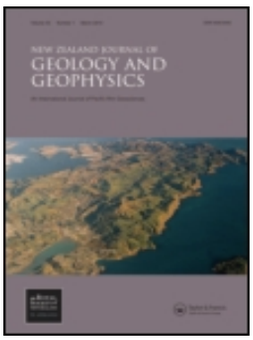


New Zealand Journal of Geology and Geophysics

ISSN: 0028-8306 (Print) 1175-8791 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzg20

Air-fall Kaharoa Ash and Taupo Pumice, and sea-rafted Loisels Pumice, Taupo Pumice, and Leigh Pumice in northern and eastern parts of the North Island, New Zealand

W. A. Pullar , B. P. Kohn & J. E. Cox

To cite this article: W. A. Pullar , B. P. Kohn & J. E. Cox (1977) Air-fall Kaharoa Ash and Taupo Pumice, and sea-rafted Loisels Pumice, Taupo Pumice, and Leigh Pumice in northern and eastern parts of the North Island, New Zealand, New Zealand Journal of Geology and Geophysics, 20:4, 697-717, DOI: 10.1080/00288306.1977.10430729

To link to this article: http://dx.doi.org/10.1080/00288306.1977.10430729

Published online: 14 Feb 2012.

N.Z. Journal of Geology and Geophysics Vol. 20, No. 4 (1977): 697–717

AIR-FALL KAHAROA ASH AND TAUPO PUMICE, AND SEA-RAFTED LOISELS PUMICE, TAUPO PUMICE, AND LEIGH PUMICE IN NORTHERN AND EASTERN PARTS OF THE NORTH ISLAND, NEW ZEALAND

W. A. PULLAR, B. P. KOHN*, AND J. E. COX

Soil Bureau, DSIR, Rotorua; Geology Department, Victoria University of Wellington; and Soil Bureau, DSIR, Auckland, New Zealand*

ABSTRACT

This widespread and intensive field and laboratory (mineralogical and chemical) investigation aims to check the validity of Ohui Ash as a separate air-fall tephra deposit, and to re-examine the age of sea-rafted Loisels Pumice. Ohui Ash is here considered to be probably Kaharoa Ash at Whiritoa Beach, eastern Coromandel Peninsula and definitely air-fall Taupo Pumice at Opoutere Beach, eastern Coromandel Peninsula. Primary sea-rafted Loisels Pumice is probably younger than Kaharoa Ash, but, as yet, its stratigraphic relationship is still uncertain. The investigation discloses that Wellman's sea-rafted light coloured Loisels Pumice is sea-rafted Taupo Pumice. It was also found that air-fall Kaharoa Ash and Taupo Pumice occur in Northland—much further north than previously suspected.

INTRODUCTION

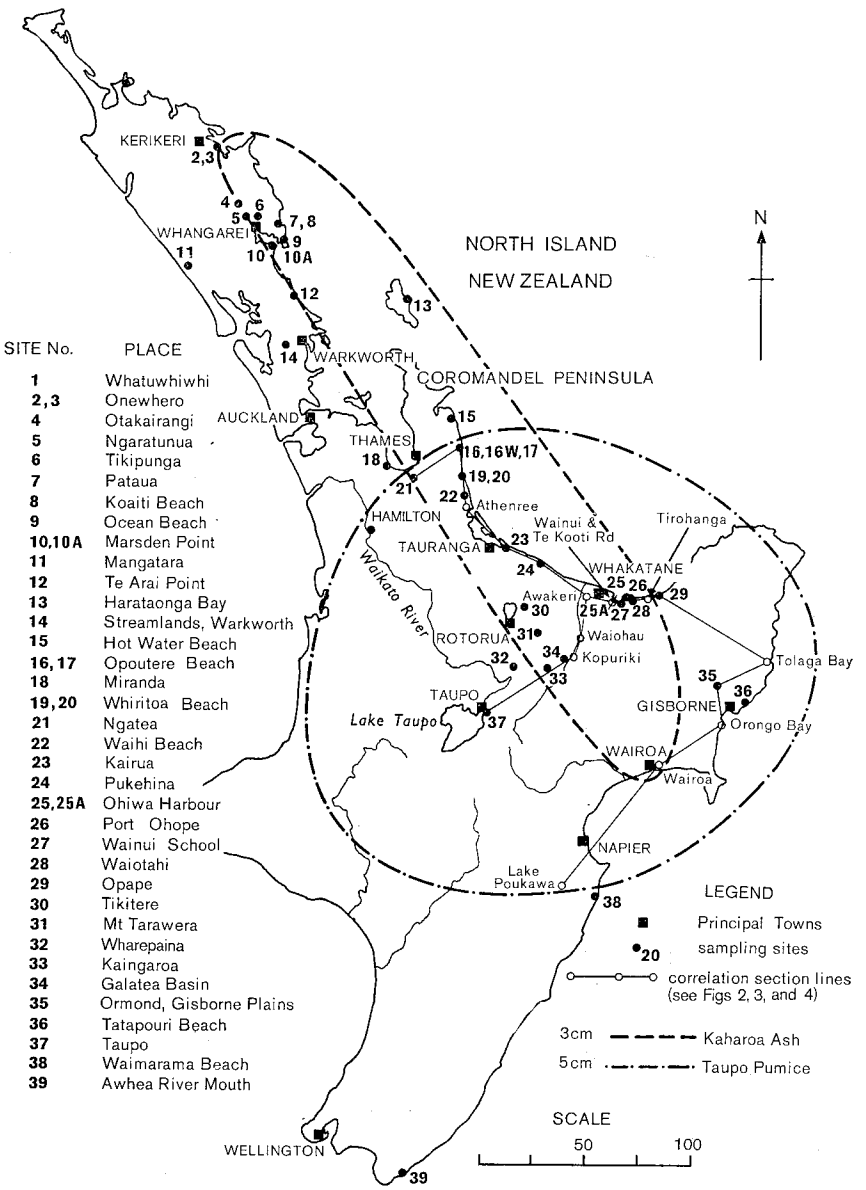
In his reconnaissance mapping of Holocene coastal deposits of the North Island of New Zealand, Wellman (1962) identified the established air-fall tephra layers Kaharoa Ash and Taupo Pumice and named a new air-fall tephra, Ohui Ash. He also named sea-rafted pumices, Loisels Pumice(s) and Leigh Pumice. Suggested ages were allotted to Ohui Ash and the sea-rafted pumices.

Ohui Ash was noted by Wellman particularly at Onewhero Bay, Northland; north end of Opoutere Beach, eastern Coromandel Peninsula (type locality); at the south end of Whiritoa Beach, eastern Coromandel Peninsula; and tentatively on Wainui Road, Ohiwa Harbour, Bay of Plenty. A probable terrestrial limit of Ohui Ash was shown by Wellman (1962, fig. 3, p. 34) to stretch from Onewhero Bay in the north to near Taupo and Wairoa in the south (see Fig. 1 for all localities described in this paper). Ohui Ash, however, was not recorded in the Bay of Plenty district by Vucetich & Pullar (1964) who mapped tephra formations as far north as Waihi Beach.

The purpose of this study is to check the validity of Ohui Ash as a separate air-fall tephra formation, to examine the different types of sea-rafted Loisels Pumice, and to re-examine the age of sea-rafted Loisels Pumice in the light of new ^{14}C dates.

Received 26 August 1976, revised 21 April 1977.

*Present address: Geology Department, Ben Gurion University of the Negev, Beer Sheva, Israel.



SITE No.	PLACE
1	Whatuwhiwhi
2,3	Onewhero
4	Otakairangi
5	Ngaratunua
6	Tikipunga
7	Pataua
8	Koaiti Beach
9	Ocean Beach
10,10A	Marsden Point
11	Mangatara
12	Te Arai Point
13	Harataonga Bay
14	Streamlands, Warkworth
15	Hot Water Beach
16,17	Opoutere Beach
18	Miranda
19,20	Whiritoa Beach
21	Ngatea
22	Waihi Beach
23	Kairua
24	Pukehina
25,25A	Ohiwa Harbour
26	Port Ohope
27	Wainui School
28	Waiotahi
29	Opape
30	Tikitere
31	Mt Tarawera
32	Wharepaina
33	Kaingaroa
34	Galatea Basin
35	Ormond, Gisborne Plains
36	Tatapouri Beach
37	Taupo
38	Waimarama Beach
39	Awhea River Mouth

FIG. 1—Sampling sites and location of tephra correlation sections in northern, central and eastern North Island. Distribution of Kaharoa Ash (3 cm isopach) and Taupo Pumice (5 cm isopach) is also shown. Section correlation lines relate to Figs 2–4. Scale is in miles.

TABLE 1—Stratigraphy of air-fall tephra and sea-rafted pumices.

