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THE GEOLOGY OF EKETAHUNA (N.Z.M.S.1. N.153)

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Part 1 is a published paper: Rhythmic alternations of Early Pliocene Sediments at Alfredton, New Zealand.

Part 2 is, The Geology of Eketahuna (N.Z.M.S.1. N.153)

PART 1

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RHYTHMIC ALTERNATIONS IN EARLY PLIOCENE SEDIMENTS AT ALFREDTON, NEW ZEALAND

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ABSTRACT

An interesting rhythmic sequence consisting of massive mudstone and groups of graded beds each about 10 ft thick is exposed near Alfredton, in the southern part of the North Island. During Opoitian time, rotation along a north-east-trending hinge line west of Alfredton caused one side of a fault block to be relatively uplifted and the other depressed, at intervals of several tens of thousands of years, while sedimentation from south-west-flowing turbidity currents was in progress. The sandy fractions of post-faulting turbidity currents were channelled along the depressed side just to the east of the submarine fault scarp, while on the middle and upper slopes of the tilted block mud was deposited from the turbidity-current clouds. As sedimentation proceeded, graded beds on-lapped eastwards up the slope of the tilted block and across the area where muds had been deposited. Later tilting of the block initiated a new rhythm.

INTRODUCTION AND TECTONIC SETTING

Alfredton is a small settlement 11 miles east of the larger township of Eketahuna and about 70 miles north-east of Wellington (Fig. 1). The structure of the Eketahuna and Alfredton districts is dominated by a series of north-east-trending dextral transcurrent faults, most of which downthrow to the east (Fig. 2). Blocks of Tertiary strata between the faults are tilted up to 25° to the north-west.

Elsewhere in the Eketahuna district paleogeographic evidence (as yet unpublished) suggests that some of the north-east-trending faults were active during Kapitean, Opoitian, Waitotaran, and Nukumaruan times.

Kingma (1958) introduced a basin and bar theory to explain the origin of alternating sandstones and siltstones in Central Hawke's Bay, near Napier (Fig. 1); his theory requires shallow-sea conditions, which were absent during the deposition of the Opoitian turbidites at Eketahuna. The writer adopts as a working hypothesis the Kuenen–Migiliorini (1950) turbidity current theory, which has gained world-wide acceptance from sedimentologists.

A regional survey of the Eketahuna district by the writer shows that Alfredton lay on the eastern margin of a sedimentary trough (Fig. 3) whose axis moved progressively westwards during the Opoitian. The axis of the trough trended east of north, and at the centre it is considered to have been 4,000–5,000 ft deep. Flute casts show that it was filled with sediment transported by turbidity currents that originated at the north-east end and travelled

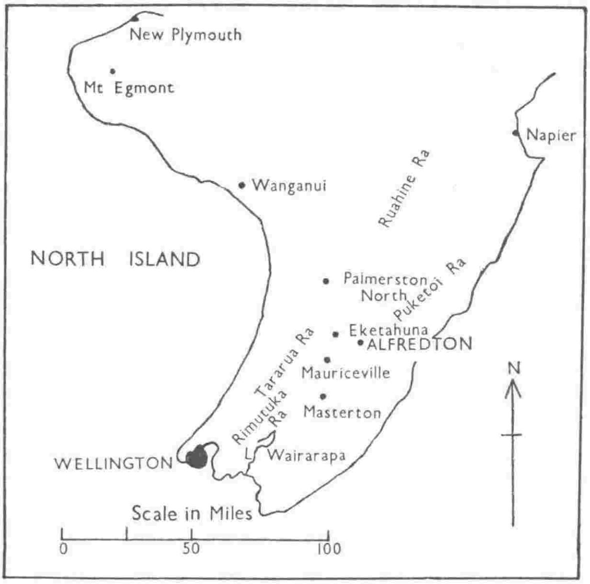

FIG. 1—Locality map.

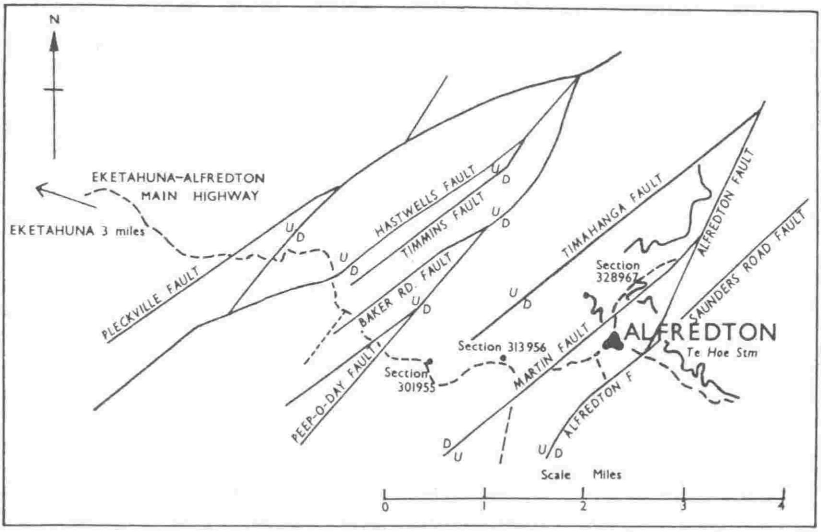

FIG. 2—Map showing major faults in the Alfredton area and the location of sections containing rhythmic sequences.

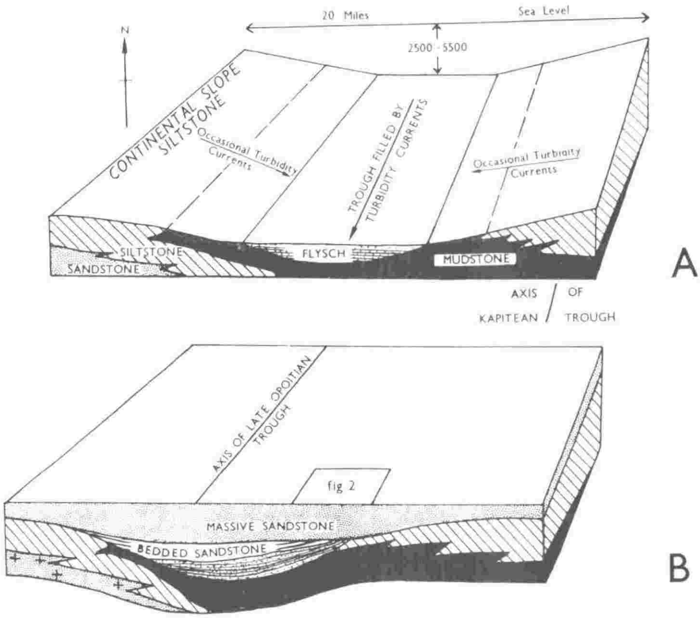

FIG. 3—Block diagrams of the Eketahuna trough in (A) middle, and (B) late Opoitian time. Faults are not shown.

mainly south-south-west, roughly parallel to the axis. These turibidity currents had flowed several tens of miles along the trough before they deposited material in the Alfredton area. Muddy siltstones were laid down on the flanks of the trough, and their progressive accumulation caused an inward migration of the lateral slopes. Rare turbidity currents flowed down the sides as well as along the axis of the trough. During Late Opoitian time a southward-extending deep-sea deposit filled the trough with sandstone (bedded and massive).

DESCRIPTION OF SECTIONS

Recent road-cuts along the Alfredton–Eketahuna main highway reveal Opoitian strata. One of these at grid reference N153/313956 (Fig. 2) exposes a series of alternating groups of graded beds and massive mudstone units (Fig. 4A), which are light blue-grey and only slightly indurated. The groups of graded beds range from 5 to 8 ft thick, and each contains 6 to 9 graded beds. The mudstone units range from 5 to 12 ft thick, and there appears to be a direct relation between their thickness and that of the over-

Inset

lying graded-bedded units. Individual graded beds average 10·8 in. in thickness and each is fairly sharply divided into a lower part consisting of sandstone and an upper part grading from siltstone at the base to mudstone at the top. Most of the sandstones are about 3 in. thick. They are typically made up of quartz grains in the $\frac{1}{16}$–$\frac{1}{8}$ mm range (very fine-grained sandstone), although in one bed the grain size is $\frac{1}{8}$–$\frac{1}{4}$ mm range (fine sandstone). Worm borings extend through the mudstone and siltstone to the underlying sandstone. Flute casts at the sandstone–mudstone interfaces demonstrate that the turbidity currents flowed south-south-westwards.

In the Alfredton area, the large exposures needed for the correlation of sections such as the rhythmic sequence exposed at 313956 are found only along incised rivers and road-cuts. There is, however, an apparent continuity of the rhythmic sequence for 1 mile to the north-east, where it crops out along a branch of the Te Hoe stream at 328967.

A section at a road-cut at 301955 (Fig. 4B) contains four rhythmic units of siltstone and siltstone–sandstone. The rhythmic sequence occurs near the base of the bedded sandstone (Fig. 3) that overlies the graded-bedded strata at Alfredton and Eketahuna. The rhythms show the same direct relation between the thicknesses of the siltstone and siltstone–sandstone units as was noted between mudstone and groups of graded beds at the road-cut at 313956.

From the coarseness of the sediment and the lack of grading it seems probable that this depositional area was closer to the source of the turbidity clouds and that the mud fraction was swept further south-westwards along the trough.

DISCUSSION

Two types of sedimentary rhythm occur in the road section at 313956 (Fig. 4A). Within the groups of graded beds the rhythm of beds is almost certainly due to deposition by successive turbidity curents. The beds are similar to graded beds in other parts of New Zealand, as described by Webby (1959) and Glennie (1959), and abroad, though the mudstone part of the rhythm appears to be in a greater proportion than usual. The sandstone/mudstone ratio is similar to that of the Silurian Aberystwyth Grits at Harp Rock, Wallog, and Clarach of Wales, which Wood and Smith (1959) considered to have been deposited as a result of turbidity currents that had travelled a considerable distance north-eastwards along the upper Llandoverian Cardigan trough.

The sparse continental-slope molluscan fauna found in the massive siltstone on the flanks of the trough (*see* Fig. 3) includes *Comitas onokeana* King, and *Zephos onokeana* King. The fauna is similar to the modern archibenthal fauna of New Zealand described by Dell (1956). Basinwards, where the siltstone grades to mudstone, no such molluscs are found. Echinoid fragments are commonly present in the massive siltstone; one large specimen of *Brissopsis* sp. is considered by Professor H. B. Fell (pers. comm.) to indicate a depth of deposition between 1,500 and 3,300 ft. Dunbar and Rodgers (1957, p. 55) estimated that the gradient of the present continental slopes varies between 1 in 10 and 1 in 25. The locality

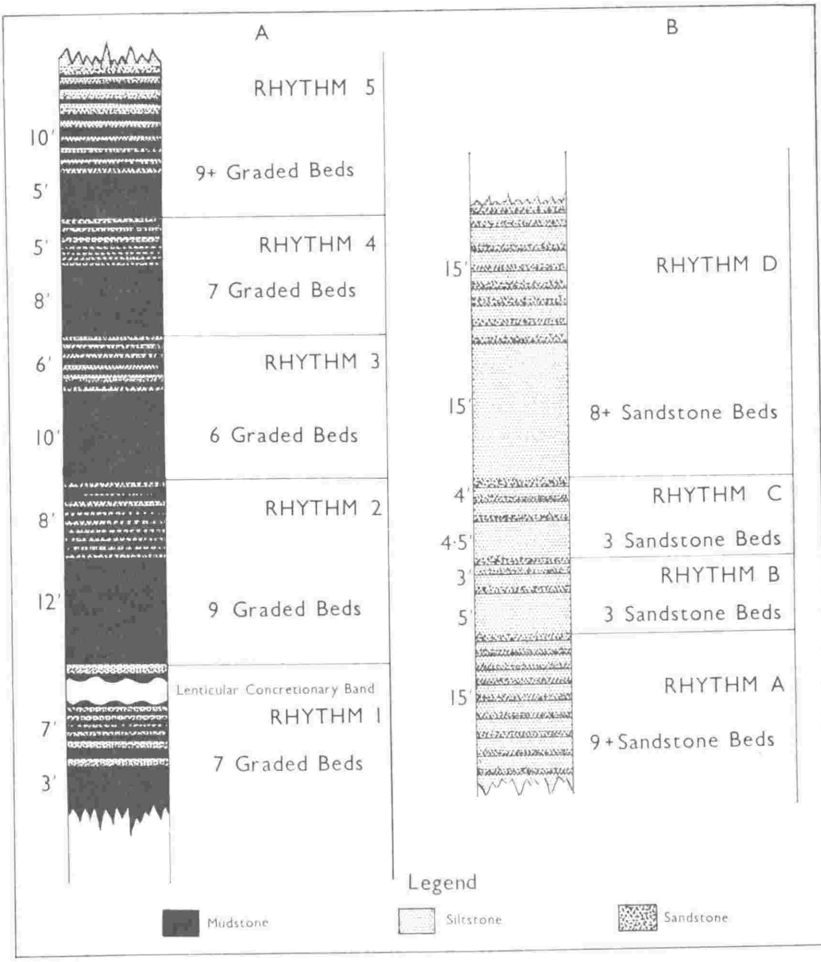

FIG. 4A—Rhythmic sequence of groups of graded beds and massive mudstone units exposed at road section at 313956.

FIG. 4B—Rhythmic sequence of sandstone–siltstone beds and massive siltstone units exposed at road section at 301955. (Figures at left of columns show thickness in feet.)

where the specimen of *Brissopsis* was found is about 4 miles from the area where the graded beds were deposited. The depth of deposition was therefore probably between 2,500 and 5,500 ft. An analysis of Opoitian Foraminifera collected from Eketahuna leads to a similar conclusion (Dr P. Vella, pers. comm.).

The major rhythmic units, consisting of alternations of groups of graded beds and mudstone units, must be due to some rhythmic process other than deposition from simple turbidity currents. The formation of turbidity currents could possibly be controlled by changes in climate and consequent changes in sea level, as was suggested by Daly (1936). Daly wrote: "During the glacial stages of the Pleistocene Period the sea level was lowered all over the world, in maximum from 200 to 300 ft. Then wind waves and tidal waves were everywhere breaking on the loose muds and sands of the continental shelves, and for long intervals of time not far from the upper limits of the continental slopes. The water so agitated was specially loaded with suspended sediment and therefore had effective density exceeding that of cleaner sea water elsewhere. The loaded water tended to slide down the continental slopes, along the bottom." Such a process could be expected to introduce irregularities into the turbidite rhythm at the beginning and end of each group of graded beds. The abrupt appearance and disappearance of the graded beds in the sequence at 313956 is, however, inconsistent with such climatic control.

It seems more likely that the alternations of mudstone and groups of graded beds were tectonically controlled. It is considered that such tectonic control could be provided by a series of regular fault movements that rotated a fault block west of Alfredton, while sedimentation from turbidity currents was in progress. It is assumed that each of these rotational movements produced a vertical displacement of the order of 5–10 ft on the south-east side of either the Alfredton Fault or one of the faults to the north-west of Alfredton; displacements of this order are known at some of the dominantly transcurrent faults of the South Island, such as the Wairau Fault described by Wellman (1955). The interval between fault movements was probably of the order of 20,000 to 30,000 years (*see* p. 885).

There is some evidence that a turbidity current cloud does not extend far above the sea bottom. Gould (1951) has shown that in Lake Mead (a man-made lake formed by the drowning of the Colorado River Valley up stream from the Hoover Dam) periodical slow-moving turbidity currents (under-flows) carry fine-grained material. For the greater part of the 100 miles that these turbidity currents travel they are restricted to the lowest $3\frac{1}{2}$ ft of water. North-west of Alfredton the lower parts of the post-faulting turbidity currents transporting the sandy fractions would be channelled east of the submarine fault scarp (Fig. 5A). The middle and upper parts of the turbidity current cloud would deposit some silty mudstone on the slope of the tilted block. The actual thickness deposited would be proportional to the height of the turbidity current cloud above the point of deposition. An area far from the active fault would at first receive little mud from turbidity current clouds, but, as deposition of graded beds proceeded, successive flows would deposit material further eastward (Fig. 5B) and the total thickness of mud would increase with each succeeding turbidity current. Finally, after the fault-angle depression had been filled, the sand fractions of the turbidity currents would be deposited as increasingly wide east-west sheets. These sandstones would extend proportionately less in a southward direction than when the early turbidity currents were channelled in the fault-angle depression. The net result of deposition from different parts of a turbidity current would be to produce a wedge-shaped mudstone unit (*see* Fig. 5B).

The graded beds appear to be thinner at 313956 than they are at Eketahuna—10·8 inches as against 2 ft 3 in. It may be that more active

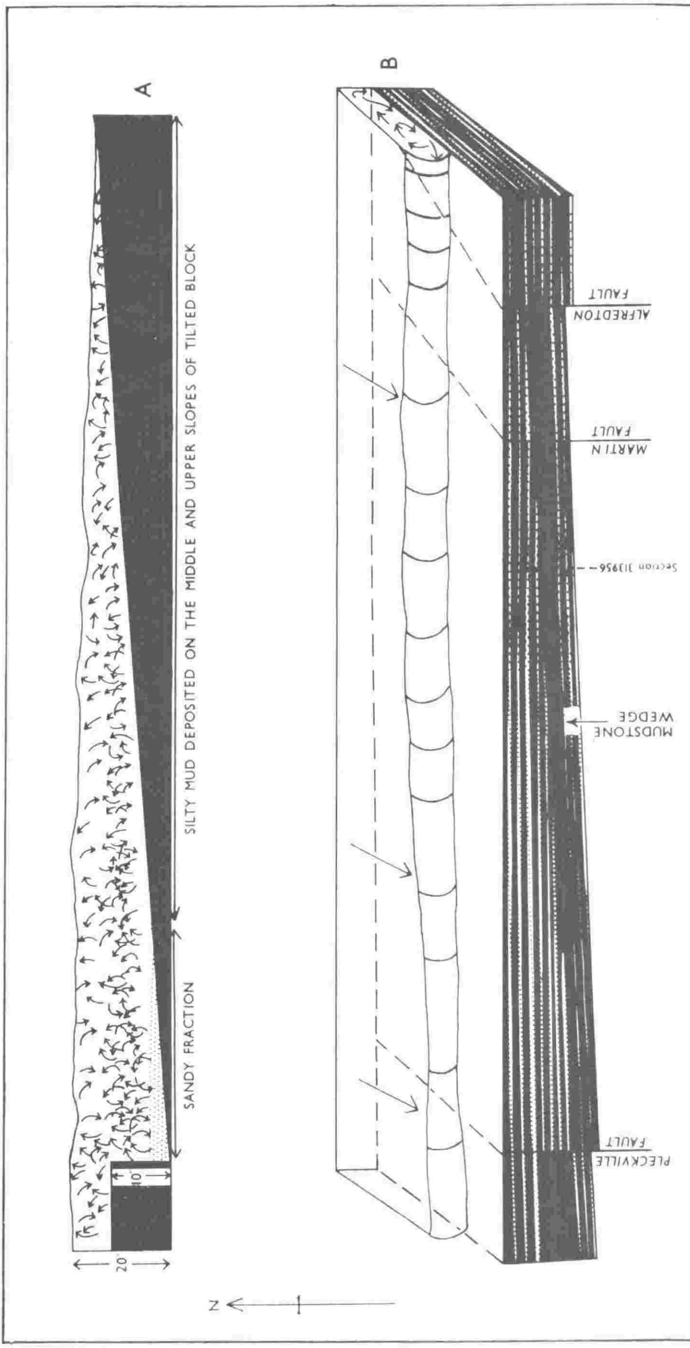

FIG. 5A—Diagrammatic cross section demonstrates localisation of the sandy fraction of the turbidity current in the fault-angle depression immediately after faulting and fault block rotation.

FIG. 5B—Diagrammatic block diagram of the Alfredton area during a period in middle Opoitian time, when graded beds were being deposited at site of section at 313956.

subsidence along the axis of the trough some 10 miles to the west at Eketahuna produced thicker graded beds there. Alternatively, the thinner graded beds in the section at 313956 could be due to uplift of this area by gradual creep on the Martin Fault during turbidite deposition (*see* Fig. 5B).

TIME INTERVAL BETWEEN TURBIDITY CURRENTS

Hills and Thomas (1953) calculated the average interval between turbidity currents to be 40,000 years for the Ordovician of Victoria, Australia. Their data suggest that locally, as at Ballarat during the Lancefieldian, the interval between turbidity currents was about 15 times the average for the whole of the Ordovician. Kuenen (1953) estimated the following intervals between turbidity currents:

Pliocene of the Ventura Basin, California	100 years
Silurian of Aberystwyth, Wales	1,000 ,,
Ordovician and Silurian of Southern Uplands, Scotland	1,000 ,,
Cambrian of Harlech, Wales	100,000 ,,

The interval between turbidity currents at Alfredton during the Opoitian is difficult to estimate. Only part of Opoitian time is represented by graded-bedded deposits, and hence an estimate must be made of the time of non-flysch sedimentation. Thicknesses of the Opoitian strata in the Eketahuna district (Fig. 3) are:

Sandstone (bedded and massive units)	3,205 ft	(non-flysch except near the base)
Graded beds	1,865 ,,	(flysch)
Mudstone	600 ,,	

The sandstone was probably deposited faster than the other sediments. Deposition of graded beds would probably be faster than the deposition of mud by a factor of say 3. The writer suggests that as a rough estimate the graded beds, sandstone, and mudstone each accumulated in one-third of Opoitian time.

Squires (1960) polled the views of five prominent New Zealand paleontologists and stratigraphers on the percentage of Tertiary time occupied by each of the New Zealand Tertiary stages, and derived a figure of 3% for the Opoitian. Holmes (1959) estimated the length of the Tertiary period as 70 million years (plus or minus 2 million years). Opoitian time is therefore equal to 3% of 70 million years, or 2,100,000 years. In the writer's opinion this is a considerable underestimate, but assuming it is correct it is possible to arrive at some estimate of the timing of events in the Eketahuna basin.

The number of beds in the Opoitian flysch at Eketahuna is the total thickness of flysch, 1,865 ft, divided by the average thickness, 2·25 ft, of graded beds, or 829. The total time represented by the flysch is one-third of Opoitian time or 700,000 years. The interval between turbidite flows is accordingly about 844 years.

It is next assumed that that timing of turbidite flows is the same for the sides as for the centre of the basin. The massive mudstone unit accumulated as the mud fraction of graded beds on the middle and upper slopes of the tilted block, and at about half the rate of the overlying and underlying graded beds. Considering now rhythm 2 of Fig. 4A: 144 in. of mudstone is equivalent to $(144 \times 2)/10{\cdot}8$ graded beds or 27 beds and the time of its accumulation would be 844×27 or about 23,000 years. The 9 graded beds were deposited during a period of 9×844 or 7,596 years, and the rhythm as a whole was therefore laid down over some 30,000 years. Similarly, the times of accumulation of rhythms 3 and 4 would be about 24,000 and 21,000 years respectively, and these periods would therefore also represent the time between the earth movements or other events causing the rhythms.

CONCLUSION

The sequence of events at the time of the deposition of the mudstone and mudstone–sandstone rhythms is deduced to have been as follows:

(1) Deposition of sandstone–mudstone beds across the area of the fault block.

(2) Fault-block rotation, causing one side of the block to be relatively uplifted and the other depressed. The sand fractions of post-faulting turbidity currents were channelled along the depressed side just to the east of the submarine fault scarp, while on the middle and upper slopes of the tilted block mud was deposited from the turbidity current cloud. As flysch deposition proceeded, graded beds on-lapped eastwards up the slope of the tilted block and across the area where muds had been deposited, until they were once again deposited as a wide continuous sheet across the area of the sections at 313956 and 328967.

(3) Renewed faulting, producing a fault-angle depression on the sea floor, which initiated another rhythm of sedimentation.

ACKNOWLEDGMENTS

The writer is indebted to Professors J. Bradley, R. H. Clark, and H. W. Wellman, and Mr R. Martin of Victoria University, and to Dr H. Pantin of the Oceanographic Institute, D.S.I.R., for help with the manuscript, and to Mr E. Hardy for help with the early drafts of the diagrams. The figures were drawn for publication by the Cartographic Section, D.S.I.R.

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P A R T 2

Frontispiece Eketahuna

1891

(Looking North)

Original watercolour in Alexander Turnbull Library.

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CHAPTER 1 - GENERAL INFORMATION

GENERAL DESCRIPTION OF THE EKETAHUNA DISTRICT

AREA MAPPED

The area geologically described and mapped includes the whole of the N.Z.M.S.1 Sheet N153 Eketahuna (see Figure 1). About three-quarters of the mapped area occurs in northern Wairarapa region. The remainder consists of the northern Tararua Mountains. The extreme northwest corner of the mapped area, at Tokomaru, extends across the Tararua Range on to the Horowhenua Plains.

POPULATION

There has been no increase in the population of Eketahuna in recent years. Census figures show that there were 774 inhabitants in 1956, and 770 in 1963. About 3,000 people reside in the sheet district. Most of the population is concentrated in small farming settlements on the plains east of the Wellington Fault and west of the Makakahi River.

INDUSTRY

Eketahuna is a small business centre which provides little employment for its inhabitants. Most of the people work on the land; sheep farming is predominant in the sparsely populated east, and on the western plains dairying and fat lamb rearing is of primary importance.

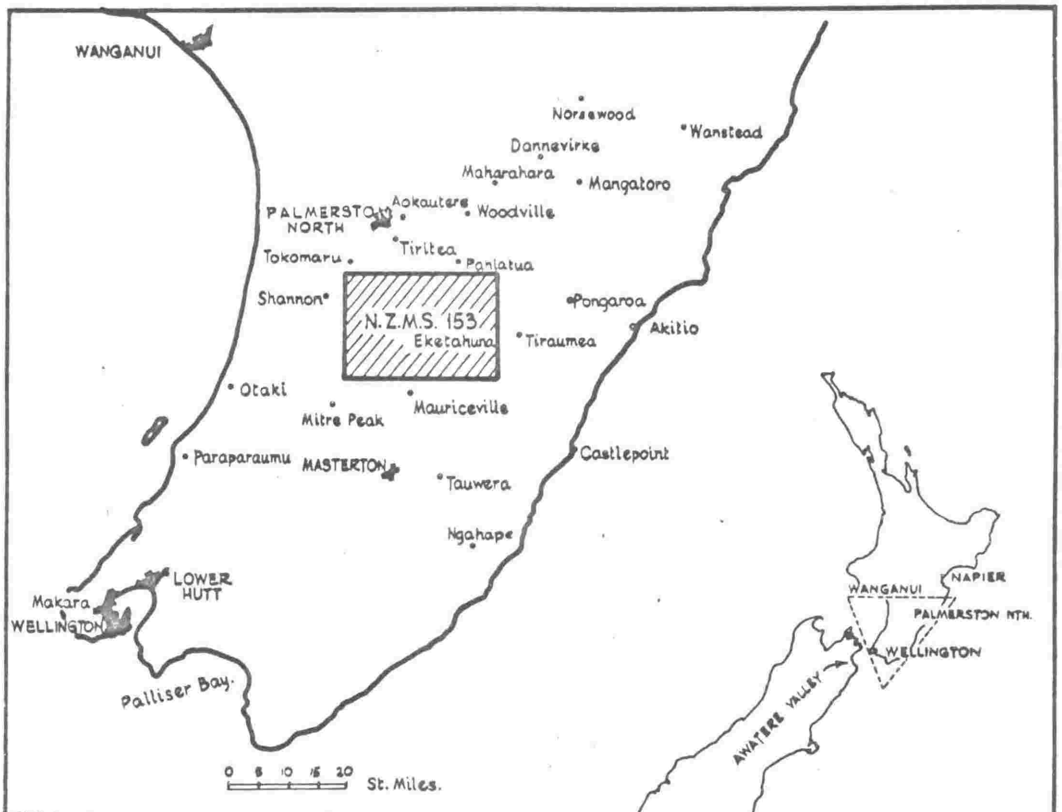


FIG.1. Map of the southern part of the North Island showing the location of N.Z.M.S. 153. and many of the nearby settlements referred to in the text.

Dairy factories located at Nireaha, Mangamaire, Kaitawa and Rongokokako employ the largest number of the adult male population not engaged in farming.

ROADS AND RAILWAYS

The Woodville-Masterton railway, and main highway pass through Eketahuna. Elsewhere, especially in the east, the area is largely served by gravel roads. A programme of sealing these back country roads with bitumen is in progress. Some gravel roads, especially in the eastern Puketoi area, are rough. The Kaitawa, and Cliff roads have recently fallen into disuse.

SOME ASPECTS OF WEATHER AND CLIMATE

During much of the year the weather of the mapped area is characterised by a succession of cold fronts with southerly winds moving northwards up the Wairarapa Valley every few days, bringing periods of cooler temperatures and rain. The rain, which often lasts for a day or so, with a maximum of four days, is followed by a period of fine weather for several days prior to the arrival of the next southerly.

At times throughout the year, strong winds invariably ~~blowing~~ from the west, may be incessant for several hours.

In some years, during the months of January and February, daily thunderstorms occur in the late afternoon over a period of a few days.

At night during the winter months at times of little wind and cloud, cold air is ponded in the low ground to the east of the Tararua Range and dense fogs occur; the sun often does not break through such fogs until the afternoon. Heavy frosts are common during the winter months, but snowfalls are rare and are never thick.

The rainfall of the Eketahuna area is distributed throughout the year with maxima during the winter and spring. The annual rainfall ranges from 50 inches east of Eketahuna to 250 inches near Mt Ruapai in the Tararua Range to the west. Most of the area underlain by Upper Tertiary strata receives between 50-70 inches of rain per annum, which is some 20-30 inches more than the low lying areas of Martinborough and Woodville to the south and north respectively. Droughts are rare, and the grassland even in mid summer is invariably a lush-green, in marked constrast to the summer straw-coloured landscape of southern Wairarapa.

HISTORY OF SETTLEMENT

Prior to 1872, most of the mapped area west of Alfredton formed the southern part of the densely forested Forty Mile Bush. The need for better communications between the main urban centres;- Wellington, Wanganui and Napier - became especially apparent during the Maori wars. To improve communications the government arranged for migrants from Denmark and Norway to cut roads and a railway line through the bush, and to settle the land.

The hardships endured by the early settlers has been chronicled by Peterson, in Walters (1965). The farm allotments, at a cost of £1 per acre, were small, only forty acres each. The settlers were employed on public works and cleared their farms during their spare time. The need to increase the size of the tiny farms by amalgamation into larger units soon became obvious, but even so, most of the income of the settlers was gained from employment on public works.

During the 1880's, the advent of refrigeration in ships led to a more profitable return from animal husbandry. Franklin (1960) has noted that small dairy factories were established at Mauriceville, Kaitawa and Nireaha in this period (1889 - 1897).

By 1900 nearly all the Forty Mile Bush had been felled, the rail link with Napier and the Manawatu completed, and the present farming pattern established.

Franklin (1960) has shown that ~~the~~ motor transport became sufficiently common about 1925 to decrease the need for resident rural services, and this has led to a continuing rural depopulation. Other factors causing the depopulation have been the increasing mechanisation of farm machinery and the subsequent need for less labour, and also the amalgamation of some of the smaller dairy factories.

Most of the larger farms in the district, some as large as 5,000 acres, are found in the eastern part of the area, especially near Alfredton. Recently there is a tendency to subdivide into smaller farms of 500 - 1000 acres, which can then be farmed by one man.

VEGETATION

Apart from the forested Tararua Range most of the mapped area is in grass. Small stands of native bush, often a few acres in area, have been preserved. Elsewhere, especially in remoter areas, clumps of Cabbage Trees (Lilliacea) and tree ferns (Punga-Cyathia sp) have not been felled.

If the land is not well farmed it reverts to gorse and manuka scrub in the period of a few years. There appears to be a correlation in the location of manuka scrub with areas underlain by sandstone. Introduced trees include macrocarpa, blue gums and willows. The macrocarpa, now often fully grown, are common near old farm buildings and are being increasingly cut for timber; willows are common along some water-courses.

BACKGROUND TO GEOLOGICAL MAPPING

PREVIOUS GEOLOGICAL WORKERS

Previous work is referred to in the historical sections of the text. From 1931 - 1934 Ongley mapped the 1700 square mile Eketahuna Subdivision, but only a summary report of this work is available (Ongley 1935). Apart from this work little geological investigation had been made previously. Orbell, (1962) mapped subsheet 2 of the N.Z.M.S1 Sheet N.158 (Masterton), the northern margin of which forms the central part of the southern margin of the mapped area.

FIELD WORK

Some fourteen months were spent in the field at periods between June 1959 and April 1963, during a period when the writer was a post-graduate student at Victoria University.

The Tertiary strata have been examined in greater detail than the Mesozoic greywacke strata (Tararua and Castle formations).

The lightly indurated upper Tertiary Strata occupy about two-thirds of the sheet district, but are exposed almost solely along the banks of streams and rivers. Some limestones however crop out in the steeper parts of the hills. The majority of Tertiary outcrops have been examined, detailed observations, and collections of macrofossils and samples for microfossil study being made in the more continuous sections. Between these sections more isolated outcrops have provided additional control for the mapping.

Much of the Northern Tararua Range is covered by particularly heavy bush; only the highest peaks, Ngapuketerua and Ruapai rise above the bush line. Undergrowth such as Lawyer (*Rubus*) and supplejack (*Rhipogonum scandens*) greatly impede progress ~~through the bush~~, while on the "tops" extensive developments of Matagouri (*Discaria*) shrubs may be almost impenetrable.

Geological examination of the forested part of the Tararua Mountains has been largely confined to the rivers and the larger streams, along which good exposures occur.

Access to the central-westernmost part of the area is by the road from Shannon to the hydro-electric dam on the Mangahao River, situated a short distance west of the mapped area. The Ngapuketerua and Ruapai mountains can be reached by the Schorman Track from Putara.

ACKNOWLEDGEMENTS

The fieldwork was undertaken as part of the requirements for the degree of Doctor of Philosophy, while the writer was a student of Victoria University; it was completed in 1967.

The writer is grateful for help and encouragement of the following people, both in the field and in the later work of discussion and presentation:

Professor H.W. Wellman of Victoria University for guidance in the field and help in compiling a 1-inch-to-1 mile map; Doctors C. Fleming and J. Marwick and Messrs A. Beu and P. Wellman, and Dawn Rodley for help in identifying molluscan macrofossils; Dr P. Vella, Professor H.B. Fell, Mr D.J. McIntyre, Mr B. Wilson and Dr J. Yaldwyn for identification of microfossils and non-molluscan macrofossils; Dr W.H. Mathews and Mr T.L. Grant-Taylor for help in mapping terrace deposits; Professor R.H. Clark for examining petrological sections.

Dr R.W. Willett kindly allowed the writer to examine Mr M.O. Ongley's Eketahuna Field Sheets. The British Petroleum Company lent the writer photogeological maps of a scale of 20 chains to 1 inch. Mr Ralph Wheeler of the Geography Department of Victoria University kindly supplied notes on which part of the section on settlement is based. Dr H. Pantin assisted with the Appendix on Dye-Staining.

The writer is indebted to Victoria University for the award of a Senior Jacob Joseph Scholarship (1960), and a V.U.W. Research Scholarship (1962). The text was written during an eight month period (1965-6) when the writer was with the New Zealand Geological Survey at Christchurch.

The writer is especially grateful to Mr Alan Beck and Dr R.P. Suggate of the Geological Survey for encouragement and helpful critism, during the writing stage, and to Professor H.W. Wellman who also read and corrected much of the text.

The writer is grateful to those settlers who made available their ~~these~~ shearing quarters as temporary residences. Thanks are due to Mr Skilton of Pahiatua in maintaining the writer's motor-bicycle in running order.

CHAPTER II - PHYSIOGRAPHY*

RELATION OF STRUCTURE TO PHYSIOGRAPHY

* The writer has incorporated an unpublished report by Dr W.H. Mathews of the University of British Columbia into this text. Two figures, Figures 3A and 3B, are entirely the work of Dr Mathews.

The forested Tararua Range rises to an elevation of 4,000 ft within the mapped area and is largely composed of well-indurated Tararua Formation. Since the formation is rather homogeneous in its resistance to erosion, and as forest covers the topographic expression of beds within it, individual strata only rarely form obvious geomorphic features.

Topographic expression of structure is good in the lightly indurated Upper Tertiary sediments. The cores of synclines, particularly the Pori and Mangamahoe synclines, have resisted erosion better than adjacent tilted upper Tertiary strata, and form elevated tracts of land. Land-forms within upper Tertiary sediments are largely controlled by the bedding, with the development of dip and scarp slopes. Many of the dip slopes were mapped photogeologically on a scale of 20-chains-to-the-inch by Mr Johnson of the British Petroleum Company. The absence of bedding features near a few of the major faults may be due to the local influence of jointing controlling the pattern of erosion.

The texture of the drainage is due partly to the nature of the underlying sediments. Where the underlying strata are rather impervious, such as mudstone or siltstone, the texture is dominated by close-spaced rills and small streams. The drainage in standstone country is more widely spaced. Stream courses are generally not well developed on limestone strata within the Pori Syncline. Much of the drainage is underground, and in the southern part of the syncline many sinkholes are present in sandstones overlying the limestone.

RIVERS

Most of the Sheet District is within the watershed of the Manawatu River and its large tributaries, the Mangahao, Mangatainoka, Makakahi, Tiraumea and Makuri Rivers which flow north across the district to join the Manawatu River a short distance east of the Manawatu Gorge. The Tokomaru River flows through the north-eastern part of the Tararua Range to join the Manawatu west of the Tararua Range. The drainage divide between the northward flowing rivers of the Northern Wairarapa and the southward flowing rivers of Southern Wairarapa is generally not far south of the sheet. In the extreme south-west, the Ruamahanga River drains south-westwards. In the south-central part of the mapped area, at Mangamahoe, some streams flow southwards towards Mauriceville.

Terraces are commonly developed adjacent to the rivers, particularly to the Makakahi, Mangatainoka and Mangahao rivers. The projected profiles of the misfit terrace flight at Hukanui and the terrace flight adjacent to the Makakahi and Mangatainoka rivers were calculated and drawn by Professor W.H. Mathews. (See Figures 3 A &3B)

HIGH LEVEL SURFACES

East of the Tararua Mountain range the lightly indurated Tertiary sediments range from 500 to 2000 ft in elevation. Eight surfaces, some built up by aggrading rivers, have been delineated and listed below (in ~~downward~~ inferred sequence of time):

Terraces cut during Holocene time (shown on the map)

Hukanui Surface (shown on the map)

Pukewhai Surface (partly shown on the map)

Eketahuna Surface (shown on the map)

Flat Top Surface (shown on the map)

Hinemoa Surface (not shown on the map)

Puketoi Surface (not shown on the map)

Tararua Arched Surface (not shown on the map)

Wellman (1949) contoured the trigonometric stations of the Tararua Range and delineated a broad north-northeast trending arched surface. Wellman noted that Upper Tertiary marine beds appear to overlie the arched surface at the Manawatu Saddle, and along the Taupo-Napier main Highway. To Wellman, then unaware of the important Wellington Fault, it appeared that the arched surface passed over, and hence was younger than, strata of the Mangahao Formation (Okehuan) of this ~~Bulletin~~ thesis, ~~(Okehuan)~~ along the East flank of the Northern Tararua Range. Mapping of the Wellington Fault by Lensen (1958) has shown Holocene movement along its full length, and, because this is certainly only the youngest movement of this major fault, it is no longer necessary to consider the surface younger than the Mangahao Formation. The surface is considered to have been formed in late-Upper Tertiary time.

In the period between the Tongaporutuan and Okehuan the central and eastern part of the District had been a depositional area in which a thick sequence of sediments had been deposited. Since the Okehuan, however, the land has been progressively raised with respect to sea level. As the land was raised it was incised by streams and rivers, but there were times when stream incision ceased and large areas of low-lying plains were formed, largely by aggradation of gravel. The remnants of these once widespread plains provide the only record of post Okehuan events.

Willett (1950) estimated that the snow line was at 3,930 ft in the Tararua Range during the cold periods of the Upper Pleistocene. Previously Adkin (1912) recorded "U"-shaped valleys and glacial cirques, near Mt Dundas and Mitre Peak, in the Southern Tararua Range, indicating that valley glaciers were present there during late-upper-Pleistocene time. The highest peak in the mapped area, Ruapai (4,195 ft), though above the Pleistocene snowline was too low to support substantial valley glaciers.

Puketoi Surface

A much dissected surface, here named the Puketoi Surface, at about 2,000 ft elevation is inferred from a widespread accordance of summit heights of the Puketoi Range. The surface is especially apparent from the air. The Fox Massif is considered to be a southern remnant of the surface.

Hinemoa Surface

The type area of the Hinemoa Surface is between the Tiraumea River and the Alfredton Fault, east of Hinemoa. The surface is greatly dissected, and has been recognised only by the presence of flattish, narrow interfluves. The surface is gently arched, along a north-northeast axis, parallel to the Alfredton Fault and somewhat to the east.

Aneroid spot heights on Ongley's field sheets, indicate that in the type area the surface is ~~at~~ about 1080 ft elevation.

The accordance of summit heights of hills at about 1400 ft, north of the Taumata Fault, indicates the presence of a surface ~~there~~, which is thought to be the Hinemoa Surface. Vertical displacement of about 300 ft is thought to have taken place across the Taumata Fault since the formation of the surface. A widespread erosion surface at about 1400 ft elevation ~~is present~~ at Castle Hill, ~~It~~ may be the Hinemoa Surface. Between the type area and the Wellington Fault, remnants of the surface are considered to be approximately delineated by the summits ~~heights~~ of the higher hills (see Figure 2).

LOW LEVEL SURFACES

Since the formation of the Hinemoa Surface there have been four periods when stream incision was not occurring. At these times the rivers aggraded their beds with gravel to form widespread terraces. During each ensuing period of stream incision parts of these constructional terraces were removed.

Figure 2 East-northeast facing air-view, from the vicinity of Huru Trig, along northern flank of east-west misfit valley west of Eketahuna. Foreground, Hukanui Surface somewhat dissected by stream erosion during Holocene time. Left centre, Priests Road. Centre, Eketahuna Surface, behind which the Flat Top Surface and terrace edge occur. Background, hill country, the hill tops approximately delineate the Hinemoa Surface.

At Eketahuna, Hukanui, and Marima, flights of four terraces are usually present, but east of the Makakahi River where the valleys are narrower, the oldest and highest post Hinemoa Surface, the Flat Top Surface, is absent.

The youngest, the Hukanui surface, is the most prominent and most easily recognised surface, forming about 50 per cent of most of the valley bottoms. The older surfaces are largely correlated on their height above the Hukanui Surface.

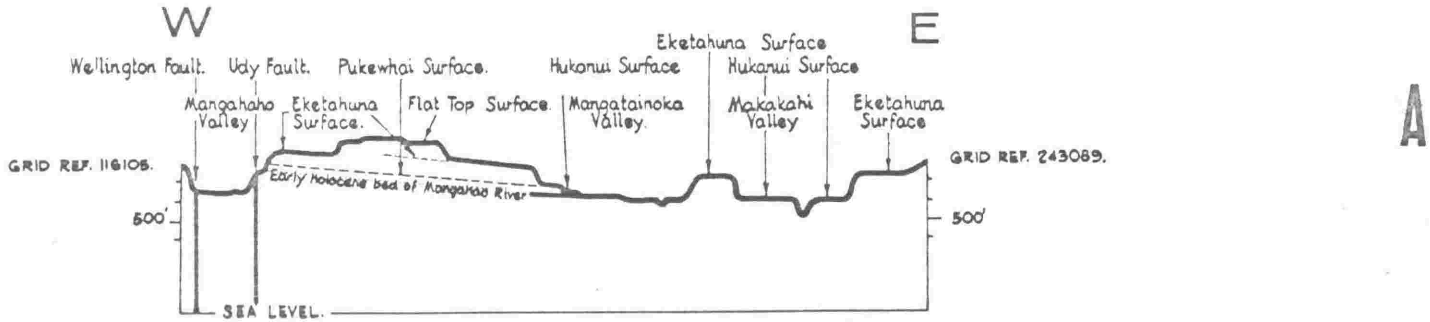
Flat Top Surface

On the north side of ~~the~~ a misfit valley west of Eketahuna, the Flat Top Surface (see Figure 2) is found at different heights, due to faulting at the Huru, Rongokokako, and Newman faults, (see Figure 3B).

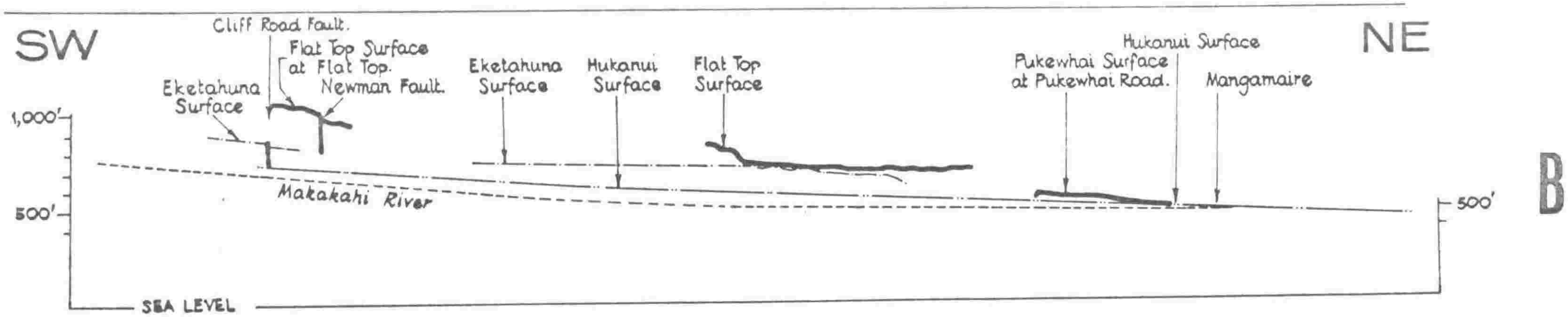
West of the Rongokokako Fault the surface is at elevation 1,040 ft, about 150 ft higher than the Eketahuna Surface. Although the terrace has not been subjected to much more stream dissection than the younger Eketahuna Surface the terrace edge has been much more severely dissected (Figure 2). The lower slope of the terrace edge is gentle, due to solifluction ~~of material~~ transport down the terrace slope.

At the northern side of the Hukanui misfit valley, the altitude of the Flat Top Surface is 910-920 ft, only about 110 ft above the Eketahuna Surface.

Many remnants of the Flat Top Surface occur west of the Mangahao River in the Marima area. The Surface also occurs at Putara and Kopikopiko. In the Saunders Road area the higher slopes of the hill country are gentle,



PROJECTED PROFILES OF TERRACES,
NORTH SIDE OF THE HUKANUI *MIS*FIT VALLEY.



PROJECTED PROFILES OF TERRACES, & RIVER BED
OF THE MAKAKAHI VALLEY.

0 1 2 3 4 5 MILES.

VERTICAL EXAGGERATION X 10.
PROFILES BY PROFESSOR W.H. MATHEWS.

FIG.3

while the lower slopes are much steeper. This gives the topography a two storied aspect (see Figure 15). It is thought that the upper slopes may have been formed in the interval between the formation of the Hinemoa and Flat Top Surfaces, and have been little modified except by the smoothing effect of solifluction.

Eketahuna Surface

Much of the Eketahuna township is built on the Eketahuna Surface; the surface has a much wider distribution than the older Flat Top Surface. The Eketahuna Surface is well developed on both sides of the misfit valleys at Eketahuna and Hukanui. West of Eketahuna, the Surface is often dissected as much as 15 ft, but drainage is now largely subsurface. In the past the surface was particularly extensive in a triangular shaped area, which is approximately delineated by the Rongokokako, Kaiparoro, and Eketahuna settlements.

Elsewhere in the mapped area generally, small remnants of the surface dissected by flattish bottomed stream channels occur along most of the major rivers and streams. The terrace edge formed by dissection of the surface is commonly unmodified by solifluction, partly perhaps because in most places it was cut in the interval after the formation of the Pukewhai Surface, but also because gravels which usually make up the full height of the terrace' face are not particularly susceptible to mass movement.

Pukewhai Surface

The Surface is named after the Pukewhai Road which is made the type area. The road trends across the south-western part of the surface about 1½ miles south west of Mangamaire (grid ref. 212 132). At the type area the surface is especially prominent because it is tilted about ½ a degree to the northwest. The eastern part of the outcrop is 20 ft above the Hukanui Surface; further to the Northwest it is buried beneath the Hukanui Surface (see Figure 3B). An ash bed presumably of the same age as those at Aokautere and Ngaturi was found by Dr Mathews (per com) in the cover beds of Pukewhai Surface.

Usually the surface is only slightly higher than the Hukanui Surface and cannot always be identified with certainty. At the northern side of the eastern end of the Hukanui misfit valley, the terrace is about 13 ft above the Hukanui Surface.

At several localities especially at the mouth of Pukohai Stream, rounding of the junction between the surface and the hill slopes behind it indicates ~~that some~~ solifluction ~~took place that is~~ not shown by younger topography.

Hukanui Surface

The Hukanui Surface extends across a considerable part of the low-lying country. On vertical air photographs the surface is featureless due to a thin blanket of loess. Conspicuous rill marks are found on all ~~lower,~~ younger (Holocene) terraces ~~which~~ because they have no loess cover. The terrace was formed during the climax of the last major stadial of the Last Glaciation during which aggradation of the streams was a dominant feature. The terrace face between the Hukanui and the Eketahuna Surface is not rounded by solifluction.

In the minor valleys the Pukewhai Surface is not represented, and is probably buried by thin deposits of Hukanui aggradation deposits. The streams ~~in this area~~ were too feeble to erode the solifluction debris at the junction with the hills.

Within the Tararua Range a terrace which is thought to be a remnant of the Hukanui Surface is present locally along the left bank of the Mangahao River in the reach downstream from Ngapuketerua Stream.

Terraces Formed During Holocene Time

Since the formation of the Hukanui Surface many rivers have entrenched their courses to form miniature chasms, which are commonly about 100 ft deep. At Kakaraki, the Mangahao River has entrenched its course 140 ft since early Holocene time, when it flowed eastwards along the misfit valley at Hukanui. Further downstream, at Marima, Holocene entrenchment is about 100 ft. Much of the course of the Mangatainoka River, however, is only a little below the Hukanui Surface.

Although most of the larger rivers and streams have been able to do no more than to entrench their beds vertically from the Hukanui Surface on which they flowed in pre Holocene time, others, notably the Mangahao and Makakahi rivers, have been able, by the gradual down-valley swing of the meanders of the river course, to form low lying depressions. Unmatched terrace remnants at varying elevations along the valley sides demonstrate that entrenchment was substantially continuous.

CORRELATION WITH TERRACES IN OTHER AREAS

Fleming (1953) ~~mapped the terrace sequence in the Wanganui area,~~ and ~~he~~ was able to correlate the terrace sequence in the Wanganui area with periods of dune formation, and changes in sea level. Unfortunately, due to the lack of continuity of the terraces ~~developed~~ from east of the Tararua Range through the Manawatu Gorge on to the Horowhenua Plains it is not possible to correlate directly with the Wanganui area.

Lillie (1953) did not ~~differentiate~~ map the terrace sequence at Dannevirke, but in his text some aspects ~~of the terraces sequence~~ are described. Lillie found (p.87) a widespread terrace 110 ft above the Manawatu River bed near Dannevirke which he called the Dannevirke Cycle. A terrace remnant 120 ft above the "Dannevirke Cycle" at Maharahara, was named the "Maharahara Cycle", and an unnamed terrace 250-300 ft above the "Dannevirke Cycle" was also found.

Vella (1963c) has given an account of the geomorphology of the Wairarapa Valley; where he recognised four surfaces (see Table 1).

Table 1

Correlation of terraces in the mapped area with those of Southern Wairarapa and Dannevirke.

DANNEVIRKE	EKETAHUNA	SOUTHERN WAIRARAPA	
(Lillie 1953)	(This Thesis)	(Vella 1963c)	
Dannevirke Cycle	Hukanui Surface	Waiohine Surface	) Plains
?	Pukewhai Surface	?	)
Maharahara Cycle	Eketahuna Surface	Ramsley Surface	) Group
Terrace 250-300 ft above Dannevirke Cycle at Dannevirke	Flat Top Surface	Waipoua Surface	)
?	Hinemoa Surface	Bruce Surface	) Bruce
?	Puketoi Surface	?	) Group

Correlation of the Hinemoa Surface with the Bruce Surface of Southern Wairarapa is thought to be good, for both surfaces precede a long period of stream erosion and in both places the next developed surface is at a much lower elevation.

SOLIFLUCTION DURING LATE PLEISTOCENE TIME

During a late period in Pleistocene time, perhaps during the formation of the Eketahuna Surface, mass movement on an especially large scale, was developed in steep hill-country, such as on the northern and western slopes of the Pori Massif, and on the eastern flanks of the Tararua Range.

At Kaitawa Creek and Hirinakitu Stream 20 ft-thick solifuction tongues, containing blocks of limestone often 5 ft in length, flowed ~~a maximum distance of a~~ as much as a mile down previously-excavated stream channels. Since the formation of the solifluction tongues, the streams have entrenched their courses through the solifluction material to the approximate level ~~position~~ of the original stream courses.

On the eastern flanks of the Tararua Range, solifluction flow was sheet like, rather than tongue like. Occasionally intermediate types, cone-shaped solifluction deposits, were developed along the site of former stream courses, where ~~At the latter localities,~~ some the solifluction deposits ~~material~~ are ~~sometimes~~ as much as 40 ft thick.

THE MISFIT VALLEYS

The reason for the defeat of the rivers flowing in the east-west misfit valleys is obscure. Pebble imbrication at three localities in the Eketahuna Gravels in the southern misfit valley at Eketahuna clearly shows that a large river ~~on~~ once flowed ~~flow was from west to~~ eastward. The Hukanui ~~T~~terrace slopes ~~at Hukanui~~ ~~is~~ at a very low angle to the east; probably less than that of the original river ~~stream~~ gradient from the mountains, this may be due to tilting to the westward of the fault block bounded by the Wellington and Huru faults. River flow is certain to have been from west to east in both misfit valleys.

In the case of the Hukanui misfit valley, most of the recent course of the Mangahao River is to the west of the north-northeast trending Udy Fault (see Figure 3A). The fault down-throws the Hukanui Surface 15 ft to the west, the period of faulting could have coincided with and caused the diversion of the river from its previous easterly course through the misfit valley in Early Holocene Time. It may be, however, that the defeat is due largely to climatological factors. During glacial epochs when all rivers aggraded their courses there was a tendency for them ~~rivers~~ to flow eastwards away from ~~normal to the strike of the~~ mountains, ~~caused by the normally eastward slope of the aggradation~~ fans. During interglacials periods when there was degradation, flow tended to be north-easterly, being influenced to a greater extent by the grain of the country.

The defeat of the proto-Mangatainoka River in the Eketahuna misfit valley is not as well established as that of the Mangahao in the Hukanui misfit valley. Originally the proto-Mangatainoka may have been diverted from a northeasterly course by alluvial cones built eastwards by the Mangaroa Stream. A subsequent change of climate may have caused a rapid removal of this detritus by the Mangatainoka River.

An east trending misfit valley, similar to the Hukanui and Eketahuna misfit valleys, lies athwart the Ohai Coalfield in Southland. Lillie (1950) found that the reason for the defeat of the ancient east-flowing Wallace River, which flowed through the valley is obscure. The misfit valley at Ohai is similar to the misfit valleys of mapped area in that high mountains of the main watershed lie not far to the west. It lies, however, in a much less tectonically active part of New Zealand; which indicates that the misfit valleys both at Ohai and Hukanui and Eketahuna are more likely to be due to changes of climate, than to folding or faulting.

