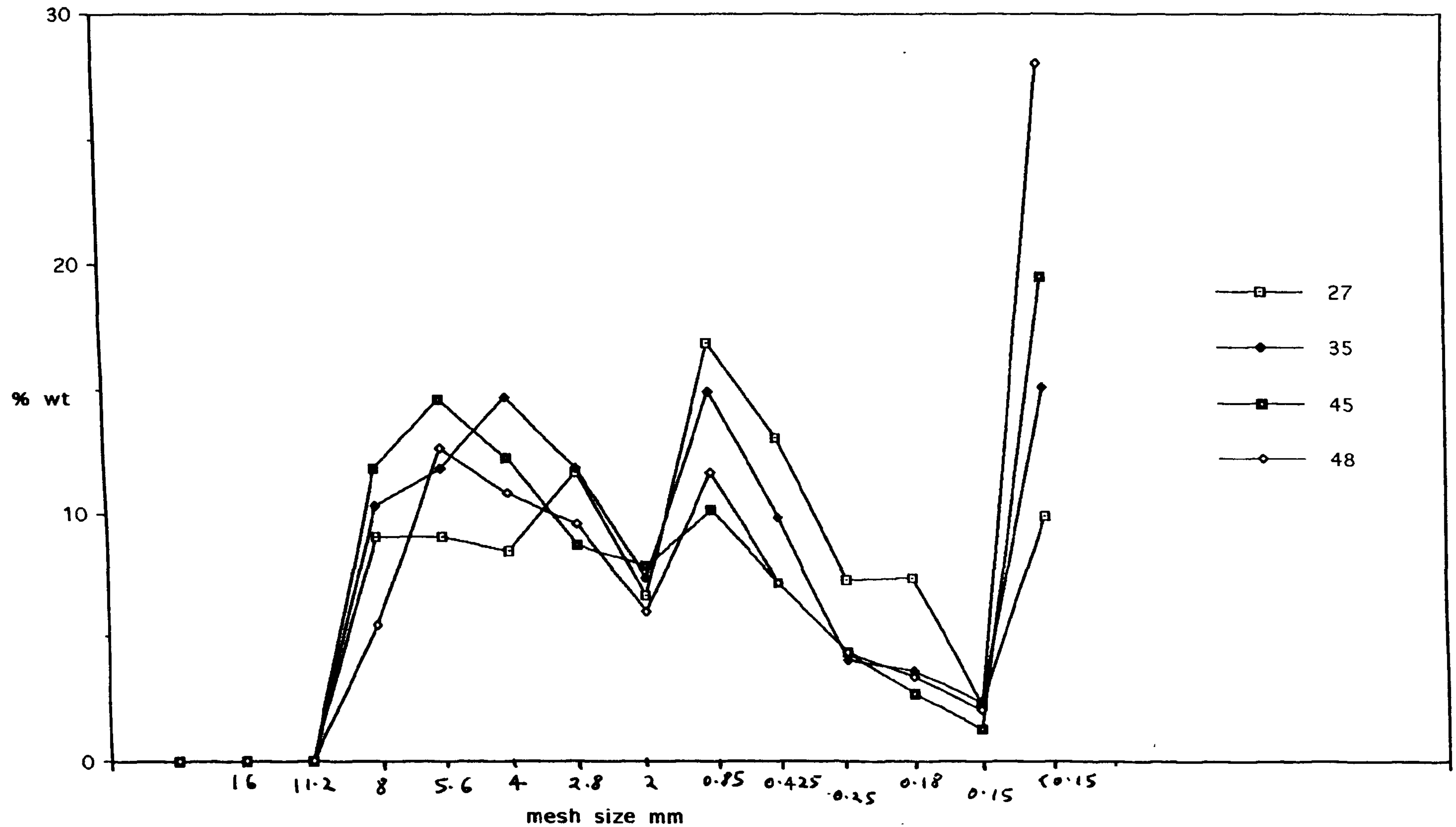


Fig. 142 Stanton Low 1

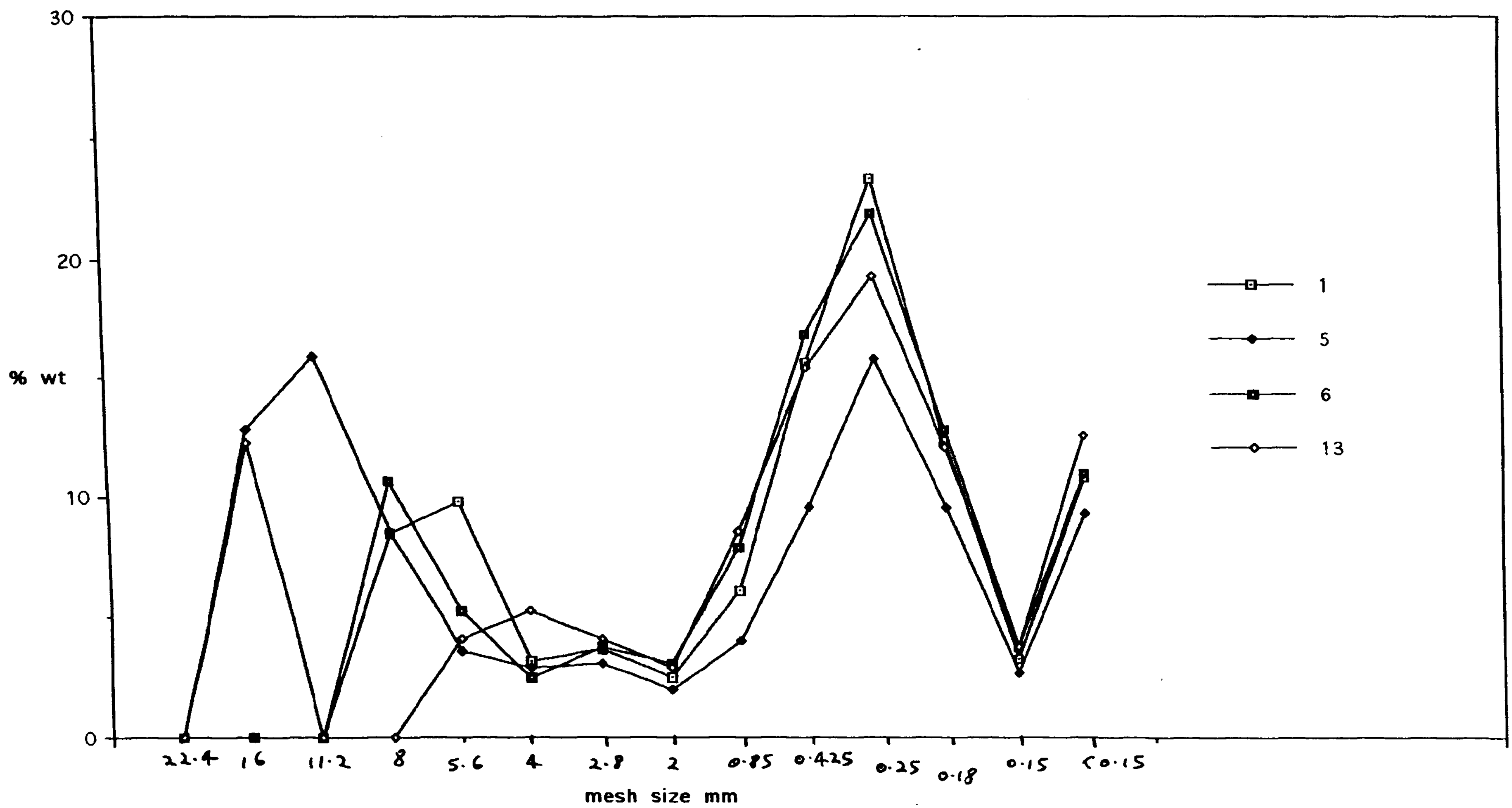


Fig. 143 Stanton Low 2

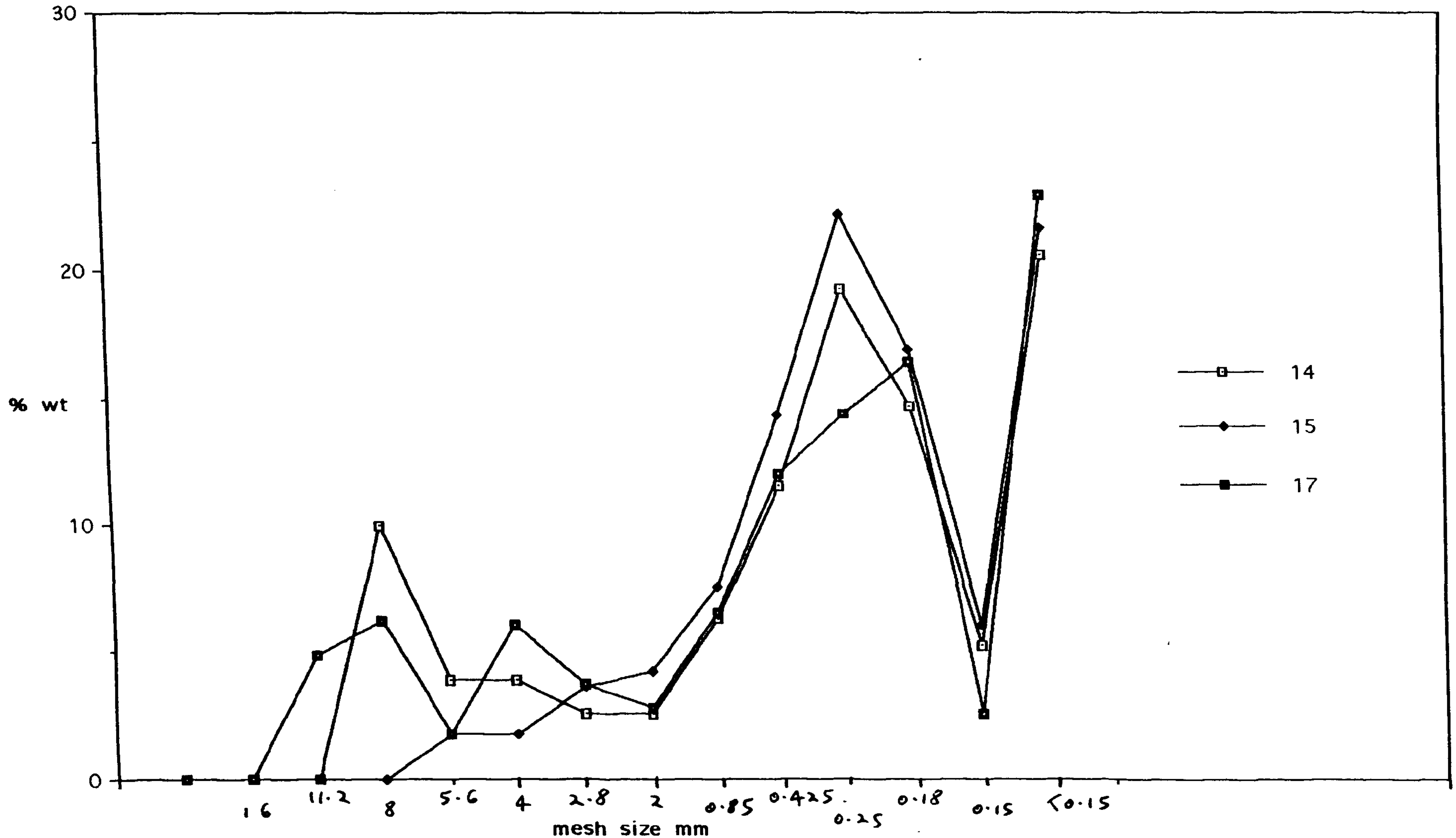
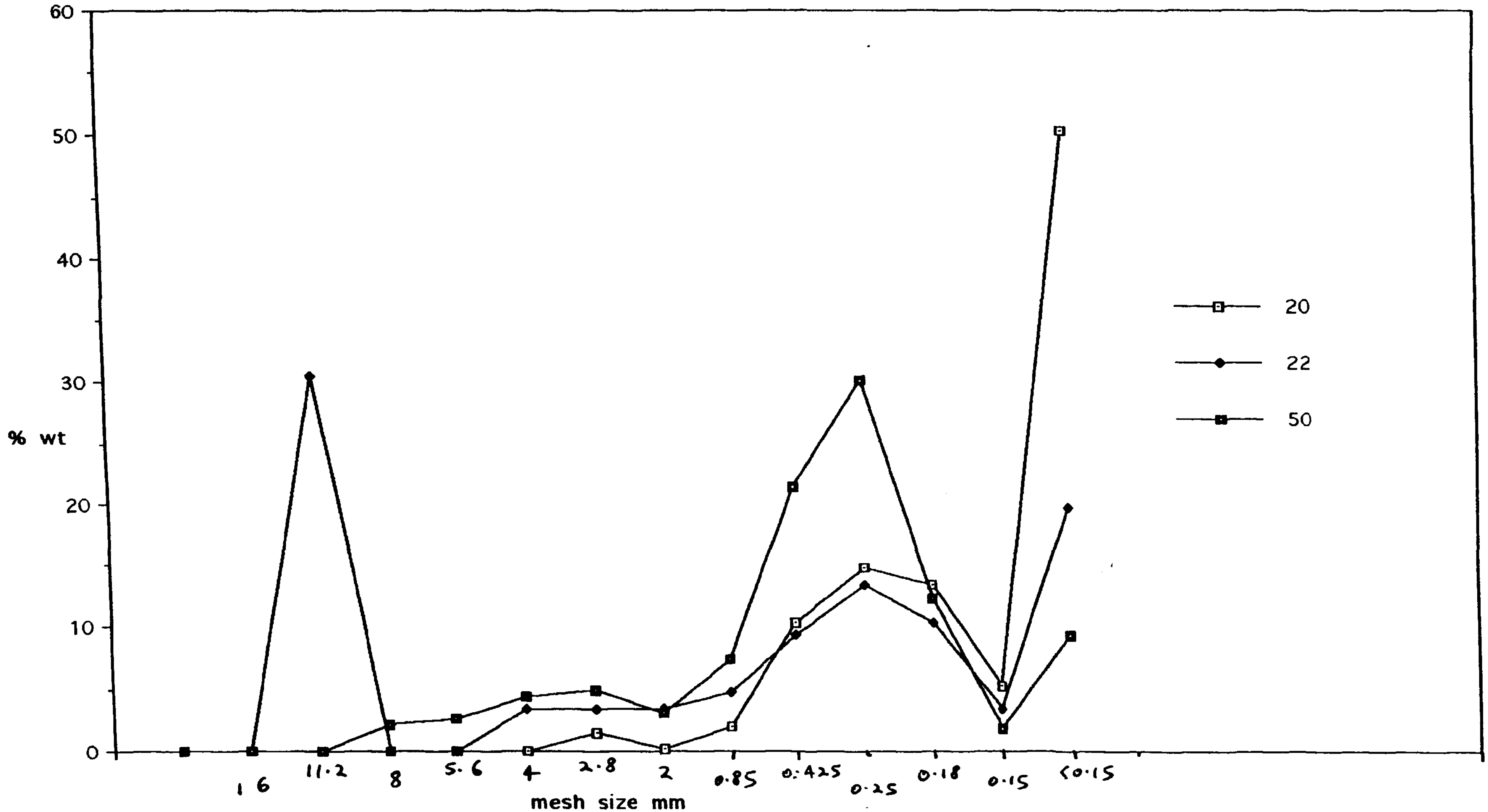


Fig. 144 Stanton Low 3



Stanwick, Northamptonshire
Redlands Farm site.
Britannia (1991) 22: 253 - 5
Keevil 1990

A collection of mortars from a Roman farm / villa complex.

The geology of the area, being calcareous in nature, meant that the usual method of simply dissolving out the lime with dilute hydrochloric acid could not be used as the calcareous aggregate would also be removed. The technique was modified by partially crushing the somewhat friable mortar and using limited quantities of dilute acetic acid to remove the lime. This process obviously does remove some aggregate, but by carefully controlling the reaction the results are probably close to the true lime to aggregate proportions.
Geological investigation of the aggregate showed the presence of various type of limestone, ranging from oolitised or or oolitic types to very shelly material and calcareous sandstone. Fragments of shells, belemnites, crinoids and other fossils were found in the aggregate. Also present were ferruginous sandstones, flint, quartz pebbles and round to sub-angular quartz sand. Small amounts of sandy red brick or tile were also found. The mortars were fairly similar in appearance, being mainly cream to orange in colour with varying amounts of gravel and sand. The aggregate compositions of the mortars were all very similar, being composed of:- limestone, iron stone, flint and occasional quartz pebbles in the gravel component, round to sub-angular quartz, iron stone and limestone fragments in the sand size and brown silt with traces of all the other materials in the residue. The presence of red tile or brick is noted in the comments below. Two samples also contained pieces of painted plaster. It was not clear whether these samples were re-used as aggregate or had simply become mixed up with the mortar during burial or excavation (the excavator considered that they were in fact re-used fragments).There was no sign of secondary mortar on the painted surface.

The lime or soluble contents were very varied, ranging from 10% to 50%, with a cluster around 25%. Assuming this to be representative (in view of the calcareous aggregates), it is a reasonable figure for Roman mortar. The higher values for the plaster, 37% and 39%, may reflect the finer grade size of material used. They are much higher than the lime values usually found in Romano-British wall plaster but the calcareous aggregate must be taken into account. Thirty two samples were analysed and four pigment identifications carried out.

EXAMPLES OF PLASTER DESCRIPTIONS

4a) White or light grey splashes on dark pink to red, 0.05mm thick, on pale cream or off white sandy *intonaco* , 0.5mm thick, possibly burnished, on cream sandy plaster, 13mm thick. Burnishing suggests a high standard of workmanship.
21a) Green on black, 0.05mm - 0.1mm thick, on pale cream to off white sandy *intonaco* , 0.5mm - 1mm thick, on sandy plaster, 10mm thick. The red was red ochre, the grey was lime plus carbon (probably soot) and the green was "green earth" or glauconite.

COMPOSITIONS

sample	gravel	sand	silt	"lime"	comments
1	28	59	13	21	
2	31	59	10	23	
3	21	52	27	21	some brick and soil
4	28	58	14	31	and painted plaster fragment; 4a
4a	26	63	11	37	brick traces
5	35	49	16	37	with soil
6	46	46	8	22	
7	61	33	6	17	some brick
8	59	35	6	25	some brick
10	56	33	11	19	
11	51	39	10	23	
12	48	44	9	22	
13	48	38	14	24	
14	54	37	9	32	
15	44	40	16	18	
16	40	42	18	30	
17	52	40	8	13	
18	54	42	4	11	
19	62	32	6	22	some brick
20	57	34	9	17	some brick
21	41	47	12	25	and painted plaster fragment;
21a					
21a	18	71	11	39	

sample	gravel	sand	silt	"lime"	comments
22	70	25	5	10	
23	37	47	16	23	
24	42	41	17	27	
25	34	52	14	45	brick and soil
26	28	55	17	50	some brick and soil
27	56	34	10	27	
28	59	32	9	17	brick traces
29	52	39	9	20	
30	31	49	20	47	with soil

PAINTING TECHNIQUE

The painting technique appeared to be *buon fresco*, and showed possible pseudo marbling with splashes of white to grey on dark pink to red, and uncertain features of green on black. The suggestion of burnishing pointed to high quality work.

PIGMENTS

The pigments present were natural red ochres (haematite), green earth (glauconite), white lime and carbon as soot or charcoal.

