New Zealand Journal of Geology and Geophysics, 1995, Vol. 38: 399–402 399
0028–8306/95/3803–0399 $2.50/0

Letter to the Editor

Age of the Rotoehu Ash

Comment

INTRODUCTION

In their note, Whitehead & Ditchburn (1994) considered some U-Th, ESR, and ^{14}C dates that relate to the age of the Rotoehu Ash and Rotoiti Ignimbrite members of the Rotoiti Tephra Formation (Froggatt & Lowe 1990). They suggested that the U-Th disequilibrium age (71 ± 6 ka) of Ota et al. (1989) is almost certainly incorrect, the true age being much younger, and hence, by implication, that the K-Ar age (64 ± 4 ka) of Wilson et al. (1992) is likely to be too old. To support this contention, Whitehead & Ditchburn (1994) pointed firstly to problems with the ESR age (45.2 ± 8.2 ka) of Buhay et al. (1992), making it younger by 5% (42.9 ± 7.8 ka). Secondly, they presented and discussed four ^{14}C ages said to be "surprisingly closely clustered and form[ing] a coherent set with no outliers", and with a mean of 35.1 ± 2.8 ka*. The four ages comprise NZ877 and NZ1126 (both published previously), revised according to current IGNS procedures to give 37.7 ± 8.3 and 36.6 ± 5.3 ka, respectively; and NZ1357 and NZ1366 (purportedly not cited previously), similarly revised to give 31.4 ± 4.4 and 34.6 ± 7.9 ka, respectively. Whitehead & Ditchburn (1994) thus concluded that the age for Rotoehu Ash is likely to be <50 ka and that more work is required to explain why this result differs from the K-Ar age of 64 ± 4 ka.

We comment briefly here on the findings of Whitehead & Ditchburn (1994) and present an alternative interpretation for the age of Rotoiti Tephra.

U-Th AGE

Froggatt & Lowe (1990, p. 99) published the following comment about the 71 ± 6 ka age of Ota et al. (1989):

> ..."this age should be regarded as provisional because the isochron from which the age is derived (Ota et al. 1989, fig. 4) is essentially based on only one data point, that of the whole rock sample. The other three points are on the equilibrium line or within two standard deviations of it (C. H. Hendy pers. comm. 1989). In addition, analyses of at least two mineral species, and of ^{234}U as well as ^{238}U, are desirable in dating pyroclastic deposits such as Rotoehu Ash (Hendy et al. 1980)."

Whitehead & Ditchburn's (1994) results thus support Froggatt & Lowe's (1990) statement, which was apparently overlooked or ignored, but we would dispute the implicit corollary that a problematic U-Th age raises doubt as to the veracity of the K-Ar age of Wilson et al. (1992), which was derived independently using a well-established geochronological technique.

*All radiocarbon ages are reported as conventional (Libby) ages.

ESR AGES

The results of Buhay et al. (1992) were criticised by Whitehead & Ditchburn (1994), who suggested that the validity of their 5% correction depends on detailed analysis of U and Th in the ash samples. Such analysis has not been done and hence we infer that the ESR age is best regarded as provisional only. Individual ages of Buhay et al. (1992, p. 269) range from 35.1 ± 7.4 to 62.1 ± 25.2 ka and have very large errors, although *t*-test comparisons show that they are statistically indistinguishable from one another.

RADIOCARBON AGES

The problems in interpreting radiocarbon ages older than c. 35 ka, especially relating various pretreatment fractions, are well recognised and have been widely discussed (e.g., Bailey et al. 1975; Goh & Pullar 1977; Goh et al. 1978; Goh 1979; Grant-Taylor 1979; Suggate 1984; Wellman 1984; Evin 1990; Gillespie 1991; Hammond et al. 1991). Whatever may be the precision of the radiocarbon measurement, if the pretreatment indicates that the analysed carbon is not original, then the actual age of the sample is indeterminate. Beyond c. 35 ka, very good material will often give problems, even when very selective pretreatment is used (Evin 1990). Thus, use of the ^{14}C technique to date the Rotoiti Tephra is likely to produce difficulties in interpretation unless exceptional circumstances prevail regarding the type, amount, and quality of datable material.

