Citation: Lowe, D. J.; Tippett, J. M.; Kamp, P. J. J.; Liddell, I. J.; Briggs, R. M.; Horrocks, J. L. 2001. Ages on weathered Plio-Pleistocene tephra sequences, western North Island, New Zealand. *In*: Juvigné, E.T.; Raynal, J-P. (Eds), "Tephras: Chronology, Archaeology", CDERAD éditeur, Goudet. *Les Dossiers de l'Archéo-Logis* 1: 45-60.

Ages on weathered Plio-Pleistocene tephra sequences, western North Island, New Zealand

Âges de séquences de tephras Plio-Pleistocènes altérés, Île du Nord-Ouest, Nouvelle Zélande

David J. Lowe[1], J. Mark Tippett[1], Peter J. J. Kamp[1], Ivan J. Liddell[1], Roger M. Briggs[1] & Joanna L. Horrocks[1]

Abstract: *using the zircon fission-track method, we have obtained five ages on members of two strongly-weathered, silicic, Pliocene-Pleistocene tephra sequences, the Kauroa and Hamilton Ash formations, in western North Island, New Zealand. These are the first numerical ages to be obtained directly on these deposits. Of the Kauroa Ash sequence, member K1 (basal unit) was dated at 2.24 ± 0.29 Ma, confirming a previous age of* c. *2.25 Ma obtained (via tephrochronology) from K/Ar ages on associated basalt lava. Members K2 and K3 gave indistinguishable ages between 1.68 ± 0.12 and 1.43 ± 0.17 Ma. Member K12, a correlative of Oparau Tephra and probably also Ongatiti Ignimbrite, was dated at 1.28 ± 0.11 Ma, consistent with an age of 1.23 ± 0.02 Ma obtained by various methods on Ongatiti Ignimbrite. Palaeomagnetic measurements indicated that members K13 to K15 (top unit, Waiterimu Ash) are aged between* c. *1.2 Ma and 0.78 Ma. Possible sources of the Kauroa Ash Formation include younger volcanic centres in the southern Coromandel Volcanic Zone or older volcanic centres in the Taupo Volcanic Zone, or both. Of the Hamilton Ash sequence, the basal member Ohinewai Ash (H1) was dated at 0.38 ± 0.04 Ma. This age matches those obtained by various methods on Rangitawa Tephra of 0.34–0.35 Ma, supporting correlation with this Whakamaru-caldera derived deposit. The origin of the other Hamilton Ash beds is unknown but various younger volcanic centres in the Taupo Volcanic Zone are possible sources. The topmost member, Tikotiko Ash (H6–H7), is estimated to be aged between* c. *0.18 and 0.08 Ma. Various silicic pyroclastic deposits documented in North Island and in marine cores may be co-eval with members of the Kauroa Ash and Hamilton Ash sequences on the basis of their age.*

Keywords*: tephra, fission-track ages, zircon, geochronology, brown ashes, Kauroa Ash, Hamilton Ash, Oparau Tephra, Ongatiti Ignimbrite, Ohinewai Ash, Rangitawa Tephra, Plio-Pleistocene, Waikato region, New Zealand.*

Résumé : *en utilisant la méthode des traces de fission sur zircon, nous avons obtenu cinq âges sur des membres de deux séquences de téphras siliciques fortement altérés du Pliocène final et du Pléistocène : les formations de Kauroa Ash et de Hamilton Ash du North Island occidental, Nouvelle-Zélande. Ce sont les premiers âges numériques obtenus sur de tels dépôts. De la séquence de Kauroa Ash, le membre K1 (unité inférieure) a été daté de 2,24 ± 0,29 Ma, confirmant un âge de 2,25 Ma obtenu antérieurement (par téphrochronologie) à partir d'âges K/Ar de coulées de basalte associées. Les membres K2 et K3 ont donné des âges compris entre 1,68 ± 0,12 and 1,43 ± 0,17 Ma. Le membre K12, corrélatif du Oparau Tephra et probablement aussi de l'Ongatiti Ignimbrite, a été daté de 1,28 ± 0,11 Ma, ce qui est consistant avec un âge de 1,23 ± 0,02 Ma, obtenu par différentes méthodes sur l'Ongatiti Ignimbrite. Des mesures paléomagnétiques indiquaient que les membres K13 to K15 (unité supérieure, Waiterimu Ash) ont un âge compris entre environ 1,2 Ma and 0,78 Ma. Les sources possibles de la formation Kauroa Ash comprennent des centres volcaniques récents dans la partie méridionale de la Zone Volcanique Coromandel, ou des centres plus anciens de la Zone Volcanique Taupo, ou les deux. Le membre basal de la séquence de Hamilton Ash (H1) a été daté de 0,38 ± 0,04 Ma, ce qui correspond à l'âge de 0,34–0,35 Ma obtenu par différentes méthodes sur le Rangitawa Tephra, supportant ainsi la corrélation avec les dépôts dérivés de la caldera Whakamaru. L'origine des autres lits de la Hamilton Ash est inconnue, mais divers centres volcaniques récents de la Zone Volcanique Taupo sont possibles. L'âge du membre sommital de la Tikotiko Ash (H6–H7), est estimé entre 0,18 and 0,08 Ma. Divers dépôts pyroclastiques siliciques signalés dans la North Island et dans des carottes océaniques devraient être en corrélation avec des membres des séquences de la Kauroa Ash et de la Hamilton Ash, sur la base de leur âge.*

