THE LATE QUATERNARY COVER BED STRATIGRAPHY AND TEPHROCHRONOLOGY OF NORTH-EASTERN AND CENTRAL TARANAKI, NEW ZEALAND.

A thesis presented in partial fulfilment
of the requirements for the degree of
Doctor of Philosophy in Soil Science at
Massey University, Palmerston North,
New Zealand.

by
BRENT VICTOR ALLOWAY
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" We shall never achieve harmony with land, any more we shall achieve justice or liberty for people. In these higher aspirations the important thing is not to achieve, but to strive......"

Aldo Leopold

DEDICATION

This thesis is jointly dedicated to:

Ana Pickering, who, since the time of our marriage, has been a pillar of support and encouragement.

C.G. Vucetich, my lecturer at Victoria University and Ph.D supervisor, who made late Quaternary geology so animating and alluring.

T.L. Grant-Taylor, geologist and friend, who kindled my first, very early interest in geology.

DECLARATION

Except where otherwise acknowledged in the text, this thesis represents the original research of the author.

B.V. Alloway

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ABSTRACT

This study involved the recognition and description of tephra, lahar and debris avalanche deposits generated from activity centred at Egmont Volcano over the last c.130kyrs B.P. Stratigraphic relationships between the various cover bed deposits of north-eastern and central Taranaki are discussed and their distributions mapped where possible.

The stratigraphic record indicates that tephra emission and lahar inundation are typical, recurring features of Egmont Volcano. Average periodicity for moderate to major sized eruptions (>10^7 m^3) may be as frequent as, one every 250 years. Tephras from Egmont Volcano have been correlated to both the adjacent Wanganui and Waikato districts.

Six rhyolitic tephras erupted from the Central North Island have been identified in Taranaki and are especially valuable as widespread time planes within the andesitic cover bed succession.

At least thirteen lahars are shown to have been deposited over extensive areas of the ring plain during the last 22.5kyrs B.P. Many of these lahars became channelised within stream and river catchments to extend to the North Taranaki coastline.

Partial or complete collapse of Egmont Volcano at c.23kyrs and much earlier at c.100kyrs B.P. generated large volumed, debris avalanches that spread principally over a wide north-eastern to south-eastern arc. The resulting deposits are characterised by extensive areas of mounds now deeply buried by a younger late Pleistocene and Holocene tephra mantle.

The stratigraphy of an alternating sequence of reddish (S-units) and yellowish (L-units) medial beds was also investigated. Generally their thinning pattern is similar to that of coarse ash and lapilli suggesting tephric origin. The thinning pattern of L-units however, is occasionally interrupted by localised overthickening and indicates localised aeolian deposition during cool to cold climatic periods. The biostratigraphic record constructed from pollen examinations support the climatic interpretations made from the medial stratigraphy.

The measurement of quartz content in medial units is shown to be a particularly useful parameter for assessing past climatic conditions. Two peaks in quartz influx were recorded and correlated to the full-glacial periods of oxygen isotope stages 2 and 4.

Forming the North Taranaki coastal plain are five uplifted marine terraces, that provide a c.0.45 Ma record of successive sea level oscillations with moderate to low rates of crustal deformation. The present extent of these terraces is related to lahar deposits within their cover beds which have repeatedly advanced the coastline and retarded coastal erosion.

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1.0 INTRODUCTION

1.1 REGIONAL GEOLOGY

The Taranaki Volcanic Succession is a group of four Quaternary andesitic volcanoes which collectively form the constructional landscape of the Taranaki Peninsula. The three main volcanoes, Mt.Egmont, Pouakai Range and Kaitake Range define a volcanic lineament along which volcanism appears to have migrated south-eastwards over the last c.0.5 million years (Plate 1.01). Minor outcrops of volcanic breccias in the vicinity of New Plymouth represent a fourth, older (c.1.7 million year) volcano, now represented by Paritutu and the Sugar Loaf Islands.

Taranaki volcanoes may be classified as a high-potassium andesite association, characterised by high Al_2O_3 and total alkalis and by low TiO_2, total Fe and MgO relative to typical andesites (Neall et al. 1986). Available geochemical data show distinct compositional differences between the Taranaki andesites and those of the Taupo Volcanic Zone (e.g. Cole 1969, 1978; Hackett 1983) that appear to be linked (Hatherton 1969; Neall et al. 1983) with the present subduction regime beneath the Central North Island. The chemical characteristics of the Taranaki andesites are consistent with their position further from the trench and depth to the underthrusting Pacific Plate.

The dipping plate boundary is expressed by a zone of earthquake foci (Hatherton 1970; Adams and Ware 1977) which deepen from east to west to 250km depth. A small number of very deep earthquake foci at about 600km depth in Taranaki are thought to be caused by a detached slab of the subducting plate (Adams and Ferris 1976; Christoffel and Calhaem 1973) since they lie approximately 250km below the lower margin of the seismically continuous Benioff Zone

Plate 1.01: Taranaki Volcanic Succession with Egmont Volcano (left), Pouakai Volcano (centre) and Kaitake Volcano (left).

and are separated from the main zone of earthquakes by a seismically quiet region.

Underlying the Volcanic Succession and extending westwards beyond the edge of the continental shelf is the Taranaki Basin, which is filled with up to 7000m of Late Cretaceous to Plio-Pleistocene sediments (Katz 1974; McBeath 1977). The Taranaki Basin was subdivided on the basis of prevailing deformation style (Knox 1982) into three structural units which were separated by tectonic lineaments, across which a distinct change in structural style occurs. These lineaments - the Taranaki Boundary Fault, the Cape Egmont Fault Zone and the Cook-Turi Lineament, consist of a complex zone of en-echelon north-west and south-east dipping normal to reverse faults. In general, activity along the Cape Egmont Fault Zone and Cook-Turi Lineament is restricted to a few faults that persisted throughout Pliocene-Recent time. Movement along other faults died out during Late Miocene time and others were truncated following the development of the basal Pliocene unconformity and subsequent marine transgression (Pilaar and Wakefield 1978).

1.2 VOLCANIC SETTING

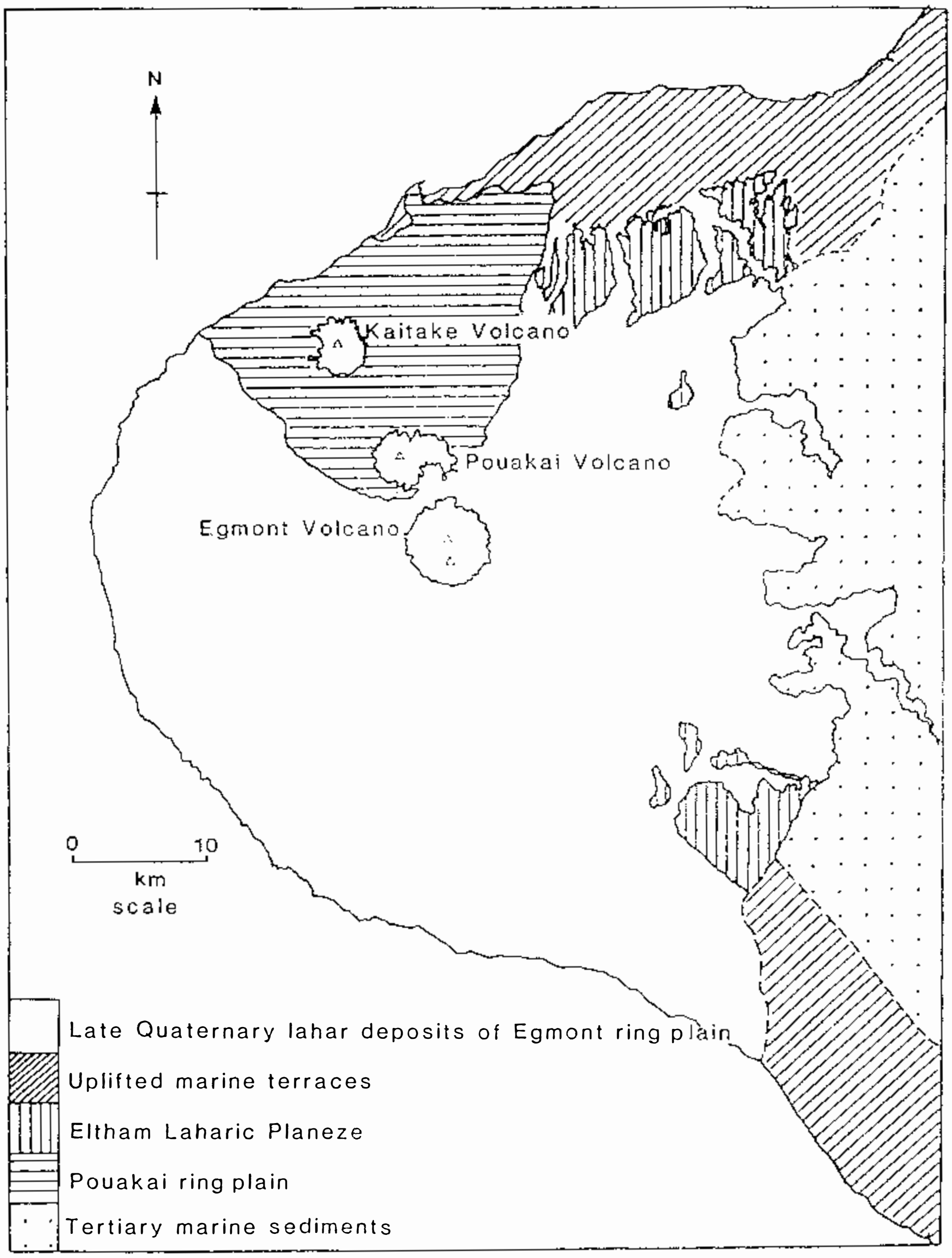
Egmont, the youngest and most southerly volcano of the Taranaki Volcanic Succession, is the second highest mountain in the North Island and the largest andesitic strato-volcano in New Zealand. Over a horizontal distance of 25km the slopes of Egmont Volcano rise from sea level to a summit at 2518m elevation; a vertical to horizontal ratio (V:H) of 1:10 (Neall et al. 1986). Its slopes within a 9.6km radius of the summit, are conserved in Egmont National Park.

Egmont Volcano can be sub-divided into upper and lower sections. The upper section comprises principally lava flows that have been extruded over the last c.10kyr B.P. and forms a prominent cone with a small summit crater. The lower section, volumetrically much larger, comprises volcaniclastic material that has been deposited over the last c.130kyrs B.P. forming a gently sloping surface that flattens away from the upper section. This section has been named the **ring plain** and is near circular in outline except where Pouakai Volcano and the Eltham laharic planeze breaks the landscape in the north, and where it merges with a hilly landscape of upper Tertiary marine mudstones and sandstones in the east (Figure 1.01).

The Egmont ring plain in the vicinity of Inglewood is bordered by an ancient laharic planeze mapped by Hay (1967) as Eltham Lahars (Figure 1.01). The southern margin of this planeze approximates to the upthrown side of the north-east trending Inglewood Fault. In this vicinity, the planeze is extensively dissected and forms a remnant surface (Neall 1982). As the planeze gradually dips towards the coast, it becomes less dissected with wide planar inter-fluves and deeply entrenched north-south trending river valleys with steep sloping valley sides and wide floodplains. The seaward margin of the planeze is marked by a prominent cliff, cut during a subsequent, high sea level event.

Immediately northward of the Eltham laharic planeze on the North Taranaki coastal plain are several uplifted marine terraces running roughly parallel to the present coastline (Figure 1.01). These terraces, descend step-like to the coast from up to 20km inland and from over 100m above present sea level. Only a narrow strip of coastal plain is preserved north of Whitecliffs to beyond Awakino, buttressed inland by higher dissected cliffs and narrow terrace remnants. Further south, the North Taranaki coastal plain and terraces pass into the dominantly volcaniclastic stratigraphy of the Egmont ring plain.

FIG. 1.01 Principal Physiographic Units of Taranaki



CHAPTER 2

TEPHROSTRATIGRAPHY AND TEPHROCHONOLOGY OF NORTH-EASTERN AND CENTRAL TARANAKI

2.1.0 Introduction

2.1.1 Previous Work

Evidence of recent volcanic activity at Mt Egmont was first recognised by A.W.Burrell who in 1883 observed pumice fragments lodged in the forks of living matai (*Prumnopitys taxifolia*) trees (Oliver 1931). The earliest published suggestion of recent activity so far traced is by Skeet (1901) who noted:

" Judging from the different layers of pumice and earth, I think there have been three comparatively recent eruptions ".

In 1929, a Maori oven or 'umu' was found close to the site of the Stratford Mountain House, beneath the previously recognised pumiceous deposit now formally named the Burrell lapilli (Oliver 1931; Druce 1966). About this time Grange and Taylor were conducting the first soil survey of Taranaki in which two further widespread tephra showers were recognised as soil forming. The Stratford Ash (Shower) was mapped between a point 6km south of Waitara to a point 5km north of Normanby; while the Egmont Ash (Shower) was mapped to the north and south of these points (Grange and Taylor 1933). The Stratford Ash was thought to overlie the Egmont Ash, to form the parent material of four principal soil series. Two major soil series were recognised on Egmont Ash.

In 1962 Wellman reported numerous thin andesitic ashes interbedded within Holocene coastal sections along the North Taranaki coastline. The upper ashes were correlated with the 'last Egmont eruptions' i.e. the Burrell Shower (Oliver 1931), Newall Ash (Taylor *et al*. 1954) and Stratford Ash (Taylor *et al*. 1954), whilst beneath these ashes, five previously unrecognised eruptives were identified - three grouped into Stent Ash and two into Onaero Pumice.

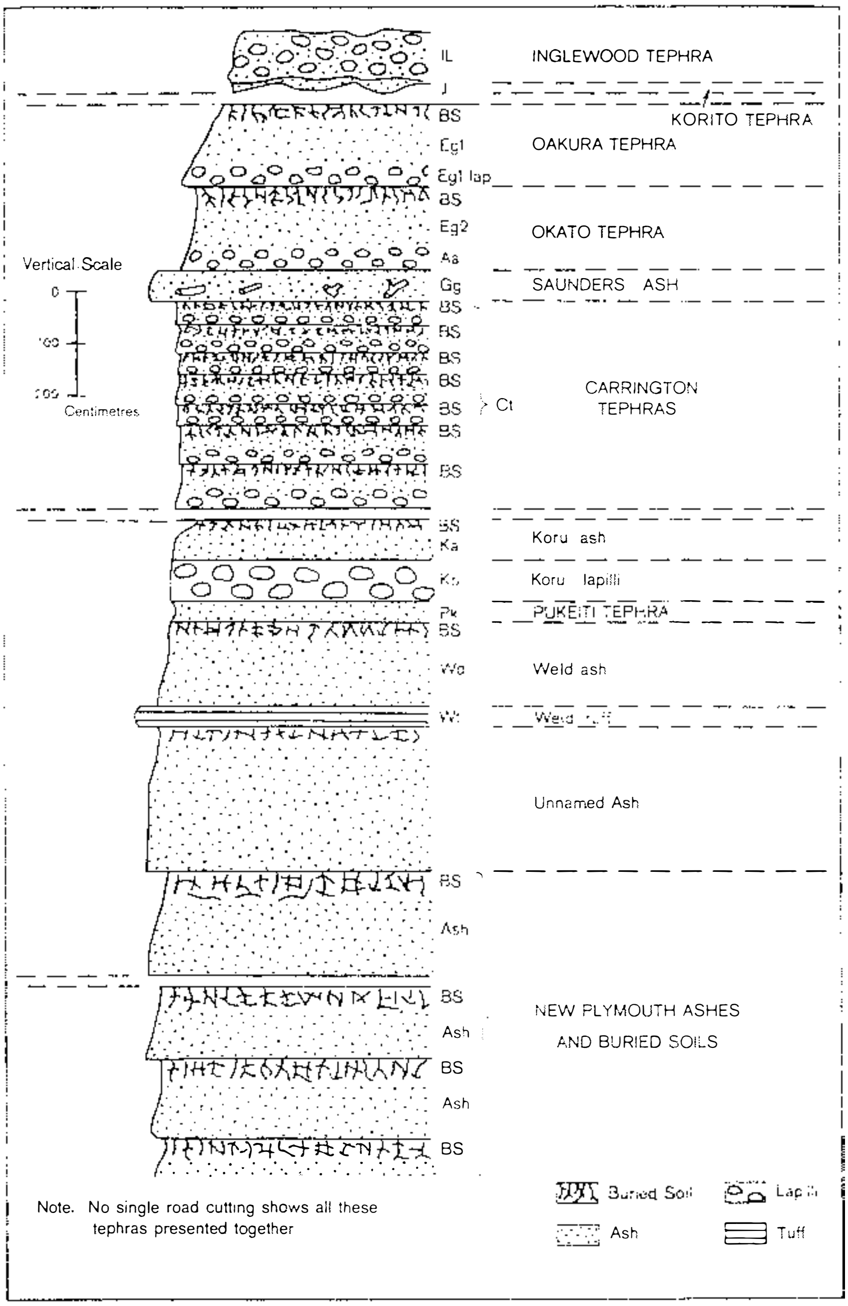
Later Druce (1966), outlined the most recent volcanic history of Egmont Volcano by describing, mapping and approximately dating volcanic ash and lapilli layers in peat and soil on the upper flanks of the volcano. Nine eruptives were grouped into three formations that were considered to have been erupted from Egmont Volcano since c.1600 A.D. The influence of these tephras on soil development in the Dawson Falls region was the subject of a study by Tonkin (1970).

The first detailed investigation of prehistoric volcanic activity at Egmont Volcano was that of Neall (1972), who reported upon the tephras mantling the western Taranaki landscape. Ten new tephra formations and constituent members were named (Figure 2.01). The oldest of these newly named tephra formations was considered to represent the earliest tephra erupted from Egmont Volcano. In 1984, Franks described in detail tephra beds within the previously defined Egmont and Stratford Ashes in Eastern Taranaki (Figure 2.02). These beds comprised the informally defined Kaupokonui, Maketawa and Manganui tephras (McGlone et al. 1987) which overlie the formally defined Inglewood and Korito Tephras (Neall 1972), which in turn overlie the informally defined E5 (youngest), E4, E3, E2, E1 and Mahoe (oldest) tephra units (Franks 1984).

2.1.2 Composition of the Egmont and Stratford Ashes

The Stratford Ash and Egmont Ash originally defined by Grange and Taylor (1933) were arbitrarily named 'Ash' rather than 'Ashes' or 'Ash-beds'. The 1933 publication was supplemented by an unpublished internal report which describes in detail many additional Stratford Ash (Shower) localities and sections but no type sections were ever designated. Originally the ashes

FIG. 2.01 Tephrostratigraphy of Neall (1972)



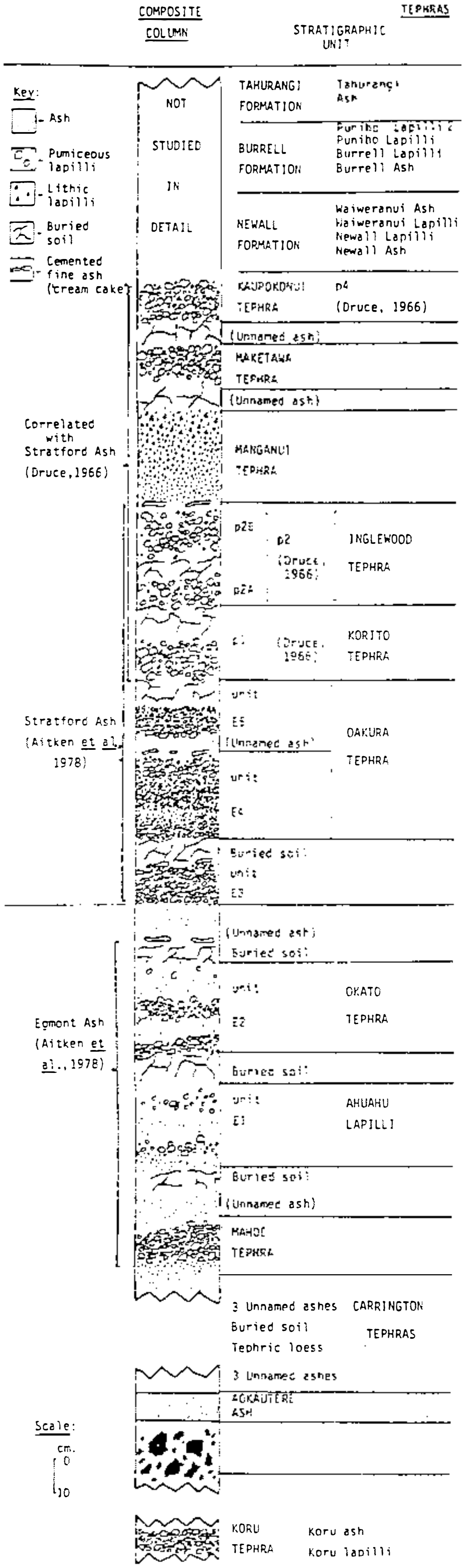


FIG. 2.02 Tephrostratigraphy of Franks (1984)

(Showers) were assumed to be younger than the mudflow deposits of the Opunake and Okato districts but later this was shown to be only partially correct (Neall 1972). Subsequent publications refer specifically to Stratford Ash and Egmont Ash, e.g. Druce (1966) correlated four discrete pumiceous tephra units (P4, P3, P2 and P1) along the Stratford Plateau Road with the 'Stratford Ash' of Taylor (1953).

In 1972, Neall subdivided the Egmont Shower in Western Taranaki into two separate formations: the Oakura Tephra (upper) considered to be less than (NZ1144A) 6,970 years +/- 76 years B.P. and the Okato Tephra (lower) between NZ1144A and (NZ942A) 16,100 +/- 200 years B.P. The Korito Tephra overlying Oakura Tephra was considered to form the lowermost part of the previously designated Stratford Ash (Neall 1972).

On the eastern lower flanks of Egmont Volcano in Stratford County Aitken et al. (1978) further restricted the usage of the term 'Stratford Ash'. Here, Rowan and Lowgarth soil series were differentiated from Stratford soil series on areas with a younger unnamed lithic lapilli deposit overlying 'Stratford Ash', in effect defining the upper limit of Stratford Ash. This unnamed deposit was informally referred to as the Manganui tephra by Whitehead in 1976.

More recently in the same sector, Geddes & Neall (1982) and Franks (1984) recognised a sequence of five informally designated tephras comprising Stratford Ash, extending from the base of Manganui tephra to the base of E3 tephra unit (Figure 2.02). Prominent lapilli units within this stratigraphic interval were observed by Franks to be "creamy coloured and less weathered". Egmont Ash beneath was found to comprise three informally named, orange coloured and well weathered tephra units. It is worthy to note that the basal boundary for the Egmont Ash has never been defined. This study, based on the tephrostratigraphy in north-eastern and central Taranaki, emphasises the composite nature of the Stratford and Egmont Ashes which are shown to comprise numerous tephra units deposited over a considerable length of time. On this basis the terms `Stratford Ash' (Shower) and `Egmont Ash' (Shower) are therefore considered redundant.

2.1.3 Nomenclature

The term 'tephra' was introduced by Thorarinsson (1944) and later defined by him (in Pullar et al. 1973 p.497) as "all the clastic volcanic materials which during an eruption are transported from the crater through the air".

A subsequent problem arose as to whether the term should include both fall and flow deposits. Thorarinsson (1974 p.xvii - xviii) advises that he had not wished to restrict the use of this definition (1954), but had not seriously considered including flow deposits in the original definition. Cole and Kohn (1972) suggested that all predominately unconsolidated pyroclastic materials be designated tephra and if their origin was known, be designated tephra-fall or tephra-flow. Although this usage is widely used, a recent trend in New Zealand and the United States has been to loosely equate tephra with pyroclastic fall deposits and the term ignimbrites (welded or unwelded) for pyroclastic flow deposits. This usage of tephra is adopted here.

Tephra as a term is appropriate to this study because it applies in a lithologic sense to the wide size range of materials (ash, lapilli, blocks) making up unconsolidated deposits with a genetic connotation as to its origin.

Descriptive size terms of Fisher (1961) for tephra are defined as follows: blocks >64mm; lapilli 64mm - 2.0mm; coarse ash 2.0 -

0.25mm and fine ash <0.25mm. These grades correspond with size groupings used in sedimentology.

In describing **weathered** fine grained tephric materials in Taranaki, soil particle size class names are not used. The concept of either texture or particle size is here considered not applicable to amorphous materials, particularly if they cannot be dispersed readily. Consequently no soil particle size class names are used if the exchange complex is dominated by amorphous materials.

In this study, six classes from the Andisol Proposal (Smith 1984) are adopted to describe the changing field characteristics of andesitic tephra-beds with distance from eruptive source. These classes, based on combinations of both particle size and mineralogy, were originally proposed by Smith (1984) as new improved criteria for classifying volcanic soils. The selected classes used here in this study are defined as follows:

Pumiceous

More than 60% of the whole soil is composed of pumice-like fragments coarser than 2mm, with insufficient fine earth to fill interstices coarser than 1mm in at least 10% of the volume of the soil; pumiceous fragments are two thirds or more of the fragments coarser than 2mm.

Ashy

More than 60% of the whole soil (by weight) volcanic ash, cinders, pumice, or other vitric volcaniclastics; less than 35% (by volume) is 2mm in diameter or larger; water retention at 15-bars is less than 30% on undried samples of fine earth, and less than 12% on air dried samples.

Ashy - Pumiceous

Thirty-five percent or more by volume is greater than 2mm; pumice or pumice-like fragments larger than 2mm are two-thirds or more (by volume) of the fraction greater than 2mm; fine earth fraction is otherwise ashy.

Medial

Less than 35% (by volume) is greater than 2mm; water retention at 15-bars is 12% or more on previously dried samples; or water retention at 15-bars of undried samples is between 30 and 100%; the exchange complex is dominated by amorphous materials.

Medial - Pumiceous

Thirty-five percent or more (by volume) is greater than 2mm; pumice or pumice-like fragments larger than 2mm are two-thirds or more (by volume) of the fraction greater than 2mm; fine earth is otherwise medial.

Hydrous

Less than 35% (by volume) is greater than 2mm; water retention at 15-bars is 100% or more on undried samples of the fine earth; the exchange complex is dominated by amorphous materials.

2.1.4 Isopachs

In this study the distribution of tephra marker beds is best defined by isopach maps. Irregular or discontinuous thicknesses were avoided. With distance from Egmont Volcano tephra marker beds thin markedly and it becomes increasingly difficult to obtain reliable thicknesses. Increased dispersal of coarse grains in a matrix of medial material makes thickness determinations additionally difficult.

All isopachs with the exception of the Manganui tephra show a thickening towards Egmont Volcano, which is interpreted as having been the approximate site of the source vent. Caution must be exercised in adopting this approach however, because the maximum thickness might be displaced downwind (i.e. Walker 1980; Sarna-Wojcicki & Shipley et al. 1981; Dzurisin 1981) or more than one maximum may occur within a single tephra-fall sheet (i.e. Larson 1937; Bogaard 1983).

2.1.5 Stratigraphic Procedure

In Western Taranaki andesitic tephra formations were defined by Neall (1972) in a manner similar to that of rhyolitic tephra formations - the lower contact was usually marked by a coarse lapilli horizon resting on a buried soil of medial material of fine ash grade. The upper contact was bounded above by a buried soil which was usually developed within the top 10cm of tephra. The recognition of buried soils between the formations indicated that nearly every boundary was marked by a period of minimal deposition, with associated weathering and minimal erosion. This boundary was recognised as a paraconformity by Neall (1972) following the terminology of Dunbar and Rodgers (1957).

On the north-eastern and central lower flanks of Egmont Volcano, andesitic tephra marker beds often do not have the well developed paleosols or buried soils which have been most appropriate in defining rhyolitic or andesitic formational boundaries elsewhere. The absence of prominent buried soils on the lower eastern flanks of Egmont Volcano in contrast to Western Taranaki where more prominent soils are preserved, suggests that fine ash and lapilli accumulated more rapidly in the east and north-east.

Andesitic tephra formations are defined in this study in terms of either - (a) constituting a single discrete regional marker bed or (b) a set of closely spaced tephras that merge together with distance from eruptive source. Andesitic tephra formations are intercalated with medial material of either tephric or combined tephric and aeolian origin. Irrespective of origin, each inter-bed of medial material forms part of a 'soil accession' and represents a period of intermittent accretion of fine grained volcaniclastic materials with associated weathering. Because the medial inter-bed need not be genetically related to either the overlying or underlying tephra bed, it therefore remains unnamed.

For each andesitic tephra formation defined here a type section and type area of specified extent is defined. This is thought necessary for the preservation of a permanent stratigraphic record of weakly consolidated tephras, because tephra type sections exposed in road cuttings are very vulnerable to erosion, reafforestation, road reconstruction and other engineering works. If necessary another type section may practicably be established within the defined type area. Many reference localities have been designated (Figure 2.03) to show lateral variation and for ease of future tephra correlation throughout the region.

2.1.6 Methods of Study

Over 700 sections were examined in detail extending from the eastern 450m contour of Egmont Volcano to sites just above sea level along the North Taranaki coastline. Supplementary investigations were also carried out within Egmont National Park.

On the eastern and south-eastern lower flanks of Egmont Volcano tephra beds are best expressed in numerous, near vertical road

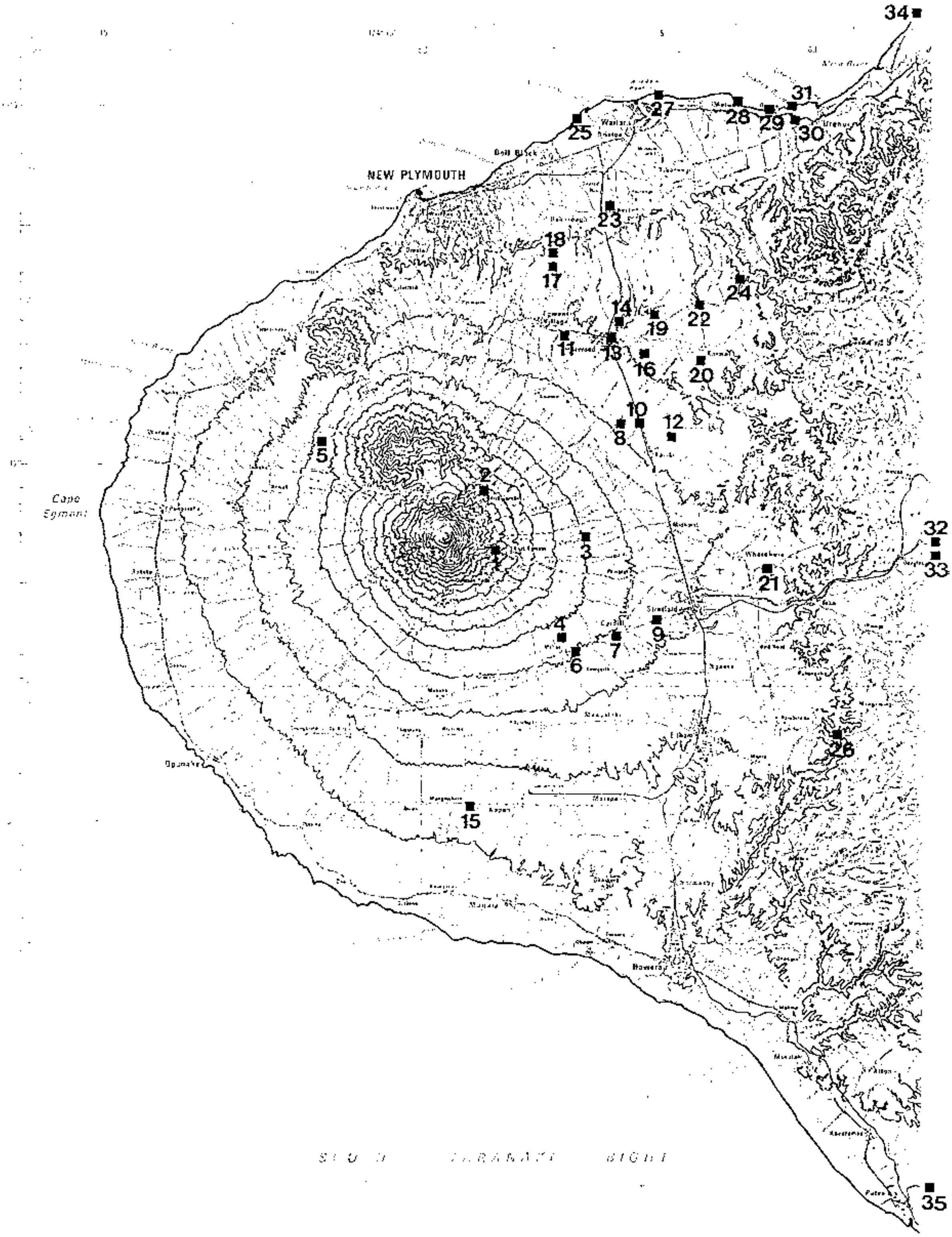


FIG. 2.03 Reference Sections

sections of appreciable lateral extent. Here, deposition of tephra has occurred largely uninterrupted from erosion or burial by laharic deposits.

On the north-eastern lower flanks there are fewer road exposures. Thus mapping and correlation of tephra beds was determined from exposures within deep drains and farm cuttings. In this sector tephra beds are frequently interstratified with numerous laharic deposits. Correlation has been advanced by an extensive network of gas and water pipelines, new roads and quarries due to recent development of petrochemical industries throughout the region.

2.1.7 Tephra Deposits

The tephras recognised as most useful for correlating and dating purposes occur near to source, are commonly thick and/or coarse grained, and comprise lithologically distinct layers that have resisted post-depositional pedogenic mixing. In correlating andesitic tephra marker beds difficulties arise in the field from (a) lateral variability in particle size and lithology of tephra constituents; (b) loss of identifying characteristics as individual tephras thin and/or merge from source to grade into medial beds; and (c) the masking effects of post-depositional mixing and weathering in the soil forming environment. The two latter problems have been overcome by examining sites where estuarine, peaty or lacustrine sediments preserve discrete dominantly unweathered ash and lapilli beds. Here, many conformable, often thin fine ash layers are preserved between the more prominent tephra marker beds. This is in marked contrast to the soil forming environment where such thin fine ash layers cannot be macroscopically identified because they have been modified by pedogenic mixing and transformed into either medial or hydrous materials.

This study identifies those Egmont-sourced tephras extending throughout much of north-eastern and central Taranaki which are likely to extend into other adjacent districts of the North Island.

2.2.0 TOKO TEPHRA SUB-GROUP TEPHROSTRATIGRAPHY

2.2.1

Toko Tephra Sub-group is named after the east Taranaki farming community of Toko, c.9.4km east of Stratford Borough. On the lower eastern flanks of Egmont Volcano Toko Tephra Sub-group includes nine tephra formations with at least thirty-three constituent coarse ash and lapilli units (Figure 2.04). Included within the sub-group are two unnamed lapilli beds. **Toko Tephra Sub-group** is intercalated with medial inter-beds of **S1** (see Chapter 4).

Type Section

The type section designated here for **Toko Tephra Sub-group** occurs c.13.2km south-east from Egmont summit at a prominent north-facing road cut on Opunake Road, 0.5km west of Mangatoki Stream bridge and 0.9km east of the junction of Opunake Road with Upper Palmer Road, (Q20/119027) (**Section 6** of Appendix 1).

Upper and Lower Contacts

On the lower eastern and north-eastern lower flanks of Egmont Volcano, the uppermost formation of **Toko Tephra Sub-group** is Manganui tephra. This tephra is separated from coarse ash and lapilli dispersed in medial material that constitutes the topsoil developed on the present day ground surface. On the upper flanks, Manganui tephra is overlain by informally named tephras (i.e. Maketawa and Kapokonui tephras), which are presently being studied by other researchers. These informally named tephras may later, be practicably incorporated within the sub-group.

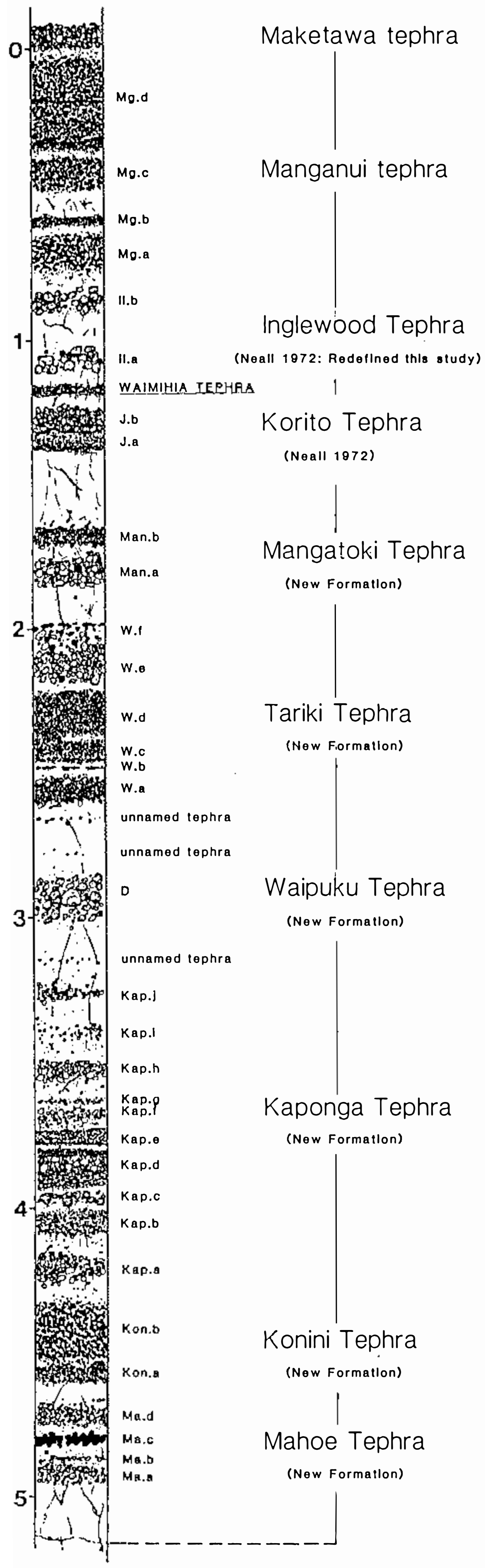
In the south-eastern sector, the lowermost formation of **Toko Tephra Sub-group** is Mahoe Tephra. This tephra is separated from constituents of upper Tuna Tephra Sub-group below, by <0.5m of medial material.

FIG. 2.04

Composite Stratigraphic Column

Toko Tephra Sub-group

(Intercalcated by S1)



Thickness Variation

The principal thinning direction of Toko Tephra Sub-group extends from the Egmont Volcanic Centre towards the east and south-east. In this direction, the pattern of thinning appears more rapid, than that observed for the northern and north-eastern sectors. A maximum recorded thickness of c.4.2m for **Toko Tephra Sub-group** was obtained at the type section, 0.9km east of Mahoe in the south-eastern sector. Determining the axis of distribution, is precluded by incompletely exposed sections or lahar burial to the eastern and north-eastern sectors.

With increasing distance from Egmont Volcanic Centre, coarse ash and lapilli beds that comprise **Toko Tephra Sub-group** visibly thin and become finer grained. The number of tephra beds in the profile also visibly decline, accompanied by a steady increase in the proportion of either ashy and/or medial material within the same profile. Near Mahoe, **Toko Tephra Sub-group** comprises at least 35 tephra beds, with as many proportionately thinner medial and/or ashy inter-beds. However near Inglewood, only c.10 tephra beds occur with proportionately thicker medial inter-beds. In South Taranaki and on the North Taranaki coastal plain, tephra beds of **Toko Tephra Sub-group** are only rarely visible in a profile that comprises almost entirely of medial material.

Age

The age range of **Toko Tephra Sub-group** is determined from the position of radiocarbon dated peats and woods with respect to constituent tephra formations and the rhyolitic chronohorizon - Waimihia Tephra. On this basis, **Toko Tephra Sub-group** has an estimated age ranging between c.3.0 kyrs B.P. (see Manganui tephra; this Chapter) and c.11.5kyrs B.P. (see Mahoe Tephra; this Chapter).

2.2.2 Manganui tephra (informal formation)

Manganui tephra was first recognised and mapped on the upper and lower eastern flanks of Egmont Volcano by Neall in unpublished work subsequent to his 1972 publication. It was Whitehead (1976) however, who informally named Manganui tephra after the Manganui River that flows eastwards from Egmont Volcano, crossing State Highway 3 just north of Midhurst.

On the upper eastern flanks of Egmont Volcano, Manganui tephra comprises a closely spaced set of four lithic coarse ash and lapilli beds separated by up to 0.10m of hydrous or medial material (e.g. **Section** 1 of Figure 2.05). These beds are here informally named **Mg.a** to **Mg.d** in order of decreasing age. On the lower eastern flanks only **Mg.a**, **Mg.c** and **Mg.d** are clearly identified as layers, either merging together or separated by thin (<0.02m) medial material.

Criteria

Units of Manganui tephra comprise profuse, firm, finely vesicular scoriaceous and very firm lithic coarse ash and lapilli which are moderately well to poorly sorted. It is massive to shower bedded and dark greyish brown (10YR 4/2), grey (10YR 5/1 - 4/1) and dark grey (7.5YR N4/) in colour.

Reference Sections

A type section is yet to be defined by other researchers, but a reference section is here designated as Stratford Mountain Road at P20/055103, (1,040m altitude). The upper part of this section was previously described by Druce (1966, p.38) (**Section 1** of Appendix 1 and Figure 2.05).

Maketawa tephra

0.00m ------------- Distinct and wavy boundary ---------------

0.08m	Dark brown (10YR 3/3), firm, weakly developed coarse blocky structured hydrous material. Sharp and wavy boundary.
0.31m **Mg.d**	Profuse, very firm to firm, shower bedded moderately sorted to poorly sorted, grey, very dark grey, greyish brown and dark greyish brown, fine to coarse lapilli. Sharp and wavy boundary.
0.02m	Dark yellowish brown (10YR 3/6), very firm, weakly developed coarse blocky structured medial material. Sharp and wavy boundary.
0.11m **Mg.c**	Profuse, unstratified, loose, moderately sorted, very dark grey (7.5YR N3/) fine to medium lapilli. Many very fine reddish yellow (7.5YR 6/8) rootlets. Sharp and wavy boundary.
0.11m	Brown to dark brown (10YR 5/3 - 4/3), very firm, massive structured hydrous material. Sharp and wavy boundary.
0.06m **Mg.b**	Profuse, loose, moderately well sorted, very firm, dark grey (7.5YR N4/), coarse ash grading downwards to reddish -yellow (7.5YR 6/8) coated fine grey lapilli. Distinct and wavy boundary.
0.04m	Dark brown (10YR 3/3), firm, weakly developed, coarse blocky structured hydrous material. Sharp and broken boundary.
0.10m **Mg.a**	Profuse, unstratified, moderately well sorted, dark greyish brown fine lapilli. Sharp and broken boundary.
0.04m	Dark brown (10YR 3/3), firm, moderately developed, coarse blocky structured hydrous material. Indistinct and wavy boundary.
0.19m	Greyish brown (10YR 5/4), firm, weakly developed, coarse blocky structured, hydrous material. Common, medium to coarse red (5YR 5/8) mottles. Sharp and irregular boundary.

0.01m	Very firm, red (5YR 5/8) Pan. Sharp and irregular boundary.
0.11m	Brown (10YR 5/3), firm, weakly developed, coarse blocky structured hydrous material. Few dispersed coarse, very pale brown pumiceous lapilli towards base.

1.18m ------------- Abrupt and wavy boundary -------------------

Il.b of **Inglewood Tephra**

Ten further reference localities are here designated for Manganui tephra.

1. Prominent road cut, North Egmont Mountain Road (P20/046152). (**Section 2** of Appendix 1 and Figure 2.05).

2. Deep drain on farm property 0.56km north of Denbigh Road, 6.1km west of junction with State Highway 3 (Q20/129112). (**Section 3** of Appendix 1 and Figure 2.05).

3. West facing road cut, 100m north of stream bridge, Upper Palmer Road, 1.4km above the junction with Opunake Road, (Q20/108038) (**Section 4** of Appendix 1 and Figure 2.05).

4. Prominent north facing road cut on Opunake Road 0.5km west of Mangatoki Stream bridge and 0.9km east of the junction of Opunake Road with Upper Palmer Road (Q20/119027). This section was originally described by Franks (1984) and subsequently reinterpreted (this study). (**Section 6** of Appendix 1 and Figure 2.05).

5. Farm cutting in contoured stream valley, c.150m south-east from the milking shed, Bains Property, Tariki Road (Q20/192194). (**Section 12** of Appendix 1 and Figure 2.05).

6. Driveway cutting on Inglewood Marae, 100m south of Inglewood BMX track and opposite Catholic School playground (Q19/147267). (**Section 13** of Appendix 1 and Figure 2.05).

7. Drain in paddock, 100m west of Kaimata Road, c.0.6km south along Kaimata Road from Junction Road (Q19/216257). (**Section 20** of Appendix 1 and Figure 2.05).

8. South facing road cut, junction of Bristol and Kaimata Roads (Q19/213296). (**Section 22** of Appendix 1 and Figure 2.05).

9. Wave cut bank, west end of Onaero Beach, 0.4km west of Sutton Road (Q19/268448). (**Section 29** of Appendix 1 and Figure 2.05).

10. Cutting on beach behind Waitara Surf Lifesaving Clubrooms, Onaero River mouth (Q19/282449). (**Section 31** of Appendix 1 and Figure 2.05).

Upper and Lower Contacts

Throughout the eastern and north-eastern lower flanks of Egmont Volcano, the upper contact of Manganui tephra is nearly always topsoil developed on the present day ground surface (e.g. **Sections** 6, 10 and 13 of Figure 2.05). However within and directly adjacent to Egmont National Park the thin coarse ash and lapilli beds of Druce (1966) and their inter-beds of medial/hydrous material, overlie Manganui tephra (e.g. **Sections** 1, 3 and **4** of Figure 2.05). The lower contact of Manganui tephra is separated from either Inglewood Tephra or Ngatoro Formation (Neall 1979) below, by <0.05m of medial material (Figure 2.05). Manganui tephra is interstratified by at least two units of Te Popo debris flows (e.g. **Section** 3 of Figure 2.05).

Age

At Ahukawakawa Swamp (P20/008167), a minimum radiocarbon date (NZ3423A) of 2890 +/- 100 years B.P. was obtained from peat c.1.25m above the upper contact of Manganui tephra. Also, at the same site, a maximum age (NZ3139A) of 3,320 +/- 60 years B.P. is established from radiocarbon dating of peat c.1.9m beneath the lower contact of Manganui tephra (McGlone *et al*. 1988). From a peat accumulation rate between the two radiocarbon dates, Manganui tephra is here estimated to have an age of between 3,050 - 3,100 years B.P.

Isopachs

An isopach map has been constructed for a combined total thickness of Manganui tephra (Figure 2.06). Isopach data by Whitehead (1976) indicates three principal axes of distribution extending to the north, east, and south-east of Egmont Volcano, from Fanthams Peak. The 0.10m isopach extends through Egmont Village and Inglewood in the north-eastern sector to just south of Tariki in the eastern sector and finally through Cardiff and Rowan in the south-eastern sector.

This study, firstly, confirms the previous isopach data for the northern and eastern sectors and secondly, extends its known distribution further east and north-eastward. Beyond the 0.10m isopach, Manganui tephra progressively thins to smaller and fewer lapilli that become increasingly mixed with pumiceous lapilli of Inglewood Tephra that are dispersed in medial material just below the topsoil (e.g. **Sections 13** and **22** of Figure 2.05).

East beyond the Egmont ring plain and on the North Taranaki coastal plain, Manganui tephra is rarely obvious as a macroscopic layer but it is commonly seen as a single lithic coarse sandy ash and fine lapilli layer within peat and estuarine deposits (e.g. **Sections 20** and **28** of Figure 2.05).

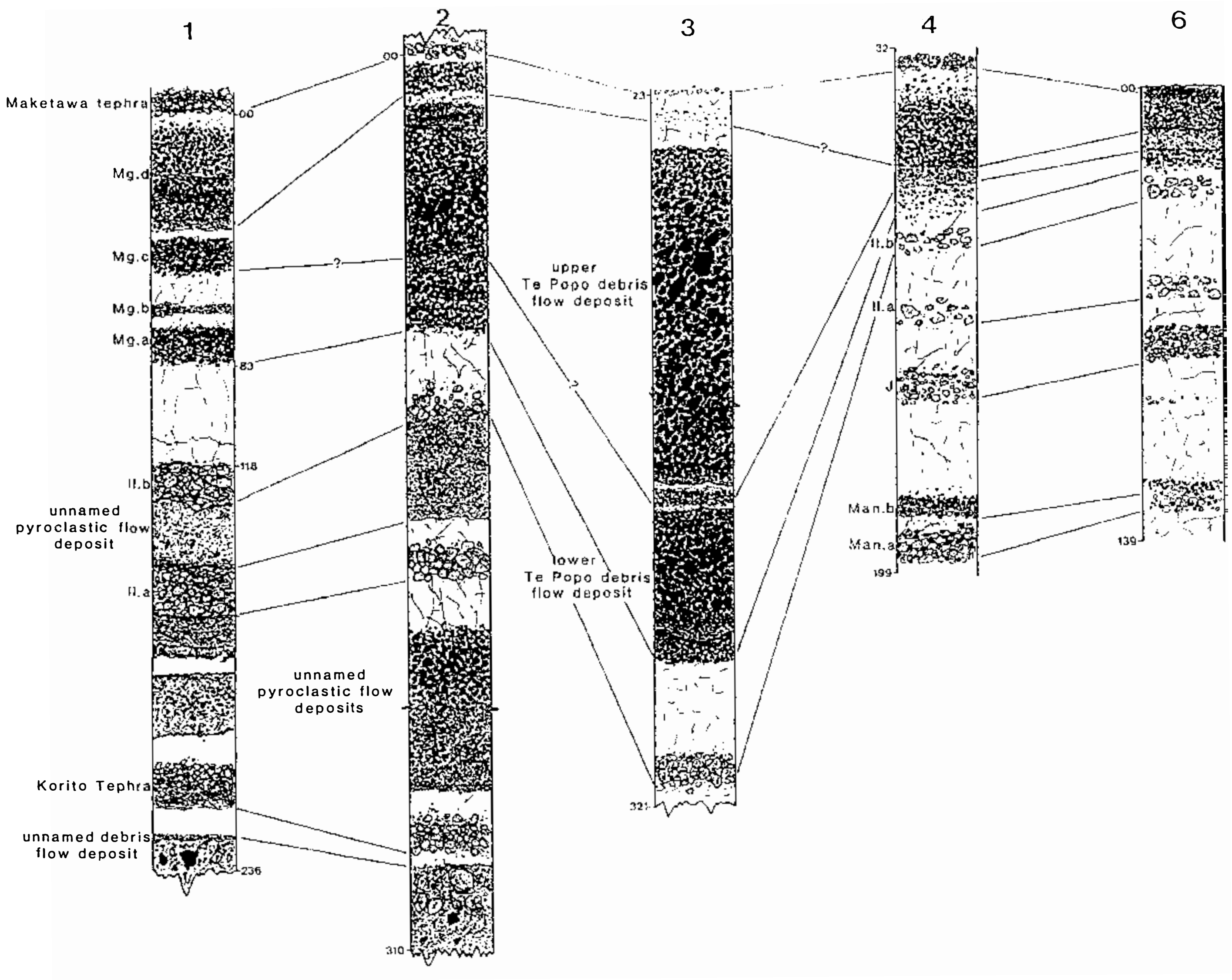
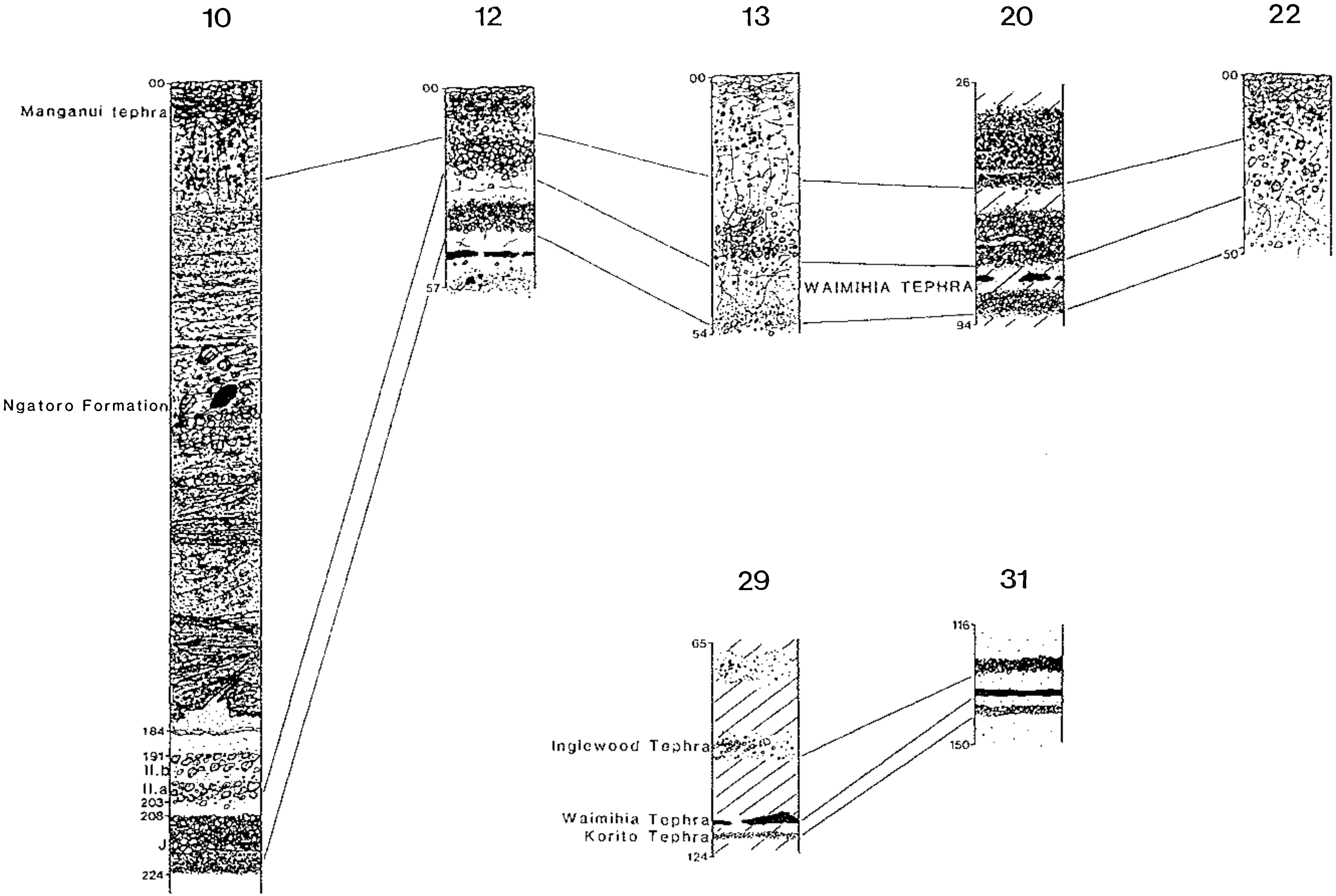


FIG. 2.05 Correlation Columns of Manganui tephra, Inglewood and Korito Tephra


10
12
13
20
22
00
Manganui tephra
Ngatoro Formation
184
191
II.b
II.a
203
208
J
224
00
57
00
54
26
94
WAIMIHIA TEPHRA
00
50
29
31
65
Inglewood Tephra
Waimihia Tephra
Korito Tephra
124
116
150

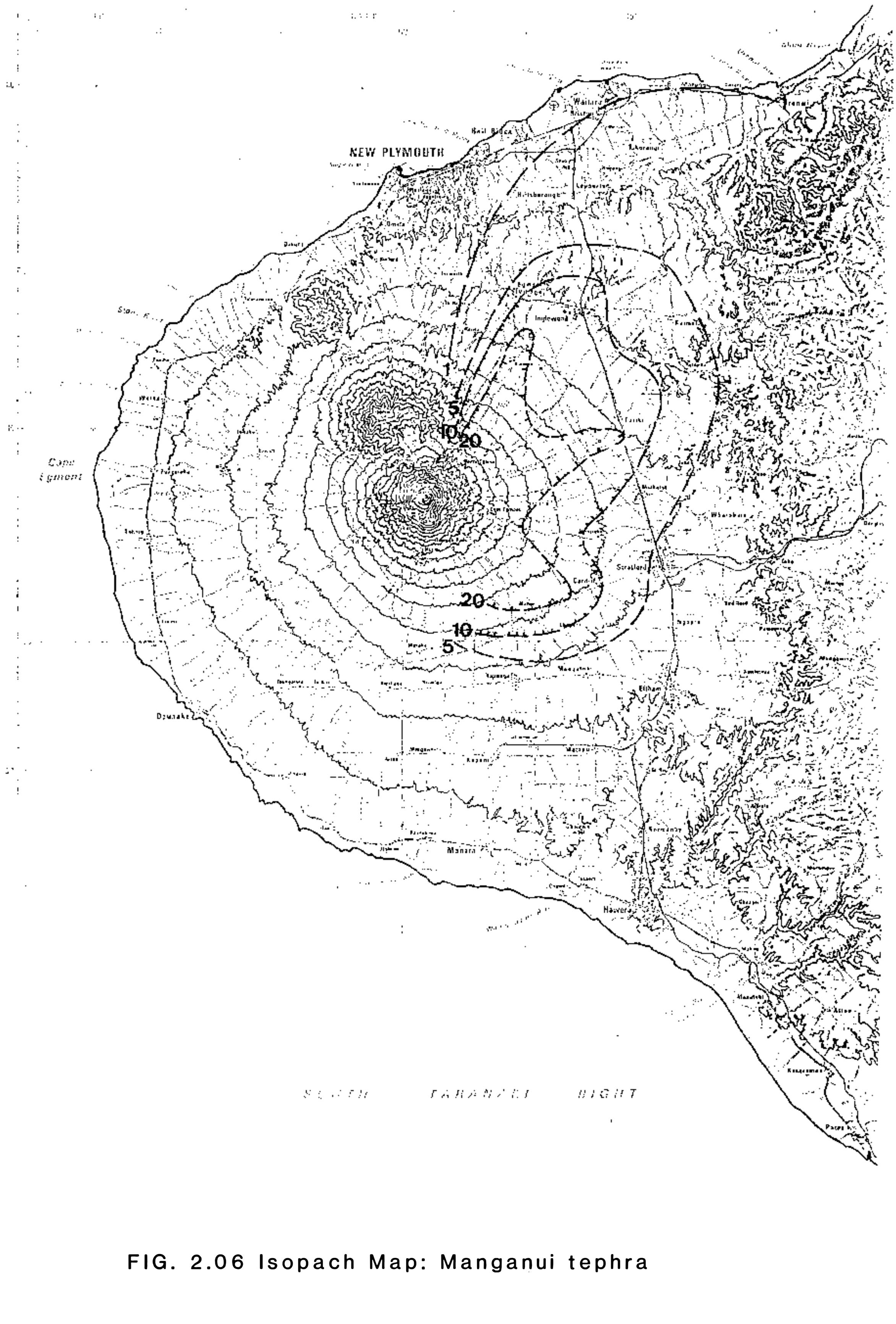


FIG. 2.06 Isopach Map: Manganui tephra

2.2.3 Inglewood Tephra

(Neall 1972; redefined in this study)

Formally named by Neall (1972) after the township 15km south-east of New Plymouth. Inglewood Tephra was first described on the north-eastern lower flanks of Egmont Volcano as -
"....a single creamy pumiceous lapilli bed containing blocks near to source ... whose upper contact is nearly always topsoil developed on the present day ground surface".

