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Age of the Auckland Volcanic Field

Jan Lindsay and Graham Leonard

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INTRODUCTION

In 2008 a multi-disciplinary research programme was launched, a GNS Science – University of Auckland collaboration with the aim of **DE**termining **VO**lcanic **R**isk in **A**uckland (DEVORA). A major aspiration of DEVORA is development of a probabilistic hazard model for the Auckland Volcanic Field (AVF). This will be achieved by investigating past eruption magnitude-frequency relationships and comparing these with similar data from analogous volcanic fields. A key data set underpinning this is an age database for the AVF. To this end a comprehensive dating campaign is planned as part of DEVORA. This report, *Age of the Auckland Volcanic Field*, is a synthesis of all currently available age data for the AVF. It represents one of several reports carried out as part of the 'synthesis' phase of DEVORA, whereby existing data from all previous work is collated and summarised, so that gaps in current knowledge can be identified and addressed.

PROJECT OBJECTIVES

Determining eruption magnitude-frequency relationships in volcanic regions is a critical first step in assessing volcanic hazard (e.g. Condit and Connor 1996; Conway et al. 1998; Connor et al. 2006). Such analysis has been hampered in the AVF due to a lack of reliable age data. Carbonised material is rare and many centres are older than 40,000 years, thus limiting the use of ^{14}C dating. Early attempts to date Auckland lavas using the K-Ar technique revealed excess Ar, making the lavas appear older than they are (e.g. McDougall et al. 1969). The tephra record obtained from drilling the paleolake sediments of Auckland's maars is providing excellent interpolated ages for basaltic AVF tephras. However, as yet only a few tephras retrieved from these cores have been reliably correlated to individual centres (e.g. Rangitoto tephra in Pupuke core; Crater Hill tephra in Pukaki core, Mt Wellington tephra in Panmure core). This is due in part to poor age control of the individual volcanoes of the field. Recent Ar-Ar dating of AVF basalts has yielded promising results (e.g. Cassata et al. 2008), and future dating using this technique promises to fill many of the gaps in the chronology of the field.

Attempts in recent years to model probabilistic hazard in Auckland (e.g. Magill et al. 2005) have drawn attention to the lack of good age control. Clearly a comprehensive dating programme is needed to fill the gaps and provide reliable data for future models. In this report our aims are:

- to present a summary of all currently available radiometric ages for the AVF;
- to provide a thorough re-evaluation of all these ages, including an assessment of their reliability;
- to present calibrated ages for the >70 ^{14}C ages available for the AVF so as to enable comparison with ages determined by other techniques;
- to present a summary of minimum ages for those explosion craters/maars that have been drilled as part of the maar drilling programme;
- to provide, where possible, best estimate ages for all centres of the AVF based on both published and unpublished ages; and
- to identify priorities for future dating campaigns.

This synthesis will serve as a baseline from which to launch the DEVORA dating programme, as well as a preliminary framework for the correlation of tephra layers from drill cores with their source volcanoes.

METHODOLOGY

We have reviewed all published literature that reports ages of volcanic rocks in the AVF, and have tracked down as many unpublished age data as possible. Where the same age was reported in several different publications, we have attempted to go back to the original source. In doing this, we have identified several instances of typographical errors in papers subsequent to the original, which, in some cases have been propagated in literature to the present day. These cases are referred to in the age database in Appendix 1. For ^{14}C ages we also queried and cross-checked with the Fossil Record Database (FRED; http://www.fred.org.nz), and extracted the Fossil Record Number. Where dated samples were also recorded in the PETLAB database (http://pet.gns.cri.nz) we extracted the PETLAB collection number and cross-checked with FRED and the literature. In almost all cases the ages lodged in PETLAB are different from those in the original literature. In the case of K-Ar ages this likely relates to an adjustment made to all the ages derived in the 1960s and early 1970s based on the recommended Steiger and Jäger (1977) decay constant (Nick Mortimer, written comm. 2009). The reason for the differences in ^{14}C ages probably relates to recalculations of pre-1977 ages carried out in the 1990s (discussed in detail below). All variations on a single age determination are presented in Appendix 1.

In this report 'age' is used to refer to a time before present. The terms 'date' and 'dated' refer to a scientific result and are abbreviations of 'age date determination'. The alternative meaning of 'date' as in a specific year (e.g. the year 1946) is not used in this report.

GEOLOGICAL FRAMEWORK

The AVF is a small-volume, intraplate monogenetic-cone-dominated basaltic field (Figure 1) located within New Zealand's largest city, Auckland (population 1.3 million). Activity in the field has occurred from at least 49 scattered eruption centres in the form of maars, scoria cones and tuff rings over the past ca. 250,000 years. The most recent eruption produced the largest volcano in the field, Rangitoto, about 600 years ago.

Eruptions have typically progressed from explosive to effusive over the lifetime of a volcano. Where the magma initially interacted with sufficient groundwater or surface water, a maar volcano formed, with a wide low tuff ring around the vent. Examples preserved in the AVF include Panmure, Onepoto, Hopua and Orakei Basin. Dry explosive volcanism produced scoria and/or finer tephras, and dry effusive activity, typical in the late stages of some eruptions, led to the development of lava flows. While tuff rings and scoria cones form in and around the vent, lava flows and tephra falls may extend for some distance from the vent. Not all volcanoes exhibit all of these features.

The tephra record that is emerging from maar drilling (e.g. Molloy et al. 2009), together with recent paleomagnetic and Ar-Ar results (e.g. Cassidy and Locke 2004; Cassidy 2006; Cassata et al. 2008), is providing growing evidence that past activity in the field has not been regular. Volcanoes may have erupted in clusters over time, followed by long quiet periods. In particular, multiple tephra layers in the period 25,000 to 35,000 years BP indicate a period of high activity in the field during this time period. In contrast very little has occurred in the last 10 thousand years; since the eruptions of Mt. Wellington and Purchas Hill around 10 kyr ago the only known activity has been from Rangitoto, ca. 600 years ago.

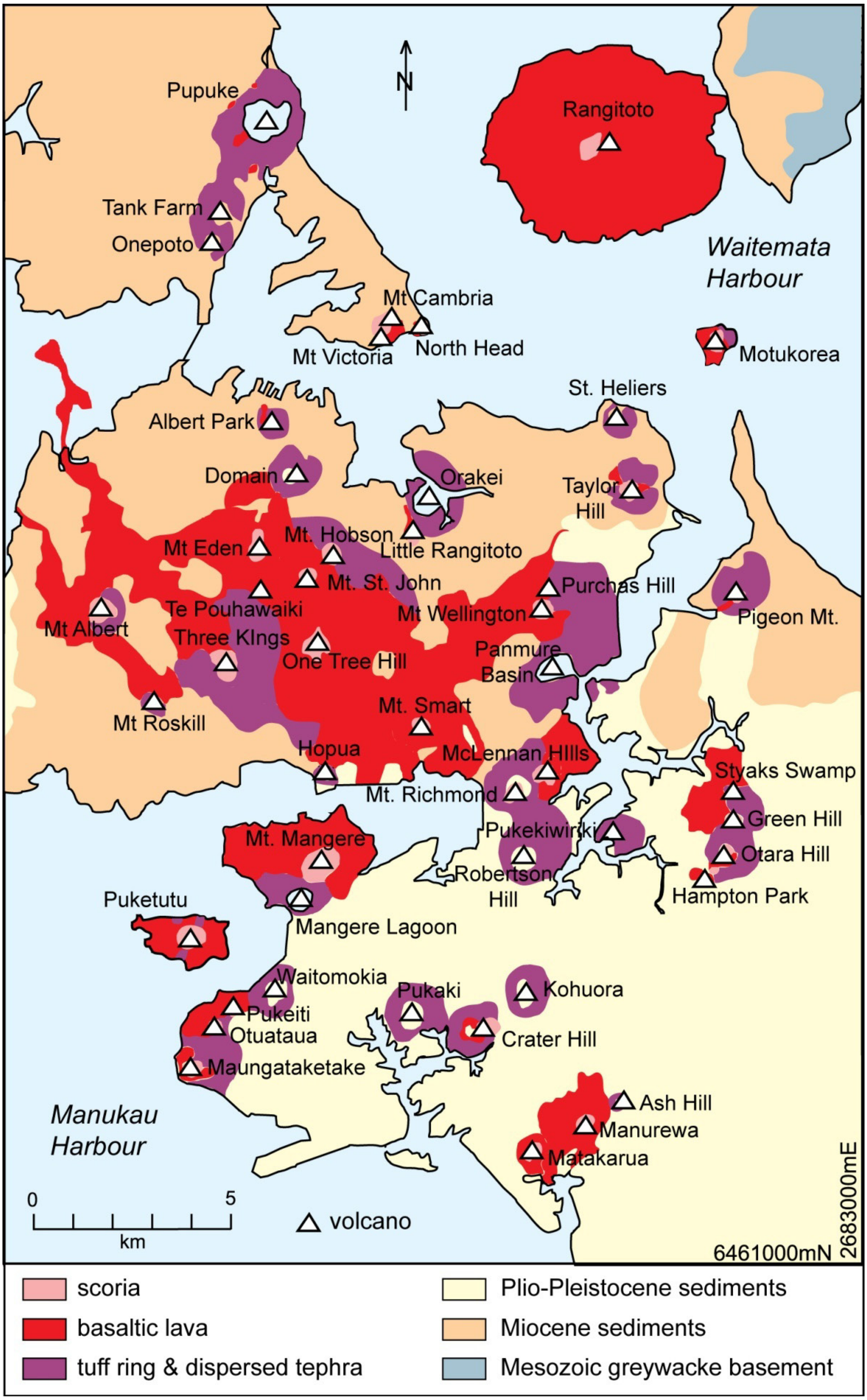

Figure 1: Geological sketch map of the Auckland Volcanic Field showing the location of the 49 centres referred to in this report.

DATING TECHNIQUES USED IN THE AUCKLAND VOLCANIC FIELD

The timing of past eruptions has been explored by previous workers using four main approaches: (1) radiocarbon dating of organic material preserved beneath or within erupted material, (2) direct dating of the erupted rock, (3) inferring a minimum age based on the presence of known-age tephras in sediment cores from explosion craters, and/or (4) age correlation of palaeomagnetic signature to known-age volcanic rocks. Most available data are derived from the first two approaches. Few ages are available using the 4th approach.

Below we provide a summary of the different dating techniques that have been applied in the AVF, and briefly discuss the advantages and disadvantages of each. We also note the specific problems that have been encountered with these techniques with respect to the AVF. Radiometric dating techniques (radiocarbon, K-Ar, $^{40}Ar/^{39}Ar$) are a measurement of isotopic ratios which change at a known rate over time. The ratio begins to change from a standard initial ratio once an organism dies in the case of radiocarbon dating, and once magma cools in the case of K-Ar and $^{40}Ar/^{39}Ar$ dating.

RADIOCARBON DATING

In the AVF ^{14}C dating has been applied to fossil material preserved beneath or within erupted material. These may be shells, roots, twigs, leaves or soils that have been buried by scoria, ash or lava. In general, natural exposures of such fossils are rare. The rapid weathering environment in Auckland results in rapid leaching and also contamination of the material that is available.

^{14}C age determinations rely on being able to measure sufficient quantities of the radioactive isotope of carbon, ^{14}C, in relation to the stable isotopes ^{13}C and ^{12}C. ^{14}C makes up only about 10^{-12}% of all carbon. In the radioactive decay of ^{14}C, by about 10 half-lives there is less than 0.1% of the original amount of ^{14}C, which becomes too small to distinguish from background. The half-life of ^{14}C of 5730 years means that for most samples older than 45,000 - 50,000 years, there is too little ^{14}C left to measure with current methods. Unfortunately, it is difficult to tell if an age in this range is real, or a minimum age representing an older deposit. The threshold for this detection limit has increased over the decades with better mass spectrometry instrumentation, from about 30,000 years in the 1960s.

In this report, we list ^{14}C ages published in peer-reviewed journals. Where ages are available but unpublished we list the age supplied by the investigator (usually from the laboratory worksheet). Many of the published ages and errors are present in the PETLAB database but are slightly different in value. The reason for this is unclear, however, DSIR ^{14}C ages given to clients before 1979 may differ from PETLAB ages because a “Conventional Radiocarbon Age” was not defined until 1977; until then different standards may have been used (C. Proir, pers. comm. 2009). In the 1990s, the old gas counting ^{14}C dates were recalculated and converted into Conventional ages, and these were the values supplied to PETLAB. Thus CRAs in PETLAB may differ from ^{14}C dates that were published before 1977. Dates presented in the FRED database, however, tend to align with the published ages. Although we present all versions of the age determinations available (see Appendix 1), it is the published ages (or the ages from the original dating laboratory worksheet) that appear in the tables in this report.

Most ^{14}C ages presented in the literature are conventional (uncalibrated) ages. In Appendix 1, we present these conventional ages, and indicate the analytical technique where known (decay counting vs. AMS). We also calibrate all ages using CalPal-Online (http://www.calpal.de) for comparison with ages obtained using different techniques. Exceptions are the young Rangitoto ages, which have been calibrated using OxCal 4.1 (curve ShCal04), which is thought to be more accurate for young ages determined in the Southern Hemisphere. It should also be pointed out that the half-life value used for calculating conventional ^{14}C ages has been revised over time.

Our CalPal-Online calibrations were carried out on the original published or worksheet ages, and therefore are based on the half-life applied at the time of original analysis.

K-AR DATING

The K-Ar approach relies on the decay of radioactive ^{40}K to stable ^{40}Ar. Abundances of K and Ar are measured on separate aliquots of sample. The technique assumes that all non-radiogenic argon present in the sample has a present-day atmospheric composition. Early K-Ar dating was conducted on whole-rock samples (McDougall et al. 1969). This tended to produce overly-old ages due to the presence of phenocrysts containing excess ^{40}Ar on top of that produced by ^{40}K decay alone (McDougall et al. 1969). More recent K-Ar (Mochizuki et al. 2007) and $^{40}Ar/^{39}Ar$ dating (Cassata et al. 2008) has been conducted on groundmass only and has overcome the phenocrystic excess argon limitation. Due to the added precision of $^{40}Ar/^{39}Ar$ dating, this is now the preferred method for age determination of volcanic rocks in the AVF.

$^{40}AR/^{39}AR$ DATING

$^{40}Ar/^{39}Ar$ dating yields more precise ages and exposes contamination (such as 'excess argon') better than K-Ar dating. Samples are irradiated to produce radioactive ^{39}Ar from stable ^{39}K. This allows age determinations by measuring only argon isotopes on the same aliquot in a mass spectrometer. Gas is typically extracted incrementally allowing identification of non-radiogenic fractions. Applications to the AVF are still in their infancy but are showing great promise (e.g. Cassata et al. 2008).

Basaltic rocks are relatively low in potassium. What potassium is present in the magma tends to crystallise last into groundmass feldspar. Therefore, crystalline groundmass separates produce the best age experiment results using this technique. Individual groundmass feldspar crystals also need to exceed 10µm in all dimensions so as to overcome an effect known as *^{39}Ar recoil* (physical displacement of ^{39}Ar atoms during irradiation). If the groundmass is too fine, the proportion of atoms shifted from one crystal to another skews the age result. This is compounded in step-heating $^{40}Ar/^{39}Ar$ experiments because different phases of the groundmass release argon at different temperatures; for example, one crystal can release some of the argon that started out in, and should be melted out from, another crystal.

PALEOMAGNETIC DECLINATION

The paleomagnetic declination technique is based on determing the paleomagnetic signature preserved within iron bearing minerals in lava flows, such as basalt. As basalt lava crystallises, the iron-bearing minerals within the melt align themselves to the orientation, polarity and intensity of the Earth's magnetic field at that particular point in time. Various experiments are used to determine the paleomagnetic declinations for a suite of samples, which are then compared to known declinations in the geologic record, thus allowing the age of the rock's formation to be determined (e.g. Robertson 1983). In the AVF this technique has been applied to just a few centres (e.g. Robertson 1983, Cassidy 2006).

OPTICALLY STIMULATED LUMINESCENCE DATING

Source: http://crustal.usgs.gov/laboratories/luminescence_dating

Luminescence dating is a form of geochronology that measures accumulated stored energy of photons within sediments. In natural settings, ionizing radiation (derived from the common radioactive elements U, Th, Rb, & K) is absorbed and stored in the crystal lattice of minerals that occur in sediments. This stored radiation dose can be released with stimulation and revealed as luminescence. The calculated age is a measure of time since the sampled sediment was last exposed to sunlight or intense heat. The sunlight bleaches away the luminescence signal and resets the time 'clock'. As time passes, the luminescence signal increases through exposure to ionizing radiation (and also cosmic rays). Luminescence dating is based on quantifying both the radiation dose received by a sample since its zeroing event (normally burial), and the dose rate which it has experienced during the accumulation period. The principal minerals used in luminescence dating are quartz and potassium feldspar.

THERMOLUMINESCENCE DATING

Thermoluminescence ages are obtained by dividing the total amount of radiation accumulated by a crystal with the amount of radiation accumulated per year. Lab tests heat the crystals, which excites and gradually releases the trapped radiation. The amount of radiation released is proportional to the amount that has accumulated in the crystal over a certain period of time since it crystallised (Adams 1986). Thermoluminescence is a useful alternative if carbonaceous material is not available for radiocarbon dating. Thermoluminescence dating of plagioclase crystals has been attempted for several AVF centres by three MSc students at the University of Auckland (Adams 1986, Phillips 1989, Wood 1991).

REVIEW OF AGES

Ages discussed here are stored in an Excel database (Appendix 1). It is intended that this database will grow and be amended with time. Here we review 179 known radiometric and proxy age determinations available for volcanic rocks from 25 of the volcanic centres of the AVF. These are summarised in Table 1, and the complete database is presented in Appendix 1. We also review minimum and relative age determinations (Tables 2 and 3, respectively). The radiometric and proxy ages have been obtained through a range of methods (Table 1): radiocarbon (74), K-Ar (68), thermoluminescence (14), Ar-Ar (10 reported ages; of which 7 are from Cassata et al. 2008 and are based on 41 step-heating experiments), Optically Stimulated Luminescence (2; both for Maungataketake) and Magnetic Declination (11; all for Rangitoto). Rangitoto is by far the best-dated centre, with 50 age determinations (Table 1).

Minimum ages based on tephrochronology and sedimentation rates of core are available for 9 explosion craters that have been drilled in the maar drilling programme (Table 2), and four of these also have associated age determinations of their erupted products (Auckland Domain, Onepoto, Panmure, and Pupuke; Tables 5, 19, 21 and 24, respectively). A further 20 centres are as yet undated, although relative age estimates have been made in some cases based on morphology and/or stratigraphic relationships between erupted products of different volcanoes (Table 3). Although age determinations have been obtained for 25 centres, not all of these are reliable and some centres have yielded conflicting ages or only minimum ages. Each of the 25 centres with one or more age is discussed individually below, in alphabetical order.

Table 1. Number and type of age determinations available for 25 centres of the AVF.

Volcano	^{14}C	K-Ar[1]	Therm[2]	Ar-Ar[5] Cassata	Ar-Ar Other	Mag Dec[3]	OSL[4]	Total
Ash Hill	1							**1**
Auckland Domain	1	2						**3**
Crater Hill tuff ring	2	2		1(7)				**5**
Green Hill	1							**1**
Hampton Park		1		1(6?)				**2**
Mangere Mountain	3	1						**4**
Matakarua		1						**1**
Maungataketake	14	10	1				2	**27**
McLennan Hills	1	12	1	1(8)				**15**
Mount Albert	1	2						**3**
Mount Eden	1	1	3					**5**
Mount Richmond	1							**1**
Mount Saint John	1							**1**
Mount Wellington	6	5	1					**12**
One Tree Hill		1	3					**4**
Onepoto	2				1			**3**
Otuataua		2						**2**
Panmure Basin tuff ring	2	1						**3**
Pukeiti		1						**1**
Puketutu Island		2	1	1(7)				**4**
Pupuke tuff ring	3	7	1	1(4)	2			**14**
Purchas Hill	1							**1**
Rangitoto	24	12	3			11		**50**
Three Kings	7	1						**8**
Wiri Mountain	2	4		2(11)				**8**
Total	**74**	**68**	**14**	**7**	**3**	**11**	**2**	**179**

1= Although the McDougall et al. (1969) analyses produced a great range of results which were severely affected by excess Ar, all the individual age determinations are included here. 2 = Thermoluminescence age; 3 = Paleomagnetic declination age; 4 = Optically stimulated luminescence age. 5 = number in brackets refer to the number of step heating experiments carried out to obtain weighted mean ages.

