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USES OF VOLCANIC ASH BEDS IN GEOMORPHOLOGY

W. A. PULLAR

New Zealand Soil Bureau, Whakatane

Abstract

In geomorphology air-fall volcanic ashes possess high value as marker beds. These have proved particularly useful in studies associated with infilling of flood plains, fan building, terrace correlation and chronology, erosion, shoreline and sea level changes, recent tectonics, archaeology and ground surfaces. Ash beds and the community are also discussed.

INTRODUCTION

The separating, mapping and naming of the ash showers that cover a large part of the North Island of New Zealand has advanced to the point where the information can be used by geomorphologists, pedologists and others interested in earth sciences.

This report summarises field observations collected in the course of detailed soil surveys of Gisborne Plains, Wairoa Valley, Rangitaiki Plains, and Te Puke swamp and more extensive ash mapping in the Rotorua, Taupo, Bay of Plenty, Gisborne, and Hawkes Bay districts. It brings together documented case studies conducted over the period 1950-1967.

Ash beds and their value as marker beds are set out in Table 1. Some of the names have already been published by Vucetich and Pullar (1964) and the remainder, marked by an asterisk, are new names proposed by the same authors *(in press).* Radiometric ages are rounded off but the figures obtained from the N.Z. Institute of Nuclear Sciences are quoted in the papers cited above.

INFILLING OF LOWLANDS

(a) *Gisborne Plains:* A detailed examination of the Gisborne Plains using buried soils and dated ash beds as markers has allowed estimates to be made of the rate of accumulation during each stage of infilling. The volume and rate of infilling for each stage is given in Table 2.

Table 1: ASH BEDS AND THEIR VALUE AS MARKER BEDS

Ash Bed	Age — Years Ago Radiometric	Estimated	Value as Marker Bed	Rating
Tarawera Ash	80		Restricted to coastal Bay of Plenty from Te Puke to Opotiki and to Galatea basin; occurs as a black ash ½ to 3in. thick; pale grey at Te Puke because of high content of Rotomahana mud; useful in flood plains.	low; of value to eastern Bay of Plenty only. Of high value to present sedimentation on Whakatane and Rangitaiki flood plains.
Kaharoa Ash	900		Restricted to Bay of Plenty, Galatea basin, and Wairoa where it occurs as a shower bedded white ash 2 to 12in. thick; too thin at Gisborne where less than ½in. Useful in peat swamps and flood plains.	high in establishing maximum age of oldest surfaces on valley floors.
Taupo Pumice	1,900		Widespread in Waikato, Bay of Plenty, Rotorua, Taupo, Gisborne, and Hawkes Bay districts; pale yellowish white highly vesicular lapilli conspicuous and diagnostic of this ash along with grey Rotongaio Ash; useful in peat swamps and flood plains and low terraces.	high because of widespread occurence.
Waimihia Lapilli	3,000		Restricted to Galatea basin, Hawkes Bay and Gisborne where it occurs as a 2 to 6in. bed of yellow or white coarse ash like sago; little use because of patchy distribution and deep burial.	low; buried too deeply on flood plains and valley floors for easy observation.
Whakatane Ash		5,000	Restricted to Rangitaiki Plains and valley where it occurs as yellow ash and rounded lapilli; useful on terraces, fans and dunes.	low; restricted distribution.
Rotoma Ash		between 8,000 and 11,000	Restricted to terraces and fans in Rangitaiki and Whakatane valleys.	low; restricted distribution.
Waiohau Ash	11,000		Widespread in eastern Bay of Plenty and Gisborne districts as basal ash capping greywacke gravel terraces; fan in Galatea basin.	high; widespread occurrence of underlying gravels suggests erosion climatically controlled.
Rotorua Ash		13,000	Restricted to Mamaku plateau where it mantles ignimbrite and Waikato River terrace at Pairere where it rests on Hinuera gravels.	high; beginning of climatic amelioration; minimum age to Hinuera gravels.