THE MANAWATU GORGE

The origin of the Manawatu Gorge has been discussed by many authors largely before the realisation that active faults, such as the Wellington Fault, are a very common ~~factor~~ in the mobile belt of New Zealand. A resumé of previous discussion of the origin of the gorge has been given by Lillie (1953). The gorge is antecedent, in so far that the land has been persistently upthrown to the west of the Wellington Fault, which forms the eastern boundary of the Tararua Mountains. A ~~geomorphic~~ surface cut above the gorge at about 900 ft was noted by Lillie (1953), ~~It~~ can probably be correlated with ~~either the Puketoi or more probably~~, the Hinemoa Surface. Thus, evidence of superimposition of the present drainage system is also present. ~~However~~, gorges on a smaller scale are also cut through greywacke "highs" by the Mangatainoka and the Makakahi rivers near Putara and near Kaiparoro. In these places faulting is not involved,

~~in the formation of~~ the gorges ~~which~~ owe ing their origin to ~~the~~ superimposition from ~~of~~ a previous drainage system. It is thus thought that superimposition is the major factor in the formation of the Manawatu Gorge.

CHAPTER III - STRATIGRAPHY

GENERAL ASPECTS OF STRATIGRAPHY

OUTLINE OF STRATIGRAPHY

Well-indurated greywacke and argillite rocks of Lower to Mid — Mesozoic age (Triassic-Jurassic), form the Tararua Range and are the oldest rocks found in the mapped area. Relatively small outcrops of greywacke, found east of the Tararua Range, are generally on the upthrown (western) side of the major north-northeast trending faults. At Castle Hill, in the extreme south-eastern part of the mapped area, greywackes and argillites of uppermost Jurassic to Cretaceous age, crop out over an area of several square miles.

The youngest greywackes of the mapped area are separated by an unconformity, representing a period of about 100 million years, from thenext-deposited strata of Upper Miocene to Pleistocene age. This younger group of sediments, lightly indurated, is about 10,000 ft thick. It was deposited almost continuously during a period of about 15 million years. The younger rocks have been studied in greater detail than has the greywacke.

The younger sediments are invariably lightly indurated, and samples left to soak in water overnight lose their cohesion entirely. Commonly grains of volcanic glass and mica flakes are present. Most of the sand grains are quartzose and ~~seen under a binocular~~

~~microscope~~ are angular or subangular; the grains are speckled black and white (salt and pepper). The grains are considered to have been largely derived from Triassic-Cretaceous greywacke. Orbell (1965) found that the heavy-mineral content ~~within~~ of the Upper Tertiary strata at the nearby settlement of Mauriceville indicated an origin from a greywacke parent rock.

Small aggregates of fine-grained brown ~~coloured~~ siderite, are common, and a few pyrite casts of microfossils show where the tests ~~shell material~~ have been ~~removed by~~ weathered out.

In the mapped area pumiceous beds are rare in mid-Tongaporutuan to Waipipian rocks, and are common in Okehuan rocks. Several ash beds are listed in Geological Sections of Tongaporutuan to Opoitian age at Mauriceville (see Orbell 1962). Orbell (1965) found that the Kapitean to Waitotaran rocks contain the clay mineral montmorillonite in third order of abundance after illite and chlorite. Orbell considered the amount of montmorillonite surprisingly high; and ~~he~~ considered that it ~~the montmorillonite~~ was probably formed by the devitrification of a glassy basic ash. Reworking of the ash by an active infauna incorporated it into the sediment. In the mapped area ash beds less than 2½ inches thick have not been recognised; ~~thicker ones are rarely greatly disturbed by the infauna~~. The writer considers it possible that ash falls of about 2½ inches thick killed the infauna while falls of less than 2½ inches did not. If montmorillonite is unusually abundant in the Eketahuna area also, then it presumably results from ash falls of less than 2½ inches ~~thick~~. Kear (1957) considered the source of Taranakian pumiceous ash to be from the southeast and ~~that~~ the source of Opoitian, Waipipian, and Waitotaran age to be from Cape Colville.

HISTORY OF STRATIGRAPHIC CLASSIFICATION

Prior to field work by the writer there had been two periods of earlier geologic investigation; firstly by Crawford (1870) and McKay (1877 and 1892); and secondly by Ongley (1935), and Firth and Feldmeyer (1943). The emphasis on all previous work has been on the Upper Tertiary strata.

Crawford and McKay (1877) examined the mapped area at a time when it was still covered by thick virgin forest. Crawford observed Tertiary sandstone, limestone, blue clay and gravel at Eketahuna. McKay (1877) produced a geologic sketch map on the scale of about eight miles-to-an-inch, ~~but could not have covered the area in detail during his reconnaissance survey~~. ~~No doubt~~ He was severely limited by not having an adequate topographic map, but he gives~~,~~ ~~nevertheless,~~ the start of a stratigraphic synthesis.

McKay (1877) thought that the bulk of the Tertiary strata at Eketahuna and Alfredton was Lower Eocene in age, although a cross section by Hector, incorporated in McKay's report, indicated that Hector thought that the strata were largely of Miocene age. McKay approximately delineated the Tertiary-greywacke contact, and the belts of Waitotaran limestone.

Much of the detailed stratigraphic sequence in the Marima, Mangamaire, and Konini areas was elucidated by McKay (1892), during an investigation of the thin lignite beds of the Mangahao Formation.

During the period 1930 - 1934, Ongley (1935) mapped the 1700 sq. mile Eketahuna subdivision and published a geologic map on the scale of 1:253440. Ongley considered many of the Pliocene strata of the mapped area to be Tutamoe (Miocene) in age, and outlined the approximate distribution of the post-Opoitian (post-Lower Pliocene) strata. Ongley's map is particularly accurate where he found well defined lithological changes such as that between the F_2 limestone of the Makuri Group and the underlying the Opoitian Tane Sandstone in the Tane-Kaitawa areas. Ongley's map particularly demonstrates the faults at many of the greywacke-Tertiary contacts. Firth and Feldmeyer (1943) examined the northern part of the mapped area and, though they wrote a report, they did not produce a geologic map. They largely used Ongley's stratal subdivision, but they subdivided the Waihoki and Te Aute series into four foraminiferal zones: TW1, TW2, TW3 and TW4. They considered the two lower zones, TW3 and TW4, to be Opoitian and the two upper zones, TW1 and TW2, to be post-Opoitian. They state that the basal Te Aute Limestone lies between the two upper zones; so that only the uppermost zone is actually post-Opoitian.

Table 2

Stratal Subdivision by Previous Workers

McKAY (1877) *		ONGLEY (1935) **	FIRTH & FELDMEYER (1943)	This Bulletin	
Recent Deposits / Old High Level Gravels		RECENT AND PLEISTOCENE		ALLUVIUM	
				TERRACE GRAVELS	
Scinde Island Limestone		Mangahao Series	Mangahao Series	MANGAMAIRE GROUP	MANGAHAO Fm
Rotella Beds	PLIOCENE	Petane Series	Petane Series		TOTARANUI Fm
Limestone		Te Aute Series	TW 1	MARIMA SANDSTONE AND MAKURI GROUP	
Lower Tertiary-Eocene	MIOCENE	Waihoki Series	TW 2 / TW 3 / TW 4	EKETAHUNA GROUP	
		Mapiri Series	Mapiri Series	SOREN AND TE HOE GROUPS	
		Tutamoe Series	Tutamoe Series	NGARATA FORMATION	
	JURASSIC	Waewaepa Series			
		Taitai Series		CASTLE FORMATION	
Rimutaka	LOWER MESOZOIC or PALEOZOIC	Tararua Series		TARARUA FORMATION	

* Taken from Map Legend - Only formations relevant to the mapped area are listed.

** Only the formations relevant to the mapped area are listed.

Table 3

Foraminifera, Pecten and Pelicaria ZONES in Northern Wairarapa Correlated with the UPPER TERTIARY AND PLEISTOCENE STAGES.

STAGES	DEEPWATER/FORAMINIFERA ZONES After Vella (1954 and 1962b) partly superseded by Kennett (1966d)	SHALLOW WATER FORAMINIFERA ZONES After Vella (1962b)	PECTEN ZONES Largely after Kennett (1966b)	PELICARIA ZONES
NUKUMARUAN		Notorotalia zelandica		Pelicaria convexa and Pelicaria fossa
HAUTAWAN		Notorotalia rotunda		Pelicaria n. sp. aff tricarinata
		Notorotalia mangaoparia		
WAITOTARAN		Notorotalia kingmai		Pelicaria n. sp. aff acuminata
WAIPIPIAN				Pelicaria canaliculata
OPOITIAN	Turborotalia inflata (Vella 1962b); Globorotalia crassaformis (Kennett 1966d)			
KAPITEAN	Sigmoilopsis zeaserus (Vella 1962b); Globorotalia conomiozea (Kennett 1966d)			
UPPER TONGAPORUTUAN	Bolivinita pliozea (Kennett 1966d)		Sectipecten grangei Boreham	
MID TONGAPORUTUAN	Bolivinita pohana (Vella 1954)		Sectipecten grangei Boreham	
WAIAUAN? ≡ LOWER TONGAPORUTUAN	Bolivinita quadrilatera (Vella 1954)		Lentipecten hochsetteri Zittel	

Previous workers in nearby areas

Fleming (1953) subdivided the thick post-Opoitian sediments at Wanganui, to the northwest, into formations which were assigned to the Wanganui Series (Waipipian to Castlecliffian Stages). A ~~separate~~ different stratal subdivision, also based on formations, was used by Lillie (1953) to map rocks of the same span ~~of ages~~ at Dannevirke, to the north.

Advances in the field of micropalaeontology, largely the work of Finlay, enabled Lillie (1953) to assign the Tertiary formations of the Dannevirke area to the standard stages of that time. Lillie (1953, p.45) predicted that the strata mapped as Tutamoe (Lillburnian to upper Tongaporutuan) by Ongley would ~~be younger~~ belong to the Mapiri (Tongaporutuan-Kapitean or an even younger formations). Such has been found to be the case.

Orbell (1962), mapped subsheet 2 of the N.Z.M.S. sheet N158, the northern margin of which forms the central part of the southern margin of the Eketahuna sheet covered by this ~~bulletin~~ thesis. Orbell's mode of stratal subdivision was by stages, identification of which was by foraminifera examined by Dr P. Vella.

Vella (1963b) has attempted to subdivide the lower Pleistocene strata by means of cyclothems. He considered that the cyclothems were due to sea-level oscillations of 150-500 ft in a region which was sinking at a decelerating rate. Vella ~~considered~~ equated his cyclothem units ~~to be equivalent to~~ with the Wanganuian stages, as modified by Fleming (1962).

BASIS OF STRATIGRAPHIC MAPPING

The Problem

Within the mapped area, Miocene-Pleistocene strata ~~sediments~~ are about 10,000 ft thick, many ~~much~~ being typical "papa" (blue grey mudstone, siltstone, sandstone and turbidite). Limestones in the upper part of the sequence and conglomerates in the lower and upper parts are usually good mappable horizons. ~~but~~ The subdivision and mapping of the thick sequences of mudstone, siltstone, sandstone and turbidite was not straightforward.

With the exception of the C_4 Mudstone of the Ngarata Formation which may be a little darker blue-grey than younger sediments, ~~there are only slight local changes in colour, and~~ colour changes cannot be used as a basis of subdivision.

Lithologic Subdivision

It was considered that it might be possible to map lithologic units within the "papa" sequence. A sand-gauge-folder containing samples of various grain sizes of sand and silt manufactured by the Geological Speciality Company of Oklahoma City, U.S.A., was consulted at frequent intervals during an intensive field study of the grain size of the sediments. This enabled ~~the~~ mudstone, siltstone, very fine sandstone and fine sandstone ~~units~~ to be distinguished as units. ~~mapped;~~ These ~~units~~ together with ~~and also~~ limestone and conglomerate ~~units~~ form the basis of the stratal subdivision. In general the ~~boundaries of~~ Waipipian, Waitotaran and Hautawan formations are less well defined than those of Taranakian, Kapitean and Opoitian. ~~formations and the content within formations is more variable.~~

In streams, rivers, and road cuts the dominant grain size of an outcrop can commonly be predicted from about twenty yards away. Mudstone generally has a conchoidal fracture pattern, whereas sandstones are usually pockmarked with insect burrows. Siltstone shows neither feature; most of the deeper gorges are in massive siltstone ~~with~~ and have smooth precipitous sides. Calcareous concretions are fairly common in the siltstone and sandstone, but rare in the mudstone.

Generally the grain size of a mapped unit fell within a single grain size category, but at places two grain sizes of two units could be recognised, in ~~almost~~ sub equal quantities. In such places the dominant grain size was prefixed with the subordinate grain size; such as a silty very fine sand etc, on field sheets.

CHRONOSTRATIGRAPHY

Microfossils (Foraminifera) and mollusca, were used for stage definition.

Microfossils

Foraminifera studied by Dr Paul Vella have provided approximate ages which were useful during stratal synthesis. They were reliable in defining the Kapitean-Opoitian boundary. Kennett (1966b) examined three sections in the mapped area in detail, two in the Mangatainoka Valley near Putara, and one at Mangaoranga Stream. Subsequently he revised the Tongaporutuan-Kapitean foraminiferal zones previously established by Vella (1962b). The revision places the Tongaporutuan-Kapitean boundary at a higher stratigraphical position than that considered by Vella.

Kennett's revised Kapitean Stage (Upper R_5 Mudstone and S_1 Siltstone) is only about 300 ft. thick at Mangaoranga Stream, and he considered that the Kapitean is absent at Putara. Previously Firth and Feldmeyer (1943, p.14) found that "The only definitely Urenuian* microfaunas were ~~found in~~ from the samples taken from the south end of the Paeroa Ridge. The remainder are all either Tongaporutuan or non-diagnostic Taranakian."

Foraminifera are not as useful as Mollusca in determining the age of post-Opoitian strata. Vella (1964) found that foraminiferal faunas became progressively depleted during Pliocene time, few new elements being introduced.

Macrofossils

Macrofossils in large numbers are restricted to the C_1 Sandstone (Ngarata Formation), R_3 Sandstone, (Mangaoranga Formation), the Atea Sandstone, the Marima Sandstone, and some formations of the Mangamaire and Makuri Groups.

The C_1 Sandstone, R_3 Standstone, and Atea Sandstone each has its own distinctive macrofauna. The fauna of the C_1 Sandstone contains most of the elements of the distinctive Hurupi fauna (Dell, 1952). The macrofauna from the younger R_3 Sandstone differs from the Hurupi fauna, ~~and~~ but the diagnostic Kapitean fossils ~~such as~~ *Sectipecten wollastoni* and *Austrofusis tuberculatus* are missing. The Atea Sandstone contains species that are restricted to the Opoitian.

* Later partly superseded by the Kapitean Stage.

The species of *Pelicaria* described by Vella (1953) from southern Wairarapa at Martinborough are not present within the mapped area, but tentative correlation with the Wairarapa is possible ~~by~~ because the endemic species from the Marima area ~~which~~ pass through similar progressive morphological changes to those in the Wairarapa (program evolution). *Pelicarias* characteristic of the Marima area are also occasionally found in the Wanganui area, this allows some correlation with the type area of the Waitotaran and Hautawan Stages, at Wanganui.

The zones of *P.* n.sp. aff. *acuminata* and the *P.* n. sp. aff. *tricarinata* ~~zones~~ ~~can be~~ are only approximately correlated with the Waitoraran and Hautawan stages; the lower part of the *P.* n. sp. aff. *tricarinata* zone is considered to be ~~of~~ about Waitotaran age. The *P.* *canaliculata* zone is of Waipipian age.

Correlation of the Totaranui Limestone with the Nukumaru Limestone at Wanganui is based on faunal evidence, largely the sudden appearance of *Pelicaria fossa* and *Pelicaria convexa* at both Wanganui and Marima.

A summary of the more important zonal fossils employed in correlating the Lower Tongaporutuan-Nukumaruan strata with the standard New Zealand stages is given in Table 3.

STRATAL SUBDIVISION

The writer's ~~has employed a stratal~~ subdivision of the Upper Tertiary-Pleistocene strata (Table 4) ~~which~~ is different from that of Ongley (1935), partly because many more formations have been established, ~~but also~~ and partly because most of Ongley's formations had previously been imprecisely defined some two hundred miles or more to the northeast, at Gisborne. Further, although in some areas the writer's mapping is ~~often~~ in broad agreement with Ongley's, elsewhere it differs significantly.

Formations established at Wanganui by (Fleming, 1953) and at Dannevirke by (Lillie, 1953) cannot be traced with certainty to the Eketahuna area, and cannot therefore be used.

Apart from the Pelicaria zones of the Marima Sandstone, the mapped groups, formations and members are largely based and correlated across fault blocks on ~~by~~ lithology. ~~considerations~~. (See type locality Table 4). Broad tentative ages of the formations, from ~~suggested by~~ foraminifera, studied by Dr P. Vella, were found useful in correlation.

Vella (1963b) stated that ~~considered~~ "Low sea-level phases represented by unconformities are considered to be more reliable than fossils for correlation." The writer considers Vella's thesis of eustatic sea-level changes affecting the nature of the post-Waipipian sedimentation (cyclothems) to be broadly valid, but doubts if this is the best way to correlate strata at present. Vella's mode of stratal subdivision is based on the mapping of ~~negative criteria, i.e.~~ stratigraphical breaks. Such breaks can ~~may~~ be demonstrated at some localities, but may not exist elsewhere. Furthermore (see page 250), the writer has considered that the break in deposition beneath the Hautawan limestone at Mauriceville is too long in time to be anything but a "tectonic unconformity" (Compare the lower Nukumaruan break in deposition at Takapau and Te Aute inferred by Beeham 1963). It is uncertainties such as these (see also page 222) that cause considerable doubt whether ~~if~~ Vella's mode of correlation, in such an unstable region as the Wairarapa, is feasible, until the stratigraphy of the Upper

Pliocene - Lower Pleistocene strata is better known.

It is considered that fossils will always be needed to decide which particular beds overlie any horizon tentatively identified as representing a low sea-level phase, and that correlation, especially at localities some distance apart, is ultimately by fossils. The writer considers that a first step in the mapping of Tertiary strata should be ~~by~~ the establishment of local formations. (In mapping away from the type localities, palaeontological criteria often provide useful checks). It is likely, however, that cyclothemic units, such as those delineated by Vella, will eventually be substantiated in Wairarapa.

The mapping of strata by means of stages rather than by formations is likely to lead to confusion at a later time, as and when the stage boundaries are redefined by later workers. Such redefinitions are almost certain to occur in regions such as Wairarapa which are hundreds of miles from ~~those~~ the type areas ~~where~~ of such stages as the Waiauan and Kapitean. ~~have been defined~~. For example, Kennett (in press) has redefined the Kapitean Stage to coincide with the *Globorotalia conomiozea* zone. In the Awatere Valley the base of this zone coincides with the base of the *Sigmoilopsis zeazerus* zone, but in the mapped area the base of the G. *conomiozea* zone occurs in the middle part of the S. *zeazerus* zone. ~~This is important as~~ Previously Vella (1962b) ~~had~~ defined the Kapitean to coincide with the *S. zeazerus* zone. Clearly one of the zones is diachronous in the area between Eketahuna and Awatere Valley. Further problems of redefinition are likely to arise at successive intervals in the future.

TABLE 4 (Lower Part)

	SAUNDERS SILTSTONE		Saunders Road	c 4800	EKETAHUNA MUDSTONE	TANE SANDSTONE	OPOITIAN
		E_5 Sandstone tongue	Near Makuri Trig	150 +	SAUNDERS SILTSTONE	SAUNDERS SILTSTONE	"
	ATEA SANDSTONE		Davenports Creek	800	R_3 Sandstone	SAUNDERS SILTSTONE	"
	TIRAUMEA MUDSTONE		Tiraumea River	1500	TE HOE TURBIDITE	EKETAHUNA MUDSTONE	MID TONGA-PORUTUAN
	TE HOE TURBIDITE		Te Hoe Stream	1500	C_4 Mudstone	TIRAUMEA MUDSTONE	- KAPITEAN
		S_4 Limestone	Kaiparoro	35	S_2 Sandstone	EKETAHUNA MUDSTONE	KAPITEAN
		S_3 Conglomerate	Ngamaia Stream	40	R_3 Sandstone	ATEA SANDSTONE	"
	KAIPARORO	S_2 Sandstone	Makakahi River	80	R_5 Mudstone	EKETAHUNA MUDSTONE	"
		S_1 Siltstone	Mangaoranga Stream	80	R_5 Mudstone	EKETAHUNA MUDSTONE	"
SOREN		R_5 Mudstone	Mangaoranga Stream	800	R_4 Siltstone	S_1 Siltstone	MID TONGA-PORUTUAN-KAPITEAN
		R_4 Siltstone	Mangaoranga Stream	100	R_3 Sandstone	R_5 Mudstone	MID TONGAPOR-UTUAN
	MANGAORANGA	R_3 Sandstone	Mangaoranga Stream	480	R_1 Conglomerate	R_4 Siltstone	" "
		R_2 Marl	Mangaoranga Stream	120	R_1 Conglomerate	R_1 Conglomerate	" "
		R_1 Conglomerate	Mangaoranga Stream	700	TARARUA FORMATION	R_3 Sandstone	LOWER TONGA-PORUTUAN?
		C_5 Ash bed	Near Trig 1071	9.5	C_4 Mudstone	TE HOE TURBIDITE	LOWER-MID TONGAPORUTUAN
		C_4 Mudstone	Te Hoe Stream	700	C_3 Siltstone	TE HOE TURBIDITE	LOWER-MID TONGAPORUTUAN
	NGARATA	C_3 Siltstone	Te Hoe Stream	120	C_1 Sandstone	C_4 Mudstone	LOWER TONGA-PORUTUAN
		C_2 Conglomerate	Southwest of Alfredton	20	C_1 Sandstone	C_1 Sandstone	" "
		C_1 Sandstone	Te Hoe Stream	285	CASTLE FORMATION	C_3 Siltstone	" "

Formations versus zones for Local Upper Tertiary - Lower Pliestocene Correlation

Vella (1965) has stated, "Geologists long ago rid themselves of the naïve belief that all stratigraphic boundaries are synchronous from place to place. Many have yet to rid themselves of the equally naïve belief that all stratigraphic boundaries are diachronous from place to place..."

Many of the Upper Tertiary to Pleistocene formations show a parallelism ~~of outcrop distribution~~ throughout. Others, especially some formations of the Eketahuna Group such as the Sanders Siltstone and Eketahuna Mudstone, have wedge-like distributions and are diachronous at least in part, having been deposited at different times in different areas.

For local correlation the boundaries of the formations that show parallelism of outcrop distribution are taken to ~~approximately~~ delineate approximate time planes.

The average rate of deposition of the 10,000 ft of Upper Tertiary-Pleistocene sediments was, on the average, about 660 ft per million years. Zeuner (1946, p.392) has considered that the maximum rate of species evolution in the animal kingdom to be about 500,000 years per species step; he also found (p.389) that the rate in marine Mollusca was much slower than that in terrestrial animals.

The rate of *Pelicaria* evolution at Marima was probably much faster than for most mollusca; the two distinct species *P*. n. sp. aff. *acuminata* and *P*. n. sp. aff. *tricarinata* were evolved in the period since late *P. canaliculata* (Waipipian) times. Evolution of the

Pelicaria lineage was not fast prior to Waipipian time ~~as~~ Kennett's discovery (1966a) of ~~found~~ *P. canaliculata* in basal Opoitian sediments in the Awatere Valley. has shown.

Squires (1960) polled five prominent palaeontologists and stratigraph~~s~~ers on the length of the Tertiary Stages; He found that the weighted mean of Waitotoran time was 4 per cent of total Tertiary time. Squires did notdifferentiate Waipipian from Waitotaran, nor is it certain if his Nukumaruan Stage is in the sense of Fleming (1962), or if it emcompasses the Hautawan Stage as well. Nevertheless Squire's weighted mean ~~it~~ allows a very approximate estimation of the time period involved; four per cent of Tertiary time is about 2,800,000 years. The two species steps in *Pelicaria* evolution occurred at intervals of about 1,400,000 years.

With regard to the average rate of deposition the differentiation of sediments by morphological changes of the indigenous Mollusca is unlikely to allow subdivision of strata less than 1,000 ft thick unless sedimentation rates were slower than the average. in the mapped area.

Kennett (1962) studied the evolutionary series *Textularia moizea* - *T. kapitea kapitea* - *T. kapitea martinima* ~~lineage~~ at Cape Foulwind. He found that the *T. kapitea kapitea* subspecies was restricted to less than three hundred ft, apparently representing the whole of ~~the~~ Kapitean Stage. Squires (1960) considered the Kapitean to be 3 per cent of total Tertiary time; some 2,100,000 years. Rates of sedimentation at Cape Foulwind during the Kapitean were thus much slower than the average ~~sedimentation~~ rate at Eketahuna, and only about

150 ft per million years. Using Kennett's rate of morphological change with respect to the average rate of sedimentation at Eketahuna, then about 1,320 ft would have been deposited at Eketahuna during the time of the species step ~~morphological changes took place~~ at Cape Foulwind. Thus rates of evolution in the foraminifera were not faster than those ~~that~~ in the gastropod <u>Pelicaria</u>.

The introduction ~~of a new fauna~~, or the extinction of a fauna can be quite sudden. Events of this nature are very useful in local stratal correlation, but, unfortunately, they are not common. Such events occurred only about five times from Taranakian to Nukumaruan time, or for two to three million years (compare 2 million year cycle of Van der Hammen (1957); or alternatively ~~on the average once~~ during the accumulation of about 2,000 ft of strata.

Apart from the Marima Sandstone, non-diachronous formations of the mapped area are unlikely to be further subdivided by species steps ~~changes~~ in fossils, unless the units are more than a thousand feet thick. Apart from the diachronous Saunders Siltstone few units are much more than a thousand feet thick (see Table 4).

In Southern Wairarapa the Taranakian, Kapitean, and Opoitian stages have similar lithologies, the formations are thus thicker and fossils ~~so that fossils~~ will prove to be more important for local subdivision ~~of the strata there~~ than they ~~have~~ are ~~been~~ at Eketahuna.

<u>Pliocene - Pleistocene boundary</u>

Flint (1965) (assisted by Boreham) suggests that there is wide agreement amongst workers in New Zealand, (see Boreham, 1963;

Fleming, 1962; and Vella, 1962b) that the Pliocene-Pleistocene boundary occurs at ~~a horizon~~ between the Waitotaran and Hautawan Stages.* Vella (1963a, p.2) ~~has also~~ later placed the Plio-Pleistocene boundary at a lower stratigraphic position, between the Waipipian-Waitotaran stages. The writer prefers ~~a~~ the Waipipian-Waitotaran as the Pliocene-Pleistocene boundary as many mollsucs ~~including the~~ including the warm-water-indicating gastropod genus ~~Polinices~~ Polinices are found in the Pelicaria canaliculata Zone of the Marima Sandstone (Waipipian) but are absent in the overlying P. n. sp. aff. acuminata zone (Waitoraran). Further the P. n. sp. aff. acuminata zone contains the cold water Chlamys delicatula. Also as there is no evidence of a pre-Waipipian cooling in the South Island, the climatic deterioration at the Waipipian-Waitotoran boundary is thought to have been abrupt.

* His table 1, however, is inconsistent with his text.

MESOZOIC ERA

TARARUA FORMATION

NAME

The formation is named after the Tararua Mountains which form the axial region of the southern part of the North Island. The formation is largely synonymous with the Tararua Series of Ongley (1935).

Greywackes in the vicinity of Mt Bruce mapped by Ongley as Waewaepa are included in the Tararua Formation, partly because Upper Jurassic fossils are restricted to one locality ~~but also~~ and partly because the rocks associated with the Jurassic fossils are not distinguishable from those with the Triassic fossils.

Previous Work

Apart from an investigation of the geology of the dam site on the Mangahao River by Adkin (1921), the writer can find no reference to previous geological exploration of that part of the Tararua Range which lies in the mapped area. McKay (1888) made a detailed examination of the limestone and basalt near Mt Munroe and ~~similar rocks~~ at the saddle near Mt Bruce. ~~McKay~~ He also examined river boulders at the eastern margin of the Northern Tararua Range, but did not investigate the geology of the range.

Ongley (1935) mapped the Tararua Formation-Upper Tertiary contacts but did not mapp~~ing~~ ~~within~~ the greywacke. itself.

Physiography

In the non-forested part of the Tararua Mountains, the formation generally forms an irregular knobbly topography (see Figure 4); bedding planes, such as can normally be delineated on vertical air photographs of Tertiary strata, and even of the Castle Formation, can only very rarely be found. This is largely due to the steeply dipping nature of the beds, the amount of deformation that the rocks have suffered since deposition, and to their relatively uniform strength. The rocks can be considered to be an almost isotropic medium crossed by a few ~~in which the major~~ flaws - the joints and fault planes - which have been subsequently excavated by streams, ~~are joint and fault planes~~.

Structure

The detailed structure of the Triassic-Jurassic greywacke ~~of New Zealand~~ has not generally been elucidated in most parts of New Zealand. The structure of the greywackes is difficult to interpret ~~complicated~~ because of the lack of marker horizons and because of ~~the known~~ tectonic complication, ~~within the many thousands of feet of alternating argillite and sandstone beds~~. The greywackes of the mapped area are more difficult to map in detail than those in the Wellington area because, though "top" and "bottom" can often be distinguished ~~delineated~~ in Wellington, ~~but~~ it cannot generally be distinguished ~~delineated~~ in the Northern Tararuas. Kingma (1957b) in a discussion of the North Island Geanticline showed ~~found~~ that the regional strike is north in the Ruahine Range and ~~swings~~ northeast in the Rimutaka and Tararua ranges.

Figure 4. Air view northwards from Larsens Road. Centre Taiko Trig. Foreground Mangaroa Stream flanked by the terraces of the Hukanui Formation. Background Tararua Mountains sloping gently northwards to the Manawatu Gap (upper right).

Although there is a scatter of bedding inclinations ~~in many directions~~, more beds (44 per cent) are inclined to the south-east at about seventy degrees than in any other direction. Furthermore, at the northwestern part of the mapped area where some stratigraphy has been ~~delineated~~ determined along a right branch tributary of the Tokomaru River the mapped units trend north-eastwards and are inclined to the south-east. The presence of Upper Triassic fossils at Otaki, and Jurassic Buchia sp. and Aucellina sp? at Eketahuna ~~however,~~ indicates that the greywacke, if it is not generally overturned, may generally young in a south-eastward direction. Kingma (1957a) reported that the greywackes of the Kaimanawa Range ~~decreased in age in an~~ became younger eastward ~~direction~~.

At Huru Trig. and 1000 yards to the west features thought to be bedding indicate that the greywacke is vertical and strikes north-west. ~~to south-east.~~

Although small-scale folds, such as can be ~~delineated~~ seen in an outcrop, ~~were~~ are quite common, ~~evidence indicating~~ large scale folds have not been found. The plunge of the small-scale folds is invariably to the north-north-east. Zig zag folds, with limbs about 2 ft long crop out in a right branch tributary of the Tokomaru River at grid ref. 048141; the fold axes strike at 015°. Because of a lack of marker beds and ~~vertical~~ a lack of grading in the alternating sandstone and argillite beds it has not been possible to establish the structure and stratigraphy.

East of the Tararua Range the Upper Tertiary strata invariably

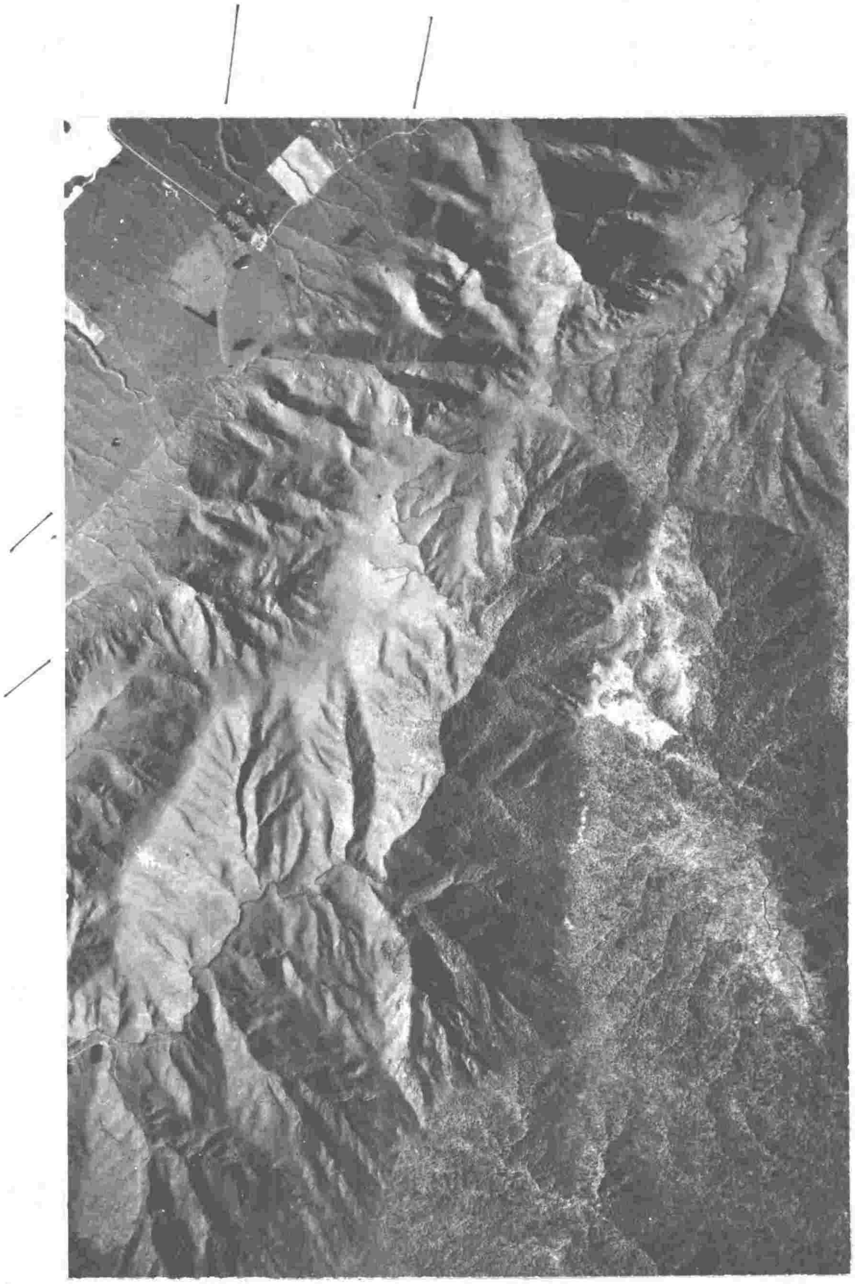


Figure 5: Vertical air photograph of the western margin of the Tararua Range near Tokomaru. Note lineaments at the margin, which trend due north and north-east, and which are thought to be faults.

dip to the north-west while very young strata west of the Range dip at low angles to the west. It is thought that the greywacke of the Tararua Range may have also been progressively tilted to the west during Upper Tertiary time.

<u>Faults in the Tararuas</u>

The Wellington and Huru faults delineate the eastern margin of the Tararua Mountains.

Lensen (1958) mapped the Wellington fault and an active north-east trending branch fault in the extreme south-western part of the mapped area.

Though much of the ~~ground~~ surface of the Tararuas is masked by thick bush, lineaments, thought to be faults, have been mapped with the aid of aerial photographs. The pattern of the lineaments is not significantly different from the pattern of recent faulting within the upper Tertiary strata, to the east.

In the south-western part of the mapped area one mile east of the Wellington Fault at grid ref. 040915, one north-northeast trending lineament is thought to have been active dextrally during Late-Quaternary time.

Two lineaments which trend north-northeastwards one mile south of Ngapuketerua, can be traced southwestwards beyond the mapped area into active fault traces (one mile east of Mt Dundas at grid ref. 970910, and 970903 on NZMS sheet N152 Levin).

In the north-eastern part of the mapped area near Tokumaru, the junction of the Upper Pleistocene Tiritea Formation and the Tararua

Formation is thought to be faulted ~~controlled~~ (see Figure 5).

Subdivision of the formation

The formation is composed largely of unfossiliferous, well-indurated, alternating sandstone and argillite beds which are many thousands of feet thick; Wellman (1952) has considered the rocks to be of the Alpine facies of the New Zealand Geosyncline. It has not been possible to subdivide the strata with regard to age, but some lithological units have been mapped within the formation, particularly in the western part of the mapped area. ~~Similarly~~ Grant-Taylor and Waterhouse (1963) have determined ~~established~~ some lithological units ~~stratigraphy~~ in the western flank of the Tararua Mountains near Otaki. It is probable that a detailed geologic synthesis will be more readily established in the north-western part of the Tararuas, than in the eastern part which contains fewer marker horizons.

Distribution

The Tararua Formation crops out over some 100 square miles of the western part of the mapped area; the formation is largely bounded in the east by the Wellington Fault. In the southern sector of the area east of the Wellington Fault, the formation crops out in a triangular area, bounded in the west by the Mangatainoka River and in the east by the Huru Fault. The apex of this triangular area is cut by Priests Road near Kerrydale Farm.

The formation crops out between the East and West Taiko Faults at two exposures ~~localities~~, a large one at Taiko Trig (see Figure 4), and a much smaller one ~~which is exposed~~ in Mangaroa Stream ~~at~~ (grid ref. 098934).

West of the Smiths Line - Rongomai faults the Tararua Formation crops out at Mt Bruce, and near Mt Munroe. Further north two small outcrops are ~~located~~ at grid ref, 212963 and at grid ref, 228978, and a somewhat larger one at ~~also along~~ Central Mangaone Road at grid ref, 247024.

The formation is assumed ~~presumed~~ to directly underlie the Tertiary strata east of the Rongomai Fault. Its relationship to the Cretaceous-Jurassic Castle Formation in the south-east corner of the mapped area is obscure.

Content

The bulk of the Tararua Formation is mapped as A_1; mappable variants are distinguished as the A_2, A_3, A_4, A_5, A_6, A_7 and A_8 members.

Most of the formation, especially in the east, is composed of grey, well-indurated, alternating beds of sandstone and argillite each of which are from a few inches to many feet thick. Beds of about the same thickness ~~approximately equal order of thickness~~ are usually ~~normally~~ developed in an ~~any one~~ outcrop. Jointing is extremely variable, with many joints in some places and with few in others. ~~The rocks are either relatively non-jointed, or are shattered.~~

Well indurated breccias such as that figured (see Figure 6) are perhaps more common along the eastern margin of the range than elsewhere. Reed (1957) considered that autoclastic breccias are due to extensive shearing at some time prior to final compaction and induration of the greywacke. Suggate (1963) has considered that much of the 300 mile transcurrent movement on the Alpine Fault occurred during the Rangitata Orogeny (Late Jurassic-Early Cretaceous). It may be that the autoclastic breccias were formed by shearing at this time, when the sediment was still lightly indurated.

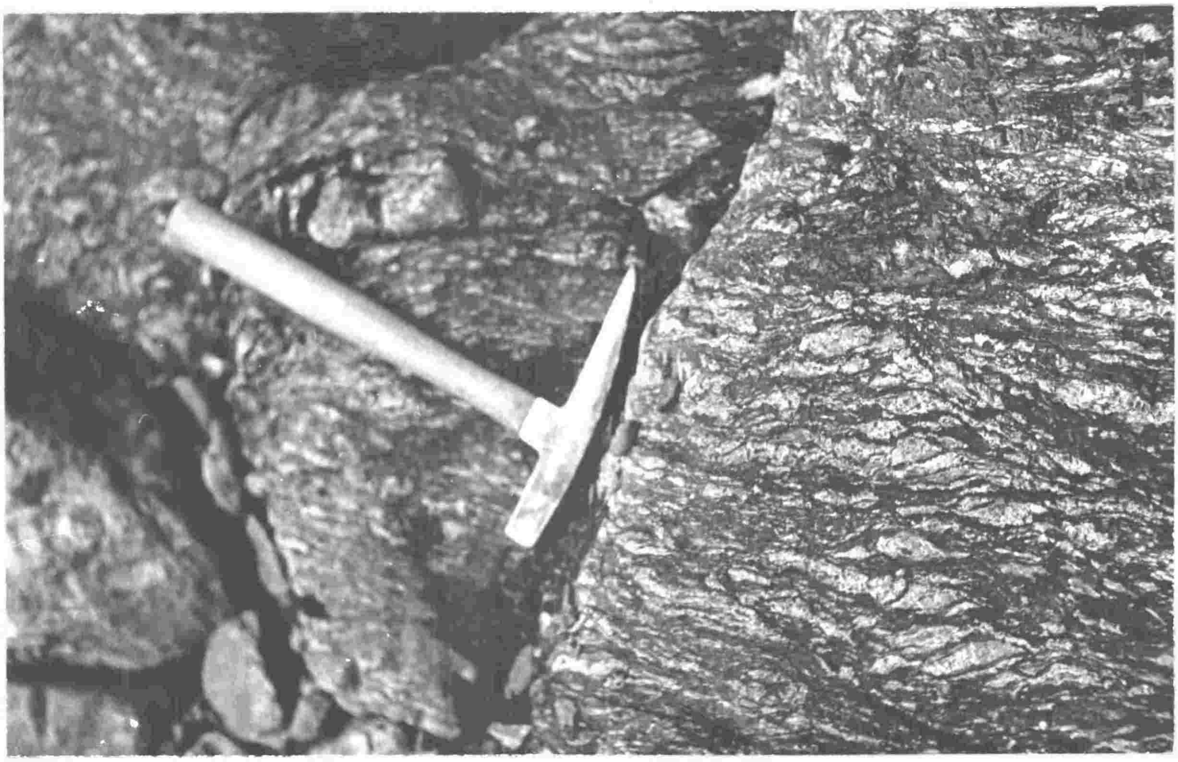


Figure 6: Autoclastic breccia exposed at Otangue Stream at grid ref. 151181. "Note wedge shaped fragments of greywacke arranged more or less parallel to the argillaceous layers which may also "flow" around the fragments"*

* Description taken from Reed (1957) p.31.

The beds frequently contain quartz veins. Greywacke, perhaps of lower rank than usual, containing abundant but unidentifiable plant fragments up to ¾ of an inch long occurs southwest of Kaiparoro at grid ref, 102903. Plant fragments were not found ~~in the formation~~ elsewhere.

Conglomerates are restricted ~~in distribution,~~ to boulders~~, not found in place,~~ along a reach of the Makakahi River, Boulders-containing conglomerate ~~were~~ not found upstream of grid ref 085915.

The conglomerate has been examined by Prof. R.H. Clarke who reports: This is a fine-grained conglomerate containing rounded fragments up to 10 mm in length of indurated argillite, and what is probably devitrified tuff in a greywacke matrix. The rock could be considered as an intraformational conglomerate with patches and veins of quartz and calcite.

Reed (1957) considered that three types of conglomerate occur within the greywacke at Wellington, of which two ~~were~~ definitely intraformational and one ~~of~~ possible intraformational ~~origin~~. Conglomerates containing exotic material are very rare. Lauder (1962), however, has described ~~such~~ a conglomerate containing pebbles of metamorphic, igneous, and sedimentary rocks from Greta Point, Evans Bay, Wellington.

Pre-Consolidation Slumping A_2, parts of the sedimentary sequence of the Tararua Formation have been disturbed at some time prior to their consolidation. ~~The phenomena~~ is particularly well developed in 2,800ft strata in the Tokumaru River and 2,000 ft of strata at Ngamaia Stream. Elsewhere slumped beds are common especially in the western part of the mapped area.

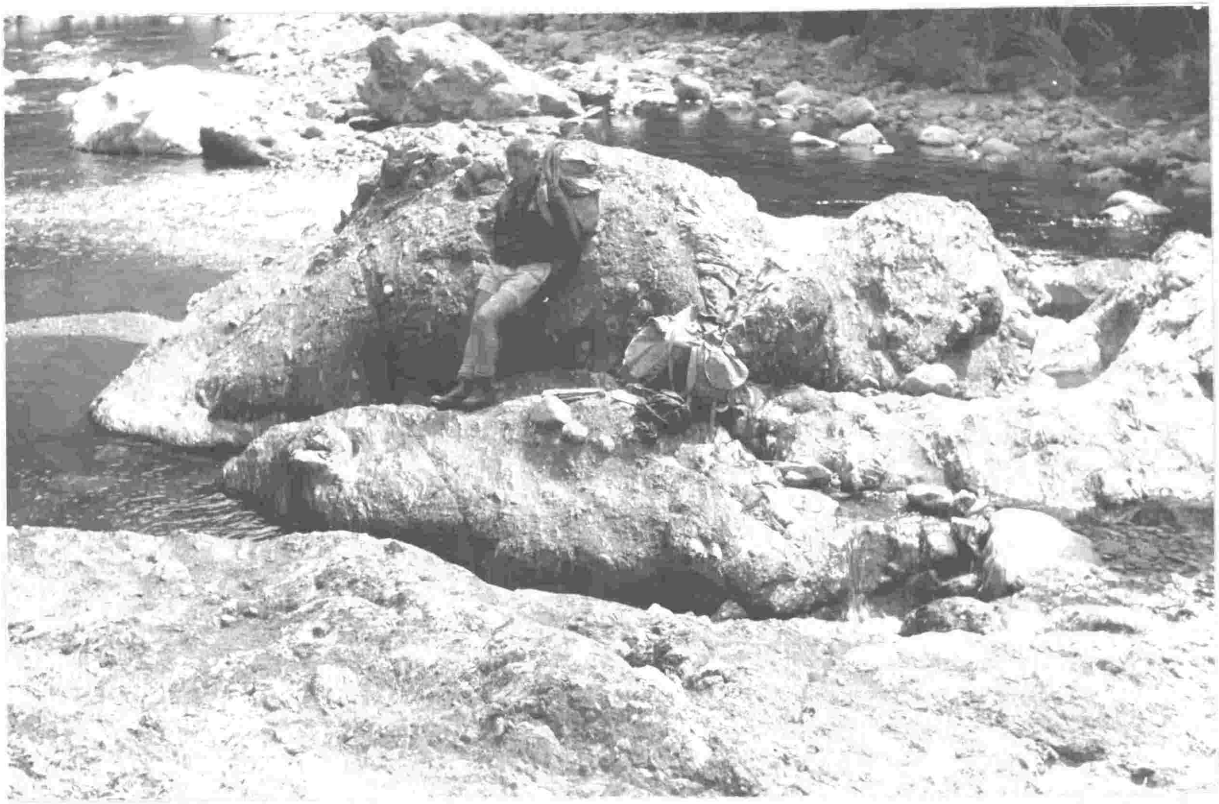


Figure 7: Outcrop of Greywacke, which has been disturbed by preconsolidation-slumping, exposed in the bed of the Tokomaru River at grid ref 053153.
Note "balls" of light coloured greywacke in darker coloured argillite matrix.

The slumped nature of the beds is deduced largely by the presence of sandstone balls up to several feet long in an argillite matrix. The balls are considered to be slump balls.

The preconsolidation strata are much thicker and the ~~original~~ bedding much less in evidence than slumped strata found by Grant-Mackie and Lowery (1964) in Norian Strata at Kiritehere south west Auckland. This is considered to be due to the strata having slid further ~~down slope~~ than those at Kiritehere point.

Massive grey Sandstone A_7. Thick massive sandstone bands, some at least 750 ft thick are more common in the western part of the mapped area. As the thick sandstone bands are more resistant to erosion than thin alternating sandstone-mudstone beds, gorges tend to be developed in the sandstone. The right abutment of the Mangahao Dam is situated on a massive sandstone band.

Reed (1957) found sandstone bands (greywacke) up to 300 ft thick in the Wellington District; and Grant Taylor and Waterhouse (1963) found a 400 ft-thick sandstone bed at Otaki.

A massive blue-grey argillite, (A_8 on map) about 1,200 ft thick, containing a few thin sandstone beds and calcareous concretions crops out along the Mangahao River a short distance upstream ~~of~~ its confluence with Ngapuketerua Stream. Wellman (1952 p.23) considered thick bands of mudstone to be rare; recently Grant-Taylor and Waterhouse (1963) ~~have~~ found a 1,000 ft-thick argillite band in the Otaki Area.

Greyish-green and red argillites are very rare; they were found in Otangue Stream above two water falls (at grid ref. 152183) and are about 200 ft thick. The coloured argillites are associated with

Oligoclase dolerite and jasper beds.

In the Wellington area red and green argillites occur at Red Rock, and at Island Bay, associated with spilites, (see Wellman (1949) and Brodie (1953)). Wellman found ~~that~~ the average chemical composition of the green and red argillites at Red Rock to be intermediate between pillow lava and typical argillite. He inferred from ~~their~~ chemical composition and field relations that the rocks were tuffaceous.

Basalt (mapped as A_6) was traced for some three-quarters of a mile north-eastwards from grid ref. 165929, largely by a reddening of the soil. Good exposures of the basalt are rare. Angular fragments ~~of basalt~~ that may have come from the Tararua Formation were found near Kaiparoro at grid ref. 163924, within the Eketahuna Gravels.

Lavas showing pillow structure are common in the Alpine facies of the Mesozoic period in the Wellington District. They have not been found interbedded in the Tararua Formation.

A fossiliferous limestone (mapped as A_7) is interbedded with the basalt. It was found at only one locality (at grid ref. 171936). Here a section contained in downward sequence (see also McKay 1888):

	Feet
Thin vesicular basalt	1
Grey, lenticular, well-indurated, cryptocrystalline limestone containing a profusion of *Aucellina* shells	1-10
Vesicular basalt	20-30

The fine-grained cream-coloured, very pure limestone is crowded with ~~an~~ unidentified shells of *Buchia* sp. or *Aucellina* sp.; an unidentified fish tooth was also found. Locally the limestone overlies a purplish-grey well-indurated bed containing well-rounded fragments of spilitic lava, 2-6 mm in length and fragments up to 1½ inches long of a thin-shelled Inoceramus sp. (maximum length 1½ inches ~~long~~).

McKay (1888) found that a brecciated, purplish-green highly-calcareous tuff occurred below and graded up into the purplish-grey granule bed. The purplish-green bed was not found during the present survey.

Although a thorough search for fossils other than Inoceramus sp. and Buchia sp or Aucellina sp was made, none except the fish tooth were found.

Analysis of the Limestone from grid ref. 171936.
Lab No. 4690.

	Per Cent
Carbonate of lime	90.86
Magnesia	2.79
Alumina	2.80
Iron Oxides	Traces
Silica	3.41
Water	.14
	100.00

It is considered that the limestone was developed in small depressions present in the upper surface of the thicker basalt. If this is so, the basalt is not overturned . A basalt at least 30 ft thick which crops out along the side of the "Old Coach Road" (grid ref 166932,) is thought to have been a 'feeder dyke'. No evidence of an unconformity underlying the basalt was found; overlying beds were turbidites in appearance.

A sample of the purplish-grey well-indurated fossiliferous granule bed has been examined by Professor R.H. Clarke who reports:- "This is a remarkable rock consisting of sub-rounded fragments of fine-grained spilite and fragments of limestone all set in a calcareous matrix, veined and cemented by calcite. The spilite is remarkably rounded and fairly well sorted."

Lenses of jasper mapped as $\underline{A_3}$ occur in many localities in the Northern Tararuas. It is thought that the lenses are not more than 100 ft thick and that the original lateral extent of the larger lenses in any one direction was not more than a mile.

Six hundred yards south east of the basalt and fossiliferous limestone beds, and across the Mt Bowen Fault a well-indurated three-quarter-mile-long, north east trending jasper bed mapped as $\underline{A_3}$ Jasper, is generally about 50 ft thick. It is especially prominent because it has resisted erosion better than the overlying and underlying greywacke and argillite beds. Although almost all of rock is jasper a few tiny patches of unaltered grey ~~coloured~~ chert are present.

At the southern end of the outcrop at grid ref 173928 the massive red ~~coloured~~ 60 ft thick jasper bed is replaced by about 20 ft of jasper, 20 ft of limestone and 20 ft of basalt. The jasper ~~lying~~ to the east and the limestone to the west. It is thought that the basalt flow advanced over the limestone heating it and changing it to marble. The jasper bed was then deposited. It is inferred that the sequence youngs to the east and that it is overturned.

If it is not white coloured in what respect would it be white?

A sample of the coarsely crystalline limestone from 173928 has been examined by Professor R.H. Clark who reports:- "A coarse-grained carbonate rock with large well twinned calcite crystals up to 0.5 cm long."

A thick jasper lens has been mapped north of the Mangahao Gorge along a north-east leading ridge to Trig (XIII). Jasper lenses are common along the banks of the Mangahao River in a reach downstream of Ngapuketerua Stream; one lens at grid ref 075980 is 70 ft thick. East of Taiko Trig at grid ref. 136072, the jasper and associated spilite locally contains cinnabar (HgS). (See Reed, 1952). East of the Mangatainoka Valley at grid ref 067978 a 25 ft-thick banded red and white ~~coloured~~ jasper, subsequently largely recrystallised to quartz, forms a prominent bedding-plane feature which is 300 yards long.

Thickness

The writer has been unable to synthesise the structure or stratigraphy of the Tararua Formation. Even if much of the greywacke is ~~much~~ repeated by faulting and folding the thickness of the sediments must be of the order of many tens of thousands of feet.

Age and Correlation

Fossils other than those of the AG Limestone have not been found within the mapped area. Most of the fossils of Triassic-Jurassic age have been found in the South Island; these have been listed by Campbell and Warren (1965). Fossil localities in the North Island are much rarer; Grant-Taylor and Waterhouse (1963) have reported Monotis richmondiana at Otaki which indicate a Norian (Late Triassic) age. Webby (1959) found tubes of Terebellina

(Torlessia) mackayi (Bather) and Titahia corrugata (Webby) near Porirua indicating a Triassic-Jurassic age for the rocks there.

In the mapped area, fossils were reported by a tramper from north of the Mangahao Gorge near Trig (XIII). They could not be found by the writer. Ongley (1935) mapped the indurated greywacke and argillite east of the Huru Fault as the Waewaepa Series, and that west of the Huru Fault as Tararua Series. His subdivision is largely due to the Buchia sp. or Aucellina sp. at grid ref. 171936. The writer has not followed Ongley's mode of division largely because the age of the greywacke further west is not known, and some of this could be equivalent in age to the Waewaepa Series. It is thought best to include all the greywacke strata within the Tararua Formation.

Conditions of Deposition

In the Wellington area where graded beds are common Reed (1957) and Webby (1959) have considered that the greywacke was deposited as the result of turbidity currents in deep water. Graded beds have not been found within the mapped area; graded-bedding, if present, is certainly not as well-developed as in the Wellington area. With regard to general considerations, such as the general uniform alternation of greywacke and argillite beds, the huge thicknesses deposited, and especially the association with jaspers, it is thought that the alternating argillite-greywacke beds were deposited in deep water, perhaps by turbidity currents. Non-graded Tertiary turbidites are known in the mapped area, (Te Hoe Turbidites north of Happy Creek) and in Taranaki (see Glennie 1959). In both ~~cases~~ the Tertiary beds are less well-graded in the direction of their source. The lack of grading in the alternating greywacke and argillite beds of the Tararua Formation could be due to the Tararua Formation being near the sediment source. ~~a similar cause.~~ Webby (1959), however found that at Porirua current directions indicated a south-southwest source. That the Pre-Consolidation slumped beds are quite common, indicates that much submarine sliding occurred after the strata were deposited and before they were consolidated and indurated.

The thick massive sandstones of the western part of the mapped area, are considered to have been deposited in somewhat shallower water than the thin alternating greywackes and argillite beds.