Type Section

The type section was designated by Neall (1972) on Maude Road, 0.2km above the junction with Kent Road (N109/673752). The Inglewood Tephra is here further defined on the eastern lower flanks of Egmont Volcano, to include two prominent closely spaced pumiceous lapilli beds here informally named **Il.a** and **Il.b** in order of decreasing age (Plate 2.01). On the lower flanks of Egmont Volcano both units are separated by <0.14m of medial material which thins with distance from source. The two units of Inglewood Tephra merge to form a single regional tephra marker. Where this occurs, constituents of **Il.a** are indistinguishable from those of **Il.b.** On the upper flanks of Egmont Volcano, **Il.b** and **Il.a** are separated by a thin 'pyroclastic density current' deposit (an informal term encompassing both pyroclastic flow and surge; Siebert et al. 1987) (e.g. **Sections 1** and **2** of Appendix 1; Plates 2.02 and 2.03, respectively).

Criteria

Throughout the lower eastern flanks of Egmont Volcano both **Il.a** and **Il.b** of Inglewood Tephra are similar in appearance, comprising dominantly 'creamy' white (10YR 8/2) sub-angular to sub-rounded pumiceous lapilli and blocks with minor sub-angular dense light grey (7.5YR N6/) to grey (10YR 5/1 - 4/1) lapilli (Plate 2.01).

Reference Localities

Thirteen new reference localities have been designated for Inglewood Tephra, of which eleven are the same as those designated for Manganui tephra (**Sections 1, 2, 3, 4, 6, 12, 13, 20, 22, 29** and **31** of Appendix 1 and Figure 2.04). The other two designated localities are described as follows -

1. Newly cut drainage channel 0.1km north of farm track and 0.2km north-west of Rawhitiroa Road, (Q20/318962) (**Section 26** of Appendix 1).

2. West facing road cut on State Highway 3 at Tariki railway overpass, opposite junction with Johns Road; (Q20/167202) (**Section 10** of Appendix 1 and Figure 2.05; Plate 2.01). Here at this section the following section is exposed:

c.1.45m **Ngatoro Formation**	Moderately to poorly sorted, massive (upper portion) to stratified (lower portion), inversely graded sub-units of light greyish brown to greyish brown (10YR 6/2 to 5/2) angular to sub-rounded gravels supported in a very firm matrix of pebbly sand of similar lithology. Common pumice layers occur near base of unit which exhibits planar, as well as low angle cross-stratification. Sharp and irregular boundary to <0.20m of firm, well sorted fine sand with flame dewatering structures evident.
1.84m -------------	Sharp and irregular boundary ------------
0.07m	Brownish yellow (10YR 6/6), firmly friable, massive structured medial material. Abrupt and wavy boundary.
0.04m **Il.b**	Abundant, moderately sorted, unstratified, white to very pale brown (10YR 8/2 to 8/4, 7/3) coated red (2.5YR 4/8) fine to coarse pumiceous lapilli. Few to common, very firm grey to dark grey, fine lithic lapilli dispersed throughout. Abrupt and wavy boundary.

0.03m	Pale brown (10YR 6/3), very firm, massive structured medial material that wedges out along section. Distinct and wavy boundary.
0.05m **Il.a**	Abundant to profuse, poorly sorted, unstratified, white to pale brown (10YR 8/2 to 8/4, 7/3) fine to very coarse pumiceous lapilli. Few dispersed fine to medium grey lapilli. Distinct and wavy boundary.
0.05m	Pale brown (10YR 6/3), friable to firm, massive structured medial material. Few to common, fine red (2.5YR 4/8) mottles.

2.08m ------------ Sharp and wavy boundary --------------------

J.b of **Korito Tephra**

Upper and Lower Contacts

On the lower eastern flanks, the upper contact of Inglewood Tephra is separated from either Manganui tephra (e.g. **Section 4** of Figure 2.05; Plate 2.04) or Ngatoro Formation (e.g. **Section 10** of Figure 2.05; Plate 2.01), above, by <0.05m of medial material. In the same vicinity the lower contact of Inglewood Tephra is separated from Korito Tephra below, (e.g. **Section 10** of Figure 2.05; Plate 2.01) by <0.14m of medial material. At infrequently exposed sections, the Central North Island rhyolitic chronohorizon - **Waimihia Tephra** (**Sections 20, 29** and **31** of Figure 2.05) intervenes between Inglewood and Korito Tephras (Plate 2.05).

Age

A radiocarbon date (Wk-1031A) from a peat sample immediately beneath **Il.a** of Inglewood Tephra at west Onaero Beach (**Section 29** of Appendix 1) provides an age of 3,690 +/- 80 years B.P. Another radiocarbon date (NZ3353A) from wood immediately beneath the Ngatoro Formation (Neall 1979) confirms a minimum age of 3,610 +/- 80 years B.P. for the underlying Inglewood Tephra.

On the basis of the above radiocarbon dates, Inglewood Tephra is here considered to have an age of c.3.6 kyr B.P.

Correlation

Franks (1984) considered Inglewood Tephra (Neall 1972) to be principally a correlative of the unit p2 of Druce (1966). On the upper south-eastern flanks of Egmont Volcano, Franks (1984) subdivided unit p2 into two informal members - p2A and p2B. These two informal members are here correlated to **Il.a** and **Il.b** on the lower eastern and south-eastern flanks of Egmont Volcano.

Both **Il.b** and **Il.a** of Inglewood Tephra are correlated with two, thin, closely spaced Egmont sourced tephras named **Eg-2** and **Eg-3** by Lowe (1987) preserved within sediment of Lakes Okaroire and Rotomanuka in the Waikato district. Both **Eg-2** and **Eg-3** have been radiocarbon dated (Wk-539A and Wk-540A, respectively) at 3,610 +/-60 and 3,750 +/- 70 years B.P., respectively.

Isopachs

An isopach map has been constructed to combine both Il.**a** and **Il.b** of Inglewood Tephra. This isopach map shows the principal axis of distribution as a well defined lobe extending from Egmont Volcano towards the north-eastern sector (Figure 2.07). In this sector the 0.2m isopach extends through Egmont Village, Inglewood and a point midway between Tariki and Inglewood. This particular isopach separates pumiceous material nearer to source, from pumiceous-medial material further away from source i.e. to the north-east.

Beyond the 0.15m isopach, Inglewood Tephra progressively thins to smaller and fewer lapilli that become increasingly dispersed in a matrix of medial material and/or mixed with constituents of Korito Tephra, below (e.g. **Section 22** of Figure 2.05).

East beyond the Egmont ring plain and on the northern coastal plain, Inglewood Tephra is rarely obvious as a macroscopic layer within or near the topsoil. However Inglewood Tephra, like Manganui tephra, is commonly observed as a single layer of fine pumiceous lapilli within peat and estuarine deposits (e.g. **Sections 20, 29** and **31** of Figure 2.05).

Plate 2.01: **Inglewood** and **Korito Tephra** overlain by **Ngatoro Formation** and underlain by **Tariki Tephra** at Tariki Under-pass (Section 10; Q20/167202).

Plate 2.02: **Inglewood** and **Korito Tephra** with intercalating unnamed pyroclastic density current deposits on Stratford Plateau Road (Section 1; P20/055103).

Plate 2.03: **Inglewood** and **Korito Tephra** with intercalating unnamed pyroclastic density current deposits. Note **Manganui tephra** above **Inglewood Tephra** and unnamed debris flow deposit below **Korito Tephra** (Section 2; P20/046152).

Plate 2.04: **Inglewood** and **Korito Tephra** with medial inter-beds. Note **Manganui tephra** closely overlying **Inglewood Tephra** (Section 4; Q20/108038).

Plate 2.05: **Inglewood**, **Korito**, **Tariki** and **Waipuku Tephra** interbedded by bluish-grey muds. Note pinkish coloured **Waimihia Tephra** between **Inglewood** and **Korito Tephra** (Section 31: Q19/282449).

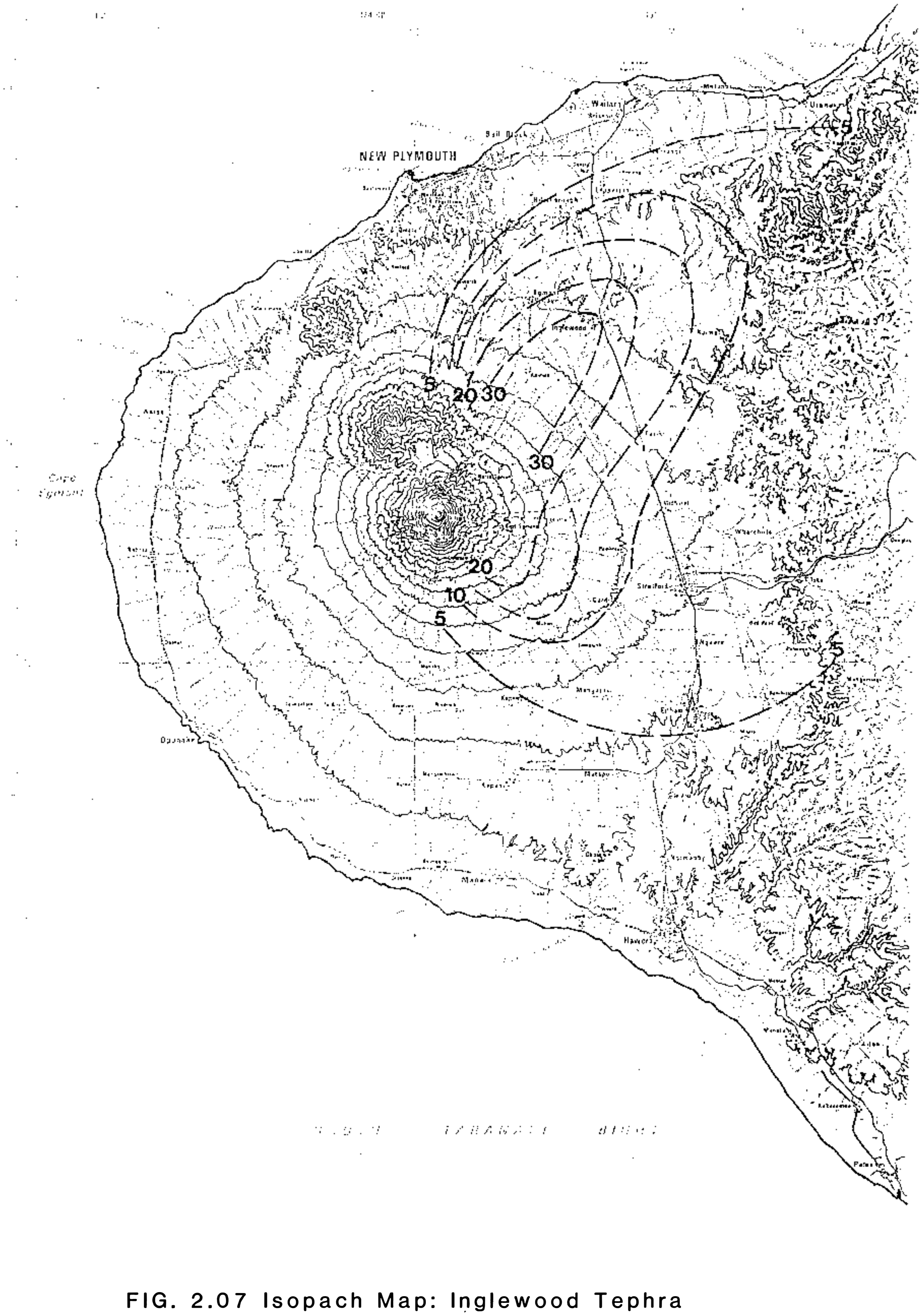


FIG. 2.07 Isopach Map: Inglewood Tephra

2.2.4 Korito Tephra
(Neall 1972)

The next tephra marker bed beneath Inglewood Tephra is Korito Tephra (Neall 1972). This tephra was named after Korito Road on the lower north-eastern flanks of Egmont Volcano, where the formation was first described as -

"... a distinctive pale yellow coarse ash devoid of fine ash which occurs as pockets in most road cuts between Korito Road and Inglewood. "

Type Section

The type section was designated by Neall (1972) at the same locality as that for Inglewood Tephra.

Criteria

Throughout the eastern flanks of Egmont Volcano, Korito Tephra is recognised in this study, as comprising **two** distinctive tephra layers, here informally named **J.a** and **J.b** (Plates 2.01 and 2.02). The intervening boundary between the layers is sharp and wavy. The lower layer (**J.a**) is distinguished by yellow (10YR 7/6) moderately sorted, pumiceous lapilli (devoid of coarse ash and lithic lapilli) that grades upwards to a very distinctive, 'olive - yellowish' and black speckled pumiceous coarse ash. **J.a** is directly overlain by the thicker upper layer (**J.b**) which comprises moderately sorted, yellow (10YR 7/6) coated, white (10YR 8/2) pumiceous lapilli with blocks near to source.

Reference Localities

Twelve new reference localities have been designated for Korito Tephra throughout the eastern lower flanks of Egmont Volcano. These localities are the same as those designated for Inglewood Tephra (**Sections 1, 2, 4, 6, 10, 12, 13, 20, 22, 26, 29** and **31** of Appendix 1). Korito Tephra at **Section 10** is exposed as follows:

Il.a of Inglewood Tephra

2.03m ------------- Abrupt and wavy boundary -------------------

0.05m	Pale brown (10YR 6/3), friable to firm, moderately developed, medium blocky structured medial material with few to common, fine red (2.5YR 4/8) mottles. Sharp and wavy boundary.
0.10m **J.b**	Uppermost boundary marked by a well cemented (<0.01m thick) red (2.5YR 4/6) Iron pan. Sharp and wavy boundary. Moderately sorted, faint normal graded, fine to coarse (few very coarse) light grey to very pale brown (10YR 7/2 - 7/3) coated yellow (10YR 8/6,8/8 and 7/8) pumiceous lapilli, abundantly dispersed in a subordinate coarse 'sandy' pumiceous ash matrix. Sharp and wavy boundary.
0.06m **J.a**	Moderately well sorted, profuse, firm fine (few medium) yellow (10YR 8/8) pumiceous lapilli and coarse ash grading upwards to well sorted stippled white (10YR 8/2) to yellow (10YR 8/8) fine to medium 'sandy' pumiceous ash. Sharp and wavy boundary.
0.12m	50% brown (10YR 5/3) and 50% dark yellowish-brown (10YR 4/6) mottled, friable, moderately developed, fine to medium blocky structured, medial material.

2.36m ------------- Sharp and broken boundary ------------------

W.f of Tariki Tephra

Upper and Lower Contacts

On the lower eastern flanks, Korito Tephra is separated from either Inglewood Tephra or Waimihia Tephra above, by <0.14m of medial material. In the south-east lower flanks, the lower contact of Korito Tephra is separated from Mangatoki Tephra below, by <0.50m of medial material (e.g. **Sections 4** and **6** of Figure 2.05) but in the eastern and north-eastern sectors (e.g.

Sections 10 and **12** of Figure 2.05) the lower contact is separated from Tariki Tephra below, by <0.10m of medial material.

Age

At Kaimata and west Onaero Beach (**Sections 20** and **29** of Appendix 1) two radiocarbon dates (NZ6702A and Wk-1032A) of 3,580 +/- 80 and 3,870 +/- 110 years B.P., were respectively obtained from midway in the variably thick peat between Korito Tephra and the overlying Waimihia Tephra. The older of these two dates provides a minimum age for Korito Tephra.

A further radiocarbon date (Wk-1033A) of 4,150 +/- 100 years B.P. was obtained from peat immediately beneath Korito Tephra at west Onaero Beach (**Section 29** of Appendix 1) and provides a maximum age for Korito Tephra.

Correlation

Korito Tephra is here directly correlated to the **p1** of Druce (1966) and Franks (1984) and correlated with the c.4.1 kyr B.P. **Eg-4** preserved within sediments of Lakes Rotomanuka and Okaroire of the Waikato district (Lowe 1987).

Isopachs

An isopach map (Figure 2.08) combining both layers of Korito Tephra shows a similar but less widespread northeastly distribution to that of Inglewood Tephra. The 0.10m isopach located in the vicinity of Inglewood, separates pumiceous-ashy material from medial-pumiceous material. Beyond the 0.10m isopach, Korito Tephra thins markedly forming thin, discontinuous pockets of unstratified coarse ash and lapilli, which beyond the 0.10m isopach generally become dispersed in a dominant matrix of medial material and mixed with the pumiceous constituents of Inglewood Tephra above, and Tariki Tephra below. Here, Korito Tephra is dispersed just below the topsoil as distinctive white euhedral specks or 'ghost grains' within unnamed medial material (e.g. **Section 22** of Figure 2.05). Beyond the Egmont ring plain, Korito Tephra is only observed macroscopically as a single, thin, fine ash at sites in peat and/or estuarine sediments (e.g. **Sections 20, 29** and 31 of Figure 2.05).

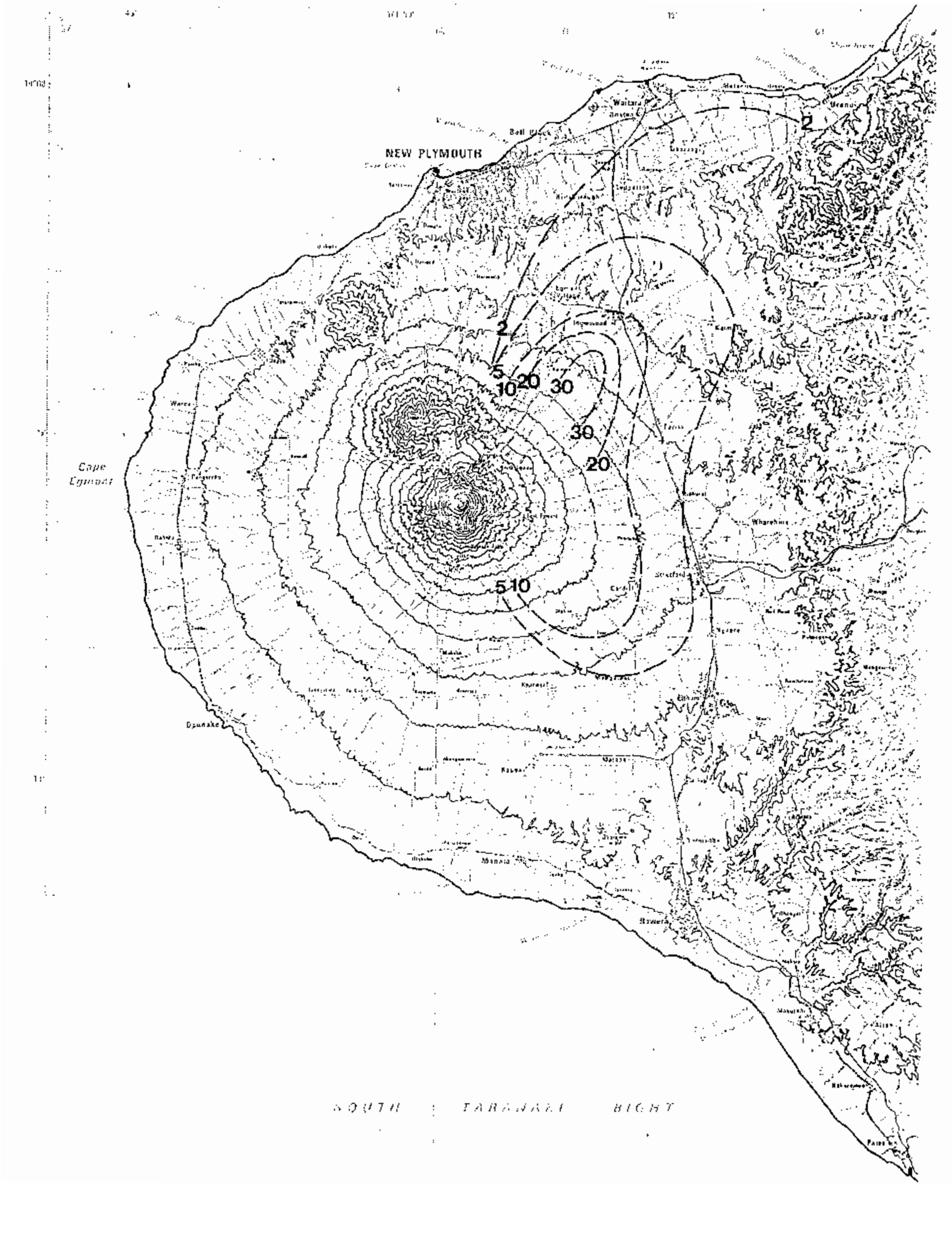


FIG. 2.08 Isopach Map: Korito Tephra

2.2.5 Mangatoki Tephra
(new formation)

Below Korito Tephra in the south-eastern sector, is a new tephra formation named Mangatoki Tephra after Mangatoki Stream that flows south-east from Egmont Volcano, crossing Opunake Road 0.9km east of Mahoe.

First recognised and informally named **E5 tephra unit** by Franks (1984), Mangatoki Tephra is identified here, as comprising **two** closely spaced lapilli beds, which are informally named **Man.a** and **Man.b** (Plate 2.06). Both units in the vicinity of Mahoe, are separated by <0.04m of **medial material**. Nearby in a south-easterly direction from Egmont Volcano this medial material rapidly thins out, so that both units of Mangatoki Tephra merge together (Plate 2.07).

Type Section

An informal type section was designated by Franks (1984) on an east-facing road cut adjacent to Mangatoki Stream bridge on Upper Palmer Road (N119/746545). No stratigraphic or descriptive details were provided by Franks. Since this section has been destroyed by road reconstruction a formal type section is established in a west-facing road cutting 0.10km further north (see **Section 4** of Appendix 1 and Figure 2.09; Plate 2.06). Here Mangatoki Tephra is exposed as follows:

J.a of **Korito Tephra**

1.36m ------------- Distinct and wavy boundary ----------------

0.30m	Yellowish brown (10YR 5/6), firmly friable, weakly developed, fine to medium blocky structured medial material. Sharp and wavy boundary.

0.08m **Man.b**	Moderately well sorted, profuse, very pale brown to yellow (10YR 8/4 - 8/6), brown to dark brown (7.5YR 4/4), coated fine to medium pumiceous lapilli. Many light grey to grey (10YR 7/1 to 5/1) fine to medium lapilli dispersed throughout. Distinct and wavy boundary.
0.04m	As per 1.36 - 1.66m interval. Common, fine pumiceous lapilli dispersed throughout. Wedging. Distinct and wavy boundary;
0.13m **Man.a**	Moderate to poorly sorted, abundant, very pale brown (10YR 8/3 - 8/4), granule to very coarse pumiceous lapilli. Common, grey, fine to medium lithic lapilli dispersed throughout. Distinct and wavy boundary.
0.12m	Yellowish brown (10YR 5/6), moderately developed, fine to medium blocky structured medial material.

2.07m ------------- Distinct and wavy boundary ----------------

W.f of **Tariki Tephra**

Upper and Lower Contacts

The uppermost unit of Mangatoki Tephra (**Man.b**) is separated from **Korito Tephra** above, by <0.30m of medial material (e.g. **Section** 4 of Figure 2.05). Occasionally a thin unnamed lapilli bed may interstratify this medial material (e.g. **Section 6** of Figure 2.04). The lower unit (**Man.a**) is separated from **Tariki Tephra** below, by <0.15m of medial material (e.g. **Section 4** and **6** of Figure 2.09).

Age

A radiocarbon date (Wk-1033A) from a peat sample immediately beneath Korito Tephra at west Onaero Beach (**Section 29** of Appendix 1) indicates a minimum age of 4,150 +/- 100 years B.P. Another radiocarbon date (Wk-1034A) of a peat sample between tephra layers of Tariki Tephra at the same site as above, indicates a maximum age of 4,590 +/- 100 years B.P. for Mangatoki Tephra. On the basis of these radiometric dates, Mangatoki Tephra has an age range of between c.4.1 and 4.6 kyr B.P. In this study Mangatoki Tephra is considered to have a probable age of c.4.4 kyr B.P.

Correlation

Mangatoki Tephra is directly correlated to the informally named **E5 tephra unit** of Franks (1984). **E5 unit** was described by her in the south-eastern sector as comprising three informal members -

"... an upper bed of profuse, spalling, grey (10YR 5/1) pumiceous lapilli with subordinate lithic lapilli. A middle bed of speckled dark yellowish-brown (10YR 4/4) coarse ash and a basal white (10YR 8/1) pumiceous lapilli with subordinate lithic lapilli ...".

The middle member of Franks **E5 unit** is correlated to the medial material which intervenes between **Man.a** and **Man.b** of Mangatoki Tephra.

Isopachs

Franks (1984) mapped the upper and lower members of **E5 unit** (now recognised as **Man.b** and **Man.a**, respectively) south-eastwards from Egmont Volcano. The interpreted axes of distribution were interpreted to extend through Mahoe and Lowgarth, with the 0.10m isopach passing through Kaponga and Stratford. Northwards from the axes of distribution both units of Mangatoki Tephra merge and thin, so that north of Tariki the tephra is not obvious as a macroscopic layer. Similarly, the medial material enveloping Mangatoki Tephra between Korito Tephra above, and Tariki Tephra below, also thins from 0.49m near Mahoe to 0.12m at Tariki Underpass on State Highway 3.

Reference Localities

Franks (1984) designated three reference localities for **E5 unit** (now Mangatoki Tephra) but again supplied no stratigraphic or descriptive details. A reference locality is designated here as -

A prominent north-facing road cut on Opunake Road, 0.5km west of Mangatoki Stream bridge and 0.9km east of the junction of Opunake Road with Upper Palmer Road (**Section 6** of Appendix 1). This section is also the reference locality for Manganui, Inglewood and Korito tephras.

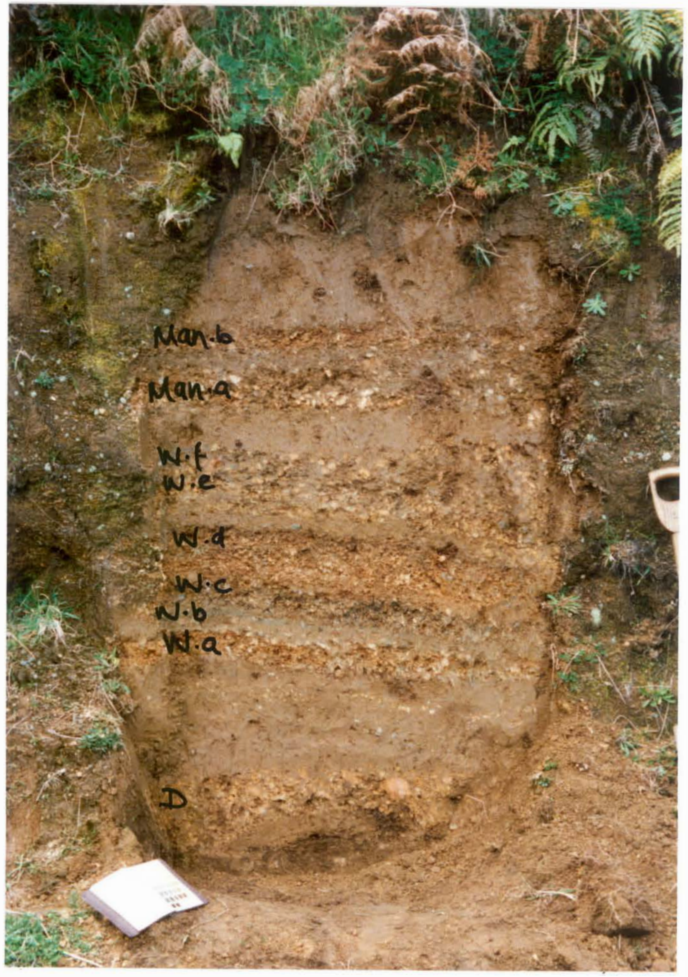


Plate 2.06: **Mangatoki** and **Tariki Tephra** at their type section on upper Palmer Road (Section 4; Q20/108038). Note unnamed tephra and **Waipuku Tephra** below **Tariki Tephra**.

Plate 2.07: **Mangatoki**, **Tariki** and **Waipuku Tephra** near Mangatoki Stream on Opunake Road (Section 6; Q20/119027).

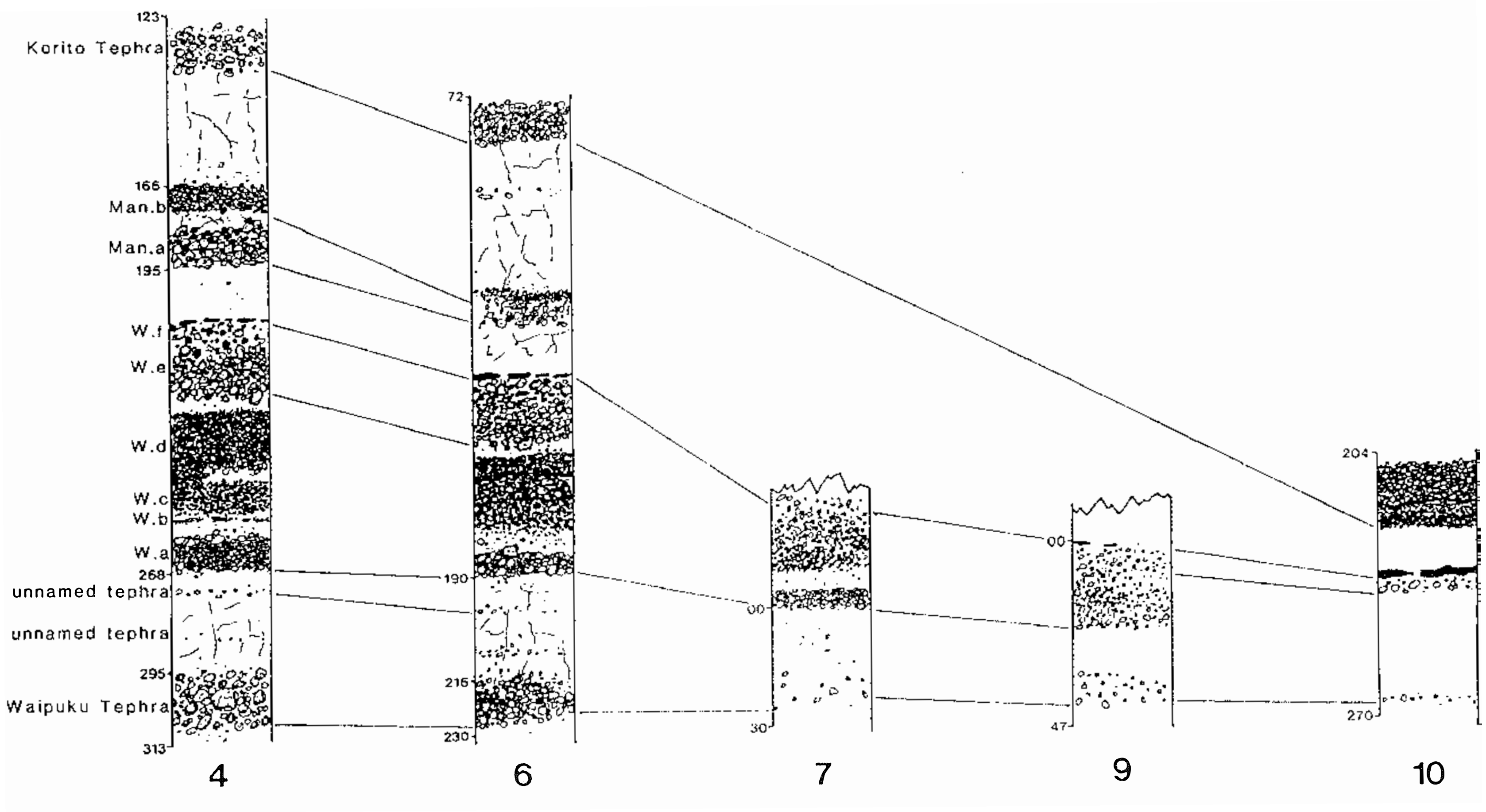
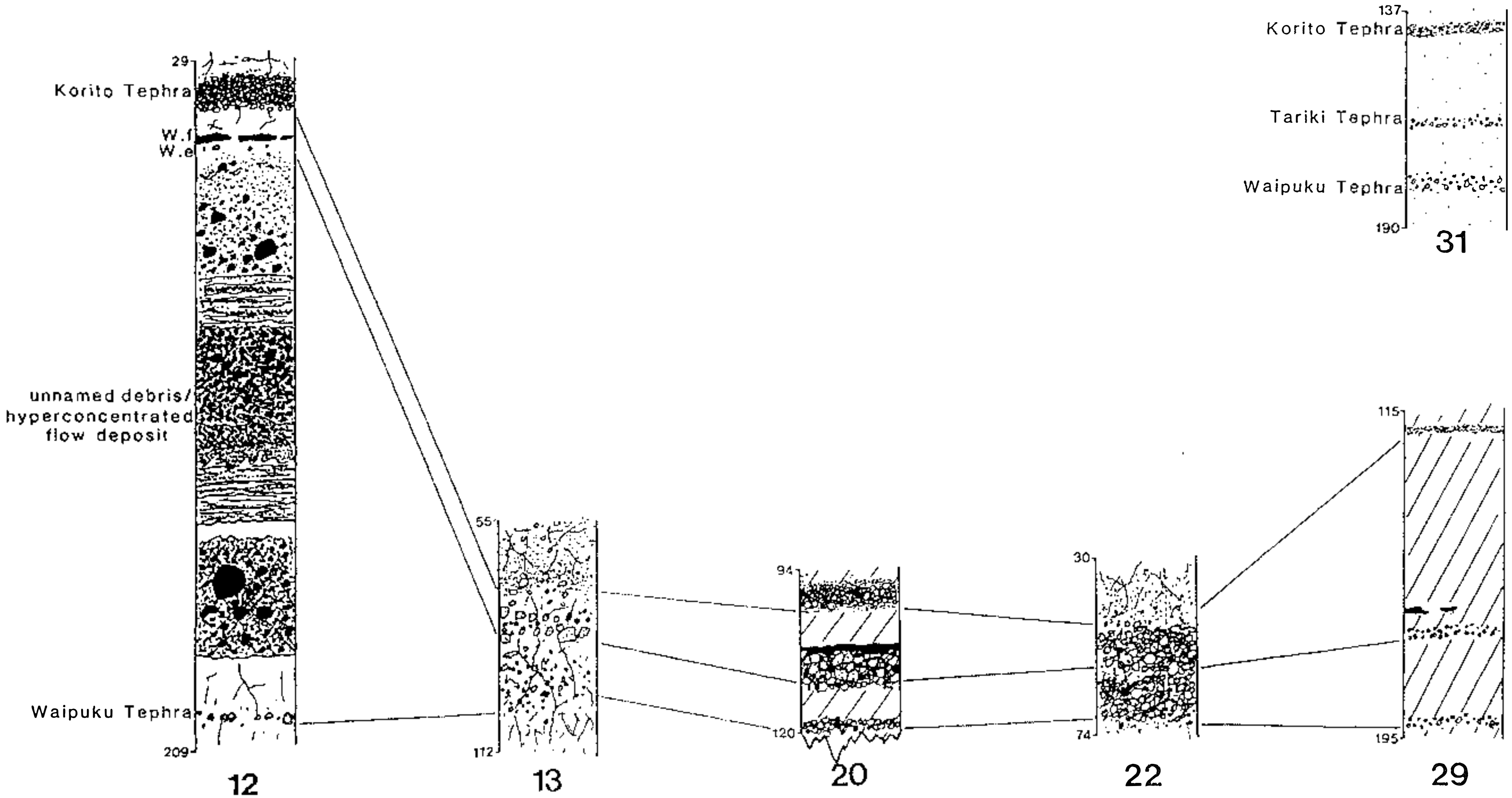


FIG. 2.09 Correlation Columns of Mangatoki , Tariki and Waipuku Tephra



Korito Tephra
W.f
W.e
unnamed debris/
hyperconcentrated
flow deposit
Waipuku Tephra
29
209
12
55
112
13
94
120
20
30
74
22
115
195
29
137
Korito Tephra
Tariki Tephra
Waipuku Tephra
190
31

2.2.6 Tariki Tephra
(new formation)

Tariki Tephra, a new formation, is named after the community of Tariki located 10km south-east from Inglewood on State Highway 3. On the lower south-eastern flanks of Egmont Volcano, Tariki Tephra comprises at least **six** closely spaced coarse ash and lapilli beds separated by <0.03m of ashy and medial material containing few dispersed lapilli (Plate 2.07). The beds are here informally named **W.a** to **W.f** in order of decreasing age. On the lower north-eastern flanks, only **W.e** and **W.f** of Tariki Tephra are clearly identified as layers (Plate 2.08).

Type Section

The type section is designated as a -

> West-facing prominent road cut 0.1km north of stream bridge, Upper Palmer Road, 1.4km above junction with Opunake Road (**Section 4** of Appendix 1 and Figure 2.09). This type section is the same as that designated for Mangatoki Tephra and the type area lies within a 2km radius from the type section.

Man.a of Mangatoki Tephra

1.95m ------------- Sharp and wavy boundary -----------------

0.12m	Yellowish brown (10YR 5/6), firm, moderately developed, fine to medium blocky structured medial material. Distinct and wavy boundary.
0.01m **W.f**	Moderately well sorted, very firm, grey to very dark grey, fine lithic ash creamcakes. Sharp and broken boundary.
0.18m **W.e**	Well sorted, many, medium to coarse yellow (10YR 8/6 to 8/8) pumiceous lapilli and many soft grey (7.5YR N4/) lithic lapilli grading downwards to profuse, moderately sorted dominantly yellow fine to coarse pumiceous lapilli. Sharp and wavy boundary.

0.03m	Brown (10YR 5/3), firm, weakly developed, medium blocky structured ashy material. Sharp and wavy boundary.
0.17m **W.d**	Profuse, moderate to poorly sorted, fine to coarse, very pale brown to yellow (10YR 8/4 to 8/6,7/6) pumiceous lapilli; with dispersed common dark grey (7.5YR N4/) fine lithic lapilli throughout. Grades upward to abundant, moderately well sorted, lithic coarse ash and fine lapilli with common dispersed fine pumiceous lapilli throughout. Sharp and wavy boundary;
0.01m	Yellowish brown (10YR 5/4), firm, massive structured ashy material. Distinct and wavy boundary.
0.09m **W.c**	Profuse, moderately sorted, fine to medium, grey (10YR 6/1 to 5/1) lapilli with common fine to medium yellow pumiceous lapilli dispersed throughout. Sharp and wavy boundary.
0.01m	As per 2.42 - 2.43m interval. Sharp and broken boundary.
0.01m **W.b**	Discontinuous, well sorted, light grey to grey (7.5YR N6/) coarse ash. Sharp and broken boundary.
0.03m	Yellowish brown (10YR 5/6), firm, massive structured medial material. Sharp and wavy boundary.
0.07m **W.a**	Profuse, moderately well sorted, fine to coarse, very pale brown (10YR 8/4), coated yellow (10YR 7/6) pumiceous lapilli. Common light grey to grey (10YR 6/1 - 5/1) fine to medium, lapilli dispersed throughout. Sharp and wavy boundary.
0.05m	Strong brown (7.5YR 5/6), friable, moderately developed, fine to medium blocky structured medial material. Indistinct and irregular boundary.
0.03m	Common, moderately sorted, fine to coarse yellow (10YR 8/6 - 7/8) pumiceous lapilli dispersed in a matrix of medial material. Distinct and irregular boundary.

0.19m As per 2.64 - 2.69m interval. Few grey (7.5YR N6/) medium to coarse lapilli dispersed throughout.

2.95m ------------- Distinct and wavy boundary ----------------

Waipuku Tephra (D)

Upper and Lower Contacts

On the lower south-eastern flanks of Egmont Volcano, uppermost Tariki Tephra (**W.f**) is separated from Mangatoki Tephra above, by <0.15m of medial material. In the same vicinity, lowermost Tariki Tephra (**W.a**) is separated from Waipuku Tephra below, by <0.30m of medial material (e.g. **Sections 4, 6** and **7** of Figure 2.09). Two discontinuous and unnamed lapilli layers may occasionally interstratify the medial material between Tariki and Waipuku Tephras.

On the lower eastern and north-eastern flanks, where only **W.e** and **W.f** are identified as layers, Tariki Tephra is closely underlain by an unnamed laharic deposit (e.g. **Section 12** of Figure 2.09) and closely overlain by **Korito Tephra** (e.g. **Sections 10** and **12** of Figure 2.09).

Age

A radiocarbon date (Wk-1034A) of a peat sample intervening midway between **W.e** and **W.f** at west Onaero Beach (see **Section 29** of Appendix 1) gives an age of 4,590 +/- 100 years B.P. for the uppermost part of Tariki Tephra. Another radiocarbon date (Wk-1035A) of a peat sample beneath Waipuku Tephra at the same site as above indicates a maximum possible age of 5,260 +/- 90 years B.P. for Tariki Tephra.

On the basis of the above radiometric dates, Tariki Tephra has an apparent age range of between c.4.6 to 5.2 kyrs B.P. However, it is here considered to have a probable age range of between c.4.6 to 4.7 kyrs B.P.

Correlation

In the south-east sector **W.e** and **W.f** correlate with the 'uppermost lapilli member' of the informal **E4 unit** of Franks (1984). **W.d**, **W.c** and **W.b** correlate with the 'central member' of the **E4 unit**, while **W.a** correlates to the 'lowermost lapilli member'. **W.e** is correlated with the c.4.4 kyr B.P. **Eg-5** preserved within lake sediment of the Waikato distict (Lowe 1987).

W.e and **W.f** of Tariki Tephra were first recognised in the north-eastern sector and informally named 'W1 and W2 couplet' by Neall in unpublished work subsequent to his 1972 publication. **W.e** and W.f are the most widespread units of Tariki Tephra on the eastern lower flanks of Egmont Volcano and both extend beyond the Egmont ring plain, where they occur as thin layers generally preserved in peat, estuarine or lacustrine sediments. Because of their value in correlation W.f and **W.e** are here designated as formal members.

Member - **W.f**

Criteria

Discontinuous layer of firm to very firm, well to moderately well sorted, grey to greyish brown (10YR 5/1 to 5/2), shower stratified to massive, fine to coarse ash (Plate 2.08).

Distribution

W.f shows a lobe of distribution extending north-east from Egmont Volcano with an axis parallel with Norfolk Road (Figure 2.10). A maximum recorded thickness of 0.07m occurs west of State Highway 3 midway between Tariki and Inglewood.

Member - **W.e**

Criteria

In the north-eastern sector, **W.e** comprises unstratified, pale brown to yellow (10YR 7/4 to 7/6), moderately well sorted, firm, pumiceous lapilli with subordinate dense grey lapilli dispersed throughout (Plate 2.08). Towards the south-eastern sector, the proportion of dark grey (10YR 4/1), soft, lapilli increases towards this unit's upper contact (Plate 2.07).

Distribution

W.e exhibits a generally bilobed distribution extending from Egmont Volcano (Figure 2.11). The most prominent lobe shows a north-eastern axis of distribution which is generally parallel with Dudley Road. In the area surrounding Inglewood Borough, W.e comprises pumiceous-medial material, which grades to medial material beyond the 0.10m isopach. In this same vicinity, Tariki Tephra merges with Waipuku Tephra below, and both tephras become progressively mixed and dispersed in a steadily increasing proportion of medial matrix.

The lesser lobe occurs in the south-eastern sector with the principal axis of distribution from Mahoe through to just north of Eltham. A maximum recorded thickness of 0.25m was recorded in the vicinity of Mahoe.

Reference Localities

Eleven reference localities are designated for Tariki Tephra, of which eight are the same as those designated for **Inglewood Tephra** (**Sections 6, 10, 12, 13, 20, 22, 29** and **31** of Appendix 1 and Figure 2.09). The other three designated localities are as follows:

1. Prominent north-facing road cut opposite Cardiff Walkway carpark, 0.1km west of the Waingongoro River Bridge, on Opunake Road, (Q20/158043) (see **Section 7** of Appendix 1 and Figure 2.09).

2. Prominent south-facing road cutting on Opunake Road, 0.1km east of Tuikonga Stream Bridge and c.2.6km east of Cardiff Road junction, (Q20/185051) (see **Section 9** of Appendix 1 and Figure 2.09).

3. Between the corner of Glenn and Skeet Roads, and stream bridge 100m further westwards, (P20/042908) (see **Section 15** of Appendix 1). Here Tariki Tephra is exposed in both north and south facing road cuts and closely underlies a laharic deposit mapped as Wr4 by Neall (1979).

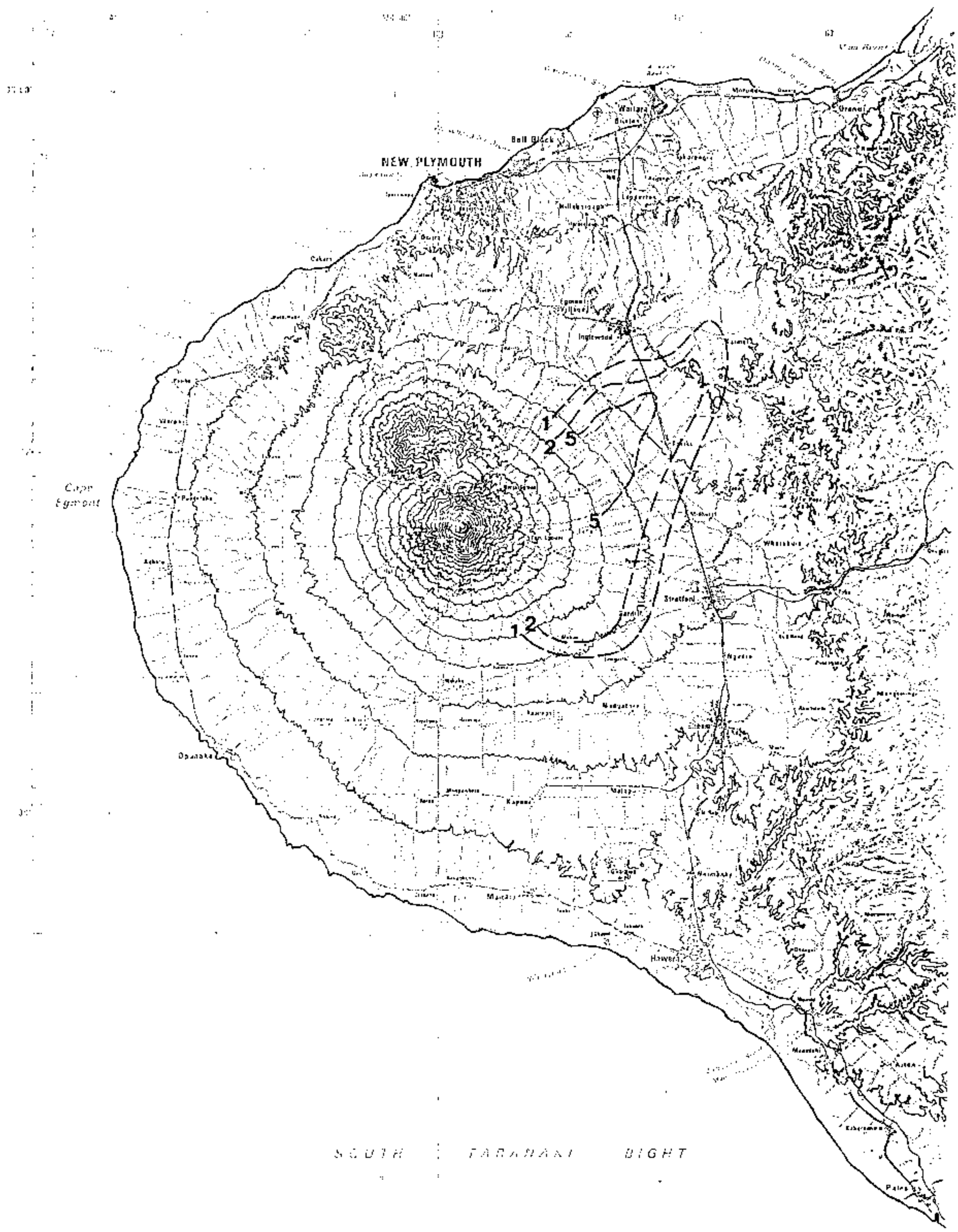


FIG. 2.10 Isopach Map: W.f of Tariki Tephra

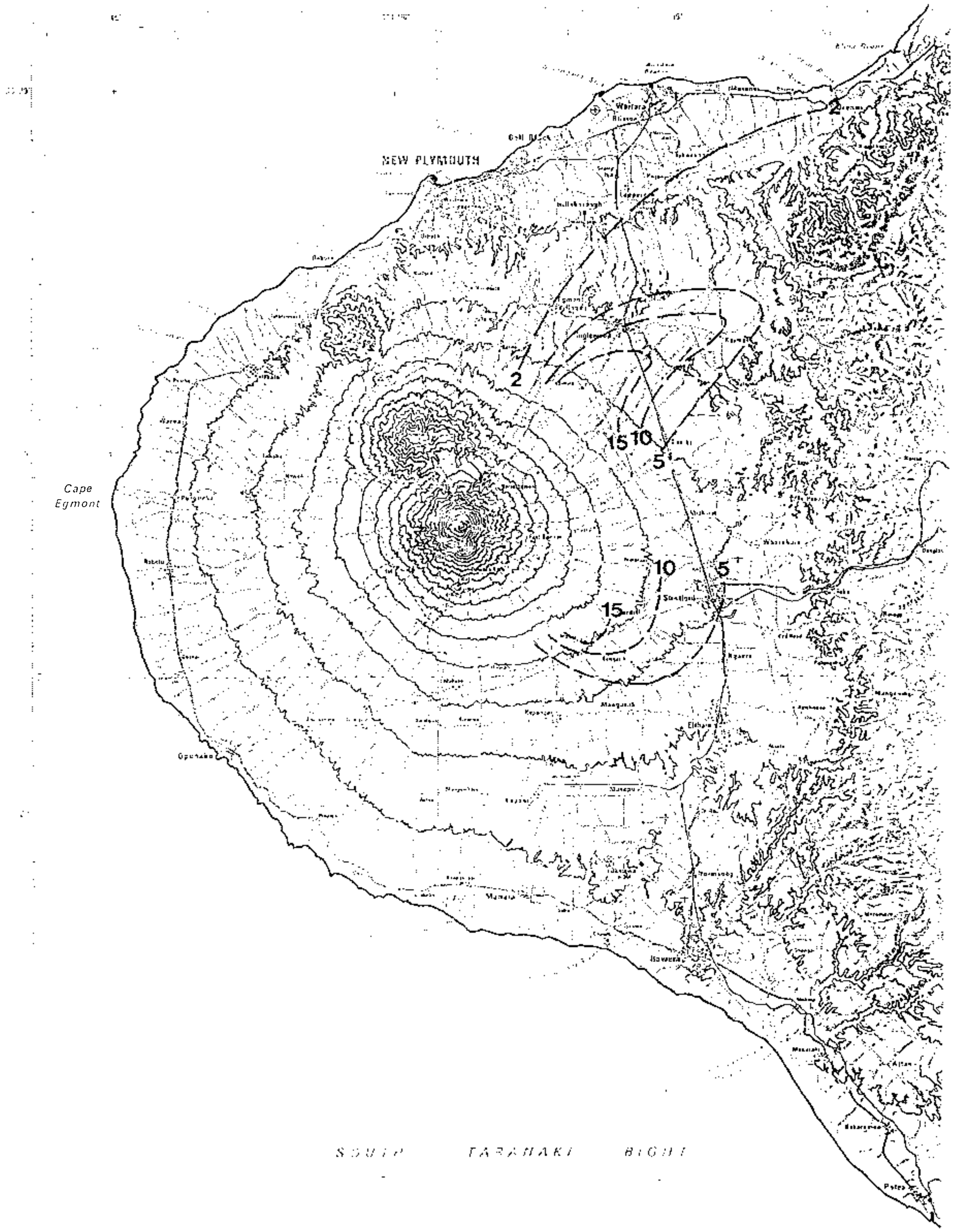


FIG. 2.11 Isopach Map: W.e of Tariki Tephra

2.2.7 Waipuku Tephra
(new formation)

Beneath Tariki Tephra is Waipuku Tephra, named after Waipuku Stream which flows eastwards from Egmont Volcano crossing State Highway 3, c.1.5km south of Tariki. Waipuku Tephra was first recognised in the north-eastern sector and informally named **'tephra - D '** by Neall in unpublished work subsequent to his 1972 publication.

Criteria

On the lower eastern flanks of Egmont Volcano, Waipuku Tephra comprises a single, massive to weakly graded bed of moderately to moderately well sorted, yellow (10YR 8/6 to 7/8), pumiceous lapilli, with upwardly increasing proportions of reddish-yellow (7.5YR 6/8) coated pumiceous lapilli (Plates 2.06 and 2.07). Common to few, light brownish-grey to greyish-brown (10YR 6/2 to 5/2) lapilli are dispersed in the lower part of the tephra bed.

Type Section

The type section designated here for Waipuku Tephra is the prominent north-facing road cut on Opunake Road, 0.5km west of Mangatoki Stream bridge and 0.9km east of the junction of Opunake Road with Palmer Road, (Q20/119027) (**Section 6** of Appendix 1; Plate 2.09). This section is the reference locality designated for Manganui, Inglewood, Korito, Mangatoki and Tariki tephras. The type area lies within a 2km radius from the type section. At this section Waipuku Tephra is exposed as follows:

W.a of Tariki Tephra

1.90m ------------- Sharp and wavy boundary ------------------

0.07m	Strong brown (7.5YR 5/6 to 5/8), friable, moderately developed fine to medium blocky structured medial material. Distinct and broken boundary.
0.03m	Common, moderately sorted, fine to medium yellow (10YR 8/6 to 7/8) pumiceous lapilli and few fine grey lapilli, dispersed in medial material. Indistinct and broken boundary;
0.09m	As per 1.80 - 1.87m interval. Distinct and wavy boundary.
0.02m	Common, moderately sorted, fine to coarse, light brownish grey to greyish brown (10YR 6/2 to 5/2) lapilli dispersed in medial material. Distinct and wavy boundary;
0.05m	As per 1.80 - 1.87m interval. Indistinct and wavy boundary.
0.14m	Profuse, upwardly becoming abundant, moderately well sorted, medium to coarse yellow (10YR 8/6 to 7/8), pumiceous lapilli few, with dispersed fine to medium lapilli near basal contact. Sharp and wavy boundary. **Waipuku Tephra**
0.21m	Dark yellowish brown (10YR 4/4), firm, weakly developed, fine to medium blocky structured medial material. At 2.30 - 2.33m discontinuous layer of few to common, very pale brown to yellow, fine to medium pumiceous lapilli.