Rerewhakaaitu Ash	15,000		Restricted to Kaingaroa plateau and Huiarau Range where it mantles ignimbrite and greywacke respectively; perhaps gravel terraces on Mohaka River and Hawkes Bay.	low; but could be high for pedology if this ash could be established in Hawkes Bay.
*Okareka Ash	20,000		Restricted to 950ft and 1100ft terraces near Atiamuri Dam where it rests on Hinuera gravels and loess respectively.	high in establishing minimum ages to upper Waikato terraces.
*Oruanui Tephra		more than 20,000 but less than 36,000	Observations restricted to terraces at Wairoa and Hawkes Bay where ash is buried by Holocene ash, loess or alluvium up to 10ft. Rests on lake sediments at Rotorua.	low at present but after further field study could prove high for loess and for pedology in Hawkes Bay.
*Mangaoni Lapilli		25,000	Observations restricted to lower Whakatane valley where it rests on terraces of soft, rusty greywacke gravels; also old fans at Maungapohatu, Huiarau Range.	low; much eroded but value may become high in erosion studies,
*Rotoehu Ash	36,000		Restricted to a few Pleistocene terraces at Houpoto and Te Kaha along Bay of Plenty coast; headwaters of Waipaoa River and at Waihua. High value in establishing base of late Pleistocene ash in coastal Bay of Plenty and eastern Waikato district.	low for terrace correlation because older terraces few in number. High as base of Late Pleistocene ash.
*Undifferentiated brown ash		more than 36,000	Observations restricted to uplands on Mamaku plateau, Kaingaroa plateau, Atiamuri, and Napier. Outcrops few and scattered.	low; remnants too scattered for direct correlation.
Hamilton Ash		more than 36,000 years	Beds continuous along coastal Bay of Plenty but scattered remnants elsewhere; examined in Waikato by Ward (in press) and reviewed by Pullar (1967a); as yet no correlation established between Hamilton Ash in Waikato and Hamilton-like beds elsewhere but reddish brown colours and clayey textures of fossil soils common everywhere; name Hamilton ash is a useful "hold-all" for this marker bed.	high when individual beds correlated.

Proposed names are correlated with descriptive names in Pullar (1967c) as follows:

Okareka
Oruanui "pinkish brown beds"
Mangaoni Lapilli "yellow block and white block beds"
Rotoehu Ash "grey banded bed"

Table 2 VOLUME AND RATE ON INFILLING OF GISBORNE PLAINS

Stage	Infilling		Marker Bed
	Volume in M. cub. yd.	Rate in M. c. yd. per annum	
1932-1950	27	1.5	Matawhero soils
1820-1932	19	0.17	Matawhero friable soils
1650-1820	40	0.23	Waihirere soils
130-1650	210	0.14	Taupo Pumice
1,400BC-130AD	430	0.28	Waimihia Lapilli

From this table it is clear that the rate of present sedimentation resulting from accelerated erosion attributed to large scale deforestation at time of European settlement is 5 to 10 times that of previous stages. Sedimentation during stage 1650-1820 is attributed to catastrophic storm damage c. 1650AD (Grant, 1963) and that during stage 1,400BC-130AD is attributed to tectonics shortly before the Taupo Pumice eruptions.

(b) *Other Lowlands in Gisborne and Hawkes Bay districts:* Taupo Pumice has proved to be the best marker bed because of its widespread distribution and shallow burial. In alluvium at Tolaga Bay, Whangara, and Pouawa the pumice occurs at a depth of 5ft in natural levees and 1 to 3ft in swamps and in Hawkes Bay, air-fall Taupo Pumice occurs at the surface on low terraces (Grant, 1965) and at about 9in. in peat swamps (Pullar 1965c). Wairoa Valley has been examined in detail (Pullar and Ayson, 1965; Fig. 3) and infilling after the Taupo Pumice eruptions found to range from 2 to 10ft.

Waimihia Lapilli has been noted at Tolaga Bay and Pouawa where it occurs 2 to 3ft below Taupo Pumice.

(c) *Rangitaiki Plains:* A detailed examination of the meander trough at Whakatane using the Tarawera Ash as a marker bed showed that flood sediment had raised the floor 1 to 3ft in 75 years (Pullar, 1963). Flood storage has thus been reduced by about 10% and so more frequent threats of flooding to Whakatane can now be expected.