Wellman (1962)	This paper†
Kaharoa Ash (air-fall) A.D. *c.* 1300 (650 yr B.P.*)	Kaharoa Ash (air-fall) 890 ± 80 yr B.P. (NZ10C†)
Loisels Pumice‡ (sea-rafted) A.D. ? 700 (1250 yr B.P.)	Sea-rafted dark grey Loisels Pumice‡ Age equivocal—between 560 ± 40 yr B.P. (NZ631C) and 1110 ± 60 yr B.P. (NZ651C)
Light coloured Loisels Pumice (sea-rafted) A.D. ? 700 (1250 yr B.P.)	Sea-rafted light grey Loisels Pumice‖ (= Taupo Pumice) > 1590 ± 110 yr B.P. (NZ862C)
Ohui Ash (air-fall) A.D. ? 500 (1450 yr B.P.)	Probably Kaharoa Ash in Northland and Bay of Plenty; definitely Taupo Pumice at Opoutere Beach (Ohui type site); Kaharoa Ash at Whiritoa Beach; either Taupo Pumice or Kaharoa Ash at Onewhero Beach.
Taupo Pumice (sea-rafted) A.D. ? 150 (1800 yr B.P.)	Taupo Pumice (sea-rafted) > 1590 ± 110 yr B.P. (NZ862C)
Taupo Pumice (air-fall) A.D. 150 (1800 yr B.P.)	Taupo Pumice (air-fall) 1830 ± 50 yr B.P. (NZ1548)
Leigh Pumice (sea-rafted) A.D. *c.* 1 (1949 yr B.P.)	Refers to one of the "un-named pumices" (sea-rafted). Unable to establish a reference for Leigh Pumice.

*B.P. = Before 1950.

†Radiocarbon dates are converted to the new half-life ($T_{\frac{1}{2}}$) and corrected for secular effect (Column C in Table 5).

‡Loisels Pumice is the proper name but to avoid confusion with colours the qualifier "dark grey" has been added.

‖"Light grey" refers to pumice in the dry state.

AIR-FALL TEPHRA STRATIGRAPHY

Air-fall tephra stratigraphy at sites over a wide area, including the eastern part of the North Island, coastal Bay of Plenty, eastern Coromandel Peninsula, Hauraki Plains, and Rangitaiki River valley to Taupo (see Fig. 1) is shown by correlation sections in Figs 2–4. The correlations are based on the work of Green & Pullar 1960, Wellman 1962, Vucetich & Pullar 1964, Pullar 1967, Pullar & Penhale 1970, Pullar 1970, and Pullar & Selby 1971, supplemented by field observations in the present study particularly of Kaharoa Ash and Taupo Pumice in coastal Bay of Plenty, eastern Coromandel Peninsula, and eastern Northland. For this investigation the stratigraphy is limited to formations no older than Taupo Pumice, although older formations have been included in the correlation sections in Figs 2–4 for completeness.

The air-fall tephra and sea-rafted pumice stratigraphy established by Wellman and that arrived at in this paper are given in Table 1.

d dominant ferromagnesian assemblage of Holocene sea-rafted pumices, air-fall tephra, and beach and dune sands in northern and eastern North Island, New Zealand.

		Sample examined	Locality	NZMS 1 Grid reference (edition)	Collector(s)	Analyses ‡ 1	2
			SEA-RAFTED DEPOSITS				
		.s Pumice (dark grey) man's section 39)	Whatuwhiwhi, Northland	N7/912975 (1964)*	H.W. Wellman	x	A
		:e (large vesicles; pumice nered brown) (un-named pumice)	Koaiti Beach, Pataua, Northland	N20/043979 (1964)	J.E. Cox	x	A
		.ce (white; slightly weathered) n-named pumice)	Koaiti Beach, Pataua, Northland	N20/043979 (1964)	J.E. Cox	x	A
9	1942 (pt)	.sels Pumice (dark grey)	Ocean Beach, Whangarei Heads	N24/073855 (1968)*	J.E. Cox	x	A
9	1942 (pt)	Loisels Pumice (light grey)=Taupo Pumice	Ocean Beach, Whangarei Heads	N24/073855*	J.E. Cox	x	A
13		Loisels Pumice (dark grey)	Harataonga Bay, Great Barrier Island	N30/990434 (1953)	R.G. Law	x	-
15		Pumice associated with Loisels Pumice (dark grey)	Hot Water Beach, Coromandel Peninsula	N44/317559 (1966)*	A. Leahy	x	A
16		Loisels Pumice (light grey) = Taupo Pumice	Opoutere Beach, north end (Ohui), Coromandel Peninsula	N49/377331 (1967)*	B.P. Kohn	x	A
19		Loisels Pumice (dark grey)	Whiritoa Beach, south end, Coromandel Peninsula	N53/391079 (1965)	B.P. Kohn	x	A
26	1870/M	Loisels Pumice (dark grey)	Port Ohope, Bay of Plenty	N69/565210 (1969)	W.A. Pullar	x	x
26	1871/M	Loisels Pumice (light grey)= Taupo Pumice	Port Ohope, Bay of Plenty	N69/565210	W.A. Pullar	x	A
36		Loisels Pumice (dark grey)	Tapapouri Beach, Gisborne District	N98/519389 (1965)	B.P. Kohn	x	A
38		Loisels Pumice (dark grey)	Waimarama Beach, Hawkes Bay District	N142/401985 (1969)	H.W. Wellman	x	A
			AIR-FALL DEPOSITS				
14	1903	? Rotoehu Ash	Streamlands, Warkworth	N34/137148 (1967)	J.E. Cox	-	B^P
2	1950	? Taupo Pumice	Onewhero Beach	N11/564567 (1969)	J.E. Cox	-	A
7	1955	Taupo Pumice (+ beach sand)	Pataua, Northland	N20/030985 (1964)	J.E. Cox	-	A^R

Figs
Figna-
for
Pu
2–4.
ished by

21	1949	Taupo Pumice	Ngatea peat factory	N52/953060 (1967)	J.E. Cox	-	A
33		Taupo Pumice	Kaingaroa Forest Headquarters	N86/023711 (1968)	B.P. Kohn	x	A
37		Taupo Pumice	Napier-Taupo Highway	N94/564354 (1969)	B.P. Kohn	x	A
39		Taupo Pumice	Raised beach, east of Awhea River mouth, south east Wellington district	N169/023958 (1969)	B.P. Kohn	x	A
21	1906	Resorted Taupo Pumice	Ngatea peat factory, Hauraki Plains	N52/953060	J.E. Cox & W.A. Pullar	-	B
16		Ohui Ash = Taupo Pumice† (Type section Ohui Ash)	Opoutere Beach, north end (Ohui) Coromandel Peninsula	not given	H.W. Wellman	x	A
16	1898	Ohui Ash = Taupo Pumice† (lapilli analysed)	Opoutere Beach, north end (Ohui) Coromandel Peninsula	N49/377331	J.E. Cox & W.A. Pullar	x	A
17	1901	Ohui Ash = Taupo Pumice (lapilli analysed)	Savage's farm, Opoutere	N49/373299	J.E. Cox & W.A. Pullar	x	A
3	1868/M	Kaharoa Ash	Onewhero Beach (swamp)	N11/567558	J.E. Cox	-	C
4	1905	Kaharoa Ash	Otakairangi Swamp, Whangarei	N20/697111	J.E. Cox	-	C
5	1952	Kaharoa Ash	Ngaratunua, Northland	N20/772034	J.E. Cox	-	C
6	1904	Kaharoa Ash	Tikipunga, Whangarei	N20/827019	J.E. Cox	-	C
10	1951	Kaharoa Ash	Marsden Point, Northland (dune)	N24/002814	J.E. Cox	-	C
12	1940	Kaharoa Ash	Te Arai Pt, Mangawhai, Northland	N29/159446 (1969)*	J.E. Cox	x	C
20	1856	? Kaharoa Ash = Ohui Ash (contaminated by beach sand) (Wellman's section 24)	Whiritoa Beach, south end	N53/392076	J.E. Cox & W.A. Pullar		C^R
22	1855/M	Kaharoa Ash	Waihi Beach (swamp)	N53/421928 (1957)	J.E. Cox & W.A. Pullar	-	C
23	1853/M	Kaharoa Ash	Kairua, near Mt Maunganui	N58/732573 (1965)	J.E. Cox	-	C
24	1851/M	Kaharoa Ash	Court's farm, Pukehina	N68/003426 (1967)	J.E. Cox & W.A. Pullar	-	C
25	BP 391	Kaharoa Ash	Port Ohope, Bay of Plenty (sand flat, Ohiwa Harbour)	N69/556212	W.A. Pullar	-	C
25▲	BP 392	Kaharoa Ash	Port Ohope, Ohiwa Harbour (root flange of stumps)	N69/556212	W.A. Pullar	-	C
28	BP 390	Kaharoa Ash	Looney's Rd, Waiotahi, Bay of Plenty	N78/623186 (1962)	W.A. Pullar	-	C
29	BP 389	? Kaharoa Ash	Opape, Bay of Plenty (swamp)	N70/829212 (1970)	W.A. Pullar	-	B
30		Kaharoa Ash	Rotorua-Whakatane Highway, Tikitere	N76/829133 (1964)	B.P. Kohn	x	C
31		Kaharoa Ash	Mt Tarawera	N77/985942 (1965)	B.P. Kohn	x	C