2.51m ------------- Indistinct and wavy boundary --------------

Kap.j of Kaponga Tephra

Upper and Lower Contacts

On the lower eastern flanks of Egmont Volcano, medial material with two discontinuous and unnamed lapilli layers, separates the upper contact of Waipuku Tephra from either **Tariki Tephra** (e.g. **Section 6** of Figure 2.09) or an unnamed laharic deposit (e.g. **Section 12** of Figure 2.09), above.

Throughout the eastern lower flanks, the basal contact of Waipuku Tephra is separated from the uppermost units of **Kaponga Tephra** below, by <0.20m of medial material (Plate 2.09; Figure 2.12).

Age

An inferred minimum age for Waipuku Tephra of 5000 +/- 90 years B.P. is established from a radiocarbon date (NZ3352A) of wood obtained from directly beneath a debris flow deposit exposed in a drain at Balmoral Farm, Dudley Road. A maximum age of 5,260 +/- 90 years B.P. is established from a radiocarbon date (Wk-1035A) of a peat sample immediately beneath Waipuku Tephra at west Onaero Beach (see **Section 29** of Appendix 1). On the basis of the above radiometric dates, Waipuku Tephra is here considered to have an age of c.5.2 kyrs B.P.

Correlation

Waipuku Tephra is directly correlated to the informal **E3 tephra unit** of Franks (1984) and provisionally correlated with the thin basal pumiceous lapilli layer of **Oakura Tephra** (Neall 1972). It is also correlated with the c.5.2kyr B.P. **Eg-6** preserved within lake sediment of the Waikato (Lowe 1987).

Isopachs

Franks (1984) indicated that **E3 tephra unit** (Waipuku Tephra correlative) had a bilobed distribution to the south-east and east of Egmont Volcano. The eastern lobe was controlled by a single 0.2m thickness measurement at Tariki Bypass. Many measurements for Waipuku Tephra in this study at this same locality, are less than 0.09m and this evidence does not support the eastern lobe of Franks (1984).

The isopach map (Figure 2.13) for Waipuku Tephra shows a new and pronounced lobe of distribution in the north-eastern sector, similar but less extensive than W.e of Tariki Tephra. Within the 0.1m isopach less than 13km from Egmont Volcano, pumiceous-medial materials dominate. Beyond the 0.1m isopach, the proportion of medial material increases to >65%. Here also, Waipuku Tephra and overlying medial material thin to merge with Tariki Tephra, above.

Beyond the Egmont ring plain, Waipuku Tephra is rarely obvious macroscopically below the topsoil but is commonly seen as a pumiceous, coarse ash to fine lapilli layer within peat, estuarine and lacustrine deposits.

Reference Localities

Ten reference localities are designated for Waipuku Tephra (Sections 4, 7, 9, 10, 12, 13, 20, 22, 29 and 31 of Appendix 1). These localities are the same as those designated for Manganui, Inglewood, Korito and Tariki tephras.

Plate 2.08: **W.e** and **W.f** near Norfolk Road on State Highway 3 (Q19/164214).

Plate 2.09: **Waipuku**, **Kaponga** and **Konini Tephra** near Mangatoki Stream on Opunake Road (Section 6; Q20/108038).

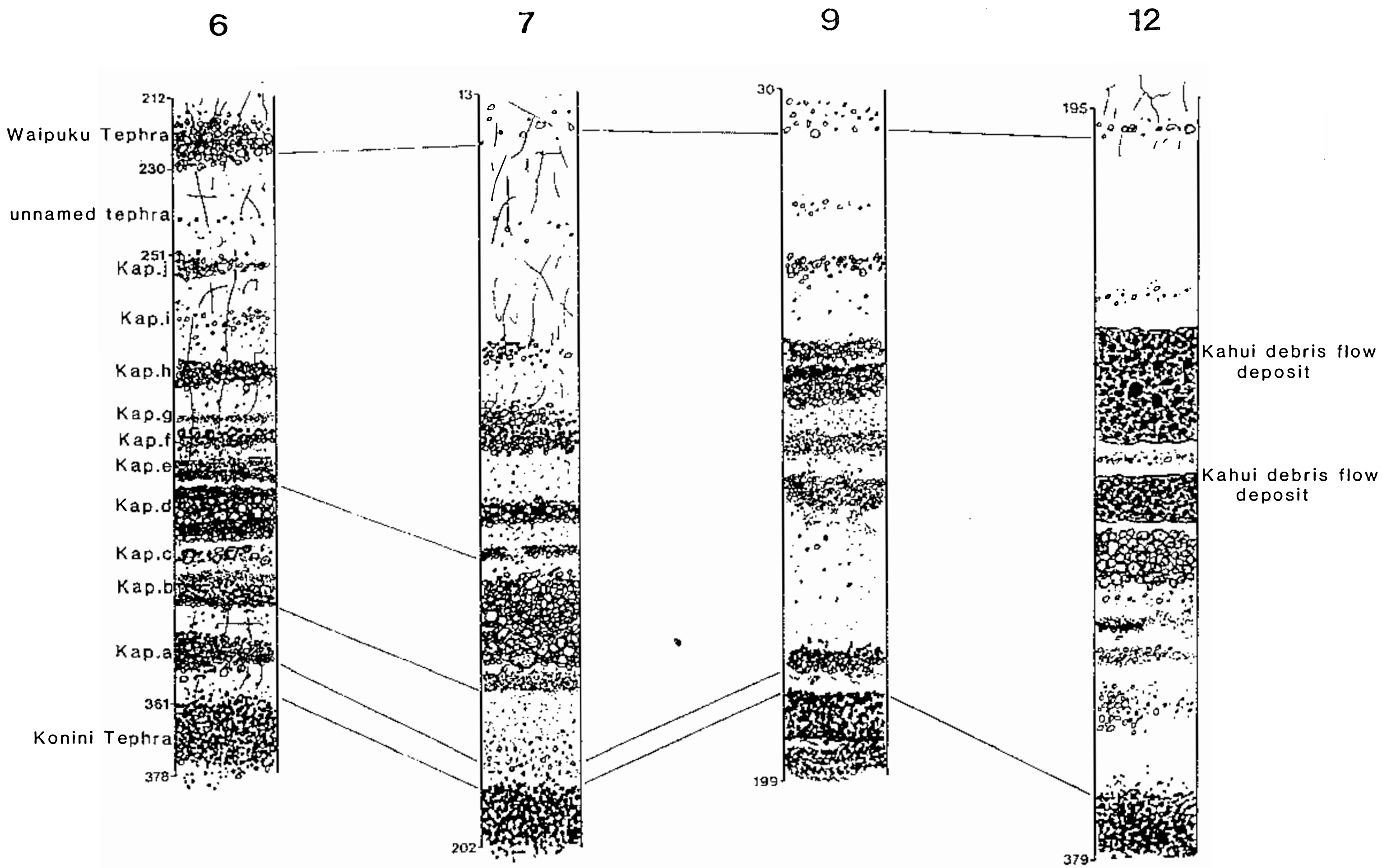
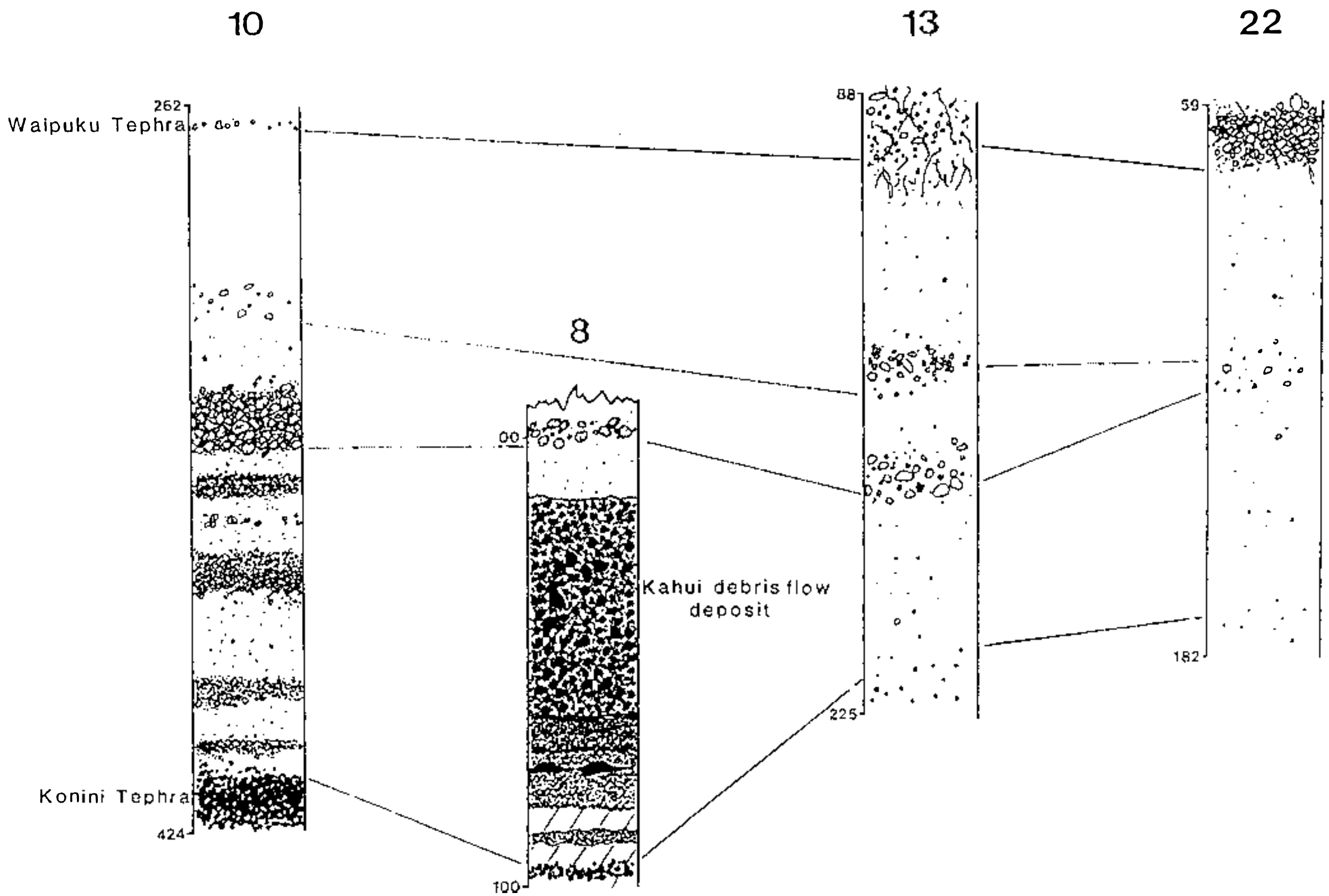


FIG. 2.12 Correlation Columns of Kaponga and Konini Tephra



10
8
13
22
262
Waipuku Tephra
Konini Tephra
424
00
100
Kahui debris flow deposit
88
225
59
182

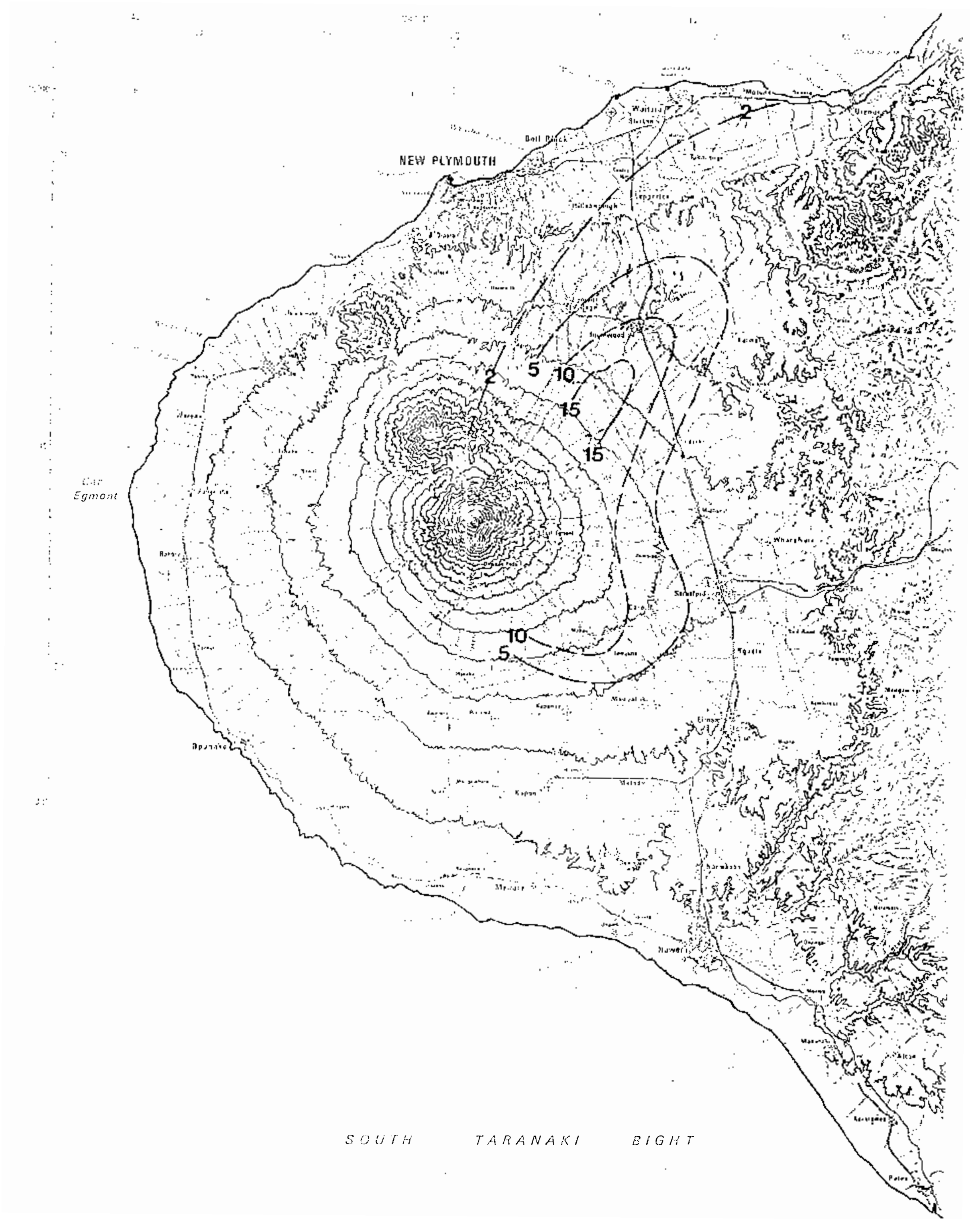


FIG. 2.13 Isopach Map: Waipuku Tephra

2.2.8 Kaponga Tephra
(new formation)

Kaponga Tephra is a new formation, named after the farming community of Kaponga 14km west from Eltham Borough. Kaponga Tephra comprises a closely spaced set of at least **ten**, dominantly reddish-yellow coarse ash and lapilli beds intervening between the laterally persistent **Waipuku Tephra** above, and **Konini Tephra** below (Plate 2.09). These beds are best represented in sections on the south-eastern lower flanks of Egmont Volcano, where each bed is separated by inter-beds (<0.1m) of medial or ashy material. The beds informally named Kap.a to Kap.j, are mostly of limited correlative usage.

While the distinctive 'orange' colour of most units, has enabled easy identification of Kaponga Tephra (Plate 2.10), the identification and correlation of most individual units that comprise Kaponga Tephra has proved difficult. Correlation of most units is therefore here considered provisional. Kap.f is the only unit of Kaponga Tephra that can be correlated with any degree of certainty in central Taranaki.

Type Section

The type section and type area are the same as those designated for Waipuku Tephra (**Section 6** of Appendix 1 and Figure 2.12). Here Kaponga Tephra comprises:

Waipuku Tephra

2.30m ------------- Sharp and wavy boundary -------------------

0.21m	Dark yellowish-brown (10YR 4/4), firm, weakly developed, fine to medium blocky structured medial material. At 2.30 - 2.33m discontinuous layer of few to common, very pale brown to yellow fine to medium pumiceous lapilli. Indistinct and wavy boundary.

0.07m **Kap.j**	Many, moderately sorted fine to coarse dominantly yellow (10YR 8/6), few reddish yellow (7.5YR 6/8) pumiceous lapilli. Common light grey to grey (10YR 7/2 to 5/1) fine to medium lapilli dispersed in medial material. Indistinct and wavy boundary.
0.11m	Dark yellowish brown (10YR 4/4), firm, weakly developed, fine to medium blocky structured medial material. Indistinct boundary to yellowish-brown (10YR 5/6), very firm, medial material. Indistinct and wavy boundary.
0.03m **Kap.i**	Many, moderately well sorted fine to medium reddish-yellow (7.5YR 6/8) pumiceous and light grey to grey (10YR 6/1) lapilli scattered in a matrix of yellowish-brown ashy material. Distinct and wavy boundary.
0.08m	Yellowish-brown (10YR 5/6), very firm, massive structured medial material. Indistinct and wavy boundary.
0.07m **Kap.h**	Abundant, moderately sorted medium (few coarse) reddish-yellow (7.5YR 6/8) pumiceous lapilli. Proportion of lapilli decreases upwards from moderately well sorted, common, fine to medium lapilli to moderately sorted few fine to coarse lapilli. Distinct and wavy boundary.
0.07m	Dark yellowish-brown (10YR 4/6), very firm, massive structured ashy material. Sharp and wavy boundary.
0.01m **Kap.g**	Many, moderately well sorted, medium, yellow (10YR 7/8 to 7/6) pumiceous lapilli. Sharp and straight boundary.
0.01m	As per 2.77 - 2.84m interval. Distinct and wavy boundary.
0.05m **Kap.f**	Abundant, moderately well sorted, medium 'sandy' dark grey (10YR 4/1) lithic ash grading downwards to very coarse sandy lithic ash with common, reddish-yellow pumiceous coarse ash and fine lapilli. Distinct and wavy boundary.
0.02m	As per 2.77 - 2.84m interval. Distinct and wavy boundary.

0.06m **Kap.e**	2cm of profuse, well sorted, medium 'sandy' dark grey (10YR 4/1) ash grading downwards to very coarse sandy lithic ash. Few to common reddish yellow fine pumiceous lapilli at base. Gradational and wavy boundary to 4cm of common, poorly sorted, fine to coarse yellow (10YR 8/8) and reddish-yellow (7.5YR 6/8) pumiceous lapilli dispersed in a matrix of pumiceous coarse ash and fine lapilli. Sharp and wavy boundary.
0.13m **Kap.d**	Shower bedded, abundant to profuse, moderate to poorly sorted yellow (10YR 8/6 to 7/8), coated reddish-yellow (7.5YR 6/8) fine to very coarse pumiceous lapilli and subordinate dark grey, fine to medium lapilli dispersed throughtout a matrix of yellow to reddish-yellow coarse pumiceous ash. Sharp and wavy boundary.
0.02m	Yellowish-brown (10YR 4/4), very firm, massive structured ashy material. Distinct and broken boundary.
0.04m Kap.c	Discontinuous layer, many moderately well sorted subrounded, very coarse to coarse yellow (10YR 8/6 to 7/8) pumiceous lapilli. Distinct and broken boundary.
0.03m	Yellowish-brown (10YR 4/4), firm, massive structured, ashy /medial material. Sharp and wavy boundary.
0.07m **Kap.b**	Abundant to profuse, moderately sorted shower bedded very coarse to coarse yellow (10YR 7/6) pumiceous and grey sandy ash. Common fine to medium yellow pumiceous and grey lapilli increasing in proportion towards base. Sharp and wavy boundary.
0.08m	Yellowish-brown (10YR 5/4 to 4/4), firm, weakly developed, medium block structured, medial material. Few to common medium to fine dark reddish-brown (5YR 3/2) rootlets. Indistinct and wavy boundary.

0.10m **Kap.a**	Abundant, moderately sorted fine to coarse (10YR 8/4 to 8/8) pumiceous lapilli dispersed in a matrix of coarse to very coarse yellow pumiceous and dark grey to very dark grey (7.5YR N4/ to N5/) sandy ash. Proportion of reddish-yellow (7.5YR 6/8) lapilli steadily increases towards upper contact of unit. Distinct and wavy boundary.
0.05m	Yellowish-brown (10YR 4/4), very firm, massive structured medial material.

3.61m ------------- Distinct and wavy boundary ---------------

Kon.b of **Konini Tephra**

Upper and Lower Contacts

Within the type area, the uppermost unit of Kaponga Tephra (**Kap.j**) is separated from Waipuku Tephra above, by <0.20m of medial material with a discontinuous and unnamed pumiceous lapilli unit (e.g. **Section 6** of Figure 2.12). In the same vicinity, the lowermost unit of Kaponga Tephra (**Kap.a**) is separated from Konini Tephra below, by up to 0.08m of medial material.

Moving from the south-eastern sector towards the north-eastern and south-western sectors, most coarse ash and lapilli units of Kaponga Tephra thin and wedge out. In the north-easten sector, only **Kap.f** and **Kap.g** are identified as macroscopically visible layers (e.g. **Section 13** of Figure 2.12), while, in the south-west sector, only **Kap.f** is identified (e.g. **Section 15** of Figure 2.12). Kaponga Tephra is occasionally interstratified by at least three debris and hyperconcentrated flow deposits of **Kahui Formation**, (e.g. **Sections 8** and **12** of Figure 2.12; Plate 2.11).

Age

A minimum age for Kaponga Tephra of 5,260 +/- 90 years B.P. is established from a radiocarbon date (Wk-1035A) of peat immediately beneath Waipuku Tephra (**Section 29** of Appendix 1).

A further radiocarbon date (NZ5409A) of 9,280 +/- 130 years B.P. was obtained from a peat sample separating two central units of Kaponga Tephra (**Kap.d** and **Kap.e**) at Durham Road (see **Section 8** of Appendix 1). An age (NZ5410A) of 10,450 +/- 200 years B.P. obtained from peat beneath the underlying Konini Tephra at the same site establishes a maximum possible age for Kaponga Tephra.

From the above radiometric dates, Kaponga Tephra has a possible age range of between c.5.3 to 10.4 kyr B.P. However, the closely spaced beds of **Kap.b** to **Kap.h** are here considered to have a more confined age range of between c.8.0 to 10.0 kyrs B.P.

Correlation

Kaponga Tephras are directly correlated to the informal **E2 tephra unit** of Franks (1984) and upper portions of her **E1 tephra unit.** **Kap.b** and **Kap.d** are here tentatively correlated to the c.9.3 kyr B.P **Eg-9** and c.9.6 kyr B.P. **Eg-10** preserved within lake sediment of Lake Rotomanuka of the Waikato district (Lowe 1987).

Member - **Kap.f**

Criteria

In the north-eastern sector, **Kap.f** is characterised by a normal graded to massive bed of soft, sub-rounded, moderately well sorted, reddish-yellow (7.5YR 6/8), medium to coarse pumiceous lapilli with sub-ordinate grey fine lapilli (Plate 2.11). The proportion of grey coarse ash and lapilli within the bed progressively increase towards the eastern and south-eastern sectors.

Distribution

Kap.f shows a broad eastern lobe of distribution extending from Egmont Volcano (see Figure 2.14) with the principal axis of distribution directed towards the north-east from Kaimiro through to Inglewood.

Reference Localities

Eight reference localites have been designated for Kaponga Tephra. The localities of seven have previously been described (**Sections 7, 9, 10, 12, 13, 15** and **22** of Appendix 1 and Figure 2.12). A further reference locality is here designated as:

> Prominent drain, south-side of Durham Road, c.1.85km south-west of the junction of Durham Road and State Highway 3, (Q19/144226) (**Section** 8 of Appendix 1 and Figure 2.12).

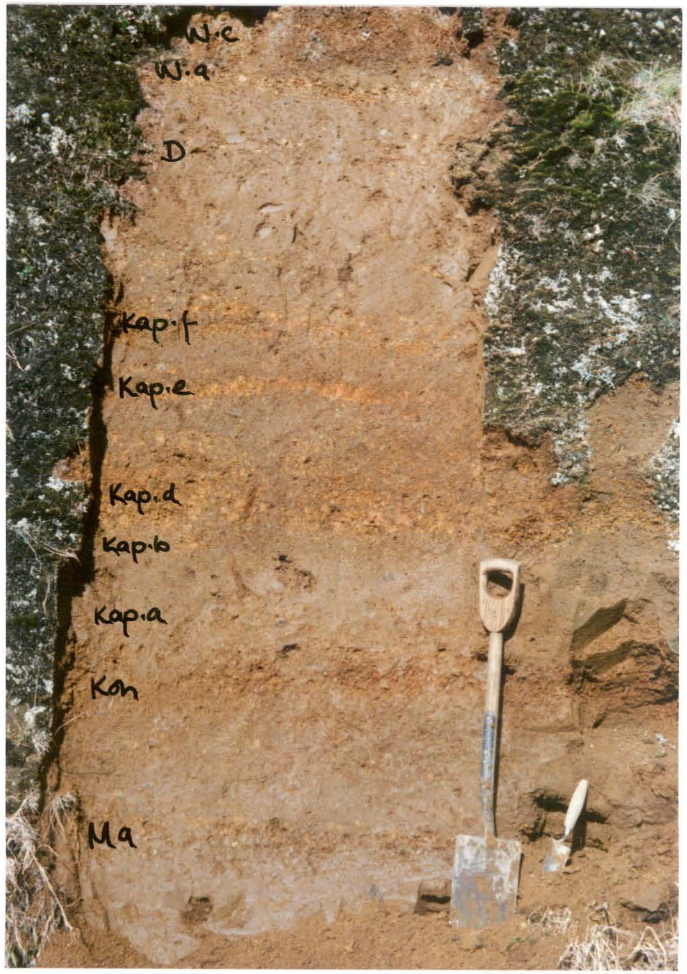


Plate 2.10: **Waipuku**, **Kaponga** and **Konini Tephra** near Waingongoro River-Cardiff Walkway, on Opunake Road (Section 7; Q20/158043). Note **Tariki Tephra** above **Waipuku Tephra** and **Mahoe Tephra** below **Konini Tephra**.

Plate 2.11: **Waipuku**, **Kaponga** and **Konini Tephra** on Bains Farm, Tariki Road (Section 12; Q20/192194). Note unnamed debris/hyperconcentrated flow deposit above **Waipuku Tephra** and debris flow deposits of **Kahui Formation** intercalating **Kaponga Tephra**.

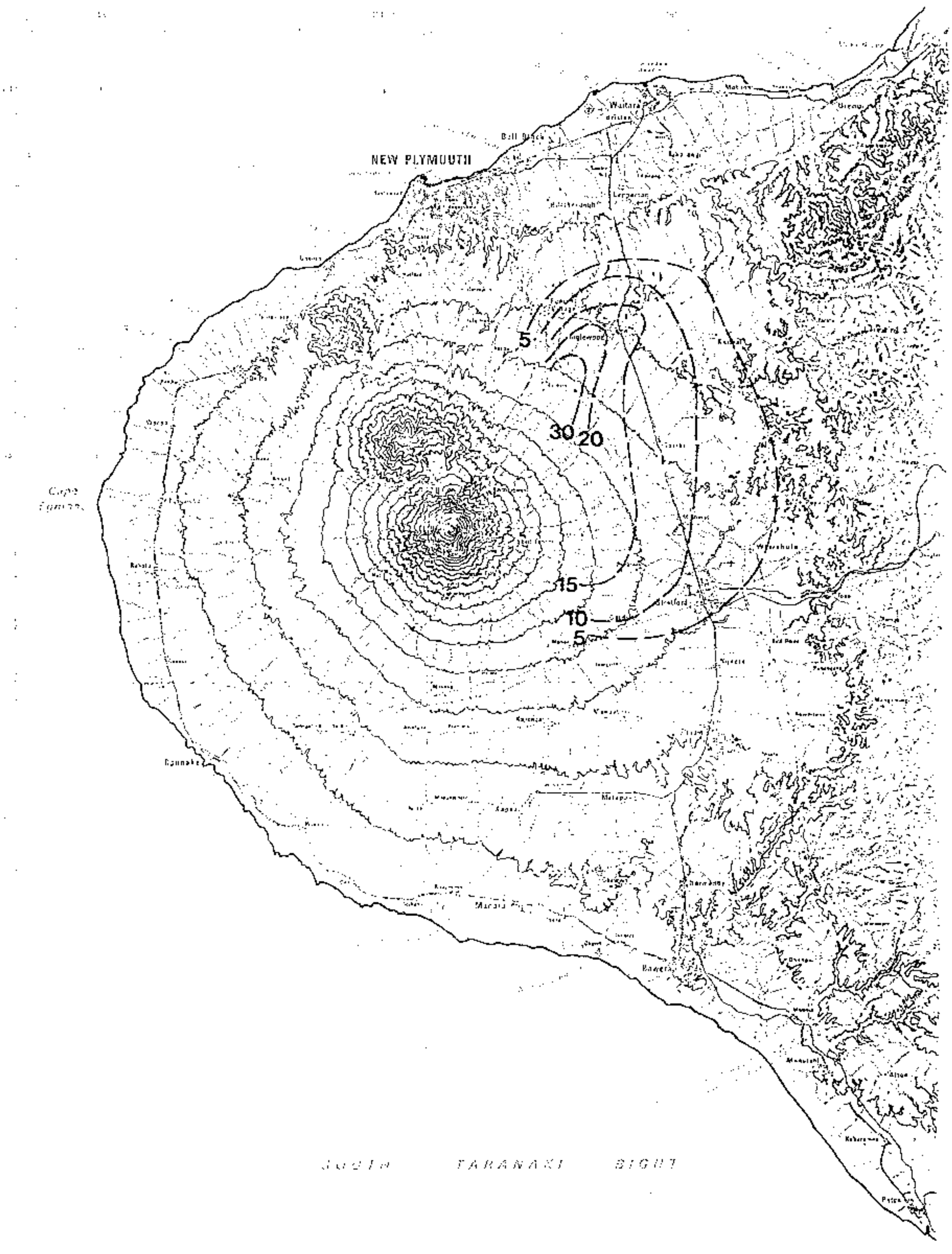


FIG. 2.14 Isopach Map: Kap.f of Kaponga Tephra

2.2.9 Konini Tephra
(new formation)

Underlying Kaponga Tephra is Konini Tephra a new formation named after Konini Stream, which flows south-east from Egmont Volcano connecting with Paetahi Stream, 2.5km west of Stratford Borough.

On the lower eastern flanks of Egmont Volcano, Konini Tephra comprises **two** closely spaced lapilli beds separated by <0.06m of medial material (Plate 2.12). These beds informally named **Kon.a** and **Kon.b**, thin eastwards and merge together to form a single regional tephra marker. Where this occurs, **Kon.a** is distinguished from **Kon.b** only on the basis of finer grain size.

Criteria
The upper bed of Konini Tephra (**Kon.b**) is similar in appearance to the lower bed (**Kon.a**) but is of greater thickness and coarser grained. Both beds are often characterised by profuse to abundant, dark grey to very dark grey (10YR 4/1 to 3/1) and greyish-brown (10YR 5/2) finely vesicular lapilli, with a basal layer of few to common reddish-yellow (7.5YR 6/8) and yellow (10YR 6/8) pumiceous lapilli (Plate 2.13). Lapilli constituents may be surface coated red (2.5YR 4/6) or (10YR 4/4) dark yellowish-brown.

Type Section
The type section designated here for Konini Tephra is the prominent north-facing road cut on Opunake Road, 0.5km west of Mangatoki Stream bridge and 0.9km east of the junction of Opunake Road with Palmer Road, (Q20/119027) (**Section 6** of Appendix 1 and Figure 2.15; Plate 2.13). This section is the type locality designated for Waipuku and Kaponga Tephra. The type area extends over a similar area to that designated for Kaponga Tephra. At this section Konini Tephra is exposed as follows:

Kap.a of Kaponga Tephra

3.56m ------------- Abrupt and wavy boundary -----------------

0.05m	Dark yellowish-brown (10YR 4/4), very firm, massive structured medial material. Indistinct and wavy boundary.
0.15m **Kon.b**	Moderately sorted, abundant, fine to very coarse, dark grey to very dark grey (10YR 4/1 to 3/1) soft to firm lapilli coated dark yellowish-brown (10YR 4/4), common brownish-yellow (10YR 6/8) coarse ash to fine pumiceous lapilli dispersed throughout. Indistinct and wavy boundary.
0.06m	Dark yellowish-brown (10YR 4/4), firm, weakly developed, medium blocky structured medial material. Distinct and wavy boundary.
0.05m **Kon.a**	Moderately well sorted, profuse, dark grey to very dark grey coarse ash. with few fine lapilli increasing in proportion to common towards lower contact of unit. Sharp and wavy boundary.
0.09m	Dark yellowish-brown (10YR 4/4), firmly friable, weakly developed fine to medium blocky structured medial material.

3.96m ------------- Distinct and wavy boundary ----------------

Ma.d of Mahoe Tephra

Upper and Lower Contacts

On the south-eastern lower flanks of Egmont Volcano, the uppermost unit of Konini Tephra (**Kon.b**) is separated from **Kap.a** of **Kaponga Tephra** above, by 0.05m of medial material (e.g. **Sections 6** and **10** of Figure 2.12). In the same sector, the lower unit (**Kon.a**) is separated from **Mahoe Tephra** below, by <0.10m of medial material (Figure 2.15).

In the north-eastern sector, Konini Tephra is separated from **Kap.f**(?) of Kaponga Tephra above, by c.0.40m of medial material (e.g. **Section 22** of Figure 2.12). Here, the lower contact of Konini Tephra is separated from Kaihouri tephras below, by <0.20m of medial material (e.g. **Section 13** of Figure 2.15).

Age

A radiocarbon date (NZ5410A) of a peat sample 0.03m below **Kon.b** at Durham Road (**Section 8** of Appendix 1) establishes a maximum age of 10,450 +/- 200 years B.P. This maximum age is similar to another radiocarbon date (NZ3153A) of 10,150 +/- 100 years B.P. obtained from a bulk peat sample that enveloped a prominent grey lapilli layer at *c*.7.3m depth below surface in Eltham swamp (McGlone and Neall *pers. comm.* 1987). In this study, the grey lapilli bed has been correlated with **Kon.b** of Konini Tephra.

On the basis of the above radiometric dates, Konini Tephra is considered to have an age of *c*.10.1 kyrs B.P.

Correlation

Konini Tephra is here correlated to the fine basal lapilli bed of the **E1 tephra unit** of Franks (1984). Konini Tephra is correlated with the *c*.10.1 kyr B.P. **Eg-11** preserved within sediment of Lakes Maratoto and Rotomanuka in the Waikato district (Lowe 1987).

Isopachs

An isopach map (Figure 2.16) combining both units of Konini Tephra indicates a broad lobe of distribution extending from Egmont Volcano to the east. A maximum recorded thickness of 0.22m occurs in the vicinity of Mahoe. The 0.15m isopach extends from just north of Tariki to the eastern outskirts of Stratford Borough and continues further southwards through Eltham and Kaponga.

Beyond the 0.15m isopach, Konini Tephra rapidly thins to smaller and fewer lapilli increasingly dispersed within a steadily increasing proportion of medial material. North beyond Inglewood, Konini Tephra ceases to occur as a continuous, visible layer but occurs as a few, fine grey lapilli scattered in a dominantly medial matrix.

Reference Localities

The reference localities designated for Konini Tephra are the same as those designated for Kaponga Tephra (see **Sections 7, 8, 9, 10, 12, 13, 15** and **22** of Appendix 1).

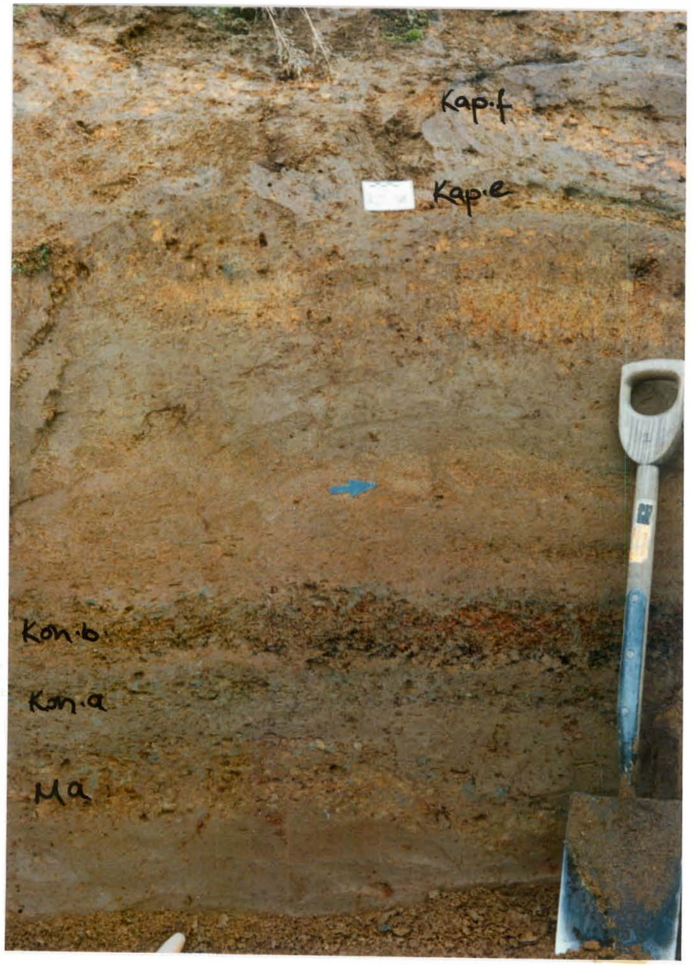


Plate 2.12: **Kaponga**, **Konini** and **Mahoe Tephra** at Tariki Underpass on State Highway 3 (Section 10; Q20/167202). Blue arrow indicates position of **Kap.b** of **Kaponga Tephra**.

Plate 2.13: **Konini Tephra** at type section near Waingongoro River-Cardiff Walkway, on Opunake Road (Section 7; Q20/158043). Note **Kaponga Tephra** above **Konini Tephra** and **Mahoe Tephra** below.
Blue arrow indicates position of **Kon.a** of **Konini Tephra**.

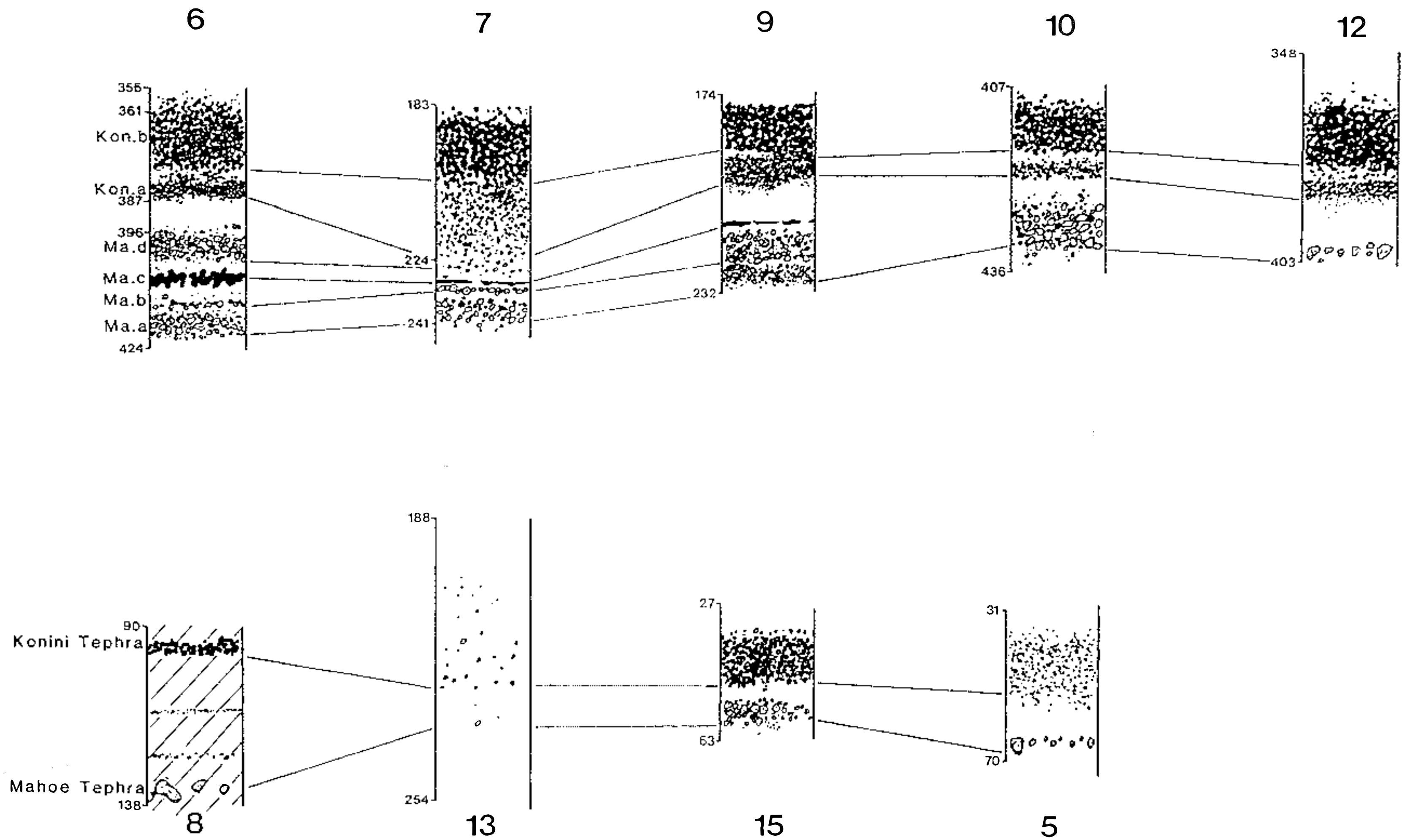


FIG. 2.15 Correlation Columns of Mahoe Tephra

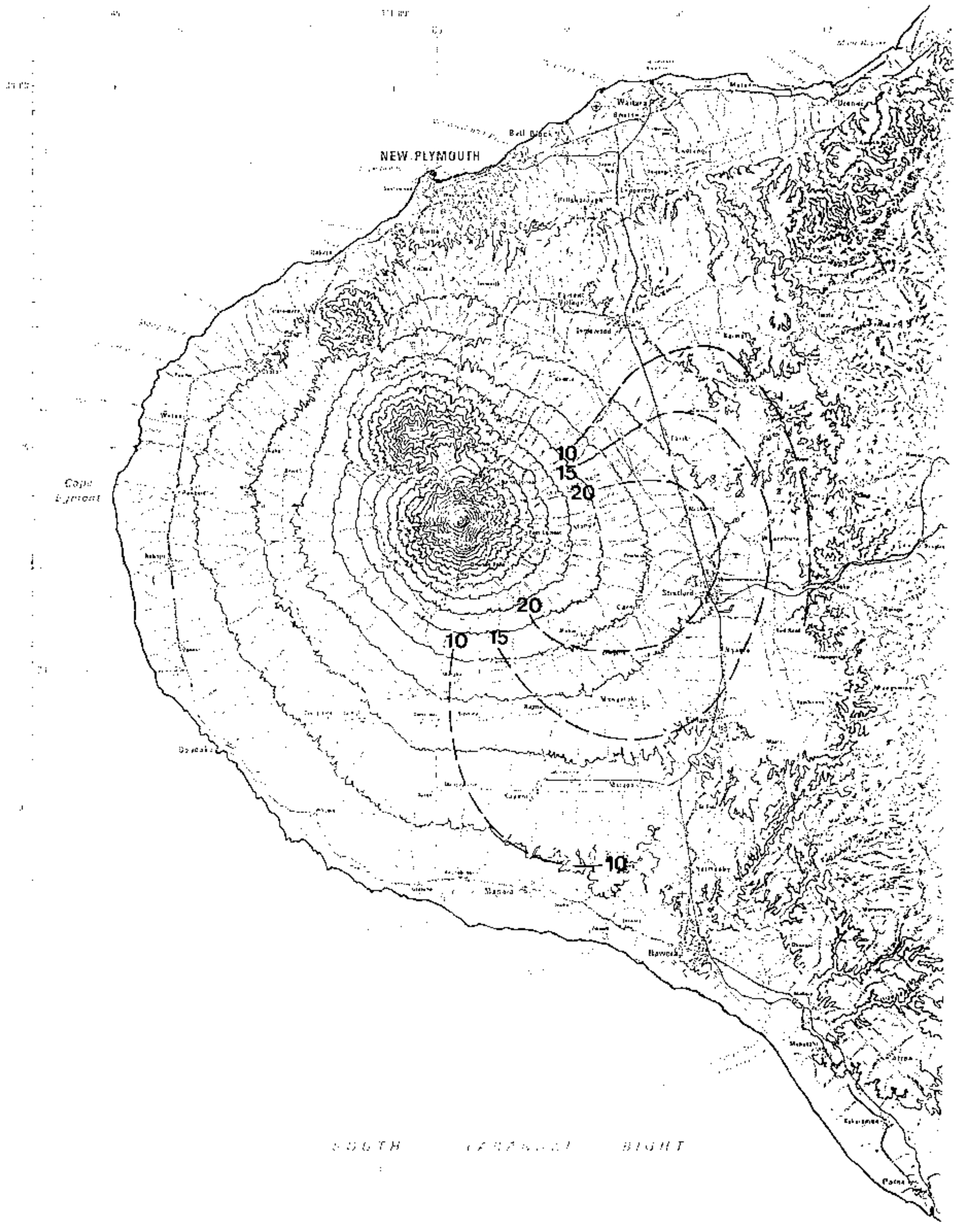


FIG. 2.16 Isopach Map: Konini Tephra

2.2.10 Mahoe Tephra
(new formation)

Mahoe Tephra was first recognised by Franks (1984) as a single unit of dominantly pumiceous lapilli and was informally named Mahoe tephra, after the farming community of Mahoe 10km south-west from Stratford Borough. On the lower south-eastern flanks of Egmont Volcano, Mahoe Tephra comprises a closely spaced set of **four** tephra beds (here informally named **Ma.a** to **Ma.d**) separated by <0.05 m of medial material (Plate 2.14).

Criteria

With distance from source, the medial inter-bed thins between **Ma.a** and **Ma.b**, resulting in the merging together of both units to form a single regional tephra marker bed (Plate 2.15). This bed comprises dominantly firm, yellow (10YR 8/8), very pale brown (10YR 8/4) and subordinate reddish-yellow (7.5YR 6/8), moderately well sorted pumiceous lapilli and blocks. Dispersed throughout are subordinate, soft, light grey (10YR 7/1 to 6/1) lapilli. Occasionally in the south-eastern sector, grey lapilli tend to concentrate towards the base of the bed.

Ma.c comprises a distinctive, firm dark grey (10YR 4/1) to reddish grey (5YR 5/2), massive fine ash, while, **Ma.d** is of similar field appearance to **Ma.a** and **Ma.b** (Plate 2.14). Both **Ma.c** and **Ma.d** of Mahoe Tephra are of limited correlative usage, because they are restricted in distribution to the south-eastern lower flanks of Egmont Volcano, in the vicinity of Mahoe and Cardiff.

Type Section

The type section is designated as a prominent north-facing road cut opposite Cardiff Walkway carpark, 0.1km west of Waingongoro

River Bridge, on Opunake Road (**Section 7** of Appendix 1 and Figure 2.15). This section is chosen in preference to Sections 6 or 9, because of an absence of erosional unconformities in the medial material below Mahoe Tephra (Plates 2.16 and 2.17, respectively). Here Mahoe Tephra is exposed as follows:

Kon.a of **Konini Tephra**

2.24m ------------- Indistinct and wavy boundary --------------

0.05m	Yellowish brown (10YR 5/4), firmly friable, weakly developed fine to medium blocky structured medial material. Few dispersed fine yellow (10YR 7/8) pumiceous lapilli downwardly increasing in proportion to common. Sharp and broken boundary.
0.01m **Ma.c**	Well sorted, very firm, pinkish grey to reddish grey (5YR 6/2 to 5/2), massive, fine ash. Sharp and broken boundary.
0.03m **Ma.b**	Moderately well sorted, many, fine to medium yellow (10YR 8/6 to 8/8) pumiceous lapilli dispersed in medial matrix. Distinct and wavy boundary.
0.02m	As per 2.05 - 2.10m. Distinct and wavy boundary.
0.06m **Ma.a**	Moderately sorted, abundant to profuse, fine to coarse, yellow (10YR 8/6 to 8/8) and very pale brown (10YR 8/4 to 7/4) pumiceous lapilli, with common fine to medium, grey (10YR 7/1) soft lapilli. Distinct and wavy boundary.
0.22m	Dark yellowish brown (10YR 4/6), firm, moderately developed fine to medium blocky structured medial material. Diffuse and wavy boundary.
0.25m	Dark yellowish brown (10YR 4/4), very firm, weakly developed, coarse blocky structured medial material.

2.88m ------------ Sharp and broken boundary ----------------

Kai.h of **Kahouri tephra**

Best Locality

A best locality is designated in the south-eastern sector at a prominent north-facing road cut on Opunake Road 0.5km west of Mangatoki Stream Bridge and 0.9km east of the junction of Opunake Road with upper Palmer Road (see **Section 6** of Appendix 1 and Figure 2.15). Here the four tephra units of Mahoe Tephra are clearly and continuously exposed along the section but are separated from units of Poto Tephra below, by a prominent disconformity (Plate 2.16).

Upper and Lower Contacts

The uppermost units of Mahoe Tephra, in the south-eastern sector (**Ma.d**) and eastern sector (combined **Ma.a** and **Ma.b**) are separated from Konini Tephra above, by <0.10m of medial material (Figure 2.15). The lowermost units of Mahoe Tephra in the south-eastern and eastern sectors (combined **Ma.a** and **Ma.b**) are separated from Kaihouri tephras (e.g. **Section 7** of Figure 2.17) and Warea Formation correlatives (Plate 2.18) below, by <0.5m of medial material.

Age

A radiocarbon date (NZ5410A) of peat (c.0.36m) above Mahoe Tephra at Durham Road (**Section 8** of Appendix 1), establishes a minimum age of 10,450 +/- 200 years B.P. Here also peat c.0.60m below Mahoe Tephra has been dated (NZ5411A) at 12,900 +/- 200 years B.P. giving a maximum age.

Mahoe Tephra is here estimated to have an age of between c.11 and 11.4 kyrs B.P. based on the extrapolation of peat accumulation rates between the two radiocarbon dates.

Correlation

Mahoe Tephra is correlated with the <u>c</u>.11 kyr B.P. **Eg-12** preserved within sediment of Lakes Rotomanuka and Maratoto in the Waikato district (Lowe 1987).

Isopachs

An isopach map combining **Ma.a** and **Ma.b** (Figure 2.18) shows a broad east and south-eastward lobe from Egmont Volcano. From meagre thickness data the 0.15m isopach occurs between Tariki and Pembroke, west of State Highway 3. The 0.10m isopach occurs just north of Tariki in the eastern sector and between Cardiff and Mahoe in the south-east sector. The extent of this isopach eastward is presently unknown. Beyond the 0.10m isopach, Mahoe Tephra rapidly thins to smaller and fewer lapilli dispersed within steadily increasing proportions of medial material. Beyond the 0.05m isopach situated just south of Inglewood, Mahoe Tephra is occasionally identified by a discontinuous layer of few coarse yellow pumiceous lapilli.

Reference Sections

Five reference localities have been designated for Mahoe Tephra (see Sections **8**, **9**, **10**, **12** and **15** of Appendix 1 and Figure 2.15).

Plate 2.14: **Mahoe Tephra** at its best locality near Mangatoki Stream on Opunake Road (Section 6; Q20/108038).

Plate 2.15: **Konini** and **Mahoe Tephra** at Tariki Underpass on State Highway 3 (Section 10; Q20/167202). Note boundary between **S1** and **L1.1** (indicated by arrow) and **Kai.h** of **Kaihouri tephra** beneath boundary.

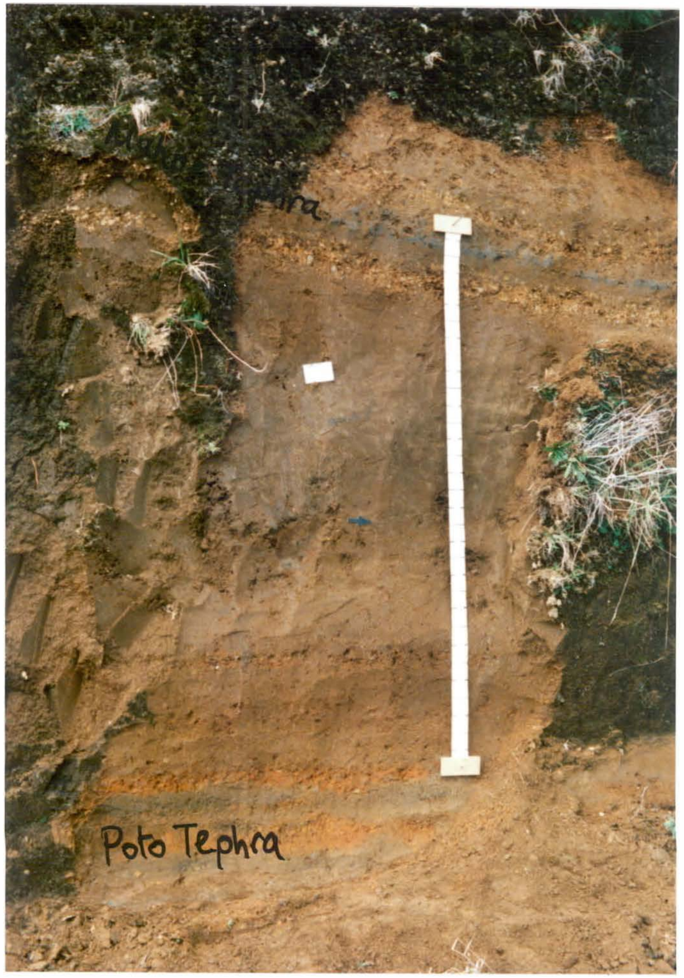


Plate 2.16: **Mahoe Tephra** and **Poto Tephra** near Mangatoki Stream on Opunake Road (Section 6; Q20/108038). Note boundary between **S1** and **L1.1** position just above card and erosional unconformity (indicated by arrow).

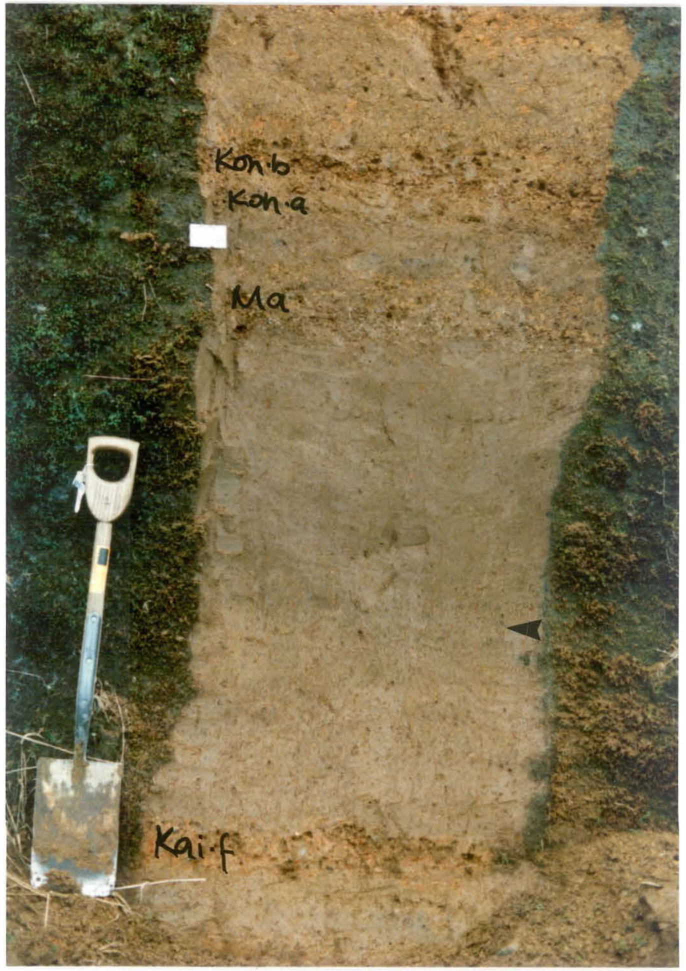


Plate 2.17: **Konini** and **Mahoe Tephra** near Tuikonga Stream on Opunake Stream (Section 9; Q20/185051). Note **Kai.f** of **Kaihouri tephra** beneath **Mahoe Tephra** and intervening erosional unconformity (indicated by arrow).