Kaharoa Ash has proved useful in dating terraces on the floor of Whakatane valley where it occurs within 3ft of the surface. In detailed soil mapping both Tarawera and Kaharoa ashes have proved acceptable in designating the age of parent materials as post-Tarawera, post-Kaharoa, and pre-Kaharoa (Pullar, 1965a; Pullar, Pain and Johns in press). In general, Taupo Pumice is buried too deeply to be of much value as a marker bed.

(d) *Other swamp lands in Waikato district and coastal Bay of Plenty:* In coastal peat swamps Kaharoa Ash is buried from 6 to 12in. and Taupo Pumice from 1 to 5ft. In peat bogs near Hamilton, Tonkin (1967) measured a 2in. seam of Taupo Pumice 18 to 20in. from the surface.

FAN-BUILDING

Ash beds are useful markers for measuring the rate of fan-building. For example, Tarawera Ash, which fell 80 years ago, is buried by 12in. of alluvium on the fans at Whakatane. On the same fans Kaharoa Ash has been noted at depths of 2 to 4ft.

The Rangitaiki River fan at Te Teko is composed wholly of Taupo Pumice alluvium about 35ft thick. At the base is water-borne Hatepe ash (the first of the Taupo Pumice eruptions) and the surface is capped with Kaharoa Ash.

The numerous fans fronting the Ikawhenua Range on the eastern perimeter of Galatea basin, dated by identifying their mantling ash beds, are comprised of alluvium deposited pre-Taupo Pumice, pre-Whakatane Ash, pre-Rotoma Ash, and pre-Waiohau Ash. Thus major fan-building has occurred in stages of before 2,000, 5,000, 8,000 and 11,000 years ago. The Horomanga fan is particularly interesting in that the middle part is capped by Waimihia Lapilli and Taupo Pumice but the apex is capped only by Taupo Pumice. The stream, in degrading deeply through the fan, formed three terraces—the alluvium on the lowest is post-Tarawera Ash, that on the second is pre-Tarawera Ash with no accumulation since the eruption and that on the third is post-Kaharoa Ash. In the Drywash fan, a fan-building period was noted between the Whakatane Ash and Taupo Pumice (Pullar, 1965a). At Maungapohatu and Mataatua in the Huiarau Range boulder fans are mantled with Mangaoni Lapilli and Rotoehu Ash respectively.

TERRACE CORRELATION AND CHRONOLOGY

By the term "terraces" is meant planar surfaces in the geographical sense. The principle adopted is that the lowermost air-fall bed resting on the alluvium indicates a minimum age to the surface, usually a constructional landform. Of course, an interval of time will have elapsed between the terrace assuming its finished form and the fall of the ash. Surfaces, however, are not perfectly flat and are often traversed by stream courses and associated levees in which the "capping" ash may be reworked. Thus many observations are required to establish both the validity and identity of the basal air-fall ash immediately overlying the alluvium and a single spot examination is insufficient.

Observations have been extended since the report of Pullar (1965a) but in most instances are merely spot measurements taken in the course of Late Pleistocene ash bed mapping; they are summarised in Table 1. A detailed study of the lower Whakatane valley, however, was undertaken by Pullar, Pain and Johns (in press). It showed that the 200-250ft Pleistocene terrace is highly dissected and the basal mantling ash may be represented by remnants of Hamilton ash, undifferentiated brown ash, and Rotoehu Ash. The 100-150ft terrace is flat topped, but the fossil surface of rusty greywacke gravels is masked by 30ft of Mangaoni Lapilli. The 100ft terrace of fresh greywacke gravels is mantled with Waiohau Ash and is a vestige of a once-large fan at Ruatoki.

Ash bed mapping suggests interesting case studies at Wairoa and Hawkes Bay where, after much searching, Oruanui Tephra was found buried at depths of 10 to 12ft by alluvium or (?) loess. At Te Puke, terraces bordering the flood plain of Kaituna River comprised 10 to 20ft of Rotoehu Ash alluvium overlain by Mangaoni Lapilli and Holocene ash.