Average results

	Thicknesses		"Lime"
paint	(0.05 - 0.1)	0.07mm	-
intonaco	(0.5 - 1)	0.75mm	-
plaster	(10 - 13)	12mm	-
mortar	-		25%

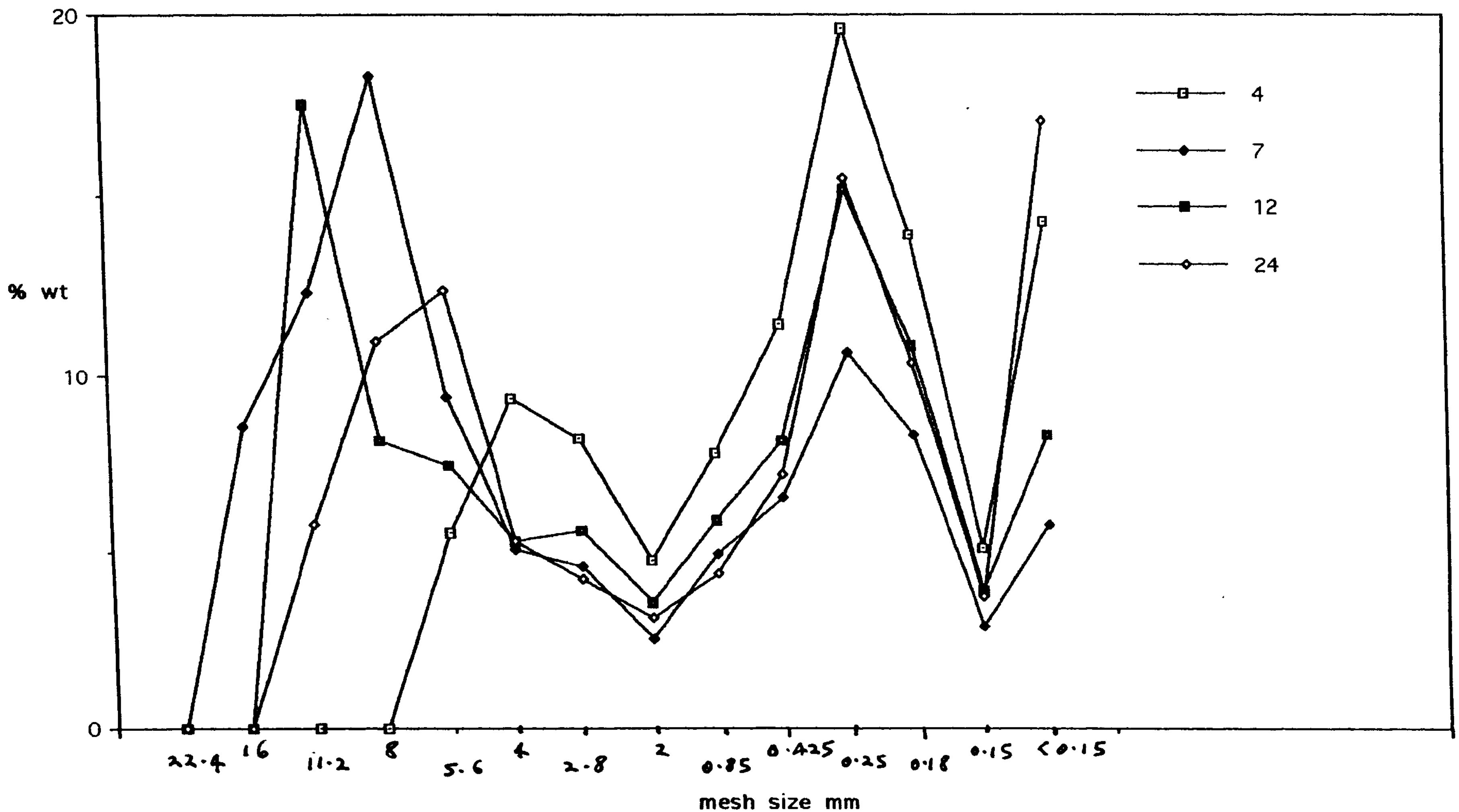
Samples illustrated in the aggregate particle size distribution graphs:

Fig No. 145

4, 17, 12, 24.

The particle size distribution graphs show the general spread of the particles from gravel to silt and clay. They are all very similar, and no useful phase separation can be seen. The differences shown relate to the nature of the samples (fine or coarse mortar or plaster) rather than differences in the source of materials.

Fig. 145 Stanwick - Redlands Farm



Star Roman Villa, Shipham, Somerset
Barton 1964
Roberts 1989

The fragments from Roman villa at Star were borrowed from the collections of the Axbridge Museum. The aggregates were mainly weathered residues and fossil fragments from the local limestone with: quartz, quartzite, feldspars, red siltstone, white chert, grey flint, glauconite, mica and ferruginous sandstones. The muddy nature of some of the plaster pointed to a naturally weathered deposit. The presence of limestone in the aggregate gave somewhat high value for the 'lime" content, perhaps twice that for non-calcareous plasters. The *intonaco* levels are however about right. Whilst the local coloured limestone could have been used for general lime making, white limestone had been selected to make the *intonaco* lime. The plaster was dated to around the mid fourth century. Thirteen samples were examined and eighteen analyses carried out.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments	phase
2)	-	-	-	83%	*intonaco*	2
plaster	8	61	31	60%	upper layer	2
	5	42	53	56%	lower layer	2
3)	-	-	-	92%	*intonaco*	2
plaster	10	58	32	61%	upper layer	2
	19	40	41	55%	lower layer	2 / 1
4)	-	-	-	89%	*intonaco*	1
plaster	11	56	33	64%	upper layer	1
5a)	-	-	-	96%	*intonaco*	1
plaster	8	37	55	62%	upper layer	1
	9	33	58	43%	lower layer	1

EXAMPLES OF PLASTER DESCRIPTIONS

1) Pale green on white *intonaco*, 0.5mm, on light sandy plaster with lime, 11mm, on buff plaster traces.

2) room 2 G5 plaster below south wall: traces of yellow on pink *intonaco* ? with white lime lumps, 0.2 - 0.5mm, on light sandy plaster, 10mm, on brown muddy plaster with limestone and grass or straw impressions, 25+mm thick.

3) miscellaneous: yellow on pink *intonaco*, 1mm, on sandy plaster, 10mm, on muddy plaster with lime and grass impressions, 30mm thick.

4) G5 above floor 1:
a) yellow on pink *intonaco* as 3).
b) yellow stripe or circle, 12mm wide, on buff *intonaco*, 0.4mm, on sandy plaster, 7mm, on muddy plaster traces.
5) G5 room 2 plaster from west wall, box 32:
A) lower painting; painted *intonaco* on light sandy plaster on brown plaster (with secondary plaster traces on top):
plaster traces on yellow on red inter-locking circles on white *intonaco*, 0.5mm, on light sandy plaster, 6mm, on brown plaster, 15mm thick. Also present were samples with red lines 7mm wide, black lines 6mm wide and yellow lines c.f. 4)?.
B) secondary painting; red on light sandy plaster with pick mark casts on the rear:
white line, 9mm wide, on red on pink *intonaco*, 0.2 - 0.4mm, on light sandy plaster, 16mm, on brownish plaster, 6mm thick. The brownish plaster layer may be the primary painting layer as it was not shown on the sample with the pick mark casts.
C) white *intonaco* on dark sandy plaster on brown plaster.
5a) G5 room 2: plaster over wobbly yellow line, 7mm wide, on *intonaco*.
6) G5 room 2 from west wall:
white *intonaco*, 0.5mm, on dark sandy plaster, 15mm, on traces of brown plaster, 5+mm thick.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* technique. The primary style of painting seen on the fragments was of interlocking circles on white ground, apparently forming a border over a red dado. The primary painted surface had been pecked with a pointed implement before being over-plastered and re-painted in red and yellow on a pink *intonaco* layer.

PIGMENTS

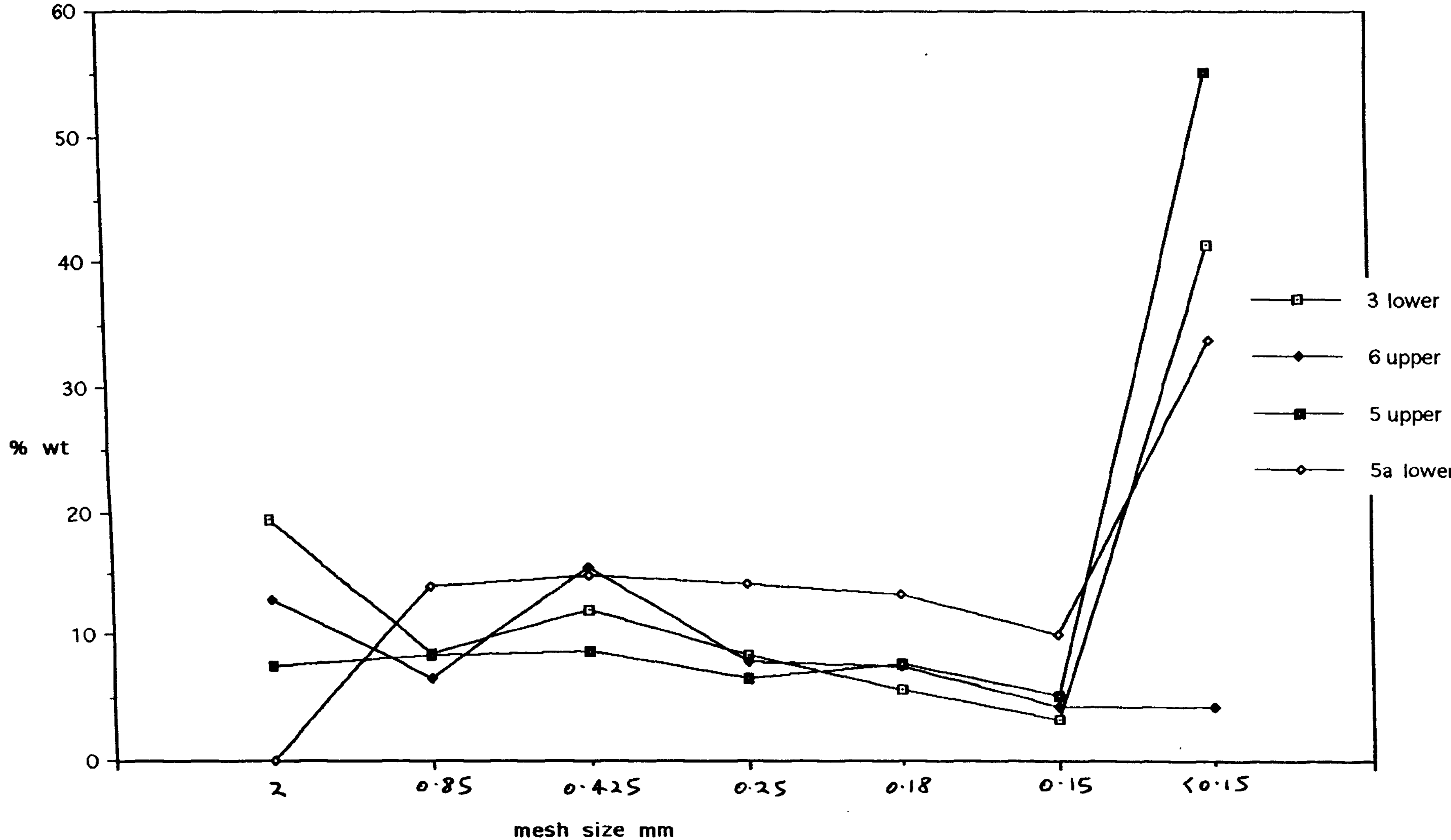
The pigments were the natural materials: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), white lime and carbon as soot or charcoal.

Average results

	Thicknesses		"Lime"
intonaco	(0.2 - 0.5)	0.5mm	89%
secondary plaster	(10 - 16)	12mm	58%
intonaco	(0.4 - 0.5)	0.5mm	93%
primary:			
upper plaster	(6 - 15)	9mm	60%
lower plaster	(5 - 30)	19mm	43%

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 146
3), 6), 5), 5a). The graphs show the very poorly graded nature of the aggregates.

Fig. 146 Star


60
50
40
30
20
10
0
% wt
2
0·85
0·425
0·25
0·18
0·15
<0·15
mesh size mm
3 lower
6 upper
5 upper
5a lower

Thorpe by Newark, Nottinghamshire
Burnham and Wacher 1990, 272 - 3

Painted plaster from the Roman town of Ad Pontem.
This plaster was exceptionally thick, up to 55mm in three or four layers, and very friable. Its appearance under the microscope showed iron and manganese staining, presumably due to waterlogging from the nearby river. This may also explain the loss of lime and the presence of silica in the plaster, although sand size silica fragments were also seen in the aggregate. The aggregates were mainly round to sub-angular quartz sand with some quartzite, flint, sandstone, crushed brick or tile and glauconite grains. Some of the samples showed traces of over-plastering in white sandy plaster. Twenty samples were examined and eight analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1)	-	77	23	75%	*intonaco*
	1	81	18	19%	plaster, upper layer
	1	81	8	16%	plaster, lower layer
2)	-	80	20	16%	plaster, upper layer
	1	91	8	15%	plaster, middle layer
	-	93	7	17%	plaster, lower traces

EXAMPLES OF PLASTER DESCRIPTIONS
1) plain yellow, <0.05mm, on white *intonaco*, 1mm, on sandy plaster, 13mm, on sandy plaster, 23mm thick.
2) plain white *intonaco*?, 1mm, on sandy plaster, 10mm, on a white interface?, 1mm, on sandy plaster, 25mm, on sandy plaster traces, 5+mm thick.

PAINTING TECHNIQUE
The paint appeared to be in the *buon fresco* method for the basic painting with over painting in *fresco secco*. The general layout was fairly complex, suggesting a scenic or decorative study, with only small fragments of border style straight lines. It should be noted that relatively few fragments survived for examination. The colours included: blue outlined in red on yellow, blue on black, red on yellow, white and black on red* on yellow, brushed blue, black, white on red* on white, white on blue on yellow, green on blue on white and burnished black on burnished white.

PIGMENTS

The pigments used were: red ochre (haematite), red* (cinnabar), yellow ochre (limonite), green earth (glauconite) carbon as soot or charcoal, white lime and finely crushed Egyptian blue.

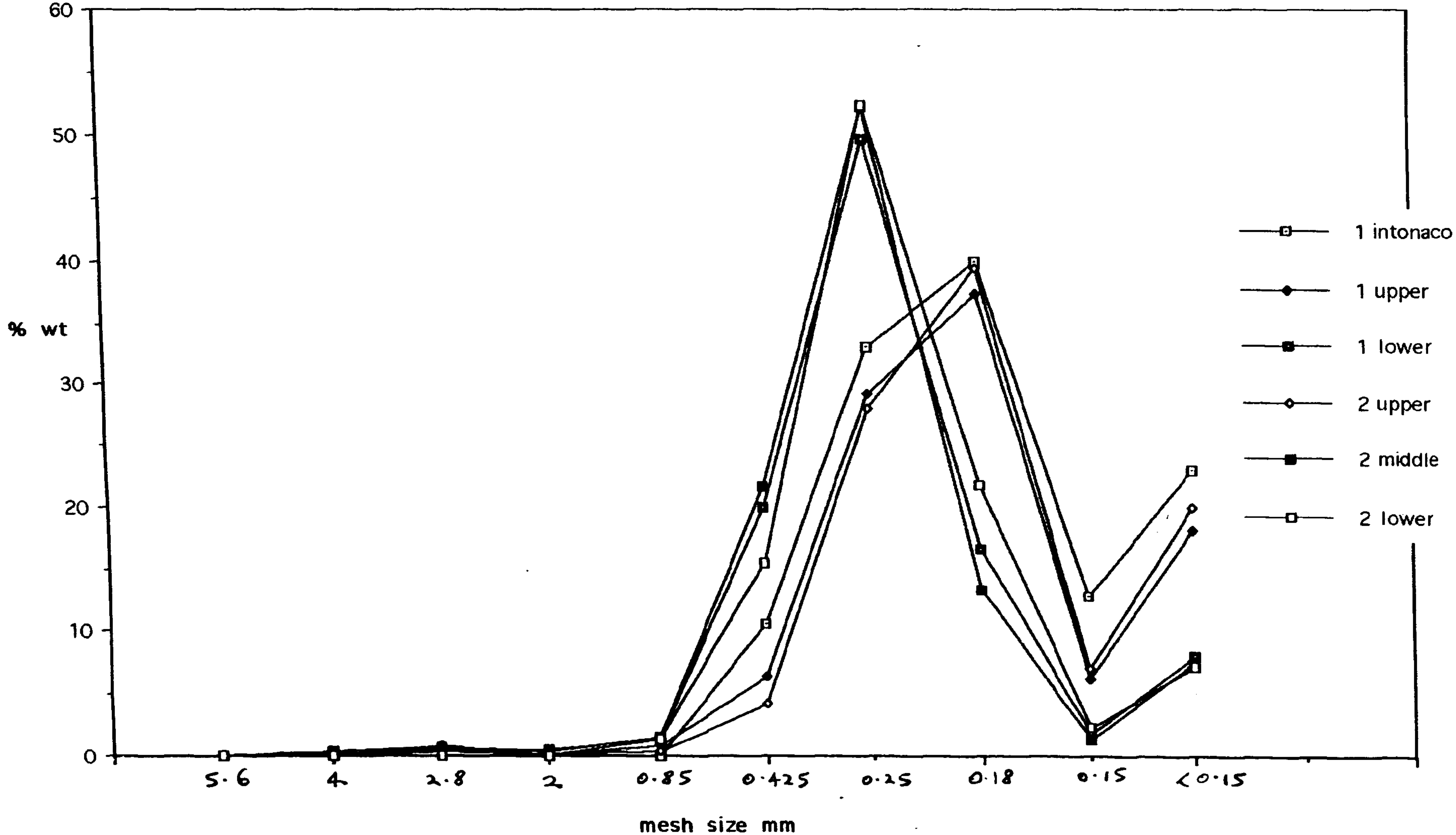
<u>Average results</u>

	<u>Thicknesses</u>	<u>"Lime"</u>
paint	0.05mm	-
intonaco	1mm	75%
upper plaster	10mm	18%
middle plaster	25mm	16%
lower plaster	10mm	16%

The dry sand densities ranged from 1.5 to 1.6 g/cc.

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig No. 147
1), 2). The graphs show the well graded nature of the river? sand used. Of interest was the use of slightly finer grades for the upper and *intonaco* layers.

Fig. 147 Thorpe by Newark



Verulamium, St Albans, Hertfordshire.
Frere 1972
1) Wallplaster from Insula XIX

This collection of painted wallplaster fragments was examined microscopically and, to a limited extent, chemically to investigate its composition and structure.

The aggregates appeared to be river sand and gravel, being mainly rounded to sub-angular quartz and angular to sub-angular flint. The *intonaco* layers were mainly rounded quartz sand. There was very little clay, the silt size component being very fine sand, perhaps the sand had been washed free of mud. Comparison with the local sand and gravel deposits would be of interest. There was no evidence for the source of the lime, but the lack of amorphous silica in the residue suggests the use of chalk or similar limestone. Further sampling of the wallplaster, aggregate and limestone sources would give a clearer picture of the origins of the material used here. Seven samples were examined and three analyses carried out. These results are unpublished.

COMPOSITIONS
sample 2)

gravel	sand	silt	"lime"	comments
2	85	13	19%	top layer
45	38	17	20%	middle layer
26	60	14	12%	lower layer

EXAMPLES OF PLASTER DESCRIPTIONS
(the numbers are arbitrary)

1) White lines on burnished red, 0.1 mm, on white *intonaco*, 0.4 mm, on sandy mortar (with tile traces), 5.5 mm, on pink sandy mortar with gravel and grass / straw, 12+ mm. The lower layer may have been burnt. The white lines contained traces of Egyptian blue. This was the only obviously burnished sample. It may have been from a specifically burnished area or from a different wall or room to the rest of the samples.

2) White band, 11.5mm wide, over a black / red interface on white, 0.5 mm, on pale grey sandy mortar, 5.5 mm, on light buff mortar traces as above. A much larger sample with a similar design (with the same

white band on black / red and a grey stripe and a patch of white with Egyptian blue traces) was analysed for composition of the mortar / plaster layers; paint layers on white *intonaco*, on light grey sandy mortar (some of these upper sandy layers appeared to be partly pink and may have been burnt), 5.5 mm, on light buff sand and gravel mortar, 17 mm, on buff sand and gravel mortar, 15 mm, on mud traces. The mud appeared on many of the samples and was probably a calcified mud layer from a mud or daub structure.
This large sample may have been part of a *giornata di lavoro* join, as the paint layer / *intonaco* is varied in its layering. The *intonaco* was pure white lime to sandy lime up to 2mm thick on a lime smear or layer, 0.5 - 0.75mm, with traces of black paint drips or runs or fine lines and grey lime. This could possibly have been an under-painting or marking / trial painting. The remains were too small to say for sure.

3) Very pale blue or white with Egyptian blue traces, on black, 0.05 mm, on white *intonaco*, 0.5 mm, on sandy mortar, 5.5 mm, on light buff sand and gravel mortar with grass or straw impressions, 18 mm, on buff sand and gravel mortar, 15 mm, on buff mud traces.

4) White stripe with Egyptian blue specks, < 0.05 mm, over light a green / dark green interface and pink, red, yellow, white all on light green, total 0.1 mm, on red, 0.1 mm, which thinned out under the mixed pigment area, on off white to buff *intonaco*. 0.5 mm thick. The under red appeared to be completely over painted on this sample.

5) Grey on white on green on grey / white on white *intonaco* as above.

6) Black to very dark red on white on grey on white on mortar as above. This may be a *giornata* join and was possibly part of 2).

7) A large sample - white stripe over a red / grey interface, and pink stripe with Egyptian blue specks on red, (grey overlaps the red) with spots of black, red , yellow and white on grey, on off white *intonaco* on grey sandy mortar as above to 40 mm with mud traces. This appeared to be a red border around a pseudo grey marble panel. The rest of the material was mixed in style.

All the plaster was of a similar construction as the analysed sample 2), with varying preservation of the three layers, with total thickness up to 50mm and all (where the full thickness survives) showed traces of mud from a daub or mud wall structure on the rear. It probably represented a single phase of building if not a single decorated room. The over painting was possibly from differently painted panels or walls or a slightly later phase. The burnished sample 1) may have been a specialised area or a different wall.

PAINTING TECHNIQUE

The basic painting was in the *buon fresco* method with the over painting possibly in *fresco secco* The following colours or schemes were noted:- white on pale green on red on white *intonaco*; white band ? on green with Egyptian blue specks on white *intonaco*; green with Egyptian blue specks on black on white *intonaco* and mixtures of red / grey / green, possibly an over-painting.

PIGMENTS

The pigments were mainly natural ochres, red and yellow (haematite and limonite), green earth (glauconite), white lime, black as charcoal or soot. The blue was Egyptian blue.