Age estimates for the Rotoiti Tephra based on ^{14}C have been debated previously at some length (e.g., Pullar & Heine 1971; Nathan 1976; Pullar 1976; McGlone et al. 1984; Berryman 1992). In their review paper, Froggatt & Lowe (1990) listed all known dates considered to apply to the Rotoiti Tephra. In addition to NZ877 and NZ1126, Froggatt & Lowe (1990, p. 107) listed both NZ1357 and NZ1366 (not labelled with "NZ" laboratory numbers but identifiable as such by their equivalent fossil record numbers N77/553 and N78/542, respectively), plus NZ643 (>41.0 ka), NZ4303 (>40.4 ka), and Wk-590 (>35.0 ka). Therefore, the four dates presented by Whitehead & Ditchburn (1994) do not represent the entire set of (published) valid dates that apply to Rotoiti Tephra, and so any conclusion based on them alone is misleading. As stated by Nathan (1976), McGlone et al. (1984), Froggatt & Lowe (1990), Berryman (1992), and Wilson et al. (1992), the fact that several dates (four in Froggatt & Lowe 1990) are beyond background limits of the ^{14}C dating technique (i.e. they are infinite) means that supposedly finite ages must be regarded as minima. Strong support for this conclusion is evident in Froggatt & Lowe (1990) for sample N77/553 (=NZ1357): the untreated charcoal returned an age of 33.7 ± 2.3 ka (or 31.4 ± 4.4 ka, as adjusted by Whitehead & Ditchburn 1994), but the extract of chemically pretreated charcoal gave an age of 23.2 ± 0.85 ka (the residue was 27.9 ± 1.5 ka). The much younger age for the extract shows clearly that the sample had been severely contaminated with younger carbon, and therefore the original age cannot represent an accurate finite age for Rotoiti Tephra*. That the age on the residue is also considerably younger than that assayed for the untreated charcoal also indicates unreliablity of sample—which is why it was classified as being of little value by Froggatt & Lowe (1990). We consider it highly likely that the other three samples are similarly contaminated and are minimal ages.

Consequently, the mean ^{14}C age of 35.1 ± 2.8 ka for Rotoiti Tephra put foward by Whitehead & Ditchburn (1994) should be disregarded. The suggestion by Whitehead & Ditchburn (1994) that this age might actually be even younger because of the work of Bard et al. (1990) on corals is a red herring, as it is not known whether such a correction applies (as noted by Whitehead & Ditchburn 1994 themselves).

AMINO ACID RACEMISATION AGE

Kimber et al. (1994) used amino acid racemisation (AAR) of loess, tephra, and paleosol materials to estimate the age of Rotoehu Ash at Tapapa (Mamaku Plateau). Their age of 61 ka (no error published) is in good agreement with that of Wilson et al. (1992).

STRATIGRAPHIC CONSIDERATIONS

Berryman (1992) presented a stratigraphic age of 52 ± 7 ka for Rotoehu Ash and concluded that previous ^{14}C ages of c. 42 ka are minima. His stratigraphic age, statistically consistent with the age estimate of Wilson et al. (1992), was based on correlation of marine terraces at Mahia Peninsula, on which Rotoehu Ash is present, with dated coral reef sequences (Berryman 1993). Kennedy (1988, 1994) suggested from stratigraphic evidence and correlation with oxygen isotope stages that Rotoehu Ash at Tapapa is aged c. 50 ka. Pillans & Wright (1992), in a tephrostratigraphic study on sediments in marine cores from Bay of Plenty, tentatively identified Rotoehu Ash in one core (S794) and ascribed it an age, based on extrapolated sedimentation rates, of c. 55 ka.

The period of time between the eruption of the Rotoiti Tephra and the overlying tephras of the Mangaone Subgroup (Froggatt & Lowe 1990) needs consideration. The occurrence of conspicuous paleosols on these deposits (Howorth 1975) indicates that considerable time must have elapsed between the Rotoiti eruption and each subsequent event. How much time is uncertain, because the four earliest Mangaone Subgroup tephras are not yet dated, but the fifth tephra in the sequence (Hauparu Tephra) has ^{14}C ages of 39.0 ± 5.6 and 35.7 ± 1.3 ka (error-weighted mean c. 36 ka); the sixth (Mangaone Tephra) is dated at c. 32 ka, stratigraphically consistent with this estimate on Hauparu (McGlone et al. 1984; Froggatt & Lowe 1990; Lowe & Hogg 1992). Thus, the four earliest Mangaone Subgroup tephras and their associated paleosols, and the paleosol on Rotoiti Tephra, must all predate c. 36 ka. This constraint means that the age of c. 35–43 ka derived by Whitehead & Ditchburn (1994) for the Rotoiti Tephra allows essentially no time, or only a few thousands of years, for the development of five paleosols since its eruption, indicating therefore that the estimate is probably much too young.