TABLE 2—*Continued*

Site No. (Fig.1)	Soil Bureau Field No.	Sample examined	Locality	NZMS 1 Grid reference (edition)	Collector(s)	Analyses‡ 1	2
34		Kaharoa Ash	Te Teko-Murupara Road, Galatea Basin	N86/206783 (1968)	B.P. Kohn	x	C
35	BP 388	Kaharoa Ash	Lovelock's farm, Ormond, Gisborne Plains	N98/299524 (1965)	W.A. Pullar	-	C
11	1953	Basic ash (unnamed) (local)	Mangatara	N23/326688 (1964)	J.E. Cox	-	A
			BEACH AND DUNE SANDS				
12	1943	Sandy subsoil 7.5-15 cm below Kaharoa Ash	Te Arai Pt, Mangawhai (north end of site), Northland	N29/159446*	J.E. Cox	-	B^R
12	1944	Fresh sand under Kaharoa Ash	Te Arai Pt, Mangawhai (south end of site), Northland	N29/159446*	J.E. Cox	-	$B^{R,D}$
16	1900	Sand, present beach	Opoutere Beach, north end (Ohui)	N49/378331	J.E. Cox & W.A. Pullar	x	B^R
16	1899	Sand adhering to light grey Loisels Pumice (= Taupo Pumice)	Opoutere Beach, north end (Ohui)	N49/377331	J.E. Cox & W.A. Pullar	x	B^R
18	1954	Beach sand + ? ash	Miranda, Firth of Thames		J.E. Cox	-	A
20	1857/M	Sand 15-23 cm above Ohui Ash = ? Kaharoa Ash	Whiritoa Beach, south end	N53/392076	J.E. Cox & W.A. Pullar	-	A^R
20	1858/M	Sand 15-23 cm below Ohui Ash = Kaharoa Ash	Whiritoa Beach, south end	N53/392076	J.E. Cox & W.A. Pullar	-	A^R

* Grid reference approximate (open area with poor local topographic control).

† Deposit slightly water sorted by the sea.

‡ Analyses by B.P. Kohn: 1 = Titanomagnetite separated, and then analysed by optical emission spectrograph (see Table 3).
x = titanomagnetite separated and analysed from sample.
- = titanomagnetite not separated, or not enough available for analysis.

2 = Ferromagnesian minerals separated, and then identified by petrographic microscope

Dominant ferromagnesian assemblage: A = hypersthene ± augite; B = hypersthene + calcic-hornblende ± cummingtonite; C = biotite + calcic-hornblende ± hypersthene; - = not determined.

Superscripts: R = with well sorted, smooth and rounded ferromagnesian minerals (beach sands); P = cummingtonite dominant ferromagnesian mineral; D = with some augite present.

(pt) = part of sample

NOTE: Banded dark and light grey also occur in all samples where Loisels (dark grey) is specified.

Identification of individual tephra formations in the field has now been confirmed by microscopic examination of their ferromagnesian assemblages (Table 2), by chemical analysis of their titanomagnetites (Table 3) by the method of Kohn (1970), and by spectrographic analysis of ash and pumiceous lapilli (Table 4). All pumice lapilli and blocks examined for ferromagnesian mineralogy were sieved and then placed in an ultrasonic vibrator to remove any loose adhering sand grain contaminants.

Localities sampled are shown in Fig. 1.

AIR-FALL KAHAROA ASH AND TAUPO PUMICE

North of Waihi Beach, Kaharoa Ash and Taupo Pumice have been identified. Identifications of Kaharoa Ash were made on the basis of abundant biotite in the ferromagnesian assemblage. They were confirmed by a ^{14}C date of 850 ± 54 yr B.P. (NZ872A*) from peat enclosing a biotite-bearing ash at Otakairangi Swamp, Whangarei, and a titanomagnetite analysis (Table 3) from a biotite-bearing ash at Te Arai Point, Mangawhai, Northland (Table 2) which is similar in composition to titanomagnetite of known Kaharoa Ash near source (Table 3, sites 30, 31). No other biotite-bearing tephra in sections north of Waihi Beach contained enough titanomagnetite for chemical analysis. Relatively high Ba content and lower Sr content in ash samples from Otakairangi Swamp, a swamp near Onewhero Beach, and a swamp near Marsden Point in Northland (Table 4) also support the identification of Kaharoa Ash (compare values for Taupo Pumice in Table 4).

In the vicinity of the small car park beside Bream Bay Beach near Marsden Point, the dunes are being cut back by marine erosion. In the cliffed face a prominent tephra layer is enclosed by two thin layers of black humus-stained sand. Twig-like fragments of charcoal in the lower humus layer just beneath the tephra were collected, washed and submitted for radiocarbon dating. The tephra was identified as Kaharoa Ash by its biotite-rich ferromagnesian assemblage (Table 2, site 10). However, the radiocarbon date for the charcoal was 656 ± 55 yr B.P. (Table 5, NZ1765C), considerably younger than other Kaharoa Ash dates, so contamination with younger organic matter is suspected.

In his sections 20 and 21, at Opape and Waiotahi estuary respectively, Wellman tentatively correlated an air-fall tephra with Kaharoa Ash. In the present study this tephra was mapped in swamps near Opape and Waiotahi and its presence confirmed by abundant biotite. At nearby section 22 (Wainui Road), however, Wellman introduced Ohui Ash, presumably because it underlies Loisels Pumice, but this tephra is now considered to be Kaharoa Ash. As this section has now been destroyed there is no way of checking the Ohui Ash/Kaharoa correlation.

*Most radiocarbon dates used in this study are converted to the new half-life ($T_{\frac{1}{2}}$) and corrected for secular effect, but see column C in Table 5.

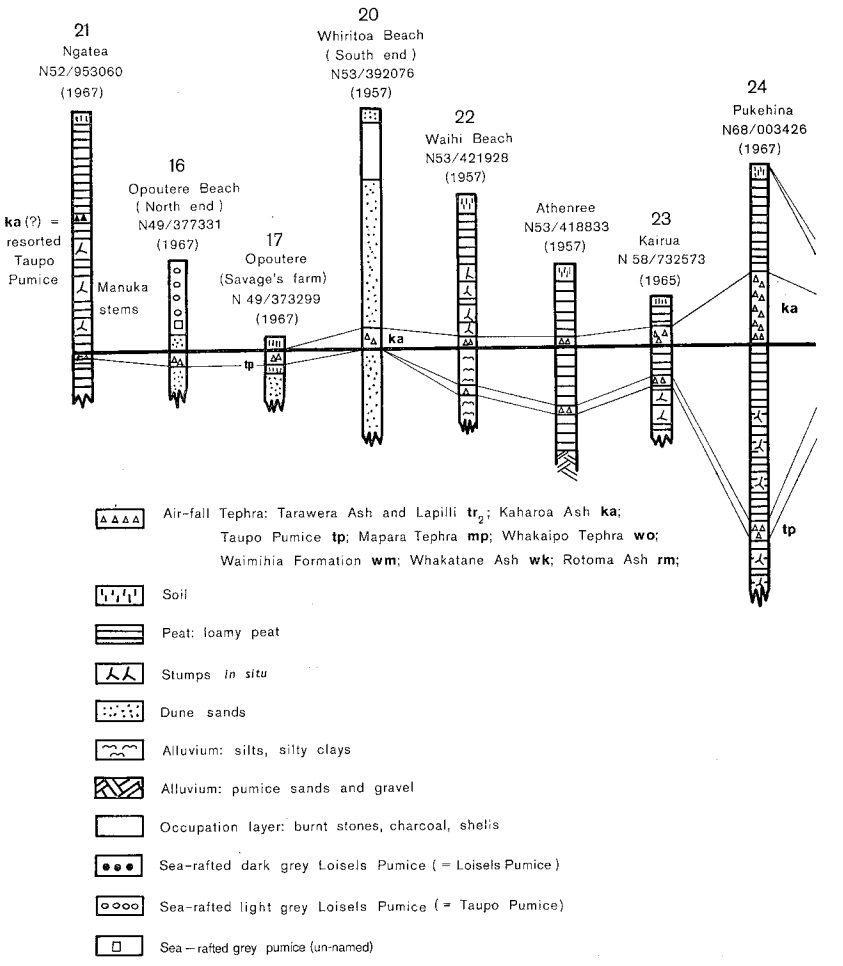
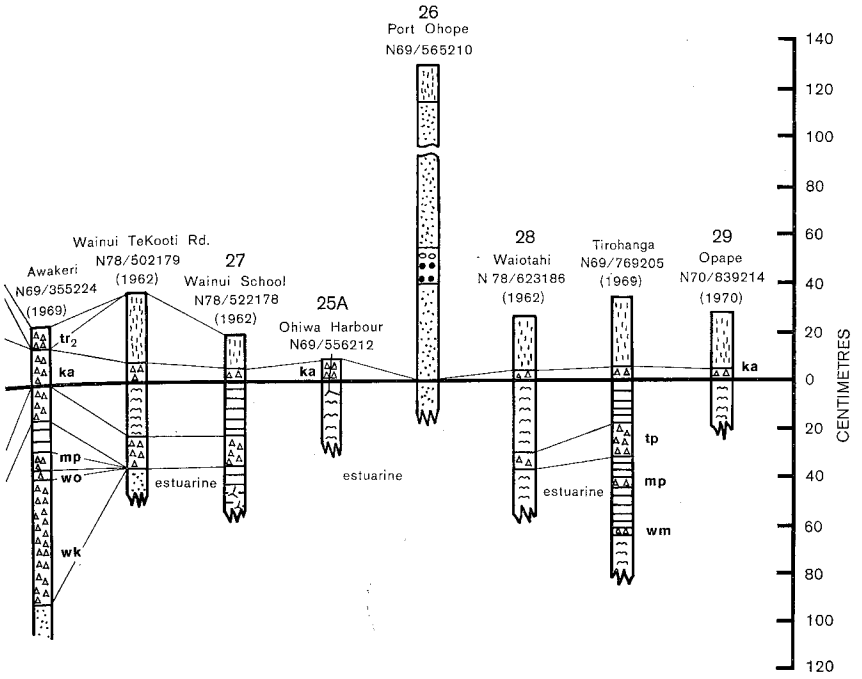


