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ENVIRONMENT AND ARCHAEOLOGY IN NEW ZEALAND

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"It is not possible to dig a hole in a different place by digging the same hole deeper."

Edward de Bono,
The Use of Lateral Thinking.

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ABSTRACT

This thesis deals mainly with central New Zealand. The writer's archaeological excavations are described in Appendices. Lists are prepared giving all archaeological radiocarbon dates on wood, charcoal, moa bones, human bones and marine shells, for New Zealand up to 1974. The dates are sorted according to material, and the dates and their standard errors corrected. A stratigraphic system based on soils and Loisels pumice and tied to the corrected radiocarbon dates is set up for central New Zealand. Radiocarbon and stratigraphy provide dates for vegetation changes, Moahunter sites, cultivation sites, and for the artifact assemblages that are independently grouped as either Early or Late. Change from Early to Late is explained by cultural breakdown and an initial movement of culture from south to north. The sequence of events postulated is summarised in a Table at the end of the text.

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CHAPTER I

ARCHAEOLOGY, ENVIRONMENT AND DATING.

INTRODUCTION

According to Pakeha interpretation of Maori traditions and genealogies, commonly attributed to S. Percy-Smith, New Zealand was discovered by Kupe in 950 AD, and settled before the arrival of Toi in 1150 AD. Migration continued for two centuries, ending with the arrival of the "Great Fleet" in 1350 AD which successfully introduced the important tropical cultivated food plants kumara, taro, yam and the gourd. According to Simmons (1969) the genealogies were badly in error. Moreover, the assumed length of a generation, 25 years, was too large, judging from recent estimates of 15 years based on a prehistoric population from Wairau Bar (Houghton, 1976). Strangely, despite the errors, the date for the discovery and settlement of New Zealand is about right.

Maori traditions record events in varying detail. "Fires of Tamatea" are thought by Best (1942) to refer to extensive forest fires some 600 years ago. But of the moa, a giant flightless bird known to have become extinct since human settlement, tradition is virtually silent (Duff, 1956). Archaeology provides an independent account of environmental and cultural events in New Zealand.

Environmental events are of two kinds: cultural and natural. Those caused by the Maori include changes to vegetation and soils, and animal extinctions; none are necessarily synchronous. Those which occur naturally include climate change, episodes of erosion and deposition, and volcanic eruptions (primary and secondary effects); they are possibly, and are assumed to be, synchronous for the central part of New Zealand.

In the following, the words correlation and correlate are used. If two events correlate then they are synchronous. Correlation is finding synchronous events. Because the time interval of New Zealand prehistory is short, radiocarbon is less useful for correlation than first thought and maximum use is made of stratigraphy. Only after events have been correlated is the attempt made to give them calendar dates.

Identifiable pumices proved most valuable for correlation. They occur extensively in the North Island and are particularly useful along the North Island east coast. Uplifted beach ridges, of localised importance for correlation along the North Island south coast, are considered to be produced by earthquakes. Soils of two kinds, buried and ground soils, are the most widely distributed features for correlation and are found in both the North and South Islands. The soils are considered here to be of major importance and to mark rhythmic climatic changes.

DISTRIBUTION OF ARCHAEOLOGICAL REMAINS STUDIED

Archaeological remains, in order of increasing stratigraphic importance, are described below.

Pa sites are earthwork fortifications. They are usually on a hill, and often in conspicuous places. Many are full of pits and are possibly fortified store houses. There are more in the north than in the south, and they are rarely found south of Banks Peninsula (Figure 1).

Gardens are mostly on Holocene marine and fluvial deposits, which are more easily dug and possibly more easily cleared of vegetation than older deposits. No gardens are known for certain south of Banks Peninsula. There are more soil types which are friable in the northern part of the North Island, particularly in the Waikato, Taupo and Northland regions, and in these regions volcanic deposits, not all Holocene, were used for gardens.

In the writer's opinion, in central New Zealand many gardens are fairly easily recognised being marked either by stone row systems (Appendix 2); or by gravel or grit added to an original soil. For convenience, these soils are termed Plaggen soils (Appendix 1): Maori Plaggen Soils if prehistoric, Plaggen-like Soils if not prehistoric or age is unknown.

The stone row systems are common on stony soils. Their purpose is not fully understood. Almost all are on the coast, the furthest inland being 4 km from the coast. All are north of Banks Peninsula and are generally on Holocene deposits.

Plaggen soils are generally easily found because borrow pits, from which grit or gravel have been obtained, are conspicuous, being up to 1 m deep, and because the soils themselves are distinctive. Their coastal distribution is similar to stone row systems, and in addition, large areas of inland plaggen soils are found in the Waikato basin (2,000 ha) and on the Waimea Plains (400 ha). Their usual size is less than 2.5 ha. There may have been garden sites without stone row systems or plaggen soils, but these are hard to recognise.

It is generally accepted, but not proved, that gravel and grit were added to make soils more suitable for growing kumaras and taro (Best, 1925). Garden soils are similar in that all contain silt, sand, gravel, and are sufficiently friable to be worked with a digging stick. Almost all are much lighter than optimum soils for European gardens in New Zealand.

Although specifically stated by Best (1925) that the Maori did not irrigate, even when they could and water was needed, there are traces of irrigation systems at several places in New Zealand, the most definite being near Clarence River mouth in the South Island.

The best defined gardens are in coastal central New Zealand, and are most obvious along parts of the coast where

Maori gardening had stopped by European contact and the ground was not used by the European as arable land. Gardens are more easily recognisable in the south than in the north. Their South Island distribution is fairly well known, being recognised by borrow pits, but in the north where volcanic soils were used, grit was less often added and they are difficult to recognise. There must be large areas of unrecognised gardens on volcanic soils.

The gardens are often in the same places favoured by Europeans for baches, such as the Bay of Plenty and Coromandel coasts, and in places less favoured such as along the east coast between East Cape and Cape Palliser. East coast sites are today extremely windy, so windy that it seems surprising that the Maori could have lived there let alone gardened. In many places on the coast today it is only with difficulty that hedges can grow.

Middens vary from heaps to extensive layers of food refuse: shells and animal bones, generally with charcoal and oven stones. They are rarely dominant features, but some kind of midden is found in all sheltered coastal places in the North Island, and most of the South Island. They are much more extensive in the north than in the south. An important exception is moa bone middens, which are found mainly in the south near river mouths such as the Waitaki and Rakaia Rivers. They have played an important part in New Zealand archaeology.

In evaluating the importance of moa bones it is not assumed that all bones are equally preserved in all climates. Crop-stones, cave finds and young natural deposits and middens, show that moas existed throughout New Zealand at human settlement. Maximum numbers of bones are found where the climate is dry and a high rainfall didn't dissolve them away. Moa bones littered the ground surface on plains in Canterbury and Otago (Haast, 1871), and at Makara (Yaldwyn, 1959) at European settlement.

Occupation layers are traces of Maori occupation not sufficient to be called middens. They are generally traces of charcoal and, rarely, oven stones, associated with, but more extensive than, middens. They are conspicuous in coastal and in river bank sections. They appear to be unique to New Zealand, possibly because there is a variable sediment supply and the New Zealand coastline is unprotected by sea walls.

HISTORY OF STRATIGRAPHIC ARCHAEOLOGY AND RELATED TOPICS

The following is a brief account of stratigraphic archaeology in New Zealand and is restricted to views relating to stratigraphy.

Haast, first director of the Canterbury Museum, was first to recognise "Moahunters" in New Zealand prehistory. According to Haast (1871) their main pursuit was moa hunting, and because they used unpolished stone tools, were palaeolithic. Maoris were different, a younger race that lived after the moa became extinct. They used polished stone tools and hence were neolithic.

Haast (1871) knew of vast numbers of moa bones found on the Canterbury Plains, and in swamps. The bones indicated enormous numbers of moas. The Maoris knew nothing of the bones and the moa was therefore considered to have become extinct in pre-Maori times. At Rakaia River mouth moa bones, found in ovens, were associated with flake tools (Haast, 1871).

Haast's data from the west coast of the South Island included polished stone tools found deep in sands below (400 year old) forest (Haast, 1871). Maori occupation was thus considered old; and Moahunter occupation, much older.

At Shag River and Redcliffs, stratigraphic verification was found for two different kinds of people (Haast, 1874a,b). Unfortunately for Haast's palaeolithic theory, at Moa Bone Point Cave at Redcliffs there were two layers separated by barren sand, but the lower layer with moa bones contained polished stone tools. He reluctantly conceded his palaeolithic theory wrong (Haast, 1874a) because McKay, who helped in the excavations, would have forestalled him (McKay, 1874).

McKay (1874) minimised cultural differences between Moahunter and Maori. After McKay, interest in archaeology passed from geologists to ethnologists, and the usefulness of stratigraphy was almost forgotten.

Duff, the present director of Canterbury Museum, described Moahunter material culture from Wairau Bar, and distinguished it from Maori material culture (Duff, 1956). He denied the usefulness of stratigraphy (Duff, 1949) and repeated the argument known to Haast for the greater antiquity of Moahunters: the artifacts were associated with moa bones, moa bones were old because the Maori had no traditional knowledge of the moa, hence the artifacts were older than the Maori.

Duff (1956) is responsible for the popular view of prehistory throughout New Zealand today, held by both Maori and Pakeha. Moahunter culture is the oldest in New Zealand. According to Duff, after the arrival of the "Fleet" in 1350 AD with the kumara, Moahunter culture changed to Maori culture. The date of the Fleet's arrival was traditional.

Lockerbie, an "amateur" archaeologist, revived interest in stratigraphic archaeology (Lockerbie, 1940, 1954). He found sites with deep stratigraphy that had been continuously occupied for a long time. For correlation he used radiocarbon (Lockerbie, 1959) and was the first to be independent of cultural dating.

Golson, a lecturer in prehistory at Auckland University, established a tradition of stratigraphic archaeology among academically-trained archaeologists for determining cultural sequences on sites. He defined more objectively the cultural sequence in New Zealand (Golson, 1959) and replaced the name <u>Moahunter</u> with <u>Archaic Maori</u>, and <u>Maori</u> with <u>Classic</u>

Maori. He questioned the value of tradition for dating, and he questioned the absence of agriculture in the Moahunter or Archaic period. He used radiocarbon for correlation.

Green (1963), an American fulbright scholar at Auckland University (now Professor of Archaeology at Auckland), assumed an increasingly complex cultural sequence for correlation.

Wellman, like Haast, is a geologist. His archaeological studies are purely stratigraphic being based on the study of sections exposed by marine and river erosion (Wellman, 1962a,b), without formal archaeological excavation. The important advance made by Wellman's work on that of contemporary archaeologists is his use of stratigraphy for correlation. His study of D'Urville Island is strongly archaeological; and that of the North Island, less so. He found Haast's two layers at several places on D'Urville Island and on the East Coast of the North Island. Two sea-rafted pumices, Taupo pumice and Loisels pumice, were used for correlation. Stratigraphic dates were estimated by assuming uniform rates of deposition, but are 50% too old because, as discussed later, deposition has not been uniform. He collected some of the critical radiocarbon samples discussed below.

In terms of the archaeology done in New Zealand, no attempt has been made to get a systematic coverage over the country. A high percentage of excavated sites are within 100 km of main cities. Some places, such as the Bay of Plenty, Waikato, and East Coast, have large parts virtually untouched as far as systematic stratigraphic archaeology is concerned. Adzes and other artifacts in Museums are mostly from surface collecting, and from fossicking.

Pre-European Vegetation Changes

New Zealand vegetation at European settlement (1840) is reasonably well-known (Holloway, 1960), and there is an increasing awareness that the Maori caused dramatic changes. There is no map of pre-Maori vegetation.

Areas of special interest are the Canterbury Plains, and the central North Island volcanic region. Canterbury Plains were under grass at European contact, but the temperature and rainfall indicate that the area could have supported forest. Charcoal in the soils show that the area was forested at the time of Maori settlement (Molloy et al, 1963). In the volcanic region, vast areas of forest were destroyed by the Taupo eruption; but soils (Vucetich and Pullar, 1963) show that the area was later forest-covered at Maori settlement.

Animal Extinctions

Some 34 species of birds have become extinct during the last 1,000 years (Kinsky, 1970). There is still controversy as to why. Geologists realised that the birds lived through the extreme climatic fluctuations of the Pleistocene, and that their period of extinction coincided exactly with the increase in Maori population. Because of the time coincidence, extinction is blamed on the arrival of the Maori (Fleming, 1962), although how he caused the extinction is uncertain.

Zoologists are less impressed by the time coincidence, and are more concerned to understand the exact cause of extermination. They consider only that the "process of extinction of moas was probably greatly accelerated following the arrival of man in New Zealand before AD 1000" (Williams, 1966: 575). Archaeologists tend to follow zoologists (Green, 1975a).

Climate

A 1°C warming up in New Zealand during the last 70 years (Meteorolgical data; Tomlinson, 1976) has been correlated with recorded changes in New Zealand West Coast glaciers (Sallinger, 1976): glaciers advance when temperatures fall; and retreat when temperatures rise. Lichens, tree growth, and radiocarbon dates used to date minor advances or stationary periods of both east and west coast glaciers during a period of overall retreat indicate that minor advances or stationary periods occurred 1,450-1,050 years ago, more than 300 years ago, and between 300 and 100 years ago (Wardle, 1973); (Burrows, 1973).

Oxygen isotopes give a continuous record and measurements on stalagmites in northwest Nelson indicate temperature changes of less than 1°C during the last 1,000 years (Hendy, 1969). Temperatures were warm 1,000 years ago, cool 550 years ago, warm 350 years ago, and cool 200 years ago.

Changes in climate have been inferred by botanists for the last 800 to 1,000 years from changing patterns of vegetation. The most widespread vegetation change is a marked decrease in regeneration in some New Zealand conifers, especially rimu, beginning some 400 to 600 years ago, and a partial resurgence in the last 100 years (Wardle, 1963). The cause is not fully understood, but is thought by botanists (Wardle, 1963; Holloway, 1954) to be due to a deterioration in climate. H.W. Wellman suggested at the 1962 Ecological Society Conference at Rotorua, that moa extinction may be a cause.

Soils

Soils concerned with here are those developed on deposits less than 10,000 years old. They are generally related to specific events including dune advances (Cowie, 1963), river aggradation (Pullar and Penhale, 1970; Cox and Mead, 1963), river down-cutting (Ward *et al*, 1964), and beach ridge formation.

ARCHAEOLOGY AND STRATIGRAPHY

The importance of archaeological stratigraphy was stressed in the 1920's by Sir Mortimer Wheeler. According to Wheeler (1954) each stratigraphic layer in a site is a time plane. Archaeological stratigraphy was first used in New Zealand by Lockerbie in the 1940's, and has been used extensively since the mid-1950's.

In addition to Wheeler's kind of stratigraphy, which is here termed "on-site" stratigraphy, there is another kind here termed "off-site" stratigraphy. On-site stratigraphy is restricted in its extent and is concerned largely with man-made irregularities such as pits, postholes, and middens, etc. By contrast, off-site stratigraphy is concerned with extensive regular layers. It is normal geological stratigraphy, the kind used for correlation by Haast (1874a) and by Wellman (1962a,b).

On most archaeological sites in New Zealand on-site stratigraphy covers less than 100 years. By comparison with other archaeological sites in the world on-site stratigraphy has been most useful for identifying man-made irregularities rather than for providing a sequence of cultural changes. Lockerbie's sites in the southern South Island are an exception. For some unknown reason they were occupied for a long time. Off-site stratigraphy provides sections with a stratigraphic record to which on-site stratigraphy can be tied.

In general, archaeologists look for what is unique in on-site stratigraphy, but stratigraphers look for what is common in off-site stratigraphy so that they can correlate.

In its simplest form a "section" is a near-vertical exposure a few metres high, often along a coastline or river bank, where natural events are best recorded and human disturbance minimal. Its meaning is extended here to include a generalised section determined from several exposures, including dug holes. Most sections are through coastal deposits younger than 6,000 years (end of the post-glacial eustatic sea level rise), and places where the record for the last 2,000 years is between 2 m and 5 m thick give the best section.

Ideal sections contain a mixture of fluvial, aeolian and marine deposits, sea-rafted pumice of known age, buried soils, occupation remains, and give some idea of the nature and age of deposits in bays behind.

SOILS AND OFF-SITE STRATIGRAPHY

Soils are all-important for correlation and, depending on relative rates of soil development and sediment accumulation, are of two kinds: buried and ground. Figure 2 shows the simplest case of soil stratigraphy for accumulating layers. Deposition rates range from high to zero, but with no erosion. A soil forms when sediment accumulation is slower than soil formation, and is buried when sediment accumulation is faster than soil formation. Buried soils and their correlation are considered later.

A time of sediment accumulation is called here an unstable phase, and a time of soil formation, a stable phase. The relative length of an unstable phase to a stable phase is highly variable. Continued deposition need not occur throughout an unstable phase. For some sand dune areas and fans, continual reworking of deposits prevents soil formation.

Deposits are layers, and in vertical section they commonly exhibit sedimentary character and are often seen, by reason of their bedding (size, shape and orientation of their components), contrasted with soils. Soils exhibit "layering" but their sedimentary character is often obscured by past or present biological activity. The layers, called "soil horizons", have formed in situ and are therefore non-deposits, and in this thesis are not considered as layers. A soil is recognised by its organic content, structure, and dark colour (see page 11c).

A soil horizon is a zone approximately parallel to the top of the landsurface on which it formed. When part of the present land surface it is called a "ground soil" (Ruhe, 1969); when part of a past land surface, a "buried soil".

Soils that have been forming for a short time show little soil development, but soils that have been forming for a long time may show several soil horizons: a top horizon (topsoil); a middle horizon (subsoil); and a lower most horizon. The topsoil and subsoil must have properties induced by soil processes, but the lower most horizon may not.

All soils in this account contain a topsoil. Younger soils have only a topsoil, older soils have in addition a recognisable subsoil. Degree of soil profile development dates the underlying deposit (Figure 3).

A topsoil may appear as an occupation layer when shells, charcoal, or ovenstones are abundant, but can usually be recognised by following the occupation layer laterally until the shells etc. are no longer abundant.

For a section, the time involved is partly that of sediment deposition, and partly that of soil formation. The sum of the two is the total time represented. For sediments the passage of time is represented by layers: the top is younger than the bottom. For soils, passage of time is represented by degree of soil formation: the development of horizons within sedimentary layers.

A contrasting situation is river terraces cut into old gravels so that soils become younger downwards. Degree of soil development dates terrace surfaces, but not underlying deposits.

Soil description of Section on left bank of Te Unu Unu Stream, Flat Point (N166 (1957)/421273)

Depth	Layer	Horizon Designation*	Soil Organic matter** (%)	Description
0-20	1	A	2.0	Dull yellow orange (10YR6/3) silty sand, very friable, moderately developed very fine to fine nut structure, few fine roots, indistinct boundary.
20-63	2	C	0.9	Dull yellow brown (10YR4/3) sand, very friable, single grain with some weakly developed fine nut and fine granular structure, few fine roots, indistinct irregular boundary
63-75	3	uA	2.2	Brownish black (10YR2/3) sand with many fine distinct dull yellow brown (10YR4/3) mottles, very friable, weakly developed fine and medium granular and very fine nut structure with some single grain, very few fine roots, indistinct boundary.
75-90	4	uA	1.8	Brownish black (10YR2/2) sand, very friable, weakly developed fine and medium granular structure with some single grain, very few fine roots, indistinct boundary.
90-107	5	C	0.6	Dark brown (10YR3/3) sand, loose,single grain, very few fine roots, indistinct boundary.

Depth	Layer	Horizon Designation*	Soil Organic matter** (%)	Description
107-123	6	uA	1.2	Brownish black (10YR2/2) sand, very friable, weakly developed fine to very fine nut structure with some single grain, very few fine roots, very rare fragments of charcoal and shell, indistinct boundary.
123-160+	7	C	0.5	Dark brown (10YR3/3) sand, loose, single grain, no roots.

* according to Taylor and Pohlen (1970)

** determined according to Kosaka _et al_ (1963). Small shell fragments (< 0.5mm) were seen in layers 3 to 7. Only layer 7 (basal) reacted to dilute acid. Carbonate determinations showed only 0.1% for layer 7. It is considered that carbonate levels are lower in layers 1-6. Carbon determinations are consistent with the colour (value) of the buried soils.

METHODS OF CORRELATION

Cultural change in its widest sense is the method of correlation most used by archaeologists. Moahunter culture is the best example for New Zealand. The presence or absence of moa bones in section provides a good correlation for a small island such as D'Urville Island; but for the whole of New Zealand the matter is entirely different because it is not certain that the moa became extinct everywhere at the same time. Other cultural changes are similar, and no cultural changes are assumed to be synchronous in this account.

New Zealand, the last large land area in the world to be populated, was settled only a thousand years ago. Few places have such short prehistory and correlation must be extremely accurate to be effective. Radiocarbon is generally considered the final answer for dating and hence for correlation, but this is not true here because of the short prehistory. In the writer's opinion several methods of correlation are better: volcanic ash eruptions, earthquakes, sea-rafted pumices, soils and sea level changes.

Hydration rim thickness of obsidian has been useful for dating overseas. Within New Zealand the method is useless for reasons not fully understood. Details are given in Appendix 8.

Sea rafted pumice proved most useful. As an example of the exactitude of pumice dating, there is the 1962 eruption in the Southern Sandwich Islands to the south of South America, 9,000 kilometers from New Zealand. Pumice, driven by westerly winds, took less than a year to reach New Zealand (Coombes and Landis, 1966).

Two important sea-rafted pumices are Taupo pumice (1,800 years old; Healy et al, 1964) and Loisels pumice (700 years old; see Chapter II).

Taupo pumice was erupted from near Lake Taupo. The eruption was about 10 km^3 in volume and pumice was washed down nearly all major North Island rivers. It occurs on all North Island coasts except North Auckland, and in the northern South Island. It is found in sand dunes as lapilli-like granules, and in beach deposits as exceptionally large pieces up to 0.5 m. It is recognised by its light yellowish-brown colour and coarse irregular gas cavities, is easily broken, and can often be crushed in the hand.

The distribution of Loisels pumice (Figure 4) suggests an origin outside New Zealand, possibly Melanesia. It is entirely different from the South Sandwich and Taupo pumices, and occurs only along the eastern North Island coast, the western North Island coast only at the extreme north, and possibly along the northeast South Island coast. It is most abundant at the extreme north. In addition to the localities given by Wellman (1962b) the writer has found the pumice along the southeast Wairarapa coast between Flat Point and Cape Palliser, and just west of Cape Palliser at the base of Wellman's (1962b) Kupe's Sail section. Small pieces of Loisels-like pumice have been found by Mr Murray Efford in an archaeological excavation at Kaikoura. It is recognised by its grey colour with black bands and fine gas cavities. It is strong, and difficult to crush in the hand.

The usefulness of sea-rafted pumice for dating depends first on its correct identification; and second, on the pumice being a primary and not a secondary (reworked) deposit.

For the Holocene, Taupo pumice appears to be unique, there is no other pumice quite like it. Loisels pumice is similar to two older pumices, both are grey with black bands, but the older pumices are only found on the southwest coast of the North Island. Both are considerably older than Loisels pumice: one is between 2,000 and 5,000 years old (Fleming, 1965); the other about 7,000 years old (Appendix 5).

Taupo and Loisels pumices are found as secondary deposits in sections. Primary deposits are the lowest in a section, are the thickest layers, and include the biggest lumps.

The two pumices provide the simplest example of archaeological correlation. The earliest evidence of human occupation in New Zealand is above the Taupo pumice and below Loisels pumice, the two pumices and the occupational material being in sections along almost the whole length of the North Island eastern coast. The pumices prove man's arrival within a restricted period of time for a considerable length of coastline. The restricted period of time is an important fact irrespective of exactly when it occurred.

The two pumices provide two time planes only, several more younger time planes are required if stratigraphic dating is to be useful. The two pumices are overlain in many sections by three soils, two buried and one at the ground surface.

The two buried soils appear to be unrelated to any special events recorded in the sections themselves, such as sea level changes, tectonic uplift, vegetation clearance by man, and are thought to have been caused by changes in climate. Tephra layers, the sea-rafted pumice, radiocarbon dates, and occurrence of European artifacts, make it likely that the two soils are synchronous over the greater part of New Zealand. It is thus considered that they can be correlated and used for dating archaeological remains in much the same way as the pumice layers.

For the last 2.0 kyrs there are three deposits and three associated soils. Each deposit and its soil is considered to be a stratigraphic division which is considered to be a time division. The divisions are named, from old to young; Tirean, Ohuan and Hunan. Each division consists of a phase of deposition (or unstable phase) and a phase of soil formation (or stable phase).

Deposits and soils are best correlated with the stratigraphic divisions by matching the sea-rafted pumices and buried soils with an ideal sequence. Where the pumices and, or, buried soils are absent, radiocarbon dates, degree of soil profile development of ground soils, and the occurrence of European remains may be used.

Most of New Zealand's archaeological sites are near the coast and if the two pumices and two buried soils are accepted as being time planes then divisions for the last 700 years that have a duration from 150 to 300 years can be established. Most archaeological events can thus be effectively correlated by stratigraphy.

An exception is around the Wellington coast where Loisels pumice is absent and soils are of limited extent and therefore of limited use for correlation. But here, by a fortunate coincidence, shoreline displacement correlation is most useful.

Shoreline displacement curves record the changing level of land with respect to sea, and are the kind of record given by a tide gauge, but extended backwards for several thousand years by the record of natural features which formed at known heights above sea level. Most useful natural features are uplifted beach ridges and coastal lagoon deposits. Dating is by radiocarbon, sea-rafted pumice, soils and historic earthquakes. Sudden displacements are attributed to sudden tectonic movements or earthquakes; and gradual displacements, to eustatic sea level changes and slow tectonic movements. Tectonic changes extend over limited areas (less than 100 km). Eustatic changes are worldwide.

CHAPTER II

RADIOCARBON DATING

INTRODUCTION

Colin Renfrew (1976) has given a readable account of the attitude of overseas archaeologists to radiocarbon dating. Overseas archaeologists initially hesitated, then generally accepted the method, until it was found that corrections were necessary to convert reported radiocarbon dates to calendar dates. Now archaeologists are split: on the one hand there are those who reject the corrections and accept previously established theories of culture change; on the other hand, there are those who accept the corrections and reject the theories. In New Zealand radiocarbon was accepted with enthusiasm but without full appreciation of the kinds of errors involved: in particular counting errors (standard errors quoted with dates), and inbuilt age (time lapsed between the death of the sample dated and the event dated).

COUNTING ERRORS

Counting errors for more than 70% of New Zealand archaeological dates are greater than 50 years. They are statistical errors and it should be noted that radiocarbon dates are generally unsuitable for distinguishing with any certainty (more than 95%), events closer together in time than 150 years.

CONVERSION OF RADIOCARBON DATES TO CALENDAR YEARS

For the purposes of correction (Figure 5), there are three main groups of samples:-

1. Freshwater shells, and marine fishes and animals.
2. Terrestrial plants and bone collagen.
3. Marine shells.

Corrections for the first group are uncertain and are not considered further. No samples in this thesis are from this group.

Corrections for the second group are for half-life, and for changes with time in the concentration of radiocarbon in the atmosphere (secular variations). Radiocarbon "dates" are normally reported using a half-life of 5,568 years for radiocarbon decay ($T^{\frac{1}{2}}$= the time taken for the radiocarbon activity of a sample to be halved). New measurements indicate that a half-life of 5,730 years is probably more correct. A half-life correction is incorporated in the correction for secular variation.

Secular variations are indicated by the difference between the radiocarbon dates of tree-rings and tree ring dates (Suess, 1970a; Olsson, 1970). They are irregular short term variations (up to several hundred years) (Suess, 1970a) superposed on a sinusoidal long term variation with a period of about 10,000 years (Suess, 1970b), and they cause radiocarbon dates less than 6,500 years old to differ from calendar dates by up to 1,000 years; and dates less than 1,000 years, by up to 200 years.

Reported radiocarbon dates are converted into calendar years using radiocarbon-dated tree-rings. There are two types of calibration curves. Both have short term and long term variations. In one the short term variations have been smoothed out more than the other. With the less smoothed calibration curves (e.g. Suess, 1970a) there is the strange situation that a radiocarbon date may correspond to as many as five calendar dates. With the more smoothed calibration curves (e.g. Damon et al, 1972; Michael and Ralph, 1972) each radiocarbon date corresponds to one calendar date only. At first sight a more smoothed curve seems better, but short term variations are correlated with changes in solar activity (Stuiver, 1961; Suess, 1965, 1970b) and climate (Bray, 1966; Suess, 1970b; Appendix 10) which would suggest that the short term variations are real and are not due to errors.

The calibration curve used here is the "Suess" curve (Suess, 1970a: Plate I). It is based on tree rings radiocarbon dated at La Jolla and is assumed here to represent the variation in radiocarbon activity of the atmosphere for the last 6,500 years. Errors in the Suess curve itself are taken into account by increasing standard errors of radiocarbon dates converted to calendar dates by using the formula recommended by Waterbolk (1971):

$$se^2 = se_1^2 + (60)^2$$

where se_1 is the standard error of a radiocarbon date before conversion to calendar years.

It is important to note that, because some radiocarbon dates correspond to more than one calendar date, when standard errors of dates are taken into account, <u>all remains less than 500 calendar years old cannot be arranged in order by radiocarbon dating</u>.

Variations in the radiocarbon activity of plant remains over very short periods of time have been related to the "11 year" solar cycle by Baxter and Farmer (1973), and according to them they are equivalent to an error of ±80 years for short-lived samples such as twigs which were a year old at time of death. The variations were not detected on southern hemisphere wood (Farmer and Baxter, 1972), and Damon <u>et al</u> (1973) consider them to be an order of magnitude smaller than reported by Baxter and Farmer (1973). They are disregarded here.

Corrections for the third group are for half-life, and for differences in the radiocarbon activity of the marine environment compared with that of the terrestrial environment.

The half-life correction is made by multiplying reported dates by 1.03 (= 5,730/5,568).

Up to the present, marine shell dates have been based on the radiocarbon activity of a sample of live shells taken from Pounawea in 1955. Six additional samples have been analysed in the last few years, results are given in Appendix 9. The average of the seven samples gives dates 55 years younger than the Pounawea shells and the average is adopted here. The standard error of the average is 40 years. The errors quoted with shell dates are merely counting errors of the samples and, when shell dates are compared with dates from group 2, must be increased by adding the standard error of the average using the formula:

$$se^2 = se_1^2 + (40)^2$$

where se_1 is the standard error of a marine shell date before correction.

Corrections made so far only correct for the present day depletion of the marine environment. There is no generally accepted correction curve like that for terrestrial samples. According to Yang and Fairhall (1972) the radiocarbon activity of surface sea water shows a long term sinusoidal variation similar to that of the atmosphere, but with a smaller amplitude and a lag of several hundred years. Judging from the increase in the radiocarbon activity of surface sea water around the world following the testing of atomic bombs, which was 20% to 25% of the increase in atmospheric radiocarbon (Rafter and O'Brien, 1972; Gulliksen et al, 1972; Linick and Suess, 1972), short term variations were probably much smaller than those of the atmosphere. There seems to have been almost no long term variation in the radiocarbon activity of surface sea water for the last 1,000 years (Yang and Fairhall, 1972) and, after the standard correction of -55 years, reported radiocarbon dates less than a thousand years old used here are thought to be reasonably close to calendar dates.

In this account the following conventions are used to distinguish between reported (uncorrected) and corrected radiocarbon dates. Dates with NZ numbers suffixed with "A" are reported dates ($T^{\frac{1}{2}}$ = 5,568 years). Dates with NZ numbers suffixed with "B" are corrected shell dates ((reported age X 1.03) - 55). Dates with NZ numbers suffixed with "C" are corrected wood and bone dates. All dates are reported in years B.P. and the year 1950 is taken as the present day.

The Flow diagram in Figure 5 shows corrections to dates and standard errors. As an example take sample NZ 2696A (70 ± 40 years BP) from Table 10. First enter into the Suess curve and get a range of (270 - 100). The standard error for the date is ±40 years which, after correction, becomes ±70 years. Double the resulting standard error (±140 years) to give 95% probability limits and add to, and subtract from, the date range from the Suess curve to get (410 - 0 years BP).

DATING EVENTS BY RADIOCARBON

Events are the things that need to be dated. The following discusses ways in which radiocarbon dates are related to events.

Sample date is the time of death of a sample (years BP). Inbuilt age is the time-lapse between the date of death of a sample and the date of an event. Event date is the time of an event (years BP). Trees "live" several hundred years, but are dead inside and central tree wood may be as much as several hundred years old when the tree dies (growth age). Trees may last many hundred years after they die before rotting away (storage age). Inbuilt age is thus storage age plus growth age. A sample used to date an event may thus be several hundred years older than the event itself.

Use of old wood with a large inbuilt age appears to have been fairly common in prehistoric New Zealand. Differences of several hundred years in radiocarbon ages of stratigraphically contemporary charcoal samples listed in Table 1 are not random ($\chi^2 = 12.8$, $p \ll 0.005$), and are thought to be due to use of old wood as firewood and posts. Trotter and

McCulloch (1975) have shown that charcoal dates for South Island sites are, on the average, some 300 years "older" than contemporary marine shell dates. On present day beaches or in forest, average age for wood is probably 100 to 200 years. Maximum age for wood on the ground surface is about 3,000 years, and older where wood is under water.

Kauri and totara logs would have littered the beaches when the Maori arrived, and have been gradually burnt off. Near swamps there is no problem in obtaining old swamp wood. Away from swamps there is a definite limit of lasting time. At Turakirae near Wellington wood found on an uplifted beach ridge containing Taupo pumice appears to have lasted 2,000 years. The quantity of wood however is small, and wood is entirely absent on all older beach ridges.

For a stratigraphic situation, an event is a layer, and a sample may be above, within, or below the layer. An important exception, discussed below, is the formation of a soil. Depending on whether a sample has no inbuilt age, or an unknown and possibly high inbuilt age, there are six situations set out in the following classification of radiocarbon "dates" for dating events. Samples are of two kinds with respect to inbuilt age, and can have three stratigraphic positions relative to the layer marking the event. "Close" is used for radiocarbon dates that closely date an event; and "open", for samples that are disregarded for dating the event because their inbuilt age is unknown and possibly large.

Inbuilt Age	Stratigraphic Relationship of Sample to Event		
	Below	Contemporary	Above
Unknown, possibly large	Maximum	Maximum	Open
Negligible	Maximum	Close	Minimum

Classification of radiocarbon "dates" for dating events.

The six situations give four kinds of dates: maximum, minimum, close and open. Close dates give dates; maximum dates give maximum dates; minimum dates give minimum dates; open dates give no dates. The reason why open dates do not provide useful dates is that inbuilt age is unknown and hence may be longer than the time between the event and deposition of the sample.

The following list gives kinds of samples according to "inbuilt" age. Kinds of samples assumed to have negligible inbuilt age are listed in Column 1. Each sample is assumed to be the age of the layer in which it was found and gives a maximum date for an event if it comes from a lower layer, a close date if it comes from the layer, and a minimum date if it comes from an overlying layer. Kinds of samples which are assumed to have an unknown and possibly long inbuilt age include those listed in Column 2. Each sample gives a maximum date whether it comes from the layer to be dated, or from a lower layer, and a useless date if it comes from an overlying layer.

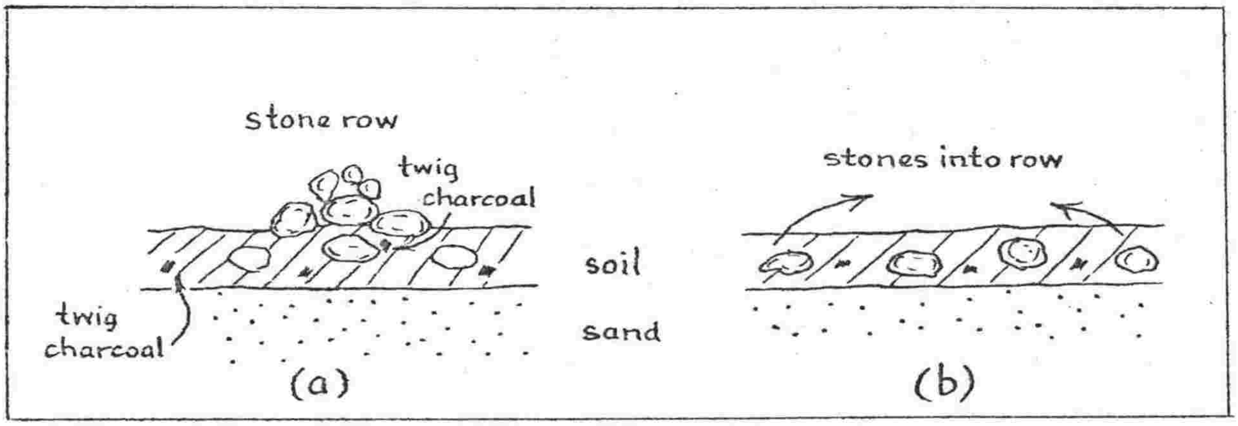
1 Negligible	2 Unknown, possibly large
Wood and charcoal known to be from short-lived trees.	Unidentified wood and charcoal.
Twigs and small sticks.	Wood and charcoal known to be from long-lived trees.
Outer rings of trees.	Non-midden disarticulated bones.
Bones and shells in middens.	Non-midden disarticulated bivalves.
Bones in position of articulation.	Non-midden gastropods.
Bivalves in position of articulation.	

Kinds of radiocarbon samples listed according to "inbuilt" age.

A sample within a soil layer is not necessarily younger than the formation of the soil. Soil formation is represented by the formation of horizons within sedimentary layers. It is assumed, however, that cultural remains found in a topsoil, particularly shell middens and plaggen soils, are younger than the beginning of soil formation.

A special situation for dating is wood or charcoal from a tree root in position of growth in a buried soil. Providing that the tree grew when the buried soil was a ground soil, it gives a minimum date for underlying layers, and a maximum date for overlying layers, irrespective of whether or not the inbuilt age is known.

Some cultural events are difficult to date using samples from soils. Consider the following: an attempt to date a stone row:



Sketch (a) represents an excavation. Important features are the soil, the twig charcoal in the soil, and the twig charcoal between the stones of the stone row. Both twig charcoals have an age of 800 years. It has been argued that the charcoal formed when the row was built (H. M. Leach, 1976); however, this need not be true. Charcoal may have been present in the stony soil before the row was built (Sketch b).

KINDS OF EVENTS, KINDS OF SAMPLES AND A DATE FOR LOISELS PUMICE

Events such as the Taupo eruption cause trees to burn, and produce close dates that allow an event to be directly dated. Events like the stranding of Loisels pumice do not produce closely dateable material and have to be indirectly dated by using maximum and minimum dates from samples below and above the pumice, that is, by "bracketing".

The best date for events that are directly dated is the average of many close dates. The standard error of the mean of k dates, assuming all dates were counted for 1,000 minutes, is calculated using the formula:

$$se_{\bar{x}}^2 = (se_1^2 + se_2^2 +..+ se_k^2)(1/k^2)$$

where se_1, ... se_k, are the standard errors of the separate dates.

There is no best date like that using the average of many close dates for events that are indirectly dated, but merely the range mentioned above. The method used is that illustrated below by the Loisels pumice (Figure 6). Two minimum dates, NZ 1296 and NZ 1297, are averaged. They are both determined on shells from the same occupation layer at Hot Water Beach (Leahy, 1974). They are not statistically different and are considered here to be the same age. A date from a sample of charcoal (NZ 631; Table 3), taken from above the Loisels pumice at Cooks Cove (Wellman, 1962b), is not used as a minimum date because the charcoal has not been identified as being from a short-lived species.

The samples may be considered as max-min pairs which successively reduce the age range (Figure 6). The final pair give an age range of 300 years. Samples which gave an age range of more than 700 years are disregarded. It is shown later how an age can be estimated using stratigraphy in conjunction with radiocarbon age range.

CHAPTER III

PROPOSED LATE HOLOCENE STRATIGRAPHIC DIVISIONS FOR CENTRAL NEW ZEALAND

INTRODUCTION

Stratigraphic divisions (Figure 7) for central New Zealand have already been named in the discussion on correlation. Division boundaries are the top of the two buried soils. The Tirean includes all the time from the Taupo pumice until the end of formation of the lower buried soil. The Ohuan includes all the time from the end of the Tirean to the end of formation of the upper buried soil. The Hunan includes all the time from the end of the Ohuan until the present day. It is not known as yet whether the divisions apply to the whole or merely to central New Zealand.

TYPE LOCALITY FLAT POINT

At Flat Point aeolian sands form a belt about 1 km wide across the Holocene bench (Figure 8) and extend for more than 6 km to the south. Ground soils show three different stages of profile development.

It is inferred that sand accumulated in three distinct phases, each being followed by a phase of soil formation. There are thus three time divisions which are named Tirean, Ohuan and Hunan, each being a phase of sand accumulation followed by a phase of soil formation.

North of the Te Unu Unu stream (Figure 8), raised beach ridges indicate Flat Point is being uplifted. Beach ridges immediately south of the stream are obscured by sand dunes. The growing beach ridge and the two youngest uplifted beach ridges (A, B and C; Wellman, 1971b) are shown in Figure 8. Loisels pumice lies along the outer edge of Beach Ridge B just below the crest, and Taupo pumice lies behind Beach Ridge C south of Flat Point (Wellman, 1971b). Beach Ridge B was thus uplifted after the Loisels pumice was deposited; and Beach Ridge C, after the Taupo pumice was deposited.

A cross-section exposed in the left bank of the Te Unu Unu stream between beach ridges B and C (Section 1) is 2 m thick and 200 m long.

SECTION 1: On left bank of Te Unu Unu Stream, Flat Point, being the type locality for the three late Holocene stratigraphic divisions (N166(1957)/421273).

	metres
Hunan	
Dull yellow silt loam soil	0.25
Yellow silt with thin bands of blown sand	0.45
Grey slightly silty sand	0.10
Ohuan	
Brownish-black sand (topsoil) with charcoal and occasional shells. Pieces of iron, chinaware and red brick on the upper surface	0.15
Grey sand	0.26
Tirean	
Brownish-black sand (topsoil) with occasional charcoal, shell and bone	0.15
Brown sand	0.65
Black sand, charcoal and oven stones forming a lens in Tirean sand about 20 cm below the Tirean topsoil immediately behind Beach Ridge B	0.25
Brown sand same layer as above	0.45
Stream gravels	0.50+

The oldest cultural remains are below the Tirean soil in the steam section. There are shell middens among the sand dunes, on the Tirean and Ohuan soils. A generalised cross-section at right-angles to the coast is shown in Figure 9.

Tirean sand overlies beach ridges B and C and contains primary sea-rafted Taupo pumice. It thus began accumulating before the Taupo Pumice eruption. Dunes are subdued and rounded. Tirean ground soil has a well-defined topsoil and a poorly defined subsoil. A representative profile is:

Topsoil: 0.12 m black to brownish-black (10YR2/1-2/2) sand; weakly developed coarse and medium blocky structure; few roots; diffuse boundary.
Subsoil: 0.30 m brown (10YR4/4) sand; single grain with few very weak aggregates; loose; diffuse boundary.
on: dull yellowish-brown (10YR4/3) sand; loose.

Tirean soil is younger than the uplift of Beach Ridge B and is thus younger than the Loisels pumice.

Ohuan sand is behind Beach Ridge A and overlies Tirean soil. Dunes are more hummocky and less subdued than Tirean dunes. Ohuan ground soil has a reasonably well-defined topsoil, but no subsoil, and is a brownish-black sand 10 cm thick over loose dark grey-yellow sand. European artifacts are found on the surface of the buried Ohuan soil.

Hunan sand extends inland from the foreshore and is interbedded with silt. It overlies Ohuan and Tirean soils and European artifacts. Dunes are mobile and fixed. Elongated isolated dunes, aligned southeast-northwest, are separated from the sea by a near-continuous foredune. They include sand from the coast and from eroded Ohuan and Tirean dunes. Hunan ground soil on sand is a thin layer of plant litter. On silt it is a dull yellow silt loam without appreciable darkening.

The following table summarises the relationship between the Stratigraphic Divisions and dated events at the type locality.

Stratigraphic Division	Event
Hunan unstable phase	-
Ohuan stable phase	Oldest European artifacts (150 years BP)
Ohuan unstable phase	-
Tirean stable phase	-
Tirean unstable phase	Loisels pumice (700 years BP) Taupo pumice (1,800 years BP)

RECOGNITION OF STRATIGRAPHIC DIVISIONS ELSEWHERE IN NEW ZEALAND

The following account includes the whole of the North Island, only the South Island east coast, and there only as far south as Rakaia River. Sites are described in clockwise order starting from Flat Point, along the southeast Wairarapa coast, across to the Wellington coast, and down to the South Island east coast. A jump is made to D'Urville Island, across to the southwest North Island coast, and then north to west Auckland. A further jump is made north to the east Northland coast, which is followed south to the Coromandel Peninsula, around the Bay of Plenty, along the East Coast, and back to Flat Point.

Southeast Wairarapa Coast

Halfway between the Rerewhakaitu River and the Okoropunga stream 30 km southwest of Flat Point (Figure 10), at a place informally called "North Pa", are six uplifted Holocene marine beach ridges each thought to have been uplifted suddenly during earthquakes. Loisels pumice lies along the front of the second uplifted beach ridge (Beach Ridge C). Date of uplift of Beach Ridge C was after the beginning of the Ohuan unstable phase (Appendix 4) and a Stone Row System (site N166/57) situated on Beach Ridge C and beach ridges further inland as younger than the beginning of the Ohuan unstable phase.

At Okoropunga, on the coast 34 km southwest of Flat Point, are five uplifted marine beach ridges each thought to have been uplifted suddenly during earthquakes. Loisels pumice lies along the front of the second uplifted beach ridge (C); Taupo pumice lies behind the beach ridge. Date of uplift of Beach Ridge C was after the beginning of the Ohuan unstable phase (Appendix 4).

At Okoropunga a fixed sand layer mantles the two highest beach ridges (E and F), (Figure 11). The sand layer buries a soil on Beach Ridge F and charcoal, from a tree root in position of growth in the soil, has a radiocarbon date of 750±40 years BP (NZ 3116A). The ground soil on the sand has a reasonably well defined topsoil but no subsoil (Appendix 2). From the radiocarbon date and degree of soil development, the fixed sand layer is Ohuan in age.

At Okoropunga a Maori Plaggen Soil 0.7 ha in area, is partly surrounded by the sand layer (Figure 11) and the plaggen soil and sand layer are thought to be the same age. The plaggen soil is described in detail in Appendix 1. A Plaggen-like soil 0.3 ha in area, immediately north of the Maori Plaggen Soil, is formed in the ground soil on top of the sand layer by the addition of gravel from a nearby gravel bed, and is younger than the beginning of the Ohuan stable phase.

At Okoropunga there are two Stone Row Systems (Figure 11). Stone Row System 1 extends across beach ridges D, E and F and is described in detail in Appendix 2. Tree charcoal excavated from a buried soil below a stone row, gave a radiocarbon age of 530±60 years BP (NZ 3115A); and tree charcoal from soil between the stones gave a radiocarbon age of 340±60 years BP (NZ 3114A). Part of the northernmost stone row was destroyed when the Maori Plaggen Soil was made. It is inferred, from the radiocarbon dates and destruction of the northernmost stone row, that the Stone Row System and Maori Plaggen Soil are the same age. Stone Row System 2 extends across Beach Ridge C and is thus younger than the beginning of the Ohuan unstable phase.

At Te Awa Iti (Figure 10), on the coast 3 km southwest of Okoropunga, are two good sections (2 and 3) examined by the writer.

SECTION 2: On right bank of small stream 4 km north of Oterei River, Te Awa Iti (N166(1957)/104013).

	metres
Hunan	
Dull yellow-brown silt loam soil	0.15
Dull yellow-brown stream alluvium	1.00
Ohuan	
Brownish-black gravelly silt loam (topsoil) with charcoal, shells and heat fractured stones. European artifact on upper surface	0.10
Dull yellow-brown stream alluvium	1.40
Tirean	
Greyish-yellow-brown gravelly silt loam (topsoil) with charcoal, shells (radiocarbon dated), fish-bones and heat-fractured stones	0.25
Dull yellow-brown stream alluvium	0.30+

A stream at Te Awa Iti has built a fan across the Holocene bench (Figure 12), and has cut down exposing Section 2 in its right bank. The fan is composed mostly of fluvial deposits which, at the coast, are interbedded with beach deposits. The lowest fluvial deposits, exposed by digging, are more than a metre below high water mark and are overlaid by a metre thickness of lagoon muds. The lagoon muds, which record a lower sea level than at present (Appendix 4), contain primary Loisels pumice at their base (Section 3), and are overlaid directly by Ohuan sediments. There is no primary Taupo pumice.

SECTION 3: At coast, south side of mouth of small stream 4 km north of Oterei River, Te Awa Iti (N166 (1957)/104013).

	metres
Hunan	
Silty sand with poor soil	0.20
Fine and medium beach gravel	0.10
Ohuan	
Buried soil	0.15
Fine and medium stream gravels	0.20
Fine stream gravels and coarse sand	0.15
Fine silty sand	0.15
Fine gravels and silt	0.20
Tirean	
Blue-grey mud with charcoal	1.00
Blue-grey mud with Loisels pumice, Taupo pumice and charcoal	0.10
Sand	0.05
Stream gravel	0.20+

The Tirean and Ohuan soils at Te Awa Iti are reasonably well defined in Section 2, but the Ohuan soil only is present in Section 3. Both buried soils contain shell midden near where the stream flows from hills behind the Holocene bench, and a piece of iron was found on top of the Ohuan buried soil in the left bank of the stream. A radiocarbon date for rocky shore shells from the midden on the Tirean soil is 410±60 years BP (NZ 1874A).

At Te Awa Iti four stone rows are located on the right bank of the stream on fan depoists and are some 20 m from the beach. They are a metre wide, less than 0.5 m high, and between 10 m and 30 m long. They are built from stones and large gravels cleared from Ohuan deposits, leaving between the rows a soil similar in texture to some plaggen soils. It is assumed that the rows and cleared area between them were used in some way for Maori cultivation. An active fan surface is unlikely to have been so used, and the age of the stone rows is thus thought to be Ohuan stable phase or younger.

At Te Oroi (Figure 10), on the coast 18 km southwest of Te Awa Iti, good sections examined by the writer are (Figure 13): Section 4, exposed in the left bank of the Oroi Stream; and Sections 6 and 7, exposed along the coast for some distance north and south of the Oroi Stream.

SECTION 4: Left bank Oroi Stream, Te Oroi (N168(1953)/961899).

	metres
Hunan	
Stream gravels and silt with poorly developed soil	0.80
Dark brown silt loam (buried topsoil) with charcoal and shell, changing downstream to a thin silt band	0.50
Ohuan	
Brown sandy silt with occasional shells and charcoal	0.25
Tirean	
Dark brown gravelly silt loam (buried topsoil) with charcoal and shells, merging downstream with silty gravel overlying silt	0.10
Stream gravels and silt with occasional charcoal, shells and bone	0.60+

Te Oroi Section 4 extends continuously for 100 m back from the coast and is mostly fluvial deposits which interfinger with beach deposits near the coast. Section 5 was uncovered by digging at the coast near the stream mouth.

SECTION 5: North side of mouth of Oroi Stream (dug out) (N168(1953)/961897).

	metres
Hunan	
Windblown sand, iron at base	0.50
Ohuan	
Shell midden in top of	0.03
Gravelly topsoil	0.25
Silt	0.25

	metres
Tirean	
Sandy topsoil with charcoal, moa bone (*Pachyornis* sp.), Loisels pumice at base	0.30
Brown sandy lagoon mud	0.50+

Te Oroi Sections 6 and 7 are through old lagoon deposits and are capped with windblown sand, but there are no dunes. Remains of the beach ridge (Beach Ridge C) which formed the lagoons is preserved at the north end of Section 6, and at the south end of Section 7. The lagoon muds contain secondary Taupo pumice. All three coastal sections contain primary Loisels pumice: as a lagoon deposit in Sections 5 and 7, and as a terrestrial deposit in Section 6.

SECTION 6: Coast north of Oroi Stream (N168(1953)/963897).

	metres
Windblown sand	0.20
Brown mud with charcoal	0.30
Silty sand, stream gravels, Loisels pumice and charcoal	0.10
Brown mud	0.30
Grey mud with charcoal	0.20
Brown mud with charcoal and sand	0.10
Lens of stream gravel and charcoal	0.30
Dark grey mud with rare charcoal	0.10
Lens of rounded gravels and sand	0.20
Lens of brown mud	0.05
Dark brown mud	0.30
Dark grey peaty mud grading to silty sand at south end of section	0.50
Beach ridge gravel	0.20+

SECTION 7: Coast south of Oroi Stream (N168(1953)/956890).

	metres
Sandy silt with round and angular stones, strap iron, fencing wire	0.30
Medium grey silt loam buried soil	0.15
Light grey mud	0.60

	metres
Blue-grey mud with yellow mottles and Loisels pumice	0.10
Blue-grey mud with yellow mottles and rare charcoal	0.30
Blue-grey mud with iron mottles	0.15
Peat with stones and wood	0.15
Blue-grey mud	0.15
Alternating layers of peat and grey, brown and black mud overlain by driftwood and occasional Taupo pumice	1.35

At Te Oroi, Tirean and Ohuan buried soils are well-defined in Sections 4 and 5. Both soils contain shell midden deposits; and a piece of iron was found on Ohuan soil in Section 5. Numerous moa bones, including some in position of articulation, were found in Tirean lagoon muds (between Taupo and Loisels pumices) in Section 7. Sections 6 and 7 are important for determining sea level changes (Appendix 4).

At Te Kau Kau Point, 3 km south of Te Oroi, wave erosion has exposed two longitudinal sections of a raised beach ridge (Beach Ridge C, Wellman, 1971a). Section 8, the northeast section (Figure 14), is beach ridge deposits overlying lagoon mud and peat; the southwest section is beach ridge deposits overlying only lagoon mud.

SECTION 8: Te Kau Kau Point, Northeast Section (N168(1953)/940877).

	metres
Dark grey gravelly soil, scattered shells, bones and charcoal	0.15
Beach ridge gravel	0.50
Beach ridge gravel in mud	0.60
Peat, fibrous with Loisels and Taupo pumices near top, rare charcoal, marine shells, and logs of driftwood up to 30 cm diameter	0.30
Blue-grey mud	0.05
Beach ridge gravel and sand	0.05
Tertiary mudstone	1.0+

At Te Kau Kau Point the peat, and the lagoon mud in the southwest section, contain primary Loisels pumice; but there is no primary Taupo pumice and no Tirean or Ohuan soils. Shells from a hollow in the top of the wave-cut bench underlying the beach ridge have a radiocarbon date of 2.4 kyrs (Appendix 4) for the uplift which began formation of Beach Ridge C. A small scatter of midden on top of Beach Ridge C is Ohuan or Hunan in age. Moa bones found in lagoon mud in the southwest section represent several species, and include mature, sub-mature and immature birds. Some were in position of articulation. All are late Tirean in age (younger than Loisels pumice).

Wellington Coast

On the Wellington west coast (Figure 10), 100 km west of Flat Point, are up to 6 uplifted Holocene marine beach ridges. Some beach ridges are thought to have been uplifted suddenly during earthquakes; some are thought to have been stranded by eustatic sea level lowerings and to have been uplifted during earthquakes before the sea level rose again. The most important earthquake uplift is the Haowhenua earthquake of Maori tradition, dated about 500 years ago and older than an eustatic sea level high at the end of the Tirean stable phase (for details see Appendix 5). The beach ridge raised above the effect of wave action during the earthquake is identified by the writer on the north shore of the Pauatahanui Inlet, at Makara, and at Te Ika amaru Bay.

At Te Ika amaru Bay are two Plaggen-like soils dated by the uplifted beach ridge (Figure 15). Plaggen-like Soil 1 (site N164/115) is a layer of beach gravel 0.2 m thick spread over a sand dune overlying the higher of two uplifted beach ridges (Beach Ridge C); Plaggen-like Soil 2 (site N164/17) is a layer 0.4 m thick, of charcoal-blackened sand similar in size to that at present high water mark (Figure 16), behind Beach Ridge C and extending over the beach ridge crest. Uplift of Beach Ridge C is correlated with the Haowhenua earthquake and both Plaggen-like soils are thus younger than the earthquake, and are late Tirean in age or younger.

On the north shore of the Pauatahanui Inlet a Maori Plaggen Soil is thought to be older than the Haowhenua earthquake and of Tirean age. At Paremata (near the entrance of the Pauatahanui Inlet), at Makara, and at Te Ika amaru Bay, are Moahunter sites thought to be younger than the Haowhenua earthquake. Details are given in Appendix 5. The Paremata Moahunter site is thought to be older than the sea level high and thus to be late Tirean in age.

East South Island Coast

In the lower reaches of the Waimakariri River in the South Island, 350 km southwest of Te Oroi and more than 10 km inland from the coast, is a series of fluvial deposits and soils dated by radiocarbon. The deposits and soils have not been seen by the writer. Deposition was followed by downcutting giving four age-groups of sediments and soils as described by Cox and Mead (1963). Only the two youngest, Waimakariri followed by Selwyn, are within the time range of the stratigraphic divisions discussed here. According to the radiocarbon dates, Waimakariri sediments (2,400 to 700 years BP) are Tirean in age; and Selwyn sediments (less than 300 years BP) are Ohuan in age. Hunan sediments and soils are absent. An important abandoned river channel (Figure 17), which has many Moahunter ovens along its banks (Haast, 1879), contains both Waimakariri and Selwyn sediments (Raeside and Rennie, 1974) deposited when the Waimakariri River flowed to the south of Banks Peninsula, not to the north as at present.

The Avon-Heathcote estuary lies 20 km south of the present Waimakariri River mouth (Figure 17). On the north side of the estuary is a wide belt of dunes (Figure 18), on the south side are hills: volcanic rocks of Banks Peninsula, flanked by a discontinuous narrow belt of dunes. According to Raeside and Rennie (1974) there are two degrees of soil profile development on the dunes (Waikuku sandy loam, more developed; and Kairaki sand, less developed). The writer, who has not examined the dune belt, infers two ages of dunes named, from the soils, Waikuku and Kairaki.

At Redcliffs, immediately south of the estuary, the dunes are Waikuku. Haast in 1874 found a layer of blown sand on Redcliffs Flat and in Moa-Bone Point Cave separating his Moahunter from his "Shellfish-eater" occupation layer. According to Trotter (1975b) some Moahunter remains rest on a stained sand which is thought by the writer, after discussion with Mr Trotter, to possibly be a buried young soil. Trotter (1975b) gives close radiocarbon dates for Moahunter remains on the Flat and in the cave of between 750 and 500 years BP. Correlation of the sand layer with Kairaki sand; and overall correlation of Waikuku dunes with the Tirean, and Kairaki with the Ohuan, is based on the radiocarbon dates. The Moahunter remains are therefore Tirean stable phase, and the Shellfish-eater remains, Ohuan stable phase.

At the mouth of the Rakaia River 50 km southwest of Banks Peninsula are three down-cut river terraces,younger from highest to lowest. Ward et al (1964) correlated the soil on the lowest terrace with Selwyn soil, and the soils on the two higher terraces with Waimakariri soils. Moa bone collagen from the highest terrace has a radiocarbon age of 580±65 years BP (mean of NZ 930C and 932C) (Trotter, 1972a) a date that is the same as the date of Waimakariri soils according to Cox and Mead (1963). The soils on the two higher terraces are therefore Tirean in age; and that on the lowest terrace, Ohuan in age. Haast (1871, 1879) made brief mention of Moahunter ovens on the lowest terrace, but did not explain why he thought them to be Moahunter.

D'Urville Island

At D'Urville Island, at the north of the South Island, there is an easily accessible source of good rocks for adzes. Adzes would have been traded, probably for moas, as suggested by Wellman (1962a). As at Moa-Bone Point Cave there are two occupation layers. Tradeable adzite, moas and snapper are in the bottom layer; no moas, no tradeable adzite, and barracouta only are in the top layer. The layers on D'Urville Island are unusually well defined, the best defined are in dune sand. There is Taupo pumice but no Loisels pumice. Dates for occupation layers were estimated (Wellman, 1962a) by assuming uniform accumulation rates. Wellman collected radiocarbon samples but published his estimated ages before the samples were dated. The dates (Table 7) were some hundreds of years younger than his estimates. Buried soils exist immediately below the occupation layers in some places. Some are modified by added gravel and are considered here to be Maori Plaggen Soils. Satisfactory correlation of Wellman's (1962a) lower occupation layer with the Tirean soil, and upper occupation layer with the Ohuan soil, is based on the Taupo pumice, the radiocarbon dates, and soil formation.

Southwest North Island Coast

The southwest coast of the North Island is about 120 km northeast of D'Urville Island, and 70 km northwest from the type locality at Flat Point. From the Manawatu River in the south to the Wanganui River in the north, belts of Holocene dune sand parallel the coast (Cowie, 1963; Campbell, 1974). Three distinct periods of sand accumulation, called by Cowie (1963) Dune Building Phases, are inferred from sharp differences in the degree of ground soil development on the sand belts. In general, the oldest sands are the furthest inland. According to Cowie (1963) the sequence of Dune Building Phases younger than 2,400 years is Motuiti followed by Waitarere. Motuiti dunes contain Taupo pumice (Cowie, 1963).

The soils on Motuiti sand are dated in the Manawatu district. There, Motuiti sands have advanced inland over a tree radiocarbon dated 700 to 800 years BP (Table 3). The soil, younger than 700 to 800 years BP, has a profile development similar to that of the Tirean ground soil at Flat Point.

Two kilometres north of the Manawatu River, and 2.5 km from the sea, is an important archaeological site (N148/1) investigated by the writer. The site is on the eastern side of a lake, locally called the Pothole, and rests on a thin soil formed in Motuiti sand (Appendix 6).