It is difficult to determine precisely how much time is represented in the five paleosols concerned. Clay content, which provides a general measure of time for weathering (Lowe 1986), averages c. 12% (range c. 5–15%) in the paleosols on the lower Mangaone Subgroup tephras, and c. 25% (range c. 10–30%) in the paleosol on Rotoiti Tephra (Birrell & Pullar 1973; Howorth 1976; Lowe 1986). Judging from analyses of paleosols on well-dated late Quaternary tephra beds of similar composition near Rotorua (Green 1987; Hodder et al. 1990; Lowe & Percival 1993), and assuming similar weathering conditions, then such clay contents are indicative of weathering intervals between eruptions of perhaps c. 3000 years for the Mangaone Subgroup tephras and c. 7000 years or more for the Rotoiti paleosol. On this basis, and assuming no periods of erosion, the Rotoiti Tephra could have erupted c. 19 000 years before the Hauparu eruption (i.e. at c. 55 ka).

CONCLUSION

We suggest that the article by Whitehead & Ditchburn (1994), although presenting useful new data on ^{230}Th/^{232}Th analyses, is flawed and misleading in suggesting that the Rotoiti Tephra is considerably younger than c. 50 ka. It is evident that the Ota et al. (1989) age is likely to be erroneous, but the ESR age is problematic, and the ^{14}C ages as presented can only be considered minimal ages at best. The database used by Whitehead & Ditchburn (1994) for the ^{14}C analysis and interpretation was incomplete: previously published infinite ages were not taken into account and neither was the likely contamination (demonstrable for NZ1357) by younger carbon of samples with supposedly finite ages. Stratigraphic evidence, not considered by Whitehead & Ditchburn (1994), plus new AAR data, all suggest that an age >c. 50 ka—rather than the ESR or ^{14}C age proposed by Whitehead & Ditchburn (1994)—is most likely for Rotoiti Tephra, and that the age of 64 ± 4 ka of Wilson et al. (1992) is evidently the most reliable radiometric age so far obtained for the deposit.

In reaching this conclusion, we acknowledge that the K-Ar technique is not without difficulties, and that the Wilson et al. (1992) age estimate is at its younger limit (cf. Houghton et al. 1991; Itaya et al. 1991). The 1 SD error on the age is probably an underestimate, the "true" error being reduced by the averaging of five individual age determinations. Consequently, we agree with Whitehead & Ditchburn (1994) that more work is required to firmly establish the age of the eruption of Rotoiti Tephra, because of its stratigraphic and volcanological importance. To this end, we and colleagues are currently attempting to re-date Rotoiti Tephra (and hence also the Earthquake Flat Tephra Formation, erupted immediately after Rotoiti Tephra; Nairn & Kohn 1973; Froggatt & Lowe 1990) using various techniques including

*Sample NZ1357 may well be irrelevant anyway, irrespective of its demonstrable contamination, because (weakly welded) Kaingaroa Ignimbrite (Nairn 1989) rather than Rotoiti Ignimbrite occurs at the sampling locality designated by the collector (Pullar & Heine 1971).

liquid scintillation radiocarbon spectrometry, isothermal plateau fission track dating of hydrated glass shards (B. V. Alloway, University of Auckland), and optically stimulated luminescence dating (S. Stokes, University of Oxford). Oxygen isotope analysis of material from marine cores containing Rotoehu Ash would also be useful to help define its eruption age.

ACKNOWLEDGMENTS

We thank R. M. Briggs, C. H. Hendy, and J. D. Green (University of Waikato), and B. V. Alloway (University of Auckland), for useful comments on a draft of this letter.

27 October 1994

D. J. LOWE
A. G. HOGG
Geochronology Research Unit
University of Waikato
Private Bag 3105
Hamilton, New Zealand

REFERENCES

Bailey, J. M.; Lee, R.; Rankin, P. C.; Speir, T. W. 1975: Humic-acid contamination of charcoals from Quaternary tephra deposits in New Zealand. *Royal Society of New Zealand bulletin 13*: 53–55.