Somewhat different conditions of sedimentation prevailed during the deposition of the basalt, and limestone near Kaiparoro. It is unlikely that the well rounded granules are redeposited, the sequence basalt-granules to limestone is one that would be expected under conditions of a reef on the sea floor subjected to some wave action. Fragments of Inoceramus sp. are restricted to the granule bed. Wellman (1959) found that Cretaceous Inocerami were facies-tolerant and that they occurred both with fossils restricted to the shelf and in deep water. Wellman (1959) also found that Inoceramus and Aucellina sp. are the only shells which are commonly found in redeposited sediments. As fossils characteristic of shallow water are absent it is thought that deposition took place at a depth which was neither exceptionally shallow nor deep. ~~A sequence of events involving a period of emergence to form the granules, followed submergence to deposit fairly deep~~

~~water limestones, would be special pleading, and shallow water indicating molluscs would be expected to be retained along with the granules of spilite.~~ All means what ?

INTRUSIVES INTO TARARUA FORMATION

Small intrusions of a uniform greenish variolitic-textured dolerite are relatively common within the Tararua Formation. Often the dolerite occurs as narrow irregular stringers 1 - 2 inches thick. The thickest intrusion, 50 ft thick, is at Ngapuketerua Stream (grid ref. 022007), and dips 70° at 330°. The adjacent greywacke upstream of the intrusion appears to be metasomatised.

A sample of dolerite collected from the Mangahao River (grid ref. 067073) has been examined by Professor R.H. Clark who reports:- "This coarse-grained igneous rock consists mainly of cloudy plagioclase, principally oligoclase, perhaps the product of albitization. Augite is present, sub-ophitically enclosing small plagioclase crystals. Fairly abundant interstitial "chlorite" is present and there are patches of carbonate and a fibrous zeolite. The zeolite is length-fast with inclined extinction and is probably scolecite. Ilmenite and leucoxene are also present. The rock as it is at present could be called an oligoclase dolerite and it probably represents an altered teschenite."

McKay (1888) found that chertose quartzites, jasperoid and diabasic rocks appear on both flanks of the Tararua mountain system. It is thought that McKay's diabase rock may be ~~synonomous for~~ the dolerite of the mapped area. Reed (1957) makes no mention of dolerite in the Wellington area and presumably ~~these rocks are~~ dolerite is either rare or absent there. McKay (1888) also noted that a greater number than usual of igneous rocks were found in the bed of the Ruamahanga River.

Age of the intrusives

The thin stringers of dolerite, now representing the original teschenite, that closely follow the bedding within some of the greywackes were clearly intruded before the sediment was indurated and compacted. The intrusion of teschenite may have been synchronous with the deposition of Triassic-Jurassic sediments or alternatively the intrusion can, perhaps, be correlated with the teschenite intrusions at Ngahape, East Wairarapa. Teschenite rocks at Ngahape have been mapped by Brown (1943) and described by Hutton (1943). Wellman (1959) reviewing their work considered the teschenites to be Haumurian in age. If the Tararua Formation was not compacted and indurated before the Haumurian there would be a considerable period of time for the autoclastic breccias to form. If such a late period of induration and compaction of the greywacke is correct, it is likely that a thick sequence of Cretaceous rocks had been deposited above the Tararuas Formation during the Cretaceous and subsequently removed. A palaeogeographic map of the Cretaceous Period by Wellman (1959) suggests ~~indicates~~ however, that the western limit of the Cretaceous Geosyncline was about halfway between Tinui and Eketahuna. Wellman however, considers, "The original limits of Cretaceous sedimentation are not as well known in the North Island". It is not known if the intrusives are Triassic-Jurassic~~,~~ or Cretaceous ~~inage,~~ in age.

CASTLE FORMATION

Name and Subdivision

The formation is named after Castle Trigonometrical Station (Trig O), in the extreme southwestern part of the mapped area. The formation consists mainly of several thousands of feet of well indurated greywackes and argillite. No subdivision of the formation is established. The Castle Hill Fault, however, approximately separates two facies. North of the fault thick massive sandstones are more common than alternating sandstones and mudstones, while south of the fault the reverse is true.

Distribution and Stratigraphic Relations

The formation covers only about five square miles in the extreme southwestern part of the mapped area. It is reasonably well exposed along Te Hoe Stream and some of its tributary streams.

The relationship of the formation to the Tararua Formation of Jurassic-Triassic age is not known. It underlies the Ngarata Formation.

Content

Most of the alternating argillite and sandstone beds and bedded sandstones are inclined to the northwest at angles of 50° to 70°. In most localities it is usually not possible to determine whether the beds are overturned or not. Apart from pillow lavas no marker horizons have been found. Small scale folding observable in a single exposure is uncommon. The beds are less indurated and less shattered than those of the Tararua Formation.

Graded bedding and sole marks in the extreme southwestern part of the mapped area at grid ref. 426906 indicate that the beds there are not overturned. In this area features considered to be bedding planes are inclined in the same direction as the graded bed at grid ref. 426906; they have a fairly wide distribution which indicates that in this area the sequence generally youngs northwestwards. One-and-a-half miles to the northwest in a right branch of Te Hoe Stream (grid ref. 414929), well developed grading in a sequence of thin graded beds establishes that the beds are overturned. In a left branch tribuatory of the Te Hoe Stream (grid ref. 410896) a 10 ft sequence of thinly-bedded greywacke and argillite beds are gently folded, while overlying and underlying beds are not, the folding is considered to be intraformational.

In the area east of the intersection of the Ngarata Farm and Castle Hills Roads the B_2 Pillow Lava and Pods of B_2 Basalt and B_2 Jasper occur within the Castle Formation. At a cut along the Castle Hill road (grid ref. 427904) and in the nearby Te Hoe Stream the B_2 Pillow Lava (spilite) is about 15 ft thick and contains pillows about 2 ft long set in a grey argilite matrix. A half-a-mile to the east the B_2 Pillow Lava crops out in a 700 yard reach of a right branch tribuatory of Te Hoe Stream (grid ref. 443908). Between the two B_2 Pillow Lava outcrops at approximately the same stratigraphic horizon a 600 yard long elongate pod of massive chocolate brown coloured B_2 Basalt crops out 50 yards north of Te Hoe Stream. Other pods of B_2 Basalt with obscure relations to the adjacent greywacke occur along

Ngarata Road at grid ref 427019, where it has been quarried for road metal, and at the Southern margin of the mapped area at grid ref 426870. Three oval shaped pods of ~~Red~~ (B_3 Jasper) and greyish greenish chert each 100-400 yards long overlie the B_2 Pillow lava at grid ref 440910. The jaspers contain abundant radiolaria. ~~microfossils.~~

Four (50-100 yards in diameter) B_4 Sandstone Knolls occur in the northern part of the outcrop at grid refs. 421929, 438937, 439916 and 446926. The structure within the sandstone knolls indicated by bedding is much more complex than that in the nearby sediments. It is thought that much of this complication is due to slumping while the sediments were still soft. South-east of Ngarata Farm the B4 Sandstone ~~forming the Taitai Knoll~~ is tuffaceous.

Age and Correlation

The estimation of the age of unfossiliferous greywacke, such as the Castle Formation, is ~~rather subjective~~ not straight forward. Ongley (1935) placed the rocks of this formation in his Waewaepa Series (Jurassic) perhaps because Ongley and Dr Marwick had found the fossil "Buchia" at three localities east of the Tararua-Ruahine Ranges. Earlier annual reports by Ongley show that Buchia sp. was found in the Waewaepa Range and at Eketahuna (1931-32) in Makirikiri Stream, and west of Manawa Trig (1932-33). The "Buchia" sp. from Makiri Stream has been identified as Buchia cf. hochstetteri* which indicates a Puaroan Tithonian age.

* Fossil identifications and stratigraphic notes kindly supplied by Dr Charles Fleming.

~~While~~ The Buchia sp. from the Waewaepa Range is Malayomaorica aff. malayomaorica* ~~is~~, perhaps the same as Cheviot Hills specimens and an undescribed form from the Puaroan of Kawhia (Tithonian)*.

~~Stratigraphic considerations suggest that many thousands of feet of beds intervene between the fossiliferous Jurassic of Manawa Trig and the rocks of the Castle Formation. The Castle Formation~~ is probably of Taitai (Korangan) age.

Conditions of Deposition

The Castle Formation is considered to have been deposited from turbidity currents in deep water. Flute casts found at grid ref. 426906, indicate a direction of derivation of 120°, while a groove-cast found at grid ref. 413929 was derived from either ~~a bearing of~~ 25° ~~degrees~~ or ~~one of~~ 205°. ~~degrees~~.

Wellman (1959) has suggested an interesting mode of origin for the Taitai Sandstone (Taipos) in the Tapuwaeroa Valley. He considered the sandstone to be a redeposited unit which had sunk into ~~the then~~ uncompacted Mokoiwian Mudstone to accumulate as discontinuous lenses. After compaction and induration, differential erosion has exposed the sandstone lenses as isolated perched masses. Alternatively the sandstone knolls could be due to penecontemporaneous slumping during sedimentation. If the degree of disturbance is taken to classify slumped beds the B_4 Sandstone Knolls would be classified about mid-way between the incipient slump sheets mapped in Southwest Auckland at Kiritehere Point by Grant Mackie and Lowery (1964), and the Pre-consolidation slump beds of the Tararua Formation.

During the time that the pillow lavas were extruded on to the sea floor the massive chocolate-coloured pods of basalt were probably intruded into young wet sediment at a shallow depth. The association of jasper-chert beds ~~in the vicinity of~~ with lavas is a common feature of the Mesozoic Greywackes. During the volcanism large quantities of silica would be released into the sea, which would favour the biochemical deposition of ~~chert by masses of~~ radiolaria.

UPPER TERTIARY AND QUARTERNARY STRATIGRAPHY

NGARATA FORMATION (Not in Table 4) (p 38)

Name, type section and subdivision

The formation is named after Ngarata Farm at grid ref 446934 (see Figure 8). The section ~~exposed~~ along Te Hoe Stream west of Castle Hill is made the type section. The sequence comprises massive fine sandstone, overlain by siltstone and followed by mudstone. A thin basal conglomerate and a thin pumice ash, which locally delineate the base, and the top of the formation are not present in the type section. A local conglomerate within the upper part of the Sandstone is mapped west of the Alfredton Fault as a separate member. On the map the following members are distinguished.

C_5	Ash	(Top)
C_4	Mudstone	
C_3	Siltstone	
C_1	Sandstone $< C_2$ Conglomerate	(Bottom)

Distribution and Stratigraphic Relations

The Ngarata Formation crops out in the southeastern part of the mapped area, both north and west of Castle Hill, and also between the Alfredton and Martin faults near Alfredton.

Near Castle Hill the formation rests unconformably on well indurated and ~~non~~ [un]-weathered Castle Formation, ~~In this area~~ the out crop ~~of the formation is~~ [being] from a half to three-quarters of a mile wide. The basal contact is particularly well exposed in a right branch

Figure 8: Castle Formation: Foreground, Ngarata Farm; Centre, Hill Country composed of lightly indurated upper Tertiary sandstone, probably Ngarata C_1 Sandstone; Middle distance.

tributary of Te Hoe Stream.

South-west of Alfredton the base of the formation is not exposed but is thought to be not far below the ground surface.

The Ngarata Formation is overlain by the Te Hoe Turbidites.

Content and Thickness

C_1 Sandstone

At Castle Hill the following sequence is exposed: a thin basal sandy conglomerate, 3-5 ft thick containing many broken fossils, ~~and~~ at many places ~~is~~ cemented ~~with~~ by calcite, with well-rounded to subangular pebbles of greywacke are generally 1-2 inches long ~~and~~ that are thought to have been locally derived from the Castle Formation. Locally the basal conglomerate is absent. The overlying blue-grey massive sandstone locally contain concretions about a foot in diameter. The sandstone, fine-grained at the base, grades upwards into very fine sandstone at about 100 ft from the top of the member. In the thin sequence at Te Hoe Stream and at grid ref. 451952 (see Figure 9) 1-foot-thick calcite-cemented shell beds are present. At one locality, in a left branch tributary of Te Hoe Stream at grid ref 397914, the sandstone is laminated. Scattered fossils are common in the upper part of the sandstone. At one locality near the top of the C_1 Sandstone (at grid ref. 398921) well-rounded greywacke pebbles are present. Shells collected from fossil locality 543 are distorted, elongation being in a 020° ~~-200° plane~~ direction, indicating local compression at right angles ~~to this plane (110°-290°)~~.

At Alfredton the C_1 Sandstone is composed of massive brown-weathering fine sandstone with a few thin pebble horizons containing

Figure 9: Exposure of shell beds and sandstones of Ngarata C_1 Sandstone in large tributary of Tiraumea River at grid ref 451952 - Note beds dip 8° to south-west - normal fault, at left by hammer, ~~is~~ downthrow strata 34 inches to left (fault plane dips at 70° ~~to~~ at ~~bearing of~~ 052°) - At right a fault with a larger but unknown throw dips at 70° at a bearing of 210°.

well rounded one-inch-long pebbles. The sandstone at the horizon of the C_2 Conglomerate is coarser grained than the rest of the member. The base is not exposed.

C_2 Conglomerate

The C_2 Conglomerate lies near the top of the C_1 Sandstone, at two localities, (grid ref. 301914 and grid ref. 310928), on the extreme south-western and extreme north-eastern sectors of an anticlinal limb, which is cut near the axis by the Alfredton Fault. In the southwestern outcrop the conglomerate is up to twenty feet thick, and consists of well-rounded cobbles and pebbles and scattered lignite fragments. It has been worked for road metal in three small quarries (see Figure 10). In the easternmost quarry a horizon within the conglomerate contains *Glycimeris* cf. *monadusta*. The C_2 conglomerate at Alfredton occurs at about the same stratigraphic position as a pebble horizon in the C_1 Sandstone at Te Hoe Stream.

C_3 Siltstone

The C_3 Siltstone is blue-grey, sparsely fossiliferous, and muddy.

C_4 Mudstone

The C_4 Mudstone is generally a little darker blue than younger mudstone formations; this may be due to a lower ash content of the rock. Locally the mudstone is dark brown in colour. A few macro-fossils are found near the base of the mudstone. At fossil locality 577, *Limopsis lawsi* was found. Calcareous concretions are rare except near the base where spherical concretions about 9 inches in diameter occur locally.

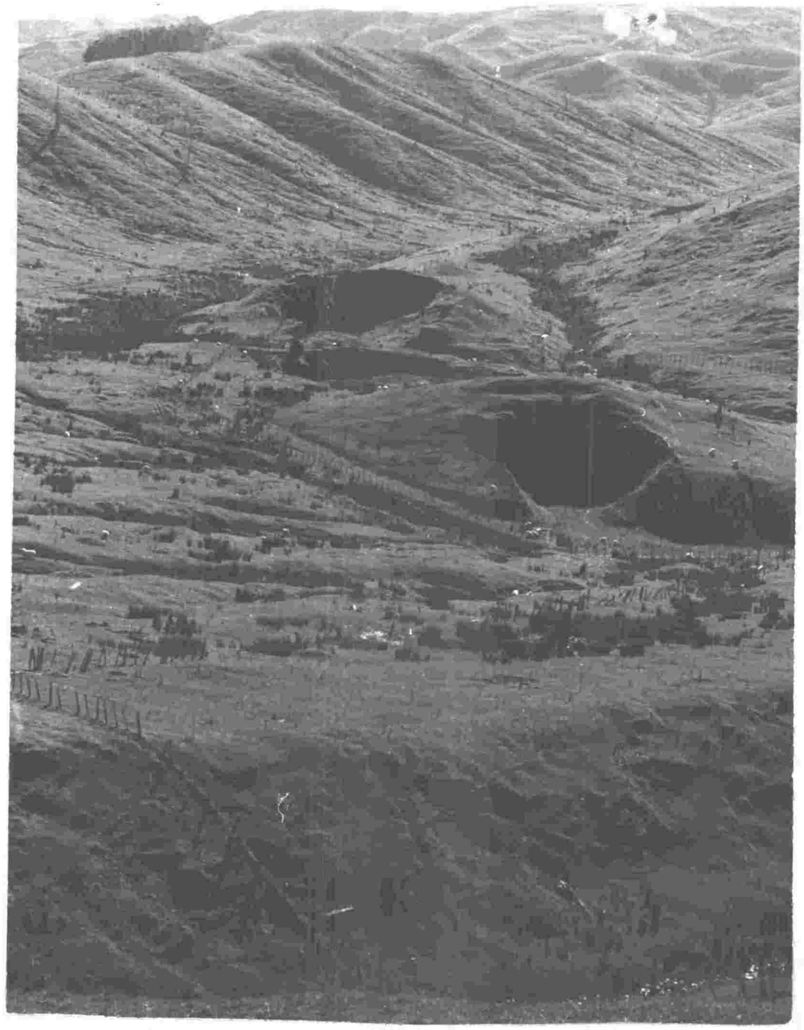


Figure 10: Foreground: Alfredton Fault Scarp, upthrow on northwest side. Centre: Quarries in Ngarata C_2 Conglomerate - at southern sector of anticlinal limb. Left background: Hill slope of Ngarata C_4 Mudstone.

C_5 Ash Bed

One hundred yards north of Trig 1071 a light grey pumiceous ash bed 6½ ft thick, contains well sorted very fine grained $^1/8^{th}$ - $^1/16^{th}$ mm quartz particles set in a very fine-grained off-white ~~coloured~~ matrix. Further south (grid ref. 384905) the ash bed is 8 ft thick and is finely laminated. The ash bed forms a distinct break of slope on the hillside, and can be easily ~~distinguished~~ seen on air photographs. ~~The feature~~ It was traced about a mile south of the mapped area to near Arnott Trig (N.Z.M.S. 1 N158 grid ref. 364877), but ~~The ash bed~~ does not occur north of Te Hoe Stream or at Alfredton.

Thickness Variations of the Members

East of the Alfredton Fault the C_1 Sandstone is thinnest at the type section; it thickens north-eastwards.

Te Hoe Stream	Section at grid ref. 419030	North of Ngarata Farm
c 285 feet	c 400 feet	c 480 feet

Further thickening of the C_1 Sandstone in a northeastward direction beyond the mapped area is probable; the upper Tertiary Sandstones presumably Tongaporutuan are very extensive there, (see Figure 8.)

West of the Alfredton Fault the C_1 Sandstone is at least 790 feet thick.

The C_3 Siltstone is usually about 120 ft thick. In the extreme eastern part of the mapped area, at grid ref. 447962, it thickens abruptly to about 480 ft across a north-northwesterly trending fault.

East of the Alfredton Fault the C_4 Mudstone is fairly uniform in thickness, In comparison ~~to~~ with the C_2 Sandstone there is only a slight increase in thickness in a north-east direction.

South Te Hoe Stream near Trig 1071	Happy Creek	Stream section near the Tiraumea River.
c 710 feet	c 860 feet	c 760 feet

West of the Alfredton Fault the C_4 Mudstone is about 1,300 ft thick.

Macropalaeontology and Correlation

Dell (1952) described a large Molluscan fauna from Hurupi Creek, which he considered to be approximately Tongaporutuan in age. He noted, that although most of the mollusca were common to Hurupi and the type area at Tongaporutu in Taranaki, ~~that~~ there were a few species endemic to either Hurupi or Taranaki. Mollusca from the C_1 Sandstone show a closer affinity to the ~~fauna~~ mollusca from Hurupi Creek than ~~these~~ ~~that~~ to those from Taranaki: apart from Kuia ~~cf.~~ cf. macdowelli fossils with affinities to those of Taranaki have not been found.

A single specimen of Architectonica (Discotectonica) platyplegia Dell is two and a half times greater in size, but otherwise identical to the single specimen found and described by Dell (1952). Dell's described specimen is probably a juvenile.

The genus Astrea is not commonly found fossil. The specimens from fossil localities 1105 and 1107 have spines on their periphery similar to A. stirps (see Laws 1952) but are smaller. ~~in size~~. The spines on the periphery are different than those of Astrea n.sp from Te Waewae Bay (see Fleming 1955). The specimens are ~~quite separate~~ distinct from A. ~~fimbriata~~ subfimbriata described by Suter (1917).

A stirps Laws

height	width	Height of spire
67 mm	75 mm	37 mm

A n. sp. aff stirps from the C_1 Sandstone

	height	width	height of spire
(1)	30 mm	32 mm	18 mm
(ii)	42 mm	38 mm	27 mm

The ash bed which Ongley (1935) mapped at the base of the Mapiri Formation, but could not find in the sheet district, is probably the C_5 ash bed. Ongley found that the ash is 10-20 ft thick in the Mangapakehe, Puketoi, and Aohange Survey Districts, about 8 miles east and south-east of the Southeastern corner of the sheet district. Fifty miles north-east of the mapped area, at Te Manuiri Road, Lillie (1953, p.49) mapped a band of white pumiceous ash at the base of the Mapiri Formation. Kear (1957) inferred a south-eastern volcanic source ~~of~~ for the ~~Tt-TK~~ pumice ash which he considered to be andesitic initially.

Conditions of Deposition

A thin sequence of C_1 Sandstone containing shell beds was deposited near Te Hoe Stream at a time when thicker massive beds were being deposited further north-east; this indicates that the Te Hoe Stream area was a local high which was more gradually inundated by Taranakian seas than that to the north-east. North-east of Te Hoe Stream the basal part of the formation contains massive fine sandstone with interbedded thin shell beds, which are thought to have been deposited in shallow water, equivalent in depth to the Zethalia Biofacies of Vella.

At the boundary between fine-sandstone and massive very-fine-sandstone, scattered molluscs of adult appearance, such as Struthiolaria praenuntia, Callusaria callosa and Alcithoe huruniensis occur. Fleming (1962b) has considered ~~that~~ the presence of extinct epifaunal Struthiolaria in Upper Southland rocks at Wainuioru, to indicate a depth of deposition of about 25 fathoms. Similar depths of deposition are likely for the upper part of the C_1 Sandstone.

The thick-shelled Glycimeris cf. monsadusta in the C_2 Conglomerate suggests that the conglomerate was deposited in very shallow water, perhaps at about low-tide mark. While lignite fragments in the C_2 Conglomerate at Alfredton indicate that a land mass with a cover of trees was nearby.

Scattered macrofossils in the C_3 Siltstone indicates that the siltstone was deposited in shallower water than the unfossiliferous Mangaoranga R_4 Siltstone, ~~where macrofossils are absent.~~

Macrofossils are not common in the C_4 Mudstones except near ~~the~~ its base. Many of the molluscs are Limopsis lawsi which Vella (1962a, p.36) considered to indicate deeper water than that usually preferred by molluscs. In the upper part of the mudstone mid-upper bathyal depths of deposition are indicated by foraminifera. The rolled Pseudechinus-like spines at fossil localities 966 and 971, indicate ~~that there were~~ bottom currents ~~present~~ capable of transporting very small particles. The absence of silt may be due to an absence of silt and sand available for transportation; generally widespread deep sea conditions are probable. Small local highs may have supported a hard bottom fauna including Pseudechinus (see Appendix 3).

The ash bed is thought to have been deposited from a ash fall. Graded beds, however, overlie the bed and the possibility that the bed is redeposited cannot be excluded.

TE HOE GROUP

The Te Hoe Group comprises the Te Hoe Turbidite and the Tiraumea Mudstone.

TE HOE TURBIDITE

Name and Type Section

The Te Hoe Turbidite is named after Te Hoe Stream, in which the type section is exposed. North-east of Te Hoe Stream part of the formation passes laterally into mudstone (Tiraumea Mudstone), ~~after the Tiraumea River~~

Distribution and Stratigraphic Relations

Most of the outcrop of the Te Hoe Turbidite is east of the Alfredton Fault, in a arcuate belt which lies north and west of the outcrop of the Ngarata Formation which it overlies. West of the Alfredton Fault, in the Mangatakoto Road area, the lower part of the formation, poorly exposed, crops out as an arcuate belt west of the Ngarata Formation. The upper parts of the Te Hoe Turbidite are poorly exposed north of the Hastwells Fault and along the crest of the Arakoa Anticline. The formation is overlain by the Eketahuna Mudstone.

Content

At Te Hoe Stream the basal 20 ft of the Te Hoe Turbidite is composed of alternating sandstone and mudstone beds, the sandstones ~~of which~~ are about one foot thick and the mudstones are up to eight feet thick. The overlying fifty feet of beds are obscured. Overlying the obscured beds there are 130 ft of strata containing sandstones ~~sandstones which are~~ up to 5 ft thick, interbeded with mudstones which are thinner than the sandstones. The sandstones have sharp contacts both at their bases and tops, and contain irregular ½-inch-long mudstone inclusions.

The middle and upper parts of the Te Hoe Turbidite consist of turbidites characterised by graded sandstones rarely more than 2 inches thick, while the mudstone fraction is on the average 1 ft thick. Flute casts and micro cross-bedding indicates that the turbidites flowed southwards. Mudstone beds 10-20 ft thick containing concretions, are common near the middle, and near the base of the formation.

The lower part of the formation is exposed halfway between Te Hoe Stream and the Tiraumea River at Happy Creek (grid ref. 425952). Some of the sandstone beds are graded, and all have sharp contacts with the underlying mudstones. One flute cast indicates that the turbidites flowed southwards. Further north east, just south of the Tiraumea River at grid ref. 445973, the basal Te Hoe Turbidite sequence is about 40 ft thick. The sandstones, often calcareous, are not well-graded and are frequently worm-bored. Flute casts were not observed, but the contact between the sandstone and the underlying mudstone is always sharp and irregular. One two-inch-thick shell bed containing many unbroken shells was found. North-east of Te Hoe Stream, the upper part of the Te Hoe Turbidite wedges out into the Tiraumea Mudstone which does however contain rare, 1 inch thick sandstone beds. In the upper part of the Te Hoe Turbidite, two sandstone beds, each about 8 ft thick, form distinctive horizons from near the 96 Fault to near Tiraumea (2) Trig. Between the marker sandstones some 220 ft of graded beds are present.

West of the Alfredton Fault the basal beds of the Te Hoe Turbidite are exposed at grid ref. 294909. The turbidites are composed of sandstones from 4 to 7 inches thick and mudstones from 26 to 52 inches thick. The gradation from sandstone to mudstone takes place within one inch. Many of the sandstones contain unusually large proportions of foraminifera and shell fragments, and commonly are conspicuously micro-cross-laminated. About four inches above the base three micro-cross laminations were measured in one bed showing directions of sediment derivations from 270° (2) and 350°. Other sandstone beds showed that they were derived from 250° and 325°. The mean of the five determinations suggests that the sediments were derived from a bearing of 290°. No flute casts were found.

North of the Mangamahoe Road the upper 300 ft of the formation is exposed at the crest of the Arakoa Anticline. Two light-grey pumiceous beds, 1 ft and 1 inch thick, are interbedded with the turbidites.

Thickness

The Te Hoe Turbidite is 1500 ft thick in the type section. Four miles north-east, in a section west of Tiraumea (2) Trig, the ~~sum of the~~ Tiraumea Mudstone and Te Hoe Turbidite formations ~~is~~ total 1,900 ft. Ten miles south-west of the type section a sequence of turbidites, probably of the same age as those of the type section, was considered by Orbell (1963) to be 3,000 ft thick.

Age

Prior to Kennett's (1966d) revision of the Tongaporutuan-Kapitean boundary in Wairarapa (see also Appendix 2) the Te Hoe Turbidite had been considered to be of Kapitean age a Kapitean age had been deduced by Vella (1963d) for the turbidites at Cleland Creek. The lower and middle parts of the Te Hoe Turbidite are now considered to be of Tongaporutuan age, and only the upper part to be Kapitean.

Conditions of deposition

The Ngarata C_5 Ash is restricted to an area south of Te Hoe Stream. It is considered that the Te Hoe Stream approximately marks the boundary between two provinces, one to the south of Te Hoe Stream where turbidity currents deposited material, and one to the north where turbidity currents were erosive picking up material, including the C_5 Ash from the sea floor.

The scattered lightly-indurated mudstone fragments in some of the thicker sandstone beds near the base of the formation indicates that not all of the material of the bed was thoroughly mixed prior to its deposition. The beds are thought to be turbidity current deposits rather than fluxoturbidites (which have been considered by Dzulynski et. al. (1959) to have been deposited by mechanisms transitional between suspension and slumping) but they are much closer to fluxo-turbidites than the rest of the Te Hoe Turbidite. It is thought that the sandstones containing the mudstone fragments were redeposited from areas close by.

The turbidites which overlie the fluxo-turbidites are characterised by thin sandstones and thick mudstones. They are thought to have been developed at the proximal part of the Tongaporutuan-Kapitean trench at a time when the sand fraction of the turbidity "cloud" was still being transported further south by the rapidly moving turbidity currents. The thick mudstone part of the graded beds is considered to be the muddy tail of the turbidity "cloud" which was deposited in fairly slowly moving water, perhaps hours or even days after the proximal part of the turbidity current had crossed the depositional area.

The gradual change from well-graded to imperceptibly-graded sandstone in a direction towards the source of the turbidity currents is thought to be due to deposition from slower moving and less turbid currents. A similar change from well-graded to less-well-graded interbedded sandstones and mudstones partly in the direction towards the source has also been noted and mapped in the Mahoenui Formation King Country near Tarnaranui by Glenie (1959 p.614).

Vella (1963d) found that the turbidites at Cleland Creek were deposited at depths "certainly greater than 2,000 ft, and probably between 4,000 - 6,000 ft". The graded beds of the Te Hoe Turbidite were deposited at the same time as those of Cleland Creek, and at about the same ~~order of~~ depth; and as gradients on the abyssal floor ~~are known to be~~ were very low. Vella (1963d) found that the turbidites at Cleland Creek ~~were~~ are somewhat thicker than those of at Te Hoe Stream: 3 ft ~~as to about~~ in contrast to 1 ft. Further the sandstone fractions ~~were~~ are usually thicker, 6 inches ~~as to about~~ in contrast to 2 inches.

The graded beds which crop out west of the Alfredton Fault at grid ref. 294909 are similar to the laminated beds described by Kingma

(1960 figure 3 p.208). It is thought that micro-cross-bedding and lamination in the upper part of the sandstone part of the graded bed is due to deposition from the tail of a turbidity cloud, which would be travelling at a slower rate.

TIRAUMEA MUDSTONE

Name and type section

The Tiraumea Mudstone is named after the Tiraumea River in which it is exposed in two bands separated by a wedge of Te Hoe Turbidite.

Distribution

Most of the formation is developed below the lower and middle wedges of Te Hoe Turbidite near the Tiraumea River. About a mile north east of Te Hoe Stream it wedges out into the Te Hoe Turbidite.

Content

The formation is a blue-grey mudstone; locally tabular concretions are not uncommon; sandstone beds about 2 inches thick are very rare.

Relations to other Formations

The Tiraumea Mudstone interdigitates with the Te Hoe Turbidite and is nowhere in contact with other formations.

Conditions of Deposition

It is not known if the mudstone is largely pelagic or if it was deposited from the tails of turbidity currents. The rare sandstone beds, and also its stratigraphic relation with the Te Hoe Turbidite indicate that some of the formation was redeposited.

SOREN GROUP

The group is named after Soren Trig, it is composed of two formations, and nine members. The members include; deep water mudstones, shallow-water-marine-conglomerates, sandstones and limestones, and non-marine conglomerates.

The formations and members of the Soren Group are listed below.

FORMATION	MEMBER	
KAIPARORO	S_4	Limestone
	S_3	Conglomerate
	S_2	Sandstone
	S_1	Siltstone
MANGAORANGA	R_5	Mudstone
	R_4	Siltstone
	R_3	Sandstone
	R_1	Conglomerate < R_2 Marl

The Soren Group is nowhere in contact with the contemporary Te Hoe Group at the surface. These groups are shown in cross section meeting at the Pleckville Fault which was either a active line of movement at the time of deposition causing rapid faces change, or has been subject to large transcurrent movement subsequent to the deposition of the groups.

MANGAORANGA FORMATION

Name and Type Section

The formation is named after Mangaoranga Stream, ~~which is~~ a right branch tributary of the Makakahi River. The section exposed along Mangaoranga Stream is made the type section.

Subdivision

At the type section, the conglomerate, sandstone, siltstone and mudstone members occur in upward sequence; at two localities lensoid bodies of varicoloured marl are present within the conglomerate member. In the Mangatainoka Valley the R_4 Siltstone and R_5 Mudstone Members are absent.

Distribution

The Mangaoranga Formation has two major areas of distribution: ~~in~~ a broad north-northeast trending belt from Kaiparoro, through the area of the type section to the Rongomai Valley; and ~~in~~ the Mangatainoka Valley upstream of Nireaha. Smaller outcrops ~~areas~~ occur west of Morgans Road, between the Falkner Road and Huru faults, and west of Kaiparoro.

Content

R_1 Conglomerate and R_2 Marl

The R_1 Conglomerate contains ~~marine and non-marine~~ well-rounded greywacke cobbles and pebbles. It is partly marine and partly non-marine. At the type section (Mangaoranga Stream) the R_1 Conglomerate is composed of the following:-

	Feet
Conglomerate and sandstone beds	240
Conglomerate	200
R_2 Marl (Green and red mottled marls)	120
Conglomerate	20
Basal Breccia	120

The basal Breccia is composed of well-sorted 3 inch-long angular greywacke fragments, which appear to have been derived locally from the underlying greywacke. The breccia passes up abruptly into the overlying conglomerates.

The R_2 Marl is largely a grey-green waxy clay with subordinate qualities of brownish red clay. Occasionally the grey-green clay is mottled brownish-red.

A typical section within the R_2 Marl at grid ref. 211967 contains:-

	Feet
Very-fine sandstone	1
Laminated grey clay and silt	1
Grey clay	1.75
Carbonaceous horizon	.2
Grey clay grading down into	5
Greyish-green silty-clay with some purple mottles	

Apart from the type section, the distribution of the R_2 Marl is restricted to a small outcrop along the Railway line at grid ref 194951.

Northeast of the Mangaoranga Stream at grid ref. 203969 the conglomerates overlying the R_2 Marl have failed and slipped ~~along~~ over the top of the marl. Near their base, the conglomerates are well rounded and contain boulders up to 18 inches long. Higher up in the sequence, the ~~maximum diameter of the~~ boulders ~~decreases to about~~ are not more than 9 inches long. The conglomerates are normally well sorted, and ~~there is usually little finer-grained material as a matrix.~~ closely packed. West of the Rongomai Valley a few sacks of lignite have been taken from near the base of the Conglomerate.

Near Kaiparoro in Bruce Stream a lensoid outcrop of breccia 500 yards long has been mapped as R_1. It has a maximum thickness of 120 ft and is composed of angular fragments of the underlying greywacke (Tararua Formation). The fragments are generally about a half an inch long with a maximum length of six inches. Lenses of grey silt and clay up to a foot thick occur near the contact with the overlying R_3 Sandstone. Local ~~ly~~ cross-bedding indicates that the breccia was derived from the east-southeast.

South-west of Kaiparoro, between the Falkner Road and Rongokokako faults, the formation contains many ~~large~~ boulders up to four ~~ft~~ long. The R_1 Conglomerate is ~~locally not developed~~ absent at places between ~~the~~ Huru and Rongokokako faults.

A tiny outcrop of partly indurated conglomerate, tentatively assigned to the R_1 Conglomerate, crops out in the Makakahi River west of the Huru Fault at grid ref. 091917. It contains boulders up to three feet long interbedded with cobble beds containing cobbles 9 inches long and thin coarse sandstone beds.

In the Mangatainoka Valley the R_1 Conglomerate is restricted to an area between Ngamaia Stream and the Wellington Fault. The conglomerate, partly cemented, is largely composed of well rounded boulders 2-3 feet long set in a coarse gravel matrix.

<u>R_3 Sandstone at Mangaoranga Stream (type section)</u>

The R_3 Sandstone in the Mangatainoka Valley, ~~is~~ younger than the R_3 Sandstone at Mangaoranga Stream; ~~it~~ is described separately.

At Mangaoranga Stream the contact between the R_3 Sandstone and R_1 Conglomerate is quite abrupt. At some localities however, including Tiratahi Stream, and along the Eketahuna Alfredton main highway, the contact is ~~more~~ gradational. Sandstone beds, 10-20 ft thick, ~~are~~ interbedded with conglomerate beds about 3 ft thick, ~~this~~ are overlain by ~~sequence grades upwards into~~ massive sandstones containing a ~~few~~ few pebble horizons.

A small section near the base of the R_3 Sandstone at grid ref 229981 contains:-

	Feet
Fine sandstone with rare pebbles	3.3
Pebble bed, pebbles 1 inch long	0.5
Fine sandstone	3.2
Pebble bed, pebbles 1 inch long	1.0
Fine sandstone	3.5
Conglomerate bed, cobbles 8 inches long	4.2
Fine sandstone	11
	BASE NOT SEEN

North-east of Mangaoranga Stream near Mt Hansen the upper 50 ft of the R_1 conglomerate, wedges out northeastwards into R_3 Sandstone.

At Mangaoranga Stream the lower 300 ft of the R_3 Sandstone is composed of massive fine-sandstone, and the upper 200 ft of very-fine-sandstone. The lower part of the fine sandstone is unfossiliferous. The upper part of the fine sandstone contains many broken and unbroken molluscan shells. Fossils in the very fine sandstone are scattered and unbroken. Spherical concretions 3-15 inches long are common near the top of the R_3 Sandstone. Near the top of the Sandstone at the base of a cliff on the right side of the Makakahi River (grid ref. 176947) many well preserved but unidentified plant stems and leaves occur.

West of Morgans Road and the Rongokokako Fault the R_3 Sandstone is very fine-grained, massive, and macrofossils are absent.

R_3 Sandstone in the Mangatainoka Valley

In the Mangatainoka Valley ~~the R_3 Sandstone contains a much more specialised macrofauna than the R_3 Sandstone at Mangaoranga Stream. Although macrofossils are quite common the number of species present is small.~~ the macrofauna is dominated by three large pelecypods; Glycimeris mahiana, Cucullaea cf. hamptoni; and Eucrassatella cf. ampla cf. marshalli. The lower part of the formation is particularly well exposed in a section along the left bank of the Makakahi River near the Putara School ~~at~~ (grid ref. 076985):-

	Feet
Sparsely fossiliferous very fine sandstone	c 100
Fossiliferous fine sandstone	c 125
Sandy shell beds composed entirely of Tawera. cf. marshalli.	c 30
Very-coarse sandstone grading down to a thin basal conglomerate	5

The upper part of the R_3 Sandstone is exposed in Davenports Creek (grid ref. 071986) where it is unfossiliferous. Northeast of the Putara School Section, the R_3 Sandstone not well exposed, and is similar to that near Putara School. At Ngamaia Stream the R_3 Sandstone is coarser than near the Putara School. It contains some thin granule and conglomerate beds and locally some scattered pebbles and cobbles. ~~are present~~. Southwest of Ngamaia Stream the sandstone is interbedded with thin conglomerates and grey carbonaceous clays (perhaps non marine). Sandstones containing Cardium sp. have, however, been reported (pers comm Mr G. Lensen).

R_4 Siltstone

The R_4 Siltstone is absent in the Mangatainoka Valley.

The R_4 Siltstone does not contain macrofossils. Stratigraphically it occurs between the R_3 Sandstone and the R_5 Mudstone. The contact between the R_3 Sandstone and R_4 Siltstone is quite abrupt. Locally at Kaipararo, grid ref. 147929, the R_4 Siltstone containing scattered fossils overlies the Tararua Formation at the site of a buried topographic high.

R_5 Mudstone

The R_5 Mudstone is absent in the Mangatainoka Valley.

The R_5 Mudstone overlies the R_4 Siltstone and underlies the S_1 Siltstone. Macrofossils are absent in the R_5 Mudstone. At the type section some silty horizons are present. Calcareous concretions are rare and ~~they~~ are often elongate. ~~in shape~~.

Yellow stained black ~~coloured~~ ash beds each about 2½ inches thick, were found about 330 ft and 120 ft below the top of the R_5 Mudstone, at ~~along the banks of the~~ Makakahi River (grid ref. 184961) and at Mangaoranga Stream (grid ref. 201982).

Relation to underlying strata

The Soren Group is unconformable on the Tararua Formation. East of the Mangatainoka Valley a landscape of moderate relief had been cut into the Tararua Formation prior to the deposition of the R_1 Conglomerate and R_3 Sandstone; perhaps in Lower-mid Tongaporutuan time. The R_1 Conglomerate was deposited in the hollows ~~topographic lows of~~ the landscape and ~~while~~ the overlying R_3 sandstone was ~~partly~~ deposited partly on the conglomerate and partly on the greywacke. ~~further up the hillsides of the buried landscape~~.

Near Putara on the right bank of the Mangataihoka River (grid ref. 094996) a 20 ft high pinnacle of greywacke crops out on ~~along~~ the surface ~~plane~~ of the unconformity. It is considered to have been sculptured as a sea stack during the Upper Tongaporutuan marine transgression.

Thickness

Due to the irregular nature of the unconformity beneath the Soren Group east of the Mangatainoka Valley, the thicknesses of the R_1

Conglomerate is very variable. Maximum thicknesses are listed below:-

WEST		EAST
At Putara between Ngamaia Stream and Wellington Fault	Southwest of Kaiparoro, between Rongokokako and Falkner Rd faults	Type section at Mangaoranga Stream
400 ft	330 ft	700 ft

East of the Huru Fault the R_3 Sandstone is variable in thickness. It is thickest in areas which were topographic lows in the Lower-Mid Tongaporutuan landscape. Locally at Kaipararo (grid ref 149930) it is absent.

SOUTH WEST				NORTH EAST
Bruce Stream	Near Soren Trig	Mangaoranga Stream	Near Fernhill Farm Grid ref 233005	Central Mangaone Road
90 ft	270 ft	480 ft	500 ft	320 ft

In the Mangatainoka Valley the R_3 Sandstone is much more uniform in thickness. The formation is thickest northeast of Putara School and thins south-westwards.

SOUTH WEST		NORTH EAST
Ngamaia Stream	Putara School	grid ref 094995
400 ft	510 ft	540 ft

The R_4 Siltstone and the R_5 Mudstone are very uniform in thickness, the R_4 Siltstone being about 100 ft thick and the R_5 Mudstone about 800 ft thick.

Macropalaeontology

Macrofossils are restricted to the R_3 Sandstone. The fauna from the Mangaoranga area differs somewhat ~~in content~~ from that from ~~fauna at~~ Putara. The faunas are listed separately, (See Table 6 and Table 7).

Age and Correlation

The R_3 Sandstone is ~~thought to be~~ diachronous, being older at Mangaoranga Stream where the overlying R_4 Siltstone and R_5 Mudstone are developed, than at Putara where the R_4 Siltstone and R_5 Mudstone members are absent. This ~~contention has been~~ is confirmed by Kennett (1966d) who found that the foraminifera ~~contained in the R_3 Sandstone at~~ from Putara ~~were~~ are significantly younger than those from Mangaoranga Stream. The macrofauna of the R_3 Sandstone (east of the Huru Fault) contains some species which ~~also~~ occur in the Hurupi fauna, such as Callusaria callosa, but many ~~others~~ that are absent from the Hurupi fauna. ~~The macrofaunal assemblage is distinct from the Hurupi fauna.~~

Table 6

MACROFAUNA OF THE R_3 SANDSTONE EAST OF THE HURU FAULT

	539	894	897	911	920	921	1065	1127
Struthiolaria praenuntia Marwick	X		X	X		X	X	
S. nana (Marwick)						X		
Struthiolaria. sp.		X		X				
Struthiolaria (Callusaria) callosa Marwick		X						
S. (Callusaria) obesa (Hutton)	X				X			
Sigapatella. sp.						X		
Mariocrypta. sp.		X						
Austrofusus pagoda Finlay				X		X		
Cominella (Acominia) cf. hendersoni Marwick						X		
Alcithoe cf. solida Marwick				X				
Spinemelon. sp.	X			X				
Baryspira. sp.				X		X		
Murexsul espinosus (Hutton)						X		
Austrotoma hurupiensis Dell						X		
Zeacuminia murdochi Powell		X						
Vermicularia sipho	X			X				
Vexillitra. aff. marwicki Vella					X			
Cucullaea. sp. aff. hamptoni Marwick		X						
Pteromyrtea dispar (Hutton)						X		
Sectipecten grangei Boreham	X			X				
Pleuromeris. sp.				X				
Eucrassatella. cf. marshalli (Powell) cf. ampla (Zittel)								X
Dosinia (Dosinia) lambata (Gould)	X					X		

	539	894	897	911	920	921	1065	1127
D. (*Kereia*) *cottoni* Marwick				X				
Kuia singularis Marwick	X	X						
Eumarcia (*Atamarcia*) aff. *benhami* Marwick								X
Gari lineolata Gray	X			X				
Tellina n.sp. aff. *gaimardi* (Iredale)	X					X		
Panopea zelandica (Q & G)						X		
Zenatia acinaces (Q & G)	X			X		X		
Dentalium sp.				X				
Plathelia distans (Tension Woods)				X				X
Vertebrae of a Whale		X						

Table 7

MACROFAUNA OF THE R_3 SANDSTONE IN THE MANGATAINOKA VALLEY

	828	829	831	898	1033
Struthiolaria sp.					X
Callusaria obesa (Hutton)					X
Penion crawfordi (Hutton)			X		
Penion sp.			X		
Zegalarus aff tenius (Gray)				X	
Glycimeris (*Manaia*) *manaiensis* Marwick			X		
Glycimeris mahiana Marwick			X		
Cucullaea cf. *hamptoni* Marwick		X	X		
Mesopeplum sp.		X			
Sectipecten grangei Borham		X	X		
Ostrea sinuata LK	X			X	
Dosinia lambata (Gould)				X	
Tawera cf. *marshalli* Marwick			X		
Eucrassatella cf. *ampla* (Zettel) cf. *marshalli* (Powell)	X	X	X		
Balanus. sp.				X	
Brachiopod. sp.			X		

At Putara *Cucullaea* n. sp. aff. *hamptoni*, and *Sectipecten grangei* show that the R_3 Sandstone is pre-Opoitian, and probably upper Tongaporutuan in age.

The 70 ft-thick limestone and the 69 ft-thick gritty mudstone found near the bottom of the Tane Bore (see Cross section K-L), are ~~can~~ probably part of ~~be attributed to~~ the Mangaoranga Formation.

~~Also~~ Orbell (1962) described a Tongaporutuan succession North of Mauriceville, which is similar in content and stratigraphic position to that found at Mangaoranga Stream.

McGovern's Stream Section (Orbell, 1962)

	Feet
Greenish-blue-grey mudstone	550
Cemented fossiliferous sandstone	10
Greywacke conglomerate	5
Greenish-blue freshwater mudstone	200
Carbonaceous shale grading to impure coal	2
Greywacke conglomerate resting unconformably on greywacke	10

Mangaoranga Stream

	Feet
R_5 Mudstone	800
R_4 Siltstone	50
R_3 Sandstone	480
R_1 Conglomerate and sandstone	400
R_2 Marl	120
R_1 Conglomerate	20
Basal breccia	120

Conditions of Deposition

A relief of about 1,200 ft was present in the south-western part of the mapped area between Mangaoranga Stream and Kaiparoro prior to the accumulation of the Mid-Tongaporutuan Strata. At first deposition of sediments almost kept pace with down-warping; first non-marine, and then shallow-water marine sediments were deposited. Later downwarping was more rapid than the accumulation of sediment and pelagic muds accumulated in deep water.

The basal breccia at Mangaranga Stream indicates that a climate favouring physical, rather than chemical weathering predominated. The R_2 Marls were probably deposited in the abandoned meanders of a Tongapourutuan water course. Mcintyre in Orbell (1962) found that a carbonaceous shale, which occurs near the base of the Tertiary strata near Mauriceville at McGoverns Stream and which is thought to be equivalent to the R_2 Marl, contains a diversified flora from cold and warm environments. The diversified flora is likely to ~~be due~~ elevated land mass to the south-west.

Kennett (1966d) studied the marine microfaunas of the Mangaoranga section, and was able to recognise the biofaces zones; listed below:-

Member	Biofacies	Assumed depth below sea level in feet
Eketahuna Mudstone	Karreriella	1,000 ± 100
S_1 Siltstone	Haeuslerella	600 ± 300
R_5 Mudstone	Robulus	2,000 ± 1000
	Karreriella	1,000 ± 100
R_4 Siltstone	Haeuslerella	600 ± 300
R_3 Sandstone	Elphidium	200 ± 100
R_1 Conglomerate (Upper)	Zeaflorilus	0 ± 20
R_1 Conglomerate (Lower)	Non-marine ?	

Southwestwards from the type area at Mangaoranga Stream the R_3 sandstone onlaps on to the greywacke undermass. The ~~plane of the~~ unconformity is dominated by two ~~planed,~~ wave-cut ~~surfaces~~, some 90 ft and 280 ft below the top of the R_3 Sandstone, this indicates that on two occasions the relationship of sea level to the depositional surface was not changing.

The conglomerate-breccia at Kaiparoro, located on the south-western slope of an Upper Tongaporutuan topographic high, is considered to have been deposited as submarine talus material at a time when the R_3 Sandstone was deposited nearby.

It is thought that the R_4 Siltstone was deposited at greater depths than the Ngarata C_3 Siltstone because although macrofossils are present locally in the C_3 Siltstone, they have not been found in the R_4 Siltstone. A rapid increase in depth of deposition is indicated in late R_3 time. At a period during late R_4 or early R_5 time the coral Plathelia distans lived on top of the submerged stack at Kaiparoro.

In the Mangaoranga Stream section, Kennett (1966d) has shown that most of the R_5 Mudstone was deposited within the Robulus Biofacies. New species of foraminifera have been described by Vella (1963a) from fossil localities 910 & 896 in the R_5 Mudstone, (see also fossil locality 1006). The ecologic ranges of the new species differ in detail but are of the same order of depth as those described by Kennett (1966d) from the Mangaoranga Stream section. The R_5 Mudstone does not demonstrate the shallowing in the southwestward direction shown by the overlying S_2 Sandstone.

In contrast to the R_3 Sandstone east of the Huru Fault the R_3 Sandstone in the Mangataiuoka Valley overlies only one, rather than two placed surfaces. Perhaps down-warping was less rapid in mid-to-late-Tongaporutuan time than in mid-Tongaporutuan time; locally sea stacks had resisted marine plantation.

The increase of grain size of the sandstone south-westwards, and the location of conglomerates and non-marine carbonaceous clay beds west of Ngamaia Stream, indicates that the upper Tongaporutuan shoreline was generally near and parallel to Ngamaia Stream.

The number of fossils found in the Sandstone is large in number of specimens, but small in number of species. The bulk of the fauna is composed of ~~specimens of~~ Glycimeris mahiana, Cucullaea cf. hamptoni and Eucrassatella cf. ampla, cf. marshalli. Other fossils are very rare. The small number of species present is probably due to some special condition such as reduced salinity. Depth analysis of foraminifera by Drs P. Vella and J. Kennett indicates shallow-water deposition. Kennett (1966d) considered that much of the R_2 Sandstone at Putara was deposited near the overlap of the Elphidium and Haeuslerella biofacies (about 200 ft).

KAIPARORO FORMATION

Name and Subdivision

The formation is named after the small settlement of Kaiparoro, at the north end of Mount Bruce.

The formation is composed of four members, which were deposited at about the same time in separate localities on the southwestern part of the mapped area. At Kaiparoro two members, the S_2 Sandstone

Figure 11: Airview north-eastwards to Kaiparoro mid-background, from near the Saddle on the Masterton-Woodville State Highway. Middle distance left, features made by S_4 Limestone and the base of the S_2 Sandstone. Middle distance right bush-clad slope of Tararua Formation approximately delineates the plane of the unconformity beneath the R_3 Sandstone.

and the S_4 Limestone occur in succession. The S_2 Sandstone extends north-eastwards from Kaiparoro for several miles and near Mangaoranga Stream it wedges out into the S_1 Siltstone. The S_3 Conglomerate is restricted to the Mangatainoka Valley at Ngamaia Stream, and to west of Morgans Road.

The members both underlie and overlie formations which were deposited in deeper water. Each of the members is less than one hundred feet thick. The following members are distinguished.

WEST		EAST
NGAMAIA STREAM AND MORGANS ROAD	KAIPARORO	EKETAHUNA
	S_4 Limestone	
S_3 Conglomerate	S_2 Sandstone	S_1 Siltstone

Distribution and Stratigraphic Relations

The S_2 Sandstone and its lateral equivalent the S_1 Siltstone overlie the R_5 Mudstone along a belt from Kaiparoro to the Central Mangaone Road. The S_2 Sandstone wedges relatively abruptly into the S_1 Siltstone in the vicinity of Mangaoranga Stream. The basal contact of the S_2 Sandstone forms a subdued bedding plane feature below thatof the S_4 Limestone along the east flank of the Kaiparoro Syncline (see Figure 11). The S_2 Sandstone is best exposed along the Makakahi River. It is also exposed along the railway line at grid ref 192973 (fossil locality 483). Between grid ref 192973 and the Central Mangaone Road the formation crops out in hill country of low relief. The Eketahuna Mudstone abruptly overlies the S_4 Limestone, the S_2 Sandstone, and the S_1 Siltstone. The S_3 Conglomerate is restricted to two small outcrops at Ngamaia Stream, and west of Morgans Road. It overlies the R_3 Sandstone at both localities. At Ngamaia Stream the S_3 Conglomerate is overlain by the Atea Sandstone, at Morgans Road it is overlain by the Saunders Siltstone.

Content and Thickness

S_2 Sandstone and the S_1 Siltstone

The S_2 Sandstone and S_1 Siltstone are each about 80 ft thick; the sandstone wedges out abruptly into the siltstone near Mangaoranga Stream.

The S_2 Sandstone is very fine-grained and commonly contains many large, almost spherical concretions about 3 ft in diameter. In the Eketahuna area the distribution of the S_2 Sandstone and to a lesser extent the S_1 Siltstone is indicated by the spherical concretions lying on the ground surface, especially on gentle dip slopes.

South-west of Kaiparoro, at grid ref. 114905, moulds of the fossils *Cucullaea* sp, *Dosinia* sp, *Diavarcella* sp, and *Notocorbula* sp, occur; northeastwards the only common macrofossil is the brachiopod *Neothyris* cf *ovalis** Hutton. *Neothyris* cf. *ovalis* is fairly common at fossil localities 483, 912, 1007 and 1009. One specimen of *Limea*? n. sp. was found (by Ongley) at fossil locality 483. At Mangaoranga Stream (grid ref. 201983) which is situated near the facies change from S_2 Sandstone to S_1 Siltstone only one specimen

* *Neothyris* cf. *ovalis* and *Limea*? n. sp. were kindly identified by Mr P.A. Maxwell.