OBSERVATIONS ON UPLANDS

Hundreds of sections have been measured "hand-over-hand" along main roads on uplands in the Waikato, Rotorua, Taupo, Bay of Plenty, Gisborne, and Hawkes Bay districts. A representative sample of basal ash associated with rock type and land form is given in the following table (from west to east):

TABLE 3. BASAL ASH ON ROCK TYPE AND LAND FORM

Rock type	Land form	Basal ash resting on rock	District	Locality
Pleistocene Sediments	Rolling hills	Hamilton	Waikato	Hamilton
Jurassic greywacke	Steepland	Hamilton	Waikato	Cambridge
Quaternary ignimbrite	Plateau	Hamilton Undiff. brown ash Rotorua Rerewhakaaitu	Waikato Waikato Rotorua Bay of Plenty	Cambridge Tapapa Mamaku Kaingaroa
Jurassic-Permian greywacke	highly deformed steepland	Rotoehu Rerewhakaaitu	Urewera National Park	Tarapounamu Ikawhenua Ra. Huiarau Ra.
Cretaceous argillites and shales	highly deformed-hilly, slumps and flows	Rotoehu Mangaoni Lapilli no ash	Gisborne	Matawai Tarndale Tapuwaeroa valley near Ruatoria
Tertiary siltstones & mudstones	hilly and steepland	Rotoehu Hamilton no ash Rotoehu Rotoehu Waiohau	Gisborne	Waipiro Bay Te Puia Tokomaru Bay Waimata Ngatapa Pehiri
Pleistocene sediments	hilly	(?) Rerewhakaaitu	Hawkes Bay	Puketapu near Napier

In the Gisborne district, the four mile to an inch soil map has proved to be a useful plan in plotting the distribution of ash remnants and this has been correlated with a rock type map prepared by O'Byrne (1967; Fig. 1). Distribution of ash is a prerequisite to a study of the chronology of Pleistocene erosion and of pedology.

EROSION

There must be some connection between the presence of terraces in the lowlands and the patchiness of older ash beds in the uplands. The widespread occurrence of the former, suggests broad climatic control of erosion. From an examination of Holocene and Late Pleistocene tephric deposits mantling a range of relief, Vucetich and Pullar (in press) find that in peripheral areas of low altitude of less than 1,000 feet, the ash column is generally complete with insignificant erosion breaks; at moderate elevations of up to 1,500 feet there are many breaks, and at higher altitudes, only the Holocene ashes are well represented.

To the east of Murupara, Rotoehu Ash is the first deposit to mantle greywacke, argillite, and old fans and this arrangement implies extensive erosion prior to 36,000 years ago when much of the Hamilton ash was removed from uplands. This debris probably forms the terraces at Te Kaha along the Bay of Plenty coast. On Kaingaroa plateau, Mangaoni Lapilli is severely truncated and this suggests erosion between c.25,000 years and c.20,000 years. It now seems clear that the extensive alluvial deposits in the Lower Waikato valley (Hinuera Formation) were partly derived from long continued erosion during a cold period of material ejected during the Oruanui eruptions (Vucetich and Pullar, in press).

Gravels in the Mohaka terrace have been dated at more than 33,000 years but the mantling ash appears to be Rerewhakaaitu (15,000 years old). An explanation of this apparent time gap must await further field work. In the lower Whakatane Valley, greywacke gravels are mantled with Waiohau Ash (11,000 years old) confirming that the gravels were laid down during a period of erosion between 11,000 and 20,000 years ago when the climate was cold.

Gravel terraces in Waioeka gorge, Matawai, and Waikohu valley are also capped with Waiohau Ash and their widespread occurrence suggests climatic control of erosion, perhaps just after the Rerewhakaaitu eruption but before the Rotorua eruption. The terminal date is suggested from the Mamaku plateau where Rotorua Ash sealed the ignimbrite from further erosion.

Some alluvium in the lower Whakatane Valley and most of that in the Rangitaiki and Tarawera valleys can be attributed directly to the products of the Kaharoa, Taupo, and Waimihia eruptions.

Near Cambridge, Selby (1966) used Taupo Pumice and Rotoma Ash to show that moulding of land forms by erosion is of recent origin.

Vucetich (1960; p.15) considers that . . . "Extensive outwash deposits, particularly on the Horomanga fan, post-date the Kaharoa ash and may be taken as marking the first major disturbance in the catchment for several thousand years. Doubtless this coincides with the first firing of the Ikawhenua Range by early Maoris occupying Galatea Basin. This is estimated to have occurred about 300 years ago . . ."