Bard, E.; Hamelin, B.; Fairbanks, R. G.; Zindler, A. 1990: Calibration of the ^{14}C time scale over the past 30,000 years using mass spectrometric U-Th ages from Barbados corals. *Nature 345*: 405–410.

Berryman, K. R. 1992: A stratigraphic age of Rotoehu Ash and late Pleistocene climate interpretation based on marine terrace chronology, Mahia Peninsula, North Island, New Zealand. *New Zealand journal of geology and geophysics 35*: 1–7.

Berryman, K. R. 1993: Distribution, age, and deformation of late Pleistocene marine terraces at Mahia Peninsula, Hikurangi subduction margin, New Zealand. *Tectonics 12*: 1365–1379.

Birrell, K. S.; Pullar, W. A. 1973: Weathering of paleosols in Holocene and late Pleistocene tephras in central North Island, New Zealand. *New Zealand journal of geology and geophysics 16*: 687–702.

Buhay, W. M.; Clifford, P. M.; Schwarcz, H. P. 1992: ESR dating of the Rotoiti Breccia in the Taupo Volcanic Zone, New Zealand. *Quaternary science reviews 11*: 267–271.

Evin, J. 1990: Validity of the radiocarbon dates beyond 35,000 years B.P. *Palaeogeography, palaeoclimatology, palaeoecology 80*: 71–78.

Froggatt, P. C.; Lowe, D. J. 1990: A review of late Quaternary silicic and some other tephra formations from New Zealand: their stratigraphy, nomenclature, distribution, volume, and age. *New Zealand journal of geology and geophysics 33*: 89–109.

Gillespie, R. 1991: The limits of radiocarbon technology. *In*: Gillespie, R. *ed*. Quaternary dating workshop 1990. Canberra, Australian National University. Pp. 8–10.

Goh, K. M. 1979: Radiocarbon dates: reply. *New Zealand journal of geology and geophysics 22*: 529–531.

Goh, K. M.; Pullar, W. A. 1977: Radiocarbon dating techniques for tephras in central North Island, New Zealand. *Geoderma 18*: 265–278.

Goh, K. M.; Tonkin, P. J.; Rafter, T. A. 1978: Implications of improved radiocarbon dates of Timaru peats on Quaternary loess stratigraphy. *New Zealand journal of geology and geophysics 21*: 463–466.

Grant-Taylor, T. L. 1979: Radiocarbon dates: reply. *New Zealand journal of geology and geophysics 22*: 528.

Green, B. F. 1987: Weathering of buried paleosols on late Quaternary rhyolitic tephras, Rotorua region, New Zealand. Unpublished M.Sc. thesis, lodged in the Library, University of Waikato, Hamilton.

Hammond, A. P.; Goh, K. M.; Tonkin, P. J. 1991: Chemical pretreatments for improving the radiocarbon dates of peats and organic silts in a gley podzol environment: Grahams Terrace, North Westland. *New Zealand journal of geology and geophysics 34*: 191–194.

Hendy, C. H.; Hogg, A. G.; Van der Lee, T. 1980: The prospects of dating tephra and other pyroclastics from the central North Island by uranium-thorium disequilibria. Abstract, Tephra Workshop, Victoria University of Wellington, 1980.

Hodder, A. P. W.; Green, B. E.; Lowe, D. J. 1990: A two-stage model for the formation of clay minerals from tephra-derived volcanic glass. *Clay minerals 25*: 313–327.

Houghton, B. F.; Lloyd, E. F.; Wilson, C. J. N.; Lanphere, M. A. 1991: K-Ar ages from the Western Dome belt and associated rhyolitic lavas in the Maroa-Taupo area, Taupo Volcanic Zone, New Zealand. *New Zealand journal of geology and geophysics 34*: 99–101.

Howorth, R. 1975: New formations of late Pleistocene tephras from the Okataina Volcanic Centre, New Zealand. *New Zealand journal of geology and geophysics 18*: 683–712.

Howorth, R. 1976: Late Pleistocene tephras of the Taupo and Bay of Plenty regions. Unpublished Ph.D. thesis, lodged in the Library, Victoria University of Wellington, Wellington.