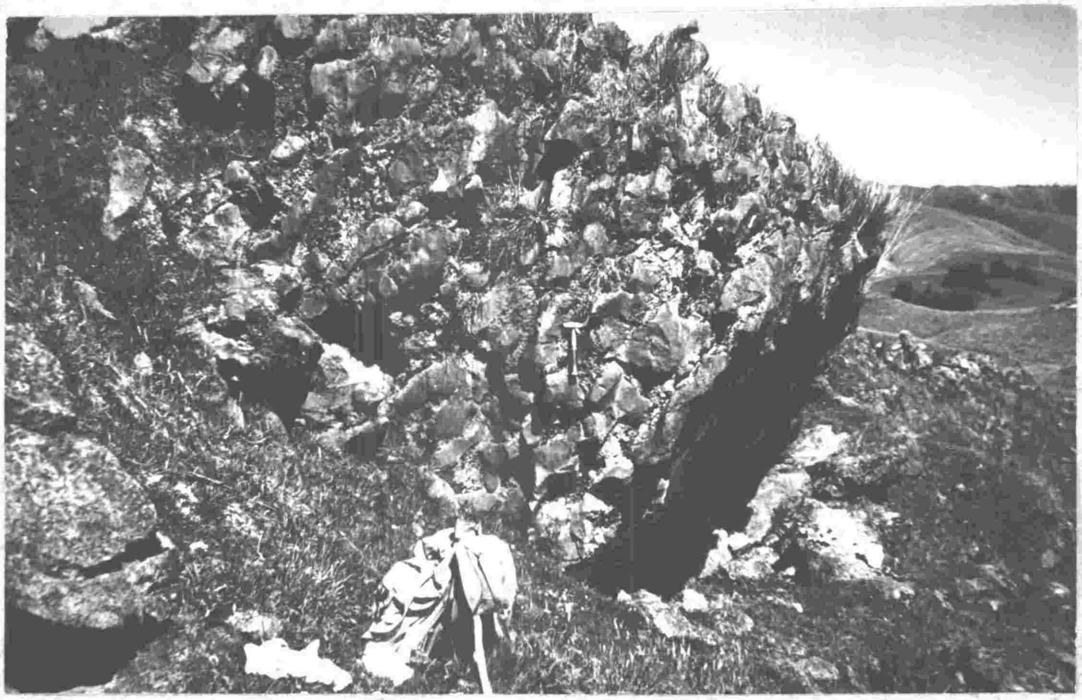


Figure 12: S_4 Limestone at grid ref. 113908, bedding inclined at 50°, contact with S_2 Sandstone bottom right. Note irregular "lumpy" bedding.

of *Neothyris* cf. *ovalis* was found. Although the facies change is fairly abrupt, some six feet of fine sandstone is interbedded with the S_1 Siltstone in the vicinity of Mount Turner. The S_1 Siltstone thins to the north east and does not crop out north of the Central Mangaone Road.

S_4 Limestone

The coquinoid S_4 Limestone is composed almost entirely of light-grey, well-sorted, and well-rounded fragments of limestone. ~~Fragments of mollusca and brachiopoda are largely absent,~~ The fossil fragments are considered to be entirely algal. One *Sectipecten diffluxus* was found at grid ref (113908). The size of the fragments and the thickness of the Limestone are directly related to the distance from the Faulkner Road Fault (see Figure 13). At Cavelands Farm (grid ref 126914) a 1 inch thick shell bed occurs at the base of the limestone. Locally the base of the Limestone is sandy and glauconitic. Northeast of Cavelands Farm (near grid ref 126914) the limestone wedges out abruptly into the upper part of the S_2 Sandstone. It is absent at Onepu Farm.

Professor R.H. Clark reports the S_4 Limestone from grid ref 126914 to be a "fine-grained shelly limestone with abundant small fossils. Calcite is ~~mainly present and~~ dominant, other minerals include glauconite, quartz, plagioclase, and iron ore. Occasional rock fragments include argillite."

The S_4 Limestone is 34 ft thick on the west flank of the Kaiparoro Syncline near the Faulkner Road Fault, ~~it is~~ and only 12 ft thick on the east flank near Cavelands Farm.

Locally, near Cavelands Farm, sink holes are developed where the Eketahuna Mudstone overlying the S_4 Limestone is a few tens of feet thick. Most of the sink holes mark the position of caves below, access to one cave is by a stream which emerges ~~from underground~~, near Cavelands Farm.

Close to the Faulkner Road Fault on the west flank of the syncline at grid ref. 113913 the limestone is overturned. The overturning ~~of the limb,~~ is due to gravity-collapse. In south east Persia such superficial structures have been described and classified by Harrison and Falcon (1934) see also Hills (1963, p.342). They described a sequence of collapse structures on the limbs of folds which they classified with regard to the degree of collapse; according to them the overturned limb at grid ref. 113913 is a "Flap".

<u>S_3 Conglomerate</u>

At Ngamaia Stream (grid ref. 046965) the Conglomerate is 40 ft thick. It is composed of well rounded greywacke boulders which are commonly 2-3 ft in diameter. The contact with the underlying R_3 Sandstone is abrupt.

West of the Morgan Road at grid ref. 114938 the S_3 Conglomerate is 25 ft thick, unfossiliferous, and ~~S_3 Conglomerate~~ is composed of well rounded cobbles and pebbles ¼ to 4 inches long set in a matrix of fine loose sandstone. North of this locality the conglomerate is better sorted and rounded, the pebbles which form 50 per cent of the rock are between a ¼ and ½ inch long ~~the~~ and are set in a matrix ~~is a~~ of very coarse sandstone. Northwards at grid ref. 118951 the conglomerate is 12 feet thick, and is cemented with a brown-stained calcite. Fragments of fossils especially Pecten. sp. and Cardium. sp. are common ~~especially~~ near the base.

Age and Correlation

A Miocene period of deposition of the S_2 Sandstone is indicated by Cucullaea sp. which became extinct in New Zealand in late Miocene time.

Foraminifera examined by Vella indicate that the S_2 Sandstone, and S_1 Siltstone are Kapitean in age; this ~~contention~~ has been confirmed by Kennett (1966d). Kennett ~~also~~ considered that the Kapitean Stage is absent ~~in~~ from the Mangatainoka Valley, and ~~he~~ considered ~~that~~ the S_3 Conglomerate to be of Opoitian age. He had, however, no evidence to support this contention. The writer considers that the S_3 Conglomerate is ~~to be correlated with the other members of the~~ part of the Kaipararo Formation, rather than ~~with the~~ part of the Eketahuna Group, largely because the Conglomerate west of Morgan Road is intermediate in character between the S_3 Conglomerate at Ngamaia Stream and the S_4 Limestone, at Kaiparoro.

Foraminifera from the Mangaoranga Stream section examined by Kennett (1966d) show that a temporary shallowing of about 400 ft occured during the deposition of the S_2 Sandstone. In the eastern part of the mapped area the Kapitean Strata were deposited in water several thousands of feet deep and fluctuation of a few hundreds of feet are unlikely to have affected the kind of sediment deposited, and shallowing of this order would not ~~be noticed~~. affect sediments deposited.

The shallowing in the western part of the mapped area could be due to: ~~one of the following~~: a eustatic drop of sea-level caused by an ice age; a temporary epeirogenic rising of a number of fault blocks; or ~~that~~ to sedimentation being ~~had been~~ faster than downwarping. Of these three possibilities the ~~former~~ first is favoured.

Faunal evidence of cooling at about the time of the Kapitean is quite strong. The warm-water-indicating genus Cucullaea became extinct in New Zealand at this time, and is now restricted to warmer water in Australia. Kennett (1966b) has suggested that the most important change in the Globorotalia crassaformis bioseries is the loss of a peripheral keel. This is important as Kennett quotes Bandy (1964) as reporting that keeled Globorotalias are restricted to waters warmer than 17°C while non-keeled Globorotalias are restricted to waters warmer than 9°C. Presumably a Kapitean period of cooling could have induced keeled Globorotalias to become non-keeled.

Previously van der Hammen (1957, p.74) showed that the entrance of new species and the extinction of old species of Maestrichtian to Miocene floras had a periodicity of 2 and six million years. In his diagram (figure 5, p.74), he predicted a temperature decrease at the Miocene-Pliocene boundary. There is good agreement between van der Hammen's six year cycles, or multiples of them, and the boundaries of the Tertiary ~~systems~~ divisions.

Outside the mapped area, temporary shallowing during the Kapitean has been noted by Kennett (1966a) in two sections in the Awatere Valley; but not at the type section itself ~~of the Kapitean~~ at Kapitea Creek (see Kennett 1966c). Graham Jenkins (1965), however, found that in many localities in Italy an unconformity separates beds equivalent to the Kapitean of New Zealand, ~~to~~ beds equivalent to the Opoitian of New Zealand.

It is possible therefore that the temporary falling of sea-level during the Kapitean may have been due to the growth of continental ice caps with an ~~convergent~~ shift of temperature belts in the oceans.

If so the Kapitean stage as defined by Kennett (1966d) may be partly time transgressive, being longer in Westland and Marlborough where cold waters are thought to have persisted for a longer period of time, and shorter in the northern Wairarapa where the ~~incursion~~ of cold water ~~was~~ likely to have been more brief. The alternative which has been ~~indicated~~ by Kennett (1966b) is that sedimentation rates were slower over much of the southern part of the North Island, than ~~these current~~ in much of the South Island.

~~The conclusion to be drawn from these considerations, is, perhaps,~~ ~~that~~ the Kapitean Stage is unsatisfactory as a time-indicating unit for the whole of New Zealand. It is rather a biozone dependant on facies, notably water temperature, useful locally in a stratigraphic sense but probably indicating a different time interval in different areas.

Conditions of Deposition

Because of the uniform thickness of the S_2 Sandstone and S_1 Siltstone and because the strike of the Kaiparoro Formation is parallel to the underlying Mangaoranga Formation, it is considered that there was only a small gradient on the sea bottom during the deposition of the S_2 Sandstone. Kennett (1966d) found that the S_1 Siltstone at Mangaoranga Stream was deposited within the Haeuslerella biofacies 600 ft ± 300 ft. Stride (1963) has shown that such a depth is about the lower limit that bottom currents can sweep sand along the sea bottom of the English Channel at present. It is thought that the S_2 Sandstone and S_1 Siltstone may have been deposited from sand waves which moved along the sea bottom by tidal streaming; It is further thought that much of Waipipian-Nukumaruan strata in the mapped area was ~~also~~ deposited in this way. Further, Dr P. Vella invariably found an association of foraminifera indicating medium depths c.50 - 100 fathoms, and neritic foraminifera in the samples. Deepish water foraminifera would have lived on the sea floor within the depositional area while neritic foraminifera are thought to have been transported into the area from nearby areas of shallow water.

A southwestward shallowing of the S_2 Sandstone is indicated by the present of Molluscan macrofossils at Kaiparoro grid ref. 115905, and their absence further northeast; and by the distribution of the S_4 Limestone.

The depth preferred by the brachiopod Neothyris cf. ovalis is from lower neritic, to a lower limit within the Haeuslerella biofacies.

Abrupt thinning and a decrease in the size of algal fragments of the S_4 Limestone in a direction normal to the Faulkner Road Fault, indicates that an algal reef was located a short distance west of the depositional area, at the time when the Limestone was deposited (see

Figure 13). The fine grained sediments found above and below the S_4 Limestone indicate that the shallow-water algal material was washed into relatively deep-water. Faulting along the Faulkner Road Fault is thought to have produced an environment suitable for the development of the Reef on the upthrow side, while on the downthrow side, detritus from the Reef accumulated, to form the S_4 Limestone.

The coarseness of the S_3 Conglomerate, and the presence locally of many broken macrofossils indicates deposition occured in very shallow water. Both at Putara and Morgans Road there is an apparent south-westward shallowing.

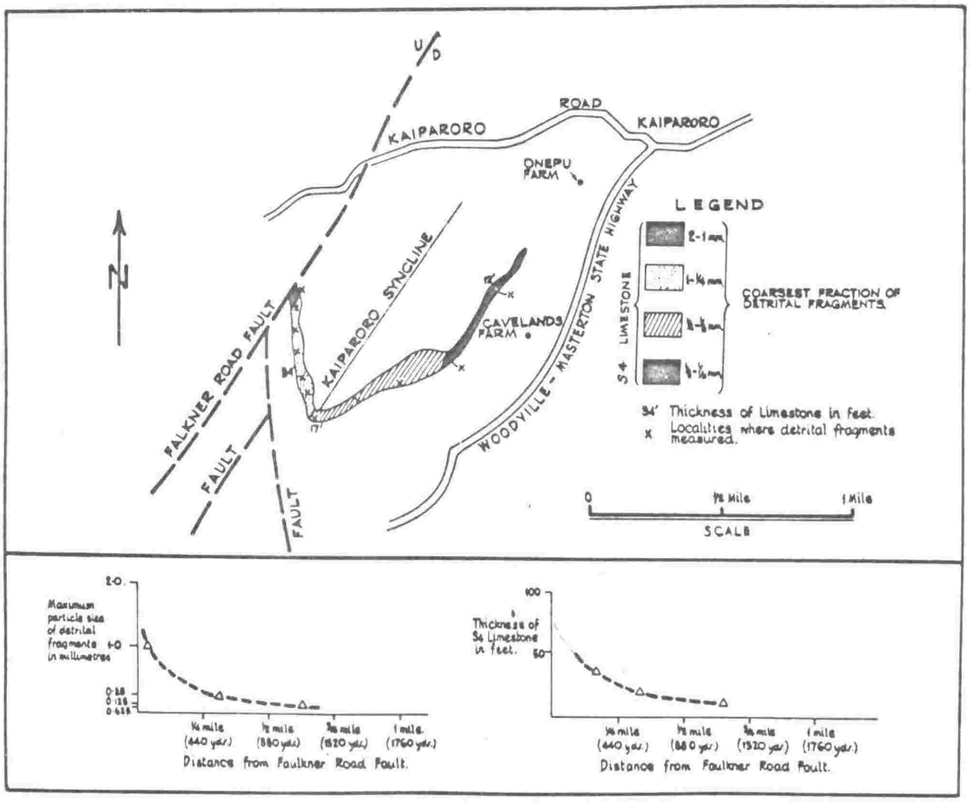


FIG. 13 OUTCROP DISTRIBUTION OF THE S4 LIMESTONE.

EKETAHUNA GROUP

The group is named after the Eketahuna Settlement. At the type locality at Eketahuna, the sequence comprises a mudstone, overlain by turbidite beds, and followed by a bedded sandstone and a massive siltstone. In the Mangatainoka Valley at Putara a fossiliferous sandstone forms the basal part of the sequence which is overlain by massive siltstone; the ~~latter~~ siltstone is well developed in the northern and eastern parts of the mapped area. In the northern, eastern and central parts of the mapped area massive sandstones form the upper part of the sequence. On the map the following formations are distinguished:

TANE SANDSTONE

NEWMAN SILTSTONE

TAWATIA SANDSTONE

EKETAHUNA TURBIDITE

EKETAHUNA MUDSTONE

SAUNDERS SILTSTONE

ATEA SANDSTONE

The group cannot be subdivided by microfossils or macrofossils; mollusca are rare except in the Atea Sandstone. The rapidity of Opoitian sedimentation in the mapped area makes it doubtful whether further study of microfossils will enable the group to be subdivided in greater detail than has been possible by lithology. (See Chapter III, formations versus zones for local Upper Tertiary - Lower Pleistocene Correlation).

The group has a very extensive distribution within the sheet district, about half of the area east of the Wellington Fault ~~lie~~ being underlain by formations of the group. In the southern part of the mapped area, the group is generally the youngest Upper Tertiary Strata present, and generally the group crops out east of the major north-northeast trending faults, on the downthrow side. In the northern part of the mapped area, where the Makuri and Mangamaire groups are present, the group is invariably the oldest exposed ~~group which is not subsurface. In this area, formations of the group~~ (and is ~~are~~ found on the upthrow side of the major north-northeast trending faults.

It is inferred that the Eketahuna Group was deposited at the axis and sides of a 20-mile-wide, north-northeast-trending Eketahuna Trough, which locally was up to 5,000 ft deep.

The formations of the group have been delineated and mapped by considerations of grain size, and the interrelationship of the formations have been summarised previously by Neef (1964). (See Figure 14).

The depositional history of the group can be subdivided into two periods; an early period, during which the deposition of sediment was less, or no more rapid than downwarping of the Eketahuna Trough; and a later period when deposition of sediment was largely more rapid than downwarping, and the trough was infilled.

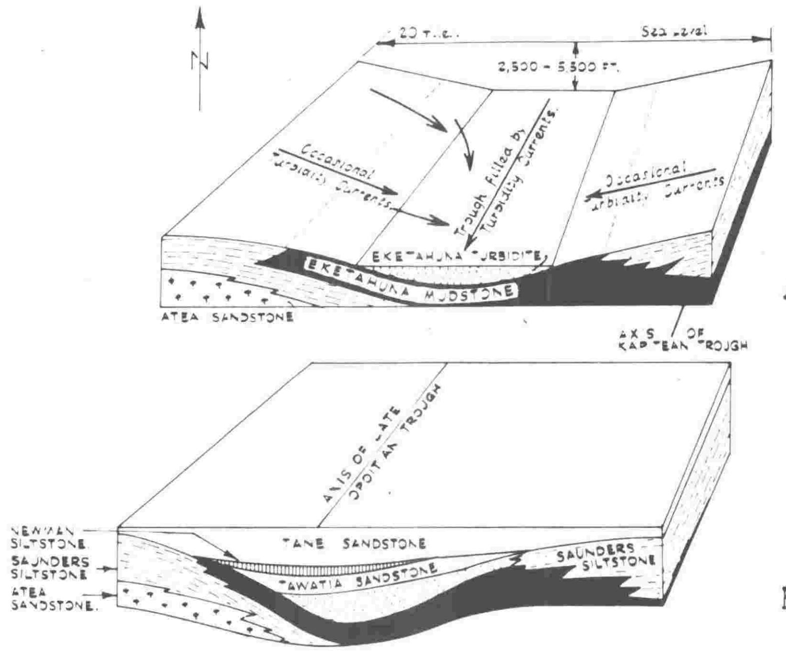


FIG.14 BLOCK DIAGRAMS OF THE EKETAHUNA TROUGH IN (A) MIDDLE AND (B) LATE, OPOITIAN TIME. FAULTS ARE NOT SHOWN. (After Neef 1964)

Formations deposited during the first period, are the Atea Sandstone, Saunders Siltstone, Eketahuna Mudstone, and Eketahuna Turbidite. These formations invariably have a wedge like distribution both laterally and vertically, ~~with respect to each other~~.

Formations deposited during the second period are the Tawatia Sandstone, Newman Siltstone, and Tane Sandstone, which were deposited largely in succession. The Newman Siltstone, however, was ~~developed~~ deposited during a short period when downwarping gained a temporary ascendancy over the rate of deposition.

The Eketahuna Mudstone is usually the basal formation of the Eketahuna Group. It overlies the Tiraumea Mudstone and the Te Hoe Turbidite near Alfredton, and the S_1 Siltstone, S_2 Sandstone and R_5 Mudstone near Eketahuna. In much of the central, eastern and northern areas the base of the Eketahuna Mudstone is not exposed. West of Eketahuna, the Eketahuna Mudstone is absent and the Saunders Siltstone and Atea Sandstone overlie the R_3 Sandstone of the Soren Group.

The group is unconformably overlain by the Makuri Group, east of the Makakahi River, and by the Marima Sandstone at Marima.

ATEA SANDSTONE

Name, Type Section and Subdivision

The formation is named after the small settlement of Atea. The type section occurs along a small left branch of the Mangatainoka River, here named Davenports Creek (the confluence of Davenports Creek and Mangatainoka River is opposite ~~the~~ Putara School).

Most of the formation is a very massive, very fine sandstone. Bedded sandstones containing some pabble horizons occur locally at the base of the formation, and throughout the formation at Ngamaia Stream. On the map the formation is not subdivided.

Distribution

The Atea Sandstone crops out in a north east trending belt, from Ngamaia Stream ~~at Putara~~ in the south, ~~to north of~~ the Kerrydale Farm in the north, where is it cut off by the Huru Fault. The formation also crops out near Atea on both sides of the Mangaroa Stream.

Stratigraphic Relations

At Ngamaia Stream the Atea Sandstone overlies the S_3 Conglomerate of the Kaiparoro Formation with apparent conformity. North eastwards the S_3 Conglomerate is absent, and the Atea Sandstone overlies the R_3 Sandstone of the Mangaoranga Formation. The ~~differentiation~~ of the R_3 Sandstone ~~and~~ from the Atea Sandstone is not precise at localities north-east of Ngamaia Stream where the S_3 Conglomerate is absent. ~~The separation of the formations~~ At Davenports Stream differentiation depends on macrofossils; northeastwards however, macrofossils are rare, and the mapped contact between the R_3 Sandstone and Atea Sandstone is tentative. Locally at Atea (grid ref. 098033) the formation overlies the Tararua Formation. The upper part of the formation at Ngamaia Stream wedges out northeastwards into siltstones (Saunders Siltstones). The formation is overlain by the Saunders Siltstone.

Content

Most of the Atea Sandstone consists of massive blue-grey sparsely fossiliferous, carbonaceous, poorly exposed, very fine sandstones.

Mollusca and fragments of lignite occur sporadically throughout most of the formation, except at the base and at Ngamaia Stream.

Shell beds and calcareous concretions are rare; it is not possible to delineate bedding at every outcrop. At Davenports Creek the formation consists of:-

	Feet
Saunders Siltstone	
Massive, very fine, blue-grey sandstone, containing scattered <u>Zeacolpus</u> sp.	400
Massive, fine to very fine, blue-grey sandstone, containing scattered molluscs and fragments of lignite	400
Shell-bed (fossil locality 903)	0.25

Further northeast the formation is thinner and contains few macrofossils. Near Atea the formation is similar to the type section. The lower part of the formation is well exposed at Ngamaia Stream where a section contains:-

	Feet	
Brown-weathering, fine-grained sandstones, with some thin pebble horizons	150	Atea Sandstone
Obscured	30	Atea Sandstone
Cross-bedded fossiliferous sandstones - cross-beds trough type. (See Potter and Pettijohn (1963, p.70)	8	Atea Sandstone
S_3 Conglomerate (Kaipaoro Formation)	40	

Beds immediately overlying the brown weathering sandstones with thin pebble horizons are not exposed but near the top of the formation fossiliferous fine sandstones occur (fossil locality 1057).

Thickness

The Atea Sandstone is 1,100 ft thick at Ngamaia Stream; it thins northeastwards. It is 800 ft thick at Davenports Creek, and only 400 ft thick at grid ref 088000.

Near Atea ~~complete sections~~ part of the formation ~~are absent~~ is faulted out, but a minimum thickness of 750 ft is established at grid ref 083028.

Macropalaeontology, Age and Correlation

Macrofossils from the Atea Sandstone are listed in Table 8.

Kennett (1966d) found that the Atea Sandstone contained G. crassaformis and ~~thus was~~ is Opoitian in age. The S. obesta shells present in the Atea Sandstone do not have an ornament of spiral lirae. The lack of such an ornament has been considered to indicate an Opoitian age by Dr Fleming (pers. com). Kennett (1966a) found that in the Awatere Valley Coluzea spectabilis makes its first appearance in the basal Opoitian, (Allani zone) ~~C. spectablis~~ it also occurs in the Atea Sandstone. Stiracolpus n. sp. aff. procellosus Marwick was collected from fossil locality 1057; it may indicate an Opotian age since Marwick (1957, p. 43) found that S. procellosus is restricted to the Opoitian.

Negative evidence that the Atea Sandstone is post-Kapitean in age is ~~that~~ the absence of typical Miocene genera such as Sectipecten and Culculaea ~~are absent~~.

Conditions of Deposition

Kennett (1966d) examined the foraminiferal content of two sections, at Ngamaia Stream and 1 5/8 miles to the northeast at Davenports Creek.

	719	720	902	903	1057	1114	1115	1116
Spisula aequilateralis (Deshayes)				X				
Gari aff. *amarutica* Finlay				X				
Pleuromeris zelandica Deshays)		X						X
Balanus sp.		X			X			

At Davenports Creek, Kennett found "... a gradual increase in depth of deposition from about 200 ft at the base of the Mangatainoka upper Sandstone (Atea Sandstone) to nearly 1,000 ft at the top of the sandstone". (Kennett's fossil locality 1183, however, is within the outcrop of the Saunders Siltstone.)

At Ngamaia Stream, Kennett found, that "Shallow depth of deposition throughout is shown by coarseness, common current-bedding, common mollusca, and by a foraminiferal fauna almost entirely made up of abundant Zeaflorilus parri, Florilus flemingi and common Quinqueloculina, representing the Zeaflorilus Biofacies. Depth of deposition of the whole of the sandstone at Ngamaia Stream was probably less than 100 ft".

Assuming that the strata at Kennett's fossil locality 1183, (Davenports Creek) were deposited approximately contemporaneously with the upper part of the Atea Sandstone at Ngamaia Stream, it is calculated that the slope on the sea floor between what is now Ngamaia Stream and what is now Davenports Creek was about eight degrees (1 : 9).

How could a locality be deposited

Much of the macrofossil evidence, and the nature of the sediments examined by the writer confirm Kennett's palaeoecological contentions. Very shallow water conditions at Ngamaia Stream are indicated by the trough cross-bedded unit (see page 114), pebbly sandstone, and the fossiliferous sandstone, which occur there in succession. The basal shell bed at Davenports Creek is composed of wave-sorted shells of shallow aspect; and was also probably deposited in fairly shallow water. Between the West and East Taiko Faults at grid ref. 098033 cross-bedded standstone, indicating very shallow water conditions occur in the basal part of the formation.

Except at fossil localities 903 and 1057, the Atea Formation is sparingly fossiliferous. The most abundant macrofossil considered to be a biocoenose is the extinct *Struthiolaria obesa* which King (1934) has shown is also the most common fossil of the brown sands of the Upton Series in the Awatere Valley. *Poirieria zelandica* Q and G, occurs at three localities, but has no well defined depth range.

Dell (1956) suggested that the upper limit of the Archibenthal fauna of New Zealand occurs at about 100 fathoms. The sparseness of the neritic fauna of much of the Atea Sandstones, and the absence of elements of the Archibenthal fauna, indicates that the average depth of deposition of the sediments above the basal beds was about 70-100 fathoms. The presence of *Modelia* cf. *mukumaruensis* at fossil locality 1115 is anomalous, because it normally indicates very shallow water conditions, being usually associated with *Haliotis*, *Cellana*, and *Bembicium*. Fossil locality 1115 is only 1100 yards east of the Wellington Fault. It may be that the fault was active during the deposition of the Atea Sandstone and formed the boundary ~~of~~ between very-shallow and moderately-deep water. ~~and~~ Transportation after death of some shells into deeper water, ~~and~~ consequently ~~burial~~ occurred.

SAUNDERS SILTSTONE

Name, Type Area, and Subdivision

The formation is named after Saunders Road, a no-exit road which trends east-northeast from the Alfredton-Pori Road at grid ref. 390997.

No type section is named, largely because no one section within a fault block reveals a sufficiently thick unfaulted sequence of strata. The area between Saunders Road and Waipori Stream is designated the type area (see Figure 15).

Apart from the E_5 Sandstone Towngue developed north of the Makuri Gorge near Makuri (D) Trig; the formation is not subdivided.

Distribution

In the eastern part of the Sheet District, the Saunders Siltstone is well developed in three large areas, at Saunders Road, Hinemoa, and east of the Makuri River. These areas are separated by the Alfredton-Saunders Road Fault complex, and the Taumata Fault. Southwestwards from these best-developed areas, the formation wedges out into the Eketahuna Mudstone and the Eketahuna Turbidite. In the western part of the Sheet District the Saunders Siltstone occurs west of a line between Kaiparoro to Kakariki, but is best-developed in a belt close to the Wellington Fault.

Stratigraphic Relations

In the type area, the Saunders Siltstone underlies the Tane Sandstone and probably overlies the Tiraumea Mudstone (see Cross Section E-F) It wedges out southwestwards into the Eketahuna Mudstone and Eketahuna Turbidite formations. In the type area, near Hinemoa, and east of the Makuri River, the upper most part of the formation extends further southwestwards towards the axis of the Eketahuna Trough than does the lower part. Near the eastern margin of the Eketahuna Trough the Saunders Siltstone overlies the Eketahuna Mudstone and the Eketahuna Turbidite formations and is overlain by the Tawatia Sandstone.

The formation is largely absent near the axis of the Eketahuna Trough but it has been mapped on the east limb of the Rongomai Anticline. At this locality it wedges out northwards into the Eketahuna Mudstone and underlies the Tawatia Sandstone.

West of Morgans Road, the Saunders Siltstone overlies the S_3 Conglomerate and the R_3 Sandstone and is overlain by the Eketahuna Mudstone. It wedges north-eastwards into the Eketahuna Mudstone.

At Putara the formation overlies the Atea Sandstone and is overlain by the Eketahuna Mudstone. It wedges out northeastwards into the Eketahuna Mudstone. Between the West Taiko and Wellington faults the Saunders Siltstone overlies the Atea Sandstone. At this locality it is the youngest formation of the Eketahuna Group developed.

Content

The bulk of the formation consists of massive muddy siltstones; locally the siltstones are sandy and occasionally they grade into mudstone. The blue-grey massive siltstones can be subdivided (but are not mapped separately) into siltstones which contain rare macrofossils, and siltstones in which macrofossils are virtually absent. Macrofossils are most common in the uppermost part of the formation, at Waipori Stream and east of the Makuri River. Macrofossils are also relatively common near the base of the formation at Putara and west of the Mangaranpiu Road.

Figure 15: Air view of Saunders Road, the type area of the Saunders Siltstone, Rata (M) Trig right centre. Foreground and centre hill country composed of massive siltstones. Note the deeply incised nature of the main left branch of Waipori Stream, and some of its tributaries.

Within the greater part of the formation it is difficult to distinguish bedding. Locally, near the base of the formation where it overlies the Eketahuna Mudstone or the Eketahuna Turbidite, the Siltstone is laminated.

About ten thin, graded-sandstone beds have been found within the formation in the eastern part of the mapped area, and at two localities the graded beds have been studied in detail. At grid ref. 419120 the base of the very-fine sandstone grades upwards into siltstone some six inches from the base. One excavated flute mark at the sandstone-siltstone interface indicates that the sediment of the sandstone bed was derived from a bearing of 80°. In Ngaturi Creek at grid ref. 422177 two graded sandstone beds each about three inches thick are separated by about two feet of massive blue grey siltstone. No flute casts occur at the sandstone-siltstone interface, but micro-cross-bedding found a short distance above the base indicates that both beds were derived from a bearing of 140 degrees.

Calcareous concretions ~~found within the formation~~ range in shape from spherical to disc-like, or are elongated along one axis to be sausage-shaped. They are normally from a few inches to 15 ft long. The largest concretion found was in the bed of the Tiraumea River at grid ref. 363085; the upper surface of the concretion measured 20 ft by 50 ft; its thickness is unknown. The surface of the concretion is bulbous, and it is considered to have been formed by the amalgamation of many centres of concretion growth.

It was assumed that planes indicated by flattening of concretions indicated the bedding, but generally there was no way to test this assumption. However the bedding determined in this way is in agreement with the bedding of the formations ~~found~~ above and below. ~~Further~~ Bedding mapped photogeologically by W.M. Johnson of British Petroleum Company invariably agreed with the bedding indicated by the long axis of the concretions.

At localities where several concretions are present it was found that the concretions ~~are all~~ of the same size ~~and~~ ~~could~~ are invariably be aligned in a plane which is in agreement with the bedding indicated by the long axis of the flattened concretions. ~~Apart from the development of concretions in planes, Further evidence that the concretions occur at certain horizons and not at others is inferred from some composite concretions which are aligned in planes parallel to bedding indicated by the flattened concretions.~~ Cylinders composed of material identical to that forming the calcareous concretions are uncommon. They usually trend normal to the assumed bedding, and they often have cork-screw shaped segments (see Figure 17.) The cylinders are from four to nine inches in diameter and have a central cavity one inch in diameter along their axis; they are often five feet long.

~~Occasionally~~ It was found that the Saunders Siltstone had been extensively bored at places. At one locality in Waipori Stream (at grid ref. 417025) the borings, shown by slight changes of grain size between the bored area and the non bored matrix were $\frac{1}{4}$ - $\frac{1}{8}$ of an inch diameter.

The E. Sandstone tongue, composed of massive unfossiliferous very fine sandstone occurs in the lower part of the Saunders Siltstone in the extreme eastern part of the mapped area near Makuri D Trig.

Figure 16: Outcrop of massive Saunders Siltstone in a right branch of Ngaturi Creek (grid ref. 437176). Left centre Large spheroidal disc shaped concretion. Background Rarer sausage-shaped concretion 15 ft long. Note smooth surface of outcrop.

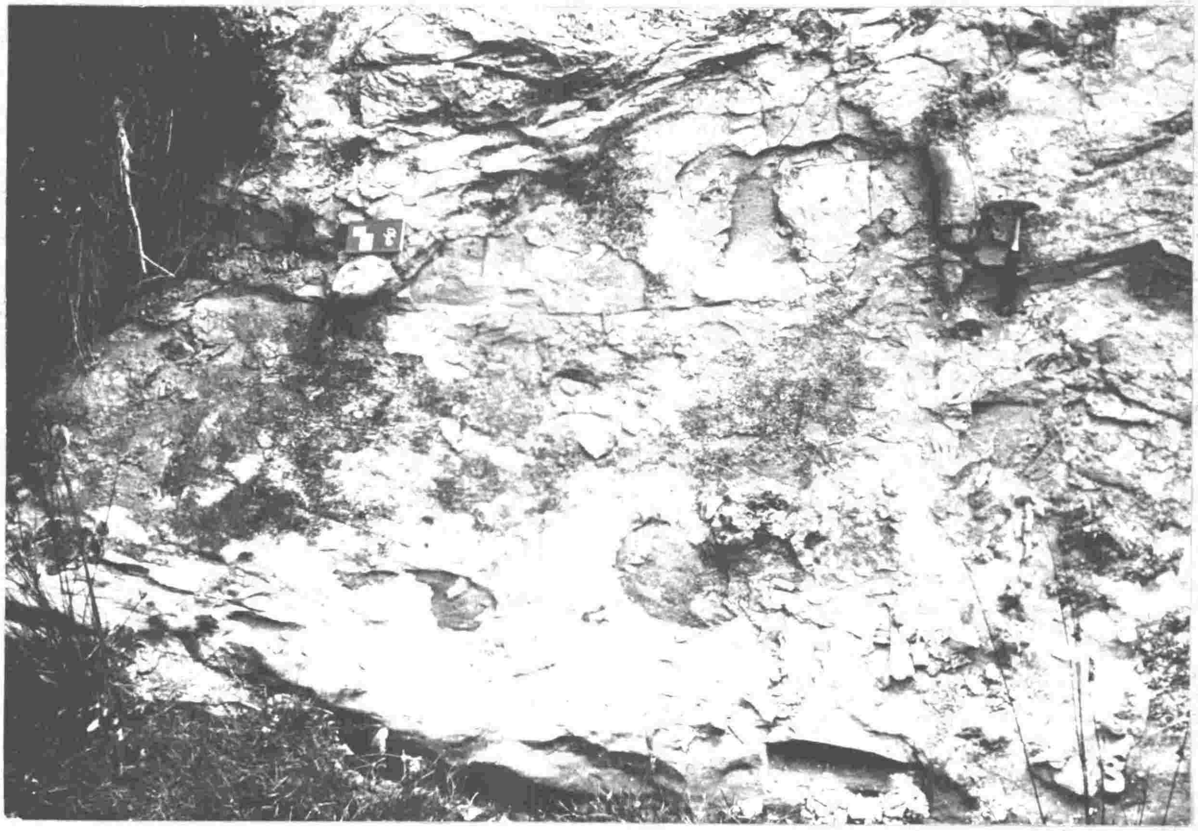


Figure 17: Outcrop of massive Saunders Siltstone at grid ref. 426181. Left centre bedding is indicated by small disc like concretion (below field note book) Upper right centre Left of hammer Cylinder of concretionary material about four inches in diameter. Cylinder trends approximately normal to bedding. Other segments of the cylinder occur at extreme top of photograph above the hammer and Lower Left Centre.

It is not known if the Sandstone tongue is the upper-part of an underlying formation or if it is a sandstone wedge developed within the massive siltstone.

Thickness

The Saunders Siltstone is very thick (perhaps about 4,800 ft), in the type area, but its thickness cannot be accurately estimated because it is cut by many faults which have unknown throws. ~~North of Te Hoe Stream the formation wedges out into 4,800 ft of Eketahuna Mudstone and Eketahuna Turbidite; Siltstone about 4,800 ft thick is considered to be developed at Saunders Road.~~

About 2,000 ft of massive siltstone is thought to be present between the Wellington and the West Taiko faults.

Macropalaeontology

Macrofossils from the Saunders Siltstone are listed on Table 9. Macrofossils are rare, usually not more than two or three fossils occur at any one fossiliferous locality. Usually the fossils ~~are considered to~~ represent an archibenthic biocoenose assemblage. The macrofossil most frequent ~~found~~ is Nemocardium, generally its ~~distribution was~~ scattered, at fossil locality 726 it is especially common. At one locality at grid ref. 436142 it was abundant within a thin bed. Apart from Nemocardium the most abundant fossil is a large gastropod about two inches long which looked like a Coluzea sp.; it always disintegrated when an attempt was made to remove it from the matrix.

TABLE 9

MACROPALAEONTOLOGY OF THE SAUNDERS SILTSTONE

	726	738	811	835	846	847	949	953	981	983	989	1032	1088	1089	1122	1123
Stiracolpus huttoni (Cossman)												X				
Coluzea aff. spiralis (Adams)												X				
Coluzea n.sp.			X								X					
Austrofusus sp.			X													X
Bonellitia sp.												X				
Alcithoe cf. strongi (Variable) Marwick							X			X	X			X	X	
Alcithoe n.sp. B Marwick			X													
A. subgracilis Marwick				X												
A. gatesi Marwick												X				
A. sp.												X				
Comitas onokeana King								X					X			
Awateria (Mioawateria) pahaoensis Vella												X				
Awateria sp.												X				
Marshallena decens Marwick												X				
Marshallena curtata Marwick							X									
Marshallena sp.							X					X				
Antizafra sp.						X										
Zephos onokeana King											X					
Micantapex sp.												X		X		
Antimelatoma aff. buchanani (Hutton)												X				
Cardita sp.												X				
Scalpomactra n.sp.						X										
Nemocardium (Pratulum) finlayi Bartrum and Powell	X				X											
Nemocardium pulchellum (Gray)		X														
Pleuromeris zelandica (Deshays)												X				
Dentalium zealandicum Sowerby						X										
Dentalium sp.															X	
Brissopsis sp.									X							
Araeosoma cf. thetidis (H.L. Clark)			X													
Caryophyllia profunda Moseley		X														

The biocoenose assemblage containing the largest number of species is from the Davenports Creek (fossil locality 1032), near the contact with the underlying Atea Sandstone.

The cylinders of concretionary material are considered to be due to the calcification of sediment just beyond the exterior of a hole bored through the sediment by a marine animal, perhaps a polycheate worm. Polycheate worms are about 1 inch thick and may be several feet long, ~~they~~ are known in inhabit deep water at the present time. (pers. com. Mr E. Dawson).

Conditions of Deposition

Comitas onokeana from Ngaturi Creek is considered to indicate depths of deposition of the order of 200 - 330 fathoms (1,200 - 1,980 ft), ~~there~~, the same as that indicated by the recent Comitas onokeana viviens from which it can scarcely be distinguished. In the type area, at fossil locality 981, Brissopsis sp. has been considered by Fell (see Appendix 3) to indicate depths of deposition of 250 - 550 fathoms (1,500 - 3,300 ft). Close by, at fossil locality 982, Vella found that foraminifera indicated a slightly shallower depth of deposition, of lowermost neritic-uppermost bathyal (c200 - c1,000 ft) - (1,000 - 2,000 ft) (see Appendix 2).

Basinwards where macrofossils are absent, depths of deposition, indicated by foramifera, are not deeper than in the type area; an exception occurs at fossil locality 905 (Mid-bathyal). The lack of macrofossils in the area where the formation wedges out is considered to be good evidence for deposition in deeper water. It may be that some foraminifera were swept into deeper water by the gentle deep-sea currents which deposited the siltstone, to ~~and~~ indicate analogous shallower depths.

On the west flank of the Eketahuna Trough near Atea, depth analysis of foraminifera indicate that much of the formation was deposited in outer-neritic ~~depths~~ to upper-bathyal ~~depths~~ (200 - 2000 ft). Most of the macrofossils from the western side of the Eketahuna Trough are of archibenthic type, which indicates that depths of deposition were at least 600 ft ~~below sealevel,~~ (see Dell 1956). The depth-range of Araeosoma thetidis is 360 - 2400 ft below sealevel at the present time and depths of this order are indicated by the Opoitian fossil from at fossil locality 811, (see appendix 3) for the siltstone there. At four localities abundant unrolled spatangid spines occur with foraminifera indicating upper bathyal depths of deposition.

The great thickness of uniform sediments indicates that uniform conditions of deposition persisted for a long period of time. Slight fluctuations of the depositional enviroment are indicated by the ~~uniform size of concretious in the~~ concretionary horizons. There was some control, (physical, chemical, or rates of deposition) which determined the size and position of the concretions. Acoustic reflection profiles of recent continental slopes, notably by Moore and Curray (1963), show that many of the theoretical contentions made long ago by Cotton (1918), that continental slopes are the result of aggradation along foreset slopes are correct. Cotton (1918, figure 5) envisaged that material would be deposited either in topset, foreset, or from a pelagic environments, and that most of the topset beds would be subsequently removed by erosion. Cotton (1966) considered that most of the continental slopes are of the "Up-and-Out Building" type due to a plentiful supply of sediment and either a continuing rise of sea level, or alternatively progressive downwarping of the sedimentary interface. Flute-marks and micro-cross-bedding of the graded beds near the Makuri Gorge and at Ngaturi Creek indicate that locally the paleoslope and the direction from which the silt was derived was normal to the strike of the Eketahuna Trough. ~~That~~ Basically the formation is one of foreset deposition as described by Cotton.

Most of the Cretaceous and Lower Tertiary rocks, which crop out east of the mapped area, especially of the Dannevirke and Pareora Series, (see Kingma 1960) are fine-grained. Their erosion would provide an ample source of fine-grained material.

Generally the continental slopes were aggraded continuously, the supply of silt was greater than downwarping and the foreset beds, (see Cotton (1918) advanced basinwards. Near Alfredton, both west and east of the Alfredton Fault, the outcrop distribution of the Saunders Siltstone indicate that the continental slope advanced, receeded, and then advanced again.

Pollen from fossil locality 949 is richer in angiosperms and contains a few moist-habitat-species, more than in most other Opoitian, Kapitean, and Taranakian samples (pers. comm. Graeme Wilson). If the pollen is primary and has not been derived from a Lower or Middle Tertiary formation further to the east, (such as has been proved at fossil localities 942 and 943) it may be that some trees grew relatively close by, perhaps on small islands along what is now the East Coast Range.

Carbonaceous material and pebbles are absent in the graded beds, indicating no large areas of elevated land east of the mapped area.

The lithology of the Saunders Siltstone is similar to recent deposits on the continental slope between the San Pedro - Santa Monica Basins and to that on the coast of Southern California (see Gorseline and Emery, 1959, p.286). Gorseline and Emery found contorted structures in sediment at the toe of the Continental slope which they considered to be due to slumping; these structures are absent in the Saunders Siltstone. Their absence is not due to an insufficiently steep gradient as the average steepest gradient of the San Pedro - Santa Monica Basin is less steep (1 : 13) than the calculated palaeogradient of the Opoitian sediments between Ngamaia Stream and Davenports Creek (1 : 9) (see page 117).

EKETAHUNA MUDSTONE

Type Section and Subdivision

Mangaoranga Stream, a right branch tributary of the Makakahi River is made the type section of the Eketahuna Mudstone. The formation is not subdivided.

Distribution

The formation crops out in five main northeast trending belts, which are 5 - 10 miles long, and ½ mile wide. These occur from west to east at: 1. east of the East Taiko Fault; 2. east of the Huru Fault near Rongokokako; 3. the Kaiparaoro Mangaoranga Stream - Rongomai belt; 4. a belt between the Martin and Taumata faults; and 5. a smaller bifid belt near Te Moe Farm.

Stratigraphic Relations

West of the Rongomai Fault the formation wedges out in a southwestwards into Saunders Siltstone, while east of the Rongomai Fault the formation wedges out northeastwards into the Saunders Siltstone.

Locally, in the Alfredton area the formation underlies and overlies the Eketahuna Turbidite.

Between the East Taiko and Huru faults, the Eketahuna Turbidite is absent and the Eketahuna Mudstone directly underlies the Tawatia Sandstone.

Content

The Eketahuna Mudstone is blue-grey; macrofossils are virtually absent and calcareous concretions are rare. Those in the bed of the Makakahi River south of Eketahuna are spherical and about four feet in diameter, and those along on the left bank of the Mangatainoka River (grid ref 146062) are tabular and about 9 inches thick.

A 3 inch thick yellow stained, quartz-rich pumiceous bed crops out about 400 ft above the base of the formation at Happy Creek (grid ref 412965). The bed overlies a ripple-marked surface in which the strike of the crests trend at 335°. A thin ash bed is thought to occur near the top of a high cliff on the left bank of the Makakahi River (grid ref. 181969); its stratigraphic position is about 220 ft above the base of the formation.

Locally near Rongokokato (grid ref. 119962) the formation contains ~~vegetation~~ plant fragments.

Thickness

The Eketahuna Mudstone was deposited contemporaneously with the Saunders Siltstone and the Eketahuna Turbidite within the Eketahuna Trough. Its thickness at any one locality is proportional to the thickness of the other two formations. The formation is thinnest at the Tiraumea River and in the type area.

The formation is probably thickest west of the Huru Fault, where the Eketahuna Turbidites are absent; it is also thick near Te Hoe Farm.

Mangatainoka River east of Taiko Trig	Eketahuna	Arakoa Anticline	Te Hoe Farm Lower Mudstone	Te Hoe Farm Upper Mudstone	Tiraumea River
1,100 + ft	600 ft	500 ft	1,080 ft	700 ft	250 ft

Macrofossils and Conditions of Deposition

Two macrofossils have been found, Coluzea sp. from Mangaoranga Stream, and Mantellum aff. marwicki Powell (fossil locality 481 from west of Alfredton).

Most of the foraminiferal samples from the formation indicate mid-bathyal depths of deposition (1,000 - 4,000 ft). Locally, close to the contact of the overlying Eketahuna Turbidite at fossil locality 916 lower bathyal depths of deposition are indicated.

The formation is considered to have been deposited by accumulation of pelagic mud, largely basinward of the Continental Slope, at localities where bottom currents capable of transporting silt were absent.

EKETAHUNA TURBIDITE

Type area and Subdivision

No complete section has been studied in great detail, but the strata exposed south of Eketahuna, along the Makakahi River and along the Woodville-Masterton State Highway, are made the type area. Apart from the E_6 Sandstone bed, which occurs at the top of the turbidite sequence at Alfredton, the formation is not subdivided.

Distribution and Exposure

Between the Huru and Pleckville faults, in the south-central part of the mapped area, the Eketahuna Turbidite crops out as three one-mile-wide, north-northeast trending belts. East of the Pleckville Fault the formational outcrop-width of several north-northeast trending belts is about half a mile. In the area north of the central Mangaone Road the formation is found at the outer margin of the Arakoa Anticline. The turbidites are especially well exposed along the Makakahi and Mangone rivers, and Ngatahaka Creek.

Stratigraphic Relations

At Mangaoranga Stream, 6-inch-thick siltstone beds, alternate with 30 ft-thick mudstone beds, immediately beneath the mapped Eketahuna Turbidites. The turbidites are overlain by the Tawatia Sandstone.

Such a stratigraphic relationship is present west of the type area between the Rongokokako and Huru faults, and is commonly developed between the Rongomai and Alfredton faults. In the north-eastern part of this area, however, wedges of Saunders Siltstone occur between the Eketahuna Turbidite and the Tawatia Sandstone. On both flanks of the Peep-o-Day Syncline the Eketahuna Turbidite is overlain by the Eketahuna Mudstone. East of the Alfredton Fault, the formation is enveloped by the Eketahuna Mudstone; in a north eastward direction the formation wedges out, quite abruptly, into the Saunders Siltstone.

Content

Most of the graded beds at Eketahuna are very uniform. Invariably they are composed of angular quartzose fine sandstone, or very fine sandstone, 2 - 3 inches thick at the base of the bed, grading upwards into a mudstone. Though the beds are graded, there is usually a fairly sharp contact between the sandstone part ~~of a bed~~ to the mudstone part of a bed. The contact between the basal part of a bed and the top of the underlying bed is quite abrupt also. Foraminifera, broken molluscan shells (particularly *Nemocardium pulchellum*) are frequently found within the basal inch or two of the graded bed. Near Alfredton at grid ref 313956 *Neilo australis*, *Nemocardium pulchellum*, , and *Proxiuber* were found at the base of a graded bed. Frequently foraminifera especially Robulus-type tests are prominent at the base of graded beds (see Figure 18).

In Ngatahaka Creek (grid ref 147963) three specimens of N. gen. aff. *Procardia* were found in close association in the upper most part of a graded bed; the fossils are thought to have been a biocoenose assemblage. No other non-redeposited fossils have been found.

At Eketahuna the beds are on an average about 2.25 ft thick, while near Alfredton (grid ref 313956) they are about 11 inches thick. Thicker sandstone beds, some as much as five feet thick, occur near Rongokokako.

On the right bank of the Makakahi River near Eketahuna (at grid ref 203013) in the middle part of the formation, a sequence of graded beds about 50 ft thick is characterised by thin very-fine grained sandstones and particularly thick mudstones. It is not known if the sequence has continuity along the strike.

Neef (1964) described a rhythmic sequence of groups of graded beds and mudstone units each about 10 ft thick, at a road cut west of Alfredton (grid ref 313956). These beds, figured below, have some continuity laterally; they crop out in a left branch tributary of Te Hoe Stream at grid ref 328967.

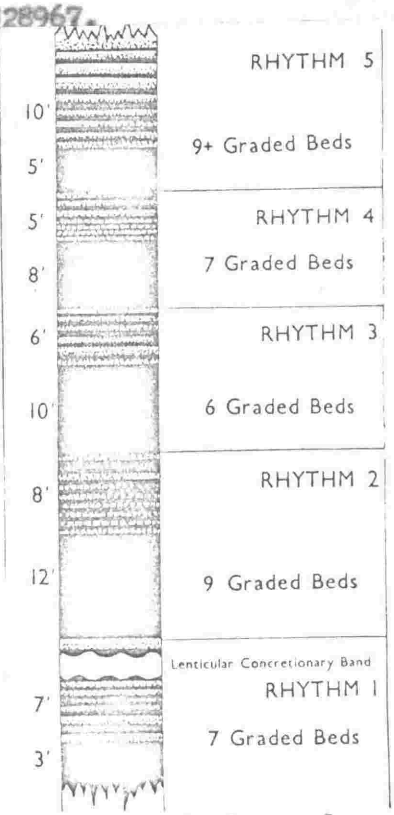


Figure 19. Rhythmic sequence of groups of graded beds and massive mudstone units exposed at road section 313956.

(After Neef 1964)

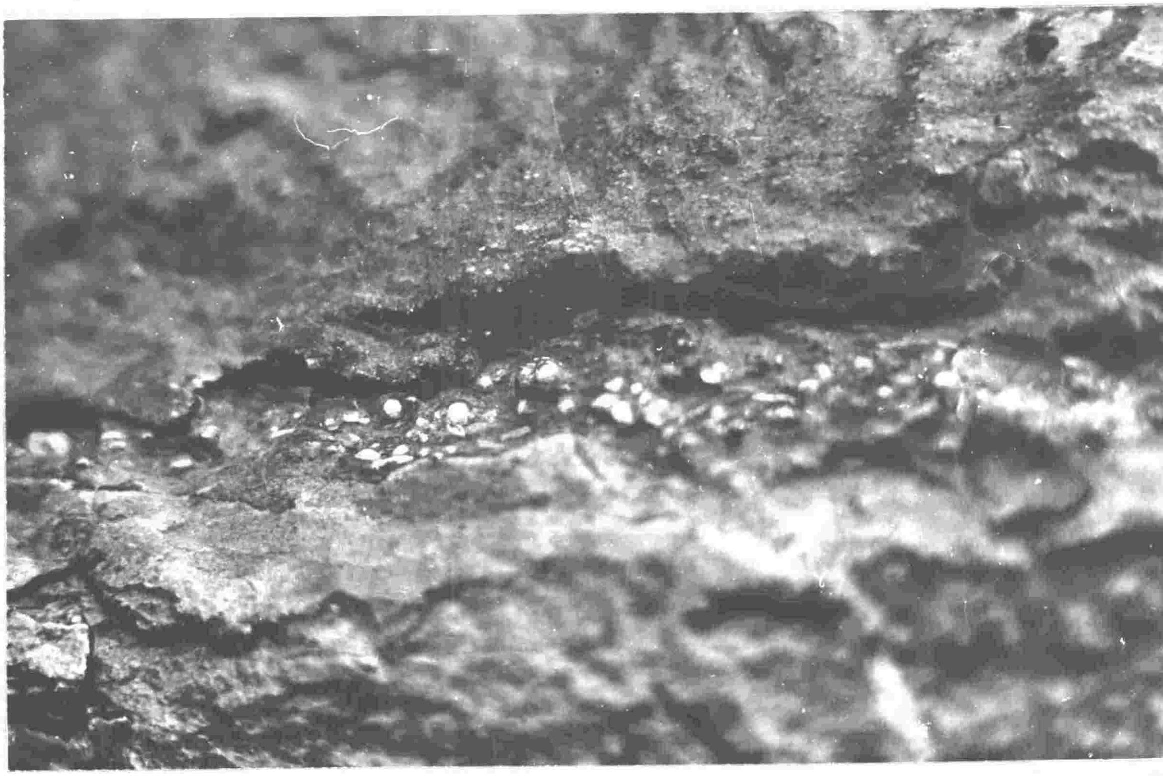


Figure 18: Close up photograph* of a graded bed from east of Alfredton at grid ref 371937, section approximately normal to direction of transport. Note abrupt, irregular contact between sandstone and underlying mudstone. _Robulus_ type foraminifera are white ~~coloured~~, they are concentrated near the base of the bed; higher up in the bed smaller foraminifera are also present.

* _Robulus_ is about the size of a pin head.

The graded beds of the Eketahuna Turbidites are distinctive enough to be able to map small scale normal and reverse faults where the throw is not more than about 5 ft. It is doubtful if a particular bed can be traced beyond an exposure unless the relationship of the bed to some distinctive marker bed is known. In the Eketahuna area there are about four distinctive graded beds.

About 800 yards east of the Makakahi River, at grid ref. 216032, a graded bed contains:-

	Inches	
Silty mud,	6 +	obscured
grading down to		
very fine-grained sandstone,	20	
grading down to		
Rounded greywacke granules containing numerous shell fragments	1	

No flute marks are present at the base.

The bed is unusual because it has a thick sandstone part, and because ~~that~~ granules of greywacke occur at its base; granules at the base of a bed have not been found elsewhere.

In Ngatahaka Creek, (at grid ref. 156971) a 2 ft thick graded bed contains numerous scattered fragments of lignite. Flute marks at the base of the bed indicates that the bed was derived from a bearing of 040°.

At the base of cliff cut by the Makakahi River, (at grid ref. 208031), a graded sandstone approximately 1 ft thick, contains many more shells than usual, particularly specimens of *Nemocardium pullchellum*, echinoid spines, and small pelecypods. Near the top of the graded sandstone there is a ½ inch-thick carbonaceous horizon.

One yellow stained 14 inch-thick light-grey conspicuously worm bored ash-bed crops out at a road cut south of Eketahuna at grid ref 191982.

Only one composite graded bed is known. It crops out in the right branch of Ngatahaka Creek at grid ref 160963. A small coral, identified by Dr D.F. Squires as *Caryophyllia coronatus* was found in the lower part of the bed.

	Inches
Light, blue-grey, silty mudstone	5
Light blue-grey, fine-sandstone, grading upward to siltstone	3
Light-blue-grey, laminated sandstone, grading upward to siltstone containing *Caryophyllia coronatus* (fos. loc. 1055)	5

Locally west of Alfredton a distinctive sandstone bed, ~~as~~ often as much as 15 feet thick, occurs at the top of the Eketahuna Turbidite; it has been mapped as the E6 Sandstone. It crops out on the east and southern flanks of the Peep-o-Day Syncline, south of the Mangatakato Road Fault, and between the Hastwells and Peep-o-Day Faults.

Thickness

The Eketahuna Turbidite is thick at Eketahuna, ~~the formation~~ ~~is~~ probably ~~as~~ equally thick between the Huru-Pleckville faults, and the

Rongomai-Pleckville faults. The formation thins across the Rongomai Anticline, and wedges out southwards along its eastern flank into the Saunders Siltstone.