There are numerous moa bones on the western side of the site. Only those from a single trench 4 m^2 in area have so far been identified. They are the remains of 11 birds, belonging to 4 and possibly 6 species. The species identified by Mr G.S. Markham, are *Anomalopteryx didiformis*, *Pachyornis mappini*, *Dinornis struthioides*, *Euryapteryx curtus*, and possibly *Emeus exilis* and *Euryapteryx geranoides*. The layer with the moa bones has a radiocarbon date (NZ 682C) of 600 to 800 years determined on charcoal (Table 3). The dated charcoal is from a tree that is thought to have grown on the thin soil on Motuiti sand. The charcoal is thus considered to give a minimum date for soil formation.

There are two occupation layers: Layer I and Layer II, on the eastern side of the site. They are separated by a well-defined buried soil which probably took between 100 and 200 years to form. Layer I is older than Layer II and is mostly composed of shell midden with landsnails, moa bones and Moahunter artifacts. The artifacts include 1 piece unbarbed bone fish-hooks and an unbarbed perforated lure hook point. Layer II is a Moahunter kitchen with cooking shelter and fireplaces, shell midden, house and flaking floor. The midden contains moa bones and landsnails. Artifacts are typically Moahunter and include a bone reel necklace unit, one piece unbarbed bone fish-hooks, a perforated lure hook point, a minnow lure in serpentine and a Duff (1956) type 2A adze. The flaking floor contained a nephrite flake. Moa bones from Layer II are identified by Mr G. S. Markham as *Euryapteryx geranoides*, *Anomalopteryx didiformis*, *Emeus exilis*, *Dinornis* sp., and possibly *Pachyornis* sp. Each occupation layer is radiocarbon dated using shells and, for Layer II, charcoal unidentified as to species.

The shells dated are estuarine cockles (*Chione stutchburyi*) and ocean beach tuatuas (*Paphies (Mesodesma) subtriangulatum*). The radiocarbon dates are older for the estuarine cockles than they are for the ocean beach tuatuas. Each shell midden consists of a series of lenses, each lens containing estuarine and ocean beach shells.

In order to determine the age of each occupation layer, a tuatua and a cockle sample was taken from the same shell lens in each of the two layers giving four samples in all. In addition, two cockle samples were taken from above the lens in Layer II, one cockle sample was taken from below the lens, and a charcoal sample was taken from above and below an oven in Layer II. The results, shown by Figure 19, are surprising. The radiocarbon age difference between the cockles and tuatuas increases from 180 years in Layer I to 490 years in Layer II, and the shells with the oldest radiocarbon age are the shells with the youngest stratigraphic age. The stratigraphy is definite, the cockle ages are inverted, and the most reliable dates are considered to be the tuatua ages. The charcoal dates from Layer II do not conflict with the tuatua dates. Occupation Layer I is taken to be 550±70 years BP (NZ 1480B); and Occupation Layer II. 320±65 years BP (NZ 1250B).

Waitarere dunes, which have patchy, poorly developed soils, have not previously been dated. If it is assumed that the coast prograded when the dunes began to accumulate, then a date for their accumulation may be inferred from an inland rise of ground water table level caused by the progradation. The method is not very satisfactory, but is the best at present available. Details are given in Appendix 6.

The Pothole lake, 2.5 km inland, is 3.3 m above sea level and used to seep to the sea. It now has an artificial outlet which has lowered its level by 1.4 m. Past changes in water level at the lake are inferred from the archaeological excavations, and from two old lake shore benches. A rise of 2.5 m took place since 550 years ago, and at European settlement the site was under water. The site was exposed by drainage of the lake in the last 70 years. The 2.5 m rise is attributed to rapid coastal progradation beginning between 500 and 300 years ago.

Correlation of Motuiti dunes with the Tirean Stratigraphic

Division, and of Waitarere dunes with the Ohuan and Hunan Stratigraphic Divisions, is based on radiocarbon dates, on inferred coastal progradation, and on ground soil profile development. Occupation Layer II at the archaeological site appears to have been deposited after the beginning of the progradation marking the Waitarere Dune Building Phase, and its age is thus considered to be early Ohuan unstable phase.

West Auckland

Along the west Auckland coast, 300 km north of the southwest North Island coast, an area not visited by the writer, are coastal sections described by Wellman (1962b). As at Moa-Bone Point Cave at Redcliffs in the South Island there are two occupation layers, but both are poorly defined. The sections are mostly sand, Taupo pumice is present, but not Loisels pumice. One reasonably well defined buried soil exists below the lower occupation layer and above the Taupo pumice. The buried soil has been modified at Marakopa by added gravel and is considered here to be a Maori Plaggen Soil. Four sections (44, 47, 48 and 49, Wellman, 1962b) are correlated with the proposed stratigraphic divisions in Figure 20 according to soils described by Wellman (1962b). Deposits between the Taupo pumice and the top of the buried soil are Tirean in age; and above the buried soil, Ohuan-Hunan in age.

North Auckland

Along the North Auckland coast, 220 km northeast of the west Auckland coast, an area not visited by the writer, are coastal sections described by Wellman (1962b). The sections contain one well defined occupation layer, with charcoal in underlying deposits. The sections are mostly dune sand or gravel. Loisels pumice is present, but not Taupo pumice. Below Loisels pumice is brown pumice called Leigh. Tirean and Ohuan soils are not evident from Wellman's (1962b) descriptions, but are assumed here to be present. Charcoal extends unusually far below Loisels pumice in most sections.

Coromandel Peninsula

Along the Coromandel Peninsula, 100 km southeast of the North Auckland coast, coastal sections are described by Wellman (1962b). There is one well-defined occupation layer, which is exposed in sections composed principally of sand. Taupo pumice is absent, Loisels pumice is present. Buried soils are not evident from Wellman's (1962b) descriptions. Buried soils correlated by the writer with Tirean and Ohuan stable phases were seen by the writer at Hot Water Beach and are described by Smart and Green (1962) at Tairua, and they are assumed to be present in the sections described by Wellman (1962b).

At Hot Water Beach the soils are in an archaeological site (N44/69) in dune sand. The site is described by Leahy (1974), who numbered the layers from top to bottom. The Tirean and Ohuan soils are identified by the writer with layers 4 and 2. Taupo pumice is absent, Loisels pumice is in Layer 5, and European artifacts in Layer 2. A close radiocarbon date for occupation remains in Layer 4 is 510±55 years BP (mean of NZ 1296B and 1297B). Youngest moa bones are in Layer 3b. Correlation of Layer 4 with the Tirean soil, and Layer 2 with the Ohuan soil, is based on Loisels pumice, radiocarbon and European artifacts.

Tairua, an archaeological site (N44/2) in dune sand, contains two occupation layers separated by dune sand. Each is part of a poorly developed buried soil. Taupo pumice, Loisels pumice and European artifacts are absent. The lower occupation layer (Layer 2) has a close radiocarbon shell date of 570±60 years BP (NZ 1875A); and two maximum radiocarbon dates, 443±40 years BP (NZ 595A) and 878±49 years BP (NZ 594A), on charcoal from an oven. The upper occupation layer (Layer 6) has a close radiocarbon shell date of 250±70 years BP (NZ 1876A). A fishing lure made from pearl shell was found in the lower occupation layer (Green, 1967). Pearl shell is confined to tropical waters, and the lure possibly indicates that the site was occupied shortly after the arrival of a group of settlers from Polynesia. The lower occupation layer has many moa bones. The upper occupation layer has no moa bones. Correlation of the lower buried soil with the Tirean stable phase, and the upper buried soil with the Ohuan stable phase, is based on the radiocarbon dates.

Bay of Plenty - East Coast

Along the eastern Bay of Plenty and East Coast, 300 km southeast of the Coromandel Peninsula, are coastal sections described by Wellman (1962b). As at Moa-Bone Point Cave there are two well-defined occupation layers which are considered by Wellman (1962b) to be determined by population density, a uniform rate of sediment accumulation being assumed by him. Taupo pumice and Loisels pumice are both present. The writer considers the occupation layers to be times of non-deposition and soil formation, and the layers are correlated with the Tirean and Ohuan soils.

Of the 21 East Coast and Bay of Plenty sections described by Wellman (1962b) the most important for archaeology are reproduced and correlated with the writer's stratigraphic divisions in Figure 21. In all sections there are two buried soils above the Loisels pumice. For sections 5, 7, 19, 21 (numbers according to Wellman (1962b)), which the writer did not see, the buried soils are based on Wellman's (1962b) descriptions; for sections 8, 9, 13, 14, 15 and 18, on the writer's observations; and for Section 9, on Green and Pullar's (1959) observations.

The Ohuan soil contains European artifacts at three places. At Maraetaha Diggings (Section 8), a fortified pa on the banks of the Maraetaha River, Wellman's (1962b) upper occupation layer is a cultivated soil containing clay pipe (E. Shaw, pers. comm.). At Cooks Cove (Section 15) the upper occupation layer is a ground soil containing iron and earthenware. At Anauru Bay (Section 18) there is iron in the top of the upper occupation layer.

At Cooks Cove, as already mentioned in Chapter II, Loisels pumice has a maximum radiocarbon date of 925±46 years

BP (NZ 651A) determined on wood; and a minimum radiocarbon date of 700±56 years BP (NZ 632A) determined on shell.

In the Gisborne Plains Basin, on the East Coast, are 5 alluvial formations named by Pullar and Penhale (1970), in order of decreasing age, Kaiti, Waihirere, Early Matawhero, Late Matawhero, and Post-Matawhero. The last four named formations are separated by buried soils; the first two, by Taupo pumice. Pullar (1959) describes Loisels pumice in Waihirere soil at the Maraetaha River mouth. Basal layers of Early Matawhero alluvium are olive-yellow in colour and contrast strongly with the black Waihirere buried soil which they cover, indicating that alluvium was deposited rapidly after a long period with no flooding. Basal layers of Late Matawhero alluvium are olive in colour and contrast with the very dark greyish-brown early Matawhero buried soils which they cover, indicating that alluvium was deposited rapidly after a period with no flooding. Late Matawhero alluvium began accumulating about 1820 AD. Correlation of Waihirere and Early Matawhero soils with the Tirean and Ohuan soils is based on the Taupo and Loisels pumices.

In the Tukituki River Valley in southern Hawkes Bay 200 km southwest of Gisborne, are four down-cut river terraces, younger from highest to lowest. Taupo pumice is on the oldest terrace surface. The soil on the second oldest terrace surface is correlated by Grant (1965) with Waihirere soils in the Gisborne Plains Basin; and the soil on the third oldest terrace, with Matawhero soils. According to tree-ring ages the Waihirere terrace is more than 500 years old; the Matawhero, more than 300 years old; and the youngest terrace, more than 170 years old.

From the Tukituki River, the last section to be described, it is 160 km southwest to Flat Point, the type and first section described.

ADOPTED AGE DIVISIONS FOR LATE HOLOCENE DEPOSITS

Adopted age divisions for the late Holocene deposits of the North Island and northeastern part of the South Island are given in Figures 22 and 23. Tirean, Ohuan and Hunan deposits are present in the northeastern South Island and North Island, but Hunan deposits are absent from central Canterbury. The Tirean soil is present on deposits in the northeastern South Island, and on the eastern and western sides of the North Island. The Ohuan soil is present in the northeastern South Island and on the eastern side of the North Island.

Correlation, and estimated date of uplift, of beach ridge deposits is given in Figure 24. Beach ridge deposits which began accumulating before the beginning of the Tirean unstable phase along both the Wellington and southeast Wairarapa coasts were uplifted above the effects of wave action shortly before the end of the Tirean stable phase at Wellington (Haowhenua earthquake), and shortly after the end of the Tirean stable phase at southeast Wairarapa (Beach Ridge C). Beach ridge deposits which began accumulating after these uplifts were themselves uplifted during the early Hunan unstable phase at Wellington (1855 AD), and during the late Ohuan or early Hunan at southeast Wairarapa.

DATING STRATIGRAPHIC DIVISIONS

Dating stratigraphic divisions is a two step procedure. The first step is to determine the age range for the start of each phase in the same way as the age range for the Loisels pumice was determined. Data for determining age ranges of the start of each phase are set out in Figure 23. The second step, shown on Figure 25, is to set out the age ranges in stratigraphic order and to use the order to control the ranges.

Adopted ages for stratigraphic events are as follows:

Stratigraphic Event	Years BP	Years AD
Ohuan soil buried	150	1,800
Ohuan soil begins to form	300	1,650
Tirean soil buried	400	1,550
Tirean soil begins to form	650	1,300
Loisels pumice deposited	700	1,250

The first three events are likely to be about 100 years in error, the last two events, somewhat less.

CHAPTER IV

ENVIRONMENTAL AND CULTURAL CHANGES

DEPOSITIONAL EPISODES

In previous chapters it is established that for the last 2,000 years there were three well defined episodes, each synchronous over central New Zealand, and each with two phases: a phase with a high rate of deposition (unstable phase) followed by a phase with a low rate of deposition, and soil formation (stable phase). The pattern is somewhat different in different parts of New Zealand. The youngest episode is absent from central Canterbury and the soil between the two younger episodes is absent from the North Island west coast (Figure 26).

In the North Island there is no obvious correlation of depositional episodes with tectonics. Tirean sand at Flat Point mantles Beach Ridges B and C and contains primary sea-rafted Taupo pumice, also found behind Beach Ridge C. Accumulation of Tirean san thus spans two tectonic uplifts. Ohuan and Hunan sands however are both younger than the most recent uplift.

The depositional episodes are unrelated to volcanic eruptions. Tirean sand at Flat Point began accumulating before the Taupo Pumice eruption. Pumice (Taupo and Loisels) occurs as well-defined deposits in the Tirean sand but its volume is unimportant relative to the sand, and pumice has not been found in the Ohuan or Hunan sands. South Island rivers are too far removed from the North Island volcanic centres to have been influenced by volcanic eruptions.

In Chapter 3 unstable phases in coastal dune systems are correlated with river aggradation and fan building. Sand along the southwest North Island coast is shown by its mineral content to have come from the larger North Island rivers (Oliver, 1948;

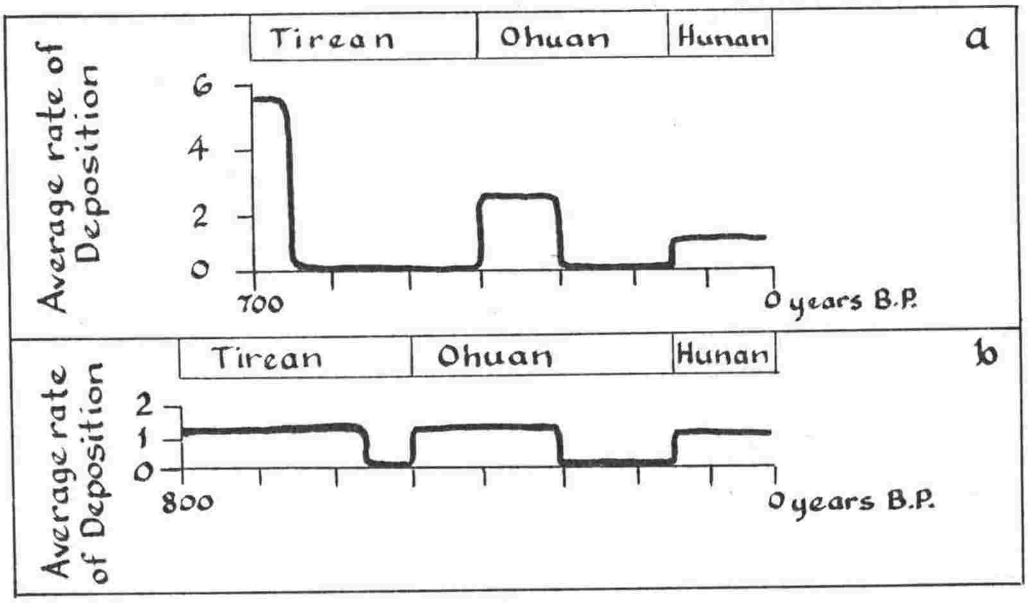
Cowie and Smith, 1958). The depositional episodes are therefore explained by changes in erosion rates in river systems: unstable phases occurring when rates were high; stable phases when rates were low.

Erosion is generally considered to follow forest clearance. Except for alpine areas and the central Otago basins, New Zealand is thought to have been forest covered at human settlement (see page 48). Man arrived during the Tirean unstable phase which had begun more than 800 years earlier, and lowest charcoals in coastal sections mark the beginning of forest fires shortly before the Loisels pumice. The Maori cleared about half the forest and it can be assumed that he would have burnt when he could. The formation of Tirean soils after some 300 to 400 years of burning is surprising.

Europeans cleared a further quarter of the forest. Sediments deposited during the Hunan unstable phase are recognised in the North Island and in the northern South Island, but not on the Canterbury Plains. Deposition by the lower Rakaia and Selwyn Rivers (Ward et al, 1964), indicated by the distribution of Selwyn soils, has been relatively minor compared with deposition during earlier unstable phases. "Severe" erosion in the South Island since European settlement (Gibbs et al, 1945) does not appear to be reflected in the river deposits.

Forest clearance may possibly have accelerated erosion during unstable phases, and would appear to account for examples of severe erosion in the North Island since European settlement, but how much erosion since European settlement is due to forest clearance, and how much is due to the present unstable phase is uncertain.

Average deposition rates for deposits younger than the Loisels pumice are given in the following diagrams. The rates are determined in Appendix 11 from sediments thicknesses at 16 selected sections along the east North Island coast between the Coromandel Peninsula and Cape Palliser. They are expressed as a proportion of the rate for the last 150 years. It is assumed that all deposition occurred during unstable phases. Two sets of rates are shown. The set shown by Diagram a uses the adopted ages for stratigraphic events given on page 46. The set shown by Diagram b assumes a maximum error of 100 years for the adopted ages of the Loisels pumice and the formation and burial of the Tirean soil. There is every indication that the rate of deposition has decreased with time or remained steady, and the depositional episodes are thus considered to be independent of vegetation clearance and hence of cultural influence.



The phases are thought to be climatically controlled. Slips are the most important kind of erosion in much of New Zealand (Gibbs et al, 1945; Grange and Gibbs, 1947) and are caused by occasional very heavy and long-continued rain. Thunderstorms appear to be unimportant because they rarely last long enough, but the effect of tropical storms on erosion, even under forest, is well-established (Selby, 1967; Pain, 1969). The worst tropical storms cause widespread flooding, severe forest damage, and bring down many slips (Kidson, 1924; Thomson, 1936; Gabites, 1968; Tomlinson, 1975; Barnett, 1938).

It is shown on page 50 that during the Tirean stable phase forest vegetation established on formerly unstable sand in the Manawatu and at Flat Point. Favourable climatic conditions would be frequent tropical storms, and drying windy conditions poor for the establishment of vegetation on dunes and on coasts. Favourable climatic conditions for soil formation would be fewer tropical storms, and more uniformly moist conditions with less violent winds good for the establishment of vegetation on dunes and on coasts.

Depositional episodes and existing climatic records are compared in the following diagram (p.47e) but there is poor correlation Some South Island glaciers appear to indicate minor advances or still -stands superposed on a gradual retreat that began at an uncertain date. The advances or still-stands begin on west coast ca 400 years ago (Wardle, 1973); and on the east coast ca 800 years ago (Burrows, 1973) but do not correlate with either stable or unstable phases. Somewhat better correlation appears to exist between depositional episodes and temperatures inferred from oxygen isotope measurements on the northwest Nelson stalagmites reported by Hendy (1969). As illustrated in the following diagram, unstable phases appear to correlate with times of high temperatures; stable phases with times of low temperatures.

It is possible that tropical storms may occur more frequently during warm periods than during cold periods. If tropical storms are responsible for depositional episodes then obviously they are of extreme importance, but further details of the topic are outside the scope of this thesis and cannot be discussed further.

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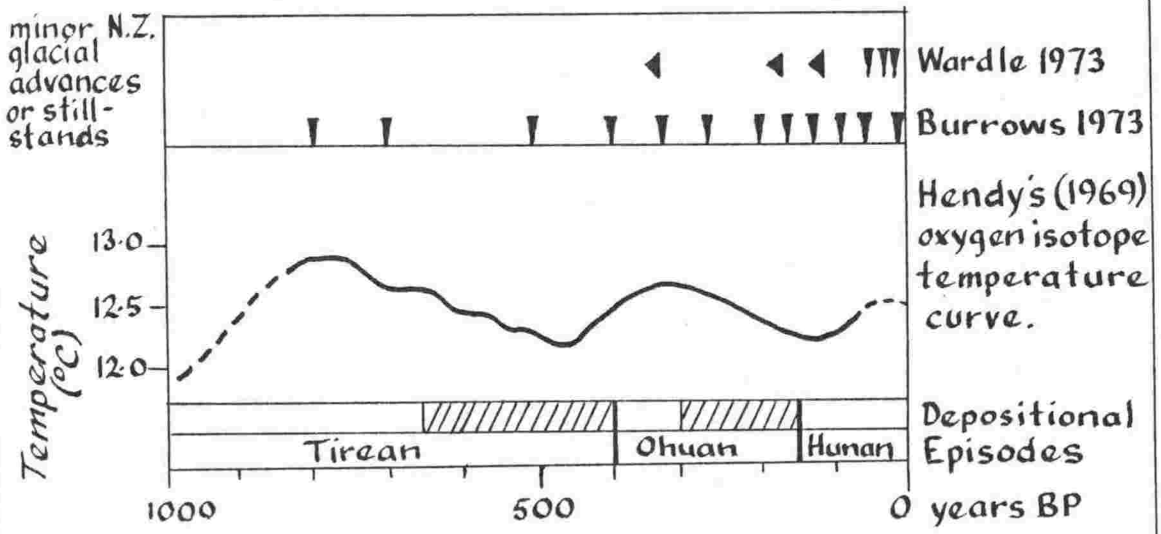


Diagram comparing depostional episodes with existing climatic records. Cross-hatching = stable phases, no hatching = unstable phases. Downwards-pointing arrowheads = times of minor glacial advances or still-stands; sidewards-pointing arrowheads = minimum dates of glacial advances or still-stands.

VEGETATION

An estimate of the rate of forest clearance in New Zealand since Maori settlement is given by Figure 27.

According to present day temperature and rainfall, all areas except the alpine regions and central Otago Basins were probably in forest before Maori settlement (A, Figure 27). Three critical areas are the dry east coasts of the North and South Islands, and the volcanic region of the North Island where large areas of forest were destroyed by the Taupo Pumice eruption 2.0 kyrs ago. A summary of the evidence for the east South Island coast is given by Molloy _et al_ (1963). A summary of the evidence for the North Island is given by Table 4.

In Table 4, charcoal and wood from forest trees, soils formed only under forest, pollen of forest trees, and subfossil landsnails and insects from forests, are used to determine whether forest existed in areas of the North Island under scrub, bracken fern, or grass, at the beginning of European settlement (1840) (Figure 28). Landsnails are particularly abundant in some shell middens. They indicate whether there was forest near the middens when the middens were laid down; hence if the middens are dated, so is the forest. _Stable_ species of landsnails require forest conditions and live in damp forest litter or in rotting logs; or are arboreal and live in leaf axils or in suspended litter. Some _Tolerant_ species normally live in damp forest litter but can tolerate dry open conditions; others live in litter in dry open conditions, but can tolerate damp forest litter.

Molloy _et al_ (1963) showed that wood charcoal is relatively abundant in soils on the Canterbury Plains and foothills, and inferred the existence of extensive forest before Maori settlement. The forest was cleared during the last 600 years, presumably by the Maoris.

Lake Poukawa, which is in the driest part of the North Island, contains evidence for a complete change in vegetation. According to McGlone (pers. comm.) matai pollen in a radiocarbon dated peat core is suddenly replaced by bracken fern and tutu pollen about 900 years ago.

In the volcanic region Vucetich and Pullar (1963) describe forest soils in areas covered by scrub and bracken fern at European settlement. The soils formed in Taupo Pumice and show that there was extensive forest regeneration after the Taupo eruption. It is suggested below that the forest was cleared some 500 to 600 years ago.

The Maori would have begun to clear the forest from the time of first settlement, and at an increasing rate as population increased (A-B, Figure 27).

Until steel tools were introduced, methods of Maori forest clearance did not change, and whether or not the Maori could clear the forest depended largely on rainfall. If it became drier, he could clear more, but if it became wetter, the forest would re-advance over the areas he had cleared. It has already been mentioned that unstable phases are thought to have been drier than stable phases. During unstable phases the Maori is likely to have driven the forest back (A-B, C-D, Figure 27). During stable phases, the forest is likely to have advanced over previously cleared areas or naturally bare areas (B-C, D-E, Figure 27).

It is shown below that during formation of the Tirean soil in the Manawatu, along the southeast Wairarapa coast, and on the East Coast the forest advanced almost to the coast. Each of these areas was forest-free at European settlement; the Manawatu, and Flat Point on the southeast Wairarapa coast were bare at Maori settlement.

Increase in the area of forest cleared is indicated by the absence of forest on Ohuan soils in each area.

In the Manawatu, at the Foxton site already mentioned, a shell midden with landsnails appears to have been accumulated near forest (McFadgen, 1972). Motuiti soil the same age as the midden, is carried by Motuiti sand. The soil began forming about 650 years ago and contains charcoals from kahikatea and totara (Appendix 7). Humic acid analyses of the soil confirm podocarp-dominated vegetation (Appendix 7). At the time of European settlement the forest had been replaced by bracken fern and scrub.

On the southeast Wairarapa coast forest vegetation on Tirean soil is indicated by landsnails from shell middens at Flat Point (Figures 29, 30), at Te Awa Iti (Figure 31), and at Te Oroi (Figure 32). At Te Kau Kau Point forest vegetation during the late Tirean is indicated by landsnails and insect remains from the late Tirean peat (Figure 33, Table 6). A paucity of landsnails in shell middens on the Ohuan soil at Flat Point and Te Awa Iti indicates that the forest edge was well inland of the middens. According to Colenso, in the 1840's and 1850's the coast was barren and treeless (Bagnall and Petersen, 1948). It is noteworthy that at the Oroi stream, where Colenso does mention one of the few stands of bush on the coast, a midden on the Ohuan soil does contain landsnails (Figure 32).

At Cooks Cove forest vegetation on Tirean soil is indicated by landsnails from a shell midden (Figure 34). Landsnails were not found in shell middens on the Ohuan soil.

In the volcanic region large areas of forest were destroyed by the Taupo Pumice eruption 1,800 years ago. In the east, along the western edge of the Urewera forest, are stands of rimu and matai trees some 400 to 500 years old (McKelvey, 1973). It is thought here that the forest re-established itself less than 400 years after the Taupo eruption, continued to grow for at least 600 years, and was cleared by the Maori more than 500 years ago.

After European contact the Maoris had steel axes and began to grow "Irish" potatoes. Cameron (1964), a forester, estimates that the rate of forest clearance by the Maori in the latter decades of the eighteenth century and first half of the nineteenth century (E-F, Figure 27), almost equalled the maximum rate of European clearance (F-G, Figure 27).

MAORIS AND MOAS

There were two Maori cultures: moa remains are often found with the earlier culture, but never with the later one. Some early archaeological sites in the South Island contain remains of many moas (Skinner, 1924; Teviotdale, 1937a), and most early sites have some moa remains (Figure 35), but in the North Island the situation is different. Moas are absent from all early archaeological sites along the east coast up to the Bay of Plenty (Hill, 1914; Brodie, 1950), and are rare in many early archaeological sites elsewhere.

The absence of moas from early archaeological sites on the North Island east coast is not due to their being no moas on the east coast. Moa bones in natural deposits younger than Loisels pumice and older than 400 years on the southeast Wairarapa coast have already been mentioned. An important deposit is at Te Kau Kau Point where moa bones from adult birds were found in the position of articulation. Additional bones included those from submature and immature birds, and the birds were probably a breeding population.

That the Maoris ate moas is not in dispute, the problem is why there are so many moa bones at some early sites, and so few or none at all the others. The South Island early archaeological sites containing many moas are thought by the writer to be special places to which the moas could be easily transported. The quantity of bones is so large in them, and in some early archaeological sites in the North Island, that moas must have been carried there. Too many moa bones have been found on the sites for the birds to have been caught only in their immediately surrounding area. Moas on D'Urville Island would never have been numerous, but moa bones were found in the lower occupation layer in almost every section examined by Wellman (1962a), who suggested that many bones were from birds transported from the South Island.

Based on the analogy of the Maori treatment of pigs in the Wairarapa reported by Weld in 1845 (Mair, 1972) it is likely that where transport was difficult, they only took the flesh and left the bones behind. Where transport was relatively easy moas were taken alive to be butchered when required, as described by Chapman (1884). Adkin (1948) described what he thought was a butchering site in a remote part of the Tararua Ranges.

For successful transportation of live moas, a place is needed to load them, rafts or canoes are needed to carry them, and a populated place, probably near the coast, to unload them and keep them until required. South Island rivers, e.g. Clarence and Waitaki Rivers, are large and generally suitable for rafts; Wairau Bar is on the edge of a lagoon. The Coromandel Peninsula and North Auckland have sheltered bays and moas could have been transported over some distance. But on the North Island east coast there are few raftable rivers and few harbours. The accessibility by water transport explains the large number of bones on almost all of the sites.

Man began to eat moas as soon as he arrived in New Zealand (Figure 36), and moas had been virtually killed off about 300 to 400 years ago. Some moas are likely to have lingered on in remote parts of New Zealand inhospitable to Maoris, as did the takahe which survived in Fiordland until the present day, but over most of New Zealand moas were extinct by the end of the Ohuan unstable phase.

AGRICULTURE

The study of prehistoric agriculture is made difficult by problems of sampling. In areas climatically marginal for agriculture, south of Poverty Bay and the Bay of Plenty, cultivated soils are easily found because sand and gravel were added by the Maori - the plaggen soils discussed above. North of Poverty Bay and the Bay of Plenty cultivated soils are much harder to identify because sand and gravel were less frequently added.

Rectangular pits were used by the Maori in which to store kumaras and rectangular pits are therefore accepted by Law (1969), Fox (1974b), and others, as evidence for Maori agriculture; but the pits may have had other uses and they are therefore less conclusive than soils or stone row systems as evidence of agriculture.

Dates for agricultural sites in New Zealand (Figure 37), including the northern South Island, are given in Table 10 and illustrated by Figure 38. The dates indicate the presence of agriculture in the North Island and northern South Island by the beginning of the Tirean stable phase. For northern and marginal areas the sequence of agriculture is:

	Marginal Areas	Northern Areas
Tirean stable phase	agriculture	agriculture
Ohuan unstable phase	agriculture	agriculture
Ohuan stable phase	no agriculture	agriculture

Wind would limit agriculture and would probably have controlled agriculture on the east coast. Trees for shelter would have been essential during unstable phases, but less so during stable phases.

TIMES OF FIRST SETTLEMENT OF THE NORTH ISLAND AND NORTHERN SOUTH ISLAND

The coastal sections are all important for dating times of first settlement. In most coastal sections the lowest angular charcoal is only a short distance below definite cultural remains. The angular charcoal is assumed to mark the time of first settlement of the nearby coast. Each section contains either one or two buried soils. It is already mentioned that soils represent periods of non-deposition, and that the rate of deposition in each section was uniform when soils were not forming. In general, deposition rates differ in different sections.

The method of dating the earliest charcoal, by proportion, is shown in Figure 39.

The stratigraphic sections for New Zealand are conveniently discussed under east North Island coast, D'Urville Island coast, and west Auckland coast. The basic stratigraphy for the three coasts is shown by Figure 39. The east North Island coast exhibits two buried soils and the Loisels pumice; the D'Urville Island coast exhibits two buried soils; and the west Auckland coast only one buried soil. The time of first settlement is given most accurately in those sections where a time plane, i.e. one of the two buried soils or the Loisels pumice, is closest to the lowest charcoal.

There is no good evidence for newspaper reports of settlement prior to the Taupo Pumice eruption. As already mentioned there is no trace in any section of Maori occupation below or immediately above the Taupo Pumice. The most recent newspaper report (1960's) is for settlement at Poukawa,an inland site in southern Hawkes Bay. In the last 40 years, ploughing, draining of Lake Poukawa, and cracking of peat, allowed Maori artifacts to drop below the level of Taupo Pumice (see Appendix 3 for writer's report on the site).

Order of first settlement of the North Island and northern South Island

It is likely that Maoris arrived in New Zealand more than 900 years ago, that they had visited all of the coast some 800 years ago, and had occupied all of the favourable parts of the coast 700 years ago. At the time of Maori arrival all inhabitable places were forested, therefore the forest had to be burnt before they could settle. The first charcoal is therefore assumed to represent first settlement as distinct from the first visit to the coast. Stratigraphic dates for the first charcoal are given in Figure 40. If the dates are correct then the Maori first settled North Auckland, the Cook Strait region, and near Kawhia and Aotea harbours. The East Coast and Hawkes Bay were settled later.

It may be seen from Figure 40 that the stratigraphic dates are in substantial agreement with the close radiocarbon dates of early South Island sites. The sites are at Clarence River mouth (site S42/20), the "Old Pier Point Site" (site S49/46) at Kaikoura, and at Oturehua (site S134/1). The date for the Clarence River mouth site determined on shell (NZ 1836B) (M. M. Trotter, pers. comm.) indicates a period of occupation sometime between 895 and 655 years ago. Dates for the Kaikoura site determined on shell (M. M. Trotter, pers. comm.) indicate a period of occupation sometime between 950 and 750 years ago. A date for the Oturehua site determined on twig charcoal (NZ 850C) (Leach, 1969) indicates a period of occupation sometime between 1,000 and 600 years ago.

A Possible Later Settlement of the North Island

The evidence set out above indicates that New Zealand was settled from end to end about 700 years ago. Migration may have continued for several hundred years but the evidence is inconclusive. The possibility of a later settlement is indicated by a "pearl shell" fishing lure found at Tairua (site N44/2) on the Coromandel Peninsula (Green, 1967). The site is closely dated by radiocarbon on shell as 525±70 years

BP (NZ 1875B). Pearl shell occurs in tropical parts of the Pacific but not in New Zealand. If it is assumed to have been used it is unlikely to have survived for the 300 to 400 years that had elapsed from the time of first settlement.

POPULATION CHANGES

The evidence given using Loisels pumice and radiocarbon dating, suggests that all of New Zealand was settled at 700 years BP. The population is estimated at 5,000, based very tentatively on 1 extended family (10 people) at 500 river mouths. From the size of the population, and assuming a doubling time in 20 to 50 years, it is possible to infer a first settlement date of 800 to 1,000 years BP (950 AD to 1150 AD) (Figure 41). This date agrees with the stratigraphic date inferred from the depth of the lowest charcoal.

Assuming a population doubling time of 20 to 50 years, the population about 400 years ago had reached the figure estimated by Forster (1778) some 200 years later (Figure 41). It has been suggested above that moa hunting ceased 300 to 400 years ago, and that agriculture came to an end about the same time in the South Island and southern North Island when large areas of lowland and hill forest were burnt. The important food supplies which remained were shellfish and fish. Already mentioned is the change described by Haast (1874a) from moa hunting to shellfish gathering at Moa-Bone Point Cave; and on D'Urville Island Wellman (1962a) notes a greater emphasis on fishing in the culture associated with the upper occupation layer than in that of the lower occupation layer. About 400 years ago the population stopped growing and the first fortifications were built (Figure 42).

When Cook arrived there were few people south of Gisborne, and the population was in a state of warfare from one end of the country to the other. All of the advantage was to the people in the north, who were the only ones with continuous and regular food supplies.

CULTURE CHANGE

It is generally accepted that there were two cultures in prehistoric New Zealand: an early (Moahunter or Archaic Maori), and a late (Maori or Classic Maori); for convenience the two cultures are called here "Early" and "Late". Figure 43 sets out differences between the two cultures for 30 "fossils" (artifacts plus moa bones).

According to Duff (1956) the early people were moa hunters and did not have agriculture, the late had agriculture but did not hunt moas. However, Wellman (1962a) showed that the early Maori at D'Urville Island did eat moas and did have agriculture, and it has been shown above that the early to late sequence with regard to moas and agriculture is somewhat different in different parts of New Zealand, i.e.

Culture Age	Marginal Areas (southern North Island and northern South Island)	Northern Areas (northern North Island)
Early Tirean	Moa hunting and agriculture	Moa hunting and agriculture
Late Ohuan	No moa hunting, no agriculture	No moa hunting, agriculture

In addition there are changes in food gathering indicating a change in diet: southern South Island and Banks Peninsula (Haast, 1874a,b; and Lockerbie, 1959), from moa hunting to shellfish collecting; D'Urville Island (Wellman, 1962a), from moa hunting and snapper fishing to barracouta fishing; and at Tairua in the North Island (Smart and Green, 1962), from moa hunting and collecting rocky shore shellfish to collecting estuarine shellfish.

The most noteworthy change was in where people lived, which entailed a fundamental change in their way of life. At D'Urville Island the early people lived in sheltered valleys while the later people lived on exposed headlands (look-out points) (Wellman, 1962a). In the North Island, all pa sites are thought to have been built by the later people (Figure 42).

Because of the change in where people lived, there are unlikely to be many sites continuously occupied throughout Maori prehistory and therefore few, if any, single sections contain sufficient artifacts to provide a full record of culture change. The artifact sequence thus has to be determined and dated indirectly.

Plenty of early artifacts, but fewer late artifacts, have been dug up. Late artifacts are mostly from pa (fortified) sites. Figure 43 is an analysis of "fossil" collections (artifacts plus moa bones) from 58 sites grouped as early or late assemblages according to key age fossils. There is only stratigraphic information for 7 sites, all early and, as might be expected, in or below the Tirean buried soil and hence older than 400 years.

Figure 44 shows bar diagrams of radiocarbon dates for closely dated early and late sites. In Figure 45a the early and late bars are summed according to probability, to give probability histograms. The histograms are spread by the standard errors of the dates and, in the case of the younger histogram, by an increase in the range of some dates corrected for secular variation using the Suess curve. Because of the spread the two cultures show a large overlap of several hundred years. When the standard errors and increased ranges are taken into account, Figure 45b is thought to represent the true situation, and shows a maximum overlap of 150 years. Three ways in which the cultural change may have taken place are discussed later.

Duff (1956) recognised most of the key fossils listed in Figure 43. Some exceptions are the early common use of greenstone and barbed fish-hooks in the South Island and southern North Island.

The most difficult change to understand is that from an "adze kit" of several types to a single generalised adze type of simple design. Of some estimated ten thousand adzes in New Zealand museums, more than 95% are now without stratigraphic age. For the Wellington district, of 159 adzes in the National Museum, 76% are early types, 13% are late types, 11% are unclassifiable.

Of the early types, some 75% are made from a distinctive rock found in the Nelson ultra-basic belt, particularly at D'Urville Island, and termed "adzite". Some are made from other rocks, and availability of adzite did not determine adze construction. Of the late types, perhaps some 25% are made from adzite. Adzite is an ideal rock for adzes and it is suggested by Wellman (1962a) that decline in the use of adzite represents a decline in trading caused by increase in warfare.

All the adzes collected by early explorers belong to the single generalised type. From the high percentage of early adzes in the National Museum it is clear that the late Maori could have reused early adzes at European contact but did not. Why he did not would be understood if the early adzes were tapu to him.

There are striking regional differences among the early, but not among the late artifact assemblages. There are many more artifact types in the early southern assemblage, especially south of Banks Peninsula, than in the early northern assemblage. In the southern assemblage, but not in the northern are: barbs on fish-hooks, unperforated lure hook points, slate knives and blade flakes.

If the term "homeland" is used, as "Hawaiki" and "origin" have been (Duff, 1956; Green, 1967), for places where there are artifacts of the same kind and the same age as those in New Zealand, then the "homeland" for the northern North Island is either Tahiti or the Marquesas, and for the southern North Island and South Island, either Hawaii or Easter Island.

Correlation with Tahiti is given by Duff (1956) and Emory and Sinoto (1964); with Marquesas, by Green (1967). That with Hawaii and Easter Island is made by the writer by comparing early South Island artifacts (particularly blades, unperforated lure hook points, and barbed fish-hooks) with those illustrated from sites of the same age in Hawaii by Emory et al (1959), Emory and Sinoto (1969), and Kirch (1975); and in Easter Island by McCoy (1976).

Despite the use of different raw materials in New Zealand and Polynesia, the styles of early New Zealand artifacts closely match those of Polynesia. The early styles persist virtually unchanged for 600 years and then change drastically in less than 150 years.

Three possible models of cultural change are summarised in Figure 46. The first is based on Duff (1956), the second on Green (1963), the third is new.

In the first model there are Moahunters throughout New Zealand, but no agriculture. Then in 1350 AD, the traditional Maori date, The Fleet of some ten canoes arrives with some 100 people in each. They introduce agriculture and new artifacts. The agriculture gives the immigrants prestige and they replace the Moahunters, multiply and spread throughout New Zealand.

The date of 1350 AD, 600 years ago, is some 200 years earlier than the date postulated here for the change. No more than a thousand people could have arrived in The Fleet, and not all went to the same place. It is difficult to understand how The Fleet people could have displaced the Moahunters who would have numbered at least 20,000.

In the second model, there is no "Fleet" unless it marks the first human arrival some 1,000 years ago. Cultural change from early to late is gradual throughout New Zealand, but not necessarily synchronous. Agriculture begins immediately after first settlement and is always more important in the north than in the south.

There is no evidence whatever for the gradual change (Figure 45). It probably took less than a hundred years and could not have taken 200 years.

There are many more artifacts in common between the early southern and late assemblages, than between the early northern and late assemblages, and in the third model, that of the writer, there are three early places of settlement (A, B and C) a thousand years ago, one possible place of later settlement (D) 600 years ago, and a cultural change which moves northward 300 to 400 years ago. Settlements A and B are defined by the different stratigraphic time interval between the lowest cultural charcoal and the Loisels pumice. Settlement C is distinguished from A and B by artifacts. Settlement D is based solely on a "pearl shell" fishing lure from Tairua in eastern Bay of Plenty. Agriculture begins from the time of first settlement, and is almost entirely north of Banks Peninsula, increasing in importance northwards. Moa hunting takes place all over New Zealand and is more important in the south than in the north. There is no warfare and tribes are assumed to have well-defined territories. Moas decrease in numbers due to hunting. Agriculture declines due to forest clearance and unfavourable climate in central New Zealand. The decrease in moas and decline in agriculture cause a cultural and territorial breakdown. Warfare becomes endemic and spreads northwards so that the once peaceful northern agriculturalists become warlike. The late culture develops from the breakdown of the early culture. The northern tribes, with the advantage of climate and food supply, increase and continually invade their less fortunate southern neighbours.

Maori tradition records the southern movement only. But Simmons (1976) has shown that tradition may not be fully reliable for more than 15 generations.

If there had been a movement northwards and then southwards, then there would be an overlap zone in which the cultural sequence would be early northern, early southern, late northern. It may be possible to demonstrate the three-culture sequence by site correlation. Radiocarbon would not be very useful because its resolution is poor with respect to the short time involved, and a more detailed stratigraphy than that described here would be better. Best would be a continually re-occupied site with the three cultures one above the other. As already mentioned, continually re-occupied sites are rare. As the Cook Strait area is likely to be within the overlap zone, and quarry sites attract people over a long time, D'Urville Island would be a good place to look.

CONCLUSIONS

The following table summarises the writer's ideas on the history of New Zealand for the last 900 years. Dates for the first 400 years, from radiocarbon, are probably in error by up to 100 years. The error would be reduced if the soil layers, to which dates are referred, could be better dated.

YEARS BP	YEARS AD	ARTIFACT ASSEMBLAGE	MAORI HISTORY AND POPULATION	VIOLENCE	FOREST VEGETATION	INFERRED EAST COAST CLIMATE
900	1,050		Arrival of c.10^2 at several places in New Zealand from at least two distinct homelands. Moa hunting. Agriculture probable		Burning begins, forest retreats.	Windy Dry
800	1,150					
700	1,250		Population c.5 X 10^3 well distributed around North Island coasts and East Coast of South Island.			
600	1,350	ASSEMBLAGE S_E ASSEMBLAGE N_E	New arrivals at Tairua inferred from pearl-shell lure. Plaggen soils prove agriculture.	No fortifications No stone weapons No cannibalism	Forest advances over burnt areas.	Less Windy Moist
500	1,450					
			Moas becoming rare.			
400	1,550		Population close to upper limit (c.10^5). Agriculture becoming difficult in central New Zealand. Population pressure from south.		Burning continues, forest retreats	Windy Dry
Tasman 300	1,650	ASSEMBLAGE S_L ASSEMBLAGE N_L		Forts Warfare	Burning continues, forest advances	Less Windy Moist
			Population pressure from north.			
200 Cook	1,750		Estimate of population 10^5.	Guns and intense warfare, cannibalism		
100	1,850				Burning accelerates, forest retreats rapidly.	Windy Dry
			Population declines to c.10^4			
000	1,950					

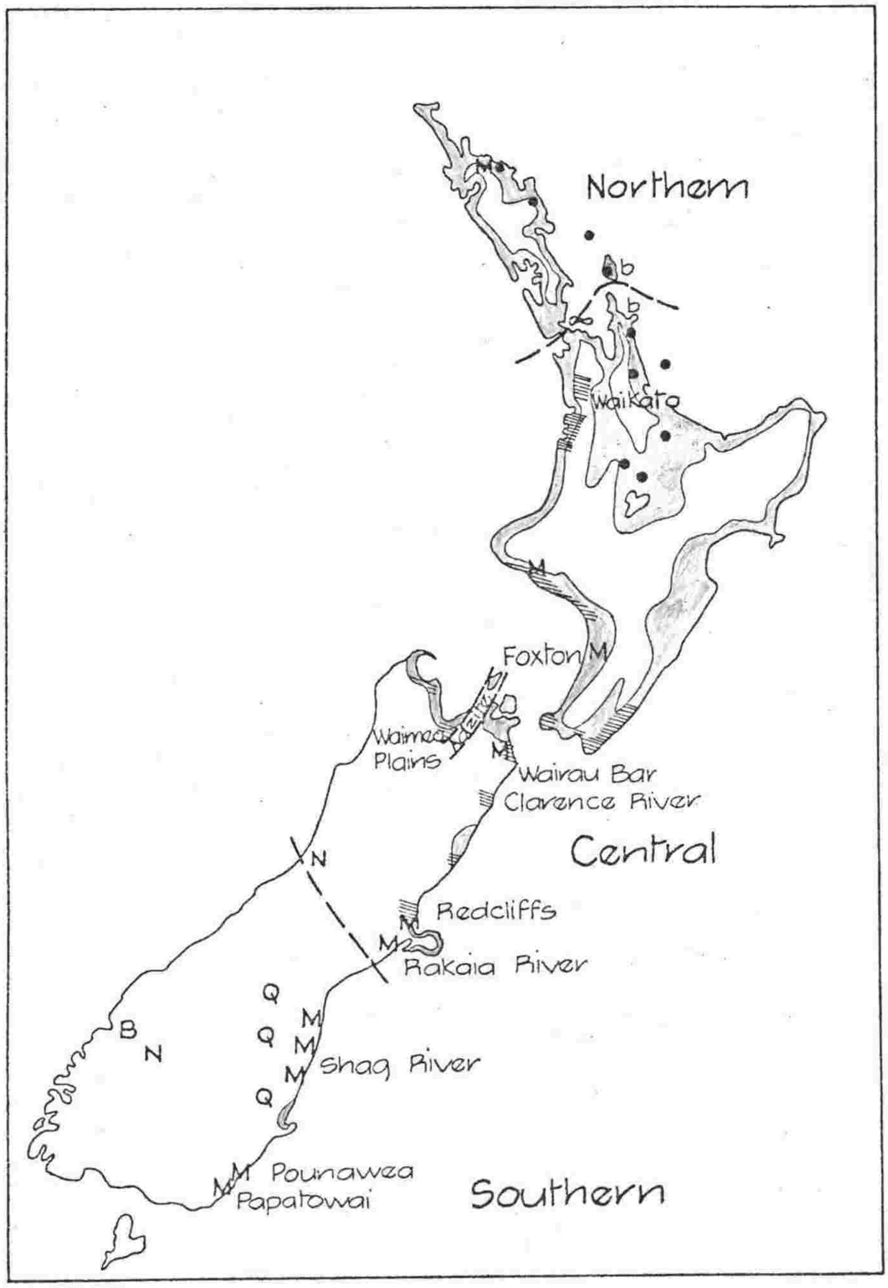


FIGURE 1 - Map of New Zealand showing places of particular interest to Maori archaeology. M = Moa bone middens; Q = Quartzite quarries; N = Nephrite sources; B = Bowenite sources; b = Basalt sources; ● = Obsidian sources; cross-hatching = Garden areas still well defined (central N.Z. only); greyshading = Pa sites.

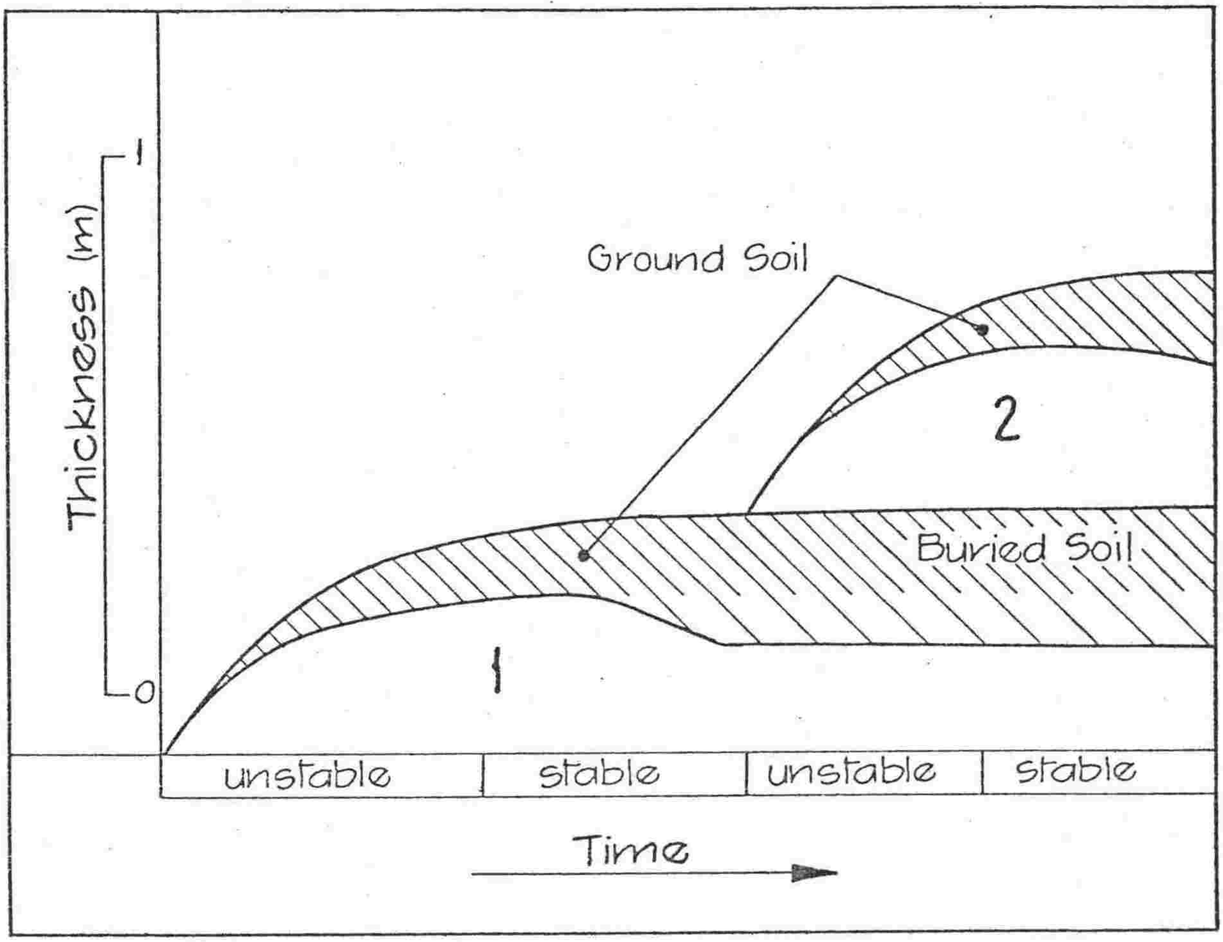


FIGURE 2 - A time-thickness diagram for sand dunes and fans showing two depositional episodes. For each episode deposition was at first rapid and slows to zero. Development of first soil began when first period of depositon slowed down, and ended when second period of deposition began. A soil is first a "ground" soil and then a "buried" soil. Periods of rapid accumulation and little soil formation are termed "unstable" phases; periods of slow accumulation and appreciable soil formation are termed "stable" phases. Thickness represented generally more than one metre.

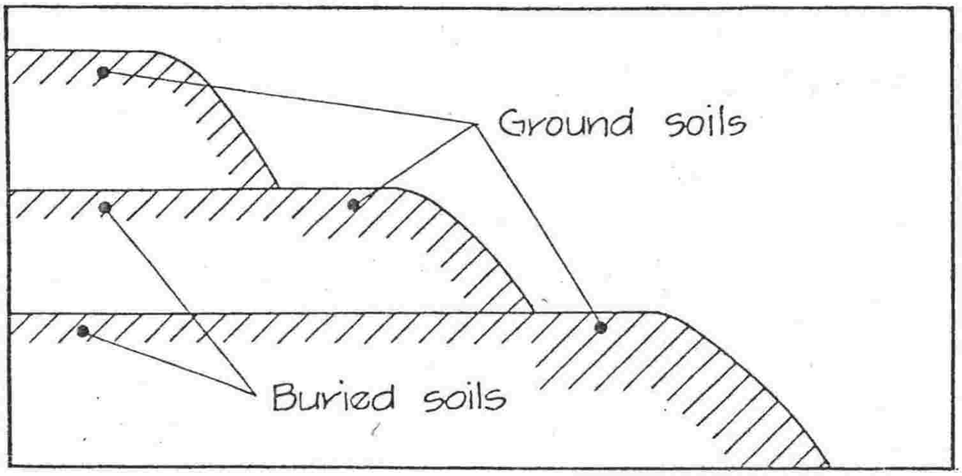


FIGURE 3 - Idealised cross-section of three partly overlapping layers each with its own ground soil. Boundary between layers shown by buried soils. Ground soil development greatest on oldest layer. Degree of soil profile development shown by depth of cross-hatching.

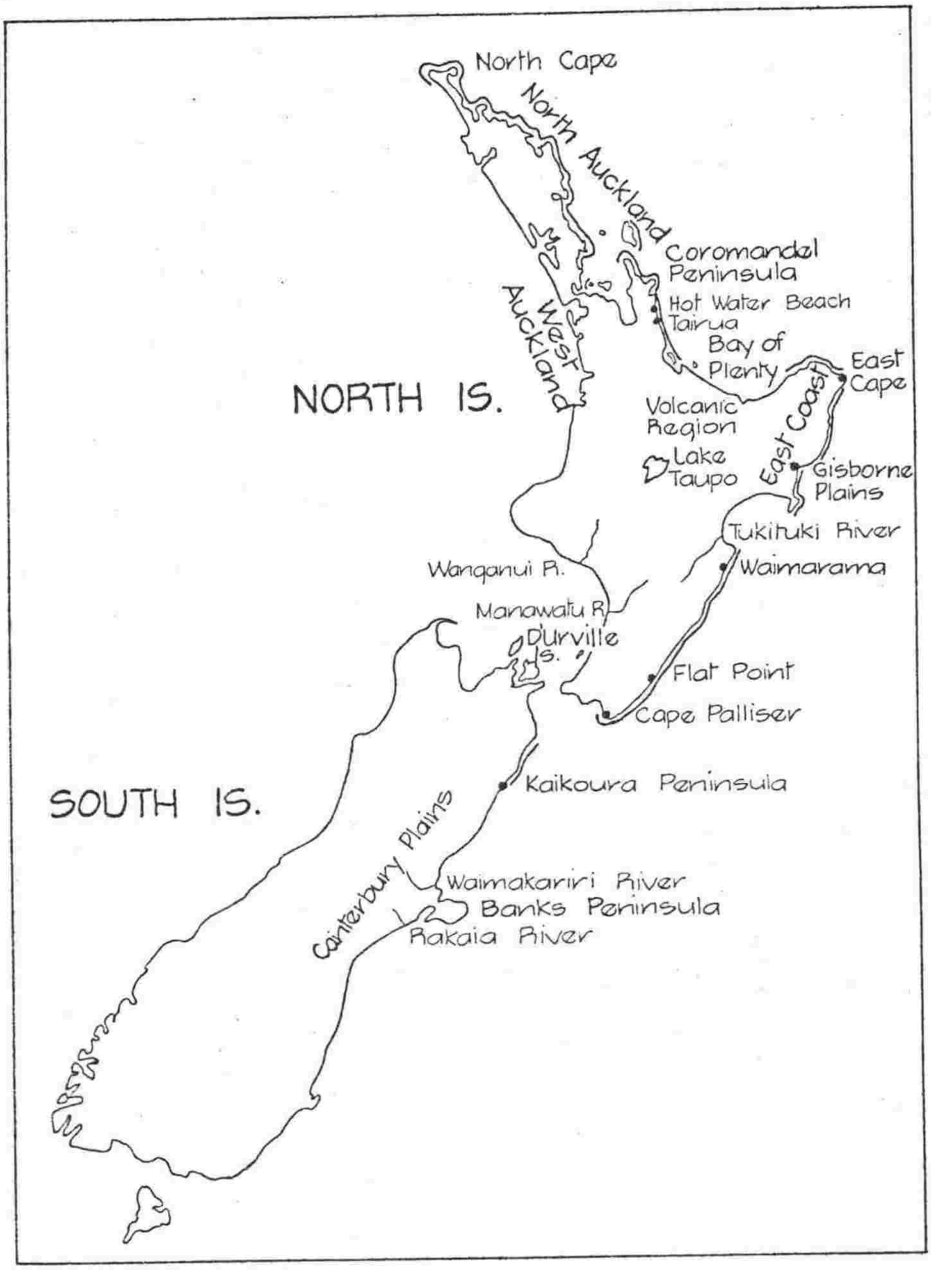


FIGURE 4 - Map of New Zealand showing distribution of Loisels pumice (heavy line) and localities of particular interest to late Holocene stratigraphy.

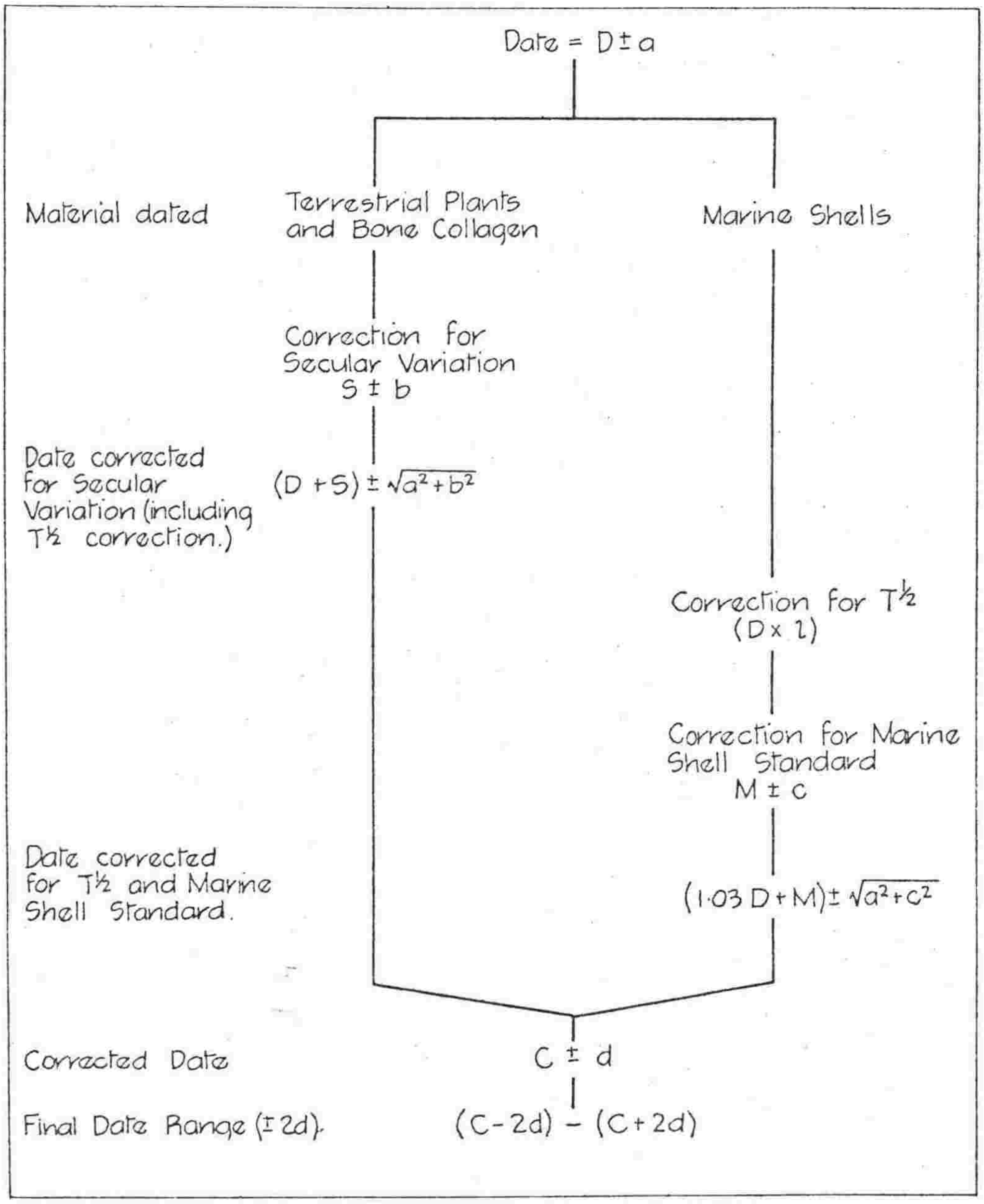


FIGURE 5 - Flow diagram showing steps necessary to convert radiocarbon dates to calendar dates. Terrestrial plants and bone collagen on left hand side; marine shells on right.