FIG. 2—Correlation sections in Hauraki Plains–eastern Coromandel Peninsula–Bay of Plenty. Sections are drawn relative to the base of Kaharoa Ash (ka). Localities and site numbers are shown in Fig. 1.

Wellman (1962, p. 52) also discussed the stratigraphy at nearby sections on the southern side of the spit at Port Ohope on the northern side of Ohiwa Harbour. He mentioned Taupo Lapilli overlying stumps on the floor of the harbour, and also underlying water-borne Loisels Pumice associated with an occupation layer on the Port Ohope spit nearby. A sand flat in the same area was later examined by W. A. Pullar who noted sea-rafted dark grey Loisels Pumice, overlying air-fall lapilli thought to be Taupo Pumice. However, up to 50% of the ferromagnesian assemblage of the air-fall lapilli at Port Ohope contains calcic-hornblende and biotite (Table 2, sites



25, 25A). This assemblage suggests correlation with Kaharoa Ash rather than with Taupo Pumice.

In the lower slope of a sand dune on the margin of a swamp at Pataua in Northland (Fig. 1, site 7), a lens of fine-grained tephra overlies small burnt stumps of manuka. The mineralogy of the ferromagnesian assemblage of the ash was dominantly hypersthene and indicated that it was likely to be Taupo Pumice rather than Kaharoa Ash. A radiocarbon date for the charred wood, after boiling in hydrogen peroxide to remove humus (and incidentally removing all actual charcoal in the process), gave an age of 1795 ± 65 yr B.P. (Table 5, NZ1764C) confirming that the tephra overlying the stumps was Taupo Pumice. Scattered burnt stones from a Maori oven were enclosed in the ash in places. These and the charred manuka stumps suggest that man was living in the vicinity before the Taupo eruption, but no intact oven could be found to confirm this.

Taupo Pumice was identified mineralogically from a swamp at Ngatea, Hauraki Plains (Table 2) and with less certainty in a beach-cut at Onewhero Beach. At Ngatea a sample of decayed rush and sedge containing Taupo Pumice gave an age of 1660 ± 70 yr B.P. (NZ3121C). At the same site a layer of pumiceous ash lying well above Taupo Pumice (Fig. 2) and previously thought to be Kaharoa Ash in the field, does not contain any biotite (Table 2). Its mineralogy, and the radiocarbon ages from samples of manuka wood on which the base of the ash rests and from sphagnum peat enclosing

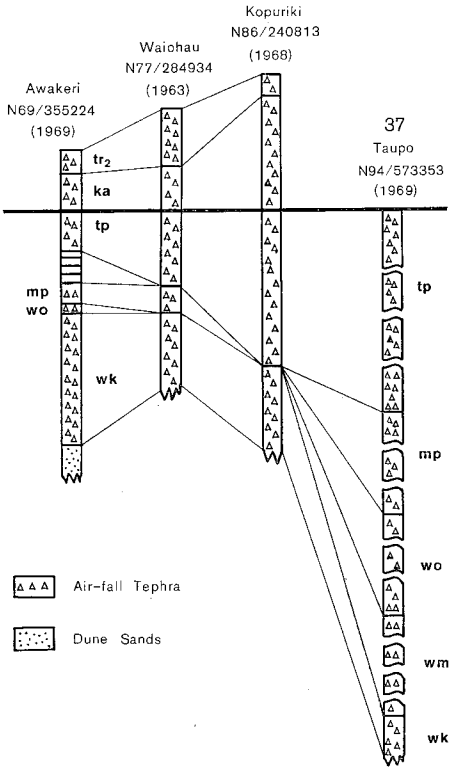


FIG. 3—Correlation sections in Rangitaiki valley–Taupo. Sections are drawn relative to the base of Kaharoa Ash (ka). Localities and site numbers are shown in Fig. 1.

the tephra (780 ± 60 yr B.P. (NZ3119C); 440 ± 20 yr B.P. (NZ3120C) respectively), suggest that the material is reworked Taupo Pumice. Charcoal bands in the peat suggest that fire may have exposed the tephra to reworking.

AIR-FALL OHUI ASH

Wellman (1962, p. 80, under "Ohui Ash" heading) described the Ohui Ash type site at the north end of Opoutere Beach near Ohui, Coromandel Peninsula, as follows: "... Ohui Ash ... is about 3 in. thick (8 cm) ... light brown-grey in colour, and ranges in grain size from fine silt to lapilli. It directly underlies a thick layer of sea-borne Loisels Pumice ..." (continuing description in para. 1 of p. 80) "... there being a downward gradation from dark pumice like that at the type (Loisels) locality, to abundant lighter coloured pumice with large gas cavities and silky threads." No grid reference was given for the type site, and the present authors were only able to locate a site which fitted in all respects except that the dark Loisels Pumice (with dark and light bands as in mineralogy samples M9 and M10 described by Challis in Wellman 1962, pp. 91, 92) was absent. They have, therefore, referred to Wellman's site as 16W and their own as 16 in Table 2. At their

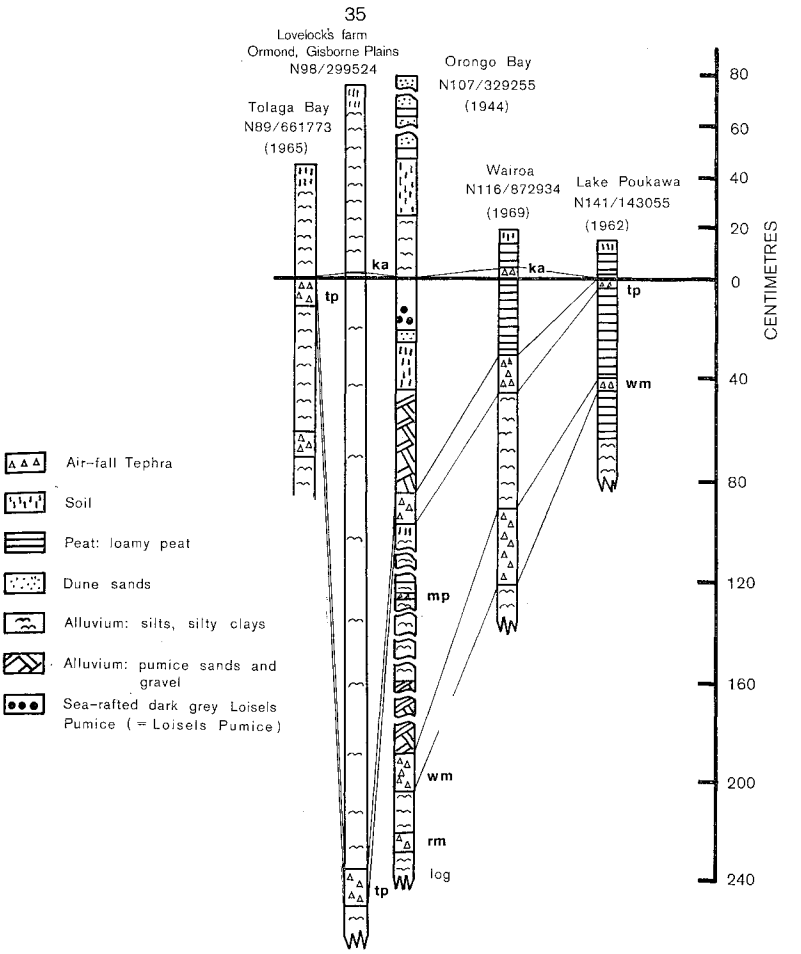


FIG. 4—Correlation sections in Gisborne–Hawkes Bay. Sections are drawn relative to the base of Kaharoa Ash (ka). Localities and site numbers are shown in Fig. 1.

site the sea-rafted pumice was nearly all light grey Loisels Pumice (= sea-rafted Taupo Pumice in this paper) except for less than 5% of a "grey non-banded unnamed pumice" with prominent nests of crystals (Figs 2, 5).