		Feet
Eketahuna	c	1,870
Mt Baker	c	1,300
East flank of the Rongomai Anticline	c	650
West of Alfredton, between the Timahanga and Martin faults	c	320
Te Hoe Farm	c	700

Sedimentary features developed at the Interface between two graded beds and within a graded bed (Micro-crossbedding)

The Eketahuna Turbidite beds are only lightly indurated, and in contrast to more indurated turbidite strata elsewhere, the sandstone-mudstone interface is virtually never exposed. Before ~~To examine~~ the sandstone-mudstone interface could be examined ~~the excavation of~~ the sandstone had to be excavated. ~~is a prerequisite.~~ Most of the sandstone was excavated with the aid of a geological pick, but near the base of a graded bed excavation was by penknife and a light whisk. During hot sunny days, sand grains could be lightly whisked away as they dried. Generally about a square foot of the sandstone-mudstone interface was exposed by ~~excavated~~ excavation.

Some of the finer detail which normally occurs ~~found~~ at the base of turbidite beds, such as bounce-casts, is destroyed during the excavation, but the major features, flute marks, and grooves, would become apparent ~~evident~~ if they are present (see Figure 20).

Figure 20: The base of a graded bed, revealed by excavation, ~~on~~ at an outcrop on the east flank of the Rongomai Anticline at grid ref 282085. Two parallel groves, far left, and far right, are each 6 inches long and ½ inch wide and ½ inch deep. They strike at 070° ~~- 250°~~.

The base of the turbidite bed is sometimes indurated with calcite; if this part of the bed was carefully removed and cleaned, flute casts are often revealed. The direction of flow of the turbidity current which produced the flute casts was apparent once the broken bed was reassembled.

Flute-marks are common in the Aketahuna area. Excavation invariably revealed ~~flute marks~~ them, ~~they~~ they are probably rarer east of the Rengomai Fault where exhaustive excavation at three localities failed to reveal ~~flute marks~~ them.

The excavation of the plane of microcrossbedding occasionally found within the sand part of a graded bed was found to be much less time-consuming. Excavations of crossbeds and determinations of the direction of flow were made whenever microcrossbedding was noticed.

Flute Marks

The more deeply incised part of the flute marks has been widely held to be the proximal part of the sedimentary feature, indicating the direction from which the current flowed. Often flute marks are 1/8 - ¼ inch wide and about an inch long. Larger flute marks some 3 inches wide and two inches deep are not uncommon.

Ramsay (1961) has shown that the aximuth of a bedding plane lineation, such as a flute mark is altered less than three degrees if ~~the dip of~~ the dip of the beds ~~are tilted up to~~ is less than 25 degrees. Within the Sheet district ~~thus~~ correction of tilt is not necessary, as beds with a tilt of more than 25 degrees were not examined, and three degrees is the order of accuracy of the original observations.

This remark needs qualifying

Flute marks and microcrossbedding indicate that most of the Eketahuna Turbidite was derived from a bearing of 0° - 030° (see Figure 21). A smaller number of beds were derived from the north-northwest. A few anomalous flute marks in the south-central part of the mapped area indicate deposition from north-flowing turbidity currents. Uncommon local reversals of regional palaeocurrent trend, indicated by flute casts, have also been found by other workers in turbidite basins abroad (see for example, Scott, 1966).

Flute marks were examined in sequence at three localities, listed below; at one locality microcrossbedding was found and examined.

From Makakahi River, north of Eketahuna (grid ref. 203013).

Source indicated by flute marks
degrees
030
010
?
?
020

From Ngatahaka Creek at grid ref. 142959

Source indicated by flute marks
degrees
350
025
340
015

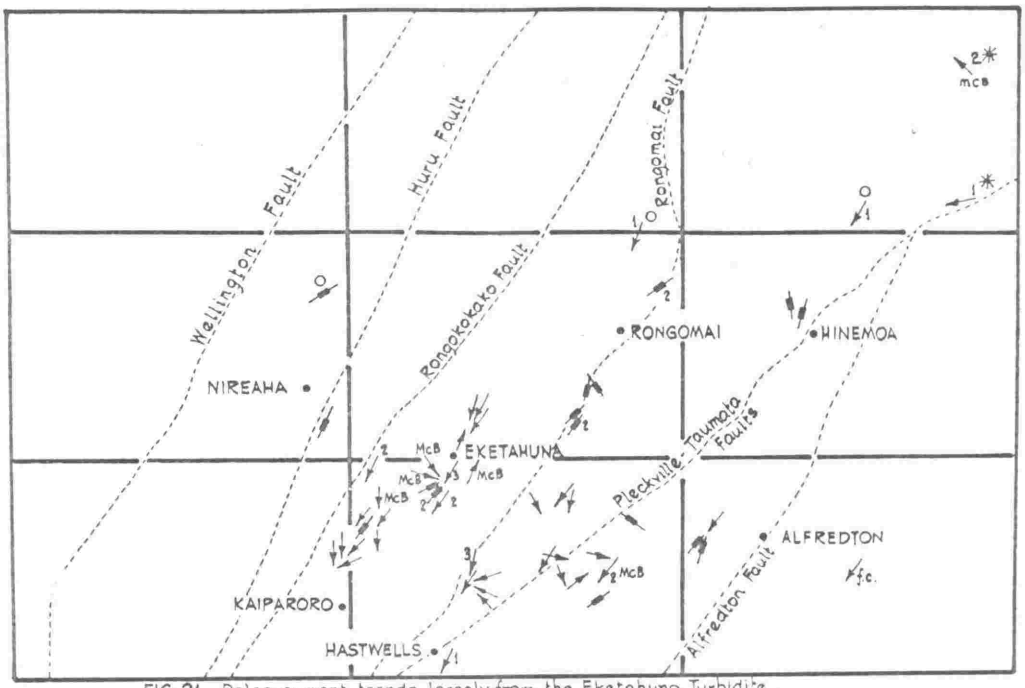


FIG. 21. Paleo-current trends, largely from the Eketahuna Turbidite, from Saunders Siltstone (*), and from the Tawatia Sandstone (o)

2 Paleo current trend from 2 flute marks showing direction of flow.

f.c. Paleo current trend from flute cast showing direction of flow.

2 Paleo current trend from 2 flute marks, and/or grooves but direction of flow uncertain.

2 McB Paleo current trend from 2 microcross beds showing direction of flow.

Note northwesterly and northeastly directions of derivation, in table above.
The following directions were observed—
In the Makakahi River, south of Eketahuna (at grid ref. 188990)

Lithology		Inches	Source indicated by flute marks	Source indicated by Microcross-bedding
		Inches	Degrees	Degrees
TOP	Mudstone	12		
Bed 3	silt	6	020	315
	very fine sand	1.5		
	mudstone	18		
Bed 2	silt	4	025	270
	very fine sand	1		
	mudstone	12		
Bed 1	silt	3	020	?
	very fine sand	1		

Thick mudstone 3 ft thick.

Note that in the section above, fluting showed a very constant source, but that indicated by microcrossbedding was much more variable. There is a fairly abrupt break between the sandstone and siltstone parts of the beds.

Many sedimentary features which have been described in graded-bedded sequences overseas have not been found here: these include washouts; load casts; sand volcanoes; and prolapsed bedding; or slumped beds. Convolute lamination (minor stratal contortion) was found at only one locality (southwest of Eketahuna at grid ref. 162970).

Conditions of Deposition

The Eketahuna Turbidite is considered to have been deposited on a deep sea plain at the axis of the Eketahuna Trough. Deposition on the plain was by turbidity currents which spread graded beds usually 2 - 1 ft thick. Neef (1964) calculated that the period between flows was 844 years (say 1,000 years).

Dr Vella found that foraminiferra in the graded beds were derived from both shallow and deep water environments, the deep water ~~indic-ators~~ foraminiferra suggested that the deep sea plain was at outer bathyal-abyssal depth. Such depths were considered by Vella (1962b) to be at least 4,000 ft deep. Neef (1964, p.880) came to a similar conclusion (2,500 - 5,500 ft).

Vella (1963d) found that ~~there was~~ no autochthonous sediment between the Kapitean turbidite rhythms at Cleland Creek; these rhythms though of different age than those of the Eketahuna Turbidite are essentially similar. The three specimens of N. sp. gen Procardia which were found in close association in the upper part of the mudstone fraction of a graded bed at grid ref. 147963, are thought to be a biocoenose assemblage, and indicate that some autochthonous sediment is present between some of the graded beds.

The absence of such features such as load casting, slumped beds, prolapsed bedding etc., indicates that gradients on the sea floor were ~~of an~~ exceptionally low ~~order~~. It may be that the sea floor was deepest near Eketahuna, and that the ~~unusual~~ anomalous ~~flute~~ directions ~~marks~~, which indicate that a few turbidity currents were derived from the south, are real. The absence of washouts indicates that the turbidity currents had relatively low velocities.

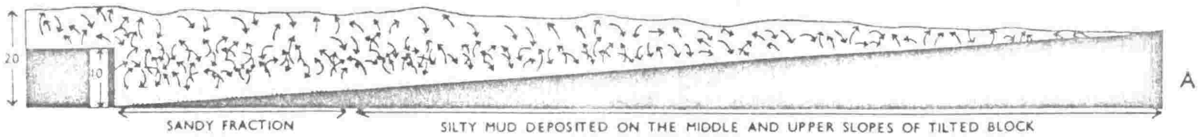
The E, Sandstone bed at the upper/most part of a turbidite near Alfredton, parallels the development of thicker sandstone beds in the upper part of the Te Hoe Turbidite near the Tiraumea River. The Sandstone is an ~~are~~ indicator of marginal conditions for the development of turbidites.

Wedges of Saunders Siltstone which overlie part of the Eketahuna Turbidites and which underlie the Tawatia Sandstone near Tane and Alfredton indicate that the toe of the aggrading continental slope had moved westward, at a time when the turbidites were still being deposited further west.

Penecontemporaneous folding of the Rongomai Anticline is indicated by the marked thinning of the formation near the crest of the fold.

Neef (1964) has considered that a sequence ~~of groups~~ of mudstone and groups of graded beds ~~each about 10 ft thick,~~ found at a road cut at Alfredton, (see page 137) are ~~were~~ due to penecontemporaneous fault block rotation movements.

Neef considered "rotation along a north-east-trending hinge line west of Alfredton that caused one side of a fault block to be relatively uplifted and the other depressed, at intervals of several thousands of years, while sedimentation from south-west flowing turbidity currents was in progress. The sandy fraction of post-faulting turbidity currents were channelled along the depressed side just to the east of a submarine fault scarp, while on the middle and upper slopes of the tilted block mud was deposited from the turbidity current clouds. As sedimentation proceeded, graded beds on-lapped eastwards up the slope of the tilted block and across the area where muds had been deposited. Later tilting of the block initiated a new rhythm." (See Figure 22.)



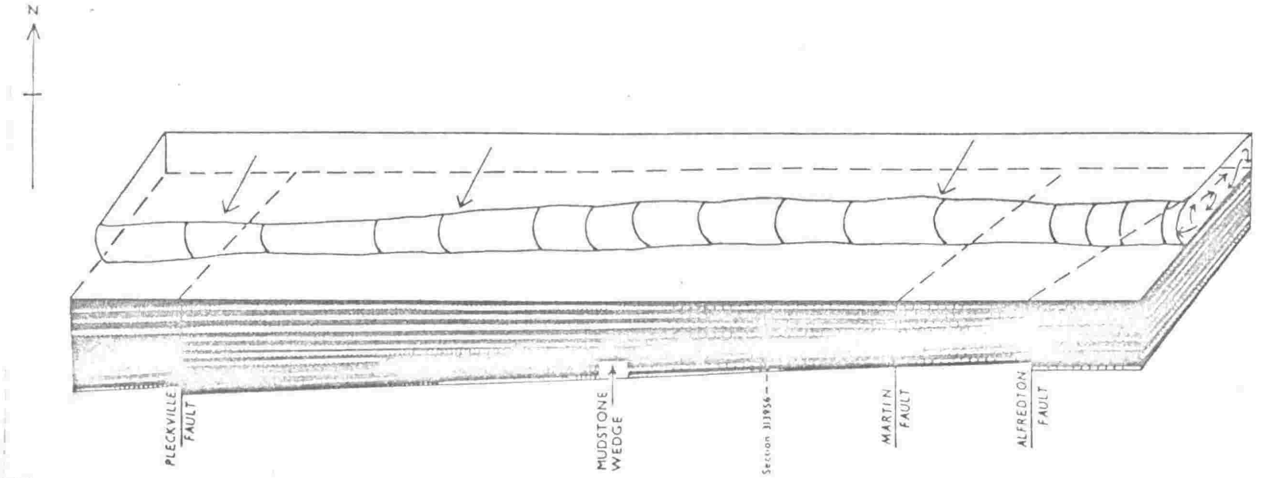


Figure 22A - Diagrammatic cross section demonstrates localisation of the sandy fraction of the turbidity current in the fault-angle depression immediately after faulting and fault block rotation.

Figure 22B - Diagrammatic block diagram of the Alfredton area during a time, when graded beds were being deposited at site of section 313956.

(After Neef 1964)

Turbidity Currents as ~~a~~ the Mode of origin for the graded beds

It ~~has been~~ is suggested that the graded beds of the mapped area have been deposited from turbidity currents, in deep water. The reasons for the hypothesis are many. The submarine relief of the Eketahuna Trough is deduced from the direction of current flow of turbidites in the Saunders Siltstone. The wedging out basinwards of Saunders Siltstone containing some macrofossils into the unfossiliferous Eketahuna Mudstone and Eketahuna Turbidites, and the depths of deposition indicated by foraminifera, ~~this evidence~~ establishes that ~~there was much~~ deeper water occurred along ~~along~~ the axis of the Eketahuna Trough ~~where the Eketahuna Turbidites were deposited~~.

In recent years photographs of the deep-sea bottom have shown ripple marks; such is the evidence for deep-sea currents. It is significant, however, that flute marks have not been photographed, they are, however, ubiquitous beneath graded beds. Why have the flute marks not been seen? Surely it is because the interval between the formation of this sedimentary feature and the deposition of the overlying graded bed is very short indeed.

If graded beds were deposited from slow moving currents, then the currents would ~~have to~~ flow ~~periodically,~~ every thousand years or so, (in the intervening period silt and mud would be deposited). There is some evidence that minor quantities of autochthonous sediment occur between graded beds locally, but it is considered very unlikely that more than an inch or two of the upper part of a graded bed is autochthonous.

The Kuenen-Migliorini (1950) theory of turbidity currents is thought to accommodate all the evidence. The progressive rapid breakage down slope of several submarine ~~submarial~~ telegraph cables has been interpretated ~~as~~ being due to the passage of turbidity currents by some writers (see Heezen and Ewing, (1952)) and ~~as~~ being due to rapid progressive compaction of recent sediment by Terzaghi (1957). Houtz and Wellman (1962), however, have shown that the 1953 Suva Earthquake broke the Suva-Norfolk Island Cable. From a recovered length of cable they deduced a sequence of events consistent with the passage of a turbidity current flowing across the cable. First the cable was sand-blasted while it was partly buried in sediment, then it was torn up and twisted and shifted two miles from its original position.

During the passage of a turbidity current there is first a period of erosion during which the flute marks at the base of the graded beds are developed; followed by a period of deposition during which the sandstone part of the bed was deposited; first the coarser fraction then the finer. Later still the muddy part of the turbidity current was deposited from suspension and the deposition of the graded bed is completed.

An alternative hypothesis on the origin of graded beds by Kingma (1958), and (1960), suggested that they are due to oscillations of a sand bar at the margin of a basin. Occasionally sand is brought across a bar at the margin of a basin, while at other times silt was deposited longitudinally along the axis of the basin. Many of the factors which make Kingma's theory unlikely have been discussed by Kueuen (1960). Basically his theory fails because of the large number of special conditions which are required to occur in sequence for his sedimentary model to operate. The oscillation of the sand bar, the lack of mixing of sand and silt fractions of the graded bed, and the huge amount of downwarping of the depositional area while the source area and the bar remains near sea level. It is thought that the likelihood of a thick sequence of graded beds being formed in the manner suggested by Kingma is remote.

The only prerequisite of the Kuenen-Migliorini (1950) theory for the origin of graded beds is that much sand and mud accumulated at or near the top of a submarine slope.

The Eketahuna Turbidites are not extensively bored while other formations of the Eketahuna Group also deposited in deep water are usually extensively bored (see Appendix 5). The material of the turbidite beds is likely to have been thoroughly worked over by burrowing organisms at a time prior to its redeposition. During this period the food content of the sediment would be extracted. After its redeposition from a turbidity current, it would be anticipated that the material would have little food value, and would therefore not be bored by burrowing scavengers. If graded beds had a non-redeposited mode of origin such as that suggested by Kingma (1958) they might be expected to contain food particles and would be thoroughly bored after deposition.

Provenance

Differences in gradient in the depositional area, mode of accumulation, nature of the material to be redeposited, and stability of the continental slope at the margin of a trough are thought to be some of the factors which determine what sort of turbidite beds are deposited in any one deep-water trough. At Eketahuna the graded beds are usually of the same order of thickness (unimodal). In Taranaki the Makara Facies of the Mahoenui Formation locally contains interbedded thick and thin graded beds (bimodal). (See Kingma, 1960, Figures 1, and 2).

The Eketahuna Turbidites do not contain much carbonaceous material; pebbles are absent at the base of the graded beds, and granules at the base of the graded beds have been found at only one locality. The mud fraction of the beds is invariably much thicker than sand fraction. The uniformity of graded beds at Eketahuna is striking; it is probable that the material forming the bulk of the formation had previously been sorted by marine currents prior to redeposition. Flute marks and microcrossbedding indicate that the turbidites were generally derived from the north-northeast; it is from this direction that most of the material was derived. Geologic cross sections by Lillie (1953) show that Kapitean-Opoitian Strata are comparatively thin at Dannevirke and at Woodville; macrofossils are not common. ~~By-passing of sediment south-southwestwards in moderate depths of water is considered to have occurred.~~ The writer considers that sand, silt and mud may have been transported ~~by traction~~ by tidal streaming in a south-southeastward direction along the axis of a proto East Coast Strait, (see Stride (1963), with respect to the English Channel). Such a mode of sediment transport would continually bring large quantities of fine-very-fine muddy-sand in a general direction towards Eketahuna. The northern margin of the Eketahuna Trough would be situated somewhere between Woodville and the northern part of the mapped area. Sediment would spill over at the northern margin of the Eketahuna Trough and accumulate there. Every thousand years or so the dumped material ~~would become~~ unstable, ~~It would~~ slump down slope perhaps triggered off by an earthquake such as occurred at Suva in 1953 and rapidly accelerate to form a turbidity current. The material would then travel rapidly south-southwestwards down the steep incline in the general direction of Eketahuna.

Such a mode of sediment accumulation and subsequent redeposition would ~~produce~~ occur along a fairly wide ~~area from which the turbidity currents originated; such a pattern has been found (see Figure 21)~~ front. Point sources of origin such as delineated in turbidites of Upper Miocene age at Tarzana, Southern California, by Sullwold (1960) may be due to turbidity currents being concentrated within submarine canyons, and may well be characteristic of turbidites which were derived laterally rather than longitudinally, like those at Eketahuna.

A hypothesis of initial concentration of material by tidal streaming ~~of prior material~~ to ~~be~~ redeposit, would ~~be~~ better fit the evidence than the mechanism ~~has been previously~~ suggested by Neef (1964), who ~~Neef~~ considered that the turbidity currents had travelled a considerable distance before ~~prior to~~ reaching the Eketahuna area.

TAWATIA SANDSTONE

Name, Type Section and Subdivision

The formation is named after the small settlement of Tawatia. The type section of the Tawatia Sandstone is made a short distance east of the Tawatia Creek and parallel to it. A massive brown-weathering fine sandstone occurs near the base of the formation at Tawatia, and at Mount Heale, and as far north-east as the Tane Settlement. This sandstone has not been mapped separately.

Distribution and Stratigraphic Relations

The Tawatia Sandstone is extensively developed in the south-central part of the mapped area; its distribution is bounded in the west by the West Taiko Fault and in the east by the Alfredton Fault.

Near Makahikatea Trig the formation wedges out ~~in~~ north-eastwards. Near Pukenui in the western part of the outcrop there is no evidence of such north-eastward wedging. The formation overlies either the Eketahuna Turbidites, the Eketahuna Mudstone or the Saunders Siltstone. The basal contact is very abrupt in the Tawatia - Tane - Mount Heale districts providing a reference line to map many cross faults. It underlies either the Tane Sandstone or the Newman Siltstone.

Content

Most of the Tawatia Sandstone is composed of interbedded sandstones of varying grain sizes ~~and sandstone~~ and siltstone beds. Graded beds occur near the base of the formation even at localities where the formation is not thick. Thin non-graded mudstone beds

1/16 - ½ inch thick are interbedded with massive sandstones 1 - 4 ft thick: near Hukanui; Pukohai Stream; between the West and East Taiko faults; and also at localities about 1½ miles north west of Newman. Calcareous concretions are very rare.

At the type section about 180 ft of massive friable brown-weathering fine to medium-sandstone abruptly overlie the Eketahuna Turbidite; these sandstones are overlain by bedded very fine and fine sandstones about 1350 ft thick.

Basal massive fine sandstones of the same order of thickness can be traced westwards to the Rongomai Fault. West of the fault massive basal sandstones occur ~~at the base of the formation~~ on the east flank and on much of the west flank of the Rongomai Anticline; south-westward of the west flank (near the Hawera Road) the massive basal sandstone wedges out into bedded sandstones. Massive basal fine sandstones ~~also~~ occur ~~at the base of the formation~~ between the Mangatainoka River and the East Taiko Fault. North east of the type section, the massive basal friable brown-weathering sandstone occurs as far north-eastwards as the Tane Road; further north-east it wedges out into very fine sandstone.

Near Tane (at grid ref. 332064) small trees and shrubs are developed along the base of the Tawatia Sandstone, further emphasising the abrupt contact. Also near Tane at grid ref 334065 the formation has an apparent tilt of 4 degrees greater than the underlying Saunders Siltstone.

On the east flank of the Peep-o-Day Syncline at grid ref 301955 the basal beds of the formation show a rhythmic alternation of sandstone - siltstone beds; these beds were described by Neef (1964), and were considered to have the same origin as the rhythmic sequence of groups of graded beds and mudstone units at Alfredton (see page 148). The rhythmic sequence is figured below.

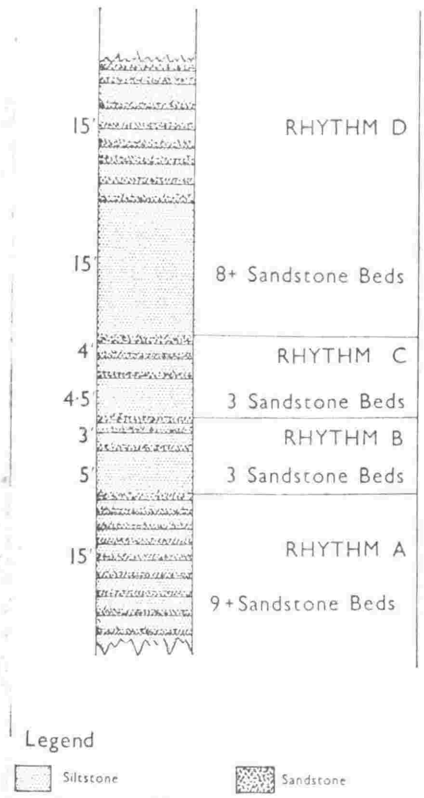


Figure 23: Rhythmic sequence of sandstone-siltstone beds and massive siltstone units exposed at road section ~~at~~ grid ref. (301955). (Figures at left of columns show thickness in feet).

Ripple marks are extremely rare features of the deep water Taranakian, Kapitean, and Opoitian formations. Well-developed ripple marks were seen at one 18-inches-thick horizon a half-a-mile east of Erinlee Farm at grid ref 242090. The strike of the ripples is parallel to the strike of the tilted block.

Intra-formational slumping is a rare feature of the Tawatia Sandstone, but it is more common in that sandstone than in other formations of the Eketahuna Group.

At one isolated locality near Tane (grid ref 330081) a bed in the uppermost part of the formation contains slump balls of fine sandstone, 0.5 to 5 ft in diameter, in otherwise massive sandy siltstone. At a road cut near Nireaha (grid ref 159045), massive sandstone beds about two feet thick are interbedded with muddy siltstone beds 2 - 4 inches thick. The beds are gently folded and the folds strike 50 - 230 degrees. It is thought that the folding may be due to incipient intraformational slumping. On the west flank of the Peep-o-Day Syncline (at grid ref 295956), one thin sandstone bed is gently folded, almost in the form of a sine curve, while beds above and below are unaffected. The amplitude of the intraformational folds is about 3½ feet.

Thickness

The formation is thickest at the type section; it is also very thick at Mangamahoe. Only minimum thicknesses are known at Eketahuna and Nireaha where younger formations of the Eketahuna Group are not present.

Thickness of Tawatia Sandstone

	Feet
Nireaha	330
South of Cliff Road Fault at Eketahuna	810 +
Mt Heale	1290
Tawatia	1550
South Tane	620
S.W. of Estcourt Stn between Peep-o-Day and Timmins faults	650
Mangamahoe	1330 +

Macropalaeontology and Conditions of Deposition

Only one fossil, Awateria miocenica ~~has been~~ was found (at fossil locality 876).

All the spatangoid spines examined by Professor Fell were rolled, indicating that they had been transportated prior to deposition. Dr Vella found that foraminifera from the formation generally indicated upper bathyal to lower neritic depths of deposition (c200 - 1,000) to (1,000 - 2,000) ft. From general considerations such as graded beds in the overlying Eketahuna Turbidite, and the shape of the sedimentary body, a depth of deposition of at least 2,000 ft would have been anticipated. The anomalous shallower depths may be due to a greater amount of transportation of foramanifera from shallow water into deeper water than usual.

In the northern part of the mapped area the abrupt change of lithology from turbidites to bedded and massive sands is thought to be due to a deep sea fan moving southwards and depositing sandstone along the axis of the Eketahuna Trough, into an area where previously turbidites had been deposited. Deep-sea fans described by Menard and Ludwick (1951) have many delta-like features, including distributary channels and levees. Locally near Tane (grid ref 334065) the Tawatia Sandstone has a greater tilt than the underlying Saunders Siltstone, indicating that the south-southwestward moving deep sea fan (Tawatia Sandstone) had buried the westward aggrading foreset beds of the continental slope, (Saunders Siltstone).

NEWMAN SILTSTONE

Name, Type area, Subdivision

The formation is named after the small settlement of Newman which is situated along the Woodville - Masterton State Highway, two-and-a-half miles north of Eketahuna. The Newman area is designated the type area.

The Newman Siltstone consists of finer-grained sediments than the previously deposited Tawatia Sandstone. Generally the Newman Siltstone consists of massive siltstones which wedge out into the Tane Sandstone in a north-northeastward direction. Locally massive mudstones and graded beds occur. On the map the formation is not subdivided.

Distribution and Stratigraphic Relations

The Newman Siltstone is more restricted than other formations of the Eketahuna Group. It is best developed between the Makakahi River and the West Taiko Fault: especially at Newman; west of Hukanui; east of Taiko Trig; and north-west of Eketahuna. East of the Makakahi River formation distribution is lenticular, and is restricted to synclinal areas.

The formation is conformable on the Tawatia Sandstone and is overlain by the Tane Sandstone; locally it wedges out into either the Tane or the Tawatia Sandstone.

Content and Thickness

At the type area, most of the Newman Siltstone consists of massive blue-grey unfossiliferous siltstones. Locally some 6-inch sandy graded beds are present. Scattered macro fossils, probably a biocoenose assemblage, occur near the abutments of the Makakahi Bridge; locally the siltstones have been bored for a maximum of some three feet. In the type area the formation, a part faulted out by the Rongokokako Fault, is at least 1,400 ft thick.

Near Whetu Trig, the formation is composed of about 520 ft of massive siltstone; A mile to the northeast the siltstone wedges out into the Tawatia Sandstone.

Massive siltstone, about 210 ft thick, occurs on both flanks of the Kawerau Syncline. On the east flank the siltstone wedges out northeastwards into the Tane Sandstone, but no such wedging occurs on the west flank.

South of the Rongokokako Fault near Eketahuna (grid ref. 176020), massive mudstone, at least 200 ft thick, is developed along the axis of a small north plunging syncline.

East of Taiko Trig, the formation is at least 580 ft thick; it consists of graded beds, often one-foot thick, interbedded with thicker massive mudstones and siltstones.

East of the Makakahi River (at grid refs. 237100 and 294993) the formation is about 100 ft thick near the axis of synclines; it is absent along the crests of anticlines.

Macropalaeontology

The macrofossils collected from the formation are listed in Table 10.

Table 10

	Fossil Localities		
	703	704	1035
Stiracolpus sp.	X	X	X
Vexillitra marwicki Vella	X		
Awateria miocenica Vella	X		
Awateria sp.	X		
Micantapex* aff. paucispiralis (Suter)	X		
Unidentified Crab			X

Half-a-mile northwest of Mount Heale (grid ref. 254097), at fossil locality 1035 a large concretion contained a large number of Stiracolpus sp. shells and many fragments of a crab species as yet unidentified.

Conditions of Deposition

That the formation is finer-grained than the underlying Tawatia and the overlying Tane Sandstones indicates that the bottom currents which deposited the siltstones were weaker than those which deposited the sandstones. East of the Mongomai Fault siltstones are characteristically developed in synclinal areas, while sandstones of the lowermost Tane Sandstone were deposited along the crests of adjacent anticlinal areas. It is thought that these incipient synclinal areas were being downwarped penecontemporaneously during the deposition of the Siltstone. That small differences in bottom topography could affect the nature of the sediments deposited, indicates that there was probably a general lowering of the sedimentary interface with respect to sea level at this time. Only a few samples for foraminifera were collected from outcrops of Newman Siltstone. At one locality (fossil locality 923) an upper bathyal depth of deposition 1000 - 2000 ft was determined (see fossil record lists). This is a little deeper than the inferred average depth of deposition of the Tawatia Sandstone.

TANE SANDSTONE

Name, Type area, Subdivision

The formation is named after the Tane Settlement. It is well developed near Tane, which is designated the type area. The formation is not subdivided.

Distribution and Stratigraphic Relations

The Tane Sandstone has a wide distribution in the northern and eastern parts of the mapped area. Besides the type area, it is particularly well developed north of Mt Heale, at Ngaturi, and near Hinemoa. It is absent at Mangamahoe and Eketahuna.

In the type area, and at Hukanui, the Tane Formation overlies the Tawatia Sandstone and the Newman Siltstone; in the north eastern and eastern part of the mapped area the formation overlies the Saunders Siltstone.

Where the Tane Sandstone overlies the Saunders Siltstone the contact between the two formations can generally be ~~mapped~~ defined to within about 100 ft. ~~From such known contacts,~~ The base of the formation ~~has been~~ was extrapolated along the strike by viewing air photographs stereoscopically. Contacts between the Tane Sandstone and Newman Siltstone ~~have been~~ were ~~mapped~~ defined with the same order of accuracy. At localities where the formation overlies the Tawatia Sandstone it was more difficult to map the contact, ~~as~~ because the change from bedded non-concretionary sandstone to massive concretionary sandstone is gradational.

The Marima Sandstone and the Makuri Group unconformably overlie the Tane Formation, the Marima Sandstone at Marima and the Makuri Group east of the Makakahi River.

Content

The Tane Sandstone is almost entirely composed of light blue-grey, massive, unfossiliferous, concretionary, fine and very-fine sandstones. Macrofossils are less common, and fewer in numbers of species, than at those localities where macrofossils occur within the Saunders Siltstone. At only one locality does ~~have~~ massive siltstones occur ~~been found~~ within the formation; they ~~these~~ crop out along the Mangaone River (at grid ref 325100) where they are at least 180 ft thick.

Calcareous concretions are quite common. The inclination of the long axis of the concretions ~~from the horizontal~~ are ~~is~~ invariably the only criterion for ascertaining the dip of the strata. ~~A greater proportion of~~ Many the concretions are tabular ~~than in other formations~~. At grid ref 421166 a concretionary horizon, about 1 ft thick, extends down-dip for about 100 yards.

Cylinders of concretionary material, up to 5 ft long and 9 inches in diameter, containing a central concavity, 1 inch in diameter, are rare; They are identical to those in the Saunders Siltstone and are thought to have had a similar origin. South of the Hastwells Fault at grid ref 312988 a hundred feet thick sequence of the formation, is riddled with $\frac{1}{4}$ - $\frac{1}{2}$ wide calcified organic borings; the sequence forms a prominent bedding-plane-feature because ~~as~~ it resists erosion better than the Sandstone nearby.

Thickness

It is not known how much of the formation was removed by submarine erosion prior to the deposition of the Makuri Group and the Marima Sandstone. ~~Because of this all~~ The Thicknesses given below are thus minimum thicknesses. The formation is particularly thick at Kaitawa Creek.

Thickness of Tane Sandstone	Feet
North of Mt Heale	c 1,800
Tane area	1,000 +
North of Marine Creek Fault	c 1,080
Kaitawa Creek	c 2,900
Eastern flank of Hinemoa Syncline at Hirinakitu Stream	c 730
Pori Syncline near Waipori Stream	c 330
Pori Road at grid ref. 391008	c 420
Between Saunders Road Fault and Alfredton Fault at Green Ridges	1,000
West of Timahanga Fault	c 800 +
East of Alfredton Fault at Flat Bush Road	c 1,550

Macropalaeontology

The macrofossils collected from the formation are listed in Table 11.

Table 11

	486	521	566	877	983
Zeacolpus. cf. kanieriensis (Harris)			X		
Stiracolpus procellosus Marwick		X			
Stiracolpus sp.				X	
Baryspira sp. (juv)					X
Awateria miocenica ? Vella					X
Awateria cf. streptophora Suter			X		
Maritomella sp.					X
Micantapex paucispiralis (Powell)	X				

Conditions of Deposition

With the deposition of the Tane Sandstone the Eketahuna Trough was infilled. Much of the sand is thought to have been brought ~~into the area of deposition~~ from the north. In the eastern part of the area sand may have been brought in ~~introduced~~ from the ~~due~~ east, as a high percentage of Nothofagus (brassi group) pollen occurs at fossil locality 942, indicates redeposition from early Tertiary or Mid Tertiary strata (pers com. Mr G. Wilson). ~~This material was presumably derived from the Northeast and east.~~

Foraminifera from fossil localities 942 and 954, (see Appendix 2) have been attributed to the Haeuslerella Biofacies 600 ± 300 ft. Deeper maximum depths of deposition were given by Vella (1963a) in his description of two new species of foraminifera. Vella considered that Hoferuva (Laminiuva) rodleyi tutamoides from fossil locality 990 indicated depths of deposition of about 20 to less than 800 ft; and

Nonionella sp. from fossil locality 877, was considered by him to indicate depths of deposition of 1,000 to 3,000 ft.

The general lack of macro-fossils (fewer than those of the Makuri Group) indicates that depths of deposition were of the order of 1,000 ft, such as indicated by _Nonionella_.

MARIMA SANDSTONE

Name, Type area and Subdivision

The Marima Sandstone is named after Marima Settlement~~, on the Mangahao River in the northern part of the sheet district~~. Continuous unfaulted sections are absent, and a complete sequence can be assembled only through the recognition of biostratigraphic zones, based on an evolutionary sequence of the gastropod *Pelicaria* sp. The Mangahao River provides the most important exposures.

As ~~a rock unit,~~ the Marima Sandstone is a satisfactory mapping unit, and, as with other formations, individual members or beds comprising only a minor part of the sequence are mapped separately. ~~mapped.~~ ~~Further~~ Subdivision of the Marima Sandstone is ~~due to~~ by the biostratigraphic zones, and accordingly a dual system of units is adopted on the map. Three zones are designated by the italic lower-case "t_1 t_2 t_3" and the individual members and beds are designated by the capital T with appropriate numerals, analogous with the usage for rock units used in the subdivision of the remainder of the stratigraphic column. Fossil evidence is adequate for assigning biostratigraphic zones throughout the outcrop area of the Marima Sandstone, and the use of undifferentiated T is not needed. So far as is known, individual members and beds do not transgress zone boundaries.

The mapped subdivisions of the Marima Sandstone are:

	ZONE	Member or Bed
Marima Sandstone	*Pelicaria* n.sp.aff.*tricarinata* (t_3)	T_6 Shell bed
		T_5 Shell bed
		T_4 Shell bed
	Pelicaria n.sp.aff.*acuminata* (t_2)	T_3 Shell bed
	Pelicaria canaliculata (t_1)	T_2 Conglomerate
		T_1 Limy Sandstone

Pelicaria canaliculata, *P*. n.sp.aff. *acuminata*, and *P*. n.sp. aff. *tricarinata* are illustrated in Figure 24.

Pelicaria canaliculata is locally found in the T_1 *Limy Sandstone*, the basal bed of the Marima Sandstone. The top of the t_1 and the base of the t_2 zone are defined as the top of the highest bed with *P. canaliculata*. The species of *Pelicaria* that succeed are closer to *P.* n.sp.aff. *acuminata*, which is not found characteristically until the middle part of the t_2 zone. Similarly the top of the t_2 zone and the base of the t_3 zone is defined by the highest bed with P. n.sp. aff. *acuminata*, and, after a succession of *Pelicaria* specimens closer to *P*. n.sp. aff. *tricarinata*, this species is characteristically found in the lower mid- to upper part of the t_3 zone. About 100 ft of Marima Sandstone above the highest *P*. n.sp. aff. *tricarinata* lacks *Pelicaria* n.sp. aff *tricarinata*, but has been arbitarily assigned to the zone.

Distribution and Exposures

The Marima Sandstone crops out in the north-western part of the mapped area between the Wellington and Huru Faults. Generally the western boundary occurs a short distance east of the Wellington Fault, but between Kakariki and Atea the western part of the outcrop is bounded by the fault. The eastern margin of the outcrop ~~area~~ trends somewhat further east of north than does the Wellington Fault; the outcrop width increases in a north-easterly direction, reaching a maximum ~~width~~ in the Marima-Mangamaire area. At Henderson's Farm the outcrop width is reduced by the presence of younger strata along ~~and near~~ the axis of the Henderson Syncline.

The T_2 Conglomerate is restricted to an area between the Mangaraupiu Road and the Wellington Fault; northwards it wedges out into the sandstones of the Pelicaria canaliculata zone.

The Mangahao River flows northeastwards along much of the central part of the outcrop area; the formation would be poorly exposed if it were not for the chasm-like course which the river and the ~~left branch~~ Tainui, Otangue, Wahaoteika and Patupaiarehe Streams have cut beneath the Hukanui Surface. The incision of the Mangahao River has rejuvenated many small tributary ~~streams;~~ ~~they~~ are also incised near the confluence of the Mangahao River and reveal excellent exposures ~~there~~. Some road cuts particularly between Mangamaire and Marima reveal the Marima Sandstone.

Stratigraphic Relations

An angular unconformity of 8 degrees (see Figure 25) separates the P. canaliculata zone from the underlying Tane Sandstone; the increase of dip from ~~eight~~ to fifteen degrees at the unconformity is apparent on air photographs. Apart from the Pholas-bored surface and the phosphatised contact, evidence of an appreciable break in deposition is that

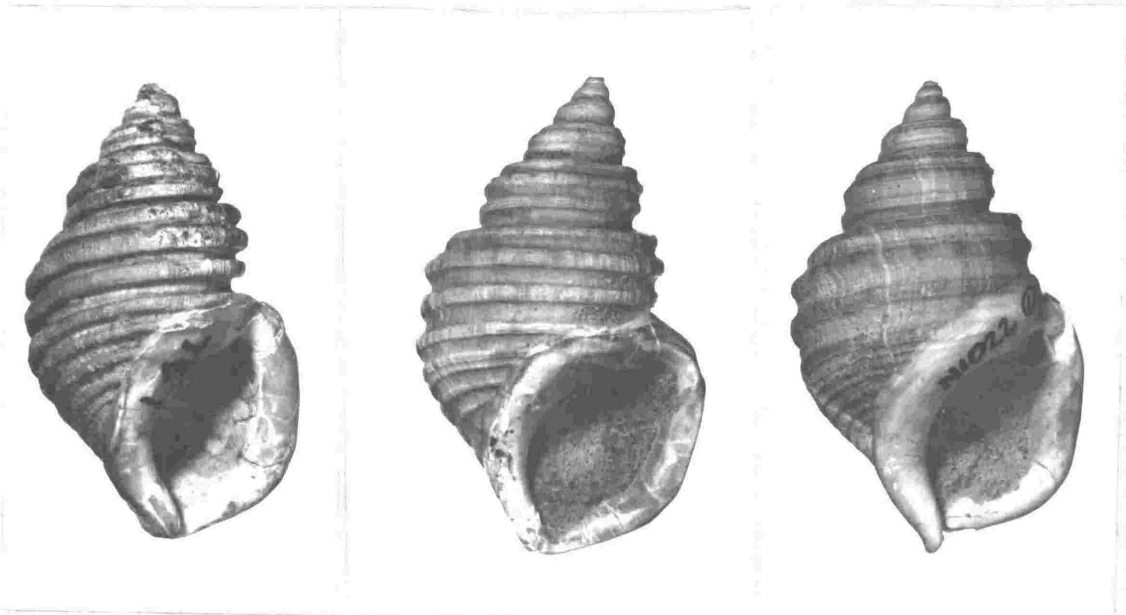


Figure 24: From left to right - Pelicaria canaliculata, P. n.sp. aff. acuminata, and P. n.sp.aff tricarinata.

(All figures approximately 1½ times natural size).

locally at Pukohai Road the strike of the P. *canaliculata* zone is at right angles to the underlying Tawatia Sandstone and Newman Siltstone. The formation is overlain by the G_1 Limestone of the Totaranui Formation, perhaps after a period of non-deposition.

Content

The Marima Sandstone consists predominately of fossiliferous lightly-indurated fine and very-fine sandstone, massive or in beds several feet thick. The thick wedge of T_2 Conglomerate occurs in the lower part of the Marima Sandstone in the area between Kakariki and Atea. Thin coquinoid shell beds are locally interbedded with the sandstone; four are prominent enough to be mapped.

Apart from the southwest transistion to the T_2 Conglomerate facies changes are minor, and are indicated by a coarsening of the sandstone in a southwest direction. Minor lithologies include: rare thin conglomerate (or pebbly sandstone); siltstone in thin layers with some overlying ripple marked sandstones; and concretionary sandstone.

The Pelicaria Facies is a particular biocoenose assemblage of macrofossils found in the P. n. sp. aff. *acuminata* and P. n. sp. aff. *tricarinata* zones.

For convenience the detailed description of the Marima Sandstone is ~~considered~~ given in zonal units.

Zone of Pelicaria canaliculata

The best exposed section, which is a composite one, occurs stratigraphically above the prominent angular unconformity which is exposed in the right bank cliff at grid ref. 167133, (see Figure 25).

Figure 25: View southwards from Kopikopiko Road (grid ref. 167133)

Centre: Angular unconformity exposed in cliffs between the Tane Sandstone and the overlying Marima Sandstone; Hukanui Gravel beneath Hukanui Terrace above unconformity.

The lower part of the composite, best exposed section, is exposed along the left bank of the Mangahao River along a south-flowing reach upstream of the ~~exposed~~ angular unconformity. The upper part of the section is exposed in a left bank cliff below the Kopikopiko Road downstream of the ~~exposed~~ angular unconformity along a northward flowing reach.

	Feet	Fossil Locality
Massive very-fine sandstone	c 140	1119
Upper shell bed	1	
Massive sparsely fossiliferous very-fine sandstone	c 30	
Middle shell bed	1	1079
Massive sparsely fossiliferous very-fine sandstone	c 30	
Lower shell bed	1	
(Blue-grey fossiliferous fine sandstone (grading up into very-fine sandstone with ((Some particularly fossiliferous horizons (up to 8 ft thick	c 220	762
Fine sandstone with many scattered fossils	c 20	{761 {757
Obscured	c 20	
Pecten bed (temporary exposure in bed of Mangahao River, containing abundant Phialopecten triphooki)	3	
Obscured	c 15	
Massive fine-sandstone	c 20	
Very-fine sandstone	0.5	756

Concretionary horizon	0.75
Glauconitic fine-sandstone	0.5
(Scattered _Pholas_-bored concretions ((and concretion fragments	0.25
Unconformity	
Tane Sandstone (~~Tane Sandstone~~ locally phosphatised beneath unconformity)	

The best-exposed-section is located in about the centre of a $1\frac{3}{4}$ mile long segment where the basal _T_1 Limy Sandstone_ is absent. ~~In this segment~~ The base of the zone is marked by a bed about six inches thick composed of concretion fragments ~~which are~~ 1 - 2 inches long. Most of the concretion fragments contain concavities which are ~~certainly~~ obviously ? the parts of the walls ~~which occured between~~ of the burrows of the rock borer _Pholas_, perhaps _Pholadidea spatulata_ (an intertidal rock borer). Locally at grid ref (152018) concretion fragments occur as much as 10 ft above the base of the bed. In the northern part ~~of its development~~ (from grid ref 184182 to 196194) the basal T_1 Limy Sandstone forms a prominent bedding plane feature. Typically it is 4 - 5 ft thick, and consists of 70 per cent sand, and 30 per cent shell fragments; locally-derived, bored-concretions up to 9 inches long and 3 inches thick and greywacke pebbles up to three inches long also occur. About half of the sandstone is medium-grained and most of the remainder is very-fine grained. Fragments of _Cardium spatiosum_ and _Phialopecten ongleyi_ are fairly common. Sediments overlying the bed are invariably very-fine sandstone. In the southern area ~~of the development~~ between the Pukohai Road at

Waiwera and south-west of Makaera Trig (at grid ref. 156014) the T_1 Limy Sandstone is about 2½ ft thick and contains greywacke pebbles, coarse sandstone, and broken fossils.

North-east of the best-exposed section (at grid ref. 167133) the P. canaliculata zone crops out along a belt of low hills and is not well exposed. The sequence is of fine sandstone overlain by very fine sandstone, as in the best exposed section.

South-west of grid ref. 167133 the upper very-fine-sandstones are replaced by fine sandstones. In Wahaoteika Stream near its confluence with the Mangahao River the uppermost part of the zone is well exposed, and is more fossiliferous than that in the best-exposed-section. Between the West Taiko and Udy faults the sediments of the zone contain many 1 ft thick conglomerate beds. Fossils and lignite fragments are common, and are generally wave-sorted. Further south-west, in the cliffs below the misfit valley at grid ref. 132998, massive fine sandstones contain abundant Zethalia zealandica and rare greywacke pebbles. Sandstones which are locally much bored occur west of the Mangaraupiu Road area (at fossil locality 813). The fine sandstones grade upward, and wedge out south-westwards into the T_2 Conglomerate. The T_2 Conglomerate generally consists of ~~unfossiliferous~~ well-rounded cobbles and boulders of greywacke.

Zone of Pelicaria n.sp.aff. acuminata

The broad pattern of sedimentation, established during the canaliculata zone, with coarser-grained sandstone in the south-west, continued during the deposition of the *P.*n.sp.aff, *acuminata* zone.

The *P.* n.sp.aff. *acuminata* zone does not crop out west of the West Taiko Fault. The sediments of the zone are variable; they differ in content within short distances ~~along the strike~~. Five composite sections are described (see Figure 26).

Pelicaria shells with morphologies intermediate between *P. canaliculata* and *P.* n.sp.aff. *acuminata* occur at fossil localities 753, and 758; and at fossil locality 753 in association with *P. canaliculata*.

The zone is best exposed, and contains a more diverse macrofauna, along an east-southeast reach of the Mangahao River one mile north-west of Koti (2) Trig. (See Column 4).

The 12 ft thick *T*$_3$ Chlamys *bed* is composed almost entirely of *Chlamys* shells, probably *C. delicatula*; other molluscs present are *Stiracolpus* sp. and *Marama* sp. ~~The bed is thought to be developed within a steep hillside some five hundred yards to the north.~~ It was also found at grid ref 187044 where it occurred at the base of the massive light blue grey sandstone; but it was not found further west.

Six hundred yards southwest of Column 4, a section at grid ref 182139, see Column 3, contains two 2 ft thick shells beds which are absent in Column 4. The shell beds occur 40 and 80 ft below the top of the zone. They are largely composed of shell fragments, and unbroken *Cardita* sp.

Seven hundred yards west of Column 3, a section along Otangue Stream (grid ref. 170136) contains in its central part a 90 ft-thick sequence of 10 ft thick massive fine-sandstone beds interbedded

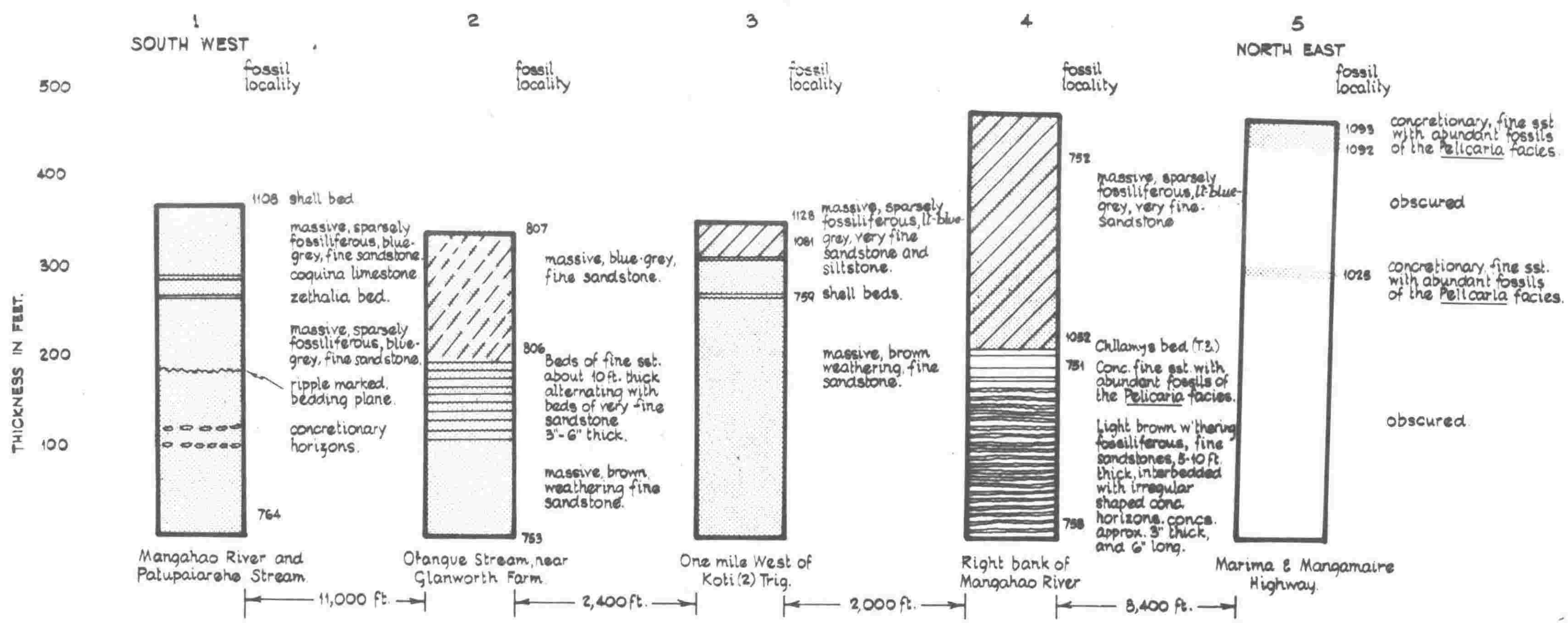


FIG.26 Stratigraphic Columns of the _Pelicaria_ n. sp. aff. _acuminata_ Zone (MARIMA SANDSTONE)

with 3 - 6 inch thick ripple marked beds of very fine sandstone and siltstone. Above the bedded part of the zone, the massive fine grained sandstones contain sporadic macrofossils particularly Pinna, Offadesma and Bassina. (see Column 2) A section along the Mangahao River and Patupaiarehe Stream contains coarser grained sandstones than to the northeast. Bedding is indicated by a one-inch thick clay horizon which overlies a ripple-marked surface. Assymetry of the ripple marks show that the current which formed the ripple marks was flowing from the south-southeast (180° and 155°). Higher up in the ~~stratigraphic~~ sequence a 1½ inch thick bed composed entirely of unbroken shells of Zethalia zealandica occurs 20 ft below a 31 inch thick coquinoid limestone. These beds are overlain by massive fine sandstone. (See Column 1). Northwest of the best-exposed section the upper beds of the zone are well exposed along the Marima - Mangamaire Road (see Column 5). Other parts of the zone are not well exposed. Most of the strata are massive very fine sandstones. The Pelicaria Facies is present near the middle of the zone at fossil locality 1028, and at the top at 1092 and 1093 (where fossil crabs are quite abundant). It is thought that the beds of the Pelicaria Facies at fossil locality 1028 were deposited contemporaneously with those at fossil locality 751 of Column 4. Pelicaria facies developed on the left bank of the Mangahao River at fossil locality 780 are probably of the same age as the beds at 1092 and 1093, on the Marima Road. Massive very-fine-sandstones on the right bank of the Mangahao River at grid ref. 209172 (fossil locality 743) probably underlie the Pelicaria Facies of fossil localities 780, 1092 and 1093.

East of the Paiwai Fault, the zone is very poorly exposed and delineated. It crops out along the road to Hendersons Farm.

Zone of Pelicaria n. sp. aff. tricarinata

Coarser-grained sandstones occur at Kopikokopiko than at Marima, repeating the facies pattern of the *P. canaliculata* and *P.* n. sp. aff. *acuminata* zones. In contrast to the *P. canaliculata* and *P.* n. sp. aff. *acuminata* zones the *P.* n. sp. aff. *tricarinata* zone is thinner than usual in the south-western part of the outcrop area at Kopikopiko. Near Marima the zone includes three calcite-cemented coquinoid shell-bed-members (T_4, T_5 and T_6). The T_4 shell bed crops out downstream of Tainui Stream on the left bank of the Mangahao River; the T_5 and T_6 shell beds are restricted to the western flank of the Henderson Syncline between Kareara and Paranui Trigs. The shell beds do not crop out in sequence, and their stratigraphic relations are somewhat uncertain. It is thought that the T_4 shell bed is not the T_5 shell bed because the sandstone overlying the T_4 shell bed is more than 120 ft thick, while at Karearea Trig only 15 ft of sandstone separate the T_5 and T_6 shell beds.

Massive blue-grey very-fine sandstone containing specimens of *Pelicaria* intermediate between *P.* n. sp. aff. *acuminata* and *P.* n. sp. aff *tricarinata* occur along the Mangamaire - Marima Road (fossil locality 1094) and ~~The massive sandstone~~ overlies the concretionary fine sandstone containing *P.* n. sp. aff. *acuminata* (fossil localities 1092 and 1093). Shells identical to those at fossil locality 1094, occur at fossil locality 1128; elsewhere the contacts between the P. n.sp. aff. tricarinata and the P. n.sp. aff. acuminata zones are not ~~based~~ marked ~~on the distribution of~~ by intermediate shells.