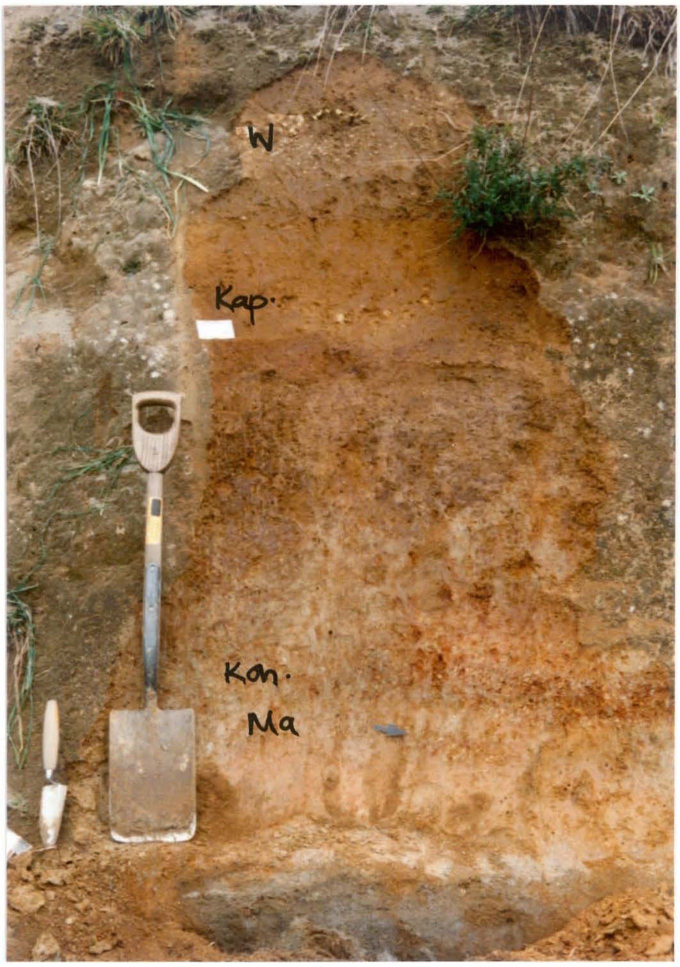


Plate 2.18: **Konini** and **Mahoe Tephra** (latter indicated by arrow) at corner of Skeet and Glenn Roads (Section 15; P20/042908). Note debris flow deposit of **Warea Formation** below **Mahoe Tephra**.

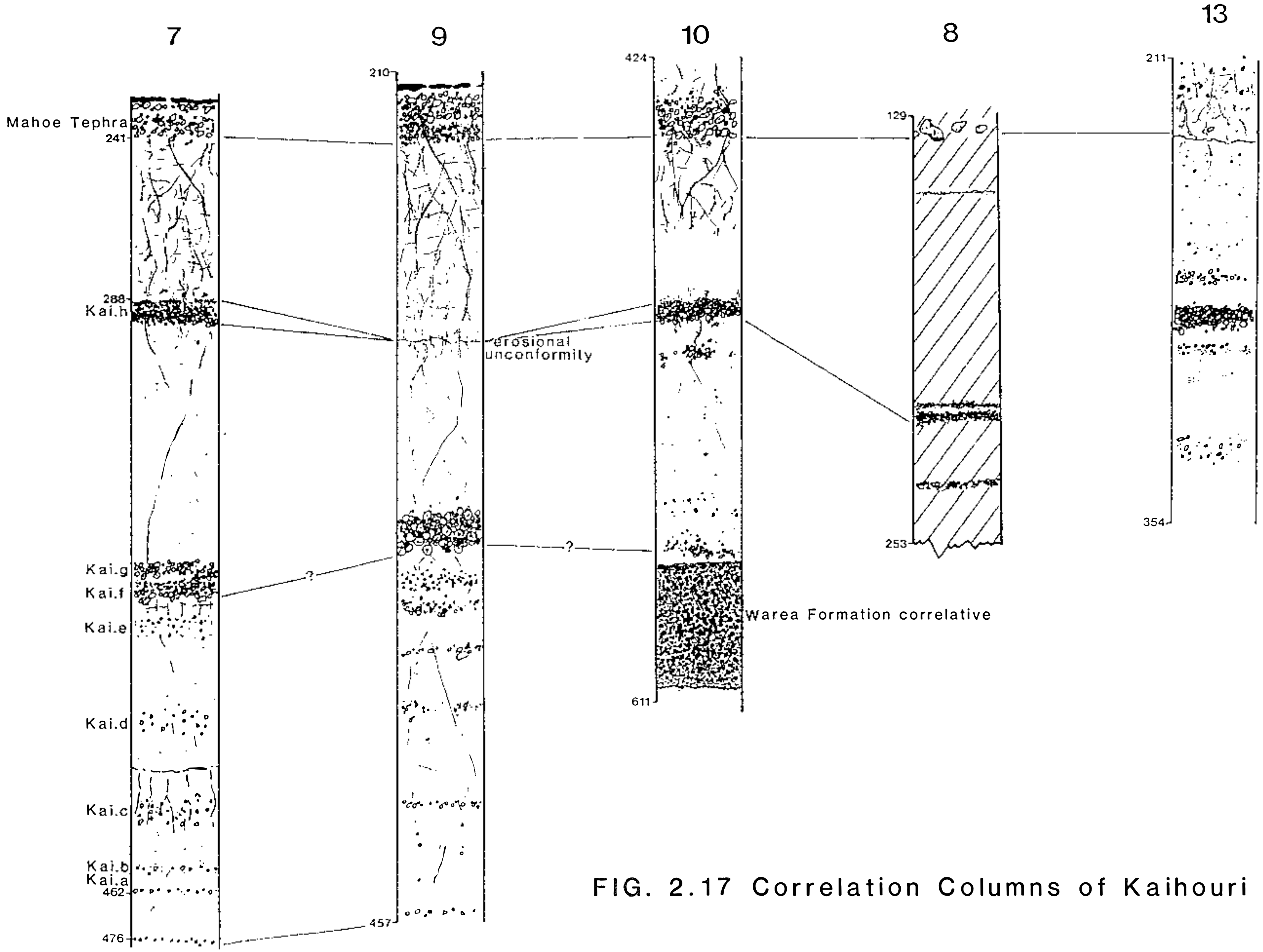


FIG. 2.17 Correlation Columns of Kaihouri tephra

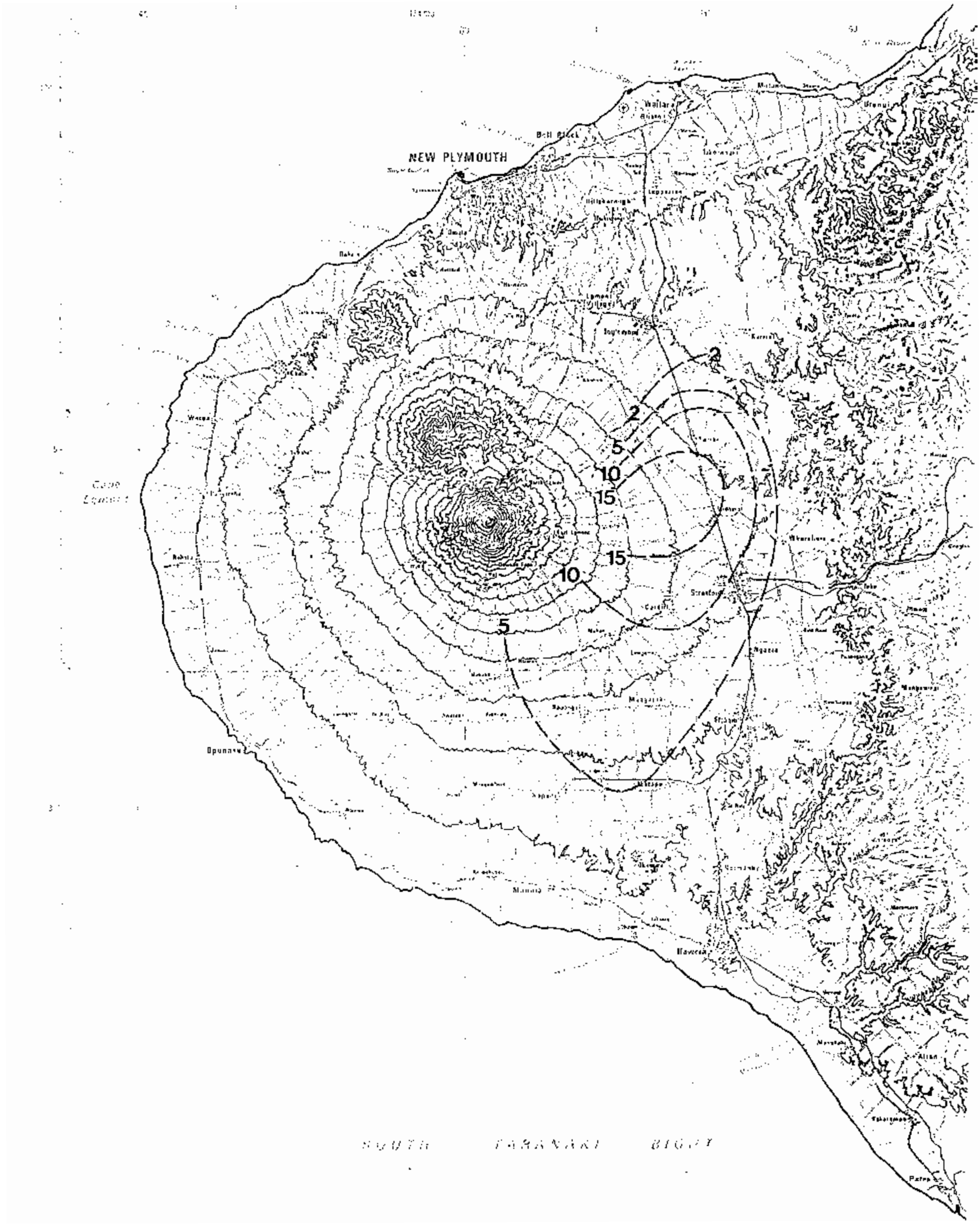


FIG. 2.18 Isopach Map: Mahoe Tephra

2.3.0 TUNA TEPHRA SUB-GROUP TEPHROSTRATIGRAPHY

2.3.1
Tuna Tephra Sub-group is named after the east Taranaki farming community of Tuna, c.3.9km north-east of Midhurst. On the lower eastern flanks of Egmont Volcano, **Tuna Tephra Sub-group** is subdivided in two; here informally referred to as '**upper**' (youngest) and '**lower**' (oldest) **Sub-group.**

Upper Tuna Tephra Sub-group

(hereafter abbreviated to Upper TT Sub-group)

Upper TT **Sub-group** includes **Kaihouri tephra**, Paetahi Tephra and Poto **Tephra** which total at least **twenty-nine** constituent coarse ash and lapilli units (Figure 2.19). The **upper TT Sub-group** is intercalated by medial inter-beds of **L1.1** (see Chapter 3).

Type Section:
The type section designated here for the **upper TT Sub-group** occurs c.14km south-east from the present Egmont summit, at a prominent north-facing road cut opposite Cardiff Walkway Carpark, 0.1m west of Waingongoro River Bridge on Opunake Road (**Section 7** of Appendix 1).

Lower Tuna Tephra Sub-group

(hereafter abbreviated to Lower TT Sub-group)

Lower TT Sub-group includes the **Tuikonga**, **Koru**, **Pukeiti** and **Waitepuku Tephras** which total at least **eleven** constituent coarse ash and lapilli units (Figure 2.19). The **lower TT Sub-group** is intercalated by medial inter-beds of **L1.2** (see Chapter 3).

Type Section

The type section designated here for the **lower TT Sub-group** occurs c.19.5km north-east from the present Egmont summit, at a prominent driveway cutting at Inglewood Marae, 0.10km south of the Inglewood BMX track and opposite the school playground, (Q19/147267) (**Section 13** of Appendix 1).

Age

The age range of **upper TT Sub-group** is determined from the position of constituent tephras with respect to a few radiocarbon dated peats and woods, and the rhyolitic chronohorizon - Aokautere Ash. On this basis the **upper TT Sub-group** has an estimated age range of between c.12 and c.23.4 kyrs B.P.

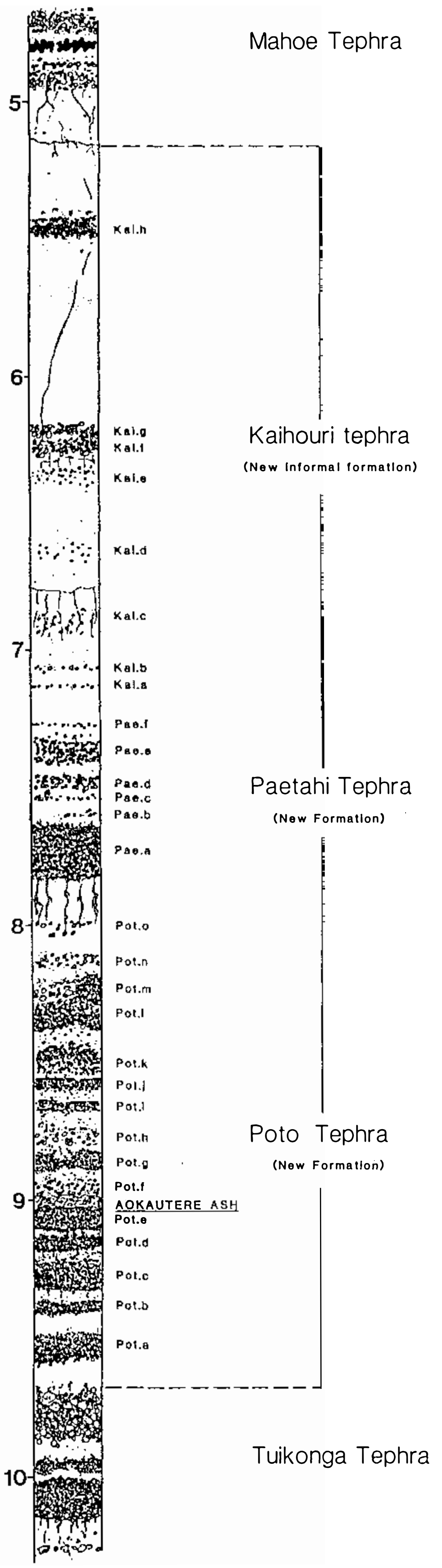
The **lower TT Sub-group** has an estimated age range of between c.23.4 and 28.0 kyrs B.P. This age range is determined on the basis of assumed constant accumulation rate of medial material between **Aokautere Ash** and the c.50 kyr B.P **Rotoehu Ash.**

Isopachs

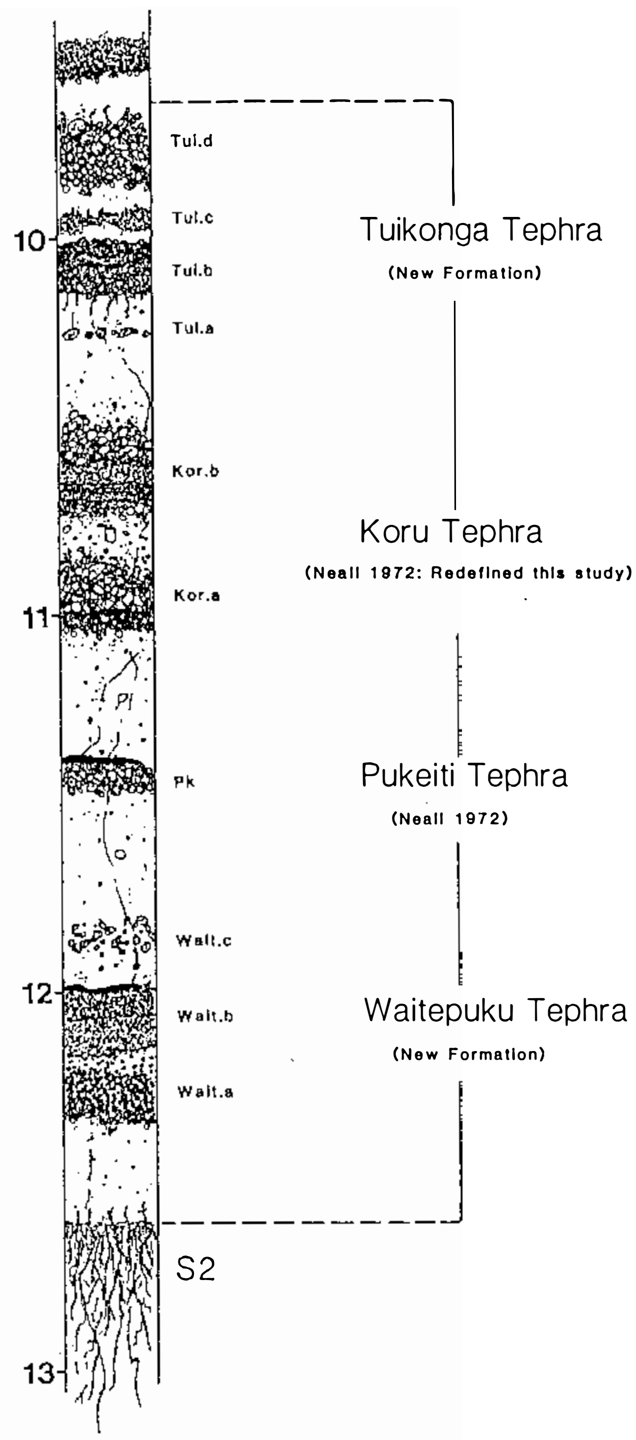
Isopach data of constituent formations within **lower TT Sub-group**, appears to indicate a predominant direction of tephra distribution extending from the Egmont Volcanic Centre towards the eastern and north-eastern sectors. In contrast, the constituent formations of **upper TT Sub-group** appear to be predominantly distributed towards the eastern and south-eastern sectors. This latter distribution is consistent with that of the overlying **Toko Tephra Sub-group.**

FIG. 2.19

Composite Stratigraphic Column
upper Tuna Tephra Sub-group
(Intercalcated by L1.1)



Composite Stratigraphic Column
lower Tuna Tephra Sub-group
(Intercalcated by L1.2)



2.3.2 Kaihouri tephras (new informal formation)

Kaihouri tephras are a newly named **informal** formation, named after Kaihouri Stream, that flows eastwards from Egmont Volcano, crossing State Highway 3, midway between Stratford and Tariki.

Kaihouri tephras are best represented in exposures on the south-eastern lower flanks of Egmont Volcano, occurring between **Toko Tephra Sub-group** above, and **Paetahi Tephra** below. Kaihouri tephras comprise a set of at least **eight** lapilli beds informally named **Kai.a** to **Kai.h** in order of younging (e.g. **Section 7** of Appendix 1 and Figure 2.17).

Kaihouri tephras have proven more difficult to identify and correlate than individual constituents of Kaponga Tephra, since, most Kaihouri tephras are thinner, less widespread and confined in distribution to the south-eastern sector. Further restricting correlation is the conspicuous, localised absence of either the entire formation (e.g. **Section 6** of Appendix 1; Plate 2.16) or one or more Kaihouri tephras (e.g. **Section 9** of Figure 2.17; Plate 2.17) due to disconformities in this portion of the cover-bed sequence.

Of all the coarse ash and lapilli units that comprise Kaihouri tephras in the eastern and south-eastern sectors, only the uppermost bed (**Kai.h**) is distinctive enough macroscopically to allow confident identification (Plate 2.15). Construction of an isopach map for **Kai.h** is precluded by meagre outcrop data. In the north-eastern sector, only three thin unnamed Kaihouri tephras occur, of which, only one is visibly continuous (see **Section 13** of Appendix 1 and Figure 2.17).

Criteria
Most Kaihouri tephras comprise dominantly yellowish-red (5YR 5/8) or reddish-yellow (7.5YR 6/8 and 5YR 6/8) pumiceous lapilli, with subordinate grey to greyish-brown lapilli (Plate 2.19). The lithic component is either dispersed throughout the unit or increases in proportion towards the upper contact of the unit.

In the south-eastern and eastern sectors, **Kai.h** comprises two distinct layers. The lower layer is unstratified comprising variable proportions of yellowish-red and reddish-yellow (5YR 5/8 and 6/8) pumiceous and grey (10YR 5/1 to 4/1) coarse ash and fine lapilli. The upper layer consists of very firm, massive to normal graded, well sorted grey (7.5YR N4/), coarse ash (Plate 2.20). In the northern and north-eastern sectors, Kai.h comprises unstratified, moderately sorted yellowish-red and reddish yellow (5YR 5/8 - 6/8) pumiceous lapilli.

Upper and Lower Contacts
Throughout the eastern sectors of Egmont Volcano, Kai.h is separated from Mahoe Tephra above, by <0.5m of medial material (Plate 2.15). In the same vicinity, lowermost Kaihouri tephra is separated from **Pae.f** of **Paetahi Tephra** below, by <0.14m of medial material (Plate 2.19). However, in the north-eastern sector, the lowermost Kaihouri tephra is separated from **Pae.d** of **Paetahi Tephra** by a significantly greater thickness (<0.3m) of medial material.

Kaihouri tephras are interstratified by thin wedges of localised, aeolian andesitic sands, here correlated to the **Katikara Formation** of Neall (1975) (see Chapter 5). No deposits of Katikara Formation have yet been observed to overlie uppermost Kaihouri tephra. Kaihouri tephras are also interstratified by at least two debris/hyperconcentrated flow deposits of **Warea**

Formation Correlatives (after Neall 1979) (e.g. **Section 10** of Figure 2.17; Plate 2.20).

Type Section

An informal type section and type area of Kaihouri tephras are designated the same as for Mahoe Tephra (**Section 7** of Appendix 1 and Figure 2.17). This section is chosen because Kaihouri tephras are best represented here and occur without intercalating disconformities. Here, Kaihouri tephras are exposed as follows:

Ma.a of **Mahoe Tephra**

2.41m -------------- Distinct and wavy boundary --------------

0.22m	Dark yellowish-brown (10YR 4/6), firm, moderately developed, fine to medium blocky structured medial material. Diffuse and wavy boundary.
0.25m	Dark yellowish-brown (10YR 4/4), very firm, weakly developed, coarse blocky structured medial material. Sharp and broken boundary.
0.07m **Kai.h**	0.1m discontinuous, massive, well cemented very firm dark grey (7.5YR N4/)fine ash. Sharp and broken boundary. 0.06m profuse, moderately to poorly sorted, very firm grey to dark grey (10YR 5/1 to 4/1) fine to coarse lapilli with many fine to medium reddish-yellow (5YR6/8) to yellowish-red (5YR 5/8) pumiceous lapilli dispersed throughout. Distinct and wavy boundary.
0.72m	Yellowish-brown (10YR 4/4), very firm, weakly developed, coarse blocky structured medial material. Sharp and wavy boundary.
0.03m **Kai.g**	Moderately well sorted, abundant reddish yellow (5YR 6/8) fine to medium pumiceous lapilli. Few to common, poorly sorted fine to very coarse grey lapilli dispersed throughout. Sharp and wavy boundary.

0.02m	Yellowish-brown (10YR 4/4), very firm, massive structured medial material. Distinct and wavy boundary.
0.04m **Kai.f**	Moderately sorted, abundant reddish yellow (5YR 6/8) and strong brown (7.5YR 5/8) fine to coarse pumiceous lapilli. Few dispersed grey, fine lapilli. (Along section this unit merges with unnamed lapilli unit above). Distinct and wavy boundary.
0.07m	Yellowish-brown (10YR 5/3 to 5/4), firm, weakly developed, medium blocky structured, medial material. Distinct and wavy boundary.
0.05m **Kai.e**	Many, moderately sorted, fine to coarse reddish-yellow (7.5YR 6/8) pumiceous lapilli and fine to medium grey to dark grey (10YR 6/1 to 4/1) lapilli upwardly increasing in proportion from few to many. Indistict and wavy boundary.
0.09m	Yellowish-brown (10YR 5/6), very firm, massive structured medial material. Indistinct and wavy boundary.
0.12m	Yellowish-brown (10YR 5/4), firm, massive structured medial material. Distinct and wavy boundary.
0.07m **Kai.d**	Moderately well sorted, common to many, fine, grey (7.5YR N6/ to N5/) and pumiceous, yellow to brownish-yellow lapilli dispersed in medial matrix. Distinct and wavy boundary.
0.10m	Yellowish-brown (10YR 5/6), very firm, massive structured medial material. Sharp and wavy boundary.
0.08m	Pale brown (10YR 5/3), weakly developed, coarse to medium blocky structured medial material. Indistinct and wavy boundary.
0.09m **Kai.c**	Moderately well sorted, common, medium strong brown to reddish-yellow (7.5YR 6/8 to 5/8) pumiceous and grey (7.5YR N6/ to N5/) fine lapilli dispersed in brown (10YR 5/3) medial material. Distinct and wavy boundary.

0.12m	Yellowish-brown (10YR 5/4), **firm, massive** structured medial material. Distinct and wavy boundary.
0.01m **Kai.b**	Moderately well sorted, many, fine to medium reddish-yellow to strong brown (7.5YR 6/8 to 5/8) pumiceous lapilli dispersed in medial matrix. Distinct and wavy boundary.
0.05m	Yellowish-brown (10YR 5/4), firm, massive structured medial material. Distinct and wavy boundary.
0.01m **Kai.a**	Moderately well sorted, abundant fine to medium reddish-yellow to strong brown (7.5YR 6/8 to 5/8) pumiceous lapilli. Distinct and wavy boundary.
0.14m	Yellowish-brown (10YR 5/4), very firm, massive structured medial material grading downwards to yellowish brown (10YR 5/8), firm medial material.

4.76m ------------- Distinct and wavy boundary ----------------

Pae.f of **Paetahi Tephra**

Age

A radiocarbon date (NZ5411A) of a sandy peat sample, 0.06m below **Kai.h** at Durham Road (**Section 8** of Appendix 1) establishes an age for it of 12,900 +/- 200 years B.P.

On the basis of assumed constant accumulation rates of medial material in the cover-bed succession between the c.10.1kyr Konini Tephra above, and c.22.5kyr Aokautere Ash below, Kaihouri tephras are here estimated to have an age range between c.12.9 and c.18.5 kyrs B.P.

Correlation

In the north-eastern sector, **Kai.h** is here correlated to **Ahuahu Lapilli** of Neall (1972).

Reference Localities

Three reference localities are here designated for Kaihouri tephras (see **Sections 7, 9** and **13** of Appendix 1 and Figure 2.17).

Plate 2.19: Kaihouri tephra and Paetahi Tephra near Tuikonga Stream on Opunake Stream (Section 9; Q20/185051).

Plate 2.20: Kai.h of Kaihouri tephra at Tariki Underpass on State Highway 3 (Section 10; Q20/167202). Note debris flow of **Warea Formation** below tephra.

2.3.3 Paetahi Tephra
(new formation)

Paetahi Tephra is a newly defined tephra formation named after Paetahi Stream that flows south-eastwards from Egmont Volcano to the western confines of Stratford Borough, where the Stream joins the Patea River.

On the lower south-eastern flanks of Egmont Volcano, Paetahi Tephra comprises a closely spaced set of **six** coarse ash and lapilli beds that underlie **Kaihouri tephra** and overlie a prominent buried soil and **Poto Tephra** (Plate 2.21). Close to source in the south-eastern sector, each successive tephra bed is here informally named **Pae.a** to **Pae.f** in order of decreasing age, and are separated by <0.05m of medial material.

The lowermost lapilli bed (**Pae.a**) is a widespread marker bed throughout eastern Taranaki, and is the most important chronohorizon for correlation in the time range c.12 - 22,000 years B.P.

Despite the distinct appearance of **Pae.d** and **Pae.e** in the south-eastern sector, correlative usage is limited because they are more restricted in their distribution than **Pae.a**. Beds **Pae.b** and **Pae.c** in the same sector, have little diagnostic character. On the lower north-eastern flanks only **Pae.a** and **Pae.d** of Paetahi Tephra occur, of which, only the former is visibly continuous.

Upper and Lower Contact

Throughout the eastern lower flanks of Egmont Volcano, the uppermost unit of **Paetahi Tephra** (**Pae.f**) is separated from **Kaihouri tephra** above, by <0.15m of medial material (e.g. **Sections 7** and 9 of Appendix 1 and Figure 2.20). The lowermost unit (**Pae.a**) is separated from **Poto Tephra** below, by a prominent buried soil (<0.17m) (Figure 2.20 and Plate 2.21).

Paetahi Tephra, like Kaihouri tephras above, are interstratified at some localities, by either aeolian andesitic sands of **Katikara Formation** or debris flow/hyperconcentrated flow units of **Warea Formation Correlatives.**

Pae.a is occasionally observed at sites to the east of the Egmont ring-plain, to unconformably mantle thin colluvial wedges of admixed medial material and siltstone that overlie in situ outcrops of Tertiary siltstone (Plate 2.22).

Type Section

The type section and type area of Paetahi Tephra are the same as for those formally designated for Mahoe Tephra and informally designated for Kaihouri tephras (see **Section 7** of Appendix 1 and Figure 2.20; Plate 2.21).

Kai.a of **Kaihouri tephra**

4.62m ------------- Distinct and wavy boundary ----------------

	0.14m	Yellowish-brown (10YR 5/4), very firm, massive structured medial material grading downwards to yellowish-brown (10YR 5/8), firm medial material. Distinct and wavy boundary.
	0.01m **Pae.f**	Moderately sorted, common, reddish yellow (7.5YR 6/8) fine to medium, pumiceous lapilli with few grey lapilli dispersed in medial matrix. Sharp and wavy boundary.
	0.02m	Yellowish-brown (10YR 5/6), very firm, massive structured medial material. Indistinct and wavy boundary.
	0.10m **Pae.e**	Moderately well sorted to well sorted, abundant, fine, grey to dark grey (7.5YR N6/ - N4/) lapilli. Few fine to medium reddish-yellow pumiceous lapilli dispersed at base. Sharp and wavy boundary.

0.05m	Yellowish brown (10YR 5/6), very firm, massive structured medial material. Distinct and wavy boundary.
0.05m **Pae.d**	Moderately well sorted, abundant, fine to coarse, subrounded reddish-yellow (7.5YR 6/8 and 5YR 6/8) pumiceous lapilli. Few poorly sorted, granule to coarse light grey to dark grey (10YR 7/1 to 4/1) lapilli. Distinct and wavy boundary.
0.01m	Yellowish brown (10YR 5/6), massive structured medial material. Distinct and wavy boundary;
0.02m **Pae.c**	Moderately sorted, fine to medium, reddish yellow (7.5YR 6/8) pumiceous and firm grey lapilli, discontinuous and pocketed. Distinct and wavy boundary.
0.05m	Yellowish brown (10YR 5/6), firm, massive structured medial material. Distinct and broken boundary.
0.02m **Pae.b**	Moderately sorted, medium to coarse, reddish yellow (7.5YR 6/8) dominantly pumiceous lapilli, discontinuous and pocketed. Indistinct and broken boundary.
0.05m	Yellowish brown (10YR 5/6), very firm, massive structured medial material. Indistinct and wavy boundary.
0.17m **Pae.a**	Shower bedded, multiple normal graded layers. Each layer comprises of profuse, moderately well sorted, fine to coarse grey (7.5YR N6/ - N4/) lapilli with few to common fine to coarse, brownish yellow (10YR 6/8) to yellow (10YR 7/8) pumiceous lapilli dispersed at the base. Each layer then grades to profuse, moderately well to well sorted, grey fine lapilli and coarse ash. Sharp and wavy boundary.
0.17m	Brown (10YR 5/3), firm, moderately developed, medium to coarse blocky structured medial material.

5.48m ------------- Distinct and wavy boundary ----------------

Pot.o of Poto Tephra

Age

On the basis of assumed constant accumulation rates of medial material in the cover-bed succession between the c.10.1 kyr Konini Tephra above, and c.22.5 kyr Aokautere Ash below, Paetahi Tephra is here provisionally ascribed an age range of between c.19.0 and c.19.9 kyrs B.P.

Member: **Pae.a**

Criteria

Throughout the lower eastern flanks of Egmont Volcano, **Pae.a** is a distinctive marker bed comprising firm, multiple normal graded layers of dominantly grey (7.5YR N6/ - N5/) lapilli and coarse ash. A variable, subordinate proportion of reddish-yellow (7.5YR 6/8) pumiceous lapilli may either be concentrated towards the base or dispersed throughout each layer. **Pae.a** directly overlies a prominent, brown (10YR 4/3 - 5/3) buried soil developed into massive structured medial material and uppermost Poto Tephra, below (Plate 2.21).

Isopachs

Despite meagre isopach data (Figure 2.21), **Pae.a** is recognised extensively eastwards from Egmont Volcano. A maximum recorded thickness of 0.22m occurs in the vicinity of Cardiff (e.g. **Section 7** of Figure 2.20). A 0.10m isopach is provisionally drawn extending north as far as Inglewood and south between Kaponga and Kapuni. Eastwards this isopach occurs in the area midway between Stratford and Toko. North and east beyond the Egmont ring-plain, **Pae.a** is clearly identified as a 0.20m thick yellowish-red (5YR 4/6) layer of friable, moderately well developed, fine blocky structured medial material with a reddish-yellow (7.5YR 6/8) basal pumiceous lapilli bed (e.g. **Sections 23** and **32** of Appendix 1 and Figure 2.20; Plates 2.23 and 2.24, respectively).

Reference Localities

A total of seven reference localities are here designated for Paetahi Tephra, of which, three have been described previously (**Sections 9, 13** and **15** of Appendix 1 and Figure 2.20). A further four new reference localities are designated as follows:

1. Cutting along Leppers cow race, Manutahi Road, 0.3km west of the Waiongana Stream Bridge (Q19/142373) (**Section 23** of Appendix 1 and Figure 2.20; Plate 2.23).

2. Farm track cutting in coastal cliffs behind Buchanan's Farm House, Turangi Road (Q19/242456) (**Section 28** of Appendix 1).

3. Very prominent road cutting, 0.3km north along State Highway 3 from Onaero Domain Motor Camp (Q19/285441) (**Section 30** of Appendix 1).

4. Prominent north-facing road cutting, 0.1km west of Te Wera Forest Headquarters (Q20/477181) (**Section 32** of Appendix 1 and Figure 2.20; Plate 2.24).

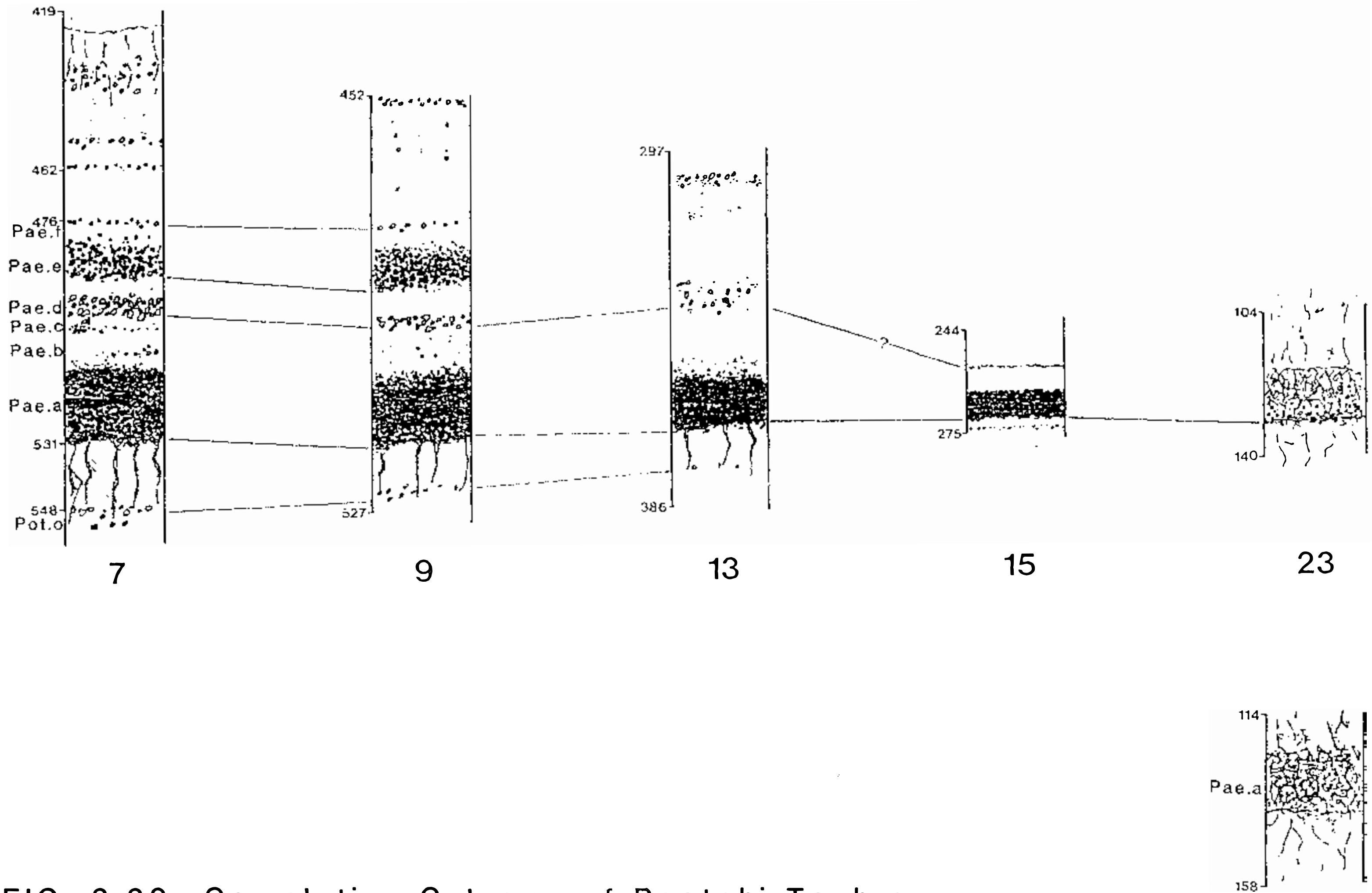


FIG. 2.20 Correlation Columns of Paetahi Tephra

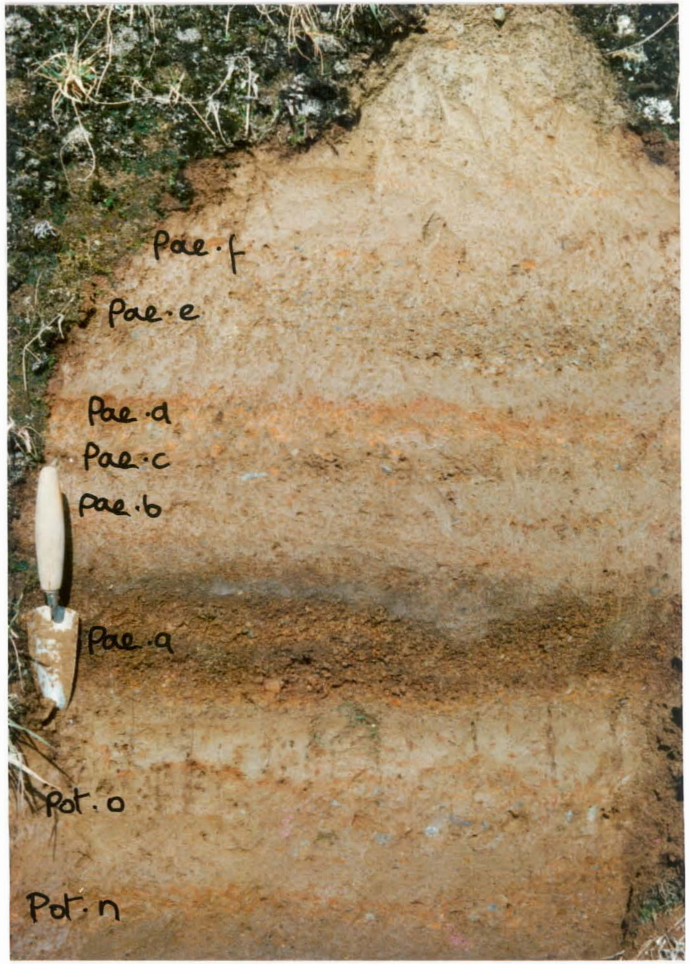


Plate 2.21: **Paetahi Tephra** at its type section near Waingongoro River-Cardiff Walkway, on Opunake Road (Section 7; Q20/158043).

Plate 2.22: **Pae.a** closely overlying admixed medial material and siltstone resting on in situ Tertiary siltstone on Kaimata Road (Q19/218236).

Plate 2.23: **Pae.a** enclosed within L1 near Lepperton (Section 23; Q19/142373). Note **S1** above **Pae.a** and **S2** below. The trowel (left centre) indicates the position of **Aokautere Ash** within the section.

Plate 2.24: **Pae.a** enclosed within **L1** near Te Wera (Section 32; Q20/477181). Note **S1** above **Pae.a** and **S2** below.

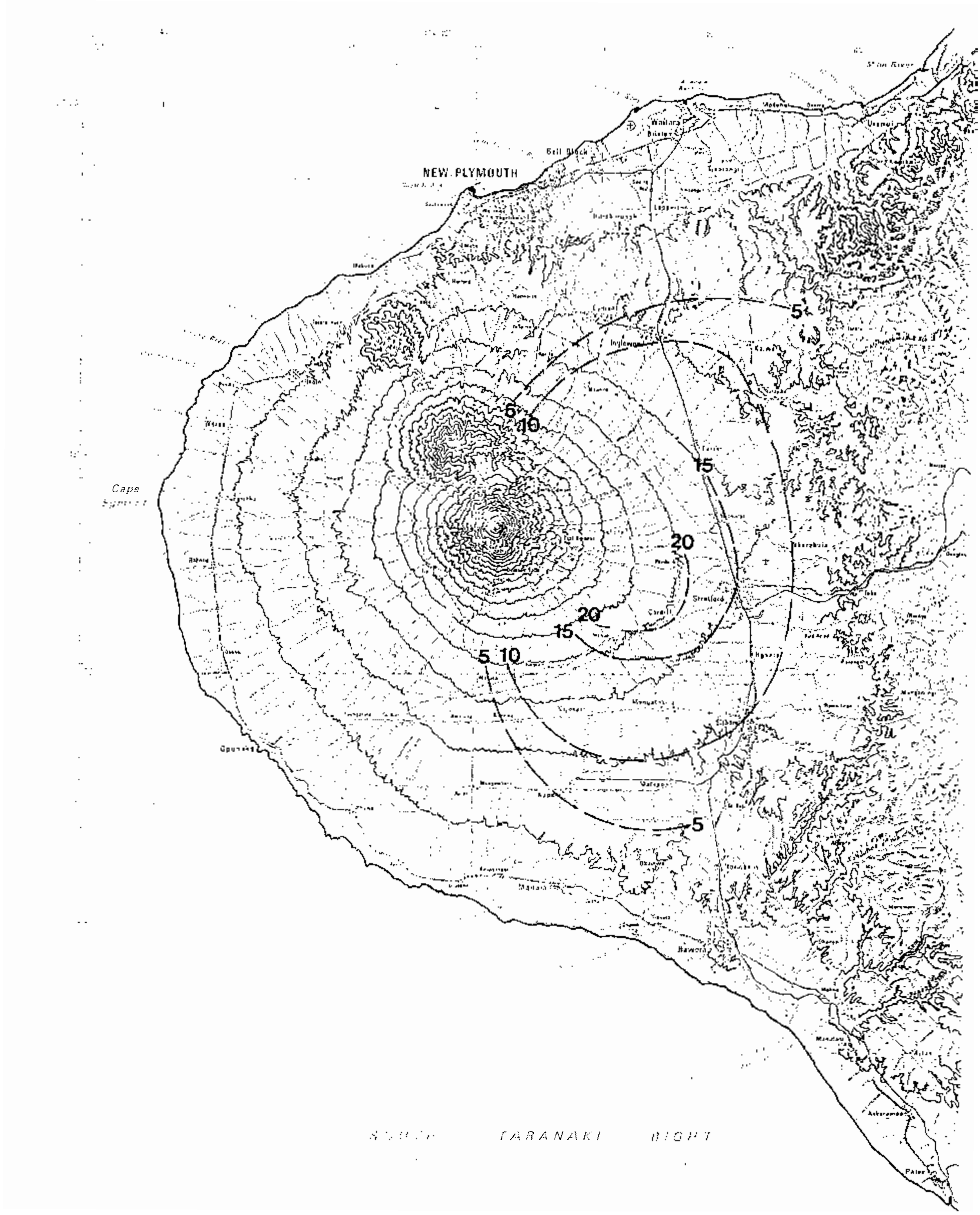


FIG. 2.21 Isopach Map : Pae.a of Paetahi Tephra

2.3.3 Poto Tephra
(new formation)

Poto Tephra is a new formation, named after Poto Road which joins Opunake Road midway between Mahoe and Cardiff in the south-east sector.

On the south-eastern lower flanks of Egmont Volcano, Poto Tephra comprises a closely spaced set of at least **fifteen** coarse ash and lapilli beds (Plate 2.25) that intervene between **Paetahi Tephra** above, and **Tuikonga Tephra**, below. Each bed of Poto Tephra is separated by <0.08m of medial material.

Poto Tephra is best represented in exposures on the south-eastern lower flanks, where each successive bed is informally named **Pot.a** to **Pot.o**. However, in other sectors, where Poto Tephra is poorly represented, identification and correlation of individual units is difficult through lack of diagnostic character.

Upper and Lower Contacts
In the south-eastern sector, the uppermost unit of **Poto Tephra** (**Pot.o**) is separated from **Pae.a** of **Paetahi Tephra** above, by a **prominent buried soil** (<0.17m thick) (Plate 2.25). In the same sector, the lowermost unit (**Pot.a**) is separated from **Tuikonga Tephra** below, by <0.15m of medial material (e.g. Section 7 of Appendix 1; Plate 2.26).

Disconformities are occasionally interpreted in the coverbed sequence between the upper and lower contacts of Poto Tephra.

Poto Tephra is interstratified by at least two debris flow units of **Warea Formation Correlatives** (after Neall 1979) and the c.22.5 kyr Central North Island rhyolitic chronohorizon - the **Aokautere**

Ash (Plate 2.25). Poto Tephra is also interstratified by **Ngaere Formation** (Plate 2.26).

In the south-eastern sector, **Aokautere Ash** lies between **Pot.e** below, and **Pot.f**, above. **Ngaere Formation** directly overlies Pot.b and closely underlies **Pot.c.**

Criteria

Most units of Poto Tephra comprise moderately to moderately well sorted, normal graded to massive layers of profuse to abundant grey to dark grey (7.5YR N5/ - N6/) coarse ash and lapilli with downwardly increasing proportions of reddish-yellow (7.5YR 6/8) pumiceous lapilli (Plate 2.25). In contrast to all other units of Poto Tephra in the south-eastern sector, the **Pot.b** that directly underlies **Ngaere Formation** is unusual in being extremely well sorted (see Chapter 8) and reverse graded (Plate 2.27).

Type Section

The type section of Poto Tephra is designated at a prominent north-facing road cut opposite Cardiff Walkway Carpark, 0.1m west of Waingongoro River Bridge, on Opunake Road (**Section** 7 of Appendix 1 and Figure 2.22; Plate 2.25). This type section is the same as that designated for Mahoe Tephra, Paetahi Tephra and Kaihouri tephra. At its type section Poto Tephra is exposed as follows:

Pae.a of **Paetahi Tephra**

5.31m -------------		Sharp and wavy boundary -------------------
	0.17m	Brown (10YR 5/3), firm, moderately developed, medium to coarse block structured medial material. Distinct and wavy boundary.

0.04m **Pot.o**	Many, unstratified, moderately sorted fine to medium (few coarse) reddish-yellow 7.5YR 6/8) to yellow (10YR 7/8) pumiceous lapilli and common grey to greyish-brown (10YR 6/1 5/2) lapilli dispersed in brown (10YR 5/3) medial material. Distinct and wavy boundary.
0.08m	Brown (10YR 5/3), firm, weakly developed, medium to coarse block structured medial material. Indistinct and wavy boundary.
0.05m **Pot.n**	Many, unstratified, moderately well sorted fine to medium reddish-yellow (7.5YR 6/8) pumiceous and few grey (10YR 6/1) lapilli dispersed in greyish-brown (10YR 5/2), very firm medial material. Distinct and wavy boundary.
0.06m	Greyish-brown (10YR 5/2), very firm, massive structured medial material. Distinct and wavy boundary.
0.06m **Pot.m**	Many, unstratified, moderately well sorted fine to medium reddish-yellow (7.5YR 6/8) pumiceous lapilli dispersed in greyish-brown (10YR 5/2) medial material. Distinct and broken boundary.
0.12m **Pot.l**	0.04m thick layer of profuse moderately well sorted dark grey (7.5YR N4/) coarse ash which downwardly grades to profuse, moderately sorted fine dispersed in a coarse ash matrix. Sharp and broken boundary to 0.08m thick layer of profuse poorly sorted strong brown (7.5YR 5/6) coated, reddish-yellow (7.5YR 6/8) fine to very coarse pumiceous and many grey to dark grey (7.5YR N5/ N/6) lapilli. Distinct and wavy boundary.
0.05m	Brown (10YR 5/4), very firm, massive structured medial material. Distinct and broken boundary.

0.12m **Pot.k**	0.06m of abundant moderately well sorted reddish-yellow (7.5YR 6/8) fine to medium pumiceous lapilli dispersed in a subordinate pumiceous coarse ash matrix. Sharp and broken boundary to 0.06m of profuse moderately sorted dark greyish-brown (10YR 4/2) fine (few medium) lapilli dispersed in a coarse ash matrix. Layer downwardly grades to fine to medium (few coarse) lapilli. Sharp and smooth boundary.
0.04m **Pot.j**	0.01m of very firm, well sorted grey to light grey (7.5YR N6/) medium to coarse ash. Sharp and straight boundary to 0.03m of abundant moderately well sorted dark grey (7.5YR N4/) coarse ash and fine lapilli. Common yellow (10YR 7/8 - 8/8) medium pumiceous lapilli dispersed at base. Distinct and wavy boundary.
0.04m	Yellowish-brown (10YR 5/6), very firm, massive structured medial material. Sharp and wavy boundary.
0.05m Pot.i	0.03m of laminar (millimetre) bedded well sorted to very well sorted, very firm brownish-yellow (10YR 6/6) fine ash downwardly grading to coarse ash. Sharp and wavy boundary to 0.02m of abundant to profuse poorly sorted yellowish-brown (10YR 5/6) coated, yellow to brownish-yellow (10YR 8/8-6/8) pumiceous coarse ash to coarse lapilli. Distinct and wavy boundary.
0.06m	Yellowish-brown (10YR 5/4), very firm, massive structured medial material. Indistinct and broken boundary.
0.04m **Pot.h**	Many, unstratified, moderately well sorted, reddish-yellow (7.5YR 6/8) fine to medium pumiceous lapilli with few dispersed fine to medium grey lapilli. Distinct and wavy boundary.
0.04m	Yellowish-brown (10YR 5/4), very firm, massive structured medial material downwardly grading to greyish-brown (10YR 5/2) vey firm, massive structured ashy material. Sharp and irregular boundary.

0.06m **Pot.g**	Profuse, unstratified, very firm, well sorted dark grey (10YR 4/1) coarse ash and fine lapilli. Sharp and irregular boundary.
0.05m	Greyish-brown (10YR 5/4), very firm, massive structured, medial material.
0.06m **Pot.f**	Many to abundant, moderately to poorly sorted yellowish-brown (10YR 5/6) coated, strong brown to reddish yellow (7.5YR 6/8 - 5/8) fine to very coarse pumiceous lapilli, with subordinate (few to common) fine to medium grey lapilli dispersed throughout. Distinct and wavy boundary.
0.05m **Aokautere Ash**	Yellow (10YR 7/6; 60% and 10YR 7/8; 40%) mottled, massive, well sorted, fine to medium fine glassy ash. Indistinct and irregular boundary.
0.07m **Pot.e**	Profuse to abundant, normal bedded, very firm, moderately well sorted grey (5YR 5/1), medium to coarse ash downwardly grading to fine to medium grey lapilli, with common reddish-yellow (5YR 6/8) fine to medium pumiceous lapilli dispersed at base. Sharp and wavy boundary.
0.03m	Greyish-brown (10YR 5/4), very firm, massive structured medial material. Distinct and wavy boundary.
0.03m **Pot.d**	Profuse, very firm, moderately well sorted grey (5YR 5/1) coarse ash grading downwards to fine to medium lapilli with common reddish-yellow (5YR 6/8) fine pumiceous lapilli dispersed at base. Sharp and wavy boundary.
0.07m	Dark greyish-brown (10YR 4/2), very firm, massive structured medial material. Sharp and wavy boundary.
0.10m **Pot.c**	Profuse, well sorted, very dark grey (7.5YR N4/-N3/) medium to coarse ash downwardly grading to moderately sorted fine to coarse lapilli with many reddish-yellow (7.5YR 6/8) pumiceous lapilli at base. Sharp and wavy boundary.

0.06m	Yellowish-brown (10YR 5/6), firm, massive structured medial material. Distinct and wavy boundary.
0.58m	Unstratified, extremely poorly sorted, heterolithologic many to abundant clasts (fine lapilli to boulder) randomly orientated within brown to yellowish-brown (10YR 5/3 - 5/4), firm, medial material. Sharp and wavy boundary. (**Axial b facies** of **Ngaere Formation**)
0.06m **Pot.b**	Profuse, extremely well sorted, reverse graded dark grey (10YR 3/1) medium to coarse ash. Sharp and wavy boundary.
0.09m	Greyish-brown (10YR 5/2), firm, massive structured medial material. Sharp and wavy bouundary.
0.09m **Pot.a**	Profuse, moderately well sorted, very dark grey to very dark greyish-brown (10YR 3/1 3/2) coarse ash and fine lapilli downwardly grading to abundant strong brown (7.5YR 4/6) coated, yellow (10YR 7/6 - 7/8) fine to medium pumiceous lapilli. Sharp and wavy boundary.
0.14m	Dark yellowish-brown (10YR 4/6), firm, massive structured medial material.

7.87m ------------- Distinct and wavy boundary ---------------

Tui.d of **Tuikonga Tephra**

Age

Poto Tephra is here estimated to have an age range between c.20.7 and c.23.0 kyr B.P on the basis of an assumed constant accumulation of medial material between the c.12.9 kyr **Kai.h** and the c.22.5 kyr **Aokautere Ash.**

Correlation

Poto Tephra is here correlated with **Saunders Ash** and three other pumiceous beds identified as Carrington Tephras, at the Saunders

Ash Type Section of Neall (1972) (reinterpreted this study; **Section 5** of Appendix 1 and Figure 2.22). The age range of **Poto Tephra** is clearly older than the radiocarbon date (NZ942) of 16,100 +/- 200 years B.P. obtained from charcoal preserved within **Saunders Ash** at its type section. This age difference problem, has been resolved by the occurrence of the Aokautere Ash. On the north-western lower flanks, Saunders Ash at its type section (Neall 1972) is separated from Aokautere Ash below, by <0.11m of medial material (**Section 5** of Appendix 1 and Figure 2.22). Since the Saunders Ash closely overlies the Aokautere Ash without any intervening unconformities, Saunders Ash is here interpreted to be older than its radiocarbon date would otherwise suggest.

Thickness Variation

From limited outcrop data, Poto Tephra has a combined maximum recorded thickness of c.1.25m between Mahoe and Cardiff (e.g. **Section 7** of Figure 2.22). On the western outskirts of Stratford Borough, Poto Tephra has a similar thickness to that recorded at Cardiff (e.g. **Section** 9 of Figure 2.22; Plate 2.28).

The principal axis of distribution is interpreted to extend in a south-eastly direction from the Egmont Volcanic Centre to between Cardiff and Mahoe. South and north-east from the axis, fewer units persist as prominent and continuous layers. The majority of these units become increasingly dispersed and finer grained within a steadily increasing proportion of medial material. In the southern sector (e.g. **Section 15** of Figure 2.22) five, thin (each less than 0.03m) units of Poto Tephra envelope the Aokautere Ash between Paetahi Tephra above, and Ngaere Formation, below (Plate 2.29). In the north-east sector in the vicinity of Inglewood (e.g. **Section 13** of Figure 2.22), a total of eight units of Poto Tephra intervene between Paetahi Tephra, above and Tuikonga Tephra, below.

Reference Localities

A total of five reference localities are designated for Poto Tephra (**Sections 6, 9, 13, 15** and **22** of Appendix 1). An informal reference locality is designated as follows:

> Prominent east facing road cut on State Highway 3, 0.1km north of junction with Croydon Road, (Q20/182153).