D = Radiocarbon Age($T^{\frac{1}{2}}$ = 5,568 years),
a = Counting error,
S = Correction for secular variation using Suess curve,
b = Counting error of Suess curve,
1 = Half-life correction (x 1.03),
M = Correction required to laboratory Marine Shell Standard (-55 yrs),
c = Counting error of correction to Marine Shell Standard,
C = Corrected date (any sample) ($T^{\frac{1}{2}}$ = 5,730 years),
d = Combined counting errors of corrected date (any sample).

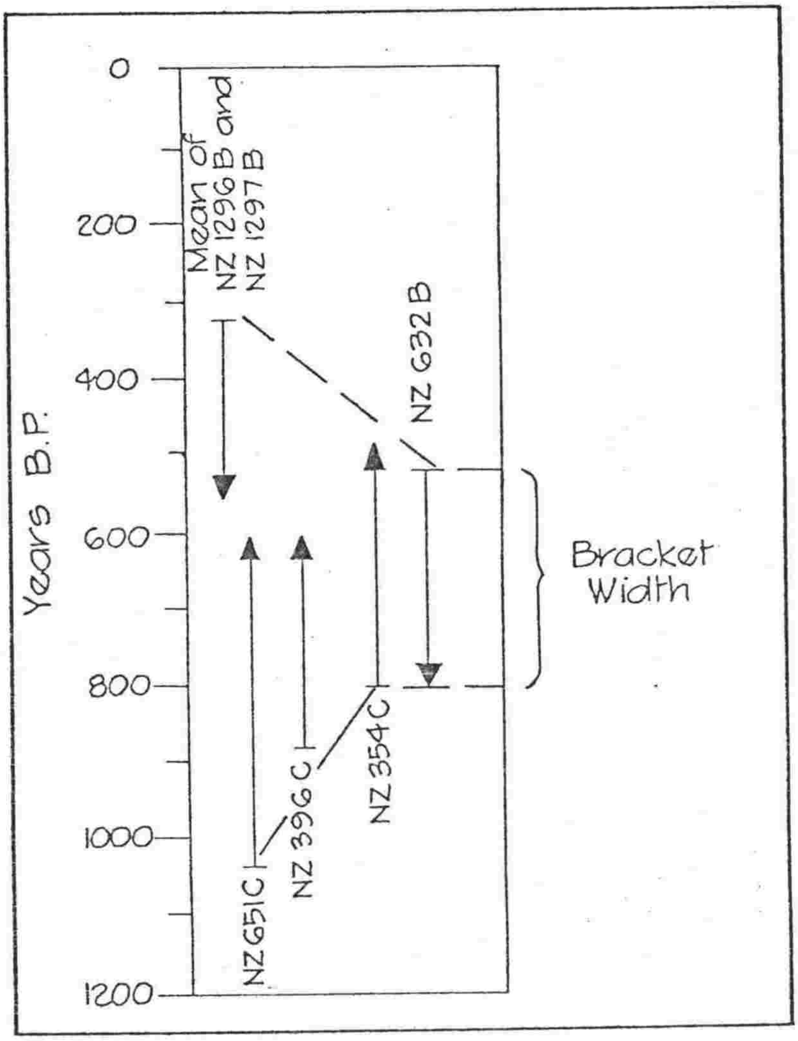


FIGURE 6 - Diagram showing method of determining, by bracketing, calendar age-ranges from corrected radiocarbon dates of events that are dated indirectly. Loisels pumice is the example used. The upward directed arrows are for samples below the pumice, downward directed arrows for samples above. Each arrow length is four standard errors.

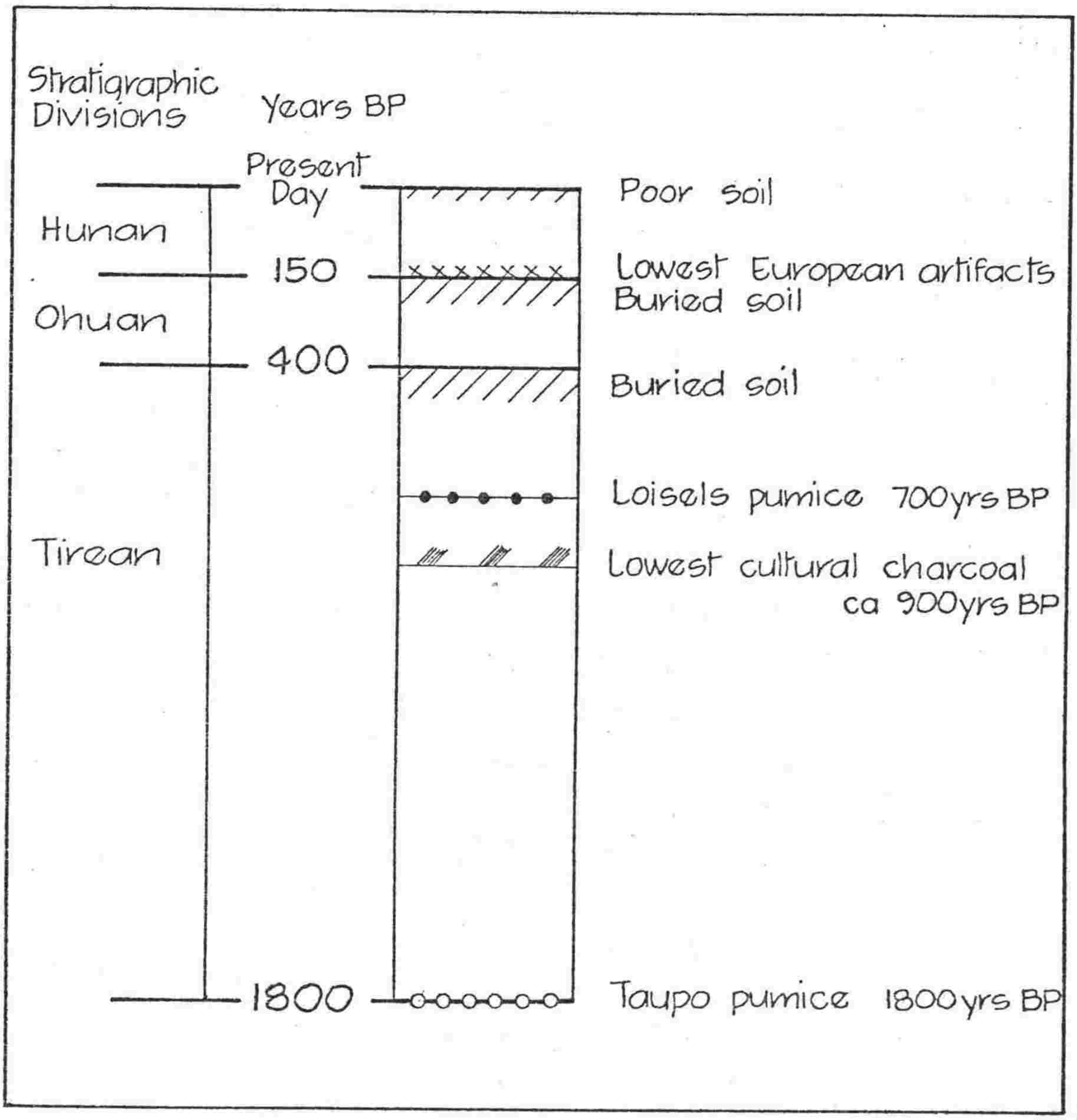


FIGURE 7 - Idealised section showing late Holocene soils and the Loisels and Taupo pumices. Inferred ages in calendar years ago.

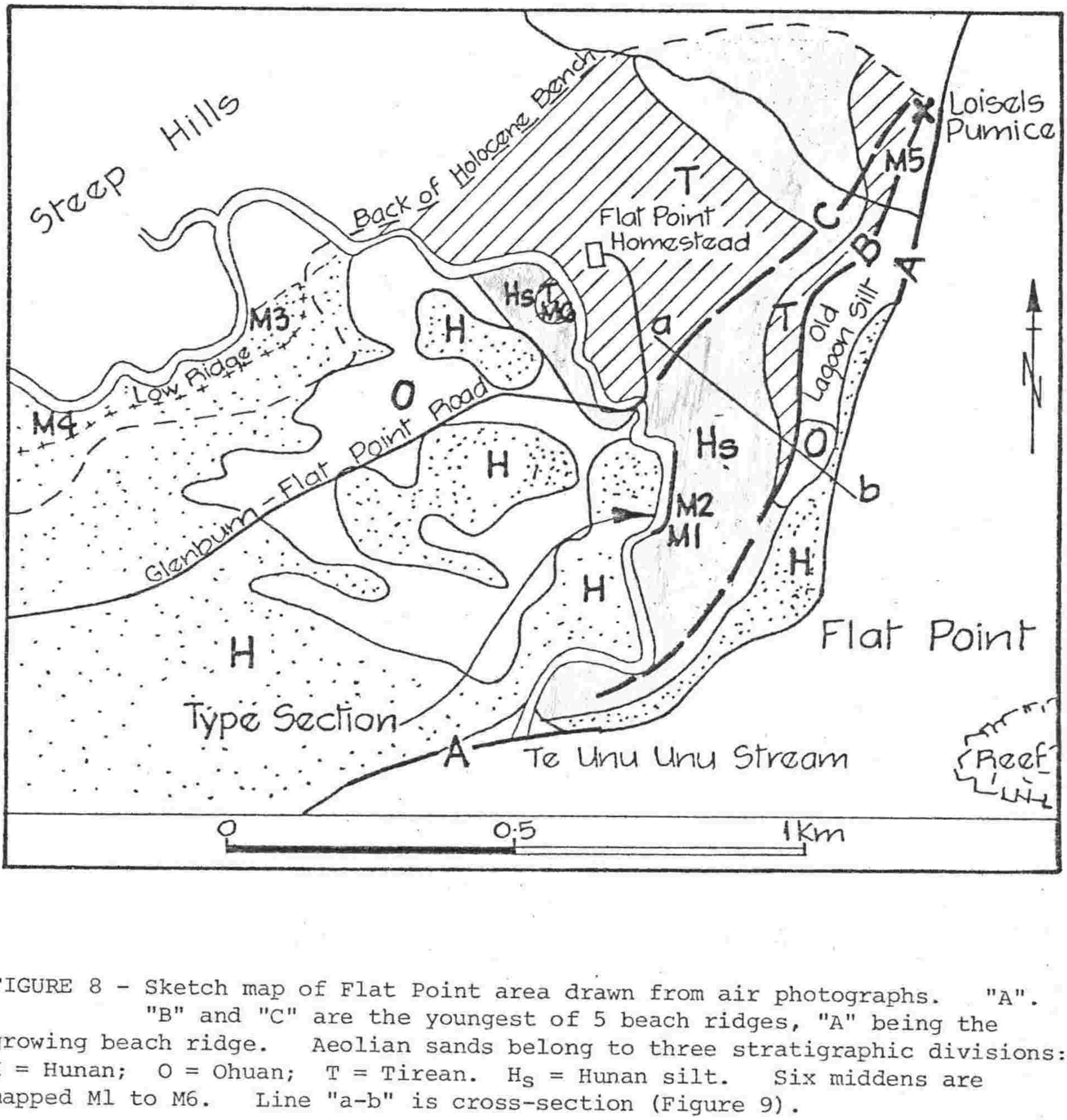


FIGURE 8 - Sketch map of Flat Point area drawn from air photographs. "A". "B" and "C" are the youngest of 5 beach ridges, "A" being the growing beach ridge. Aeolian sands belong to three stratigraphic divisions: H = Hunan; O = Ohuan; T = Tirean. H_s = Hunan silt. Six middens are mapped M1 to M6. Line "a-b" is cross-section (Figure 9).

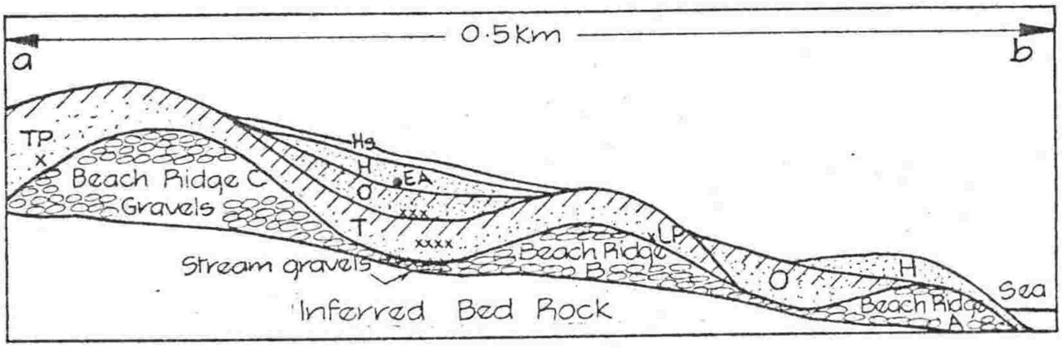


FIGURE 9 - Generalised cross-section along line "a-b" in Figure 8. Symbols as in Figure 8. "xxx" = midden layers; TP = Taupo pumice; LP = Loisels pumice; EA = European artifacts. Soils shown cross-hatched.

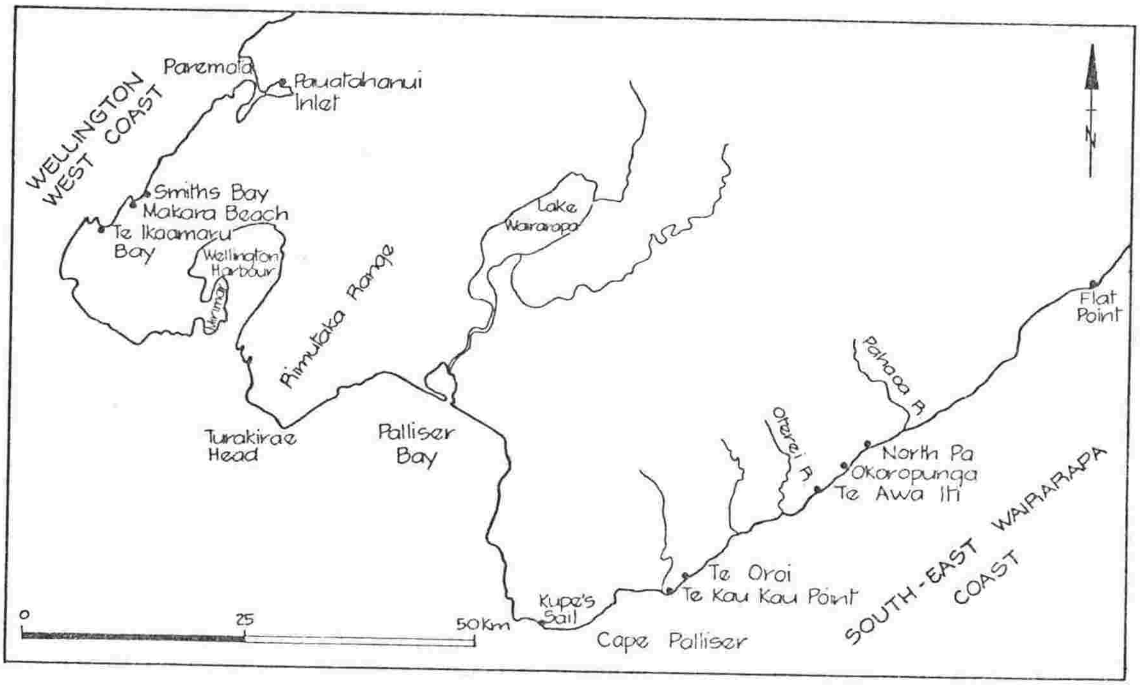


FIGURE 10 - Map of southern part of North Island showing sites (infilled circles) with late Holocene sections.

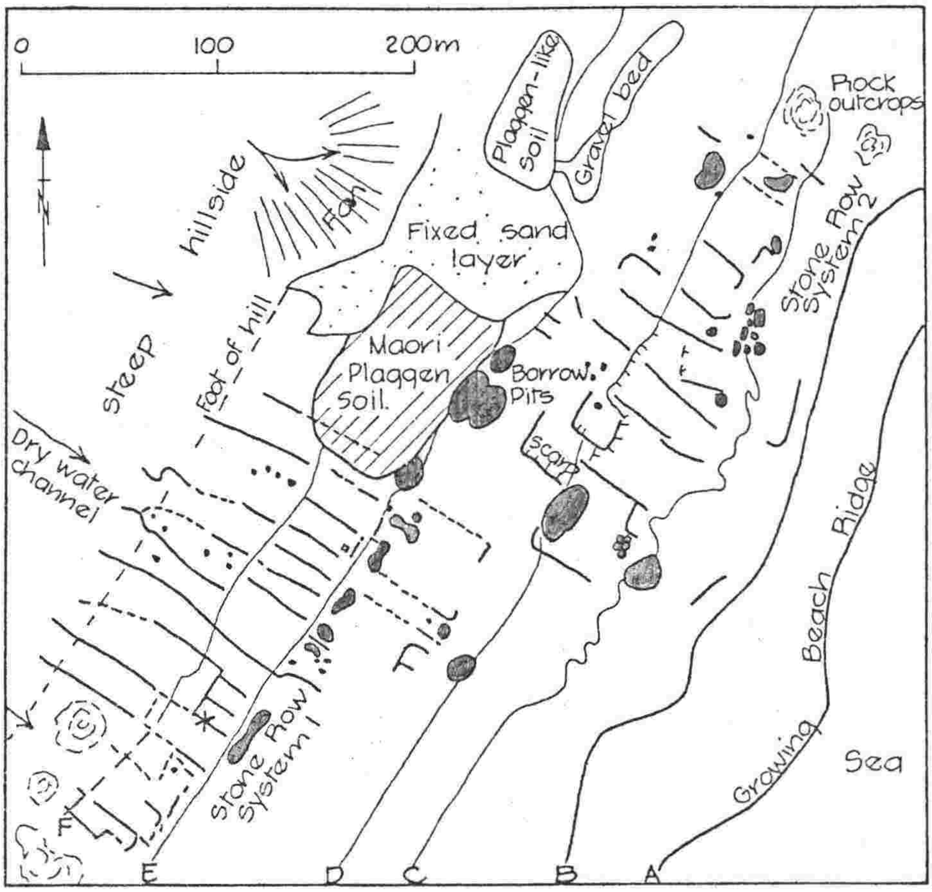


FIGURE 11 - Sketch map of Okoropunga site (N166/55: Grid Ref. N166(1957) /133033) between Oterei and Pahaoa Rivers, showing positions of beach ridges A to F (light lines), stone rows (heavy lines, and broken heavy lines for disturbed stone rows), stone mounds (heavy dots), borrow pits (grey shading), and Maori Plaggen and Plaggen-like soils. Excavated stone row shown by a cross.

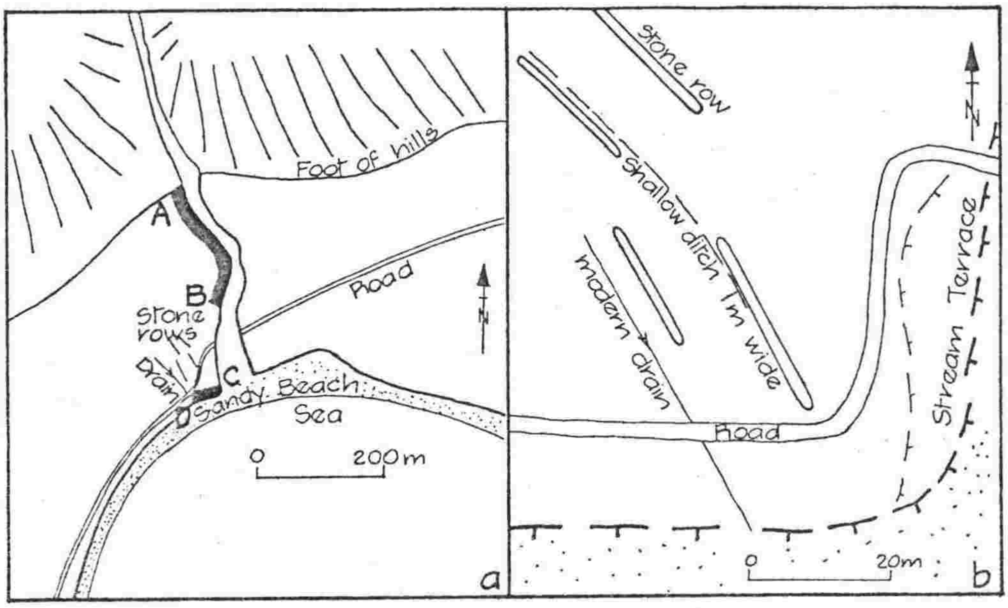


FIGURE 12 - Diagram for sections and stone rows at Te Awa Iti site (N166/67: Grid Ref. N166(1957)/104013).

Fig.a. Locality diagram. A-B = Section 2; C-D = Section 3. For diagram of Section 3, see Figure 1 in Appendix 4.

Fig.b. Sketch plan of stone rows.

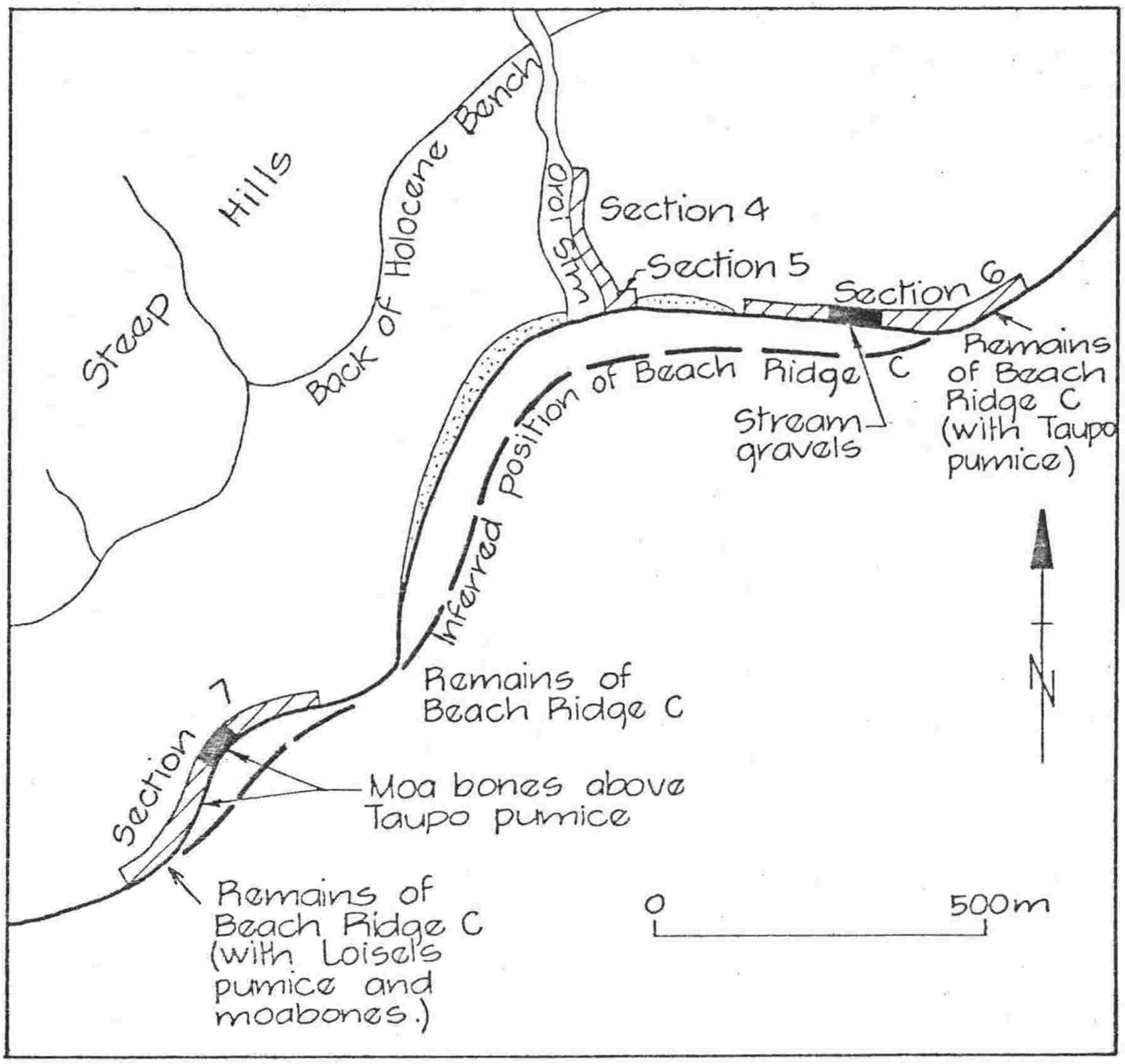


FIGURE 13 - Sketch map of Te Oroi showing locations of sections 4 to 7. The parts of sections 6 and 7 shown solid are illustrated in Figure 1 in Appendix 4. Section 6 contains stream gravels and wind-blown sand interbedded with lagoon muds, and Taupo pumice in remains of Beach Ridge C, but no moa bones. Section 7 contains Taupo pumice and moa bones, but no interbedded terrestrial deposits.

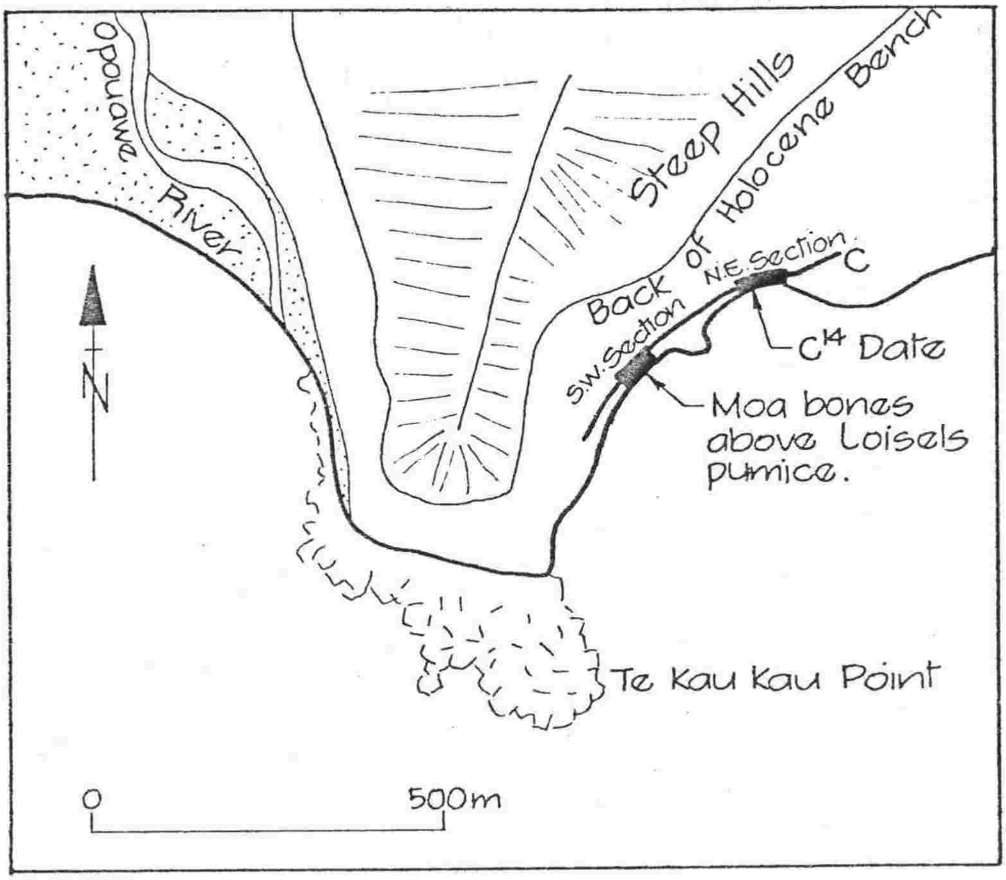


FIGURE 14 - Sketch map of Te Te Kau Point showing locations of two sections identical except for basal part: NE section (= Section 8) with peat, and radiocarbon-dated shells; SW section with numerous moa bones in mud above Loisels pumice. Line C = Beach Ridge C. For diagram of NE section see Figure 1, Appendix 4.

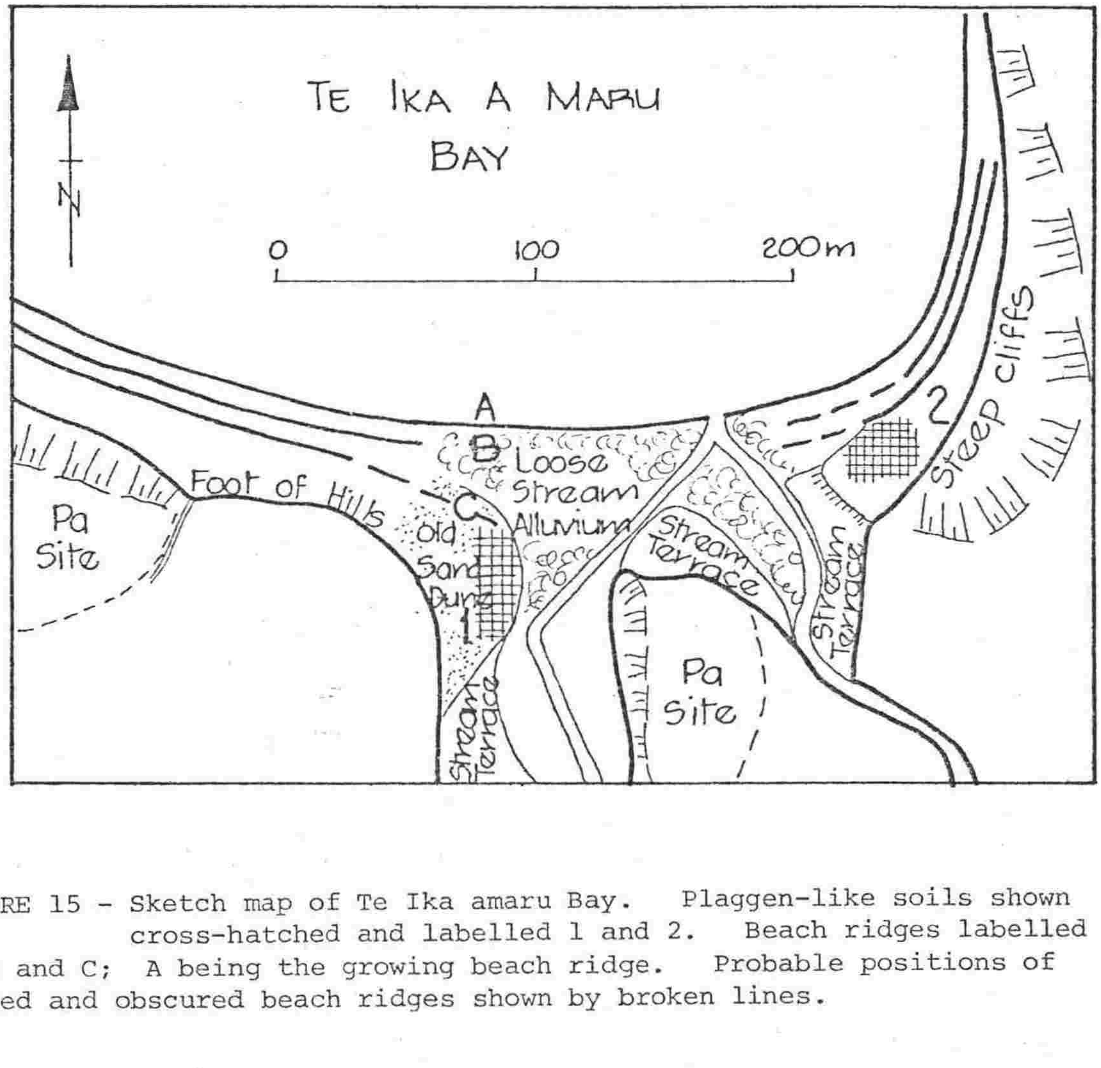


FIGURE 15 - Sketch map of Te Ika amaru Bay. Plaggen-like soils shown cross-hatched and labelled 1 and 2. Beach ridges labelled A, B and C; A being the growing beach ridge. Probable positions of eroded and obscured beach ridges shown by broken lines.

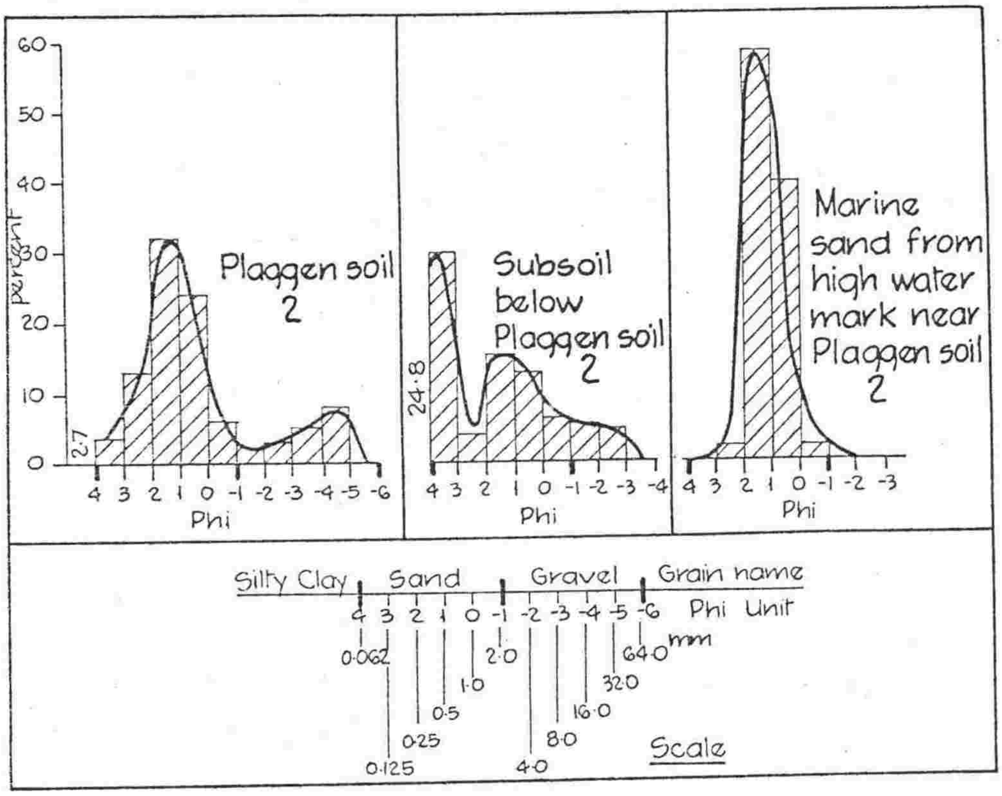


FIGURE 16 - Particle-size histograms to show similarity between Plaggen-like soil 2 and marine sand from high water mark at Te Ika amaru Bay. Note the difference between the Plaggen-like soil and its subsoil. All bars represent one phi unit (= $-\log_2$ diameter in mm). Bar heights in percent. Percentage of sample smaller than smallest phi unit measured is shown at left hand end of histogram. Percentages determined by dry seiving.

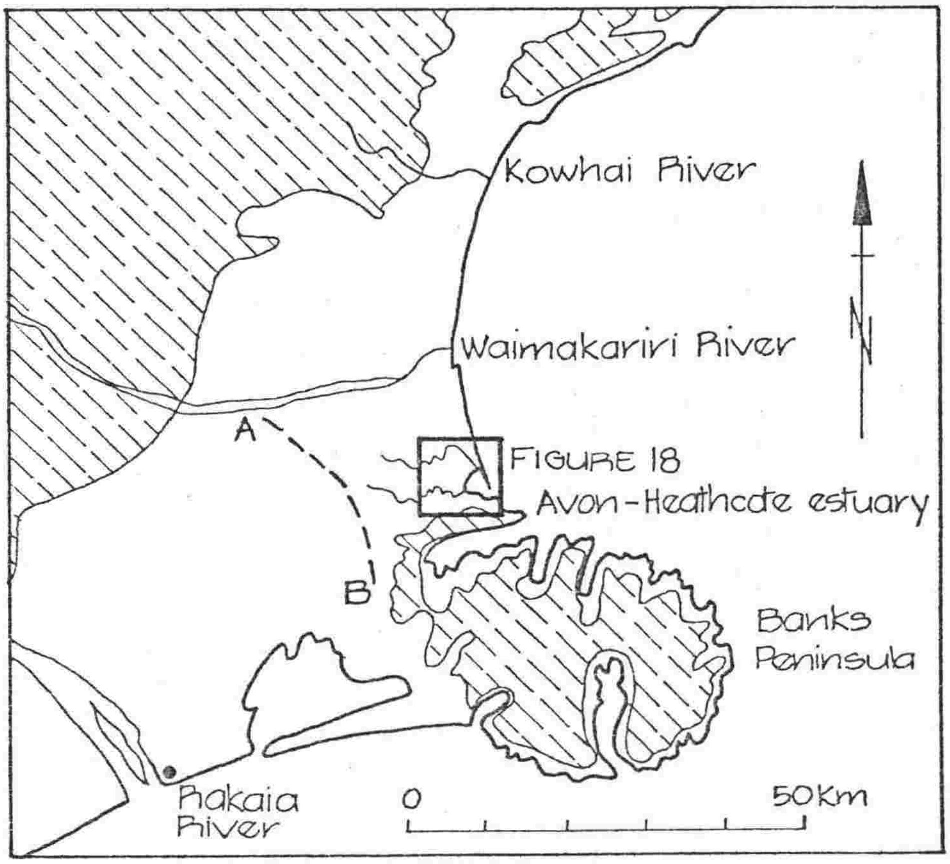


FIGURE 17 - Sketch map of central Canterbury Plains. Land above 450 m shown broken cross-hatching. A-B = approximate position of old river channel occupied by Waimakariri River twice in last 1,000 years (dating from Cox and Mead, 1963). Moahunter site at Rakaia River mouth shown by heavy dot.

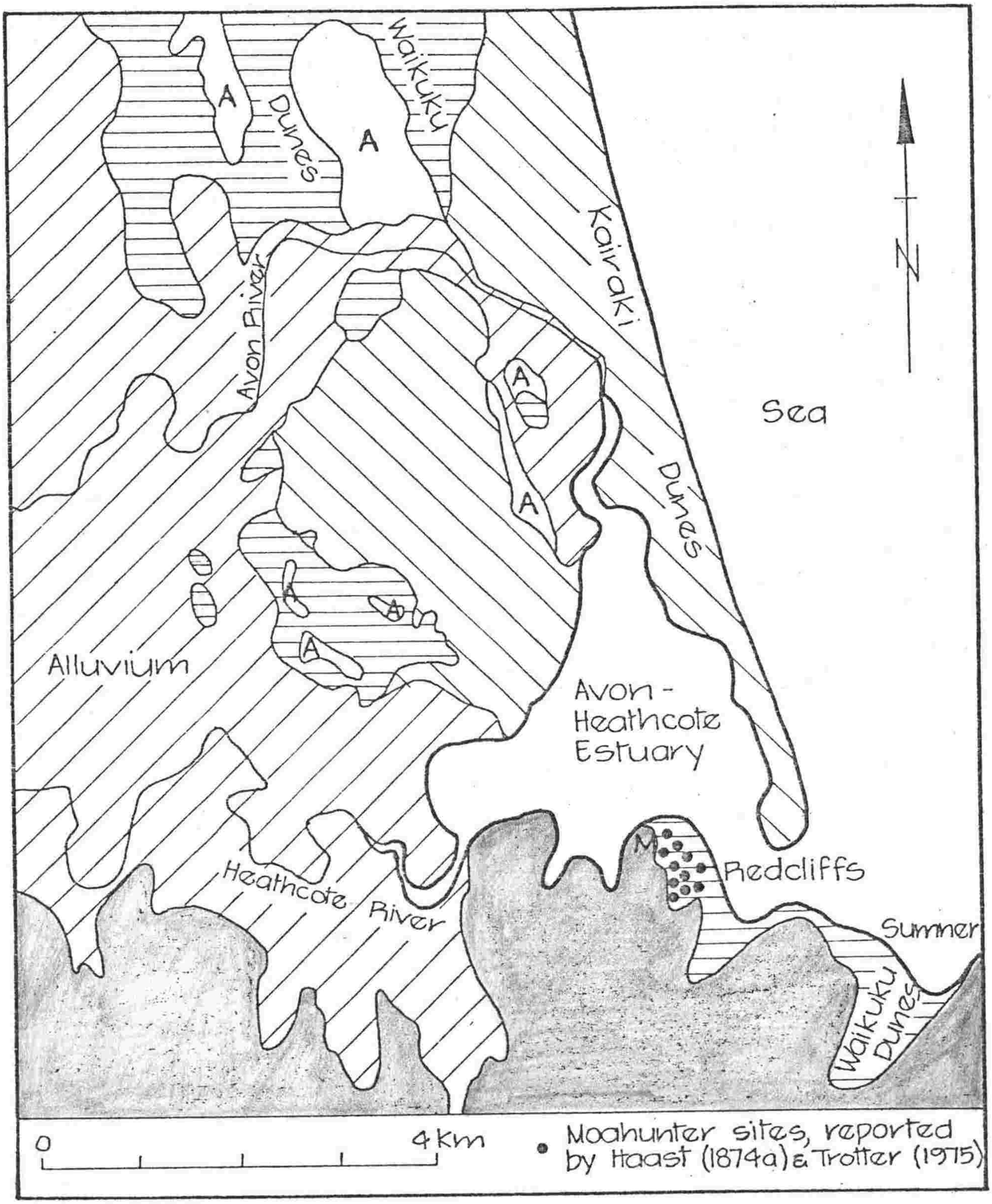


FIGURE 18 - Sketch map of Avon-Heathcote estuary and coast north of Banks Peninsula showing dune belts inferred from soil data in New Zealand Soil Survey Report No. 16 (Raeside and Rennie, 1974): Waikuku dunes (older) defined by Waikuku sandy loam, and soils of Aranui complex (A); Kairaki dunes (younger) defined by Kairaki sand. M = Moa-Bone Point Cave. Hills in Banks Peninsula volcanic rocks shown grey.

Occupation Layer	Corrected radiocarbon dates on charcoal (Years BP)	Stratigraphic Layer		Corrected radiocarbon dates on shells (Years BP)	
				Cockles	Tuatuas
II	$(180-240)^{+65}_{-105}$ (above oven)	Shell lens	4	810 ± 80 800 ± 65	
		Shell lens	3	620 ± 70	320 ± 65
	560 ± 85 (below oven)	Shell lens	2	620 ± 70	
I		Buried soil	▨		
		Shell lens	1	730 ± 65	550 ± 70
		Buried soil	▨		

FIGURE 19 - Diagram showing corrected radiocarbon dates for occupation layers I and II at Foxton site (N148/1). Dates arranged in stratigraphic order. Charcoal dates from above and below an oven in Occupation Layer II; shell dates from one shell lens in Occupation Layer I, and three shell lenses in Occupation Layer II. Details of dates given in Table 2. Note buried soil between occupation layers.

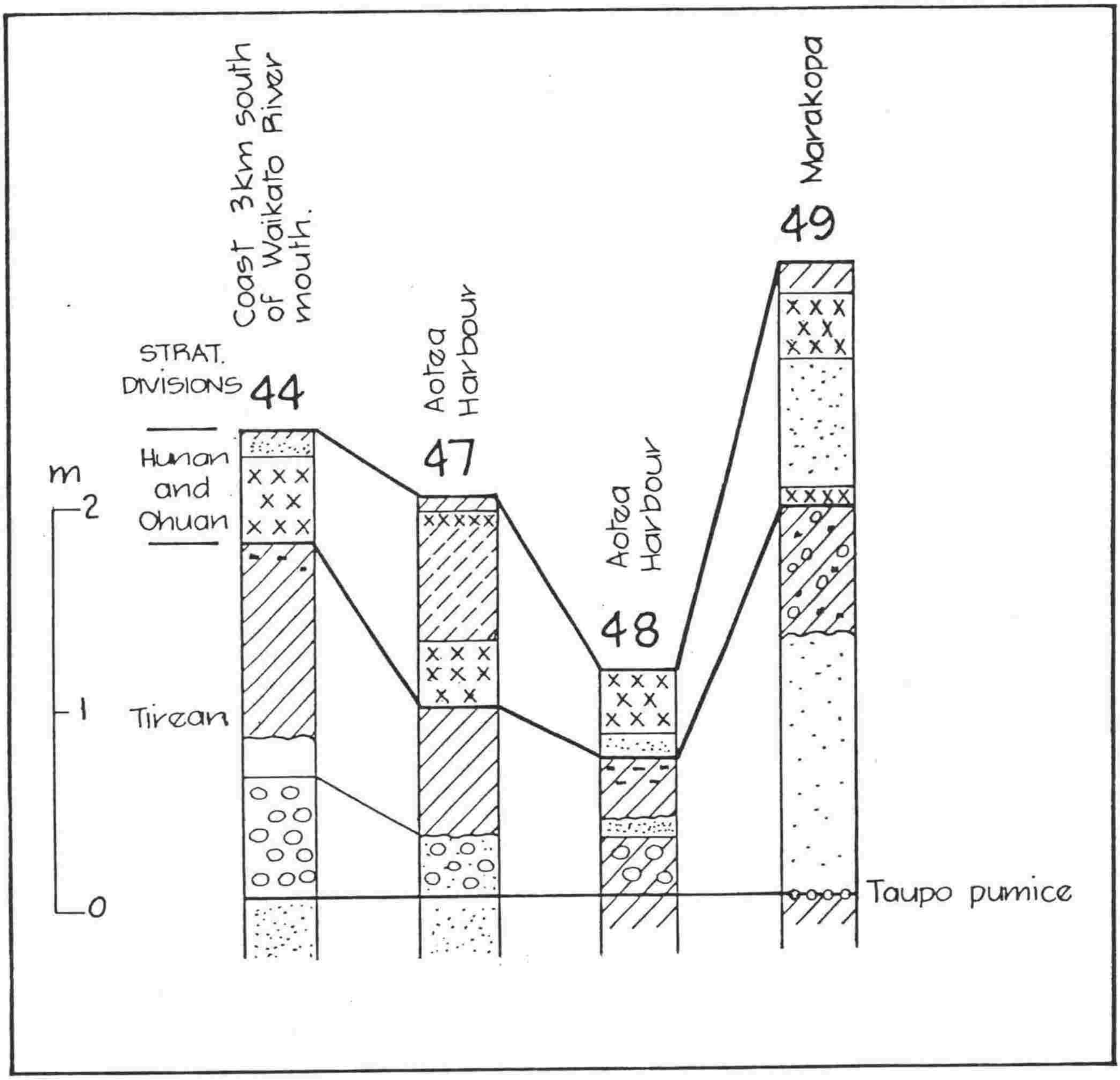


FIGURE 20 - Application of writer's proposed Stratigraphic Divisions to Wellman's (1962b) West Auckland coastal Holocene sections most important to archaeology. Section numbers from Wellman (1962b). Symbols as for Figure 21. Note absence of Loisels pumice and Ohuan soil.

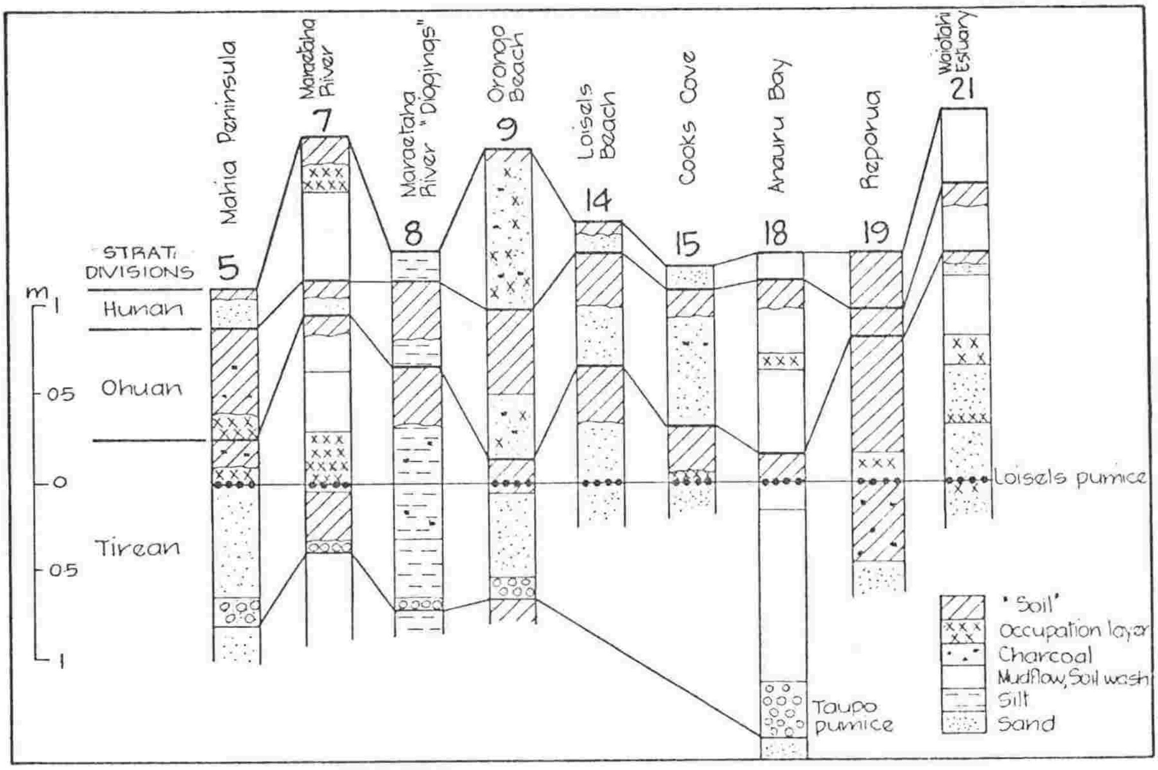


FIGURE 21 - Application of writer's proposed Stratigraphic Divisions to Wellman's (1962b) East Coast and Bay of Plenty coastal Holocene sections most important to archaeology. Section numbers from Wellman (1962b).

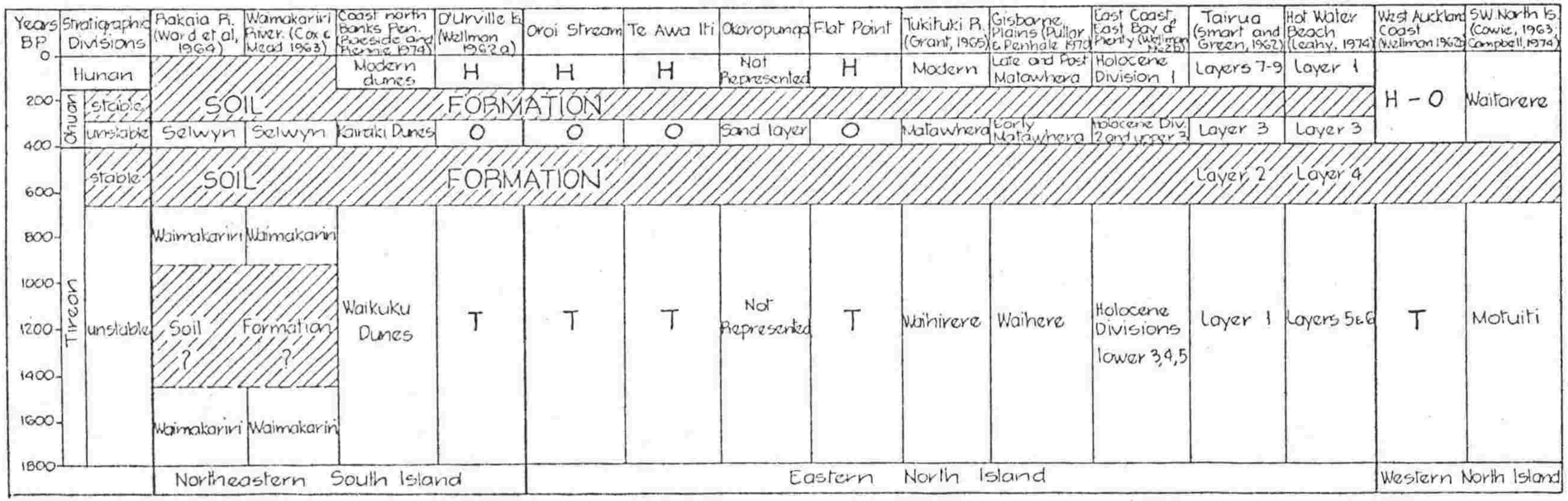


FIGURE 22 - Columns showing adopted age divisions for late Holocene deposits of the North Island and northeastern part of the South Island.

Divisions thus: H = Hunan; O = Ohuan; T = Tirean. Sites first described by authors at head of columns, and the authors' formation names are given in columns, except for Banks Peninsula where the dune phases were not named.

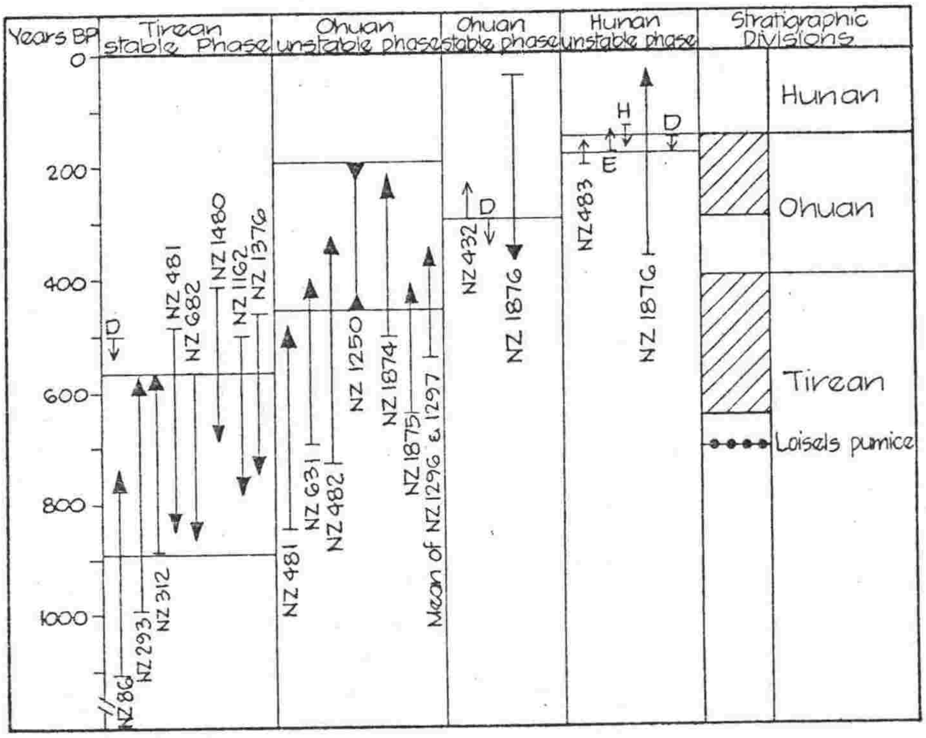


FIGURE 23 - Diagram showing calendar age ranges for key stratigraphic events: beginning of Tirean stable phase, Ohuan unstable phase, etc. Included are all known tree-ring dates (D), all historic dates (H), and all corrected radiocarbon dates within a bracket width of 700 years. Arrow heads indicate three kinds of dates: upward-pointing = maximum dates; downward-pointing = minimum dates; inward-pointing = closed dates. Arrow length equals four standard errors. Two dates (NZ 432 and 483) were reported as being younger than "X" years and cannot be given a standard error. European artifacts (E) used to indicate a maximum age of 180 years.

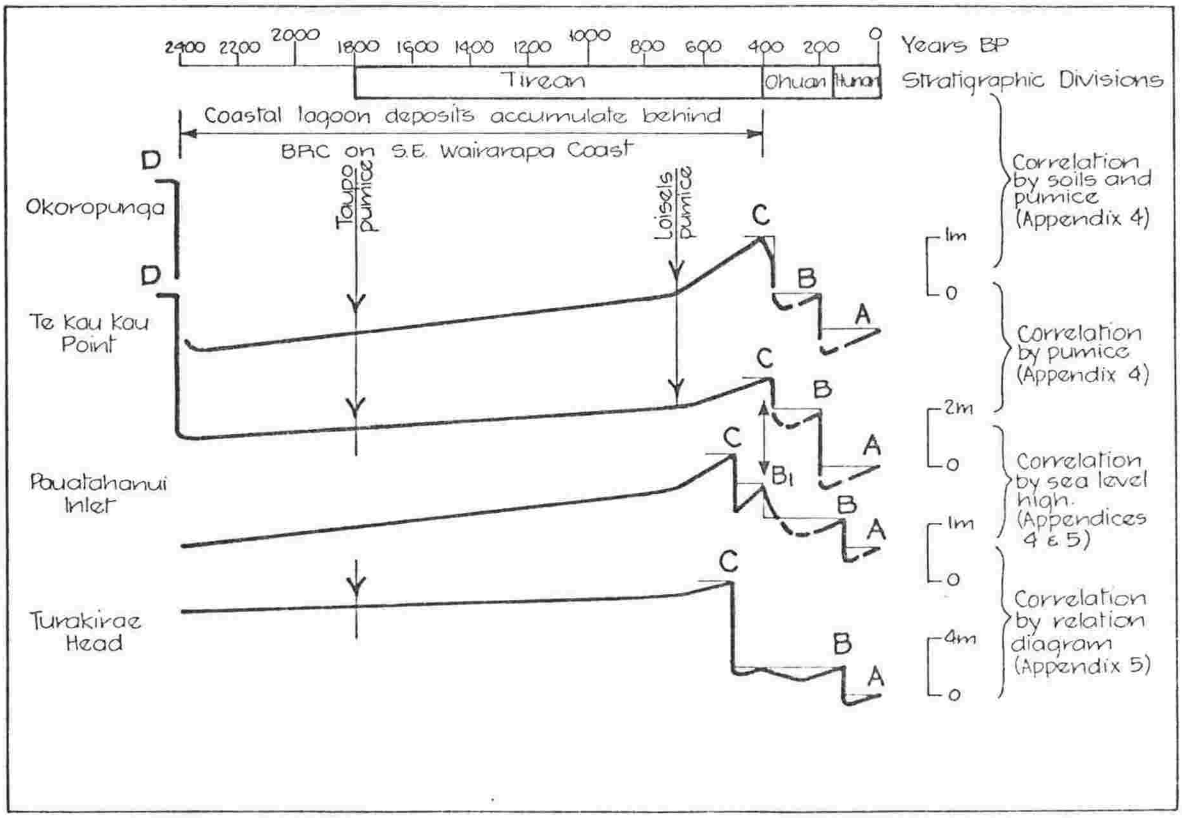


FIGURE 24 - Shore-line displacement curves for four places on the southern North Island coast. Curves used for late Holocene correlation. For each curve note that the vertical axis represents measured displacements, and the horizontal axis estimated time. Beach ridge deposits lettered A, B and C, etc.

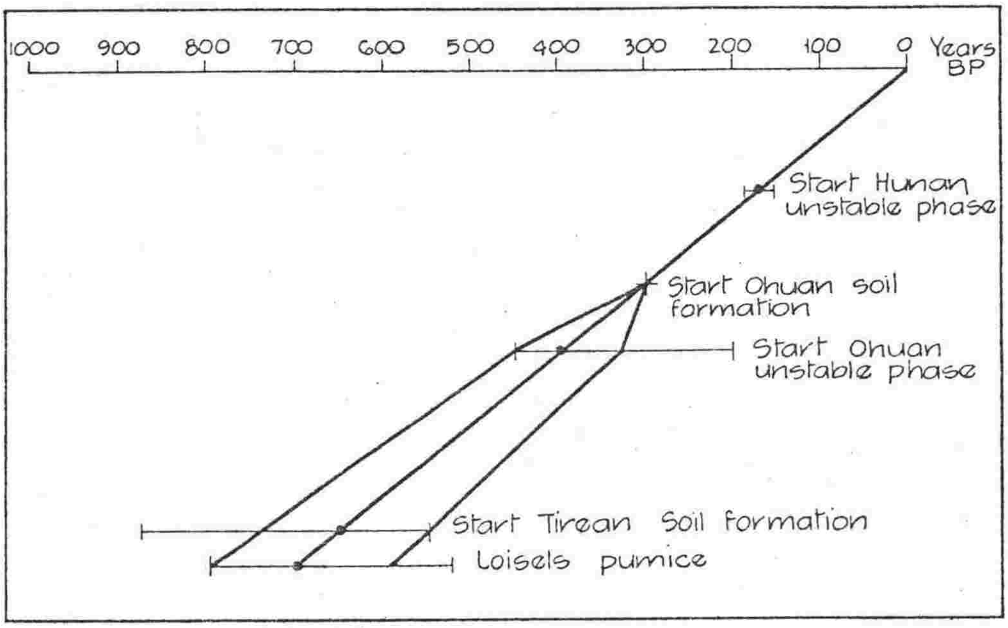


FIGURE 25 - Corrected radiocarbon age ranges and stratigraphy combined to give calendar ages and age ranges to key stratigraphic events. Vertical scale arranged to make adopted ages fall on a straight line.