Samples of Ohui Ash from Opoutere Beach were collected independently by H. W. Wellman (site 16W), and J. E. Cox and W. A. Pullar (site 16). A sample of air-fall lapilli from a nearby swale in dunes (Savage's farm, site 17, Figs 1, 2) was also examined. This site was not seen by Wellman.

The ferromagnesian assemblages of these tephras contain only hypersthene plus small amounts of augite. Titanomagnetite analyses of the same samples (Table 3) show that they are similar in composition to known near-source

TABLE 3—Titanomagnetite analyses of Holocene sea-rafted pumices, air-fall tephra, and beach and dune sands in northern and eastern North Island, New Zealand.

Site No. (Fig. 1)	Soil Bureau Field No.	Victoria University Petrology Collection No.	Locality	Grid Reference	Ti	Mg	Mn	Ca	V	Cr	Co	Ni	Zr	Cu
					(%)				(ppm)					
SEA-RAFTED PUMICES			LIGHT GREY LOISELS PUMICE (= Taupo Pumice)											
9	1942		Ocean Beach	N24/073855	7.97	0.87	0.81	0.38	641	98	91	75	43	76
16			Opoutere Beach	N49/377331	7.89	0.79	0.83	0.64	794	132	43	73	79	54
26	1871/M	11935	Port Ohope	N69/565210	6.86	0.98	0.85	0.40	536	166	45	63	61	90
			DARK GREY LOISELS PUMICE											
1			Whatuwhiwhi Beach	N7/912975	7.44	1.01	0.59	0.96	1135	11	72	46	44	53
9	1942		Ocean Beach	N24/073855	4.78	1.63	0.78	1.33	1181	31	101	55	34	113
13			Harataonga Bay, Gt Barrier Is.	N30/990434	7.16	0.91	0.57	0.68	1519	74	80	66	65	49
19			Whiritoa Beach (S. end)	N53/391079	7.31	1.19	0.52	0.65	2509	131	105	54	53	55
26	1870/M	11840	Port Ohope	N69/565210	4.72	1.75	0.78	0.75	2492	104	153	76	31	140
36			Tatapouri Beach	N98/519389	5.22	1.17	0.51	0.76	1033	10	125	148	21	110
38			Waimarama Beach	N142/401985	5.79	1.28	0.48	1.15	1175	141	78	54	58	90
			UN-NAMED PUMICE ASSOCIATED WITH DARK GREY LOISELS PUMICE											
15		11934	Hot-Water Beach	N44/317559	7.41	0.84	0.86	0.19	4245	~1101	114	250	287	87
			UN-NAMED PUMICES											
8	1945(a)	11936	Koaiti Beach, Pataua (white pumice)	N20/043979	6.71	1.53	1.30	0.41	1280	36	68	24	50	87
8	1945(c)		Koaiti Beach, Pataua (large vesicles, pumice weathered brown)	N20/043979	8.18	1.62	1.35	0.19	1150	43	68	36	58	76

AIR-FALL TEPHRA														
				"OHUI ASH" (= TAUPO PUMICE)										
16	1898*	11933	Opoutere Beach	N49/377331	6.79	0.79	0.63	0.63	579	96	64	38	62	28
16W			Opoutere Beach (collected by H.W. Wellman)	not given	8.17	0.75	0.84	0.67	780	132	30	37	61	47
17	1901*		Savage's Farm, Opoutere	N49/373299	6.88	0.82	0.61	0.11	641	97	48	37	66	38
				TAUPO PUMICE										
33			Kaingaroa Forest Headquarters	N86/023711	8.16	1.06	0.69	0.57	596	122	16	25	62	35
37		11843	Napier-Taupo Highway	N94/564354	7.92	1.06	0.69	0.54	649	131	16	27	68	22
39			Raised beach, east of Awhea River	N169/023958	7.64	0.83	0.83	0.78	590	119	35	50	65	63
				KAHAROA ASH										
12	1940		Te Arai Point, Mangawhai	N29/159446	4.70	0.67	0.73	0.27	1294	61	59	69	241	72
30			Rotorua-Whakatane Highway, Tikitere	N76/829133	5.64	0.54	0.78	0.43	1482	71	31	27	880	48
31			Mt Tarawera	N77/985942	5.08	0.72	0.80	0.51	1266	73	33	40	595	61
34			Te Teko-Murupara Road, Galatea	N86/206783	5.53	0.65	0.71	0.45	1016	40	32	26	621	41
BEACH AND DUNE SANDS														
				SANDS AT OPOUTERE BEACH										
16	1900		Sands present day beach	N49/378331	7.41	0.55	0.55	0.11	2411	303	85	118	176	53
16	1899		Sand adhering to light grey Loisels Pumice	N49/377331	9.64	1.18	0.53	0.09	2252	294	85	121	237	87

* Lapilli analysed

Analyses are the averaged composition of samples which have generally been run in triplicate. Samples were analysed at Chemistry Division, Department of Scientific and Industrial Research, using a Hilger-Littron optical spectrograph. Operating conditions are given by Kohn (1970). The analytical precision, expressed as a relative deviation, is approximately ± 10%.

TABLE 4—Spectrographic analyses of whole samples*.

Site No. (Fig.1)	Field Number	Sample analysed	Mn	Mo	Cu	Ni	Co	Cr	V	Ga	Ti	Zr	Ba	Sr	Ash (%)	Locality
			(ppm)													
		Sea-rafted Deposits														
16	1863	Grey un-named pumice	1000	2	20	2	8	2	50	10	4000	30	300	250	100	Opoutere Beach, north end (Ohui) N49/377331 (1967)
16	1862	Loisels Pumice (light grey) = Taupo Pumice; centre, after outside of blocks was pared away	550	4.5	3	2	<3	3	<10	15	2500	300	800	250	93	
		Air fall Deposits														
32	-	Taupo Pumice (SB 7669 D, 36-43 cm)	1000	3	15	1	<1	3	20	12	2500	250	1500	400	98	Wharepaina N85/793738 (1967); N.Z. Soil Bureau Reference site
32	-	Taupo Pumice (SB 7669 F, 51-69 cm)	1000	3	10	1	<1	2	10	12	2000	250	1590	400	98	
32	-	Taupo Pumice (lapilli)(SB 7669 G, 86-107 cm)	700	3	5	1	<3	3	<10	15	3000	300	1000	300	100	
16	*1861 (lap)	Ohui Ash = Taupo Pumice (airfall)‡; type section Ohui Ash under Loisels Pumice; lapilli and coarse ash only	450	3	9	2	<3	2	<10	9	2000	300	800	200	93	Opoutere Beach, north end (Ohui) N49/377331 (1967)
27	1848	Taupo Pumice (upper part)	600	2.5	4	2	<3	4	<10	17	2500	250	700	250	84	Wainui School N78/522178 (1962)
27	1849	Taupo Pumice (lower part); whole sample	400	2	5	1	<3	2	<10	12	2500	300	800	200	95	
27	*1849 (lap)	Taupo Pumice (lower part); lapilli and coarse ash only	500	5	40	1	<3	3	<10	10	2000	300	700	150	96	
24	1851	Kaharoa Ash	600	3	5	2	<3	4	<10	15	2000	250	2000	200	99	Pukehina N68/003426 (1967)
22	1855	Kaharoa Ash	400	5	10	1	<3	2	<10	15	2500	300	2000	100	96	Waihi Beach (in swamp) N53/421928 (1965)
20	1856	Ohui Ash = Kaharoa Ash (Wellman's section 24) - contaminated by beach sand	600	4.5	1	1	<3	3	<10	15	2500	220	2000	200	90	Whiritoa Beach, south end N53/392076 (1965)
4	1867	Kaharoa Ash	400	4	8	2	<3	5	<10	30	1000	200	3000	100	96	Otakairangi swamp N20/697111 (1964)
3	1868	Kaharoa Ash	500	100	8	3	<3	3	<10	25	1000	250	2500	150	96	Onewhero Beach (in swamp) N11/567558 (1969)
10 A	1827	Kaharoa Ash	400	5	8	2	<3	4	<10	10	2000	200	3000	150	100	Marsden Point (in swamp) N24/995825(1968)

* For samples 1861 (lap) and 1849 (lap), lapilli and coarse ash for analysis were separated from fine ash by sieving on nylon netting.
‡ The deposit of Ohui Ash = airfall Taupo Pumice had been slightly water-sorted by the sea (Fig. 5).

TABLE 5—Radiocarbon dates.