Table 2. Minimum ages of drilled AVF maars based on tephrochronology and sedimentation rates

Centre	Minimum age	Comment on key evidence (specific tephra) encountered	Depth to tephra	Total depth of core; material at base	Estimated age of oldest lake sediment/deposit based on sedimentation rates
Auckland Domain	>45 ka	Rotoehu tephra (> 45 ka) present within 2 m of surface in drill core from the Domain	2 m	10 m	Sediments disturbed, sedimentation rate undetermined
Hopua Basin	>29 ka	Poihipi tephra 0.3 m from bottom is 28.9 ka	48.5 m	49m; scoria	~29 ka
Kohuora	> 27 ka	The Kawakawa/Oruanui tephra (ca. 27 ka) is present in one of two cores at this crater, as a 2 cm thick layer at 7.11 m.[5]	7.11 m	7.5 m; tuff deposits	ca. 32 ka[5]
Onepoto	>45 ka	Rotoehu tephra (> 45 ka) present as a 63-cm-thick layer with base at 41.1 m. See also Table 19 for Ar-Ar age of lapilli at base of core.	41.4 m	61.2 m; basaltic ash and lapilli[1]	> 220-150 ka[4]
Orakei tuff ring	>83 ka	A basaltic tephra at 80m depth in bottom of Orakei core is estimated at 83.1 ka based on Rotoehu-constrained sedimentation rates[2]	80 m	81 m; lake sediments	> 85.5 ka
Panmure Basin	>17 ka	Two cores in Panmure Basin contain Rerewhakaaitu tephra (17.6 ka)	40.5 & 42.8 m	46m/43.5 m; lava/scoria	Sediments disturbed, sedimentation rate undetermined
Pukaki tuff ring	>52 ka	An Egmont tephra at ~65m at base of Pukaki core is estimated at 52.4 ka based on Rotoehu-constrained sedimentation rates. Significant sediment below this layer hints at a much greater age for Pukaki[3]	65 m	69 m; basaltic tuff	> 65 ka[4]
Pupuke	>48 ka	An Egmont tephra at ~73 m at base of Pupuke core is estimated at 48.6 ka[2] based on sedimentation rates tied to the >45 ka Rotoehu tephra at 72.4m	72.8 m	73 m; Egmont tephra	>48.6 ka
St Heliers tuff ring	>45 ka	Rotoehu tephra (> 45 ka) present within 2 m of surface in drill core from Glover Park	2 m	27 m; scoria & lava	>> 45 ka (significant sedimentation pre-Rotoehu is unconstrained in age)

1=Shane and Sandiford (2003), 2=Molloy et al. (2009); 3=Shane (2005); 4=Bruce Hayward, written. comm. 2009. 5=Newnham et al. (1999; 2007).

Table 3. AVF centres for which no radiometric or minimum ages are available; age estimates and explanations are shown.

Centre	Estimated age	Key evidence	Reference
Albert Park			
Browns Island/Motukorea	≥ 7,000-9,000	Early Holocene high stand (Flandrian) terrace built over lava flows	Bryner (1991)
Little Rangitoto	Might be younger than Orakei	Thick basaltic tuff in Orakei Basin might be from here, also L. Rangitoto flow runs around the base of Orakei tuff ring	Hayward (written comm. 2009) Kermode et al. (1992)
Mangere Lagoon	Older than Mangere Mountain	Mangere Lagoon tuff is overlain by lava from Mt. Mangere	Kermode (1992)
Mount Cambria			
Mount Hobson			
Mount Roskill	Older than Three Kings	Morphology	Allen and Smith (1994)
Mount Smart	Younger than One Tree Hill Younger than Mangere Older than Mt Wellington	Tephra overlying One Tree Hill lava flows at Puka St. Grotto likely from Mt. Smart; Mt. Smart lavas rest on Mangere tephra.	Hayward (2008b) Kermode (1992) Kermode et al. (1992) Searle (1962)
Mount Victoria			
North Head			
Otara Hill/ Smales Hill	Equal to or younger than Hampton Park	Otara Hill flows invade Hampton Park explosion crater	Hayward (written comm. 2009) Sibson (1968)
Pigeon Mountain			
Pukewairiki/Waiuru	Older than Styaks Swamp Older than 130,000	Morphology Morphology (shore platform)	Allen and Smith (1994) P. Shane pers. comm. (2007)
Robertson Hill			
Styaks Swamp	Equal in age or younger than Green Hill	Styaks Swamp tephra overlies Green Hill scoria	Hayward (written comm. 2009) Sibson (1968)
Tank Farm (or Tuff Crater)	Equal in age or older than Onepoto	Small terrace on inside of Tank Farm in the south may be tuff draped from Onepoto	Hayward (written comm. 2009)
Taylors Hill	May be 32-34 ka	Part of the same paleomagnetic cluster as Puketutu, Wiri and Crater Hill	Cassata et al. (2008)
Te Pouhawaiki			
Waitomokia	Older than Pukeiti	Morphology	Searle (1959)

THE AGE OF INDIVIDUAL CENTRES OF THE AVF

In this section we evaluate the reliability of ages for each centre for which geochronological data are available, and, where possible, present a best estimate age for that centre based on these age determinations. The best estimate ages are summarised in Table 30.

ASH HILL

A single radiocarbon date is available for Ash Hill; this was collected and analysed in 2007 (Table 4). This age appears reliable and is the current best estimate age for this centre.

Table 4: Age determination available for Ash Hill. For more detail see Appendix 1.

Age (^{14}C = Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference
31,800 ± 159	$^{14}C^{c}$	27,065 ± 199	4 cm diameter trunk of an in situ (rooted) probably Manuka buried by tephra on the slopes of the mound of Ash Hill. The exposure was a recent cutting at the back of a building platform.	Hayward (2008a)

1 = ^{14}C age presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age; c= Conventional age.

AUCKLAND DOMAIN

Two K-Ar dates and one ^{14}C minimum age are available for the Auckland Domain; the K-Ar ages may be too old due to excess Ar (McDougall et al. 1969; Table 5). Although the Domain is considered one of the oldest centres in the AVF (based on geomorphology - Kermode, 1992), the only age constraint is the minimum age of 60 ka based on a single ^{14}C age determination.

Table 5: Age determinations available for Auckland Domain. For more detail see Appendix 1.

Age	Method	Description	Reference
>60,000	^{14}C	Tree beneath Domain tuff at the Blind Institute	Grenfell and Kenny (1995)
148,000 ± 10,000	K-Ar		McDougall et al. (1969)
152,000 ± 5,000	K-Ar		McDougall et al. (1969)

CRATER HILL TUFF RING

There are two radiocarbon dates, two K-Ar dates, and one recent Ar-Ar date available for Crater Hill (Table 6). The most recent age of 32 ka determined by Cassata et al. (2008) is within error of all previous ages except for the McDougall et al. (1969) K-Ar age.

GREEN HILL

There is only one published date for Green Hill, namely a ^{14}C age of 19.8 Cal kyr BP (Table 7). This sample was dated using the methanol synthesis – liquid scintillation counting (LSC) method by Prof. O. Yamada of Kyoto Sangyo University (Sameshima 1990).

Table 6: Age determinations available for Crater Hill. For more detail see Appendix 1.

Age (^{14}C = Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference[3]
33,332 ± 671	$^{14}C^c$	29,000 ± 700	Wood from trunk of sapling 7.5 cm in diameter buried in tuff exposed in roof of tunnel.	Searle (1965), Grant-Taylor and Rafter (1971)
34,016 ± 265	$^{14}C^c$	29,700 ± 200	Wood in tuff overlain by a shell bed and tuff, and underlain by green-grey tuff. From 20ft depth in tunnel	Searle (1965), Grant-Taylor and Rafter (1971)
60,000 ± 30,000	K-Ar			Itaya et al. (unpublished data)[5]
117,000 ± 5,000	K-Ar			McDougall et al. (1969)
32,100 ± 5,400	Ar-Ar[4]		weighted mean plateau age of 7 aliquots using different increments	Cassata et al. (2008)

1 = ^{14}C ages presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age; c= Conventional age; 3 = original reference listed first. 4= see Appendix 1 for results of individual Ar-Ar step heating experiments as well as associated composite isochron ages. 5 =cited in Allen and Smith (1994).

Table 7: Age determination available for Green Hill. For more detail see Appendix 1.

Age (^{14}C= Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference
19,827 ± 8,976	^{14}C	17,000 ± 8,000	Chunk of wood sample from beneath the Green Hill lava	Sameshima (1990)

1 = ^{14}C ages presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age.

HAMPTON PARK

Two recent attempts have been made to date Hampton Park, unfortunately producing contrasting results. The Cassata et al. (2008) Ar-Ar experiments on this centre were problematic, and did not yield a reliable weighted mean plateau age. The weighted mean isochron age (26,600 ± 8,000) proved somewhat more reliable, however, this is clearly different from the available K-Ar age of 55,000 ± 5,000 (Table 8). Hampton Park explosion crater is invaded by Otara Hills' lava flows, but as no age is available for Otara Hills this does not further constrain the age of Hampton Park.

Table 8: Age determinations available for Hampton Park. For more detail see Appendix 1.

Age	Method	Description	Reference
55,000 ± 5,000	K-Ar	Weighted mean from 3 experiments	Mochizuki et al. (2004)
26,600 ± 8,100	Ar-Ar[1]	Weighted mean of 6 isochron ages (preferable over plateaus in this case)	Cassata et al. (2008)

1= see Appendix 1 for results of individual Ar-Ar step heating experiments as well as associated individual isochron ages.

MANGERE MOUNTAIN

Three ^{14}C ages are available for volcanic activity at Mangere Mountain; these range from 21.9 to 34.9 Cal kyr BP (Table 9). The oldest of these ages is the most recent, carried out just a few years ago, and may be the most reliable. We therefore prefer this age for a best estimate for Mangere Mountain. A much older K-Ar age (120,000 ± 30,000) was apparently obtained by Itaya (Allen and Smith 1994). However, given the difficulties with K-Ar dating in the past, this is considered less reliable than the available ^{14}C ages.

Table 9: Age determinations available for Mangere Mountain. For more detail see Appendix 1.

Age (^{14}C= Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference[3]
21,937 ± 395	$^{14}C^c$	18,280 ± 265	Peat from mud underlying Mangere Mt lava, from AMDB Siphon line across Manukau Harbour	Searle (1959; 1965), Grant-Taylor and Rafter (1971)
32,340 ± 1,433	$^{14}C^c$	27,800 ± 1,600	Wood beneath lava in Manukau Harbour, between Mangere and White Bluff, on Siphon line	Searle (1959; 1965), Grant-Taylor and Rafter (1971)
34,943 ± 389	^{14}C	30,790 ± 290		Ann Williams, Beca Carter, pers. comm.
120,000 ± 30,000	K-Ar			Itaya et al. (unpublished data)

1 = ^{14}C ages presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age; 3 = original reference listed first; c= Conventional age, a= AMS age

MATAKARUA/MCLAUGHLIN'S HILL

There is one K-Ar date available for Matakarua, an unpublished date obtained by Itaya in the 1990s and cited by Allen and Smith (1994) (Table 10). There is a huge error associated with this age, and although it is the only estimate available for this centre we do not consider it particularly reliable.

Table 10: Age determination available for Matakarua. For more detail see Appendix 1.

Age	Method	Description	Reference
110,000 ± 40,000	K-Ar		Itaya et al. (unpublished data)

MAUNGATAKETAKE/IHUMATAO

Although there are a number of age determinations available for Maungataketake/Ihumatoa (Table 11), these are inconclusive. The ten available K-Ar ages are likely to be too old due to excess Ar (McDougall et al. 1969), and the Optically Stimulated Luminescence (OSL) ages are much older than the available ^{14}C ages (Table 11). Marra et al. (2006) claim that their OSL dates are consistent with a > 127,000 age estimate for this volcano based on morphology, claiming that a marine terrace of this age cuts the sequence. Given the vast range of age estimates for this centre (33.5 – 177 ka) we do not feel there is enough evidence to support a best-estimate age – although we do note that the single thermoluminescence age (38 ka) falls within the range of the radiocarbon ages obtained from several different fractions of four samples (33-47 Cal kyr BP; Table 11).

Table 11: Age determinations available for Maungataketake. For more detail see Appendix 1.

Age (^{14}C= Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference[3]
33,435 ± 1,267	^{14}C	29,000 ± 1,500	Wood from tree stump (from fossil forest) enclosed by tuff (NZ-215)	Fergusson and Rafter (1959), Grant-Taylor and Rafter (1963)
35,464 ± 1,062	^{14}C	31,000 ± 1,000	ANU 9 Stump encased in tuff	Polach et al. (1969)
42,206 ± 2,909*	^{14}C	38,390 +3,100, -2200	ANU-9 W (Outer soft part of ANU-9)	Polach et al. (1969), McDougall et al. (1969)
47,244 ± 1,944	^{14}C	43,620 ± 1,400	ANU-9 C (Cellulose of core of ANU-9 after removal of rootlets)	Polach et al. (1969), McDougall et al. (1969)
46,063 ± 2,092	^{14}C	42,130 ± 2,000	ANU-9 L (Lignin of core of ANU-9, after removal of rootlets)	Polach et al. (1969), McDougall et al. (1969)
	^{14}C	>36,400	ANU-32 SW. Limb of tree in tuff. Soft wood, outer part, as is.	Polach et al. (1969), McDougall et al. (1969)
40,484 ± 2,056	^{14}C	36,330 ± 2,100	ANU-32 H. Heart wood (inner part), as is.	Polach et al. (1969), McDougall et al. (1969)
42,824 ± 1,310	^{14}C	38,450 ± 1,800	ANU-32 S. NaOH-soluble fraction on portion of total cross section of ANU-21.	Polach et al. (1969), McDougall et al. (1969)
44,539 ± 1,531	^{14}C	40,670 ± 1,800	ANU-32 I. NaOH-insoluble residue	Polach et al. (1969), McDougall et al. (1969)
45,963 ± 2,681*	^{14}C	41,800 +2,800, -2,000	ANU-32 CL. Cellulose and lignin.	Polach et al. (1969), McDougall et al. (1969)
	^{14}C	>36,400	ANU-34. Sapling in tuff. Wood, as is.	Polach et al. (1969), McDougall et al. (1969)
	^{14}C	>33,500	ANU-36. From a portion of the original sample (NZ-215) dated by Ferguson and Rafter (1959). Wood, as is.	Polach et al. (1969), McDougall et al. (1969)
>55,000	^{14}C	>55,000	Wood from beneath phreatomagmatic tuff	Marra et al. (2006)
>55,000	^{14}C	>55,000	Wood from beneath phreatomagmatic tuff	Marra et al. (2006)
126,000 ± 9,000	K-Ar		Basalt lava	McDougall et al. (1969)
74,000 ± 15,000	K-Ar		Basalt lava	McDougall et al. (1969)
106,000 ± 11,000	K-Ar		Basalt lava	McDougall et al. (1969)
125,000 ± 22,000	K-Ar		Basalt lava	McDougall et al. (1969)
131,000 ± 6,000	K-Ar		Basalt lava	McDougall et al. (1969)
138,000 ± 7,000	K-Ar		Basalt lava	McDougall et al. (1969)
109,000 ± 11,000	K-Ar		Basalt lava	McDougall et al. (1969)
107,000 ± 6,000	K-Ar		Basalt lava	McDougall et al. (1969)
108,000 ± 4,000	K-Ar		Basalt lava	McDougall et al. (1969)
110,000 ± 6,000	K-Ar		Basalt lava	McDougall et al. (1969)
38,100 ± 1,900	Therm		Plagioclase crystals in lava	Wood (1991)
177,100 ± 23,400	OSL			Marra et al. (2006)
140,300 ± 14,200	OSL			Marra et al. (2006)

*1 = ^{14}C age presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age, 3 = original reference listed first; *for calibrations the largest of the two errors in the original age was used.*

MCLENNAN HILLS

Various contradictory age determinations are available for McLennan Hills (Table 12). Four K-Ar experiments carried out by Mochizuki et al. (2007) yielded a weighted mean age of 50,000 ± 6,000 years. This is within error of more recent Ar-Ar experiments carried out by Cassata et al. (2008) which yielded a weighted mean plateau age of 42,600 ± 3,800 years. Both these ages are within error of an earlier thermoluminescence age, but are inconsistent with an early ^{14}C age (Table 12). We are cautious about early ^{14}C ages of 30 ka or greater, and in cases where more recent K-Ar and Ar-Ar are available these are preferred. For this reason we exclude the ^{14}C age for McLennan Hills in the preferred age range presented in Table 30. We note that this is not inconsistent with a minimum age of 29.2 Cal kyr BP for a lava flow near Mt Richmond that may be from McLennan Hills (see Table 15).

Table 12: Age determinations available for McLennan Hills. For more detail see Appendix 1.

Age (^{14}C = Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference[3]
31,697 ± 172	$^{14}C^{c}$	26,910 ± 190		Polach et al. (1969); McDougall et al. (1969)
40,000 ± 19,000	K-Ar			McDougall et al. (1969)
59,000 ± 5,000	K-Ar			McDougall et al. (1969)
90,000 ± 5,000	K-Ar			McDougall et al. (1969)
101,000 ± 5,000	K-Ar			McDougall et al. (1969)
104,000 ± 3,000	K-Ar			McDougall et al. (1969)
105,000 ± 8,000	K-Ar			McDougall et al. (1969)
107,000 ± 4,000	K-Ar			McDougall et al. (1969)
113,000 ± 3,000	K-Ar			McDougall et al. (1969)
124,000 ± 3,000	K-Ar			McDougall et al. (1969)
41,000 ± 10,000	K-Ar			Mochizuki et al. (2007)
63,000 ± 10,000	K-Ar			Mochizuki et al. (2007)
33,000 ± 13,000	K-Ar			Mochizuki et al. (2007)
64,000 ± 18,000	K-Ar			Mochizuki et al. (2007)
48,800 ± 2,500	Therm			Wood (1991)
42,600 ± 3,800	Ar-Ar[4]		Weighted mean plateau age analyses of 8 aliquots using different increments	Cassata et al. (2008)

1 = ^{14}C age presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age; 3 = original reference listed first. 4= see Appendix 1 for results of individual Ar-Ar step heating experiments as well as associated composite isochron ages. c= Conventional age.

MOUNT ALBERT

Excluding two unreliable K-Ar dates determined by McDougall et al. (1969), there is only a single minimum ^{14}C age of >30,000 years available for this centre (Table 13).

Table 13: Age determinations available for Mount Albert. For more detail see Appendix 1.

Age	Method	Description	Reference[1]
>30,000	^{14}C	Charred branch beneath 15ft of sub-recent lava; Oakley Creek Quarry, Mt Albert	Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)
129,000 ± 4,000	K-Ar		McDougall et al. (1969)
140,000 ± 6,000	K-Ar		McDougall et al. (1969)

1 = original reference listed first.

MOUNT EDEN

Only one ^{14}C date is available for Mt. Eden, namely 28,386 ± 345 Cal yr BP from a large log of wood to the north of Mt Eden at Lauder Road (Table 14). Thermoluminescence ages are much younger (14-16 ka) and the single available K-Ar age is clearly too old, reflecting excess Ar (McDougall et al. 1969). Of these, we consider the ^{14}C age most reliable, and note that this is very similar to (possibly slightly younger than) the Three Kings age (see Table 28). The relative age between Mt Eden and Three Kings is unknown, and thus a similar age for these centres is not incompatible with field evidence. It is worth noting that Mt Eden lavas overlie One Tree Hill lava and Domain tephra, and that Mt Eden is therefore younger than One Tree Hill and the Domain (Kermode 1992).

Table 14: Age determinations available for Mt. Eden volcano. For more detail see Appendix 1.

Age (^{14}C= Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference
28,386 ± 345	$^{14}C^{c}$	23,480 ± 180	Large log of wood, Lauder Rd, Mt Eden	East and George (2003)
14,420 ± 1,250	Therm		Plagioclase crystals from lava	Adams (1986)
16,200 ± 2,000	Therm		Plagioclase crystals from lava	Phillips (1989)
14,020 ± 1,220	Therm		Plagioclase crystals from lava	Wood (1991)
154,000 ± 4,000	K-Ar		Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)

1 = ^{14}C age presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age; c= Conventional age.

MOUNT RICHMOND

One date is available for a lava flow at Mt Richmond (Table 15), however the source of the lava flow is ambiguous. Sandiford et al. (2002) indicate that the lava could have come from Robertson Hill, McLennan Hills or Mt Richmond. To date no-one has identified any lava flows from Mt Richmond or Robertson Hill, and thus McClennan Hills seems the most likely candidate as a source for this lava flow. This date of 29.9 Cal kyr BP for silt above the lava flow is consistent with the 42.6 ka age obtained by Cassata et al. (2008) for the McClennan Hills flow itself (see Table 12). We also note that, although Mt Richmond remains undated, it does belong to the same paleomagnetic cluster as Crater Hill, Wiri and Puketutu (Cassata et al. 2008), and may therefore be of similar age (32-34 ka).

Table 15: Age determinations available for Mount Richmond(?). For more detail see Appendix 1.

Age (^{14}C = Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference
29,908 ± 603	^{14}C	25,060 ± 530	Charcoal fragment from the base of a loamy silt horizon overlying a basaltic lava in an exposed section at Mt Richmond.	Sandiford et al. (2002)

1 = ^{14}C age presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age.