SHORELINES

Dated air-fall ash beds mantle old dunes and beach ridges at Whakatane, Gisborne, and Mt. Maunganui and are useful in indicating the position of the shoreline in past time and in suggesting a rate of progradation of the coast. For purposes of ageing the dunes and ridges the ash bed lying immediately on the sand is selected:

Whakatane: On the eastern Rangitaiki Plains belts of dunes are separated by wide swales of peat. The furthest inland belt, about 350ch. from the present shoreline, is capped with Whakatane Ash, and the succeeding belts seaward are mantled with Waimiha Lapilli, Taupo Pumice, Kaharoa Ash, and Tarawera Ash. Rating of shoreline advance is summarised in the following table, and for convenience, radiometric ages of eruptions are converted to calendar years.

TABLE 4: SHORELINE ADVANCE AT WHAKATANE

Dune building in calendar years	Advance in chains	Rate in feet per year
From c.3,000 BC to 1,400 BC (1,600 years)	130	5
From 1,400 BC to AD 130 (1,600 years)	145	6
From AD 130 to AD 900 (800 years)	64	5
From AD 900 to 1886 (950 years)	18	1
From 1886 to 1960	5	4

The material that has extended the Rangitaiki Plains nearly 4½ miles seawards was alluvium derived from the Waimihia and Taupo Pumice eruptions. The small advance after the Kaharoa eruption when much pumice alluvium was swept down the Tarawera River is surprising and suggests a severe cut-back of the coast line in recent times.

Gisborne: The emergent beach at the eastern end of Poverty Bay (Pullar, 1962b) consists of a belt of 100, low, smooth, closely spaced, parallel and continuous beach ridges about 3 miles long and 4 miles wide and rising from about 12ft at the coast to 40ft inland. Emergence is the result of tilting. Ash beds capping the dunes include Waimihia Lapilli, Taupo members 9-13, Taupo Pumice, and Kaharoa Ash. Though possible shorelines, apart from that at the time of the Taupo Pumice eruptions, are somewhat obscure, measurement of ridge advance and rate of coastal progradation is still worth attempting. The transect was along Lytton Road.

TABLE 5: SHORELINE ADVANCE AT GISBORNE

Beach ridge building in calendar years	Advance in Chains	Rate in feet per year
From 1,400 BC to 850 BC (600 years)	20	2
From 850 BC to AD 130 (1,000 years)	15	1
From AD 130 to AD 900 (800 years)	44	4
From AD 900 to AD 1650 (700 years)	31	3
From AD 1650 to 1956 (300 years)	25	5

The last two periods were not deduced from ash but are included for the record. AD 1650 was a time when catastrophic erosion from storm damage occurred in the Gisborne district, and from 1932 accelerated erosion and sedimentation became pronounced in the Waipaoa River catchment.

Mt. Maunganui: The tombolo joining the rhyolite dome at Mt. Maunganui to the mainland at Matapihi and Papamoa comprises about 50 closely spaced, parallel dunes striking north-west—south-east (Pullar and Cowie, 1967). Most of the dunes are mantled with air-fall Taupo Pumice only and a chronological subdivision was effected by comparing the morphology of soil profiles on the dunes with those at Whakatane where identifiable dated ash beds enabled an age to be allotted to a soil with a particular profile. At Whakatane, the soil mantled with Taupo Pumice only has a B horizon of diffuse iron oxide-coated sands; that with Taupo Pumice plus Waimihia Lapilli has a thin pan of iron oxide-coated sand in the B horizon; and that with Taupo Pumice plus Waimihia Lapilli plus Whakatane Ash has a thick iron pan in the B horizon. These profiles are easily recognised in the field and so enable a rough order of dune advance to be measured. The transect was taken along Golf Road in the Omanu locality.