Tephra Deposit	Locality (Site Number, see Fig.1)	A Old $T\frac{1}{2}$	B New $T\frac{1}{2}$	C New $T\frac{1}{2}$ corrected for secular effect	N.Z. ^{14}C Number
		(Years B.P. = before 1950)			
Taupo Pumice (air-fall)	Upper Rangitaiki	1840 ± 50*	1900 ± 50	1830 ± 50	1548
———	Pataua (7)	1805 ± 65	1860 ± 65	1795 ± 65	1764
———	Ngatea (21)	1680 ± 70	1730 ± 70	(1660 ± 70)‡	3121
Taupo Pumice (sea-rafted)	Opoutere Beach (south end) (17)	1610 ± 95	1660 ± 90	1590 ± 110	862
Taupo Pumice (reworked)	Ngatea (7)	350 ± 30	360 ± 30	440 ± 20	3120
———	——— (7)	800 ± 60	830 ± 60	780 ± 60	3119
Loisels Pumice (sea-rafted)	Hot Water Beach, Coromandel Peninsula (15)	421 ± 40	450 ± 50	470 ± 50	1169
———	———	484 ± 79	510 ± 90	‡	1170
———	Mahinapua Bay, Coromandel Peninsula	640 ± 50	650 ± 50	660 ± 50	354
———	Matai Bay, Merita, Northland	799 ± 40	800 ± 40	750 ± 40	396
———	Cooks Cove, North of Gisborne	519 ± 41	540 ± 40	560 ± 40	631
———	——— (earlier report of 15 years ago clearly in error)	1120 ± 50	1150 ± 50	1110 ± 60	651
Kaharoa Ash	Northern Boundary Road, Rerewhakaaitu	930 ± 70*	960 ± 80 (based on "age to old $T\frac{1}{2}$" as original run is not identifiable)	890 ± 80	10
———	Otakairangi, Whangarei (4)	850 ± 54	890 ± 70	(840 ± 70)‡	872
———	Marsden Point, Whangarei (10)	607 ± 55	625 ± 55	656 ± 56	1765

* Commonly used for ^{14}C ages in central North Island

‡ Secular correction for peat is dubious, for soils meaningless at this stage except in unusual cases. (H.S. Jansen, N.Z. Institute of Nuclear Sciences).

Taupo Pumice titanomagnetite especially in their relatively low V and high Ti content (Table 3, sites 33, 37).

Spectrographic analysis (Table 4) of the sea-rafted light grey Loisels Pumice at Opoutere Beach shows that it, too, is similar in composition to identified Taupo Pumice from elsewhere and markedly less basic in composition than the co-existing grey non-banded unnamed pumice.

Green hornblende is recorded in Ohui Ash at Opoutere Beach by Challis (in Wellman 1962, p. 92), but is not recorded by B. P. Kohn in this paper. In order to check for possible contamination of the Ohui Ash by beach sands at Opoutere Beach, ferromagnesian assemblages and titanomagnetite analyses were determined from two samples of beach sand associated with the Ohui Ash. The ferromagnesian assemblage contains up to 40% of rounded and

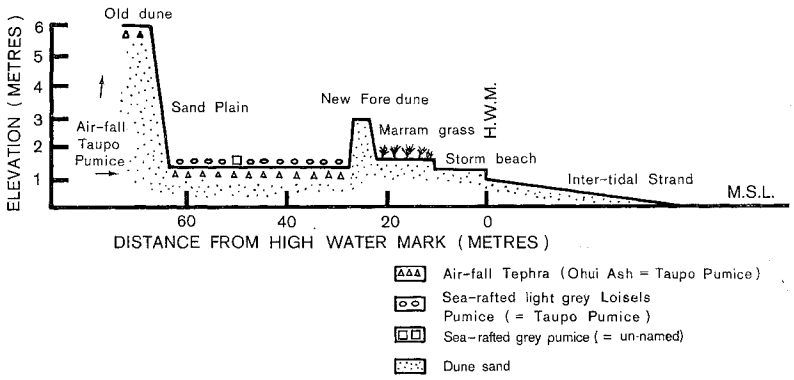


FIG. 5—Cross section of dunes at Ohui, north end of Opoutere Beach (Site 16 in Fig. 1), showing relationship of sea-rafted light grey Loisels Pumice (= sea-rafted Taupo Pumice) to Ohui Ash (= air-fall Taupo Pumice) N49/377331 (1967).

smoothed grains (not seen in air-fall lapilli after cleaning) of calcic-hornblende without any attached glass.

The titanomagnetite is higher in Mg, V, Cr, Co, and Ni (Table 3) than the titanomagnetite from the air-fall lapilli. These data indicate that samples of lapilli from Ohui Ash examined after cleaning were not appreciably contaminated by sand grains and suggests that the green hornblende found in Ohui Ash at Opoutere Beach could have been derived from beach sand.

Because of severe wind erosion of the dunes at Opoutere Beach the presence of Kaharoa Ash was unable to be established with certainty.

At the south end of Whiritoa Beach, Coromandel Peninsula, Wellman (1962, p. 54, section 24) identified a layer 0·3 ft (9 cm) thick of very fine light grey ash as Ohui Ash (Challis sample M13, in Wellman 1962, p. 92). A sample of the massive coherent deposit was collected by the present authors and was pared as clean as possible of adhering sand. Its ferromagnesian assemblage contained dominantly biotite, but with some rounded heavy minerals indicating some contamination with beach sand (Table 2, site 20). The probability, from the mineralogy, that this was Kaharoa Ash was strengthened by spectrographic analysis of the whole sample which showed the characteristic high level of barium (Table 4, site 20).

At Onewhero Beach, Northland, a fine light yellow biotite-rich tephra (= Kaharoa Ash) was found in a peat swamp just south of the beach (Table 2, site 3); while in the seaward face of the bank on the north side of the small stream that cuts through the raised beach, an indistinct ash bed is probably Taupo Pumice from the mineralogy of its ferromagnesian assemblage (Table 2, site 2). It is, therefore, uncertain whether Wellman's Ohui Ash at Onewhero (section 37, p. 60) is Kaharoa Ash or Taupo Pumice.

The principal basis for the recognition by Wellman (1962) of Ohui Ash as a separate entity, different from Taupo Pumice and Kaharoa Ash, was that green hornblende was found only in the three samples of Ohui Ash (Challis in Wellman 1962, p. 95). However, Cole (1970, table III) shows green hornblende to be present in 10 out of 11 samples from the Kaharoa Ash type section at Rerewhakaaitu (N86/943824) of Vucetich & Pullar (1964), so presence of green hornblende does not differentiate supposed Ohui Ash from Kaharoa Ash.

Refractive indices of glass from Ohui Ash (Wellman 1962, p. 97) range from 1·501–1·503. These values are typical of rhyolitic glass from tephras erupted from the central North Island and support an origin for Ohui Ash from Taupo Volcanic Zone.

The air-fall Ohui Ash of Wellman (1962) at Whiritoa Beach is thus probably Kaharoa Ash, and that at Opoutere Beach is undoubtedly Taupo Pumice. Ohui Ash at Onewhero Beach may be either Kaharoa Ash or Taupo Pumice; the former has been positively identified, and the latter possibly so, in and near the area of Wellman's observations at his section 37.

LOISELS PUMICES

Much of the controversy over the validity of Ohui Ash as a separate tephra is directly related to the assumption that it is older than "primary" Loisels Pumice deposits. Data presented, however, show that Ohui Ash at different localities may be either Kaharoa Ash or Taupo Pumice. This and ^{14}C dates which have come to hand since Wellman's (1962) paper have prompted a critical re-examination of the age of Loisels Pumice.

Wellman made a distinction between primary sea-rafted Loisels Pumice, which came on to the shore suddenly and in abundance at the time of the eruption, and reworked pumice that was deposited later. According to Wellman (1962, p. 79) "... Typical Loisels Pumice is dark grey when wet and medium grey when dry.... It is usually streaky, sharply defined grey and light bands extending through about a quarter of the lumps...." Most of Wellman's "primary" deposits of Loisels Pumice comprised only the typical kinds, but at several sites, there was also a non-banded light grey pumice. This light grey variety was considered by Wellman to have been erupted from the same source and simultaneously with the banded pumice. From the mineralogy and texture of pumices dredged from near the summits of five seamounts near White Island, Bay of Plenty (Duncan (1970) suggested that this group of seamounts may have been the source of the Loisels Pumice. However, B. P. Kohn and G. P. Glasby (in preparation) did not find any Loisels Pumice in 32 piston cores which were taken over a wide area of the continental shelf and slope of the Bay of Plenty, even though the cores penetrated sediments up to *c.* 30 000 years old.