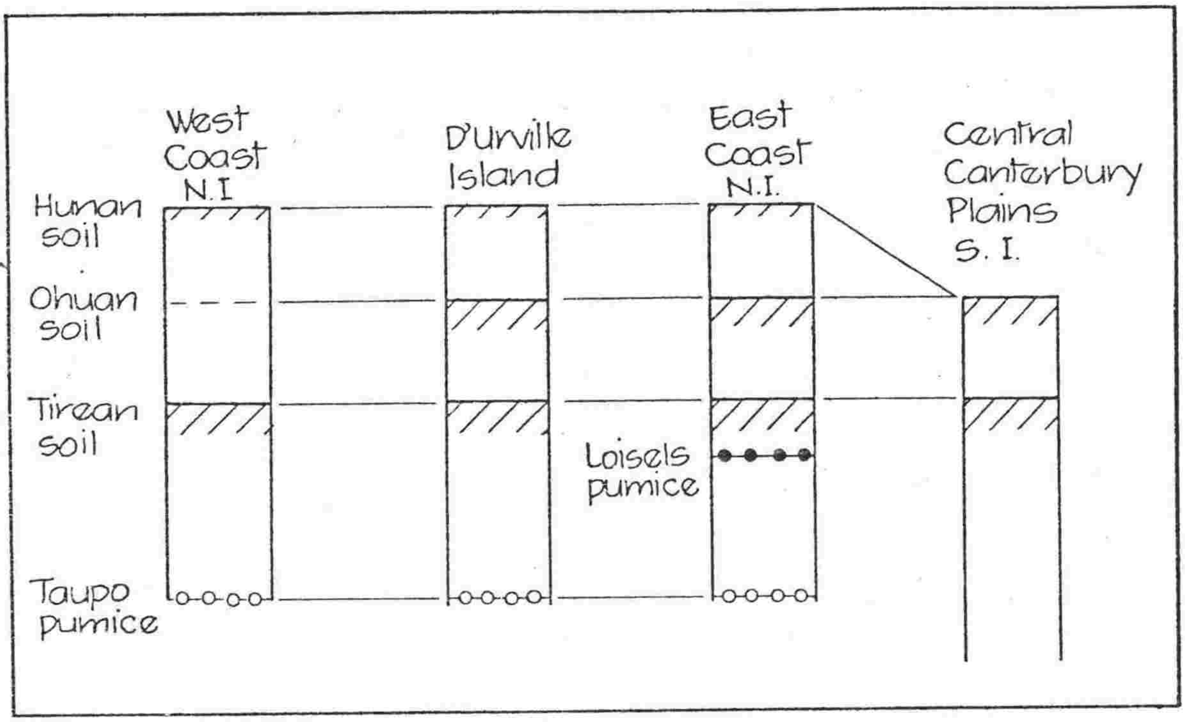


FIGURE 26 - Four columns to show the soils present on the west coast of the North Island; east coast of the North Island; D'Urville Island; and the central part of the Canterbury Plains, South Island.

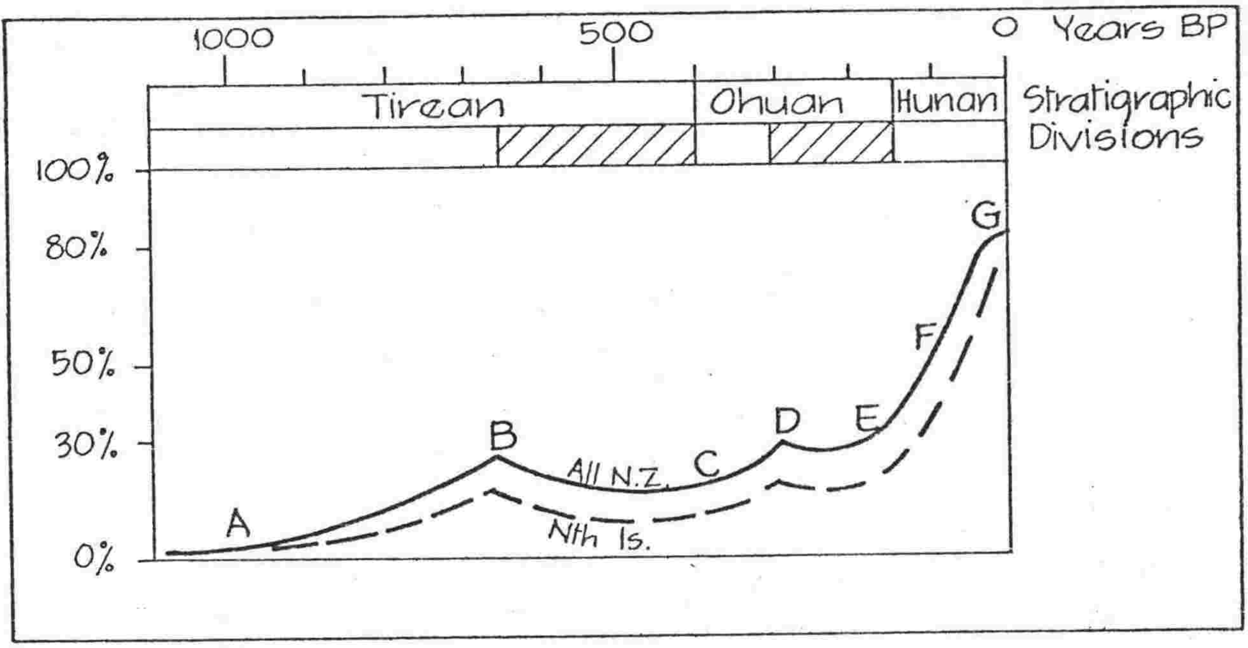


FIGURE 27 - Diagram showing estimated rate of forest clearance from New Zealand plains and hills. Solid line = all New Zealand; broken line = North Island only. Letters mark times of important events:
A = human settlement and probable introduction of cultivated plants;
B = start of Tirean stable phase; C = start of Ohuan unstable phase;
D = start of Ohuan stable phase; E = introduction of "Irish" potato;
F = date of European settlement (1840); G = "present day" decline in forest clearance. Area of cleared forest in 1840 and at present day according to Wendleken (1976). Stable phases of stratigraphic divisions shown cross-hatched.

FIGURE 28 - Map of North Island showing forest, scrub and grass boundaries at 1840 generalised from Holloway (1962). Dots mark sites where pre-1840 vegetation changes have been reported (for details, see Table 4).

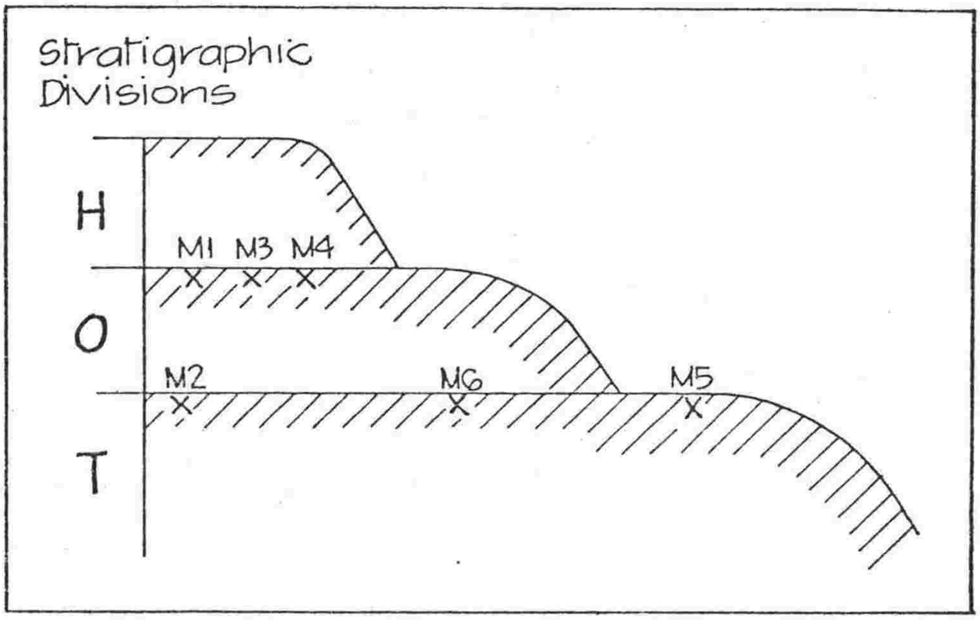


FIGURE 29 - Diagram showing stratigraphic divisions, soils and middens at Flat Point. Soils cross-hatched. Middens lettered M1 to M6. Snails from middens show evidence of forest on Tirean soil and no evidence of forest on Ohuan soil (snails listed in Figure 30).

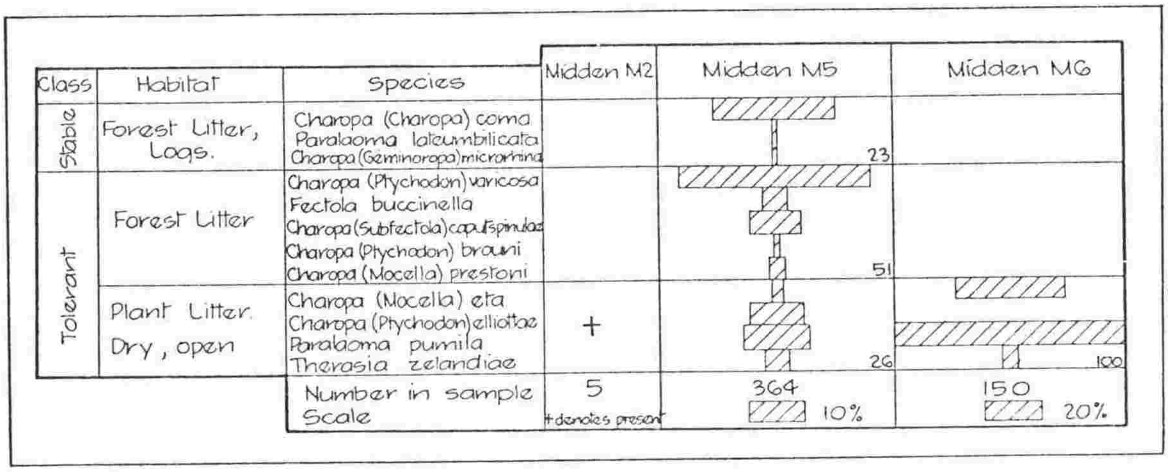


FIGURE 30 - Percentage abundance of different species of landsnails from samples of shell middens in Tirean soil at Flat Point. Species divided into three habitats and two classes. Percentage abundance shown by boxes on right hand side. Midden numbers same as Figure 29.

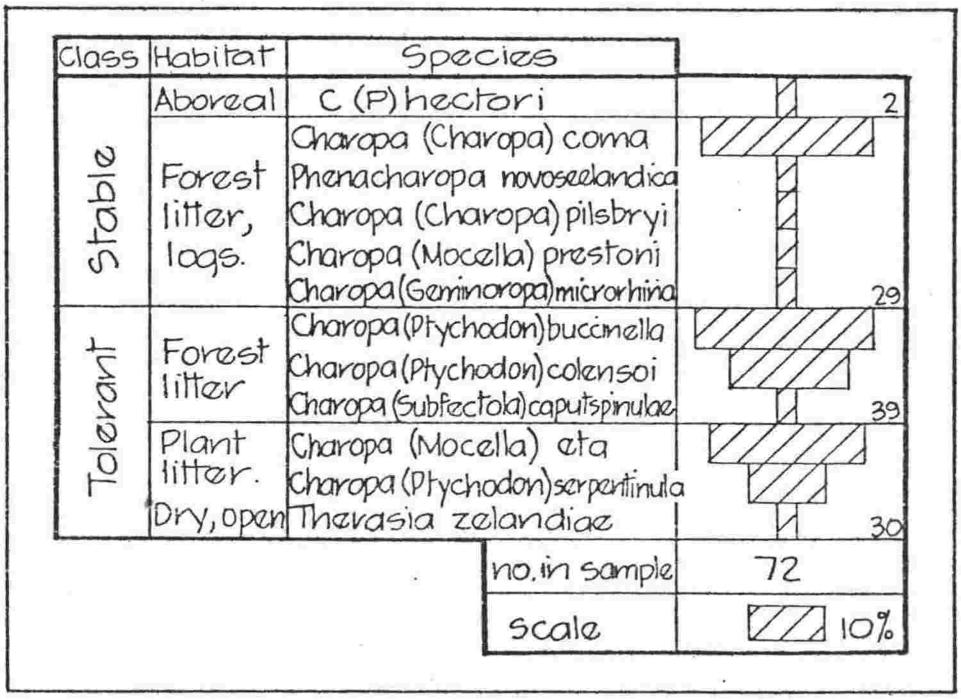


FIGURE 31 - Percentage abundance of different species of landsnails from a sample of shell midden in Tirean soil at Te Awa Iti site (N166/67). Species divided into four habitats and two classes. Percentage abundance shown by boxes on right hand side.

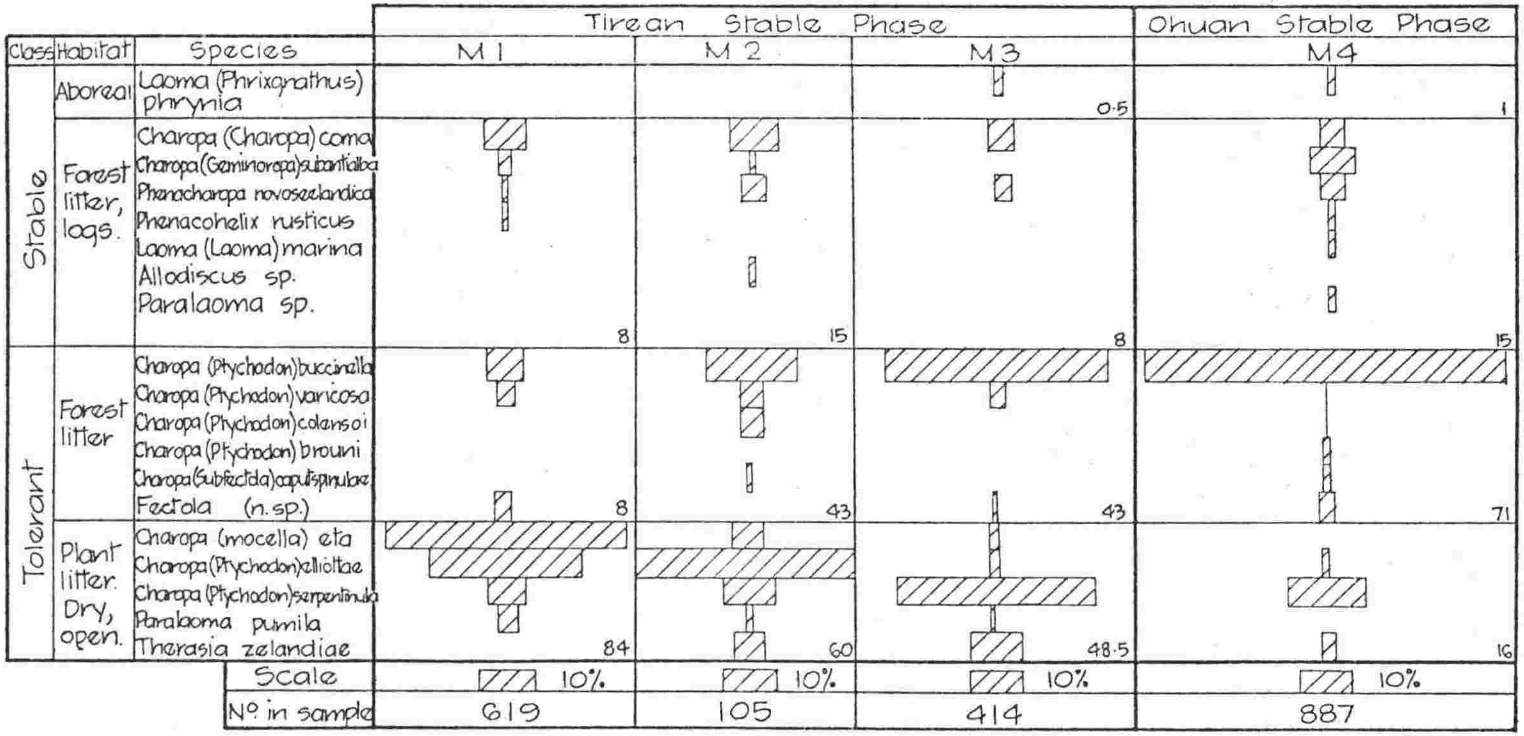
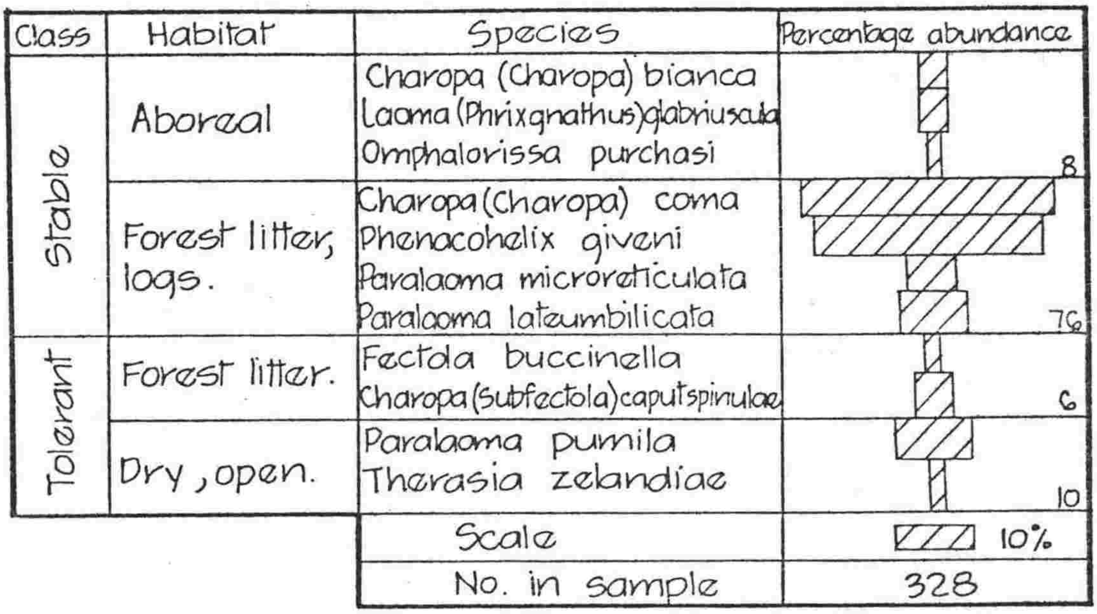


FIGURE 32 - Percentage abundance of different species of landsnails from samples of shell middens (M1 to M4) in Tirean and Ohuan soils in the left bank of the Oroi Stream. Species divided into four habitats and two classes. Percentage abundance shown by boxes on right hand side. M1 = site N168/131 (45 m from stream mouth); M2 and M4 = site N168/134 (100 m from stream mouth); M3 = site N168/133 (75 m from stream mouth).



Class	Habitat	Species	Percentage abundance
Stable	Aboreal	Charopa (Charopa) bianca Laoma (Phrixgnathus) glabriuscula Omphalorissa purchasi	8
	Forest litter, logs.	Charopa (Charopa) coma Phenacohelix giveni Paralaoma microreticulata Paralaoma lateumbilicata	76
Tolerant	Forest litter.	Fectola buccinella Charopa (Subfectola) caputspinulae	6
	Dry, open.	Paralaoma pumila Therasia zelandiae	10
		Scale	▨ 10%
		No. in sample	328

FIGURE 33 - Percentage abundance of different species of landsnails from a sample of late Tirean peat at the Te Kau Kau Point section. Species divided into four habitats and two classes. Percentage abundance shown by boxes on right hand side.

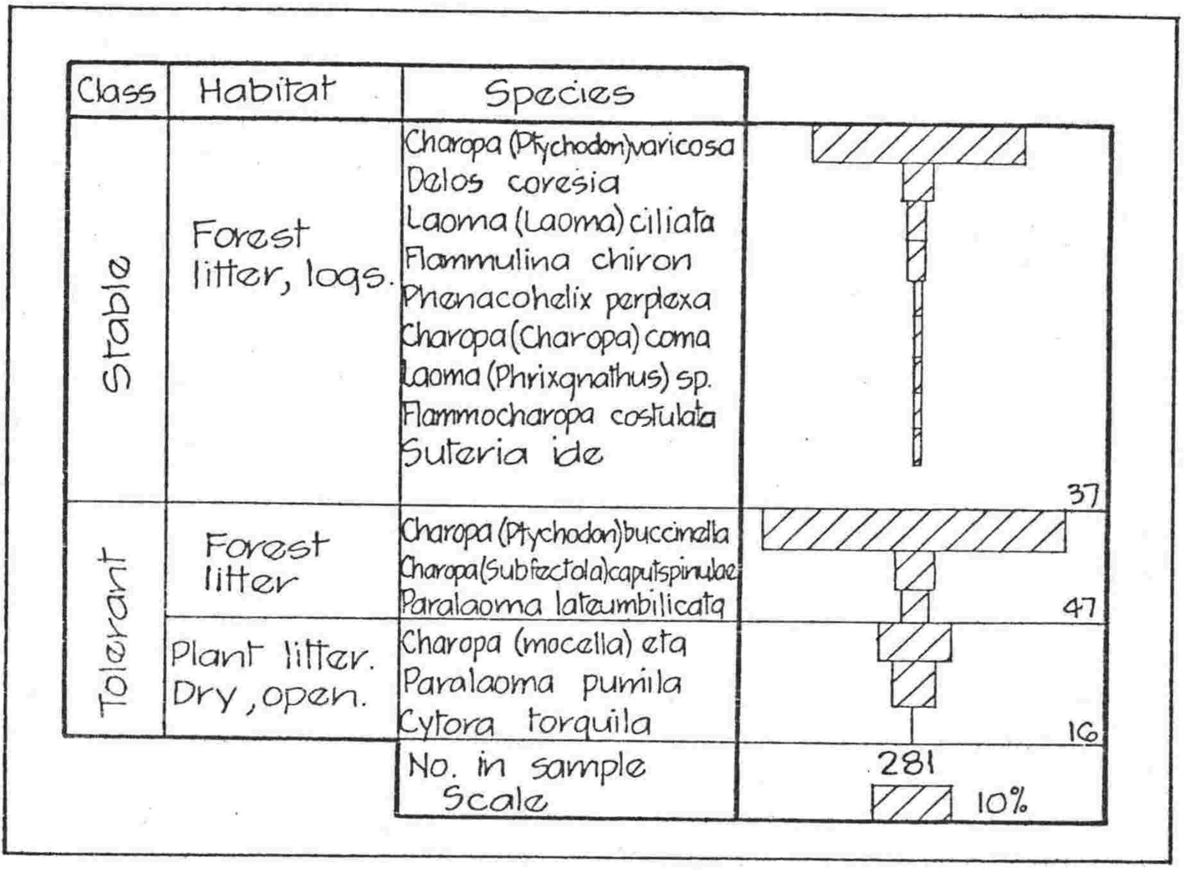


FIGURE 34 - Percentage abundance of different species of landsnails from a sample of shell midden in Tirean soil at Cooks Cove. Species divided into three habitats and two classes. Percentage abundance shown by boxes on right hand side.

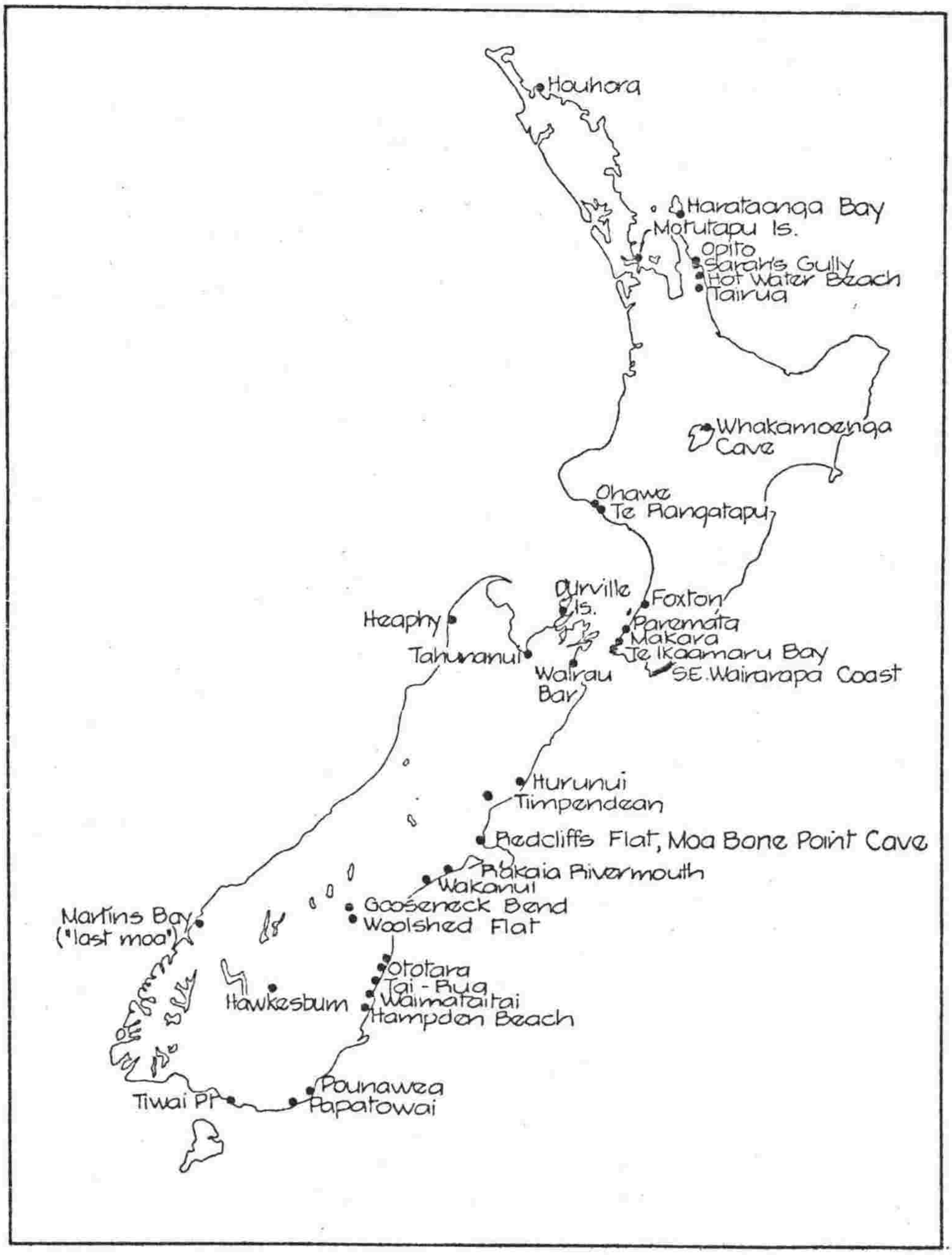


FIGURE 35 - Map of New Zealand showing places where moas living after man's arrival have been dated (either by radiocarbon or by stratigraphy).

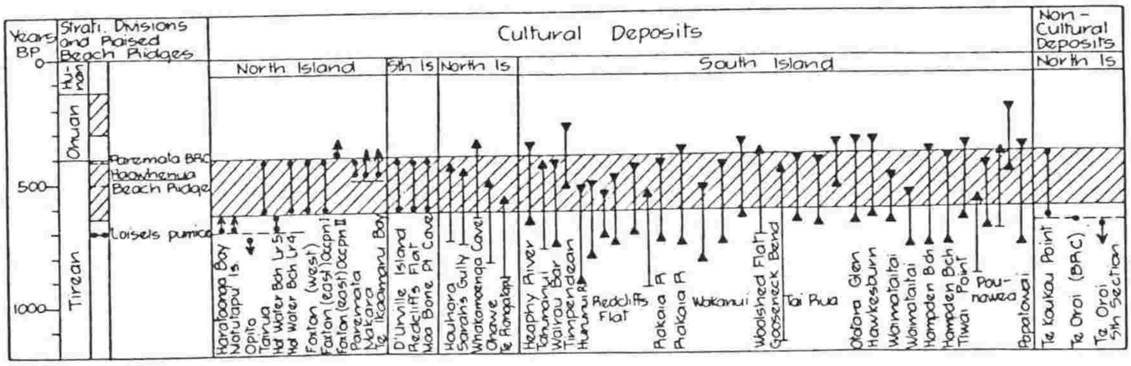


FIGURE 36 - Diagram showing calendar dates for moas living after man's arrival in New Zealand. Moas are assumed to have been alive if the bones are in position of articulation; If the bones are in ovens; if the bones, if in middens, are useless for making artifacts; or if they are thought to have been broken green. Dating is by radiocarbon and by stratigraphy. Arrow heads are used as before (Figure 23) to indicate the three kinds of radiocarbon dates. An analagous system is used for the stratigraphic dates (infilled circles) on the left and right hand sides of the diagram: upward-pointing arrows = maximum dates; downward-pointing arrows = minimum dates; two infilled circles = close dates. Stable phases of stratigraphic divisions shown cross-hatched.

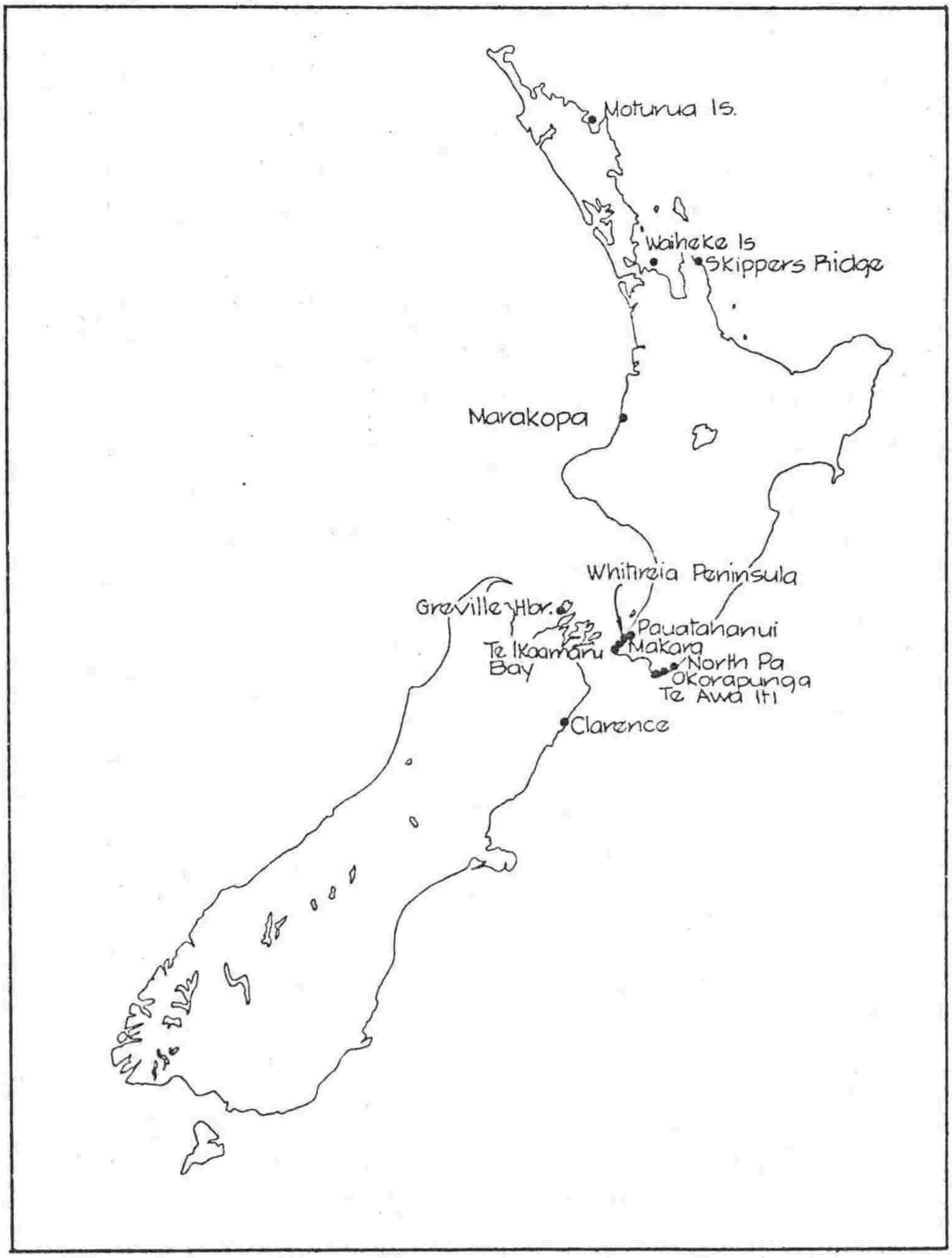


FIGURE 37 - Map of New Zealand showing sites where Maori cultivation has been dated either by radiocarbon or by stratigraphy.

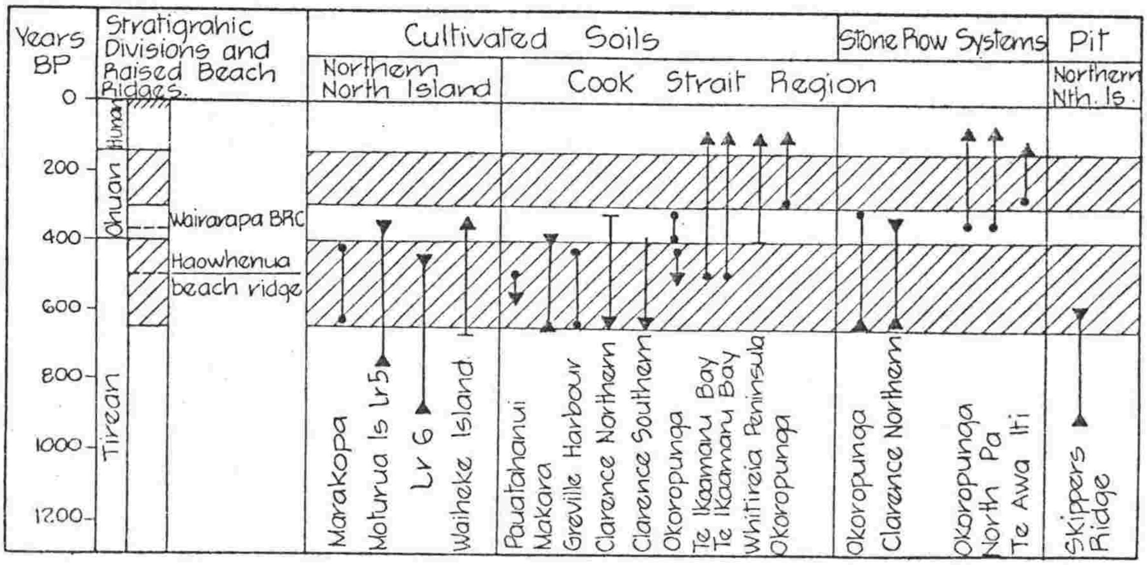


FIGURE 38 - Diagram showing calendar dates, either from radiocarbon or from stratigraphy, for Maori cultivation. Arrows used as before (see Figure 36).

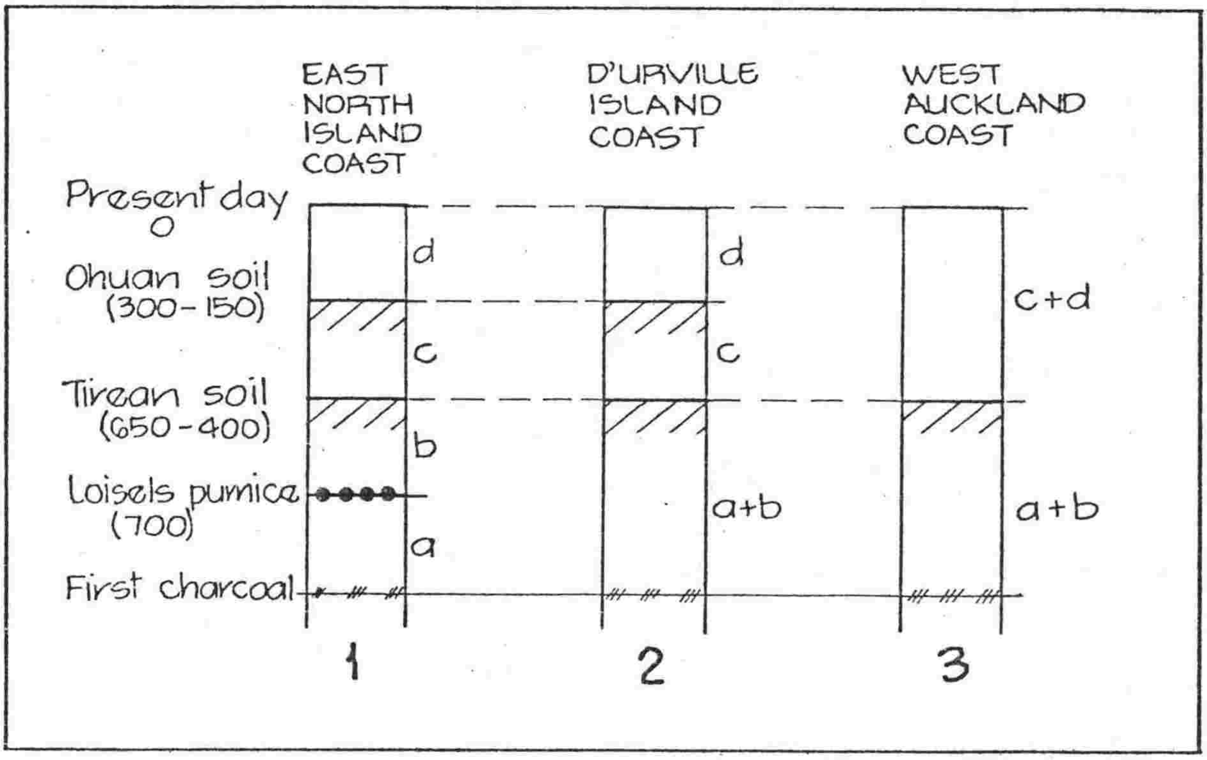


FIGURE 39 - Diagram showing method used to infer age of first cultural charcoal in coastal sections.

1. Age = $700 + 300 \left(\frac{a}{b+c+d}\right)$
2. Age = $650 + 250 \left(\frac{a+b}{c+d}\right)$
3. Age = $650 + 400 \left(\frac{a+b}{c+d}\right)$

Bracketed ages indicate times of non-deposition and soil formation (see Figure 25). Lower case letters indicate sediment thicknesses.

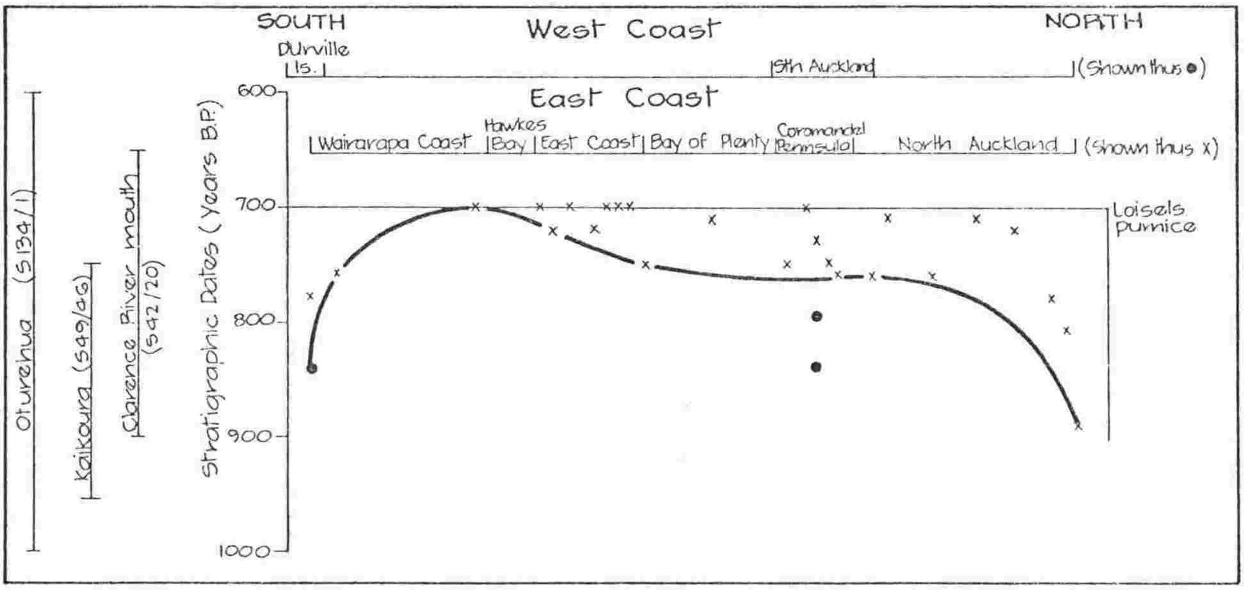


FIGURE 40 - Inferred stratigraphic dates for first cultural charcoal in coastal deposits. Data from Wellman (1962a,b) and this thesis. Infilled circles = west coast stratigraphic dates; crosses = east coast dates. Close radiocarbon dates (4 standard error range) for earliest South Island sites (S42/20, S49/46 and S134/1) given on left. Probable ages of first charcoal shown by heavy line.

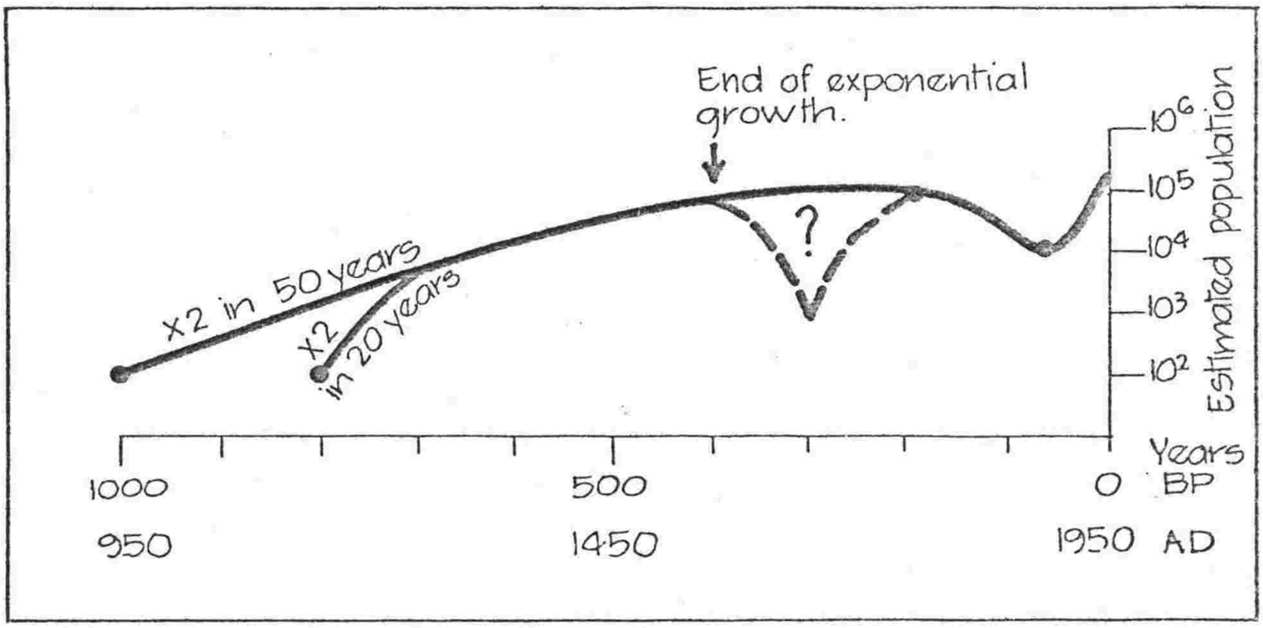


FIGURE 41 - Diagram showing estimated changes in Maori population. Note expotential scale. Dates for arrival depend on population doubling time assumed.

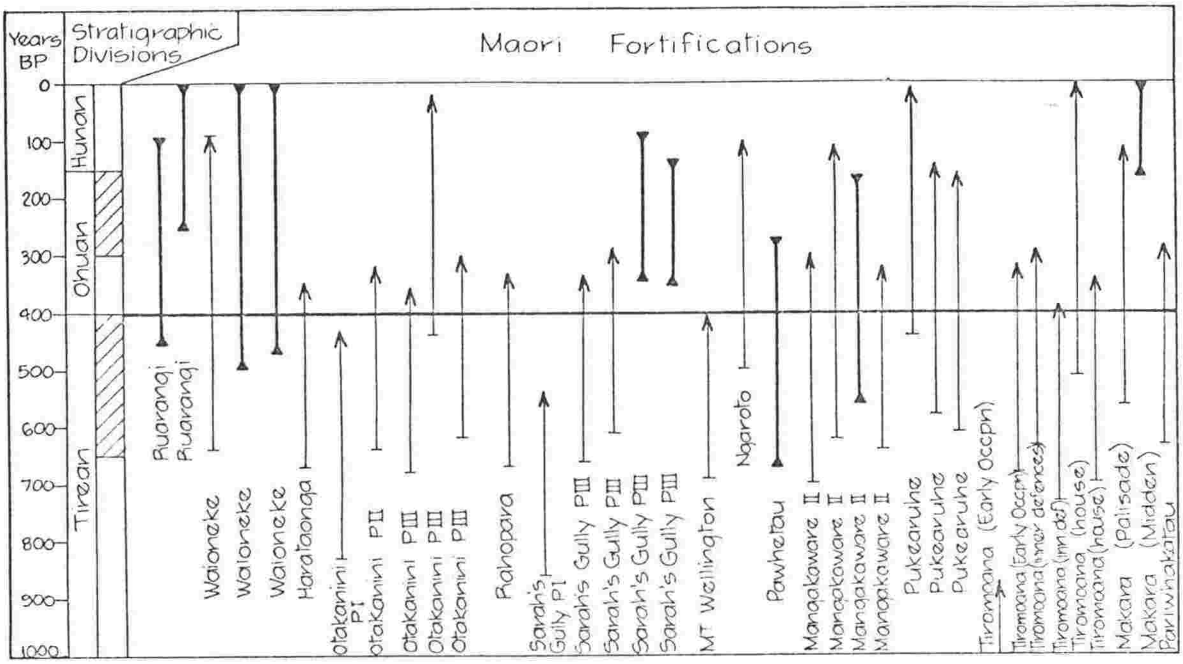


FIGURE 42 - Diagram showing calendar dates, from radiocarbon, for Maori fortifications. Arrows used as before (Figure 23). Close dates shown by heavy lines for emphasis.

N_L	S_L	N_E	S_E	ASSEMBLAGE	
12	8	12	24	NO. SITES USED TO DEFINE ASSEMBLAGE	
	r		C	Blade flaking	Old Key Age Fossils
			C	Slate knives	
		C	C	Perforated lure hook points	
		C	C	Moa bones	
		C	C	Stone and bone minnow lures	
	r	r	C	Awls	
	C	r	C	Barracouta points	
	C		C	Unperforated lure hook points	
r			C	Harpoon points	
r	r	C	C	One piece unbarbed bone fish-hooks	
r	r	C	C	Adzes (not 2A or 2B)	
r	r	C	C	Necklaces (not human teeth)	
C	C	C	C	Bird spears	
C	C	r	C	Needles	
C	C	r	C	Composite Bait hooks	
r	C	r	C	Nephrite artifacts	
C	C	r	r	Tattooing chisels	
C	C		C	Barbed fish-hook points	
C	C		r	Worked human bone	
r	C		r	Nephrite ornaments	
C	C		r	Pendants worn singly	
r	C		r	Cloak pins	
r	C		r	Musical instruments	
C	C		r	Toggles	
C	r		r	Beaters	
C	r			Fortifications	Young Key Age Fossils
C	C			Weapons	
r	r			One piece shank-barbed fish-hooks	
C	C			Adzes (2B)	
r	C			Necklaces of human teeth	
r	C	?		Combs	

FIGURE 43 - Diagram set out to show changes in fossils (artifacts plus moa bones from archaeological sites) with time and area. There are four assemblages: S_E, early in the South Island and southern North Island; N_E, early in the northern North Island; S_L, late in the South Island and southern North Island; N_L, late in the northern North Island. Nature of fossil shown at top of diagram. C = common (found at 25% or more sites); r = rare (found at less than 25% sites). Sites on which assemblages based listed in Table 12. Ethnological material collected by Cook and other early explorers is disregarded here, being non-archaeological.

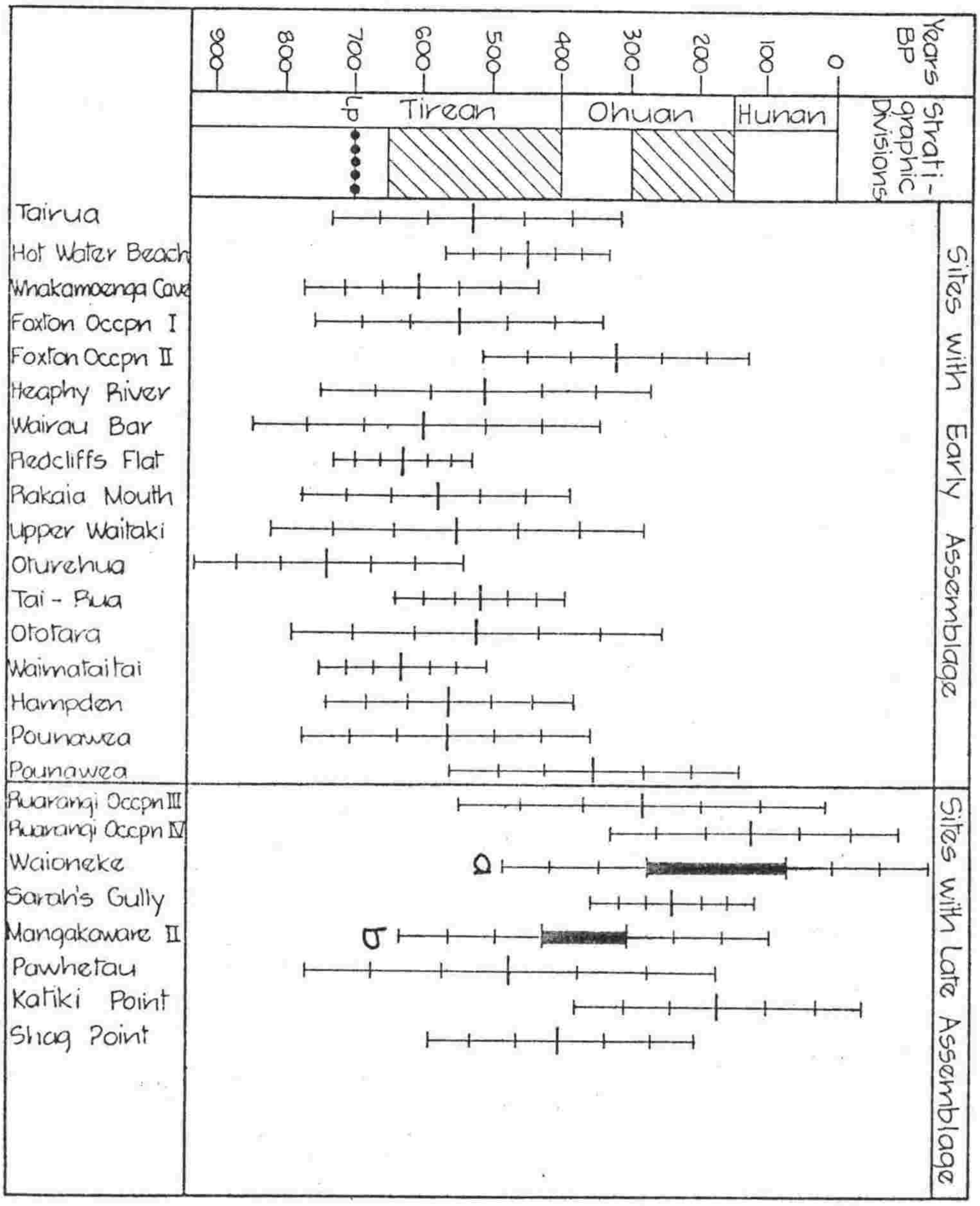


FIGURE 44 - Diagram of calendar dates, from radiocarbon, of closely dated sites with early and late artifact assemblages. All dates shown as a bar with a range of 6 standard errors. Dates labelled "a" and "b" have an increased range due to short term variations in the "Suess" calibration curve (see Chapter III).

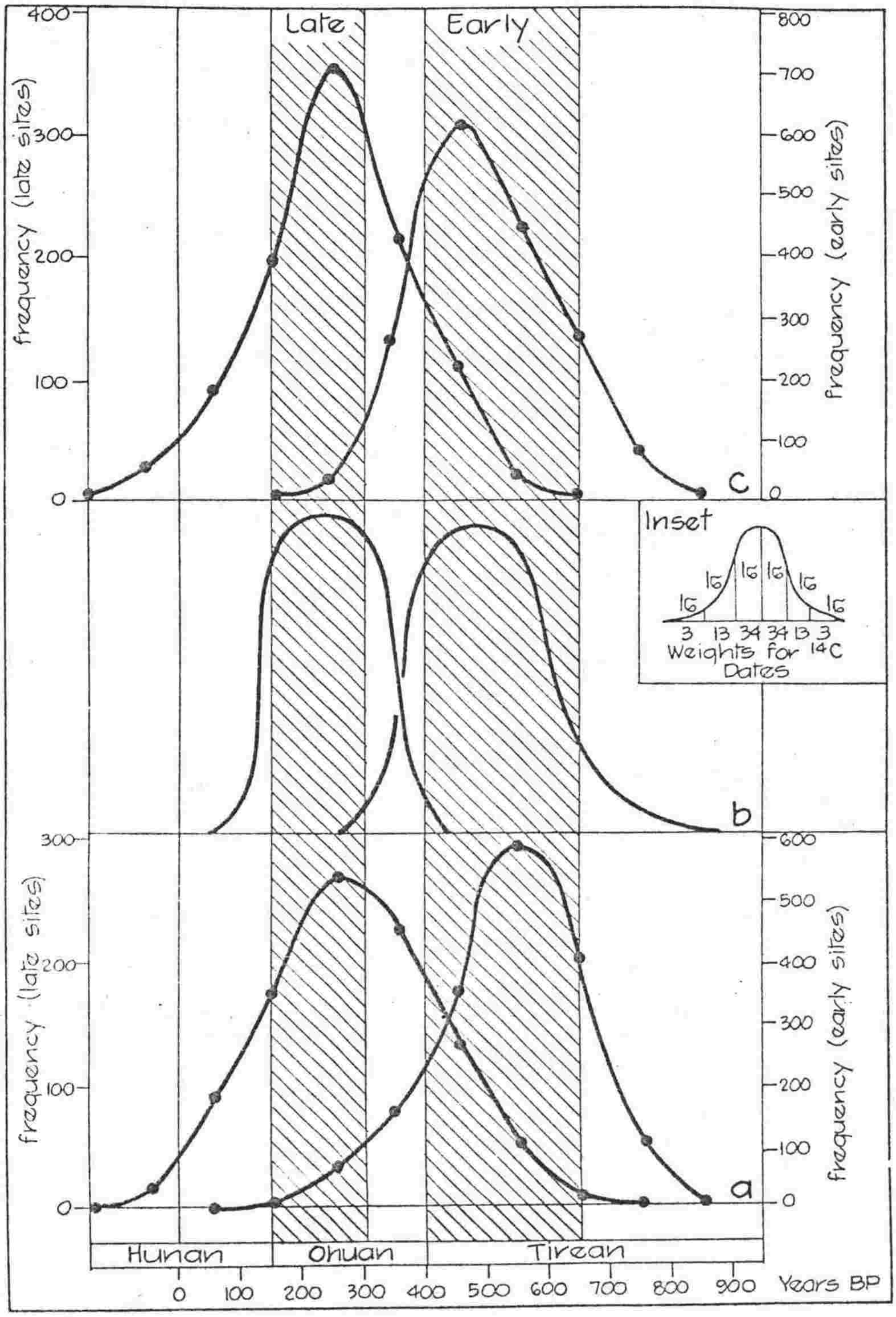


FIGURE 45 - Diagram of probability distribution for dates of sites with early and late artifact assemblages.

Fig.a. Probablility distribution based on sites given in Figure 44. Dates weighted as shown in inset and probabilities summed. Note the different frequency scales for the early and late assemblages, and note also the overlap of the two distributions (700 years).

Fig.b. Probability distributions thought to represent actual site ages. Note the reduced overlap of the two distributions (150 years) compared with Fig.a.

Fig.c. Probability distributions based on dates of a random sample of 17 early and 8 late sites from the distributions in Fig.b. A standard error of 60 years is assumed for each date, and two late samples are assumed to be charcoal. Note the similar overlap of the two distributions (500 years) to that of Fig.a.

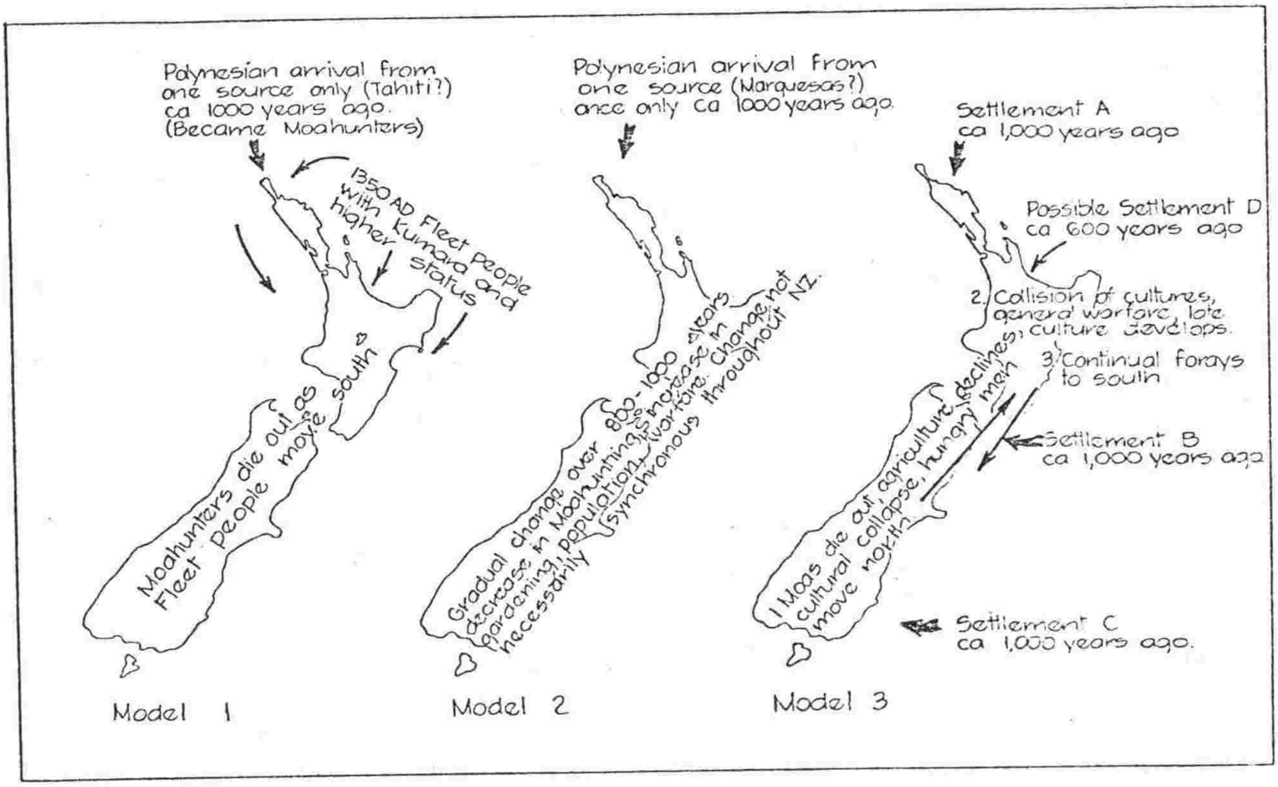


FIGURE 46 - Three models to explain culture change from early to late. Model 1, after Duff (1956); Model 2, after Green (1963) and based on the Auckland Province; Model 3 is new. Note that in Models 1 and 2 sources of first Polynesian arrivals are postulated, and places of first settlement are unknown. In Model 3, sources of first Polynesian arrivals are not postulated, although from artifact types 2 sources seem likely and places of first settlement are known approximately.

TABLE 1

A list of radiocarbon dates for events dated by multiple radiocarbon dates on charcoal. Also included are radiocarbon dates from successive stratigraphic layers where the numerically youngest date is stratigraphically the oldest. All dates are determined by the N.Z. Institute of Nuclear Sciences. Dates are determined on wood (W), charcoal (C) and twig charcoal (tc). Numerically youngest date for an event = a; numerically older dates = b. Observed distribution of

$$\frac{(b - a)}{\sqrt{se_b^2 + se_a^2}}$$

differs significantly from that predicted by the normal distribution which would apply if differences were due solely to statistical variation.

$(\chi^2 = 12.8,\ df = 2,\ p \ll 0.005)$.