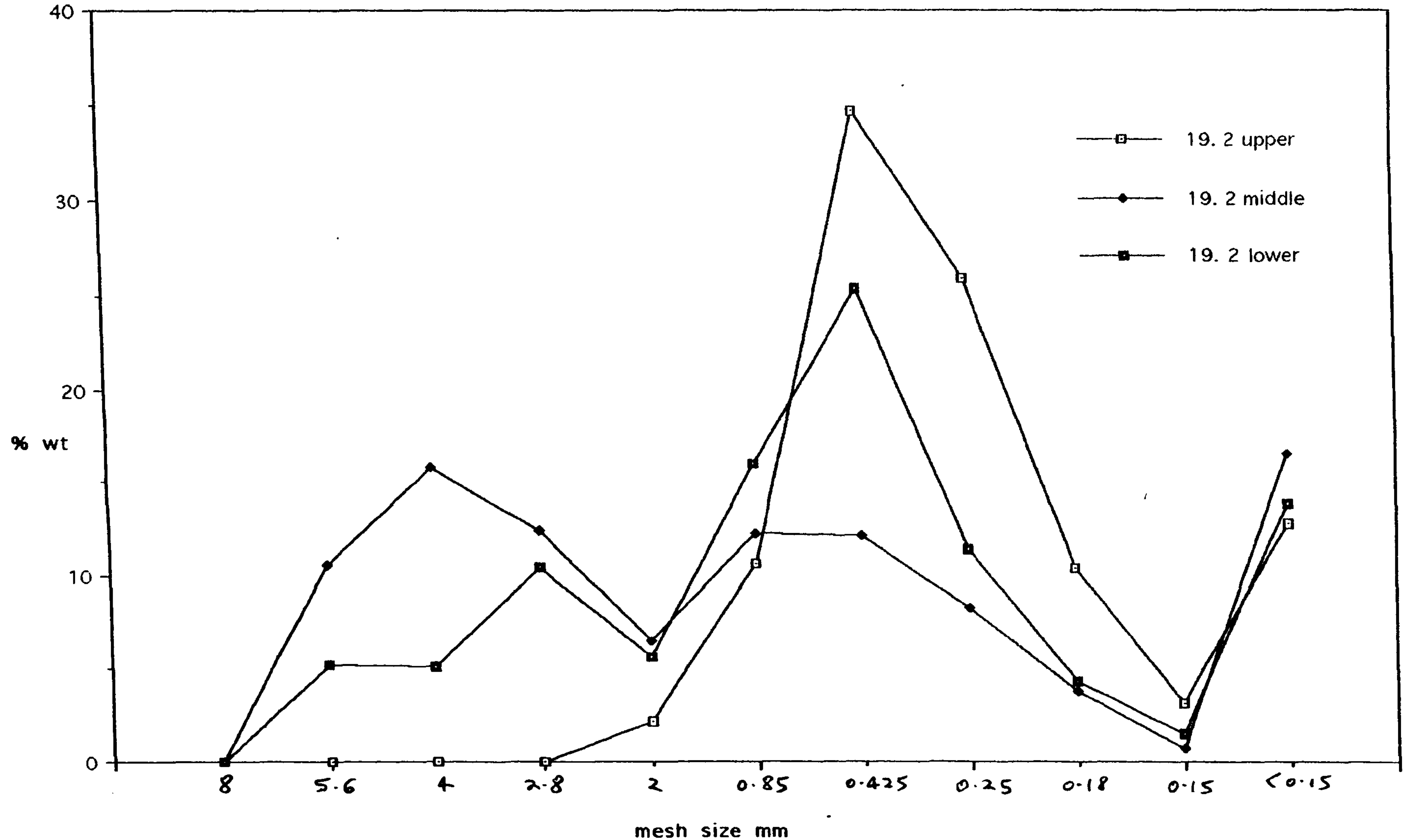
Average results

	Thicknesses		"Lime"	
paint	(0.05 - 0.1)	0.08mm	-	
intonaco	(0.4 - 0.75)	0.5mm	-	
plaster		5.5mm	19%	upper layer
	(12 - 18)	16mm	20%	middle layer
		15mm	12%	lower layer

Samples illustrated in the aggregate particle size distribution graphs:
Fig No. 148

The particle size distribution analysis curves show that the sand composition is fairly well graded but the gravel has a much broader composition. This probably reflects the collection of combined sand and gravel although, the fineness of the sand used for the top layer of plaster shows that the sand was available separately from the gravel or has been sieved. The analysis is based on a single sample and obviously must be viewed as only tentatively representing the rest of the material. They are rather low in lime compared with some Roman plasters or mortars but this may reflect decay during burial.

Fig. 148 Verulamium Insula 19



Verulamium
Frere 1983

2) Material from the museum store, mainly from Insula XXI. Building 1 was given a destruction date of the mid to late fourth century but the building may have originated in the late first century. The plasters were made using river sand and gravel (round to sub-angular quartz, quartzite, flint and ferruginous sandstones) with traces of fossils, perhaps from the lime, chalk and crushed brick or tile. Thirty eight samples were examined and thirty analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1)	1	94	5	25%	upper layer
	-	-	-	86%	lime interface
	17	72	11	19%	middle layer
	15	76	9	20%	lower layer
3)	5	82	13	23%	upper layer only
5)	10	53	37	55%	pink *intonaco*
	67	21	12	43%	upper tile plaster
	14	64	22	50%	lower tile plaster
6)	53	30	17	40%	upper layer
	33	46	21	42%	lower layer
7)	6	65	29	36%	upper tile plaster
	25	52	23	40%	upper tile plaster
Ver 55					
1)	47	42	11	22%	upper layer only
6)	23	63	14	34%	upper layer only
7)	59	36	5	17%	upper layer only
13)	30	55	15	15%	upper layer
	43	30	27	38%	lower tile plaster
13a)	0	86	14	15%	grey *intonaco*
	36	52	12	19%	upper layer
	27	45	28	41%	lower tile plaster
14)	19	68	13	36%	secondary, upper layer
	30	54	16	19%	primary, upper layer
16)	33	78	9	18%	upper layer only
17)	-	-	-	65%	secondary *intonaco*
	40	48	12	13%	secondary, upper layer
	-	-	-	69%	primary *intonaco*

	41	49	51	19%	primary, upper layer
18)	36	52	12	24%	upper layer only

EXAMPLES OF PLASTER DESCRIPTIONS

Ver 74.6

1) pseudo marble effect plaster; splashes and spots of red, yellow and black on brushed white *intonaco* ?, 0.2 - 1mm, on sandy plaster, 5mm, on a white lime interface, 0.5mm, on sandy plaster, 12mm, on sandy plaster, 18+mm thick. Also as above with green with blue on yellow on white *intonaco*, 0.5 - 1mm, and 6mm of sandy plaster.

2) TW; burnished? red on white on two layer plaster, 4mm + 10+mm thick.

3) TP (2) contemporary with the Lyre painting II.

1) white on burnished red on white *intonaco*, 0.5 - 1mm, on sandy plaster, 10mm thick.

2) red on white on yellow on green on blue on white on black on red on white *intonaco*, 0.5 - 1mm thick as above.

3) black on red on white as above.

4) white and dark blue on pale green with blue on white *intonaco*, 2mm thick.

Ver 74.6 TP (2) lowest level below tiled floor;

5) red on pink *intonaco*, 1 - 3mm, on coarse tile plaster, 28mm, on fine tile plaster, 12mm thick.

6) tile plaster or mortar in two layers; 30mm + 15mm thick.

7) boxed sample; white concretion?, on red stripes on blue traces on brushed yellow on white *intonaco*, 0.5mm, on tile plaster in two layers, 30mm + 15mm thick. The lower layer contained flakes of re-used red and blue painted plaster. Two large samples showed mortar or plaster traces above the paint and had probably been re-used as aggregate.

Ver 55 Insula XXI building 1 D IX (9) early period: (on layered [type 1] or unlayered *intonaco*)

1) white on red on green on pale grey *intonaco*, 0.25mm, on white *intonaco*, 0.5mm, sandy plaster, 12mm thick.

2) black on red on thin white *intonaco* ?, 0.25mm, on pale grey *intonaco*, 1mm thick.

3) white or grey over black over grey *intonaco*, 0.5mm, on sandy plaster, 18mm thick.

4) white over black with blue on grey *intonaco*, on white *intonaco*.

5) black on white, 0.25mm, on sandy white *intonaco*, 0.5mm, on grey *intonaco*, 0.5mm thick.

6) dark yellow on light yellow on black on white on white *intonaco*, 0.5mm, on grey *intonaco*, 0.5mm, on sandy plaster, 17mm thick on coarse sandy plaster.

7) white on thin green on trowelled grey *intonaco* on white *intonaco*, 2mm thick.

8) yellow on red to black on white *intonaco*, 1mm thick.

9) red on white *intonaco*.

10) white on dark green on pale green and dark red on pale green without *intonaco*.

11) green on yellow on white *intonaco*, 1.5mm thick.

12) painted plaster on an *imbrex* tile fragment; red on yellow and white on grey to black sandy *intonaco*, 1mm, on sandy plaster, 12mm, on tile plaster, 8mm thick. Also: red on white on grey, red on yellow on grey, blue with black and red on yellow on white on grey sandy *intonaco*, on layered plaster as above.

(Type 2 plaster is grey sandy *intonaco* on two layered plaster.)

13) white on blue on black on red on grey sandy *intonaco*, 0.5 - 1mm, on sandy plaster, 15mm, on tile plaster, 20mm thick. The Egyptian blue particles were 0.1 - 0.2mm across. Other samples showed the upper plaster layers up to 20mm thick.

(Type 3 plaster is overplastered and painted.)

14) white spots on yellow on white *intonaco*, 0.5mm, on sandy plaster, 6mm, on black on grey *intonaco* on white *intonaco*, total 0.5mm, on sandy plaster, 14mm thick.

15) pale green on white *intonaco*, 0.5mm, on sandy plaster, 9mm, on white on blue and green on black on grey to white *intonaco*, 0.5 - 1mm, on sandy plaster, 9+mm thick.

(Type 4 plaster is painted sandy plaster on burnt pink plaster.)

16) burnt? red on white or grey, 0.25mm, on sandy white *intonaco*, 0.25mm, on pink plaster, 10mm thick.

(Type 5 plaster is massive two layered or re-used material.)

17) red, yellow and white on sandy white *intonaco*, 1 - 3mm, on pebbly plaster, 42 - 68mm, on or including; brushed red on fine white *intonaco* with some sand, 1mm, on coarse sandy plaster, 15 - 25m thick.

18) Ver 55 early period window, building 1:
dark red on green on grey *intonaco*, 0.5mm, on white *intonaco*, 1mm, on sandy plaster, 22mm thick.

PAINTING TECHNIQUE

The paint was applied mainly in the *buon fresco* technique with over painting possibly in *fresco secco*. The paintings are in part very complex, similar styles being displayed in Verulamium Museum. (Davey and Ling 1981: 169 - 191)

PIGMENTS

The pigments analysed were: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), white lime, carbon as soot or charcoal and crushed Egyptian blue. Many displayed paintings in the Museum have red cinnabar on them and there are Egyptian blue spheroids in the Museum collections.

<u>Average results</u>

	Thicknesses		"Lime"	
secondary painting				
intonaco	(0.5 - 2)	1mm	65%	
plaster	(6 - 9)	8mm	25%	
primary painting				
paint		0.25mm	-	
intonaco	(0.35 - 2)	1mm	69%	
plaster	(10 - 25)	14mm	23%	upper layer
			40%	*opus signinum*
		0.5mm	86%	lime interface
		12mm	19%	middle layer
	(8 - 25)	17mm	34%	lower layer
			44%	*opus signinum*

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig Nos 149 - 153
74.6: 1) upper, middle, 3), 5) lower, 6) upper, lower, 7) lower, upper.
Ver 55: 1), 6), 7), 13) upper, lower, 13a) upper, lower, 14) upper, lower, 16), 17) primary, secondary.
The graphs show a wide variety of gradings and that some samples were obviously made from the same sand or gravel deposits.