The ferromagnesian assemblage of both types of Loisels Pumice is essentially hypersthene plus augite (Table 2). Titanomagnetite analyses of the banded pumice and those of the light grey variety are given in Table 3. The wide range of some elements in titanomagnetite of the banded pumice

(especially V and Cr) is probably caused by the varying contributions of dacite (lighter) and andesite (darker) within samples analysed. The titanomagnetite analyses of the light grey Loisels Pumice show generally higher values for Cr and lower values for Mg, V, Co, and Ni than in the banded Loisels Pumice (Table 3). The light grey Loisels Pumice shows almost identical titanomagnetite composition to Taupo Pumice (Table 3). Spectrographic analysis of the "grey non-banded unnamed pumice" (Table 4, sample 1863) from Opoutere Beach shows markedly high Co and V contents and lower Ba and Zr contents as compared with the light grey pumice, which has a comparable composition to Taupo Pumice.

The stratigraphic, mineralogical, and chemical evidence indicates, therefore, that the light grey Loisels Pumice is sea-rafted Taupo Pumice. Furthermore, charcoal associated with sea-rafted light grey Loisels Pumice (= Taupo Pumice) at south end of Opoutere Beach gave an age of 1590 ± 110 yr B.P. (NZ862C) which post-dates the Taupo Pumice eruptions by about 200 years.

AGE OF LOISELS PUMICE

Wellman (1962, p. 97) noted "primary" sea-rafted Loisels Pumice overlain by tentatively identified Kaharoa Ash at Opape and Waiotahi estuary (Wellman's sections 20, 21 near sections 29, 28 in Fig. 1 of this paper). At the Opape site (p. 50) he described the putative Kaharoa Ash as dark grey which colour is characteristic of Tarawera Ash in the coastal Bay of Plenty area. The ash layer, however, occurs under a pohutukawa tree considered to be a hundred years old. At the Waiotahi estuary site (p. 52) he considered a white ash layer to be older than the Tarawera eruption because of its position below a large pohutukawa tree. The trees at both sites, however, may have been growing before the ash was deposited and, despite the accumulation of greywacke talus, they continued to grow, putting out new roots in the scree material. Both sections have now been destroyed by natural agencies and so the identity of the tephra layers remains unresolved.

The only other place where "primary" Loisels Pumice was found by Wellman in the central Bay of Plenty coast was at Port Ohope where underlying air-fall lapilli appears to be Kaharoa Ash rather than Taupo Pumice. Another site examined by W. A. Pullar on the Ohiwa spit at the eastern side of the harbour entrance (N69/704205) showed pebbles of Loisels Pumice overlying air-fall Kaharoa Ash, in turn overlying gravels of sea-rafted Taupo Pumice near present sea-level. Loisels Pumice, however, may not be a "primary" deposit.

Loisels Pumice would thus appear to be older than Kaharoa Ash at (?) Opape and Waiotahi estuary, and younger at Port Ohope and Ohiwa spit.

At Hot Water Beach, east coast of Coromandel Peninsula, Leahy (1971) reports dates of 470 ± 50 yr B.P. (NZ1169C) and 510 ± 90 yr B.P. (NZ1170B) for charcoal above Loisels Pumice. At Mahinapua Bay, Coromandel Peninsula, Golson (in Green 1963) reports a date of 660 ± 50 yr B.P. (NZ354C) for charcoal below Loisels Pumice. At Matai Bay, Merita, Northland, charcoal beneath Loisels Pumice is dated at 750 ±

40 yr B.P. (NZ396C) (Wellman pers. comm.). At Cooks Cove, 40 km north-east of Gisborne, charcoal from immediately above Loisels Pumice is dated at 560 ± 40 yr B.P. (NZ631C) and totara logs, some 75–170 cm under Loisels Pumice at the base of the section, at 1110 ± 60 yr B.P. (NZ651C) (H. W. Wellman pers. comm.).

Loisels Pumice at Hot Water Beach, although occurring in abundance, co-exists with other types of pumice and occurs in an archaeological occupation layer. It is probable that this pumice has been reworked or was put there by man. Loisels Pumice at Mahinapua and Matai Bay is also secondary (Wellman 1962). However, at Cooks Cove, Loisels Pumice is considered to be primary, as is Loisels Pumice at Onewhero Beach, Northland (Wellman 1962) where it overlies his Ohui Ash which has been shown to be probably air-fall Taupo Pumice, or possibly Kaharoa Ash.

Loisels Pumice appears to be younger than Kaharoa Ash on eastern Coromandel Coast, but its relationship to Kaharoa Ash is less certain on the Bay of Plenty coast.

LEIGH PUMICE

Several sea-rafted pumices whose colour, mineralogy, and/or spectrochemistry differentiate them from sea-rafted Loisels Pumice and Taupo Pumice have been found in localities studied in this investigation. One variety is grey coloured with prominent nests of crystals and has been noted at many places on the eastern Northland coast. It also occurs as a minor component in a massive deposit of light grey Loisels Pumice (= sea-rafted Taupo Pumice) at the north end of Opoutere Beach (Site 16 in Fig. 1). Its distribution and general characteristics indicate that this pumice may be the material Wellman named Leigh Pumice. However, it has not been possible to obtain samples of Wellman's original collection of Leigh Pumice to compare them with our own samples.

An attempt was made to locate his type site at Ti Point near Leigh, but the only exposure that tallies with his description is a tiny horseshoe-shaped inlet some hundreds of metres east of the grid reference given by Wellman. A large deposit of pumice is exposed on the eroding shoreline, and when cut by the spade, the deposit appeared to be a uniform grey colour, characteristic of Wellman's description and that of our own collections elsewhere in Northland. The pumice was heavily coated with clay and stained with iron oxides, but after vigorous abrasion in water, the pumice was seen to be typical Loisels Pumice, most of it intensely banded light and dark grey.

Because no typical Leigh Pumice is available at present for analysis as a standard it appears better to refer to the several varieties of pumice that might be Leigh Pumice as "unnamed pumice". The grey coloured variety with the nests of crystals mentioned above is referred to as the "grey non-banded unnamed pumice" in this report.

Small quantities of a light grey, weakly banded pumice (Sample 11934 in Table 3) and a black pumice are associated with Loisels Pumice at Hot Water Beach. At Koaiti Beach, Pataua, Northland, a light brown pumice

(especially V and Cr) is probably caused by the varying contributions of dacite (lighter) and andesite (darker) within samples analysed. The titanomagnetite analyses of the light grey Loisels Pumice show generally higher values for Cr and lower values for Mg, V, Co, and Ni than in the banded Loisels Pumice (Table 3). The light grey Loisels Pumice shows almost identical titanomagnetite composition to Taupo Pumice (Table 3). Spectrographic analysis of the "grey non-banded unnamed pumice" (Table 4, sample 1863) from Opoutere Beach shows markedly high Co and V contents and lower Ba and Zr contents as compared with the light grey pumice, which has a comparable composition to Taupo Pumice.

The stratigraphic, mineralogical, and chemical evidence indicates, therefore, that the light grey Loisels Pumice is sea-rafted Taupo Pumice. Furthermore, charcoal associated with sea-rafted light grey Loisels Pumice (= Taupo Pumice) at south end of Opoutere Beach gave an age of 1590 ± 110 yr B.P. (NZ862C) which post-dates the Taupo Pumice eruptions by about 200 years.

AGE OF LOISELS PUMICE

Wellman (1962, p. 97) noted "primary" sea-rafted Loisels Pumice overlain by tentatively identified Kaharoa Ash at Opape and Waiotahi estuary (Wellman's sections 20, 21 near sections 29, 28 in Fig. 1 of this paper). At the Opape site (p. 50) he described the putative Kaharoa Ash as dark grey which colour is characteristic of Tarawera Ash in the coastal Bay of Plenty area. The ash layer, however, occurs under a pohutukawa tree considered to be a hundred years old. At the Waiotahi estuary site (p. 52) he considered a white ash layer to be older than the Tarawera eruption because of its position below a large pohutukawa tree. The trees at both sites, however, may have been growing before the ash was deposited and, despite the accumulation of greywacke talus, they continued to grow, putting out new roots in the scree material. Both sections have now been destroyed by natural agencies and so the identity of the tephra layers remains unresolved.

The only other place where "primary" Loisels Pumice was found by Wellman in the central Bay of Plenty coast was at Port Ohope where underlying air-fall lapilli appears to be Kaharoa Ash rather than Taupo Pumice. Another site examined by W. A. Pullar on the Ohiwa spit at the eastern side of the harbour entrance (N69/704205) showed pebbles of Loisels Pumice overlying air-fall Kaharoa Ash, in turn overlying gravels of sea-rafted Taupo Pumice near present sea-level. Loisels Pumice, however, may not be a "primary" deposit.

Loisels Pumice would thus appear to be older than Kaharoa Ash at (?) Opape and Waiotahi estuary, and younger at Port Ohope and Ohiwa spit.