NZ NUMBER	DATE NZ "A"	DATE NZ "C"	MATERIAL DATED	TYPE OF DATE	$\frac{(b - a)}{\sqrt{se_a^2 + se_b^2}}$	EVENT DATED	SITE
915	556±55	580±81	C	a		Middle Occpn. Lr.	N6/4
916	690±44	700±74	C	b	1.1	Top Occpn. Lr.	(Houhora)
1282	145±50	(180-290)±78	W	a		Period III	N37/37
1676	315±54	(320-460)±81	C	b	0.3	Occupation	(Otakanini)
1281	457±49	510±77	W	b	2.0		
912	228±53	(300-420)±80	C	a		Shell Midden	N43/33
913	243±55	(300-440)±81	C	b	0.0	Deposit	(Galatea Bay)
595	443±40	500±72	C	a		Oven	N44/2
594	878±49	(740-880)±77	C	b	2.3		(Tairua)
909	196±79	300±99	C	a		Occupation	N65/18
907	850±53	(750-850)±80	W	b	3.5	Layer	(Ngaroto)
1678	232±38	(420-300)±71	W	a		Occupation	N65/35
1121	424±74	480±95	W	b	0.5	of Site	(Mangakaware II)
1125	280±76	(300-440)±97	W	b	0.0		
1679	389±54	500±81	W	b	0.7		
1677	1140±60	1100±85	C	b	6.1		
648	479±55	530±81	C	a		Occupation	N94/9
686	605±56	600±82	tc	b	0.6	Layer I	(Whakamoenga Cave)
1030	1005±57	950±83	C	b	3.6		
1029	249±59	(305-440)±84	C	a		Occupation	N94/9
1036	279±55	(310-440)±81	C	b	0.0	Layer II	(Whakamoenga Cave)
64	360±60	470±85	C	a		Oven	N119/21
63	400±60	480±85	C	b	0.1		(Mt Egmont)
718	692±59	720±84	C	a		Oven	N129/77
544	745±68	730±91	C	b	0.1		(Ohawe)
543	1015±60	950±85	C	b	1.9		
723	535±56	590±82	C	a		Oven	N129/78
545	735±58	730±83	C	b	1.2		(Te Rangatapu)
-	340±60	460±85	W	a		Area IV,	N135/1
-	550±60	570±85	W	b	0.9	Inner Defences	(Tiromoana Pa)
-	130±90	(180-280)±108	W?	a		House Posts in	N135/1
-	490±70	540±92	C	b	1.8	House Floor	(Tiromoana Pa)

NZ NUMBER	DATE NZ "A"	DATE NZ "B"	MATERIAL DATED	TYPE OF DATE	$\frac{(b - a)}{\sqrt{se_a^2 + se_b^2}}$	EVENT DATED	SITE
685	96^{+30}_{-85}	(170-280)±67	c	a		Oven	N148/1
684	517±60	560±85	c	b	2.6		(Foxton)
653	392±84	490±103	c	a		Oven	N164/2
654	880±84	(740-880)±103	c	b	1.7		(Makara)
-	769±54	730±81	c	a		Houseposts	N165/9
-	771±54	730±81	c	b	0.0		(Moikau)
1513	342±78	460±98	c	a		Occpn. Lr. 2	N168/20
1514	508±79	560±99	c	b	0.7		(Washpool)
-	108±53	(170-270)±80	c	a		Occpn. of Tce.	N-/-
-	255±54	(300-440)±81	c	b	0.3		(Pukearuhe)
-	278±54	(310-440)±81	c	b	0.4		
783	810±50	740±78	c	a		Oven	S117/3
798	860±32	(740-830)±68	c	b	0.0		(Woolshed Flat)
1028	277±48	(310-440)±77	c	a		Occupation	S123/5
803	406±79	490±99	c	b	0.4	Layer 4	(Glenorchy)
850	897±27	(740-1120)±66	tc	a		Occupation	S134/1
910	927±82	1150±102	c	b	0.2	Layer 2	(Oturehua)
61	590±50	590±78	c	a		Occupation	S143/2
62	600±50	600±78	c	b	0.1	Layer	(Hawkesburn)
605	823±45	740±75	c	a		Oven	S155/5
606	845±56	740±82	c	b	0.0		(Shag River)
933	479±51	520±79	c	a		Occupation	S176/4
934	696±40	690±72	c	b	1.6	Layer 2	(Whakapatu)
145	215±50	300±78	c	a		Oven	S184/3
143	320±50	(320-460)±78	c	b	0.2		(False Island)
144	345±50	460±78	c	b	1.5		
135	755±30	740±67	c	a		Lowest Occpn.	S184/5
134	765±30	740±67	c	b	0.0	Layer	(Papatowai)

TABLE 2

Radiocarbon dates on shells and charcoal for Occupation Layers I and II at site N148/1, Foxton. All shells have aragonite crystal structure. Tuatua shells (<u>Paphies (Mesodesma) subtriangulatum</u>) are ocean beach species, cockle shells (<u>Chione stutchburyi</u>) are estuarine species. The shells are from shell midden lenses in each occupation layer, and the shell lenses are numbered from 1 to 4 in order of decreasing stratigraphic age. Each occupation layer has one tuatua date, and the difference between the corrected tuatua date and each corrected cockle date for the layer is listed as a "date difference". Except for Occupation Layer I, date differences are statistically significant (t test, Snedecor and Cochran, 1967; $t \geqslant 3.14$, $P < 0.005$).

OCCUPATION LAYER	POSITION IN LAYER	SAMPLE DATED	^{13}C w. r. t. PDB CH. LST. STD. ‰	NZ NUMBER	^{14}C DATE YEARS BP (1950)	DATE DIFFERENCE (YEARS)
I	Shell lens 1	Tuatua shells	+1.1	1480A B	587 ± 55 550 ± 70	
I	Shell lens 1	Cockle shells	-0.4	1349A B	763 ± 52 730 ± 65	180
II	Shell lens 2	Cockle shells	-0.5	683A B	653 ± 58 620 ± 70	300
II	Shell lens 3	Tutua shells	+0.1	1250A B	365 ± 54 320 ± 65	
II	Shell lens 3	Cockle shells	-0.4	1479A B	654 ± 56 620 ± 70	300
II	Shell lens 4	Cockle shells	-0.2	1347A B	829 ± 48 800 ± 65	480
II	Shell lens 4	Cockle shells	-0.7	1251A B	839 ± 70 810 ± 80	490
II	Oven	Charcoal	-	684A C	517 ± 60 560 ± 85	
II	Layer above oven	Charcoal	-	685A C	96^{+30}_{-85} $(180-240)^{+65}_{-105}$	

TABLE 3

Radiocarbon and other dates used to define age of Loisels pumice and age of stratigraphic divisions. Stratigraphic position of samples was given by authors listed. Unpublished dates are shown by an asterisk. In this and subsequent tables, dates suffixed A are uncorrected; dates suffixed B are corrected marine shell dates; dates suffixed C are corrected charcoal, moa bone, or human bone dates. Maximum dates indicated $>$; minimum dates $<$; and close dates $=$. T_u = Tirean unstable phase, T_s = Tirean stable phase, &c.

Radiocarbon

NZ NUMBER	DATE YEARS BP (1950)	SIGNIFICANCE	LOCALITY	AUTHOR	SAMPLED LAYER AND SAMPLE
86 A	940 ± 70	$> T_s$	Waimakariri River	Cox and Mead (1963)	Wood in Waimakariri alluvium (Tu).
C	920 ± 90				
293 A	855 ± 50	$> T_s$	Manawatu sand plain	Cowie (1963)	Wood 90 rings in from outside of a tree rooted in Foxton soil and overlain by Motuiti sand. Tree thought to have been killed by advancing Motuiti sand.
C	$(730\text{-}830) \pm 80$				
305 A	1040 ± 60	$> T_u$	Waimakariri River	Cox and Mead (1963)	Peat below Waimakariri alluvium (Tu).
C	970 ± 85				
312 A	735 ± 55	$> T_s$	Waimakariri River	Cox and Mead (1963)	Wood in estuarine silt below Waimakariri alluvium.
C	720 ± 80				
354 A	640 ± 50	$> Ip$	Opito, Coromandel Peninsula	Green (1963)	Charcoal below Loisels pumice (Site N40/3).
C	650 ± 80				
396 A*	799 ± 40	$> Lp$	Matai Bay, North Auckland	Wellman (1962b)	Charcoal below Loisels pumice.
C	740 ± 70				
432 A	200	$> O_s$	Waimakariri River	Cox and Mead (1963)	Wood (kanuka) in Selwyn alluvium.
C	300				
481 A*	680 ± 67	$> O_u$	D'Urville Is. Greville sand bar, section D	Wellman (1962a)	Charcoal from outside of a prostrate charred log in lower occupation layer on top of lower buried soil. Associated with charred tree roots.
C	670 ± 90	$< T_s$			
482 A*	570 ± 90	$> O_u$	D'Urville Is. Greville sand bar, section B	Wellman (1962a)	Shells from lower occupation layer, part of lower buried soil.
B	535 ± 100				
483 A*	< 200	$> H_u$	As for NZ 482	Wellman (1962a)	Shells from upper occupation layer.
631 A*	519 ± 41	$> O_u$	Cooks Cove East Coast	Wellman (1962b)	Charcoal from lower occupation layer.
B	560 ± 70				
632 A*	700 ± 56	$< Ip$	Cooks Cove, East Coast	Wellman (1962b)	Shells from lower occupation layer just above Loisels pumice.
B	665 ± 70				
651 A*	925 ± 46	$> Lp$	Cooks Cove, East Coast	Wellman (1962b)	Wood from below Loisels pumice.
C	$(880\text{-}740) \pm 75$				
682 A	728 ± 42	$< T_s$	Manawatu sand plain	McFadgen (1972)	Charcoal from an oven on a buried soil on Motuiti sand. Probably from vegetation growing nearby (Site N148/1).
C	720 ± 75				
1162 A	615 ± 40	$< T_u$	Redcliffs, Banks Pen.	Trotter (1975b)	Moa bone collagen from occupation layer on Waikuku sandy loam (on old "stained" ground surface in sewer trench).
B	650 ± 70				

NZ NUMBER	DATE YEARS BP (1950)	SIGNIFICANCE	LOCALITY	AUTHOR	SAMPLED LAYER AND SAMPLE
1250 A* B	365±54 320±65	$= O_u$	Manawatu sand plain	Chapter III	Shells, from shell midden of Occupation Layer II (Site N148/1).
1296 A B	453±40 410±60	$< Lp$ $> O_u$	Hot Water Beach, Coromandel Pen.	Leahy (1974)	Shells from above Loisels pumice (Site N44/69).
1297 A B	524±40 485±60	$< Lp$ $> O_u$	Hot Water Beach, Coromandel Pen.	Leahy (1974)	Shells from above Loisels pumice (Site N44/69).
1376 A	581±40	$< T_u$	Redcliffs, Banks Pen.	Trotter (1975)	As for NZ 1162.
1480 A B	587±55 550±70	$< T_s$	Manawatu sand plain.	Chapter III	Shells from midden on buried soil on Motuiti sand (Site N148/1).
1874 A* B	410±60 365±70	$> O_u$	Te Awa Iti	Chapter III	Shells (*Haliotis iris*, *Lunella smaragda* *Cellana* sp., *Malagraphia aethiops*) from midden in lower buried soil (Site N166/67).
1875 A B	570±60 525±70	$> O_u$	Tairua, Coromandel Pen.	Smart and Green (1962)	Shells from lower occupation layer (Layer 2) in buried soil (Site N44/2).
1876 A	250±70 200±80	$> H_u$ $< O_u$	Tairua Coromandel Pen.	Smart and Green (1962)	Shells from upper occupation layer (Layer 6) on buried soil (Site N44/2).
Dendrochronology					
	155	$< H_u$	Tukituki River Valley	Grant (1965)	Trees growing on "modern" terrace.
	300	$< O_s$	Tukituki River Valley	Grant (1965)	Trees growing on Matawhero terrace.
	500	$< T_s$	Tukituki River River Valley	Grant (1965)	Trees growing on Waihirere terrace.
Historical Records					
	130	$= H_u$	Gisborne	Pullar and Penhale (1970)	Beginning of deposition of Late Matawhero alluvium.

TABLE 4

List of places in parts of the North Island that were forest-free in 1840 and where forest probably existed within the last 2,000 years.

LOCALITY	EVIDENCE	VEGETATION INDICATED	DATE OF YEARS BP (1950)	REFERENCE
AUCKLAND				
Motutapu Is.	Soil profiles under Rangitoto Ash (Ash maximum age 410±73 years BP (NZ 1167A): Law, 1975)	forest	more than 400	Taylor (1960)
	Leaves embedded in the underside of the Rangitoto Ash at the Sunde site	pohutukawa karaka kawakawa	less than 700	Scott (1970)
BAY OF PLENTY				
Rangitaiki Plains	*In situ* tree stumps below Taupo Ash (erupted ca 1,800 years BP: Healy *et al*, 1964)	matai totara (or Hall's totara)	more than 1,800	Pullar and Patel (1972)
	In situ tree stump below Kaharoa Ash (erupted ca 930 years BP: Healy *et al*, 1964)	totara (probably Hall's totara)	more than 930	Pullar and Patel (1972)
Te Mahoe	*In situ* tree stump below Taupo Ash	kahikatea	more than 1,800	Pullar and Patel (1972)
Ohiwa Harbour	*In situ* tree stump below Taupo Ash	totara	more than 1,800	Pullar and Patel (1972)
Te Tumu	*In situ* tree stump below Taupo Ash	matai	more than 1,800	Pullar and Patel (1972)
EAST COAST				
Cooks Cove	Landsnails in shell midden in Tirean soil	coastal forest	less than 650	Figure 34, Chapter IV
Wainui Beach	Landsnails (*Rhytida greenwoodi*) in shell middens in sand dunes (younger than human settlement of N.Z. ca 1,000 years BP)	coastal forest	less than 1,000	Hutchinson (1897)
HAWKES BAY				
Te Awanga	Radiocarbon dated wood used in construction of Tiromoana Pa (N135/1) (assumed here to have been growing nearby and not to have been driftwood.	totara	1020±120 (NZ 1914A)	Fox (1975)
Lake Poukawa	Pollen from peat above Taupo Lapilli	matai (dominant) kahikatea totara miro titoki black maire	less than 1,800	McGlone (*pers. comm.*)
WAIRARAPA COAST				
Flat Point	Landsnails in shell middens in Tirean soils	coastal forest	less than 650	Figure 30, Chapter IV
Okoropunga (N166/55)	Radiocarbon dated charcoal from tree roots in position of growth in buried soil	totara	750±40 (NZ 3116A)	Appendix 1
	Radiocarbon dated charcoal in and beneath a stone row	matai totara coprosma hebe	530±60 (NZ 3115A) 340±60 (NZ 3114A)	Appendix 2

LOCALITY	EVIDENCE	VEGETATION INDICATED	DATE OF YEARS BP (1950)	REFERENCE
Te Awa Iti (N166/67)	Landsnails in shell midden on buried Tirean soil	coastal forest	less than 650	Figure 31, Chapter IV
Te Oroi	Landsnails in shell middens on buried Ohuan and Tirean soils	coastal forest	less than 650	Figure 32, Chapter IV
Te Kau Kau Pt.	Landsnails and insect remains in peat layer containing Loisels pumice	coastal forest	less than 700	Figure 33, Chapter IV
SOUTH TARANAKI AND MANAWATU				
Foxton (N148/1)	Landsnails in shell midden; charcoals from, and humic acid analysis of, buried soils on Motuiti sand	kahikatea totara coprosma kanuka five finger	less than 650	McFadgen (1972), and Chapter III
Waverly	Radiocarbon dated wood from drowned forest	rimu	1020±60 (NZ 91A)	Fleming, (1953, 1957)
TAUPO AND WAIKATO				
Rotorua district	Soil profiles on Taupo Ash	forest	less than 1,800	Vucetich and Pullar (1963)
Tokoroa	Soil profiles on Taupo Ash	forest (rimu)	less than 1,800	Henry (1955) Law (1973)
West Lake Taupo	Soil profiles on Taupo Ash	forest	less than 1,800	McKelvey (1953, 1963)
North and east Lake Taupo	Burnt totara logs on ground surface in early European times, and Maori accounts of former forest extent	totara forest	ca.150-200	Bidwell (1841) Fletcher (1914)

TABLE 5

Dates between 1,000 and 150 years BP for burning and clearance of North Island forest.

LOCALITY	EVIDENCE	DATE IN YEARS BP (1950)	REFERENCE
EAST NORTH ISLAND COAST: Between North Cape and Waimarama.	Charcoal below Loisels pumice.	more than 700	Wellman (1962b) (especially Section 37)
AUCKLAND			
Motutapu Island	Charred twigs used for radiocarbon dates beneath the Rangitoto Ash.	770±50 (NZ 220A) to 410±73 (NZ 1167A)	Law (1975a)
BAY OF PLENTY			
Peat Bog near Whakatane	Decline in rimu and Podocarpaceae pollen, and an increase in bracken fern pollen, above the Kaharoa Ash (erupted ca.930 years BP: Healy *et al*, 1964).	less than 930	Campbell *et al* (1973)
Peat Bog near Rotorua	Charcoal, and an increase in bracken fern pollen directly beneath the Kaharoa Ash.	ca.930	McGlone (*pers. comm.*)
HAWKES BAY			
Inland Hawkes Bay	Large fires inland on the hills behind Hawke Bay, recorded by J. Banks on night of October 16th, 1769.	180	Beaglehole (ed) (1962)
Lake Poukawa	Increase in bracken fern pollen, tutu pollen, and charcoal, in peat core from north end of Lake Poukawa. Date based on an assumed uniform rate of peat accumulation between Taupo Lapilli and lowest European pollen in core.	ca.800	McGlone (*pers. comm.*)
WAIRARAPA COAST			
Flat Point and Te Awa Iti	Landsnails in shell middens on Tirean soil, but not in shell middens on Ohuan soil.	300-400	Chapter IV
Okoropunga	Radiocarbon dated charcoal from tree roots in position of growth in buried soil	less than 750±40 (NZ 3116A)	Appendix 1
	Radiocarbon dated charcoal in a stone row.	less than 340±60 (NZ 3114A)	Appendix 2
Te Oroi	Charcoal in Te Oroi Southern section, below Loisels pumice	more than 700	
SOUTH TARANAKI AND MANAWATU			
Near Tahora	Pattern of forest vegetation (dated by tree size).	200	Nicholls (1957)
Foxton (N148/1)	Change from kahikatea-dominated coastal forest present during Ohuan unstable phase, to open land probably covered with bracken fern and scrub at first European settlement.	less than ca.300	Chapter IV
Tiritea Catchment (Northern Tararuas)	Charcoal in soils. Fire dated by ring counts of relict miro in areas now scrub covered.	200	Esler (1963)
NORTH TARANAKI			
Panirau Stream (tributary of the Mokau River)	Pattern of forest vegetation. Fire dated by stage and size of vegetation.	more than 100	McKelvey (1958)

LOCALITY	EVIDENCE	DATE IN YEARS BP (1950)	REFERENCE
TAUPO AND WAIKATO			
Taupiri Range	Charcoal in soils. Dates based on pattern of forest vegetation.	300 150	Clayton-Greene (1975)
Western edge of Urewera forest	Pattern of forest vegetation. Pioneering stands of softwoods dated by ring counts of rimu and matai.	more than 400-500	McKelvey (1973)
North and east Lake Taupo	Burnt totara logs in tussock at time of European settlement. Dates based on Maori accounts of former forest.	150-200	Bidwill (1841); Fletcher (1914)
Whirinaki River Valley (western Ureweras)	Damaged Podocarp stands	250-300	Grant (1963)
EAST COAST			
Cooks Cove	Landsnails in shell midden on Tirean soil, but not in shell midden on Ohuan soil.	300-400	Chapter IV

TABLE 6

Insect species from the Te Kau Kau Point peat layer, and their typical habitats.

INSECT SPECIES	TYPICAL HABITAT
Oribatid mites*	Leaf litter under bush
Ants (*Mesoponera castanea*)*+	Bush, scrub, open coast
Hydrophilid beetle (wing cases)	Leaf litter
Staphylinid beetle (*Cafius quadri-impressus*)+	Bush, scrub, open coast
Weevils (2 species)	Bush or scrub
Spider (carapace) (?*Lycosa*)	Bush or scrub

* Abundant

\+ May have burrowed into peat from face of section

TABLE 7

List of inferred Moahunter sites that have been stratigraphically dated. Evidence for moa hunting: 1 = moa butchering; 2 = moa bones in ovens; 3 = non-industrial moa bone; 4 = moa bones with moa egg shell; 5 = moa bone thought to have been broken green; 6 = moa bone with moa crop-stones.

SITE NAME OR LOCALITY, AND SITE NO.	EVIDENCE	STRATIGRAPHIC LAYER	STRATIGRAPHIC AGE	REFERENCE TO EVIDENCE AND LAYER
Harataonga Bay (N30/5)	5	"Upper layer"	Younger than Loisels pumice	Law (1972)
Motutapu Is. (N38/24)	3	Division 10	Younger than Loisels pumice	Scott (1970)
Opito (N40/3)	3,4	Layer 4c	Older than Loisels pumice	Green (1963) Golson (1959)
Tairua (N44/2)	3	Layer 2	Tirean stable phase	Smart and Green (1962) and Chapter III
Hot Water Beach (N44/69)	3	Layer 5	Late Tirean unstable phase	Leahy (1974) and Chapter III
Hot Water Beach (N44/69)	3	Layer 4	Tirean stable phase	Leahy (1974) and Chapter III
Foxton (N148/1)	1,2,3	Western side of site: in occupation layer on poorly developed soil on Motuiti sand	Tirean stable phase	Chapter III
Foxton (N148/1)	3	Eastern side of site: Occupation I	Tirean stable phase	Chapter III
	3	Occupation II	Ohuan unstable phase	Chapter III
Paremata (N160/50)	1	Moahunter occupation layer	Late Tirean stable phase	Appendix 5
Makara (N164/2)	2	Lower Occupation Layer	Late Tirean stable phase	Appendix 5
Te Ika amaru Bay (N164/17)	2,6	Oven area on raised beach ridge	Late Tirean stable phase (maximum age)	Appendix 5

SITE NAME OR LOCALITY, AND SITE NO.	EVIDENCE	STRATIGRAPHIC LAYER	STRATIGRAPHIC AGE	REFERENCE TO EVIDENCE AND LAYER
D'Urville Is.	6	Lower Occupation Layer	Tirean stable phase	Wellman (1962b)
Redcliffs Flat (sewer trench) (S84/76)	2	On soil carried by Waikuku sand	Tirean stable phase	Trotter (1975b) and Chapter III
Moa-Bone Point Cave (S84/77)	3	Moahunter beds	Tirean stable phase	Trotter (1975b) Haast (1874a) and Chapter III

TABLE 8

List of inferred Moahunter sites, other than those given in Table 7, that have been radiocarbon-dated. Evidence for moa hunting as for Table 7. For each site the youngest date and all dates on moa bone collagen are quoted.

SITE NAME OR LOCALITY, AND SITE NO.	EVID-DENCE	MATERIAL DATED. COLLAGEN FROM MOA BONES ONLY	NZ NUMBER	DATE	TYPE OF DATE	REFERENCE TO EVIDENCE AND, OR, DATE.
Houhora (N6/4)	1,3	charcoal	915A C	556±55 580±80	maximum	Shawcross (1972)
Sarah's Gully (N40/9)	2	charcoal	357A C	590±50 600±80	maximum	Golson (1959)
Whakamoenga Cave (N94/7)	2,3	charcoal	1030A C	479±55 500±80	maximim	Leahy (1976)
Ohawe (N129/77)	2	charcoal	718A C	692±59 660±85	maximum	Buist and Yaldwyn (1960)
Te Ranga tapu (N129/78)	2	charcoal	545A C	735±58 730±85	maximum	Canavan (1960)
Heaphy River (S7/1)	3,4	shell	509A B	550±70 510±80	close	Wilkes and Scarlett (1967); Moore and Tiller (1976)
Tahunanui (S20/2)	5	charcoal	1038A C	589±70 600±90	maximum	Miller (1971)
Wairau Bar (S29/7)	4	collagen	1838A C	590±60 600±85	close	Trotter (1975a)
Timpendean (S61/4)	3,6	shell	892A B	436±50 395±65	close	Trotter (1972b) Trotter and McCulloch (1973)
Hurunui River (S62/10)	2	collagen	1839A C	730±80 720±100	close	Trotter (<u>pers. comm.</u>)

SITE NAME OR LOCALITY, AND SITE NO.	EVID- ENCE	MATERIAL DATED. COLLAGEN FROM MOA BONES ONLY	NZ NUMBER	DATE	TYPE OF DATE	REFERENCE TO EVIDENCE AND, OR DATE.
Redcliffs Flat (S84/76)	2	collagen	1113A	735±56	close	Trotter (1975b)
			C	720±80		
		shell	1111A	617±34	close	
			B	589±50		
		collagen	1162A	615±40	close	Trotter (1975b)
			C	620±70		
		collagen	1376A	581±40	close	
			C	590±70		
		charcoal	459A	787±82	maximum	
			C	740±100		
Rakaia River Mouth (S93/20)	3,4	collagen	930A	585±64	close	Trotter (1972a)
			C	590±85		
		collagen	932A	518±80	close	
			C	570±100		
Wakanui (S103/1)	2	collagen	1766A	672±56	close	Trotter (1975c)
			C	680±80		
		collagen	1767A	596±59	close	
			C	600±85		
		collagen	1768A	421±55	close	
			C	500±80		
Woolshed Flat (S117/3)	6	collagen	760A	493±70	close	Trotter (1970a)
			C	550±90		
Gooseneck Bend (S117/8)	4	charcoal and twigs	ANU48A	850±150	maximum	Ambrose (1970)
			C	(750-830) ±160		
Tai Rua (S136/1)	4	collagen	559A	503±32	close	Trotter (1967a)
			C	540±70		
		collagen	752A	543±32	close	
			C	560±70		
		shell	749A	485±32	close	
			B	445±50		

SITE NAME OR LOCALITY, AND SITE NO.	EVIDDENCE	MATERIAL DATED. COLLAGEN FROM MOA BONES ONLY	NZ NUMBER	DATE	TYPE OF DATE	REFERENCE TO EVIDENCE AND, OR, DATE.
Ototara Glen (S136/2)	3	collagen	754A	467±70	close	Trotter (1965, 1967a)
			C	520±90		
Hawkesburn (S143/2)	1,2,3	collagen	59A	400±55	close	Lockerbie (1959)
			C	500±80		
Waimataitai (S146/2)	3	shell	579A	626±30	close	Trotter (1955, 1967a)
			B	590±50		
		shell	580A	701±47	close	
			B	665±60		
Hampden Beach (S146/16)	1,3	collagen	756A	538±70	close	Trotter (1967a)
			C	560±90		
		collagen	758A	554±53	close	
			C	560±80		
Tiwai Point (S181/16)	3	charcoal	- A	442±53	maximum	Park (1971, 1969)
			C	510±80		
Pounawea (S184/1)	4	charcoal	58A	810±60	maximum	Lockerbie (1954, 1959) Grant-Taylor and Rafter (1963)
			C	730±85		
		shell	57A	600±60	close	
			B	565±70		
		charcoal	55A	520±55	maximum	
			C	550±80		
		shell	54A	390±60	close	
			B	345±70		
Papatowai (S184/5)	1,3,4	charcoal	136A	630±50	maximum	Lockerbie (1954, 1959)
			C	620±80		

TABLE 9

List of moa species, from non-cultural deposits thought to be less than 2,000 years old, at five places in the southern Wairarapa. Moa species not previously listed and dated. Note three species younger than 700 years.

SPECIES. IDENTIFICATIONS BY G.S. MARKHAM FOR HIS COLLECTION. REST BY J.C. YALDWYN, NATIONAL MUSEUM.	NATIONAL MUSEUM COLLECTION NO. REFERENCE: MC = MARKHAM COLLN.	PLACE FOUND, STRATIGRAPHIC POSITION OR RADIOCARBON DATE, AND AGE IN YEARS BP.
Euryapteryx geranoides (tibia shaft fragments)	none (bones discarded)	Oterei Coast (near Profile 2 of Singh, 1971). Above Taupo pumice, in lagoon muds beneath Wairarapa coast Beach Ridge C (between 1,800 and 400 years BP).
Euryapteryx geranoides (tarsus)	none (bone discarded)	Sandy silts below Wairarapa coast Beach Ridge B (less than 400 years BP).
Euryapteryx geranoides (parts of an individual, bones found close to position of articulation)	NMNZ S991	Te Oroi Southern Section. Above Taupo pumice and below Loisels pumice, in top of alternating beds of peat and lagoon mud (between 1,800 and 700 years BP).
Euryapteryx geranoides (parts of an individual, bones found close to position of articulation)	NMNZ S992	As for S991.
Euryapteryx geranoides (metatarsus)	NMNZ S994	In Loisels pumice deposit, in Beach Ridge C.
Euryapteryx gravis (part of a tibia)	NMNZ S1012	Above Taupo pumice and below Loisels pumice, in lagoon muds (between 1,800 and 700 years BP).
Euryapteryx geranoides (parts of an individual, bones found in position of articulation)	NMNZ MC	Te Kau Kau Point SW Section Above Loisels pumice, in lagoon muds beneath Wairarapa coast Beach Ridge C (between 700 and 400 years BP).
Euryapteryx geranoides (group of bones found together, probably one individual)	NMNZ MC	" " "
?Euryapteryx curtus (immature bones)	NMNZ MC	" " "
?Euryapteryx/Emeus exilis (parts of an individual, bones found in position of articulation)	NMNZ MC	" " "
?Euryapteryx/Emeus exilis (bones of mature, sub-mature, and immature birds)	NMNZ MC	" " "
Euryapteryx geranoides (shaft)	none (bone discarded)	Kupe's Sail (Section 1: Wellman, 1962b). Above Loisels pumice (less than 700 years BP)
Euryapteryx geranoides ("moa bone" reported by Wellman (1962b)	none (bone discarded)	Above Loisels pumice (less than 700 years BP)

SPECIES. IDENTIFICATIONS BY G.S. MARKHAM FOR HIS COLLECTION. REST BY J.C. YALDWYN, NATIONAL MUSEUM.	NATIONAL MUSEUM COLLECTION NO. REFERENCE: MC = MARKHAM COLLN.	PLACE FOUND, STRATIGRAPHIC POSITION OR RADIOCARBON DATE, AND AGE IN YEARS BP.
Pachyornis sp. (various bones)	none	Martinborough Caves (Yaldwyn, 1958) Toe bones dated by radiocarbon 1470±50 years BP (J.C. Yaldwyn, *pers. comm.*)

TABLE 10

List of cultivation sites that have been dated either by radiocarbon or by stratigraphy.

SITE LOCALITY AND SITE NO.	REMARKS	REFERENCE	AGE
	MAORI PLAGGEN SOILS		
Moturua Is. (N12/6)	Pebbles and charcoal added to two successive topsoils (Layers 5 and 6). Radiocarbon dates on twig charcoal give dates close to times of cultivation.	Peters (1975)	Layer 5: 510±85 years BP (ANU 543A), 530±90 years BP (ANU 647A), 550±105 years BP (corrected mean of ANU 543A and 647A). Layer 6: 720±100 years BP (ANU 542A), 670±115 years BP (ANU 542C).
Marakopa	Gravel and charcoal added to top of Tirean soils at Section 49 and mantled Ohuan sand.	Wellman (1962b)	Tirean stable phase.
Pauatahanui (N160/107)	Stratified between Beach Ridges D and E.	Appendix 1	Older than Haowhenua earthquake.
Makara (N160/106)	Radiocarbon dated using shells forming part of the soil.	Appendix 1	560±60 years BP (NZ1877A), 520±70 years BP (NZ 1877B).
Okoropunga (N166/55)	In use before and when Ohuan "sand layer" deposited.	Chapter III and Appendix 1	Ohuan unstable phase, and earlier.
Greville Hbr. (D'Urville Is.) (S10/13)	Pebbles added to Tirean soil at Sections A and B on the Greville sand bar and mantled by Ohuan sand.	Wellman (1962a)	Tirean stable phase.
Clarence (S42/11)	Clarence northern soil. Dated by radiocarbon using twig charcoal from on top of the soil (minimum age).	Appendix 1	Older than 390±50 years BP (NZ 3113A), 490±80 years BP (NZ 3113C).
Clarence (S42/13)	Clarence southern soil. Dated using charcoal from a tree in position of growth in a soil formed in bottom of a borrow pit next to Plaggen soil (minimum age).	Appendix 1	Older than 430±40 years BP (NZ 3397A), 520±70 years BP (NZ 3397C).
	PLAGGEN-LIKE SOILS		
Waiheke Is. (N43/72)	Gravel added to a midden above a buried soil. Radiocarbon date on charcoal from beneath soil (maximum date).	Law (1975b)	Younger than 410±60 years BP (NZ 1900A), 500±85 years BP (NZ 1900C).
Te Ika amaru Bay (N164/17)	Behind and mantling Beach Ridge C	Chapter III	Younger than Haowhenua earthquake.
Te Ika amaru Bay (N164/115)	On sand mantling Beach Ridge C.	Chapter III	Younger than Haowhenua earth-
Okoropunga (N166/55)	In top of Ohuan "sand layer".	Chapter III	Ohuan stable phase or younger.
	TERRACE CULTIVATION		
Whitireia Peninsula (N160/28)	Terraced loess soil. Radiocarbon date on bracken fern charcoal collected by writer from cultivated layer described by McNab (1969), gives a close date for last (?) cultivation.	McNab (1969)	70±40 years BP (NZ 2696A), (270-100)±70 years BP (NZ 2696C).
	STONE ROW SYSTEMS		
Okoropunga (N166/55)	Maximum age based on radiocarbon; minimum age fixed by Ohuan "sand layer".	Chapter III and Appendix 2	Younger than 340±60 years BP (NZ 3114A), 470±85 years BP (NZ 3114C); older than Ohuan unstable phase.
Okoropunga (N166/55)	On and behind Beach Ridge C.	Chapter III	Younger than uplift of Beach Ridge C.
North Pa (N166/57)	On and behind Beach Ridge C.	Chapter III	Younger than uplift of Beach Ridge C.

SITE LOCALITY AND SITE NO.	REMARKS	REFERENCE	AGE
Te Awa Iti (N166/67	On stream fan deposits. Built of stones removed from Ohuan soil.	Chapter III	Ohuan stable phase or younger.
Clarence (S42/11)	Construction closely dated by radiocarbon using twig charcoal from top of soil buried by stone row.	Appendix 1	390±50 years BP (NZ 3113A), 490±80 years BP (NZ 3113C).
	PIT		
Skipper's Ridge Coromandel Peninsula (N40/7)	Pit closely dated by radiocarbon and thought to have been used for storing kumaras	Davidson (1975)	807±57 years BP (NZ 1740A), 730±85 (NZ 1740C).

TABLE 11

Radiocarbon dates for Maori fortifications.

SITE NAME OR LOCALITY, AND SITE NUMBER	EVENT DATED	MATERIAL DATED	NZ NUMBER	DATE	TYPE OF DATE	REFERENCE
Ruarangi (N20/41)	Occupation III	shell	1895A	320±80	close	Hougaard (1971)
			B	275±90		
	Occupation IV	shell	1896A	170±60	close	Green (1975b)
			B	115±70		
Waioneke (N37/25)	Earliest ditch and bank	wood	ANU760A	290±95	maximum	McKinlay (1971)
			C	(310-420) ±110		
	Construction of final ditch and bank	twigs and flax	ANU761A	100±85	close	
			C	(170-290) ±105		
	Construction of final ditch and bank	twigs and flax	ANU762A	75±80	close	
			C	(70-270) ±100		
Harataonga (N30/3)	First use of pa interior	charcoal	A	441±55	maximum	Law (1972, 1975)
			C	510±80		
Otakanini (N37/37)	Period I	charcoal	1279A	599±78	maximum	Bellwood (1971a, 1972, 1973)
			C	630±100		
	Period II	wood	1280A	389±48	maximum	
			C	480±80		
	Period III	wood	1281A	457±49	maximum	
			C	520±80		
	Period III	wood	1282A	145±50	maximum	
			C	(180-280) ±80		
	Period III	charcoal	1676A	315±54	maximum	
			C	460±80		
Rahopara (N38/20)	Formation of ditch and bank	charcoal	1762A	378±60	maximum	Green (1970) Davidson (1974)
			C	500±85		
Sarah's Gully (N40/10)	Period I (charcoal in pit fill)	charcoal	1080A	703±46	open	Birks (1960)
			C	700±80		
	Period III	charcoal	1082A	388±49	maximum	Birks L. and Birks H, (1970, 1973)
			C	500±80		
	Period III	charcoal	1081A	335±48	maximum	
			C	450±80		
	Period III	shell	698A	260±51	close	
			B	215±65		
	Period III	shell	699A	292±41	close	
			B	245±55		
Mt Wellington (N42/4)	Occupation	charcoal	404A	512±40	maximum	Golson (1960)
			C	550±70		
Pawhetau (N43/59)	Human bones found on a terrace	human bone collagen	A	350±80	close?	Fox (1974a)
			C	470±100		
Ngaroto (N65/18)	End of occpn	charcoal	909A	196±79	maximum	Shawcross (1968)
			C	300±100		
	Occupation	wood	907A	850±53	maximum	
				(750-820) ±80		
Mangakaware II (N65/35)	Occupation	wood	1121A	424±74	maximum	Bellwood (1971a,b)
			C	500±100		
	"Early" Occpn	wood	1125A	280±76	maximum	Bellwood (pers. comm.)
			C	(310-420) ±100		

SITE NAME OR LOCALITY, AND SITE NUMBER.	EVEND DATED	MATERIAL DATED	NZ NUMBER	DATE	TYPE OF DATE	REFERENCE
	Occupation	charcoal	1677A	1140±60	maximum	
			C	-		
	Occupation	tree fern	1678A	232±38	close	
			C	(300-420) ±70		
		wood	1679A	389±54	maximum	
			C	480±80		
Mangakaware I (N65/28)	Occupation	charcoal	1120A	2670±70	maximum	Bellwood (1971a,b) Bellwood (pers. comm.)
			C	-		
Pukearuhe	First Occupation	charcoal	- A	108±53	maximum	Gorbey (pers. comm.)
			C	(170-280) ±80		
		charcoal	- A	255±54	maximum	
			C	(300-420) ±80		
		charcoal	- A	278±54	maximum	
			C	(320-450) ±80		
Tiromoana (N135/1)	Early Occupation	wood	- A	3065±100	maximum	Fox (1974c, 1975, 1976)
			C	-		
		wood	- A	1050±90	maximum	
			C	-		
		charcoal	- A	420±70	maximum	
			C	500±90		
	Inner defences, Area IV	wood	- A	340±60	maximum	
			C	460±85		
		wood	- A	550±60	maximum	
			C	560±85		
	House on pa	wood	- A	130±90	maximum	
			C	(180-290) ±110		
		charcoal	- A	490±70	maximum	
			C	520±90		
	First Palisade Site IX	wood	- A	1550±90	maximum	
			C	1420±110		
	Second Palisade Site IX	wood	- A	250±60	maximum	
			C	(300-420) ±85		
	Lr 5, Site VI	wood?	- A	410±80	maximum	
			C	490±100		
	Lr 4, Site VI	wood?	- A	350±60	maximum	
			C	450±85		
Makara (N160/1)	Palisade construction (Sample 60 rings in from outside of post-putt).	wood	- A	310±60	maximum	Brodie (1962)
			C	(340-450) ±85		
			(C-60)	(280-390) ±85		
	Midden deposit	shell	- A	< 160	close	
			B	-		
Pariwhakatau (S55/7)	Occupation	wood	- A	320±60	maximum	Duff (1961)
			C	460±85		

TABLE 12

Sites on which are based the four assemblages set out in Figure 43. * = Sites closely dated by radiocarbon. Dates listed in foregoing tables. Not listed are shell dates for Katiki Point (211±56 years BP: NZ 697A), and for Shag Point (434±50 years BP: NZ782A).

EARLY ASSEMBLAGE

Northern

SITE	SITE NO.	REFERENCE
Harataonga Bay	N30/5	Law, 1972
Pig Bay	N38/21	Golson, 1959
Opito	N40/3	Golson, 1959
Sarah's Gully	N40/9	Golson, 1959
Tairua	N44/2*	Smart and Green, 1962
Hot Water Beach	N44/69*	Leahy, 1974
Whangamata (Midden B)	N49/2	Allo, 1972
Whiritoa	N53-4/4	Crosby, 1963
Tokoroa	N75/1	Law, 1973
Whakamoenga Cave (Occupation 1)	N94/7*	Leahy, 1976
Kaupokonui	N128/3	Buist and Robinson, 1963
Foxton	N148/1*	Text, Chapter III

Southern

SITE	SITE NO.	REFERENCE
Horowhenua	Middens 4, 19	Adkin, 1948
Heaphy River	S7/1*	Wilkes and Scarlett, 1967
Jacketts Island	S14/24	Challis, 1976
Tahunanui	S20/2	Millar, 1971
Wairau Bar	S29/7*	Duff, 1956
Redcliffs	S84/76*, 77	Skinner, 1923; Trotter, 1975b
Rakaia mouth	S93/20*	Trotter, 1972a
Takamatua	S94/36	Trotter, 1973
Upper Waitaki River	S117/3*, 4, 8	Trotter, 1970a; Ambrose, 1970
Waitaki mouth	S128/1	Teviotdale, 1937; S. Willetts (*pers. comm.*)
Oturehua	S134/1*	Leach, 1969

SITE	SITE NO.	REFERENCE
Tai-Rua	S136/1*	Anon, 1960; Gathercole, 1961; Trotter, 1959
Ototara	S136/2*	Trotter, 1965
Waimataitai	S146/2*	Trotter, 1955
Hampden	S146/16*	Trotter, 1967b
Shag River	S155/5	Skinner, 1924
Little Papanui (lower and middle)	S164/1	Simmons, 1967
Tiwai Point	S181-2/16	Park, 1969
Pounawea	S184/1*	Lockerbie, 1959
False Island	S184/3	Lockerbie, 1959
Papatowai	S184/5	Teviotdale, 1937b, 1938; Lockerbie, 1953, 1959
Kings Rock	S184/6	Lockerbie, 1940

LATE ASSEMBLAGE

Northern

SITE	SITE NO.	REFERENCE
Ruarangi Pa	N20/41*	Hougaard, 1971
Waioneke Pa	N37/25*	McKinlay, 1971
Otakanini Pa	N37/37	Bellwood, 1972
Sarah's Gully Pa	N40/10*	Birks, 1960
Galatea Bay	N43/33	Terrell, 1967
Ngaroto	N65/18	Shawcross, 1968
Mangakaware	N65/28*, 35	Bellwood, 1971a, b; Peters, 1971;
Paterangi Pa	-	Shawcross and Terrell, 1966
Oruarangi Pa	-	Fisher, 1934, 1935, 1936 1937; Teviotdale and Skinner, 1947; Skinner, 1974
Whakamoenga Cave (Occupation 2, 3)	N94/7	Leahy, 1976
Horowhenua Pa	-	Rolston, 1944, 1947, 1948

LATE ASSEMBLAGE

Southern

SITE	SITE NO.	REFERENCE
Takahanga	S49/13	Trotter, 1974
Pariwhakatau Pa	S55/7	Duff, 1961
Moa-Bone Point Cave (Upper Occupation)	S84/77	Skinner, 1923
Katiki Point	S146/4 *	Trotter, 1967c
Shag Point	S146/5 *	Trotter, 1970b
Little Papanui (Upper Occupation)	S164/1	Simmons, 1967
Murdering Beach	-	Skinner, 1959
Tarewai Point	-	Teviotdale, 1939

APPENDIX 1

MAORI PLAGGEN SOILS, THEIR ORIGIN AND PROPERTIES, AND USE FOR GROWING TROPICAL PLANTS.

INTRODUCTION

Plaggen is a European term for distinctive soils containing mineral particles (sand and gravel) in the A horizon that have been transported in by man. The word is from the German Plagge, meaning sod; and Plaggen, to cut sods. It is known from historical records that the addition of the particles may have been intentional or accidental. In Ireland sand alone was intentionally added, sometimes mixed with animal dung, or seaweed (Conry, 1971). Elsewhere in northern Europe the sand and gravel was introduced accidentally, with sods and animal dung etc. (Edelman, 1950).

Equally distinctive European and Maori plaggen soils occur in New Zealand. Best known Maori localities are the mid-Waikato Basin (2,000 ha) (Taylor, 1958), the Waimea Plains near Nelson (400 ha) (Rigg and Bruce, 1923), and near Kaiapoi in north Canterbury (Stack, 1893). Plaggen soils are thought here to have formed an appreciable part of the total area cultivated by the Maoris.

The two tropical plants, kumara (Ipomoea batatas) and taro (Colocasia antiquorum), were the most important cultivated plants in prehistoric New Zealand. It is known from Colenso (1880) that sand and gravel were added to the soil in which the plants were grown. There is no evidence that the Maori added sods, seaweed, or dung, but it has been suggested that he burnt scrub on the soils to improve their fertility (Rigg and Bruce, 1923).

It is not known for certain why sand and gravel were added. It is commonly supposed that they made the soils lighter and warmer for the two tropical plants (Best, 1925).

After European contact (1769) there was a burst of agricultural activity; and in the colder parts of New Zealand the Maori rapidly changed over to non-tropical plants, in particular, Irish potato (Hargeaves, 1963). The Maoris continued to use their plaggen soils, and even appear to have created new ones (Hargreaves, 1963), and some plaggen soils may never have had tropical plants in them. Hence, to be certain that a plaggen soil was used for cropping tropical plants, it must be known to be prehistoric. Such soils are called here Maori Plaggen soils. Plaggen-like soil is used for soils not proven to be prehistoric.

MAORI PLAGGEN SOILS

In section a Maori Plaggen soil is clearly recognisable as a layer, although its lower contact may be poorly defined. Some Maori Plaggen soils are buried, but where they are the ground soil their ground surface may be hummocky. Maori Plaggen soils may be sheet-like, or strip-like as on a terrace, and may cover an area from several hectares down to a few square metres. Charcoal varies from rare and difficult to find, to abundant, and may be accompanied by shells and bones.

Reasonable evidence of sediment transport and deposition by man is the most important feature in identifying the soils. Sediments comprising all or part of a Maori Plaggen soil will normally be out of place in the sedimentary history of a site, and a common situation is marine sand or gravel in a terrestrial environment. Transport may be confirmed by particle-size analysis if the source of transported sediments can be found. The source of sand or gravel may be marked by a borrow pit, and borrow pits may contain large stones which would have been a hindrance to cultivation (Rigg and Bruce, 1923).

Maori Plaggen soils (for which the symbol θ (theta) is used for maps and sections) are represented by two extreme types depending on how much the transported sediments have been mixed with the former ground soil.

Maori Plaggen L soils (θ_L) are a layer of transported sediments between about 20 cm and 30 cm thick spread over, but poorly mixed with, a former ground soil or sedimentary layer. Transported sediments form close to 100% of these soils. Poor mixing is indicated by differences in the particle sizes between Maori Plaggen L soils and their former ground soils or sedimentary layers and, or, by preservation of the former ground soil as a buried soil. Maori Plaggen L soils are physically suitable for kumara cultivation, being light, friable and warm.

Maori Plaggen M soils (θ_M) are transported sediments which have been well-mixed with a former ground soil or sedimentary layer. Transported sediments may form more than 50%, or less than 5%, of these soils, Maori Plaggen M soils which are too heavy for kumaras may be suitable for taro.

Sand and gravel were apparently transported annually onto kumara cultivations (Colenso, 1880). A Maori method of preparing a plot of ground for cultivation was to loosen the ground with a digging stick or ko (Best, 1925), which would tend to mix into the ground any sand or gravel deposited during the previous year. This would account for the Maori Plaggen M soils, which became thicker each year as more sand and gravel were added. Maori Plaggen L soils are thought to have been deposited as a thick layer before being cultivated, and to have been increased in area by subsequent additions of sand and gravel.

Five Maori Plaggen soils (Figure 1) are described below. Two are θ_L soils, three are θ_M soils. Three of the soils are buried and are thus protected. All are within 0.5 km of the coast.

Particle sizes referred to in the following soil descriptions are: silt and clay, less than 0.06 mm; sand, between 0.06 mm and 2 mm; gravel, between 2 mm and 64 mm; and stones, larger than 64 mm.

MAKARA MAORI PLAGGEN L SOIL

The Makara Maori Plaggen L soil is located on a north-facing terrace cut into a steep hillside overlooking Fisherman's Bay at Makara Beach (Figure 2). The terrace is 3 m wide, 40 m long, and about 10 m above sea level. It is sunny and warm, and well sheltered from strong northwesterly winds which frequently blow into Fisherman's Bay.

A section exposed in a 3 m by 1.5 m trench excavated by the Wellington Archaeological Society in 1967 is described in Table 3. Layer 1, the oldest, is weathered greywacke rock into which postholes and stakeholes have been dug. Layer 3 is scree with big stones from the high steep hillside behind the terrace. It is without cultural remains or charcoal and thins from 0.4 m at the rear of the terrace to less than 5 cm thick at the front.

Layer 2, which lies between Layers 1 and 3, is the Maori Plaggen soil. It is the same composition as Layer 3, but is without the big stones and has more sand (Figure 7). It is of even thickness (25 cm to 30 cm) with a barrier of large stones along the outside of the terrace to hold it in. Its layering is quite different from that of the scree, being a series of separate lenses.

Some lenses contain shell midden, with obsidian, chert, and oven stones. A mixture of gravel and shell midden filled the postholes and stakeholes. The fill of one posthole and two stakeholes was sealed by a lens of soil without gravel indicating that midden and gravel were mixed before being deposited.

Shells from Layer 2 have a radiocarbon date of 525±70 years BP (NZ 1877B, Table 2). With the shells were limpets which are known to weather rapidly. The limpets were entire but so rotten that they broke-up when shifted. It is thought that the limpets and other shells were buried in the layer soon after they were taken from the sea.

OKOROPUNGA MAORI PLAGGEN L SOIL

Okoropunga Stream lies about half-way between Te Awa Iti and the Pahaoa River on the southeast Wairarapa coast (Figure 3a). The Maori Plaggen soil 0.7 ha in area is near the foot of a small stream fan on the coastal platform adjacent to a fixed sand layer on Beach Ridges E and F. It has a very hummocky ground surface slightly lower than the ground surface of the fixed sand layer. Immediately next to the soil are two large pits dug into gravel on the seawards edge of Beach Ridge E. To the south of the Maori Plaggen soil is the Stone Row System described in Appendix 2.

A trench was dug along the line M --- R (Figure 3b) in order to stratigraphically link together the fixed sand layer, the Maori Plaggen soil, and the Stone Row System. A section along the critical part of the trench is shown in Figure 3c, and described in Table 3. It is divided into two parts by a buried soil containing a charred totara tree root in position of growth. The lower part consists of three layers: 1 a wave-cut rock platform and 2 and 3 its natural cover of Beach Ridge F gravel and the sand in which the buried soil formed. The upper part is the Maori Plaggen soil (Layer 4), the fixed sand layer, and a thin covering of fine wind blown dust (Layer 5). The Maori Plaggen soil is composed of transported marine gravels and is separated into two parts by a silt layer. The upper part contains less than 10% silt. Poor mixing of the Maori Plaggen soil with its underlying layers is indicated by the existence of the silt layer, and the buried soil.

The trench shows the Maori Plaggen soil to be younger than the Stone Row System and the same age as the sand layer. The plaggen soil extends across what was once the northernmost stone row. The stone row was destroyed when the soil was made. In the trench, only a few metres width separates the Maori Plaggen soil from the fixed sand layer (Figure 3b). The top of the sand layer is 0.5 m higher than the top of the plaggen soil, and the "map" contact between the two is a straight line. The simplest explanation for the height difference and straight "map" contact is to suppose that a fence prevented the sand layer from moving down and burying the plaggen soil.

Charcoal from the tree root in the buried soil has a radiocarbon age of 720±70 years BP (NZ 3116C, Table 2). Charcoal in a stone row in the Stone Row System has a radiocarbon age of 470±85 years BP (NZ 3114C, Table 2). The ground soil on the sand layer is estimated from its degree of profile development to be ca. 300 years old. The age of the fixed sand layer, and the time when the Maori Plaggen soil was in use, is thus the Ohuan unstable phase.

The volume of the Maori Plaggen soil is estimated to be 1,600 m^3. The gravel is the same as that on the edge of the pits immediately eastwards of the soil on the seawards edge of Beach Ridge E (Figure 3b). The volume of the pits is only 260 m^3. The volume difference of 1,340 m^3 is probably accounted for by pits having been excavated in areas which have since been covered by the fixed sand layer.

PAUATAHANUI MAORI PLAGGEN M SOIL

On the north shore of the Pauatahanui Inlet (Figure 4a) a Maori Plaggen soil is exposed for a distance of 65 m in a road section. The section is on the inland side of the road 20 m from the sea and is separated from the road by a ditch. The section is less than a metre thick and slopes towards the south. The Maori Plaggen soil is between 1.5 m and 3 m above high water mark.

The section is shown in Figure 4b and described in Table 3. Layers are numbered from the bottom up 1 to 4. Layer 1 is well-weathered gravel of a raised Holocene beach ridge which rests on pre-Holocene loess at the northern end of the section. Layer 3 is silt (10 cm thick) with very few stones and pieces of iron and bottle glass in its upper surface. Layer 4 is a low mound of silt containing iron, stones, and road metal, and is separated from Layer 3 by a stone line.

Layer 2 is the Maori Plaggen soil. It is composed of loess-like drift and gravel and is between 20 cm and 30 cm thick. The upper part (10 cm to 15 cm thick) is brown to dark brown in colour; the lower part (also 10 cm to 15 cm thick) is more yellow-brown in colour. A small quantity of well-rounded unweathered greywacke beach gravel, and rare small pieces of charcoal, are mixed more or less uniformly through the layer. Cultivation has disturbed the weathered gravels of Layer 1, in some places dragging them a short distance up into Layer 2, but the gravels in Layer 2 are mostly unweathered. At the north end of the section Layer 2 rests on loess which is similarly disturbed: blocks of loess up to 3 cm across have been dragged into the bottom of Layer 2.

There is no shell in the Maori Plaggen soil, although there is a shell midden on Layer 2 at the north end of the section, and shells occur in a stone line which separates Layer 2 from Layer 3.

The unweathered rounded gravel is not found in Layer 1, and is rare on the present foreshore. Gravel on the present foreshore is more angular, similar to Layer 1 gravel, but much less weathered. Unweathered gravel is unlikely to have been picked out piece by piece from the foreshore. The next nearest source of unweathered rounded greywacke gravel known to the writer is the beach outside the Pauatahanui Inlet entrance, and if this is the source of the gravel in the Plaggen soil, then the gravel has been transported nearly 3 km.

A minimum age for the Maori Plaggen soil is provided by a radiocarbon date for shells from the midden. The midden is 7 m long and has a maximum thickness of 13 cm. The shells are all found locally and include cockle (Chione stutchburyi), pipi (Paphies (Paphies) australe), mudsnail (Amphibola crenata), and rare mussel (Mytilus edulis aoteanus). Some cockles are in position of articulation and are thus thought to have been deposited in the midden soon after they were collected. The cockle shells are 500±80 years old (NZ 1878B, Table 2).

CLARENCE MAORI PLAGGEN M SOILS

There are Maori Plaggen M soils at two different places less than 2.5 km north of the Clarence River mouth at Sites S42/11 and S42/13 (Figure 5a). The northern soil is part of a Stone Row System at the rear of the Holocene coastal platform. There are late Pleistocene gravels in the hillside above the coastal platform. The southern soil is on an old river terrace which abuts onto Holocene beach ridges.

Clarence Northern Soil (Site S42/11)

The Maori Plaggen soil is not exposed and was found while excavating a stone row (Figure 5b). Its area is at least 40 m^2, but its full extent is not determined. A section through the stone row and Maori Plaggen soil is shown in Figure 5c and described in Table 3. Layers are numbered 1 to 5 upwards from the bottom. Layer 1 is brown silty sand without stones or gravel. Layer 2 is the Maori Plaggen soil: stones and gravel added to the top of Layer 1. The stone row was built on top of Layer 2 and layers 3, 4 and 5 (sand, silt and sandy silt) accumulated around the stone row.

Layer 2 is a gravelly loamy sand between 30 cm and 50 cm thick. Seive analysis shows two distinct modes (Figure 7): a sand mode and a gravel mode. The gravels are round gravels similar to the late Pleistocene gravels. Although stones and gravel probably erode continually from the hillside, their density in the layers above and below Layer 2, and in the present ground soil, is generally very much lower than in Layer 2. For this reason the gravel and stones are considered to have been added to Layer 2 by man.

Layer 2 contains very little charcoal, but a number of charcoals were found on top of Layer 2 beneath the stone row. The charcoals included small diameter twigs and sticks identified as matai (Podocarpus spicatus), Coprosma sp. and Hebe sp. All are thought here to be remains of plants which grew nearby and were probably buried under the stone row soon after burning. The charcoals, which give a minimum radiocarbon age for the Maori Plaggen soil, are 500±80 years old (NZ 3113C, Table 2).

Clarence Southern Soil (Site S42/13)

Fine dust blown north from the Clarence River mouth has covered the old river terrace with 0.3 m to 0.7 m of loess. Along the northeast edge of the terrace is a 4 m high scarp below which are the Holocene beach ridges. At the rear of the closest beach ridge is a large irregular-shaped pit 280 m long (Figure 6), around which are scattered many large stones. Attention was drawn to the pit by the stones because the beach ridge sediments into which the pit is dug are mostly sand and gravel and the large stones were apparently discarded when sand and gravel were taken away. Because a firm subsoil was desired for kumara cultivation (Walsh, 1902) the loess on the terrace above the pit was examined as a likely cultivation ground. The Maori Plaggen soil was found along the top of the scarp for the full length of the pit, and up to 160 m back from the scarp. It had been formed by the addition of "grit" (coarse sand and fine gravel) to the top few centimeters of loess to produce a well-drained, friable sandy loam on top of a harder, less friable silt (Table 3), physically suitable for kumara cultivation. The soil is undisturbed by ploughing, and has a very hummocky ground surface.

The Maori Plaggen soil is strongly bimodal (Figure 7): one mode corresponding to fine sand and silt which is a major part of the loess; the other mode, to coarse sand and fine gravel which is a major part of the beach ridge sediments in the side of the pit. The pit is therefore thought to be the source of the grit.

The Maori Plaggen soil now covers 2.5 ha (Figure 6). Its original extent is uncertain because of the railway and road. Assuming an even distribution of grit, the most economical area requiring least work carrying grit is a rectangle. The original area of plaggen soil is therefore thought to have been about 4.5 ha in a rectangle as long as the pit (280 m), and as wide as the maximum distance of grit back from the scarp (160 m) (Figure 6).

The volume of grit in the existing Maori Plaggen soil is 3380 m^3, and is calculated from the thickness of grit added to the loess at each intersection of a 20 m grid (thickness of grit = depth of grit x percentage of grit in a representative sample). It is assumed that the average thickness of grit was the same over the whole soil area, and the total volume of grit in the whole soil is calculated to have been 5530 m^3.

The pit ranges up to 40 m wide and has a maximum depth of 3 m. Its volume, calculated from cross-sections measured at 20 m intervals, is 7760 m^3. It is assumed that all gravel and stones coarser than required were left behind around the pit, not in the pit; and that fine sand and silt, which would have been difficult to separate, were transported onto the terrace. The volume of coarse sand and fine gravel removed from the pit is thus the pit volume less the volume of stones and gravel larger than those found on the terrace (18%), and less the volume of fine sand and silt in the pit sediments (18%). The calculated volume of coarse sand and fine gravel removed from the pit is thus 4970 m^3, and is sufficiently close to the calculated volume of grit in the whole soil to confirm the pit as the source of the grit.

A minimum age for the Maori Plaggen soil is provided by a radiocarbon date on charcoals from a charred tree root in position of growth in a buried soil formed in the bottom of the borrow pit. The charcoals, identified as Pseudopanax sp., are $510^{\pm}70$ years old (NZ 3397C, Table 2).

PROPERTIES OF MAORI PLAGGEN SOIL

The five Maori Plaggen soils are composed of sediments which are generally distinctive when compared with the former ground soil or sedimentary layer. Their thickness is therefore easily determined, and thicknesses of between 20 cm and 55 cm have been observed (Table 1). The thickness of any one Maori Plaggen soil may vary appreciably and is probably due to the Maori practice of heaping up kumara soils into mounds in which kumaras were grown. According to Walsh (1902) these mounds were about 9 inches (20 cm) high, and about 24 inches (60 cm) in diameter. Mound formation may explain the hummocky ground surface of Maori Plaggen soils.

Colour varies from black to brown (Table 1). Charcoal is uncommon and cannot be considered a significant factor contributing to soil colour. Soils may be blackened by coastal scrub growing on them (Taylor and Pohlen 1970), which may explain the dark colour of some Maori Plaggen soils. It is interesting to note that the lower part of the Okoropunga Maori Plaggen soil, which was probably buried soon after its formation, and which contains the most charcoal of any of the soils (Table 3), is lighter in colour than the upper part which has been a ground soil since it was abandoned for kumara cultivation.

Textures range from gravelly silt loam to very gravelly sand (Table 1). Added sand and gravel are important parts of all soils except the Pauatahanui soil which is somewhat heavier than the other soils. So little gravel has been added to the Pauatahanui soil that it is difficult to know what purpose it may have served. Ideal kumara soils have a light friable topsoil for warmth, overlying a firm subsoil to prevent tubers from running. The topsoil at Makara, Okoropunga and both Clarence sites is light and friable. The subsoil at Makara is hard, and at Clarence (S42/13) is firm. The subsoil at Okoropunga and Clarence (S42/11) is very friable silty sand when damp, but becomes firm when dry in summer (kumara growing season). The soils at Makara, Okoropunga and Clarence, are thus considered suitable for kumara cultivation. The heavier Pauatahanui soil may be more suitable for taro.

There is little evidence to show how the soils were fertilised. There is midden material in the Makara soil. The midden, which contains bone and shell, probably also contained vegetable matter, and would have provided nitrogen, phosphorus and lime. There is no midden in the other soils. Rigg and Bruce (1923) have suggested that the Maoris fertilised their cultivation grounds on the Waimea Plains by burning scrub on them, but charcoal is uncommon in the soils described here.

The Makara soil is sheltered, but the other four soils are exposed to strong winds. In order to grow tropical plants successfully the exposed soils would require more shelter than they have today. The dated totara tree root found beneath the Okoropunga Maori Plaggen soil suggests that the plaggen soil may have been sheltered by forest. The identified charcoals used to date the northern Clarence Maori Plaggen soil (S42/11) suggest that it too may have been sheltered by forest. However, the Pauatahanui soil, which has the sea along its northwestern side, is exposed to prevailing northwesterly winds; and the southern Clarence soil, which covers more than 350 m by 450 m on a river delta extending into the sea, is exposed to all winds. Both soils would have been difficult to shelter by vegetation: the Pauatahanui soil because of its nearness to the sea; the southern Clarence soil, because of its large size and exposed situation, and it is therefore thought that 400 to 600 years ago conditions may have been less windy than they are today.