Fig. 149 Verulamium. 1

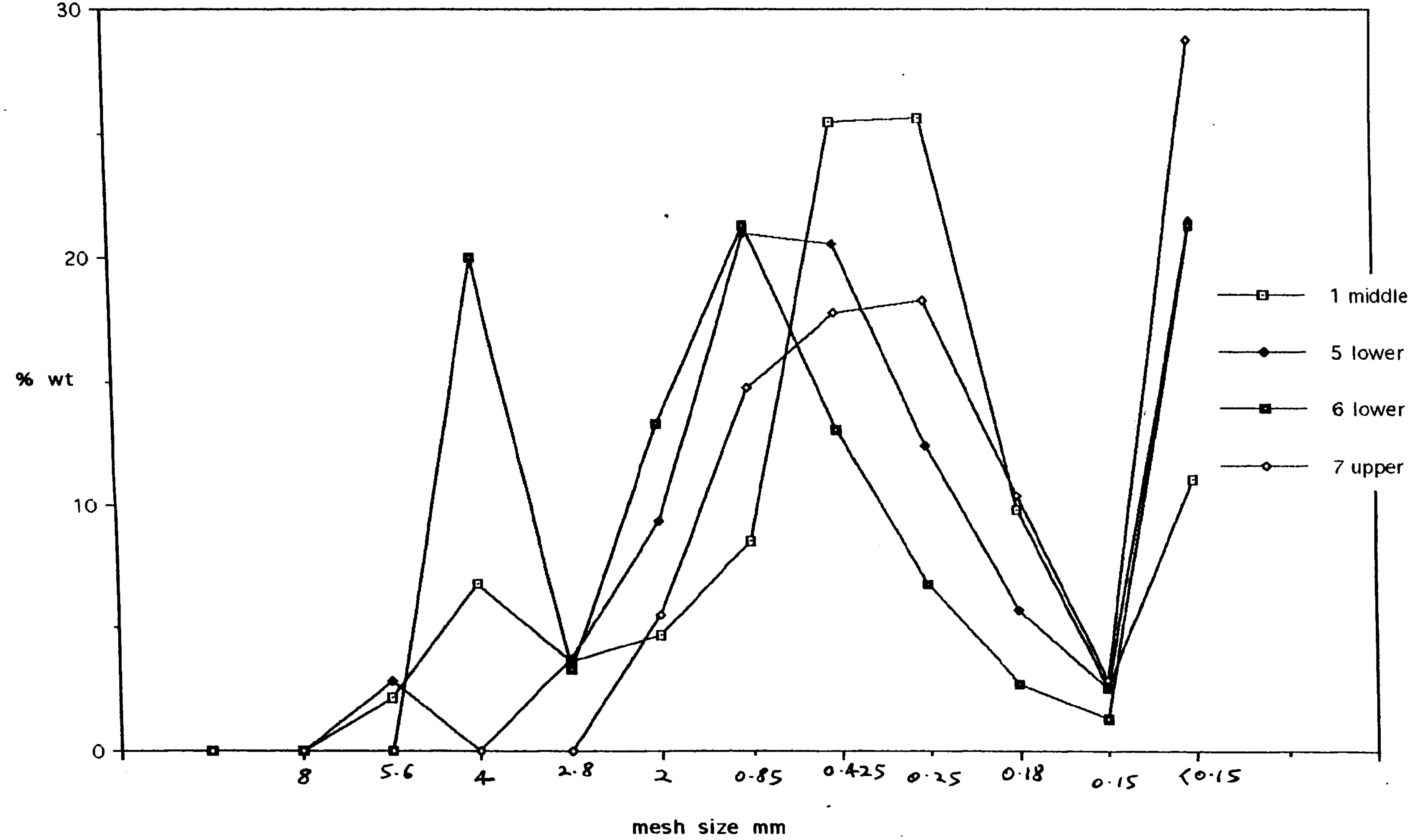


Fig. 150 Verulamium. 2

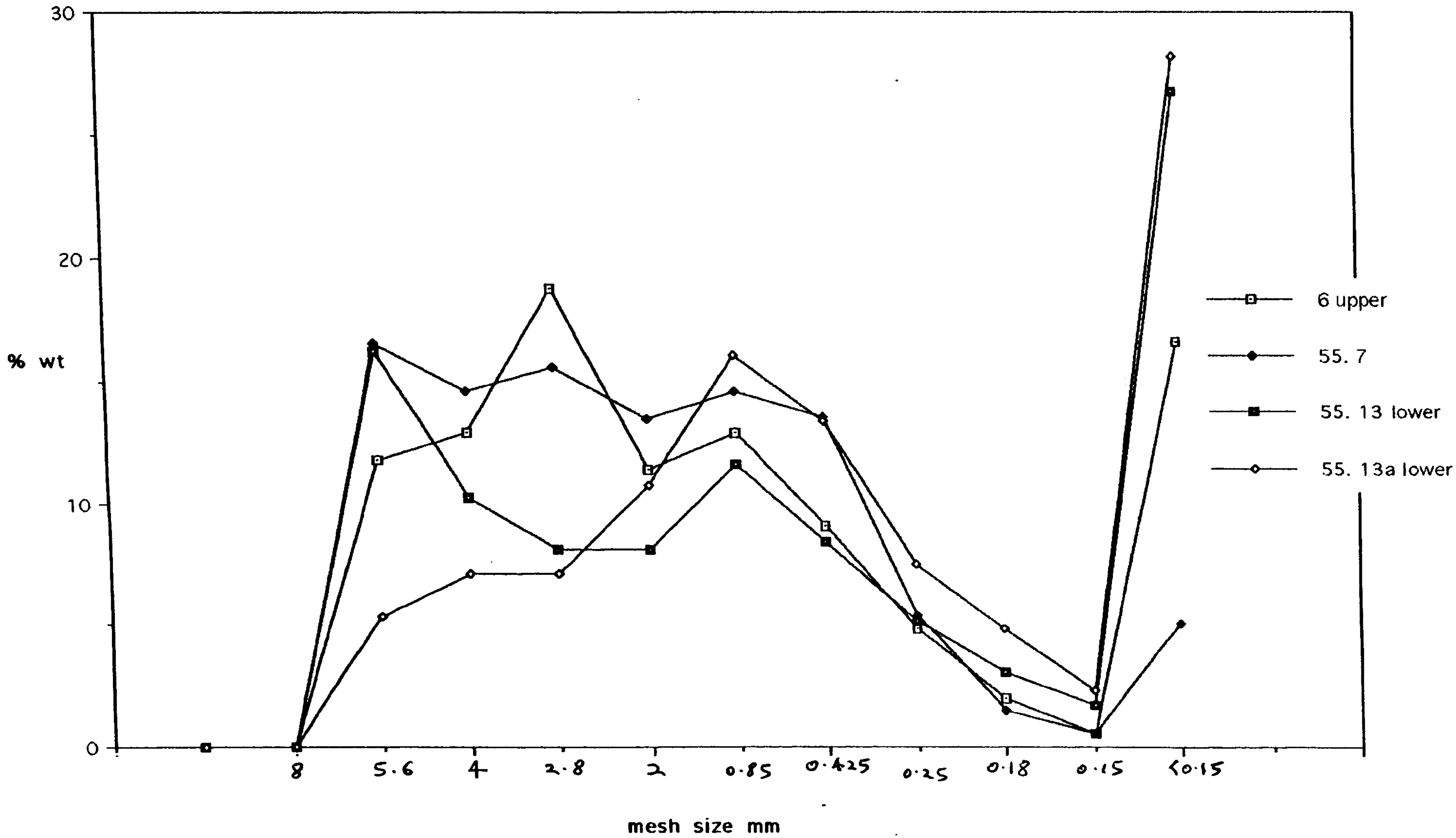


Fig. 152 Verulamium. 3

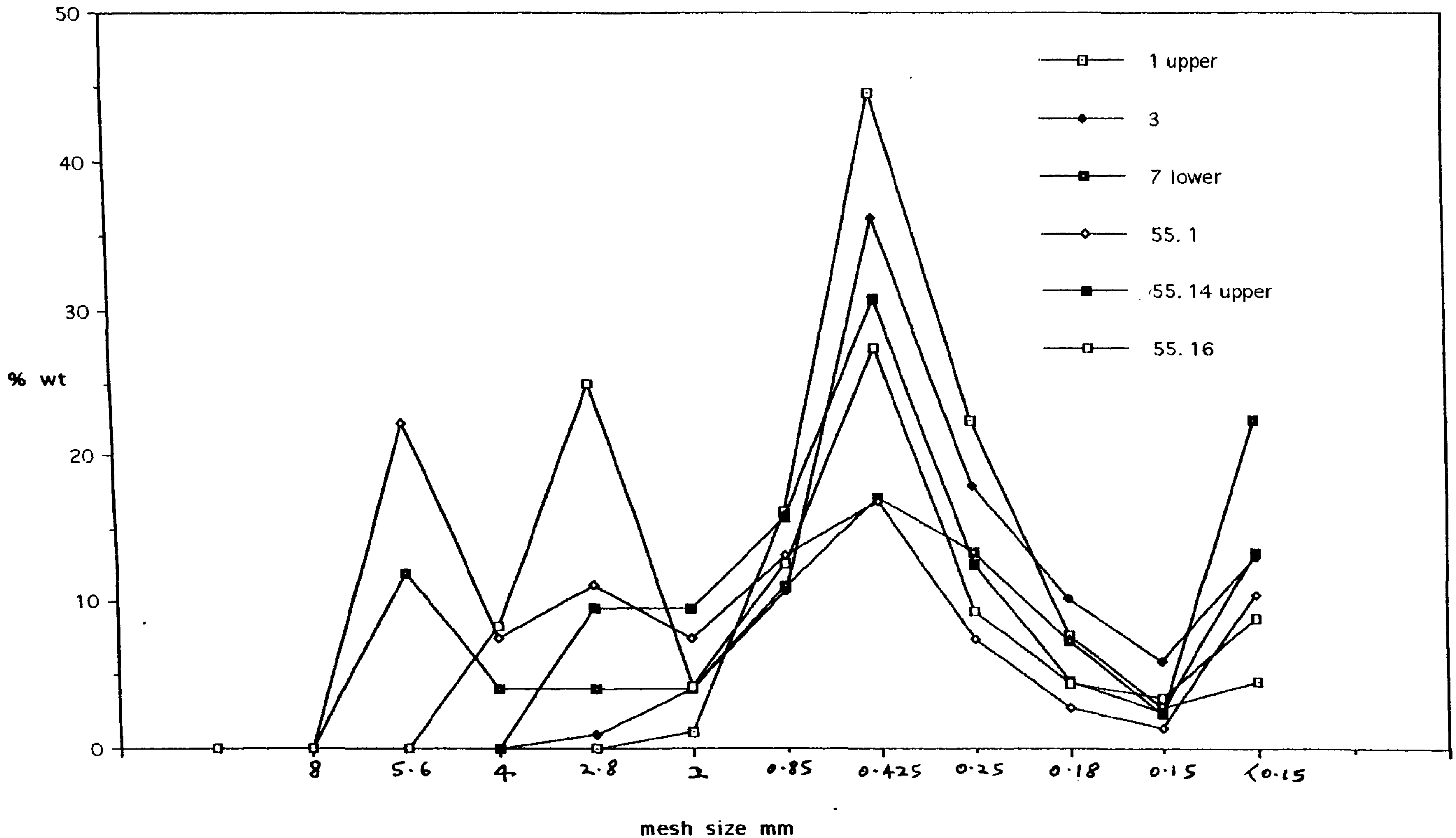
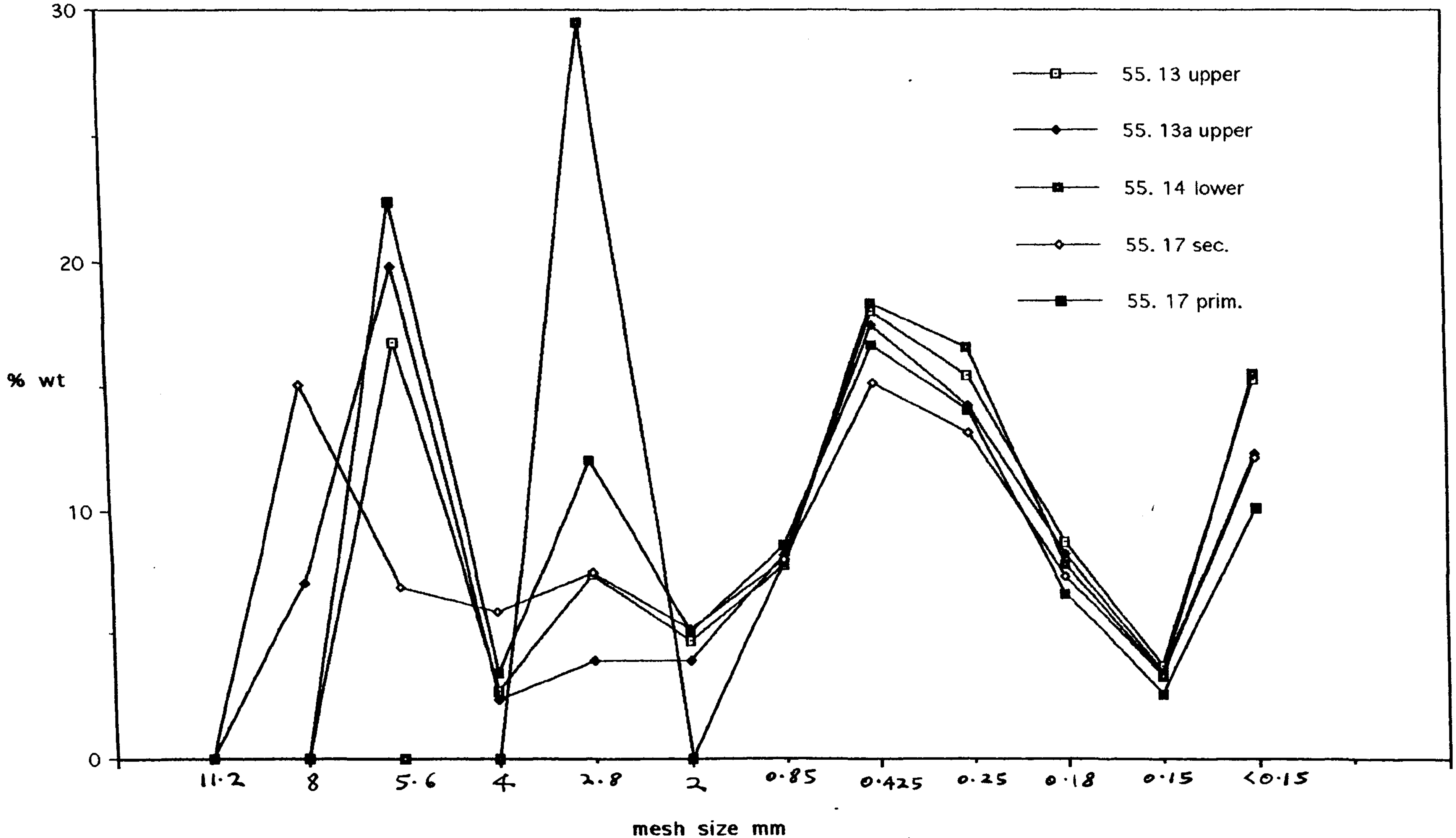


Fig. 153 Verulamium. 4



Wall, Staffordshire
Britannia 1972 3: 316; 1975 6: 247; 1977 8: 392, 394
Burnaham and Wacher 1990, 274 - 8

Excavations in 1977 and 1987 within the Roman town walls at Wall produced painted plaster and mortar from [1] a "villa" adjoining the Roman Baths and [2] from the stone built "mansio". The aggregates included river sands and gravel of quartz and quartzite with fossiliferous limestones, red sandstone and crushed brick or tile. The presence of limestone in the aggregate may have given high values for some of the "lime" contents. Thirty three samples were examined and 23 analyses carried out. These results are unpublished.

COMPOSITIONS

[1] mortars

No	gravel	sand	silt	"lime"	comments
1)	37	56	7	30%	
2)	35	50	15	38%	
3)	44	48	8	31%	
4)	35	59	6	52%	
5)	26	59	15	27%	
6)	35	59	6	28%	
7)	61	31	8	34%	some tile / *opus signinum*
8)	37	55	8	19%	
9)	32	55	13	18%	
10)	14	66	20	24%	
11)	18	58	24	27%	
12)	21	59	20	33%	
13)	39	52	9	25%	
14)	21	66	13	22%	
15)	34	57	9	28%	
16)	31	62	7	24%	
17)	17	70	13	31%	some tile
18)	10	80	10	27%	

No	gravel	sand	silt	"lime"	comments
[2] Mansio samples					
M1)	0	13	87	90%	waste lime, or plaster
M2)	0	27	73	91%	plaster
M3)	63	7	30	91%	burnt limestone
M4)	1	42	57	85%	plaster

M5)	20	70	10	17%	plaster, upper layer
	10	78	12	22%	grooved lower layer
	11	79	10	21%	upper mud or plaster
	0	53	47	4%	lower mud
M6)	45	39	16	40%	*opus signinum*
M7)	56	27	17	42%	*opus signinum*, top layer
	57	26	17	41%	*opus signinum*, middle layer
	62	20	18	37%	*opus signinum*, lower layer
M8)	1	87	12	26%	painted plaster
M9)	30	58	12	26%	ceiling plaster, top layer
	20	51	29	27%	ceiling plaster, lath impressed
M10)	22	68	10	27%	painted plaster
M11)	25	64	11	36%	painted plaster, upper layer
	49	46	6	18%	cast "concrete" lower layer

EXAMPLES OF PLASTER AND MORTAR DESCRIPTIONS

The mortar samples [1] were all very similar in appearance, being brown to red in colour. The red colour was mainly due to the presence of red sandstone pebbles and smaller fragments, although some tile or brick was also found.

The samples from [2] were much more varied and are described in detail:

M1) M 74 / 42: off white lump of light weight plaster with grass impressions and air bubbles, 35mm thick. This may have been ceiling plaster.

M2) M 74 / 51: as above.

M3) unstratified lump of burnt limestone with crinoids and other fossil fragments. The analysis of the sample showed that it could have been used as a lime source.

M4) M 74 / 40: white on off white *intonaco*, 2mm, on pale white plaster with sand traces, fired clay lumps and grass impressions, 20mm thick. The flat rear suggested that it was a flaked layer.

Unstratified samples:

M5) yellow band over red to grey interface on rough white with grass impressions, 0.25 - 1.5mm, on buff to white *intonaco*, 0.5 - 1mm, on coarse dark sandy plaster, 14mm, on light sandy plaster with a grooved rear, 6 - 14mm, on brown sandy plaster or mud in two possible layers.

M6) tile mortar from a floor or waste material, 30mm thick.

M7) tile mortar in three layers; 15mm + 15mm + 5+mm thick.

M8) red band on white *intonaco*, 4mm, on layered brown sandy plaster, 13mm thick, with parallel grooves on the rear. Also another sample with a red stripe on white *intonaco*, 1 - 2mm, on brown sandy plaster with grooves on the rear, c.f. M5).

M9) ceiling plaster with a geometric design; red on white, 0.05 - 0.1mm, on white *intonaco*, 0.5mm, on coarse sandy plaster in two layers, 11mm + 11mm thick, on brown muddy plaster with lath impressions, 20 - 35mm thick. The lath impressions were 6 - 8mm thick and up to 40mm wide. Other examples of painted ceiling plaster included:

a) red on yellow on white, 0.05mm, on white *intonaco*, 0.5mm, on coarse sandy plaster, 12mm, on brown muddy plaster traces, 3+mm thick.

b) yellow and black with brush marks on white *intonaco* on plaster as above.

c) red on yellow on white and black on white on white *intonaco* as above.

The weight loading of the ceiling samples were calculated to be: $89kg/m^2$, $71kg/m^2$ and $46kg/m^2$. (Similar calculations were carried out on the ceiling plaster from Colliton Park, Dorchester, which gave a weight loading of $53kg/m^2$.)

M10) wall plaster; black to dark grey on green and white to pale grey, <0.05mm on red on white *intonaco*, 0.1 - 0.2mm, on coarse brownish sand and gravel plaster in two layers, 20 - 25mm total thickness. Other examples of painted wall plaster included:

a) red brown stripe on green, <0.05mm, on white *intonaco*, 0.4mm, on coarse sandy plaster in two similar layers, 20 - 23mm thick.

b) plain green within blue traces on plaster as above.

c) pseudo marbling; red spots on yellow spots on pink on white *intonaco* on two layered plaster as above on a third plaster layer of coarse sand and gravel, 6mm thick.

d) pseudo marbling; white spot on yellow spots on red spots and black spots on pink, 0.2mm, as above on white *intonaco*, 0.5mm, on coarse brownish plaster, 15mm thick in a single layer.

M11) wall section; dripped orange to red spots on off white on sandy white *intonaco*, 1.5 - 2mm, on brown to buff sandy plaster, 10 - 15mm, on very coarse cast concrete-like mortar with large pebbles and tile, 50+mm thick. The cast mortar showed a possible wood frame impression.

PAINTING TECHNIQUE

The paint was applied in the *buon fresco* method with over painting possibly in *fresco secco*. The style of painting on the ceiling was of geometrical design, showing hexagons or octagons with spots at their corners. The wall painting was of borders or panel edges and pseudo marbling.

PIGMENTS

The pigments used were: red ochre (haematite), yellow ochre (limonite), green earth (glauconite), carbon as soot or charcoal, white lime and traces of crushed Egyptian blue (in the green pigment). The red and yellow were both micaceous and may have come from the same source, the red being burnt yellow ochre.

Average results

	Thicknesses		"Lime"	
wall mortar		-	29%	
cast mortar		70mm	18%	
paint	(0.05 - 0.2)	0.1mm	-	
intonaco	(0.15 - 4)	1.2mm	96%	
wall plaster	(10 - 17)	13mm	27%	upper layer
	(10 - 15)	12mm	22%	middle layer
			40%	*opus signinum*
	(7 - 35)	21mm	21%	lower layer
		-	4%	mud layer
lightweight plaster		34mm	89%	ceiling?
ceiling plaster		12mm	27%	surface layer
		12mm	27%	impressed layer

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 154 - 160

1) M5; upper, lower, upper"mud", M9 lower, 8.
2) M2, M5 lower mud.
3) M1, M3, M4.
4) M7; upper, middle and lower, 2, 7.
5) M6, 9, 10, 17.
6) 3, 6, 13, 14.
7) M78, M 10, 1, 4, 16, 18.

The graphs show the wide range of particle sizes used.