MOUNT SAINT JOHN

One ^{14}C date from the crater of Mt St John represents a minimum age for this centre (Table 16). Eade (2009) correlated unidentified lava flows beneath Three Kings and Mt Eden lava with Mt St John, and suggested that Mt St John is > 29 ka. Three Kings tephra may also mantle Mt St John scoria cone, consistent with an age older than Three Kings (B Hayward pers. comm. 2009).

Table 16: Age determinations available for Mount Saint John. For more detail see Appendix 1.

Age (^{14}C = Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference
19,515 ± 298	$^{14}C^{a}$	16,309 ± 90	from basal scoria (bulk sediment?) at base of gouge auger core, Mt St John crater	Horrocks et al. (2005a)

1 = ^{14}C age presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age; a= AMS age.

MOUNT WELLINGTON (MAUNGAREI)

Six radiocarbon dates are available for Mt Wellington; these range from 10,035 ± 189 to 10,633 ± 137 Cal yr BP (Table 17; Figure 2). The two youngest of these ages are from carbonised wood within a basalt flow and probably most accurately reflect the age of lava flow activity from Mt Wellington (10,000 Cal yr BP rounded to the nearest hundred years). The only other age determination directly associated with Mt Wellington lava flows was obtained on wood from a tree trunk underlying a lava flow (10,445 ± 115 Cal yr BP); this represents a maximum age for the lava activity. The remaining three radiocarbon ages are from organic material originally growing in the Panmure Basin tuff ring and subsequently buried by Mt Wellington tephra, and are somewhat older at 10.6 Cal kyr BP (Table 17). A single thermoluminescence age (Wood 1991) determined on plagioclase from Mt. Wellington lava is within error of these ages. The age of tephra from Mt Wellington has been very well constrained by tephrochronology as it directly overlies, and in some cases is intermingled with, the well-dated Opepe Tephra in sediment cores from Hopua, Pukaki and Panmure craters (P. Shane written comm. 2009). The Opepe Tephra is 10,075 ± 155 Cal yr BP (Lowe et al. 2008), and based on this, the Mt Wellington tephra preserved in these craters is likely to be 10,000 Cal yr BP, with an error likely less than 400 years (P. Shane written comm. 2009). Available K-Ar age determinations are much older than these ages and reflect excess Ar (McDougall et al. 1969). Based on the discussion above, the best estimate age for Mt Wellington volcano is 10 kyr BP to the nearest thousand years, although we note that the dates suggest there may have been a gap of a few hundred years between the early phreatomagmatic phase and later magmatic activity.

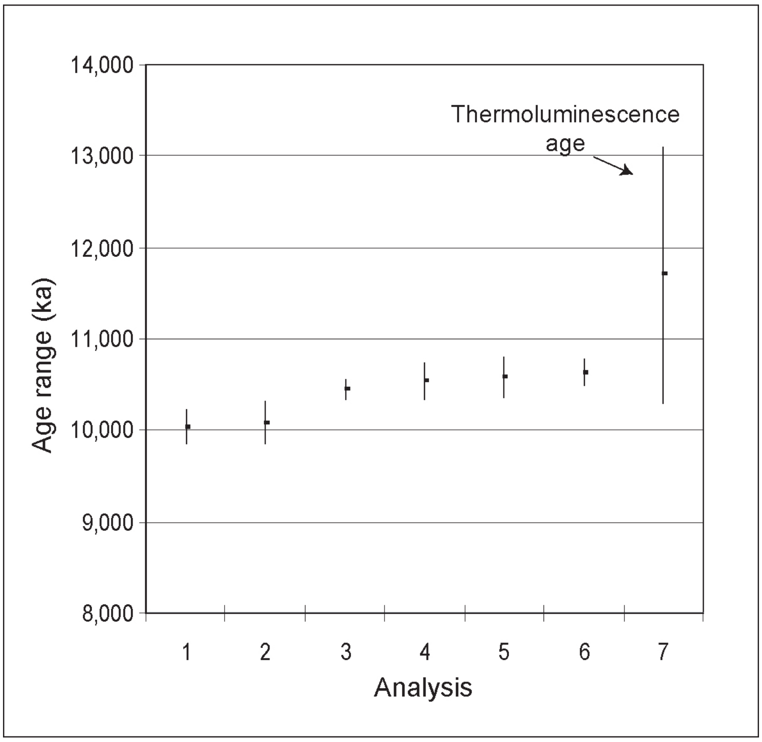

Figure 2: Plot showing dates and errors for Mt. Wellington. The six ^{14}C ages are shown (in Cal yr BP), plus the single thermoluminescence age.

Table 17: Absolute and relative age determinations available for Mt. Wellington volcano. For more detail see Appendix 1.

Age (^{14}C= Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference[3]
10,035 ± 189	$^{14}C^{c}$	8,970 ± 130	Carbonised wood from large tree mould in basalt, Quarry at Panorama Rd.	Searle (1965); Grant-Taylor and Rafter (1971)
10,084 ± 240	$^{14}C^{c}$	9,000 ± 160	Charcoal imbedded in basalt flow from Mt. Short volcano, Penrose. (Note that this original description is probably erroneous as there is no “Mt Short” volcano. We believe it is referring to a Mt Wellington flow near Mt Smart)	Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963), Searle (1961, 1965)
10,445 ± 115	$^{14}C^{c}$	9,270 ± 80	Wood from tree trunk underlying basalt flow, Penrose main road deviation	Grant-Taylor and Rafter (1963)
10,545 ± 201	$^{14}C^{c}$	9,315 ± 145	Root in tuff from Panmure basin overlain by Mt Wellington tuff, from tunnel near railway stn	Searle (1965); Grant-Taylor and Rafter (1971)
10,578 ± 221	$^{14}C^{c}$	9,330 ± 150	Tree fern fibres in Panmure Basin Tuff overlain by Mt Wellington tuff. In tunnel near railway stn	Searle (1965); Grant-Taylor and Rafter (1971)
10,633 ± 137	$^{14}C^{c}$	9,390 ± 95	Tree fern wood growing in tuff ring of Panmure volcano later buried by Mt Wellington tephra	Polach et al. (1969); McDougall et al. (1969)
11,700 ± 1400	Therm		Plagioclase crystals from 30 m below surface of basaltic lava flow in Lunn Ave quarry	Wood (1991)
9,500	Tephra[4]			Newnham and Lowe (1991)
>9,500	Tephra[4]		Tephra from Mt Wellington lies below Rotoma tephra (9.5ka Cal yr) in some maar cores.	P. Shane, written comm. 2009
≤10,000	Tephra[4]		Tephra from Mt Wellington directly overlies and in some cases is mixed in with Opepe tephra (10ka Cal yr) in several cores drilled in AVF maars.	P. Shane, written comm. 2009
57,000 ± 7,000	K-Ar		Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
66,000 ± 5,000	K-Ar		Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
81,000 ± 4,000	K-Ar		Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
81,000 ± 9,000	K-Ar		Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
82,000 ± 7,000	K-Ar		Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)

1 = ^{14}C ages presented here as Calendric Age calBP, calibration carried out using CalPal-Online; 2 = non-calibrated ages as they appear in the original literature; 3 = original reference listed first; 4 = relative ages determined by tephrochronology (other than Rangitoto, this is the only vent in the AVF for which a strongly reliable correlation to core tephra is possible); c= Conventional age.

ONE TREE HILL

We were unable to find any radiocarbon dates for One Tree Hill. Four thermoluminescence ages range from 17 – 20 ka (all different calibrations of the same sample), contrasting with a K-Ar age of 83 ka that is most likely to be elevated due to excess Ar (Table 18). The thermoluminescence dates are inconsistent with field relations: One Tree Hill lava flows and scoria cone are overlain by Three Kings tephra (B. Hayward written comm. 2009), and One Tree Hill must therefore be > 28.5 ka. One Tree Hill is also thought to be older than Mt. Mangere, Mt. Smart (see Table 3), Hopua and Mt. Eden based on stratigraphic relationships (Kermode 1992; B. Hayward written comm. 2009).

Table 18: Age determinations available for One Tree Hill volcano. For more detail see Appendix 1.

Age	Method	Description	Reference
17,060 ± 1,360	Therm	Plagioclase crystals in lava	Adams (1986)
20,000 ± 2,250	Therm	Plagioclase crystals in lava	Phillips (1989)
16,520 ± 1,350	Therm	Plagioclase crystals in lava	Wood (1991)
83,000 ± 5,000	K-Ar	lava	McDougall et al. (1969)

ONEPOTO

Other than minimum ages provided by early ^{14}C age determinations and the tephra record in drill core (Table 2), the only constraint on the age of Onepoto comes from an Ar-Ar age obtained from basaltic lapilli at the base of a sediment core from Onepoto Domain (Table 19). This age (248 ka) represents a minimum age for this centre, although it should be noted that it is inherently difficult to obtain reliable Ar-Ar ages from lapilli because the groundmass is invariably glassy and thus *recoil* is common. This age may therefore turn out to be erroneous.

Table 19: Age determinations available for Onepoto. For more detail see Appendix 1.

Age	Method	Description	Reference[1]
>42,000	^{14}C	Carbonaceous soil below 55 ft of tuff, west of Onepoto Lagoon tuff ring, Bore No 3, Harbour Bridge	Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)
>28,500	^{14}C	Bark and wood from moulds of large trees overwhelmed by tuff from Onepoto, Shoal Bay.	Grant-Taylor and Rafter (1971)
248,000 ± 28,000	Ar-Ar	^{40}Ar–^{39}Ar incremental heating isochron age for the basaltic lapilli at 61.17 m (M.O. McWilliams, personal communication, 2002).	Shane and Sandiford (2003)

1 = original reference listed first.

OTUATAUA

There are two K-Ar age determinations available for Otuataua (Table 20). Given the difficulty with excess Ar highlighted in the McDougall et al. (1969) study that produced these results we do not think this represents a reliable age for this centre.

Table 20: Age determination available for Otuataua. For more detail see Appendix 1.

Age	Method	Description	Reference
29,000 ± 10,000	K-Ar		McDougall et al. (1969)
36,000 ± 6,000	K-Ar		McDougall et al. (1969)

PANMURE BASIN TUFF RING

Two ^{14}C dates are available for Panmure Basin (Table 21). A K-Ar age obtained by McDougall et al. (1969) is not considered reliable due to excess Ar. Although these ^{14}C ages are close to the upper limit of ages able to be calculated by this technique, and as such may represent minimum ages, they represent the current best estimate age for this centre.

Table 21: Age determinations available for Panmure Basin. For more detail see Appendix 1.

Age (^{14}C = Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference[3]
32,674 ± 862	$^{14}C^c$	28,000 ± 1,000	Peat underlying Panmure basin tuff in terrace of Tamaki River	Fergusson and Rafter (1959), Grant-Taylor and Rafter (1963)
31,697 ± 172	$^{14}C^c$	26,910 ± 190	Three samples of wood from fossil forest beneath tuff	Polach et al. (1969); McDougall et al. (1969)
189,000 ± 600	K-Ar			Stipp (1968); McDougall et al. (1969)

1 = ^{14}C age presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age; 3 = original reference listed first. c= Conventional age.

PUKEITI

There is a single K-Ar age determination available for Pukeiti (Table 22). Given the difficulty with excess Ar highlighted in the McDougall et al. (1969) study we do not think this represents a reliable age for this centre.

Table 22: Age determination available for Pukeiti. For more detail see Appendix 1.

Age	Method	Description	Reference
32,000 ± 6,000	K-Ar	Basalt	McDougall et al. (1969)

PUKETUTU ISLAND

Seven dates are available for Puketutu basalt, four of which are K-Ar ages that give a weighted mean of 30,000 ± 5,000 (Mochizuki et al. 2007). The most recent age determination is a weighted mean Ar-Ar date which overlaps within error with the K-Ar age of Mochizuki et al., 2007; Table 23). We consider these most recent analyses the most reliable for this center (Table 30).

Table 23: Age determinations available for Puketutu Island. For more detail see Appendix 1.

Age	Method	Description	Reference
22,800 ± 3,300	Therm	Plagioclase crystals in lava	Wood (1991)
16,000 ± 11,000	K-Ar	Groundmass in basaltic lava from quarry	Mochizuki et al. (2007)
25,000 ± 9,000	K-Ar	Groundmass in basaltic lava from quarry	Mochizuki et al. (2007)
36,000 ± 10,000	K-Ar	Groundmass in basaltic lava from quarry	Mochizuki et al. (2007)
38,000± 8,000	K-Ar	Groundmass in basaltic lava from quarry	Mochizuki et al. (2007)
77,000 ± 9,000	K-Ar	Basaltic lava from quarry	McDougall et al. (1969)
33,600 ± 3,700	Ar-Ar[1]	Weighted mean plateau age of 7 aliquots of clean groundmass using different increments	Cassata et al. (2008)

1 = See Appendix 1 for results of individual Ar-Ar step heating experiments as well as associated composite isochron ages.

PUPUKE

Early ^{14}C experiments for Pupuke give minimum ages of 42 ka; excluding the McDougall et al. (1969) K-Ar ages, remaining ages from this centre range from 141 ka (thermoluminescence) to 260 ka (Ar-Ar) (Table 24). In fact, the three Ar-Ar ages available for this centre are similar – and, interestingly, within error of many of the McDougall et al. (1969) K-Ar ages. The age range obtained by Ar-Ar is thought to represent the currently most reliable estimate for this centre (Table 30).

Table 24: Age determinations available for Pupuke tuff ring. For more detail see Appendix 1.

Age	Method	Description	Reference
>42,000	^{14}C	Charred wood below basalt and tuff.	Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)
>40,000	^{14}C	Peat below basalt and tuff, onshore of Shoal Bay	Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)
>36,000	^{14}C	Charcoal from cinders, east face, Smales quarry	Fergusson and Rafter (1959)
178,000 ± 9,000	K-Ar		McDougall et al. (1969)
192,000 ± 7,000	K-Ar		McDougall et al. (1969)
263,000 ± 5,000	K-Ar		McDougall et al. (1969)
258,000 ± 6,000	K-Ar		McDougall et al. (1969)
252,000 ± 8,000	K-Ar		McDougall et al. (1969)
229,000 ± 6,000	K-Ar		McDougall et al. (1969)
229,000 ± 6,000	K-Ar		McDougall et al. (1969)
141,000 ± 10,000	Therm		Wood (1991)
260,000 ± 29,000	Ar-Ar		Hall and York (1984)
207,000 ± 29,000	Ar-Ar		Hall and York (1984)
200,100 ± 7,400	Ar-Ar	Weighted mean of four subsamples, no excess Ar	Cassata et al. (2008)

PURCHAS HILL

One radiocarbon date is available for Purchas Hill, namely 10,910 ± 139 Cal yr BP (Table 25). This is slightly older than the estimated age for the adjacent Mt Wellington, and is consistent with field observations of the Purchas Hill tuff ring being overlain by a lava flow from Mt Wellington (Hayward 2006). A distinctive wet tephra deposit within the Purchas Hill scoria sequence is thought to have been derived from an early Mt. Wellington event, suggesting that the eruptions from these two centres may, in fact, have been partly contemporaneous (B. Hayward, written. comm. 2009).

Table 25: Age determination available for Purchas Hill volcano. For more detail see Appendix 1.

Age (^{14}C= Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference
10,910 ± 139	$^{14}C^{c}$	9,549 ± 58	20 cm tree branch from Purchas Hill	CJN Wilson (pers. comm)

1 = ^{14}C age presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age; c= Conventional age.

RANGITOTO

Rangitoto is the youngest volcano in the AVF and has been the focus of numerous studies aimed at determining its age. The Rangitoto eruption is thought to have begun with phreatomagmatic activity that then evolved into an alkali basalt cone building eruption. This eruption showered tephra on nearby Motutapu island, where archaeological excavations have revealed that it buried cultural layers (Scott 1970); casts of human and dog footprints preserved in the volcanic tephra also provide evidence for human habitation on Motutapu before and after the eruption. Recent research by Needham (2009) has revealed that this first phase of activity was likely followed by a break of several (maybe up to 50) years, after which a new cone (the current summit) of tholeiitic basalt was formed, followed closely by the final phase of activity producing the extensive tholeiitic basalt lava field that aprons the summit cone. A thin tephra of tholeiitic composition overlying a thick tephra preserved in Motutapu swamps has been correlated to this second phase of activity (Needham 2009). Two black, coarse, 2 and 1 mm-thick tephras at 28 and 27 cm depth, respectively, in a core from Lake Pupuke are inferred to be from Rangitoto (Horrocks et al. 2005b). These two tephras are separated by laminated lake sediments, and a time gap between the tephras of 5-10 years has been estimated on the basis of sedimentation rates (B. Hayward, written comm. 2009).

Of the 24 radiocarbon dates available for Rangitoto activity (Table 26; Figure 3), only two are from beneath the lava flows on Rangitoto itself, the remaining 22 are all from tephra on Motutapu Island. Of the 22 ages from Motutapu, 12 are from charcoal or charred wood extracted from beneath or within a thick alkali basalt tephra, 9 are from charcoal, charred wood or peat extracted from above this layer, and one is from shells found in beach sands directly beneath the tephra (Table 26). Several paleomagnetic and thermoluminescence ages have been determined for the lava field, but attempts to date the lava using K-Ar have been unsuccessful due to excess Ar (McDougall et al, 1969; Table 27).

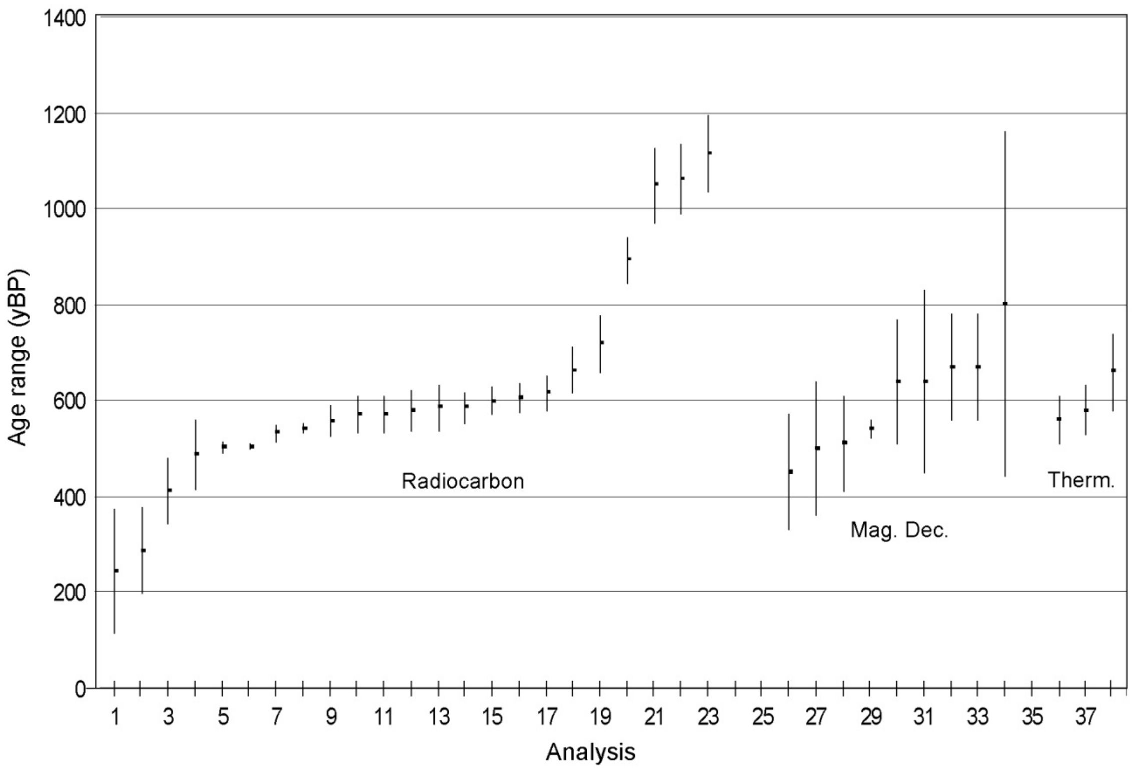

Figure 3: Plot showing ages and errors for Rangitoto. The technique used is indicated. Note the high and low paleomagnetic declination outliers are excluded from this plot as they are considered erroneous, as is the youngest ^{14}C age which unequivocally dates human activity. Analyses 5 and 6 were used to estimate the age of the second eruption and analyses 7-12 and 14-16 were used here to estimate the age of the first eruption (see text for details).