At Hot Water Beach, east coast of Coromandel Peninsula, Leahy (1971) reports dates of 470 ± 50 yr B.P. (NZ1169C) and 510 ± 90 yr B.P. (NZ1170B) for charcoal above Loisels Pumice. At Mahinapua Bay, Coromandel Peninsula, Golson (in Green 1963) reports a date of 660 ± 50 yr B.P. (NZ354C) for charcoal below Loisels Pumice. At Matai Bay, Merita, Northland, charcoal beneath Loisels Pumice is dated at 750 ±

40 yr B.P. (NZ396C) (Wellman pers. comm.). At Cooks Cove, 40 km north-east of Gisborne, charcoal from immediately above Loisels Pumice is dated at 560 ± 40 yr B.P. (NZ631C) and totara logs, some 75–170 cm under Loisels Pumice at the base of the section, at 1110 ± 60 yr B.P. (NZ651C) (H. W. Wellman pers. comm.).

Loisels Pumice at Hot Water Beach, although occurring in abundance, co-exists with other types of pumice and occurs in an archaeological occupation layer. It is probable that this pumice has been reworked or was put there by man. Loisels Pumice at Mahinapua and Matai Bay is also secondary (Wellman 1962). However, at Cooks Cove, Loisels Pumice is considered to be primary, as is Loisels Pumice at Onewhero Beach, Northland (Wellman 1962) where it overlies his Ohui Ash which has been shown to be probably air-fall Taupo Pumice, or possibly Kaharoa Ash.

Loisels Pumice appears to be younger than Kaharoa Ash on eastern Coromandel Coast, but its relationship to Kaharoa Ash is less certain on the Bay of Plenty coast.

LEIGH PUMICE

Several sea-rafted pumices whose colour, mineralogy, and/or spectrochemistry differentiate them from sea-rafted Loisels Pumice and Taupo Pumice have been found in localities studied in this investigation. One variety is grey coloured with prominent nests of crystals and has been noted at many places on the eastern Northland coast. It also occurs as a minor component in a massive deposit of light grey Loisels Pumice (= sea-rafted Taupo Pumice) at the north end of Opoutere Beach (Site 16 in Fig. 1). Its distribution and general characteristics indicate that this pumice may be the material Wellman named Leigh Pumice. However, it has not been possible to obtain samples of Wellman's original collection of Leigh Pumice to compare them with our own samples.

An attempt was made to locate his type site at Ti Point near Leigh, but the only exposure that tallies with his description is a tiny horseshoe-shaped inlet some hundreds of metres east of the grid reference given by Wellman. A large deposit of pumice is exposed on the eroding shoreline, and when cut by the spade, the deposit appeared to be a uniform grey colour, characteristic of Wellman's description and that of our own collections elsewhere in Northland. The pumice was heavily coated with clay and stained with iron oxides, but after vigorous abrasion in water, the pumice was seen to be typical Loisels Pumice, most of it intensely banded light and dark grey.

Because no typical Leigh Pumice is available at present for analysis as a standard it appears better to refer to the several varieties of pumice that might be Leigh Pumice as "unnamed pumice". The grey coloured variety with the nests of crystals mentioned above is referred to as the "grey non-banded unnamed pumice" in this report.

Small quantities of a light grey, weakly banded pumice (Sample 11934 in Table 3) and a black pumice are associated with Loisels Pumice at Hot Water Beach. At Koaiti Beach, Pataua, Northland, a light brown pumice

with large vesicles (sample 11936 in Table 3) underlies dark grey Loisels Pumice. These pumices contain a hypersthene plus augite ferromagnesian assemblage. Sample 11934 (Table 3) differs in titanomagnetite composition from other analysed sea-rafted pumices and from tephras erupted from the Taupo Volcanic Zone. The "grey non-banded unnamed pumice" may have been erupted from seamounts around White Island (Duncan 1970), but other pumices associated with Loisels Pumice are considered by one of us (BPK) to have been erupted from a source outside the Taupo Volcanic Zone. These other pumices were probably carried to the east coast of the North Island from a considerable distance beyond New Zealand. A recent example was the deposition on the south coast of New Zealand of pumice from the South Sandwich Islands eruption of March 1962 (Coombs & Landis 1966).

LIMITATIONS OF SEA-RAFTED PUMICES AS TIME MARKERS

Because sea-rafted pumices can be moved again by the sea after their initial deposition on the shore they are of much less value as time markers than are air-fall tephra layers. Where two different pumices are strongly represented in a single deposit there is a good chance that one or both may not be primary deposits and, therefore, they should not be used as time markers.

CONCLUSIONS

Air-fall Ohui Ash of Wellman is Kaharoa Ash at Whiritoa Beach and Onewhero Beach, and is definitely Taupo Pumice at Opoutere Beach (Ohui Ash type section). At Onewhero Beach it is probably Taupo Pumice, although Kaharoa Ash also occurs in a nearby swamp.

Light grey Loisels Pumice of Wellman at Opoutere Beach is sea-rafted Taupo Pumice.

Available data still do not definitely resolve the stratigraphic relationship between primary Loisels Pumice and Kaharoa Ash. Sections possibly indicating an age older than Kaharoa Ash for the first incoming of Loisels Pumice have now been destroyed by natural agencies. There is, however, much radiocarbon, mineralogical, and compositional evidence to support a post-Kaharoa age for primary Loisels Pumice. Uncertainty will be removed only when more ^{14}C dates are available for primary Loisels Pumice.

Because no type deposit of Leigh Pumice is available for reference it has not been possible to determine which of the several sea-rafted pumices collected during the present investigation should be recognised as Leigh Pumice.

Air-fall Taupo Pumice and Kaharoa Ash (Fig. 1) have been distributed much further north than shown on isopach maps of Pullar & Birrell (1973, maps 133/2, 3). Because these tephras are very thin (less than 2 cm), they may prove to be suitable as marker beds only when found in special sites such as swamps and peaty swales of coastal dunes.

ACKNOWLEDGMENTS

We thank Messrs N. Wells and J. S. Whitton for the spectrographic analyses in Table 4, Messrs T. F. Pearson and B. E. Law for draughting the figures, and Mr H. S. Jansen for converting the radiocarbon ages in Table 5. Tables 2 and 3 are part of a Ph.D. thesis by B. P. Kohn. Dr V. E. Neall and Mr E. Griffiths commented on the manuscript of this paper.

REFERENCES

CHALLIS, G. A. 1962: Mineralogy of selected North Island pumices and ash showers. Appendix *in* WELLMAN, H. W.: Holocene of the North Island of New Zealand: a coastal reconnaissance. *Transactions of the Royal Society of New Zealand (Geology) 1* (5): 90–8.

COLE, J. W. 1970: Description and correlation of Holocene volcanic formations in the Tarawera–Rerewhakaaitu region. *Transactions of the Royal Society of New Zealand (Earth Sciences) 8* (7): 93–108.

COOMBS, D. S.; LANDIS, C. A. 1966: Pumice from the South Sandwich eruption of March 1962 reaches New Zealand. *Nature 209*: 289–90.

DUNCAN, A. R. 1970: The petrology and petrochemistry of andesite and dacite volcanoes in eastern Bay of Plenty, New Zealand. (Unpublished Ph.D. thesis lodged in Victoria University of Wellington Library.) 316 p.

GREEN, R. C. 1963: Summaries of sites at Opito, Sarah's Gully and Great Mercury Island. *N.Z. Archaeological Association Newsletter 6*: 57–9.

GREEN, R. C.; PULLAR, W. A. 1960: Excavations at Orongo Bay, Gisborne. *Journal Polynesian Society 69* (4): 332–53.

KOHN, B. P. 1970: Identification of New Zealand tephra layers by emission spectrographic analysis of their titanomagnetites. *Lithos 3*: 361–8.

LEAHY, A. 1971: Preliminary report and carbon-14 datings on site N44/69, Hot Water Beach, Coromandel. *N.Z. Archaeological Newsletter 14*: 62–3.

PULLAR, W. A. 1967: Uses of volcanic ash beds in geomorphology. *Earth Science Journal 1* (2): 164–77.

———— 1970: Pumice ash beds and peaty deposits of archaeological significance near Lake Poukawa, Hawkes Bay. *N.Z. Journal of Science 13*: 687–705.

PULLAR, W. A.; BIRRELL, K. S. 1973: Age and distribution of late Quarternary pyroclastic and associated cover deposits of the Rotorua and Taupo area, North Island, New Zealand. *N.Z. Soil Survey Report 1.*

PULLAR, W. A.; PENHALE, H. R. 1970: Periods of recent infilling of the Gisborne Plains basin—associated marker beds and changes in shoreline. *N.Z. Journal of Science 13* (3): 410–34.

PULLAR, W. A.; SELBY, M. J. 1971: Coastal progradation of Rangitaiki Plains, New Zealand. *N.Z. Journal of Science 14* (2): 419–34.

VUCETICH, C. G.; PULLAR, W. A. 1964: Stratigraphy and chronology of late Quarternary volcanic ash in Taupo, Rotorua, and Gisborne districts. *N.Z. Geological Survey Bulletin 73, Part 2*: 43–88.

WELLMAN, H. W. 1962: Holocene of the North Island of New Zealand: a coastal reconnaissance. *Transactions of the Royal Society of New Zealand (Geology) 1* (5): 29–99.