Fig. 154 Wall. 1

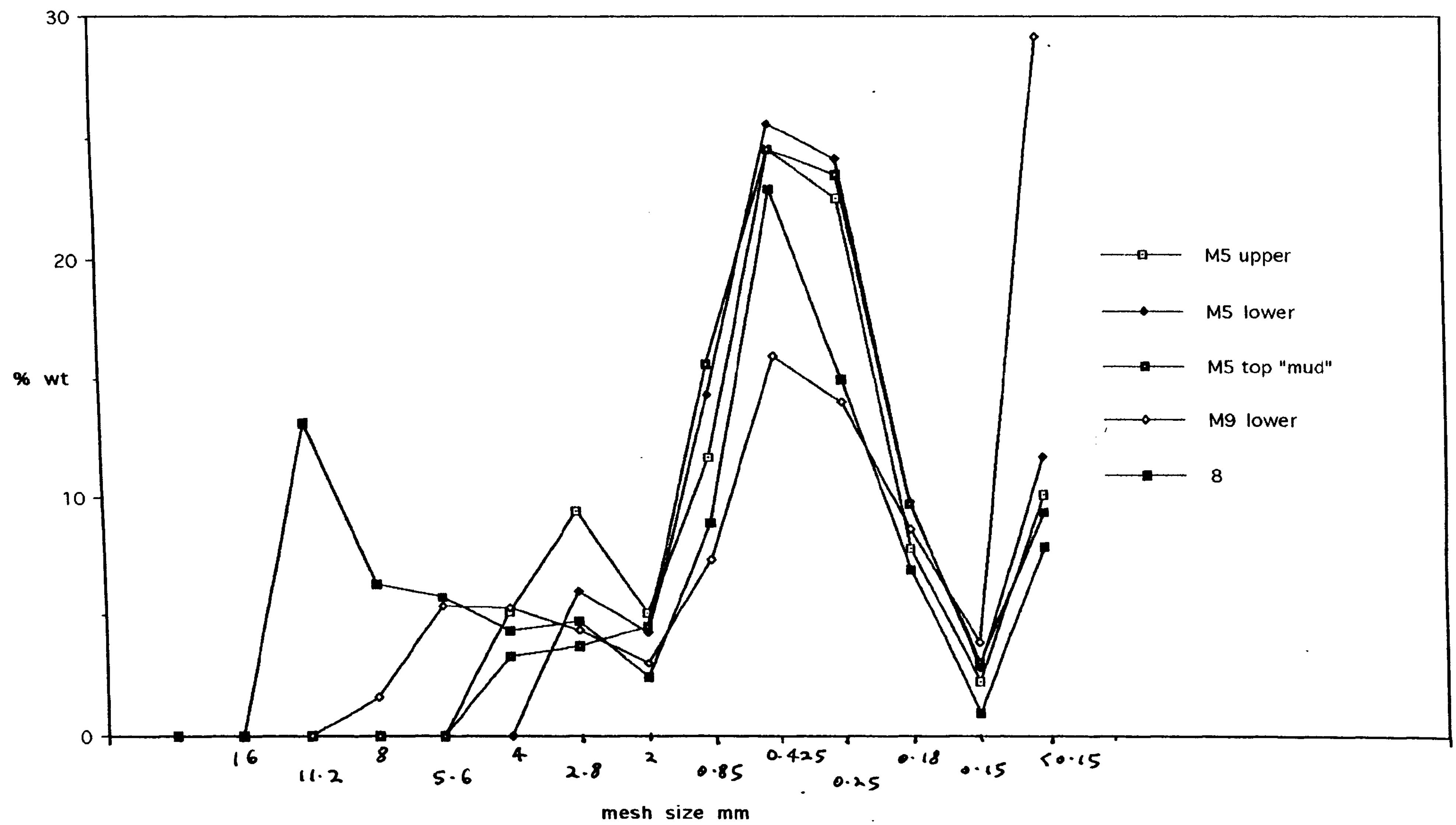


Fig. 155 Wall. 2

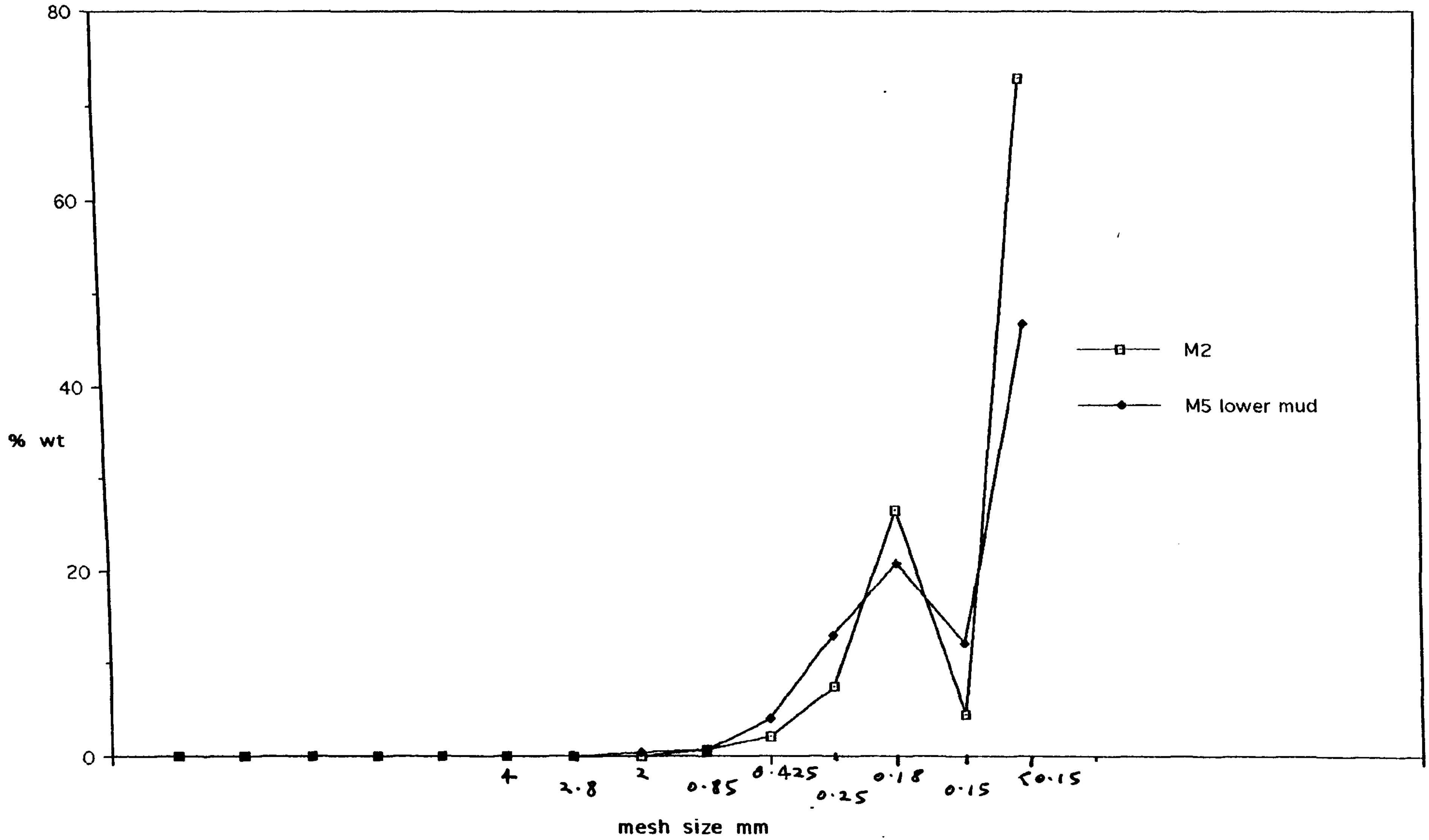


Fig. 156 Wall. 3

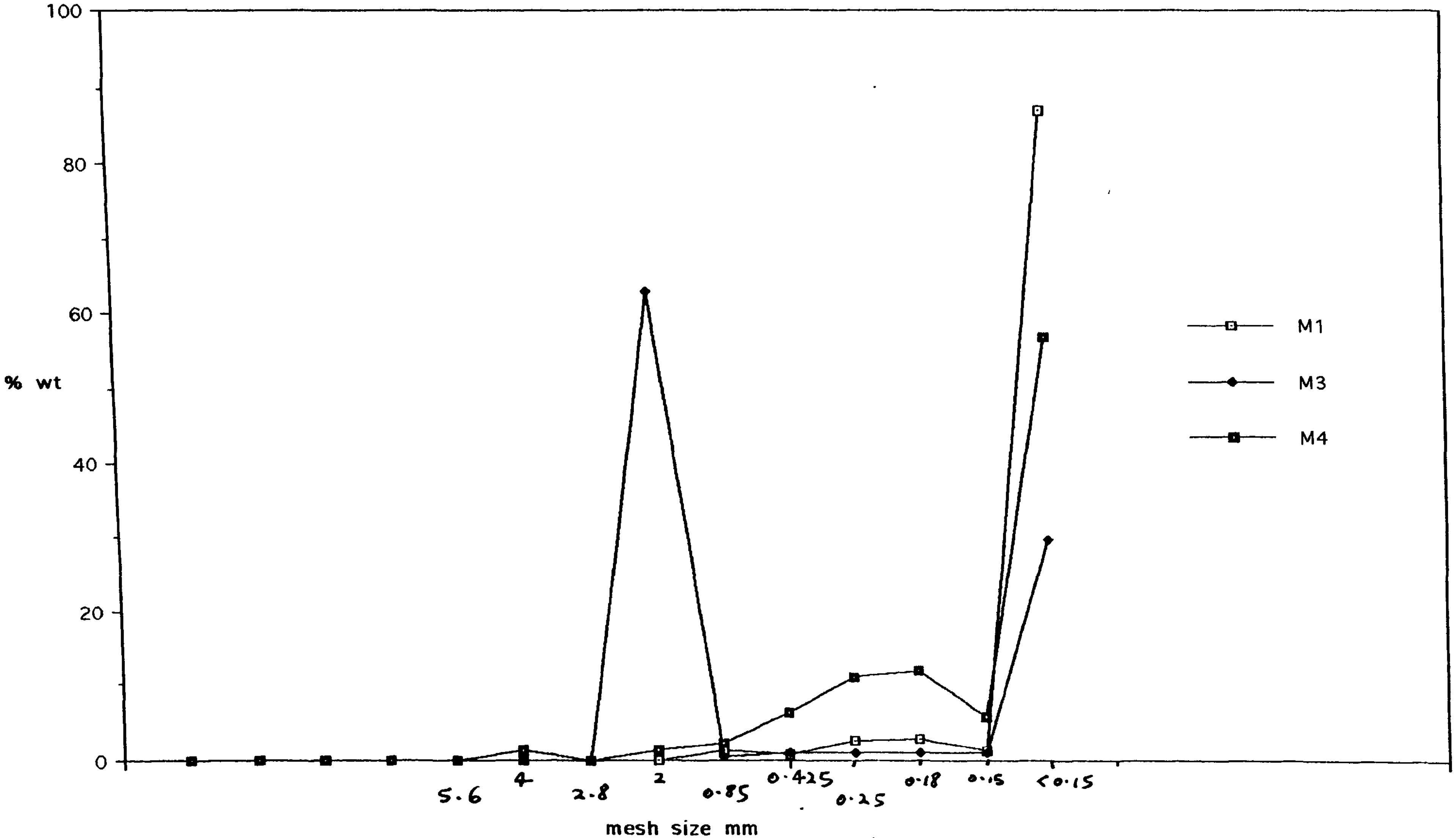


Fig. 157 Wall. 4

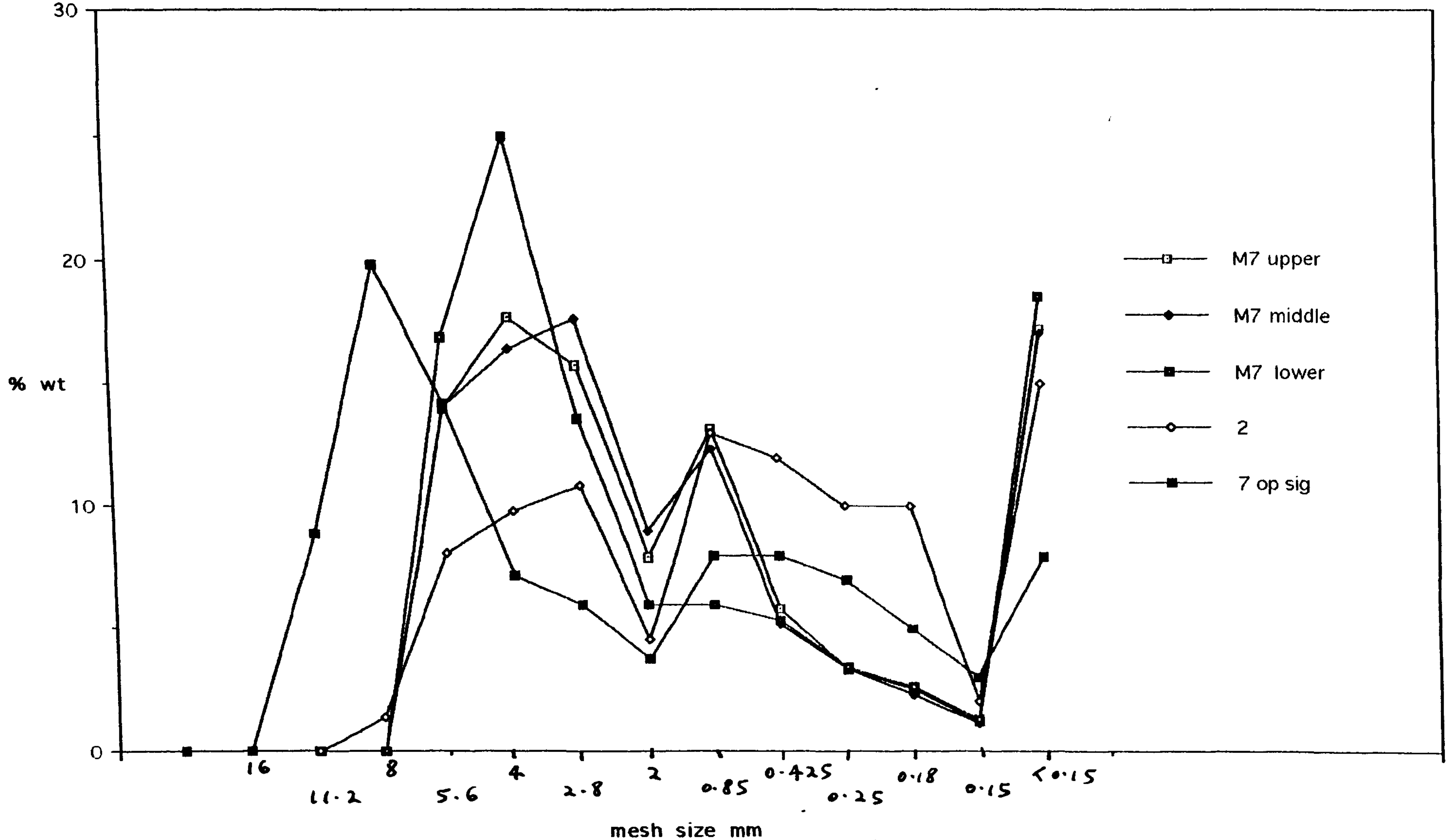


Fig. 158 Wall. 5

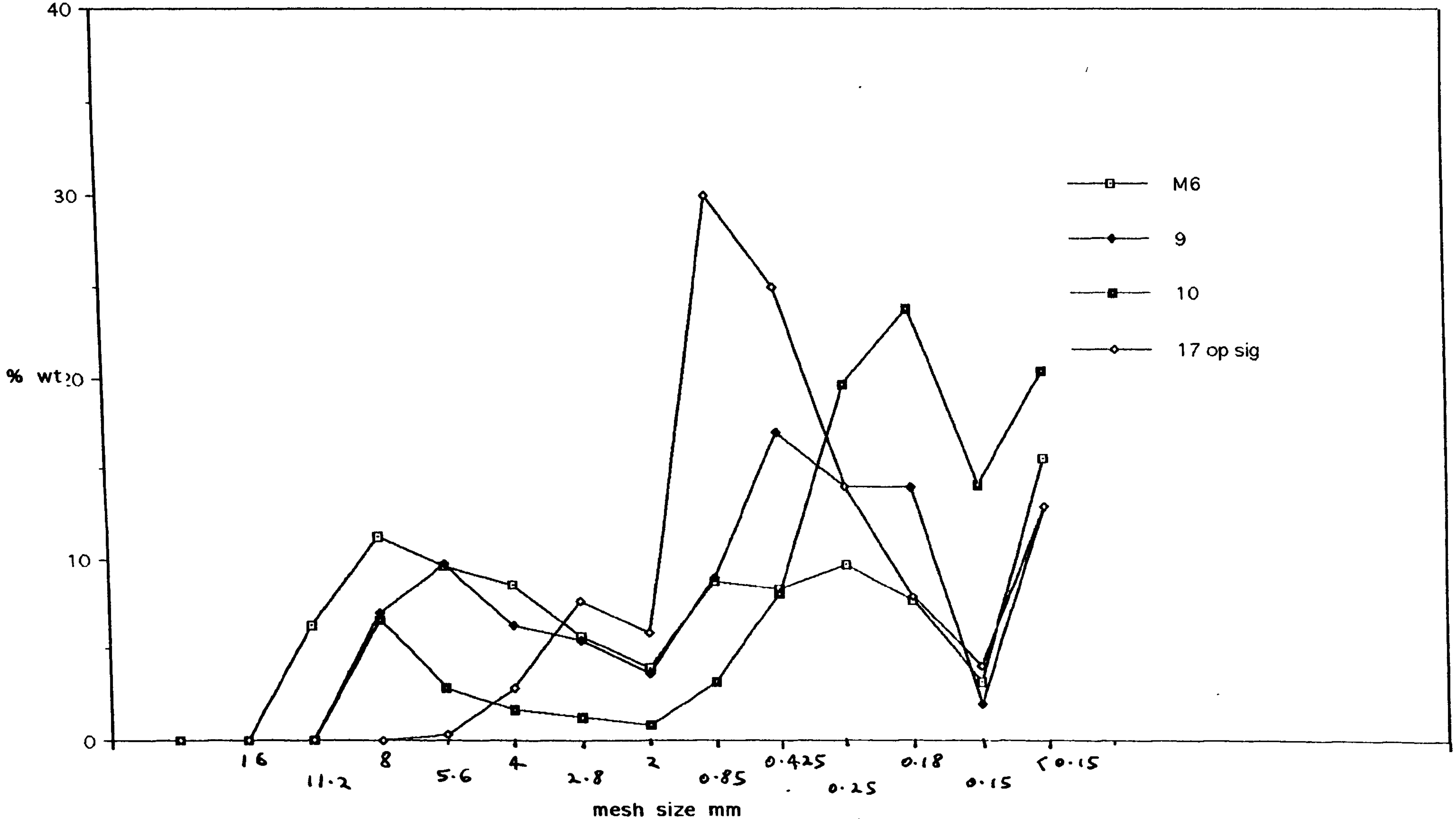


Fig. 159 Wall. 6

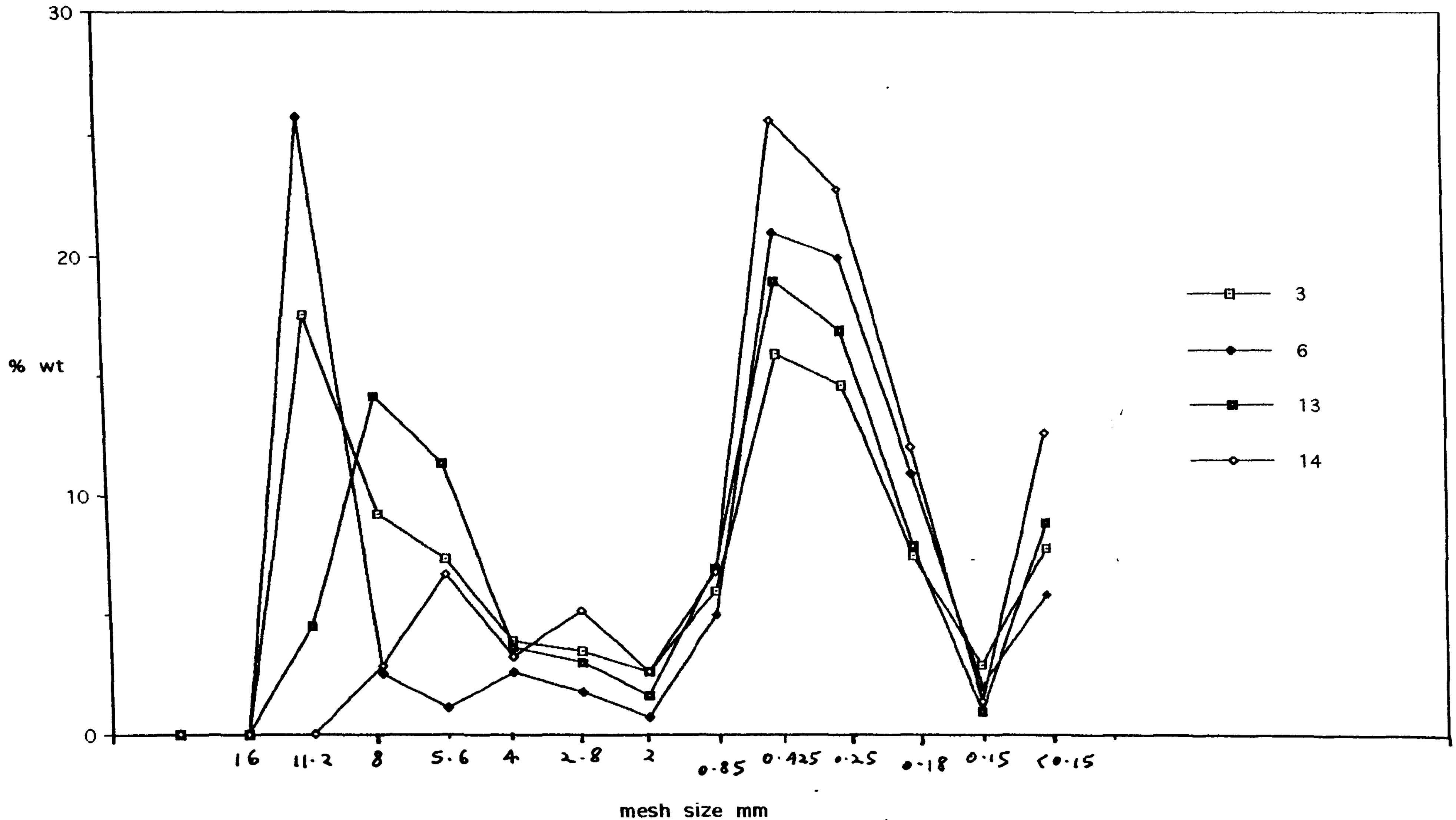
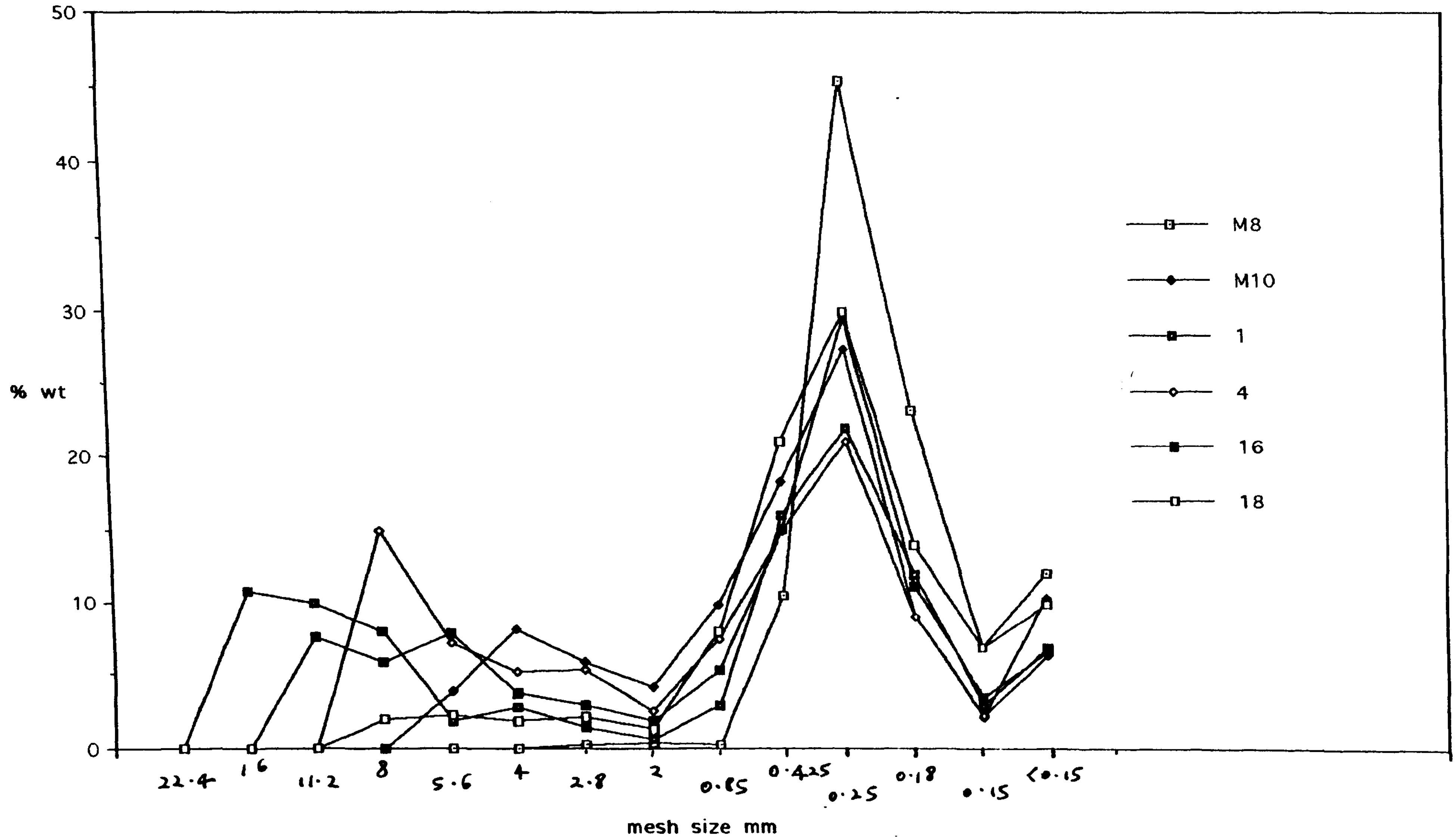


Fig. 160 Wall. 7



Wigginton Roman Villa, Oxfordshire.
Oxford Archaeological Unit - in preparation

The calcareous geological nature of the area was shown by the inclusion of various types of limestone in the aggregates. Some of the "lime" estimates are therefore higher than would expected. The aggregates included: sandy, ferruginous and fossiliferous limestones, quartz sand and crushed brick or tile. Some of the very fine sand was probably derived from the sandy limestones. Sixteen samples were examined and twenty one analyses carried out.

COMPOSITIONS

No	gravel	sand	silt	'lime"	comments
WG 133	0	79	21	63%	floor
WG 823	8	58	34	24%	floor
WG 66	0	36	64	61%	floor
WG 822	25	48	37	36%	under floor
WG 825	1	9	90	75%	floor
WG 824	6	53	41	49%	moulding
WG 600	38	28	34	42%	floor, some tile
WG 746	31	45	24	54%	*opus signinum* type
WG 881	6	53	41	31%	plaster
WG 135	2	39	59	41%	plaster
	-	-	-	84%	red
	-	-	-	66%	*intonaco*
WG 57	1	78	21	69%	plaster
	-	-	-	98%	white
	-	-	-	86%	*intonaco*
WG 803	21	38	41	80%	plaster
WG 879	9	50	41	26%	plaster
WG 556	2	57	41	37%	plaster
WG 707	35	33	32	46%	plaster, *opus signinum*
WG 687	11	43	46	27%	plaster

EXAMPLES OF MORTAR AND PLASTER DESCRIPTIONS

WG 133 floor:
limestone *tesserae* with a red tile mortar grout on a white lime setting, 5mm, on yellow sandy mortar, 15mm thick.

WG 823 floor:
pale sandy mortar with limestone and straw impressions.