AGE OF THE FIRST RANGITOTO ERUPTION

The 12 analyses of charred material/charcoal from beneath or within the thick alkali basalt tephra on Motutapu are potential candidates for dating the earlier tephra fall event, i.e. the onset of the first Rangitoto cone-building phase (Table 26). These ages range from 410 ± 69 to Cal years BP to 663 ± 47 'Calibrated years before present' (Cal years BP), with nine ages falling within error of 550-580 Cal years BP (Table 26; Figure 3). Of the remaining three ages, two lie outside this cluster (analyses 3 and 18) and one has a relatively large error (analysis 4) (Table 26). The shells from beach sands below tephra on Motutapu yielded an age of 718 ± 59 Cal years BP, which may provide a maximum age for the tephra on Motutapu. Needham (2009) presented a weighted mean age of 604 ± 15 (Cal yr BP) for the first Rangitoto eruption, based on the 6 ages obtained during his study from material within and beneath the lower tephra layer in swamps. He argued that the ages derived from material in swamps are less likely to reflect human habitation than ages obtained from archaeological sites around the island. Since his 2009 study, he has recalibrated his new ages together with previously published ages using a calibration curve that is considered more suitable for the Southern Hemisphere (OxCal 4.1, curve ShCal04). These recalibrated ages are presented in Table 26 and yield a revised weighted mean age (of the 9-sample age cluster referred to above) of 552 ± 7 years. Note that, although within error of the 9-age cluster, analyses 13 and 17 were not included in the weighted mean calculations as they were obtained on organic material from *above* the thick tephra layer.

AGE OF THE SECOND RANGITOTO ERUPTION

Two of the 9 dates from above the thick tephra on Motutapu are candidates for determining the ages of the second Rangitoto eruption. These dates, 502 ± 11 and 504 ± 6 Cal yr BP (analyses 5 and 6), are from peat from above and within the upper tephra layer, respectively (Table 26; Figure 3). A weighted mean of the two analyses yields an age of 504 ± 5 Cal yr BP (Needham written comm. 2009; note that this varies slightly from the weighted mean age given in Needham, 2009, as it uses the OxCal Southern Hemisphere calibration curve). This age may be regarded as a younger limit for the age of the second eruption.

The remaining 7 analyses of charcoal or peat extracted from above the thick tephra on Motutapu likely represent either human activity (e.g. the 159 ± 96 Cal years BP haangi preserved in tephra on Motutapu), or, where the age is older than the ages from beneath the tephra, older charcoal incorporated into younger sediments (e.g. the 893 ± 47, 1049 ± 77 and 1114 ± 80 Cal years BP ages for material in peat above Rangitoto tephra in Billy Goat Swamp; Table 26).

The two ^{14}C analyses from beneath actual lava on Rangitoto Island were carried out on non-charred wood beneath a lava flow devoid of vegetation (214 ± 129 Cal years BP) and on molluscan shells in mud baked by lava flows (1061 ± 72 Cal years BP). The latter provides a maximum age for the lava flows, but does not reveal anything more about the timing of lava flow activity as the shells may have been dead for some time before being covered by the lava. The younger of these two ages has been discussed in detail by Nichol (1992), as for a while it was thought to confirm a theory that lava flow activity on Rangitoto may be quite young, given the lack of vegetation on the island prior to 200 years ago (Millener 1953, 1979). The wood is not charred, and in fact it is unlikely that there would have been any trees in the area prior to the development of the lava field. This, together with the lack of oral evidence for an eruption as recently as 250 years ago, suggests to us that this may represent the roots of a tree that grew after the eruption and managed to penetrate down through the lava flow.

Paleomagnetic declination dating by Robertson (1983, 1986) suggests that the effusion of lava on Rangitoto occurred between 950 ± 170 and 450 ± 120 years BP (Table 27). Excluding the oldest and youngest age listed in Table 27, the latter of which is thought by Robertson (1983) to be unreliable, these age estimates fall between 585 and 570 years BP (95% confidence limit). This is broadly consistent with the thermoluminescence ages for Rangitoto lavas (Table 27) as well as the younger age limit of 504 ± 5 Cal yr BP for this second eruption.

Table 26: ^{14}C age determinations for eruptive and human activity at Rangitoto Island. For more detail see Appendix 1.

An.[1]	Age (Cal yBP)[2]	Method	C14 age[3] (original)	Description	Reference[4]
	159 ± 96	C-14	185 ± 71	Charcoal from small haangi, site N38/37, Motutapu	Davidson (1972)
1	214 ± 129	C-14	225 ± 110	Non-charred wood beneath lava flow, Rangitoto	Polach et al. (1969); McDougall et al. (1969)
2	286 ± 89	C-14[c]	280 ± 40	Charcoal from base of oven in 8ft thick tephra, Motutapu	Brothers and Golson (1959); Grant Taylor and Rafter (1963)
3	410 ± 69*[#]	C-14[c]	410 ± 73	Charred twigs from beneath Rangitoto tephra, Station Bay, Motutapu	Davidson (1972)
4	488 ± 73*[#]	C-14[c]	507 ± 74	Charred twigs from beneath Rangitoto tephra, Station Bay, Motutapu	Davidson (1972)
5	502 ± 11	C-14[a]	482 ± 20	Peat from above the upper tephra, Sandy Bay swamp, Motutapu	Needham (2009)
6	504 ± 6	C-14[a]	485 ± 15	Peat from above the upper tephra, Sandy Bay swamp, Motutapu	Needham (2009)
7	532 ± 17*	C-14[a]	558 ± 30	Wood/twig branch from base of lower tephra, Billy Goat Point swamp, Motutapu	Needham (2009)
8	541 ± 10*	C-14[a]	582 ± 15	Wood near the top of lower tephra, Station Bay swamp, Motutapu	Needham (2009)
9	556 ± 32*	C-14[a]	591 ± 30	Wood flax/twig from base of lower tephra, Billy Goat Point swamp, Motutapu	Needham (2009)
10	570 ± 38*	C-14[c]	600 ± 40	Charcoal from base of pit 5, site N38/37, Motutapu	Davidson (1972)
11	570 ± 38*	C-14[c]	600 ± 40	Charred twigs from beneath Rangitoto tephra, Station Bay, Motutapu	Davidson (1972)
12	579 ± 42*	C-14	610 ± 60	Charcoal from oven below tephra at site N38/24, Motutapu	Law (1975)
13	584 ± 46	C-14	620 ± 70	Charcoal from culture layer above tephra, site N38/24, Motutapu	Law (1975); Robertson (1986)
14	585 ± 32*	C-14[a]	621 ± 20	Wood near base of lower tephra, Station Bay swamp, Motutapu	Needham (2009)
15	599 ± 30*	C-14[a]	646 ± 30	Wood/twig bark from base of lower tephra, Sandy Bay swamp, Motutapu	Needham (2009)
16	606 ± 30*	C-14[a]	677 ± 30	Charcoal from top of lower tephra, Sandy Bay swamp, Motutapu	Needham (2009)
17	615 ± 35	C-14[a]	713 ± 20	Twigs from above lower tephra, Station Bay swamp, Motutapu	Needham (2009)
18	663 ± 47*[#]	C-14[c]	770 ± 50	Charred twig at base of tephra bed, Pig Bay, Motutapu	Brothers and Golson (1959), Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)
19	718 ± 59	C-14[c]	1153 ± 40[†]	Shells found in upper layers of tephra-free beach sand, Pig Bay, Motutapu	Brothers and Golson (1959); Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)
20	893 ± 47	C-14[a]	1045 ± 30	Peat from above lower tephra, Billy Goat Point swamp, Motutapu	Needham (2009)
21	1049 ± 77	C-14[a]	1177 ± 66	Wood from peat immediately above Rangitoto tephra, Billy goat Swamp, Motutapu	Elliot et al. (unpublished)
22	1061 ± 72	C-14[c]	1500 ± 41[†]	Shells in mud baked by lava flows, SW side, seaward end, Rangitoto	Grant-Taylor and Rafter (1971)
23	1114 ± 80	C-14[a]	1244 ± 66	Humin from peat immediately above Rangitoto tephra, Billy Goat Swamp, Motutapu	Elliot et al. (unpublished)

*1 = analysis number as shown in Figure 3; 2 = ^{14}C ages presented here as Calendric Age calBP, calibration carried out using OxCal 4.1, ShCal04; 3 = non-calibrated ages as they appear in the original literature; 4 = original reference listed first; a= AMS age c= Conventional age. * = candidates for dating the first Rangitoto eruption. # = excluded from weighted mean age calculation of first eruption. † = In early publications these two shell ages had already been treated for marine effects (C. Prior, written comm. 2009); the calibrated ages presented here are based on the original CRA ages extracted from the 'Old 14C database' by C. Prior of GNS Science.*

Table 27: Paleomagnetic, thermoluminescence and K-Ar ages for the Rangitoto lava field. For more detail see Appendix 1.

Age (yBP)	Method	Description	Reference
140 ± 150	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
450 ± 120	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
500 ± 140	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
510 ± 100	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
540 ± 20	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
640 ± 130	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
640 ± 190	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
670 ± 110	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
670 ± 110	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
800 ± 360	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
950 ± 170	Mag. Dec.	basaltic lava from the lava field	Robertson (1983, 1986)
560 ± 50	Therm	Plagioclase in lava from lava field	Wood (1991)
580 ± 50	Therm	Plagioclase in lava from lava field	Adams (1986)
659 ± 80	Therm	Plagioclase in lava from lava field	Phillips (1989)
146,000 ± 12,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
160,000 ± 13,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
163,000 ± 8,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
184,000 ± 21,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
189,000 ± 8,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
363,000 ± 13,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
386,000 ± 13,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
398,000 ± 13,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
385,000 ± 13,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
420,000 ± 10,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
404,000 ± 11,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)
465,000 ± 11,000	K-Ar	Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)

Paleomagnetic declination ages are from 11 different sites on lava field. Thermoluminescence ages all represent different calibrations of the same original sample. See Appendix 1 for more detail.

BEST ESTIMATE AGE FOR RANGITOTO

There is a cluster of ages within error of 550-580 Cal yr BP that takes in 9 of the total 24 analyses; the range of ages for this cluster is from 532 ± 17 to 606 ± 30 (Figure 3). A weighted mean of these analyses yields an age of 552 ± 7 Cal yr BP for the first Rangitoto eruption. The best estimate age for the tephra fall activity associated with the second eruption is 504 ± 5 Cal yr BP, although some activity may have occurred before then, as indicated by the slightly older paleomagnetic and thermoluminescence ages for the lava field, and the shorter time gap between the two eruptions inferred from sedimentation rates in Lake Pupuke.

THREE KINGS

Seven ^{14}C ages are available for the Three Kings volcano (Figure 4, Table 28). One dates back to 1958 and was carried out on a sample collected in 1921. The remaining six ages were carried out on organic remains found in 6 different boreholes drilled by GHD as part of the Meola Geotechnical Investigation commissioned by Auckland City Council in 2006 (see Eade 2009 for borehole locations). The charred twigs and wood were found within and beneath tephra underlying lava flows inferred from field evidence and geochemistry to be from Three Kings volcano (Kermode 1992; Eade 2009). The six dates for these samples are remarkably similar, and a weighted mean of the calibrated ages yields 28,619 ± 167 Cal yr BP. We consider this the currently most-reliable best estimate age for Three Kings.

Table 28: Age determinations available for Three Kings volcano. For more detail see Appendix 1.

Age (^{14}C= Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference[3]
28,617 ± 422	^{14}C[a]	23,669 ± 196	Charred rootlets in sediment from below tephra in Meola borehole 16	Eade (2009)
28,541 ± 407	^{14}C[a]	23,589 ± 183	Charred wood in sediment from below tephra in Meola borehole 18	Eade (2009)
28,570 ± 399	^{14}C[c]	23,631 ± 148	Charred wood in sediment from base of airfall deposit in Meola borehole 26	Eade (2009)
28,734 ± 413	^{14}C[a]	23,833 ± 188	Twigs from base of tephra in Meola borehole 27	Eade (2009)
28,673 ± 416	^{14}C[a]	23,746 ± 180	Charred twigs from paleosol at base of tephra in Meola borehole 19	Eade (2009)
28,585 ± 404	^{14}C[c]	23,644 ± 156	Large piece of bark and twigs from tephra in Meola borehole 30	Eade (2009)
32,674 ± 862	^{14}C[c]	28,000 ± 1,000	Wood from a tree stump in tephra collected in 1921 from sewage tunnel construction in Mt Eden (analysed in 1958)	Fergusson and Rafter (1959), Grant-Taylor and Rafter (1963)
117,000 ± 12,000	K-Ar		Basaltic lava (old age reflects excess Ar)	McDougall et al. (1969)

1 = ^{14}C ages presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age; 3 = original reference listed first; c= Conventional age, a= AMS age.

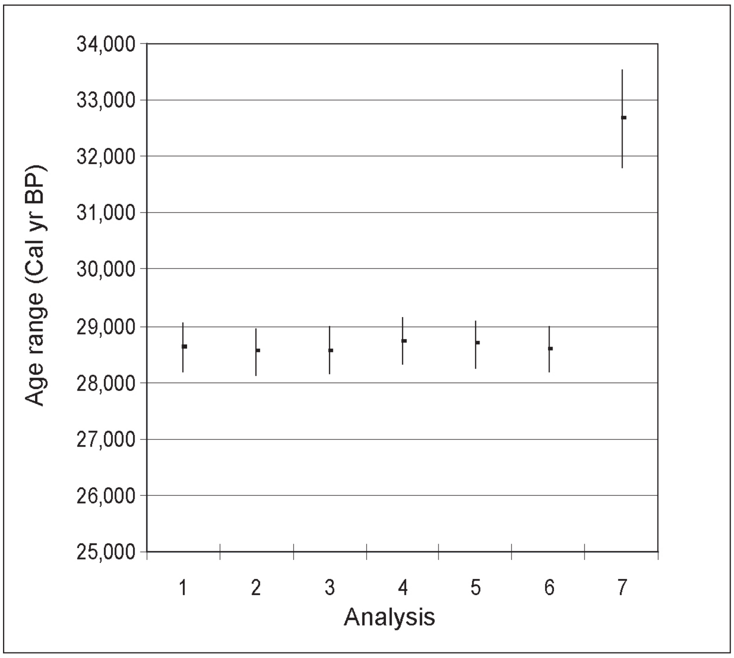

Figure 4: Plot showing ages and errors for Three Kings based on the data in Table 28.

WIRI MOUNTAIN/MANUREWA

Two radiocarbon dates, four K-Ar and two Ar-Ar dates have been published for Wiri Mountain. Excluding the K-Ar dates of McDougall et al. (1969) which are affected by excess Ar, these ages all range between 27 and 33 ka (Table 29).

Table 29: Ages available for Wiri Mountain/Manurewa. For more detail see Appendix 1.

Age (^{14}C = Cal yBP)[1]	Method	^{14}C age[2] (original)	Description	Reference[3]
30,325 ± 462	$^{14}C^{c}$	25,370 ± 350	Wood, Mt Wiri Quarry	Polach et al. (1969); McDougall et al. (1969)
32,879 ± 670	$^{14}C^{c}$	28,300 ± 690	Wood beneath lava, older limit of Wiri lava	Searle (1965); Grant-Taylor and Rafter (1971)
33,000 ± 6,000	K-Ar		Basaltic lava	McDougall et al. (1969)
60,000 ± 3,000	K-Ar		Basaltic lava	McDougall et al. (1969)
64,000 ± 3,000	K-Ar		Basaltic lava	McDougall et al. (1969)
27,000 ± 5,000	K-Ar		Groundmass in basaltic lava from quarry	Mochizuki et al. (2004)
30,100 ± 4,400	Ar-Ar[4]		Weighted mean plateau age of 4 aliquots using different increments	Cassata et al. (2008)
31,000 ± 2,700	Ar-Ar[4]		Weighted mean plateau age of 7 aliquots using different increments	Cassata et al. (2008)

1 = ^{14}C ages presented here as Calendric Age cal BP, calibration carried out using CalPal-Online; 2 = non-calibrated age; 3 = original reference listed first. 4 = see Appendix 1 for results of individual Ar-Ar step heating experiments as well as associated composite isochron ages. c= Conventional age.

DISCUSSION

BEST ESTIMATE AGES FOR AVF VOLCANOES

The best estimate ages for AVF volcanoes as described in the previous section are summarised in Table 30 and Figure 5. Despite the large number (>170) of age determinations available for centres in the AVF, it is clear from Table 30 that we still have a very poor understanding of the ages of most of the ca. 50 individual centres of this field. In order to illustrate the strength of the various ages we have assigned each centre to one of 5 reliability groups; these are explained in Table 31. Based on our reliability assessment, only three centres can be considered well-dated (Reliability Group 1): Rangitoto (0.6 ka), Mt. Wellington (10 ka) and Three Kings (28.5 ka). A further 6 seem to have reliable single ages, or several reliable ages spanning a small age range (Reliability Group 2): Ash Hill (32 ka), Crater Hill (32-34 ka), Panmure Basin (31.5–32.5 ka), Puketutu (30-34 ka), Purchas Hill (11 ka) and Wiri Mountain (27-33 ka). A minimum age can be derived for five centres based on tephrochronology and sedimentation rates in cores (Reliability Group 3): Hopua Basin (>29 ka), Kohuora (>32 ka), Orakei Tuff Ring (>85.5 ka), Pukaki Tuff Ring (>65 ka) and St. Heliers tuff ring (>45 ka). Fifteen centres have yielded conflicting or near-detection-limit ages (Reliability Group 4); the remaining 20 centres are undated (Reliability Group 5; Table 30).

Figure 5: Map of volcanic deposits from each vent in the AVF symbolised by their 'best' age from Table 30, as described in the previous section. Coloured deposits have a 'best' age. Those with an overprinting texture have a 'best' age that is considered to be of lower reliability (as detailed in the legend). Note that Kermode (1992) and others have inferred a possible age for some of those centres with no 'best' age (uncoloured) based on geomorphology and stratigraphic relationships (see Table 3).

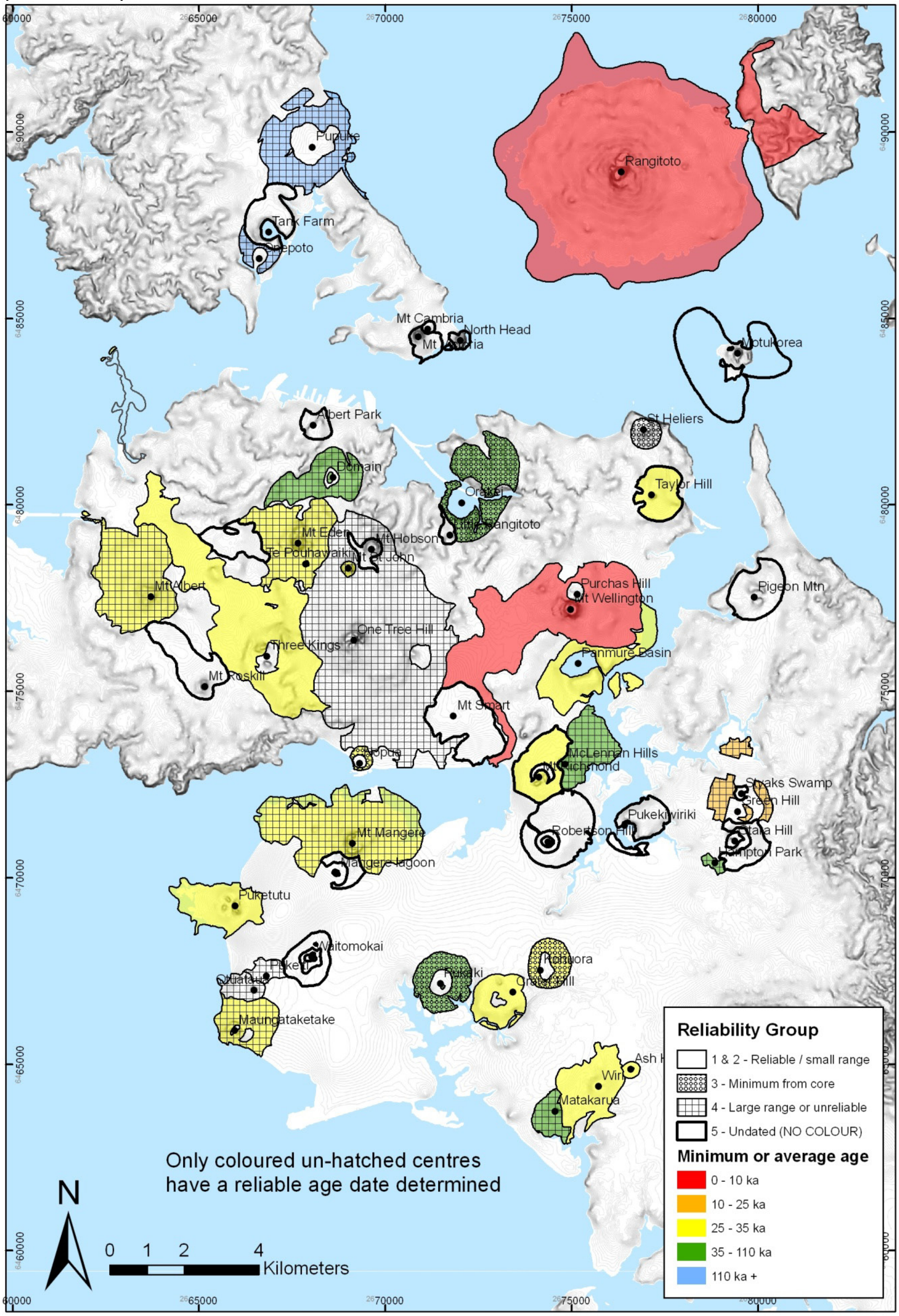

Table 30. The volcanoes of the AVF with their best estimate ages. Minimum ages are presented where appropriate. See text above for explanations of how these ages were derived.