A composite section of the basal part of the zone developed near Marima contains:-

		Feet	Fossil Locality
	Very-fine sandstone	10	
	Pelicaria rugosa bed	1	1049
	Very-fine sandstone	c. 100	1050
	Fine sandstone	10	
T_4 Shell bed	(Light grey coquinoid limestone, about 50 per cent of which is composed of whole macrofossils	10	
	Fine sandstone	10	
	Very-fine sandstone	c. 140	1024
	Shell bed	3.5	1023
	Fine sandstones with concretionary fossiliferous horizons (Pelicaria Facies)	15	742, 1022
	Very fine sandstone	c. 100	1094

There is some continuity south-westwards from Marima, of the basal beds of the P. n.sp. aff. tricarinata zone. The 100 ft thick basal very-fine sandstone is traced about a mile south-westwards to the left bank of the Mangahao at grid ref 192152 (fossil locality 750 and 1051). The T_4 shell bed has been mapped south-westwards as far as 192159. It also occurs along the right bank of Tainui Stream east of School Fault. The limestone is usually 5 - 7 ft thick, but at grid ref 190170, on the downthrow side of the School Fault the limestone increases in thickness to 15 ft in a matter of 30 yards, in a direction towards the fault.

Shells of Pelicaria rugosa are relatively rare in the Marima area; a 1 ft thick shell bed largely composed of P. rugosa found at grid ref. 188160 is unique. The associated macro-fauna includes nests of Stiracolpus sp. and rare Panopea zelandica, Penion sp. Venustas hodgei, Bassina yatei, and Cancer novaezelandiae. Scattered P. rugosa shells occur up to 5 ft above the P. rugosa bed in otherwise unfossiliferous sandstone.

A section of the upper part of the P. n.sp. aff. tricarinata zone, 1000 yards due north of Karearea Trig on the West flank of the Henderson Syncline consists of:-

	Feet
G_1 Limestone of the Totaranui Formation	
Very fine sandstone with common P. rugosa and Nemocardium pulchellum	c. 15
Very-fine sandstone	55
T_6 Coquina Limestone containing many whole shells	1 - 3
Sandy siltstones with Ostrea	15
T_5 Coquina limestone containing many whole mollusca shells	5
Ripple-marked, fine to medium sandstone	c. 20
Fine and very-fine sandstone	c. 550

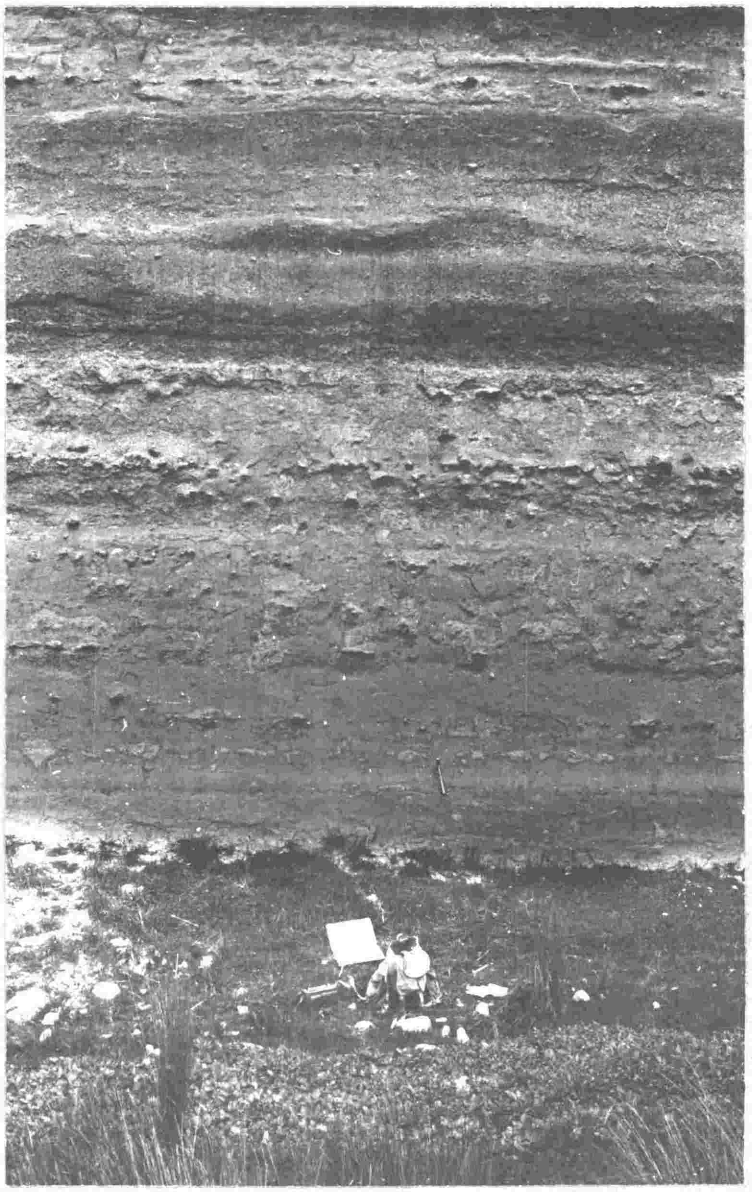


Figure 27: Outcrop of Pelicaria facies developed in the zone of P. n.sp. aff. tricarinata, in Marima Sandstone at right bank of the Mangahao River (grid ref.216186). Bedding indicated largely by thin concretionary fossiliferous horizons.

West of the School and Marima faults the T_4, T_5 and T_6 shell beds are absent; and the zone consists of massive blue-grey fine-sandstone. Near Nikau, shell beds occur in the upper parts of the zone at grid refs. 202188, and 205187. At Tainui Stream the sandstones contain some bryozoans and scattered molluscs. Shell beds are more common at Otangue Stream, where a section contains:

	Feet
Fine sandstone containing common *Zethalia zelandica* and rare pectens and *Dosinia* sp. and a few well-rounded pebbles	c. 300
Two pelecypod shell beds, each about 9 inches thick containing greywacke pebbles often 2 inches long	5
Sparsely fossiliferous very-fine sandstone containing one 1-ft-thick shell bed	c. 300

At Wahaoteika Stream the zone consists of massive unfossiliferous fine sandstone; further south-west, between the East and West Taiko faults and near the end of the Kopikopiko Road, the zone consists of unfossiliferous sandstones and conglomerate beds of marine aspect. In Patupaiarehe Stream (grid ref. 139122) the base of the zone is delineated by a shell bed, (fossil locality 1109); the fauna of the shell bed contains many ~~different~~ species and probably represents a mixed Biocoenose-Thanatocoenose assemblage. The zone is not well exposed in the much-faulted area east of the Huru Fault. Exposures along the Marima Road between Mangamaire and its junction with Hendersons Road show that most of the strata are blue-grey massive sparsely-fossiliferous very-fine-sandstone; the Pelicaria Facies is not developed.

Correlation by macrofossils serves two purposes: firstly, to zone the Marima Sandstone at Marima and, secondly, to correlate the Marima Sandstone with sediments deposited contemporaneously in adjacent regions, especially in Wanganui (where the Waipipian, Waitotoran, and Hautawan Stages were established by Fleming in 1953).

Molluscs which show progressive morphological changes during the deposition of the Marima sandstone are *Pelicaria*, on which the zones are based (Neef in preparation), and perhaps *Zelandiella* cf. *pliocenica*.

~~Neef found that there are~~ Three biocharacters of the *Pelicaria* shells ~~which~~ progressively change with time; ~~during the deposition of the Marima Sandstone;~~ 1. ~~the~~ a reduction of the height of the cinguli, 2. a gradual change from a canaliculate suture to a shelf, and 3. a reduction in the number of chords on the base. The fossils are ~~can be~~ subdivided into three groups, which are used to zone the Marima Sandstone. Intermediates occur between the *P. canaliculata* and the *P.* n.sp. aff. *accuminata* zone, but the thickness of strata containing these shells is small. Above the basal part of the *P.* n.sp. aff. *acuminata* zone the ~~morphologies of the~~ *Pelicaria* shells remain constant. ~~do not alter.~~ The shells from the basal beds of the *P.* n.sp. aff. *tricarinata* zone are distinct, but ~~are~~ broadly intermediate in character between the shells of the underlying and overlying zones. They ~~shells~~ are distinguished from *P.* n.sp. aff. *acuminata* by lower more rounded cinguli and by the introduction of spiral lirae in the interspaces between the cinguli. They are distinguished from *P.* n.sp. aff. *tricarinata* by their higher cinguli. Above the basal beds, the morphologies of the *P.* n.sp. aff.

Table 12 - Continued

	753	754	756	757	760	761	762	764	765	785	786	787	813	816	818	819	820	821
Divaricella cf. huttoniana Vanatta							X		X						X			
Divaricella sp.				X									X					
Pteromyrtea dispar (Hutton)							X											
Chlamys gemulata (Reeve)						X	X											
Chlamys. n.sp.aff.dieffenbachi (Reeve)							X											
Phialopecten hilli (Hutton)				X														
Ostrea ingens (Zittel)								X										
Spisula aequilateralis (Deshayes)																		X
Dosinia (Kereia) greyi Zittel							X											
D. (Dosinia) cf. lambata (Gould)				X														X
D. waipipiensis Marwick																		
D. cf. chathamensis Marwick														X				
Dosinia sp.																	X	
Notacallista multistriata (Sowerby)	X			X			X											
Tawera errans Marwick															X	X		X
Bassina yatei (Gray)															X		X	
Nemocardium pulchellum (Gray)		X		X														
Maoricardium spatiosum (Hutton)			X		X													
Gari lineolata (Gray)							X											X
Panopea zelandica (Q & G)																		
Zenatia acinaces (Q & G)	X													X				X
Offadesma angasi (C & F)?																		
Decapoda -																		
Carcinoplax sp.	X																	
Pisces -																		
Carcharodon probably carcharias (Linne)						X												

	838	839	1046	1047	1078	1079	1080	1110	1111	1119	1129	1130	1131	1132
Divaricella cf. huttoniana Vanatta														
Divaricella sp.														
Pteromyrtea dispar (Hutton)														
Chlamys gemulata (Reeve)														
Chlamys. n.sp.aff.dieffenbachi (Reeve)														
Phialopecten hilli (Hutton)														
Ostrea ingens (Zittel)														
Spisula aequilateralis (Deshayes)														
Dosinia (Kereia) greyi Zittel														
D. (Dosinia) cf. lambata (Gould)				X										
D. waipipiensis Marwick							X							
D. cf. chathamensis Marwick														
Dosinia sp.														
Notacallista multistriata (Sowerby)														
Tawera errans Marwick														
Bassina yatei (Gray)														
Nemocardium pulchellum (Gray)														
Maoricardium spatiosum (Hutton)														
Gari lineolata (Gray)														
Panopea zelandica (Q & G)														
Zenatia acinaces (Q & G)														
Offadesma angasi (C & F)?														
Decapoda -														
Carcinoplax sp.														
Pisces -														
Carcharodon probably carcharias (Linne)														

TABLE 13

MACROPALAEONTOLOGY OF MARIMA SANDSTONE

Pelicaria n.sp. aff. acuminata zone

	743	751	752	758	780	804	805	806	807	1028	1052	1081	1092	1093	112
Calliostoma (Maurea) hodgei (Hutton)	X	X			X										
Zeacolpus (Stiracolpus) delli vellai Marwick		X			X										
Pelicaria aff. acuminata (Marwick)		X		X	X		X			X			X	X	X
Struthiolaria papulosa (Martyn)		X		X			X	X	X				X	X	
Aeneator attenuatus Powell		X													
Penion cf. haweraensis (Powell)		X			X									X	
Austrofusus glans (Roeding)	X		X					X							
Zealandiella cf. pliocenica Powell		X											X		
Alcithoe swainsoi (Marwick)		X								X					
Baryspira (B) erica Olson			X								X	X			
Neilo australis (Q & G)		X													
Diplodonta globus Finlay	X														
Divaricella sp.		X													
Chlamys delicatula (Hutton)		X			X										
C. gemulata (Reeve)		X	X												
Chlamys n.sp.				X											
Phialopecten thompsoni Marwick						X									
Atrina zelandica (Gray)	X					X									
Crassostrea ingens (Zittel)		X													
Zenatia acinaces (Q & G)		X	X		X									X	
Dosinia (Kereia) greyi Zittel		X								X			X	X	
D. (Dosinia) lambata (Gould)	X	X											X	X	
Cyclomactra tristis (Desh)		X								X			X	X	
Notirus, n.sp.		X			X					X				X	
Bassina yatei (Gray)		X						X						X	
Panopea zelandica (Q & G)		X													
Offadesma angasi (Crosse and Fischer)	X	X							X						
Pseudechinus novaezelandae Mortensen				X											
Carinoplax. sp		X													
Jacquinotia edwardsii Jacquinot		X													
Omatocarcinus cf. macgillivrayi White		X													
Cancer novaezealandiae (Jacquinot & Lucas)					X										
Majid crab														X	
Megabalannus tabulatus Withers		X													
Balanus amphitrite Withers		X													

Table 14 - Contd

	741	742	744	745	746	747	748	749	750	769	781	782	791	792	1022	1023	1024	1025	1026	1027	1049	1050	1051	1053	1073	1074	1075	1076	1077	1082	1094	1099	1100	1101	1108	1109	1117	1118	1124	1125	1128
Cardita lillei (Fleming)														X																					X						
Dosinia (Kereia) greyi Zittel			X				X																																		
D. (Kereia) cottoni Marwick			?X				X																																		
Dosinia zelandica (Gray)																			X																			X			
Cyclomactra tristris (Reeve)		X											X		X																										
Marama murdochi Marwick			X																																					X	
Marama sp.																												X													
Notocallista multistriata (Sowerby)	X	X		X				X					X		X							X	X										X	X							
Notacallista aff. multistriata Sowerby																					X																				
cf Starborough Creek sp.												X																													
Tawera subsulcata (Sutur)								X			X	X																													
Bassina yatei (Gray)	X	X		X				X					X		X						X			X			X						X								
Paphirus largillierti (Phillips)	X	X	X					X		X	X				X						X			X								X	X								
Notiris n.sp.			X																																						
Nemocardium pulchellum (Gray)	X	X		X				X					X		X					X							X														
Gari strangeri (Gray)																																			X						
Panopea zelandica (Q & G)	X	X					X				X				X						X												X								
Zenatia acinaces (Q & G)	X	X		X							X				X												X														
DECAPODA																																									
Cancer novaezealandiae (Jacquinot and Lucas)																					X																				
Carcinoplax sp.		X																																							
Ovalipes cf. punctatus (de Haan)																																				X					

tricarinata shells do not alter up to the top of the zone.

Shells of *Zelandiella* cf. *pliocenica* are rare but occur in both the *P. canaliculata* and the *P.* n.sp. aff. *acuminata* zones; If shells from the two zones are compared it can be seen that there are some minor but constant differences.

Many of the fossil molluscs, such as *Austrofusus glans* and *Struthiolaria papulosa*, *Olivella* (*Lamprodomina*) *neozealandica* range right through the Marima Sandstone without morphological change. Specimens of *Baryspira* collected from any one fossil locality are usually very variable, and for this reason are unlikely to be useful for correlation.

Shells which are common, or are relatively common, but which are restricted to the *P. canaliculata* zone, include *Policinices waipipiensis*, *Austrofusus pagoda*, *Clavatoma pulchra*, *Astrotoma* cf. *prolixa*, and *Marshallena austrotomoides*.

The unfossiliferous T_2 Conglomerate is attributed to the *P. canalicalata* zone, largely because the conglomerate grades north-eastwards into sandstones of the *P. canaliculata* zone. Some of the upper part of the Conglomerate may have been deposited during *P.* n. sp. aff. *acuminata* time. It is possible, but unlikely that some of the Conglomerate was deposited as late as the Okehuan. (G_7 Conglomerate of the Mangahao Formation).

Correlation of the *P. canaliculata* zone is thought to be approximately with the Waipipian Stage. Correlation is mainly from

~~to~~ the occurrence of *P. canaliculata*, ~~both~~ at Marima and at Wanganui. Kennett (1966a) ~~has~~ found *P. canaliculata* shells in the Opoitian strata of the Awatere Valley. ~~It is thought that if much fossiliferous Opoitian strata had been deposited at Waipipi and at Eketahuna, that correlation between these two regions would be much more tenuous.~~ Molluscs which occur in the *P. canaliculata* zone and which probably make their last appearance in the Waipipian stage include *Dosinia waipipiensis* (see Marwick, 1926) ~~and fossil listed in Fleming 1953~~ and *Maoricardium spatiosum*, *Austrofusus pagoda* and *Zethalia coronata* (see Marwick 1948). Most of the *Zethalia* specimens, however, are *Zethalia zealandicum*, *Zethalia corunata* occurs at only one fossil locality (816).

Apart from the *Pelicarias* of the evolving *Pelicaria* lineage, the difference in faunal content of the *P.* n.sp. aff. *acuminata* and the *P.* n.sp. aff. *tricarinata* zones is slight. *Notirus* n.sp. is restricted to the *P.* n.sp. aff. *acuminata* zone and *Paphirus largillierti* is restricted to the *P.* n.sp. aff. *tricarinata* zone, however. Correlation of the *P.* n.sp. aff. *acuminata* and *P.* n.sp. aff. *tricarinata* zones with the stages at Wanganui is ~~less~~ uncertain. Boreham (1963) has outlined the difficulties of stratal correlation by Waitotaran and Hautawan faunas of strata at Dannevirke with ~~the~~ stages at Wanganui. *Pelicaria* n.sp. aff. *tricarinata* occurs in the Makokako Sand and the Hautawan Shell-bed (~~see~~ Neef in preparation) which establishes that the *P.* n.sp. aff. *tricarinata* zone is equivalent to all of the Hautawan together with ~~and~~ the upper part of the Mangapanian (Waitotaran) stages.

Stiracolpus delli vellai occurs at two localities in the P. n.sp. aff. tricarinata zone and also at its type locality (478) which may be in either the P. n.sp. aff. acuminata zone or in the P. n.sp. aff. tricarinata zone. Marwick (1957 p.25 and 27) considered Stiracolpus delli vellai to indicate a Hautawan age. Also Aeneator imperator an uncommon fossil in the P. n.sp. aff. tricarinata zone has been considered to be a key fossil of the Hautawan and early Nukumaruan Stages in southern Wairarapa. (See Vella 1963b).

Some generally-accepted fossil ranges may have to be changed. ~~Some of the fossil molluscs occur either after they had been thought to have become extinct or prior to their establishment in other parts of New Zealand.~~ Struthiolaria praenuntia Marwick is common in Tongaporutuan-Kapitean strata and has been recorded at Hurupi Creek and at Taranaki. The shell from the P. canaliculata zone at fossil locality 1047 is close in most bio-characters to the type specimen. The shell is thought to be the youngest S. praenuntia recorded. Finlay and Marwick (1940) considered that Penion haweraensis and Marshallena were restricted to the Waitotaran; it may be that these shells make their final appearances in the Pelicaria n. sp. aff. tricarinata zone at Marima. Many species of Baryspira have been found, particularly within the P. canaliculata zone. The most common species Baryspira (B) erica Olson has been considered by Olson (1956) to be restricted to the Nukumaruan stage. Its presence at Marima, within the P. canaliculata zone is thus the first recorded occurrence of the species. Baryspira (B). gulosa was thought by Olson (1956) to be restricted to the Taranakian and Opoitian Stages. Its occurrence in the P. canaliculata zone at fossil locality 753 extends the range of the species.

Pollen Analysis by D.J. McIntyre

Lab Number	Fossil Locality	Stratagraphic position
2852	1049	Zone of Pelicaria
2853	1050	n.sp. aff. tricarinata
2839	750	
2843	785	Zone of Pelicaria
2844	821	canaliculata
2840	762	

Fossil Locality 762:- Dominant pollen type is Nothofagus fusca group, (?N. truncata). Phyllocladus common, and small amounts of Cyathea smithii, Dicksonia squarrosa, Podocarpus, Dacrydium cupressinum, and D. bidwillii group, Libocedrus, Nothofagus menziesii, Compositae, and Gramineae. Other grains present are Ascarina, Eleocarpus, Hoheria, Rhopalostylis. Some Nothofagus mataurаensis and rare Microcachryidites parvus of the extinct species.

The vegetation was very similar to that of fossil localities 1049 and 1050, but more strongly beech-dominant and with little of the mixed conifer and scrub elements. The climate was probably slightly cooler than the present day or similar, but perhaps not so cool as that from fossil locality 1049 and 1050.

Fossil locality 821:- Rather poor pollen flora which, however, is rather similar to that of 785 and indicates a similar type of vegetation and climate conditions. Extinct species in this sample are Polycolpites reticulatus and Proteacidites minimus. There are slight differences in relative abundances including more Cyathea and Dacrydium cupressinum and less Phyllocladus. Climate probably similar to present day but wetter.

Fossil locality 785:- Nothofagus fusca group (?N. truncata) is the dominant pollen type. Nothofagus menziesii, Phyllocladus, and Dacrydium bidwillii group and Cyathea smithii are abundant. Other types present include Dicksonia squarrosa, Podocarpus, spp., plus P. dacrydioides, Dacrydium cupressinum, Araucariaceae, Libocedrus, Metrosideros, Compositae, Astelia, Gramineae, Cyperaceae, Coprosma, Ascarina, Weinmannia, Aristotelia. Extinct species present are Nothofagus matauraensis (common) N. cranwellae, Microcachryidites parvus, Triorites harrisii and Polycolpites reticulatus, and Elytranthe striatus.

The vegetation was beech forest with podocarp elements. Some cool temperature elements are also present and probably were part of the scrubland near to a forest or closely associated with it. Local elements are fairly common and probably grew not far from the point of deposition.

The climate was similar to that of present day or even a little cooler (quite likely), and possibly wetter.

Fossil Locality 750:- Strongly dominant pollen type is Nothofagus fusca group (?N. truncata). Podocarpus, Dacrydium cupressinum, Phyllocladus and Araucariaceae (?Araucaria and Agathis) are common. Other species present are Cyathea smithii, Dicksonia squarrosa, Podocarpus dacrydioides, Dacrydium bidwillii group, Knightia excelsa, Metrosideros, Compositae, Rhopalostylis, and Gramineae. Of the extinct species rare Nothofagus mataurensis, Microcachryidites parvus and Triorites harrisii occur.

The vegetation was beech forest with some mixed conifer elements. The climate was similar to, or probably somewhat warmer, than the present day. There is some possibility of mixed vegetation types as in samples 1049 and1050 but it is not so pronounced here and may it be that the supposedly cooler elements are part of the main vegetation type. A species-level identification would be required to confirm such a contention but this is not possible with these types at the present extent of knowledge of pollen flora. The presence of some hystrichospheres confirms marine deposition which could again account for any mixing of floral elements after transport from point of origin.

Fossil locality 1049 and 1050:- Both these samples contain almost identical pollen floras which are dominated by Nothofagus fusca group, possibly N. truncata. Phyllocladus is abundant in both and Podocarpus, Dacrydium bidwillii group and the extinct species Microcachryidites parvus are common. Compositae are also abundant but more so in 1049. Some Cyathea occurs and small amounts of Dacrydium cupressinum, Libocedrus, Nothofagus menziesii, and Gramineae are rare. Also present are Weinmannia, Eleocarpus, Aristotelia and Araliaceae. Nothofagus cranwellae occurs rarely in 1049.

Vegetation was beech forest with some Podocarpaceae, mainly of scrub of subalpine type or perhaps not quite so cold. The climate was probably a little cooler than present day, and perhaps comparable with the warmer part of the Okehuan Section at Wahaoteika Stream. The presence of Compositae indicates some shrub land and cool conditions. Very little pollen of local and swamp types. This is perhaps not surprising in view of the marine environment of deposition which is confirmed by the presence of numerous hystrichospheres.

Conditions of Deposition

Zone of Pelicaria canaliculata

The basal concretion fragment bed indicates that locally large colonies of the rock borer Pholas, were present on the sea bed prior to the deposition of the Marima Sandstone. The shallow-water-indicating Cardium spatiosum and oyster shells occur with the fragments, and the occurrence of the bed above an unconformity and below sandstones containing shallow water fossils (such as fossil locality 757), indicates that the rock borer may have been the intertidal Pholadidea spatulata. Many concretions, partly in situ, and also perhaps derived, due to submarine erosion of the fine sand matrix of the Tane Sandstone, paved the sea floor. Marine currents are thought to have been too powerful locally to allow many benthic marine animals to establish themselves. The presence of rare concretion fragments as much as ten feet above the base, and the fine grained nature of the matrix of the basal beds of the P. canaliculata zone indicates that submarine erosion of the Tane Sandstone was occuring nearby. Perhaps the area supplying the detritus was farther to the southeast, as that area would have been at a higher elevation than the depositional area if tilting had occurred shortly before deposition of the Marima Sandstone. The T_1 and T_2 Members were probably deposited in very shallow seas, or alternatively the T_2 Conglomerate could be non-marine. In the south-western part of the outcrop area of the *P. canaliculata* zone, west of the Mangaraupiu Road, and also along the right bank of the Mangahao River a mile north of Kakariki, thin conglomerate beds are interbedded with much thicker fossiliferous fine sandstone beds containing many rolled and broken fossils. The most common unbroken fossil in the fine sandstones is *Zethalia zelandica*. Powell (1937) considered *Zethalia zealandica* and *Arachnoides zelandica* to be characteristic of the semi-estuarine conditions in the outer basin of Manakau Harbour at depths of 4 - 17 fathoms. Vella (1962c p.292) considered that *Zethalia zealandica* was deposited within the Zeaflorilus Biofacies, which Vella (1963b) considered to have been deposited at depths of 0 - 20 ft. In the south-western part of the outcrop area depth analysis of foramanifera from fossil localities 765, 816 and 821 indicate deposition within the Zeaflorilus Biofacies. At fossil locality 765, *Struthiolaria papulosa* was found to be particularly abundant, as small groups of shells, as "nests", and as shell bands. It is thought that a Zeaflorilus biofacies depth of deposition with conditions of normal salinity represented the optimum conditions ~~preferred by~~ for this mollusc.

At the best-exposed section, and further to the north-east, most of the zone, apart from the basal beds, was deposited in somewhat deeper water than near Kakariki. The fossils are generally unbroken, and greywacke pebbles are rare. Shells from the lower part of the zone ~~at~~ (fossil localities 757, 762 and 1080) are wave sorted and the pelecypoda valves are normally disarticulated, indicating that most of the fossils are a thanatocoenose assemblage. The fossils are not greatly abraided and were probably not transported far prior to deposition. Depth analysis of foraminifera from fossil localities 754, 757, and 762 indicate upper neritic (20 - 200 ft) depths of deposition.

In contrast to the lower part of the zone, fossils from the middle part of the zone appear to be a biocoenose assemblage. The three thin shell beds in the upper part of the zone (at grid ref 168132) may owe their origin to sand being bypassed across the area of deposition so that shells accumulated ~~on the sea floor~~ as a shell bed. The upper parts of the zone, ~~are~~ exposed along Wahaoteika Stream, ~~some of them~~ contain macrofauna, partly of rolled appearance, ~~are~~ thought to be a thanotocoenose assemblage. Foraminifera from fossil locality 787 indicate upper-neritic to sub-litoral depths of deposition.

Depths of deposition were somewhat deeper near Mangamaire. Foraminifera at fossil locality 785 indicate mid-upper-neritic depths of deposition; ~~further Mollusca~~ and mollusca are rarer there.

The abundant Polinices waipipiensis shells (a warm water indicator) indicate that the climate during the deposition of the zone was warm, perhaps warmer than that of the present day. This premise has not been confirmed by the pollen analysis of Mr McIntyre. It could be, however, that the Marima district was under the influence of warm water currents during the deposition of the sandstones, with air temperatures similar to those of the present day.

Zone of Pelicaria n. sp. aff. acuminata

Southwest of Otangue Stream, the zone was deposited in shallow water, the most common fossil, Zethalia zelandica, indicates deposition at depths of about 0 - 20 ft. North-eastward of Otangue Stream in the Koti Trig area, and at Marima, two lithofacies are developed; massive very-fine sandstone; and concretionary fossiliferous fine sandstone. The concretionary fine sandstone contains a very uniform macrofauna here called the "Pelicaria Facies" which is considered to be a Biocoenose assemblage. The more important elements of the assemblage are:-

Pelicaria n. sp. aff. acuminata	extinct
Stiracolpus delli yellai	extinct
Penion cf. haweraensis	extinct
Alcithoe swainsoni	
Dosinia (Kereia) greyi	
Dosinia (Dosinia) lambata	
Cyclomactra tristis	

Bassina yatei

Notirus n. sp.

Panopea zelandica

Zenatia acinaces

Although *Cyclomatra tristis* has been considered by Powell (1937), to indicate estuarine conditions, its association with shells such as *Panopea zelandica*, *Pelicaria*, and *Zenatia* indicate conditions ~~that the sea was~~ of normal salinity. The pelecypoda and the gastropod *Pelicaria* are deposit feeders, feeding on minute food particles filtered from seawater while almost buried in sand; *Alcithoe* and *Zelandiella*. aff. *pliocenica* preyed on the deposit feeders. The valves of the pelecypoda are still articulated ~~which indicates that generally the fossils died during a period when they were buried~~. Fleming (1951) found that *Dosinia greyi* occurs within a 11 - 18 fathom depth-range in Fiordland, while Powell (1937) found the *Dosinia lambata* occurs within a 2 - 11 fathom depth-range in Auckland Harbour. As both shells are found in the same order of abundance, a depth of deposition of the Pelicaria Biofacies was probably about 11 fathoms.

Among the minor faunal elements of the Pelicaria Biofacies are the following fossil crabs:- *Carcinoplax* sp; *Jacquinotia edwardsii*; *Ommatocarcinus* cf. *macgillivrayi*; *Cancer novazealandica*; and a *Majid* crab.

The crabs are rare, insofar that perhaps only one crab may be found during a visit to a particularly fossiliferous locality such as that at 751, but crabs are common in comparison to the number of fossil crabs found elsewhere in the Tertiary strata of New Zealand (with the exception of Miocene crab-bed described by Fleming, 1962b).

The environment preferred by the recent crabs, *Jacquinotia edwardsii*, *Cancer novazealandica* and *Omatocarcinus macgillivrayi* is cold water (see Appendix 4); and it is thus probable that the *Pelicaria* Biofacies was deposited in cold water. Also Marwick (1957, p.25) considered *Stiracolpus delli yellai* to be a hybrid between the cold water indicator *S. symmetricus* and *S. uttleyi*. Marwick further considered *S. delli yellai* to be a cool water indicator.

Faunal assemblages, and populations of one-molluscan-species noted within the massive non-concretionary very fine sandstone of the *P.* n. sp. aff. *acuminata* and *P.* n. sp. aff. *tricarinata* zones are:-

(1) *Atrina zelandica*, *Offadesma angasi*, *Calliostoma* (*Maurea*) *hodgei* assemblage.

(2) *Zeacolpus*. sp. and *Austrofusus*. cf. *glans* assemblage.

(3) *Zeacolpus* sp. populations.

(4) *Austrofusus* cf. *glans* populations.

(5) *Bassina yatei* populations.

The *Atrina*, *Offadesma*, *Calliostoma* assemblage invariably occurs in massive muddy fine sandstone. The shells are large and are scattered. Fleming, in Wellman (1954) reported that *Atrina* and *Calliostoma* rarely occur below 30 fathoms. The fossils are thought to indicate depths of deposition of about 30 fathoms, because of the fine grained nature of the sediment and the sparseness of the fossils. The *Zeacolpus* and *Austrofusus* associations and populations are also thought to have preferred water about 30 fathoms deep. Te Punga (1952) has noted an *Austrofusus* population in the Castlecliffian strata of the Rangitiki Valley.

Populations of large *Bassina yatei* shells have only been found in Wahaoteika Creek (grid ref 152128), within massive fine grained sandstone of the Zethalia facies. ~~They~~ The shells are larger ~~in size~~ than those found in the Pelicaria Biofacies which indicates that the optimum condition ~~preferred by~~ for the species was at a shallower depth than that of the Pelicaria Biofacies.

Vella (1963b) has suggested that during Plio-Pleistocene time sea levels flucuated in the Wairarapa area; due to a waxing and waning of the polar ice caps. During glacial periods, low sea levels occurred. ~~At these times~~ and there was an increase in the turbulence of the sea ~~on the area of~~ over the continental shelves. Coarser sand was thus swept further from the coastal areas into those areas where ~~normally~~ finer grained sand and or silt ~~was~~ had been deposited. Pantin (1957) and Fleming (in Pantin, 1957) have shown that concretions, on the sea bed in Cook Strait, were formed about 19,000 years ago in fossiliferous sands containing a cold water macrofauna which are about 27,000 years old. Pantin (1965) has considered that organic material absorbed at the interface of a calcareous substance within sediment may inhibit recrystalisation indefinitely. It is clear that the concretionary Pelicaria Biofacies has reached chemical equilibrium while the non-concretionary massive very fine sandstones has not. It is possible that the organic factor, which inhibited recrystalisation, (concretion formation) is not so common during times of colder water.

Zone of Pelicaria n. sp. aff. tricarinata

Conditions similar to the P. n. sp. aff. acuminata zone prevailed in the Marima-Kopikopiko area during the deposition of the P. n. sp. tricarinata zone. Shallow water sediments often containing Zethalia were deposited south west of Otangue Stream; while at Marima concretionary fine sandstones of the Pelicaria Biofacies are interbedded with massive blue-grey silty very-fine sandstones.

Apart from the introduction of Notocallista multistrata (now seldom found above 10 fathoms (see Fleming in Wellman 1954)) and Neomocardium pulchellum, and the replacement of Notirus n. sp. by Paphirus largillierti) the macrofauna ~~of the Pelicaria Biofacies~~ is nearly identical to that of the P. n. sp. aff. acuminata zone. One anomaly is the presence of the warm-water-indicator Olivella (Lamprodomina) neozelandica, (at fossil locality 791).

The shells of the T_4, T_5 and T_6 shell beds are worn but can be identified, ~~it is thought that the shell beds were formed almost in situ at a time when sandstones were deposited nearby~~.

Boreham (1963) considered that Pelicaria rugosa indicates cold water. Pollen from the P. rugosa bed and from sandstones 20 ft below the bed are almost identical, ~~indicating little if any change of climate~~ (see pollen analysis of the Marima Sandstone by Mr D. McIntyre). Cancer

<u>novaezealandiae</u> from the <u>P.</u> <u>rugosa</u> bed, however, indicates coldish water. It could be that the bed is due to a brief incursion of cold water into the Marima area from southern Wairarapa, rather than a climatic change.

MAKURI GROUP

The group is named after the Makuri River (the type area) and is subdivided and mapped into formations and members. (See Table 15).

The Makuri Group is best developed in the type area and near the "Pori", a north-east striking strip of Opoitian sediments about 1½ miles wide, bounded in the south by the Taumata-Makuri faults, separates the two areas. The basal part of the Makuri Group is also developed east of the Alfredton Fault; near Alfredton, at Mangamahoe, and at a tiny outcrop near Eketahuna. Sediments at Marima, deposited at the same time as the Makuri Group, ~~are~~ have been described separately under "Marima Sandstone".

The group rests unconformably on the Eketahuna Group, usually on the Tane Sandstone. At Mangamahoe, the Tane Sandstone is absent and the Makuri Group overlies the Tawatia Sandstone. Near Eketahuna the basal beds of the group overlie the Tawatia Sandstone (south of the Cliff Road Fault), and the Newman Siltstone (north of the fault). The group is fully represented only in the type area, where it is overlain by the Managmaire Group. ~~But elsewhere younger marine rocks are absent.~~

MAKURI SANDSTONE

Distribution

In the type area, at the northern margin of the Sheet District, the Makuri Sandstone crops out in a three-quarters-of-a-mile-wide belt most of which trends northeastwards. Between the Tiraumea River and the Rongomai Fault, however, the strike of the formation is east

Table 15

FORMATIONS AND MEMBERS OF THE MAKURI GROUP

NORTHERN (TYPE) AREA	PORI	MANGAMAHOE	ONE MILE N.W. OF EKETAHUNA
KAITAWA SANDSTONE F_{21}	UPPER PORI LIMESTONE F_{20}		
UPPER MAKURI SILTSTONE F_{17}	(PORI SANDSTONE F_{19} ((UPPER MAKURI SILTSTONE F_{17} Chlamys bed F_{18}		
KOROPEKE LIMESTONE F_{16} KOROPEKE SANDSTONE F_{15}	LOWER PORI LIMESTONE F_{12} Upper Sandstone lens F_{14} Lower sandstone lens F_{13}		
LOWER MAKURI SILTSTONE F_8	(SKYE FARM SANDSTONE F_9 (Coquina limestone F_{11} (Coquina limestone F_{10} ((LOWER MAKURI SILTSTONE F_8	LOWER MAKURI SILTSTONE F_8	
MAKURI SANDSTONE F_5 Limy sandstone F_4 Limy sandstone F_3 Coquina limestone F_2 Limy sandstone F_1	MAKURI SANDSTONE F_5 Limy sandstone F_3 Limy sandstone F_2 Oyster bed F_1	MAKURI SANDSTONE F_5 Limestone F_7 Siltstone F_6 Limy sandstone F_1	MAKURI SANDSTONE? Coquina F_1

west. The belt has an apparent dextral displacement of a mile ~~along~~ at the Rongomai Fault.

At the "Pori" the Makuri Formation crops out extensively on both limbs of the Pori Syncline and in adjoining areas as far west as the Taumata Fault. In the south it crops out near Alfredton east of the Alfredton Fault and on both limbs of the Mangamahoe Syncline. An isolated tiny outcrop of Makuri Sandstone occurs one mile northwest of Eketahuna.

The general distribution of the individually mapped members of the Makuri Sandstone, mainly limy sandstone beds, is indicated in Table 15. The F_1, F_3 and F_4 members are discontinuous in the type area. At the "Pori" the F_1 Member is extensive as an oyster bed. The only other extensive development of one of these members is the F_2 coquina limestone in the northern area.

<u>Content - Northern (type) area</u>

In the type area, and as far east as the Tiraumea River, the lower and middle parts of the Makuri Sandstone consist of massive blue-grey, brown-weathering, fine sandstones. Locally the formation contains the F_1, F_2, F_3 and F_4 limy sandstones and coquina limestone members. East of the Tiraumea River the F_1 limy sandstone is the basal bed of the formation, ~~while~~ west of the river the F_2 member occurs at the base. West of the Tiraumea River the bulk of the formation is composed of sandstone, and the F_2 and F_3 members are restricted to the basal part of the formation. In the upper part of the formation fine sandstones grade upwards into very fine sandstones.

The F_1 limy sandstone, locally forms a prominent bedding plane feature. ~~It is~~ (about 10 ft thick). West of the Tiraumea River the F_2 Coquina limestone is composed of a sequence of three or four coquinoid limestone beds, usually totalling 10 to 12 ft, and locally ~~reaching~~ totalling 24 ft (see Figure 28). The basal bed consists of a pebbly coquinoid limestone which grades up into the second bed of coquinoid limestone; overlying is a further coquinoid bed containing abundant current-sorted _Phialopecten triphooki_ shells; ~~T~~the uppermost coquinoid bed contains abundant brachiopod shells. Locally, soft-friable-sandstone is developed between the basal pebble and coquinoid limestone beds. Cross-beds are very rare; in an outcrop near the Makakahi River at grid ref. 254115, ~~however, two cross beds~~ and indicate apparent northerly and apparent northeasterly current flow.

East of the Kaitawa Fault, at grid ref 316112, the F_2 limestone thickens greatly, and the rhythm of sedimentation previously outlined, appears to be repeated. ~~The physiographic appearance of the member~~ Near Bissets Farm (grid ref. 316103) and at the Mangaone River ~~is that~~ the upper 40 per cent of the limestone is vertically fluted ~~while~~ and the lower part has a rubbly appearance.

East of the Tiraumea River the F_2 Limestone changes to a massive, vertically fluted, fossiliferous, sandy coquinoid limestone. Much of it is cemented by a very fine grained dark-green cement, but the cement is not iron rich. Chemical and spectroscopic analysis showed that there was only about 2 per cent of iron in the cement, which was largely composed of quartz, calcite and

FIGURE 28

In folder at back

plagioclase feldspar. Cross beds at grid ref. 403165 indicate apparent northwesterly current flow.

At the Mangaone River the F_3 Limestone is 30 ft above the F_2 Limestone. It is a coquinoid limestone with Phialopecten triphooki and Cardium spatiosum throughout, locally, brachiopods occur at the top of the bed. The limestone is 5 - 10 ft thick at the Mangaone River, 2.5 ft thick at Bissetts Farm, and 2 ft thick between the Mangaone River and the Tiraumea River (grid ref. 345126.) North of the Makuri River the F_3 Limestone is 8 - 15 ft thick. It is typically a brown-weathering very-sandy coquinoid limestone, variable in appearance, being either massive or bedded; east of the Makuri River it is occasionally cross bedded. Between the Makuri River and Ngaturi Creek at grid ref. 408170, four cross-beds indicate apparent north-westerly, westerly, south-westerly, and south-easterly current flow. East of Ngaturi Creek at grid ref. 407193 four cross-beds indicate apparent northerly, northwesterly, westerly, and south-westerly apparent flow direction.

The F_4 Limy Sandstone is about 10 ft thick.

Scattered fossils occur in the upper part of the Makuri Sandstone, Mesopeplum crawfordi in the bed of the Mangaone River bed at grid ref. 328128, and brachiopod shells, and an oyster in the bed of the Makuri River at grid ref. 389159. The sandstones with scattered fossils are transitional from the underlying shell bed and massive fine sandstones sequence to the overlying Lower Makuri Siltstone, which is largely barren of fossils.

Content - Pori

The content in the Pori area is similar to that developed at the type locality. Shell beds and limestones, interbedded with concretionary fine sandstone occur in the lower part of the formation; the sandstones are coarser on the east flank of the Pori Syncline than on the west flank, the sandstones grade up into the Lower Makuri Siltstone except near the Puketoi Road where the Lower Makuri Siltstone is absent. Generally the base of the formation occurs directly beneath the (F_1) Oyster Bed, but locally, for example at Waipori Stream, the base is actually about 60 ft below the bed. Such an irregular contact may be due to channelling prior to the deposition of the F_1 Oyster Bed.

The F_1 Oyster Bed forms a prominent bedding plane feature on the eastern limb of the Pori Syncline. The original depositional area of the F_1 Oyster Bed was at least 30 square miles. On the west limb of the Pori Syncline near Mt Marchant it is only 2 ft thick, while on the east limb of the syncline it is generally about 10 ft thick (see isopach map Figure 29). Where the Oyster Bed is thin it is composed entirely of broken shells of Ostrea ingens.

Where the bed is thicker, at Puketoi Road, unbroken oysters are more common, and the bed contains more sand as a matrix. Southwestwards of Waipori Stream (grid ref. 394012) the bed is sandy and contains a greater diversity of molluscs; the bed is mapped southwest of the Pori Road. North of the Makuri Gorge the bed is well-cemented and contains some Pectens.

Figure 30: View westwards towards the central part of the eastern limb of the Pori Syncline. Front: dip slope of the F_1 Oyster Bed, Centre: bedding indicated by thin concretionary sandstones and shell beds of the Makuri Sandstone. Background: steep slopes formed in the massive lower Makuri Silstone. Top: Scrub line at extreme top of photograph is at the base of the Lower Pori Limestone.

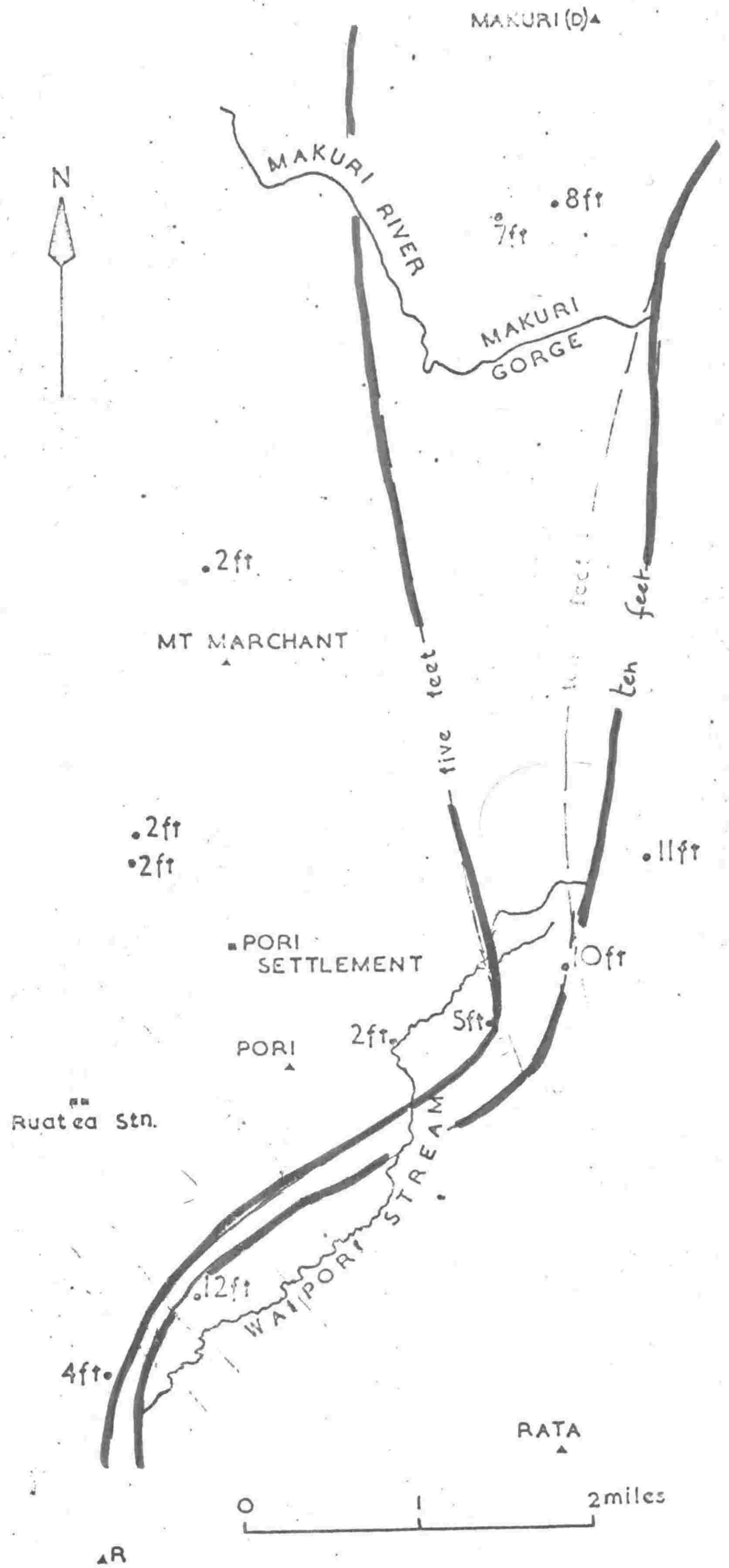


Figure 29 - Isopach map of the F_1 Oyster Bed at the Pori Settlement and the Makuri Gorge.

Along the eastern flank of the Pori Syncline many bedding plane features due to shell beds and concretionary horizons occur above the F_1 Oyster Bed (Figure 30). p.211. The two most prominent beds, the F_2 and F_3 Limy Sandstone, have been mapped separately.

The F_2 Limestone occurs 100 ft above the Oyster Bed it has been mapped south westwards from the Puketoi Road for about a mile. At a cut along the Puketoi Road at grid ref. 446065 a section of the F_2 Limestone contains:

	Feet
Coquinoid limestone containing Phialopecten triphooki and Ostrea ingens	2.3
Massive coarse to very-coarse limy-sandstone	7.5
Alternating cemented sandstone beds about 4 inches thick, and non-cemented sandstone beds about 8 inches thick	8.5
Coquinoid limestone composed largely of fragments of Ostrea and Pecten	3
Limy-sandstone	3.3

North of the Makuri Gorge the F_2 bed is a prominent 25 ft thick cross-bedded sandy limestone.

The 20 ft thick F_3 Limy Sandstone contains scattered pectens, it crops out on the east flank of the Pori Syncline about 530 ft above the base of the formation. It is well developed near the Pori Road, and has been mapped 3½ miles to the northeast.

Shell beds and concretionary horizons are not as well developed on the west side of the Pori Syncline as they are on the east side. Apart from the F_1 Oyster Bed none have been mapped. A half a mile southwest of Mt Marchant (grid ref. 401076) a 4 inch thick off-white, pumiceous, biotite-rich, fossiliferous, ash bed is interbedded with ripple-marked fine sandstone and mudstone.

At Hinemoa the Makuri Sandstone differs from that further east in the Pori area in that concretionary shell beds are not as common. An exception is in Hirinakitu Stream where concretionary horizons contain large Atrina zelandica. The macrofaunal assemblage from a left branch of Puketi Creek (fossil locality 843) contains a faunal assemblage characteristic of the Marima Sandstone.

Southwest of Alfredton the Makuri Sandstone is poorly exposed. It is bounded in the west by the Alfredton Fault. East of the Pahau Fault (at grid ref. 310901) the base of the formation is defined by a fossiliferous concretionary sandy bed which can be traced for two miles to the north-east on air photographs. Much of the formation is a concretionary fossiliferous fine brown-weathering sandstone. Sandstone exposed by cuts along the Bartons Line Road typically contains Phialopecten triphooki, Phialopecten onslowi, Mesopeplum crawfordi, Ostrea sp. and Panopea worthingtoni. Between the Pahau and Mt Cooper faults, near Mt Cooper, some concretionary sandstones containing Mesopeplum crawfordi are exposed in cuts along the road (at grid ref 332944).

Content - Northern Mangamahoe

The formation crops out along both limbs of the north trending Mangamahoe Syncline. Two members, the E_6 Siltstone and the E_7 Limestone, are restricted to the western limb. A section along the Western limb 1000 yards north east of Neil Trig at grid ref. 221901 contains:-

	Feet
Massive very-fine to fine sandstone (Makuri Sandstone)	200
F_6 Siltstone - muddy-siltstone	360
Massive very-fine to fine sandstone (Makuri Sandstone)	15
Obscurred	12
Alternating concretionary fine sandstone beds 2 - 3 in. thick and non-concretionary sandstone beds about 4 in. thick. Non-concretionary sandstone is commonly cross-bedded; it contains abundant *Arachnoides* shells some *Balanus* plates, and small pelecypods	12

Unconformity

Tawatia Sandstone

The F_6 Siltstone grades northwards into very fine sandstone on the east limb, a 8.5 ft thick shell bed occurs at the base of the Makuri Sandstone. It is best exposed along the Central Mangamahoe Road (grid ref. 243916) where it is largely composed of unidentifiable broken fragments of a large thick-shelled pelecypod. It contains rounded, tabular 2 inch long, lightly-indurated sandstone pebbles, which presumably were derived locally from the underlying Tawatia Sandstone. One 2 in. greywacke pebble was also found.

Most of the Makuri Sandstone is an unfossiliferous, very fine, brown-weathering sandstone. Near Tokamui Farm (grid ref. 239903) scattered fossils including *Panopea* sp, *Zeacolpus* sp, *Divaricella* sp, and *Alcithoe* sp. occur with a few small concretions in fine to medium sandstone in the uppermost 20 ft of the formation.

The E_7 Limestone is a sandy detrital limestone, it overlies the Makuri Sandstone and underlies the Lower Makuri Siltstone. In the mapped area ~~the limestone~~ it is restricted to the Mangamahoe Syncline. The limestone has been mapped south of the mapped area by Orbell (1962). Orbell found that ~~the limestone~~ it wedges out into massive fine sandstone on the east flank of the Mangamahoe Syncline.

The E_7 Limestone is exposed on the eastern and western flanks of the Mangamahoe Syncline. A cliff section of the western flank at grid ref 228913 contains:-

	Feet
Massive vertically-fluted coquina limestone containing abundant brachiopods	10
Massive vertically-fluted coarse grained limy-sandstone (60 per cent sandstone grains), containing a few *Phialopecten triphooki* and brachiopod horizons	50
Bedded coarse-grained coquina limestone in beds about one ft thick; base bored	10

Further north at grid ref 229918 the central part of the member grades into a limestone. The limestone is cross-bedded 20 ft above the base; the foreset beds are 20 ft thick and indicate apparent westward current flow. On the east flank of the Mangamahoe Syncline a road cut along the Central Mangamahoe Road at grid ref. 243916 a section contains:-

	Feet
Well-bedded coquina-limestone	15
Fine sandstone	5
Well-bedded coquina-limestone	15
Fine sandstone	10

Massive, sandy coquina limestone	25

Further south near Tokanui Farm at grid ref. 236903 a composite section contains:

	Feet
Vertically fluted massive coquina limestone	15
Rubbly very-coarse limestone containing common _Balanus_ plates and brachiopod fragments	15
Massive granular very coarse sandy coquina limestone	20

South of the mapped area, Orbell (1962) found a 6 in. thick silty and muddy fossiliferous glauconitic bed overlying the limestone; this bed has not been found in the mapped area.

Content - Eketahuna

A tiny outcrop of _F_1 Limestone_ crops out between the Newman and Cliff Road faults at grid ref. 183017. It is sandy coquina limestone about 3 ft thick and forms a prominent bedding plane feature. North of the Newman Fault, ~~isolated~~ a few 5 ft long residual boulders indicate that it was previously present there. Above the unconformity separating the _F_1 Limestone_ from the underlying Newman Siltstone, a 6 in. thick bed contains 1 ft long blocks of Newman Siltstone in a matrix of very fine sandstone. At the base of the limestone _Cardium_ and _Ostrea_ shells are common in a matrix of oyster fragments. Within the limestone a few lightly-indurated 3 in. long sandstone pebbles indicate that the ~~Opoitian~~ Tawatia Sandstone was being eroded nearby. An analysis of the limestone quoted by Morgan (1919, p.153) contains:-

	per cent
Carbonate of lime	59.03
Carbonate of magnesia	2.78
Iron oxide and aluminia (soluble in acid used)	1.69
Siliceous matter	36.24

About 20 ft of strata overlying the Limestone are not exposed, but are thought to be Makuri Sandstone.

Relation to Underlying Strata

A period of non-deposition prior to the deposition of the Makuri Group is indicated by the abrupt change of facies from deep-water unfossiliferous sandstone to fossiliferous shallow-water sandstone and shell beds.

Thickness

Few accurate measurements of thickness are possible. In the northern province, the following measurements are approximate:-

Makakahi Road	Bissetts Farm	Makahikatea Trig
550 ft	580 ft	460 ft

In the Pori area the Makuri Sandstone is about 1,000 ft thick.

Hinemoa	South Pori	Pori Syncline
c 800 ft	1200 ft	c 1050 ft

At Alfredton where younger formations are absent, the formation is at least 360 ft thick. At Mangamahoe it is 670 ft thick.

Macropaleontology and Conditions of Deposition

Macrofossils from the Makuri Sandstone are listed in Table 16. A shallow water depth of deposition of the Makuri Sandstone is indicated largely by ~~the contained~~ microfauna. Macrofossils were often transported along the sea bottom prior to deposition (they are thanatocoenose assemblages). Deposition generally kept pace with the lowering of the sea bottom, and hard-bottom conditions, as indicated by shell beds, were not as common as soft-bottom conditions.

The environment of deposition during the deposition of the F_1 Ostrea ingens bed in the Pori area may have been similar to ~~these~~ that ~~conditions~~ at Foveaux Strait where the sea bottom is extensively colonised by Ostrea sinuata. Cullen (1962) found the oysters in the strait ~~are~~ to be restricted to a depth range of 10 - 25 fathoms in those places where the sea bottom consists of medium-fine sandy gravel. He found "the gravel is best suited to colonisation by the oyster, the pebbles and larger shell fragments presumably providing surfaces for the attachment of spat; while the interstitial sand provided a firm level base upon which the mature oysters can grow". Gravel was absent at the Pori during the growth and deposition of the oyster bed. The spat of oysters presumably developed on oyster fragments.

West of the Mangaone River the F_2 Limestone was deposited in a sequence of four beds pebbly coquina limestone, coquina limestone, coquina limestone containing wave-sorted Pectens, and coquina limestone containing whole brachiopods (see Figure 28). It is thought that the sequence of beds of the E_2 Limestone, west of the Mangaone River were deposited in a period of deepening water; and that the brachiopod rich limestone represents the deepest water in which coquinoid limestones were deposited. Also A coquina limestone bed containing abundant brachiopod is present locally near Mangamahoe in the uppermost 10 ft of the E_2 Limestone.