Mots-clés : *téphra, datations, trace de fission, zircon, géochronologie, cendre brun, Kauroa Ash, Hamilton Ash, Oparau Tephra, Ongatiti Ignimbrite, Ohinewai Ash, Rangitawa Tephra, Plio-Pléistocène, région Waikato, Nouvelle Zélande.*

1. Department of Earth Sciences, University of Waikato, Private Bag 3105, Hamilton, New Zealand

1. Introduction

Tephra deposits resulting from large-scale volcanic eruptions provide important stratigraphic markers that assist in correlating sequences in both terrestrial and marine environments, and in linking such sequences (e.g. Pillans *et al.*, 1993; Carter *et al.*, 1995; Naish *et al.*, 1996; Shane *et al.*, 1996a). They also provide juvenile mineralogical components for numerical dating and hence a means for independently testing the veracity of dates based on biostratigraphy, magnetostratigraphy or other methods (Naish *et al.*, 1996; Newnham *et al.*, 1999a; Shane, 2000). In addition, tephras are useful as recorders of volcanism, particularly in distal environments (e.g. Kyle & Seward, 1984; Lowe, 1988a; Shane *et al.*, 1996a, 1998; Shane, 2000), because proximal, near-vent deposits are complex and typically 'incomplete' with successive eruptive events tending to destroy or bury antecedent deposits (e.g. Krippner *et al.*, 1998).

In North Island, New Zealand, there is a record of explosive, rhyolite-dominated volcanism dating from *c.* 10 Ma in the Coromandel Volcanic Zone (CVZ) (Adams *et al.*, 1994; Shane *et al.*, 1998) and from at least *c.* 1.6 Ma in the Taupo Volcanic Zone (TVZ) (Houghton *et al.*, 1995; Wilson *et al.*, 1995a; Krippner *et al.*, 1998) (Fig. 1). Despite considerable research in recent years on the stratigraphy, age, and composition of eruptives from CVZ and especially TVZ, there remain extensive, thick sequences of Quaternary or older pyroclastic deposits (including both fallout tephras and ignimbrites) in the North Island with no known source and little or no age control. Many of these deposits, commonly weathered (sometimes very strongly), have been broadly mapped as portmanteau units termed 'undifferentiated brown tuffs' or 'brown ashes' (Fig.1; Pullar *et al.*, 1973). Detailed regional studies have commenced on such deposits in an attempt to document their stratigraphic inter-relationships and to correlate them with defined units, to determine their ages, and to identify their modes of emplacement and sources (e.g. Briggs *et al.*, 1996; Manning, 1996; Newnham *et al.*, 1999b). We have begun similar work on two extended, Pliocene-Pleistocene sequences of strongly-weathered, silicic, tephra deposits in western North Island in the Waikato region, namely the Kauroa Ash and Hamilton Ash beds (Fig. 1). In this paper we review the stratigraphy of these two long sequences. We then present new zircon fission-track (ZFT) age determinations for four members of the Kauroa Ash sequence and for one member of the Hamilton Ash sequence, the first radiometric ages to be obtained directly on these deposits. Our results show that the members K1 (basal unit) to K12 (Oparau Tephra) of the Kauroa Ash sequence were erupted between *c.* 2.25 and *c.* 1.2 Ma, and that member H1 (Ohinewai Ash) of the Hamilton Ash sequence was erupted *c.* 0.38 Ma. Some implications regarding possible eruptive sources and correlations arising from these new ZFT age determinations are discussed.