Reliability Group	Volcano	Range of main age cluster[1]	Best estimate age[2]	Comment
1	Mount Wellington	10,035 ± 189 to 10,633 ± 137	10 ka	This age of Mt Wellington tephra is well-constrained by tephrochronology, and correlates with ^{14}C ages of lava.
1	Rangitoto – second eruption Rangitoto – first eruption	502 ± 11 and 504 ± 6 532 ± 17 to 606 ± 30	504 552	Ages are based largely on the recent work of Needham (2009)
1	Three Kings	28,541 ± 407 to 28,734 ± 413	28.5 ka	Weighted mean of 6 ^{14}Csamples from 6 different boreholes in the Meola catchment area.
2	Ash Hill	31,800 ± 159	32 ka	Based on a single ^{14}C age determination.
2	Crater Hill tuff ring	32,100 ± 5,400 to 34,016 ± 265	32 – 34 ka	Range Ar-Ar and ^{14}C ages.
2	Panmure Basin tuff ring	31,697 ± 172 to 32,674 ± 862	31.5 – 32.5 ka*	Based on two early ^{14}C ages
2	Puketutu Island	30,000 ± 5,000 to 33,600 ± 3,700	30 – 34 ka	Range represents weighted mean K-Ar and Ar-Ar ages
2	Purchas Hill	(single age)	11 ka	Based on a single ^{14}C age determination, but consistent with field relations suggesting an age slightly older than Mt Wellington.
2	Wiri Mountain/Manurewa	27,000 ± 5,000 to 32,879 ± 670	27 – 33 ka	Range of Ar-Ar and ^{14}C ages
3	Hopua Basin		>29 ka	Min. age based on tephrochronolgy and sed. rates (see Table 2)
3	Kohuora		>32 ka	Min. age based on tephrochronolgy and sed. rates (see Table 2)
3	Orakei tuff ring		>85.5 ka	Min. age based on tephrochronolgy and sed. rates (see Table 2)
3	Pukaki tuff ring		>65 ka	Min. age based on tephrochronolgy and sed. rates (see Table 2)
3	St Heliers tuff ring/Glover Park		>45 ka	Min. age based on tephrochronolgy and sed. rates (see Table 2)
4	Auckland Domain		>60 ka	Minimum age result from ^{14}C experiment
4	Green Hill	(single age)	20 ka	Based on a single ^{14}C age determined by liquid scintillation counting
4	Hampton Park	26,600 ± 8,000 to 55,000 ± 5,000	26.5 – 55 ka	Based on recent Ar-Ar and K-Ar weighted mean ages
4	Mangere Mountain	21,937 ± 395 to 34,943 ± 389	22 – 35 ka	Range of ^{14}C ages
4	Matakarua/McLaughlin's Hill	(single age)	?110 ka	Based on one unpublished K-Ar age with a large error.
4	Maungataketake/Ihumatao	33,435 ± 1,267 to 177,100 ± 23,400		Full range of available results given; no one reliable result
4	McLennan Hills	42,600 ± 3,800 to 55,000 ± 6,000	42.5 – 55 ka	Based on recent Ar-Ar and K-Ar weighted mean ages
4	Mount Albert		>30 ka	Early ^{14}C minimum age
4	Mount Eden	14,020 ± 1220 to 28,386 ± 345	28 ka	Based on a single ^{14}C age determination, considered more reliable that thermoluminescence.

Table 30, *continued*.

4	Mount Saint John		>28.5 ka	Minimum age based on stratigraphy
4	One Tree Hill			AGE HIGHLY UNRELIABLE
4	Onepoto	>248,000 ± 28,000	>248 ka	New Ar-Ar age on sub-ideal sample (glassy)
4	Otuataua			AGE HIGHLY UNRELIABLE
4	Pukeiti			AGE HIGHLY UNRELIABLE
4	Pupuke	200,100 ± 7,400 to 260,000 ± 29,000	200 – 260 ka	Range of ages determined by Ar-Ar.
5	Albert Park			Undated. (For relative ages see Table 3)
5	Browns Island/Motukorea			Undated. (For relative ages see Table 3)
5	Little Rangitoto			Undated. (For relative ages see Table 3)
5	Mangere Lagoon			Undated. (For relative ages see Table 3)
5	Mount Cambria			Undated. (For relative ages see Table 3)
5	Mount Hobson			Undated. (For relative ages see Table 3)
5	Mount Richmond		32 -34 ka	No direct ages available, but similar paleomagnetic signature to Wiri, Crater Hill etc.
5	Mount Roskill			Undated. (For relative ages see Table 3)
5	Mount Smart			Undated. (For relative ages see Table 3)
5	Mount Victoria			Undated. (For relative ages see Table 3)
5	North Head			Undated. (For relative ages see Table 3)
5	Otara Hill/Smales Hill			Undated. (For relative ages see Table 3)
5	Pigeon Mountain			Undated. (For relative ages see Table 3)
5	Pukewairiki/Waiuru			Undated. (For relative ages see Table 3)
5	Robertson Hill			Undated. (For relative ages see Table 3)
5	Styaks Swamp			Undated. (For relative ages see Table 3)
5	Tank Farm (or Tuff Crater)			Undated. (For relative ages see Table 3)
5	Taylors Hill		32 -34 ka	No direct ages available, but similar paleomagnetic signature to Wiri, Crater Hill etc.
5	Te Pouhawaiki			Undated. (For relative ages see Table 3)
5	Waitomokia			Undated. (For relative ages see Table 3)

1=^{14}C ages represent calibrated ages (ages expressed as ka, apart from Rangitoto, which is given in years). Outliers of unknown reliability and unreliable ages excluded; 2= Rounded to 500 years, other than Rangitoto which is rounded to 10 years. * Early ^{14}C ages 30,000 cal yr BP or older may be minimum ages.

Table 31. Explanation of the reliability groups used to categorise the ages for individual AVF centres.

Reliability Group	Definition
1	Reliable reproducible age determined (3 centres)
2	Reliable single age determination or several reliable ages spanning a relatively small range (6 centres)
3	Minimum age based on tephrochronology and sedimentation rate in core (5 centres)
4	Varied, conflicting or near-detection-limit age determinations (15 centres)
5	No direct or minimum age date determined* (20 centres)

**Taylors Hill and Mount Richmond paleomagnetic correlations to dated volcanoes are considered to probably be correct, and thus an age of 32-34 ka is likely for these two centres.*

FREQUENCY OF PAST ACTIVITY IN THE AVF

Despite the lack of good age data for the majority of centres in the AVF, one thing does stand out in the best estimate ages and age ranges in Table 30. Excluding the youngest and oldest of these age ranges (Rangitoto and Pupuke, respectively) as well as any minimum ages, all estimates fall between 10 and 55 thousand years (Figure 6). Furthermore, within this time frame there is a marked clustering of possible ages between 28 and 33 ka. This clustering corresponds well with the clustering of basaltic tephra in the same age range observed in maar sediment cores (Molloy 2008; Molloy et al. 2009), and further strengthens the argument presented by Cassidy (2006), Cassata et al. (2008) and Molloy et al. (2009) for a “flare-up” of activity in the AVF during this time period. We would like to point out, however, that the dominance of ages between 10 and 55 ka most likely reflects the limit of the ^{14}C dating technique rather than a real tendency for most centres in the AVF to fall within this age range. It is clear that many centres are older than 55 ka (reflected in, for example, the minimum ages for some centres shown in Table 2) and it is entirely possible that the majority of the remaining ca. 50 % of (as yet undated) centres will be older than 55 ka.

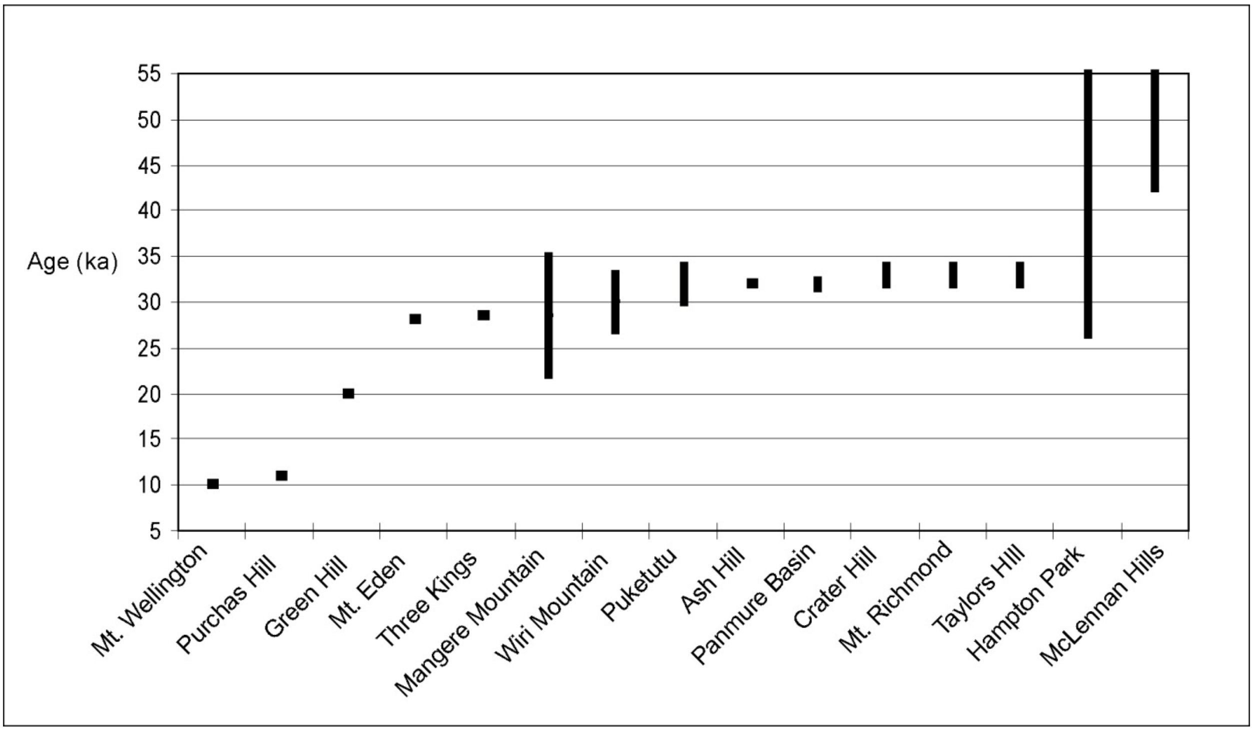

Figure 6. Plot showing the best estimate ages and age ranges for the centres in the AVF (from Table 30), excluding the youngest (Rangitoto), oldest (Pupuke) and minimum ages. Note the apparent cluster of ages between 28 and 33 ka.

CORRELATION OF TEPHRA LAYERS IN CORES WITH VOLCANIC VENTS

The age distribution of summary ages correlates broadly with the stratigraphic locations and age distribution of tephra presented in Molloy et al. (2009) (Fig. 7). The concentration of ages around 30,000 years in both plots in Fig. 7 suggests that at least some of the contributing ^{14}C ages are reliable and not minimum values. As yet, very few of the basaltic tephra layers retrieved from cores can be correlated to individual centres. A much more comprehensive understanding of the age of the individual centres of the field and of the petrological characteristics of the tephra layers is needed for a robust correlation. However, the simplified comparison based on existing data allows a few inferences to be made. There are clearly several potential candidates for the source of the numerous 30-32 ka tephra layers observed in sediment cores, but far fewer candidates for the tephra cluster around 25 ka. A 20 ka-old tephra layer in the sediment cores is the same age as the single age available for Green Hill; further work will be necessary to determine whether Green Hill represents a realistic potential source for this layer.

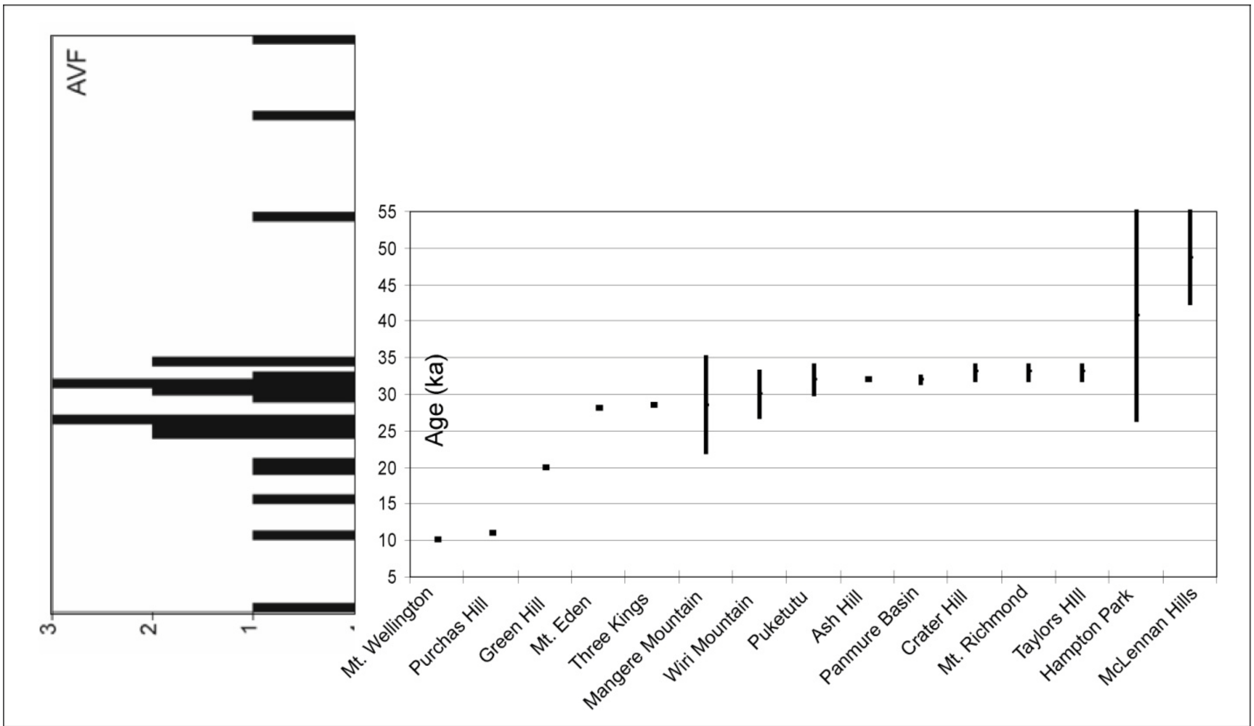

Figure 7. Comparison of the temporal distributions of basaltic tephra layers found in AVF sediment cores from Molloy et al (2009) (left) with the best estimate ages and age ranges for the centres in the AVF presented in Table 30, excluding the youngest (Rangitoto), oldest (Pupuke), and minimum ages.

IMPLICATIONS FOR HAZARD ASSESSMENT AND HAZARD MODELS

Our results have implications for any statistical treatment of the distribution of past volcanism in the Auckland Volcanic Field. Past eruption timing is a common parameter in calculations of future risk. In some (if not all) cases, the data presented in this report will alter the results of past statistical studies based on previous published data or data summaries. This is because we have made a number of revisions to the age summary for AVF volcanoes. We have:

- revised the list of volcanoes considered to have no reliable age;
- listed volcanoes for which we are suspicious of the reliability of the age; this includes some ^{14}C ages that may be a minimum ages;

- listed some new reliable ages;
- recalibrated all existing ^{14}C ages;
- in cases where multiple analyses exist, provided an assessment of which age(s) for a volcano is the most reliable;
- listed a new summary age (or age range) for each volcano based on the above revisions.

This report was conducted with the express purpose of directing new effort in dating AVF volcanoes. The fact that this report will become outdated over the course of the DEVORA project (see recommendations below) should be kept in mind when using the data presented here.

RECOMMENDATIONS FOR FUTURE WORK

This report will be used as the basis for prioritizing radiometric dating within the DEVORA project. Volcanoes listed as not having any reliable known age should be the main priority for further dating (Table 30, Figure 5). Many are poorly exposed, so drill core may represent the only samples available.

Future dating conducted by ^{14}C and Ar-Ar methods should be a priority. Modern K-Ar analyses are still considered reliable (accurate), but not as precise as Ar-Ar. For samples that have fine-grained groundmass producing reactor recoil results with Ar-Ar, a K-Ar age may still work, because no irradiation is used in the latter case. Techniques other than ^{14}C, Ar-Ar and K-Ar have produced apparently less reliable results. They should not be used as a priority, however, further testing and refining of less-conventional techniques in the AVF should not be ruled out.

Ideally, Ar-Ar dating should be carried out on all AVF volcanoes. In contrast to ^{14}C dates, the quality of Ar-Ar results increases for older deposits. Deposits older than 50,000 years cannot usually be dated by ^{14}C. For deposits older than 25,000-30,000 years, Ar-Ar may not give as precise an age, but it is a good check as to whether ^{14}C ages from about 30,000 to 50,000 are realistic, as opposed to minimum ages.

^{14}C dating should be attempted on all possible volcanoes. It is worth running new ^{14}C analyses on samples from volcanoes with existing ^{14}C ages determined more than two decades ago, especially those older than 25,000 years, because the technique has improved over the years. It is also worth running new ^{14}C ages on volcanoes with existing ^{14}C ages younger than 25,000 years, if the stratigraphic control of the sample, or the physical quality/type of sample, was in question. For any Ar-Ar ages determined as younger than 25,000 years, ^{14}C will give a more precise and probably a more accurate age than Ar-Ar.

At the conclusion of the DEVORA project a revision of this summary should be carried out.