WG 66 R 2/7/8 floor?:

pale mortar with red tile fragments on the surface and traces of brown limestone.
WG 822 R7 L5S mortar under floor:
buff mortar with brown limestone.
WG 825 R8 L44 floor:
lime and brown limestone lump.
WG 824 R8 L44 moulding:
traces of yellow sandy mortar with red tile fragments on buff mortar with lime lumps.
WG 600 R16 L2 floor:
red tile fragments on a buff mortar with brown limestone lumps. This sample also contained fragments of re-used painted plaster in the aggregate: blue on black, 0.25mm, on white *intonaco*, 0.5mm, on pale buff sandy plaster traces.
WG 746 R19 L2 floor:
pink tile mortar lump with some sand. Also with this sample was a fragment of wall plaster: tile and sand plaster, 0.4 - 0.5mm, on tile plaster, 11mm thick.
WG 881 room 1 - 4 "slate":
black on white *intonaco*, 0.2 - 0.5mm, on burnished buff sandy plaster with limestone and lime, 37mm thick.
WG 135 /50\ room 4 - 1 "brown red":
trowelled red, 0.2mm, on white sandy *intonaco*, 0.2 - 0.5mm, on yellow sandy plaster, 10mm thick, apparently a flaked layer.
WG 57 room 7 "white":
brushed white, 0.1mm, on sandy white *intonaco*, 0.5 - 0.75mm, on pale yellow sandy plaster in two layers, 20mm + 20mm thick.
WG 803 room 7 "red to brown":
red on white on white *intonaco*, 0.5mm, on buff plaster with lime and chopped grass or straw impressions in two layers, 14mm + 14mm thick. The surface showed traces of blue and green on red , perhaps being splashes from another painting.
WG 879 room 8 - 4 "flesh":
pink on white *intonaco*, 0.5mm, on pink plaster in two layers, 20mm + 26mm thick. The pinkness of the plaster was due to the use of burnt ironstone rather than brick.
WG 707 room 18 - 1 "rose":
white spots on pink, 0.1mm, on tile plaster, 26mm thick. The top 0.75mm of the plaster appeared to be compacted plaster rather than an *intonaco* layer. The pink layer was brick dust and lime.
WG 687 room 18 "grey":

grey on rough white *intonaco*, 1 - 4mm, on heterogeneous sandy plaster with lime and sandstone, 18mm thick.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* method.

PIGMENTS

The pigments used were: red ochre (haematite), crushed red brick or tile dust, yellow ochre (limonite), green earth (glauconite), white lime, carbon as soot or charcoal and Egyptian blue.

Average results

	Thicknesses		"Lime"
floor mortar		-	50%
paint	(0.1 - 0.35)	0.2mm	84% red, 98% white
intonaco	(0.25 - 0.625)	0.5mm	66%
plaster	(4+ - 37)	17mm	51%
		26mm	46% opus signinum

Samples illustrated in the aggregate particle size distribution graphs:
Fig Nos 161 - 163
WG: 66, 57, 133; 707, 746; 135, 823, 824, 687. The three graphs show the distinctive grades used for the aggregates.

Fig. 161 Wigginton 1

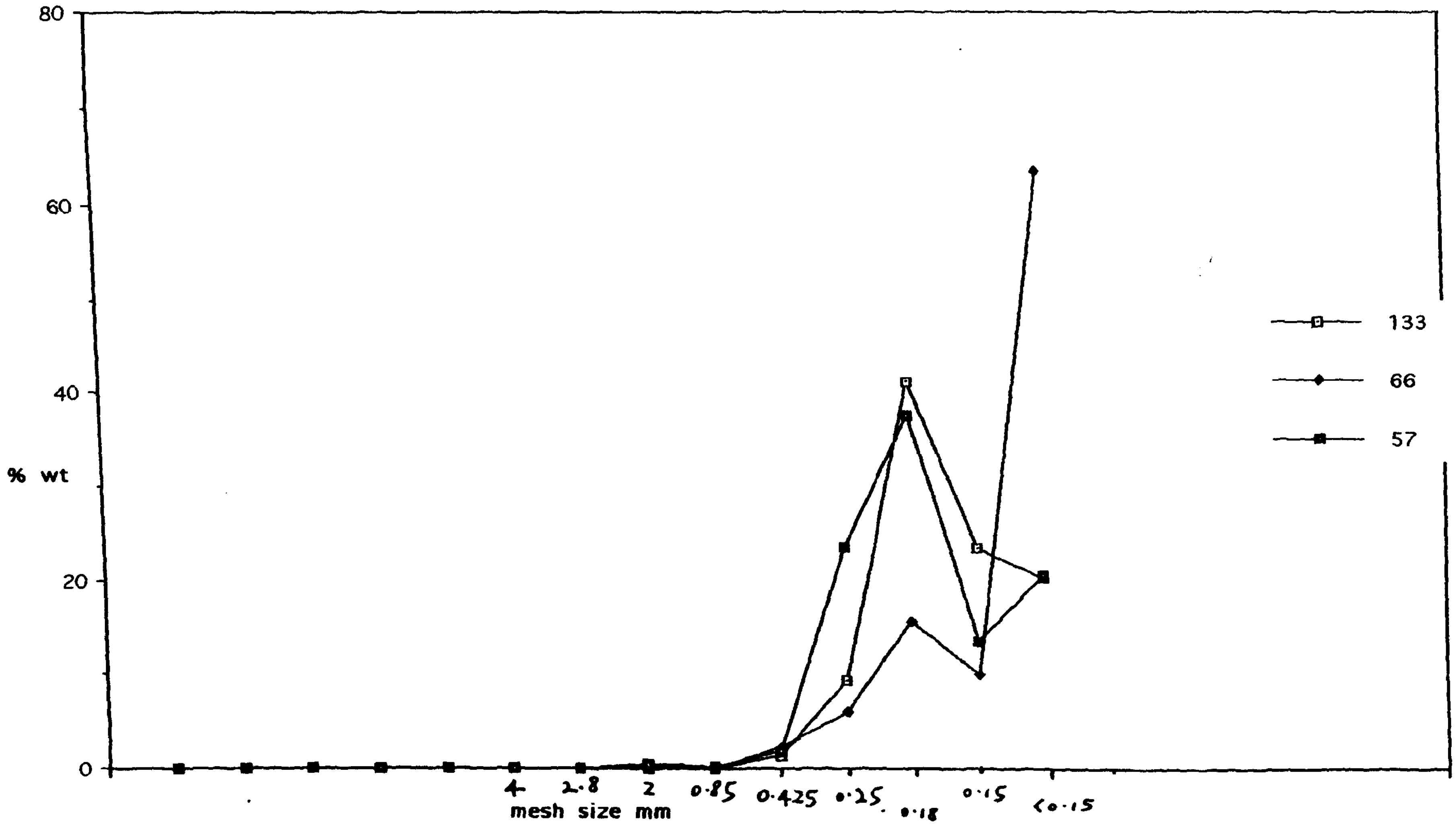


Fig. 162 Wigginton 2

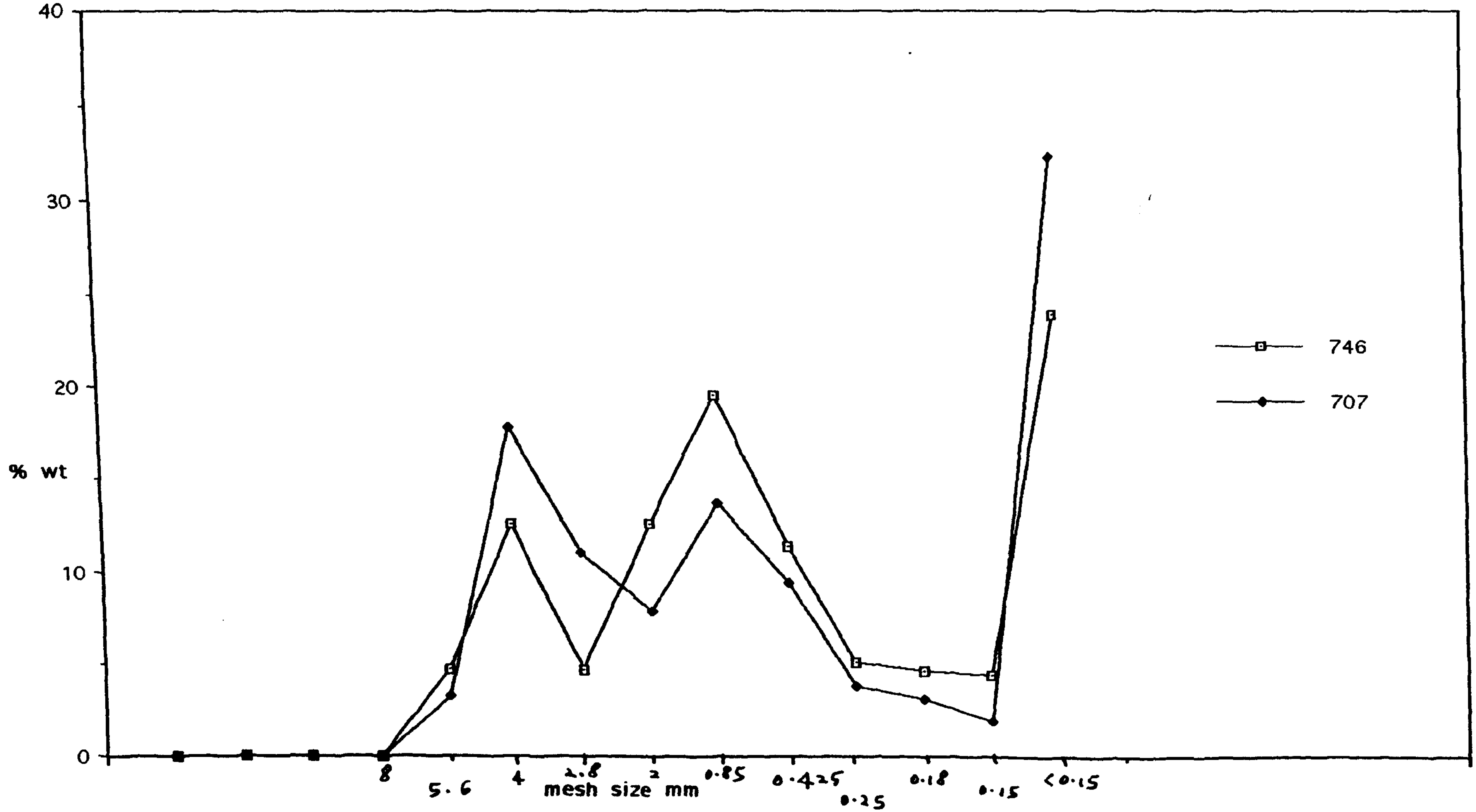
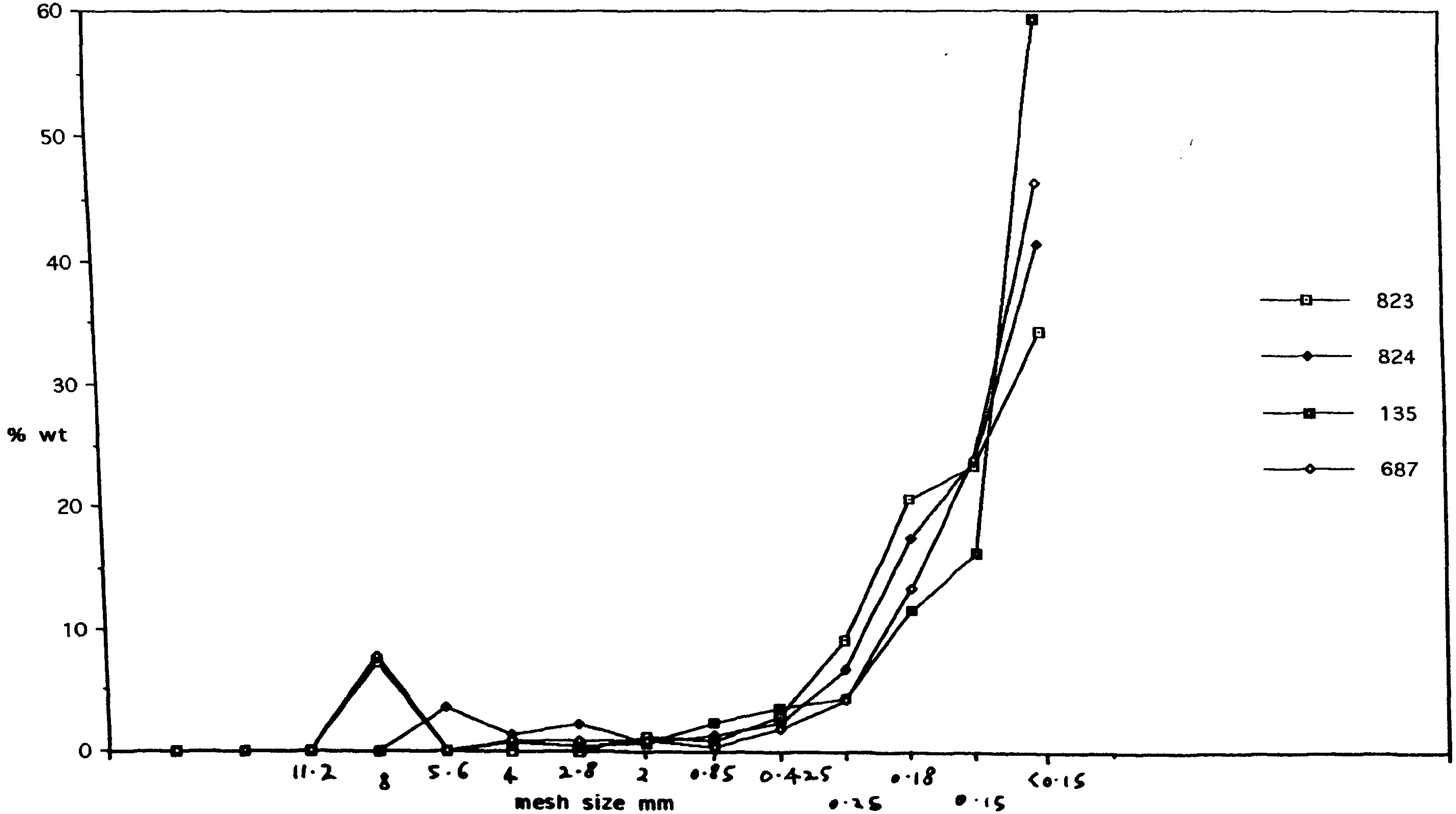


Fig. 163 Wigginton 3



Wroxeter, Staffordshire
Barker 1975
Britannia 1977 8: 394, 396
Webster 1987

The site at Wroxeter with its standing walls has produced finds for many years. Recent excavations by P. Barker and G. Webster have produced vast quantities of material which is still being analysed. Much of the painted plaster and mortar has been visually examined only. The following report is purely a summary of the initial observations.

EXAMPLES OF PLASTER DESCRIPTIONS

1) WP (42B) E185X:
light green, <0.05mm, on sandy white *intonaco*, 0.75mm, on sandy plaster to 20mm thick, possibly layered.

2) WP (26G) D283-1:
light blue, 0.05mm, on yellow on white *intonaco*, 0.5mm, on sandy plaster in two layers, 10mm + 20mm thick.

3) WP (36P) D81-2b:
a) burnished red, 0.05mm, on white with pale grey *intonaco*, 0.3mm, on pink tile plaster, 6mm thick.
b) dark green, 0.05mm, on white *intonaco*, 0.4mm, on coarse sandy plaster, 15mm thick.

4) WP (41R) D332X:
grey with mica on pink tile plaster, 9mm thick.

5) WP (53L) E200X:
white on dark green on black, total 0.05mm, on white *intonaco*, 0.5mm, on pink tile plaster, 11mm thick.

6) W7 79E (51) L1:
red on white and yellow, 0.1mm, on white *intonaco*, 0.6mm, on sandy plaster, 8mm thick.

WP 75 D unassociated:
red* on orange, 0.1mm total, on white *intonaco*, 0.75mm, on sandy plaster in two layers, 7mm + 15mm thick.

WP 81 D111-1e 22G:
polished red* on orange brown, 0.05mm, on white *intonaco*, 0.75mm, on sandy plaster in two layers, 9mm + 6mm thick.

WP 84 (34H) C527:
burnished pink with calcite, 0.5mm, on sandy plaster with tile in two layers, 13mm + 8mm thick.

WP 85 8D D2310 WR 26 a+b:
red on sandy plaster with tile, 7mm, on buff tile plaster, 22mm, on pink tile plaster, 20mm thick.

PAINTING TECHNIQUE

The paint generally appeared to have been applied in the *buon fresco* method. The inclusion of calcite in the paint layer of one sample was of note. The polished cinnabar sample was also of high quality.

PIGMENTS

The pigments included: red ochre (haematite), red* cinnabar, yellow ochre (limonite), green earth (glauconite), white lime, black soot or charcoal and crushed Egyptian blue.

AVERAGE MEASUREMENTS

paint	0.05mm
intonaco	0.6mm
upper plaster layer	10mm
lower plaster layer	14mm
third layer	20mm

Wroxeter, lime sample (ex P. Barker)
Exacavations at Wroxeter also revealed a pit filled with "lime" with the impression of a tank? on its surface. The following is the report on the "lime".
A large off white / cream lump, having a fairly hard skin over a soft core.
The block of calcareous material examined appeared to consist of several pieces of burnt limestone which had slaked together and simply allowed to set. Normally lime would be broken up during slaking to ensure a uniform structure. This lump suggested that it had either slaked itself by absorbing moisture or had water added for slaking and was for some reason abandoned. Analysis of some of the more obvious lumps, weighing about 40g, showed a varying calcium carbonate content. This may in part have been due to burial leaching, but may have represented variations in the composition of the original limestone before burning. If the limestone quarry was bedded, there may have been variation between the top and bottom of the quarry face.
Calcite / carbonate analysis of small samples showed a range from 38 - 85%.

Analysis of a large bulk sample gave an acid soluble content of 93%. The difference between the acid soluble and carbonate content, commonly being about 9%, suggested that the high figure for the carbonate analysis was comparable with the bulk sample. The residue was fine amorphous pale buff powder and white lumps of silica (presumably from fossils) and pale red / orange burnt clay or marl. The whole could have be described as; "carbonated un-mixed non - hydraulic slaked lime". It did not seem that the particular sample was ever in a "lime putty" state, and may not therefore have been exceptionally soft, with regard to the placing of a tank or other object on top of it.

Wyck, Hampshire
Cole 1988

The bath house of the Roman villa at Wyck was discovered in the nineteenth century and re-excavated in 1975 - 6. This produced painted plaster, probably of the third to fourth centuries, of which only one sample was scientifically examined, giving three results. The sample was basically *opus signinum*, and did not therefore reflect the local chalk geology, although the presence of glauconite particles may show the use of lower chalk either as a lime source or as part of the aggregate. The greensand nearby could also possibly have provided some glauconite.

COMPOSITIONS

8)	gravel	sand	silt	"lime"	comments
	-	-	-	86%	*intonaco*
	33	54	13	44%	upper layer
	37	43	20	44%	lower layer

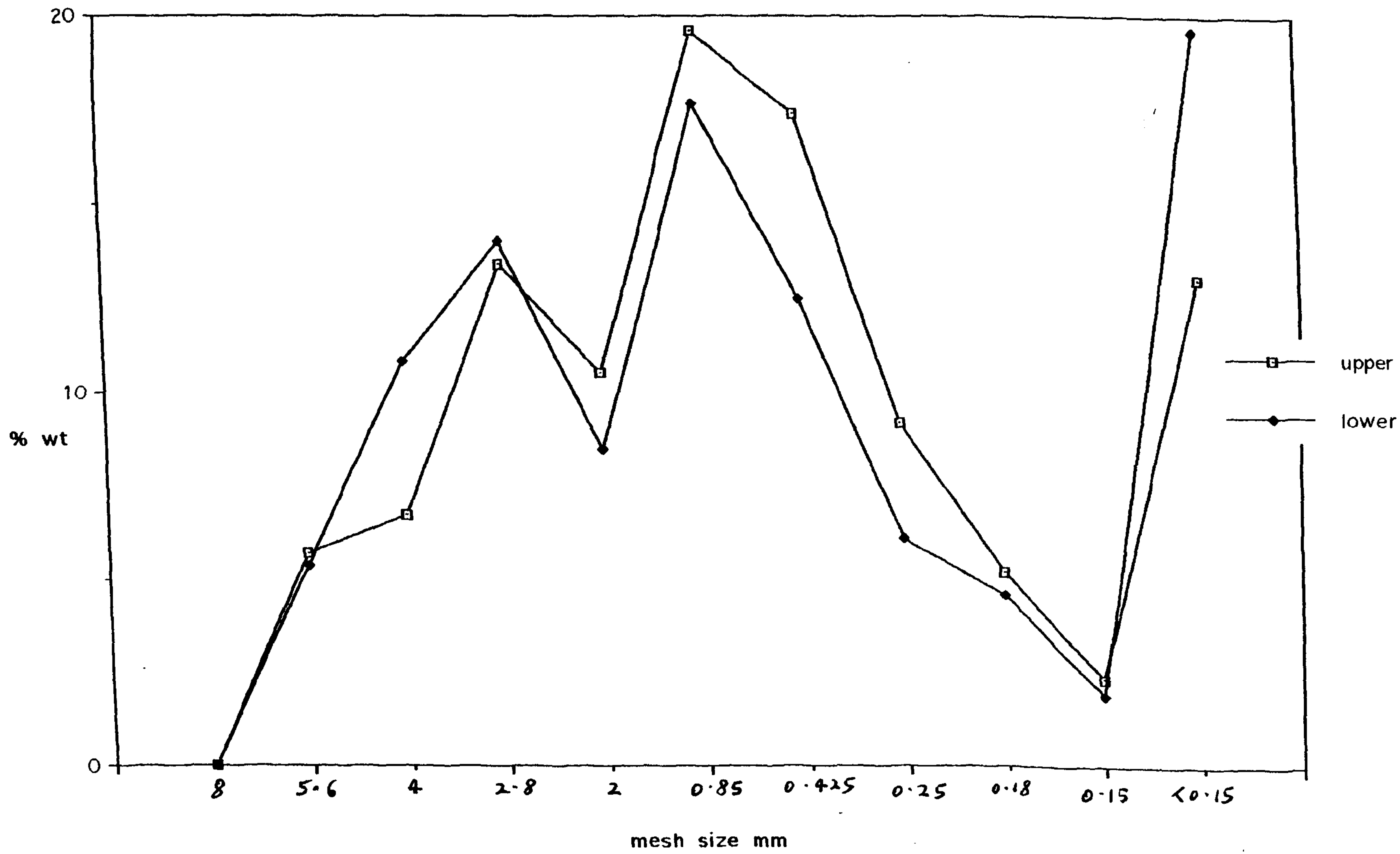
PLASTER DESCRIPTION
8) brushed red, 0.25mm, on white *intonaco*, 0.5mm, on pale pink plaster, 17mm, on dark pink plaster, 10mm thick. The back of the sample was flat, suggesting that it was probably the upper plastered surface and not directly plastered onto the wall. The impressions on other sample showed a probably wooden structure. Cole 1988, 44: 37.