Itaya, T.; Ito, H.; Nagao, K. 1991: Degassing of argon from young geological materials by low temperature stepwise heating. *Mineralogical journal 15*: 309–320.

Kennedy, N. M. 1988: Late Quaternary loess associated with the Mamaku Plateau, North Island, New Zealand. *In*: Eden, D. N.; Furkert, R. J. *ed*. Loess. Rotterdam, Balkema. Pp. 71–80.

Kennedy, N. M. 1994: New Zealand tephro-chronology as a tool in geomorphic history of the c. 140 ka Mamaku Ignimbrite Plateau and in relating oxygen isotope stages. *Geomorphology 9*: 97–115.

Kimber, R. W. L.; Kennedy, N. M.; Milnes, A. R. 1994: Amino acid racemization dating of a 140 000 year old tephra-loess-palaeosol sequence on the Mamaku Plateau near Rotorua, New Zealand. *Australian journal of earth sciences 41*: 19–26.

Lowe, D. J. 1986: Controls on rates of weathering and clay mineral genesis in airfall tephras: a review and New Zealand case study. *In*: Colman, S. M.; Dethier, D. P. *ed*. Rates of chemical weathering of rocks and minerals. Orlando, Academic Press. Pp. 265–330.

Lowe, D. J.; Hogg, A. G. 1992: Application of new technology liquid scintillation spectrometry to radiocarbon dating of tephra deposits, New Zealand. *Quaternary international 13/14*: 135–142.

Lowe, D. J.; Percival, H. J. 1993: Clay mineralogy of tephras and associated paleosols and soils, and hydrothermal deposits, North Island. Guide book for New Zealand Pre-Conference Field Trip F1, 10th International Clay Conference, Adelaide, Australia. 110 p.

McGlone, M. S.; Howorth, R.; Pullar, W. A. 1984: Late Pleistocene stratigraphy, vegetation and climate of the Bay of Plenty and Gisborne regions, New Zealand. *New Zealand journal of geology and geophysics 27*: 327–350.

Nairn, I. A. 1989: Sheet V16 AC—Mount Tarawera. Geological map of New Zealand 1:50,000. Lower Hutt, New Zealand Geological Survey, Department of Scientific and Industrial Research.

Nairn, I. A.; Kohn, B. P. 1973: Relation of the Earthquake Flat Breccia to the Rotoiti Breccia, central North Island, New Zealand. *New Zealand journal of geology and geophysics 16*: 269–279.

Nathan, S. 1976: Age of the Rotoiti Breccia Formation. *Geological Society of New Zealand newsletter 41*: 22–24.

Ota, Y.; Omura, A.; Iwata, H. 1989: ^{230}Th-^{238}U age of Rotoehu Ash and its implications for marine terrace chronology of eastern Bay of Plenty, New Zealand. *New Zealand journal of geology and geophysics 32*: 327–331.

Pillans, B. J.; Wright, I. C. 1992: Late Quaternary tephrostratigraphy from the southern Havre Trough–Bay of Plenty, northeast New Zealand. *New Zealand journal of geology and geophysics 35*: 129–143.

Pullar, W. A. 1976: Age of the Rotoiti Breccia Formation. *Geological Society of New Zealand newsletter 41*: 24–25.

Pullar, W. A.; Heine, J. C. 1971: Ages, inferred from ^{14}C dates, of some tephra and other deposits from Rotorua, Taupo, Bay of Plenty and Hawke's Bay districts. Proceedings of Radiocarbon Users' Conference, Lower Hutt. Pp. 118–138.

Suggate, R. P. 1984: The radiocarbon "infinite". *Geological Society of New Zealand newsletter 65*: 41–43.

Wellman, H. W. 1984: An exponential plot to foil the radiocarbon infinite. *Geological Society of New Zealand newsletter 64*: 47–49.

Whitehead, N. E.; Ditchburn, R. 1994: Revision of some ages for the Rotoehu Ash. *New Zealand journal of geology and geophysics 37*: 381–383.

Wilson, C. J. N.; Houghton, B. F.; Lanphere, M. A.; Weaver, S. D. 1992: A new radiometric age estimate for the Rotoehu Ash from Mayor Island volcano, New Zealand. *New Zealand journal of geology and geophysics 35*: 371–374.