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APPENDIX 1: DATABASE OF RADIOMETRIC AGES FOR THE AUCKLAND VOLCANIC FIELD

Line	Age (C-14 = Cal yr BP)	Original C14 DATE	Error	Method	Sample Material	Sample Environment	collected by	Petlab coln. #	Pet Age	Pet Err	FRED	FRED Yard
	All ages calibrated using online CapPal except Rangitoto; all Rangitoto ages are calibrated using Oxcal 4.1 using a calibration curve for the southern hemisphere (ShCal04)											
1	**Ash Hill**											
2	31,800 ± 159	27,065	199	C-14 CRA	wood	small in-situ tree directly beneath tuff	H Grenfell/ B Hayward					
3												
4	**Auckland Domain**											
5	>60,000			C-14	Tree	beneath Domain tuff	Hugh Grenfell/Jill Kenny					
6												
7	148,000 ± 10,000			K-Ar				GA3206	154,000	8,000		
8	152,000 ± 5,000			K-Ar				GA3206	154,000	8,000		
9												
10	**Crater Hill tuff ring**											
11	33,332 ± 671	29,000	700	C-14 CRA	wood from sapling	in tuff taken while building tunnel	Searle	R1381/3	29306	714	R11/f7586	N42/f0586
12	34,016 ± 265	29,700	200	C-14 CRA	wood	between 2 separate tuffs	Searle	R1023/2	29,706	1945	R11/f7585	N42/f0585
13												
14	60,000 ± 30,000			K-Ar								
15	117,000 ± 5,000			K-Ar				GA2869	120,000	5,000		
16												
17	35,700 ± 21,500			Ar-Ar			Singer/Cassidy; NZ0601a					
18	31,300 ± 12,900			Ar-Ar			Singer/Cassidy; NZ0601b					
19	30,400 ± 11,900			Ar-Ar			Singer/Cassidy; NZ0601c					
20	29,700 ± 18,100			Ar-Ar			Singer/Cassidy; NZ0601d					
21	31,000 ± 14,600			Ar-Ar			Singer/Cassidy; NZ0601e					
22	32,000 ± 13,900			Ar-Ar			Singer/Cassidy; NZ0601f					
23	35,500 ± 12,300			Ar-Ar			Singer/Cassidy; NZ0601g					
24												
25	30,000 ± 29,000			Ar-Ar			Singer/Cassidy; NZ0601a; Isochron					
26	49,000 ± 31,000			Ar-Ar			Singer/Cassidy; NZ0601b; Isochron					
27	33,000 ± 31,000			Ar-Ar			Singer/Cassidy; NZ0601c; Isochron					
28	38,000 ± 35,000			Ar-Ar			Singer/Cassidy; NZ0601d; Isochron					
29	28,000 ± 21,000			Ar-Ar			Singer/Cassidy; NZ0601e; Isochron					
30	23,000 ± 36,000			Ar-Ar			Singer/Cassidy; NZ0601f; Isochron					
31	22,000 ± 20,000			Ar-Ar			Singer/Cassidy; NZ0601g; Isochron					
32												
33	**Green Hill**											
34	19,827 ± 8,976	17,000	8,000	C-14 Methanol		from beneath the Green Hill lava	Kermode, L. O.					
35												
36	**Hampton Park**											
37	55,000 ± 5,000			K-Ar								
38												
39	29,000 ± 11,300			Ar-Ar			Singer/Cassidy; NZ0607a					
40	46,200 ± 11,300			Ar-Ar			Singer/Cassidy; NZ0607d					

Line	C14 #	Reference for date (first reference is the original source)	Description	Comment
1				
2	WK-21120	Hayward (2008a)	4 cm diam trunk of an in situ (rooted) probable Manuka buried by ash on the slopes of the mound of Ash Hill. It was rooted into a peaty soil. The exposure was a recent cutting at the back of a building platform.	Analysed in 2007
3				
4				
5		Grenfell and Kenny (1995)	Tree from beneath Domain ash at the Blind Institute	
6				
7		McDougall et al (1969)	Two ages associated with this PETLAB sample number in McDougall et al, 1969.	
8		McDougall et al (1969)	Two ages associated with this PETLAB sample number in McDougall et al, 1969.	
9				
10				
11	NZ-540	Searle (1965), Grant-Taylor and Rafter (1971)	Wood from roof of tunnel at Station 11780 in Auckland Metropolitan Drainage Board's Spring Street tunnel, Papatoetoe. Wood from trunk of sapling 7.5 cm in diameter buried in tuff from the Papatoetoe tuff cones.	McDougall calls this Crater Hill. In Searle (1965) this is an age for Crater Hill, not Kohuora.
12	NZ-488	Searle (1965), Grant-Taylor and Rafter (1971)	Wood from 20ft depth, in tuff from Kohuora tuff volcano group. Overlain by a shell bed and tuff, and underlain by green-grey tuff. Sewer tunnel portal at Spring St near railway stn, from 300 ft in tunnel	McDougall (1969) calls 'Crater Hill' . Note Grant Taylor and Rafter (1971) cite error as ± 2,000. Searle (1965) cite error as ± 200.
13				
14		Itaya et al (unpublished data)		
15		McDougall et al (1969)		
16				
17		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0601a-g) is 32,100 ± 5,400
18		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0601a-g) is 32,100 ± 5,400
19		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0601a-g) is 32,100 ± 5,400
20		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0601a-g) is 32,100 ± 5,400
21		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0601a-g) is 32,100 ± 5,400
22		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0601a-g) is 32,100 ± 5,400
23		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0601a-g) is 32,100 ± 5,400
24				
25		Cassata et al (2008)		Composite isochron age (Sample ID NZ0601a-g) is 27,800 ± 8,800
26		Cassata et al (2008)		Composite isochron age (Sample ID NZ0601a-g) is 27,800 ± 8,800
27		Cassata et al (2008)		Composite isochron age (Sample ID NZ0601a-g) is 27,800 ± 8,800
28		Cassata et al (2008)		Composite isochron age (Sample ID NZ0601a-g) is 27,800 ± 8,800
29		Cassata et al (2008)		Composite isochron age (Sample ID NZ0601a-g) is 27,800 ± 8,800
30		Cassata et al (2008)		Composite isochron age (Sample ID NZ0601a-g) is 27,800 ± 8,800
31		Cassata et al (2008)		Composite isochron age (Sample ID NZ0601a-g) is 27,800 ± 8,800
32				
33				
34		Sameshima (1990)	Chunk of wood sample from beneath the Green Hill lava	See Stipp, T6, pg 81, and 90 (East Tamaki) for more information. PETLAB no GA002859? 197,000 +- 5,000
35				
36				
37		Mochizuki et al (2004)	weighted mean from three experiments	Good mean, large xtals removed
38				
39		Cassata et al (2008)		Weighted mean plateau age of 4 aliquots using different increments. Problematic sample. (NZ0607a, d-f) is 37,500 ± 5,900
40		Cassata et al (2008)		Weighted mean plateau age of 4 aliquots using different increments. Problematic sample. (NZ0607a, d-f) is 37,500 ± 5,900

Line	Age (C-14 = Cal yr BP)	Original C14 DATE	Error	Method	Sample Material	Sample Environment	collected by	Petlab coln. #	Pet Age	Pet Err	FRED	FRED Yard
41	29,400 ± 13,500			Ar-Ar			Singer/Cassidy; NZ0607e					
42	43,300 ± 11,600			Ar-Ar			Singer/Cassidy; NZ0607f					
43												
44	24,000 ± 14,000			Ar-Ar			Singer/Cassidy; NZ0607a; Isochron					
45	10,000 ± 19,000			Ar-Ar			Singer/Cassidy; NZ0607b; Isochron					
46	18,000 ± 17,000			Ar-Ar			Singer/Cassidy; NZ0607c; Isochron					
47	16,000 ± 30,000			Ar-Ar			Singer/Cassidy; NZ0607d; Isochron					
48	19,000 ± 18,000			Ar-Ar			Singer/Cassidy; NZ0607f; Isochron					
49	28,000 ± 17,000			Ar-Ar			Singer/Cassidy; NZ0607g; Isochron					
50												
51	**Mangere Mountain**											
52	21,937 ± 395	18,280	265	C-14 CRA	peat (wood and gum)	from mud	Searle	R695/4	17715	165	R11/f7580	N42/f0580
53	32,340 ± 1433	27,800	1,600	C-14 CRA	wood	beneath lava	Searle	R1023/1	27807	1542	R11/f7584	N42/f0584
54	34,943 ± 389	30,790	290	C-14			Ann Williams					
55												
56	120,000 ± 30,000			K-Ar								
57												
58	**Matakarua/McLaughlin's Hill**											
59	110,000 ± 40,000			K-Ar								
60												
61	**Maungataketake/Ihumatao**											
62	33,435 ± 1267	29,000	1,500	C-14	wood from outer portion of tree	in growth position, bedded tuff in cliff face	EJ Searle				R11/f7538	N42/f0538
63	35,464 ± 1,062	31,000	1,000	C-14		Stump in growth position in the cliff section immediately to the south of the cone.						
64	42,206 ± 2,909	38,390	plus 3,100; minus 2,200	C-14	Outer soft part of wood	Stump in growth position in the cliff section immediately to the south of the cone.						
65	47,244 ± 1,944	43,620	1,400	C-14	Cellulose of core	Stump in growth position in the cliff section immediately to the south of the cone.						
66	46,063 ± 2,092	42,130	2,000	C-14	Lignin of core	Stump in growth position in the cliff section immediately to the south of the cone.						
67		>36,400		C-14	Soft wood, outer	Limb of a fallen tree protruding from the tuff in the cliff section immediately to the south of the cone.						
68	40,484 ± 2,056	36,330	2,100	C-14	Heart wood, inner	Limb of a fallen tree protruding from the tuff in the cliff section immediately to the south of the cone.						
69	42,824 ± 1,310	38,450	1,800	C-14	NAOH-soluble fraction on portion of total cross section of ANU-21	Limb of a fallen tree protruding from the tuff in the cliff section immediately to the south of the cone.						
70	44,539 ± 1,531	40,670	1,800	C-14	NaOH-insoluble residue	Limb of a fallen tree protruding from the tuff in the cliff section immediately to the south of the cone.						
71	45,963 ± 2,681	41,800	+2,800, -2,000	C-14	Cellulose and lignin	Limb of a fallen tree protruding from the tuff in the cliff section immediately to the south of the cone.						
72		>36,400		C-14	Wood	A sapling in position of growth in the tuff of a cliff section immediately to the south of the cone.						

Line	C14 #	Reference for date (first reference is the original source)	Description	Comment
41		Cassata et al (2008)		Weighted mean plateau age of 4 aliquots using different increments. Problematic sample. (NZ0607a, d-f) is 37,500 ± 5,900
42		Cassata et al (2008)		Weighted mean plateau age of 4 aliquots using different increments. Problematic sample. (NZ0607a, d-f) is 37,500 ± 5,900
43				
44		Cassata et al (2008)		Composite isochron age (NZ0607a-d, f-g) is 26,600 ± 8,100
45		Cassata et al (2008)		Composite isochron age (NZ0607a-d, f-g) is 26,600 ± 8,100
46		Cassata et al (2008)		Composite isochron age (NZ0607a-d, f-g) is 26,600 ± 8,100
47		Cassata et al (2008)		Composite isochron age (NZ0607a-d, f-g) is 26,600 ± 8,100
48		Cassata et al (2008)		Composite isochron age (NZ0607a-d, f-g) is 26,600 ± 8,100
49		Cassata et al (2008)		Composite isochron age (NZ0607a-d, f-g) is 26,600 ± 8,100
50				
51				
52	NZ-389	Searle (1959; 1965), Grant-Taylor and Rafter (1971)	Peat, including wood and gum, 50ft below sea level, from mud underlying Mangere Mt lava, from AMDB Siphon line across Manukau Harbour	Dates alluvium of late glaciation submerged terrace and places older limit on the flow from Mangere Mt.
53	NZ-487	Searle (1959; 1965), Grant-Taylor and Rafter (1971)	Wood beneath lava in Manukau Harbour, between Mangere and White Bluff, on Siphon line	
54		Ann Williams, Beca carter		Obtained early 2000s
55				
56		Itaya et al (unpublished data)		
57				
58				
59		Itaya et al (unpublished data)		Unclear what material was dated. Groundmass only? Was there excess Ar?
60				
61				
62	NZ-215	Fergusson and Rafter (1959), Grant-Taylor and Rafter (1963)	Wood from outer portion of tree (40.6 cm diameter) - stump in position of growth enclosed by tuff forming 4.6 m cliff. These bedded tuffs are covered with flows from Ihumatao and appear to belong to the tuff ring surrounding the scoria cone. The tree is part of an extensive fossil forest exposed on the shore platform (trees to 2.1 m in diameter).	South shore of Ihumatao, Mangere, Auckland - from a cliff face at the end of the road to the old Pa. Age determinations would provide a lower limit to the date of eruption for the centre.
63	ANU-9	Radiocarbon (1967), v9 9.19	Stump in growth position in cliff section immediately south of cone, encased in tuff	This is the original age obtained from ANU 9.
64	ANU-9 W	Polach et al (1969), McDougall et al (1969)	Stump in growth position in cliff section immediately south of cone, encased in tuff	Weighted mean of 4 samples (ANU-9, 32, 34 and 36) gives 41,750 ± 700 (45,240 ± 881 Cal yr BP). One sample (ANU-36) is a piece of NZ-215. Mean age excludes the original ANU-9 analysis from 1967. Ages may be too young because of contamination (Pollach et al 1969)
65	ANU-9 C	Polach et al (1969), McDougall et al (1969)	Stump in growth position in cliff section immediately south of cone, encased in tuff	Weighted mean of 4 samples (ANU-9, 32, 34 and 36) gives 41,750 ± 700 (45,240 ± 881 Cal yr BP). One sample (ANU-36) is a piece of NZ-215. Mean age excludes the original ANU-9 analysis from 1967. Ages may be too young because of contamination (Pollach et al 1969)
66	ANU-9 L	Polach et al (1969), McDougall et al (1969)	Stump in growth position in cliff section immediately south of cone, encased in tuff	Weighted mean of 4 samples (ANU-9, 32, 34 and 36) gives 41,750 ± 700 (45,240 ± 881 Cal yr BP). One sample (ANU-36) is a piece of NZ-215. Mean age excludes the original ANU-9 analysis from 1967. Ages may be too young because of contamination (Pollach et al 1969)
67	ANU-32 SW	Polach et al (1969), McDougall et al (1969)	Limb of a fallen tree protruding from the tuff in the cliff section immediately to the south of the cone.	Weighted mean of 4 samples (ANU-9, 32, 34 and 36) gives 41,750 ± 700 (45,240 ± 881 Cal yr BP). One sample (ANU-36) is a piece of NZ-215. Mean age excludes the original ANU-9 analysis from 1967. Ages may be too young because of contamination (Pollach et al 1969)
68	ANU-32 H	Polach et al (1969), McDougall et al (1969)	Limb of a fallen tree protruding from the tuff in the cliff section immediately to the south of the cone.	Weighted mean of 4 samples (ANU-9, 32, 34 and 36) gives 41,750 ± 700 (45,240 ± 881 Cal yr BP). One sample (ANU-36) is a piece of NZ-215. Mean age excludes the original ANU-9 analysis from 1967. Ages may be too young because of contamination (Pollach et al 1969)
69	ANU-32 S	Polach et al (1969), McDougall et al (1969)	Limb of a fallen tree protruding from the tuff in the cliff section immediately to the south of the cone.	Weighted mean of 4 samples (ANU-9, 32, 34 and 36) gives 41,750 ± 700 (45,240 ± 881 Cal yr BP). One sample (ANU-36) is a piece of NZ-215. Mean age excludes the original ANU-9 analysis from 1967. Ages may be too young because of contamination (Pollach et al 1969)
70	ANU-32 I	Polach et al (1969), McDougall et al (1969)	Limb of a fallen tree protruding from the tuff in the cliff section immediately to the south of the cone.	Weighted mean of 4 samples (ANU-9, 32, 34 and 36) gives 41,750 ± 700 (45,240 ± 881 Cal yr BP). One sample (ANU-36) is a piece of NZ-215. Mean age excludes the original ANU-9 analysis from 1967. Ages may be too young because of contamination (Pollach et al 1969)
71	ANU-32 CL	Polach et al (1969), McDougall et al (1969)	Limb of a fallen tree protruding from the tuff in the cliff section immediately to the south of the cone.	Weighted mean of 4 samples (ANU-9, 32, 34 and 36) gives 41,750 ± 700 (45,240 ± 881 Cal yr BP). One sample (ANU-36) is a piece of NZ-215. Mean age excludes the original ANU-9 analysis from 1967. Ages may be too young because of contamination (Pollach et al 1969)
72	ANU-34	Polach et al (1969), McDougall et al (1969)	A sapling in position of growth in the tuff of a cliff section immediately to the south of the cone.	Weighted mean of 4 samples (ANU-9, 32, 34 and 36) gives 41,750 ± 700 (45,240 ± 881 Cal yr BP). One sample (ANU-36) is a piece of NZ-215. Mean age excludes the original ANU-9 analysis from 1967. Ages may be too young because of contamination (Pollach et al 1969)

Line	Age (C-14 = Cal yr BP)	Original C14 DATE	Error	Method	Sample Material	Sample Environment	collected by	Petlab coln. #	Pet Age	Pet Err	FRED	FRED Yard
73		>33,500		C-14	Wood	From a portion of the original sample (NZ-215) dated by Ferguson and Rafter (1959).						
74	>55,000	>55,000		C-14	wood	Renton Road fossil forest						
75	>55,000	>55,000		C-14	wood	Renton Road fossil forest						
76												
77	126,000 ± 9,000			K-Ar								
78	74,000 ± 15,000			K-Ar				GA2856	109,000	11,000		
79	106,000 ± 11,000			K-Ar				GA2856	109,000	11,000		
80	125,000 ± 22,000			K-Ar				GA2856	109,000	11,000		
81	131,000 ± 6,000			K-Ar				GA2856	109,000	11,000		
82	138,000 ± 7,000			K-Ar				GA2856	109,000	11,000		
83	109,000 ± 11,000			K-Ar			McDougall, I.	GA2856	109,000	11,000		
84	107,000 ± 6,000			K-Ar				GA3176	110,000	6,000		
85	108,000 ± 4,000			K-Ar				GA3174	110,000	6,000		
86	110,000 ± 6,000			K-Ar			McDougall, I.	GA3176?	110,000	6,000		
87												
88	38,100 ± 1,900			Therm			Wood, I. A.	IAW-Maun	38100	3800		
89												
90	177,100 ± 23,400			OSL								
91	140,300 ± 14,200			OSL								
92												
93	**McLennan Hills**											
94	31,697 ± 172	26,910	190	C-14								
95												
96	40,000 ± 19,000			K-Ar			McDougall	GA2877	41,000	19,000		
97	59,000 ± 5,000			K-Ar			McDougall	GA2878	61,000	5,000		
98	90,000 ± 5,000			K-Ar			McDougall	GA2855	92,000	5,000		
99	101,000 ± 5,000			K-Ar			McDougall	GA2879	104,000	5,000		
100	104,000 ± 3,000			K-Ar			McDougall	GA2876	108,000	6,000		
101	105,000 ± 8,000			K-Ar			McDougall	GA2876	108,000	6,000		
102	107,000 ± 4,000			K-Ar			McDougall	GA3175	110,000	4,000		
103	113,000 ± 3,000			K-Ar			McDougall	GA2854	127,000	3,000		
104	124,000 ± 3,000			K-Ar			McDougall	GA2854	127,000	3,000		
105	41,000 ± 10,000			K-Ar			Mochizuki; NZ217-1					
106	63,000 ± 10,000			K-Ar			Mochizuki; NZ217-0					
107	33,000 ± 13,000			K-Ar			Mochizuki; NZ217-3-A					
108	64,000 ± 18,000			K-Ar			Mochizuki; NZ217-3-B					
109												
110	48,800 ± 2,500			Therm			Wood, I. A.	IAW-McL	48800	5000		
111												
112	43,500 ± 9,700			Ar-Ar			Singer/Cassidy; NZ0605a					
113	39,900 ± 9,900			Ar-Ar			Singer/Cassidy; NZ0605b					

Line	C14 #	Reference for date (first reference is the original source)	Description	Comment
73	ANU-36	Polach et al (1969), McDougall et al (1969)	See NZ-215	Weighted mean of 4 samples (ANU-9, 32, 34 and 36) gives 41,750 ± 700 (45,240 ± 881 Cal yr BP). One sample (ANU-36) is a piece of NZ-215. Mean age excludes the original ANU-9 analysis from 1967. Ages may be too young because of contamination (Pollach et al 1969)
74	Wk-3411	Marra et al. (2006)	Outer wood sample of in-situ Agathis australis stump	R11/662645
75	Wk-3412	Marra et al. (2006)	Outer trunk sample of Podocarp tree extending upwards into, and truncated by, overlying phreatomagmatic succession	R11/663645
76				
77		McDougall et al (1969)		
78		McDougall et al (1969)		Five ages associated with this PETLAB sample number in McDougall et al, 1969
79		McDougall et al (1969)		Five ages associated with this PETLAB sample number in McDougall et al, 1969
80		McDougall et al (1969)		Five ages associated with this PETLAB sample number in McDougall et al, 1969
81		McDougall et al (1969)		Five ages associated with this PETLAB sample number in McDougall et al, 1969
82		McDougall et al (1969)		Five ages associated with this PETLAB sample number in McDougall et al, 1969
83		McDougall et al (1969)		
84		McDougall et al (1969)		low age in range of 3 dates
85		McDougall et al (1969)		
86		McDougall et al (1969)		Also GA3174 collected by Stipps, JJ shows same age
87				
88		Wood (1991)		
89				
90		Marra et al (2006)	Carried out at Luminescence Dating Laboratory, Victoria University of Wellington	Marra et al. (2006) claim that their OSL dates are consistent with a > 127,000 age based on morphology, as a marine terrace cuts the sequence
91		Marra et al (2006)	Carried out at Luminescence Dating Laboratory, Victoria University of Wellington	
92				
93				
94		Polach et al (1969); McDougall et al (1969)		
95				
96		McDougall et al (1969)		Low end of range of dates
97		McDougall et al (1969)		
98		McDougall et al (1969)		
99		McDougall et al (1969)		
100		McDougall et al (1969)		Two ages associated with this PETLAB sample number in McDougall et al, 1969
101		McDougall et al (1969)		Two ages associated with this PETLAB sample number in McDougall et al, 1969
102		McDougall et al (1969)		
103		McDougall et al (1969)		Two ages associated with this PETLAB sample number in McDougall et al, 1969
104		McDougall et al (1969)		High end of range of dates. PETLAB indicates an age of 127,000 +/- 3,000. Same reference? See also GA002876, GA002877, GA002878
105		Mochizuki et al (2007)		Weighted mean of 4 experiments (NZ217-0, NZ217-1, NZ217-3-A, NZ217-3-B) is 50,000 ± 6,000
106		Mochizuki et al (2007)		Weighted mean of 4 experiments (NZ217-0, NZ217-1, NZ217-3-A, NZ217-3-B) is 50,000 ± 6,000
107		Mochizuki et al (2007)		Weighted mean of 4 experiments (NZ217-0, NZ217-1, NZ217-3-A, NZ217-3-B) is 50,000 ± 6,000
108		Mochizuki et al (2007)		Weighted mean of 4 experiments (NZ217-0, NZ217-1, NZ217-3-A, NZ217-3-B) is 50,000 ± 6,000
109				
110		Wood (1991)		Wood (1991) indicates that McLennans < Panmure Basin; > Mt Wellington, = Mt Richmond (App. C)
111				
112		Cassata et al (2008)		Weighted mean plateau age of 8 aliquots using different increments (NZ0605a-h) is 42,600 ± 3,800
113		Cassata et al (2008)		Weighted mean plateau age of 8 aliquots using different increments (NZ0605a-h) is 42,600 ± 3,800