PAINTING TECHNIQUE
The paint was probably applied in the *buon fresco* method. Other samples apparently showed border or panel styles. Cole 1988, 44: 37 - 38.

PIGMENTS
The pigments were red ochre (haematite) and white lime.

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig No. 164
The graphs are typical for poorly graded crushed brick or tile and are virtually identical for both layers.

Fig. 164 Wyck - opus signinum



York, Yorkshire
General Accident Insurance Co. site, 1983 - 4.
York Archaeological Trust: in preparation

Excavations at the above site produced quantities of painted plaster with a range of structures and aggregates. The aggregates included river sands and gravels of two types, perhaps reflecting the convergence of the two rivers at York, with their respective fluvial deposits. (It should be noted that river sand sampling suggested that there may be greater differences within the rivers than between them. Kenward and Williams 1979). The aggregates were identified geologically as: round to angular quartz, quartzite, pale, yellow and red sandstones, mafic minerals, black siltstone with mica, blue grey shale, opaque white chert, silica fossils (crinoids), glauconite and crushed red brick or tile. Many of the samples were discoloured brown or buff, presumably due to burial in the black river silts. This made colour descriptions difficult. Experimental bleaching with hydrogen peroxide lightened the discoloured *intonaco* layers to something approaching their original? white.
Forty two samples were examined and thirty six analyses carried out. These results are unpublished.

COMPOSITIONS

No	gravel	sand	silt	"lime"	comments
1)	-	-	-	89%	secondary *intonaco*
	4	76	20	40%	secondary plaster (graph 2)
	-	-	-	51%	primary *intonaco*
	15	73	12	46%	primary plaster, upper layer (graph 4)
	25	63	12	42%	middle layer (graph 5)
2)	17	65	18	41%	mortar or floor (graph 6)
3)	18	69	13	37%	upper layer (graph 7)
	32	48	20	34%	lower layer, *opus signinum* (graph 8)
4)	18	64	18	42%	window? moulding (graph 9)
5)	-	-	-	96%	*intonaco*
	38	51	11	48%	upper layer (graph 11)
	27	62	11	45%	middle layer (graph 12)
6)	15	68	17	41%	lower layer (graph 13)
7)	35	52	13	42%	mortar (graph 14)
8)	4	80	16	34%	upper layer (graph 15)
	8	76	16	34%	lower layer (graph 16)

9)	7	38	55	92%	plaster around wattle (graph 17)
	-	-	100	94%	oolitic inclusion
10)	12	66	22	32%	single layer (graph 20)
11)	25	53	22	35%	upper layer (graph 21)
12)	37	44	19	39%	upper layer, *opus signinum* (graph 23)
	40	39	21	36%	lower layer, *opus signinum* (graph 24)
13)	50	36	14	34%	single layer, *opus signinum* (g 25)
14)	-	-	-	86%	*intonaco*
	8	73	19	27%	upper layer (graph 27)
	21	58	21	39%	lower layer (graph 28)
15)	11	79	10	40%	single layer (graph 29)
16)	27	60	13	57%	single layer with straw (graph 30)
17)	40	48	12	42%	single layer (graph 31)
18)	18	71	11	40%	single layer (graph 32)
19)	21	63	16	35%	single? layer (graph 33)

EXAMPLES OF PLASTER DESCRIPTIONS

1984. 32

1) 2273 II:

brushed or trowelled buff *intonaco*, 0.6 - 0.75mm, on sandy buff plaster, 5mm, on black on rough sandy brown *intonaco*, 1mm, on buff sandy plaster, 9mm, on coarse sandy plaster, 12mm, on mud? with straw impressions - traces only. This was an over-plastered sample.

2) 1415 I:

thick mortar on pebble backing - floor?, 30mm thick.

3) 2012 II:

white plaster, 15mm, on pink tile plaster, 35mm thick.

4) 2361 II:

window or similar edge moulding; off white, 0.1mm, on brown *intonaco*, 0.5mm, on buff sandy plaster, 30mm thick.

5) 2318 II:

white spots and lines, 0.1mm, on brown on hard buff *intonaco*, 1mm, on coarse buff plaster, 23mm, on coarse buff plaster, 18mm, on fine buff plaster with straw and wattle impressions, 10mm thick. Also present with this sample was a piece of: burnished red, 0.05mm, on buff *intonaco*, 0.5mm, on buff sandy plaster, 12mm thick.

6) 1406 I:

black with traces of mica, 0.05mm, on buff *intonaco*, 0.5mm, on sandy plaster, 3.5mm, on coarse sandy plaster with straw impressions, 16.5 - 26.5mm thick.

7) 1406 I part 2:
very coarse mortar lump.
8) 1158 I:
green on brown and brown on red* on pink, 0.1mm total, on white *intonaco*, 0.5 - 1mm, on sandy plaster in two layers, 11mm + 7mm, on coarse plaster in two layers, 7mm + 11mm. Also samples with: green on white, dark green on black on pale green and pink on pale green on white, brown on yellow, red on yellow, red on pink and pale green on white and dark red on light red.
9) 4161 IV:
fine buff plaster with straw impressions around wattle casts, 35mm thick. The plaster included a piece of calcined? oolitic limestone which was analysed separately. Similarly: 2420 /2132\, which was almost identical in nature with 9); black, 0.1mm, on buff, 0.1mm, on black on buff *intonaco*, 3.5 - 4mm, on coarse brownish coarse plaster in a single? layer, 12 - 18mm, on fine buff plaster with wattle and plank? impressions, 20mm thick. The plank impression was 88mm wide.
10) 2062 II:
a single green spot on white *intonaco*, 0.5 - 0.75mm, on a single layer of pale coarse plaster, 26mm thick.
11) 3112 III:
red brown on yellow, 0.05mm, on white *intonaco*, 1mm, on sandy plaster, 10mm, on sandy plaster, 3+mm thick. Also other samples with: grey and red on yellow, red on grey on pink on white, dark red on white and dark yellow on pale yellow on white.
12) 3099 III:
pale pink tile plaster on a brown sand and tile mortar or plaster wedge shaped lump. This may have been the infill of an irregularity in a wall with a finishing coat applied on top.
13) 3052 III:
rough white *intonaco*, 1 - 2mm, on pale pink tile plaster, 23mm thick.
14) area 2 2095:
black stripe on white *intonaco*, 1.5 - 2mm, on sandy plaster, 13mm, on coarser plaster, 15mm thick.
15) 2342 II:
black stripe on buff to yellow, 0.2mm, on buff *intonaco*, 0.7mm, on coarse plaster, 8mm thick. A flaked layer c.f. 1).
16) 1406 I:
buff mortar or plaster lump with some tile and straw impressions.
17) 1406 I:
dirty buff *intonaco*, 1mm, on buff coarse plaster, 25mm thick.

18) coarse sandy plaster with a very rough surface due to added? sand grains, 15mm thick. A flaked layer.
19) 1981. 12 1239 AQ11:
white on black on burnished red brown on pink, 0.1mm, on white *intonaco*, 1 - 1.5mm, on coarse sandy plaster possibly in two layers, 30mm total thickness.
Other samples included:
1984. 32:
2489; partly burnished white on green on red, 0.1mm, on grey *intonaco*, 1mm, on coarse sandy plaster, 11mm, on coarse sandy plaster, 3+mm thick.
2320 II; red brown on yellow on buff *intonaco*, 0.5mm, on coarse plaster, 10mm, on coarser plaster, 6+mm thick. c.f 5).
4155 IV; dark green with blue on grey to white *intonaco*, on pale sandy plaster. c.f. 10).
3347 III; burnished black, 0.1mm, on buff sandy plaster, 0.5mm, on coarse plaster, 5.5mm, on plaster with pebbles, 24mm thick.
3113 III /2615\; red on blue on grey, 0.1 - 0.2mm, on buff *intonaco*, 0.6mm, on sandy plaster, 3+mm thick. A flaked layer.
2420 II; brushed buff *intonaco*, 1.5 - 2mm, on buff plaster, 3 - 3.5mm, on coarse buff plaster, 10mm thick. c.f. 1)
1981. 12:
1241 I AQ 14; green on black on buff *intonaco*, 1 - 1.5mm, on coarse sandy plaster, 10mm thick.
1220 I AQ 14; white spot on yellow on red on white *intonaco*, 1mm, on coarse sandy plaster, 18mm thick.
1264 I; red on white on white *intonaco*, 1 - 1.5mm, on white sandy plaster, 8mm, on brownish coarse plaster, 10mm thick.
1983. 32 1139 ARCH I; brushed red* on pink, 0.05mm, on white *intonaco*, 0.5 - 1mm, on sandy plaster in two layers, 10mm + 10mm thick. c.f. 1158. Also: very dark red on pink on white *intonaco*, 1mm, on layered? plaster, 12+ 8mm thick. This appeared to be a floor or ceiling edge as it had an irregular section.
1983. 32 1308 U/S I; red on white *intonaco*, 1 - 1.5mm, on *opus signinum* plaster, 18+mm thick. Also a sample of: finely burnished red, 0.1mm, on grey to buff *intonaco*, 0.5mm, on coarse sand plaster, 11+mm thick.

PAINTING TECHNIQUE

The paint appeared to have been applied in the *buon fresco* method. It was possible that over painting had been applied in the fresco secco technique. Some of the burnishing was very fine, in particular the black.

PIGMENTS

The pigments used were: red ochre (haematite), red* cinnabar, red brick or tile dust, yellow ochre (limonite), green earth (glauconite), crushed Egyptian blue, white lime and carbon as soot or charcoal. The cinnabar was not burnished and had a pink or white ground not yellow as had been seen on other samples.

<u>Average results</u>

	<u>Thicknesses</u>		<u>"Lime"</u>	
paint	(0.05 - 0.25)	0.1mm	-	
intonaco	(0.1 - 4)	1mm	81%	
plaster		5mm	40%	secondary
	(4 - 30)	14mm	39%	upper layer
	(4 - 30)	15mm	40%	middle layer
		10mm	57%	lower with straw
		35mm	92%	wattle impressed
	(15 - 19)	17mm	38%	upper *opus signinum*
		35mm	35%	lower *opus signinum*
mortar or floor		50mm	42%	

sand density - 1.7g/cc
tile density - 1.1g/cc

<u>Samples illustrated in the aggregate particle size distribution graphs</u>:
Fig Nos 165 - 172
(1) 15, 16; (2) 2, 21, 33; (3) 8, 23, 24, 25; (4) 4, 5, 6, 7, 9, 11, 12, 13, 14, 17, 20, 27, 28, 29, 30, 31, 32.
The graphs show the four main groups of aggregates.
(1) Two identical samples of fine sand.
(2) Two grades of sand.
(3) crushed tile or brick - *opus signinum*.
(4) The main sample group.