Our results are part of an ongoing programme of research on the Kauroa and Hamilton deposits including a revision of their stratigraphy, measurements of palaeomagnetic polarity and magnetic susceptibility, and analyses of various physical, mineralogical and geochemical properties together with further ZFT dating. Findings from these studies will be reported later.

2. Stratigraphy of Kauroa and Hamilton Ash sequences

2.1. Kauroa Ash Formation

The Kauroa Ash Formation comprises a sequence, up to *c.* 12 m thick, of extremely weathered, clay-rich (*c.* 70–90% <2-μm clay), multiple tephra deposits and associated paleosols, together possibly with interbedded loessic materials in places (Kirkman, 1980; Kamp & Lowe, 1981; Selby & Lowe, 1992; Briggs *et al.*, 1994; Horrocks, 2000). The formation was initially recognised and defined in the Waikato region by Ward (1967), with the type locality recorded at 'Woodstock', near Raglan (Fig. 1; Waterhouse & White, 1994). (The name 'Woodstock' derives from the original name of the adjacent farm.) The sequence is underlain by basaltic deposits of the Okete Volcanic Formation including lava dated at *c.* 2.25 Ma by Briggs *et al.* (1989), and overlain by the Hamilton Ash Formation, of which the lowermost member (H1) is dated indirectly at *c.* 0.35 Ma by tephrochronology (see below).

Two members of the Kauroa Ash sequence have been individually defined. The uppermost is Waiterimu Ash, named from the type locality at grid reference S13/095096 near Waiterimu (Fig. 1; Ward, 1967). (Grid references here and elsewhere in the text are based on the metric 1: 50,000 topographical map series NZMS 260.) The other is Oparau Tephra, an ignimbrite named from the type locality at R15/797477 at Papakura Creek (Fig. 1A; Pain, 1975; Fergusson, 1986). Salter (1979) subsequently divided the Kauroa Ash Formation at Woodstock into fifteen major members, K1 (base) to K15 (top), and this sequence, slightly modified following further work (Briggs *et al.*, 1994), is shown in Fig. 2. Distinctive sand-sized 'micaceous' or platy minerals in beds K3 and K12 have been identified as kaolinite books and stacks (Salter, 1979).

No direct radiometric ages have been obtained on any members of the Kauroa Ash Formation. However, Briggs *et al.* (1989) used tephrochronology to show that member K1 is likely to be aged *c.* 2.25 Ma because it occurs intercalated with co-eruptives of K/Ar-dated alkali basalts (basanite) of the Okete Volcanics at nearby Ohiapopoko cone (2.26 ± 0.08 Ma) and Cleaves cone (2.25 ± 0.10 Ma) of the Maungatawhiri centre (Fig. 1A). The stratigraphic inter-relationships used to obtain this age for K1 at Ohiapopoko are shown in Fig. 3. An age of <1.81 Ma was assigned to members K12 (Oparau Tephra) and K15 (Waiterimu Ash) because these members unconformably overlie co-eruptives of K/Ar-dated alkali basalts (hawaiite) of the Ngatutura Volcanics at Foxs centre (1.81 ± 0.07 Ma) in the northern Waikato region (Briggs *et al.*, 1989; Fig. 1).

2.2. Hamilton Ash Formation

The Hamilton Ash Formation comprises a sequence, up to *c.* 6 m thick, of strongly weathered, clay-textured (*c.* 60–85% <2-μm clay) multiple rhyolitic tephra beds and associated paleosols (Tonkin, 1970; Kamp & Lowe, 1981; Selby & Lowe 1992; Lowe & Percival, 1993; Briggs *et al.*, 1994). The sequence may also contain intercalated loessic beds at some sites (e.g., Birrell *et al.*, 1981). The formation, widespread throughout the Waikato and Coro-