Line	Age (C-14 = Cal yr BP)	Original C14 DATE	Error	Method	Sample Material	Sample Environment	collected by	Petlab coln. #	Pet Age	Pet Err	FRED	FRED Yard
114	48,800 ± 11,100			Ar-Ar			Singer/Cassidy; NZ0605c					
115	39,900 ± 10,600			Ar-Ar			Singer/Cassidy; NZ0605d					
116	45,900 ± 19,900			Ar-Ar			Singer/Cassidy; NZ0605e					
117	46,600 ± 10,700			Ar-Ar			Singer/Cassidy; NZ0605f					
118	38,800 ± 8,500			Ar-Ar			Singer/Cassidy; NZ0605g					
119	42,400 ± 11,200			Ar-Ar			Singer/Cassidy; NZ0605h					
120												
121	43,000 ± 13,000			Ar-Ar			Singer/Cassidy; NZ0605a; Isochron					
122	39,000 ± 13,000			Ar-Ar			Singer/Cassidy; NZ0605b; Isochron					
123	43,000 ± 13,000			Ar-Ar			Singer/Cassidy; NZ0605b; Isochron					
124	34,000 ± 19,000			Ar-Ar			Singer/Cassidy; NZ0605d; Isochron					
125	38,000 ± 42,000			Ar-Ar			Singer/Cassidy; NZ0605e; Isochron					
126	41,800 ± 8,100			Ar-Ar			Singer/Cassidy; NZ0605f; Isochron					
127	36,000 ± 12,000			Ar-Ar			Singer/Cassidy; NZ0605g; Isochron					
128	53,000 ± 20,000			Ar-Ar			Singer/Cassidy; NZ0605h; Isochron					
129												
130	**Mount Albert**											
131		>30,000		C-14	tree branch	beneath 4.5 m of lava	WE Begbie	R56/1	35269	1490	R11/f0241	no number
132												
133	129,000 ± 4,000			K-Ar				GA2865	132,000	4,000		
134	140,000 ± 6,000			K-Ar			McDougall	GA2864	144,000	6,000		
135												
136	**Mount Eden**											
137	28,386 ± 345	23,480	180	C-14	wood log	Contained in tuff ring material	Phil Shane					
138												
139	14,420 ± 1,250			Therm	Plagioclase crystals in lava							
140	16,200 ± 2,000			Therm	Plagioclase crystals in lava							
141	14,020 ± 1,220			Therm	Plagioclase crystals in lava							
142												
143	154,000 ± 4,000			K-Ar	Lava			GA2893	158,000	4,000		
144												
145	**Mount Richmond**											
146	29,908 ± 603	25,060	530	C-14	Charcoal fragments	Excavation pit at base of northern flank of Mt Richmond	Sandiford					
147												
148	**Mount Saint John**											
149	19,515 ± 298	16,309	90	C-14 AMS	bulk sediment?	auger core						
150												
151	**Mount Wellington (Maungarei)**											
152	10,035 ± 189	8,970	130	C-14 CRA	carbonised wood	large tree mould in basalt in quarry	EJ Searle	R00422	8,963	113	R11/f7544	N42/f0544
153	10,084 ± 240	9,000	160	C-14 CRA	charcoal	in basalt flow	JA Bartrum	R56/5	10,406	127	R11/f7524	N42/f0524

Line	C14 #	Reference for date (first reference is the original source)	Description	Comment
114		Cassata et al (2008)		Weighted mean plateau age of 8 aliquots using different increments (NZ0605a-h) is 42,600 ± 3,800
115		Cassata et al (2008)		Weighted mean plateau age of 8 aliquots using different increments (NZ0605a-h) is 42,600 ± 3,800
116		Cassata et al (2008)		Weighted mean plateau age of 8 aliquots using different increments (NZ0605a-h) is 42,600 ± 3,800
117		Cassata et al (2008)		Weighted mean plateau age of 8 aliquots using different increments (NZ0605a-h) is 42,600 ± 3,800
118		Cassata et al (2008)		Weighted mean plateau age of 8 aliquots using different increments (NZ0605a-h) is 42,600 ± 3,800
119		Cassata et al (2008)		Weighted mean plateau age of 8 aliquots using different increments (NZ0605a-h) is 42,600 ± 3,800
120				
121		Cassata et al (2008)		Composite isochron age (NZ0605a-h) is 39,100 ± 4,100
122		Cassata et al (2008)		Composite isochron age (NZ0605a-h) is 39,100 ± 4,100
123		Cassata et al (2008)		Composite isochron age (NZ0605a-h) is 39,100 ± 4,100
124		Cassata et al (2008)		Composite isochron age (NZ0605a-h) is 39,100 ± 4,100
125		Cassata et al (2008)		Composite isochron age (NZ0605a-h) is 39,100 ± 4,100
126		Cassata et al (2008)		Composite isochron age (NZ0605a-h) is 39,100 ± 4,100
127		Cassata et al (2008)		Composite isochron age (NZ0605a-h) is 39,100 ± 4,100
128		Cassata et al (2008)		Composite isochron age (NZ0605a-h) is 39,100 ± 4,100
129				
130				
131	NZ-223	Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)	charred branch beneath 15ft of sub-recent lava; Oakley Creek Quarry, Mt Albert	
132				
133		McDougall et al (1969)		Low end of range of dates
134		McDougall et al (1969)		High end of range of dates
135				
136				
137	WK-7136	Phil Shane (unpub data)	large log of wood, Lauder Rd, Mt Eden,	
138				
139		Adams (1986)		This age is a modification of Cox (1979) age
140		Phillips (1989); Wood (1991)		Phillips (1989) modified this age from Adams (1986), who modified Cox (1979) age
141		Wood (1991)		Wood (1991) further modified the above ages.
142				
143		McDougall et al (1969)		
144				
145				
146	WK5758	Sandiford et al. (2002)	Charcoal fragment from the base of a loamy silt horizon overlying basaltic lava in an exposed section at Mt Richmond.	Appears to be from ABOVE the basal lava flow in section at base of Mt Richmond. So, REPRESENTS a MINIMUM age for this lava (rather than a maximum age as suggested by Sandiford et al (2002). According to Sandiford et al (2002) the lava could have come from Robertson Hill, McLennan Hills or Mt Richmond.
147				
148				
149		Horrocks et al. (2005a)	from basal scoria (bulk sediment?) at base of gouge auger core, Mt St John crater	Represents a minimum age for Mt St Johns
150				
151				
152	NZ-500	Searle (1965); Grant-Taylor and Rafter (1971)	Carbonised wood from large tree mould in basalt, Quarry at Panorama rd.	Dates main lava flow from Mt Wellington. Searle (1965) also mentions an age of 9,100 +- 160 for Mt. Wellington. FRED R11/f7521?? From Smales Quarry, Takapuna
153	NZ-225	Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963), Searle (1961, 1965)	Charcoal imbedded in basalt flow from Mt. Short volcano, Penrose	"Mt Short" is probably a typo, and instead refers to "Mt Smart"; see FRED note: "Chipped from a specimen of basalt in Auckland University College collection labelled 'Penrose (Mt. Smart flow)". However, the flow is probably likely from Mt Wellington

Line	Age (C-14 = Cal yr BP)	Original C14 DATE	Error	Method	Sample Material	Sample Environment	collected by	Petlab coln. #	Pet Age	Pet Err	FRED	FRED Yard
154	10,445 ± 115	9,270	80	C-14 CRA	wood from tree trunk	underneath basalt flow	J Healy				R11/f7532	N42/f0532
155	10,545 ± 201	9,315	145	C-14 CRA	root	in tuff	EJ Searle	R695/1	9,235	73	R11/f7552	N42/f0552
156	10,578 ± 221	9,330	150	C-14 CRA	tree fern fibres	in tuff, in tunnel	EJ Searle	R695/2	9,266	73	R11/f7578	N42/f0578
157	10,633 ± 137	9,390	95	C-14 CRA	tree fern wood	in tuff ring						
158												
159	11,700 ± 1,400			Therm	Plag feldspars in lava	from 30m below lava flow surface	Wood, I. A.	IAW-Well	11,700	2800		
160												
161	9,500			Tephrochronology								
162	>9,500			Tephrochronology								
163	≤10,000			Tephrochronology		Ash found in Hopua, Pukaki and Panmure cores						
164												
165	57,000 ± 7,000			K-Ar				GA2873	59,000	7,000		
166	66,000 ± 5,000			K-Ar			McDougall	GA2872	68,000	5,000		
167	81,000 ± 4,000			K-Ar			McDougall	GA3158	18,470,000	62,000		
168	81,000 ± 9,000			K-Ar			McDougall	GA2871	83,000	9,000		
169	82,000 ± 7,000			K-Ar				GA2871	83,000	9,000		
170												
171	**One Tree Hill**											
172	17,060 ± 1360			Therm	Plagioclase crystals in lava							
173	20,000 ± 2250			Therm	Plagioclase crystals in lava							
174	16,520 ± 1350			Therm	Plagioclase crystals in lava							
175												
176	83,000 ± 5,000			K-Ar	lava		McDougall	GA2888	85,000	5,000		
177												
178	**Onepoto**											
179		>42,000		C-14			Searle	R183/3	59390	23420	R11/f7529	N42/f0529
180		>28,500		C-14			A Odell	R00423	34532	1573	R11/f7551	N42/f0551
181												
182	248,000 ± 28,000			Ar-Ar	Basalt scoria	Base of drill core						
183												
184	**Otuataua**											
185	29,000 ± 10,000			K-Ar			Stipp, J. J.	GA2874	30,000	10,000		
186	36,000 ± 6,000			K-Ar			Stipp, J. J.	GA2875	37,000	6,000		
187												
188	**Panmure Basin tuff ring**											
189	32,674 ± 862	28,000	1,000	C-14 CRA			Searle, E.J.	R183/2	27933	492	R11/f7525	N42/f0525
190	31,697 ± 172	26,910	190	C-14	wood	from fossil forest						
191												
192	189,000 ± 600			K-Ar								
193												

Line	C14 #	Reference for date (first reference is the original source)	Description	Comment
154	NZ-11	Grant-Taylor and Rafter (1963)	Wood from tree trunk underlying basalt flow, Penrose main road deviation	McDougall quotes 9210 +/-80. This is a typo. There may also be a typo in FRED.
155	NZ-386	Searle (1965); Grant-Taylor and Rafter (1971)	Root in tuff from Panmure basin overlain by Mt Wellington tuff, from roof of tunnel, 30 ft below surface near Panmure railway station	Represents older age limit of Mt Wellington
156	NZ-387	Searle (1965); Grant-Taylor and Rafter (1971)	Tree fern fibres in Panmure Basin Tuff and overlain by Mt Wellington tuff. In tunnel near Panmure railway station	Represents older age limit of Mt Wellington. Note that Poloch et al. (1969) erroneously cite this age as 9370 ± 150
157	ANU-35	Polach et al (1969); McDougall et al (1969)	Tree fern wood growing in tuff ring of Panmure volcano later buried by Mt Wellington ash (cf Searle 65 date of similar material).	
158				
159		Wood (1991)	Basaltic lava from Winstones Lunn Ave quarry.	
160				
161		Newnham and Lowe (1991)		
162		P. Shane, pers. comm. 2009	Ash from Mt Wellington lies below Rotoma tephra (9.5ka Cal yr) in some maar cores.	
163		P. Shane, pers. comm. 2009	Ash from Mt Wellington directly overlies and in some cases is mixed in with Opepe tephra (10ka Cal yr) in several cores drilled in AVF maars.	The ashfall activity well-constrained at 10ka Cal yBP; P. Shane suggests error <400 years
164				
165		McDougall et al (1969)		Low end of range of dates; reflects excess radiogenic Ar
166		McDougall et al (1969)		GA3185 80,000 +- 4,000 (TYPO in PETLAB: Stipp originally has 81,000 +- 4,000 in his thesis)
167		McDougall et al (1969)		PETLAB age correct?
168		McDougall et al (1969)		Two dates for this PETLAB sample number in McDougall, et al, 1969
169		McDougall et al (1969)		High end of range of dates; reflects excess radiogenic Ar; Two dates for this PETLAB sample number in McDougall, et al, 1969
170				
171				
172		Adams (1986)		
173		Phillips (1989)		
174		Wood (1991)		
175				
176		McDougall et al (1969)		
177				
178				
179	NZ-224	Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)	Carbonaceous soil below 55 ft of tuff, west of Onepoto Lagoon tuff ring, Bore No 3, Harbour Bridge	PETLAB error in location field: 'West of Orepoto Lagoon tuff ring' instead of 'Onepoto'
180	NZ-501	Grant-Taylor and Rafter (1971)	Bark and wood from moulds of large trees overwhelmed by tuff from Onepoto, Shoal Bay.	FROM FRED: Determined age >28,500 (79% probability); >27,500 (98% probability) Bark etc. from moulds of very large trees growing on Pleistocene silts and overwhelmed by the tuffs erupted from the centre of Onepoto Basin. Age of wood will therefore determine the maximum age of the eruption at this centre.
181				
182		Shane and Sandiford (2003)	40Ar–39Ar incremental heating isochron age for the basaltic lapilli at 61.17 m (M.O. McWilliams, personal communication, 2002).	Represents a minimum age for the crater. How was sample prepared?
183				
184				
185		McDougall et al (1969)		Low age in range of dates
186		McDougall et al (1969)		High age in range of dates
187				
188				
189	NZ-217	Fergusson and Rafter (1959), Grant-Taylor and Rafter (1963)	Peat underlying Panmure basin tuff in terrace of Tamaki River	Result may give an older age limit for volcanic activity at Panmure
190	ANU-31, 256, 257	Polach et al (1969); McDougall et al (1969)	Three samples of wood from fossil forest beneath tuff	agrees with NZ-217 which is 3km N of ANU-31; error weighted mean of three analyses
191				
192		Stipp (1968); McDougall et al (1969)		In 'East Tamaki' section of Stipp 1968, Table 6.
193				

Line	Age (C-14 = Cal yr BP)	Original C14 DATE	Error	Method	Sample Material	Sample Environment	collected by	Petlab coln. #	Pet Age	Pet Err	FRED	FRED Yard
194	**Pukeiti**											
195	32,000 ± 6,000			K-Ar			McDougall	GA3170				
196												
197	**Puketutu Island**											
198	22,800 ± 3,300			Therm			Wood, I. A.	IAW-Puk	22800	6600		
199												
200	16,000 ± 11,000			K-Ar	basalt lava	from quarry	Mochizuki; NZ222-0-A					
201	36,000 ± 10,000			K-Ar	basalt lava	from quarry	Mochizuki; NZ222-0-B					
202	25,000 ± 9,000			K-Ar	basalt lava	from quarry	Mochizuki; NZ222-1-A					
203	38,000 ± 8,000			K-Ar	basalt lava	from quarry	Mochizuki; NZ222-1-B					
204												
205	77,000 ± 9,000			K-Ar	basalt lava	from quarry	McDougall	GA2885	79,000	9,000		
206												
207	31,300 ± 14,100			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606a					
208	30,200 ± 14,700			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606b					
209	32,900 ± 14,000			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606c					
210	36,400 ± 6,000			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606d					
211	35,800 ± 11,700			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606g					
212	25,200 ± 9,400			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606f					
213	36,400 ± 9,000			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606g					
214												
215	29,000 ± 24,000			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606a; Isochron					
216	28,000 ± 20,000			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606b; Isochron					
217	34,000 ± 41,000			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606c; Isochron					
218	34,000 ± 15,000			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606d; Isochron					
219	28,000 ± 28,000			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606e; Isochron					
220	31,000 ± 15,000			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606f; Isochron					
221	29,000 ± 17,000			Ar-Ar	Clean groundmass separate		Singer/Cassidy; NZ0606g; Isochron					
222												
223	**Pupuke**											
224		>42,000		C-14			Searle				R11/f7735	N42/f0735
225		>40,000		C-14			Searle				R11/f7536	N42/f0536
226		>36,000		C-14			Searle				R11/f7523	N42/f0523
227												
228	178,000 ± 9,000			K-Ar			McDougall	GA2861	183,000	9,000		
229	192,000 ± 7,000			K-Ar			McDougall	GA2860	197,000	7,000		
230	258,000 ± 6,000			K-Ar			McDougall	GA2853	270,000	5,000		
231	252,000 ± 8,000			K-Ar			McDougall	GA2853	270,000	5,000		
232	229,000 ± 6,000			K-Ar			McDougall	GA2863	235,000	6,000		
233	229,000 ± 6,000			K-Ar			McDougall	GA2862	235,000	6,000		
234	263,000 ± 5,000			K-Ar			McDougall	GA2852	262,000	7,000		
235												
236	141,000 ± 10,000			Therm			Wood, I. A.	IAW-Pup	141000	20000		
237												

Line	C14 #	Reference for date (first reference is the original source)	Description	Comment
194				
195		McDougall et al (1969)		
196				
197				
198		Wood (1991)		
199				
200		Mochizuki et al (2007)	Groundmass in basaltic lava from quarry	Weighted mean of 4 experiments (NZ222-0-A/B through NZ222-1-A/B) is 30,000 ± 5,000
201		Mochizuki et al (2007)	Groundmass in basaltic lava from quarry	Weighted mean of 4 experiments (NZ222-0-A/B through NZ222-1-A/B) is 30,000 ± 5,000
202		Mochizuki et al (2007)	Groundmass in basaltic lava from quarry	Weighted mean of 4 experiments (NZ222-0-A/B through NZ222-1-A/B) is 30,000 ± 5,000
203		Mochizuki et al (2007)	Groundmass in basaltic lava from quarry	Weighted mean of 4 experiments (NZ222-0-A/B through NZ222-1-A/B) is 30,000 ± 5,000
204				
205		McDougall et al (1969)		
206				
207		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0606a-g) is 33,600 ± 3,700
208		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0606a-g) is 33,600 ± 3,700
209		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0606a-g) is 33,600 ± 3,700
210		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0606a-g) is 33,600 ± 3,700
211		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0606a-g) is 33,600 ± 3,700
212		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0606a-g) is 33,600 ± 3,700
213		Cassata et al (2008)		Weighted mean plateau age of 7 aliquots using different increments (NZ0606a-g) is 33,600 ± 3,700
214				
215		Cassata et al (2008)		Composite isochron age (NZ0606a-g) is 33,500 ± 6,500
216		Cassata et al (2008)		Composite isochron age (NZ0606a-g) is 33,500 ± 6,500
217		Cassata et al (2008)		Composite isochron age (NZ0606a-g) is 33,500 ± 6,500
218		Cassata et al (2008)		Composite isochron age (NZ0606a-g) is 33,500 ± 6,500
219		Cassata et al (2008)		Composite isochron age (NZ0606a-g) is 33,500 ± 6,500
220		Cassata et al (2008)		Composite isochron age (NZ0606a-g) is 33,500 ± 6,500
221		Cassata et al (2008)		Composite isochron age (NZ0606a-g) is 33,500 ± 6,500
222				
223				
224	NZ-218	Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)	Charred wood below basalt and tuff.	Age not indicated in FRED
225	NZ-219	Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)	Peat below basalt and tuff, onshore of Shoal Bay	
226	NZ-227	Fergusson and Rafter (1959)	Charcoal from cinders, east face, Smales quarry	
227				
228		McDougall et al (1969)		low end of age range
229		McDougall et al (1969)		
230		McDougall et al (1969)		Two ages for this PETLAB sample number in McDougall et al, 1969
231		McDougall et al (1969)		
232		McDougall et al (1969)		
233		McDougall et al (1969)		
234		McDougall et al (1969)		high end of age range
235				
236		Wood (1991)		
237				