Much of the sandstone on the east limb of the Pori Syncline is less fossiliferous and coarser than on the western limb, perhaps as a result of deposition in shallower water (at about low tide mark). Depth analysis from foraminifera invariably indicated that the formation was deposited at upper neritic depths (20 - 200 ft); a shallower depth of deposition, the Pseudononion facies (20 ft), was found for fossil locality 939.

Depth analysis of foramanifera from east of the Alfredton Fault from fossil locality 960 indicated a beach-sand-environment. Some erosion of nearby Opoitian sediments and redeposition of derived Opoitian foraminifera is probable ~~locally is probable during the deposition of the Makuri Sandstone~~. Foraminifera from fossil localities 841 and 842 from near the downthrow side of the Taumata Fault gave an anomalous Opoitian ages. The foraminifera were presumably derived from the Opoitian (Saunders Siltstone) on the upthrow side of the fault. On the west flank of the Mangamahoe Syncline the basal beds of the Makuri Sandstone contain abundant Arachnoides sp. but little else. Powell (1937) found that colonies of Arachnoides placenta prefer the semi-estuarine condition in the outer basin of the Manakau Harbour, in a

Table 16

MACROPALAEONTOLOGY OF THE MAKURI SANDSTONE

	563	576	842	843	851	862	874	878	879	882	928	938	962	963	965	967	979	994	1072	1084	1085	1086	1087
Calliostoma (Maurea) c.f. hawera Marwick			X																				
Zeacolpus sp.				X				X															
Stiracolpus sp.																							
Pelicaria canaliculata (Zittel)					X			X										X			X	X	
Pelicaria sp.																							
Struthiolaria papulosa Martyn																					X	X	
Maoricrypta sp.																		X					
Sigapatella sp.													X										
Poliaices sp.				X															X				
Aeneator sp.																			X				
Austrofusus c.f. glans (Roeding)				X																			
Baryspira (B) erica Olsen				X																X			
Baryspira sp.								X															
Glycymeris laticostata (Q & G)							X																
Glycymeris sp.																						X	
Chlamys radiata (Hutton)																X							
Phialopecten triphooki (Zittel)									X					X			X			X			
Pallium (Mesopeplum) crawfordi Hutton	X	X			X		X						X										
Pallium (Mesopeplum) c.f. crawfordi (Hutton)				X		X		X			X									X			
Ostrea ingens (Zittel)													X										X
Ostrea sinuata LK												X				X							
Atrina zelandica (Gray)	X		X													X							
Cardita lillei (Fleming)							X																
Divaricella c.f. huttoniana Vanetta			X	X				X								X							
Scalpomactra c.f. scalpelum (Reeve)			X																				
Bassina sp.																							
Marama murdochi Marwick				X				X															
Maoricardium spatiosum (Hutton)																				X			
Trachycardium (Ovicardium) rossi Marwick																	X						
Nemocardium pulchellum (Gray)										X													
Gari sp.																				X			
Panopea zealandica (Q & G)					X	X								X	X			X		X			
Offadesma angasi (C & F)			X																				
Dentalium sp.							X	X															
Neothyris c.f. ovalis (Hutton)					X																		
Brachiopoda. sp.							X												X				
Ogmocidaris c.f. benhami Mortensen										X													
Balanus. sp.																						X	

depth of 4 - 17 fathoms. Such depths of deposition are likely for the basal beds of the Makuri Sandstone on the west flank of the Mangamahoe Syncline.

The local development of the *E_6 Siltstone*, close to the downthrown side of the Mauriceville Fault at a time when fine sandstone was being deposited elsewhere is good evidence that the fault was active during deposition.

In the type area, data on the depths of deposition of the upper part of the Makuri Sandstone is from echinoidea and foraminifera. Spines of *Ogmocidaris* cf. *benhami* (fossil locality 882) indicate depths of deposition of 55 - 200 fathoms (330 - 1,200 ft) (See Appendix 3). Foraminifera examined by Dr Vella from the same locality indicate a similar depth, medium-lower neritic (200 - 1,000 ft) (See Appendix 2). Dr Vella found depths of deposition were deeper at fossil locality 866, deep neritic to upper bathyal (1,000 - 2,000 ft) (See Appendix 2). Subsequently he suggested even greater depths for locality 866, (2,000 ± 1,000 to 3000 ± 2,000) (See Vella (1962c) in his description of the new species *Melonis zeobesus*). Depths of deposition much greater than a 1,000 ft are unlikely because the overlying Lower Makuri Siltstone, presumably deposited in deeper water because of its finer lithology was generally deposited at mid- to lower depths (200 - 1,000 ft, see Appendix 2).

At Mangamahoe the upper part of the Makuri Sandstone is represented by the coquinoid *E_7 Limestone*. The limestone wedges out within a short distance into massive sandstone. The direction of wedging-out is the same as the apparent current flow indicated by cross beds. Vella (1963b) considered the <u>E_7 Limestone</u> to be the basal part of the Te Aute Cyclothem (Waitotaran). Vella states that a greensand was found by Orbell (1962) <u>beneath</u> the limestone. Orbell makes no mention of greensand but found (p.259) that a glauconitic mudstone and siltstone each about 3 inches thick <u>overlie</u> the limestone. Thus there is no evidence that there was a time break, not represented by deposits, beneath the limestone, in Orbell's area and, none was found beneath the Pori Limestone. The <u>E_7 Limestone</u> is attributed to the Makuri Sandstone rather than to Vella's somewhat younger Te Aute Cyclothem.

The writer considers that the <u>E_7 Limestone</u> owes its formation to local movements on the Hastwells-Pleckville faults and also perhaps on the Mauriceville Fault, rather than to eustatic change of sea level. North of the Pleckville Fault, extensive shell banks occurred in shallow ~~depths of~~ water; occasional fault movements on the Pleckville and perhaps the Mauriceville Fault produced deeper water south, and perhaps east, of the faults. At times when sea currents were moving southeastwards they picked up shell fragments from the shell bank and deposited ~~it~~ them in deeper water ~~south and east of the Pleckville-Mauriceville faults~~ to accumulate as the <u>E_7 Limestone</u>. The tectonically-controlled sedimentation is similar to that postulated for S_4 Limestone of the Soren Group.

LOWER MAKURI SILTSTONE

<u>Type Section and Subdivision</u>

The Lower Makuri Siltstone is well exposed in the Makuri River, which is made the type section. The formation is not subdivided.

Distribution and Stratigraphic Relations

The formation is well developed near Tuscan Hills Farm (grid ref. 400150) and in a belt which trends north-northeastward towards Ngaturi. Between the Tane and Nirvana faults the formation has an outcrop width of about a mile. South of Koropeke Trig, the outcrop width and formational thickness is much reduced, perhaps due to an increase in outcrop-width and formational thickness of the overlying Koropeke Sandstone. West of the Rongomai Fault the formation is dislocated by many faults, and has an east-west trend.

At the Porí the Lower Makuri Siltstone is well developed on the east flank of the Pori Syncline where it forms steep slopes beneath the Lower Pori Limestone (see Figure 30). It has a small outcrop area between the Taumata and Alfredton faults in the headwaters of Puketi Stream.

The Lower Makuri Siltstone overlies the Makuri Sandstone. In the type area it is overlain by the Koropeke Sandstone; at the Pori it is overlain by the Lower Pori Limestone, and it wedges out eastwards into the Skye Farm Sandstone. The formation overlies the F_7 Limestone at the axis of the Mangamahoe Syncline.

Content and Macropalaeontology

Near the Makuri River the formation consists of a light blue-grey massive coarse-grained, sandy-siltstone. Macrofossils are quite rare; Pallium (Mesopeplum) cf. crawfordi occurs in the basal part of the formation (at fossil locality 860), in outcrops along the Mangaone

River. Large subspherical concretions are quite common.

East of Owhaia Creek (at grid ref. 273137) (fossil locality 1083) a 2 ft-thick Chlamys delicatula shell-bed occurs about 50 ft below the G_1 Limestone. The bed overlies a sandy bed containing Marima murdochi. It is thought that the bed should be assigned to the Lower Makuri Siltstone rather than to the Totaranui Formation.

At the "Pori" horizons of scattered, fragile, macrofossils including Ostrea sp. Dosinula zelandica, Nemocardium pulchellum, Pelicaria n. sp. Stiracolpus sp. and Baryspira sp. occur throughout the formation but are especially common near the contact with the overlying Lower Pori Limestone.

At Mangamahoe the formation contains only a few macrofossils; some brachiopods of deepwater aspect were found at grid ref. 231907 in association with scattered pelecypoda, and gastropoda.

Thickness

In the type area the Lower Makuri Siltstone is thickest east of the Rongomai Fault. Measured thicknesses are given below:—

	Feet
South of the Makakahi Road Fault	320
Mangaone River	350
Tiraumea River	760 +
Kaitawa Creek	420
Makuri River near Sefton Farm	820

Near Ruatea Station at the 'Pori' the formation is about 600 ft thick. About 200 ft of Lower Makuri Siltstone crop out in the core of the Mangamahoe Syncline where the formation is not completely developed. Further south in N.Z.M.S.158 Orbell (1962) found that 650 ft of calcareous silty mudstone occurred between the <u>E_7 Limestone</u> and an erosion interval beneath the Hautawan Stage. The 650 ft-thick mudstone is correlated with the Lower Makuri Siltstone.

<u>Conditions of Deposition</u>

Depth analysis from foraminifera generally indicate mid-lower neritic (200 - 1,000 ft) depth of deposition for those parts of the formation where macrofossils are rare. <u>Pallium</u> (<u>Mesopeplum</u>) cf. <u>crawfordi</u> (fossil locality 860) was associated with upper-neritic (20 - 200 ft) indicating-foraminifera. The absence of sand in the deposits at a time when the sea was not ~~too~~ very deep indicates ~~that the~~ a distant source area ~~that supplied the material was distant~~, perhaps ~~seas were widespread~~.

SKYE FARM SANDSTONE

<u>Name and Type Section and Subdivision</u>

The formation is named after a small farm located along the Puketoi Road at the crest of the Puketoi Range. The section revealed by cuts along the Puketoi Road is made the type. ~~section~~.

The greatest part of the formation is extremely uniform. ~~in composition~~. Two thin, poorly exposed, coquina limestones, have been mapped locally within the uppermost part, ~~of the formation~~, close to the Alfredton Fault, at Mt Marchant.

Distribution and Stratigraphic Relations

The Skye Farm Sandstone is well developed at the type section, and in the Makuri Gorge. South westwards ~~from these localities~~ it wedges out into the Lower Makuri Siltstone; the uppermost part of the formation, extends furthest south-westward. The formation underlies the Lower Pori Limestone.

Near Skye Farm the formation grades downwards into the Makuri Sandstone, the contact ~~between the formations there is~~ being arbitrary and is based on the extrapolation of the Makuri Sandstone - Lower Makuri Siltstone contact north eastwards along the east flank of the Pori Syncline.

Content and Thickness

The Skye Farm Sandstone consists of massive blue-grey very-fine sandstones; concretions are not common. Locally at the Makuri Gorge the uppermost part of the formation ~~has~~ is a greenish cast. The formation is sparsely fossiliferous, but at many outcrops the association of the decorticated shells of Marama murdochi, Stiracolpus sp., and Divaricella sp. ~~shells~~ was noted.

The F_{10} Limestone is 10 ft thick at grid ref. 412096, ~~locally~~ sinkholes are developed along its outcrop; it has been mapped between the Mt Butters Road and the South Makuri faults. It is exposed at several localities along the disused ~~impassable~~ Kaitawa Road. The 3 ft thick F_{11} Limestone, overlies the F_{10} Limestone and has a more restricted distribution.

The formation is 350 ft thick at the type section.

Macroplaeontology

Macrofossils from the Skye Farm Sandstone are listed in Table 17. ~~17.~~

Table 17

	943	944	1068	1069	1070
Pelicaria. sp.			X	X	X
Pachymelion bartrumi King				X	
Chlamys radiata (Hutton)					X
Ostrea sp.		X			
Atrina zelandica (Gray)	X				
Marama murdochi Marwick				X	X
Divaricella cf. *huttoniana* Vanatta			X	X	X
Balanus sp.	X				

Conditions of Deposition

Depth analysis from foraminifera at fossil locality 943 indicates a neritic depth of deposition (see Appendix 1). The sandstone is very uniform, and the common association of the *Marama*, *Stiracolpus* and *Divaricella* shells indicates that sedimentation was just keeping pace with down-warping, perhaps at mid-lower neritic depths (200 - 1,000 ft).

The outcrop distribution of the Skye Farm Sandstone indicates that the source of the sand was from the east-northeast. Two asymetrical ripple marks, one along the Puketoi Road at grid ref. 437066 and one at grid ref. 433062, indicate that, locally, currents moving sand flowed from due west and northwest. ~~Further~~ Eocene (Mangaorapan

Stage) microplankton, especially the genus <u>Wetzeliella</u>, ~~and~~ ~~Hystrichosphaera furcata The~~ ~~were~~ was found by Mr Graeme Wilson in a sample from {fossil locality 943} (pers. comm.). (Derived Miocene foraminifera also are present locally (see fossil locality 946)) The microplankton and foraminifera indicate that lower Tertiary strata were being eroded and part of this material was being redeposited as the Skye Farm Sandstone. Large outcrops of Eocene strata, including the Mangaorapan Stage have been mapped 11 miles due east of the mapped area, at Pongaroa by O'Byrne (1963), and 35 miles north east of the mapped area at Wanstead by Kingma (1962). ~~The bulk~~ (Miocene strata also have a wide distribution in the East Coast Ranges and most) of the Skye Farm Sandstone is considered to have been derived from the ~~East Coast Ranges~~ especially from the Pongaroa area.

KOROPEKE SANDSTONE

<u>Name, Type Area and Subdivision</u>

The Koropeke Sandstone and the Koropeke Limestone are named after the Koropeke Trig, which is made the type area and type section, for the sandstone and limestone. The formations ~~is~~ are not subdivided.

<u>Distribution and Stratigraphic Relations</u>

The Koropeke Sandstone, and the Koropeke Limestone are restricted to the type area.

The Koropeke Sandstone is well developed near the Makuri River where it forms a broad belt which trends east northeast. It is not so well developed east of the Kaitawa School Fault, but its narrow outcrop has been mapped north eastwards towards Ngaturi.

Between the Makakahi River and the Rongomai Fault, the formation, much faulted, crops out in a wide discontinuous eastward trending belt.

The Koropeke Sandstone overlies the Lower Makuri Siltstone and underlies the Upper Makuri Siltstone. Near Koropeke it occurs both beneath and above the Koropeke Limestone. The formation is in part diachronous; the lower part at Koropeke was probably deposited at a time when the Lower Makuri Siltstone was still being deposited at the Makuri River. This is indicated by comparing the sum of the two formation thicknesses at the Mangaone River with that at the Makuri River.

	Mangaone River	Makuri River near Sefton Farm
	Feet	Feet
Koropeke Sandstone	850	95
Lower Makuri Siltstone	350	820

While the Koropeke Sandstone and Koropeke Limestone were being deposited in the Northern province, the Lower Pori Limestone was being deposited at the Pori.

Content

In the type area the Koropeke Sandstone consists of brown weathering, massive blue grey, fine and very fine sandstones; calcareous concretions are present locally. Macrofossils are not usually common. North of Koropeke Trig, however, friable brown-weathered well-sorted, fine sandstone containing a profusion of tests of the echinoid *Arachnoides* sp. is directly beneath the Koropeke Limestone.

In the Makuri River, and west of the Rongomai Fault, the formation is a blue-grey silty very-fine sandstone containing a few scattered macrofossils.

Thickness

The formation is thickest in the Mangaone area; it is only 30 ft, thick a short distance west of the Rongomai Fault. Further west, north of the Makakahi Road Fault it is at least 700 ft. thick.

	Feet
North of Makakahi Road Fault	700
West of Rongomai Fault	c 30
Mangaone River	850
Northwest of Kaitawa Creek (East of Nirvana Fault)	c 200
Makuri River, near Sefton Farm	c 95

Macropalaeotology

Macrofossils from the Koropeke Sandstone are listed in Table 18.

Table 18

	803	836	806	1102	1103
Maoricolpus sp.	X				
Pelicaria sp.				X	
Polinicies sp.			X		
Austrofusus cf. glans (Roeding)				X	
Pachymelon bartrumi King					X
Ostrea sp	X				
Marama murdochi Marwick	X			X	

Table 18 Contd

	803	836	806	1102	1103
Nemocardium finlayi Bartrum & Powell	X				
Nemocardium pulchellum (Gray)		X			
Pleuromeris sp.				X	
Ogmocidaris cf. benhami Mortensen			X		

Conditions of Deposition

Depth analysis from foraminifera (see Appendix 1) indicate that most of the formation was deposited at mid-lower neritic depths. Shallower water, of upper neritic depths (20 - 200 ft) accurred at fossil locality 886 associated with spines of Ogmocidaris. cf. benhami. It should be noted that this occurrence has increased the depth range of the echinoid in an upward direction from the depth range in the Makuri Sandstone.

Arachnoides sp. occurs beneath the Koropeke Limestone at several localities north of Koropeke Trig. Powell (1937) has shown that in the outer basin of Manakau Harbour Arachnoides placenta occurs in semi-estuarine conditions in water 4 - 17 fathoms deep. Sedimentation is thought to have been continuous from Koropeke Sandstone to Koropeke Limestone time.

KOROPEKE LIMESTONE

Type Section and Subdivision

The type section is made the cliff exposed at grid ref 327144 see Figure 31. The Koropeke Limestone is not subdivided.

Distribution, Content and Thickness

The Koropeke Limestone is largely limited in distribution to an area between the Rongomai and Kaitawa School faults. The limestone is usually about 10 ft thick but it thickens abruptly near the type section where it is 70 ft thick and ~~At the type section~~ the following sequence is exposed:

	Feet
Very coarse coquina limestone containing many Oysters and Pecten shells	c 5
Brown weathering massive fine sandstone	c 30
Very coarse coquina limestone containing Pectens, and brachiopoda	c 30
Medium grained sandy coquina limestone	c 5

The coquina limestone is cemented and is variably: ~~in content,~~ being massive at some localities and bedded at others; Cross-bedded strata, ~~however~~, have not been found. Locally in the western part of the outcrop greywacke pebbles up to 2 inches long occur at the base of the formation. West of the type section 1 - 2 ft thick coarse and medium sandstone beds are quite commonly interbedded with limestone. The mollusca ~~which are~~ most common are Phialopecten triphooki and Ostrea sp. Dentalium sp, and Brachiopoda sp. are rarer, and ~~they~~ occur near the base of the limestone only.

The easternmost outcrop is exposed in the bed of the Mangaone River (at grid ref. 338140) where the coquinoid Limestone is 15 ft thick; it contains many Phialopecten triphooki and Ostrea ingens. ~~shells~~.

West of the Rongomai Fault the formation is generally absent but a very sandy 7 ft thick coquinoid limestone found south of Rock Road

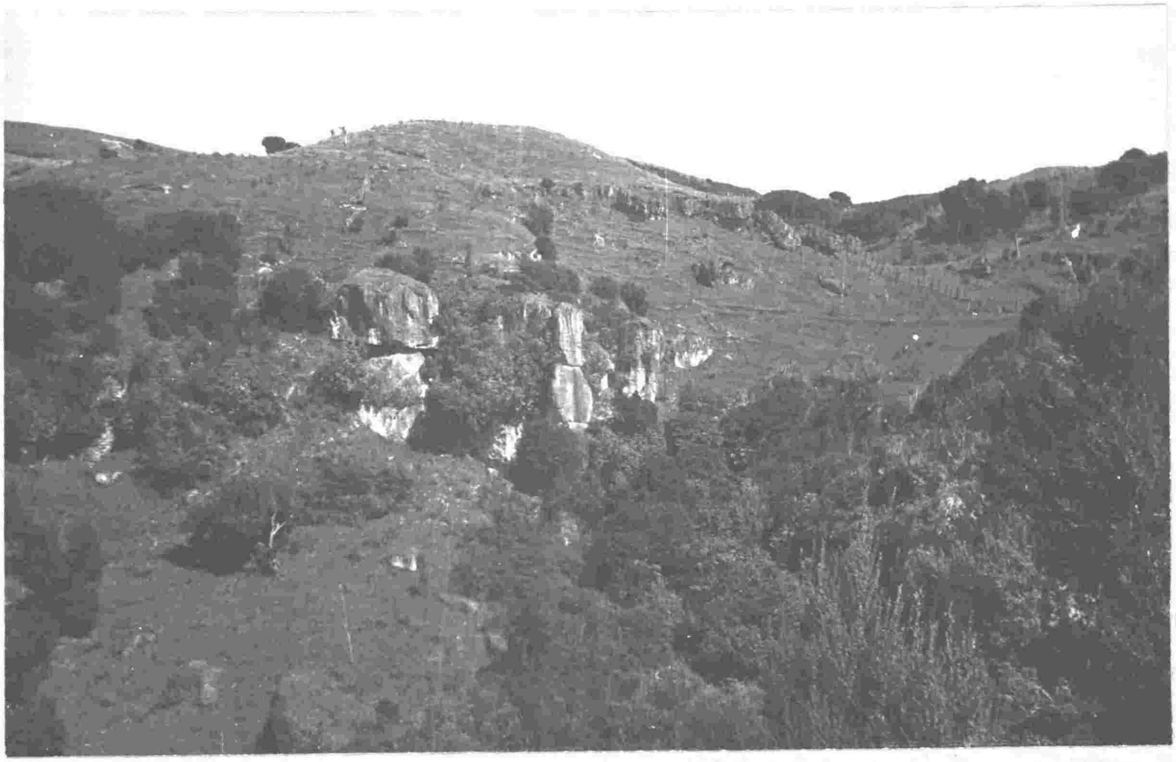


Figure 31: Koropeke Limestone at the type section (grid ref. 327144)
Centre: vertically-fluted very-coarse coquinoid limestone 30 ft thick, Upper right: thin (c. 5 ft thick) limestone.

at grid ref. 281140, is thought to be the Koropeke Limestone. The limestone was mapped some 500 yards to the east and 300 yards to the west of grid ref. 218140; in both directions it grades laterally into concretionary shell beds.

Conditions of Deposition

The absence of cross-bedded-strata, and the variability of the content of the formation along the strike, and the reefoid development at Koropeke indicates that much of the shelly detritus was not transported far before it was deposited.

The formation ~~was~~ is probably ~~deposited as~~ a fossil shell bank.

LOWER PORI LIMESTONE

Name and Subdivision

The formation is named after the Pori Settlement. Near Rangedale Station two thin sandstone members have been mapped separately within the limestone.

Distribution and Stratigraphic Relations

The Lower Pori Limestone crops out along both flanks of the Pori Syncline, and between the Taumata and Alfredton faults. It is well exposed in the steep sides of the Makuri Gorge.

The formation overlies the Lower Makuri Siltstone and the Skye Farm Sandstone and is overlain by the Upper Makuri Siltstone and the Pori Sandstone.

The interdigitation of the Pori Limestone and the Skye Farm Sandstone near Pori Trig, and also the development locally of limestone in the uppermost part of the Skye Farm Sandstone, indicates that there was probably no time break between the deposition of the Skye Farm Sandstone and the Lower Pori Limestone.

Content

The buff-cream coloured coquinoid limestone is composed of well-rounded coarse and very-coarse grained shell fragments; larger fragments (½ - 1 inch long) are present locally but a fine-grained matrix is virtually absent everywhere. Identifiable shell fragments are ~~quite~~ rare; Ostrea sp, Phialopecten triphooki and plates of Balanus sp. are the most common~~ly~~ ~~indentifiable shells~~. The limestone is fairly massive; bedding cannot be ~~delineated~~ determined at every outcrop; cross-bedded strata in beds 6 inches to 1 ft thick are more common near the base of the limestone. The limestone is very friable, often it is uncemented. It is porous and permeable, some ~~of the~~ drainage ~~is~~ being subsurface. In the northwestern part of the outcrop (at grid ref. 414109) the basal 50 - 100 ft of the formation is sandy. Near the Pori Trig the basal 30 ft of the Lower Pori Limestone wedges out north-eastwards into the Skye Farm Sandstone.

Greywacke pebbles are extremely rare, quite small (½ inch long), and tabular. ~~in shape.~~

F_{13} and F_{14} Sandstone Lenses are greenish-grey or grey in colour, fine-grained, and ~~each are usually~~ about 30 ft thick; they wedge out abruptly into the Pori Limestone a short distance south-west of Rangedale Station.

Thickness

The thickness of the Lower Pori Limestone is usually difficult to estimate partly because of the few known heights but also because of the ~~local~~ general absence of overlying strata. The thicknesses listed below are all approximate:

South of Rangedale Station	At grid ref 397043 (South of Rangedale Fault)	North of the Rangedale Fault	Puketoi Road	Makuri Gorge
400 ft	500 ft	300 ft	750 + ft	500-700 ft

~~The abrupt thinning of the Limestone north of the Rangedale Fault (at grid ref 407063) indicates that the fault was active during the deposition of the limestone.~~

Conditions of Deposition

The Lower Pori Limestone was deposited in very shallow water. Vella (1963c p.291) considered that the foraminifera Pacinonion poriensis from the F_{13} Sandstone Lens (fossil locality 944a) indicates an upper neritic (0 - 200 ft) depth of deposition.

The virtual absence of the unrolled fossils indicates that ~~virtually~~ almost all the shell detritus was transported prior to deposition. The great thickness of limestone indicates uniform condition of deposition, for a long time. In the type area limestone is not well developed, which indicates that the Lower Pori Limestone had a fairly local source.

At the Pori the thickness of the Limestone changes abruptly across the Rangedale Fault indicating that the fault was active during the deposition of the Limestone. It is thought that the Limestone owes its great thickness to deposition in a graben which developed between the Alfredton and Saunders Road faults at a time when the Alfredton Fault was dextrally active. This tectonically controlled mode of origin was previously advocated by Lensen (1958b) to account for great thickness of Waitotaran Limestone in the Ohara Graben.

There are some indications, largely from cross-beds, that sediment was transported centripetally into the "Pori Graben". (See Figure 32).

Cross-bedding is not as well developed in the Lower Pori Limestone as in the G_1 Limestone of the Totaranui Formation. Cross-bedding is best developed near the base of the formation in the central part of the outcrop area. South of Ruatea Station, no cross-beds were found ~~even after~~ during an extensive search.

The absence of cross-beds south of Ruatea Station is thought to be due to greater winnowing and sorting by currents of shell fragments in an area that was not subsiding as rapidly as areas further north. The more random orientation of cross-beds north of Rangedale Station is thought to be due to currents flowing from several directions, in an area which was subsiding more rapidly.

A local southeast source of the limestone near Pori Trig is indicated by the wedging out northeastwards of Lower Pori Limestone into Skye Farm sandstone.

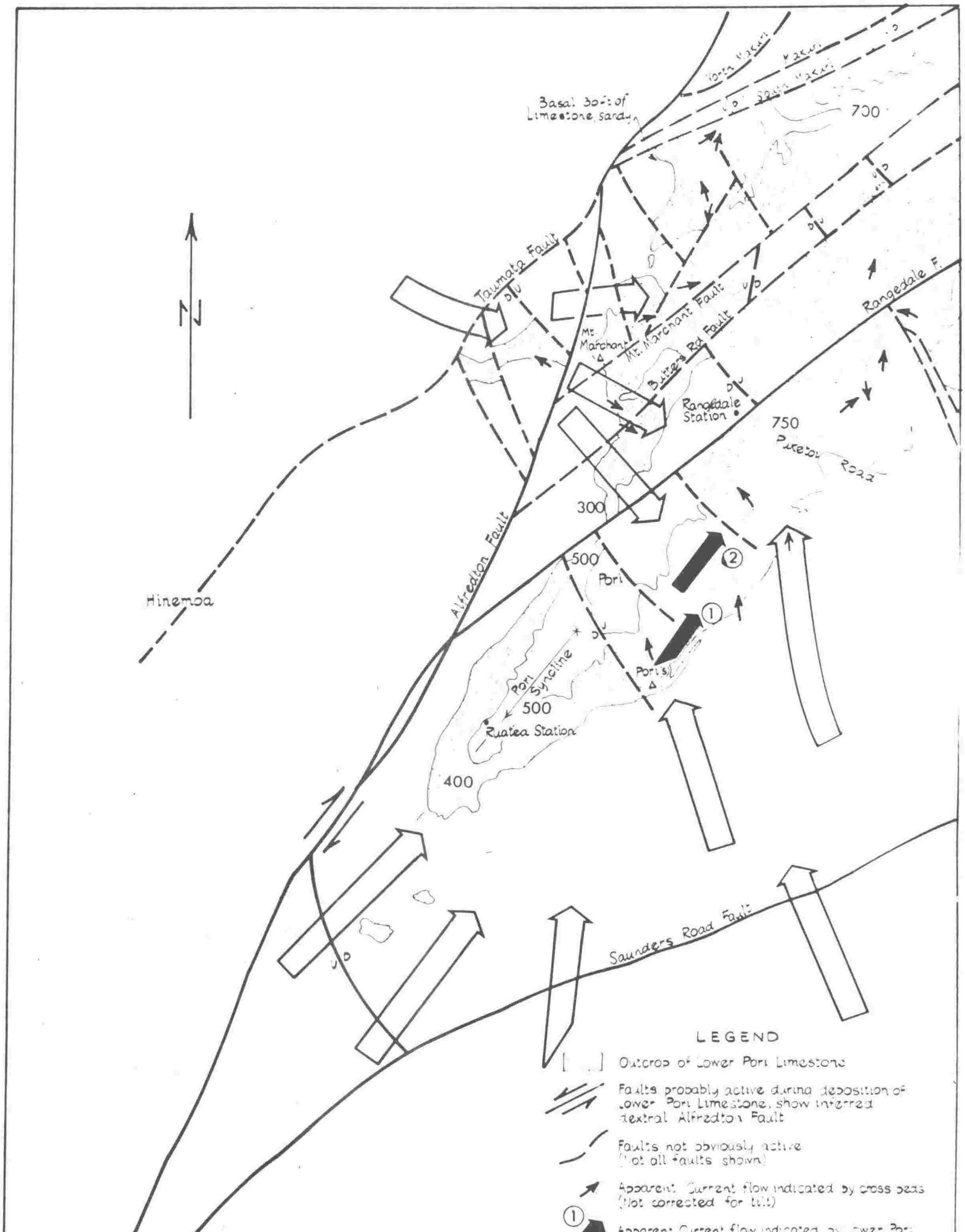


FIG.32 Inferred direction of transport of detrital shell fragments into the "Port Graben" during the deposition of the Lower Port Limestone

The F_{13} and F_{14} Sandstone Lenses were derived from the north-northeast, from the same source which provided detritus for the Skye Farm Sandstone.

UPPER MAKURI SILTSTONE

Type Section and Subdivision

The upper Makuri Siltstone is best exposed along the Makuri River, which is made the type section; the upper part of the formation is faulted out by the Nirvana Fault. With the exception of the Chlamys Bed (F_{18}) which crops out near the axis of the Pori Syncline near Rangedale Station, the formation is not subdivided.

Distribution and Stratigraphic Relations

The Upper Makuri Siltstone crops out in the type area and at the Pori. The type section occurs in the fault-block bounded by the Tane and Nirvana faults. The formation is largely faulted out between the Nirvana, and the Kaitawa School faults. West of the Kaitawa School Fault it has a large outcrop area which is bounded in the northwest by the Mangaramarama Fault, and in the west by the Rongomai Fault. North of the intersection of the Rongomai and Mangaramarama faults the formation crops out beneath the G_1 Limestone of the Totaranui Formation near the crest of the Rongomai anticline. A short distance west of the Rongomai Fault the formation is quite thin and has a narrow outcrop width. Further west, it is well developed in the triangular area bounded by the Makakahi Road Fault; the Puka (T) Fault; and the Makakahi River.

In the type area the upper Makuri Siltstone overlies the Koropeke Sandstone and is overlain by the Kaitawa Sandstone. At the Porí the Upper Makuri Siltstone overlies the Lower Pori Limestone and part of the Pori Sandstone and is overlain by the Upper Pori Limestone; south westwards along the ~~trace~~ centre of the Pori Syncline the Upper Makuri Siltstone wedges out into the Pori Sandstone. The Upper Makuri Siltstone is quite well developed near Rangedale Station. North of the Mt Butters Road Fault (at grid refs. 440120 and 432096) the formation, quite thin, is capped by the Upper Pori Limestone.

Content

The Upper Makuri Siltstone is composed of massive, light blue-grey siltstone, sandy-siltstone, muddy-siltstone, and rarer thin very-fine-grained sandy horizons. An intraformational unconformity of four degrees occurs at the type section (grid ref. 388191). A shell bed occurs along the plane of the unconformity, the underlying beds are bored for about 2 ft. Elsewhere macrofossils are quite rare; for example, in a seventy yard cut along the Mangaone Valley main Highway at grid ref 330177 only three fossils, *Chlamys radiatus*, *Ostrea* sp. and a brachiopod were found.

At Kaitawa in the hills north of the Tiraumea River a subdued sub-horizontal bedding-plane-feature is due to a horizon of large spherical concretions each about 8 ft in diameter.

At the Pori the formation is locally muddy and sandy. The 2- to 4-ft-thick F_{18} Chlamys Bed is composed almost entirely of *Chlamys delicatula* shells. The bed crops out near Rangedale Station about midway within the formation. Other fossils found in the bed include fragments of *Phialopecten triphooki* and *Balanus* sp.

Thickness

At the type section, the Upper Makuri Siltstone, partly faulted out by the Nirvana Fault, is at least 700 ft thick. Between the Koropeke and the Mangaramarama faults it is about 1000 ft thick. The formation thins abruptly west of the Rongomai Fault, where it is only 30 ft thick; further west near the Makakahi River it thickens and is at least 850 ft thick.

At the Pori the formation has a maximum thickness of about 200 ft. Between the Taumata and Alfredton faults (at grid ref. 393090) the formation is at least 180 ft thick. Only about 50 ft of the formation is developed directly beneath the two Upper Pori Limestone outcrops (at grid refs. 440120, and 432096). At these localities the Upper Makuri Siltstone overlies the Pori Sandstone.

Macropalaeontology

Macrofossils from the upper Makuri Siltstone are listed in Table 19.

Table 19

	857	858	1070	1094	1104
Zeacolpus sp.					X
Pelicaria cf. *acuminata*					X
Pelicaria n.sp. aff. *tricarinata*				X	
Chlamys delicatula (Hutton)			X		
Chlamys radiata (Hutton)					X
Ostrea sp.	X				

Table 19 contd

	857	858	1070	1094	1104
Nemocardium pulchellum (Gray)	X	X			
Cardita lilliei (Fleming)					X
Balanus sp.			X		

Conditions of Deposition

Deposition in relatively deep water may have been anticipated from the fine grained nature of the formation, and the rarity of macrofossils in comparison to those in the underlying and overlying formations. Such a contention has not been substantiated by depth analysis of foraminifera from fossil localities 853 and 863, which indicate upper neritic 0 - 200 ft depths of deposition (see Appendix 1). It may be, that part of the formation was deposited in landlocked shallow water of reduced salinity (see Appendix 1 fossil locality 863). Alternatively the shallow depths of deposition indicated by the foraminifera may be due to the transportation of shallow water foraminifera into deeper water.

An argument favouring a period of land locked seas is that the transport of sand would be reduced, and that fine grained sediments would be expected to be deposited in shallower water than usual. This argument is made later to explain the origin of the fine grained G_4, G_5 and G_6 members of the Totaranui Formation which overlie the G_1 Limestone, G_2 Sandstone and G_3 Conglomerate (deposited in shallow water.) Conditions of normal salinity are indicated for parts of the formation by the spatangoid spines at fossil locality 853, and the F_{18} Chlamys Bed at the Pori.

The *Pelicaria* cf. *acuminata* shells from fossil locality 1104 are of Southern Wairarapa type indicating some faunal exchange with the Southern Wairarapa, perhaps a direct one along the East Coast Strait.

PORI SANDSTONE

Type area and Subdivision

The formation is best developed south of the Rangedale Fault along the southern part of the Pori Syncline; this area is made the type area. The formation is not subdivided.

Distribution and Stratigraphic Relations

Apart from the type area, the Pori Sandstone crops out northwest of Rangedale Station where it overlies the Lower Pori Limestone and underlies the Upper Makuri Siltstone. It has the same stratigraphic relationship in a large outcrop between the Mt Marchant and Mt Butters Road faults at grid ref. 427095; and south of the South Makuri Fault at grid ref. 440118. The Pori Sandstone also crops out between the Mt Marchant and Mt Butters faults at grid ref. 443110, where it is poorly exposed.

Content and Thickness

At Ruatea Station the Pori Sandstone is a friable, massive brown-weathering, sparsely fossiliferous fine sandstone, and is at least 165 ft thick. Sink holes, 90 ft in diameter, and 40 ft deep, are common in the outcrop area; in contrast they are absent in the outcrop area of the Lower Pori Limestone.

Figure 33: Air view. Northwards along axis of the Pori Syncline.

Mt Marchant centre left.

Northwest of Rangedale Station the base of the Pori Sandstone is composed of fossiliferous fine and medium sandstone (Ostrea is present locally.) These beds grade upwards first into muddy very fine sandstone containing Balanus, and brachiopods .., and then into the Upper Makuri Siltstone.

Between the Mt Marchant and the Mt Butters Road faults the Pori Sandstone is at least 80 ft thick. It is composed of massive unfossiliferous light blue-grey very-fine sandstones. South of the South Makuri Fault very fine sandstones about 150 ft thick, crop out between the Lower and Upper Pori Limestones.

Conditions of deposition

The deposition of sandstone locally at the Pori at a time when siltstones were being deposited elsewhere indicates that the source of the sand lay further to the east. Deposition was probably in shallow water.

UPPER PORI LIMESTONE

The Upper Pori Limestone is restricted in distribution to two small areas, one south of the South Makuri Fault at grid ref. 440120, and one north of the Mt Butters Road Fault at grid ref. 432096. In both localities limestone about 30 - 50 ft thick cap the Upper Makuri Siltstone. The Upper Pori Limestone is the youngest formation which is developed at the Pori. Its thickness is thus uncertain and It is not known how thick the formation is ~~may be~~ elsewhere in the Puketoi Range.

KAITAWA SANDSTONE

Name, Type area, Subdivision

The formation is named after the Kaitawa Settlement which is made the type area; it ~~the formation~~ is not subdivided.

Distribution and Stratigraphic Relations

The Kaitawa Sandstone occurs north east of Kaitawa, and on both sides of the Mangaramarama Fault, where it is dislocated by many faults. West of the Rongomai Fault near Maclaughin Farm (grid ref. 296145) the formation crops out in a relatively narrow northeast trending belt.

In the Konini area it occurs on the upthrow side of the Totaranui Fault, and north-east of the Puka (T) Fault (which is almost parallel to Rock Road).

The Kaitawa Sandstone overlies the Upper Makuri Siltstone and ~~is~~ was overlain, perhaps after a short period of non deposition, by the Totaranui Formation.

Content

The Kaitawa Sandstone is generally a massive light-blue-grey concretionary sparsely-fossiliferous very-fine-sandstone; occasionally, especially in its upper part, the formation is bedded. With the exception of the Makuri Sandstone, fossils are more common, especially in its uppermost part, than in other non-limestone formations of the Makuri Group. In the Aupapa-Kaitawa area at grid ref. 368178 a 5-ft-thick-shell-bed, locally containing *Chlamys delicatula* occurs at the base.

South of the Mangaramarama Fault (at grid ref. 321172) a 2-ft-thick *Chlamys delicatula* bed overlies fossiliferous sandstones. Apart from these two localities, *Chlamys* beds are absent.

Some of the shell beds within the formation are quite thick. One mile west of Kaitawa (at grid ref. 337184) a shell bed ~~is~~ 12 ft thick, ~~it~~ contains common *Zeacolpus* sp. and *Chlamys radiatus*, and grades up into light-blue-grey unfossiliferous silty-sandstone.

A section of bedded strata, in the upper part of the formation, in ~~from~~ the headwaters of a small stream, a half a mile northeast of Kaitawa at grid ref. 368195 contains:-

	Inches
Lenticular shell bed containing brachiopoda, coral, *Chlamys*, and bryozoa	27
Fine sandstone	31
Shell bed, quite limy containing brachiopoda and bryozoa	5
Fine sandstone	85
Dark brownish-grey siltstone	2
Very-fine sandstone	64
Shell bed containing brachiopoda, *Chlamys* sp., *Aeneator*, and broken shells in a matrix of fine and medium sandstone	44
Fine sandstone	

Thickness

Because of the absence of marker beds within the Kaitawa Sandstone, and its dislocation by many faults, the precise estimation of the thickness of the formation is rarely possible.

WEST				EAST
North east of Rock Road	West of Rongomai Fault	Rongomai Anticline	Northeast of Mangaramarama Fault	West of the Kaitawa Fault
c 1,000 ft	c 350 ft	absent	c 750 ft	+ 370 ft

Macropalaeontology

Quite a number of fossils have been collected (see Table 20) or were seen in the field, but macrofaunal associations were not noticed.

Table 20

MACROPALAEONTOLOGY OF THE KAITAWA SANDSTONE

	733	735	740	770	771	793	794	795	796	797	798	799	868	871	888	1041	1113
Calliostoma (Maorea) hodgei (Hutton)				X				X									
~~Tugali rhynchia elegans (Sowerby)~~				~~X~~													
Tugali pliocenica Finlay												X					
Zeacolpus sp.												X					
Maoricolpus n.sp.				X													
Stiracolpus cf. huttoni (Cossman)		X															
Stiracolpus sp.								X		X	X						
Pelicaria n.sp. aff. tricarinata Lesson				X	X						X		X		X	X	
Aeneator sp.		X															
Austrofusus pagoda Finlay										X							
Austrofusus glans (Roeding)										X	X						
Poirieria zelandica (Q & G)									X								
Olivella (Lamprodominia) neozealandica Hutton											X						
Marshallena impar Powell										X							
Marshallena sp.										X							
Antimelatoma sp.		X															
Micantapex sp.						X			X		X						
Atrina zelandica (Gray)														X			
Chlamys delicatula (Hutton)														X			
Chlamys radiata (Hutton)	X					X											X
Chlamys sp.			X	X									X				
Pallium (Mesopeplum) convexum (Q & G)				X									X				
Ostrea sinuata LK													X				
Ostrea sp.						X											
Cardita lilliei (Fleming)														X			
Dosinia (Kereia) greyi Zittel								X									
Dosinia (Kereia) cottoni Marwick							X										
Marama murdochi Marwick	X						X			X							
Neomocardium pulchellum (Gray)					X	X	X	X						-			
Panopea zelandica (Q & G)																	

Conditions of Deposition

Foraminifera from fossil localities 796 and 868 indicate that the formation was deposited at mid-upper neritic depths; while foraminifera from fossil locality 888 indicate upper neritic depths of deposition.

AGE AND CORRELATION OF THE MAKURI GROUP

Subdivision of the Makuri Group into formations is from lithology. The formation boundaries are considered to be largely contemporaneous within the Sheet District. It is not known if the c 10 ft thick coquina limestones and limy Sandstones developed at the type area and at the Pori are contemporaneous or not. Ages deduced from foramanifera are too broad to be useful. Many samples from the Kaitawa Sandstone, however indicate Upper Ww-Wn Ages (See Appendix 1). The Makuri Sandstone, contains *Pelicaria canaliculata* and *Maoricardium spatiosum*, and is assigned to the Waipipian Stage, and to the *Pelicaria canaliculata* zone of Marima. The Kaitawa Sandstone is assigned to the Hautawan and to the *P.* n. sp. aff. *tricarinata* zone by its contained *Pelicaria* n. sp. aff. *tricarinata*. The Lower and Upper Makuri Siltstone and the Koropeke Sandstone, however, cannot be assigned with certainty to stages or to the Marima *Pelicaria* zones.

Zonal fossils are absent in the post-Opoitian F_1 Coquina Limestone at Cliff Road near Eketahuna; elsewhere, however, the Makuri Sandstone or the *Pelicaria canaliculata* zone of the Marima Sandstone overlie Opoitian Strata; the F_1 Coquina at Cliff Road is tentatively correlated with the Makuri Sandstone.

The Makuri Group is correlated with the Te Aute (except for some of the basal beds), and the Lower Kumeroa formations of the Dannevirke Subdivision.

The ~~subdivision~~ subdivision of the group into five major units does not agree with Vella's (1963b) Plio-Pleistocene Cyclothems, which parallel ~~the~~ New Zealand Stages.

Extrapolation of the Makuri Group stratigraphy southwards to Mauriceville indicates that the deposition of Vella's Hautawan Te Ahitaitai Cyclothem, composed of limestone, and also the stratigraphic break beneath it occurred during the period when the Koropeke Sandstone, Upper Makuri Siltstone, and the Kaitawa Sandstone were deposited. The limestone at Mauriceville is ~~presumed~~ assumed to have taken as long to be ~~been~~ deposited as ~~during the same order of time that~~ the Lower Pori Limestone ~~was deposited, the Lower Pori Limestone~~ which is thicker and is similar in content; Furthermore Orbell (1962) makes no mention of condensed sequences within the limestone. The time break beneath the limestone at Mauriceville is considered to be long; long enough for the deposition of the Koropeke Sandstone and the Upper Makuri Sandstone to have occurred in the mapped area. It is probable that an unconformity encompassing such a period of time is present between the "Lower Makuri Siltstone" and Vella's Hautawan Limestone.

Subsequently Vella (1965) considered that marine transgression and regression planes up the Wairarapa Valley were subparallel to time planes. The planes increase the time gap beneath the Hautawan Limestone at Mauriceville; but the time gap is still thought to be too small by the order of 100 per cent. Further, Vella's idealised diagrams indicate that larger time gaps would occur within the mapped area; this is not so. An alternative theory, ~~to Vella's which is~~ preferred by the writer, is that there is a pre Hautawan unconformity at Mauriceville due to a local tectonic factor.

ENVIRONMENT OF DEPOSITION OF THE MAKURI GROUP

Although most of the group was deposited in a soft bottom environment, for example unrolled Spatangoid spines are quite common, the proportion of pelagic material ~~contained~~ in the strata is probably quite small.

In recent years ~~much~~ many of the larger geomorphic features, and the composition of the sea floor of the English Channel ~~has~~ have been elucidated by acoustic surveys and bottom sampling, (see Stride 1963). The most important ~~sub~~division of the sea floor is: ~~into~~ areas of bare rock (degradational); and areas covered by sand, gravel and mud (aggradational). Stride has shown that ~~the areas covered by~~ unconsolidated sediment may be in the process of being moved to depositional sites ~~areas further away~~ or the sediment may have reached its final site. ~~stable state.~~ Fine sand, gravel, and mud are at present being moved ~~in~~ towards the two major depositional areas; in the Celtic Sea, and in the North German area of the North Sea. Much of the movement is longitudinal and along the axis of the Channel. It is believed that similar processes took place ~~generalisations apply~~ within the mapped area. Because of the widespread uniformity ~~homogeneity~~ and substantial thickness of formations, longitudinal transport of sediment ~~before deposition~~ along the East Coast Strait is likely (see Grant Taylor and Hornibrook (1964)). This rather than a local origin for ~~of~~ the sediments, is thought to be ~~have been more~~ important ~~common~~, especially in the Sandstone and Siltstone formations. ~~Such a mode of deposition~~ This would offer an explanation for ~~the presence of~~ the fine sandstone of the Makuri Sandstone overlying the finer-grained Tane Sandstone. Even Where there are great differences in thickness of formations across a fault line, such as across the Rongomai Fault, there appears to be no accompanying change in lithology. It is considered that deposition rate~~s~~, but not lithology, was ~~were~~ controlled by fault movements ~~at a time when~~ because sediment was moving across the area of deposition. The stratigraphic relationship of the Koropeke Sandstone and the Lower Makuri Siltstone in the Mangaone-Tuscan Hills areas, indicates that ~~some of~~ the direction of sediment-transport ~~during that time~~ was primarily from the south.

Although most of the detritus which formed the Makuri Group is thought to have been introduced into the depositional area longitudinally, some of the sediment, such as that ~~which formed~~ of the Skye Farm Sandstone, had a more local, and eastern source. The shell fragments of the Lower Pori Limestone are considered to have been derived from nearby shell banks.

Macrofossils within the Makuri Group are not as common as might be ~~have been~~ anticipated, considering that relatively shallow water that predominated during deposition. The paucity of the macrofossils is thought to be due to ~~the inferred~~ continued movement of sediment across the sea bottom. Jones, Kain and Stride (1965) found that there is a sparse infauna on the sand-waves of the Warts Bank (near the Isle of Man, Irish Sea).

MANGAMAIRE GROUP

The name Mangamaire Group, from Mangamaire settlement, is applied to the strata which overlie the Kaitawa Sandstone in the east, and overlie the *Pelicaria* n.sp. aff. *tricarinata* zone of the Marima Sandstone in the west. The Mangamaire Group is subdivided into the Totaranui formation, which contains shallow-water marine members, and the Mangahao Formation which contains non-marine members. The Totaranui Formation is equivalent in part to Ongley's (1935) Petane Series, while the Mangahao Formation is equivalent in part to Ongley's (1935) Mangahao Series.

TOTARANUI FORMATION

Name and Subdivision

The formation has been named after Totaranui Farm (grid ref. 276177) ~~which is located a short distance~~ not far ~~from~~ north-east of ~~the~~ Konini Settlement (see Figure 34).

The Totaranui Formation is composed of a lower part and an upper part, each of which contains three members:

Totaranui Formation	G_6 Sandstone	Upper Part
	G_5 Mudstone	
	G_4 Siltstone	
	G_3 Conglomerate	Lower Part
	G_2 Sandstone	
	G_1 Limestone	

The G_1, G_2 and G_3 members often occur in succession, locally however, the G_2 and G_3 members are absent, and all of the lower part of the Totaranui Formation is composed of G_1 Limestone.

The G_4, G_5 and G_6 members are largely developed in separate areas. Near Tainui Stream, however, the G_5 Mudstone overlies the G_4 Siltstone.

Distribution and Stratigraphic Relations

The Totaranui Formation crops out in the northern part of the mapped area near the Marima, Mangamaire, Konini, Kaitawa and Ngaturi settlements. The lower part of the formation has a much wider ~~greater~~ distribution than the upper part. The lower part occurs as a cap on the low hills east of Totaranui Farm (see Figure 34). Between Kaitawa and the Rongomai Fault, the Totaranui Formation is bounded in the south by the Mangaramarama Fault. East and north-east of Kaitawa the formation is much faulted and folded, and crops out on both sides of the Tiraumea River, at Aupapa Trig, and ~~at~~ a short distance both north and south of the Aupapa Road, near its junction with the Hinemoa Road.

West of Totaranui Farm the G_1, G_2 and G_3 members crop out at: 1. a short distance east of Mangamaire Railway Station; 2. at Henderson's Farm; and 3. north of Otangue Stream as a narrow belt subparallel to the Wellington Fault.

The G_3 Conglomerate is restricted to the axis of the Henderson Syncline and to a belt west of the Mangahao River. Between the Mangamaire Fault and the Mangamaire Railway Station the strata overlying the upper G_1 limestone are not exposed, and have ~~This area has~~ been mapped as G_3 Conglomerate. On the west flank of the Henderson Syncline, in the extreme northern part of the mapped area a wedge of G_3 Conglomerate occurs within the G_1 Limestone. A feature adjacent to the right bank of the Mangahao River, formed by the G_1 Limestone and G_3 Conglomerate members was ~~has been~~ traced three miles north of the mapped area on photo-mosaics. Features on photo-mosaics indicate that the members are also present south of the Tararua Track near Matarua Trig.

The G_4 Siltstone and the G_5 Mudstone members are restricted to a wedge shaped area north-west of Marima. Good exposures ~~of the~~ members are restricted to near Tainui Stream. The G_6 Sandstone is restricted to an area east of the Woodville-Masterton State Highway, the member being best developed east of the Rongomai Fault.

The Totaranui Formation ~~usually~~ overlies the Marima Sandstones at Marima and the Kaitawa Sandstone east of the Makakahi River. ~~An~~, except ~~exception is~~ south of the Makakahi Road Fault (at grid ref. 274139) where the G_1 Limestone overlies the Makuri Sandstone. The Totaranui Formation is overlain by the Mangahao Formation.

Content

There are four main areas in which the stratigraphic relationships of the G_1, G_2 and G_3 members show little variation, (see list).

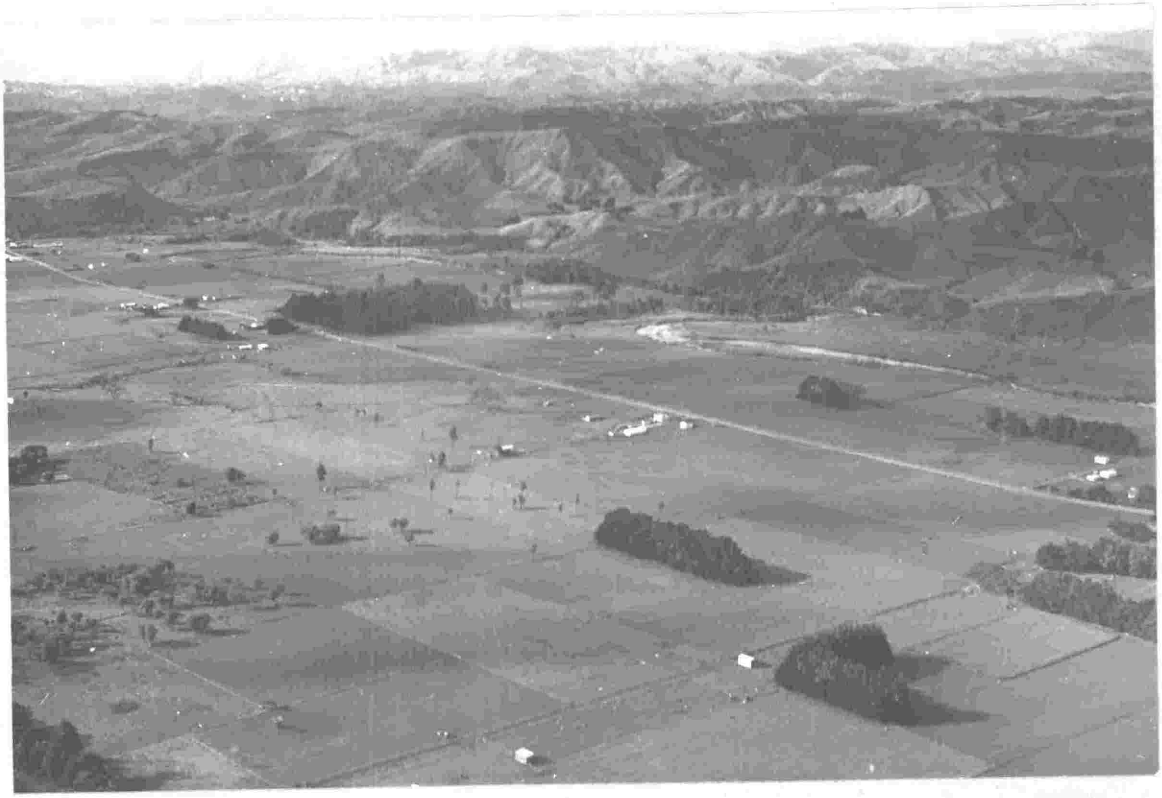


Figure 34: Airview, ~~viewing~~ looking north-eastwards: Foreground:- Hukanui Surface and Makakahi River. Centre:- low hills; ~~of~~ siltstone and sandstone formations of the Makuri Group capped by the G_1 Limestone of the Totaranui Formation. Extreme left centre:- Konini Dairy Factory. Note fine textured relief developed in the siltstone and sandstone formations, and smooth surface of the G_1 Limestone

WEST			EAST
Area between Mangahao River and Wellington Fault	Henderson Farm	Totaranui Farm	East of Totaranui Farm
(G_3 Conglomerate	G_3 Conglomerate	(	G_1 Limestone
(G_2 Sandstone	(G_1 Limestone	(G_1 Limestone	G_2 Sandstone
(G_1 Lower Limestone	(	(	G_1 Limestone

G_1 Limestone

In the type area at Totaranui Farm, the light-buff coquinoid limestone is largely composed of sub-rounded 1-20 mm-long shell fragments, particularly Balanus sp. plates. There is little interstitial material ~~of a smaller grain size~~. The large initial porosity of the limestone has been reduced by a calcite cementation of horizons 1 - 6 inches thick parallel to the bedding, ~~The cemented horizons~~ which alternate with non-cemented horizons of similar thickness, (see Figure 35). Bedding and cross-bedding, is made especially apparent by the large Balanus sp. plates. The cross-beds are tabular (see Potter and Pettijohn 1962 p.70); the forsets are inclined at about 20 - 25 degrees to the bedding and are not curved.