TABLE 6: SHORELINE ADVANCE AT MT. MAUNGANUI

Dune building in calendar years	Advance in chains	Rate in feet per year
Dunes with thin pan. From c.3,000 BC to 1,400 BC (1,600 years)	30	1
Dunes with diffuse iron oxide-coated sands. From 1,400 BC to AD 130 (1,600 years)	5	< 1
Dunes post-Taupo Pumice eruptions. From AD 130 to 1964 (1,800 years)	7	< 1

Although the method is imprecise the table shows that dune advance has been slow since the Taupo Pumice eruptions; most of the tombolo was built prior to 5,000 years ago.

Of the three places the rate of progradation is highest at Whakatane doubtless because rivers are closer to volcanoes which have showered the catchments with vast quantities of tephra from time to time. The rate during more recent times at Whakatane and Gisborne seems higher than that obtained by Cowie (1963; p.272) for the Waitarere Beach north of the Rangitikei River mouth; there, the shoreline has moved forward at 3ft per year from the time the "Fusilier" was wrecked in 1884.

SEA LEVEL CHANGES

From an examination of Holocene coastal sections Wellman (1962; p.76) infers that sea level at the time of the Taupo Pumice eruptions fell by about 3ft. At Ohiwa Harbour, he describes standing stumps of (?) totara on the floor of the estuary mantled with air-fall Taupo Pumice and suggests that sea level must have risen considerably, possibly 10ft, since the Taupo Pumice eruptions. He considers the rise of sea level to be local and induced by compaction of soft sediments or by seaward slumping caused by earthquakes.

The following are my own observations on Taupo Pumice with respect to sea level: (1) it occurs below sea level near the shoreline at Gisborne, (2) it occurs on standing stumps within the tidal range in Maketu estuary, (3) Hatepe water-borne ash occurs at –5ft in Whakatane estuary, and (4) Taupo Pumice boulders and fragments of charred wood occur at –8ft near Thornton on Rangitaiki Plains.

All of these widely spaced observations suggest a lowering of sea level at the time of the Taupo Pumice eruptions. Eustasy, however, may be compounded with tectonics since most of the sites are known to be in tectonically mobile areas. The point is well taken by Wellman who states that tectonic elevation and depression cannot be distinguished from eustatic sea level changes in individual sections, and that to avoid inferred slumping and compaction, definite evidence for either eustatic or tectonic sea level changes has to be related to compact rock.

Schofield's sea level-time curve of the Firth of Thames chenier plain (1960; p.479) shows a fall below present sea level shortly after BC/AD, but in a later paper (1964; p.364), no such fall is plotted. For the moment I am assuming that sea level was lower at the time of the Taupo Pumice eruptions.

TECTONICS

(a) *Gisborne:* During the excavation of a sewer trench in the Mangapapa locality, Waimihia Lapilli and Taupo members 9-13 intercalated with beds of organic mud were seen to be tilted about 3 degrees; after tilting they had obviously been planed by the sea and then covered unconformably with intertidal gravels and beach sands; eventually the latter were mantled with Taupo pumice. Tilting must have occurred between the eruption of Taupo members 9-13 and that of Taupo Pumice and from this and other evidence a date of c.200 BC is suggested.

(b) *Whakatane:* The surface level of the oldest inland dunes capped with Whakatane Ash is +18.0ft. and that of the bottom of the swale is −7.3ft. The swale is infilled with peat to a level of +8.7ft., and within the top 3ft of peat, air-fall Tarawera Ash, Kaharoa Ash, Taupo Pumice, and Waimihia Lapilli have been identified. As these ashes fell in peat the land must have sunk before 3,000 years ago; according to Schofield (1964; p.364), sea level was higher 4,000 years ago falling to present level 5,000 to 6,000 years ago.

Waimihia Lapilli has been noted on estuarine muds and sands at +0.5ft; both Schofield and Wellman consider sea level to have been higher at the time of this eruption so the land must have sunk with respect to the sea.

These examples indicate that the Whakatane graben was tectonically active within the last 5,000 years.