Line	Age (C-14 = Cal yr BP)	Original C14 DATE	Error	Method	Sample Material	Sample Environment	collected by	Petlab coln. #	Pet Age	Pet Err	FRED	FRED Yard
238	260,000 ± 29,000			Ar-Ar								
239	207,000 ± 29,000			Ar-Ar								
240	200,100 ± 7,400			Ar-Ar			Singer/Cassidy					
241												
242	**Purchas Hill**											
243	10,910 ± 139	9,549	58	C-14 CRA	ca 20 cm tree branch		CJN Wilson 2006; Z942/C1					
244												
245	**Rangitoto**											
246												
247	159 ± 96	185	71	C-14	Charcoal	From small haangi, Motutapu island	Davidson					
248	214 ± 129	225	110	C-14	Non-charred wood	beneath young lava flow	Pollach					
249	286 ± 89	280	40	C-14 CRA	charcoal	base of oven in ash	Brothers	R326/2	322	39	R10/f9520	N38/f0520
250	410 ± 69	410	73	C-14 CRA	twig charcoal	beneath ash	Davidson	R2678/4	410	86		
251	488 ± 73	507	74	C-14 CRA	twig charcoal	beneath ash	Davidson	R2678/3	510	87		
252	502 ± 11	482	20	C-14 AMS	Peat	above upper tephra in swamp	Needham					
253	504 ± 6	485	15	C-14 AMS	Peat	above upper tephra in swamp	Needham					
254	532 ± 17	558	30	C-14 AMS	wood/twig branch	base of Lower Tephra at 350 cm depth	Needham					
255	541 ± 10	582	15	C-14 AMS	wood	near top of lower tephra at 240 cm depth	Needham					
256	556 ± 32	591	30	C-14 AMS	wood flax/twig	base of Lower Tephra at 343 cm depth	Needham					
257	570 ± 38	600	40	C-14 CRA	charcoal	base of pit	Davidson					
258	570 ± 38	600	40	C-14 CRA	charred twigs	undisturbed contexts	Davidson	R2678/2	608	44		
259	579 ± 42	610	60	C-14	twig charcoal	beneath ash	Green					
260	584 ± 46	620	70	C-14	charcoal	above ash	Green					
261	585 ± 32	621	20	C-14 AMS	wood	base of lower tephra at 240 cm depth	Needham					
262	599 ± 30	646	30	C-14 AMS	wood twig/bark	base of Lower Tephra at 265 cm depth	Needham					
263	606 ± 30	677	30	C-14 AMS	charcoal	from top of Lower Tephra at 212 cm depth	Needham					
264	615 ± 35	713	20	C-14 AMS	twigs	from above the lower tephra at 220 cm depth	Needham					
265	663 ± 47	770	50	C-14 CRA	twig charcoal	base of ash bed	Brothers	R326/3	823	40	R10/f9521	N38/f0521
266	718 ± 59	1153	40	C-14 CRA	shells	upper layers ash-free sand	Brothers	R326/1	1153	40	R10/f9519	N38/f0519
267	893 ± 47	1045	30	C-14 AMS	Peat	Above lower tephra in swamp	Needham					
268	1,049 ± 77	1177	66	C-14 AMS	wood	peat above ash	Elliot					
269	1061 ± 72	1500	41	C-14 CRA	shells	lava baked mud	E Milligan	R695/5	1500	41	R11/f7581	N42/f0581
270	1,114 ± 80	1244	66	C-14 AMS	humin	peat above ash	Elliot					
271												
272	140 ± 150			Mag. Declination	basaltic lava		Robertson					
273	450 ± 120			Mag. Declination	basaltic lava		Robertson					
274	500 ± 140			Mag. Declination	basaltic lava		Robertson					
275	510 ± 100			Mag. Declination	basaltic lava		Robertson					
276	540 ± 20			Mag. Declination	basaltic lava		Robertson					
277	640 ± 130			Mag. Declination	basaltic lava		Robertson					
278	640 ± 190			Mag. Declination	basaltic lava		Robertson					
279	670 ± 110			Mag. Declination	basaltic lava		Robertson					
280	670 ± 110			Mag. Declination	basaltic lava		Robertson					

Line	C14 #	Reference for date (first reference is the original source)	Description	Comment
238		Hall and York (1984)		
239		Hall and York (1984)		
240		Cassata et al (2008)	Weighted mean of four subsamples, no excess Ar	Individual reseults from subsamples not presented in Cassata et al (2008)
241				
242				
243	WK-21535	analysed 2007 by Waikato Radiocarbon lab	20 cm tree branch	
244				
245				
246				
247		Davidson (1972)	Charcoal from small haangi, fill of pit 1, Motutapu site N38/37	Dates human activity after the eruption
248	ANU-258	Pollach et al (1969); McDougall et al. (1969)	Non-charred wood beneath a young lava flow devoid of vegetation	May repesent root system of modern tree
249	NZ-221	Brothers and Golson (1959); Grant Taylor and Rafter (1963)	Charcoal from base of oven in 8ft thick ash, W side Administration Bay, Motutapu	Dates human activity after the eruption
250	NZ-1167	Davidson (1972)	Charred twigs from undisturbed contexts beneath Rangitoto ash at Station Bay, Motutapu	
251	NZ-1166	Davidson (1972)	Charred twigs from undisturbed contexts beneath Rangitoto ash at Station Bay, Motutapu	
252	NZA 30588	Needham (2009)	Peat from above the upper tephra at 120 cm depth in Sandy Bay swamp, Motutapu	May place a younger limit on ash from second eruption
253	NZA 30592	Needham (2009)	Peat from above the upper tephra at 248 cm depth in Sandy Bay swamp, Motutapu	May place a younger limit on ash from second eruption
254	Wk-24172	Needham (2009)	wood/twig branch from base of the lowest tephra layer (350 cm depth) from swamp at Billy Goat Point, Motutapu island	Dates onset of first eruption
255	NZA 30583	Needham (2009)	wood near the top of the lower tephra at 240 cm depth, Station Bay swamp, Motutapu	Dates onset of first eruption
256	Wk-24175	Needham (2009)	wood flax/twig from base of the lowest tephra layer (343 cm depth) from swamp at Billy Goat Point, Motutapu island	Dates onset of first eruption
257		Davidson (1972)	Charcoal from base of pit 5, Motutapu site N38/37	May date human activity or older charcoal fallen into pit
258	NZ-1165	Davidson (1972)	Charred twigs from undisturbed contexts beneath Rangitoto ash at Station Bay, Motutapu	Dates onset of first eruption
259	NZ-1898	Law (1975)	charcoal from oven below ash on Motutapu, site N38/24	May date onset of first eruption, or human activity prior to eruption
260	NZ-1899	Law (1975); Robertson (1986)	charcoal from culture layer above ash Motutapu site N38/24	Dates human activity after the eruption
261	NZA 30584	Needham (2009)	wood near the base of the lower tephra at 240 cm depth, Station Bay swamp, Motutapu	Dates onset of first eruption
262	Wk-24170	Needham (2009)	wood/twig bark from base of the lowest tephra layer (265 cm depth) from swamp at Sandy Bay, Motutapu island	Dates onset of first eruption
263	Wk-24171	Needham (2009)	charcoal from top of lowest tephra layer (at 212 cm depth) from swamp at Sandy Bay, Motutapu island	Dates onset of first eruption
264	NZA 30585	Needham (2009)	twigs from above the lower tephra at 220 cm depth, Station Bay swamp, Motutapu	May represent older material washed into swamp
265	NZ-222	Brothers and Golson (1959), Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)	Charred twig at base of ash bed, Pig Bay, Motutapu	Dates onset of first eruption
266	NZ-220	Brothers and Golson (1959), Fergusson and Rafter (1959); Grant-Taylor and Rafter (1963)	Shells found in upper layers of ash-free beach sand, Pig Bay, Motutapu	Dates beach deposit below the ash. Note that the age quoted in published papers (750 ± 50) is not the original CRA, rather a 1958 calibration to correct for marine effects (Christine Proir, written comm. 2009).
267	Wk-24173	Needham (2009)	Peat from above the lower tephra at 302cm depth from peat-rich swamp, Billy Goat Point, Motutapu	May represent older material washed into swamp
268		Elliot et al (unpublished)	Wood from peat from immediately above Rangitoto ash, Billy goat Swamp, Motutapu	Material in peat may represent older material washed into swamp
269	NZ-440	Grant-Taylor and Rafter (1971)	Shells in mud baked by Rangitoto flows, SW side, seaward end	Places older limit on flows. Note that the age quoted in published papers (1050 ± 44) is not the original CRA, rather a 1961 calibration to correct for marine effects (Christine Proir, written comm. 2009)
270		Elliot et al (unpublished)	Humin from peat from immediately above Rangitoto ash, Billy Goat Swamp, Motutapu	Material in peat may represent older material washed into swamp
271				
272		Robertson (1983); Robertson (1986)		age is unreliable as outcrop may have subsided
273		Robertson (1983); Robertson (1986)		
274		Robertson (1983); Robertson (1986)		
275		Robertson (1983); Robertson (1986)		
276		Robertson (1983); Robertson (1986)		
277		Robertson (1983); Robertson (1986)		
278		Robertson (1983); Robertson (1986)		
279		Robertson (1983); Robertson (1986)		
280		Robertson (1983); Robertson (1986)		

Line	Age (C-14 = Cal yr BP)	Original C14 DATE	Error	Method	Sample Material	Sample Environment	collected by	Petlab coln. #	Pet Age	Pet Err	FRED	FRED Yard
281	800 ± 360			Mag. Declination	basaltic lava		Robertson					
282	950 ± 170			Mag. Declination	basaltic lava		Robertson					
283												
284	560 ± 50			Therm	Plag feldspars in lava							
285	580 ± 50			Therm	Plag feldspars in lava							
286	659 ± 80			Therm	Plag feldspars in lava							
287												
288	146,000 ± 12,000			K-Ar	basaltic lava		McDougall; Stipp	GA3177	150,000	12,000		
289	160,000 ± 13,000			K-Ar	basaltic lava		McDougall; Stipp	GA3179	164,000	13,000		
290	163,000 ± 8,000			K-Ar	basaltic lava		McDougall; Stipp	GA3180	167,000	8,000		
291	184,000 ± 21,000			K-Ar	basaltic lava		McDougall; Stipp	GA3181	189,000	21,000		
292	189,000 ± 8,000			K-Ar	basaltic lava		McDougall; Stipp	GA3178	194,000	8,000		
293	363,000 ± 13,000			K-Ar	basaltic lava		McDougall; Stipp	GA3183	373,000	13,000		
294	386,000 ± 13,000			K-Ar	basaltic lava		McDougall; Stipp	GA2895	396,000	13,000		
295	398,000 ± 13,000			K-Ar	basaltic lava		McDougall; Stipp	GA2895	403,000	13,000		
296	385,000 ± 13,000			K-Ar	basaltic lava		McDougall; Stipp	GA2894	414,000	12,000		
297	420,000 ± 10,000			K-Ar	basaltic lava		McDougall; Stipp	GA2894	414,000	12,000		
298	404,000 ± 12,000			K-Ar	basaltic lava		McDougall; Stipp	GA3182	415,000	12,000		
299	465,000 ± 11,000			K-Ar	basaltic lava		McDougall; Stipp	GA3184	477,000	11,000		
300												
301	**Three Kings**											
302	28,617 ± 422	23,669	196	C-14 AMS	Wood	Borehole from Meola catchment	J Lindsay 2007; ALC-M16-8					
303	28,541 ± 407	23,589	183	C-14 AMS	charred wood	Borehole from Meola catchment	J Lindsay 2007; ALC-M18-4					
304	28,570 ± 399	23,631	148	C-14 CRA	charred wood	Borehole from Meola catchment	J Lindsay 2007; ALC-M26-4b					
305	28,734 ± 413	23,833	188	C-14 AMS	twigs	Borehole from Meola catchment	J Lindsay 2007; ALC-M27-3					
306	28,673 ± 416	23,746	180	C-14 AMS	charred twigs	Borehole from Meola catchment	J Lindsay 2007; ALC-M19-4					
307	28,585 ± 404	23,644	156	C-14 CRA	bark and twigs	Borehole from Meola catchment	J Lindsay 2007; ALC-M30-3					
308	32,674 ± 862	28,000	1000	C-14 CRA	wood	sewage tunnel construction	G. Fairfield 1921	R256/2	20799	218	R11/f7534	N42/f0534
309												
310	117,000 ± 12000			K-Ar			McDougall	GA2890	120,000	12,000		
311												
312	**Wiri Mountain/ Manurewa**											
313												
314	30,325 ± 462	25,370	350	C-14 CRA	wood	quarry						
315	32,879 ± 670	28,300	690	C-14 CRA	wood	beneath lava	Searle 1959	R695/3	28291	549	R11/f7579	N42/f0579
316												
317	33,000 ± 6,000			K-Ar			McDougall	GA2867	34,000	6,000		
318	60,000 ± 3,000			K-Ar			McDougall	GA2868	62,000	3,000		
319	64,000 ± 3,000			K-Ar			McDougall	GA2866	66000	3000		
320	27,000 ± 5,000			K-Ar			Mochizuki					
321												
322	28,600 ± 9,400			Ar-Ar			Singer/Cassidy; NZ0603a					

Line	C14 #	Reference for date (first reference is the original source)	Description	Comment
281		Robertson (1983); Robertson (1986)		
282		Robertson (1983); Robertson (1986)		High end of range of dates presented
283				
284		Wood (1991)		This represents a recalibration of the Adams (1986) and Philips (1989) ages. Note there is a typo in Wood 1991, which cites Phillips 1989 age as 569.
285		Adams (1986)		
286		Phillips (1989)		This represents a recalibration of the Adams (1986) age
287				
288		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	Low end of a range of dates obtained; reflects excess radiogenic Ar
289		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	
290		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	
291		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	
292		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	
293		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	
294		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	In PETLAB, 3 ages were listed for collection number GA002895; all three presented here. McDougall et al, 1969 presents two ages for this sample number
295		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	In PETLAB, 3 ages were listed for collection number GA002895;McDougall et al, 1969 presents two ages for this sample number
296		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	Two ages presented for this PETLAB sample number in McDougall et al, 1969
297		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	Two ages presented for this PETLAB sample number in McDougall et al, 1969
298		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	
299		Stipp (1968), McDougall et al (1969)	Basaltic lava from the lava field	High end of a range of dates obtained; reflects excess radiogenic Ar
300				
301				
302	WK-21525	analysed 2007 by Waikato Radiocarbon lab	Charred rootlets in sediment from below ash layer in Meola borehole 16 (at 22m depth)	Lindsay, unpublished data
303	WK-21526	analysed 2007 by Waikato Radiocarbon lab	Charred wood in sediment from below ash layer in Meola borehole 18 (at 19m depth)	Lindsay, unpublished data
304	WK-21528	analysed 2007 by Waikato Radiocarbon lab	Charred wood in sediment from base of airfall deposit in Meola borehole 26 (at 24.3m depth)	Lindsay, unpublished data
305	WK-21530	analysed 2007 by Waikato Radiocarbon lab	Twigs from base of ash? Layer in Meola borehole 27 (at 15.6m depth)	Lindsay, unpublished data
306	WK-21531	analysed 2007 by Waikato Radiocarbon lab	Charred twigs from paleosol at base of ash layer in Meola borehole 19 (at 11.9 m depth)	Lindsay, unpublished data
307	WK-21532	analysed 2007 by Waikato Radiocarbon lab	Large piece of bark and twigs from ash layer in Meola borehole 30 (at 9.5 m depth)	Lindsay, unpublished data
308	NZ-216	Fergusson and Rafter (1959), Grant-Taylor and Rafter (1963)	G Fairfield collected wood from a tree stump covered with ash during sewage tunnel construction on Woodside Rd, Mt Eden, near the margin of the Mt. Eden lavas, in 1920-1921. The wood was analyzed in 1958. "Ash probably from Three kings, and sample probably antedates Mt Eden basalt". Searle (1962) cites a date of 21,000 +- 800, this is probably an incorrect transcription of this date. Also: FRED 'front of form' age is 28000 +/- 1000; the 'back of the form' age is 21000 +/- 800. According to Cox 1979 (Addendum), the age of 28,000 +- 1000, given by Fergusson and Rafter 1959, is the correct date.	
309				
310		McDougall et al (1969)		
311				
312				
313				
314	ANU-33	Polach et al (1969); McDougall et al (1969)	Wood, Mt Wiri Quarry	
315	NZ-388	Searle (1965), Grant-Taylor and Rafter (1971)	wood beneath lava, older limit of Wiri lava	
316				
317		McDougall et al (1969)		Low end of range of dates; Note that this analysis is reported in PETLAB as GA2867
318		McDougall et al (1969)		
319		McDougall et al (1969)		High end of range of dates. Excess Ar reported
320		Mochizuki et al (2004)		weighted mean from 5 samples, large xtals removed
321				
322		Cassata et al (2008)		Cassata et al. (2008) present a Wiri B weighted mean plateau age of 30,100 ± 4,400 based on 4 aliquots (NZ0603a-d) using different increments

Line	Age (C-14 = Cal yr BP)	Original C14 DATE	Error	Method	Sample Material	Sample Environment	collected by	Petlab coln. #	Pet Age	Pet Err	FRED	FRED Yard
323	29,200 ± 10,400			Ar-Ar			Singer/Cassidy; NZ0603b					
324	31,500 ± 8,400			Ar-Ar			Singer/Cassidy; NZ0603c					
325	30,300 ± 7,800			Ar-Ar			Singer/Cassidy; NZ0603d					
326												
327	22,000 ± 20,000			Ar-Ar			Singer/Cassidy; NZ0603a; Isochron					
328	25,000 ± 36,000			Ar-Ar			Singer/Cassidy; NZ0603b; Isochron					
329	29,000 ± 15,000			Ar-Ar			Singer/Cassidy; NZ0603c; Isochron					
330	37,000 ± 18,000			Ar-Ar			Singer/Cassidy; NZ0603d; Isochron					
331												
332	32,900 ± 6,100			Ar-Ar			Singer/Cassidy; NZ0602a					
333	31,400 ± 7,000			Ar-Ar			Singer/Cassidy; NZ0602b					
334	30,600 ± 8,500			Ar-Ar			Singer/Cassidy; NZ0602c					
335	32,000 ± 7,100			Ar-Ar			Singer/Cassidy; NZ0602d					
336	26,100 ± 9,900			Ar-Ar			Singer/Cassidy; NZ0602e					
337	34,800 ± 6,700			Ar-Ar			Singer/Cassidy; NZ0602f					
338	26,700 ± 6,500			Ar-Ar			Singer/Cassidy; NZ0602g					
339												
340	43,000 ± 24,000			Ar-Ar			Singer/Cassidy; NZ0602a; Isochron					
341	27,000 ± 13,000			Ar-Ar			Singer/Cassidy; NZ0602b; Isochron					
342	29,000 ± 28,000			Ar-Ar			Singer/Cassidy; NZ0602c; Isochron					
343	29,000 ± 17,000			Ar-Ar			Singer/Cassidy; NZ0602d; Isochron					
344	23,000 ± 13,000			Ar-Ar			Singer/Cassidy; NZ0602e; Isochron					
345	35,000 ± 10,000			Ar-Ar			Singer/Cassidy; NZ0602f; Isochron					
346	22,000 ± 8,000			Ar-Ar			Singer/Cassidy; NZ0602g; Isochron					

Line	C14 #	Reference for date (first reference is the original source)	Description	Comment
323		Cassata et al (2008)		Cassata et al. (2008) present a Wiri B weighted mean plateau age of 30,100 ± 4,400 based on 4 aliquots (NZ0603a-d) using different increments
324		Cassata et al (2008)		Cassata et al. (2008) present a Wiri B weighted mean plateau age of 30,100 ± 4,400 based on 4 aliquots (NZ0603a-d) using different increments
325		Cassata et al (2008)		Cassata et al. (2008) present a Wiri B weighted mean plateau age of 30,100 ± 4,400 based on 4 aliquots (NZ0603a-d) using different increments
326				
327		Cassata et al (2008)		Composite isochron age (NZ0603a-d) is 27,900 ± 8,700
328		Cassata et al (2008)		Composite isochron age (NZ0603a-d) is 27,900 ± 8,700
329		Cassata et al (2008)		Composite isochron age (NZ0603a-d) is 27,900 ± 8,700
330		Cassata et al (2008)		Composite isochron age (NZ0603a-d) is 27,900 ± 8,700
331				
332		Cassata et al (2008)		Wiri A weighted mean plateau age of 7 aliquots using different increments (NZ0602a-g) is 31,000 ± 2,700
333		Cassata et al (2008)		Wiri A weighted mean plateau age of 7 aliquots using different increments (NZ0602a-g) is 31,000 ± 2,700
334		Cassata et al (2008)		Wiri A weighted mean plateau age of 7 aliquots using different increments (NZ0602a-g) is 31,000 ± 2,700
335		Cassata et al (2008)		Wiri A weighted mean plateau age of 7 aliquots using different increments (NZ0602a-g) is 31,000 ± 2,700
336		Cassata et al (2008)		Wiri A weighted mean plateau age of 7 aliquots using different increments (NZ0602a-g) is 31,000 ± 2,700
337		Cassata et al (2008)		Wiri A weighted mean plateau age of 7 aliquots using different increments (NZ0602a-g) is 31,000 ± 2,700
338		Cassata et al (2008)		Wiri A weighted mean plateau age of 7 aliquots using different increments (NZ0602a-g) is 31,000 ± 2,700
339				
340		Cassata et al (2008)		Wiri A composite isochron age (NZ0602a-g) is 28,400 ± 4,200
341		Cassata et al (2008)		Wiri A composite isochron age (NZ0602a-g) is 28,400 ± 4,200
342		Cassata et al (2008)		Wiri A composite isochron age (NZ0602a-g) is 28,400 ± 4,200
343		Cassata et al (2008)		Wiri A composite isochron age (NZ0602a-g) is 28,400 ± 4,200
344		Cassata et al (2008)		Wiri A composite isochron age (NZ0602a-g) is 28,400 ± 4,200
345		Cassata et al (2008)		Wiri A composite isochron age (NZ0602a-g) is 28,400 ± 4,200
346		Cassata et al (2008)		Wiri A composite isochron age (NZ0602a-g) is 28,400 ± 4,200