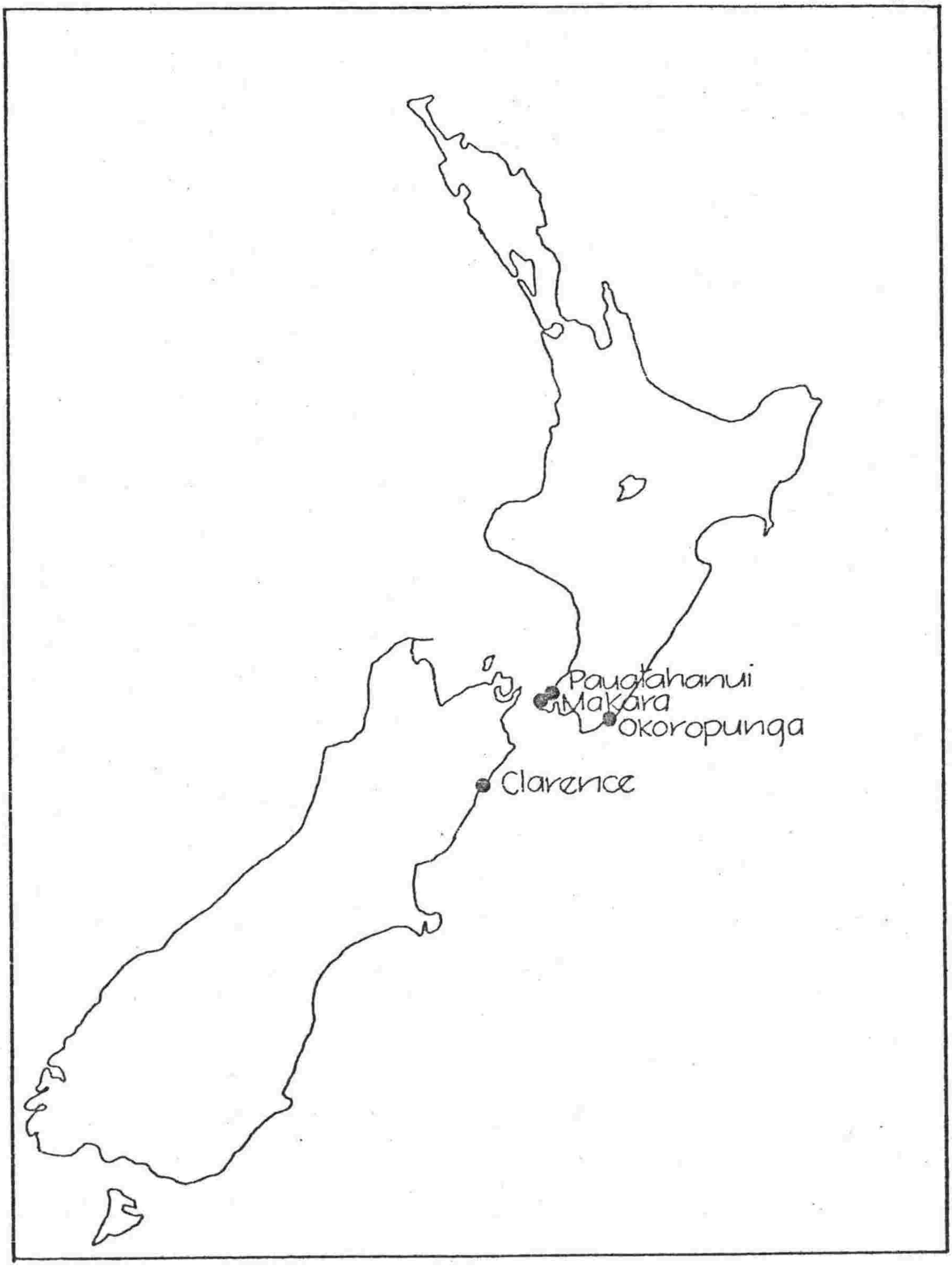


FIGURE 1 - Locality map of Maori Plaggen soils discussed in text.

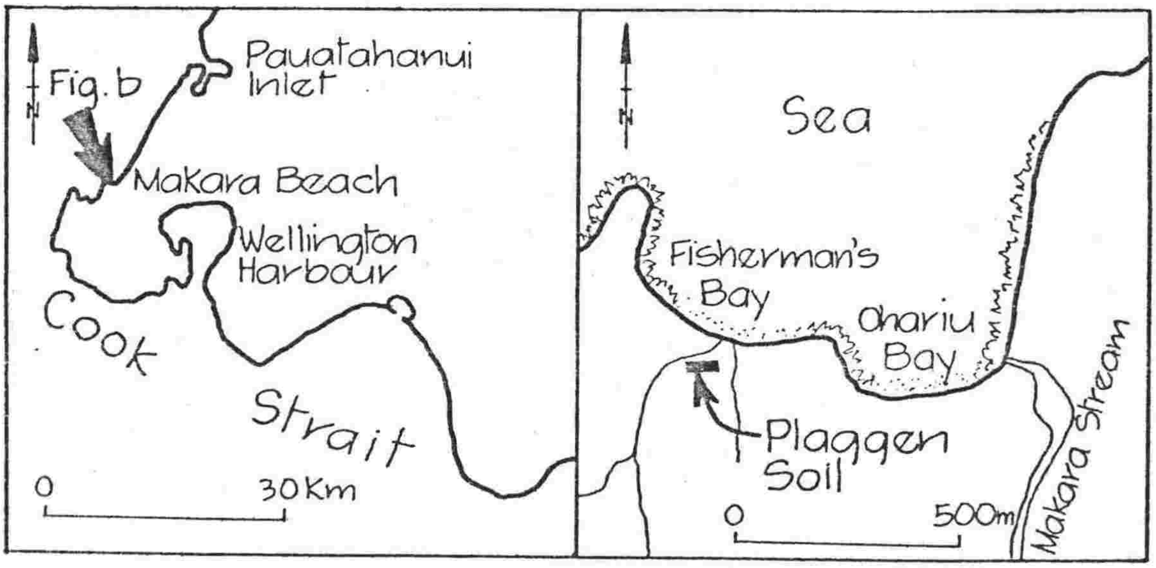


FIGURE 2 - Diagram for the Makara Beach Maori Plaggen soil (site N160/106) on the west Wellington coast.

Fig.a. Locality map showing position of Makara Beach.

Fig.b. Sketch map of Makara Beach showing position of the Maori Plaggen soil

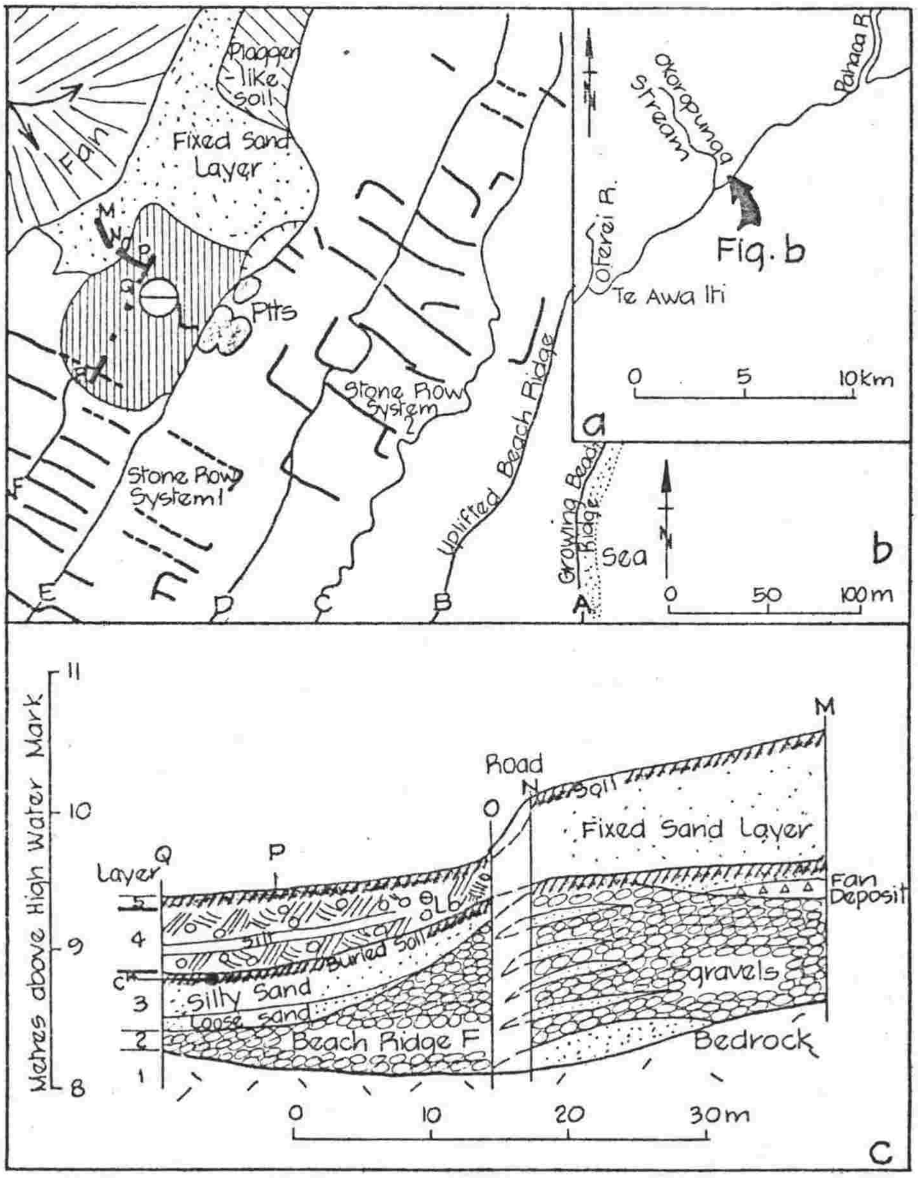


FIGURE 3 - Diagram for the Okoropunga Maori Plaggen soil (site N166/55) on the southeast Wairarapa coast.

Fig.a. Locality map showing position of Okoropunga.

Fig.b. Sketch map showing positions of Beach Ridges A to F (light lines), stone rows (heavy lines), Maori Plaggen soil (θ_L), and excavated trench (M-R).

Fig.c. Cross-section along line M-N-O-P-Q on Figure b. Radiocarbon sample shown as a heavy dot labelled C^{14}. Maori Plaggen soil shown θ_{Lb}.

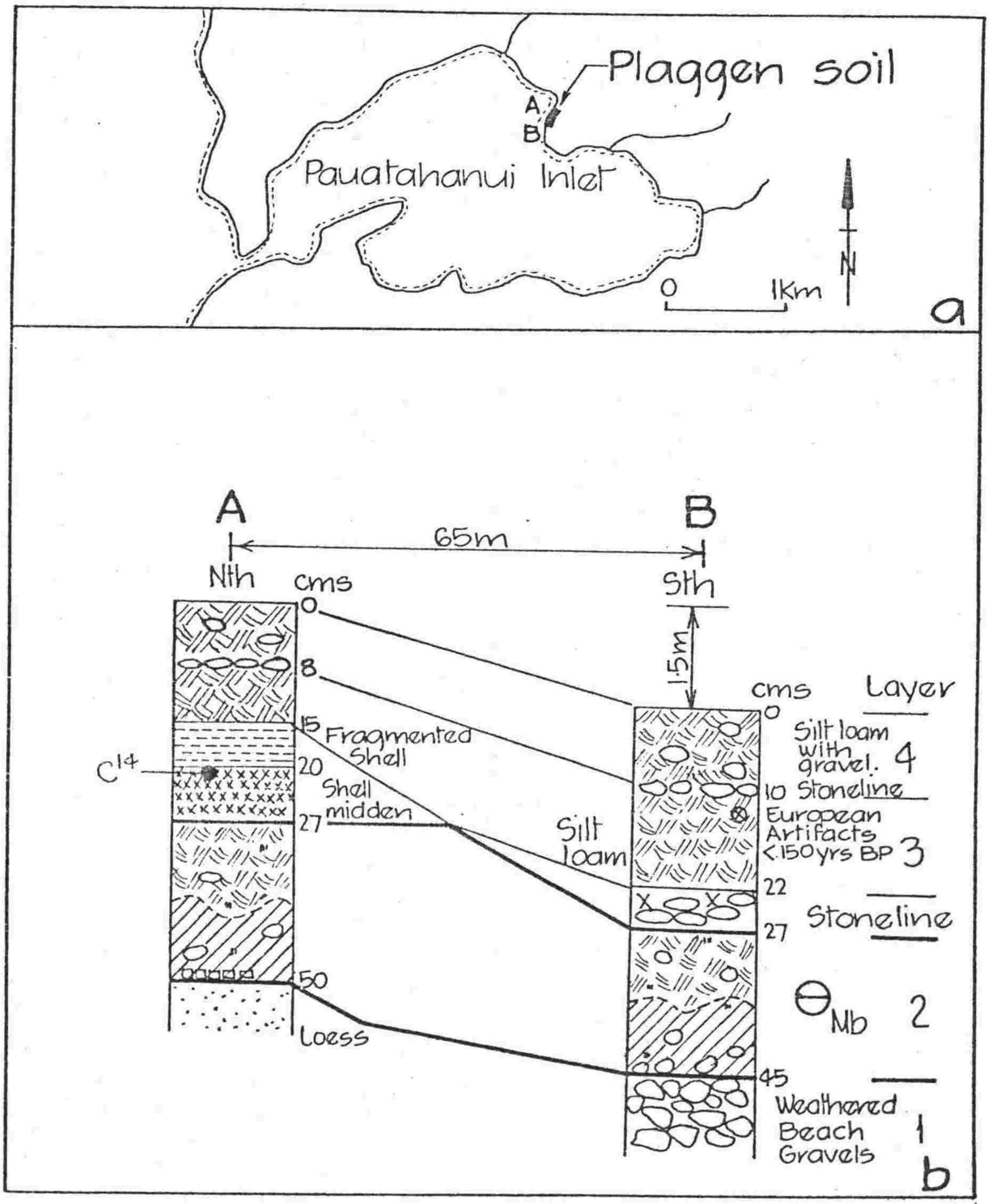


FIGURE 4 - Diagram for the Pauatahanui Maori Plaggen soil (site N160/107) on the west Wellington Coast.

Fig.a. Locality map showing position of the Maori Plaggen soil.

Fig.b. Cross-section A-B on Figure a. Radiocarbon sample shown as a heavy dot labelled C^{14}.

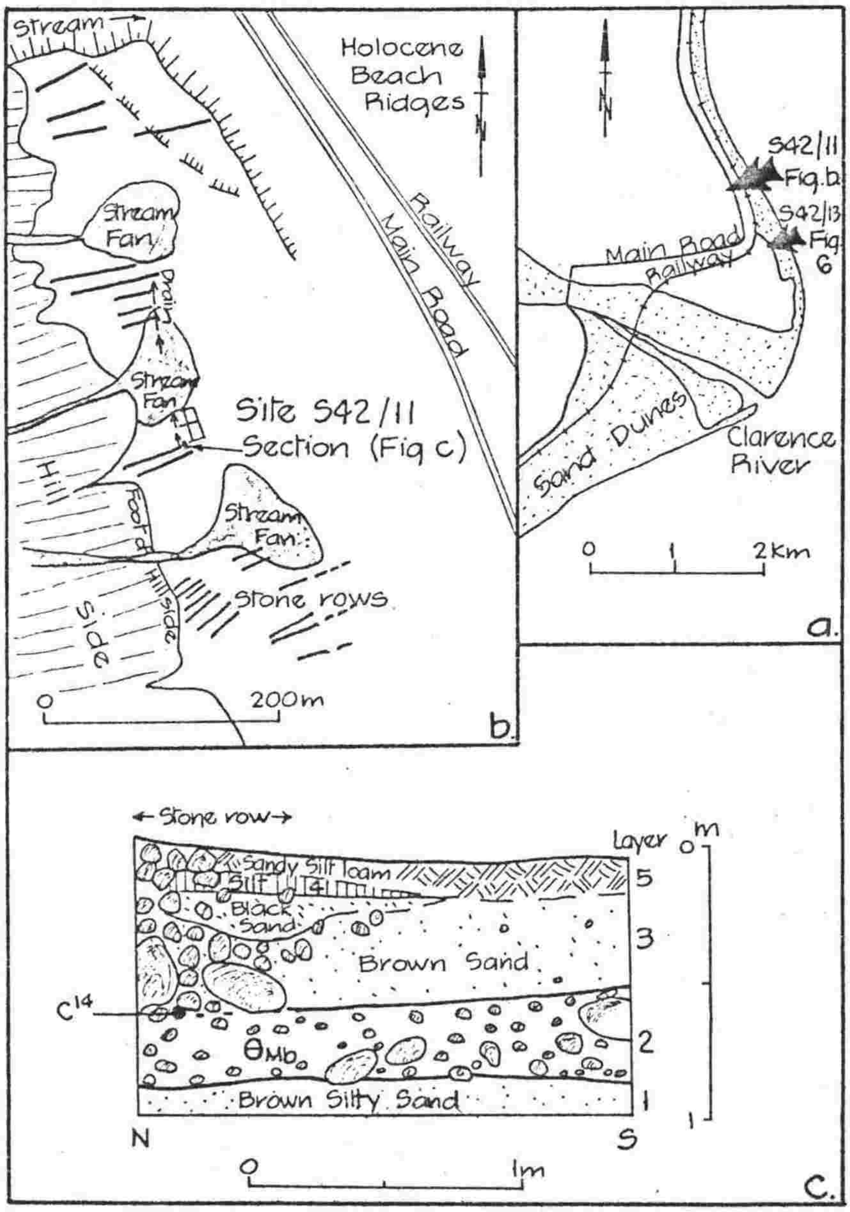


FIGURE 5 - Diagram for the Clarence River Maori Plaggen soils (sites S42/11 and 13) just north of the Clarence River mouth, east coast South Island.

Fig.a. Locality map showing positions of the Maori Plaggen soils.

Fig.b. Sketch map of the northern Clarence River site (S42/11) showing stone rows (heavy lines), and the position of a section excavated through a stone row.

Fig.c. Cross-section of the excavated stone row. Maori Plaggen soil shown θ_{Mb}. Radiocarbon sample shown as a heavy dot labelled C^{14}. Layers numbered 1 to 5.

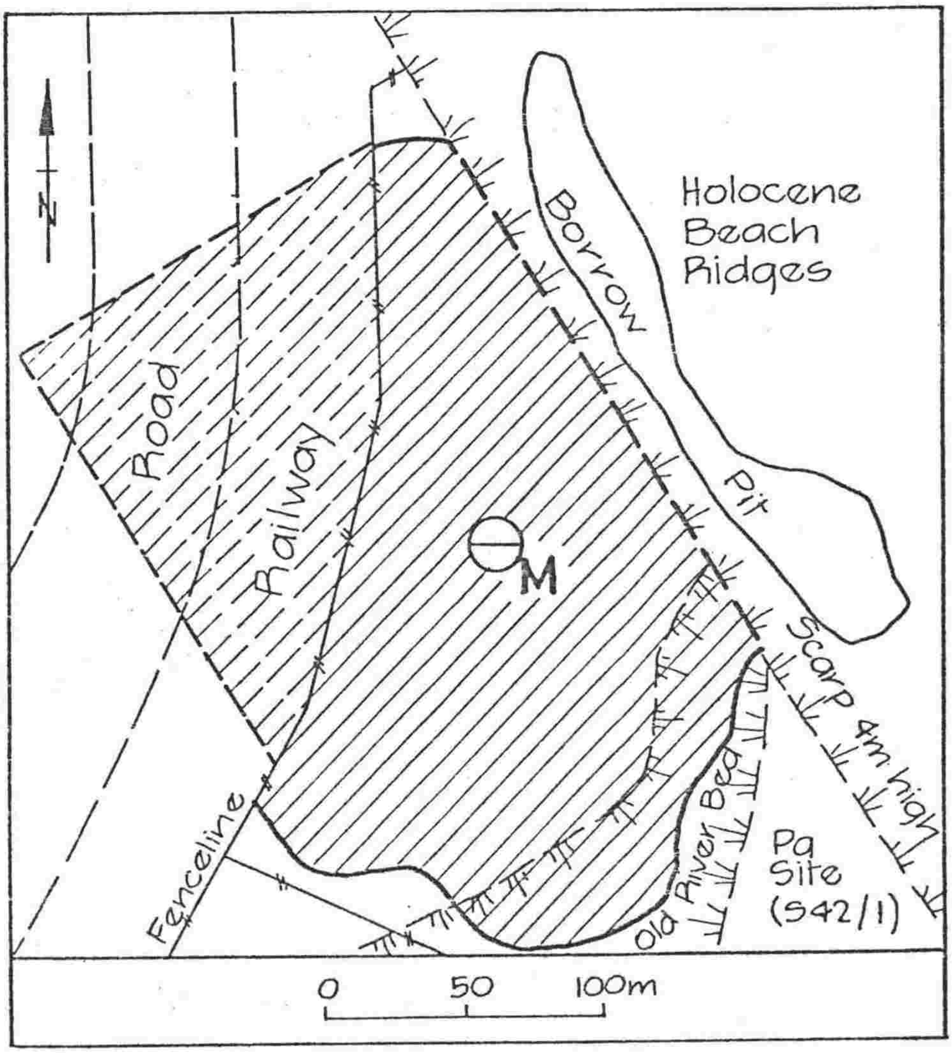


FIGURE 6 - Sketch map of the southern Clarence River site (S42/13) showing Maori Plaggen soil (cross-hatched), estimated extent of whole plaggen soil (broken cross-hatch), and borrow pit.

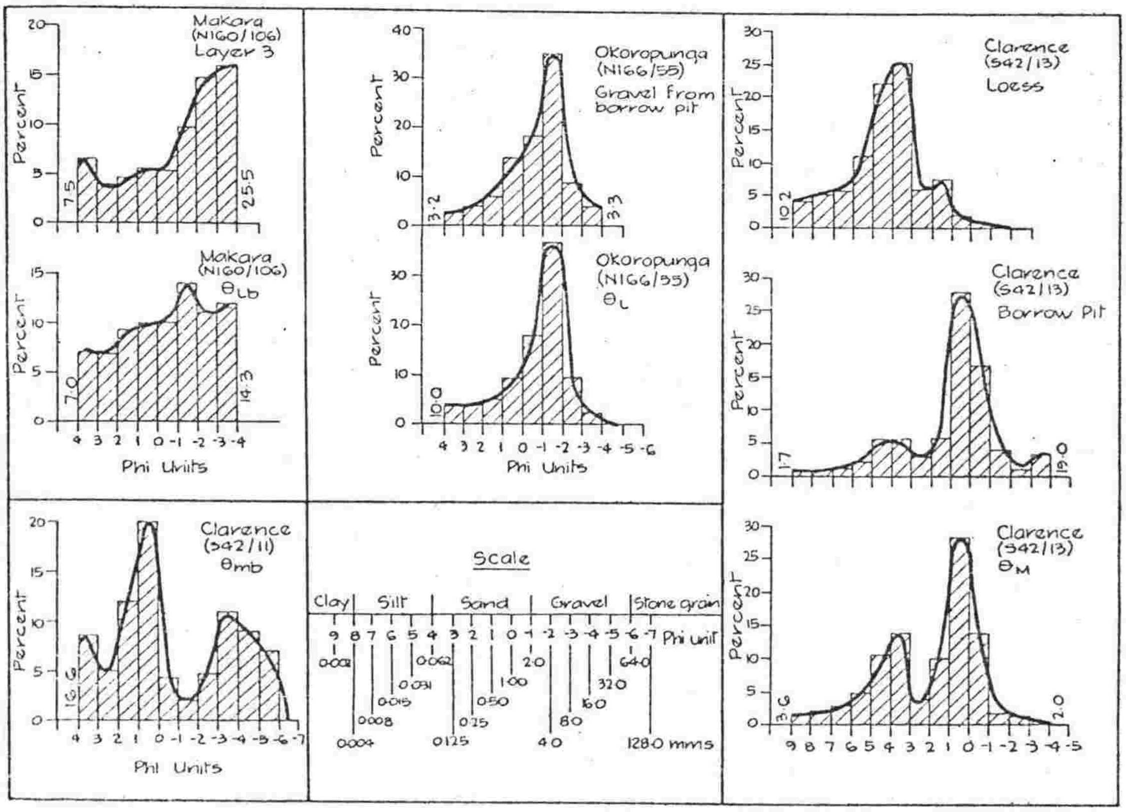


FIGURE 7 - Particle-size histograms for Maori Plaggen soils at Makara, Okoropunga, and Clarence. Makara soil compared with Layer 3 (natural talus). Okoropunga soil compared with beach ridge sediments from a borrow pit. Clarence southern soil (S42/13) compared with underlying loess, and with beach ridge sediments from a borrow pit. All bars represent one phi unit (= $-\log_2$ diameter in mm). Bar heights in percent (note different scales). Percentage of sample smaller than smallest phi unit measured is shown at left hand end of histogram. Percentage of sample bigger than biggest phi unit measured is shown at right hand end of histogram. Percentages determined by dry seiving and, for particles smaller than 4 phi in Clarence southern soil, by pipette analysis.

TABLE 1

Properties of five Maori Plaggen Soils discussed in text. Colour is given in Munsell notation, determined using Oyama and Takehara (1967). Lower contact, texture and structure are described according to Taylor and Pohlen (1970). Soil ages are determined by radiocarbon dates given in Table 2 and, for the Okoropunga soil, by stratigraphy (S).

Maori Plaggen Soil	N.Z. Archaeological Associated Site No. and Grid Reference	Thickness (cm)	Soil Colour	Lower Contact	Texture	Structure	Organic Addition	Age (Years BP)
Makara θ_L	N160/106 (N160(1965)/272300)	25-30	Black to brownish-black (10YR2/1-2/2)	Diffuse	Very gravelly sandy loam.	Granular	Shell, bone, rare charcoal.	Between 720-440
Okoropunga θ_L	N166/55 (N166(1957)/133033)	20-35	Brownish-black (10YR3/2-2/2) (upper) Dark brown (10YR3/3) (lower)	Distinct to diffuse	Gravelly to very gravelly sand.	Single grain and granular	Rare charcoal	Less than 860-400 Between 300-400 (S)
Pauatahanui θ_M	N160/107 (N160(1965)/446454)	20-30	Brown to dark brown (10YR4/4-3/4) (upper) Brown (10YR4/4-4/6) (lower)	Sharp to diffuse	Gravelly silt loam.	Granular with some nut	Rare charcoal	More than 660-340
Northern Clarence θ_M	S42/11 (S42(1968)/192218)	30-50	Brownish-black (10YR2/2)	Distinct	Gravelly loamy sand.	Granular and crumb	Rare charcoal	More than 660-340
Southern Clarence θ_M	S42/13 (S42(1968)/200211)	30-55	Black to brownish-black (10YR2/1-2/2)	Distinct	Gravelly sandy loam.	Single grain to granular with some crumb	Rare charcoal	More than 650-370

TABLE 2

Radiocarbon dates for the five Maori Plaggen Soils. Dated charcoals were identified by Dr B. P. J. Molloy, Botany Division, D.S.I.R., Christchurch. The Makara shells contained calcite and were pre-treated by dissolving off their outer one-third.

Maori Plaggen Soil and Site Number	NZ Number	C^{14} Age Years BP (1950)	Material Dated and Source of Sample
Makara (N160/106)	1877A 1877B	560±60 525±70	Shells: Paua (*Haliotis iris*), dark rock shell (*Haustrum haustorium*) and limpets (*Cellana denticulata* and *C. radians*); mixed with the Maori Plaggen soil.
Okoropunga (N166/55)	3116A 3116C	750±40 720±70	Charcoals from tree root in position of growth in topsoil buried by the Maori Plaggen soil. Charcoals identified as *Podocarpus totara-hallii* group (most probably *P. totara*), plus a very small amount of unidentifiable woody dicotyledonous material.
Pauatahanui (N160/107)	1878A 1878B	480±70 445±80	Cockle shells (*Chione stutchburyi*) from shell midden resting on top of the Maori Plaggen soil.
Northern Clarence (S42/11)	3113A 3113C	390±50 500±80	Charcoals of small diameter from on top of the Maori Plaggen soil, beneath a stone row. Charcoals identified as *Coprosma* sp., *Hebe* sp., and *Podocarpus spicatus*.
Southern Clarence (S42/13)	3397A 3397C	430±40 510±70	Charred tree root of *Pseudopanax* sp. (*P. colensoi-arboreum* type). Found in position of growth in buried soil formed in the bottom of a borrow pit from which sand and gravel had been taken to make Maori Plaggen soil.

TABLE 3

Descriptions of sections containing
the five Maori Plaggen Soils.

Section 1: Makara (Site N160/106)

Depth (cm)	Soil Horizon	Layer	
0- 6	A_1	3	Brownish-black (10YR3/2) very stony and gravelly sandy loam; weakly developed medium to coarse granular structure; diffuse boundary. The stones and gravel are angular weathered greywacke talus.
6-14	(B)		Yellowish-grey (2.5Y5/3) very stony and gravelly sandy loam; weakly developed medium to coarse granular structure; diffuse boundary. The stones and gravel are angular weathered greywacke talus.
14-40	θ_{Lb}	2	Black to brownish-black (10YR 2/1-2/2) very gravelly sandy loam; weakly developed medium granular structure; few pieces of charcoal, few fragments of shell and bone; diffuse boundary. The gravel is angular weathered greywacke talus.
40+	D	1	Weathered greywacke rock.

Section 2: Okoropunga (near p, Figure 3c) (Site N166/55)

Depth (cm)	Soil Horizon	Layer	
0- 5	sA	5	Brownish-black (10YR2/2) silt, patchy distribution, probably windborne; distinct boundary.
5-30	θ_L	4	Brownish-black (10YR3/2-2/2) gravelly to very gravelly sand; single grain and fine to very coarse granular structure; very friable; few charcoals; indistinct and diffuse boundary. The gravel is round and subround greywacke.
30-38	D_n		Olive-brown (2.5Y4/4) silt, probably water deposited; distinct and sharp boundary.
38-55	θ_{Lb}		Dark brown (10YR3/3) gravelly to very gravelly sand; single grain and fine to very coarse granular structure; very friable; many charcoals; distinct boundary. The gravel is round and subround greywacke.

Depth (cm)	Soil Horizon	Layer	
55-68	A_{1b}	3	Dark brown (10YR3/3) buried sandy loam topsoil with patches of many charcoals; indistinct boundary.
68-83	(B)		Dull yellowish-brown (10YR4/3) silty sand; diffuse boundary.
83-93	C		Loose sand; indistinct boundary.
93-135	D_n	2	Silty beach gravels.
135+	D_n	1	Greywacke rock.

Section 3: Pauatahanui (Site N160/107)

Depth (cm)	Soil Horizon	Layer	
0-10	A_1	4	Brown to dark brown (10YR4/4-3/4) silt loam with gravel; moderately developed fine to medium granular structure; indistinct boundary. The gravels are angular to subround.
10-10.5	Stone line		Weathered and unweathered angular to round gravel and stones.
10.5-22	A_{1b}	3	Brown (10YR4/4) silt loam with rare gravel; moderately developed fine to medium granular and cast granular structure; indistinct boundary.
22-27	Stone line	2	Predominantly unweathered fine to coarse round and subround gravel and broken cockle shells (Chione stutchburyi) resting on:
27-45	θ_{Mb}		Brown to dark brown (10YR4/4-3/4) gravelly silt loam grading downwards to brown (10YR4/4-4/6) gravelly silt loam; very friable; few charcoals; fine to coarse granular and cast granular structure with some fine nut; 7% to 15% of mostly unweathered round and subround fine to coarse gravel; grading over 10 cm to:
45+	(B)	1	Very weathered subround to angular stones and fine to coarse gravel, in a dull yellow-brown (10YR5/4-5/6) gritty silt loam; moderately developed fine nut and medium granular structure.

Section 4: Northern Clarence (Site S42/11)

Depth (cm)	Soil Horizon	Layer	
0-11	A_1	5	Very dark brown to brownish-black (7.5YR2/2-2/3) sandy silt loam; very friable and soft; single grain to weakly developed fine and medium crumb structure with some fine nut; indistinct boundary.
11-16	?	4	Very dark brown to brownish-black (7.5YR2/2-2/3) silt with few medium and distinct black mottles, and few fine faint dull yellow-orange mottles; indistinct irregular boundary.
16-29	?	3	Black (7.5YR2/1) sand; very friable and soft; single grain to weakly developed fine and medium crumb structure; few subangular and subround stones up to 10 cm diameter; indistinct boundary.
29-51	C		Greyish-brown to very dark brown (7.5YR4/2-2/3) sand; slightly silty; stones up to 30 cm diameter numerous within half a metre of the stone row; single grain and loose; few charcoal fragments; distinct boundary.
51-80	θ_{Mb}	2	Brownish-black (10YR2/2) gravelly loamy sand; 15% to 20% round and subround gravel up to 3 cm diameter; friable to very friable; moderately developed fine, medium and coarse granular structure with some crumb; few charcoals (less than 1 cm diameter); distinct boundary.
80-95+	(B)	1	Dark brown (10YR3/4) sandy loam; very friable; weakly developed fine and medium granular structure.

Section 5: Southern Clarence (S42/13)

Depth (cm)	Soil Horizon	
0- 4	sA_1	Brownish-black (10YR2/2-2/3) coarse sandy loam with fine gravel; very friable; single grain to weakly developed medium granular structure with some fine crumb; indistinct boundary.
4-30	θ_M	Black to brownish-black (10YR2/1-2/2) coarse sandy loam with fine gravel; many fine and medium dark brown (10YR3/3) mottles; very friable; single grain to weakly developed coarse granular structure with some fine crumb; with round and subround stones up to 7 cm diameter; rare charcoal flecks; distinct boundary.

Depth (cm)	Soil Horizon	
30+	(B)	Dark brown (10YR3/3) silt with many fine and medium distinct dull yellow-orange (10YR6/4) and black to brownish-black (10YR2/1-2/2) mottles; friable and firm; massive, breaking to weak and moderately developed medium and fine nut and granular structure; rare flecks of charcoal just below upper boundary.

APPENDIX 2

STONE ROW SYSTEMS IN CENTRAL NEW ZEALAND WITH SPECIAL REFERENCE TO OKOROPUNGA ON THE SOUTHEAST WAIRARAPA COAST.

INTRODUCTION

Stone rows as discussed below were not apparently seen in use by Europeans. They are generally thought to be connected with Maori gardening activities (Smith, 1905; Best, 1925; Adkin, 1955; Yen, 1961; Mitcalfe, 1970a,b; Leach, 1976; Leach and Leach, 1971a,b), but there is no general agreement on their exact purpose. There are two contrasting views on their use. On the one hand they are thought to be merely a by-product of agriculture: stones cleared from the ground surface. On the other hand they are thought to have played a direct and vital part, in some way not fully understood, in order to improve growing conditions.

Stone rows are ridges, consisting of small, medium and large stones, and soil, between 2 m and 3 m wide and from 0.2 m to 1 m high. By contrast, stone walls are free-standing structures with more or less perpendicular parallel sides (Daniels, 1970). Some stone walls have collapsed and they now resemble stone rows, although the amount of soil in them is generally less.

At places where stone rows occur they are many and their arrangement is systematic (Stone Row System). Main stone rows are more or less parallel and evenly spaced. They run in the direction of ground slope, which is generally towards the coast. Adkin (1955) terms these principle stone rows. There are a few stone rows at right angles to the others. Adkin (1955) terms these transverse stone rows.

At many sites there are three other features either within or close to Stone Row Systems. The first are single stone alignments, a row of single stones all about the same size, spaced between 1 m and 3 m apart. The second are stone mounds, more or less circular heaps of stones up to 3 m diameter and up to a metre high. The third are pits, irregular shaped holes up to 2 m deep.

Not all stone rows are man-made. Natural rows are sometimes found at the foot of scree slopes where stones have been guided by vegetation, and along the crests of raised beach ridges. No natural features are known which resemble Stone Row Systems.

The stones forming the rows at certain places are sufficiently distinctive to be able to determine their source. At some places they have been taken from the ground round about and they are clearly a result of ground clearance, but not necessarily for agriculture. At other places they have been taken from sources such as scree slopes, river beds, or even dug up from pits, and there has been no clearance of potential agricultural ground. Transport distance from the river was less than 200 m; from the scree, less than 200 m; and from the pits, less than 100 m. The nearest alternative source to the pits was a growing beach ridge some 200 m away.

In the New Zealand Archaeological Association site recording scheme stone rows are one of the standard features recorded. They have been reported by Adkin (1955), Elvey (1957), Jones (1962), Harrowfield (1969), Mitcalfe (1970a), Barton (1974) and Prickett and Walls (1975). The distribution of Stone Row Systems in central New Zealand is shown by Figure 1.

A STONE ROW SYSTEM AT OKOROPUNGA

Okoropunga stream lies about halfway between the Oterei and Pahaoa Rivers. There are two Stone Row Systems about 0.5 km north of the stream: a southerly system (1) on Beach Ridges E and F which is described in detail below; and a northerly system (2) on Beach Ridges C and D. Both systems are shown by Figures 2 and 3. Between the two systems and a fixed sand layer is a Maori Plaggen soil described in Appendix 1. A Plaggen-like soil, younger in age, is situated on the top of the fixed sand layer.

Cross-section of a stone row

What was thought to be a typical stone row was excavated and is shown in a cross-section in Figure 2c. The most interesting feature about the stone row is that the soil around the stones is the same as the soil beneath the stones (Figure 4), and it is inferred that soil was placed around the stones when the row was built and is not a natural accumulation.

The obvious source for the stones in the stone rows is the pits on the seaward side of Beach Ridge E (Figure 2b). An estimate was made of the volume of stones in the rows (220 m^3) and the volume of stones taken from the pits (250 m^3) and the two are substantially similar. It was also found that the stones in the pits match those in the rows, and that there is no nearer source for the stones, for instance there are no similar stones in Beach Ridge F.

Age of the Stone Row System

Two radiocarbon samples (Table 1) were obtained from the excavation through the typical stone row mentioned above. One sample was charcoal from the soil buried by the stone row, and the other sample was charcoal from the soil between the stones in the row. The buried soil charcoal (NZ 3115A) gave an age of 530 ± 60 years BP; and the charcoal from soil between the stones (NZ 3114A) gave an age of 340 ± 60 years BP. The charcoals are from trees and not shrubs and thus provide maximum rather than close ages.

At the northern end of the southern Stone Row System, the eastern end of a stone row was destroyed when the Maori Plaggen soil was formed. It is shown in Appendix 1 that the plaggen soil is 300 to 400 years old, close in age to the Stone Row System.

Soils of the Stone Row System

To determine the purpose of the Stone Row System, it is of critical importance to know whether or not the soil between the stone rows has been cultivated. The soil is compared below with a sequence of soils of increasing age on Beach Ridges B to D which are thought to be uncultivated, and with the two plaggen soils.

Beach ridge soils are all formed on sand containing stones and gravel. Soil descriptions are given in Table 3. The sand on all beach ridges overlies a stone and gravel "pavement" and rarely exceeds 1 m depth. On the backslope of the growing beach ridge there is a stone and gravel pavement formed by the wind blowing sand inland. Each uplifted beach ridge was probably covered with sand after it was uplifted and, because of the sand, the ground surface of each uplifted beach ridge is smooth.

Stones and gravel litter the surface of Beach Ridge B, and are being buried by the windblown sand. They are thought to have been thrown over the growing beach ridge during storms. Stones and gravel in older beach ridge soils are probably from earlier growing beach ridges. Sand is blown inland further than stones and gravel can be thrown and the proportion of stones and gravel in beach ridge topsoils falls off rapidly with distance inland (Figure 5).

The plaggen soils both contain gravel: the Maori Plaggen soil contains a lot of gravel spread as a layer over a former ground soil; the Plaggen-like soil, a little gravel dug well down into a ground soil. Both have very hummocky ground surfaces that are thought to be due to the Maori practice of making mounds in which to plant kumaras. The Maori Plaggen soil is dark in colour. The Plaggen-like soil is light in colour because its subsoil, which is light coloured, has been mixed with it by cultivation.

The topsoil between the stone rows is a brownish-black gravelly sandy loam on a yellow-brown subsoil (Table 2). It is generally thinner than the plaggen soils, but is about the same thickness as the topsoil on Beach Ridges B to D (Table 2). It contains less stones and gravel than the plaggen soils, but about the same proportion as the soil on Beach Ridges C and D (Figure 5). Its ground surface is smooth, in contrast to the hummocky plaggen soils, and is like that on Beach Ridges B to D.

The subsoil colour on beach ridges becomes lighter with increasing age (Table 2). Dark subsoils (young beach ridges) are due to organic matter in a rapidly accumulating soil; light subsoils (old beach ridges) are due to increased silt content. The lightest coloured subsoil is between the stone rows. Topsoil colour between the stone rows however, is dark (within the range of Beach Ridges B to D) and has not been lightened in colour by cultivation.

The soil between the stone rows fits the sequence of soils on Beach Ridges B to D., but is different from the plaggen soils. It is therefore concluded that the soil between the stone rows is uncultivated.

Inferred Use of Stone Row Systems

That soils between stone rows are uncultivated rules out stone rows as mere by-products of agriculture and indicates that stone rows played a direct and vital part in Maori agriculture. It was not necessary that stone rows enclose cultivated ground.

The most important plant cultivated by the Maori was kumara (Ipomoea batatas), a tropical plant the cultivation of which was limited by the length of the growing season. The growing season could have been lengthened by propagating kumaras in the soil covering stone rows. The stones warm up during the day and release their heat slowly during the night, thus raising minimum daily soil temperatures by about 2°C (Figure 6). On still clear nights, when heat is lost most rapidly from the ground and young kumara plants would be most vulnerable to cold air temperatures, the minimum air temperature

5 cm above the stone rows (measured by thermographs) is raised by about $1^{\circ}C$.

The stone rows are between 0.2 m and 0.5 m high and their soils are thus well-drained, an important requirement in modern kumara propagating beds (Coleman, 1972). Principle stone rows are roughly parallel with ground slope and would assist cold air drainage. The stone rows are long and narrow, which would facilitate easy handling of young plants.

Diseases are readily introduced into kumara propagating beds and to avoid diseases in modern beds the soil is renewed each year or sterilised (Coleman, 1972). Judging from the numbers of stone rows, new stone rows were probably built by Maoris, but burnt stones and charcoal in stone rows in other Stone Row Systems (Mitcalfe, 1970b; Leach, 1976) may indicate attempts to sterilise rows with fire.

The Maori Plaggen soil, the nearest cultivated soil to the Stone Row System, is thought to be an old kumara soil (Appendix 1). It is separated from the Stone Row System probably because stones and gravel occur in different parts of Beach Ridge E. Kumaras propagated in the Stone Row System are thought to have been planted out into the Maori Plaggen soil

Stone Row Systems extend along most of the southeast Wairarapa coast and around Palliser Bay. Some have plaggen soils near them and use of stone rows for propagation is considered to apply to other areas of the Wairarapa coast.

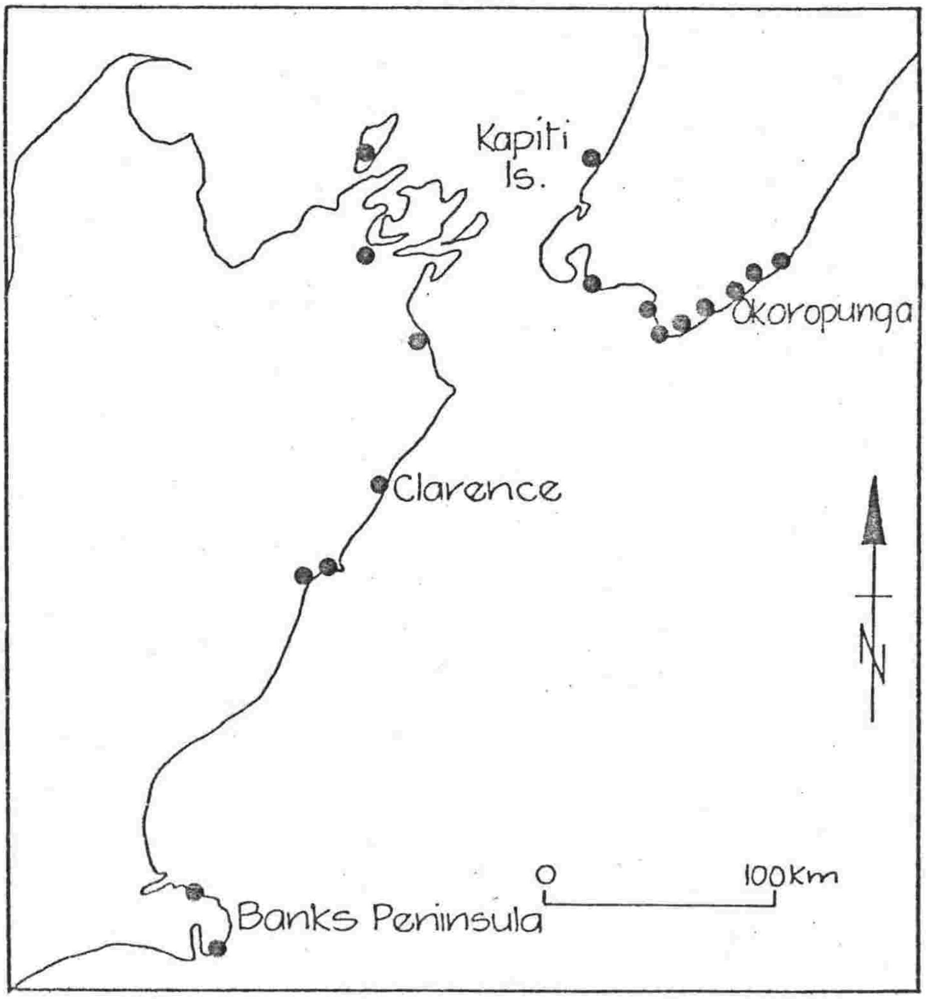


FIGURE 1 - Known distribution of Stone Row Systems (heavy dots) in central New Zealand.

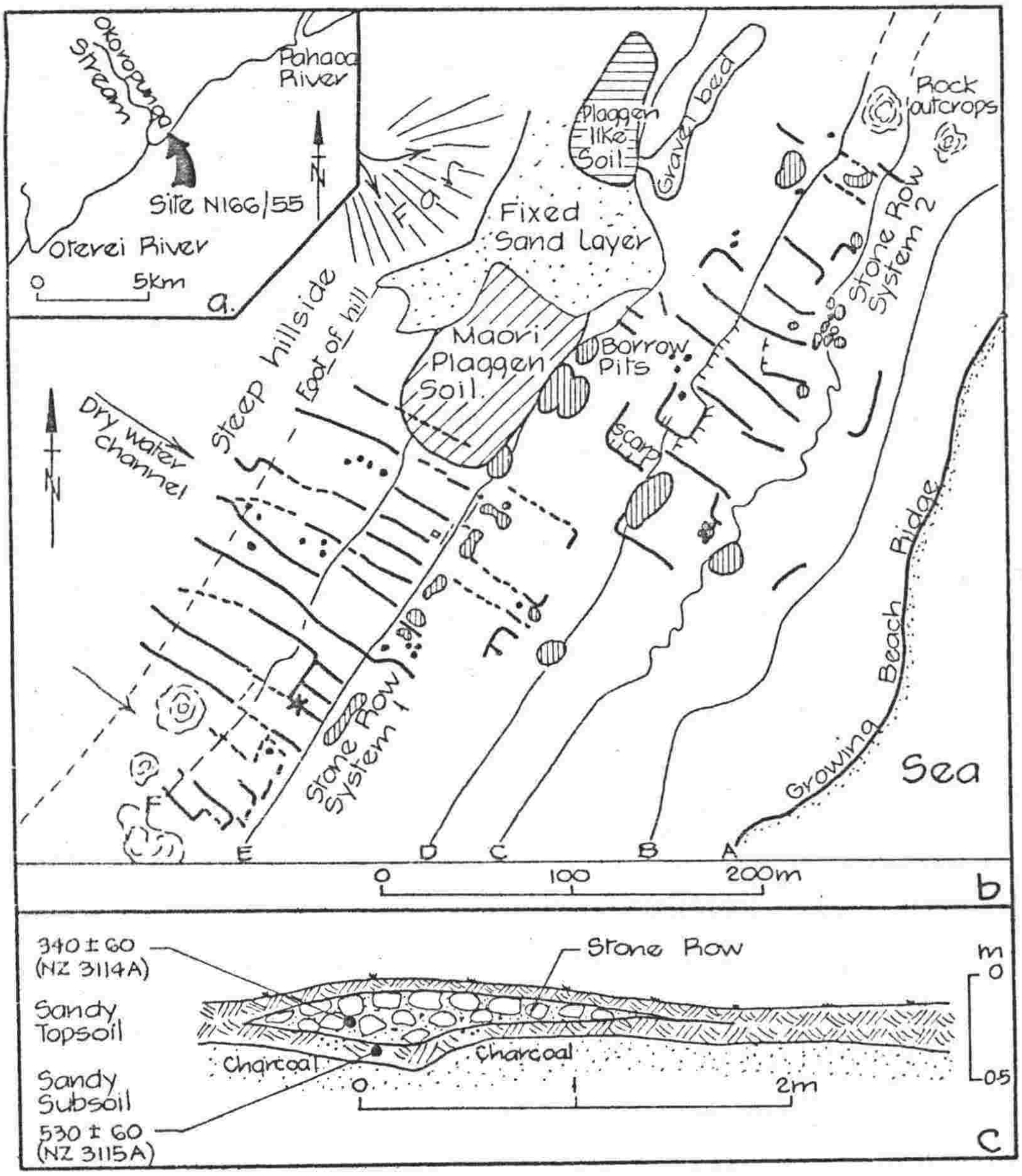


FIGURE 2 - Diagram of Okoropunga Stone Row System (site N166/55) between the Pahaoa and Oterei Rivers on the southeast Wairarapa coast.

Fig.a. Locality map.

Fig.b. Sketch map showing beach ridges A to F (light lines), stone rows (heavy lines), disturbed stone rows (broken heavy lines), stone mounds (heavy dots), borrow pits (vertical hatching), and Maori Plaggen and Plaggen-like soils. Excavated stone row shown by a cross.

Fig.c. Cross-section through excavated stone row.

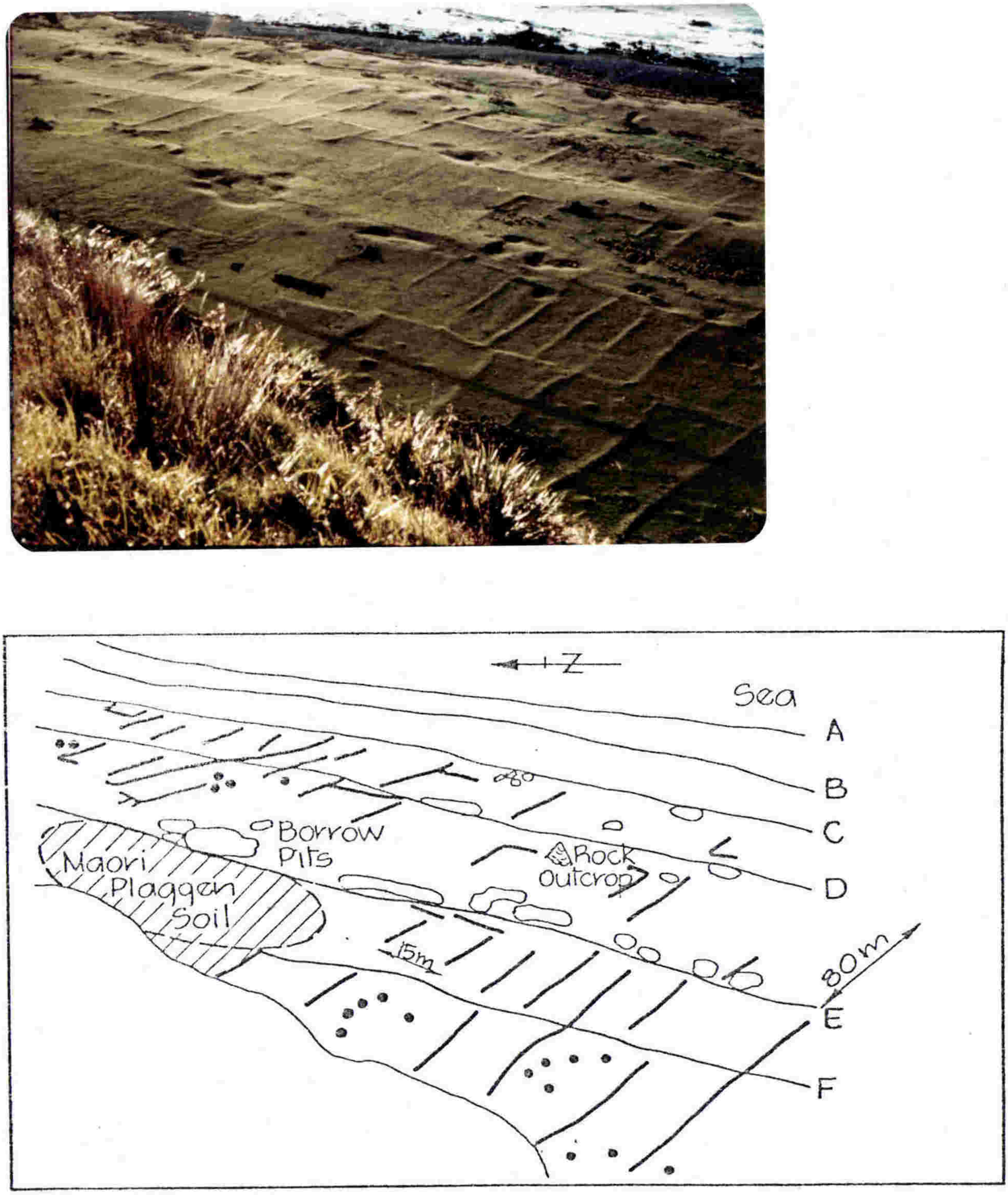


FIGURE 3 - Stone Row Systems at Okoropunga (site N166/55).

Fig.a. Stone row systems looking northeast.
Fig.b. Explanation of Figure a. Stone rows shown by heavy lines; stone mounds, by heavy dots; beach ridges (A to F), by light lines.

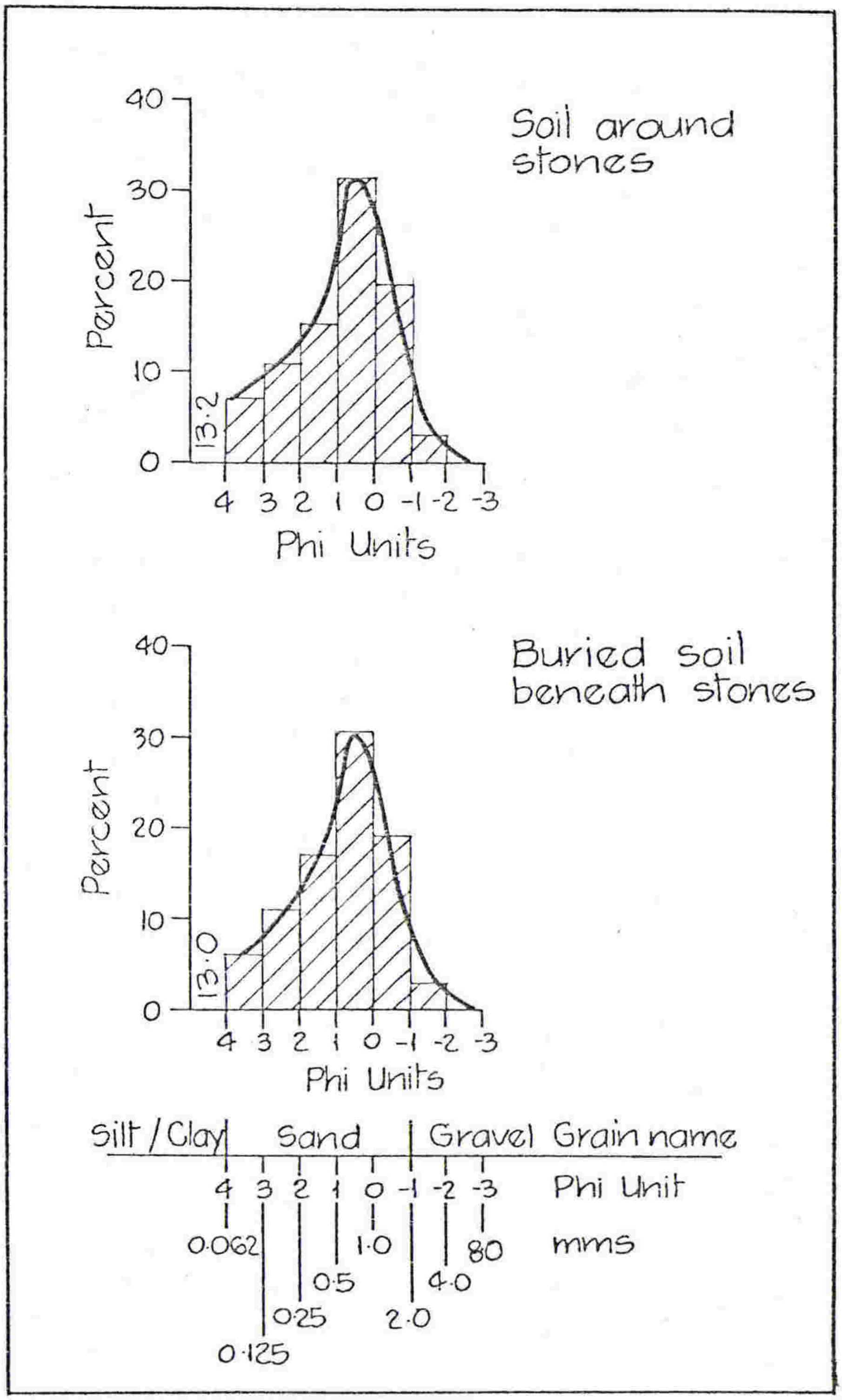


FIGURE 4 - Particle-size histograms for soil around stones in, and buried soil beneath, excavated stone row. All bars represent one phi unit (= $-\log_2$ diameter in mm). Bar heights in percent. Percentage of samples smaller than smallest phi unit measured shown at left hand end of histogram. Percentages determined by dry seiving. Note the similar particle size distribution of both soils.

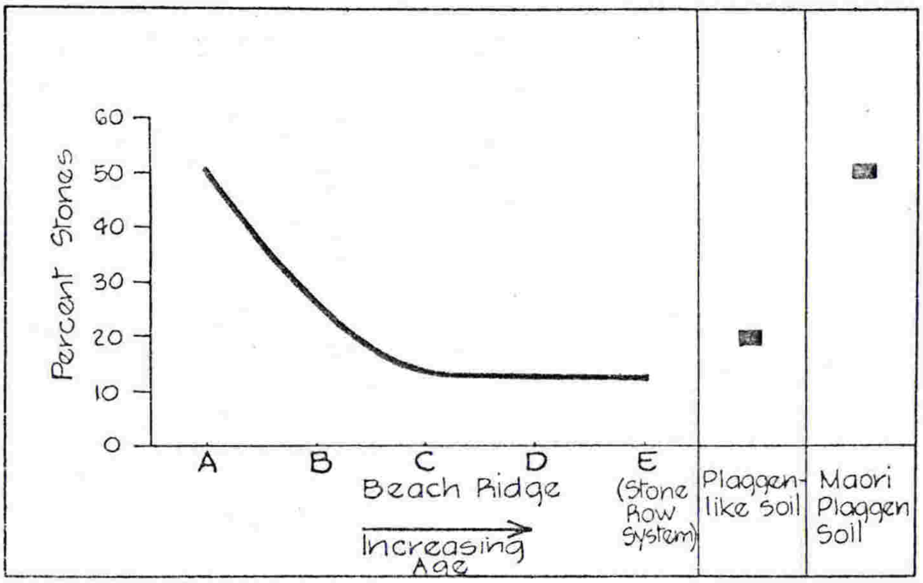


FIGURE 5 - Diagram showing percentages of stones and gravel in Okoropunga soils: on the surface of Beach Ridge A; in topsoils of Beach Ridges B to D; in the topsoil between stone rows on Beach Ridge E; and in the Maori Plaggen, and Plaggen-like soils. Note the decrease in stones and gravel with increasing beach ridge age.