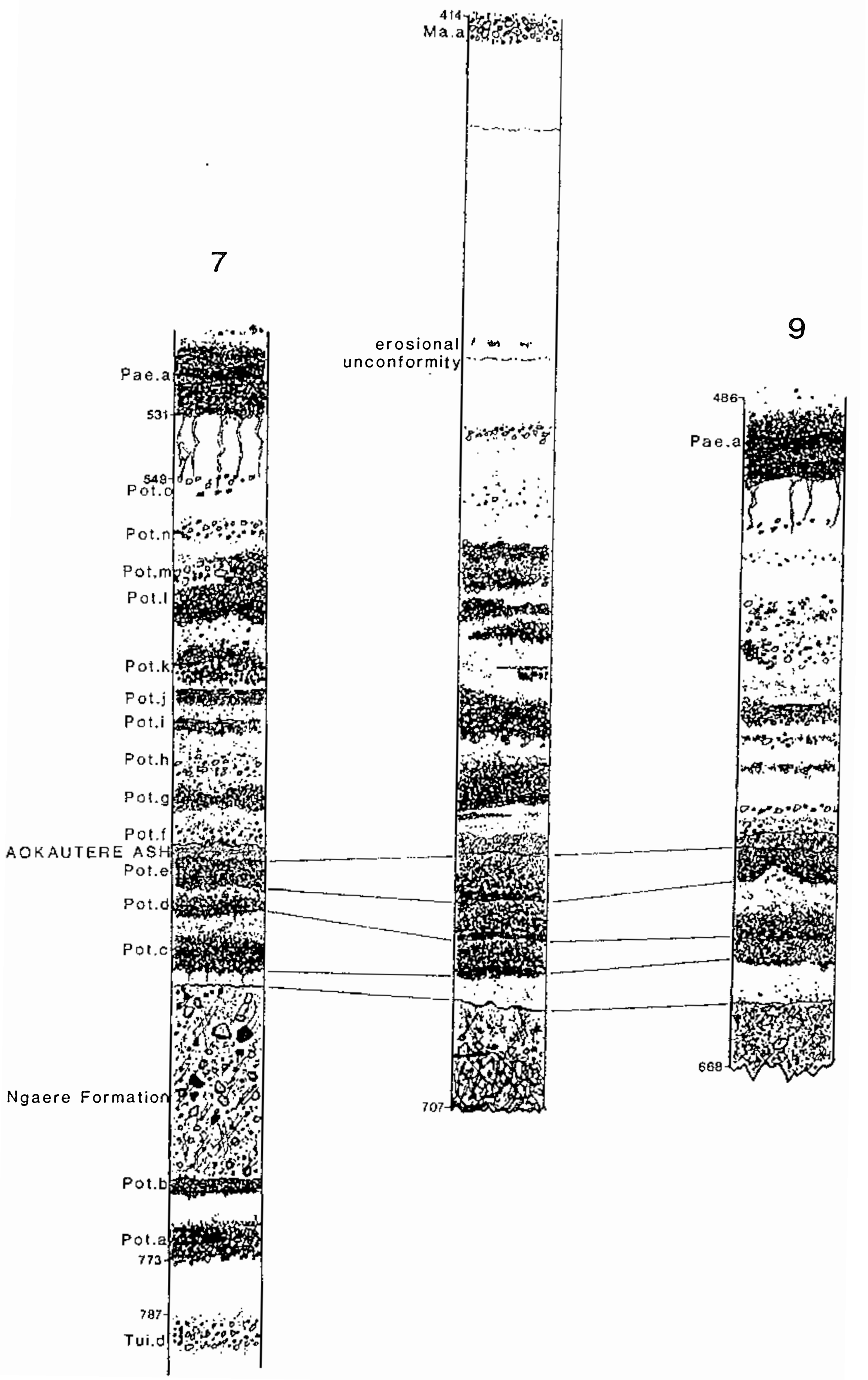
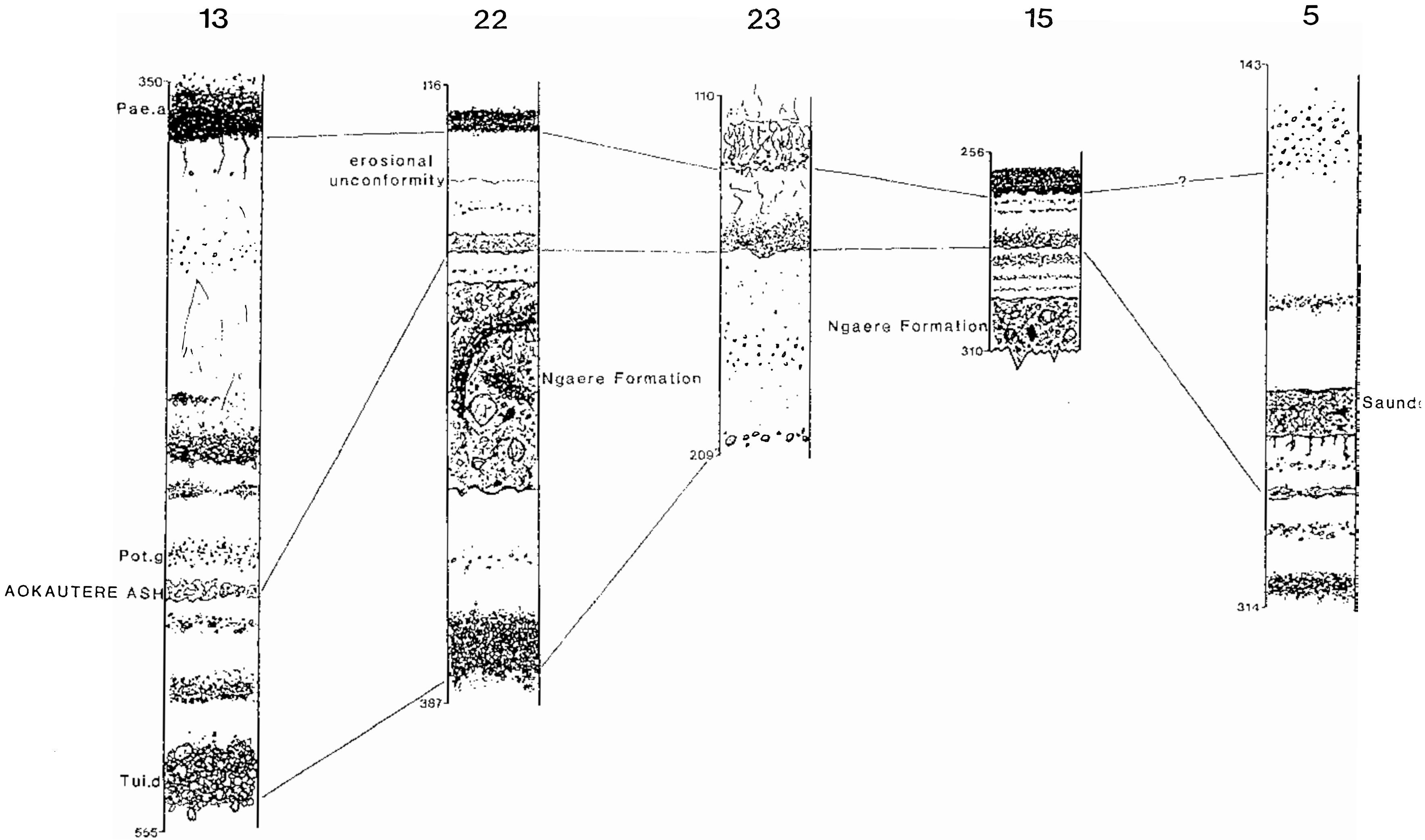


FIG. 2.22 Correlation Columns of Poto Tephra


13
22
23
15
5
350
Pae.a
Pot.g
AOKAUTERE ASH
Tui.d
565
116
erosional
unconformity
Ngaere Formation
387
110
209
256
Ngaere Formation
310
143
?
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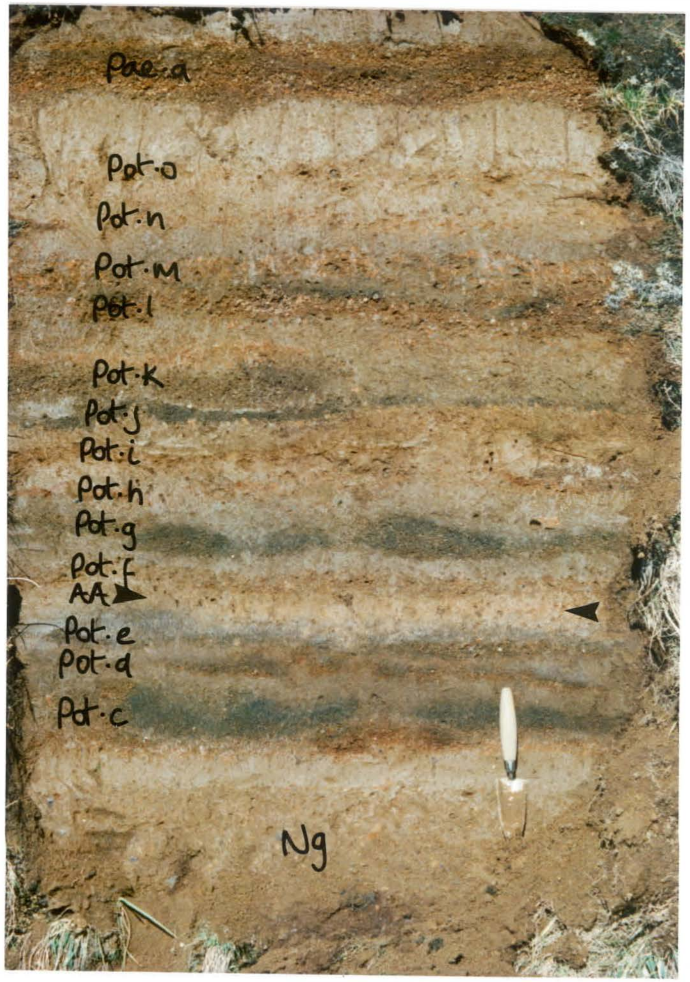


Plate 2.25: **Pot.c** to **Pot.o** of **Poto Tephra** at their type section near Waingongoro River-Cardiff Walkway, on Opunake Road (Section 7; Q20/158043). Note **Pae.a** of **Paetahi Tephra** above **Poto Tephra** and **Ngaere Formation** below. Position of **Aokautere Ash** (AA) in section indicated by arrows.

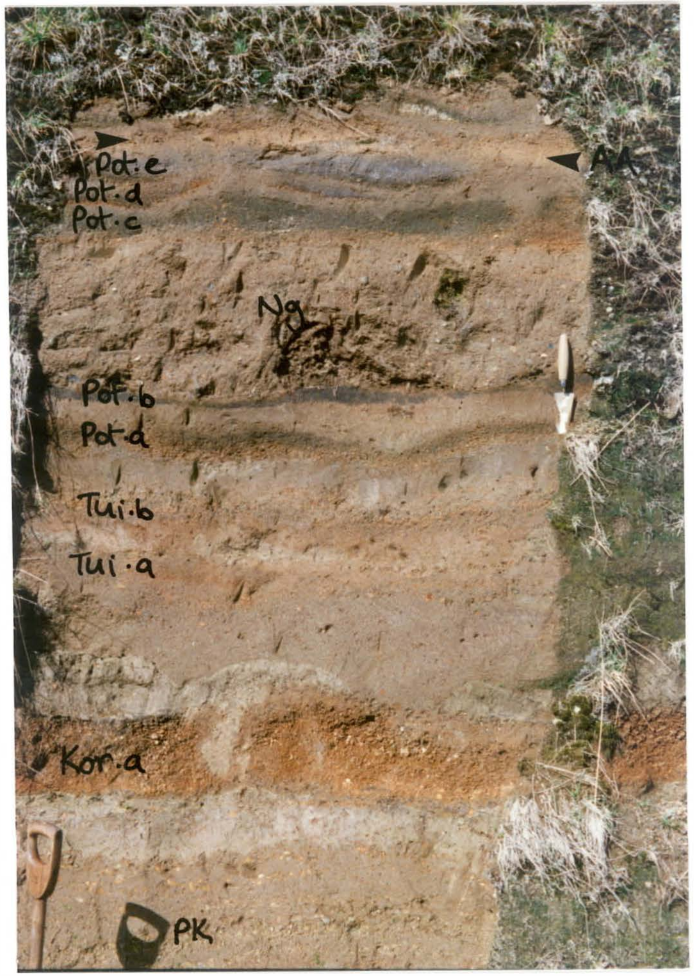


Plate 2.26: **Pot.a** to **Pot.g** of **Poto Tephra** at their type section near Waingongoro River-Cardiff Walkway, on Opunake Road (Section 7; Q20/158043). Note **Tuikonga**, **Koru** and **Pukeiti Tephra** below **Pot.a**. Position of **Aokautere Ash** (AA) in section is indicated by arrows.

Plate 2.27: **Pot.b** and **Pot.a** of **Poto Tephra** beneath Ngaere Formation at their type section near Waingongoro River-Cardiff Walkway, on Opunake Road (Section 7; Q20/158043). Note the well sorted and reverse graded nature of **Pot.b**.

Plate 2.28: **Poto Tephra** near Tuikonga Stream on Opunake Stream (Section 9; Q20/185051). Note **Pae.a** of **Paetahi Tephra** above **Poto Tephra** and **Ngaere Formation** (Ng) below.

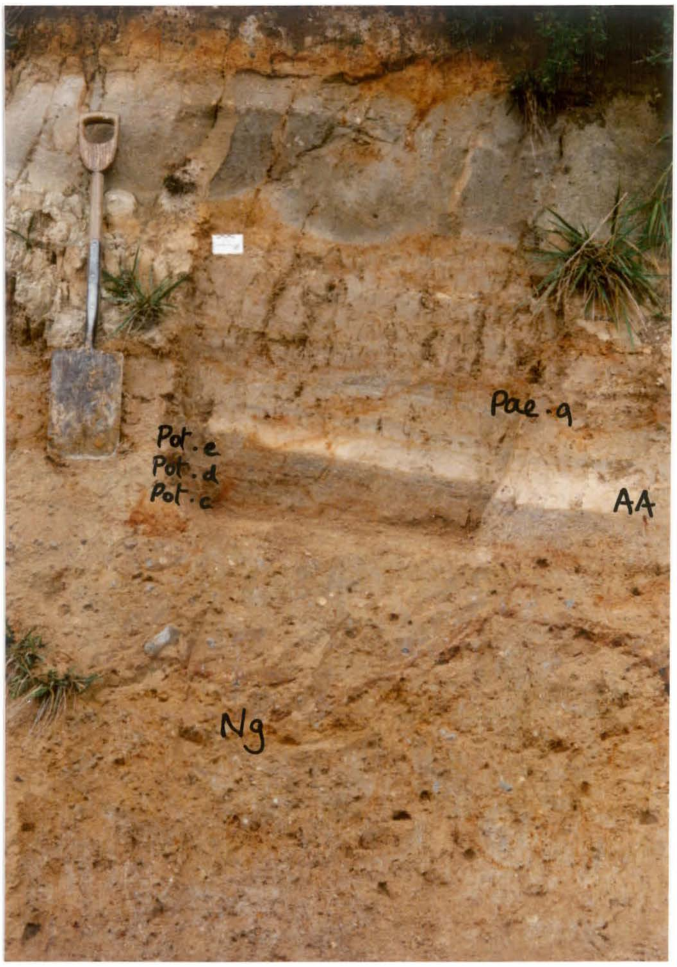


Plate 2.29: **Poto Tephra** intervening between **Aokautere Ash** and **Ngaere Formation** (Ng) at corner of Skeet and Glenn Roads (Section 15; P20/042908). Arrow indicates position of **Pae.a** of **Paetahi Tephra**.

2.3.4 Tuikonga Tephra (new formation)

Tuikonga Tephra is named after Tuikonga Stream which flows south-east from Egmont Volcano, crossing Opunake Road c.1.8km west of Stratford Borough.

Tuikonga Tephra comprises a closely spaced set of at least **four** coarse ash and lapilli beds that intervene between **Poto Tephra** above, and **Koru Tephra**, below (e.g. **Section 13** of Figure 2.23). These beds, informally named **Tui.a** to **Tui.d** in order of decreasing age, are best represented in exposures on the north-eastern lower flanks of Egmont Volcano. Here, each unit is separated by <0.11m of medial material. On the north-eastern lower flanks of Egmont Volcano, **Tui.b**, **Tui.c** and **Tui.d** are widely distributed. However, **Tui.b** and **Tui.d** constitute the most important pair of chronohorizons on the North Taranaki coastal plain for the time range c.21 - 28kyr B.P. An isopach map combining both units is given in Figure 2.24.

Criteria
On the north-eastern lower flanks, **Tui.d** is characterised by a faintly normal graded to massive bed which comprises profuse, moderately to moderately well sorted, reddish-yellow (5YR 6/8) pumiceous lapilli and few grey (10YR 5/1) lapilli (Plate 2.30). **Tui.c** typically comprises massive, very firm, moderately well to well sorted, grey to dark grey (10YR 5/1 - 4/1) and greyish-brown (10YR 5/2) coarse ash and lapilli. On the North Taranaki coastal plain, **Tui.c** thins to form distinctive but discontinuous 'creamcakes'.

In the north-eastern sector, **Tui.b** is characterised by a shower bedded layer of profuse, dark grey to very dark grey (10YR 4/1 -

3/1) coarse ash and lapilli intervening between two layers of profuse, moderately well to well sorted reddish-yellow pumiceous lapilli (e.g. Section 13 of Figure 2.23). The proportion of grey constituents within each layer is variable ranging from few to common. On the North Taranaki coastal plain **Tui.b** is similar in appearance to **Tui.d.**

The lower-most bed, **Tui.a** comprises a thin layer of dominantly yellowish-red (5YR 5/8) pumiceous lapilli. This unit is of limited correlative usage.

Type Section

The type section is designated at a prominent driveway cutting on Inglewood Marae, 0.1km south of the BMX track and opposite the school playground, (Q19/147267) (**Section 13** of Appendix 1 and Figure 2.23). Here, Tuikonga Tephra is exposed as follows:

unnamed unit of **Poto Tephra**

5.19m ------------- Indistinct and wavy boundary --------------

0.12m	Yellowish-brown (10YR 5/6), firm, massive structured medial material. Distinct and wavy boundary.
0.15m **Tui.d**	Profuse, loose, massive bedded, moderately well sorted, reddish-yellow (5YR 6/8) medium to coarse pumiceous lapilli, with few fine to medium grey lapilli scattered throughout. Very coarse sand sized euhedral mafic crystals noticeable throughout. Sharp and wavy boundary.
0.09m	Yellowish-brown (10YR 5/6), very firm, massive structured medial material. Indistinct and wavy boundary.
0.04m **Tui.c**	Profuse, discontinuous, very firm, cemented, grey - dark grey (10YR 5/1-4/1) moderately well sorted, coarse ash. Broken and wavy boundary.

0.02m	Yellowish-brown (10YR 5/4), very firm, massive structured medial material.Distinct and wavy boundary.
0.11m **Tui.b**	0.05m of profuse, loose, moderately well sorted, reddish-yellow (5YR 6/8) medium to coarse pumiceous lapilli with few fine to medium grey lapilli dispersed throughout. Sharp and wavy boundary to 0.02m of profuse, very firm, moderately sorted,dark grey to very dark grey (10YR 4/1 - 3/1) coarse ash downwardly grading to fine to medium lapilli. Distinct and wavy boundary to 0.04m of profuse, loose, moderately well sorted downwardly grading to well sorted, reddish-yellow (5YR 6/8) medium to coarse pumiceous lapilli. Few fine to medium grey lapilli dispersed throughout. Sharp and wavy boundary.
0.02m	Strong brown ((7.5YR 5/6), friable, moderately developed, medium to fine blocky structured medial material. Indistinct and wavy boundary.
0.09m	Yellowish-brown (10YR 5/4), firm, weakly developed, medium blocky structured medial material. Distinct and wavy boundary.
0.03m **Tui.a**	Many, moderately well sorted, yellowish-red (5YR 5/8) coarse to very coarse pumiceous lapilli and few light grey to dark grey (10YR 7/1 - 4/1) medium to coarse lapilli. Distinct and wavy boundary.
0.23m	Yellowish-brown (10YR 5/6), firm, massive structured medial material. Indistinct boundary to dark yellowish brown (10YR 4/6), very firm, massive, medial material.

6.09m ------------- Indistinct and wavy boundary -------------

Kor.b of **Koru Tephra**

Upper and Lower Contacts

In the vicinity of Inglewood, the uppermost unit of **Tuikonga Tephra** (**Tui.d**) is separated from **Pot.a** of **Poto Tephra** above, by

<0.15m of medial material (e.g. **Sections 13** and **14** of Figure 2.23). In the same vicinity, the lowermost unit (**Tui.a**) is separated from **Koru Tephra** below by up to 0.25m of medial material. Occasionally, Tuikonga Tephra is observed to unconformably overlie andesitic breccia of the c.100kyr **Okawa Formation.**

On the North Taranaki coastal plain in the vicinity of Lepperton, **Tui.d** is separated from **Aokautere Ash** above by c.0.50m of medial material (e.g. **Section 23** of Figure 2.23). Here also in this vicinity, the lowermost unit (**Tui.b**) is separated from dispersed constituents of **Koru Tephra** below, by <0.10m of medial material.

Beyond the Egmont ring plain but within the confines of the Waiongana and Manganui River valleys, **Poto Tephra** thins so that **Tui.d** closely underlies **Ngaere Formation** and is separated by <0.20m of medial material (Plate 2.31). Occasionally, wedges of aeolian andesitic sands and fluvial sediment disconformably overlie **Tuikonga Tephra.**

Age

Tuikonga Tephra, is here estimated to have an age range between c.23.4 and c.24.1 kyr B.P. on the basis of its stratigraphic position with respect to the closely overlying **Aokautere Ash.**

Reference Localities

Sections 7, 16, 18, 22, 23, 28 and **30** (Appendix 1 and Figure 2.23) are here designated as reference localities for **Tuikonga Tephra.** In addition to these reference localities which have been described previously, a further four reference localities are designated as follows:

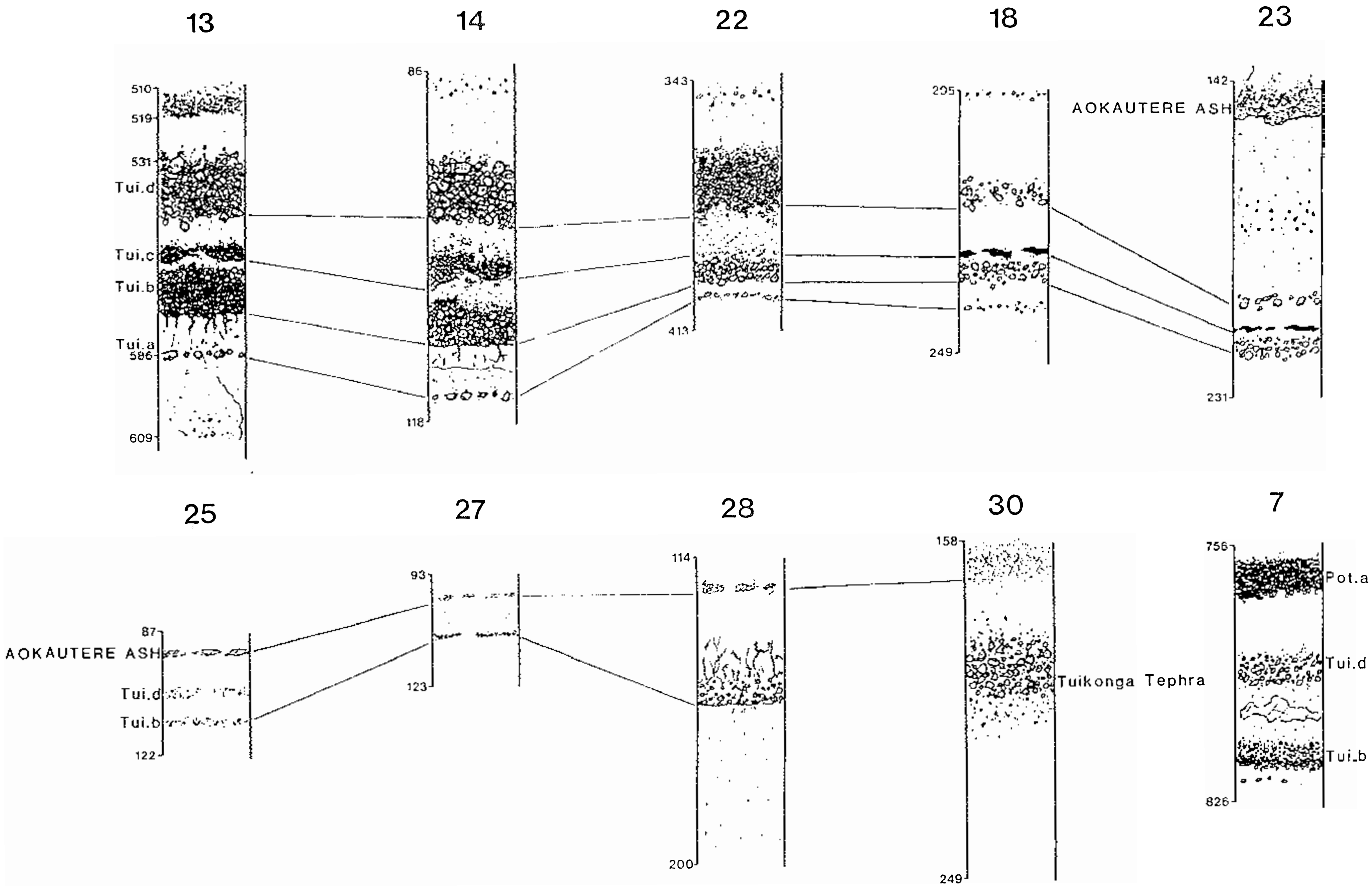
1. Prominent south-facing farm cutting, Jacksons Property, State Highway 3A (Q19/149280) (**Section 14** of Appendix 1 and Figure 2.24).

2. West facing farm cut beside milking shed, Browns Property, Durham Road, c.2.6km north-east from State Highway 3 (Q19/171259) (**Section 16** of Appendix 1 and Figure 2.24).

3. North-west facing cliff exposure 1.0km south-west of Waiongana Stream Mouth (Q19/121445) (**Section 25** of Appendix 1 and Figure 2.24).

4. North-facing cliff exposure, Airedale Reef, 1.4km east of Waitara River Mouth (Q19/178461) (**Section 27** of Appendix 1 and Figure 2.24).

FIG. 2.23 Correlation Columns of Tuikonga Tephra



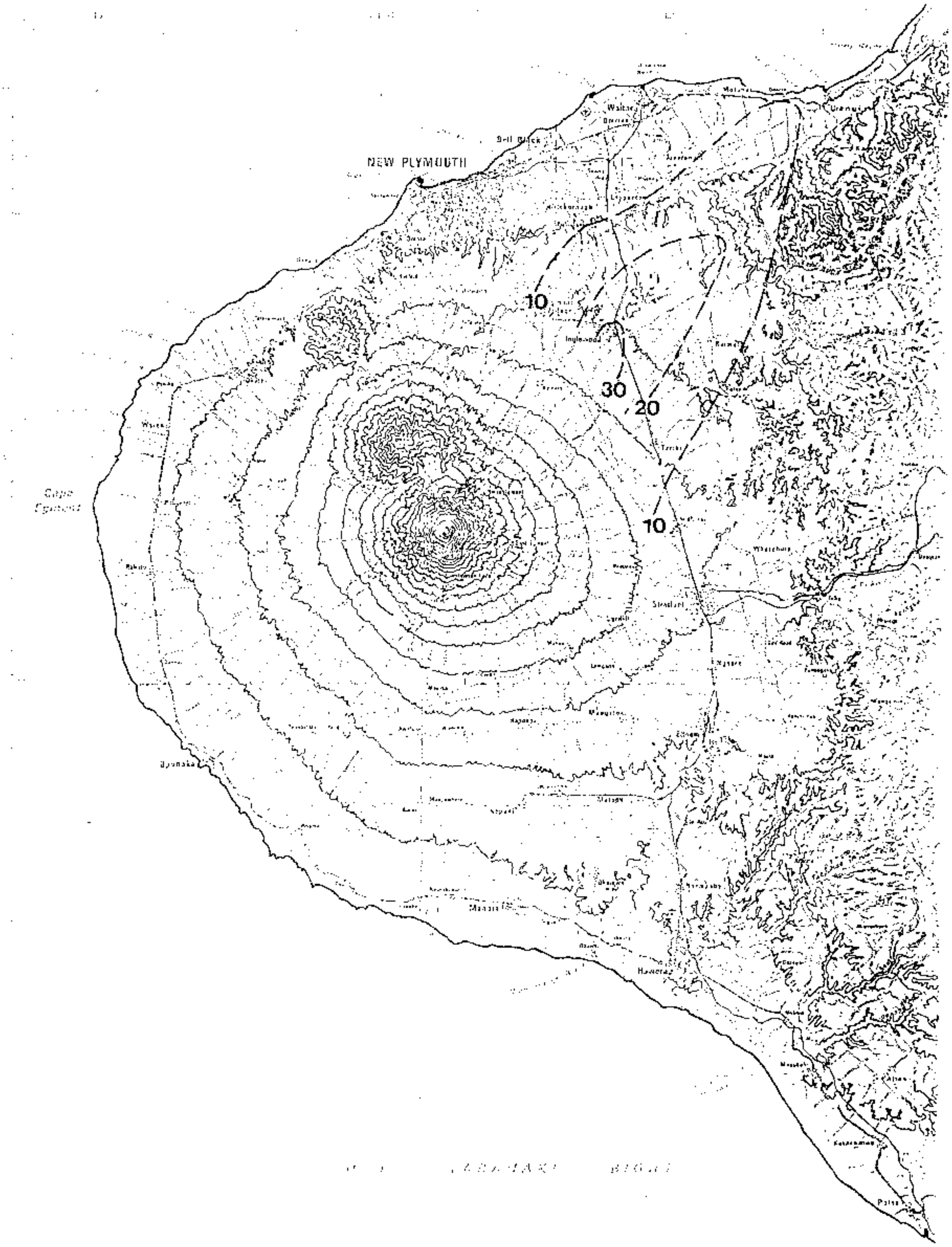


FIG. 2.24 Isopach Map: Tui.b and Tui.d of Tuikonga Tephra

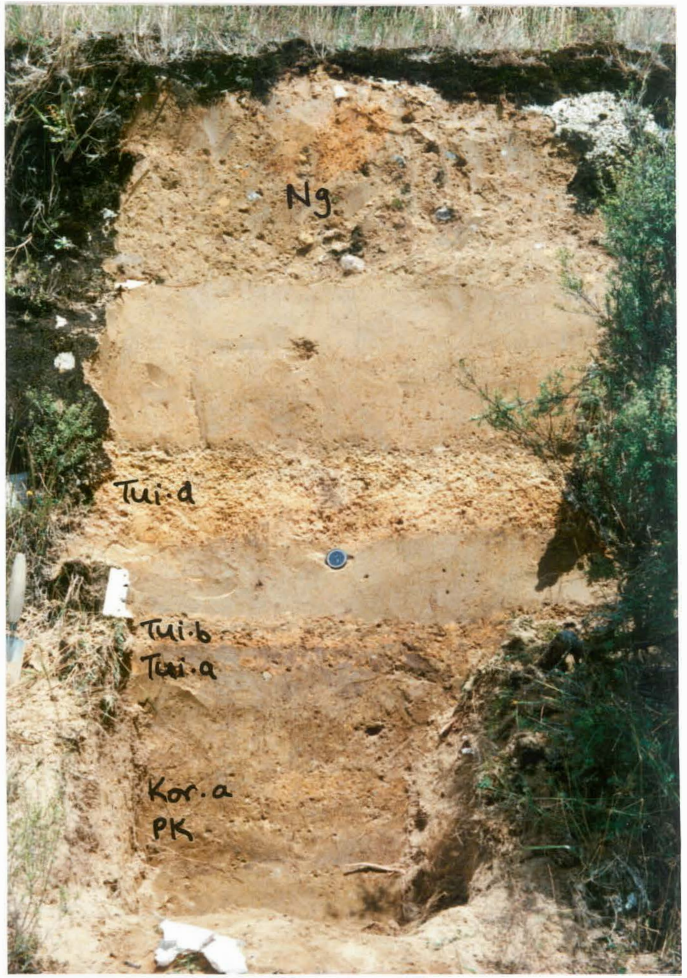


Plate 2.30: **Tuikonga Tephra** below **Ngaere Formation** (Ng) at Browns Property, Durham Road (Section 16; Q19/171259). Note **Koru** and **Pukeiti Tephra** below **Tuikonga Tephra**.

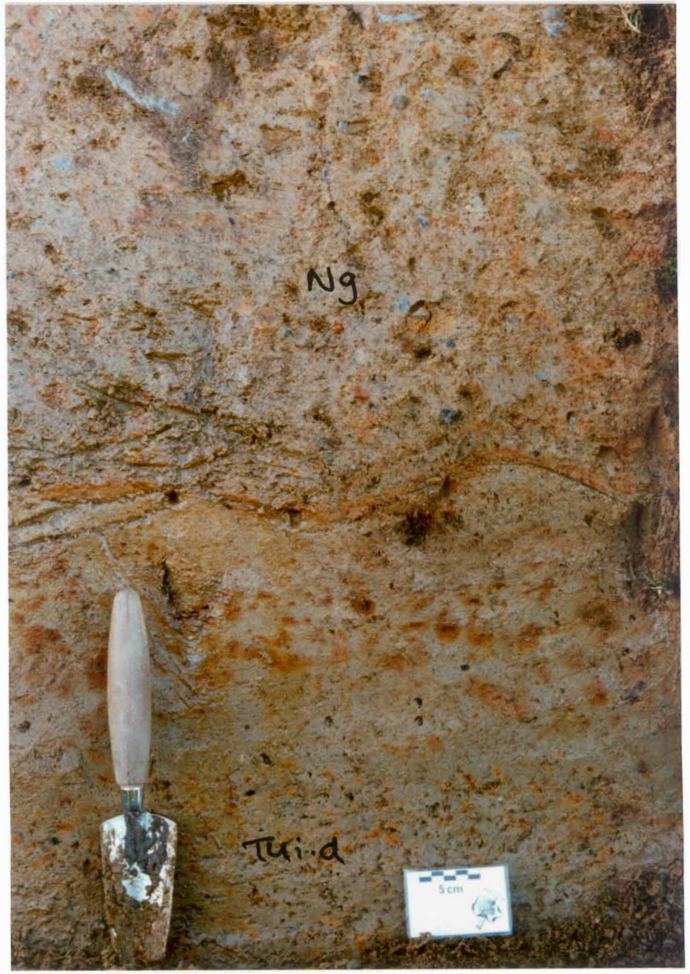


Plate 2.31: **Tui.d** of **Tuikonga Tephra** closely underlying **Ngaere Formation** (Ng) near Manganui Road in Waitara River Valley (Q19/207364).

2.3.5 Koru Tephra
(Neall 1972; redefined this study)

Koru Tephra was formally named by Neall (1972) after Koru Pa, 14km southwest of New Plymouth where the formation was first recognised and is typically exposed. **Two** informal members were originally recognised to comprise Koru Tephra - the upper member was **Koru ash (Ka)** which grades downwards into the **Koru lapilli (Kp)**. The type section was designated by Neall (1972) at a road cutting 0.1km south of Pukeiti Rhododendron Trust (N108/565742).

Koru Tephra is here further defined on the north-eastern lower flanks of Egmont Volcano to include **two** prominent closely spaced lapilli beds that intervene between **Tuikonga Tephra**, above and **Pukeiti Tephra**, below. Both lapilli beds are here informally named **Kor.a** and **Kor.b.** and are separated by up to 0.14m of medial material (**Section** 13 of Appendix 1 and Figure 2.25; Plate 2.32).

Correlation
Kor.a is here directly correlated to **Koru lapilli** (Neall 1972). **Koru ash** (Neall 1972) is here recognised as medial material. This medial material relates to intermittent accretion of fine grained volcaniclastic material that for the most part is not genetically associated with the underlying **Koru lapilli.**

Criteria
On the lower north-eastern flanks of Egmont Volcano, the upper lapilli bed (**Kor.b**) is shower bedded and comprises three distinct, moderately - moderately well sorted layers of strong brown (7.5YR 5/6) coated, reddish-yellow (7.5YR 6/8) pumiceous lapilli grading upward to grey to dark grey (7.5YR N4/ - N5/) coarse ash and fine lapilli (Plate 2.32).

Kor.a, on the lower north-eastern flanks, is either faintly normal graded or unstratified and comprises loose, poorly to moderately well sorted, strong brown (7.5YR 5/6) coated, yellowish-red to reddish-yellow (5YR 5/8 to 7.5YR 7/8 - 6/8) pumiceous coarse ash and lapilli. Few to common grey to dark grey coarse ash and lapilli are dispersed throughout (Plate 2.32). On the south-east lower flanks, in the vicinity of Cardiff, **Kor.a** is directly overlain by a 0.02m thick, very firm, dark grey (5YR 4/1) fine ash (Plate 2.26).

Best locality

A best locality for **Koru Tephra** is designated here as a prominent driveway cutting on Inglewood Marae, 0.1km south of the BMX track and opposite the school playground (Q19/147267) (see **Section** 13 of Appendix 1 and Figure 2.25; Plate 2.32). Here the following section is exposed:

Tui.a of **Tuikonga Tephra**

5.86m ------------- Distinct and wavy boundary ----------------

0.23m	Yellowish-brown (10YR 5/6), firm, massive structured medial material. Indistinct boundary to dark yellowish brown (10YR 4/6), very firm, massive structured medial material. Indistinct and wavy boundary.
0.23m **Kor.b**	0.11m of loose, moderately sorted, pale brown (10YR 5/6) coated, grey (10YR 6/3) fine to coarse lapilli, with a downwardly increasing proportion (common to profuse) of strong brown (7.5YR 5/6) coated, reddish-yellow (7.5YR 6/8) fine to very coarse pumiceous lapilli. Straight and sharp boundary to 0.05m of very firm, profuse, moderately well sorted grey (7.5YR N5/ - N4/) coarse ash and lapilli. Few to common, moderately sorted, yellow to pale brown (10YR 8/4 - 8/6) fine to coarse pumiceous lapilli dispersed throughout. Sharp and straight boundary to

0.02m of profuse, moderately well sorted, strong brown coated, reddish-yellow medium to coarse pumiceous lapilli. Sharp and wavy boundary to
0.02m of abundant, moderately sorted, grey (7.5YR N4/ - N5/) fine lapilli with few reddish-yellow fine pumiceous lapilli dispersed throughout. Sharp and wavy boundary to
0.03m of abundant to profuse, moderately sorted, strong brown coated, reddish-yellow pumiceous and grey, fine to coarse lapilli. Distinct and wavy boundary.

0.14m — Strong brown (7.5YR 5/6), very firm, massive structured medial material. Indistinct and wavy boundary.

0.19m **Kor.a** — 0.15m thick, profuse, poorly sorted layer of loose, many, strong brown coated (7.5YR 5/6) yellowish-red (5YR 5/8), fine to very coarse pumiceous lapilli and common grey to dark grey (7.5YR N/5 - N/4) coarse ash to medium lapilli dispersed throughout. Sharp and wavy base to

0.04m of firm, moderately sorted, many, yellowish-red (5YR 5/8) fine to coarse pumiceous lapilli and common, grey (7.5YR N5/ - N4/) fine lapilli. Distinct and wavy boundary.

0.33m — Yellowish-brown (10YR 5/6), very firm, massive structured medial material. Common brownish yellow to yellow (10YR 6/8 - 7/8) medium to coarse pumiceous lapilli scattered throughout.

6.98m ------------- Sharp and wavy boundary -------------------

Pukeiti Tephra

Upper and lower Contacts

On the north-eastern lower flanks of Egmont Volcano, the upper unit of **Koru Tephra** (**Kor.b**) is separated from **Tuikonga Tephra** above, by up to 0.25m of medial material (e.g. **Sections 13** and **14** of Appendix 1 and Figure 2.25). In this same area, the lower unit (**Kor.a**) is separated from **Pukeiti Tephra** below, by <0.40m of medial material. North and north-eastwards beyond the Egmont ring plain, constituents of both units are widely dispersed in medial material overlying **Pukeiti Tephra** (e.g. **Section 18** of Appendix 1 and Figure 2.25).

Distribution

Of the two units that comprise **Koru Tephra, Kor.a** is more widespread as it occurs throughout the eastern sectors. **Kor.a** has a maximum recorded thicknesses of 0.25m near Cardiff in the south-eastern sector and 0.20m near Inglewood in the north-eastern sector. An isopach map of **Kor.a** in North Taranaki is shown in Figure 2.26.

Kor.a is here provisionally identified as the 0.03m thick coarse ash layer at Makahu 45km to the east of Egmont Volcano (**Section** 33 of Appendix 1) and as the layer of coarse ash dispersed in **Rangitatau loess**, 0.21m beneath **Aokautere Ash** at Kohi Road (**Section** 35 of Appendix 1) in Wanganui district.

Kor.b is best represented in the north-eastern sector and has a maximum recorded thickness of 0.25m in the vicinity of Inglewood. North-east beyond the Egmont ring plain, **Kor.b** is often dispersed over several decimeters in medial material (e.g. **Section 22** of Appendix 1 and Figure 2.25).

Age

Koru Tephra is estimated here to have an age range between c.25.0 and c. 25.4 kyrs B.P. on the basis of its position underlying **Aokautere Ash.**

Reference Localities

Three reference localities were designated for Koru Tephra by Neall (1972). Here, **Sections** 5, 7, 14, 16, 18, 22 and 23 are further designated as reference localities for **Koru Tephra.** These reference localities are the same as those designated for **Tuikonga Tephra.**

2.3.6 Pukeiti Tephra (Neall 1972)

Neall (1972) named **Pukeiti Tephra** after Pukeiti Hill, between Kaitake and Pouakai Volcanoes, because of the nearby best exposure. The type section was designated by Neall (1972) at a large cutting along Hurford Road to the south of Omata Dairy Factory (N108/593842) where the formation was first described as "... a white, coarse, pumiceous ash which forms a distinctive marker beneath the Koru lapilli."

Criteria

Throughout the lower eastern and northern flanks of Egmont Volcano, **Pukeiti Tephra** comprises a single, unstratified bed of moderately well sorted, very pale brown to yellow (10YR 7/4 - 7/8) pumiceous lapilli (Plate 2.32). Occasionally in the northeastern sector, a discontinuous <0.02m thick bed of very firm, pinkish-grey (7.5YR 6/2) fine ash directly overlies the pumiceous lapilli bed (Plate 2.33).

Reference Localities

Seven new reference localities have been designated for **Pukeiti Tephra (Sections 5, 7, 13, 14, 16, 18** and **22** of Appendix 1). These sections are the same as those designated for **Tuikonga Tephra** and **Koru Tephra.** At **Section 14** (Figure 2.25; Plate 2.34), **Pukeiti Tephra** is exposed as follows:

Kor.a of **Koru Tephra**

1.58m ------------- Distinct and wavy boundary ----------------

0.05m	Yellowish-brown (10YR 5/1), very firm, massive structured medial material. Distinct and wavy boundary.
0.06m **Pukeiti Tephra**	Many to abundant, moderately well sorted, white to yellow (10YR 8/2 - 8/6), fine to medium pumiceous lapilli, with common light to dark grey (10YR 4/1 - 7/1) fine to medium lapilli dispersed throughout. Sharp and wavy boundary.
0.17m	Yellowish-brown (10YR 5/1), very firm, massive structured medial material.

1.86m ------------- Indistinct and wavy boundary --------------

Waite.c of **Waitepuke Tephra**

Upper and Lower Contacts

On the north-eastern lower flanks of Egmont Volcano, near Inglewood, the upper contact of **Pukeiti Tephra** is separated from **Kor.a** above, by up to 0.40m of medial material (**Section 13** of Appendix 1 and Figure 2.25). In the same vicinity, up to 0.35m of medial material separates the lower contact of **Pukeiti Tephra** from **Waitepuku Tephra**, below. Occasionally, in the north-eastern sector, **Pukeiti Tephra** closely overlies a thin and discontinuous unnamed lapilli bed, as well as, an unnamed c.2m thick debris flow unit (**Section 16** of Appendix 1 and Figure 2.28).

North-east beyond the Egmont ring plain, mixed constituents of **Koru Tephra** occur dispersed in the medial material overlying **Pukeiti Tephra** (e.g. **Section 18** of Appendix 1 and Figure 2.25). **Pukeiti Tephra** is separated by <0.04m of medial material from **Waitepuku Tephra**, below.

Distribution

Pukeiti Tephra has a maximum recorded thickness of 0.12m in the vicinity of Inglewood in the north-eastern sector. An isopach map of **Pukeiti Tephra** is shown in Figure 2.27.

Age

Though not directly dated, **Pukeiti Tephra** is here considered to have an age of c.26.4 kyrs B.P. on the basis of its position with respect to the **Aokautere Ash.**

2.3.7 Waitepuke Tephra (new formation)

Waitepuku Tephra is a new formation named after Waitepuku Stream which flows north-eastwards from Egmont Volcano crossing State Highway 3, 0.6km north of Tariki Railway overpass.

Waitepuku Tephra is best represented on the lower north-eastern flanks of Egmont Volcano where it comprises a closely spaced set of **three** coarse ash and lapilli beds (Plate 2.35). These beds, separated by up to 0.06m of medial material, are informally named **Wait.a** to **Wait.c** in order of decreasing age.

Despite the distinctive appearance of **units Wait.b** and **Wait.c** in the vicinity of Inglewood, correlative usage is restricted due to limited distribution. This contrasts with the widely distributed, lowermost lapilli bed (**Wait.a**) which occupies an important stratigraphic position at the base of the last-glacial maxima tephra succession. An isopach map of **Wait.a** is shown in Figure 2.29.

Criteria

Wait.a on the lower north-eastern flanks of Egmont Volcano comprises two distinct layers. The lower layer contains abundant, moderately sorted, strong brown (7.5YR 5/6) coated, reddish-yellow (7.5YR 7/8) pumiceous lapilli, with subordinate, grey (7.5YR N5/) lapilli dispersed throughout. The upper layer is proportionately thicker and coarser grained containing loose, abundant to profuse, moderately well sorted, grey to dark grey (7.5YR N6/ - N5/) lapilli with minor proportions of pumiceous lapilli scattered throughout (e.g. **Sections 13** and **16** of Figure 2.28; Plate 2.35). Progressively north-eastwards beyond the Egmont ring plain, **Wait.a** becomes increasingly dispersed in medial material but is still easily distinguished by common to many, moderately well sorted, dark grey to grey lapilli with minor, scattered, very pale brown to yellow (10YR 8/4 - 7/8) pumiceous lapilli (e.g. **Section** 18 of Figure 2.28).

Wait.b, in the vicinity of Inglewood, comprises a very distinctive normal graded bed of moderately well sorted to well sorted, yellow (10YR 8/8) and dark grey to grey (10YR 4/1 - 5/1) speckled coarse ash (Plate 2.35). North and north-eastwards beyond Inglewood, **Wait.b** thins markedly to form discontinuous pockets of unstratified, very pale brown (10YR 8/4) fine ash (e.g. **Section 14** of Figure 2.28). **Wait.c** comprises an unstratified bed of profuse to many, moderately sorted, dominantly, reddish-yellow (7.5YR 6/8) pumiceous lapilli with minor, finer grained, grey (10YR 6/1) lapilli dispersed throughout (Plates 2.35 and 3.36).

Type Section

The type section for **Waitepuku Tephra** is designated at a prominent south-facing farm cutting at Jacksons Property on State Highway 3A (Q19/149280) (**Section 14** of Appendix 1 and Figure 2.28; Plate 2.34). Here, **Waitepuku Tephra** is exposed as follows:

Pukeiti Tephra

1.69m ------------		Distinct and wavy boundary ---------------
	0.17m	Yellowish-brown (10YR 5/8), firm, massive structured medial material. Indistinct and wavy boundary.
	0.06m **Wait.c**	Many to abundant, moderately sorted, reddish yellow (7.5YR 6/8), fine to coarse pumiceous lapilli and few, grey (10YR 6/1), fine lapilli scattered throughout. Distinct and wavy boundary.
	0.06m	Yellowish-brown (10YR 5/6), firm to very firm, massive structured medial material. Distinct and discontinuous boundary.
	0.07m **Wait.b**	Very firm, massive, very pale brown to yellow (10YR 8/4 to 7/8) and grey (10YR 4/1) speckled coarse ash. Distinct and discontinuous boundary.
	0.05m	Yellowish-brown (10YR 5/4), firm to very firm, massive structured medial material. Distinct and wavy boundary.
	0.06m **Wait.a**	Profuse to abundant, moderately well sorted dark grey to grey (7.5YR N5/ - N4/) fine to medium lapilli, with subordinate reddish-yellow (7.5YR 7/8) pumiceous lapilli.
2.16m ------------		Distinct and wavy boundary --------------
	+0.21m (S2)	Dark yellowish-brown (10YR 3/6), moderately well developed, fine to medium blocky structured medial material.

BASE NOT EXPOSED

Upper and Lower Contacts

In the vicinity of Inglewood, the uppermost unit (**Wait.c**) of **Waitepuku Tephra** is separated from **Pukeiti Tephra** above, by up to 0.35m of medial material. A thin unnamed lapilli bed or a debris flow deposit may be occasionally exposed overlying **Wait.c** (e.g.

Section 16 of Figure 2.28; Plate 2.36). In this same vicinity, **Wait.a** is separated from uppermost Mangapotoa tephra below, by up to 0.60m of medial material (e.g. **Section 19** of Appendix 1 and Figure 2.30).

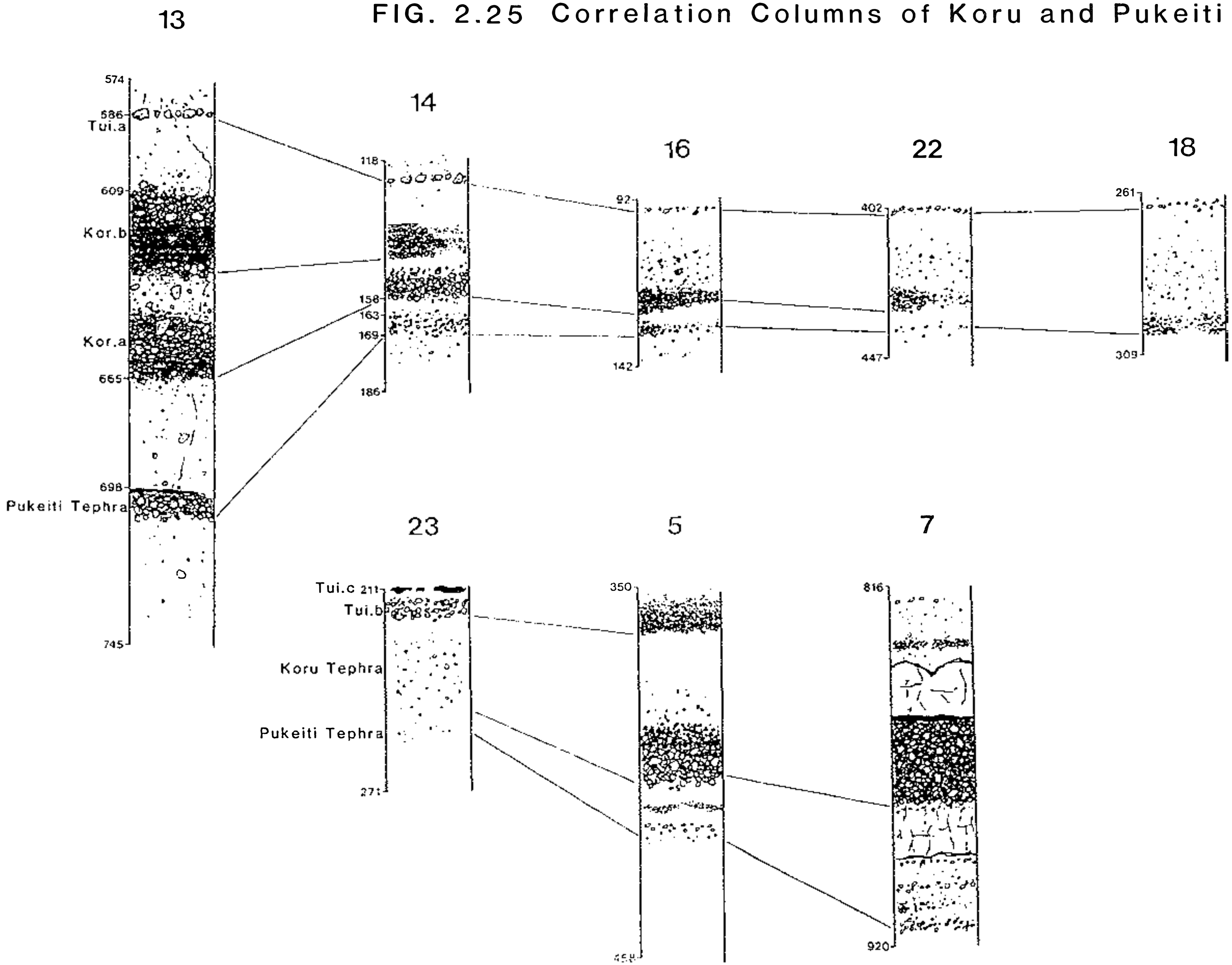
Age

Though not directly dated, **Waitepuku Tephra** is here considered to have an age range between c.27.5 and 28.0 kyrs B.P. on the basis of its position beneath **Aokautere Ash** and above the c.50kyr Rotoehu Ash (see Chapter 3).

Reference Localities

Sections 13, 16, 18, 22 and **23** (Appendix 1 and Figure 2.28) are here designated as reference localities for **Waitepuku Tephra**. The locations of these reference sections have been previously described.