GROUND SURFACES

This term was introduced by Butler (1959) who defined it as . . . "All those erosional and depositional surfaces and layers which have developed in a landscape during one interval of time and upon which a unit mantle of soil has developed . . .". It is understood to involve both the surface and the soil profile, including soil stratigraphy, and appears to be useful in designating a surface and in allotting a relative age to it. The principle has been experimented with on depositional surfaces of Gisborne Plains where, as a result of a detailed soil survey, the following ground surfaces were established (Pullar, 1965b):

TABLE 7: GROUND SURFACES AT GISBORNE

Ground Surface	Soil	Age
Waipaoa	Waipaoa; s A1/C horizons; rapid accumulation from frequent flooding.	from 1932
Matawhero	Matawhero; deep A1; slow accumulation from periodic flooding.	from AD 1650
Waihirere	Waihirere; A (B) horizons; flood-free. (Kaharoa Ash in C horizon)	from AD 1450

Ages of the Matawhero and Waihirere ground surfaces had to be borrowed from Grant (1965), who independently of Pullar, established the same pattern in Hawkes Bay and by means of tree-ring counts was able to allot an age to each surface.

In the Lower Whakatane Valley, depositional surfaces have been examined with the aid of air-fall ash beds (Pullar, Pain and Johns, in press) and the following have been designated:—

post-Tarawera (correlated with Waipaoa at Gisborne)

post-Kaharoa (correlated with Waihirere at Gisborne; at Whakatane, post-Kaharoa surfaces have Opouriao soils which have the same A (B) profile as Waihirere soils).

On alluvial flats in Kairanga County, soils with similar profiles to those at Gisborne have been mapped (Kear, 1965; p.38-9), and it is conceivable that ground surfaces at both places could be correlated.

While dated ash beds give certainty as the designation of a ground surface they can only suggest a maximum age. On flood plains remote from the direct influence of volcanic eruptions, the ground surface concept may be the only means of effecting a chronology of depositional surfaces.

ARCHAEOLOGY

In a coastal reconnaissance of archaeological sites along the Bay of Plenty and eastern Coromandel Peninsula, Wellman (1962) proposed the following stratigraphy in downwards order for air-fall ash beds and sea-rafted pumice; Kaharoa Ash, Loisels Pumice (sea-rafted), Ohui Ash, and Taupo Pumice (sea-rafted at some sites and air-fall at others). But Ohui Ash was not reported by Vucetich and Pullar (1964) nor has it been seen during the course of a detailed soil survey of Rangitaiki Plains. Its validity as a separate entity is being examined.

In the Whakatane district persistent search has failed to reveal archaeological sites older than the Kaharoa Ash. A possible site at Thornton (Pullar, 1962a) cannot be sustained on further examination (Shawcross, 1965; Pullar, 1967a), and a site on Toi's Pa on the high bluff overlooking Whakatane still remains to be excavated by archaeologists. By sieving volcanic ash in the soil, Pullar (1961) got a similar size distribution to known Kaharoa Ash in Whakatane Borough, and at that time, it appeared reasonable to assume Kaharoa Ash as a mantling bed to a definite archaeological site; but as other older sites have not been located it may be that Toi's Pa is now suspect. Search may be better rewarded in the Pukehina locality where Kahaora Ash is about 12in. thick.

The best marker bed is Tarawera Ash particularly in the Kawerau and Onepu localities; here the ash is about 12in. thick and easily recognisable as a mantling bed (Pullar, Moore and Scott, 1967; p.105-6).

In the Rotorua and Taupo districts many Maori garden soils can be recognised because the A horizon is deeper than usual; but thick topsoils must not be confused with mineral accretions such as Tarawera Ash and Rotomahana Mud, which after further darkening by organic matter, merge with the black Kaharoa Ash beneath (Pullar and Vucetich, 1960; p.6).

At Orongo Bay near Gisborne, Green and Pullar (1960) used sea-rafted Loisels Pumice and air-fall Taupo Pumice as marker beds in a detailed excavation on the coast. It was inferred from the stratigraphy that Polynesian occupation may have occurred c.500 AD but not before the Taupo Pumice eruptions of 130 AD. Referring to the latter, Hartree (1960; p.14) also comes to the same conclusion and writes . . . "In the northern areas of the Hawkes Bay the Taupo Pumice shower of AD 150 is a widespread and easily recognisable marker band; so far no occupational layer has been found under it . . ." He also says . . . "There is considerable evidence to prove the existence of several species of *Anomalopteryx, Pachyornis* and *Dinornis* moas living in the Hawkes Bay after the Taupo Pumice shower of AD 150 and as no major climatic or volcanic upsets followed, these moas must have been present when the first Polynesians arrived in the area . . ."