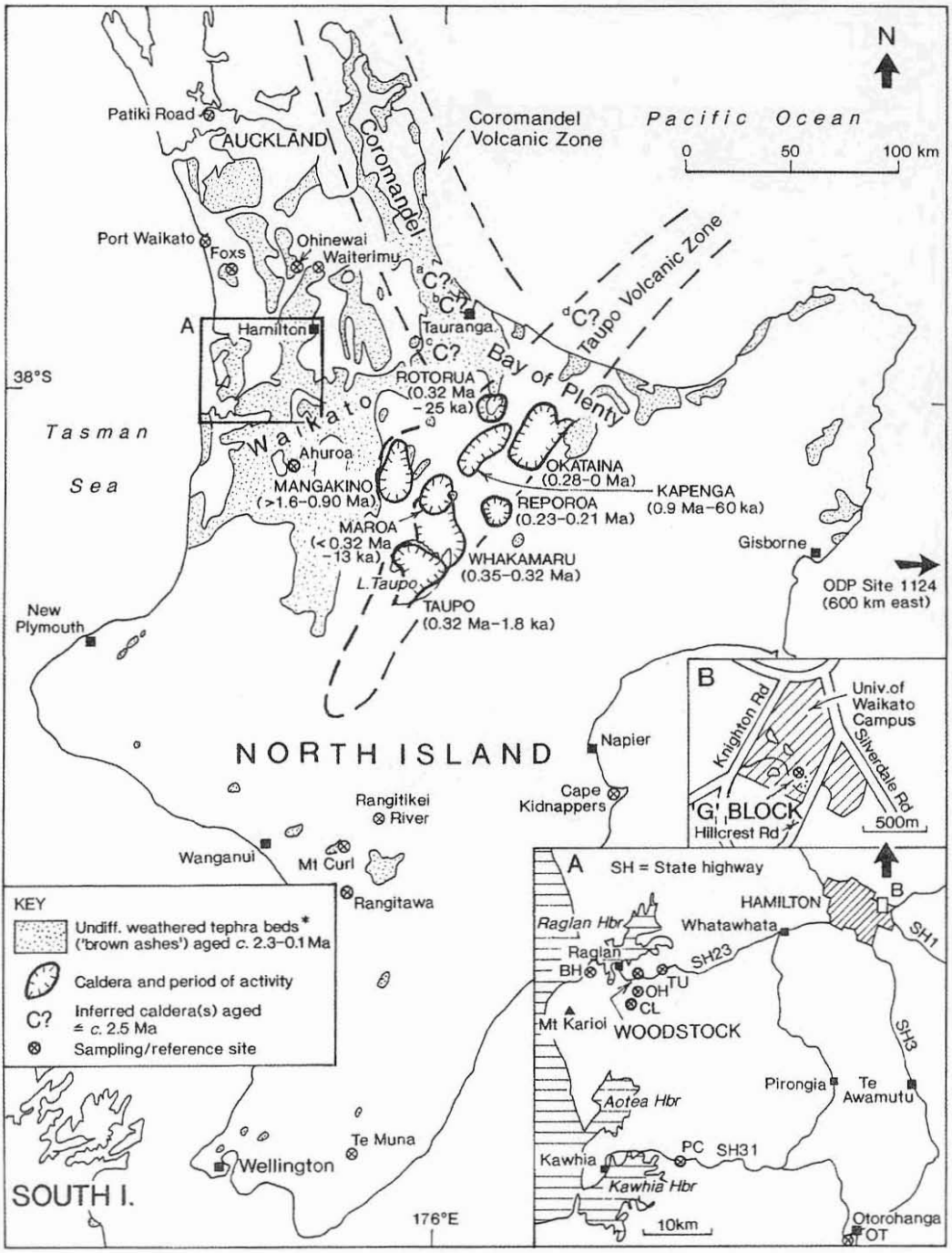

Figure 1. *Generalised distribution of weathered Plio-Pleistocene tephra deposits in North Island, New Zealand, and locations of possible source caldera volcanoes in Taupo and Coromandel volcanic zones. Caldera age ranges after Houghton et al. (1995) and Wilson et al. (1995a); inferred calderas: a, 'Katikati'; b, 'Te Puna'; c, 'Kaimai'; d, 'offshore BOP' (see text). Insets A and B show locations of ZFT sampling sites at Woodstock and 'G Block', and reference sections at Bryant Home (BH), Te Uku (TU), Ohiapopoko cone (OH), Cleaves cone (CL), Papakura Creek (PC), and Otorohanga (OT). Locations of other sections referred to in the text are shown on the main map.*

**After Pullar et al. (1973) and Kohn et al. (1992); named deposits (general occurrence, approximate age ranges) include Hamilton Ash beds (Waikato–Coromandel–Bay of Plenty, c. 0.1–0.35 Ma), Rangitawa Tephra (southern North Island, c. 0.35 Ma), Kauroa Ash beds (Waikato–W. Bay of Plenty, c. 2.3–0.35 Ma), Pahoia Tephra beds (W. Bay of Plenty, c. 2.2–0.35 Ma), and Tablelands Tephra beds (E. Bay of Plenty, <c. 0.5 Ma).*