FIG. 2.25 Correlation Columns of Koru and Pukeiti Tephra



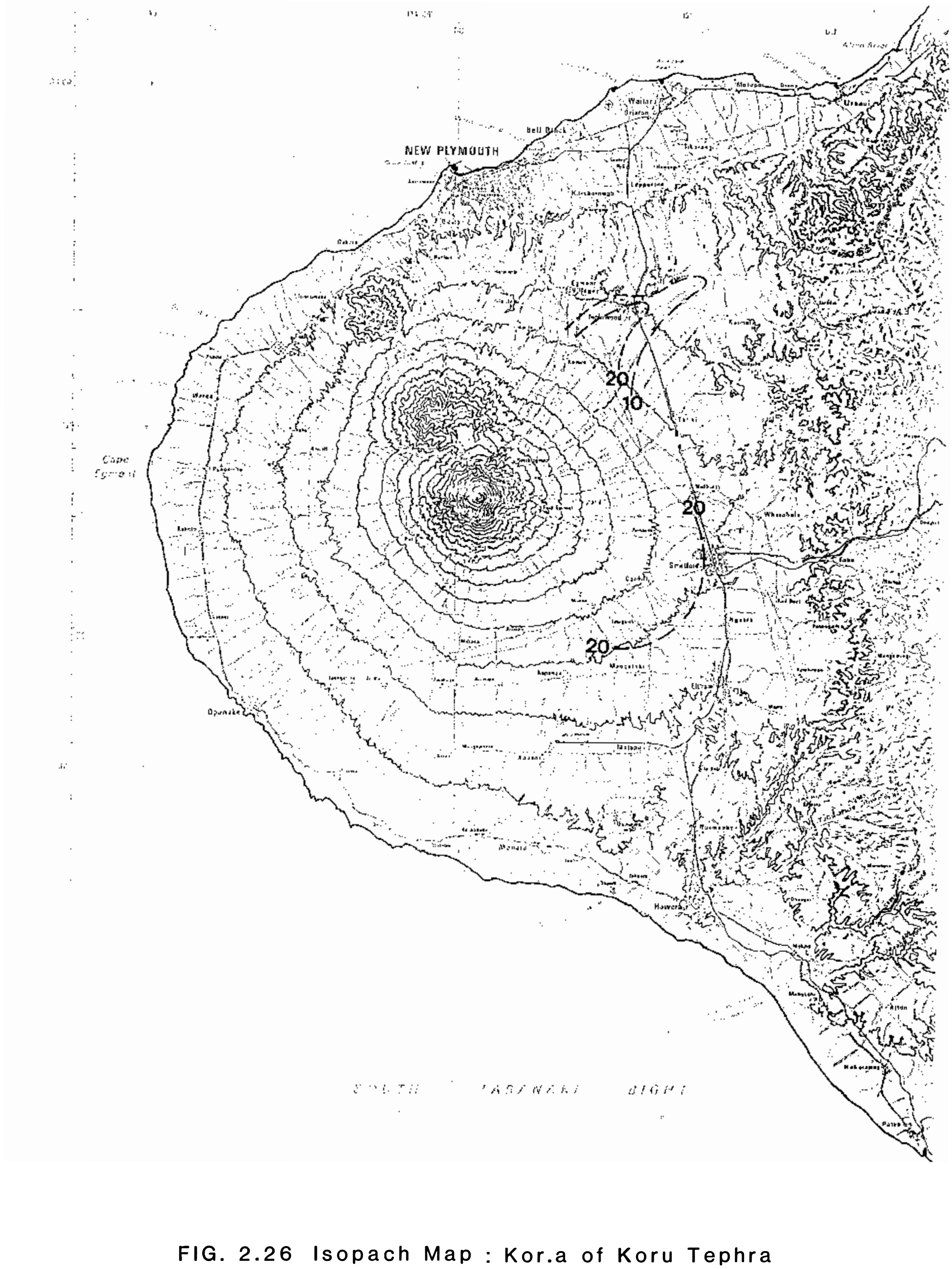


FIG. 2.26 Isopach Map : Kor.a of Koru Tephra

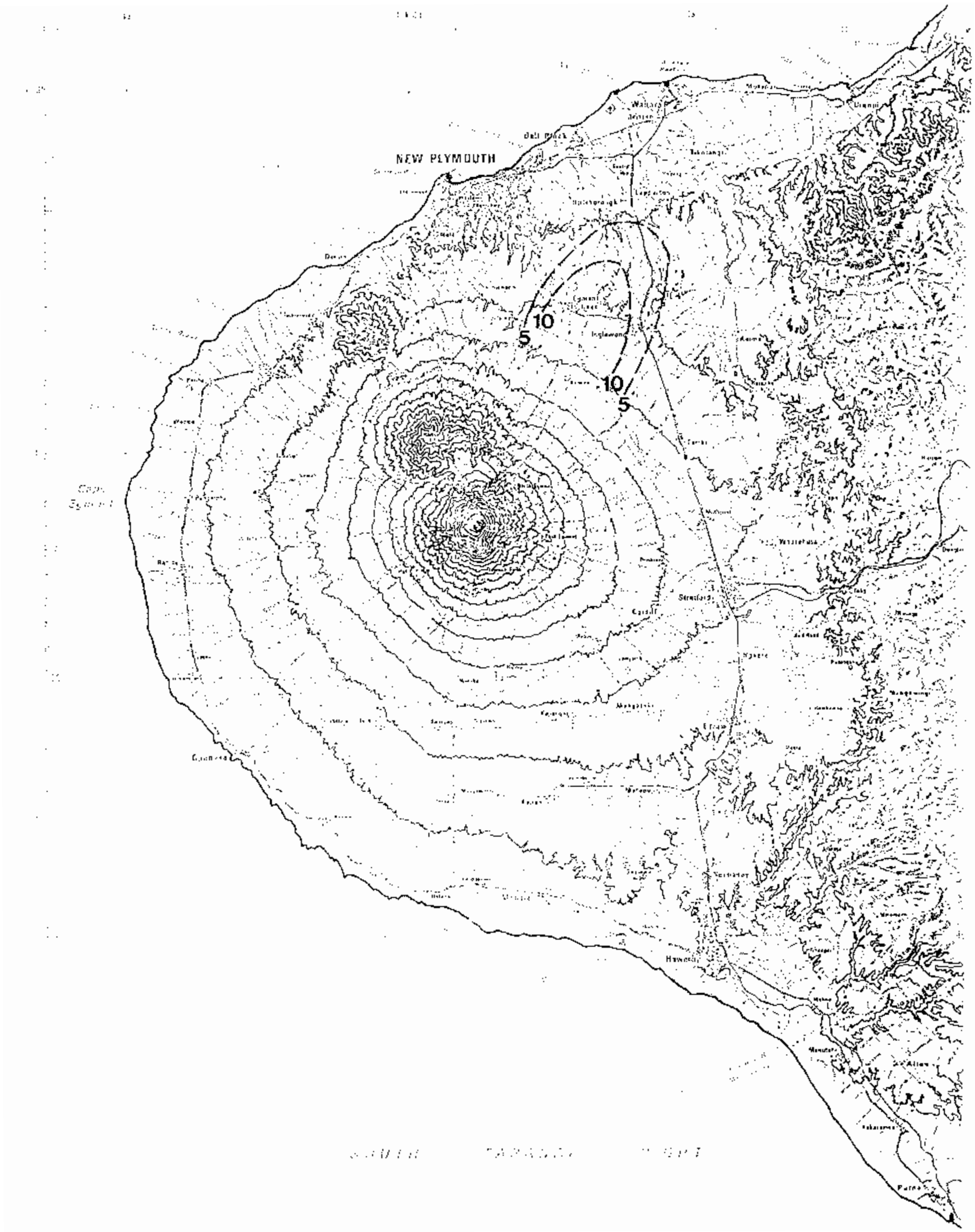


FIG. 2.27 Isopach Map: Pukeiti Tephra

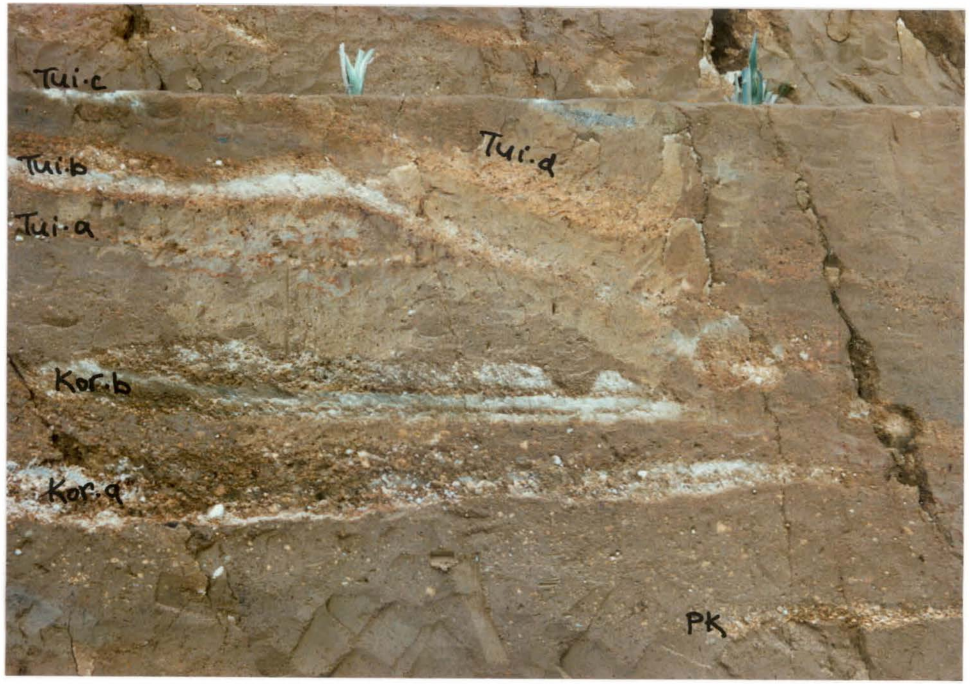


Plate 2.32: **Tuikonga Tephra** at its type section near Inglewood Marae (Section 13; Q19/147267). Note **Koru** and **Pukeiti Tephra** below **Tuikonga Tephra** and prominent disconformity.

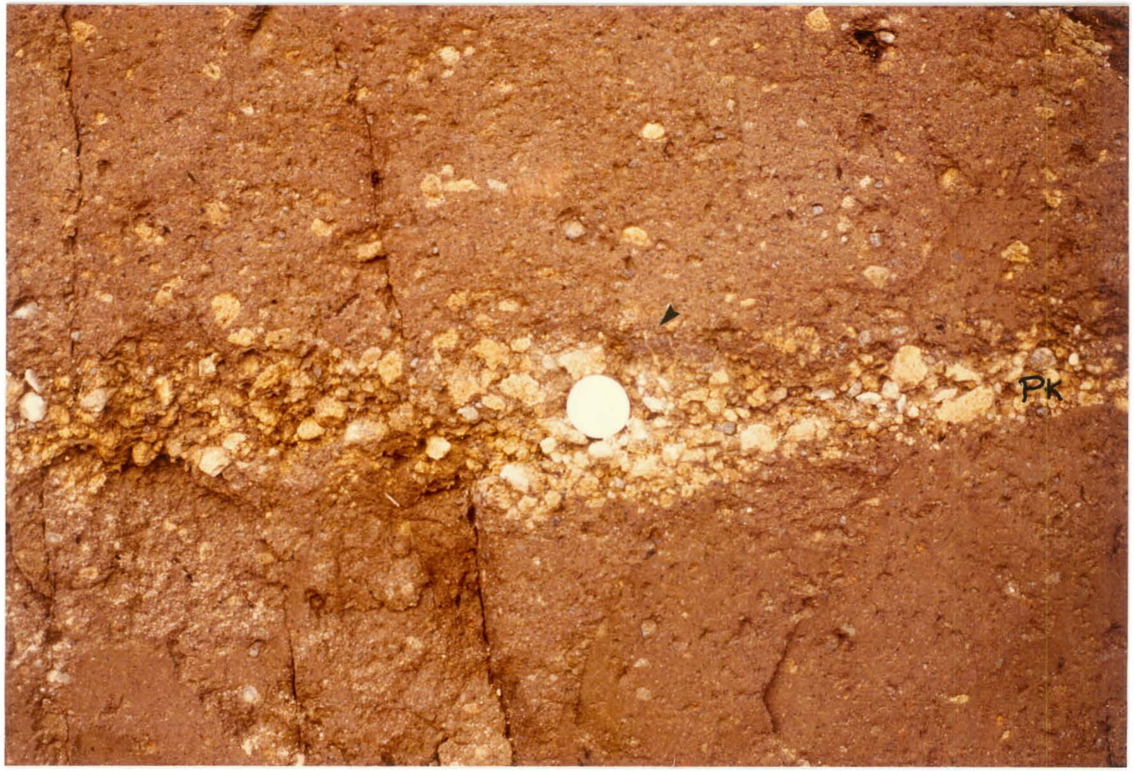


Plate 2.33: **Pukeiti Tephra** near Inglewood Marae (Section 13; Q19/147267). Arrow indicates position of firm, pinkish grey fine ash overlying lapilli.

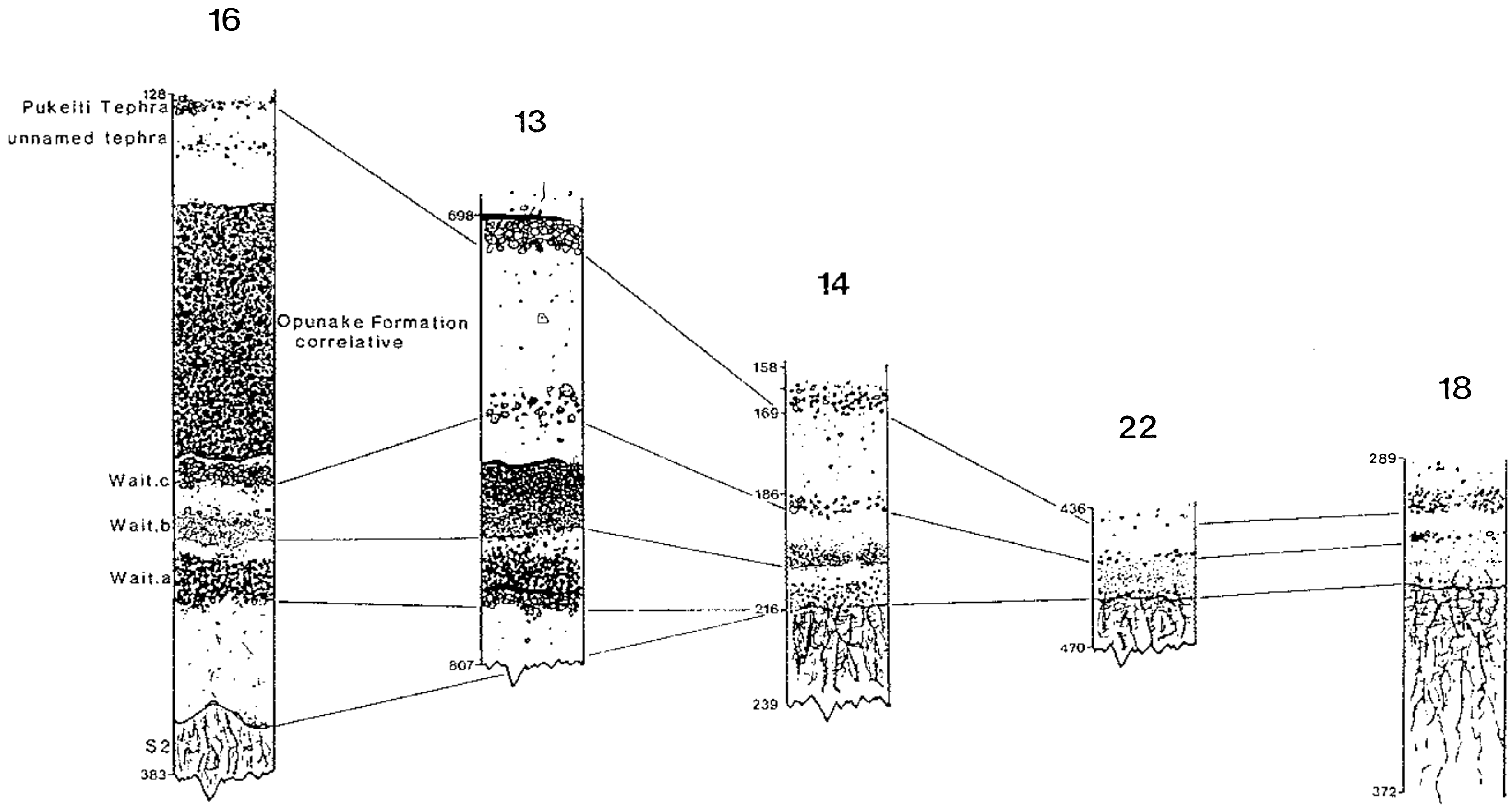


FIG. 2.28 Correlation Columns of Waitepuku Tephra

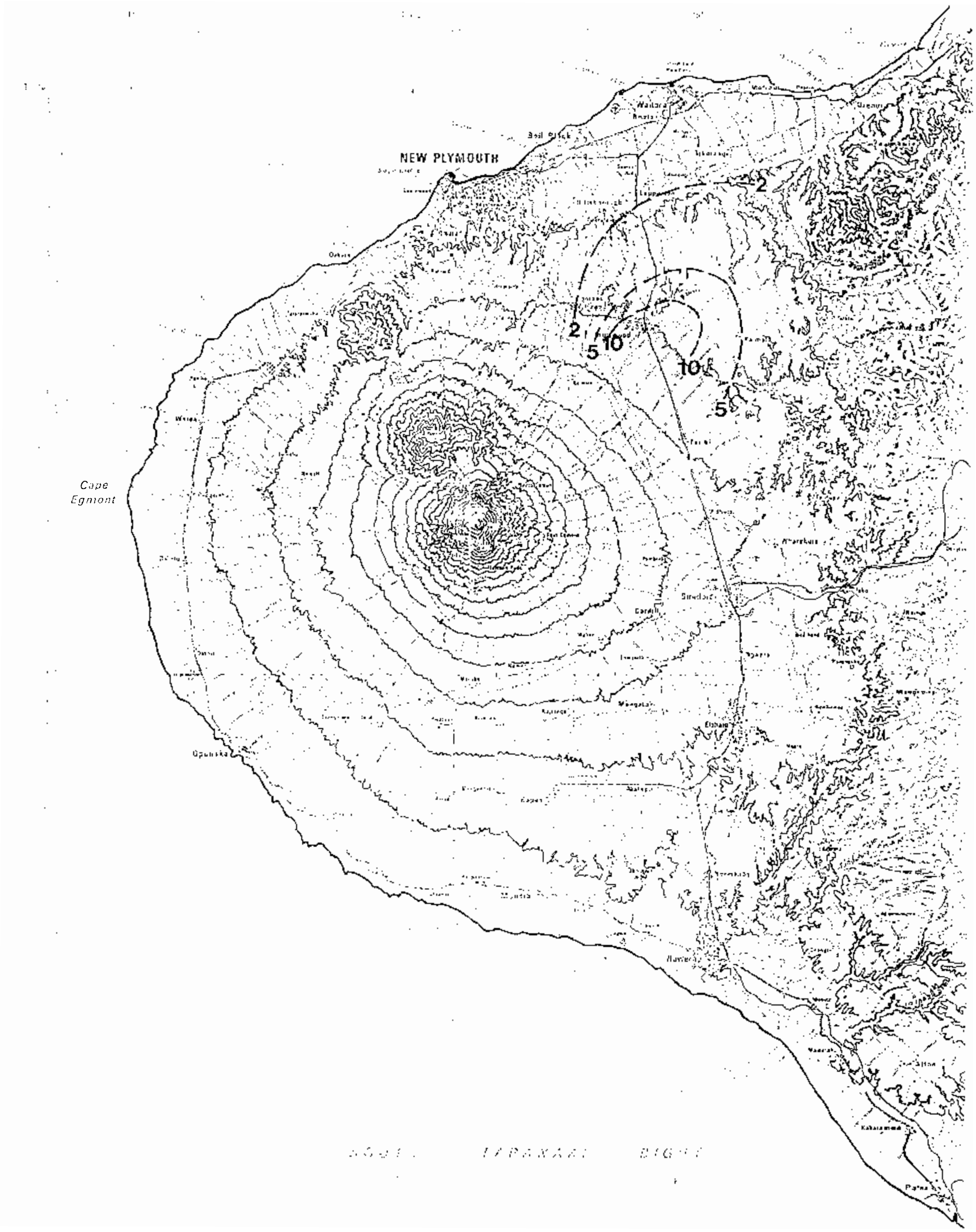


FIG. 2.29 Isopach Map: Wait.a of Waitepuku Tephra

Plate 2.34: **Waitepuku Tephra** at its type section at Jacksons Property near Inglewood (Section 14; Q19/149280). Note **Waite.a** directly overlying **S2**.

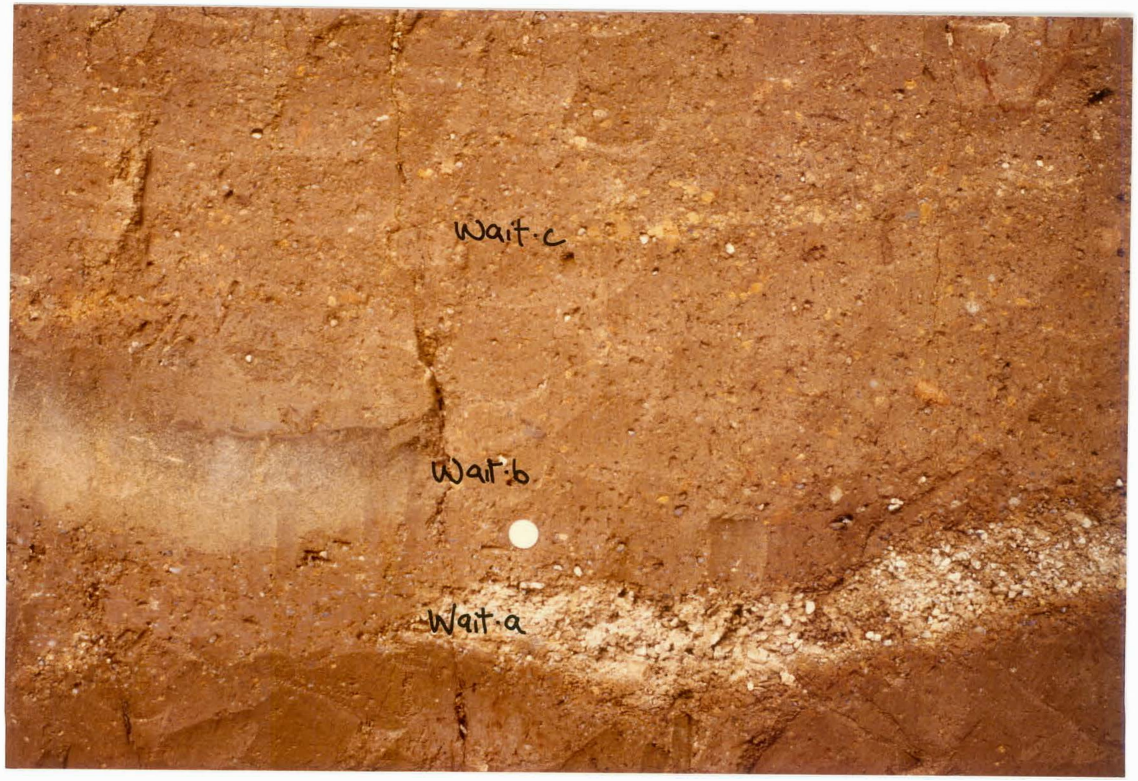


Plate 2.35: **Waitepuku Tephra** intercalated with **L1.2** at Inglewood Marae (Section 13; Q19/147267).

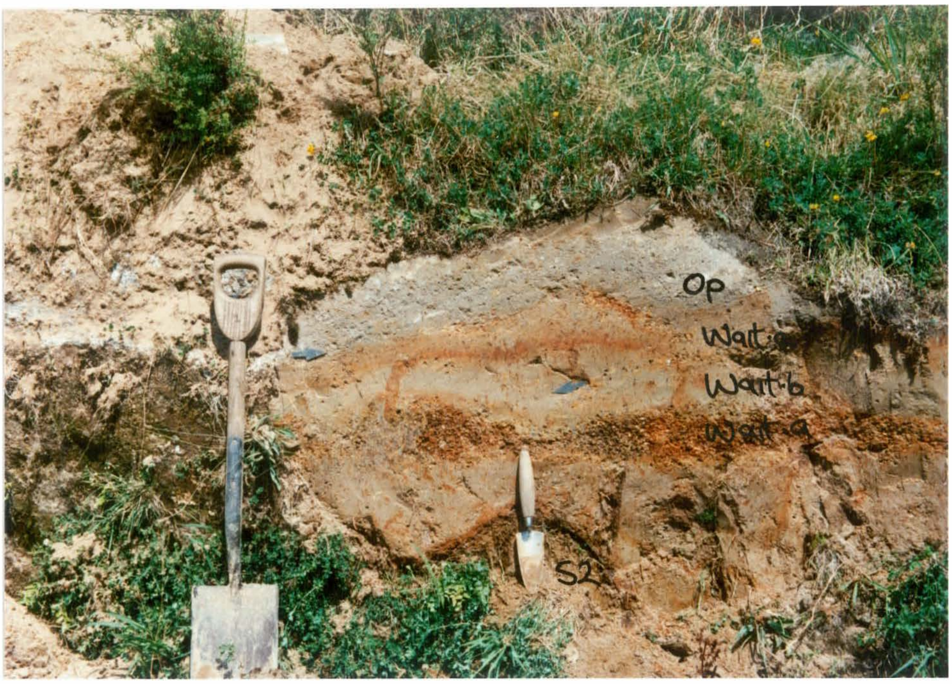


Plate 2.36: **Waitepuku Tephra** overlain by debris flow deposit of **Opunake Formation** (Op) at Browns Property, Durham Road (Section 16; Q19/171259). Note wavy and sharp boundary between **L1.2** and **S2** by the trowel.

2.4.0 PRE-TUNA SUB-GROUP TEPHROSTRATIGRAPHY

2.4.1 Introduction

In this section four new informal and two new formal tephra formations are designated beneath **Tuna Tephra Sub-group.** The base of this stratigraphic sequence, along the North Taranaki coast, is marked by Motunui lahar deposit (this study; Chapter 7) overlying near-shore sediment directly above the wave cut surface of **NT2 terrace** (Chappell 1975). This terrace was previously correlated by Hay (1967), to the **Rapanui Formation** of Wanganui (Fleming 1953). Within the dominantly medial cover-beds of the older uplifted marine terraces further inland, the base of this sequence is marked by a very prominent (c.1.0m thick) bed of "purplish" coloured, moderately developed, blocky structured medial material named **S6** (see Chapter 4).

On the lower flanks of Egmont Volcano, the pre-Tuna Sub-group tephra beds are usually buried beneath a thick sequence (exceeding 8.0m) of volcaniclastic debris and appear to be only rarely exposed in the vicinity of Inglewood overlying the **Okawa Formation.** These older tephras are better exposed but incomplete on the older constructional surfaces situated to the north and north-east of the Egmont ring plain.

The lowermost part of this older tephra sequence is best preserved in lignite and carbonaceous-rich fine grained sediment which are exposed in cliffs along the North Taranaki coastline. Here, numerous coarse ash and lapilli beds are preserved and provide a detailed distal record of eruptive activity. Between the north coast and the Egmont ring plain, most of these tephra beds tend to be highly influenced by post-depositional mixing and weathering in the soil forming environment and hence only a few of the most prominent tephra beds can be readily identified and correlated.

Correlation of these tephra beds in the dominantly medial cover-bed sequence, is facilitated by their stratigraphic position with respect to named **S-** and **L**-medial units (for S- and L- terminology see Chapter 4).

2.4.2 Mangapotoa tephra (new informal formation)

Mangapotoa tephra is a new informal formation, named after Mangapotoa Stream that flows east into the Manganui River from the Eltham laharic planeze, c.8 km north-east of Inglewood Borough.

On the lower flanks of Egmont Volcano, **Mangapotoa tephra** comprises at least **three** dominantly pumiceous lapilli and coarse ash beds of restrictive correlative usage that intervene between **Tuna Tephra Sub-group** above, and **Waitui tephra** below (e.g. **Section 19** of Appendix 1 and Figure 2.30). The beds here informally named **Mp.a** to **Mp.c**, are separated by up to 0.25m of firm, massive structured medial material (**L2**). The uppermost bed does not appear to extend beyond the Egmont ring plain.

Each unit is characterised by unstratified, moderately to moderately well sorted, reddish yellow (7.5YR 6/8) to yellowish red (5YR 5/8), pumiceous and minor light grey to grey (7.5YR N6/ - N7/) lapilli.

Upper and Lower Contacts

On the lower flanks of Egmont Volcano, the upper unit of **Mangapotoa tephra** (**Mp.c**) is separated from Waitepuku Tephra above, by 0.30m of firm, weakly developed to massive medial material (**L2**) that upwardly grades to c.0.40m of friable, moderately developed blocky structured medial material (**S2**). The lowermost unit (**Mp.a**) is separated from **Waitui tephra** below, by <0.05m of **L2** and <0.35m of moderately developed blocky structured medial material (**S3**).

Occasionally in the north-eastern sector of Egmont ring plain, redeposited andesitic sands of **Katikara Formation** (Neall 1975; redefined this study) and fluvial sediment unconformably overlie **Mangapotoa tephra** (e.g. **Section 11** of Appendix 1 and Figure 2.30).

Mangapotoa tephra has a probable age range of between c.28 and 50 kyrs B.P. based on its stratigraphic position between the indirectly dated Waitepuku Tephra above, and the c.50 kyr rhyolitic tephra datum - **Rotoehu Ash** dispersed over several decimetres within uppermost **S3** below.

Because **Mangapotoa tephra** has a wide age range, it lacks diagnostic character and insufficient thickness data is available for isopach construction, a type section has not been designated.

Sections 11, 18, 19 and **27** (Appendix 1 and Figure 2.30) are here designated as reference localities for **Mangapotoa tephra**. The locations of these reference sections have been previously described. **Mangapotoa tephra** at **Section 18** is exposed as follows:

0.12m	Yellowish-brown (10YR 6/8), firm, weakly developed, coarse blocky structured medial material with many moderately well sorted, grey (7.5YR N6/ - N5/) and minor reddish yellow (7.5YR 6/8 - 5/8) fine to medium lapilli dispersed in lower 0.03m. Distinct and wavy boundary.

3.28m	0.33m **(S2)**	Dark yellowish brown (10YR 3/6), friable, moderately developed, medium to fine blocky structured medial material. Common, grey (7.5YR N6/) and reddish yellow (7.5YR 6/8 - 5/8) fine to medium lapilli of **Waitepuku Tephra** dispersed in uppermost 0.05m. Indistinct and wavy boundary.
	0.26m	Yellowish-brown (10YR 5/6), firm, weakly developed, coarse blocky structured grading downwards to massive medial material. Distinct and wavy boundary.
	0.03m **Mp.b**	Many, moderately well sorted, unstratified, yellow and reddish yellow (10YR 7/6 and 7.5YR 6/8) fine to medium pumiceous lapilli with minor light grey to grey (7.5YR N7/ - N6/) fine lapilli. Distinct and wavy boundary.
	0.14m	Yellowish-brown (10YR 6/6), firm, massive structured medial material. Distinct and wavy boundary.
	0.09m **Mp.a**	Common, moderately well sorted, unstratified, fine to medium yellow to reddish yellow (10YR 7/6 to 7.5YR 6/8 - 7/8) and grey lapilli dispersed in yellowish brown (10YR 6/6) medial material. Clear and wavy boundary.
	0.28m (S3)	Strong brown (7.5YR 5/6), moderately well developed, fine to medium blocky structured, medial material.

4.41m ------------- Distinct and discontinuous boundary -------

Waitui tephra

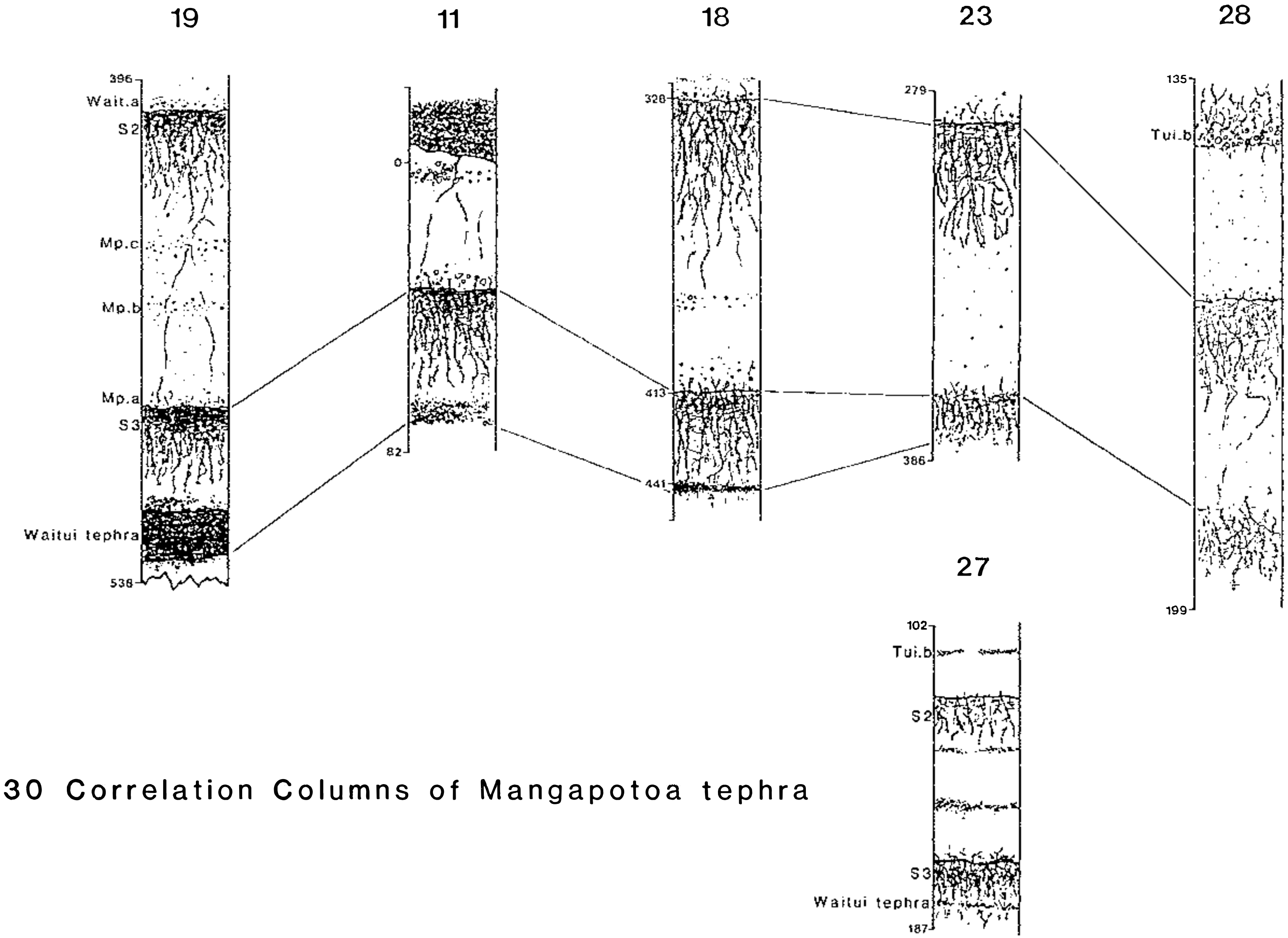


FIG. 2.30 Correlation Columns of Mangapotoa tephra

2.4.3 Waitui tephra

(new informal formation)

Waitui tephra is informally named after Waitui Well Site, c.4.5km north-east of Inglewood Borough, where the tephra was first recognised.

Criteria

On the north-eastern lower flanks of Egmont Volcano, **Waitui tephra** is shower bedded and is often characterised by well cemented layers of moderately to moderately well sorted, grey (7.5YR N4/ - N5/) to pinkish grey (7.5YR 6/2), fine to coarse ash which are separated by a proportionately thicker layer of firm, yellow to reddish yellow (10YR 7/8 to 5YR 6/8) pumiceous coarse ash and lapilli with a subordinate to equal proportion of speckled grey coarse ash and lapilli dispersed throughout (Plate 2.37).

Type Section

The type section for **Waitui tephra** is informally designated as a prominent east-facing embankment at the Toetoe Well Site, Mangaone Road extension, 1.8km north from the junction with Mangaone Road (Q19/246316) (**Section 24** of Appendix 1 and Figure 2.31). Here, **Waitui tephra** is exposed as follows:

Top of section truncated by road above.

	+0.28m	Dark yellowish brown (10YR 4/6), firm, weakly developed, coarse blocky structured medial material. Distinct and wavy boundary.
0.00m	0.20m (S3)	Dark reddish brown (5YR 3/4), firmly friable, moderately developed, fine to medium blocky structured medial material. Diffuse and wavy boundary.

0.15m	Dark yellowish brown (10YR 4/6), firm, weakly developed, coarse blocky structured medial material downwardly grading to very firm, weakly developed coarse blocky structured medial material. Discontinuous and sharp boundary.
0.06m **Waitui tephra**	0.01m discontinuous, massive layer of very firm, well cemented, moderately well sorted, pinkish-grey (7.5YR 6/2) fine ash. Broken and sharp boundary to 0.04m abundant to profuse, moderately sorted, yellowish brown (10YR 6/6) pumiceous and grey to very dark grey (10YR 3/1-5/1) coarse ash and fine lapilli. Discontinuous and distinct boundary to 0.01m of discontinuous, firm, moderately sorted, pinkish grey to grey (7.5YR 6/2 -10YR 5/1) fine to coarse ash. Discontinuous and distinct boundary.
0.39m	Yellowish-brown (10YR 5/6), firm, massive structured medial material downwardly grading to dark yellowish brown (10YR 4/4) very firm medial material.

0.80m ------------ Distinct and wavy boundary ---------------

Araheke tephra

Upper and Lower Contacts

On the northern and north-eastern lower flanks of Egmont Volcano, the upper contact of **Waitui tephra** is separated from **Mangapotoa tephra** above, by less than 0.35m of friable, moderately developed medial material (**S3**) that upwardly grades to up to 0.05m of firm, massive medial material (**L2**). Silicic glass from the Central North Island chronohorizon - **Rotoehu Ash** was detected dispersed over several decimetres in **S3** directly overlying **Waitui tephra** (e.g. **Section 30** of Appendix 1).

The lower contact of **Waitui tephra** is separated from **Araheke tephra** below, by <0.10m of friable, moderately well developed medial material (**S3**) that downwardly grades to <0.30m of firm, massive or weakly developed medial material (**L3**).

Age

Waitui tephra is here provisionally ascribed an age of c.55 kyrs B.P. since the tephra closely underlies the c.50 kyr B.P. rhyolitic tephra datum - **Rotoehu Ash.**

Distribution

Waitui tephra has a maximum recorded thickness of 0.40m, c.4km north-east of Inglewood (e.g. **Section 19** of Figure 2.31). Further north-east (c.7.5km) **Waitui tephra** markedly thins to 0.06m and becomes discontinuous (e.g. **Section 24** of Figure 2.31). North beyond the Egmont ring plain, **Waitui tephra** is often exposed as a discontinuous <0.03m thick bed of dominantly grey coarse ash. From this meagre data, it appears that **Waitui tephra** is more widely distributed towards the north-eastern sector than towards the northern sector. The distribution of **Waitui tephra** in the eastern and southern sectors is presently unknown.

Reference Sections

Sections 11, 18, 19 and **27** are here designated as reference localities for **Waitui tephra** and are the same as those designated for **Mangapotoa tephra**, above.

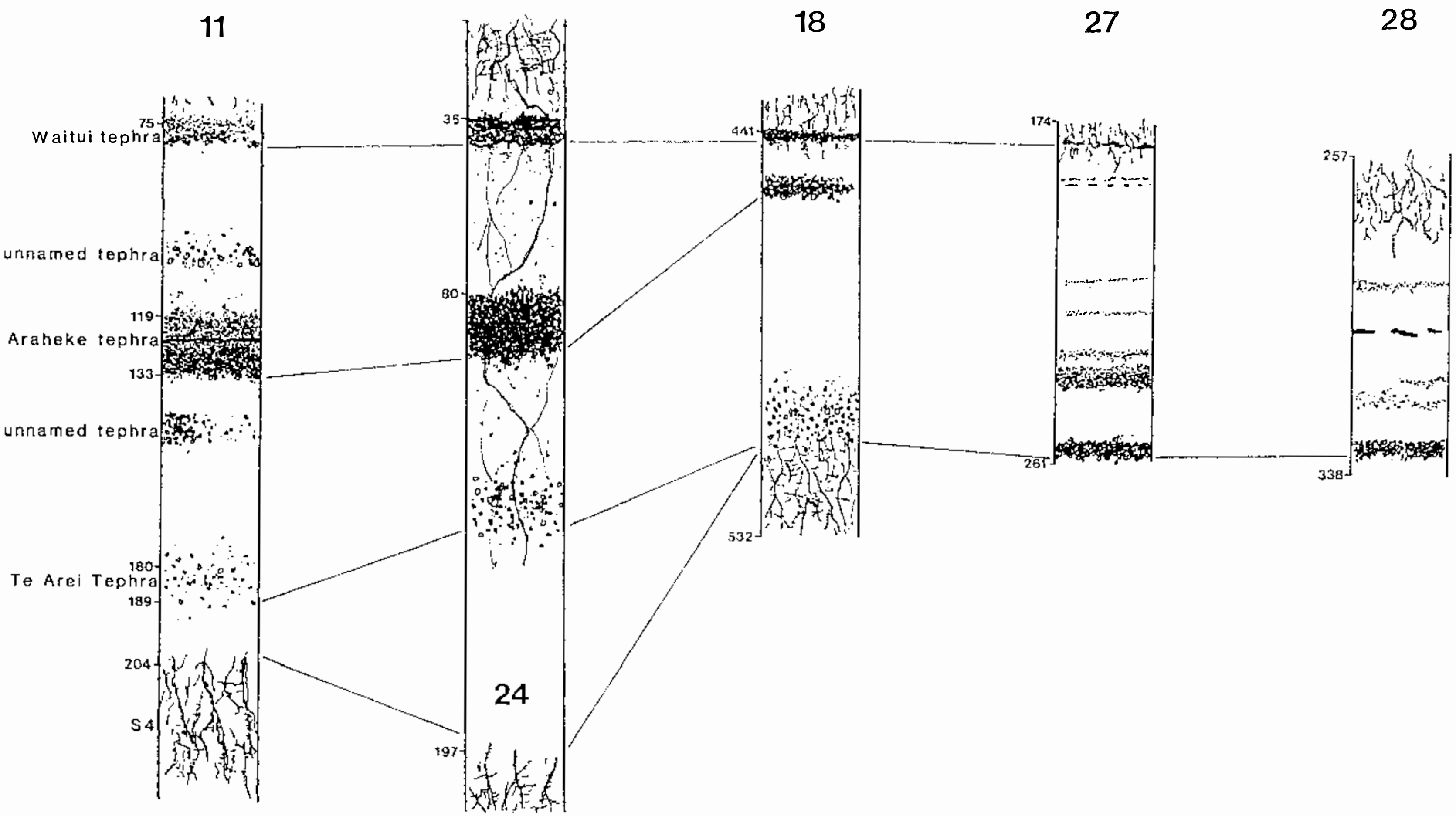


FIG. 2.31 Correlation Columns of Waitui and Araheke tephra, and Te Arei Tephra

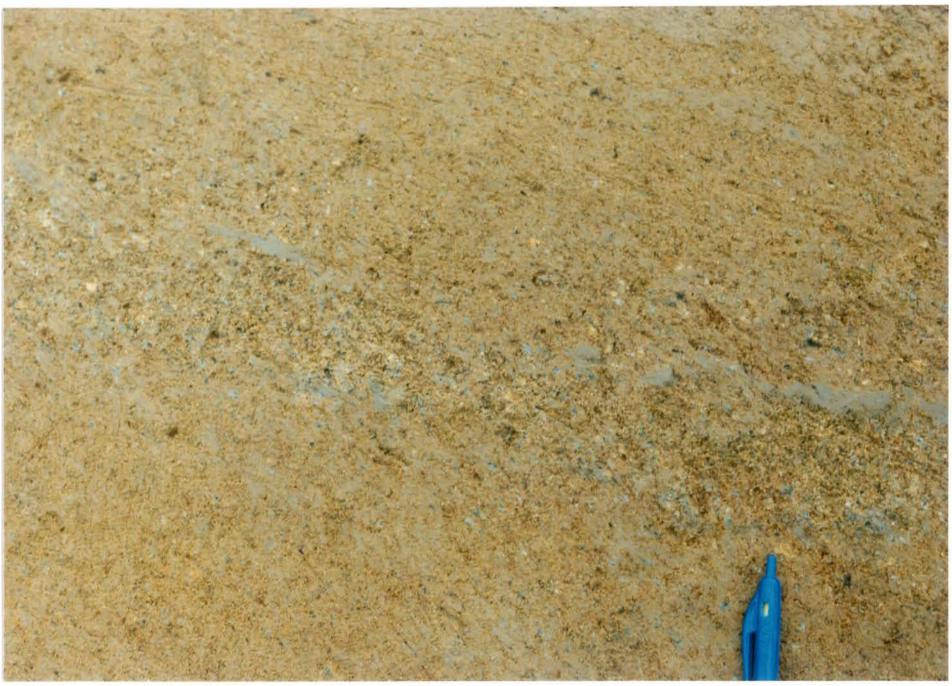


Plate 2.37: **Waitui tephra** within upper **L3** at Toetoe Well-site (Section 24: Q19/246316).

2.4.4 Araheke tephra
(new informal formation)

Araheke tephra is informally named after Araheke Stream, which flows north from Egmont Volcano, parallel with Egmont Road, crossing State Highway 3 at Egmont Village.

Criteria

On the lower northern and north-eastern flanks of Egmont Volcano, **Araheke tephra** is multiple bedded and frequently characterised by layers of very firm, well to very well sorted, grey to brown (7.5YR N5/ - 5/2) fine ash intervening between proportionately thicker layers of profuse, moderately well to well sorted, very firm, reddish yellow (5YR 5/8 and 7.5YR 6/8), yellow (10YR 8/6 - 8/8) and grey to very dark grey (7.5YR N5/ - N3/) coarse ash and fine lapilli. On the northern coastal plain, **Araheke tephra** comprises two closely spaced fine ash layers separated by 0.01m of medial material.

Upper and Lower Contacts

On the northern lower flanks of Egmont Volcano, the upper contact of **Araheke tephra** is separated from **Waitui tephra** above, by up to 0.45m of firm, weakly developed to massive structured medial material (**L3**) (e.g. **Sections 11** and **24** of Figure 2.31). **Araheke tephra** in the same vicinity, is separated from **Te Arei Tephra** below, by medial material of similar morphology and thickness to that which overlies the upper contact.

Type Section

The type section is designated as a prominent north-facing road cut on State Highway 3, opposite the junction with Kings Road, c.3.7km west of Inglewood P.O. (Q19/109275) (**Section 11** of Appendix 1 and Figure 2.31). Here, **Araheke tephra** is exposed as follows:

Waitui tephra

0.75m ------------- Discontinuous and sharp boundary ----------

0.27m	Yellowish-brown (10YR 5/6), firm, massive structure medial material. Indistinct and discontinuous boundary.
0.04m	Many to abundant, unstratified, moderately sorted, reddish yellow (7.5YR 7/8 - 6/8) and yellowish red (5YR 5/8) fine to medium pumiceous lapilli, with few grey to dark grey (7.5YR N6/ - N4/) lapilli dispersed throughout. Distinct and discontinuous boundary. (**Unnamed lapilli**)
0.13m	Dark yellowish brown (10YR 4/6 - 4/4), firm to very firm, weakly developed to massive structured medial material medial material. Indistinct and wavy boundary.
0.14m **Araheke tephra**	0.05m of faintly normal graded, abundant to profuse, moderately well sorted, yellow (10YR 8/8) pumiceous and brown (7.5YR 5/2) coated, grey to dark grey (7.5YR N5/ - N4/) coarse ash. Sharp and straight boundary to 0.01m of very firm, very well sorted, grey to brown (7.5YR N5/ - 5/2) fine ash. Sharp and straight boundary to 0.08m profuse, very firm, well sorted dominantly grey to dark grey (7.5YR N5/ -N4/) coarse ash and with minor dispersed reddish yellow (5YR 5/8 and 7.5YR 6/8) pumiceous coarse ash. Within this layer the proportion of reddish yellow pumiceous constituents notably increases downward to abundant to profuse. Distinct and wavy boundary.
0.11m	Dark yellowish brown (10YR 4/4), very firm, massive structured medial material grading downwards to yellowish brown (10YR 5/6), firm medial material. Distinct and discontinuous boundary.

0.05m	Abundant, moderately sorted, dark grey to very dark grey (10YR 4/1 - 3/1) coarse ash and fine lapilli with common, yellow and brown (10YR 8/8 and 7.5YR 5/2) coated, reddish yellow pumiceous fine lapilli dispersed near lower 0.03m of bed. Distinct and discontinuous boundary. (**Unnamed lapilli**)
0.31m	Yellowish-brown (10YR 5/6), firm, massive structured medial material.

1.80m ------------- Distinct and wavy boundary ---------------

Te Arei Tephra

Correlation

Araheke tephra is here provisionally correlated to the lower informal member (**Weld tuff**) of **Weld Tephra** (Neall 1972). The upper member (**Weld ash**) is correlated as **medial material** that relates to intermittent accretion of fine tephric material that may not be genetically associated with **Weld Tuff.**

Distribution

A rudimentary isopach map constructed from insufficient thickness data suggests that Araheke tephra probably originated from an ancestral Egmont Volcano and was directed north-east. On the northern lower flanks of Egmont Volcano (e.g. **Section 11**), **Araheke tephra** has a thickness of 0.14m. However more distally, a maximum thickness of 0.16m was recorded for **Araheke tephra** c.11.5km north-east from Inglewood Borough (**Section 24**).

Reference Localities

Sections 18, 24 and **27** are here designated as reference sections for **Araheke tephra** and are the same as those sections designated for **Waitui tephra**, above.

2.4.5 Te Arei Tephra

(new formation)

Te Arei Tephra is a new formation, which occurs between **Araheke tephra** above, and **Epiha Tephra** below, in deep exposures of the northern and north-eastern sectors. **Te Arei Tephra** is named after Te Arei Road, 3.5 km south-west of Waitara, on the North Taranaki coastal plain.

Criteria

Te Arei Tephra comprises a single bed of unstratified, moderately to moderately well sorted, very pale brown to yellow (10YR 8/3 - 8/8) pumiceous lapilli, with a similar proportion of grey to light grey (7.5YR N6/ - N5/) lapilli.

Type Section

The type section for **Te Arei Tephra** is designated as a prominent north-facing road cut on State Highway 3, opposite junction with Kings Road, c.3.7 km west of Inglewood P.O. (Q19/109275) (**Section 11** of Appendix 1 and Figure 2.31). Here, **Te Arei Tephra** is exposed as follows:

Araheke Tephra

1.33m ------------------ Distinct and wavy boundary -----------

0.11m	Dark yellowish brown (10YR 4/4), very firm, massive structured medial material grading downwards to yellowish brown (10YR 5/6), firm medial material. Distinct and discontinuous boundary.

0.05m	Abundant moderately sorted, dark grey to very dark grey (10YR 4/1 - 3/1) coarse ash and fine lapilli with common, yellow and brown (10YR 8/8 and 7.5YR 5/2) coated, reddish yellow pumiceous fine lapilli dispersed near lower 0.03m of bed. Distinct and discontinuous boundary. (**Unnamed lapilli**)
0.31m	Yellowish-brown (10YR 5/6), firm, weakly developed, coarse blocky structured to massive structured medial material. Distinct and wavy boundary.
0.09m **Te Arei Tephra**	Many, moderately well sorted, yellow (10YR 8/8) (few 10YR 8/4 - 8/6) pumiceous and grey to light grey (7.5YR N6/ - N5/) fine to medium lapilli, dispersed in a subordinate matrix of medial material. Distinct and wavy boundary.
0.15m	Yellowish-brown (10YR 5/6), firm, massive structured medial material. Distinct and smooth boundary.
0.60m (**S4**)	Dark brown (7.5YR 4/4, firmly friable, moderately developed, medium to fine blocky structured medial material.

2.64m ------------------ Indistinct and wavy boundary -------

Epiha Tephra

Upper and Lower Contacts

On the north-eastern lower flanks of Egmont Volcano, <0.45m of weakly developed to massive structured medial material (**L3**) with a discontinuous and unnamed lapilli layer separates the upper contact of **Te Arei Tephra** from **Araheke tephra** above (e.g. **Section 11**). In the same vicinity, <0.15m of **L3** separates the lower contact of **Te Arei Tephra** from **S4** and **Epia Tephra**, below. In the north-eastern sector, **L3** intervening between **Te Arei Tephra** and

S4 may occasionally wedge and attain thicknesses of <0.60m (e.g. **Section 24**). North beyond the Egmont ring plain, the lower contact of **Te Arei Tephra** directly overlies **S4** (e.g. **Section 18**).

Distribution

The few outcrops of **Te Arei Tephra** are restricted to mostly road cuttings north and north-east beyond the Egmont ring plain. An isopach map (Figure 2.32), constructed from meagre thickness data, suggests that this tephra probably originated from an ancestral Egmont Volcano.

Age

Te Arei Tephra is estimated to have an age of c.75kyrs B.P. This estimate is based on the occurrence of the tephra within lower L3, which is correlated with oxygen isotope stage 4 (see Chapter 4).

Reference Localities

Sections 18, 24 and **27** are here designated as reference localities for **Te Arei Tephra** and are the same as those designated for **Araheke** and **Waitui tephra.** Two further reference localities are described as follows:

1. North-west facing cliff exposure 1.0km south-west of Waiongana Stream Mouth (Q19/121445) (**Section 25** of Appendix 1).
2. North-east facing cliff exposure, 0.65km south-east along coast from northern road-end, Turangi Road (Q19/242456) (**Section 28** of Appendix 1 and Figure 2.30).

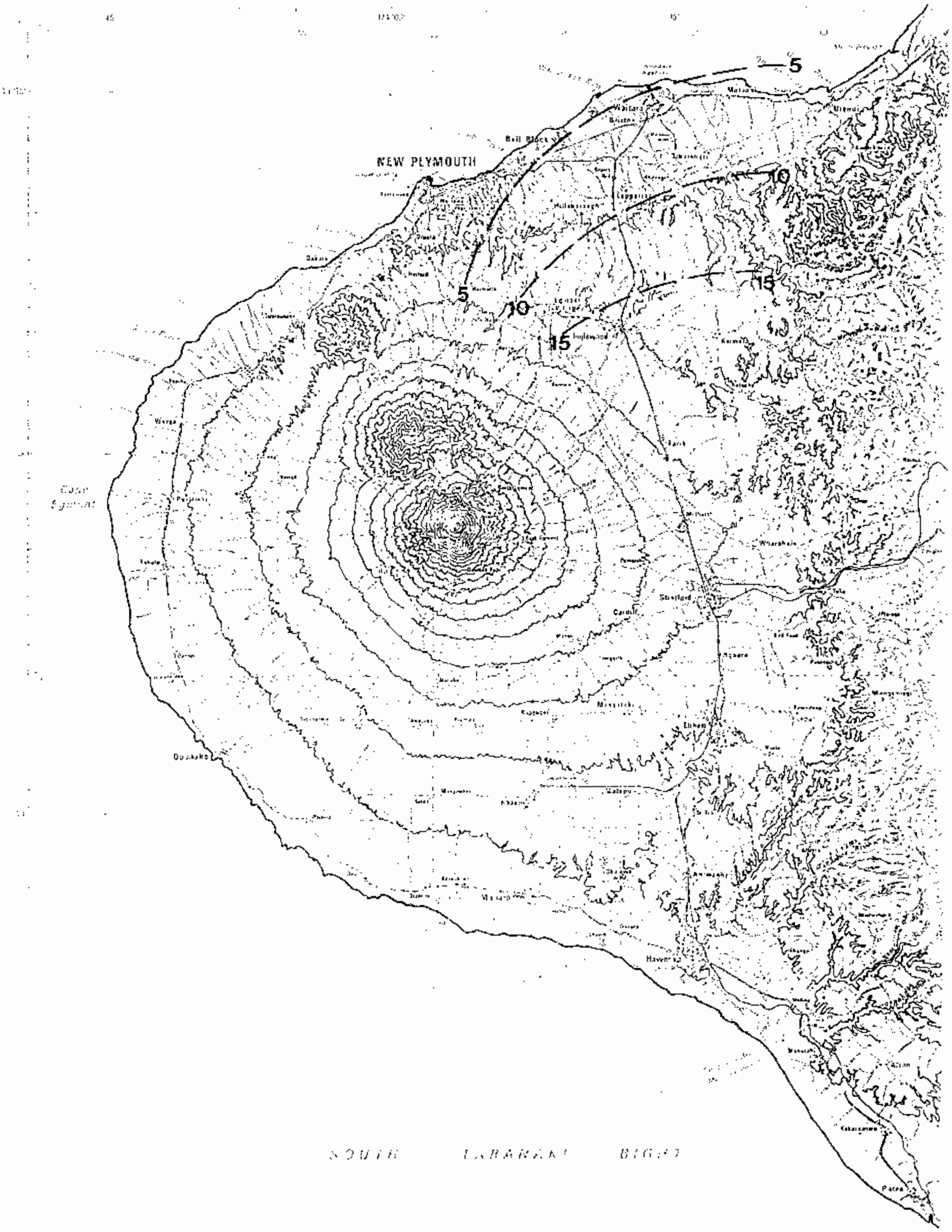


FIG. 2.32 Isopach Map: Te Arei Tephra

2.4.6 Epiha Tephra

(new formation)

Epiha Tephra is a new tephra formation named after Epiha Road, c.4km east of Waitara Borough on the North Taranaki coastal plain.

Epiha Tephra is particularly well exposed along the north Taranaki coast where it comprises a closely spaced set of at least **seven** coarse ash and lapilli beds that intervene between **Te Arei Tephra**, above and **Okawa Formation** (e.g. **Sections 25** and **27** of Figure 2.33) or **Ninia tephra** (e.g. **Section 28** of Figure 2.33), below. Here each successive bed, informally named **Epi.a** to **Epi.g**, in order of decreasing age, are separated by variably thick peaty muds.

Of the units that comprise **Epiha Tephra**, only the most prominent (**Epi.c**, **Epi.d** and **Epi.e**) can be widely correlated in the dominantly medial cover-bed sequence between the north coast and Egmont ring plain. The remaining units of **Epiha Tephra** can seldom be identified or correlated inland from the coast towards Egmont Volcano because the units are more influenced by post-depositional mixing and weathering in the soil forming environment than equivalent units in coastal sections (e.g. **Section 11**). In this case, each uncorrelated unit of **Epiha Tephra** is referred to as '**Epiha tephra**'.

Criteria

Throughout North Taranaki, **Epi.e** is characterised by a faintly normal graded layer of moderately to moderately well sorted, dominantly grey (7.5YR N6/) lapilli, with minor yellow (10YR 8/8 - 7/8) pumiceous lapilli scattered throughout.