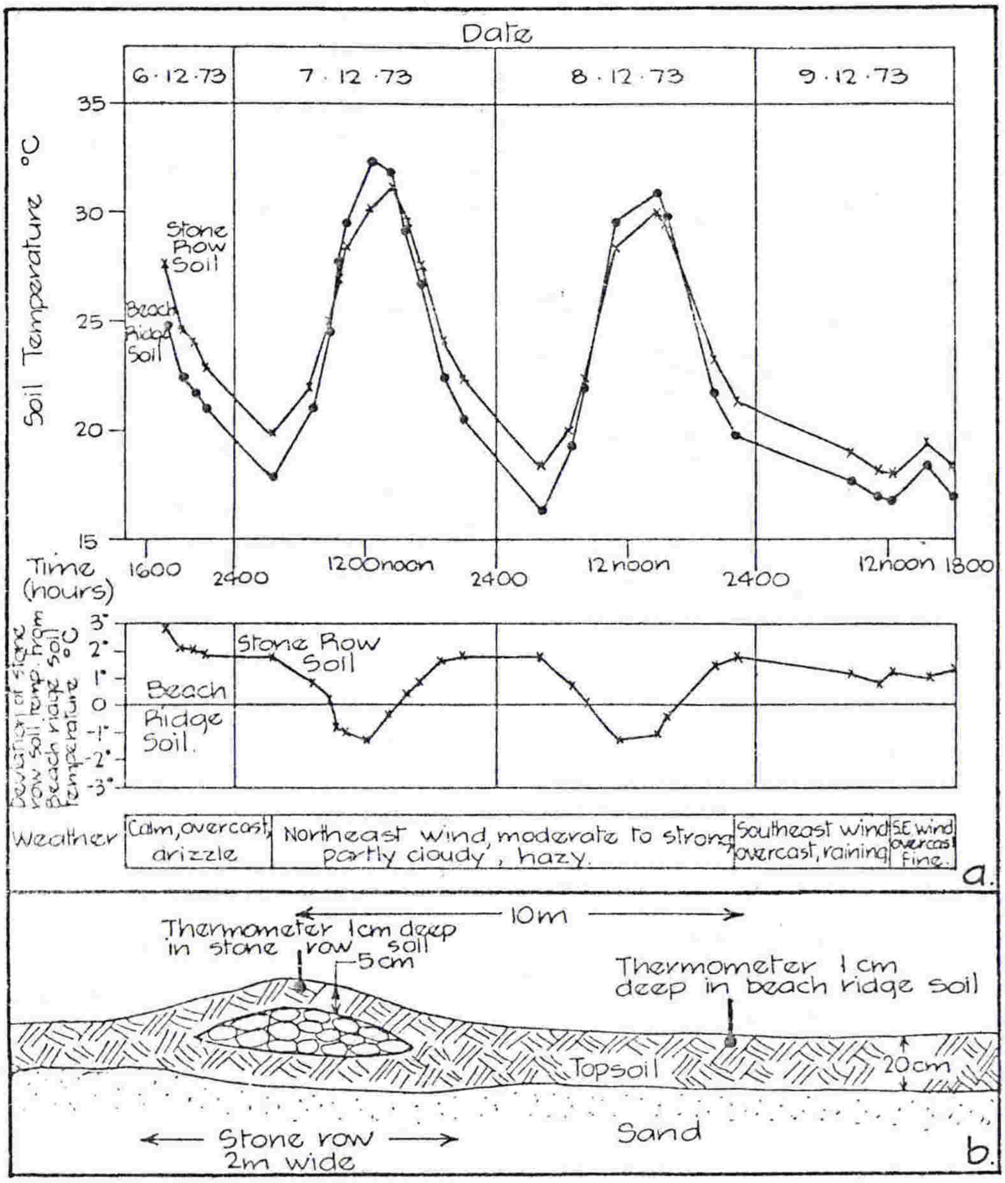


FIGURE 6 - Diagram showing soil heating effect of a stone row.

Fig.a. Daily variation of soil temperature in the top 1 cm of soil on a stone row and between two stone rows on Beach Ridge E. Measurements made with glass mercury thermometers to nearest 0.2°C. Note higher minimum temperature of stone row soil at night and on overcast days.

Fig.b. Locations of thermometers used to measure soil temperature.

TABLE 1

Radiocarbon dates and identification of charcoals from excavated stone row.

Stratigraphic Position	Species Identified	NZ Number	Date
In soil around stones of stone row.	*Coprosma* sp., *Hebe* sp. (minor), and *Podocarpus spicatus* (matai), found as scattered charcoals.	3114A: 3114C:	340±60 470±85
Buried topsoil beneath stone row, immediately below sample NZ 3114.	*Coprosma* sp. (dominant), *Podocarpus totara-hallii* group (minor), found as scattered charcoals.	3115A: 3115C:	530±60 550±85

TABLE 2

Soil colour, topsoil thickness, and smoothness of ground surface, for three soils of increasing age on Beach Ridges B to D, for the soil between stone rows on Beach Ridge E, and for the two plaggen soils. Data for beach ridge soils, stone row soil and Plaggen-like soil, from Table 3; and for Maori Plaggen soil from Appendix 1.

	Soil Colour (Munsell Notation)			
Soil	Topsoil	Subsoil	Topsoil Thickness (cms)	Ground Surface
Beach Ridge B	10YR2/2 (Brownish-black)	10YR2/3 (Brownish-black)	20	SMOOTH
Beach Ridge C	10YR2/1 (Black)	10YR2/3-3/4 (Brownish-black to Dark Brown)	25	
Beach Ridge D	10YR2/3-3/3 (Brownish-black to Dark Brown)	10YR3/4 (Dark Brown)	16	
Stone Row System (Beach Ridge E)	10YR3/2 (Brownish-black)	10YR5/3 (Dull Yellowish-brown)	20	
Plaggen Soil	10YR4/2 (Greyish-yellow Brown)	10YR5/3 (Dull Yellowish-brown)	45	HUMMOCKY
Maori Plaggen Soil	10YR2/2-3/2 (Brownish-black) to 10YR3/3 (Dark Brown)	-	20-40	

TABLE 3

Descriptions of surface sediments on Beach Ridge A; and of soils on Beach Ridges B, C and D, and between stone rows on Beach Ridge E. Percentages of stones (including large gravels) determined using visual estimation charts printed in Taylor and Pohlen (1970) except for Beach Ridge E where determined by seive analysis.

Beach Ridge A

Depth (cm)	
0	Stone and gravel "pavement" covering up of 60% of the back slope of the beach ridge. Stones up to 30 cm diameter abundant.
20+	Coarse sand and fine gravel with adhering silt.

Beach Ridge B

Depth (cm)	Soil Horizon	
0	A	Black (10YR2/2) stony sand with fine organic matter; very friable; single grain to weakly developed medium crumb structure; many grass roots; indistinct boundary. Stones: 0 to 6 cm deep, 5%; 6 to 20 cm deep, 25% (up to 5 cm diameter).
20	(B)	Brownish-black (10YR2/3) sand with fine gravel and few stones; loose to very friable; single grain to weakly developed crumb structure; few roots; indistinct boundary. Stones: 5% to 10%, mostly less than 3 cm diameter but occasionally up to 20 cm.
30+	D_n	Loose bedded gravels up to 4 cm diameter.

Beach Ridge C

Depth (cm)	Soil Horizon	
0	A	Black (10YR2/1) gravelly stony sand; very friable; single grain to weakly developed medium crumb and granular structure; indistinct boundary. Stones: relatively stone free between 0 and 6 cm; 6 to 25 cm deep, 15% (up to 10 cm diameter).
25	(B)	Dark brown to brownish-black (10YR2/3-3/4) sand with Taupo pumice and stones; single grain to weakly developed medium granular structure; indistinct boundary. Stones: 25 to 40 cm deep, 10% (up to 5 cm diameter; 40 to 60 cm deep, rare.

Depth (cm)	Soil Horizon	
60	C_g	Gleyed sand with a stone layer at 75 cm.
115+	D_n	Greywacke wave-cut platform.

Beach Ridge D

Depth (cm)	Soil Horizon	
0	sA	Brownish-black (10YR2/3) silt; soft; fine to medium crumb structure; many grass roots; distinct boundary.
7	A	Dark brown to brownish-black (10YR2/3-3/3) stony sand; loose to very friable; single grain to weakly developed fine and medium granular structure; indistinct boundary. Stones: 10% to 15%, up to 8 cm diameter.
23	(B)	Dark brown (10YR3/4) sand without stones; loose to very friable; single grain to weakly developed fine and medium structure; distinct boundary.
31	D_n	Olive-green (2.5Y4/3) fine bedded cemented gravels; distinct boundary.
36+		Fine and medium bedded gravels.

Between stone rows of Stone Row System on Beach Ridge E

Depth (cm)	Soil Horizon	
0	A	Brownish-black (10YR3/2) gravelly sandy loam; slightly hard; single grain to weakly developed fine to coarse granular structure; many roots; indistinct boundary. Stones: 14%, up to 8 cm diameter.
20	B	Dull yellowish-brown (10YR5/3) gravelly sandy loam; soft; single grain with some weakly developed fine granular structure; many roots; indistinct boundary. Stones: 20%, up to 8 cm diameter.
45+	C	Dull yellowish-brown (10YR5/3) moderately sorted gravelly sand; few roots.

Plaggen-like Soil

Depth (cm)	Soil Horizon	
0	A_p	Greyish-yellow-brown (10YR4/2) gravelly sand; weakly developed medium to coarse granular and very fine crumb structure; very friable; many fine grass roots; rare charcoal; sharp boundary.

Depth (cm)	Soil Horizon	
45+	(B)	Dull yellowish-brown (10YR5/3) sand; single grain; loose to very friable.

Fixed Sand Layer: Ground soil (adjacent to Plaggen-like soil)

Depth (cm)	Soil Horizon	
0	A_1	Brownish-black (10YR3/2) sand; soft; single grain to weakly developed granular structure; many grass roots; indistinct boundary.
20+	(B)	Dull yellow-brown (10YR4/3) sand; soft; single grain to weakly developed granular structure; few roots.

APPENDIX 3

THE ANTIQUITY OF MAN AT LAKE POUKAWA, NEW ZEALAND.

INTRODUCTION

Lake Poukawa in southern Hawkes Bay (Figure 1) is surrounded by peat containing layers of tephra erupted from the central volcanic region of the North Island. Two of the youngest tephras, Taupo Pumice (1,800 years old) and Waimihia Ash (3,400 years old) form well-defined easily identifiable layers less than a metre from the ground surface on the northern lake shore. The lake shore was a favoured place for Maori occupation and, in the mid 1960's, it was reported in newspapers and popular periodicals, and in the N.Z. Archaeological Association newsletter (Price, 1963, 1965), that Maori occupation remains: artifacts, postholes, a fireplace and burnt, cut, sawn and broken moa bones, had been found below the Taupo pumice. If the report was correct, then the evidence of the remains at Lake Poukawa conflicted seriously with the evidence of coastal stratigraphy, which indicates that human settlement of New Zealand occurred well after the Taupo Pumice eruption (Wellman, 1962a,b), and indicated a date for human settlement considerably earlier than the generally accepted date of ca. 1,000 years BP.

Remains were found at several sites around Poukawa. Identification of the tephra layers was confirmed by Pullar (1970). In August 1973, with permission of Mr Price, one of his sites (N141/12) (Grid. Ref. N141(1962)/140050) was studied by the Victoria University of Wellington Geology Department.

THE POUKAWA SITE

The site is on a raised mound of lake sediment lying very close to a recently active fault. The mound rises to a height of 2 m above the surrounding ground level and is thought to have been raised by an earthquake prior to human settlement (R. Howarth, pers. comm.). On top of the mound, at the western end of the site, was a Maori shell midden which has been almost entirely excavated away by Mr Price. The supposed pre-Taupo remains, including two alleged fireplaces (F1 and F2, Figure 1c), are in peat on the north side of the mound.

The site was tested by digging three 3 metre by 3 metre trenches (1 - 3, Figure 1c), and several test pits a short distance away from the site. Sections in the sides of trenches already dug by Mr Price were examined and a pollen core was taken on land near the lake shore.

RESULTS OF INVESTIGATION

A cross-section of the northern side of the mound is shown in Figure 2. Peat forms a layer up to 110 cm thick but becomes thinner towards the top of the mound. Taupo Pumice is found in peat on the sides of the mound, and on top of the mound in several places. Waimihia Ash is found only on the sides of the mound. Two thin and unidentified ash layers occur in the peat beneath the Waimihia Ash.

Mr Price had found that bird bones, including moa, are concentrated on the mound roughly along the edge of the Waimihia Ash. The ash edge was found to be at the same level and is thought to mark an old lake shore: ash below water level having been preserved; that above water level eroded. The presence of an old lake shore would suggest that the bird bones are from stranded carcasses.

The peat is extensively cracked (Figure 3), some cracks being more than 10 cm wide, and some passing from above the Taupo Pumice to below the Waimihia Ash. The cracks are thought to have been caused by the peat drying out after Lake Poukawa was drained in 1931 and it is likely that drying and cracking of the peat caused many of the bird bones to crack and break. Some material, including European-introduced landsnails (Hellicella caperata), were found resting on Waimihia Ash at the bottom of some cracks.

A short distance below the surface of the peat is a very fine-grained burnt, orange coloured layer (Figure 3 and 5), up to 20 cm thick on top of charred and blackened peat. According to the present land-owner, Mr D. Buddo, the peat was burnt during a large fire in 1947. The orange coloured layer contains Taupo Pumice and fills some of the peat cracks which, in section, have the appearance of postholes. Flow banding was seen in the orange coloured layer above some of the infilled cracks and the orange coloured layer is thought to have become fluid, or to have swelled, and to have flowed into the cracks when wet. The peat has been flooded at least twice by a rise in lake level since 1947 (T.R. Price, pers. comm.).

Two sandstone rocks were found down one of the cracks in Trench 2 (Figure 4). The rocks were about 10 cm diameter and were more than 10 cm below the usual level of Taupo Pumice. They were surrounded by the orange coloured layer which had flowed into the crack, and a thin layer of Taupo Pumice could be traced in the orange coloured layer down the side of the crack and beneath the rocks. The rocks are thought to have originally been above the pumice, probably in the burnt, orange coloured layer, and to have fallen into the crack dragging Taupo Pumice and the orange coloured layer down with them sometime after the peat fire. Artifacts beneath Taupo Pumice may have a similar origin.

Features similar to postholes with a grey coloured loamy fill were seen in a section, below the Taupo Pumice in lake sediment near the top of the mound (Figure 5). Their shapes were variable and included single pointed vertical channels, bifurcated pointed vertical channels, and bulbous channels. Wood, from quite large trees, was found lying horizontally in the peat near the mound, both above and below the Waimihia Ash, and the posthole-like features are thought to be old root channels from vegetation which once grew on the mound.

Two sets of disc marks were preserved in the orange coloured layer in trenches 1 and 2; and one set, in the lake sediment in trench 3. Mr Buddo later confirmed that the whole mound had been disced in 1953, and lower parts of the mound lightly disced in 1965. Before the first discing the mound was bulldozed to remove fescue and after discing the mound was harrowed. Willow trees growing along the northern side of the mound were ripped out when the mound was first disced.

The discs disturbed material down to a depth of 15 cm to 20 cm. Taupo Pumice is less than 15 cm to 20 cm deep in many places and was mixed together in a "plough layer" with introduced landsnails (Hellicella caperata), and with bones of sheep, extinct heron and Notornis (identified by Mr G.S. Markham). Disc disturbance adequately explains the occurrence of pig teeth, a pig tusk, a sheep bone and cultural items reportedly found beneath Taupo Pumice during earlier excavations by Mr Price.

In the "plough layer" a piece of "cut" bone was found on top of the mound. Its stratigraphic position suggests that it may have been cut by the discs. Bones previously found by Mr Price were examined by Mr Markham and some had marks similar to file marks which may have been caused by tree root abrasion.

Of the two "fireplaces" examined, one (F1, Figure 1c) was a scattering of pellets of burnt peat. It was not an archaeclogical feature and there was no sign of burning in situ, nor of placement of stones normally associated with Maori fireplaces. The second "fireplace" was entirely of natural origin. Some wood in the peat rested on top of the Waimihia Ash and is probably only a little younger than the ash. The burnt, orange coloured layer is at different heights at different places and near the second "fireplace" it dipped and came into contact with the wood leaving a small area of charred wood resembling a fireplace. If this "fireplace" was radiocarbon dated it would give a date consistent with the stratigraphic age of the wood, but the date of the fire is some thousands of years younger.

An examination of sections left by Mr Price through the Maori midden showed an undisturbed layer of Taupo Pumice beneath the midden in several places. Nowhere was cultural material found below undisturbed pumice although holes had been dug through the pumice and filled with midden. Artifacts from the midden include Classic Maori types as defined by Golson (1959) and at least two iron adzes (T.R. Price, pers. comm.) Bones seen in the midden sections include a moa leg-bone (Pachyornis mappini) and a pig skull. There is no chronological significance attached to the moa bone, and the midden is probably between 150 and 300 years old.

The pollen core from near the lake was taken and analysed by Mr M. McGlone (Botany Division, D.S.I.R., Christchurch). The lowest part of the core predates the Waimihia Ash. Results of the pollen analysis, which will be published separately by Mr McGlone, show a marked change from matai-dominated forest to fern and tutu, and the first appearance of charcoal, well above the Taupo Pumice. There is no evidence for man indicated either by charcoal or by vegetation clearance prior to the Taupo Pumice.

CONCLUSION

Because the peat is cracked and things have fallen down the cracks, and because the site has been bulldozed and disced, and bones and artifacts have been disturbed, Poukawa does not provide evidence for the antiquity of man in New Zealand, and is extremely misleading.

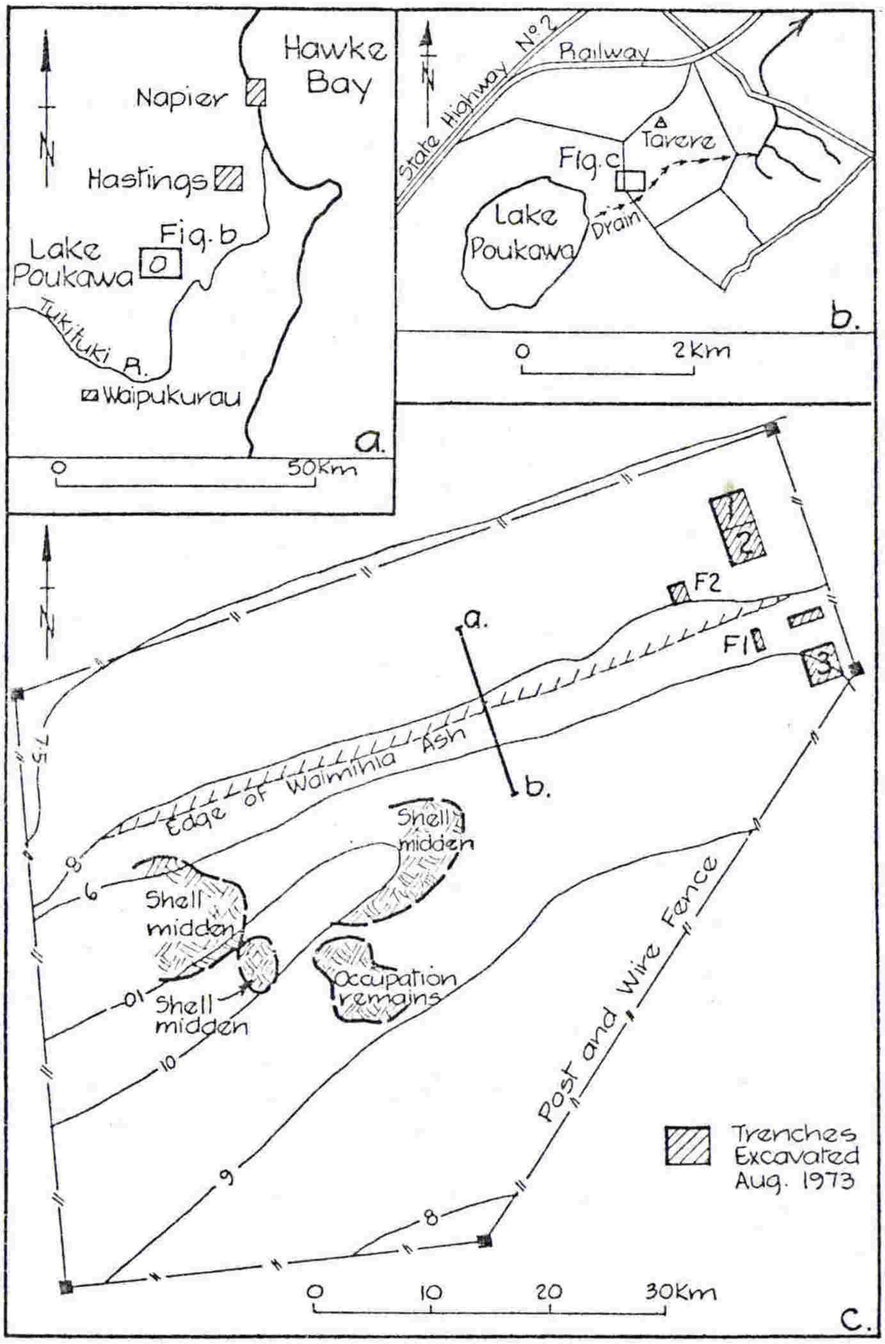


FIGURE 1 - Diagram for Poukawa site (N141/12) on north side of Lake Poukawa in southern Hawkes Bay.

Figs.a,b. Locality maps.

Fig.c. Sketch plan of site. Contours in metres above an arbitary datum. Note 7.5 m contour along northern fence. Most of area within fence has been excavated by Mr T.R. Price and is now open trenches 3 m by 3 m. a-b = cross-section shown in Figure 2. 1-3 = trenches excavated in August 1973. F1 and F2 = alleged fireplaces investigated in August 1973.

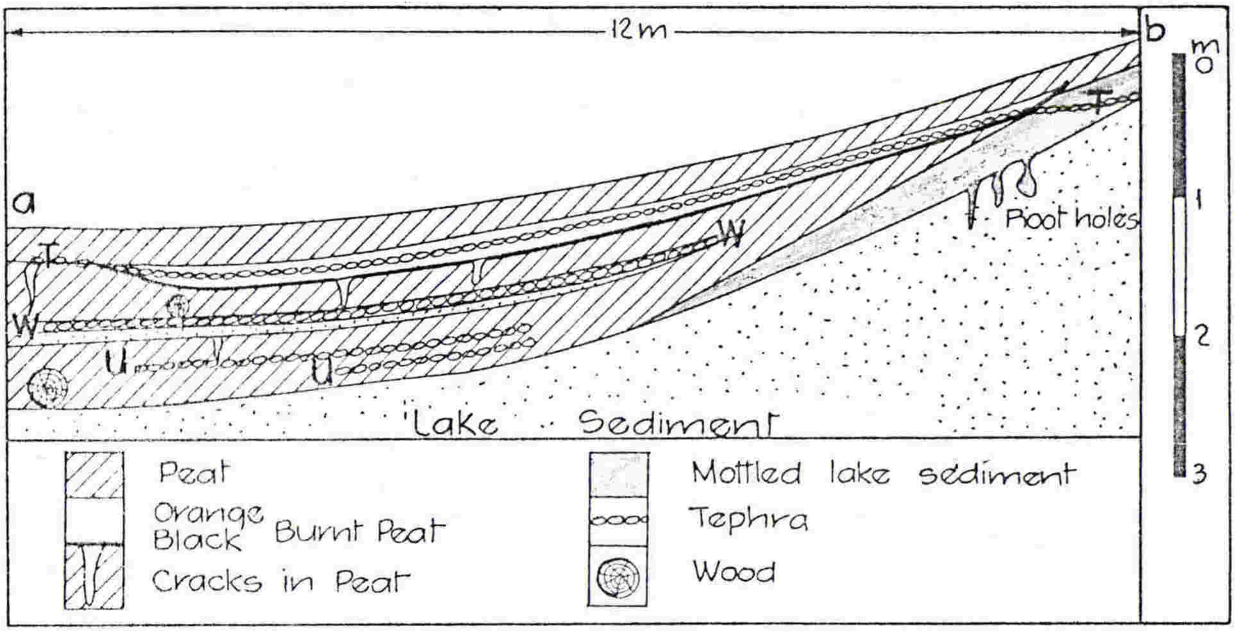


FIGURE 2 - Generalised cross-section of mound along line a-b in Figure 1c. T = Taupo Pumice Lapilli; W = Waimihia Ash; U = Unidentified tephras. Note the layer of lake sediment immediately below Waimihia Ash.

FIGURE 3 - Cracks in peat at Poukawa site. Cracks generally begin more than 10 cm from ground surface and may extend to more than 75 cm deep. Note orange coloured burnt peat at far end of excavation. Horizontal scale = 1 m.

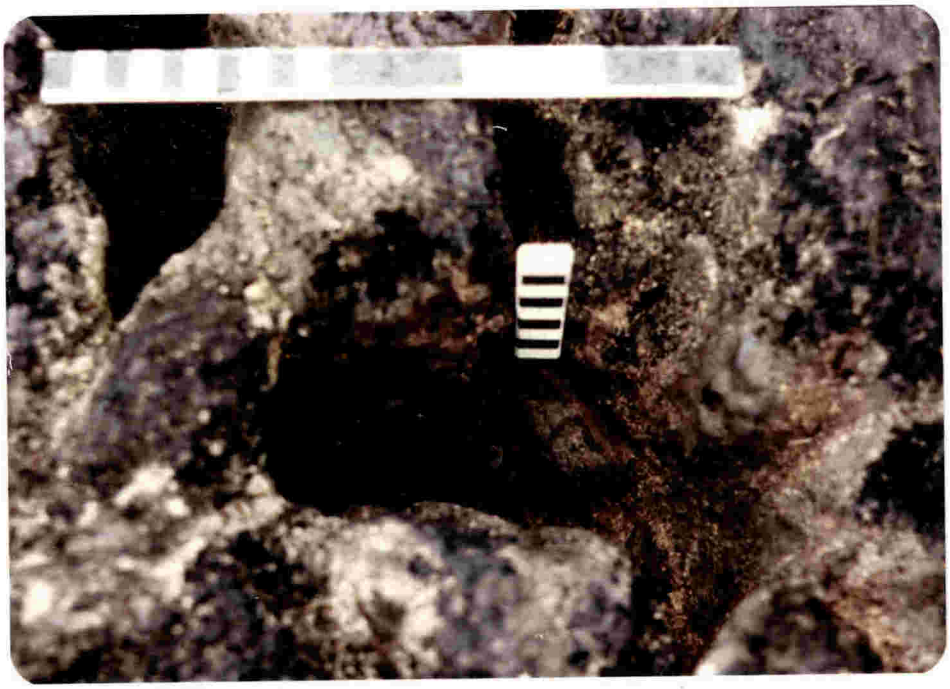


FIGURE 4 - Sandstone rock (below vertical scale) embedded in peat crack. Taupo Pumice Lapilli lines the sides of the peat crack above the rock, and passes beneath the rock. Horizontal scale = 0.25 m.

FIGURE 5 - Tree root channels in lake sediment near top of mound, section a-b (Figure 2). Note burnt, orange and black, peat layer. Vertical scale = 0.25 m.

FIGURE 6 - Disc marks in lake sediment in Trench 3 (Figure 2). Long scale = 1 m.

APPENDIX 4

COASTAL LAGOON DEPOSITS BETWEEN TE AWA ITI AND TE KAU KAU POINT, AND POSSIBLE EUSTATIC SEA LEVEL CHANGES.

The Holocene bench on the stretch of coast between Te Awa Iti and Te Kau Kau Point (Main Text: Figure 10) is continuous. On it are up to six uplifted beach ridges which extend over more than half of the coast. This account is only concerned with the beach ridge at present forming (A) and with the two youngest uplifted beach ridges (B and C). Along about half the stretch of coast, Beach Ridges B and C are eroded, and Beach Ridge A is not always present. Within the stretch of coast, Beach Ridge C contains Loisels pumice. It is therefore assumed that at all places, the beach ridge with Loisels pumice in it is Beach Ridge C.

Coastal lagoon deposits are exposed at four places where Beach Ridge C has been eroded (Main Text: Figures 12, 13 and 14). Sections of the lagoon deposits are represented by the columns shown in Figure 1 and described in Sections 3 and 6 to 8 (Main text). The columns are at different distances back from Beach Ridge C and are generalised into an idealised cross-section normal to the coast in Figure 2. The main features of the idealised cross-section are: on the seawards side, Beach Ridge C; on the inland side, lagoonal and interbedded terrestrial deposits; and a sequence of five known and inferred ages.

The oldest age is a radiocarbon date of 2.4 kyrs (Table 1) from Section 8 at Te Kau Kau Point. The sample dated was shells, which included the fragile bivalve Zeacopagia disculus, from a hollow in the top of the wave-cut bench underlying Beach Ridge C. The Zeacopagia shells were unbroken and still in position of articulation. The event dated is the uplift of Beach Ridge D and the beginning of growth of Beach Ridge C.

The next age is an inferred date of less than 1.8 kyrs: non-primary Taupo pumice in Sections 6 and 7 at Te Oroi.

The next age is an inferred date of less than 1.0 kyrs: first cultural charcoal in Sections 6 and 7 at Te Oroi. The charcoal gives a maximum date for stream gravels.

The next age is a known date of 0.7 kyrs: primary Loisels pumice in Beach Ridge C as mentioned above, and in all four sections. The pumice gives a date for the top of Beach Ridge C, for the upper part of the lagoon mud, and for wind-blown sand and stream gravels within the lagoon mud.

The youngest age is an inferred age of 0.4 kyrs: Ohuan deposits and soil in Section 3 at Te Awa Iti. The deposits and soil give a minimum date for the youngest marine deposits.

The simplest interpretation of the four sections is simultaneous growth of Beach Ridge C, accumulation of inter-bedded marine and non-marine deposits, and a rise in sea level of 3 m.

Shoreline displacement along the stretch of coast (Wellman, 1971a; Singh, 1971) is in the opposite sense to the beach ridge uplifts. Hence the 3 m rise in sea level is assumed to be a world-wide eustatic event occurring between 2.4 and 0.4 kyrs ago. Of the total 3 m rise, 1 m occurred after the Loisels pumice was deposited, between 0.7 and 0.4 kyrs ago.

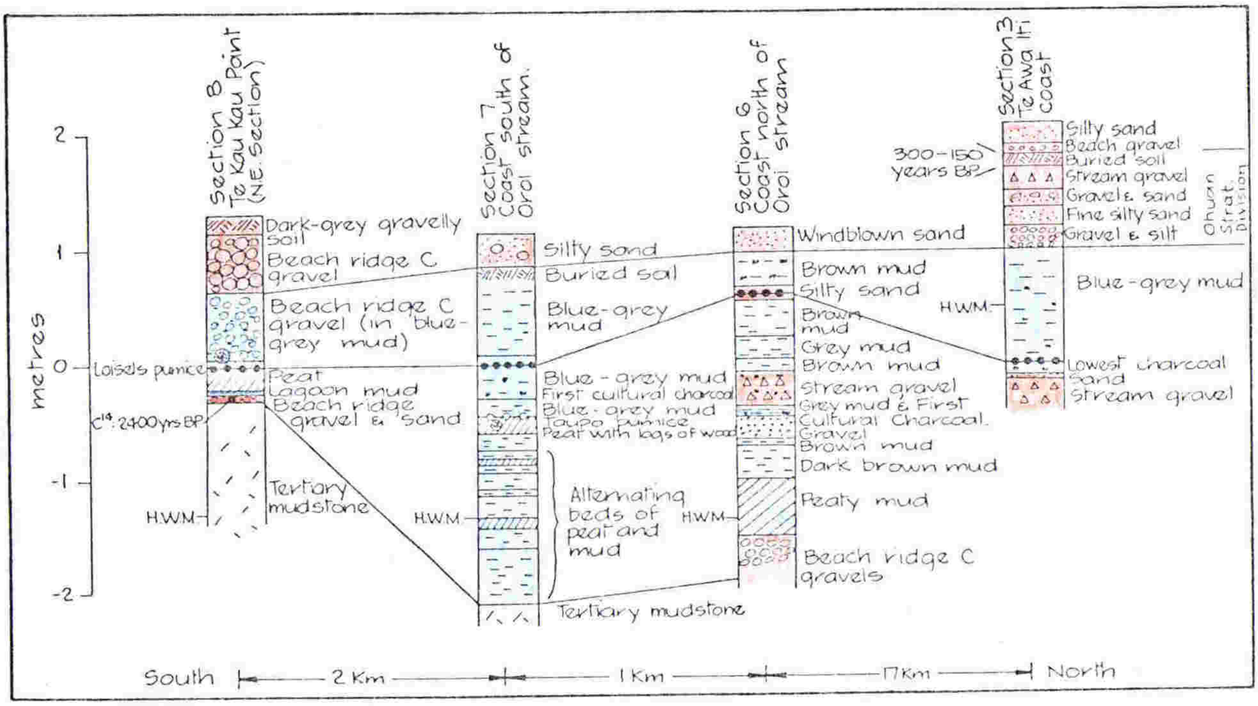


FIGURE 1 - Four columns generalised in Figure 2 to illustrate the growth of Beach Ridge C, and deposition of estuarine muds behind Beach Ridge C, during an eustatic sea level rise of 3 m. Positions of columns shown by Figures 12, 13 and 14 (main text). Blue = Marine; Red = Non-marine. Height arrangement is that inferred at time of Loisels pumice deposition. Post-Loisels uplift has been least at right hand column.

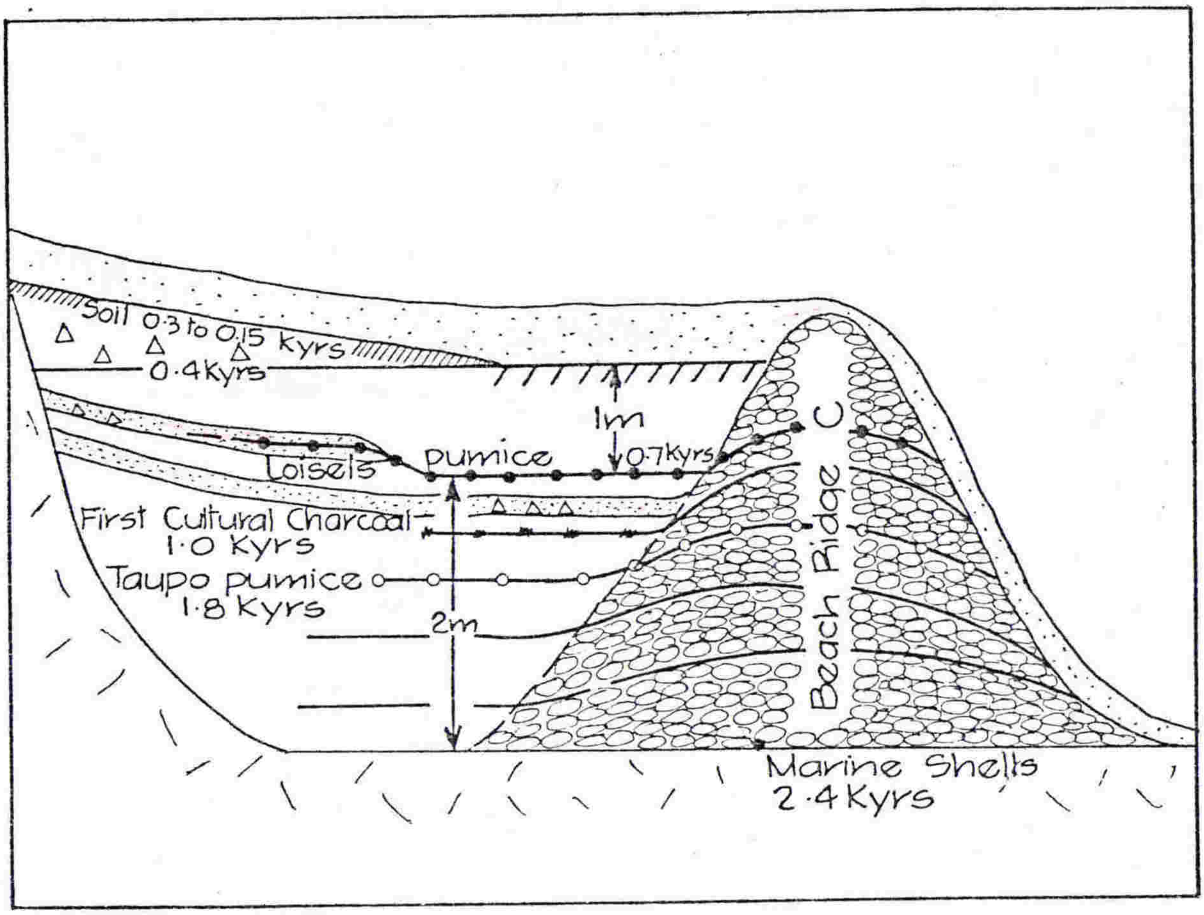


FIGURE 2 - Idealised cross-section to show evidence for a 2 m sea level rise from 2.4 kyrs to 0.7 kyrs BP (Loisels pumice), and for a 1 m sea level rise from 0.7 kyrs to 0.4 kyrs BP. Data from sections 3, 6, 7 and 8 at Te Awa Iti (Figure 12, main text), Te Oroi (Figure 13, main text), and Te Kau Kau Point (Figure 14, main text). Selected columns shown by Figure 1. Blue = Marine, mostly estuarine mud; red = Non-marine, mostly stream deposits and windblown sand. Narrow cross-hatching = Ohuan soil.

TABLE 1

Radiocarbon date for shells underlying Beach Ridge C at Section 8, Te Kau Kau Point.

NZ Number	Date	Material Dated	Source of Sample
1873A	2390±70	Shells, rocky shore and	A hollow in the top of the wave-cut bench underlying Beach Ridge C.
1873B	2460±80	subtidal species: Irus (Notirus) reflexus Protothaca crassicosta Lunella smaragda Cellana denticulata Zeacopagia disculus	

APPENDIX 5

AGE RELATION BETWEEN A MAORI PLAGGEN SOIL AND MOA-HUNTER SITES ON THE WEST WELLINGTON COAST

INTRODUCTION

In the relatively small area of west Wellington coast between Te Ika amaru Bay and Paremata (Main text: Figure 10), there are both Moahunter sites and a Maori Plaggen soil. For the Maori cultural sequence in the area it is important to know their age relation.

MOAHUNTER SITES

Three Moahunter sites are recognised: at Te Ika amaru Bay (Site N164/17), at Makara Beach (N164/2), and at Paremata (N160/50). Moa hunting is assumed only where there is evidence of moa butchering, or if moa bones were found in ovens.

At Te Ika amaru Bay a burnt moa bone, the distal end of a tibia of either *Dinornis* sp. or *Euryapteryx geranoides*, was found by the writer among oven stones in the southeast corner of the bay. Associated crop stones suggest that moas were butchered on the site.

At Makara Beach the Moahunter site is near the mouth of Makara stream among old sand dunes. It was excavated in 1958 by S. Davis (1962). There were moa bones and seven earth ovens. One oven contained part of a femur from an immature *Pachyornis mappini*; a second oven, part of a tibia from a *Dinornis hercules*. Unidentified charcoal from one of the ovens gave a radiocarbon date of 392±84 years BP (NZ 653A) and this is taken as a maximum age for the site.

At Paremata the Moahunter site was among sand dunes near the entrance to Pauatahanui Inlet (Figure 1). It is now almost entirely destroyed. In 1884 Chapman described finding the severed head of a moa lying with charred and "flintscarred" bones of the same bird nearby. In 1962 Smart reported finding moa bones in an oven; and Davidson (pers. comm.), who excavated in the same area, found bones of moas that had been eaten. Unidentified charcoal found with moa bones gave a radiocarbon date of 514±48 years BP (NZ 510A), and this is taken as a maximum age for the Moahunter occupation.

MAORI PLAGGEN SOIL

The Maori Plaggen soil (N160/107) is exposed in a road cutting on the north shore of the Pauatahanui Inlet (Figure 1), 3 km east of the Paremata Moahunter site mentioned above. Cockle shells (Chione strutchburyi) from a shell midden on top of the soil gave a radiocarbon date of 480±60 years BP (NZ 1878A), and this is taken as a minimum age for the soil. A detailed account is given in Appendix 1.

AGE RELATION OF SITES

Radiocarbon resolution is not good enough to determine the age relation of the sites. The sites are not in exactly the same area and it is this impossible to determine their stratigraphic order directly. Fortunately, all sites are near the coast and are on or near uplifted beach ridge deposits. An attempt is made below to correlate the beach ridge deposits and establish the order between agriculture and moa hunting.

Beach ridges form during a rising or stable sea level, and are stranded by a fall in sea level. Sea level can fall in two ways: by eustatic lowering, and by earthquake uplift. A beach ridge stranded by eustatic lowering may be obliterated unless lifted tectonically before being drowned by a reversal of eustatic movement. A storm effect is superposed and, on an exposed coast, will obscure height differences less than 0.5 m.

Pauatahanui Inlet is an ideal place for beach ridge preservation. It is sheltered and there is an abundant supply of material for beach ridge growth. Consequently, there are more uplifted beach ridges than elsewhere on the west Wellington coast: six uplifted beach ridges compared with two elsewhere (Figure 2; Tables 1 and 2). Beach ridges inferred to have been earthquake-stranded are lettered A, B and C, in the usual way, and those inferred to be eustatically-stranded are lettered B_1, C_1 and D_1.

Figure 3 is a relation (not a distance) diagram showing an inferred correlation of beach ridges along the west Wellington coast with beach ridges along the Turakirae coast. The profiles for the west Wellington coast lie on the extreme left hand side in the region of low uplift, and the younger beach ridges have no significant height differences. To establish the relation lines three profiles recorded by Wellman (1969) along the Turakirae coast are included: one at Turakirae Head, and one on either side of the head. Also included are two radiocarbon-dated samples 6.2 kyrs old (Table 3) taken from the west Wellington coast. The most southerly radiocarbon sample is from Smith's Bay (Main text: Figure 10; Figure 4) 1 km north of the Makara Moahunter site, the other is from about 100 m north of the Maori Plaggen soil. It is generally accepted that Beach Ridge B was uplifted during the 1855 earthquake; and that Beach Ridge C was uplifted during the Haowhenua earthquake of Maori tradition.

A date for the Haowhenua earthquake, based on Maori tradition, is about 500 years BP by Best (1923). An independent date by Wellman (1969), based on an assumption of average uniform uplift rate and uniform beach ridge formation at Turakirae Head, is 600 years BP. A radiocarbon date for the uplift on shells from a Maori midden thought to have been deposited soon after the earthquake at Turakirae Head, is 360 to 520 years ago (Moore and McFadgen, 1978).

The inferred age relation of Moahunter sites, Maori Plaggen soil, and uplifted beach ridges is shown by Figure 5.

The Maori Plaggen soil overlies Beach Ridge C_1, and is overlain by Beach Ridge C (Figure 6). It is therefore thought to predate the Haowhenua earthquake (Figure 5).

At Makara Beach the Moahunter site is in front of Beach Ridge C. At Te Ika amaru Bay the Moahunter site is on top of Beach Ridge C. Both Moahunter sites are thus thought to be younger than the Haowhenua earthquake (Figure 5).

At Paremata the Moahunter occupation layer is less than 1.2 m above high water mark. It rests directly on old intertidal gravels, and is covered by old intertidal gravels. The inferred sequence of events is: the accumulation of lower gravels; the Haowhenua earthquake; the occupation of the site immediately after the earthquake; and finally the deposition of the overlying gravels during an eustatic sea level rise which formed Beach Ridge B_1. The Paremata Moahunter site is thus thought to be younger than the Haowhenua earthquake and older than an eustatic sea level high which followed the earthquake. Estimated dates given above for the Haowhenua earthquake are 500 to 600 years BP; and for the succeeding high sea level, from the southeast Wairarapa coast, 400 years BP.

CONCLUSION

Moa hunting on the west Wellington coast continued after agriculture had started, which is in agreement with evidence for agriculture and moa hunting from the lower occupation layer described at D'Urville Island by Wellman (1962a). It is in disagreement with views expressed on theoretical grounds by Duff (1956), who postulated a Moahunter period predating Maori settlement of New Zealand, and the introduction of agriculture into New Zealand after the moa became extinct.

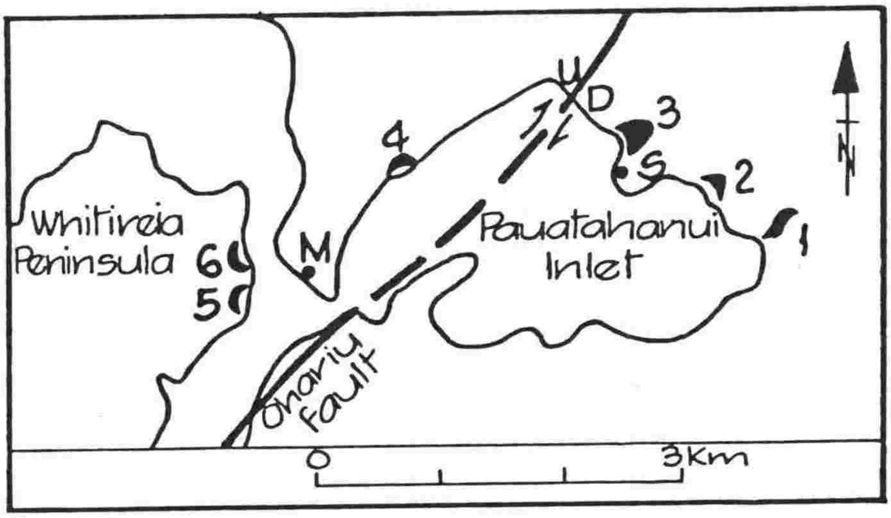


FIGURE 1 - Map of Paremata (Whitireia Peninsula and Pauatahanui Inlet) showing beach ridge localities (1 to 6), location of section with Maori Plaggen soil (S), and location of Paremata Moahunter site (M) Upthrown side of Ohariu fault shown U; downthrown side shown D. Sense of movement from Geological map. Vertical component during time of formation of Beach Ridges A to D_1 not detectable (see Figure 2).

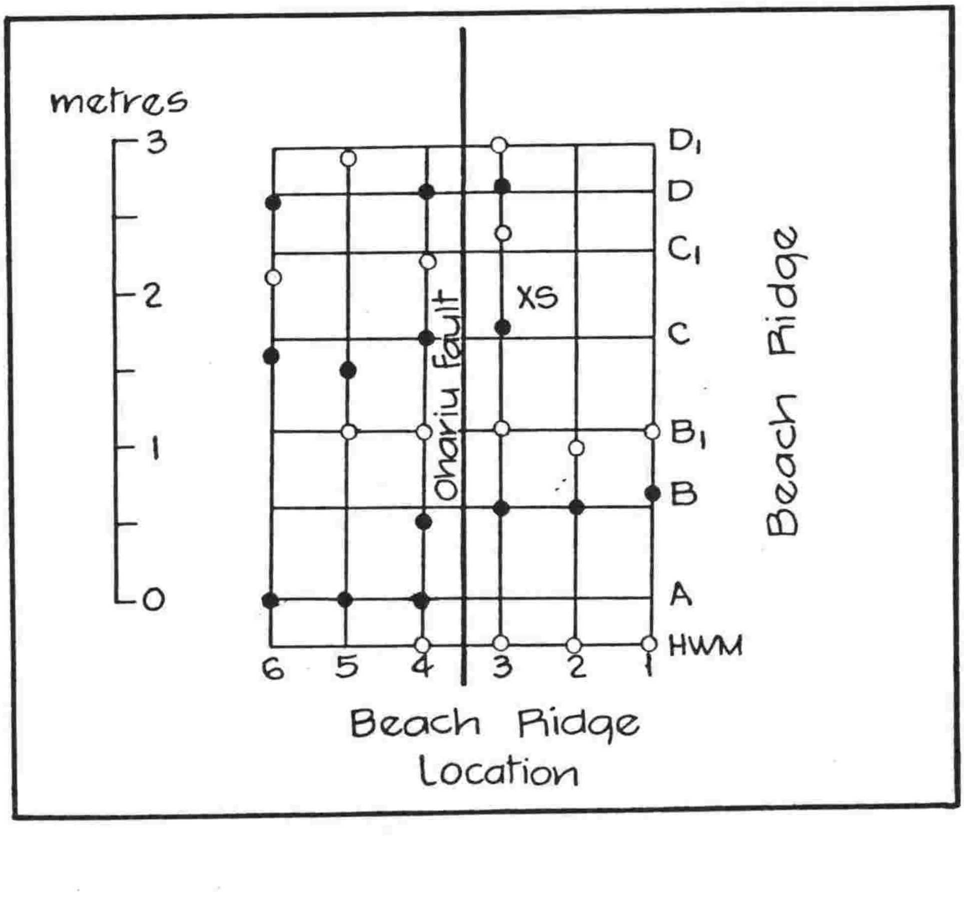


FIGURE 2 - Emergence heights of beach ridges at Paremata (localities 1 to 6) on either side of Ohariu fault, and inferred correlation. The stratigraphic position of the Maori Plaggen soil, between Beach Ridges C and C_1 = S. Beach ridges labelled with a letter and a number, and shown as an open circle, are thought to have been stranded by sea level lowerings; and labelled with a letter only, and shown as a solid dot, by earthquake uplifts. Note that there is no significant height difference for the ridges on each side of the Ohariu fault.

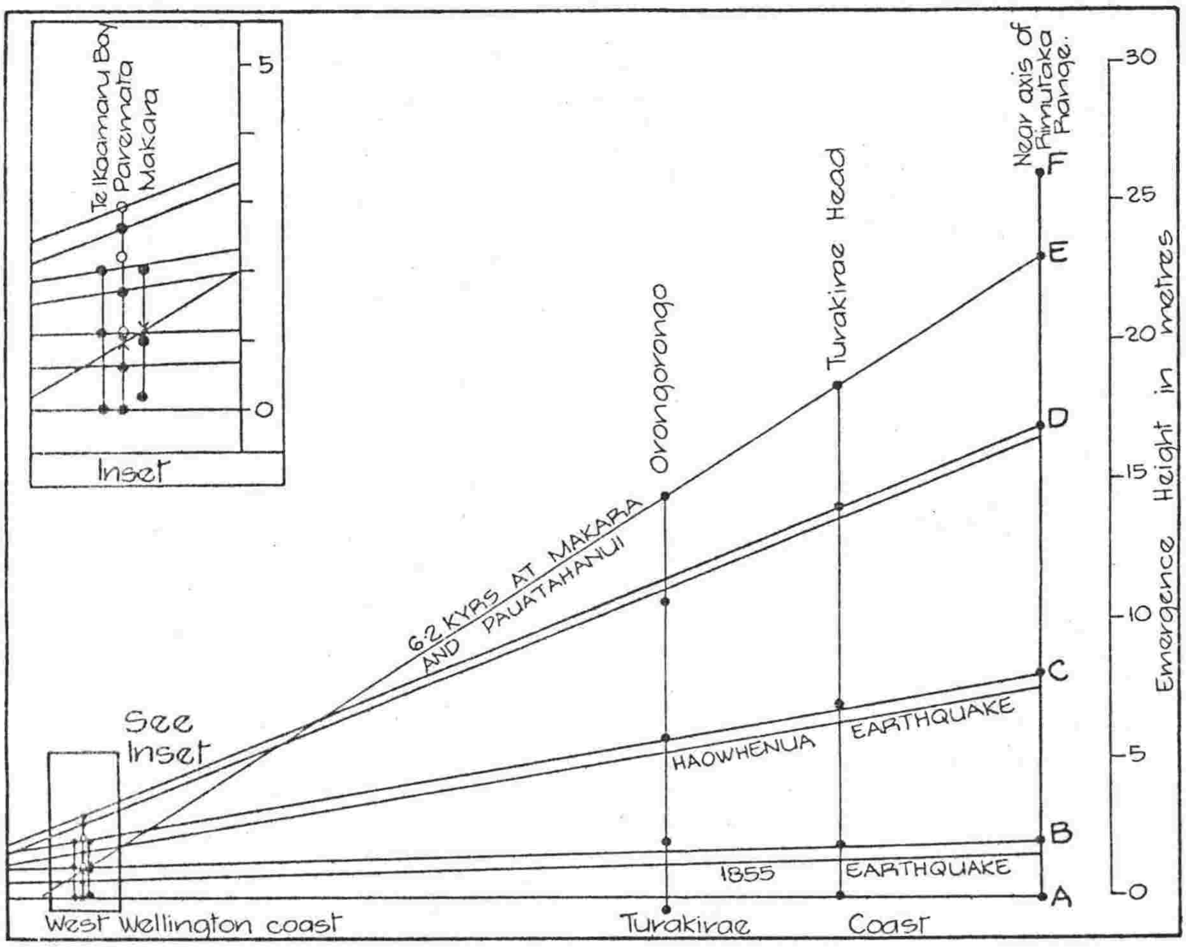


FIGURE 3 - Relation diagram showing correlation of uplifted beach ridges and radiocarbon-dated material from the west Welington coast with uplifted beach ridges B, C, D and E, along the Turakirae coast. Emergence heights from Tables 1 and 2. Growing beach ridge (A), and uplifted beach ridges stranded by earthquakes, shown by solid dots. Radiocarbon-dated material shown as crosses. Uplifted beach ridges stranded by sea level lowerings and later uplifted before being drowned by a reversal of eustatic movement (Paremata only) shown as open circles. Note that Paremata beach ridges directly correlated with Turakirae coast beach ridges are those stranded by sea level lowerings. Uplifted beach ridges stranded by the same earthquake are shown by double parallel lines. Note that the line joining Beach Ridges E passes through the emergence heights of the 6.2 kyrs old radiocarbon-dated material.

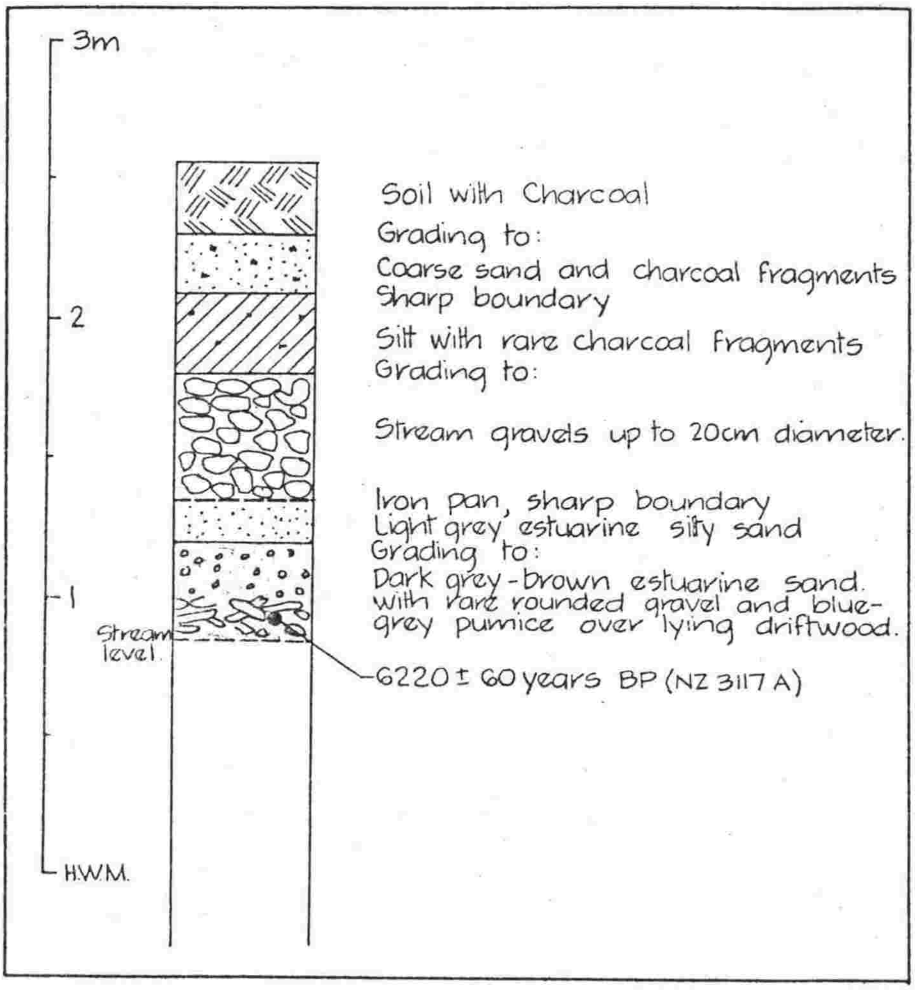


FIGURE 4 - Section in the north bank of the stream flowing into Smiths Bay, Makara Beach, 60 m from stream mouth (Grid Ref. N160(1965)/283309). Position of radiocarbon sample (sticks of driftwood from estuarine mud) shown by heavy dot.

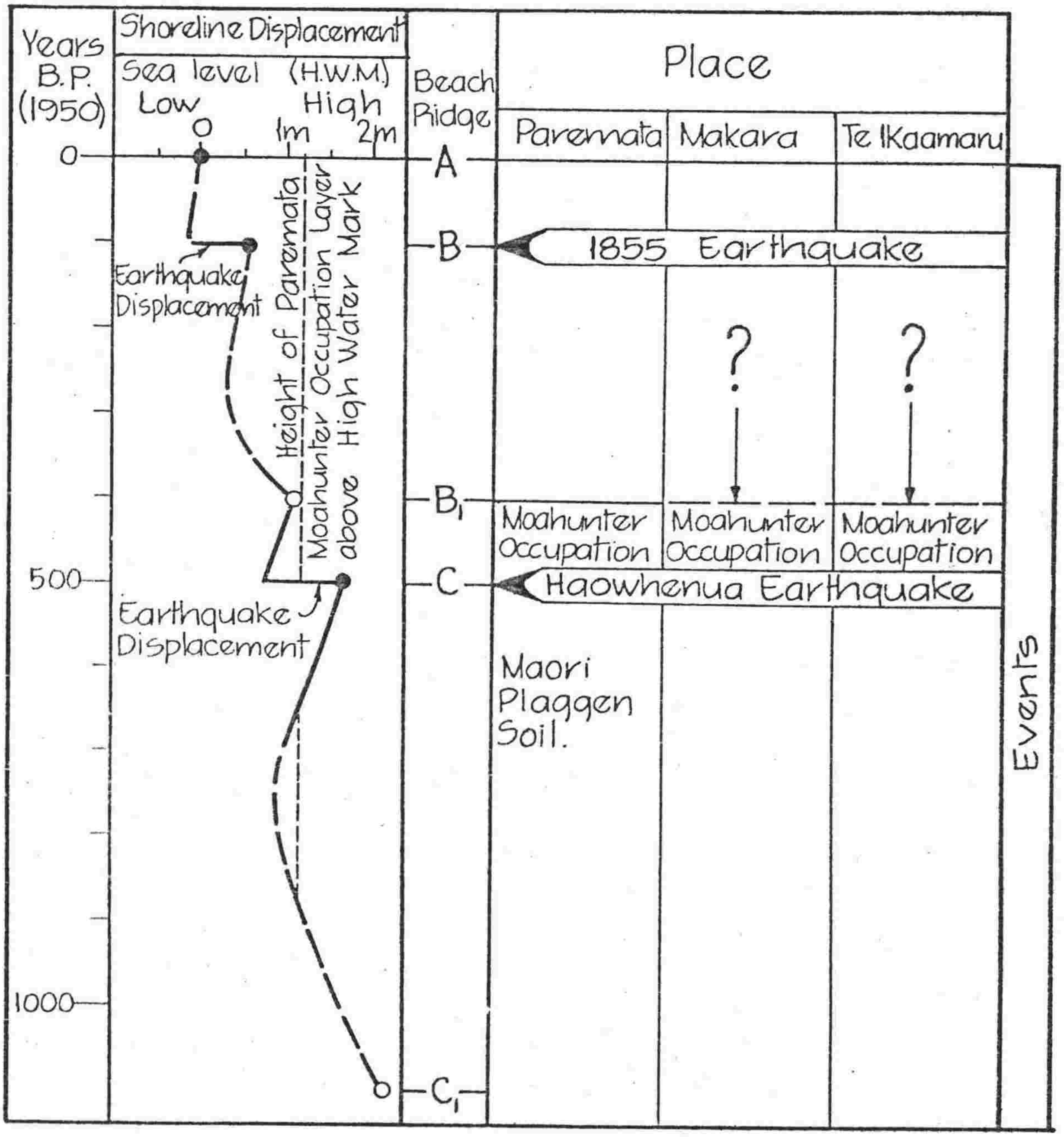


FIGURE 5 - Diagram showing inferred dates for the Maori Plaggen soil and Moahunter sites on the west Wellington coast. Also shown is a shoreline displacement curve (HWM), determined from uplifted beach ridges at Paremata, used to infer age of Paremata Moahunter site. Broken curve is uncertain. Solid curve, showing eustatic rise between 700 and 400 years ago, based on inferred eustatic rise from southeast Wairarapa coast.

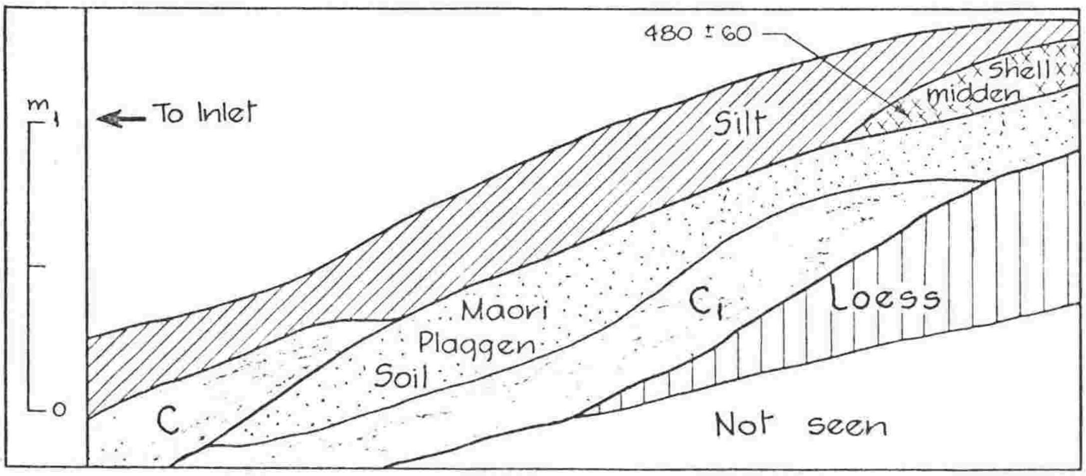


FIGURE 6 - Generalised cross-section at right-angles to coast at locality S (Figure 1), showing the Maori Plaggen soil overlying Beach Ridge C_1 and underlying Beach Ridge C. Correlation of the beach ridges is based on their height. Shell midden has a radiocarbon date on shell of 480±60 (NZ1878A). Vertical exaggeration about 5-fold.

TABLE 1

Heights (in metres) of beach ridges above Beach Ridge A, or above high water mark, at Paremata. For beach ridge localities see Figure 1.