At Poukawa, Hawkes Bay, Price (1963) has uncovered artefacts and moa bones under the Taupo Pumice and . . . "Items related to man . . ." under a lower air-fall bed assumed to be Waimihia Lapilli but not yet identified with certainty (Pullar, 1965c).

ASH BEDS AND THE COMMUNITY

Volcanic Eruptions

During the last 36,000 years most cataclysmic eruptions have emanated from centres in the Okataina Volcanic District but the most violent have issued from the Taupo Centre. Ejactamenta associated with Mangaoni Lapilli eruptions would have enveloped a town like Whakatane where lapilli beds are at least 20ft thick, and at the same place, Rotoma and Whakatane ashes 24 inches and 18 inches thick respectively would have smothered everything with dust, sand and gravel; indeed, the weight of these ashes landing on roofs of houses would be of the order of 20 to 30 tons. The effect on grassland farming would be catastrophic; even in a small eruption such as that of Tarawera, Rotomahana Mud about an inch thick was sufficient to spoil pasture at Te Puke.

River regimes

Mangaoni Lapilli would have largely filled the Rangitaiki Valley from Kopuriki to Matahina Dam, and 20 to 30ft of air-fall lapilli would have been deposited in the lower Whakatane valley. Rivers may have gone underground for a time in the loose lapilli and eventually courses would have become braided.

Although the direct effect of the Taupo Pumice eruptions on Whakatane and district would have been no more than a light mantling of ash and lapilli, their effect on the river regimes of Whakatane and Rangitaiki Rivers was tremendous. For the former river, it is estimated that slurry 3ft thick was transported, the product of Hatepe Lapilli, the first of the Taupo Pumice eruptions; for the latter river, a fan of about 30ft of Taupo lapilli was built up at Te Teko and this tapered off to about 5ft at the then coast in the Paroa locality.

After the Kaharoa eruption, the Tarawera River transported a large quantity of sand and gravel to the lower reaches below Kawerau and this material has buried swamps near the coast to a depth of 3 to 6ft. Braided channels are a feature in the Awaiti locality.

Flooding

In the lower Whakatane and Waimana valleys (Pullar, 1967b), sediment from the 1964 flood is now being deposited on the post-Kaharoa surface, and on Gisborne Plains, parts of the Waihirere ground surface of similar age were also flooded in the 1948 and 1950 floods. It is on these surfaces that towns have been built and at the time justifiably so because of the assumption that they have been flood-free for a long time — since

AD 1450. But to keep these towns flood-free now requires expensive flood control measures and means another tax on town dwellers. Those on salary and wages cannot recoup the expenditure on extra rates as can a farmer who is expected to increase production as a result of benefit received from flood protection. If possible other land forms such as contiguous terraces, easy rolling hills and dunes should be considered in the planning of a town's expansion.

Soil Engineering

Engineering soil classification has been discussed by Northey (1966), but in this preliminary examination of a wide range of soils throughout New Zealand, initial sampling was conducted at depths little greater than 3ft. Deep cuttings provided by engineers have supplied the necessary detail in the mapping of ash beds, and as a feed-back, the engineering properties of the beds could be thoroughly documented at a few points embracing both well drained and poorly drained sites: this information could then be applied over a wide area since the distribution of many ash beds is now well known. Overseers who may spend all of their working life in a district no doubt gain most of this knowledge through experience, but empiricism should not bar the way to systematic documentation of properties which would be of high value to engineers who come and go in the course of their careers. One highway recently constructed in the Rotorua district cost twice as much as the estimate and it was found that the material from cuttings could not be used for embankments; the ash beds in this locality have subsequently been mapped and the knowledge gained could then be applied to similar projects in the future.

Northey (1966; p.809) writes . . . "little use of engineering pedology has yet been made in New Zealand, perhaps owing to the complexity of the soil pattern and the irregular topography, but more probably because of the lack of any systematic work correlating the two fields . . ." Such inter-action could be encouraged in engineering schools, where in engineering geology, more emphasis might be given to the study of ash beds particularly in the North Island.

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