Epi.c and **Epi.d** are similar in appearance, comprising moderately to well sorted, dominantly reddish yellow (7.5YR 6/8 - 7/8) and yellow (10YR 8/8) pumiceous coarse ash and lapilli, with minor scattered, grey to dark grey (7.5YR N6/ - N4/) lapilli (Plate 2.38). Both units, on the lower flanks of Egmont Volcano, are separated by <0.04m of medial material, which thins northward resulting in the two units merging together to form a single tephra marker (**Epi.c/d**). Where this occurs, constituents of **Epi.c** are indistinguishable from those of **Epi.d.**

Type Section

The type section of **Epiha Tephra** is here designated as a prominent north-facing cliff exposure at Airedale Reef, 1.4km east of Waitara River Mouth (Q19/178461) (**Section 27A** of Appendix 1 and Figure 2.33). Here, Epiha **Tephra** is exposed as follows:

Te Arei Tephra

2.59m ------------- Sharp and wavy boundary -------------------

0.05m	Brown to dark brown (10YR 4/8), firm, weakly developed, medium blocky structured clay loam. Distinct and smooth boundary.
0.13m	Very dark brown (10YR 2/2) and dark yellow brown (10YR 3/4), weakly developed medium to coarse blocky structured, highly carbonaceous, clay loam. Common millimetre bedded layers of plant material throughout. Three millimetre bedded, white - very pale brown fine ashes at 2.67, 2.69 and 2.72m depth. Lower contact marked by a 0.8cm layer of black (10YR 2/1) carbonaceous material. Distinct and wavy boundary.
0.01m	Light grey (10YR 7/2), weakly developed medium blocky structured clay loam. Sharp and wavy boundary.

0.03m **Epi.g**	Profuse, unstratified, moderately well to well sorted, yellow to light yellowish brown (10YR 7/6 - 6/4) pumiceous coarse ash. Unit may laterally thicken to 0.06m. Sharp and smooth boundary.
0.01m	Light grey (10YR 7/2), firm, massive structured clay loam, with a <0.02cm fine ash bed. Sharp and wavy boundary.
0.03m **Epi.f**	Profuse, unstratified, well sorted, white to very pale brown (10YR 8/2 -8/4) pumiceous fine lapilli and minor coarse ash. Unit may laterally thicken to 0.07m. Sharp and wavy boundary.
0.02m	Light grey (10YR 7/2), firm, massive structured clay loam with discontinuous <0.03cm thick, pumiceous fine ash bed. Distinct and wavy boundary.
0.07m **Epi.e**	Abundant, moderately well sorted, white to very pale brown (10YR 8/2 - 8/4 and 7/4) pumiceous coarse ash which downwardly grades to profuse, loose, moderately sorted, red (2.5YR 4/8) coated, fine lapilli and coarse ash. Sharp and wavy boundary.
0.04m	Light grey (10YR 7/2), firm, massive structured clay loam. Sharp and wavy boundary.
0.07m **Epi.d**	Profuse, moderately firm, well sorted, very pale brown to light yellowish brown (10YR 7/4 - 6/4) and grey (7.5YR N5/) speckled pumiceous fine ash that downwardly grades to coarse ash. Laterally along section unit merges with unit, below. Sharp and wavy boundary.
0.01m	Light grey (10YR 7/2) clay loam. Merging and smooth boundary.
0.09m **Epi.c**	Profuse, moderately firm, very pale brown to light yellowish brown (10YR 7/4 - 6/4) and grey speckled, well sorted, pumiceous fine ash grading downwards to moderately well sorted pumiceous coarse ash and fine lapilli. Sharp and wavy boundary.

0.03m	Light grey (10YR 7/2), firm, massive structured clay loam. Distinct and wavy boundary.
0.05m	Black (10YR 2/2), firm, weakly developed, medium blocky structured, highly carbonaceous, clay loam. Discontinuous and sharp boundary.
0.05m **Epi.b**	Abundant, unstratified, moderately sorted dark yellow brown (10YR 4/6) fine to medium (few coarse) pumiceous lapilli. Discontinuous and sharp boundary.
0.03m	Black (10YR 2/2), moderately firm, weakly developed, coarse to medium blocky structured, highly carbonaceous clay loam. Discontinuous and sharp boundary.
0.03m **Epi.a**	Many, unstratified, moderately sorted, very pale brown (10YR 7/3) fine to medium pumiceous lapilli. Broken and sharp boundary.
0.05m	Black (10YR 2/2), moderately firm, weakly developed, coarse blocky structured, highly carbonaceous clay loam. Distinct and wavy boundary.
c.4.25m	Unstratified, extremely poorly sorted, heterolithologic, common to many rounded to sub-rounded pebble to boulder randomly orientated within a moderately firm matrix of brown (10YR 5/3) sandy clay loam. Medium, red stained rhyzomorphs are common extending c.1.0m below upper contact. Wood fragments and peaty clasts are commonly dispersed throughout. Sharp and wavy boundary. (**Marginal facies of Okawa Formation**)
0.01m	Black (10YR 2/2), moderately firm, highly carbonaceous clay loam. Tree stumps in growth position protrude up from beneath. Discontinuous and sharp boundary.
0.01m	Abundant, moderately sorted, yellow (10YR 8/6 - 8/8) pumiceous coarse ash and fine lapilli. Broken and sharp boundary. (**Unnamed lapilli**)

c.0.85m	Black (10YR 2/2), weakly developed coarse blocky structured highly carbonaceous material with many woody fragments throughout. Tree stumps in growth position occasionally occur.
8.55m -------------	Diffuse and wavy boundary -----------------
+0.30m	Massive to steep angled cross bedded, grey, very firm, slighty silty, medium sand. Base not exposed.

Upper and Lower Contacts

Along the north coast, the uppermost unit of Epiha Tephra (**Epi.g**) is separated from **Te Arei Tephra**, above, by up to 0.20m of dominantly peaty material (e.g. **Sections 25** and **27**). The lowermost unit of **Epiha Tephra** (**Epi.a**) is separated from **Okawa Formation** below, by <0.20m of lignitic material. At **Section 28**, where the underlying Okawa Formation is absent, c.5.40m of woody lignite and carbonaceous fine grained sediment with a thin, unnamed tephra inter-bed, separates lowermost **Epiha Tephra** from **Ninia tephra** overlying the **Motunui lahar deposit**, below.

Inland towards Egmont Volcano, uppermost **Epiha Tephra** is separated from **Te Arei Tephra** above, by <0.10m of firm, weakly developed medial material (**L4**) and up to 0.65m of friable, moderately developed medial material (**S4**) (e.g. **Sections 11, 18** and **24**). In the same vicinity, the lowermost identifiable tephra (**Epi.c**) is separated from **Okawa Formation** below, by up to 0.10m of **L4** and <0.40m of friable, well developed medial material (**S5**).

Age

Epiha Tephra is estimated to have an age range of between 80 and 100kyrs B.P. This estimate is based on the occurrence of **Epiha Tephra** above **Okawa Formation** and within **S4**, **L4** and uppermost **S5** (see Chapter 4).

Correlation

Epiha Tephra is here, correlated to the closely spaced set of tephra beds exposed between 0.99m and 1.64m above road level, in a lignite section along Ararata Road in South Taranaki (Q21/160823). **Epi.c/d** is correlated to the <0.10m thick pumiceous coarse ash exposed at 1.3m above road level, while, **Epi.e** is correlated to the 0.08m thick shower bedded fine lapilli and coarse ash exposed at 1.39m above road level.

Epi.c/d is here also provisionally correlated to the prominent 0.09m thick pumiceous fine ash intercalating Parao loess (Wilde and Vucetich 1988) that overlies weathered near-shore sands, c.3.9m above the **Rapanui wave cut surface** at Kohi Road (**Section** 35 of Appendix 1 and Figure 2.33) in the Wanganui district.

Distribution

An isopach map (Figure 2.34) constructed for **Epi.c/d** shows a broad eastward lobes of distribution presumably from an ancestral Egmont Volcano. The 0.10m isopachs occur at the north coast and in the vicinity of Hawera in the southern sector. Both units are expected to extend a considerable distance east beyond Taranaki Region and potentially useful markers within the Wanganui district.

Reference Localities

Sections 11, 18, 25 and **28** are here designated as reference localities for **Epiha Tephra** and are the same as those designated for **Te Arei Tephra, Araheke** and **Waitui tephras.**

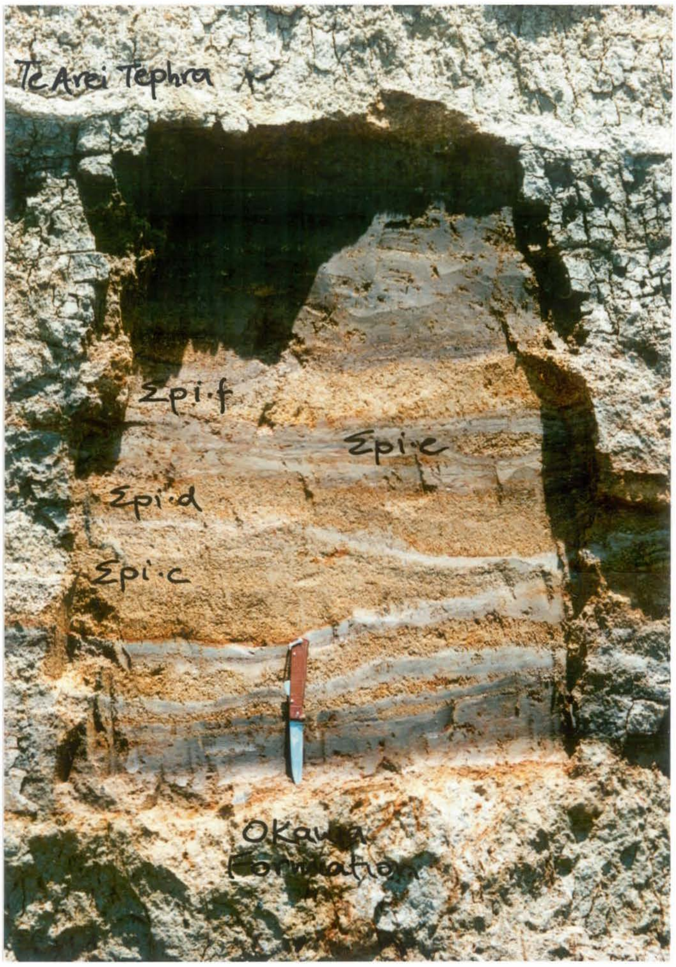


Plate 2.38: **Te Arei** and **Epiha Tephra** in carbonaceous muds above **Okawa Formation** at Airedale Reef (Section 27A: Q19/178461).

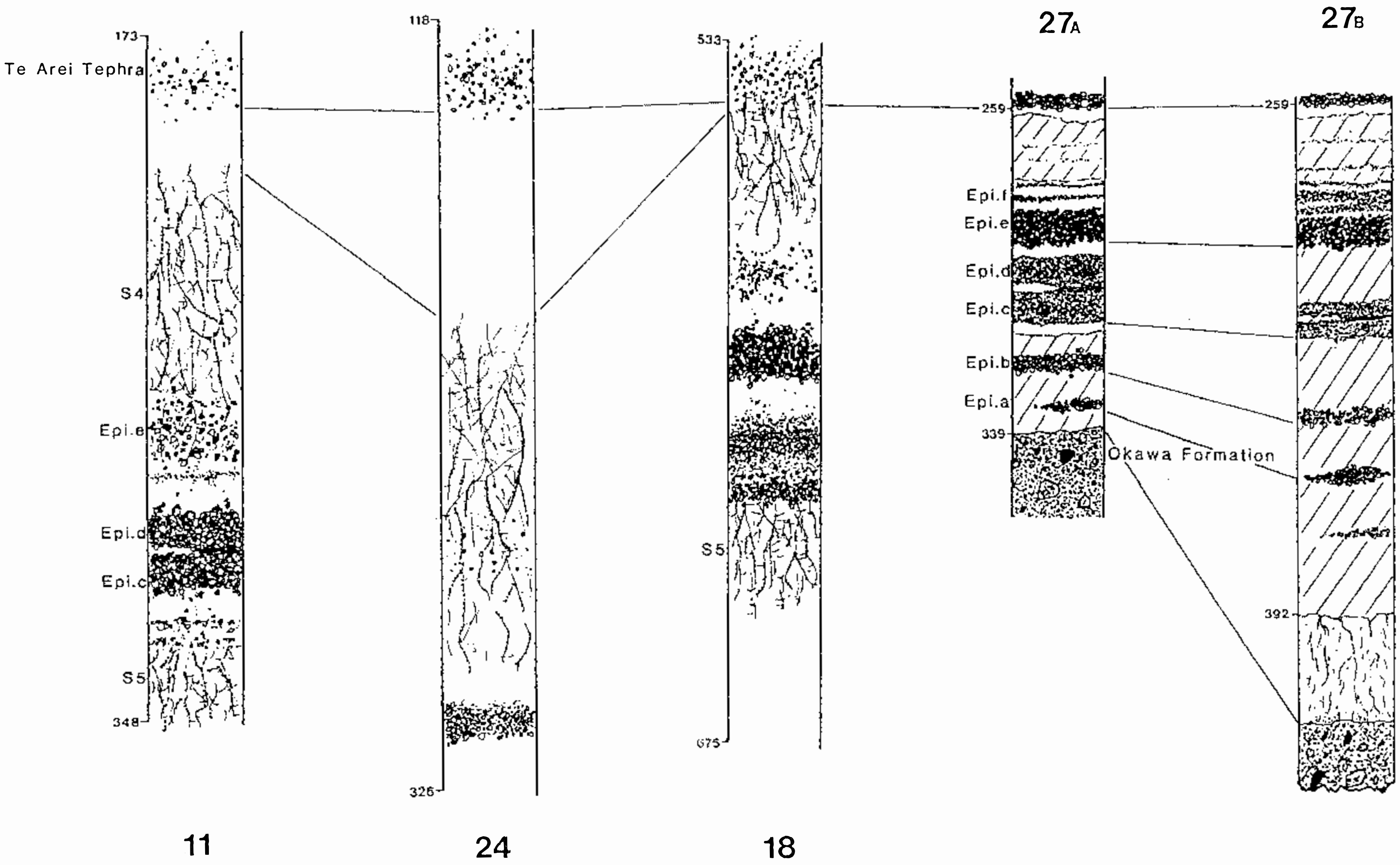
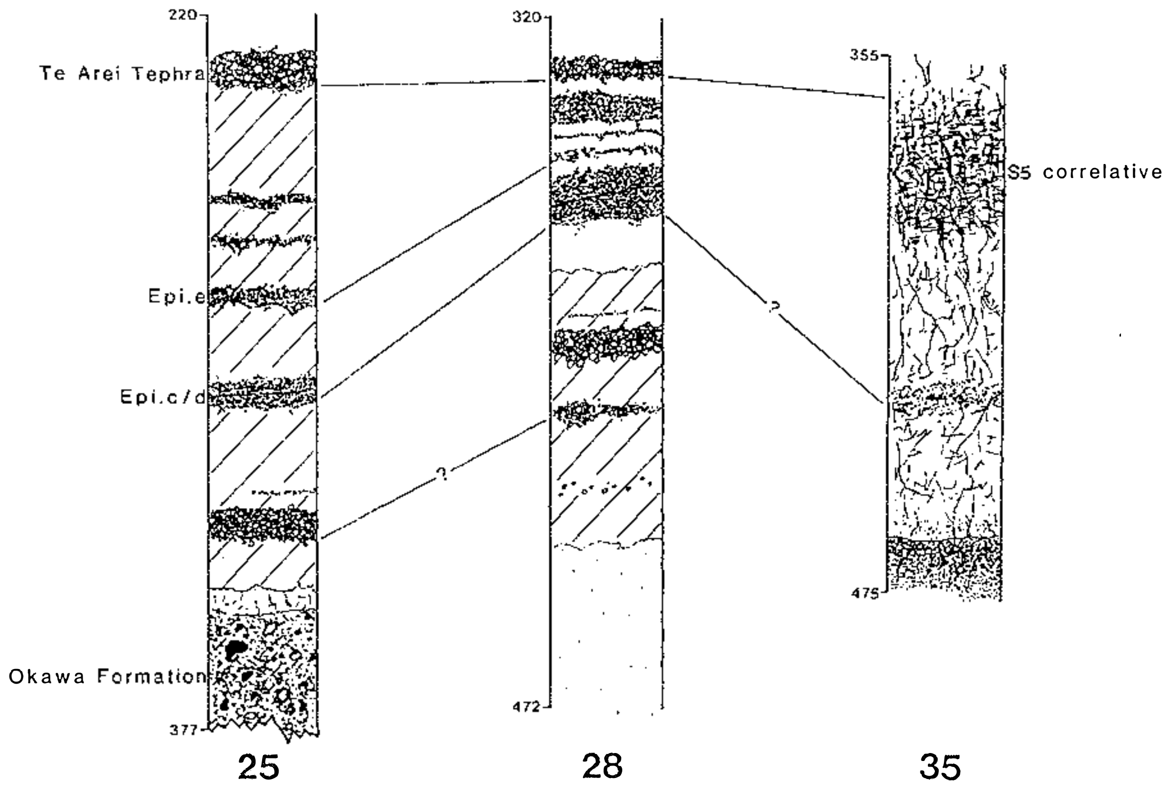


FIG. 2.33 Correlation Columns of Epiha Tephra


220
Te Arei Tephra
Epi.e
Epi.c/d
Okawa Formation
377
320
472
355
S5 correlative
475
?
?
25
28
35

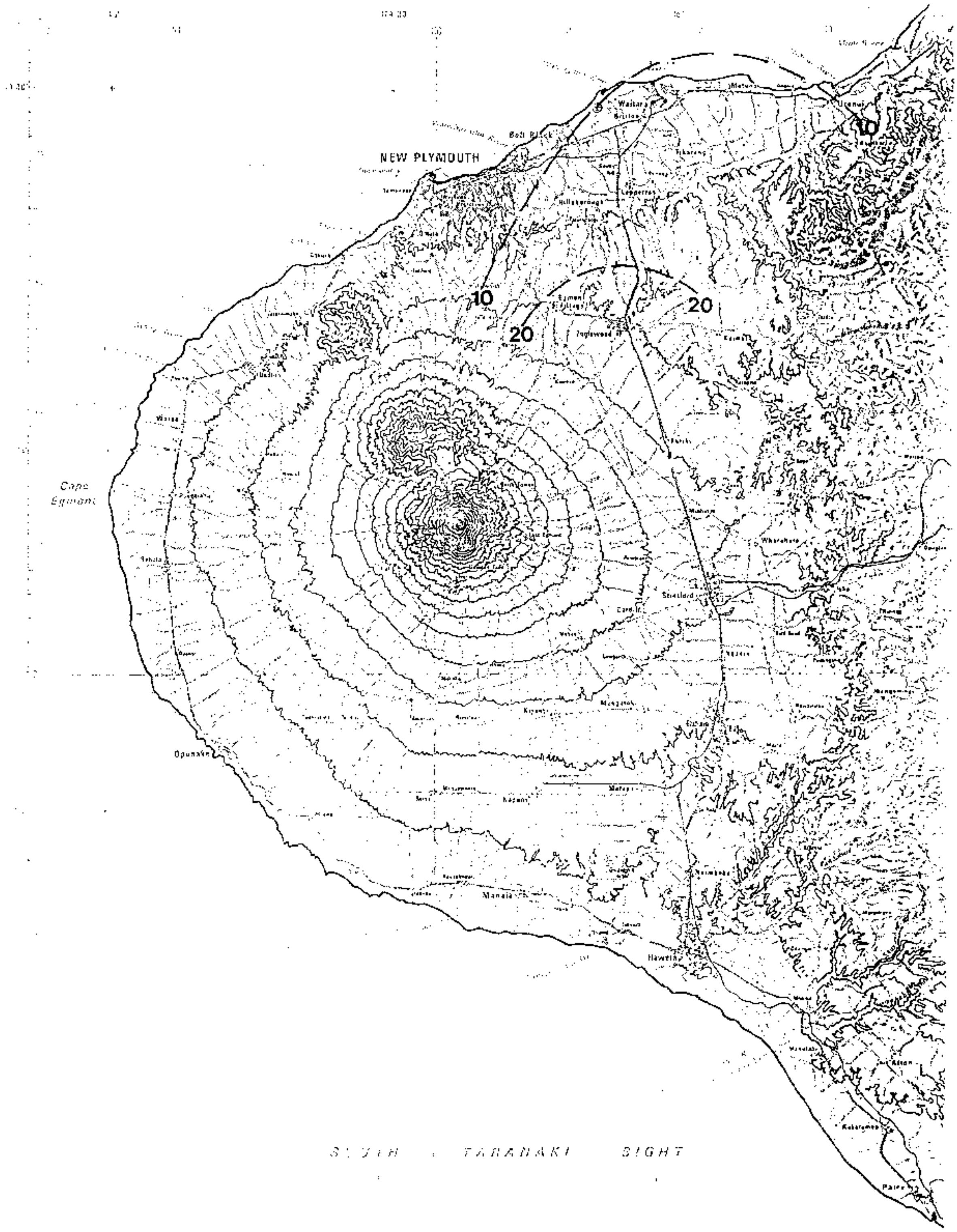


FIG. 2.34 Isopach Map: Epi.c/d of Epiha Tephra

2.4.7 Ninia tephra

(new informal formation)

Ninia tephra is informally named after Ninia Road situated on the north Taranaki coastal plain, c.6 km south-west of Waitara Borough.

Ninia tephra was first recognised as well preserved tephra layers within lignite, in coastal cliffs along the north coast, east of Waitara (e.g. **Section 28** of Appendix 1). Here, the tephra is almost continuously exposed and comprises a closely spaced set of at least **four** pumiceous coarse ash beds that occur between **Epiha** Tephra or **Okawa Formation** above and **Motunui lahar deposit**, below (Plate 2.39). Of the tephra beds that comprise **Ninia tephra** only the lowermost bed (**Ni.a**) is prominent enough to be correlated from coastal sections to the soil forming environment further inland (e.g. **Section** 30).

Ni.a is characterised by firm, unstratified, moderately well to well sorted, dominantly yellow (10YR 7/8) and minor black speckled, pumiceous coarse ash.

Ninia tephra appears best represented further inland from the coast, in a poorly accessible locality (Q19/173399) on the coastal plain, c.3.5km south of Waitara Borough. At this site, **Ninia tephra** comprises at least **thirty-four** millimetre to centimetre bedded fine ash to fine lapilli layers within a c.6.67m thick sequence between the c.>4.0m thick **Okawa Formation** above and **Motunui lahar deposit** below. The sequence between the two formations comprises an upward transition from slightly carbonaceous muds (c.1.30m) to woody peat (c.4.3m) to massive, very pale brown, clay. This section is here designated as the informal type section for Ninia tephra.

Sections 28 and **30** (previously described) are designated here as informal reference localities for **Ninia tephra.** Due to insufficient, near source, exposure and isopach data, the source of **Ninia tephra** is presently unknown.

At **Section 28** along the coast, the upper contact of **Ninia tephra** is marked by **Ni.c**, which is separated from **Epi.a** of **Epiha Tephra** above, by a c.5.20m thickness of lignite and carbonaceous olive-yellow clay. At the same section, up to 0.30m of lignite separates **Ni.a** from **Motunui lahar deposit** overlying near-shore sand above the wave cut surface of **NT2 terrace.**

At **Section 30**, slightly inland from the coast (<1.0km), uppermost **Ninia Tephra** (**Ni.c**) is separated from **Epi.c/d** above, by <c.1.0m of moderately developed medial material (**S5**) and c.0.80m of weakly developed medial material (**L4**). At the same section, Ni.a is separated from the wave cut surface of **NT2 terrace**, by >2.0m of massive, very firm, grey sand which downwardly grades to c. 3.2m of near-shore sands and gravels.

Ninia tephra, occurring beneath **S5** and Okawa Formation, is the lowermost tephra formation overlying sands above the wave cut surface of **NT2 terrace** of Chappell (1975). This terrace was correlated by Hay (1967) to the Rapanui Marine Terrace of Wanganui (Fleming, 1953; subsequently redefined and indirectly dated c.130kyr B.P by Pillans, 1981). On this basis, **Ninia tephra** has an estimated age range between c.100 and 115kyrs B.P.

Plate 2.39: **Ninia tephra** in woody lignite above **Motunui lahar deposit** (Section 28; Q19/242456).

CHAPTER 3

3.0 RHYOLITIC TEPHRAS IN TARANAKI

3.1 Introduction

Quaternary tephras erupted from the Taupo Volcanic Zone have been intensively studied over the past 25 years, and have been demonstrated to be useful as stratigraphic marker horizons which are especially valuable as widespread time planes. Early studies concentrated on the stratigraphy, age and distribution of the tephras near their volcanic source areas (Healy 1964; Vucetich and Pullar 1964, 1973; Topping 1973; Howorth 1975; Froggatt 1981a,b) whereas comparatively recent studies have examined them in detail as distal deposits (c.100km or more from their source areas) (Pullar et al. 1977; Howorth et al. 1980; Lowe et al. 1980; Hogg and McCraw 1983; Lowe and Hogg 1986).

Distal tephras, used as stratigraphic marker horizons, provide the key to the stratigraphic relationships of both aeolian units and intercalated tephras derived from different volcanic centres whose stratigraphy and age are not well known. In this study, the stratigraphy of six distal rhyolitic tephras preserved in a diversity of environments is examined. The younger rhyolitic tephras can be readily identified by direct stratigraphic control with respect to chronohorizons of Egmont-source. The older tephras, only rarely exposed, can seldom be stratigraphically related with distinctive enclosing beds to allow correlation.

3.2 Waimihia Tephra

In a detailed mineralogical study of a representative Egmont loam profile in South Taranaki, Stewart et al. (1977) identified a minor rhyolitic glass peak as the Waimihia Tephra eruption. Since that study, six sites have been located in North Taranaki at which **Waimihia Tephra** is macroscopically visible (Figure 3.01).

Criteria

Waimihia Tephra is conspicuous in appearance and can be readily distinguished from andesitic tephra on the basis of its lighter colour and its consistently fine texture. Where interbedded in peat (Plate 3.01) or coastal sands (Plate 3.02), **Waimihia Tephra** forms a discontinuous, white to yellow (10YR 8/2 to 7/6) millimetre bedded, well sorted, glassy fine ash <0.08m thick. In estuarine sediment, **Waimihia Tephra** is usually more continuous and uniformly thick (0.02m), with a characteristic pinkish (5YR 7/3) colour (Plate 2.05).

Upper and Lower Contacts

The upper contact of **Waimihia Tephra** is typically sharp and wavy and is separated from **Inglewood Tephra** above by <0.22m of peat or <0.09m of estuarine mud. The lower contact of **Waimihia Tephra** is also sharp and wavy but separated from **Korito Tephra** below, by either <0.05m of peat or <0.02m of estuarine mud.

Correlation

In Taranaki, the middle member of **Stent Ash**, first recognised by Wellman (1962) as 'a laminated silt-grade putty coloured ash' is now established as the **Waimihia Tephra** in Holocene coastal sections.

Age

Three new radiocarbon dates for Waimihia Tephra have been determined from Taranaki (Figure 3.01). At Kaimata (**Section 20**) a radiocarbon date (NZ6702A) of 3,580 +/- 80 years B.P. was obtained from a bulk peat sample midway between **Korito Tephra** and the overlying **Waimihia Tephra**. Two further radiocarbon dates (WK-1032A and Wk-1259A) of 3870 +/- 110 and 3940 +/- 70

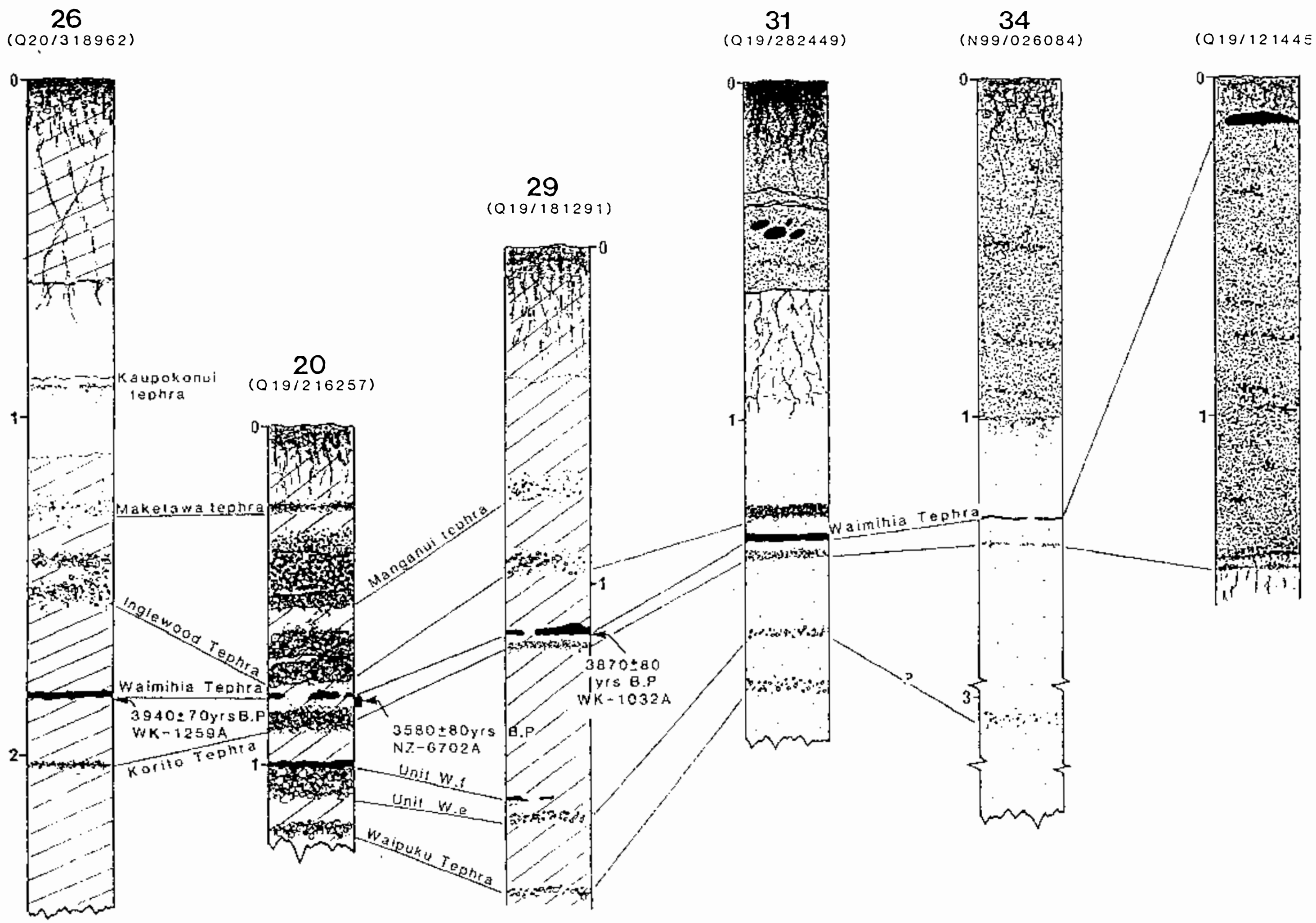


FIG. 3.01 Stratigraphy and Chronology of Waimihia Tephra in North-eastern and Central Taranaki

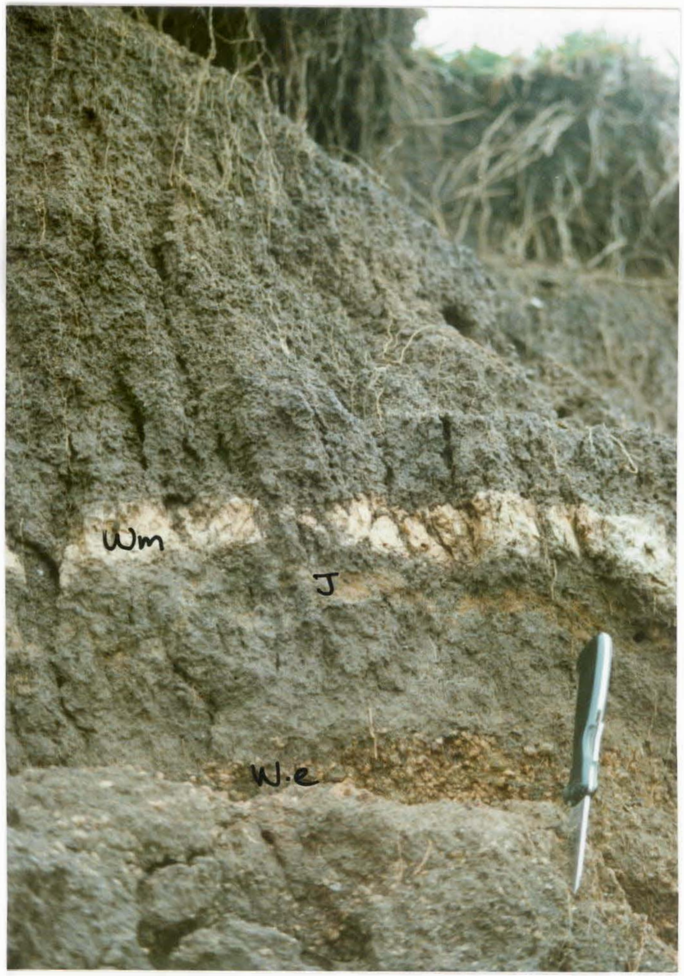


Plate 3.01: **Waimihia Tephra** (Wm) in peat near west end of Onaero Beach (Section 29; Q19/268448). Note **Korito** and **Tariki Tephra** below **Waimihia Tephra**.

Plate 3.02: **Waimihia Tephra** (Wm) in coastal dune sand near New Plymouth Airport (Q19/121445).

years B.P. were obtained from peat immediately beneath **Waimihia Tephra** from Onaero Beach and a site near Mangamingi, respectively (**Sections 29** and **26**).

The dates obtained for **Waimihia Tephra** from Taranaki appear consistent with the radiocarbon chronology established for the overlying **Inglewood Tephra** (c.3.6kyr; Wk-1031A and NZ3353A) and the underlying **Korito Tephra** (c.4.1kyr; Wk-1033A) but are consistently older than those radiocarbon dates obtained for the tephra from the Taupo, Gisborne and Hawkes Bay Districts (Baumgart 1954; Healy 1964; Pullar 1970; Vucetich and Pullar 1973; Howorth et al. 1980; Lowe and Hogg 1986). The reason for these consistently older dates remains unclear.

Ferromagnesian Mineralogy

The ferromagnesian mineralogy in the coarse to medium silt fraction of the **Waimihia Tephra** from two sites in Taranaki is hypersthene dominated, with a significant content of augite and hornblende (Table 3.01). The coarser size fractions (>63um) are dominated by augite and hornblende. Hypersthene-rich mineralogy is characteristic of a Taupo source (Froggatt 1981c; Lowe 1986). Orthopyroxene is almost invariably a minor pyroxene in Egmont-source tephras (Franks 1984; Lowe 1986). At Taranaki sites, the high content of augite and hornblende in **Waimihia Tephra** is attributed to Egmont-source tephra contamination. The absence of biotite and/or cummingtonite excludes an Okataina source.

Glass Chemistry

Twenty-two chemical analyses of glass shards (Samples 50823 and 50824 held at R.S.E.S., Victoria University of Wellington) of **Waimihia Tephra** at two sites in Taranaki (Figures 3.02; Appendix 2.1) confirm rhyolitic composition and support a

TABLE 3.01: Ferromagnesian Mineralogy of Waimihia Tephra in Taranaki.

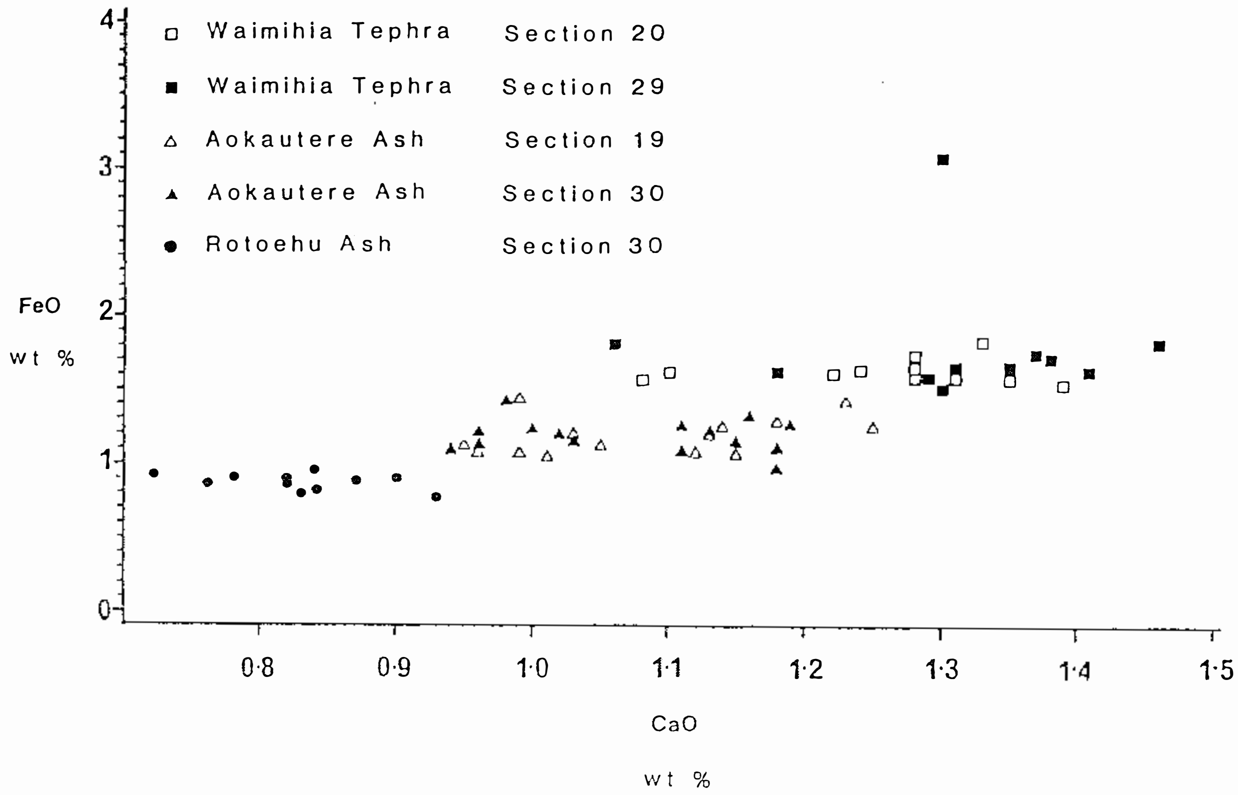
TEPHRA[a]	Hyperstene	Augite	Hornblende	Total
Waimihia Tephra Kaimata (Section 20)	47	36	21	104
Waimihia Tephra West Onaero Beach (Section 29)	42	25	34	101

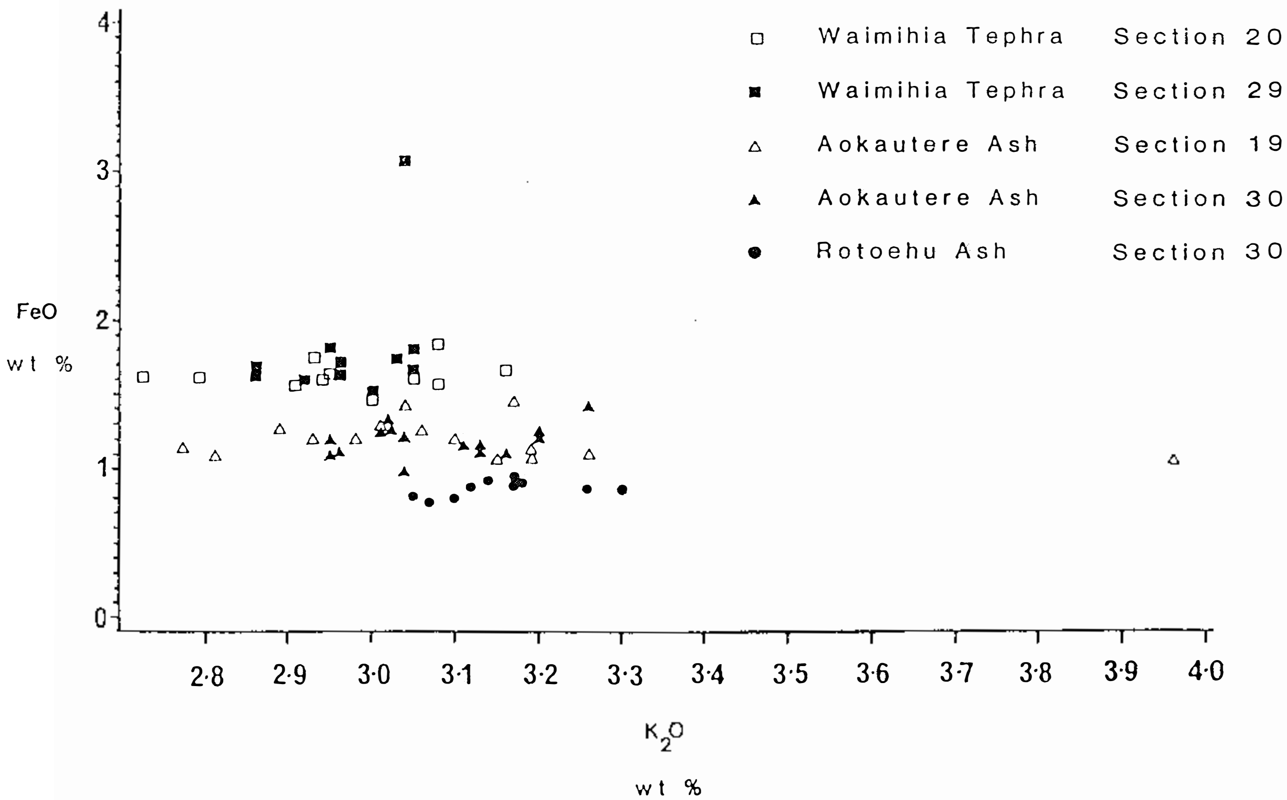
Notes:

a. Data based on point counts for 32 - 20 micron fractions.

FIG. 3.02

Selected Major Element Analyses of Rhyolitic Glass Shards





Taupo source of Holocene age (cf. glass chemistry analyses of tephras in Froggatt 1983; Lowe 1986).

Isopachs

Isopach maps of Vucetich & Pullar (1964) and Pullar & Birrell (1973) indicated that the **Waimihia Tephra** distribution was roughly elliptical, with the major lobe extending from the Taupo source area, in an east direction towards Gisborne, where 0.15m of tephra occurs. The tephra thins rapidly to the west and north-west, and is apparently absent from peat and lake sediment cores obtained from the Waikato Region (Lowe 1986). Based on the occurrences of **Waimihia Tephra** in Taranaki and previously published information of its thickness elsewhere, a suggested 0.02m isopach for the western half of the North Island is given in Figure 3.03.

Reference Localities

Six reference localities are designated for Waimihia Tephra in Taranaki and are described as follows:

1. Drain in paddock, 100m west of Kaimata Road, c.0.6km south along Kaimata Road from Junction Road, (Q19/216257) (**Section 20** of Appendix 1 and Figure 3.01).

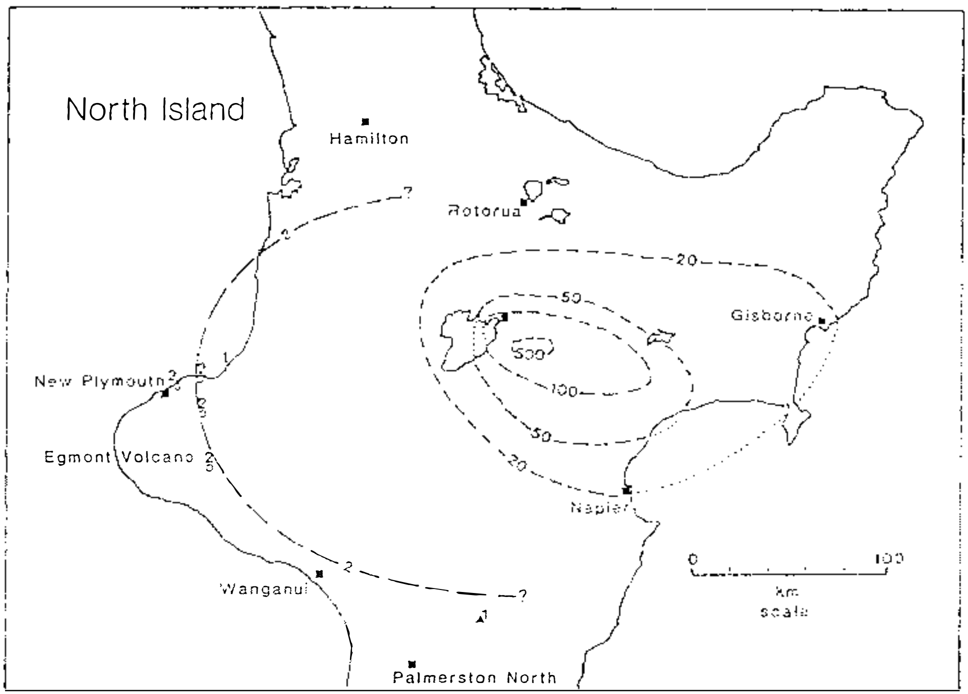
2. Wave-cut bank, west end of Onaero Beach, 0.4m west of Sutton Road, (Q19/181291) (**Section 29** of Appendix 1 and Figure 3.01; Plate 3.01).

3. Wave-cut bank on beach behind Waitara Surf Lifesaving Clubrooms, Onaero River mouth, (Q19/282449) (**Section 31** of Appendix 1 and Figure 3.01; Plate 2.05)

4. Wave-cut bank, south-west end of Wai-iti Beach, adjacent to Wai-iti Stream mouth (N99/026084) (**Section 34** of Appendix 1 and Figure 3.01).

5. Newly cut drainage channel 0.1km north of farm track and 0.2km north-west of Rawhitiroa Road, (Q20/318962) (**Section 26** of Appendix 1 and Figure 3.01)

FIG. 3.03 Distribution of Waimihia Tephra
as suggested by North Island data
and the Taranaki occurrences



Isopachs in cm

6. Coastal sand dunes overlying sea cliff adjacent to New Plymouth Airport and 1.0km south-west of the Waiongana Stream mouth (Q19/121445) (Figure 3.01 and Plate 3.02).

3.3 Aokautere Ash

In Taranaki, **Aokautere Ash** was first recognised in 1971 by J.F. Aitken as a 0.09m thick deposit in the vicinity of Hawera. The occurrence of Aokautere Ash in this area later proved important to the understanding of the parent material stratigraphy of an Egmont loam profile, in the absence of sufficient andesitic chrono-horizons (Stewart et al. 1977). Recently a more widespread distribution for **Aokautere Ash** has been established in south-east Taranaki between 200 - 450m elevation and in close proximity to Egmont Volcano (Geddes et al. 1981). Based on the occurrence of Aokautere Ash in this area, Geddes et al. (1981) postulated that the tephra thinned rapidly from about 0.10 to 0.05m between Hawera and Stratford. The stratigraphy of Aokautere Ash with respect to Egmont-source volcaniclastic deposits was only briefly examined.

Criteria

On the basis of lighter colour and glassy fine ash texture, **Aokautere Ash** is often conspicuous in outcrop and can be readily differentiated in the field from Egmont-source tephras. In north-eastern and central Taranaki, **Aokautere Ash** forms a variably thick (up to 0.10m), massive, yellow (10YR 7/6 - 7/8), moderately well sorted, glassy fine ash (e.g. Plate 2.25). Where the tephra is thin (<0.01m) or mixed within enclosing materials, the characteristics of colour, consistence, and structure are much less distinctive and field recognition may depend on the recognition of a slight textural difference, or a subtle colour change.

Upper and Lower Contacts

In the south-east sector of Egmont Volcano, above 300m elevation, Aokautere Ash is interstratified with **Poto Tephra** (see Chapter 2). The upper contact of Aokautere Ash is abrupt and wavy, and directly underlies **Pot.f** of **Poto Tephra** (e.g. Section 7; Plate 2.25). The lower contact is typically distinct and irregular, and separated from Ngaere Formation below, by **Pot.e** to **Pot.c** of **Poto Tephra** and thin medial inter-beds (e.g. Section 9; Plate 2.28).

With increasing distance from Egmont Volcano, constituents of **Poto Tephra** rapidly thin out, resulting in macroscopically visible dispersed shards or discontinuous pockets of Aokautere Ash becoming separated from either **Ngaere Formation** (Plate 3.03) or **Tuikonga Tephra** below, by a steadily reducing thickness of medial material. Aokautere Ash has also been found enclosed within aeolian andesitic sand-dunes which are correlated to the Katikara Formation of Neall (1975) (Plate 3.04).

Age

From the Howard Valley, Nelson District, a date (NZ7114A) of 21,300 +/- 450 years B.P. was obtained from peat immediately beneath **Aokautere Ash** (Campbell 1986). A similar date (NZ7373A) of 21,300 +/- 460 years B.P. was obtained at the same section from peat immediately overlying the tephra (Campbell <u>pers. comm.</u> 1987).

More recently four new radiocarbon dates were obtained from carbonised vegetation enclosed within the near to source ignimbrite equivalent which gave consistent ages with an average of 22,590 +/- 230 years B.P (Wilson <u>et al</u>. 1988).

In Taranaki the <u>c</u>.22.5 kyr age for **Aokautere Ash** is supported by a single radiocarbon date (NZ6702A) of 21,500 +/- 300 years

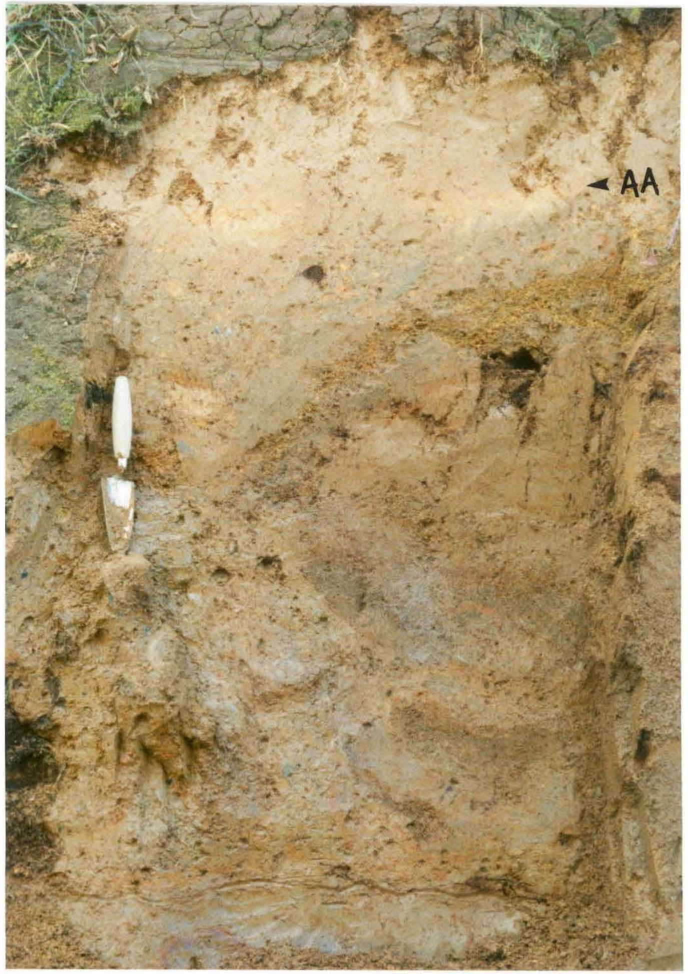


Plate 3.03: **Aokautere Ash** (AA) overlying **Ngaere Formation** (Ng) near Manganui River bridge on Bristol Road (Section 22; Q19/213296). Note plastically deformed tephra rip-up clast within Ngaere Formation.

Plate 3.04: **Aokautere Ash** (AA) interbedding massive to planar bedded andesitic sands at lectostratotype of **Katikara Formation** on Egmont Road (Section 17; Q19/101329).

B.P. from wood immediately beneath a debris flow deposit of Warea Formation in the Waiongana Stream valley (Q19/144314). On the north-eastern lower flanks of Egmont Volcano, deposits of Warea Formation post-date deposition of Aokautere Ash.

Glass Chemistry

Thirty chemical analyses of glass shards (Samples 50819 and 50821 held at R.S.E.S., Victoria University of Wellington) from **Aokautere Ash** at two sites in Taranaki (Figure 3.02; Appendix 2.1) confirm its rhyolitic composition and support a Taupo eruptive origin (cf. glass chemistry analyses of Taupo derived tephras in Froggatt 1983).

Reference Localities

Five reference localities are designated for **Aokautere Ash** in north-eastern and central Taranaki. The localities are described as follows:

1. Cutting on Carrington Road, 0.85km due east of the junction with Oxford Road (**Section 5** of Appendix 1), (P20/919188). This locality, first described by Neall (1972), was designated the type section for Saunders Ash. The occurrence of Aokautere Ash at the section was not recognised until subsequent reinterpretation (this study).

2. Prominent north-facing road cut opposite Cardiff Walkway Carpark, 0.1m west of Waingongoro River Bridge, on Opunake Road (Q20/158043) (**Section 7** of Appendix 1; Plates 2.25 and 2.26).

3. Driveway cutting at Inglewood Marae, 100m south of Inglewood BMX track and opposite school playground; (Q19/147267). (**Section 13** of Appendix 1).

4. West-facing road cutting through andesitic sand dune, Egmont Road (**Section 17** of Appendix 1 and Plate 3.04) (Q19/101329).

5. Very prominent road cutting, 0.3km north along State Highway 3 from Onaero Domain Motor Camp (Q29/285441) (**Section 30** of Appendix 1).

3.4 Rotoehu Tephra

Dispersed rhyolitic glass shards in uppermost **S3** (for **S**-terminology see Chapter 4) were first identified in a prominent road cutting on State Highway 3 near the Onaero Domain at 4.00 - 4.10m depth below surface (**Section 30** of Appendix 1).

Electron microprobe major element analyses (Sample 50820 held at R.S.E.S., Victoria University of Wellington) of eleven glass shards from this minor glass component at Onaero supports an Okataina Volcanic Centre origin (cf. glass chemistry analyses of Okataina-derived tephras in Froggatt 1983; Lowe 1987) (Figure 3.02; Appendix 2.1).

The stratigraphic position of this minor glass component is consistent with that established for **Rotoehu Ash** in the Rotorua district, where it occurs as an inter-bed within a prominent tephric paleosol (Kennedy 1988).

Mineralogical examination of the dispersed tephra grains did not reveal cummingtonite and/or biotite that are characteristic components of Rotoehu Ash at its type area. The apparent absence of these minerals may reflect wide dispersal of a minor airfall thickness and a very small abundance of heavy mineral grains (calculated as 1.7% +/- 1.5% in several Okataina-derived tephras by Lowe 1987).

Age

The age of Rotoehu Ash is indicated from several radiocarbon dates (e.g. NZ877A and NZ1126A) of wood, charcoal and peat to be at about the limit of radiocarbon dating. Indirect dating of Rotoehu Ash suggests an age of c.50 - 55kyrs B.P. (Kennedy 1987).

Distribution

Rotoehu Ash is known to cover a large area of the North Island from south of Lake Taupo (Howorth and Topping 1979) to Northland (Pullar et al. 1977; Lowe 1987) and from Taharoa on the west coast (Pain 1975) to East Cape (Vucetich and Pullar 1969; Berryman 1985).

A revised isopach map for Rotoehu Ash in the North Island has been recently constructed by Lowe (1987). The occurrence of dispersed glass shards of Rotoehu Ash in Taranaki extends its known distribution further south-west.

3.5 Smart Road tephras

Two closely spaced rhyolitic tephras here informally named Smart Road tephras were found exposed at P19/070378 near the base of a prominent cutting in the New Plymouth City Council rubbish dump. This locality occurs near the seaward edge of a surface mapped as Maitahi Lahars (Neall 1979), which was truncated by the NT3 high sea level transgression (see Chapter 9). The rhyolitic tephras are interbedded with numerous coarse ash and lapilli beds of andesitic provenance, and occur within a c.2.25m thick lens of lignite overlying a lahar deposit tentatively correlated to Maitahi Lahar (Plate 3.05). The lignite is stratigraphically separated from ground surface by up to a 30m thickness of medial coverbeds.

The sequence of andesitic tephras interbedded within the lignite differ in appearance from known sequences of late Pleistocene tephras derived from the Egmont Volcanic Centre and are thus most likely derived from Pouakai Volcano.

The upper rhyolitic tephra separated from the lower by c.0.15m of lignite, forms prominent, discontinuous lenses up to 0.16m thickness (Plate 3.06). The lower tephra forms a discontinuous layer up to 0.02m thick (Plate 3.07). Mineralogical examination shows that both tephras contain dominantly glass shards with plagioclase; heavy minerals are rare.