	Localities						Adopted Average Heights
	1	2	3	4	5	6	
HWM	0	0	0	-0.3	-	-	-
BR A	Destroyed by road			0	0	0	0
B	1.0	0.9	0.9	0.5	-	-	0.6
B_1	1.4	1.3	1.4	1.1	1.1	-	1.1
C	-	-	2.1	1.7	1.5	1.6	1.7
C_1	-	-	2.7	2.2	-	2.1	2.2
D	-	-	3.0	2.7	-	2.6	2.6
D_1	-	-	3.3	-	2.9	-	2.9

TABLE 2

Emergence heights (in metres) of west Wellington coast beach ridges correlated with Beach Ridges B, C and D, along the Turakirae coast. Also shown, emergence heights of Beach Ridges E and F along the Turakirae coast. Beach ridge heights along the Turakirae coast (three places) determined from Wellman (1969, Figure 3); the numbers in brackets are grid lines on his Figure 3 and give the positions of the three places. The higher of each pair of Paremata beach ridges is thought to have been stranded by sea level lowerings, the lower by earthquake uplifts.

		B	C	D	E	F
Turakirae Coast	Near axis Rimutaka Range (490)	2	8	17	23	26
	Turakirae Head (470)	2	7.5	14	18.5	
	Orongorongo (455)	2.5	6	11	14.5	
West Wellington Coast	Te Ika amaru Bay	1.1	2.0			
	Makara Beach	0.8	1.8			
	Paremata	0.6	1.7	2.6		
		1.1	2.2	2.9		

TABLE 3

Emergence heights of two 6.2 kyrs old radiocarbon dated samples from the west Wellington coast.

NZ Number	Date	Material Dated	Emergence Height	Locality
3117A	6220±60	Sticks of driftwood in estuarine muds ca. 1 m above present high water mark (Figure 4).	ca. 1 m	Smith's Bay, 1 km north of Makara Beach. In stream bank 60 m from stream mouth. (G.R. N160(1952)/283304)
3118A	6250±60	Cockle shells (*Chione stutchburyi*) from raised cockle bed ca. 0.2 m above present high water mark.	ca. 1 m	Pauatahanui Inlet, beneath Beach Ridge C at Locality 3 (Figure 1). (G.R. N160(1952)/448458)

APPENDIX 6

RISE IN LAKE LEVEL AT ARCHAEOLOGICAL SITE N148/1 AND PROGRADATION OF THE MANAWATU COAST, NORTH ISLAND, NEW ZEALAND.

INTRODUCTION

On the southwest coast of the North Island of New Zealand, from Patea in the north to Paekakariki in the south, there is a belt, up to 20 km wide, which consists of sand dunes, sand plains, peat swamps and shallow lakes (Figure 1a). In the central part of the belt four successive Dune Building Phases (Figure 1b) named, from oldest to youngest, Koputaroa, Foxton, Motuiti and Waitarere, have been described by Cowie (1963). Dunes of the Motuiti phase contain Taupo pumice and with the dunes of the Waitarere phase, are younger than 1,800 years.

There is a line of lakes along the boundary between Motuiti and Waitarere dunes. Since 1910 AD many of the lakes have been artificially drained and they are now well below their natural level. Natural lake levels are at natural ground-water level. Ground-water rises away from the sea and rivers and it is assumed that the gradient of rise in the past was constant. Lake levels will therefore rise in response to coastal progradation. If past lake levels can be determined, then these should indicate successive positions of the coast and hence enable rates of coastal progradation to be found.

On the eastern shore of the first lake north of the Manawatu River (Figure 1c) is an archaeological site N148/1 (Grid. Reference N148(1968)/767233) where three occupation layers have been found separated by well-defined soil horizons formed on sand (Figure 2). Two of the occupation layers are prehistoric and they indicate a rise in lake level since the archaeological site was first occupied. Evidence for the rise in lake level, based on a description of the site by

McFadgen (1972) and the results of subsequent excavations, is given in Part one of this account. Positions of the coast inferred from the lake levels, and progradation rates for the past 1,800 years, are given in Part two.

PART ONE: LAKE LEVELS AT SITE N148/1

Lake levels at the archaeological site are found from the heights of two old lake shore benches, which give reasonably accurate levels before and after the site was occupied; and from the heights and contents of the two prehistoric occupation layers, which enable lake levels at the times of occupation to be inferred. Lake levels determined at the archaeological site for the past 550 years are shown in Figure 3.

Lake levels from lake shore benches

The two old lake shore benches, labelled 1 and 2, are shown in Figures 2 and 3. Each bench is assumed to represent a constant lake level. Judging from the existing bench which has formed since the lake was first drained in 1910, benches 1 and 2 indicate a lake level which was constant for at least 65 years.

Bench 1 is a submerged shoreline cut into Motuiti sand on the eastern side of the lake. The corresponding shoreline on the western side of the lake is buried under Waitarere sand. Lake level in historic times has not been low enough to form the bench therefore Bench 1 is assumed to be prehistoric. Its level, determined by 'spirit' levelling from a Lands and Survey benchmark at Foxton, is 1.9 m to 2.1 m above present mean sea level. It is shown below to be close to the inferred lake level during the first occupation of the site some 550 years ago.

Bench 2 is cut into Waitarere sand on the western side of the lake and is 4.6 m above present mean sea level. Its position corresponds to the position of an old lake shore shown on an old cadastral map (S.O. 12963) surveyed in 1889. The height of Bench 2 is taken as lake level in 1889.

Lake levels from occupation layers

The three occupation layers (I, II and III) are shown in Figure 2. Occupation Layers I and II are prehistoric; Occupation Layer III is historic. Their ages are known reasonably accurately. Shells from Occupation Layer I have a radiocarbon date of 550±70 years BP (NZ 1480B). Shells from Occupation Layer II have a radiocarbon age of 320±65 years BP (NZ 1250B). Occupation Layer III is younger than about 1910. The buried soil between Occupation Layers I and II, from its degree of development, is thought to have been 100 to 200 years old at time of burial.

Each prehistoric occupation layer consists of two parts: a shell midden, and layers of sand. In the shell middens are duck and eel bones, seeds, small freshwater molluscs, and small landsnails. Ducks and eels were probably brought to the site as food and, with the freshwater molluscs, their bones indicate a nearby lake. The freshwater molluscs are thought to have been stranded at the edge of the lake during minor fluctuations of lake level, dried, and been blown into the site by the prevailing northwesterly wind. Seeds are probably plant litter from nearby vegetation and, with the landsnails, they indicate a well developed coastal forest (McFadgen, 1972). The landsnails are considered to have been attracted from the forest to the shell middens by decaying vegetation and a lime-rich environment. Since landsnails are generally absent from places which are periodically flooded, they indicate that the shell middens were deposited on permanently dry ground.

For each shell midden to have been deposited on permanently dry ground, mean lake level would need to have been at least 0.6 m below the lowest part of each shell midden when it was deposited. This is to allow for a ground water level at the site being 0.2 m above lake level; and for a lake level of 0.4 m above mean lake level during abnormally wet periods.

The lowest part of the shell midden of Occupation Layer I is a bin-shaped pit 0.9 m by 0.7 m by 0.5 m deep, dug into sand and filled with shell midden. The pit was intact when found and had therefore been dug into dry ground. The bottom of the pit is 3.2 m above present mean sea level. A mean lake level 0.6 m lower than the bottom of the pit would be 2.4 m above present mean sea level. Bench 1 is 1.9 m to 2.1 m above present mean sea level and is assumed to have been the lake shore when Occupation Layer I was deposited. Mean lake level is thus taken as 2 m.

For convenience the shell midden of Occupation Layer II is divided into an early part and a late part. Because the midden grew outwards as well as upwards, the lowest level of each part is 3.7 m above present mean sea level. Both parts are stratigraphically related to the same shelters, windbreaks, earth ovens and fireplaces. A maximum length of time represented by Occupation Layer II is the time wooden shelters and windbreaks would last in sand, estimated to have been 25 to 50 years.

In the early part of the shell midden landsnails are abundant and freshwater molluscs, which include Physastra variabilis, Potamopyrgus antipodum, and Pisidium sp., are less than 2% of the total numbers of landsnails and freshwater molluscs combined. Seeds are from coastal forest trees and shrubs and grasses.

In the later part of the shell midden a sudden change occurs in the landsnails and freshwater molluscs. The numbers and species of landsnails decreases, the species of freshwater molluscs changes, and the proportion of freshwater molluscs increases to 15%. The freshwater molluscs are all Planorbis corrinna and indicate a change from those which normally live on lake weed stems, on sticks, or in mud, to a species normally found only on lake weed stems. In this same part of the shell midden, seeds from lake weeds first occur: an aquatic buttercup (Ranunculus rivularis) and a semi-aquatic herb (Montia fontana). Planorbis corrinna and the lake weeds are normally found around a lake edge near the strandline and, with the decrease in numbers and species of landsnails, they suggest that lake level rose and flooded the midden while the later part of Occupation Layer II was being deposited.

Flooding does not seem to have occurred when the early part of the midden was being deposited, which indicates that lake level was below 3.1 m. The flooded part of the midden is between 3.7 m and 3.8 m above present mean sea level, which indicates that mean lake level was above 3.1 m. No lake bench corresponding to this level has been found and lake level may have been gradually rising throughout the time Occupation Layer II was being deposited. Mean lake level during deposition of Occupation Layer II is assumed to have been 3.1 m above present mean sea level.

Rate of lake level rise

Lake levels between the time when Occupation Layer I was deposited and 1889 are shown by Figure 3. Occupation Layer I is assumed to be 550 years old; and Occupation Layer II, 320 years old. Rates of lake level rise based on these dates will be faster or slower if Occupation Layers I and, or, II are older or younger than assumed here. Between 550 and 320 years ago lake level rose at an average rate of 4.8 mm per year; and between 320 years ago and 1889 AD, at an average rate of 5.8 mm per year.

PART TWO: PROGRADATION OF MANAWATU COAST

The maximum possible amount of progradation during the past 1,800 years is assumed here to be 2 km, which is the distance from the present coast to the present seawards limit of the Foxton dunes. Progradation between 550 years ago and 1889 is calculated from positions of the coast inferred from lake levels at the archaeological site. Progradation since 1889 is determined from positions of the coast plotted on the 1889 cadastral map, and on a topographical map (N148) based on aerial photographs taken in 1965.

Before lake levels can be used to find positions of the coast, the ground-water gradient between the lake and the sea or river must be found, and corrections made to the lake levels for eustatic changes in sea level and tectonic uplift. It is assumed that the ground-water gradient has remained constant with time, and that it has always sloped towards the sea or the Manawatu River. Lake level will be determined by water level in the river, or by sea level at the coast, whichever is closer. In historic times the river has been closer to the lake, and river level has determined lake level. In prehistoric times the sea was closer, and sea level determined lake level.

The ground-water gradient

The natural ground-water gradient adopted is that for 1889. The 1889 cadastral map (S.O. 12963) shows the coast, the Manawatu River, and the first lake north of the Manawatu River. Mean tide level in the Manawatu River estuary is found from measurement to be 0.3 m above present mean sea level. By measuring the height difference between Bench 2 and mean tide level in the estuary (4.3 m), and by taking the 1889 distance from Bench 2 to the river estuary (2,170 m), the 1889 gradient is found to have been 1/505.

Correction for tectonic uplift and eustatic sea level changes

A rate of tectonic uplift averaging -0.2 mm per year is calculated from 10,000 year old wood found near Foxton at a depth of 150 feet (46 m) below present mean sea level (Te punga, 1958) and a sea level (-44 m) taken from Morner (1971). The rate is small and is disregarded.

Eustatic sea level changes are controlled by adopting those inferred in Appendix 5 (Figure 5). Between 700 and 400 years ago sea level rose by 1 m to a little above its present level and then fell again. Sea level during occupations I and II was probably the same, and close to its present level. A maximum correction of +0.5 m and -0.5 m is required to lake levels if Occupation Layer I is two standard errors older or younger than 550 years. Correction to Occupation Layer II lake level is significant (+0.5 m) only if Occupation Layer II is one standard error older than 320 years.

Positions of the coast with time

Distances from Bench 2 on the western side of the lake to the coast during the past 1,800 years, are shown by Figure 4. Positions of the coast during the past 1,800 years are shown on a map in Figure 5. The coast 1,800 years ago is assumed to have been at the present seawards limit of the Foxton dunes, which are 700 m seawards of Bench 2 (Figure 1b). The distances to the coast 550 and 320 years ago are calculated from the inferred mean lake levels when Occupation Layers I and II were being deposited. Distances are also shown for Occupation Layer I if Occupation Layer I is two standard errors older or younger than 550 years; and for Occupation Layer II if Occupation Layer II is one standard error older than 320 years. Five hundred and fifty years ago the distance was 1,010 m; and 320 years ago, 1,565 m. The distance in 1889 AD was 2,615 m; and the present distance is 2,700 m.

Rates of coastal progradation

Average rates of coastal progradation for the past 1,800 years are found by dividing the distance between successive positions of the coast by the difference in the age of each position, and are shown, to the nearest tenth of a metre, on Figure 4. Between 1,800 and 550 years ago progradation was 0.2 m per year; between 550 and 320 years ago, 2.4 m per year; between 320 years ago and 1889, 4.0 m per year; and between 1889 and 1965, 1 m per year. If Occupation Layer I is older than 550 years then the rate between the times Occupation Layers I and II were deposited will be less; and if younger than 550 years, more than that shown.

The most rapid progradation during the past 1,800 years thus began between 500 and 300 years ago and continued until after European settlement.

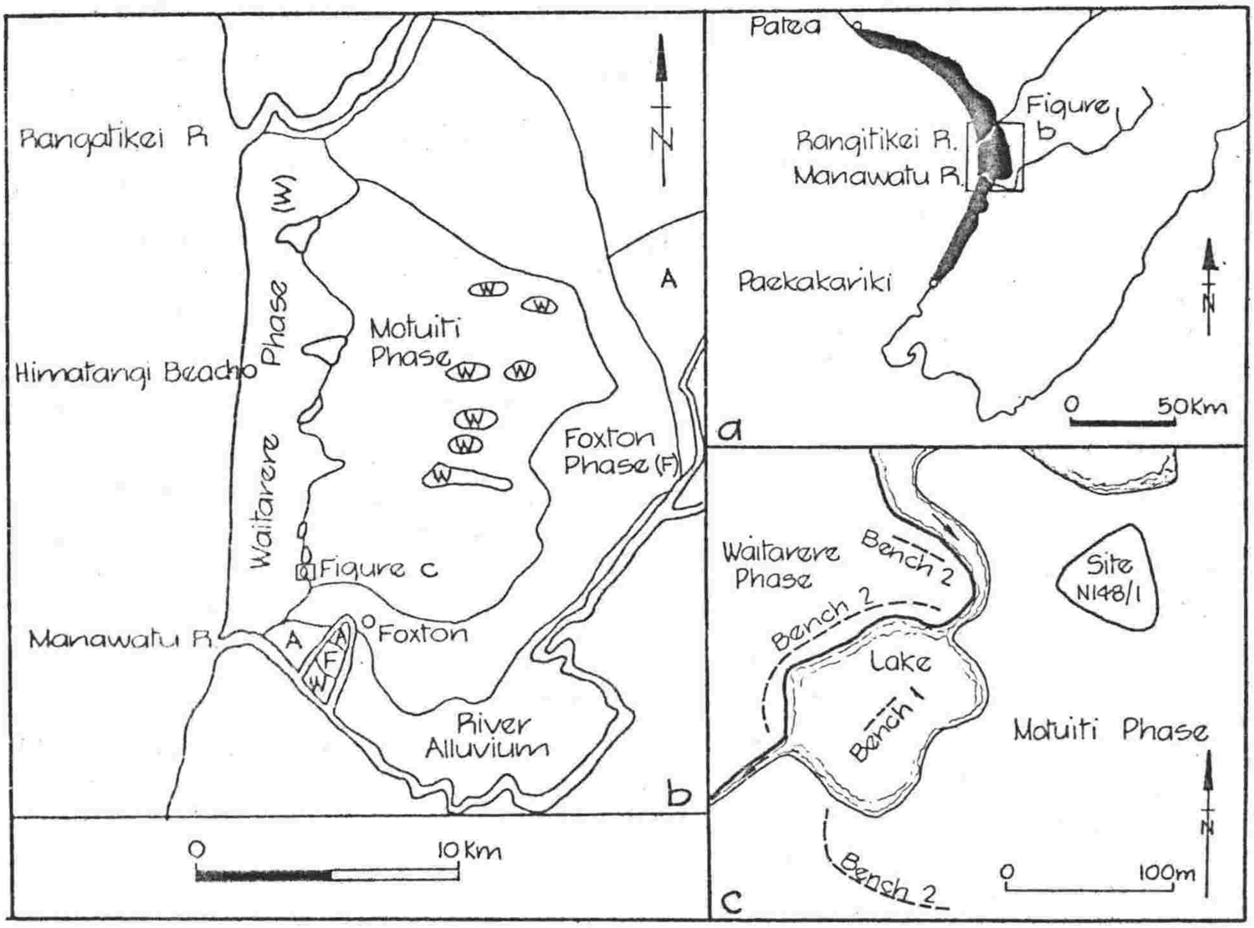


FIGURE 1 - Diagram for archaeological site N148/1 on the southwest North Island coast.

Fig.a. Map of the southern North Island showing the sand dune belt between Patea and Paekakariki.

Fig.b. Sketch map of the Manawatu sand country showing Dune-building Phases, and lakes along the Waitarere-Motuiti phase boundary.

Fig.c. Sketch plan of archaeological site N148/1 and surroundings showing positions of lake benches 1 and 2.

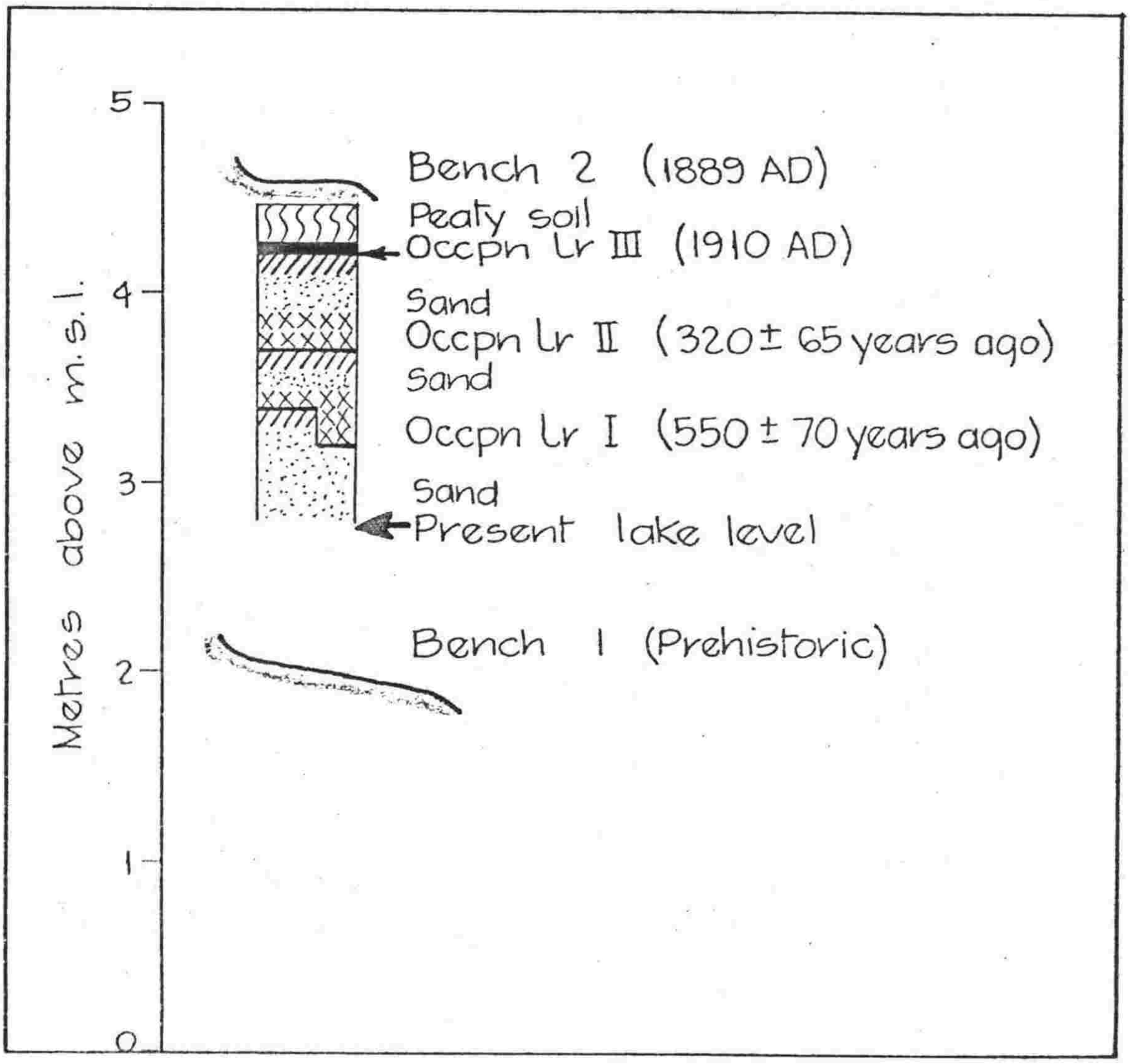


FIGURE 2 - Stratigraphic column showing three occupation layers at the archaeological site, and heights (metres above mean sea level) of lowest shell midden (crosses) in occupation layers I and II. Lowest shell midden in Occupation Layer I is in a pit dug into sand. Buried soils shown cross-hatched. Also shown are heights of lake shore benches 1 and 2, and present lake level.

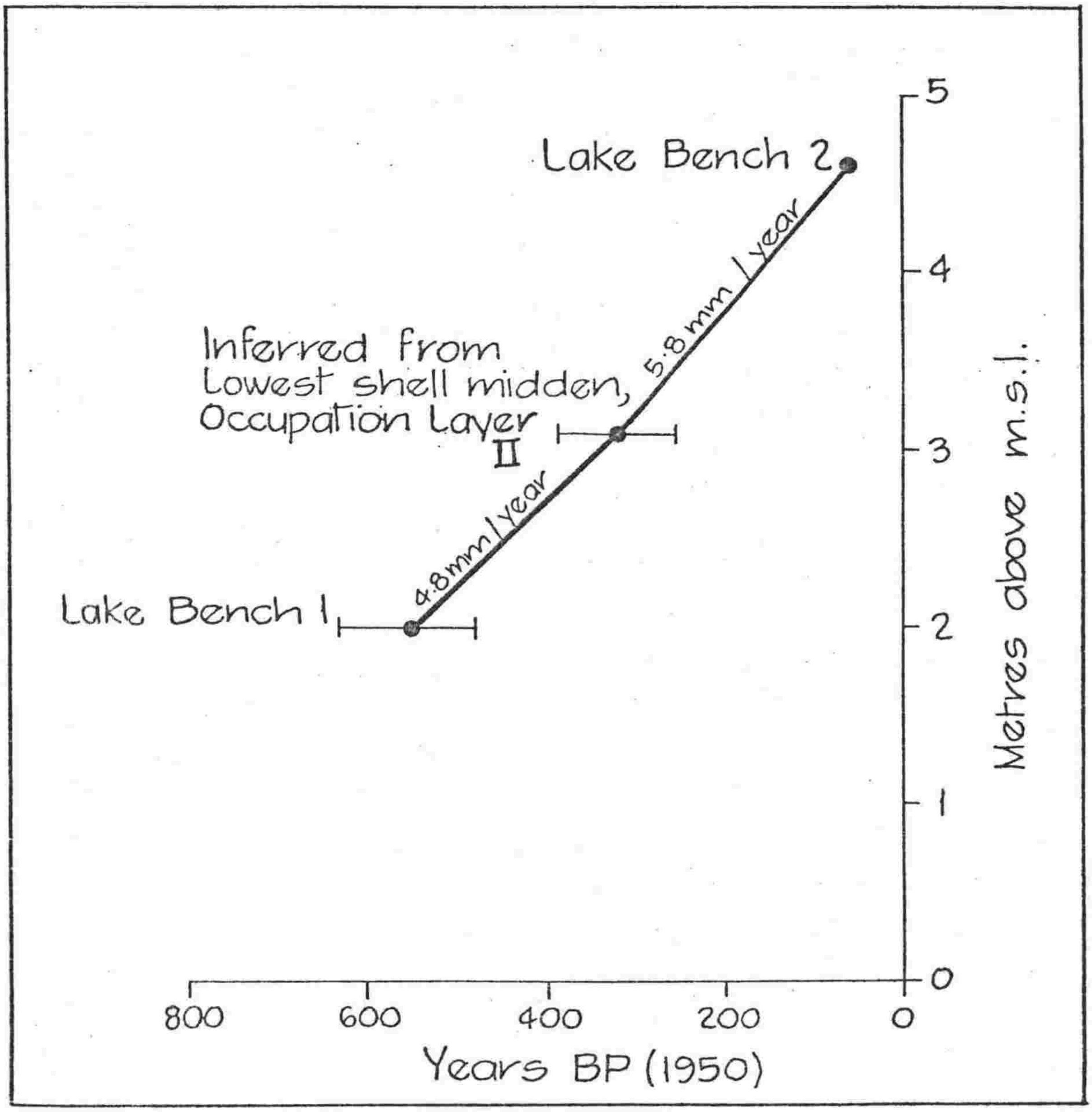


FIGURE 3 - Rise in lake level with time at the archaeological site.

Average rates of rise between 550 and 320 years ago, and between 320 years ago and 1889 AD, shown in mm per year. Dates for the 550 and 320 years old lake levels based on radiocarbon (error bars = range of ±1 s.e.). Date for the 1889 AD lake level is that of a cadastral survey. The 550 year old lake level is that of a submerged lake bench (Bench 1). The 320 year old lake level is inferred from the lowest level of shell midden in Occupation Layer II. The 1889 lake level is that of a lake bench now above lake level (Bench 2).

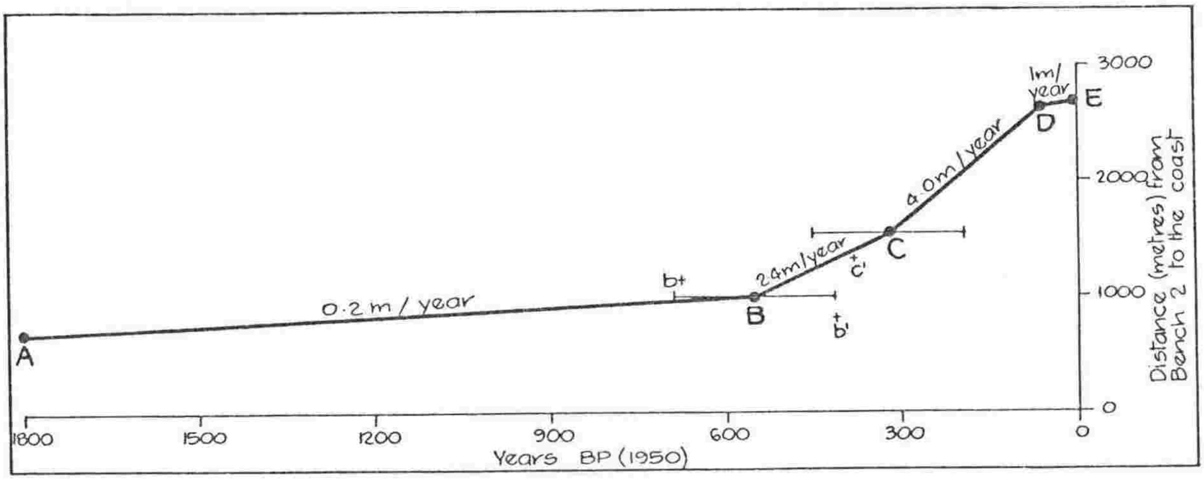


FIGURE 4 - Distances to the coast from Bench 2 on the western side of the lake, and progradation rates for the Manawatu coast, for the last 1,800 years. Inferred distances labelled A, B and C. Known distances labelled D and E. Average progradation rates given in metres per year. Radiocarbon dates for distances B and C shown with a range of four standard errors. Crosses b and b' indicate distance to coast if B is two standard errors older or younger than shown. Cross c' indicates distance to coast if C is one standard error older than shown.

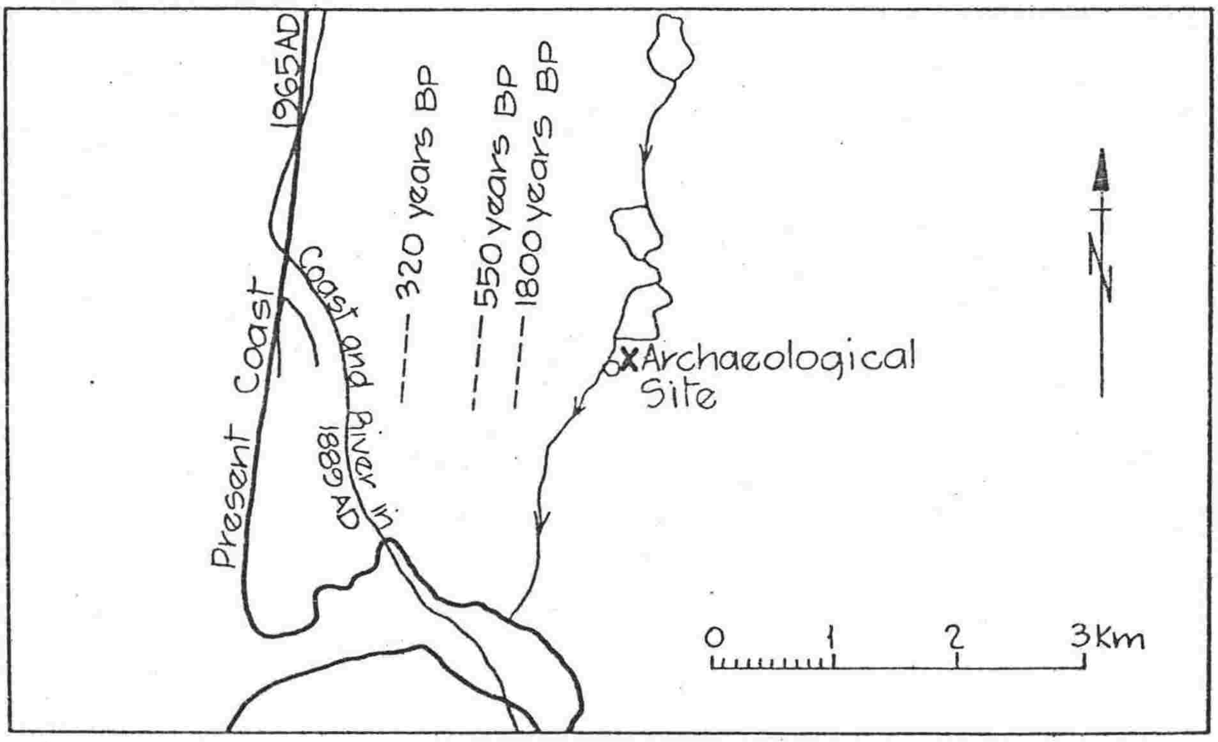


FIGURE 5 - Positions of the Manawatu coast with time. Inferred positions shown as broken lines at times labelled in years BP. Known positions (map records) shown as continuous lines at times labelled in years AD.

APPENDIX 7

DATA FOR DETERMINING VEGETATION THAT GREW ON A FOXTON PALEOSOL:

PART I: ACID HYDROLYSIS OF SODIUM HYDROXIDE EXTRACTED HUMIC ACIDS.

PART II: IDENTIFIED CHARCOALS.

PART I

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Humic acids were extracted from the two paleosol samples, VIOE and Motuiti Dune, using Goh's (1970) modification of the method of Gascho and Stevenson (1968).

After prolonged hydrolysis of the humic acids with 6M HCL the products were separated from the humic acid residue, and analysed by Gas Liquid Chromatography (GLC). Large amounts of vanillic acid (4-hydroxy-3-methoxybenzoic acid) were detected in the hydrolysis products, while 4-hydroxy benzoic acid and syringic acid (4-hydroxy-3, 5-dimethoxy benzoic acid) were either absent or present in very small amounts.

The results of the investigation are summarised in the following Table. The GLC data indicate that the Vanillic Acid/ 4-hydroxy benzoic acid was high in both samples.

Source of Humic Acid	Depth (cm)	Soil Carbon (%)	C/N	$\frac{\text{Vanillic Acid}}{\text{4-hydroxy benzoic acid}}$
Paleosol, VIOE	20-25	1.2	15	high
Paleosol, Motuiti Dune	74-84	1.3	13	high

The agreement between the data is consistent with the fact that the VIOE and Motuiti Dune samples are from the same paleosol.

The acid hydrolysis experiment indicates that the vegetation present at the archaeological site prior to Maori occupation, contained lignin with predominantly vanillyl units - this is typical of gymnosperm lignin.

I have previously examined a humic acid extracted from a topsoil beneath White Pine (*Podocarpus dacrydioides*), which I commented on at the 1971 Radiocarbon Users Conference. In that case, a high Vanillic Acid/4-hydroxy benzoic acid concentration obtained.

However, the present techniques don't allow me to be more specific than to say that a softwood, rather than a hardwood or grassland vegetation probably covered the site prior to Maori Occupation.

PART II

IDENTIFIED CHARCOALS

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Sample	Genus/Species
Paleosol, VIOE	*Podocarpus dacrydiodes* *Podocarpus totara* *Leptospermum* sp. (probably *ericoides*) *Coprosma* sp. *Pseudopanax* sp. (*colensoi* - *arboreum* type)
Paleosol, Motuiti Dune	*Podocarpus dacrydiodes* *Leptospermum ericoides*

In both samples the podocarp (softwood) elements tended to cominate. The species quite likely grew *in situ* or at least nearby.

APPENDIX 8

HYDRATION RIM THICKNESSES OF MAYOR ISLAND OBSIDIAN FLAKES COMPARED WITH FLAKE AGE DETERMINED BY RADIOCARBON DATING.

Obsidian hydration rim thickness and hydration time are related by the formula:

$$D = kT^{\frac{1}{2}}$$

where D = hydration rim thickness, T = hydration time, and k = a constant depending on chemical composition of the obsidian and the temperature during hydration (Friedman et al, 1969). In the following table, all obsidian has been identified as Mayor Island (Green, 1964). All the obsidian has been excavated from coastal sites either in Auckland or on the Coromandel Peninsula, and hydration temperatures are therefore probably similar. If hydration ages of Mayor Island obsidian flakes are reliable, then points representing the square of hydration rim thickness plotted against the age of measured flakes should lie on a straight line of increasing thickness with time. Radiocarbon dating is of proven value for determining ages providing allowance is made for standard errors of the dates, for the stratigraphic position of a dated sample, and for the age of the dated sample at death.

Hydration rim thickness^2 of Mayor Island obsidian flakes dates by radiocarbon are listed in Table 1. Mean, and, or, minimum and maximum thicknesses are given. The flakes are from five sites. Radiocarbon dates for the flakes are also listed. At three sites, because of stratigraphic position or the age of the sample dated, the dates are maximum ages; and at two sites, close ages.

Hydration rim thicknesses of the flakes are plotted against the radiocarbon ages of the flakes in Figure 1. Mean, and, or, maximum and minimum thicknesses are shown; and radiocarbon dates, corrected for half-life and secular variation , are shown with a range of ±2 standard deviations.

The resulting points do not lie on a straight line of increasing thickness with time, and it is concluded that hydration rim dates on Mayor Island obsidian are unreliable. The only explanation is that the obsidian has a variable chemical compostion

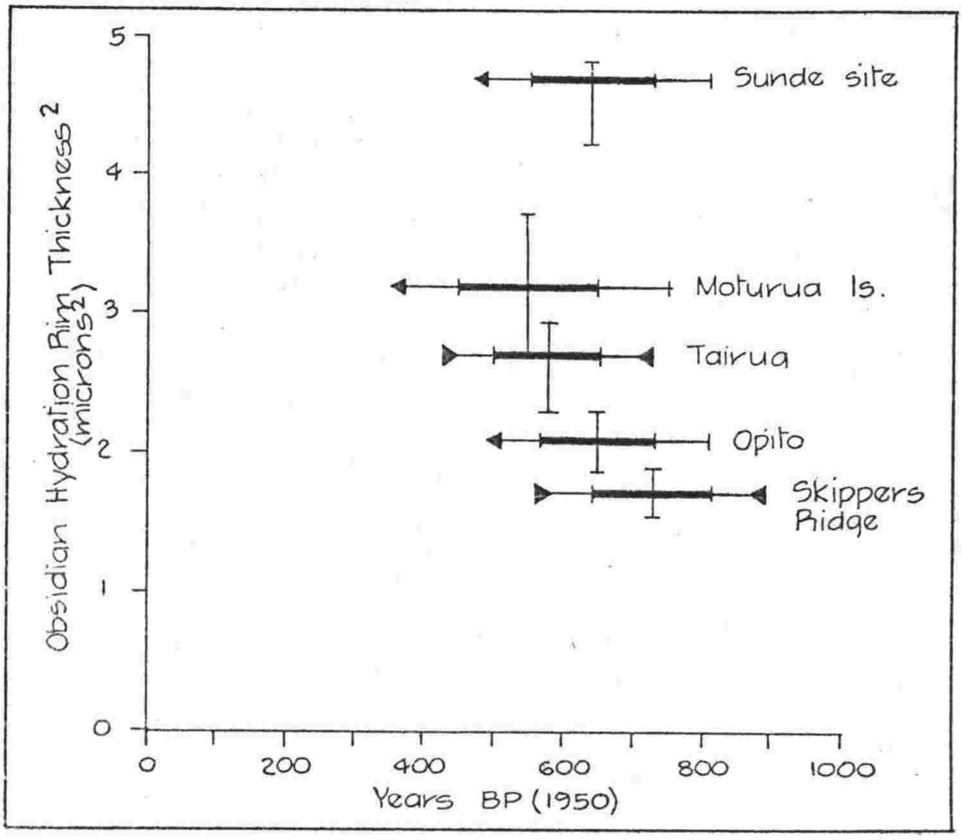

FIGURE 1 - Hydration rim thicknesses^2 (microns^2) of Mayor Island obsidian flakes compared with ages of the flakes determined by radiocarbon. Maximum and minimum thickness indicated by error bars. Radiocarbon dates are shown with a range of ±2 standard errors, and all are corrected for half-life and secular variation. Arrows pointing left indicate maximum ages; arrows pointing inward indicate close ages.

TABLE 1

A list of hydration rim thicknesses (microns^2) of Mayor Island obsidian flakes dated by radiocarbon.

Locality Site and Site No.	Layer	Obsidian hydration rim thickness^2 (μ^2) Minimum	Mean	Maximum	Reference to Measurement	^{14}C Reference Number	Date	Type of Date
AUCKLAND								
Moturua Island (N12/6)	3	2.72	-	3.72	Peters (1975)	NZ647A	530±90	
						ANU543A	510±85	
				(Mean of	NZ 647A and ANU	543A) C	550±105	maximum
Sunde site (N38/24)	10	4.24	4.71	4.84	Green (1964)	NZ1898A	610±60	
						NZ1898C	620±85	maximum
COROMANDEL PENINSULA								
Opito (N40/3)	4c	1.88	2.10	2.31	Green (1964)	NZ354A	640±50	
						NZ354C	650±80	maximum
Skipper's Ridge (N40/7)	3 & 4	1.54	1.72	1.90	Green (1964)	NZ1740A	807±57	
						NZ1740C	730±85	close
Tairua (N44/2)	2	2.31	2.72	2.96	Green (1964)	NZ1875A	570±60	
						NZ1875B	580±70	close

APPENDIX 9

RADIOCARBON IN MODERN MARINE SHELLS COMPARED WITH THE NEW ZEALAND STANDARD

INTRODUCTION

In New Zealand a marine shell standard is used for calculating radiocarbon dates from marine shells. The standard consists of modern shells collected alive in 1955 from Pounawea in southern South Island (Rafter et al, 1972). These Pounawea shells are generally believed to be uncontaminated by atom bomb radiocarbon. Modern marine shells collected alive in 1954 from Kairaki in North Canterbury were found to be depleted in radiocarbon compared with the Pounawea shells (Rafter et al, 1972). "Old" sea water depleted in radiocarbon periodically upwells near the New Zealand coast (Burling and Garner, 1959; Rafter and O'Brien, 1972) and might account for the depletion in the Kairaki shells. Because of upwelling of old sea water, the New Zealand Marine Shell Standard may not apply to all parts of New Zealand. The following results indicate that upwelling does not cause serious errors, and that the radiocarbon activity of the Pounawea standard differs slightly from the mean of 7 modern marine shell samples.

RADIOCARBON ACTIVITIES OF MODERN MARINE SHELLS

Radiocarbon activities are compared for marine shells collected alive on known dates from 7 different parts of New Zealand between Northland and Southland (Table 1: Figure 1). To avoid contamination with atom bomb radiocarbon only shells collected before 1957 are compared. After this date the radiocarbon activity of surface sea water, indicated by measurements on sea water from Makara, began to increase appreciably (Rafter and O'Brien, 1972). Samples 1 to 4 were reported by Rafter et al, (1972) and were collected between 1953 and 1957. Samples 5 to 8 have not previously been reported. They were made available to the writer from collections held by the

National Museum, Wellington, and were collected between 1923 and 1949; radiocarbon activities were determined by the Institute of Nuclear Sciences, Gracefield.

The radiocarbon activity of surface sea water decreased after about 1890 AD due to the burning of fossil fuels (Industrial effect). It did not increase again until after the testing of atom bombs began. Correction for the Industrial effect is made using an equation given by Rafter et al (1972) for correcting samples of marine shells taken above 100 m depth. To allow for the presence of upwelled water this equation includes a factor X which is the proportion of surface sea water in the water column above 100 m. No water analyses are available to determine X and for convenience X is given the value 1 for all samples. If upwelling were an important factor then a large scatter of the results would be expected. There is not a large scatter (Table 1) and upwelling is therefore not considered important.

The equation, for samples collected n_1 years after 1953, is:

$$\nabla^{14}_{1890}C = \Delta^{14}C + X(13 + 0.32n_1).$$

For samples collected n_2 years before 1953, assuming a linear decrease in radiocarbon due to the Industrial effect, the equation is:

$$\nabla^{14}_{1890}C = \Delta^{14}C + X(13 - 0.21n_2).$$

Table 1 lists a ^{13}C value for each sample. The ^{13}C values for samples 1 to 7 agree with the ^{13}C values for marine shells reported by Craig (1954). The ^{13}C value for sample 8, which is shells from the Waikanae Stream estuary, is depleted and the shells have probably incorporated carbon from non-marine sources (Rafter, 1975). Sample 8 is thus discarded.

CONCLUSIONS

Radiocarbon activities for samples 1 to 7 after correction for the Industrial effect ($\nabla^{14}_{1890}C$), range from -40‰ to -54‰. This range is not significant (F test, Snedecor and Cochran, 1967; $F = 1.10$, $p > 0.25$). Marine shell dates from different parts of New Zealand can thus be referred to the same marine shell standard without significant error. A mean value for $\nabla^{14}_{1890}C$ with respect to the 0.95 NBS Oxalic Acid Standard is -47‰ ± 5‰, which would indicate a mean activity for modern marine shells of 0.953 ± 0.005 of the 0.95 NBS Oxalic Acid Standard. Radiocarbon dates calculated using the 0.953 value would be about 55 years younger than those calculated using the present New Zealand Marine Shell Standard. Uncertainty in the radiocarbon activity of modern marine shells (±5‰) represents an age error of about ±40 years. When comparing marine shell dates with dates on other materials, the uncertainty can be taken into account by increasing the standard errors of marine shell dates according to the formula:

$$se^2 = se_1^2 + (40)^2$$

where se_1 is the standard error of a marine shell date before correction.

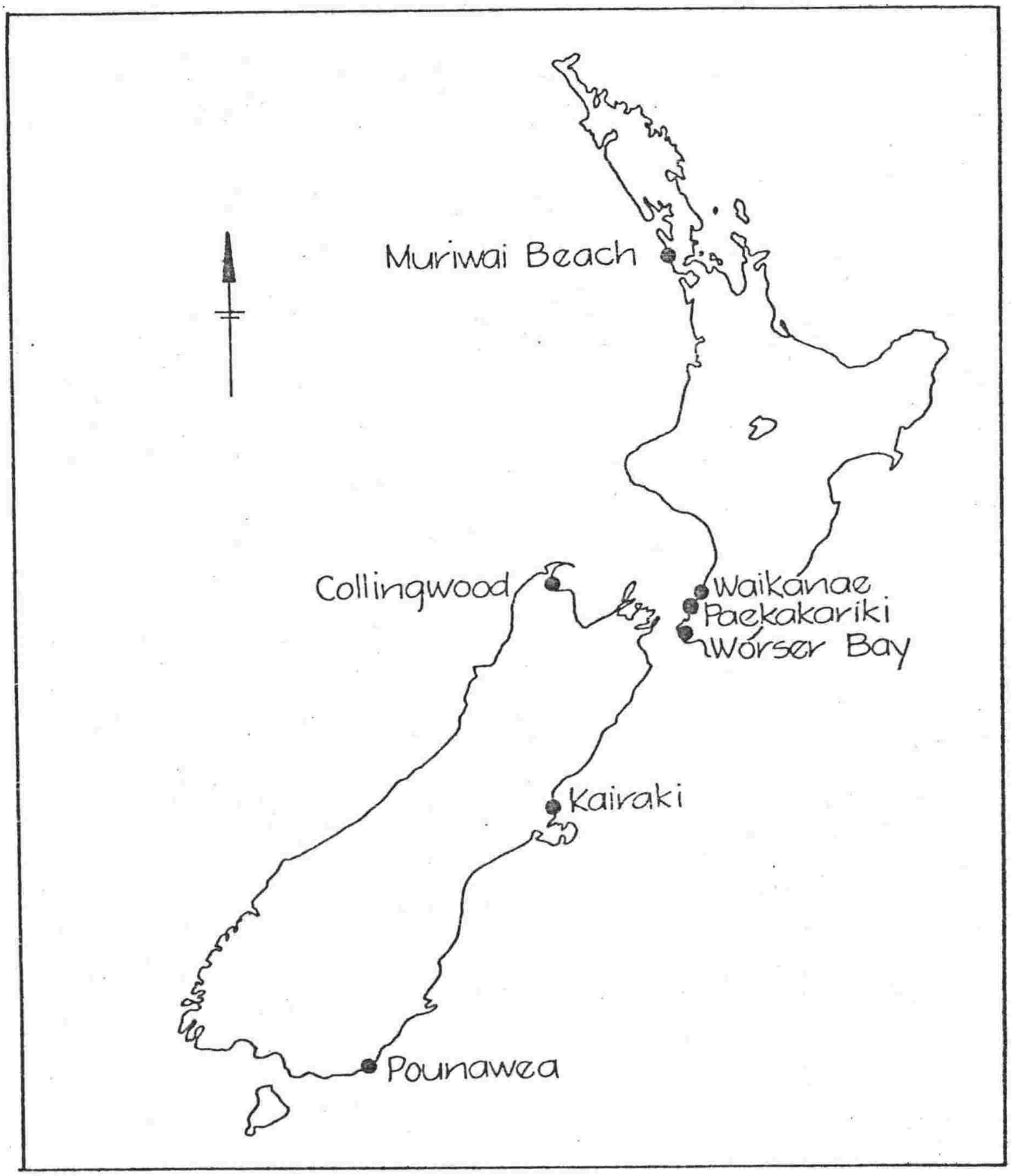

FIGURE 1 - Localities from which modern marine shells were obtained.

TABLE 1

^{14}C activity and ^{13}C content of modern marine shells. Crystal composition has been determined by X-ray diffraction for samples 5 to 8 which were stored for 25 years (5), and 50 years (6 to 8), before being measured for radiocarbon. Samples 1 to 4 were measured shortly after their collection. $\Delta^{14}C$ of shells collected before 1950 includes a correction for radiocarbon decay (0.12‰ per year) between the time of collection and 1950.

Sample	Shell Species	Crystal Composition	Locality and Date Collected	$\delta^{13}C$ w.r.t. PDB Ch. Lst. Std. ‰	$\delta^{14}C$ w.r.t. 0.95 NBS Ox. Ac. Std. ‰	$\Delta^{14}C$ corr'd for isotope effect. ‰	$\nabla^{14}_{1890}C$ corr'd for Ind. effect since 1890 AD ‰	Inst. Nuc. Scs. Ref.
1	*Protothaca crassitesta* (cockle)	-	Pounawea (1955)	+1.2	0±5	-54±5	-40±5	NZ 2439 INS NZ Marine Shell Std.
2	*Paphies* (*Mesodesma*) *ventricosum* (toheroa)	-	Muriwai Beach (1953)	-1.3	-15±4	-63±4	-50±4	NZ 114
3	*Paphies* (*Mesodesma*) *ventricosum* (toheroa)	-	Muriwai Beach (1957)	+0.4	-3±5	-55±5	-41±5	NZ 3203
4	*Paphies* (*Mesodesma*) *subtriangulatum* (tuatua)	-	Kairaki (1954)	+2.7	-7±4	-64±4	-51±4	NZ 1481
5	*Chione stutchburyi* (cockle)	Aragonite	Collingwood River mouth (1949)	-0.2	-5±5	-56±5	-44±5	NZ 1813
6	*Paphies* (*mesodesma*) *subtriangulatum* (tuatua)	Aragonite	Worser Bay (Wellington Harbour) (1925)	+1.1	-13±6	-61±6	-54±6	NZ 1814
7	*Dosinia anus*	Aragonite	Paekakariki (1923)	+0.2	-3±6	-54±6	-48±6	NZ 1799
8	*Amphibola crenata* (mudsnail)	Aragonite	Waikanae Stream estuary (1925)	-4.9	-28±5	-68±5	-61±5	NZ 1800

Long Term Cycles in the Variation of Atmospheric Radiocarbon, Related to Changes in Holocene Climate

B.G. McFADGEN*

Variations in the radiocarbon content of the earth's atmosphere are indicated by the difference between radiocarbon ages of tree-ring-dated wood and the tree ring dates (Olssen, 1970; Suess, 1970a). Long term variations in radiocarbon content have been correlated with a long term (8900 years) sinusoidal change in the geomagnetic moment (Bucha, 1970), and short term variations with short term changes in solar activity (Baxter and Walton, 1971; Bray, 1967; Suess, 1965; Suess, 1970b). A correlation exists between periods of low temperature and periods of low solar activity (Bray, 1965; Bray, 1968; Bray, 1970). Periods of low temperature during the Holocene, inferred independently from glacial advances (Denton and Karlén, 1973) and from oxygen isotope measurements of an ice core (Dansgaard *et al.* 1970), suggest that there is a long term climatic cycle with a period of about 2300 to 2700 years. Accordingly if the above correlations are correct a systematic relationship should exist between radiocarbon variations and the long term climatic cycles.

In order to avoid systematic differences in radiocarbon ages between laboratories (Suess, 1970a; Walton and Baxter, 1968; Wendland and Donley, 1971), only tree rings radiocarbon dated at La Jolla are discussed here. The tree rings are mostly bristlecone-pine wood (*Pinus aristata)* and sequoia wood (*Sequoia gigantea*), tree-ring-dated at the Laboratory of Tree Ring Research, University of Arizona (Suess, 1965; 1970a). A series of points indicating radiocarbon variations is provided when the radiocarbon ages of tree-ring-dated wood are plotted against tree ring dates (Suess, 1970a). The series of points plotted on rectangular axes are scattered in a band at approximately 45° to the axes (Inset, Figure 1).

In Figure 1 the series of points is broken into three complete cycles and two end cycles that are incomplete. The nature of each cycle is such that if a set of points comprising one half of a complete

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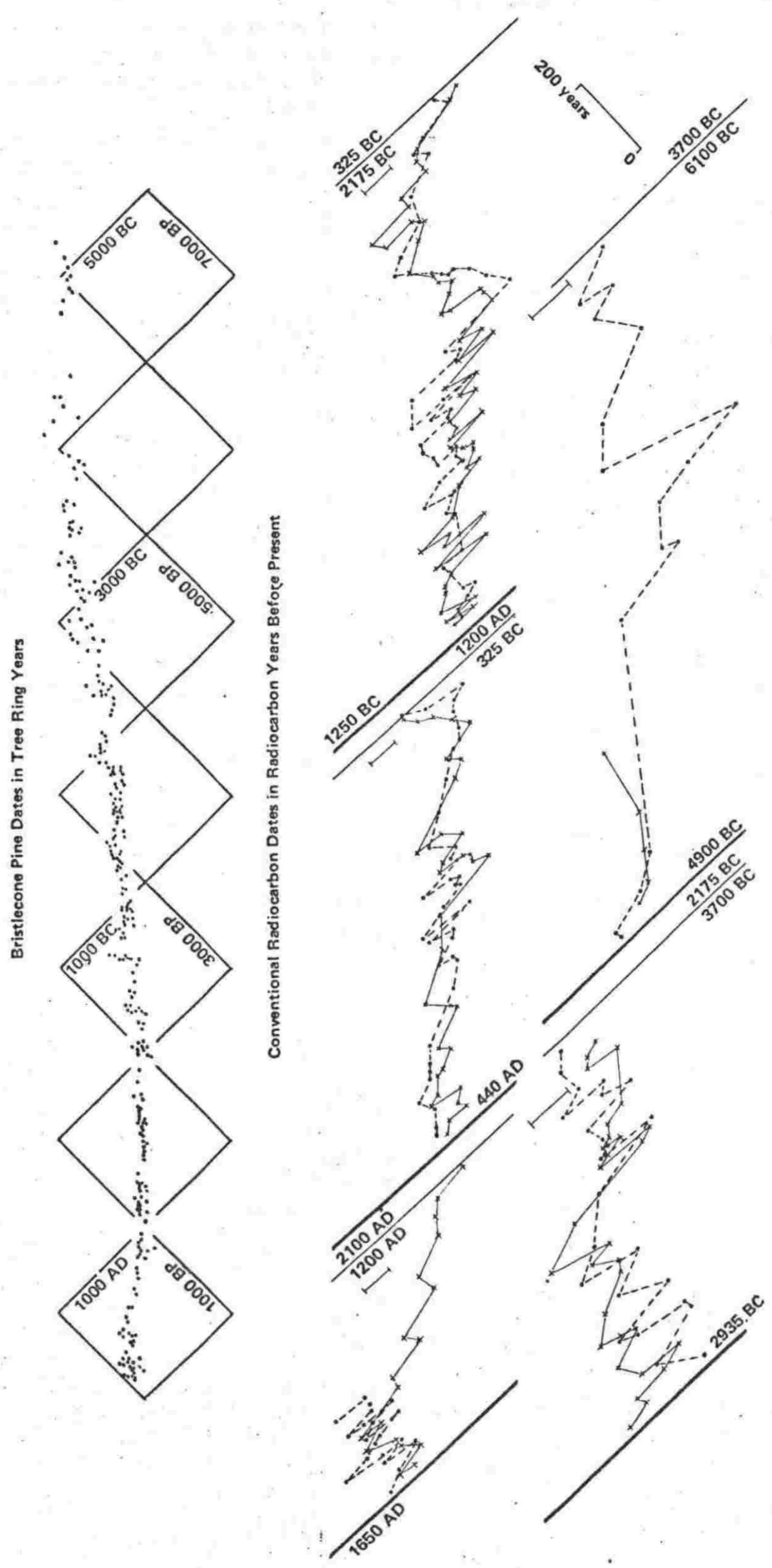

cycle is rotated by 180° around an axis normal to the paper, it closely matches the set of points in the other half of the cycle. The match can be demonstrated by rotating at the point of symmetry of the cycle so that the two half cycles are overlayed, as in Figure 1. Evidently the radiocarbon variations during the first half of each cycle were repeated in reverse and in the opposite sense during the second half of the cycle. The three complete cycles are symmetrical about the years 2935 BC, 1250 BC, and 440 AD, and are 1525, 1850, and 1525 years long.

The two end cycles necessarily have incomplete sets of points. By assuming the oldest end cycle to be symmetrical about the year 4900 BC and the present cycle to be symmetrical about the year 1650 AD, the oldest cycle is found to be 2400 years long and the youngest cycle 900 years long. The probable trends of the radiocarbon variations in the missing parts of the oldest and youngest cycles are shown in Figure 1. The inferred variations for that part of the oldest cycle between 5300 BC and 6100 BC may be verified when radiocarbon ages of tree-ring-dated wood for this period are obtained. The present radiocarbon cycle is expected to end in 150 years time. The amount of radiocarbon in the atmosphere produced by cosmic radiation is expected to rise until the end of the cycle.

A systematic relationship between the radiocarbon cycles and the long term climatic cycles of 2300 to 2700 years duration is evident from Figure 2. There

INSET, FIGURE 1
The band formed by the series of points provided when the radiocarbon ages of the tree-ring-dated wood are plotted against tree ring dates (After Suess, 1970a: Plates I and II). The axes are tilted 45° to save space.

FIGURE 1
Radiocarbon variations shown as five cycles. Each point is the radiocarbon age of a piece of tree-ring-dated wood plotted against its tree ring date (after Suess: Plates I and II). The sets of points in the second half of each cycle, shown as dots, have been rotated by 180° around an axis normal to the page at the points of symmetry and superimposed on the sets of points shown as crosses in the first half of each cycle. An error bar two standard deviations long is shown in the top right hand part of each cycle and represents the error of each radio-carbon age in the cycle. The point of symmetry for each cycle is shown by a heavy line. The dates marking the points of symmetry and the ends of each cycle are in tree ring years. Axes showing radiocarbon ages are omitted for clarity. The scale is the same in both directions.

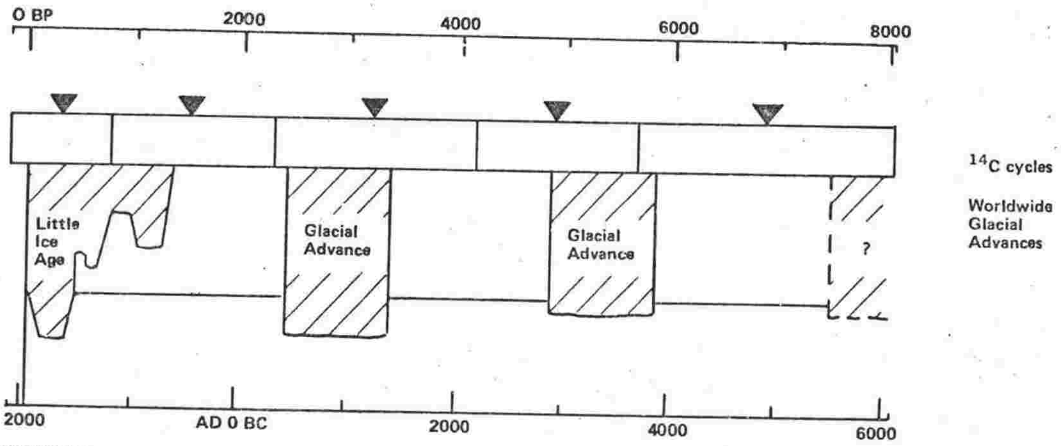

FIGURE 2
The radiocarbon cycles of Figure 1 compared with world wide Holocene glacial advances (after Denton and Karlén, 1973). The point of symmetry of each cycle is marked by an arrow.

is one glacial advance during each radiocarbon cycle. Before 2175 BC the maximum advance occurs at the beginning of the cycle, and after 2175 BC, at the end of the cycle. If solar activity is a cause of the radiocarbon variations, then a constant 2600 year solar cycle, inferred by Bray (1968) from the correlation between solar activity and temperature, is not supported and the solar cycles are probably irregular and the same length as the radiocarbon cycles.

Acknowledgement

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APPENDIX 11

RATES OF SEDIMENT DEPOSITION ALONG THE EASTERN NORTH ISLAND COAST SINCE THE TAUPO PUMICE.

Average rates of sediment deposition along the eastern North Island coast are given in the following diagram. The rates are based on thicknesses at 16 selected sections given by Wellman (1962b: Sections 5, 7-9, 14-15, 18-19, and 21), Smart and Green (1962: Tairua), Leahy (1974: Hot Water Beach), and in this thesis (Sections 1-4). Correlation of the coastal sections with the stratigraphic divisions is given in Chapter 3.

All deposition is assumed to occur during unstable phases. Rates are calculated from thicknesses between marker beds: the Taupo pumice, the Loisels pumice, the Tirean buried soil, and the Ohuan buried soil. Thicknesses are measured to the bottoms of the pumice deposits and to the tops of the buried soils, and are normalised by expressing them as a proportion of the thickness between the top of the Tirean soil and the ground surface. The rates are expressed as a proportion of the rate for the last 150 years.

The Taupo pumice occurs in 4 sections, the Loisels pumice in 11 sections and the buried soils in all 16 sections. The numbers of sections (n) on which the rates are based are: from the Taupo pumice to the Loisels pumice, 4; from the Loisels pumice to the Tirean soil, 11; from the Tirean soil to the Ohuan soil, 16; and from the Ohuan soil to the ground surface, 16. Errors shown with the rates are standard errors of the mean of n sections (Snedecor and Cochran, 1967).

Two sets of rates are shown for deposits younger than the Loisels pumice. The first set labelled a, uses the adopted ages for stratigraphic events given on page 46. The second set, labelled b, assumes a maximum error of 100 years for the adopted ages of the Loisels pumice, and the formation and burial of the Tirean soil. These errors do not significantly affect the rate of deposition between the Taupo pumice and Loisels pumice.

Taupo pumice to Loisels pumice a=1100 years b=1000 years n=4	Loisels pumice to top of Tirean buried soil a=50 years b=250 years n=11	Top of Tirean buried soil to top of Ohuan buried soil a=100 years b=200 years n=16	Top of Ohuan buried soil to ground surface 150 years n=16
0.3±0.1	a=5.8±0.4 b=1.2±0.4	a=2.4±0.1 b=1.2±0.1	1.0±0.1

Rates of deposition in eastern North Island coastal sections.

The rates of deposition between the Taupo pumice and the Loisels pumice, as determined from only 4 sections, is low. Rates of infilling of the Gisborne Plains Basin, using volumes determined by Pullar and Penhale (1970) for the period between the Taupo Pumice and Tirean soil formation, are also low. The Pullar and Penhale (1970) data supports the rates determined using the coastal data.

From the coastal data it would appear that there is every indication that deposition since the Loisels pumice has decreased with time or has remained steady.

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