Fig. 165 York 1

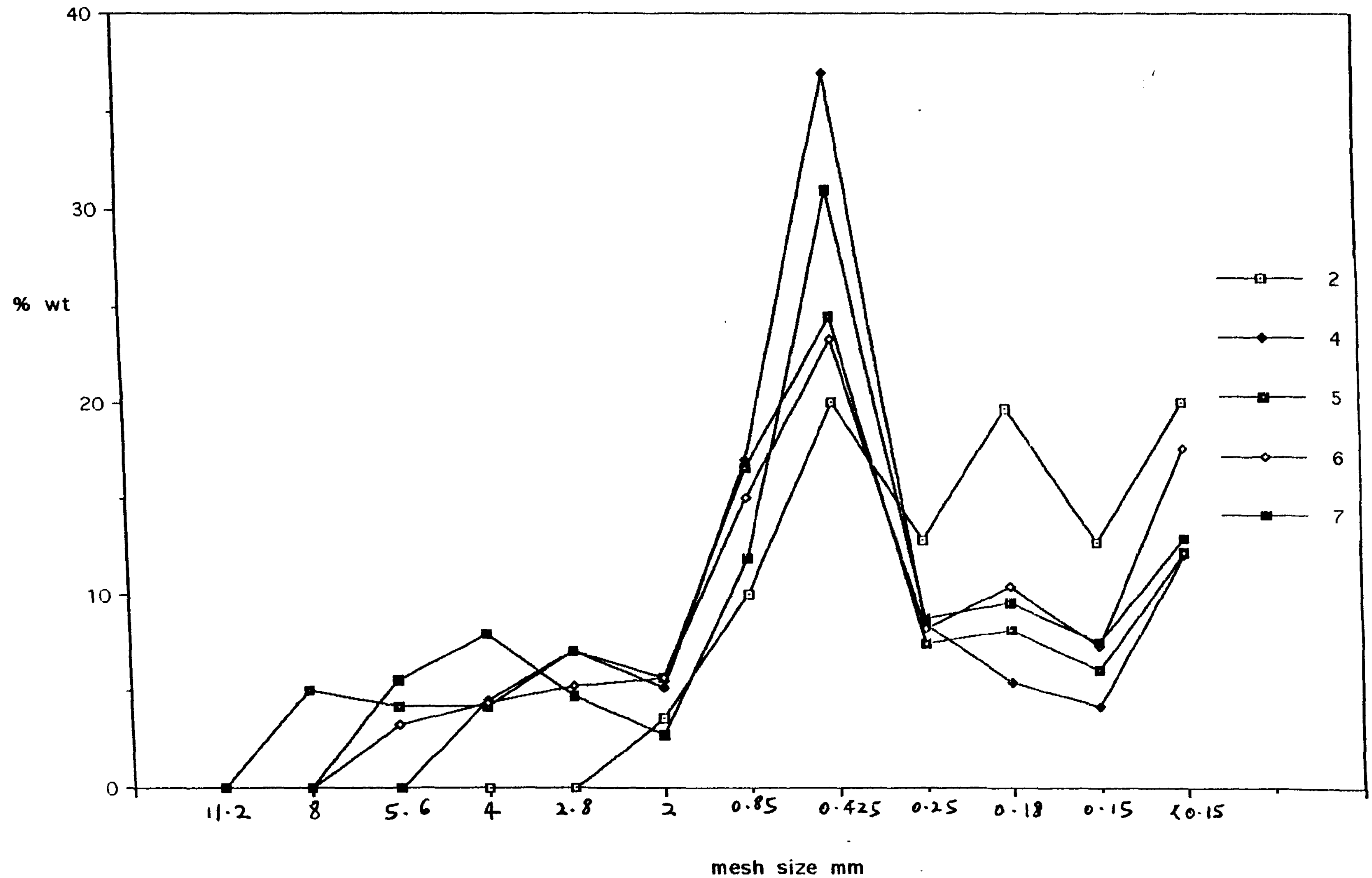


Fig. 166 York 2

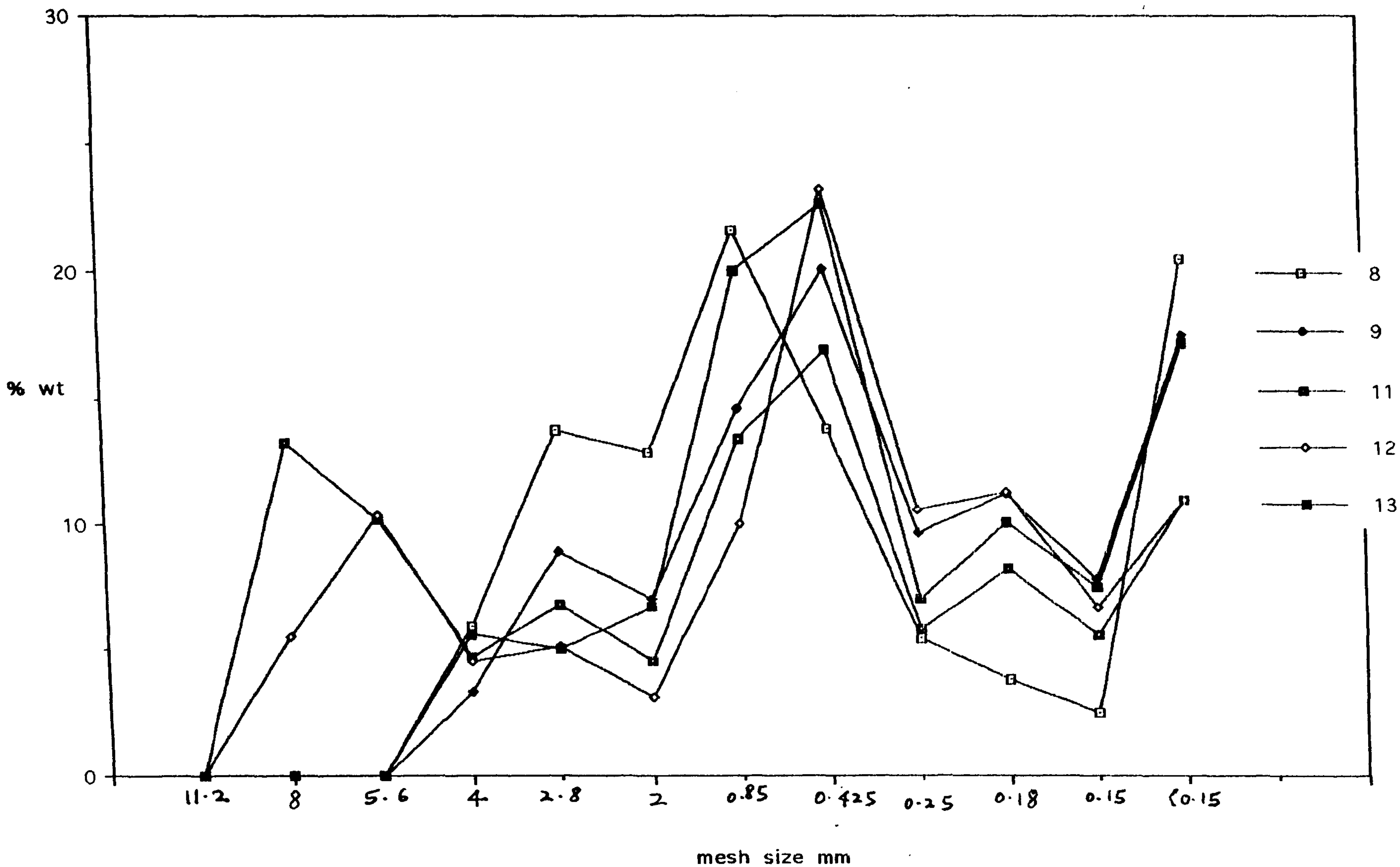


Fig. 167 York 3

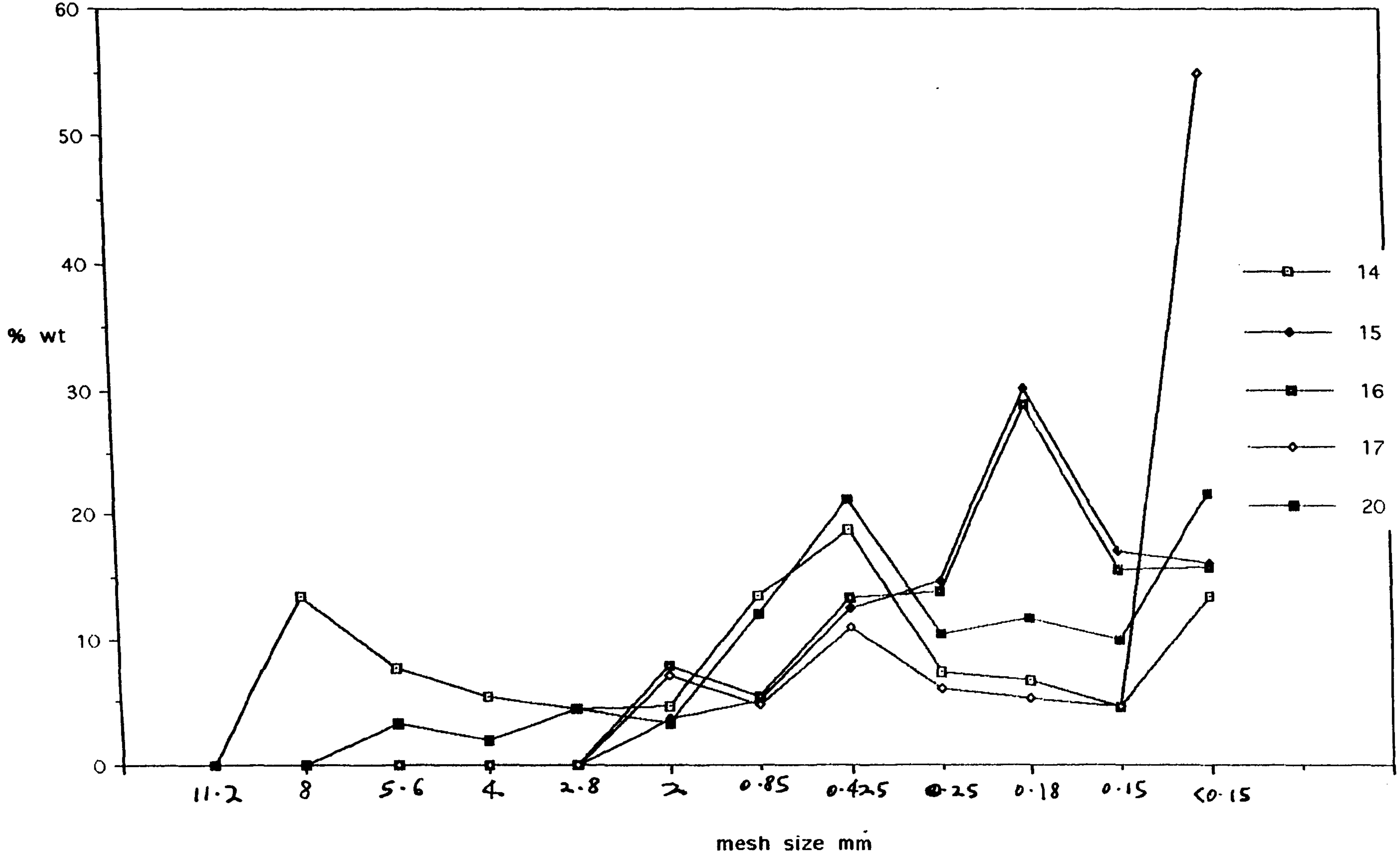


Fig. 168 York 4

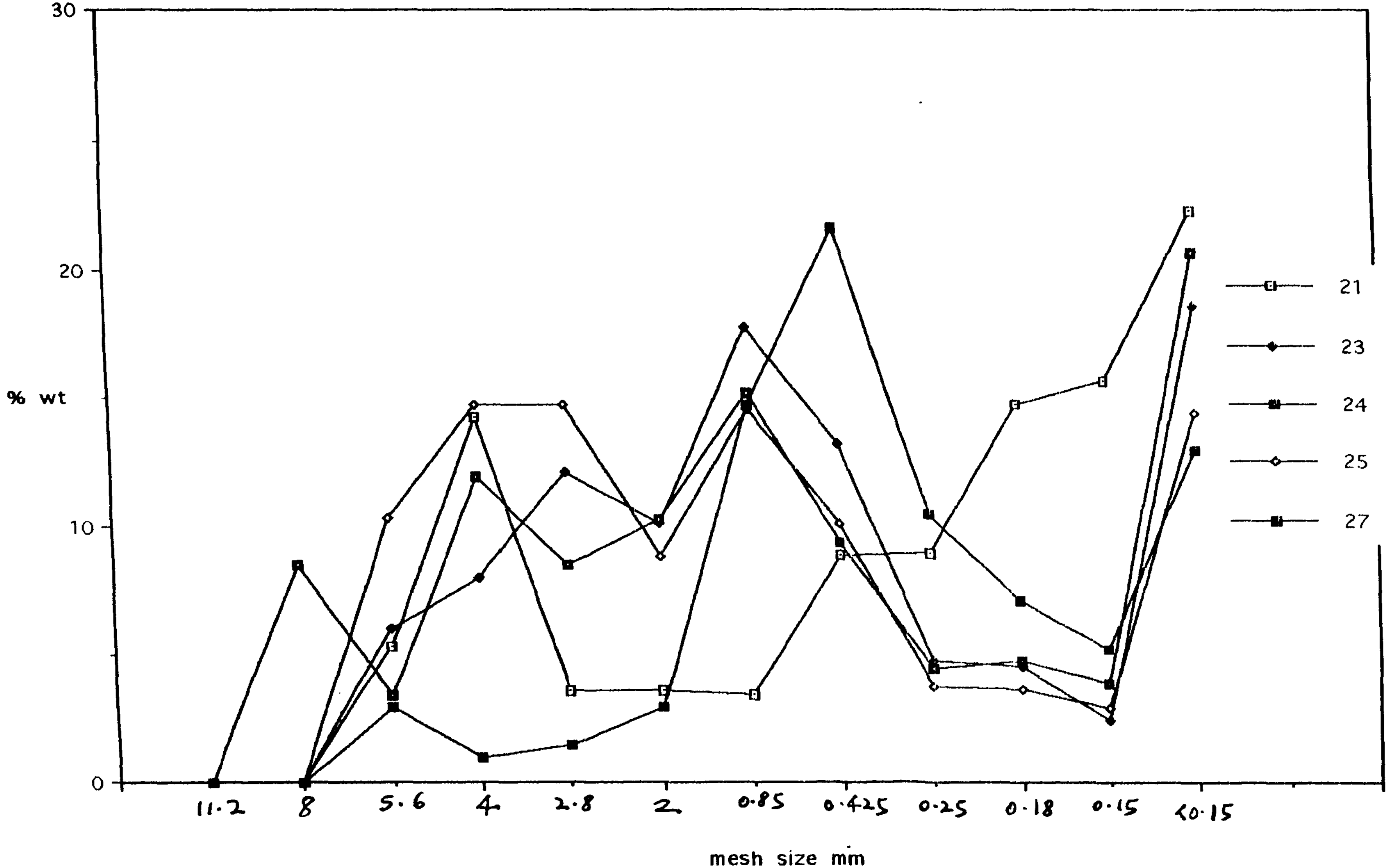


Fig. 169 York 5

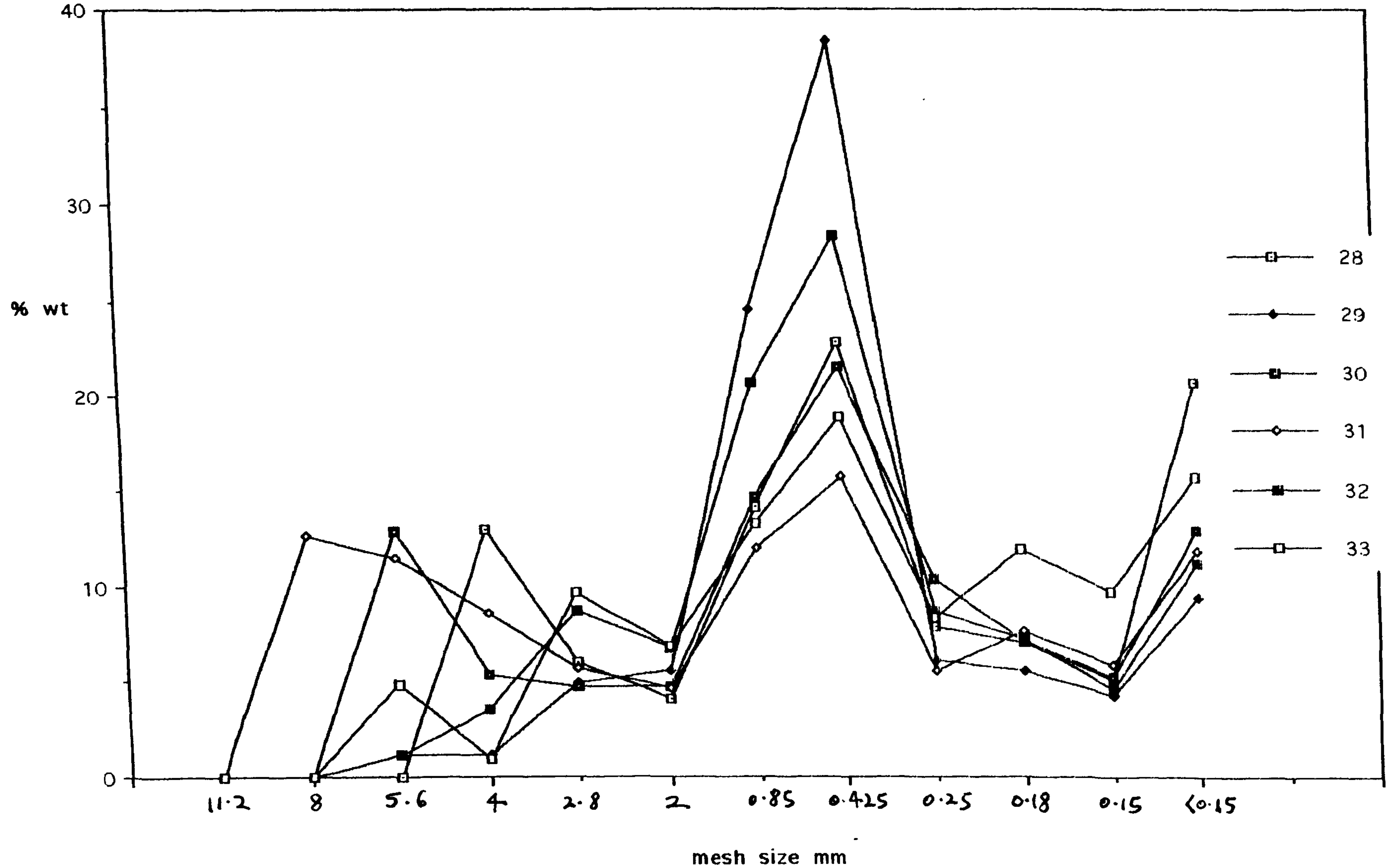


Fig. 170 York - opus signinum

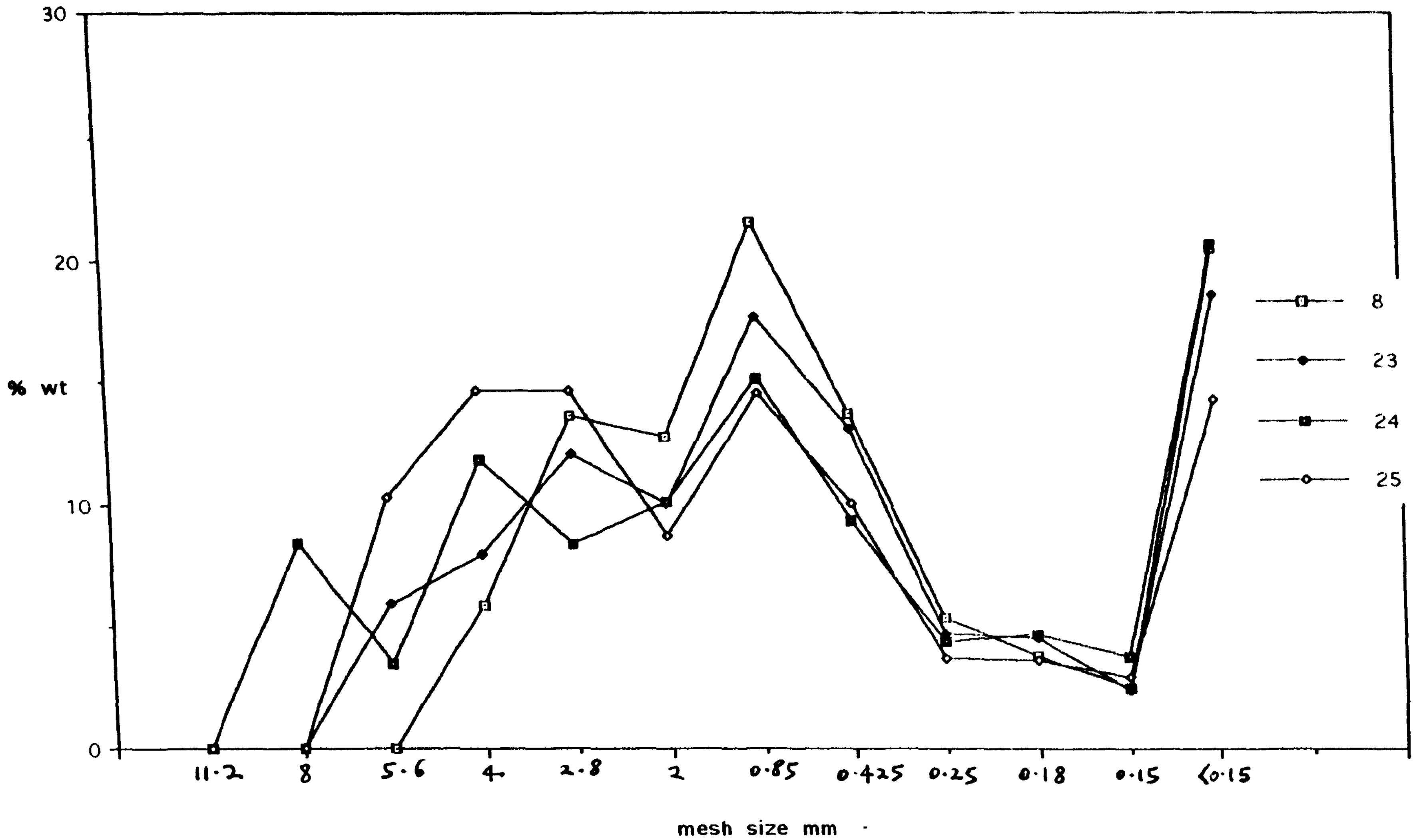


Fig. 171 York - two grades

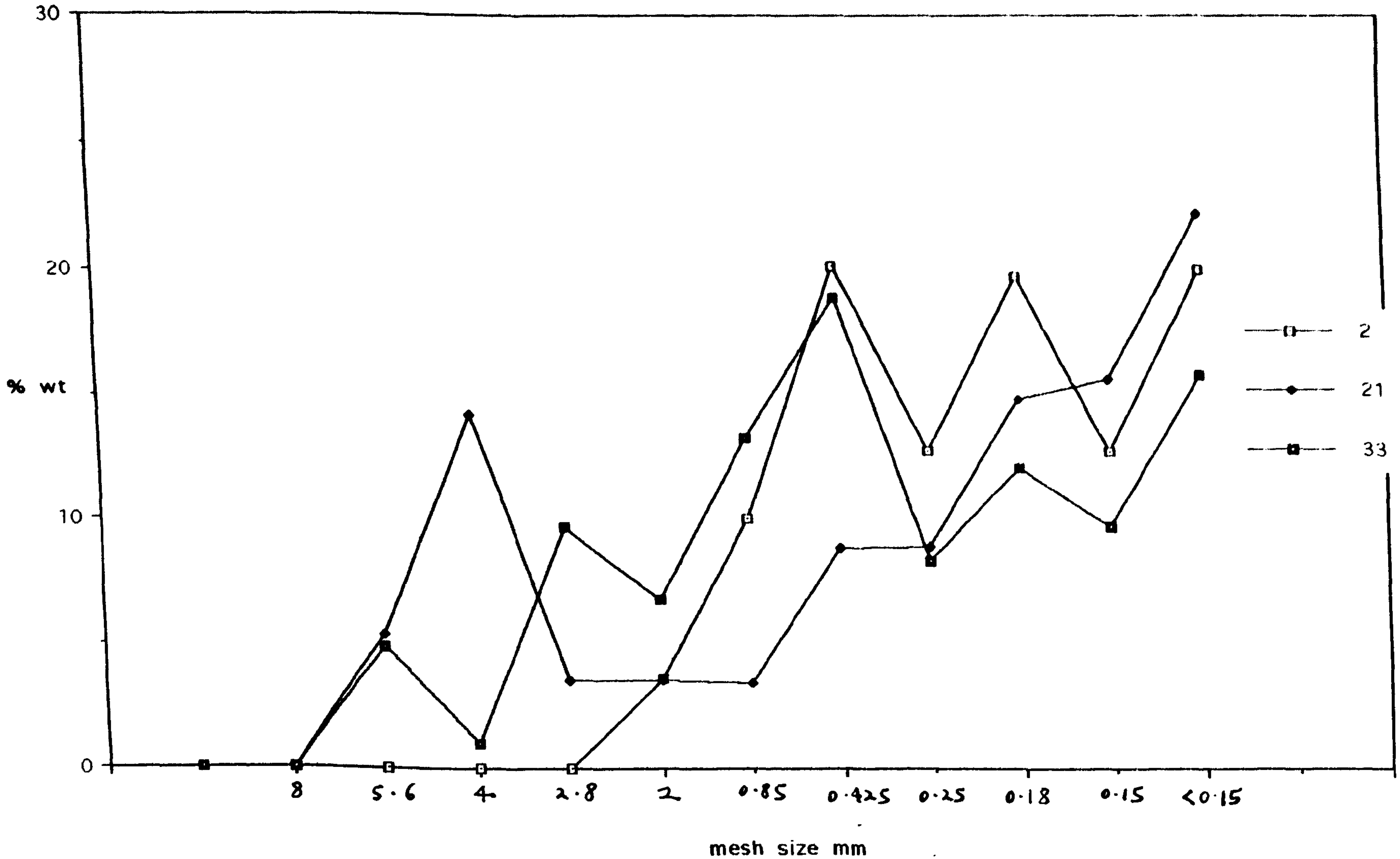
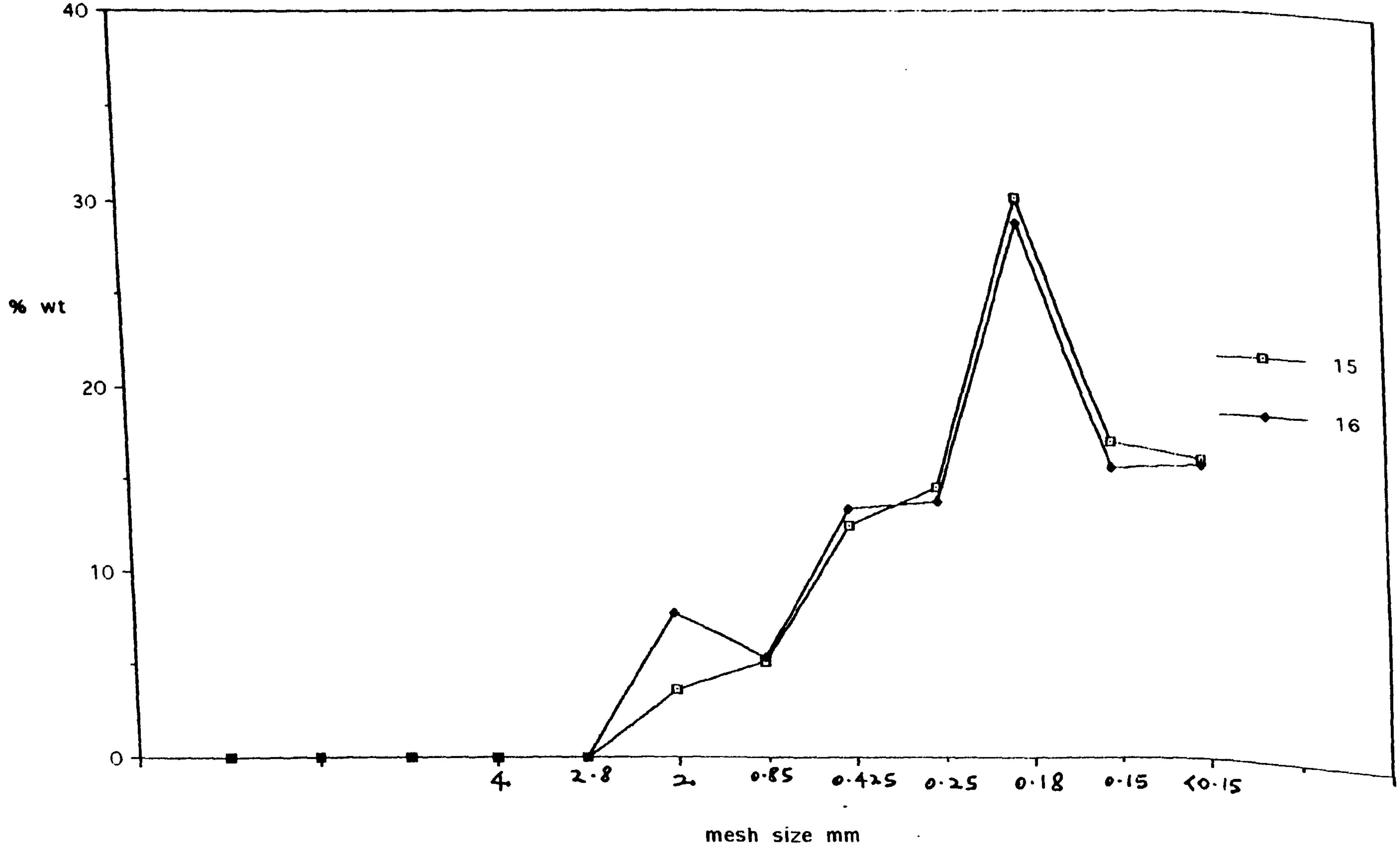


Fig. 172 York - fine sand



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