Twenty-four chemical analyses of glass shards (Samples 50825 and 50826 held at R.S.E.S., Victoria University of Wellington) from both tephras (Appendix 2.1) are similar and confirm rhyolitic composition. On the basis of indistinguishable glass chemistry, the Smart Road tephras are provisionally correlated with MGR1 and MGR2 tephras in the loess section at Griffins Road Quarry, near Marton (S22/169308) (Figure 3.04; Appendix 2.2). These Middle Griffin Road tephras are estimated to be younger than the c.240kyr Mt.Curl Tephra (mid- to late-oxygen isotope Stage 7) (Pillans 1988).

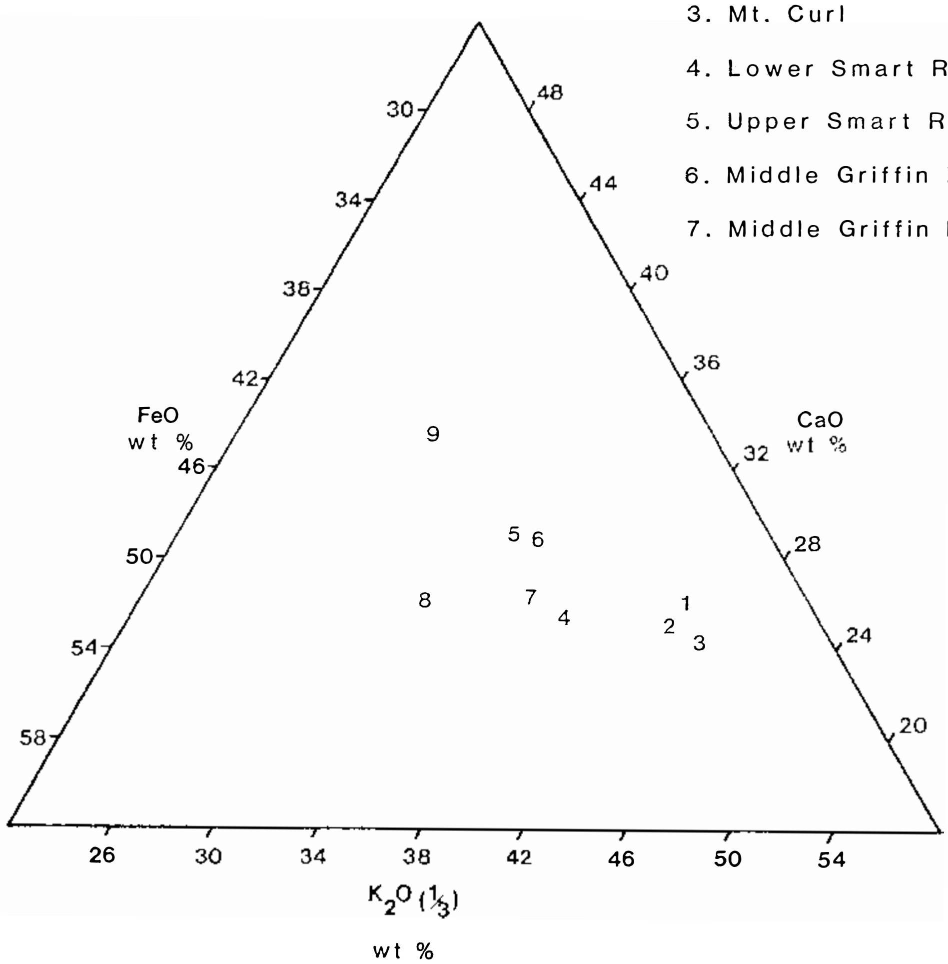
3.6 Mountain Road tephra

A rhyolitic tephra, here informally named **Mountain Road tephra**, is exposed in a prominent east-facing road cut along State Highway 3A, 4.0km north of Waiongana Stream Overbridge (Plate 3.08). The tephra occurs within the cover-bed sequence on NT5 terrace near the seaward edge of the Eltham Surface and has not been identified within the cover-beds of younger uplifted marine terraces.

Mountain Road tephra comprises a very pale brown to white (10YR 8/2 - 8/3) graded bed, up to 0.08m thick with a distinctive base of coarse sandy feldspar phenocrysts. The upper finer parts of the tephra are weathered to halloysite.

FIG. 3.04 FeO-CaO-1/3(K_2O) triangular plot showing chemical variation of glass extracted from tephra listed in Appendix 2.2

1. Mountain Road
2. Rangitawa
3. Mt. Curl
4. Lower Smart Road
5. Upper Smart Road
6. Middle Griffin Road
7. Middle Griffin Road



8. Upper Griffin Road
9. Lower Griffin Road

The tephra occurs at the base of an unnamed **L-unit** of inferred tephric and aeolian origin. It directly overlies an unnamed, 0.35m thick **S-unit** of inferred tephric origin (for **S-** and **L-** terminology see Chapter 4). The tephra, from its stratigraphic position, is therefore considered to have been deposited at the immediate onset of a cold climate interval following a warm climate interval.

Glass Chemistry
The glass chemistry of six glass shards (Sample 50827 held at R.S.E.S., Victoria University of Wellington) indicate a rhyolitic eruptive origin from the Taupo Volcanic Zone (Appendix 2.1). On the basis of its statistically similar glass chemistry (especially low Na/K ratio), the **Mountain Road tephra** correlates with either **Mt.Curl Tephra** or **Rangitawa Pumice** (Figure 3.04; Appendix 2.2).

Age
An age of 0.43 +/- 0.07 Ma was obtained by fission-track dating of zircons (Seward pers. comm. 1987) and is statistically similar to the **Rangitawa Pumice** (Seward 1976; Boellstorff and Te Punga 1977; Pillans and Kohn 1981) occurring in the lower part of loess **L10** in the Wanganui district (Pillans 1988). The age and stratigraphic position of Mountain Road tephra suggest that it was deposited towards the end of oxygen isotope Stage 11 and is in broad agreement with **Rangitawa Pumice**, which was apparently deposited at the beginning of oxygen isotope Stage 10 (Pillans 1988).

Mountain Road tephra therefore is correlated with **Rangitawa Pumice** on the basis of similar field characteristics, glass chemistry and chronology.

Reference locality

A single reference locality for **Mountain Road tephra** is designated at a east-facing road cut, State Highway 3A, 4.0km north of Waiongana Stream Overbridge (Q19/142349). Here, **Mountain Road tephra** is exposed as follows:

1.00m+	Dark yellowish brown (10YR 4/4) weakly developed very coarse blocky structured, very firm, medial material. Clear and wavy boundary. (**unnamed L-unit**)
0.08m	Very pale brown to white (10YR 8/2 - 8/3) plastic, sticky clay loam with a 0.01m thick basal layer of plastic, slightly sticky sandy clay. Euhedral feldspar crystals evident at base. Abrupt and wavy boundary. (**Mountain Road tephra**)
0.34m	Strong brown (7.5YR 5/6) moderately developed, fine to medium blocky structured, firmly friable, medial material. Gradual and wavy boundary. (**unnamed S-unit**)
0.26m	Dark yellowish brown (10YR 4/4 - 4/6), weakly developed, very coarse blocky structured, very firm medial material. Abrupt and wavy boundary.
0.03m	Common, moderately well sorted, reddish yellow (7.5YR 6/8) medium to coarse pumiceous lapilli dispersed in medial material. Abrupt and wavy boundary.(**unnamed lapilli**)
1.23m	Dark yellowish brown (10YR 4/4 - 4/6), weakly developed, very coarse blocky structured, very firm medial material. Abrupt and wavy boundary.
0.21m	Strong brown (7.5YR 4/6), moderately developed, fine to medium blocky structured, firmly friable, medial material. Gradual and wavy boundary. (**unnamed S-unit**)
0.36m	Yellowish-brown (10YR 5/6), massive, very firm medial material. Abrupt and wavy boundary.
0.03m	Common to many, moderately sorted, light grey to grey (7.5YR N7/ - N5/) fine to coarse lapilli dispersed in medial material. Abrupt and wavy boundary. (**unnamed lapilli**)

0.04m	Yellowish-brown (10YR 5/6), massive, very firm, medial material. Sharp and wavy boundary.
0.15m	Profuse, shower bedded, alternating centimetre beds of well cemented grey (10YR 7/1 - 5/1) and reddish yellow to yellow (7.5YR 6/6 - 6/8 to 10YR 7/6) fine to coarse ash. Sharp and wavy boundary. (**unnamed tephra**)
0.08m	Yellowish-brown (10YR 5/6), massive, very firm, medial material. Abrupt and wavy boundary.
0.02m	Many, moderately well sorted, yellow (10YR 8/8) fine to medium pumiceous lapilli dispersed in medial material. Abrupt and wavy boundary. (**unnamed lapilli**)
0.03m	Yellowish-brown (10YR 5/6) massive very firm, medial material. Abrupt and wavy boundary.
0.02m	Common to many, moderately well sorted, yellow to reddish yellow (10YR 7/6 - 7.5YR 6/8) fine - medium pumiceous lapilli. Abrupt and wavy boundary. (**unnamed lapilli**)
0.10m	Yellowish-brown (10YR 5/6) massive, very firm, medial material.

Base not exposed

Plate 3.05: **Smart Road tephras** within lignite at New Plymouth rubbish dump (P19/070378). Lignite with numerous interbedded Pouakai eruptives, is developed upon a lahar deposit correlated with Maitahi Lahars.

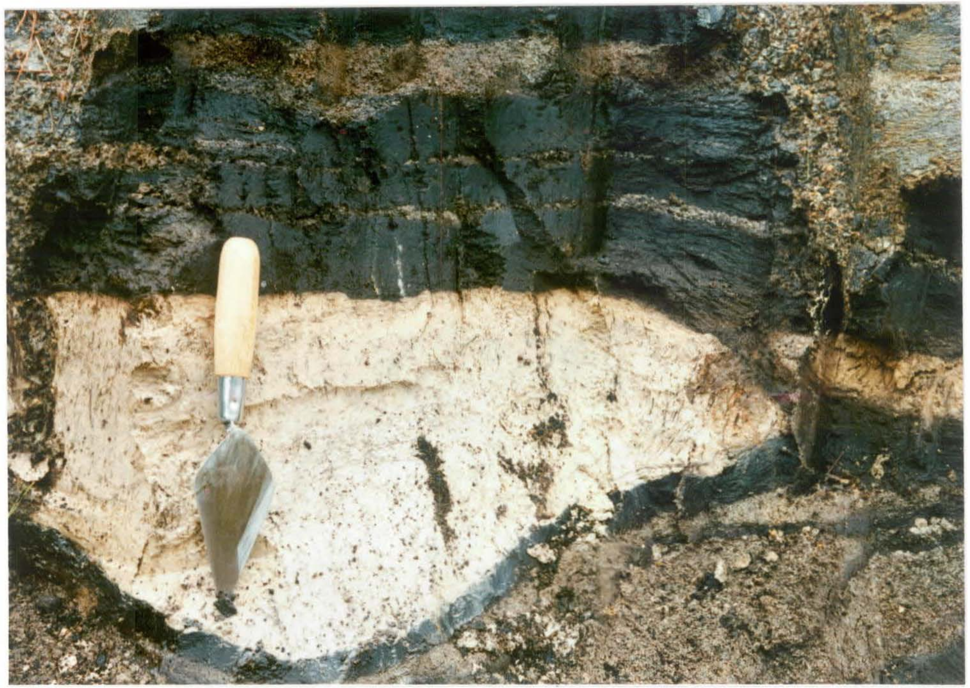


Plate 3.06: **Upper Smart Road tephra** at New Plymouth rubbish dump (P19/070378).

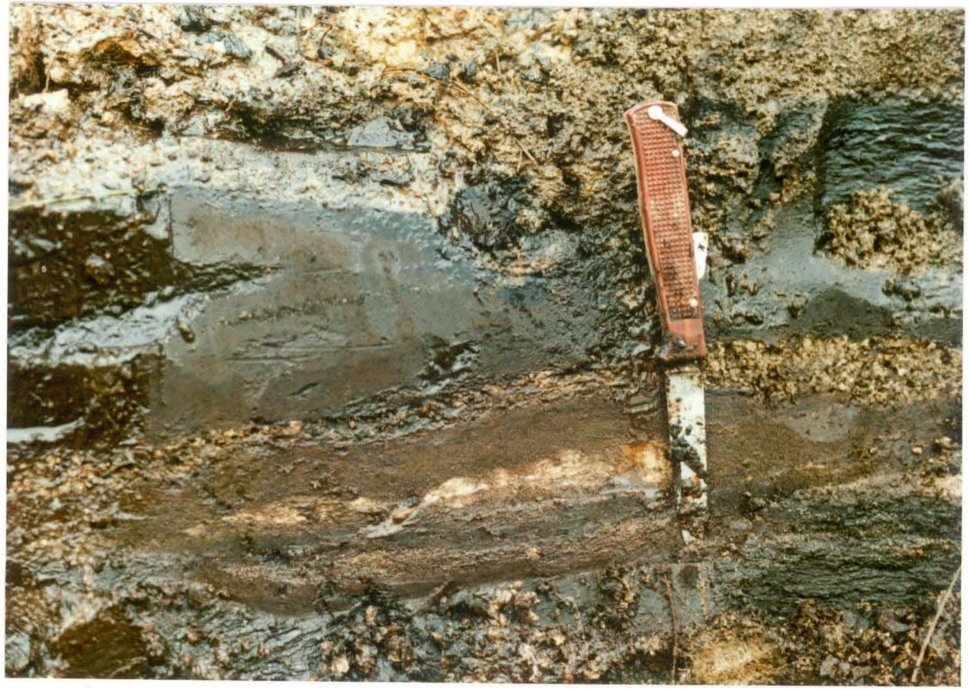


Plate 3.07: **Lower Smart Road tephra** at New Plymouth rubbish dump (P19/070378).

Plate 3.08: **Mountain Road tephra** (position indicated by arrows) at its reference section on Mountain Road (Q19/142349), c.4.0km north of Waiongana Stream Overbridge. The tephra occurs at the base of an unnamed L- medial unit and directly overlies an unnamed S- medial unit.

CHAPTER 4

4.0 MEDIAL STRATIGRAPHY

4.1 Introduction

On the late Pleistocene ground surfaces of North Taranaki, a >30m thick succession of medial cover-beds has accumulated from episodic accretion of fine grained volcaniclastic materials with accompanying weathering. The upper c.10m of this succession comprises **six** medial beds with reddish (7.5YR and 5YR) hues that alternate and clearly contrast with **five** medial beds with yellowish (10YR) hues (Plate 4.01).

Both the 'reddish 'and 'yellowish ' medial beds have distinctive physical characteristics and contain tephra inter-beds that permit their consistent recognition and mapping as stratigraphic units.

The reddish units, here informally named **S1** to **S6**, in order of increasing age, comprise friable to firmly friable, moderately to well developed, fine to medium block or nut structured medial material. In contrast the yellowish units, here informally named **L1** to **L5**, in order of increasing age, comprise firm to very firm, weakly developed, very coarse to coarse block or massive structured medial material.

Occasionally two types of S-unit are recognised and by their stratigraphic relationships most clearly demonstrated by their lowermost contact with the underlying L-unit (Figure 4.01). One type of S-unit occurs near Egmont Volcano, and is characterised by a sharp or distinct lower contact. This type of S-unit appears to have formed in situ but independently of the underlying L-unit and therefore does not strictly conform to the definition for a soil stratigraphic unit in the American Code of Stratigraphic Nomenclature (1961).

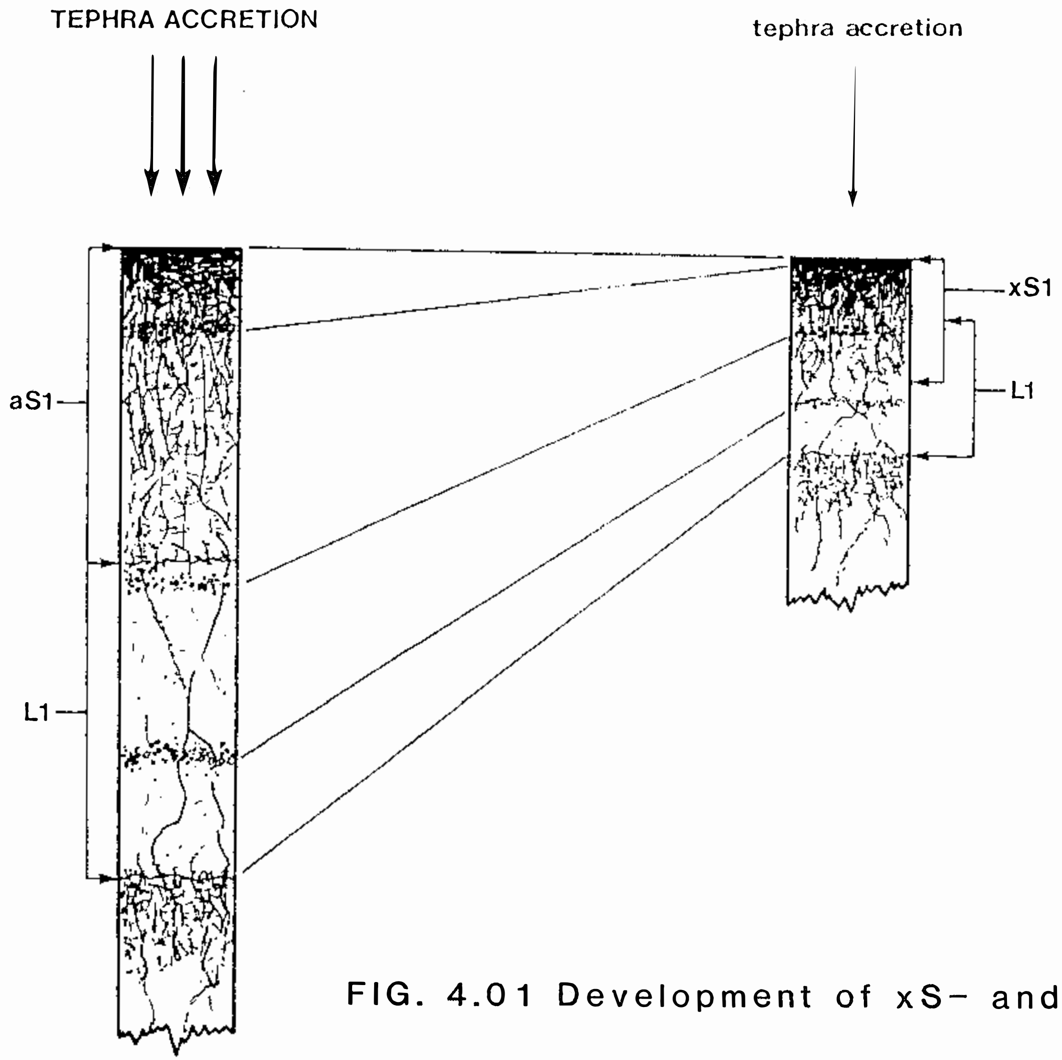


FIG. 4.01 Development of xS- and aS- medial units

The other type of **S**-unit commonly occurs further away from Egmont Volcano and has an indistinct or diffuse lower contact. This type of **S**-unit conforms to specifications of a soil stratigraphic unit in that it has partially formed in situ from the underlying **L**-unit.

The prefix **a** is therefore informally used where possible to distinguish those **S**-units that have formed in situ and largely independant of the underlying **L**-unit, from **S**-units partially formed in situ from the underlying **L**-unit which are given the prefix **x**.

The similar physical characteristics of both types of S-unit represent an intensity of surficial weathering and biological activity under similar ecological conditions but independent of those conditions that prevailed while the underlying L-unit formed.

The type of **S**-unit that has formed appears to be largely influenced by the rate of airfall accretion. As this accretion rate reduces with distance from Egmont Volcano, a corresponding increase occurs in the extent of 'soil' development into the underlying **L**-unit.

An **S**- or **L**-unit need not be exactly the same age throughout their distribution. Similarly, a **xS**-unit which is partially developed within the underlying **L**-unit is not considered strictly time parallel with its equivalent **aS**-unit further inland. Named tephra marker beds interbedded in the **S**- and **L**-units demonstrate their approximate time equivalence but also their time transgressive boundaries.

4.2 Systematics

The medial units are described in the order of increasing age, since the older units are less frequently exposed and thus increasingly difficult to correlate.

On the lower flanks of Egmont Volcano, the upper medial unit of the stratigraphic succession is **aS1**. However distally from Egmont Volcano, the upper part of the succession (**xS1**) is thinner and forms the modern soil. Above c.200m elevation on the lower flanks of Egmont Volcano, only **aS1** overlying **L1** is exposed. Both units in this vicinity, are inter-bedded by numerous coarse ash and lapilli units as well as lahar deposits. At progressively lower elevation beyond the Egmont ring plain, the older medial units are observed at increasingly shallower depths to ground surface beneath xS1.

The base of the coverbed succession along the north Taranaki coast, is marked by **L5** which overlies near-shore sands directly above the wave cut surface of **NT2 terrace** (Chappell 1975). Further inland on the older uplifted marine terraces, the base of the succession is marked by the distinctive **S6** unit which overlies an older sequence of unnamed alternating medial beds.

4.2.1 S1-Unit

Criteria

In the vicinity of Inglewood at c.200m elevation, **aS1** can be sub-divided into **four** layers which are referred to as sub-units **aS1.1** to **aS1.4**. Each sub-unit can be distinguished by colour, texture and structure variations. The uppermost sub-unit (**aS1.1**) is characterised by a variably thick (up to 0.30m), very dark greyish brown, moderately to strongly developed, fine nut structured layer. Dispersed within this sub-unit, near the ground surface, are pumiceous lapilli of an unnamed tephra. Constituents of **Manganui tephra** and **Inglewood Tephra** are also common but dispersed near its lower contact. Sub-unit **aS1.1** typically comprises an accumulation of humified organic matter intimately associated with medial material and is separated from **aS1.2** below, by a distinct and wavy transition in colour and structure. The **aS1.2** sub-unit comprises a brown to dark brown (7.5YR 4/4), friable, weakly developed nut structured layer in which the **Korito** and **Tariki Tephra** are interbedded. The base of this sub-unit is marked by **Waipuku Tephra.** Sub-unit **aS1.3** is characterised by a prominent reddish brown (5YR 4/4), firmly friable layer with moderately developed medium to coarse blocky structure. This layer is separated from sub-unit aS1.4 below, by a indistinct transition in colour and structure to **Kaponga Tephra.** Sub-unit **aS1.4** comprises a dark reddish brown (5YR 3/3), firmly friable, moderately developed, fine to medium blocky structured layer with constituents of **Konini** and **Mahoe Tephra** dispersed throughout.

On the north-eastern lower flanks of Egmont Volcano, **aS1** is interbedded by up to eighteen tephra units of **Toko Sub-group** and strong contrasts with L1 below (Plate 4.02). In addition, **aS1** is frequently interstratified by deposits of **Te Popo debris flows, Ngatoro** and **Kahui Formations.**

A notable morphological change in **aS1** occurs in well drained profiles at elevations above c.330m, in east and south-east Taranaki, where **aS1** can be interbedded by up to thirty-five tephra units of **Toko Sub-group** and interstratified by relatively localised deposits of **Te Popo debris flows** and **Ngatoro Formation.**

Here, aS1 is notably more homogenous in both colour and structure compared to lower elevations and cannot be readily sub-divided in the field (Plate 4.03). The colour of **aS1** is paler with a frequently uniform 10YR hue instead of the 7.5YR

Plate 4.01: Alternating **S-** (reddish hues) and **L-** (yellowish hues) medial units near Bishop Road on lower Egmont Road (P19/077387).

Plate 4.02: Contrasting morphology of **aS1** and **L1** at P19/083286 in the vicinity of Egmont Village. Note **Kai.h** at **aS1/L1** interface (small arrow) and erosional unconformity (large arrow).

and 5YR hues at lower elevations. The structure of **aS1** is frequently firmly friable and weakly developed coarse block, instead of the weakly to moderately developed, fine to medium block structure which is characteristic of **aS1** at lower elevations.

On the north-eastern portion of the coastal plain, **xS1** comprises two layers. The upper layer is morphologically similar to sub-unit **aS1.1** of higher elevations. While the lower layer is characterised by a reddish brown (5YR 4/4), firmly friable, moderately developed fine blocky structured layer with no visible tephra inter-beds. This lower layer is probably a composite of sub-units **aS1.2**, **aS1.3** and **aS1.4** observed at higher elevations.

xS1 can be correlated to the northern portion of the coastal plain, in the vicinity of Airedale Reef, where it comprises a single, reddish brown (5YR 4/4), friable, weakly developed medium blocky structured layer beneath a 0.25m thick layer of sand.

Upper and Lower Contacts

The base of **aS1** occurs <0.25m beneath **Mahoe Tephra** and is separated from **L1** below, by a distinct and wavy transition in medial colour and structure. In the north-eastern sector, **aS1** strongly contrasts with **L1**, in both colour hue and structure. In the south-eastern sector, **aS1** faintly contrasts with **L1** with only slight changes in colour value and chroma within the 10YR hue noted, as well as, a change from weak developed coarse block to very coarse block and massive structure. On the lower flanks of Egmont Volcano, the accretion rate of fine grained material has been sufficiently high enough that **aS1** has formed in situ but independently of **L1**.

On the coastal plain, **xS1** predominates and is separated from **L1** below, by an indistinct and wavy transition in colour and structure. **xS1** in the vicinity of Onaero strongly contrasts in colour and structure with **L1** below, while, at Airedale Reef, **xS1** only faintly contrasts with **L1**, below. In this vicinity the accretion rate of airfall material has been sufficiently low for **xS1** to have partially formed within **L1** below.

Thickness Variation

S1 with tephra inter-beds perceptibly thins with distance from Egmont Volcano. Thinning appears more rapid to the north than to north-east or east. At sites near Egmont Volcano, the medial beds of **aS1** are all conformable and laterally of regular thickness between tephra inter-beds. At distal sites, **xS1** is without visible tephra inter-beds and is laterally uniformly thick.

Correlation

S1 is correlated to the upper unit in the representative profile of Egmont loam, near Hawera in South Taranaki studied by Stewart et al. (1977). This upper unit was interpreted as of 'andesitic tephra' provenance. **S1** is also correlated with the **Oakura** and **Okato Tephras** of Western Taranaki (Neall 1972).

Age

The lower contact of **aS1** has a maximum age of 12kyr B.P. based on the assumed constant accumulation rate of medial material between the c.10.1kyr **Konini Tephra** interbedded in lower **S1** and the c.12.9kyr uppermost **Kaihouri tephra** interbedded in uppermost **L1**.

On the lower eastern and north-eastern lower flanks of Egmont Volcano, the upper contact of **aS1** is marked by topsoil of the present day ground surface which is developed from Manganui tephra. On the upper flanks the upper contact of **aS1** is also marked by topsoil of the present day ground surface. However this topsoil is developed from unnamed coarse ash and lapilli units that post-date Manganui tephra.

4.2.2 L1-Unit

Criteria

On the lower eastern flanks of Egmont Volcano, **L1** comprises two layers informally referred to as sub-units **L1.1** and **L1.2** (e.g. Section 19; Plate 4.04). Both sub-units are distinguished by variations in texture, structure and firmness. The upper sub-unit (**L1.1**) is characterised by a brownish yellow (10YR 6/8), firm, weakly developed coarse to very coarse blocky structured layer and is interbedded by **Kaihouri tephra** as well as **Paetahi** and **Poto Tephra.** Near the base of **L1.1**, the Central North Island silicic datum - **Aokautere Ash** forms a well defined marker horizon.

The lower sub-unit (L1.2) is characterised by a brownish-yellow (10YR 6/8) very firm, massive layer, inter-bedded by units of **Tuikonga**, **Koru** and **Pukeiti Tephras. Waitepuku Tephra** often occurs near the lowermost contact of **L1.**

The boundary between L1.1 and **L1.2** is typically sharp and wavy and occurs approximately midway between **Aokautere Ash** and **Tuikonga Tephra.** This boundary is usually paraconformable but in localised sections **L1.1** may unconformably mantle **L1.2** (Plate 4.04).

The two sub-units of **L1**, can readily be distinguished at progressively lower elevations north-east beyond the Egmont ring plain. However, a corresponding reduction occurs in the number and thickness of visible tephra inter-beds.

On the northern portion of the coastal plain in the vicinity of Airedale Reef, the two sub-units of **L1** merge to form a single,brown (10YR 5/3) layer, with firmly friable, weakly developed coarse blocky structure. Here, **L1** is inter-bedded by

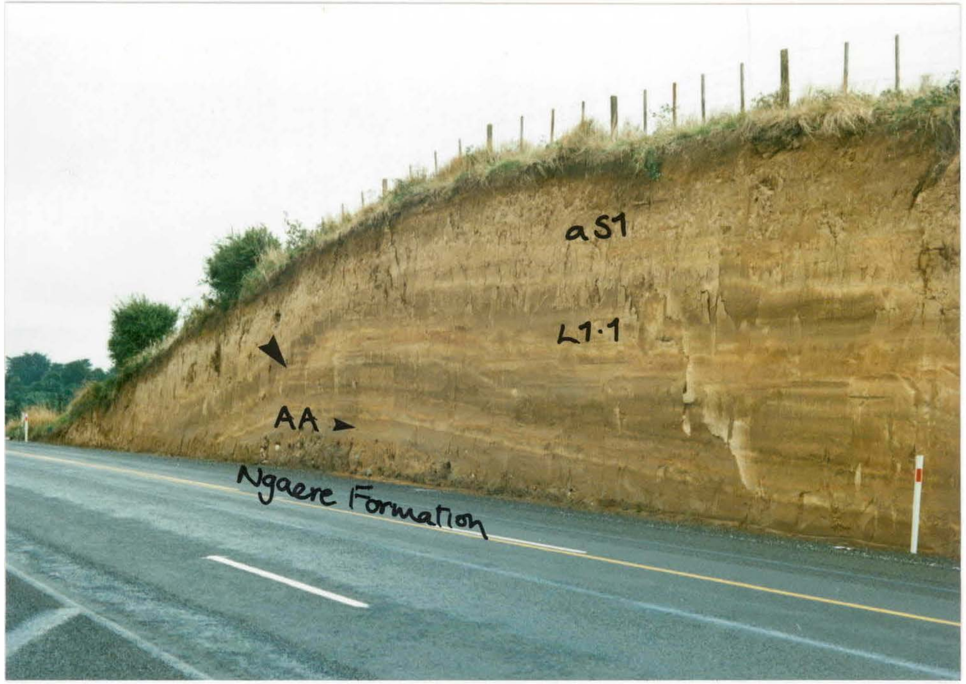


Plate 4.03: **aS1** faintly contrasting with in **L1** near Croydon Road on State Highway 3 (Q20/182153). Note erosional unconformities within **L1** (large arrow), position of **Aokautere Ash** (small arrow) and **Ngaere Formation** exposed at road level.

Plate 4.04: **aS1**, **L1.1**, **L1.2**, **S2**, **L2**, **S3** and upper **L4** at Waitui Drill Site (Section 19; Q20/181291). Note paraconformable boundary between **L1.1** and **L1.2** (small arrow), Along this same section, the boundary becomes unconformable (large arrow). Note also the thinning out of **L2** and merging of **S2** and **S3**.

three colour contrasting, thin, discontinuous units of **Paetahi** and **Tuikonga Tephra**, including the Aokautere Ash.

Upper and Lower Contacts

On the lower flanks of Egmont Volcano, **L1.1** is separated from **aS1** above, by a distinct and wavy transition in structure and colour. On the coastal plain **L1.1** is separated from **xS1** above by an indistinct or diffuse transition. At some localities in this vicinity, constituents of uppermost **Kaihouri tephra** occur narrowly dispersed at this transition.

The lower contact of **L1** is separated from **S2**, below by an abrupt and wavy transition in structure and colour (Plate 4.04). Constituents of **Waitepuku Tephra** either directly overlie this transition or occur dispersed across this transition.

In the vicinity of Inglewood, **L1.1** with **Tuikonga Tephra** near its base, unconformably overlies the c.100kyr **Okawa Formation.** However in the hill country c.10km north-east of Inglewood, L1.1 with **Paetahi Tephra** interbedded near its base, unconformably overlies in situ Tertiary mudstone (Plate 2.22). In the same area, **L1.1** is occasionally intercalated by fluvial deposits and occupies gullies that have eroded into underlying **L1.2** (Plate 4.05).

In localised areas, **L1.1** is frequently interstratified by small wedges of andesitic sand here correlated to the **Katikara Formation** (Neall 1975; redefined this study) (Plate 4.06).

<u>Plate 4.05</u>: **L1.1** intercalated by a fluvial deposit at Q20/228303 near Bristol Road. Here, the fluvial deposit occupies a gully (indicated by small arrows) that has eroded into underlying **L1.2**. The position of **Tuikonga Tephra** in the section is indicated by large arrows. Note the thinning out of **L2** and the merging together of **S2** and **S3**.

<u>Plate 4.06</u>: **L1.1** intercalated by thin wedges of **Katikara Formation** at Q20/218268 near Kaimata Road. Here the Formation post-dates deposition of **Tuikonga Tephra** and pre-dates **Kai.h** of **Kaihouri tephra**.

Thickness Variation

L1 thins with increasing distance from Egmont Volcano. The direction of thinning of **L1** is similar to that of **S1**. The majority of sections where medial beds of **L1** are laterally exposed, show a regular thickness between tephra inter beds without erosional unconformity (**e.g. Sections 18, 23** and **30**). However some medial beds of **L1** between tephra interbeds perceptibly wedge within a single outcrop (Plate 4.07). Erosional unconformities within **L1** were also observed and are prevalent particularly in **L1.1** (Plates 2.32 and 4.08).

Age

L1 is estimated to have an age range between c.12kyr and c.28kyr B.P. based on the assumption of constant accumulation rates of medial material between the c.12.9kyr uppermost **Kaihouri tephra** interbedded near the upper contact of **L1.1**, the c.22.5kyr **Aokautere Ash** interbedded near the lower contact of L1.1 and the **Rotoehu Ash** dispersed in upper S3. The intervening boundary separating **L1.1** and **L1.2** is estimated to have an age of between c.23 and 23.5 kyrs B.P.

Correlation

L1.1 is correlated to the lower unit within a representative profile of Egmont loam studied by Stewart et al. (1977) near Hawera, in south Taranaki. This lower unit was interpreted as of 'tephric loess' provenance.

L1 is here considered a correlative of **Rangitatau loess** of the Wanganui district (Wilde 1978), **Ohakea loess** of the Rangitikei, Manawatu (Milne 1973a; Cowie and Milne 1973) and Wairarapa districts (Palmer 1982a) and **Hukanui loess** of the north Wairarapa district (Kaewyana 1980).

Plate 4.07: Localised wedging of **L1** between **Tui.d** and **Tui.b** of **Tuikonga Tephra** at Q20/164288 on Lincoln Road.

Plate 4.08: Localised erosional unconformity within **L1** near Section 7 at Q20/158043. The position of **Aokautere Ash** in the section is indicated (small arrows). The tephra sequence, traced 10m along exposure to Section 7, becomes paraconformable and the erosion was found to occur between the deposition of **Tuikonga** and **Poto Tephra**.

4.2.3 S2-Unit

Criteria

Throughout north-east Taranaki, **S2** comprises a single strong brown (7.5YR 4/6), firmly friable, weak developed medium blocky structured layer with no visible tephra inter-beds (e.g. **Section 19** of Figure 2.30; Plate 4.04). In eastern Taranaki (e.g. **Section 32** of Appendix 1 and Figure 2.30; Plate 2.24), **S2** forms a dark reddish brown (5YR 3/3), firmly friable moderately developed, medium blocky structured layer. **S2** can be correlated to the northern portion of the coastal plain (e.g. **Section 27** of Figure 2.30), where it is paler in colour to sites at higher elevations. Here, it comprises a brown (10YR 5/3), moderately developed medium block structured layer that only faintly contrasts with L2 below.

Upper and Lower Contact

S2 is separated from L1 and **Waitepuku Tephra** above, by a sharp or distinct transition in colour and structure (e.g. Sections 18 and 19 of Figure 2.30). It is separated from **L2** and **Mangapotoa tephra** below, by an indistinct or diffuse transition (e.g. **Sections 18** and 19 of Figure 2.30).

S2 is occasionally absent from the stratigraphic succession at sites on the lower flanks of Egmont Volcano (e.g. **Section 11** of Appendix 1 and Figure 2.30; Plate 4.09). Since **L1**, or andesitic sands of **Katikara Formation** unconformably overlie **L2** or older medial deposits at these sites, **S2** has evidently been removed by erosion subsequent to its deposition.

Thickness Variation

The thickness of **S2** only slightly decreases with increasing distance from Egmont Volcano (Figure 2.30). On the lower north-eastern flanks of Egmont Volcano, **S2** is c.0.30m thick (e.g.

Section 19) and decreases to c.0.20m on the northern portion of coastal plain (e.g. **Section 27**). **S2** is clearly thickest (c.0.40m) east of Egmont Volcano (e.g. **Section 32**). Laterally along any exposed section, **S2** remains uniformly thick without erosional unconformity.

Correlation

On the basis of **S2** occurring beneath **L1** - containing Aokautere Ash, it is here considered a correlative of **Whanahuia Paleosol** of the Manawatu and Rangitikei districts (Milne 1973a; Milne and Cowie 1973) and the **Bidwill Hill Paleosol** of the Wairarapa district (Palmer 1982).

4.2.4 L2-Unit

Criteria

In north-eastern Taranaki, **L2** comprises a brownish yellow (10YR 6/8) very firm, weakly developed coarse blocky structured to massive layer (Plate 4.04), with up to three narrowly dispersed, thin lapilli inter-beds of **Mangapotoa tephra** (e.g. **Section 19** of Figure 2.30). However, on the northern portion of the coastal plain (e.g. **Section 27** of Figure 2.30), **L2** is characterised by being firm, light yellowish brown (10YR 6/4), and weakly developed medium blocky structured. It is inter-bedded by two colour contrasting, thin fine ashes of Mangapotoa tephra.

In north-eastern Taranaki, **L2** is separated from **S2** above, by a indistinct or diffuse transition in medial colour and structure (Figure 2.30). In the same vicinity, **L2** is separated from **S3** below, by a distinct transition in medial colour and structure (Figure 2.30; Plates 4.04 and 4.09).

Thickness Variation

With distance from Egmont Volcano, **L2** steadily thins from c.0.5m on the lower north-eastern flanks to c.0.2m on the northern portion of the coastal plain (Figure 2.30). However in the vicinity of Onaero on the north-eastern portion of the coastal plain, **L2** is considerably thicker (c.1.15m) in comparison to sites situated inland further to the south-west.

At most sections, **L2** exhibits little sudden lateral variation in thickness. However, at occasional sections (e.g. **Section 19** and Q19/239304), **L2** is observed to wedge out, resulting in the merging together of **S2** above and **S3** below (Plates 4.04 and 4.05, respectively).

Correlation

L2 contains no datable material but has a consistent stratigraphic position to **Waipunga loess** in the Wanganui district (Wilde 1978), **Rata loess** of the Rangitikei, Manawatu (Milne 1973a; Cowie and Milne 1973) and Wairarapa districts (Palmer 1982a) and **Pukewhai loess** in the north Wairarapa district (Kaewyana 1980).

4.2.5 S3-Unit

Criteria

In north-eastern Taranaki, **S3** comprises a single, strong brown (7.5YR 4/4), firmly friable, weakly developed coarse blocky structured layer with no visible tephra inter-beds (Plates 4.04 and 4.09). However on the northern portion of the coastal plain, **S3** is paler in colour compared to sites at higher elevations. Here, **S3** comprises a slightly carbonaceous, brown (10YR 4/3), moderately well developed fine to medium blocky structured layer.

On the lower north-eastern flanks of Egmont Volcano, the upper contact of **S3** is separated from **L2** above, by a distinct and wavy transition in colour and structure (Figure 2.30). Here, the lower contact of **S3** is separated from **L3** and **Waitui tephra** below, by an indistinct or diffuse transition in colour and structure.

Age

Silicic glass shards of the Central North Island rhyolitic chrono-horizon - **Rotoehu Ash**, occur dispersed over several decimetres within **S3** near its upper contact at Onaero (**Section 30** of Appendix 1; see Chapter 3). Indirect dating of **Rotoehu Ash** suggests an age between c.50 - 55kyrs B.P. (i.e. Kennedy 1987). On this basis S3, is considered to have a provisional age range between c.50 and c.60kyrs B.P.

Correlation

S3 is considered a time stratigraphic equivalent of the **Kimbolton Paleosol** in the Rangitikei and Manawatu districts (Leamy et al. 1973), the **Lake Ferry Paleosol** of the Wairarapa (Palmer 1982a) and the **Cliff Tephric paleosol** of northern Wairarapa (Kaewyana 1980).

4.2.6 L3-Unit

Criteria

In north-eastern Taranaki, **L3** is characteristically a yellowish brown (10YR 5/6) to dark yellowish brown (10YR 4/6), very firm, weakly developed medium to coarse blocky to massive structured layer (Plates 4.09 and 4.10). Here, **L3** is interbedded by **Waitui tephra** near its uppermost contact, **Te Arei Tephra** just above its lowermost contact and **Araheke tephra**, as well as, two unnamed tephras in the interval between (Figure 2.31).

Plate 4.09: **S3**, **L3** and **S4** near Inglewood on State Highway 3 (Section 11; Q19/109275). Note fluvial deposits and erosional unconformity. **Araheke tephra** is visible in **L3** to the left of spade.

Plate 4.10: **L3** and **S4** at Toetoe Well Site (Section 24; Q19/246316). The position of **Araheke tephra** (small arrow) and **Te Arei Tephra** (large arrow) within **L3** is indicated.

L3 can be correlated to the northern portion of the coastal plain, where it is characterised by a light yellowish brown (10YR 6/4), firmly friable, weakly to moderately developed, coarse blocky structured layer with six, colour contrasting, thin tephra inter-beds (eg. **Sections 25** and **27** of Appendix 1 and Figure 2.31).

L3 is separated from **S3** above, by an indistinct or diffuse transition in colour and structure (Plate 4.09), and separated from **S4** and **Epiha Tephra** below, by a distinct transition in these properties.

Thickness Variation

The medial beds of **L3** thin with distance from Egmont Volcano (Figure 2.31). However, at two distal sites (**Sections** 24 and 30) the medial bed of **L3** between **Te Arei Tephra** and **S4** below, dramatically thickens (c.0.5m) in comparison to the same bed at sites situated nearer to Egmont Volcano (e.g. **Sections** 11 and 18). This overthickening appears to represent localised erosion and redeposition of fine grained andesitic material.

Correlation

L3 is considered a time stratigraphic equivalent of **Karahaki loess** of the Wanganui district (Wilde 1978), **Porewa loess** of the Rangitikei, Manawatu (Milne 1973a; Cowie and Milne 1973) and Wairarapa districts (Palmer 1982a) and **Eketahuna loess** of north Wairarapa (Kaewyana 1980).

4.2.7 S4-Unit

Criteria

Throughout north-eastern Taranaki, **S4** comprises a firmly friable, dark brown (7.5YR 4/4 - 5/6), moderately developed fine to medium blocky structured layer with upper units of **Epiha Tephra** dispersed near its base nearer to Egmont Volcano (Plates 4.09 and 4.10). **S4** exhibits only a slight decrease in thickness from c.0.40 - 0.30m with distance from Egmont Volcano. At any one section no lateral variation in thickness was observed.

S4 is separated from **L3** and **Te Arei Tephra** above, by a distinct and wavy transition in colour and structure (Figure 2.33). While, S4 is separated from L4 and **Epi.d** of **Epiha Tephra**, by an indistinct to diffuse transition in these properties.

Correlation

A correlative of **S4** is identified in a prominent cutting on the **Rapanui Marine Terrace** (Pillans 1983) at Kohi Road (**Section** 35 of Appendix 1) in the Wanganui District (Plate 4.11). Here, correlative is separated from **Karahaki loess** (Wilde 1978) above, by a distinct and wavy transition in colour and structure at c.3.80m depth below ground surface. A prominent layer of dispersed andesitic mineral grains here provisionally correlated to **Te Arei Tephra** overlies the **S4**-correlative.

4.2.8 L4-Unit

Criteria

L4 is characteristically a firm, yellowish brown (10YR 5/4 - 5/6), weakly developed coarse to very coarse blocky structured layer with interbeds of **Epiha Tephra** (e.g. Section 30 of Appendix 1; Plate 4.12). **L4** is separated from **S4** and **Epi.e** of **Epiha Tephra** above, by an indistinct or diffuse and wavy transition in colour and structure. Below, **L4** is separated from **S5** by a distinct and wavy transition in the same properties.

Thickness Variation

The overall thinning pattern of **L4** is similar to that of other medial beds in generally thinning with distance from Egmont Volcano. Similarly, medial beds of **L4** at most sites are uniformly thick and regular bedded along lateral exposure. However at Onaero, **L4** is laterally highly variable in thickness ranging from c.2.10m to 0.20m eastward along the section (Plate 4.12).

Correlation

L4 is correlated to a newly recognised, fourth loess unit identified in a prominent cutting on the **Rapanui Marine Terrace** at Kohi Road in Wanganui District (Alloway et al. 1988; Pillans 1988) (Plate 4.11). This unit informally named Parao loess by Wilde and Vucetich (1988) is separated from the **S4** equivalent above, by an indistinct and wavy transition in colour and structure at c.4.13m depth below ground surface. A prominent layer of concentrated andesitic mineral grains within the Parao loess at c.4.31m depth is here correlated with **Epi.c/d** of **Epiha Tephra**.

4.2.9 S5-Unit

On the lower north-eastern flanks of Egmont Volcano, **S5** comprises a firmly friable, strong brown (7.5YR 4/6), moderately developed medium blocky structured layer inter-bedded by an unnamed tephra near its base (e.g. **Sections 11** and **18** of Appendix 1). On the coastal plain **S5** is morphologically similar to that further inland (Plate 4.12) but does not contain any visible tephra inter-beds (e.g. **Section 30**). **S5** is separated from **L4** and **Epiha Tephra** above, by a distinct and wavy transition in colour and

Plate 4.11: Rapanui Terrace cover beds exposed at Kohi Road in Wanganui district (Section 35; Q21/465610). Note **S4** and **L4**- correlatives overlying weathered dune sand.

Plate 4.12: NT2 terrace cover beds exposed on State Highway 3A, near the Onaero River (Section 30; Q19/285441). Note the thickness variation of **L4** along the section and its thicknesses compared to its correlative in Wanganui district.

structure, and separated from **L5** below, by a diffuse transition in these properties. In some areas **S5** overlies **Okawa Formation** (e.g. **Sections 23** and **24** of Appendix 1).

Similar to all **S**-units so far discussed, **S5** thins slightly with distance from Egmont Volcano and at all sites is uniformly thick along lateral exposure.

4.2.10 L5-Unit

L5 is rarely exposed on the north-eastern lower flanks of Egmont Volcano. However where exposed in this vicinity, it comprises a yellowish-brown (10YR 4/6), firm, weakly developed coarse blocky structured layer interbedded by an unnamed coarse ash of **Ninia tephra**. On the north-eastern portion of the coastal plain (**Section 30**), L5 comprises a c.0.40m thick reddish yellow (7.5YR 6/8), moderately developed medium blocky structured layer which downwardly becomes brownish-yellow (10YR 6/7) and massive structured.

L5 is separated from **S5** above, by a diffuse and wavy transition in colour and structure. **L5** on NT2 terrace (e.g. **Section 30**) is distinguished from near-shore sands beneath by a diffuse transition in colour, texture and structure. However, on higher uplifted marine terraces (e.g. **Section 16**), **L5** is separated from **S6** below by a diffuse transition in colour and structure.

In the vicinity of Lepperton (**Section 23**), the upper portion of **L5** appears to have been partially eroded by the overlying **Okawa Formation**. Laterally along section, **L5** wedges out so that **Okawa Formation** unconformably overlies **S6**.

Age

At the North Taranaki coast, **L5** is the lowermost medial unit that overlies the wave cut surface of the **NT2** terrace of Chappell (1975). **L5** therefore has an age that closely post-dates the **NT2** high sea level event. Based on the correlation (Hays 1967; Chappell 1975) of the **NT2 terrace** with the **Rapanui Marine Terrace** of the Wanganui district (Fleming 1953; subsequently redefined and indirectly dated between c.125kyr to c.130kyr B.P. by Pillans 1981), **L5** has a probable age range between c.108 and c.115ka B.P.

4.2.11 S6-Unit

S6 is the most distinctive and prominent of all S-units, with the exception of **S1**. It comprises a firmly friable, distinctive brown to pinkish grey (7.5YR 6/2 - 5/2), moderately developed medium blocky structured layer with no visible tephra inter-beds (Plate 4.13; **Sections** 18 and 23 of Appendix 1) and is separated from an older unnamed **L**-unit below by a indistinct and wavy transition in colour and structure (Plate 4.13).

S6 is evidently absent within the cover-beds of the **NT2 terrace** of Chappell (1975) but appears to be widespread upon older constructional surfaces. On this basis, **S6** is here considered to have accumulated the same time the **NT2** bench was being wave cut during the highest Last Interglacial sea level transgression between c.115 and c.130kyrs B.P. (O^{18} sub-stage 5e).

4.3 Type Sections

The type section for units **S1 - L5** is designated as a prominent north-facing road cutting on State Highway 3, 0.3km north of the Onaero Domain Motor Camp (Q19/285441) (**Section 30** of Appendix 1; Plate 4.12). This section occurs c.40m above sea level and exposes the entire cover-bed succession above the wave cut surface of NT2 terrace (Chappell 1975).

The type section for **S6** is designated as a prominent road cutting on Egmont Road, (Q19/102334) (**Section 18** of Appendix 1). This section occurs c.140m above sea level and exposes >10m of coverbeds on a surface previously mapped as Eltham Lahars (Neall 1979). This section is also here designated as the reference section for units **S1 - L5**.

4.4 Discussion

Field studies indicate **S-** and **L-**units thin with increasing distance from Egmont Volcano. The thinning pattern is more rapid to the north compared to the east and north-east and is similar to that of inter-bedded coarse ash and lapilli units. This suggests that the medial units (like their tephra inter-beds) are of tephric origin and their distribution is primarily influenced by the prevailing wind patterns.

However, the thinning pattern of **L-**units from Egmont Volcano is occasionally interrupted by localised overthickening and in the case of **L1**, erosional unconformities and wedging aeolian sands of Katikara Formation. Such features demonstrate localised aeolian origin.

The contrasting morphological characteristics of **S-** and **L-**units appear to indicate differences in the intensity of surficial weathering and biological activity under different climatic conditions. These differences can be verified in part from the palynological record obtained from peat and lignite sections in Taranaki (see Chapter 11). Climatic conditions inferred from vegetation changes in relation to tephra marker beds in a peat,

Plate 4.13: The purplish to pinkish grey **S6** exposed on Barrett Road near New Plymouth (P19/996346). This unit is evidently absent within the cover beds of the NT2 terrace and is widespread on older constructional surfaces.

can be related to an equivalent medial unit using the same tephra markers. The palynological record indicates that during the episodes in which uppermost **L1.1** and **L4** were forming, the landscape was dominated by a mosaic of grassland and scrubland with isolated stands of forest. In contrast, during the episodes in which lower **S1**, **S4** and **S5** were forming, the landscape was dominated by forest (Figure 4.02). This partial vegetation record for Taranaki, tends to confirm that **L**-units formed during cool or cold intervals, and **S**-units formed during warm intervals.

The chronology of medial units is estimated from the presence of interbedded, dated rhyolitic and andesitic tephras, and by matching the climatic intervals deduced from the medial succession to the standard record of O^{18} stages in deep sea cores (Shackleton et al. 1983) (Figure 4.02).

The youngest recognised medial unit is **S1** of late last-glacial and post-glacial age (late-O^{18} stage 2 and stage 1). Underlying **S1** is the uppermost **L**-unit (L1) which contains the c.22.5 kyr B.P. Aokautere Ash and is correlated with early and mid- O^{18} stage 2. Underlying **L1** is **S2** and **L2** which are correlated with late and mid-O^{18} stage 3 respectively. **S3** which contains the c.50kyr B.P. Rotoehu Ash in its uppermost part is correlated with early O^{18} stage 3. **L3** from its stratigraphic position is correlated with O^{18} stage 4.

The remaining medial units are correlated to the warm and cool climatic intervals of the Last Interglacial (O^{18} stage 5). **S4** and **L4** are correlated with O^{18} sub-stages 5a and 5b, respectively, while, **S5** and **L5** are correlated with O^{18} sub-stages 5c and 5d, respectively.

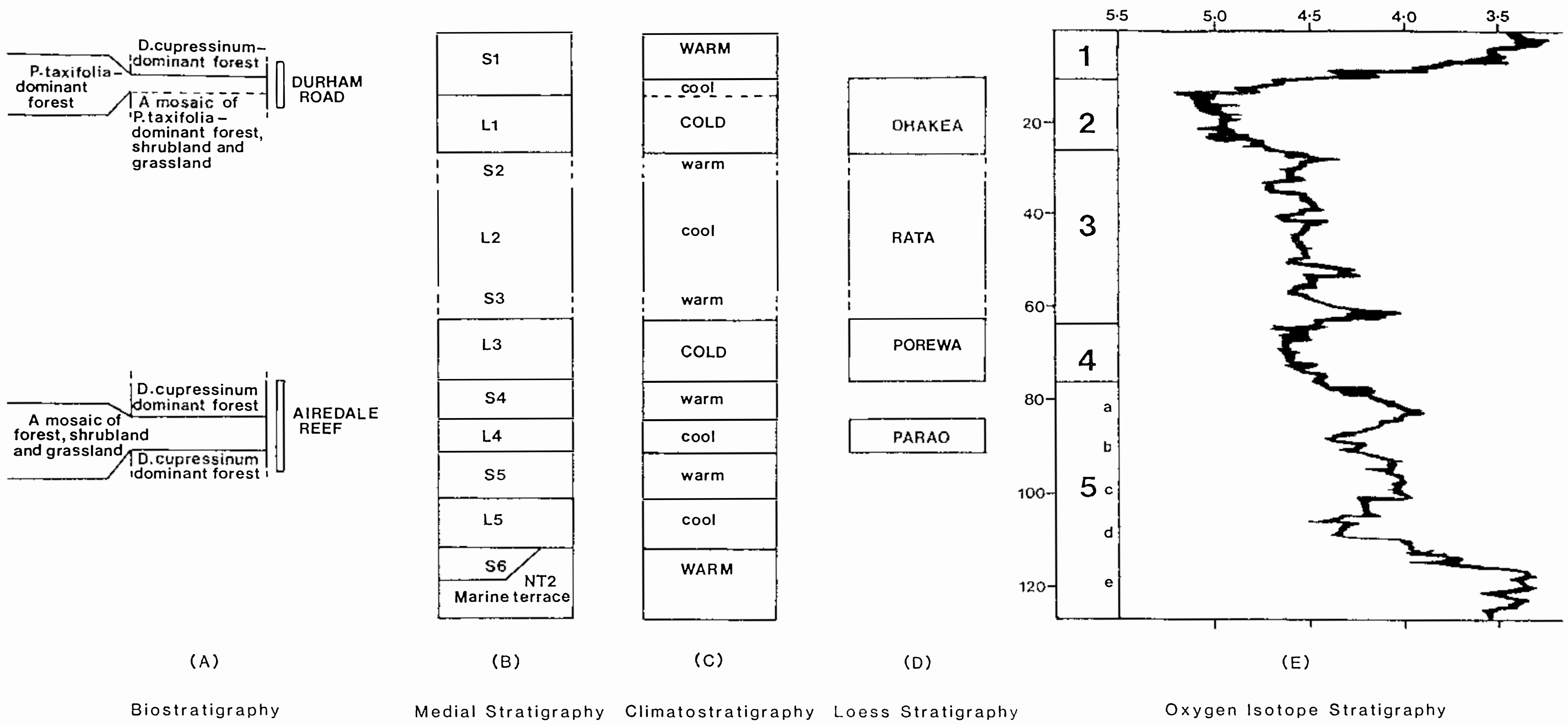


FIG. 4.02 Summary Correlations

The thin, strongly weathered **L5** is the lowermost medial unit that overlies marine sediments of the NT2 terrace (O^{18} sub-stage 5e). **L5** is underlain by the prominent **S6** on all constructional surfaces older than NT2 terrace and suggests that **S6** formed during O^{18} sub-stage 5e.

L1, **L2** and **L3** represent time-stratigraphic correlatives of the three widespread, dominantly quartzo-feldspathic loess units recognised in the Late Pleistocene cover-bed sequences of the southern North Island (Milne 1973; Milne and Smalley 1979; Wilde 1979; Palmer 1982). **L4** already recognised in Wanganui district (Alloway et al. 1988), is here correlated to the informally defined Parao loess of the Wanganui district (Wilde and Vucetich 1988), while, **L5** presently remains uncorrelated outside the Taranaki Region (Figure 4.02).