Macrofossils, especially brachiopoda, are more common in sandy beds and some are considered to be biocoenose assemblages.

Greywacke pebbles, usually tabular and 1.5 to 3 inches long, are fairly common near the base. Pebbles usually about ½ inch long occur in the upper part of the limestone and in the soil which overlies the limestone.

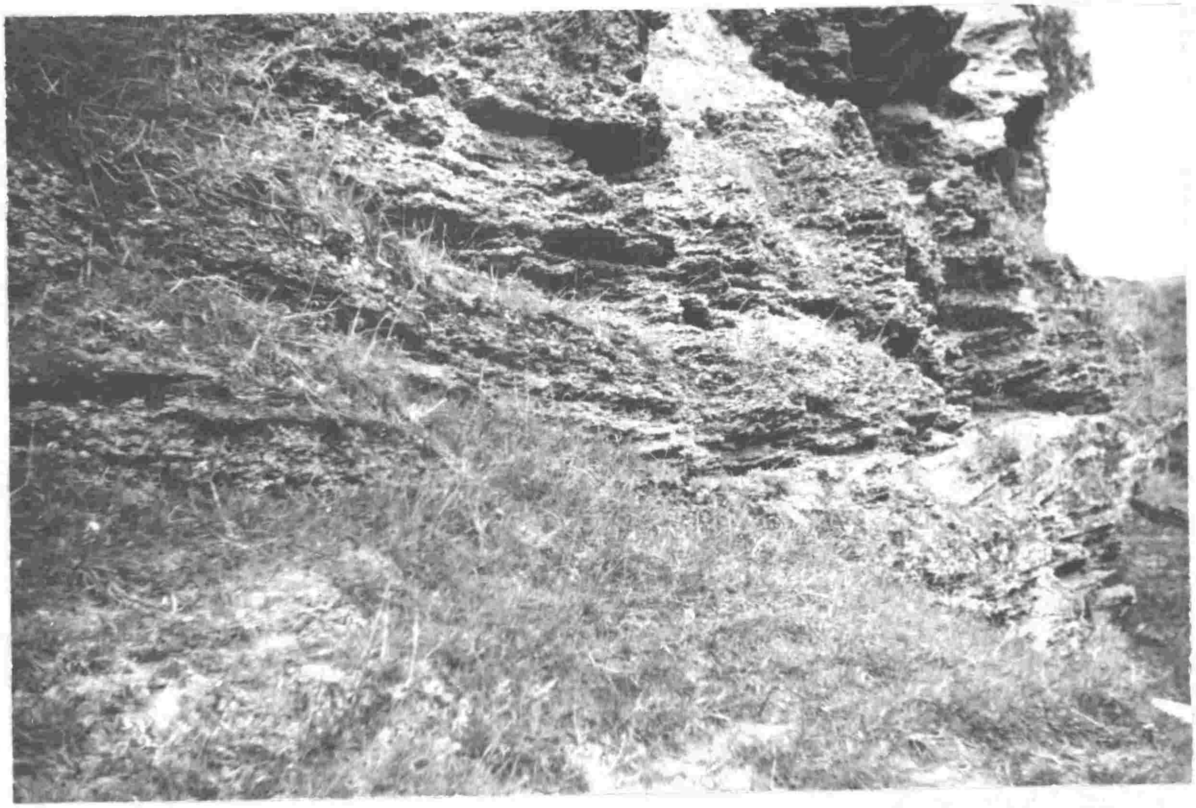


Figure 35: G_1 Limestone in the type area. Note cross-bedding centre far right and partial cementation along certain bedding planes.

Morgan (1919, p.149) quotes Aston that the G_1 limestone at the Pahiatua Waterworks at Konini contains 90 per cent $CaCo_3$. Four other analyses ~~taken from the G_1 Limestone~~ indicates a range of $CaCo_3$ ~~content~~ from 70 per cent to 91 per cent.

South of the type area, near the Makakahi Road (at grid ref. 273138), a 3 ft thick "rubble bed" containing broken pelecypoda, brachiopoda and *Pelicaria fossa* set in a very-fine-sandstone matrix occurs at the base of the G_1 Limestone. The overlying beds are cross-bedded *Balanus* limestones.

East of Totaranui Farm most of the G_1 Limestone, except the basal and uppermost parts, wedges out into massive brown-weathering G_2 Sandstone.

The basal G_1 Limestone is generally somewhat thicker than the upper limestone, being 10 - 15 ft thick near the Rongomai Fault, and 20 - 50 ft thick near the Tiraumea River. The limestone is missing in the fault block east of the Rongomai Fault. A short distance west of the Rongomai Fault (at grid ref. 298160), the lower part of the G_1 Limestone is 5 - 10 ft thick. It is very variable: ~~in content,~~ at one locality the limestone is composed entirely of *Balanus* fragments, while 300 yards away it is composed largely of whole Brachiopoda. Between ~~these localities~~ these localities the limestone is composed of interbedded Brachiopod beds & *Balanus* beds, each, from 2 to 5 ft thick.

The upper limestone is the thickest (20 ft) just south of the Totaranui Fault, at grid ref. 299175. Elsewhere it is generally about 10 ft thick, except one hundred yards north of the mapped area at grid ref. 340201, where it is at least 15 ft thick.

Near Henderson's Farm, the G_1 Limestone crops out on both flanks of the Henderson Farm Syncline. It grades upwards from very pebbly limestones, through conglomerates containing marine shells, to unfossiliferous conglomerates possibly partly ~~of~~ non-marine ~~origin~~. Where the strata contain 50 per cent pebbles or more, the strata have been mapped as the G_3 Conglomerate.

A section from near the base of the G_1 Limestone on the west flank of the Henderson Syncline at grid ref. 221187 contains:-

	Feet
Cross bedded pebbly limestone (pebbles of greywacke tabular, and about ½ inch long), containing very common *Chlamys delicatula*, and a few *Balanus* plates and *Panopea* sp.	3
Massive blocky limestone with common unrolled *Chlamys delicatula*, *Balanus* plates and *Ostrea* sp.	5

UNCONFORMITY

MARIMA SANDSTONE

The overlying limestone is largely composed of *Balanus* sp. fragments, pebbles ½ - 2 inches long are common locally. Near the northern boundary of the sheet district, on the western flank of the Henderson Syncline, a thick conglomerate wedge crops out within the G_1 Limestone. There is a change of facies and an increase of thickness in a southward direction along the hogback west of Mangamaire Railway Station (see Figure 36). In the northern part of the hogback, the lower part of the Totaranui Formation is composed entirely of *Balanus* sp. ~~rich~~ (G_1 Limestone). Southwards it thickens and its central part is replaced by fine sandstone

Figure 36: Air view. Lower left-centre to centre: hogback formed by steeply dipping G_1 Limestone. Lower right: Mangamaire Railway Station. Centre: road leading to Henderson's Farm (obscured by clump of trees). Background, Mangahao Valley.

(G_2 Sandstone).

A composite section south west of the Mangamaire Railway Station at grid ref. 218158 contains:

		Feet
G_1	(Well-sorted, very coarse, coquinoid limestone composed largely of Balanus plates. Bedding planes about 2 ft apart	9
	(Gravel bed 40 per cent coquinoid limestone 60 percent Pebbles well-sorted, well-rounded $\frac{1}{4}$-$1\frac{1}{2}$ inches long Shell fragments largely plates of Balanus Some Ostrea sp. fragments	15.5
G_2	Massive fine-sandstone	c130
G_1	(Pebbly coquinoid limestone, pebbles $\frac{1}{2}$-3 inches long tabular, limestone largely composed of Balanus sp. fragments	c 25

G_2 Sandstone

East of Totaranui Farm the G_2 Sandstone is very friable, massive, rusty-brown-weathering, and fine to medium grained. Locally it is fossiliferous, particularly in the Kaitawa area.

G_3 Conglomerate

The type area of the G_3 Conglomerate is at Henderson Farm. See Figure 36). Locally at Henderson's Farm a thin-fine-grained sandstone occurs between the G_1 Limestone and the G_3 Conglomerate. In the type area the conglomerate largely consists of well-rounded well-sorted greywacke pebbles $\frac{1}{2}$ - 2 inches long, with a maximum length of 6 inches. The pebbles are difficult to dislodge from their matrix. Near the base of the conglomerate rolled Balanus sp. Ostrea sp, Mytilus sp., and Panopea shells are quite common.

At grid ref. 224177 the imbrication of pebbles indicates that they were transported by currents flowing south-southwestwards.

In the area between the Mangahao River and the Wellington Fault the G_1 Limestone is not well developed, and is largely replaced by the G_2 Sandstone and the G_3 Conglomerate members. The best-exposed sections occur along Tainui and Otangue Streams.

The section at Tainui Stream contains:-

	Feet
G_3 Conglomerate	
Interbedded conglomerates 3-4 ft thick and dark blue-grey fine sandstones 3-10 ft thick	c 140
G_2 Sandstone	
Massive rusty-brown-weathering fine sandstone with some one-inch-thick pebble horizons	c 140
G_1 Limestone	
Indurated shell bed	8
Fine sandstone and thin coarse-sandstone horizons	10
Coarse very-sandy coquina limestone	12
Shell bed and sandstone	12
Fine sandstone (fossil locality 775)	25
Pebble bed with many bryozoa fragments	0.25
Conglomerate with shells	5
Medium sandstone	1
Lower Shell beds	15

The content of the G_1, G_2 and G_3 members is fairly constant along the strike, the G_1 Limestone thins south westwards, it is only six ~~ft~~ thick north of Naenae Road at grid ref. 174163, and four ft in Otangue Stream. In Wahaoteika Stream the G_1 Limestone consists of a 4 ft-thick oyster bed.

East of the Omata Fault the G_1 Limestone is absent.

G_4 Siltstone and G_5 Mudstone

The section along Tainui Stream (see map) provides the type section of the G_4 Siltstone. The G_5 Mudstone is not well exposed and no type section is designated.

At the type section the G_4 Siltstone is composed of massive blue-grey siltstone, containing three shell beds, each one shell thick. South-westwards, in a right branch tributary of Tainui Stream four shell beds are present. The ~~shell beds~~ are composed almost entirely of *Tawera* cf. *spissa*; single specimens of *Ostrea* sp, *Austrofusus* sp, and *Chlamys radiatus* were found, however, (fossil locality 778).

The blue-grey G_5 Mudstone is very poorly exposed, macrofossils are absent, except at grid ref 182187, where *Tawera* cf. *spissa* occurs.

G_6 Sandstone

The G_6 Sandstone is very poorly exposed, a type section is not designated.

~~A few~~ isolated outcrops ~~of sandstone were found~~ east of the Rongomai Fault near Taiepa Trig (grid ref. 309183) some brachipods ~~are present~~.

Attitude

At most places ~~Usually~~ the G_1, G_2 and G_3 members of the Totaranui Formation are tilted at low angles ~~generally~~ (less than fifteen degrees). The members have been much faulted ~~since they were deposited,~~ but the throws on many of the faults are small, ~~however~~. ~~Near the Rongomai Fault,~~ the formation is ~~though~~ dislocated by the Rongomai ~~fault~~ and is also arched across it.

At two localities, both east of the Huru-Paiwai fault complex, the members are highly inclined. North of the railway line near the Konini Railway Station, the upper and lower G_1 Limestones crop out in a narrow north-south belt bounded by two cross faults which trend northwards towards the Paiwai Fault. In the north of the belt both limestones dip ~~are inclined to the~~ west at fifty-five degrees, in the southern part of the belt, however, the eastern limestone dips ~~is inclined to~~ the east at forty-five degrees. Other parts of the limestone outcrop examed on air photographs appear to be vertical~~ly inclined~~. It is thought that the limestone is generally vertical at depth but close to the surface parts of the outcrop have slumped, either to the east or to the west. Locally near Mangamaire Railway Station (at grid ref 224169) the G_1 Limestone is tilted ~~as much as~~ seventy-five degrees to the south-east, and forms a prominent hogback (see figure 36).

Thickness

The G_1, G_2 and G_3 members were deposited at or near sea level and variations of thickness ~~from the average~~ are due to penecontemporaneous faulting ~~during deposition~~. The average thickness of 100 - 200 ft ~~can~~ is ~~be~~ taken as being ~~to be~~ the regional ~~amount of~~ downwarping ~~that took place~~ during the deposition of the G_1, G_2 and G_3 members. Thicknesses greater than this, such as in the Henderson Syncline, are probably due to local downwarping. ~~during deposition~~.

The G_1 Limestone is about 150 ft thick at Totaranui Farm. To the east ~~of Totaranui Farm~~ the Lower part of the Totaranui Formation has a relatively constant thickness, ~~of about~~ 100-120 ft.

~~At Hendersons Farm the lower part of the Totaranui Formation is much thicker than at Totaranui Farm.~~ There is a wide range in the thickness of the G_1 Limestone ~~differs markedly in thickness~~, It is at least 440 ft thick at Henderson's Farm, and no more than 150 ft at Totaranui Farm. The limestone thins north-westwards on the west flank of the Henderson Syncline; it is about 370 ft thick at grid ref 218181 and 180 ft thick at grid ref 230194.

At least 300 ft of G_3 conglomerate are present along the core of the Henderson Syncline. The lower part of the Totaranui Formation is therefore at least 700 ft thick at Henderson's Farm, ~~where it is incompletely developed~~.

Between the Mangahao River and Wellington Fault, the G_1, G_2 G_3 members are usually about 300 ft thick.

The upper part of the Totaranui formation is generally thicker than the lower part. At Tainui Stream the G_4 Siltstone is 130 ft thick. North-eastwards the G_4 Siltstone and the G_5 Mudstone are about 450 ft thick. The increase of thickness of the upper part of the Totaranui Formation takes place abruptly across a fault which trends at ~~a bearing of~~ 324° (parallel to Tainui Stream.) The fault is considered to have been active during the period of deposition of the G_4 Siltstone and G_5 Mudstone members. Beds which overlie the G_6 Sandstone are not found within the mapped area, in consequence the G_6 Sandstone is thicker than the thickest section measured, (650 ft).

Pollen Analysis by D.J. Mcintyre

Lab. Number	Fossil locality	Stratigraphic position
	778	G_4 Siltstone
2841	775	G_1 Limestone

Fossil locality 775: A rich pollen flora with the dominant pollen type Nothofagus of the fusca group (?N. truncata). Abundant types are Cyathea smithii, monolete fern spores, Podocarpus sp, Dacrydium cupressinum, Phyllocladus, Metrosideros, Myrtus (s.l.) Nothofagus menziesii, Myrsine, Compositae, Cruciferae, Coprosma, Cyperaceae. Common types are Dacrydium bidwillii group, Libocedrus, Dodonaea viscosa, Aristotelia, Astelia, Gramineae. Other types present include Cyathea medullaria, Agathis, Eleocarpus, Quintinia, Griselinia, Rubus, Ascarina, Weinmannia, Plagianthus, Urtica, Plantago, Astelia, Cordyline. The extinct species Nothofagus mataurаensis and Microcachryidites parvus are present in small numbers.

The pollen flora indicates that the vegetation which shed the pollen was rich and diversified, predominantly forest, mainly beech, but with much Podocarpaceae. The presence of a mixed forest is further indicated by some of the pollen of trees such as Eleocarpus, Weinmannia, Metrosideres and others. The presence of Dodonaea indicates that coastal forest existed in the area. The presence of numerous hystrichospheres confirms the marine environment of deposition which may in part account for the richness of the pollen assemblage which possibly contains a mixture of floras from different environments or different altitudes. In general, mild or warm conditions, at least as warm as the present day, and probably warmer, are indicated by the mixture of pollen grains of forest types plus ~~[illegible]~~ Dodonaea. Gramineae, Compositae and Dacrydium bidwillii type and perhaps Nothofagus menziesii, are generally indicative of cooler conditions than indicated by the rest of the pollen flora. In this sample these may have come from coastal scrub and dune vegetation but another possible explanation is that they have been stream-and river-transported from higher altitudes, ~~and cooler climate~~, and had been deposited with the pollen of the lowland forest ~~of warmer conditions~~, to giving a pollen assemblage of mixed-vegetation-types and climate. The pollens of the cooler element are indicative of scrub type vegetation, either coastal and controlled by exposure and lack of water and perhaps physiological factors such as salinity, or montane and controlled by temperature largely.

Fossil locality 778:- The assemblage is dominated by pollen of Nothofagus fusca group (?N. Truncata). Abundant pollen types are Cyathea smithii and dealbata, Podocarpus, Dacrydium cupressum, Phyllocladus. Pollen of Gramineae is common. Other types present include Podocarpus dacrydioides, Metrosideros, Nothofagus meiziesii, Compositae, Hoheria, Cruciferae, Ascarina, Weinmannia, Eleocarpus, Dysoxylum, Dodonaea. Rare Nothofagus mataurаensis occurs.

Vegetation is beech forest, either with a large Podocarp element mixed in, or as in stands nearby. Some mixed broadleaf forest elements, and coastal forest elements are also present.

The flora differs from that of the Okehuan Wahaoteika Stream section in that it contains more Podocarpaceae, is richer in species, contains coastal elements, and has a slightly warmer appearance.

Macropalaeontology

Unbroken fossils are relatively rare in the coquinoid G_1 Limestone. A large proportion ~~of the limestone~~ is composed of disarticulated barnacle plates (*Balanus* sp,), ~~perhaps~~ fragments of several species are probably present. The next most common element is a brachiopod ~~sp~~, which locally is as abundant as the barnacles. ~~locally~~ *Ostrea*, sp *Chlamys delicatula*, *Panope zelandica*, are common locally.

The fossil locality containing the greatest number of species is 1044 from the basal G_1 Limestone at Otangue Stream. ~~(fossil locality 1044)~~. The fossils are scattered and include; *Ryenella impacta* (which during life was attached by a byssus to some object on the sea floor, such as a stone), and *Pelicaria convexa* which is a deposit feeder. They were presumably derived from several habitats and are a thanatocoenose assemblage.

Fossils are not common in the G_2 Sandstone except near Kaitawa (fossil localities 869, 870 and 889).

Macrofossils from the G_1 G_2 and G_3 Members of the Totaranui Formation are listed in Table 21.

MACROPALAEONTOLOG

Pelicaria fossa (Marv

Pelicaria convexa (Ma

Struthiolaria sp.

Zegalerus tumens. Finl

Zegalerus aff. tenius

Sigapatella sp.

Tanea n.sp. aff. zealai

Aeneator aff. imperato:

Aeneator sp.

Notosaria cf. nigrica:

Waltonia cf. inconspi

Lepsiella n.sp.aff. s

Oliviella (Lamprodom: neozelandica Hutto:

Baryspira (Baryspira) (Sowerby)

Baryspira sp.

Astraea heliotropium

Chlamys delicatula (H

Chlamys n.sp.aff.delic

Chlamys sp.

Phialopecten ongleyi

Ryenella impacta (Herm

Ostrea angasi Sowerby

Ostrea sp.

Dosinia (Phacosoma) su

Tawera subsulcata (Su

Panopea zelandica (Q

Megabalanus tabulatus

Balanus sp.

Brachiopoda sp.

Cancer novaeazealandia

Age and Correlation

The Totaranui Formation is extensive and the lithologies of the component members are distinct; subdivision is entirely by lithology. The brown-weathering friable sandstones, limestones, and conglomerates are unlikely to be confused with the underlying light blue-grey massive Marima and Kaitawa sandstones.

Foramanifera from the G_1 G_2 and G_3 members indicate a Nukumaruan age; as do the gastropods _Pelicaria convexa_ and _P. fossa_. Foramanifera from the G_4 Siltstone indicates a Waitotaran to Recent age.

The Totaranui Formation, (~~Fetane~~) is correlated with the Upper Kumeroa of Dannevirke (see Lillie 1953 p.59). Stratigraphic sequences near Pahiatua, (see Firth and Feldmeyer (1943)), at the Manawatu Saddle (see Ower 1943), and at Wanganui (see Fleming 1953) are similar to those of the mapped area (see Table 22). Correlation with the Southern Wairarapa is not certain, but correlation of the lower part ~~of the Totaranui Formation~~ with the Eringa Cyclothem and with the upper part with the Haungarua Cyclothem (see Vella 1963b) is probable, especially as the Haungarua Cyclothem contains both non-marine and estuarine beds.

At the Manawatu Saddle, Ower (1943) found that the basal Petane Conglomerate is 300 ft thick, and thinned both southwards and northwards. The Conglomerate occurs at the base of the Petane, while in the mapped area it overlies the G_1 Limestone or the G_2 Sandstone. It is probable that the conglomerate is diachronous and is younger in the mapped area than at the Manawatu Saddle.

Table 22

Correlation of Members of the Totaranui Formation with strata near Pahiatua, Manawatu Saddle, and Wanganui

This ~~Bulletin~~ Thesis	Feet	Near Pahiatua (Firth & Feldmeyer 1943)	Feet	Eastern part of Manawatu Saddle (Ower 1943)	Feet	Wanganui Fleming (1953)	Feet
G_4 Siltstone, G_5 Mudstone and G_6 Sandstone	c 450	Blue grey silty Mudstone	300-500	Blue grey Mudstones	800-1500	Tewkesbury Formation	90
G_2 Sandstone)	100-700	Coarse, massive argillaceous brown sand	100-300	?		Nukumaru brown sand	95
G_3 Conglomerate) G_1 Limestone)		Limy conglomerate grading eastwards into pebbly shell limestone	25 -75	Limestone	100	Nukumaru Limestone	100
				Conglomerate	30		

<u>Conditions of Deposition</u>

The lower part of the Totaranui Formation was deposited at about sea level, ~~while~~ but the beds beneath the Totaranui Formation were deposited at a depth of 25 fathoms, at Marima, and considerably more, perhaps 50 fathoms east of the Makakahi River.

Pollen from fossil locality 775 and *Olivella* (*Lamprodominia*) *neozealandica* (see Fleming 1962a p.82) from fossil locality 1044 indicate that the lower part of the Totaranui Formation was deposited ~~during a~~ in warm ~~climate~~ water. But ~~The~~ the Crab, *Cancer novaezealandiae*, and the common *Chlamys delicatula* shells, ~~however~~, are cold water indicators.

It is thought that the unconformity beneath the Totaranui Formation is due to a low sea level during the culmination of a glacial period, and that lower part of the formation was deposited after a rise of temperature and sea-level. Some cold-water-indicating-fossils had, however, established themselves in what was ~~now~~ to be an unfavourable environment.

Three lithofacies are recognised; 1. conglomerates in the north-west, especially in the Henderson Syncline; 2. limestones at Totaranui and Henderson's Farms; ~~and~~ 3. pebbly fine ~~+~~ to coarse sandstone between the Wellington Fault and the Mangahao River, and ~~also~~ to the east of Totaranui Farm.

The ~~distribution of the~~ Limestone at Totaranui and at Henderson's Farms, ~~while nearby the limestone is~~ replaced nearby ~~by~~ by massive sandstone indicates that the limestone ~~accumulated in place; they~~ had a reef-like origin. Further more *Balanus*. sp. is largely restricted to the surf-zone, between high and low tide, and requires a hard bottom, and strong wave-action.

The cross-bedded limestone, and also the partial rounding of the *Balanus* sp. plates, indicates that there was some transportation of the *Balanus* plates into quieter deeper water ~~(presumably~~ on the lee-side of ~~the~~ a Reef). ~~Current-flow indicated by cross beds is apparent, the cross-beds have not been corrected for tilt.~~ ~~There is~~, however, ~~a wide agreement~~ between cross-beds from ~~of readings from~~ the lower part of the G_1 Limestone, ~~which~~ indicate northward current flow, ~~with~~ but those from the upper part of the limestone, which indicate both southward and northward flow (see Figure 37). The distribution of the G_3 Conglomerate, ~~and~~ and the distribution of pebbles within the G_1 Limestone at Totaranui Farm, ~~however,~~ ~~indicates that the pebbles were derived from the northwest;~~ ~~and~~ is strong evidence for much southward flow during the deposition of the upper part of the limestone. The pebbles are elongate and tabular and are considered to have been shaped by wave-action on a beach and subsequently transport southwards by long-shore-drift.

The G_4 Siltstone, G_5 Mudstone, and G_6 Sandstone members have the appearance of having been deposited in deeper water than the G_1 G_2 and G_3 members.

Pollen analysis from both the lower and upper parts of the Totaranui Formation ~~have~~ indicated warm climates; but there is no evidence that the finer grained nature of the sediment is due to a sudden eustatic rise of sea level after a glacial period. It is improbable that there was a sudden regional downwarping of the basement during the deposition of the G_4 G_5 and G_6 members,

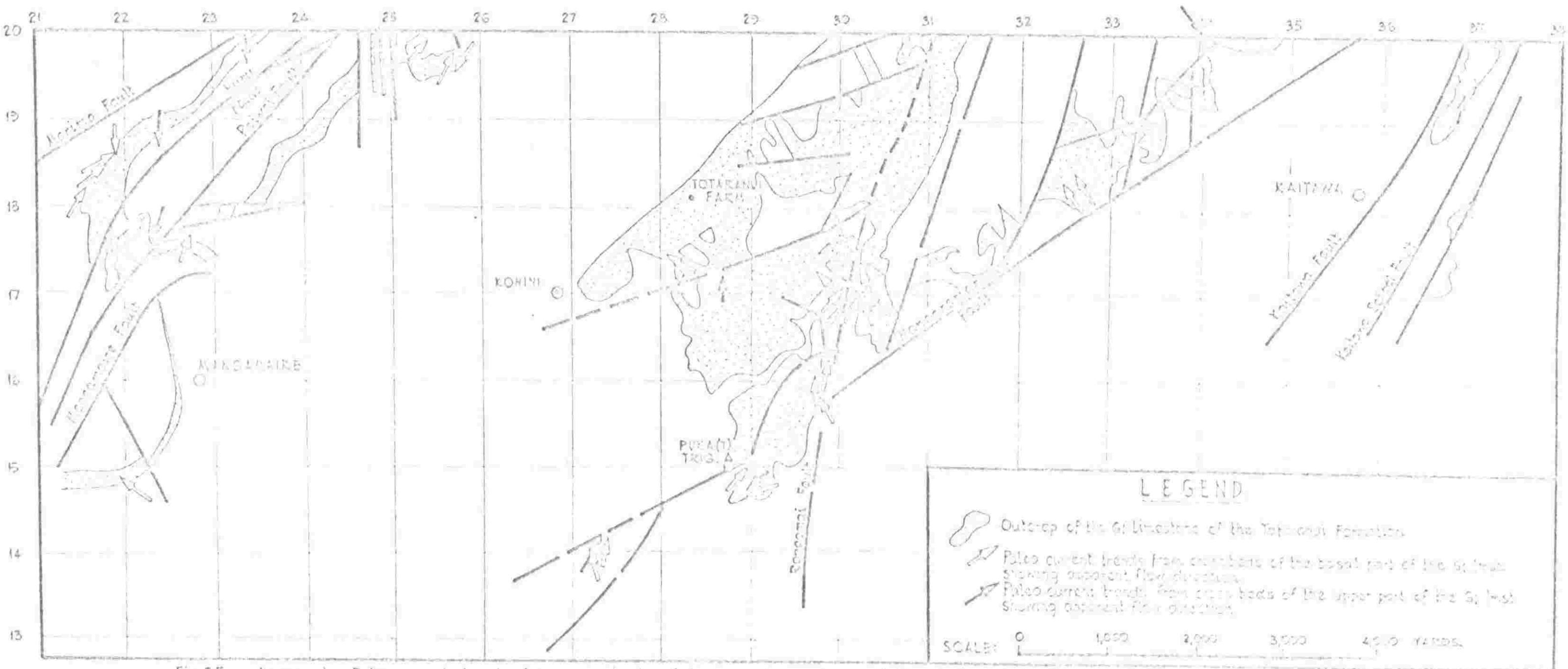


Fig 35. Apparent Paleocurrent trends from cross beds of lower and upper parts of the G1 Limestone of the Totaranui Formation. (not corrected for tilt) Not all faults are shown.

because subsequent regional movements of the basement were positive. The most likely explanation for the fine grained nature of the upper-part of the Totaranui Formation is that deposition was in a land-locked embayment; ~~the continuity of~~ the East Coast Marine Strait was at last blocked by land. Further evidence for land-locked deposition is the rarity of macrofossils (except for Tawera cf. spissa) ~~perhaps because of deposition in conditions of reduced salinity,~~ and ~~also~~ the absence of coarse clastics, ~~perhaps because there was little long shore drift~~. The fossil pollens indicate that elevated land at this time lay a short distance west of Marima. ~~during the deposition of the G_4 Siltstone~~.

MANGAHAO FORMATION

Name and Subdivision

The Mangahao Formation is a synonym for the Mangahao Series of Ongley (1939); the members of the formation are listed below:-

Mangahao Formation	G_9	Breccia
	G_8	Sandstone
	G_7	Conglomerate

Most of the formation is composed of the G_7 Conglomerate; the G_8 Sandstone and the G_7 Breccia are relatively thin, and are restricted to relatively small areas. The G_7 Conglomerate and the G_9 Breccia are invariably massive and no further subdivision is likely. The G_8 sandstone is composite, it contains many thin beds of different lithology; but the beds are unlikely to have anything more than ~~a very~~ local significance.

The Formation is in substantial agreement with Ongley's Mangahao Series. ~~Although the mapped outcrop area differs somewhat from that mapped by Ongley, it is considered that the formational outcrop is now in better agreement with Ongley's lithologic description.~~

Distribution and Stratigraphic Relations

The outcrop of the Mangahao Formation is restricted to a north-northeast-trending, 1,000 yards wide, much-faulted belt bounded ~~in~~ on the west by the Wellington Fault. ~~The formation~~ It is absent south of ~~the~~ Udy Fault. The G_8 Sandstone ~~is~~ best-developed near Tainui Stream, wedges out southwestwards into G_7 Conglomerate, and ~~It~~ is absent southwest of Naenae Road. Outcrops of the G_9 Breccia ~~has only been found in~~ are confined to Otangue, Wahaoteika, and Patupaiarehe Streams.

The Mangahao Formation overlies the Totaranui Formation; apart from the Terrace gravels the formation is the youngest ~~rock~~ formation ~~unit of~~ in the mapped area.

Content

G_7 Conglomerate

~~Near Tainui Stream~~ About 45 ft of G_7 Conglomerate occur beneath the G_8 Sandstone at Tainui Stream. The conglomerate contains rounded and subangular pebbles and cobbles and boulders of greywacke and jasper that are up to one foot long.

Above the G_8 Sandstone, the G_7 Conglomerate consists of thick beds of well-rounded cobbles and thin beds of sandstone and clay; these beds crop out along the upper courses of Tainui and Otangue streams. In Wahaoteika Stream 125 ft of conglomerate crops out beneath the G_9 Breccia. Above the Breccia the conglomerate consists of rounded cobbles about 4 inches in diameter; clay and sandstone beds are very rare. Massive conglomerate is also developed above the G_9 Breccia in Patupaiarehe Stream.

The section at Wahaoteika Stream contains:-

			Feet
G_7	Massive Greywacke conglomerate with cobbles usually about four inches long.	c	90
	Thin clayey silt, (F.L.* 1098)		1
	Massive greywacke conglomerate - cobbles usually about four inches long.		40
	Obscured		75
G_9	G_9 breccia - uniform angular fragments of greywacke ½-1 inch long with a matrix of very-fine sandstone - one 9 inch thick blue-grey silt bed (F.L. 1030)		70
G_7	Massive greywacke conglomerate - cobbles well-rounded 3-6 inches long - with a few thin clayey siltstone beds (F.L. 1097)		75
	Obscured		50
	Grey carbonaceous mudstone (F.L. 1096)		1
	Massive blue-grey sandstone - (F.L. 1095)	c	50
	Conglomerate non-marine, containing a 1 ft thick mudstone bed (F.L. 1029)*	c	40
G_2	Brown weathering, friable, quartzose fine sandstone with some 1 inch thick pebble beds - sandstone is of marine aspect	c	160
G_1	Ostrea Bed		5

* F.L. ~~(1029)~~ = fossil locality ~~1029~~

G_8 Sandstone

The G_8 Sandstone is composed of beds from a few inches to a few feet thick of: gravel; quartzose sandstone; grey pumiceous sandstone; brown and green ~~coloured~~ clays; and thin lignite seams. It is well exposed in Tainui Stream, (where it is 190 ft thick), and in a right branch tributary of the stream

A typical section in Tainui Stream (grid ref. 166185) contains:-

	Feet
Light-grey very fine sandstone	2.0
Light-grey and chocolate-coloured clay	0.5
Light-grey clay and sandstone	0.5
Coarse sand with interbedded thin very-fine-grained sandstone and pebble beds	5.0
Gravel	2.0
Medium sandstone	1.0
Coarse sandstone and granules	2.0
Chocolate-coloured fine and coarse sandstone	2.5
Gravel	1.0
Fine sandstone	1.0
Light grey, ~~coloured~~ pumiceous, very-fine sandstone	0.5
Fine-sandstone and ½ inch-thick-pebble beds	3.0

G_9 Breccia

The G_9 Breccia occurs about 220 ft above the base of the Mangahao Formation; it is quite distinct from the uniform well rounded cobbles which occur above and below. The breccia is composed of angular fragments of greywacke ½-1 inch long in a matrix of very fine sand. At Wahaoteika Stream a nine-inch-thick bed of blue-grey siltstone occurs within the breccia. Near the Wellington Fault in Patupaiarehe Stream (grid ref. 137024), the breccia contains 6-inch-long angular greywacke fragments.

The G_9 breccia is seventy ~~ft~~ feet thick in Wahaoteika Stream; it is twenty ~~ft~~ feet thick at Otangue Stream, and eight ~~ft~~ feet thick in Patupaiarehe Stream.

Thickness

With the exception of the terrace gravels, the formation is the youngest within the mapped area. It is thought that the gravels were deposited as the Tararua Mountains rose ~~to the west~~. Later, there was a change from a period ~~dominant~~ dominated by the deposition of sediments to one of erosion of the previously deposited sediments. This has been called a "phase change" by Vella (1963c). This change probably occurred at about the time that the Puketoi Surface, now at about 2,000 ft was formed. Gravels deposited beneath the Puketoi Surface are likely to have been ~~of~~ similar ~~character~~ to those of the G_7 Conglomerate, and would presumably have been attributed to them. It may be that about 1,000-1,500 ft of the top of the formation ha~~ve~~s since been removed by ~~subsequent~~ erosion.

The formation is much faulted: and thicknesses are ~~variable within separate~~ different in each fault blocks. At its maximum development, at Tainui Stream, it is at least 1,000 ft thick. It is at least 850 ft thick in Otangue Stream.

Pollen Analysis by D.J. McIntyre

Pollens from a section at Wahaoteika Stream

Lab. number	Fossil locality No.	Stratagraphic position
L. 2856	1097	G_9 Conglomerate
L. 2957	1098	
L. 2372	1030	G_7 Breccia
L. 2855	1096	G_9 Conglomerate
L. 2854	1095	
L. 2342	1029	

Fossil locality 1029: The dominant pollen type is *Nothofagus fusca* group (probably *N. truncata*). *Compositae*, *Dacrydium bidwillii* type, and *Cyathea smithii dealbata* are abundant, and *Phyllocladus*, *Dicksonia squarrosa*, and *Nothofagus menziesii* are common. Other types present include *Podocarpus* sp., *Dacrydium cuppressinum*, *Myrtus*, *Epacridaceae*, *Plagianthus*, *Hoheria*, *Ascarina*, and *Coprosma*. *Gramineae* are rare. ~~Both~~ *Nothofagus mataurensis* and *N. cranwellae*, of the *brassi* group are present in small numbers.

Vegetation is typical *Nothofagus* (Beech) forest but with apparently a little more variation than in the other samples from this section.

The climate was probably a little cooler than the present, and more comparable with that of fossil localities 1098 and 1030 than with fossil localities 1097 and 1096. The beeches, *Nothofagus mataurensis* and *N. cranwellae*, are probably remnants of a richer vegetation and in such small numbers, and associated with cooler elements, do not indicate a climate any warmer than that indicated by the bulk of the pollen flora in this sample.

Fossil locality 1095: Practically no flora. A little *Nothofagus fusca* group, *Podocarpus*, smaller trees, *Gramineae* and tree ferns. *Triorites harrisii* also present. It is difficult to draw any definite climatic inferences but possibly similar to present day.

Fossil locality 1096: Dominant pollen type is *Nothofagus fusca* group (probably *N. fusca*). Rare *Podocarpaceae*, *Nothofagus menziesii*, *Compositae*, *Gramineae*, and ferns. *Cyperaceae* abundant. Rare grains of an extinct species, *Microcachryidites parvus*.

As in sample 1097 the vegetation consisted of beech forest close to point of deposition. More *Cyperaceae* growing at site of deposition. Climate same as in 1097 and similar to present

Fossil locality 1030: A pollen flora basically similar to that of 1098 but is considerably richer in total number of grains and species. Co-dominant pollen types are *Nothofagus fusca* group (probably *N. truncata*) and *Compositae* (?*Olearia* and *Senecio*). *Cyperaceae* very abundant, ferns and *Phyllocladus* abundant. *Chrysobactron* and *Gramineae* common. No extinct species seen and very few *Podocarpaceae* other than *Phyllocladus* present. A little *Nothofagus menziesii* present. Other types include *Cruciferae*, *Umbelliferae*, *Hoheria*, *Hebe*, *Euphrasia*, *Ranunculaceae*, *Coprosma*. No *Cyathea*.

Climate and vegetation apparently rather similar to that inferred for 1098, but richer pollen flora in 1030 probably indicates better preservation conditions and perhaps a richer vegetation closwer to the point of deposition.

Fossil locality 1098: This sample contains a pollen flora which contains few species. The dominant pollen type is of Nothofagus fusca group (probably N. fusca). Pollen of Compositae is abundant and that of Gramineae and Chrysobactron hookeri, Cyperaceae and Coprosma common. Rare Phyllocladus sp. Dacrydium bidwillii type and Nothofagus menziesii are present. No other Podocarpaceae or any extinct species were seen. Very few other pollen types seen. No Cyathea.

The pollen assemblage indicates that the climate was cooler than that of the present day and possibly even slightly drier.

Vegetation probably mainly beech forest with areas of Compositae scrub (?Olearia, Senecio, Cassinia) and associated grasses. Chrysobactron and Cyperaceae probably occurred in damp area where sediment deposited. Coprosma associated with beech. Compositae scrub probably closer to point of deposition than beech forest.

Fossil locality 1097: The dominant pollen type, apart from Cyathea, is Nothofagus fusca group (?N. truncata). Spores of Cyathea smithii and C. dealbata are extremely abundant. A few monolete fern spores present but very little else. Some Lygodium articulatum. Rare Podocarpaceae, Nothofagus menziesii and Compositae. No extinct species.

Climate possibly slightly cooler than present or similar. Rather similar to samples 1098 and 1030 but perhaps slightly warmer, possibly because of lower altitude. Vegetation consisted of beech forest with abundant Cyathea, probably near margins, and some ferns, shrubs and herbs. Probably deposited only a short distance from point of origin, judging by absence of local elements such as Gramineae and Cyperaceae.

Af6 of the samples from Wahaoteika Stream is almost certainly pre Hawera and post Waitotaran.

In summary: the pollen floras all indicate typical beech forest without much flora diversity, which, such as it is, is of associations nearby, but not part of the forest. These variations probably depend largely on aspect, but possibly also on slight climate variations (rainfall, wind??). Slight fluctuations of climate occurred during deposition of this group. The climate was at first cool, warming slightly to be similar to present day, then cooling again to a similar temperature which occurred at start of period represented. Vegetation probably of climax type, beech forest, of a montane or lower montane type, with little Podocarpaceae, and the forest may even have been at or close to the upper altitudinal limit of forest.?? Present altitude of the area is of order of 1,000-1,200 ft, and the vegetation of the cooler phases may have been a type representing up to 2000 ft higher today. Would only need average of 1-2 degrees difference to achieve this.

G_7 Conglomerate	(1097	Climate as present or slightly cooler	Warming ↓
	(1098	Climate slightly cooler than present	
G_9 Breccia	1030	Climate warmer than 1098.	Cooling
	(1096	Climate as present or slightly warmer	
G_7 Conglomerate	(1095	Climate similar to present day	Warming
	(1029	Climate cooler than present	

Conditions of Deposition

The cobbles and pebbles of the G_7 Conglomerate were transported by streams flowing eastwards out of the Tararua Range to be deposited in the fault angle bounded in the west by the Wellington Fault.

The G_8 Sandstone was deposited in a low lying area where stream gradients were low. At times the area supported trees. Later when only massive conglomerates were deposited gradients and stream velocities may have been higher, perhaps due to the rapid elevation of the Tararua Mountains.

Volcanic explosions in the Rotorua-Taupo area caused pumiceous ash beds to be deposited, they were preserved locally, especially in the G_8 Sandstone.

It is probable that the distinctive G_9 Breccia owes its origin to climatic fluctuations. Perhaps after an extensive period of frost shattering, at the time of a glaciation the slopes of the Tararua Mountains were mantled with a thick cover of angular detritus. With a return to warmer, wetter climate the angular fragments were spread eastwards beyond the Wellington Fault as a sheet-like bed of breccia.

Age and Correlation

The formation overlies the Lower and Mid-Nukumaruan Totaranui Formation with apparent conformity, It is tilted to the same extent as the Totaranui Formation and the Marima Sandstone. The Hawera Terraces are still horizontal which indicates that there was a fairly long period not represented by strata during which the tilting

TIRITEA FORMATION

Name and Subdivision

The formation was named by Rich (1959) after Tiritea Stream near Palmerston North. Previously the formation had been mapped as the Otaki Sandstone by Oliver (1949).

The formation is not subdivided.

Distribution and Stratigraphic Relations

The distribution of the Tiritea Formation is restricted to a small area in the extreme north-western corner of the mapped area; south-east of Tokomaru.

At the surface the contact of the Tiritea Formation and the Tararua Formation is dominated by a series of straight lines trending due north and north east which are thought to be faults (see Figure 5.). It is not clear if these presumed faults have been active since the deposition of the Tiritea Formation or not, but there is no evidence of very recent movement. ~~Subsurface~~ Oliver (1948 p.5) considered that the base of the Otaki Sandstone was delineated by a gravel aquifer. Loess and the Aokautere Ash (see Cowie 1964) overlie the Tiritea Formation, and deposition is considered to have largely ceased at a time when the land was lifted above base-level, and stream dissection initiated.

North of the mapped area Rich (1959) considered that the Tiritea Formation overlies the Castlecliffian Stage.

Firth and Feldmeyer (1943) considered "the Otaki beds along the west front of the Tararua Ranges to be post-faulting in age". Rich

(1959, p.128) however, found that the ~~small~~ Track and Bryant Hill faults, some eight and ten miles north east of Tokomaru, displace the Tiritea Formation (Otaki Beds), indicating some faulting since the deposition. ~~of the formation~~.

Content

In the mapped area, the formation is horizontal; it is dissected by rivers and streams giving a relief of some 50-100 ft. Exposures are limited to a dozed track at grid ref. 015189 (see Figure 38) and ~~in~~ to a few small streams.

A section at the dozed track contains:-

	Feet
Soil and Fossil Soils with some light-grey ash horizons, including the Aokautere Ash.	20
Blue-grey sandstone	5
Gravel sandy at base	15
Obscured	30
Light blue-grey sandy-siltstone	5
Gravel with sandy lenses	10
Light blue-grey carbonaceous silty-clay	4
Obscured	10
Sub-rounded gravel	20
Sandstone, part cross-bedded	10

Thickness

Oliver (1948, p.5) recorded the well log of the bore ~~constructed~~ drilled by Parkinson and Rasmusson at Tokomaru.

Feet	Log.	Interpretation
100	big boulders (Tokomaru recent alluvium)	
337	Quicksand	Otaki Formation
57	"Papa"	
17	Sand	
37	"Papa"	
9	Gravel	basal fan gravels

The section at grid ref. 015189 occurs topographically and presumably stratigraphically above the sequence penetrated by the Parkinson-Rasmusson bore; it is probable that the Tiritea Formation is at least 650 ft thick at Tokomaru.

Age and Correlation

Outside the mapped area near Tiritea Creek, Rich (1959) found that two "Conglomerate"* beds could be traced for about two miles along the strike, and for about half a mile down the dip. Further north near Palmerston North at Anzac Park, Rich considered that a further two bands of "conglomerate" similar to those at Tiritea Creek occurred about one hundred feet higher up in the sequence. A simplified composite section based on the rocks described by Rich (1959) at Tiritea Creek and at Anzac Park consists in downward sequence of:

	Feet
Yellow-grey silt, including Aokautere Ash 5 ft below top and ferruginous nodules 12 ft below top	20
Sands and silts with scattered pebbles	75

---

* "Conglomerate" imples a induration which is absent, Rich's "conglomerates" are gravel beds.

	Feet
Discontinuous band of pumiceous blue-grey silty sand	0–1
Sandy "conglomerate"	15–20
Loose sand, locally ripple-marked and cross-bedded	12–15
"conglomerate"	12
Sand yellow brown massive, lensing	0–2
Carbonaceous silt, blue grey in part laminated	10
Obscured	100
"conglomerate"	8–20
Sand and silt	12–15
"conglomerate"	8–20

The section in the mapped area (grid ref. 015189) shows good correlation with the sequence exposed at Anzac Park, but as the mapped area is south west of Tiritea Creek a correlation with the lower part of the composite section is perhaps more probable.

Rich (1959) considered the Tiritea Formation (Otaki Formation) was deposited contemporaneously with the Halcombe Conglomerate, the Mangaone Sandstone and the upper portion of the Waituna Conglomerate of the Manawatu.

The seaward margin of the formation, located a short distance west of the mapped area, was considered by Te Punga (1962) to have been cliffed during the thermal maximum of the Holocene, some 8000 years ago. ~~The formation is at least 8,000 years old.~~ Further Confirmation of a pre-Holocene time of deposition is from radiocarbon age determinations by Fergusson and Rafter (1957). They

Figure 38: View North-northeastwards from grid ref. 015189.

Right foreground: Tiritea Formation exposed in track.

Left foreground and centre: Alluvium and Tokomaru River.

found that fossil wood from 120 ft below the top of the formation at Anzac Park indicated that the formation there is more than 37,000 years old.

Fleming (1953) has shown that some six formations and alluviums comprising the Pouakai Group were deposited during Post-Castlecliffian - pre-Holocene time, (the Hawera age) at Wanganui.

These are listed below:-

Youngest		Papaiti Alluvium
		St. Johns Alluvium
		Undifferentiated Alluvium
	Pouakai Group	Rapanui Formation
		Brunswick Formation
Oldest		Kaiatea Formation

The degree of stream dissection of the formation and ~~also~~ the 20 ft thick fossil soil and ash beds cover, indicates that ~~the formation~~ it is probably older than the Rapanui Formation. It is correlated tentatively with the Brunswick Formation.

Conditions of Deposition

Rich (1959) noted, that down-dip from Anzac Park, the upper "conglomerate" bed breaks up into gravel bands separated by beds of sand and silt which contain the only macrofossils found in the Tiritea formation. Such a down-dip facies change ~~offers an explanation~~ explains why sandstone is found in the deep bore holes situated some distance west of the front of the Tararua Range while outcrops of sand and gravel are found near, and at, the range margin.

Rich found that 11 out of the 12 microfaunal samples processed contained foraminifera, indicating marine conditions of deposition for much of the formation. Oliver (1948) and Rich (1959) also found that parts of the formation had a aeolian mode of origin; perhaps ~~as~~ dunes.

Rich found no evidence of cliffing during Tiritea time, which led him to consider that the strand-line was generally some distance west of the front of the Range. It is thought, ~~however~~, that cliff features are buried beneath. ~~the deposits.~~ Most of the sand and gravel of the formation is considered to have been transported into the area of deposition by the proto-Manawatu River.

TERRACE GRAVELS EAST OF THE TARARUA MOUNTAINS

Terrace Gravels are subdivided into two groups, high-level and low-level; the high-level terrace deposit is very small and is not shown on the map.

HIGH LEVEL TERRACE DEPOSIT

Boulders of well rounded greywacke, 1-2 ft long, crop out south of Mangaroa Stream (at grid ref. 084012) at an elevation of about 1400 ft. The gravel is thought to be a tiny remnant of a high terrace deposit, perhaps the Hinemoa Terrace, rather than an outcrop of the T_2 Conglomerate of the Marima Sandstone.

LOW LEVEL TERRACE GRAVELS

The low level terrace gravels are largely subdivided on physiography, and the following subdivisions are mapped (in order of increasing age) (see p. 12)

Alluvium

Hukanui Gravels

Pukewhai Gravels

Eketahuna Gravels

Flat Top Gravels

Two miles northwest of Eketahuna a terrace at a higher elevation than the surrounding country is here named Flat Top, and is designated the type area of the Flat Top Formation (see Figure 2).

The Eketahuna and Hukanui Gravels are named after the Eketahuna township and the Hukanui Settlement and these localities are made the type areas.

Distribution

The Gravels are best developed in the west central part of the mapped area, at the margins of the Makakahi, Mangatainoka and Mangahao rivers.

The Flat Top Gravel is largely restricted to an area between the Makakahi River and the Wellington Fault. It is best developed on the north sides of the Eketahuna and Hukanui Misfit Valleys. It also occurs west of the Mangahao River at Marima.

Between Eketahuna and Hukanui the Eketahuna Gravel is well developed on both sides of the Makakahi River. West of the river it occurs on both sides of the Eketahuna and Hukanui Misfit Valleys. South of the Eketahuna Misfit Valley as far south as Kaiparoro, the gravels occur as caps on some of the higher hills. The Eketahuna gravels are fairly well-developed adjacent to the Mangahao River, especially near Marima. East of the Makakahi River isolated remnants of the gravel have been mapped in areas adjacent to rivers and creeks.

The Hukanui Gravels have been mapped along part of the margins of all the rivers and along some of the larger creeks. They are particularly well developed at the margin of the Mangatainoka River, downstream of Priest's Road, and at the margin of the Makakahi River downstream of Hukanui.

Content

The gravels are composed of rounded cobbles and pebbles of well indurated greywacke. Exceptions are rare; but angular fragments of Mezozoic basalt, indicating a local source, occur in the Eketahuna Gravel near Kaiparoro. Although the gravels are sandy, beds of sand are only rarely developed. The gravels are similar to each other in any one area, largely because they were formed ~~under similar climatic conditions,~~ during periods of aggradation. The maximum size of the cobbles and pebbles found ~~within them~~ is usually smaller than those found in the nearby river beds.

Rivers draining the eastern part of the mapped area have little of their catchments on greywacke terrain. Terrace deposits adjacent to these rivers contain very fine gravel, and the pebbles are rarely more than an inch long.

In the west, the gravels ~~are~~, permeable and porous, ~~and~~ are relatively good aquifers. Commonly an iron-pan is developed at base of the gravel where it overlies relatively impermeable Tertiary sediments.

The gravels in the Mangahao and the Makakahi rivers valleys are usually 10-25 ft thick. Their relatively uniform thickness ~~of the gravels~~ indicates that prior to their deposition ~~of gravel~~ the rivers had excavated broad valleys and were in a temporary stage of maturity.

At Kakariki, the Hukanui Gravel is 70 ft thick. This great thickness is due to the following events:— After the deposition of the Eketahuna Gravel the Mangahao River flowed eastwards through the Hukanui misfit valley to incise its channel, down to elevation 650 ft(which is only some 40 ft above the elevation of the river bed at the present time). This channel was backfilled with cobbles and boulders to about elevation 720 ft during the periods when the Pukewhai and Hukanui surfaces were formed.

South-east of Mangamaire (grid ref. 223138) a well at indicates that the gravels beneath the Hukanui Surface are at least 30 ft thick. At the eastern margin of this lowlying area, Tertiary strata are exposed along the Makakahi River, indicating that here the gravels are not so thick.

Distinctive red soils, such as described by Grant-Taylor (1959) do not overlie any of the gravel formations. The depth of loess overlying the gravel and the degree of weathering of the gravels offer subjective and not too discriminating criteria for correlation of terrace deposits. The Ngaturi Ash, found at only two localities, would have been useful for terrace correlation if it had been a more wide spread. ~~distribution~~.

A Volcanic Ash Bed at Ngaturi

Quaternary ash beds found in the mapped area are restricted to two isolated localities at Ngaturi, and to near Mangamaire.

Near Ngaturi (grid ref. 391203), a pumiceous ash-soil sequence is revealed by a 50 yard long cut along the Pahiatua-Akitio via Pongaroa Main Highway, where it cuts an alluvial fan. The fan is considered to have been formed at the time when the Pukewhai Gravel was deposited.

The four-inch-thick ash bed directly overlies a planed surface of Waitotaran Upper Makuri Siltstone (see Table 23). It is probable that the soils, presumably previously present above the Makuri Siltstone were removed either by solifluction at a time prior to the ash fall; or alternatively the soil was removed by high winds and

Table 23

Late Quaternary ashes at Aokautere, Ngaturi and Mangaroa

	Aokautere (see Cowie 1964)	Inches	Ngaturi near Pahiatua	Inches	Mangaroa (see Te Punga 1963)	Inches
LOESS + SOIL	Dark brown friable silt loam	7				
	Pale brownish-grey silt loam, many small reddish concretions	3				
	Grey compact clay loam, many yellowish-brown mottles	15	Clay soil variable	36		
	Grey compact clay loam, many fine yellowish-brown mottles and many grey vertical veins	18	Iron stained horizon	2		
			Clayey soil	24		
			Tuffaceous sand	6	Topsoil	6
	Grey fine sandy loam, few vertical grey veins	29	Brownish non marine silt	18	"Subsoil"	24
AOKAUTERE ASH	White fine pumiceous sand, diffuse, lower boundary	2.5	(Coarse ash	3		
	Pale grey medium pumiceous sand, sharp lower boundary	2	(White band	0.75	Mangaroa Ash	9
	White pumiceous silt, sharp undulating boundary	0.5				
LOESS AND SOLIFUCTION DEPOSIT					Slightly wavy, highly siliceous, hard grey layer (Loess)	4
					Yellow-brown silty clay (Loess)	9
	Grey fine sandy loam (Loess)	72			Yellow-brown clay with small greywacke pebbles and streaks and pockets of reddish clay (Solifluction Deposit)	12
					Unconformity, 20°	
FOSSIL SOIL	Grey plastic clay, many brownish mottles, many black concretions	48			Greywacke gravel	
	Yellowish-brown slightly greasy silty clay loam	75				
ROCK	Otaki Sandstone Banded sands at least	24	Upper Makuri Siltstone			

deposited elsewhere as Loess. The 18-inch-thick brownish non-marine silt which overlies the ash bed has the appearance of being reworked Upper Makuri Siltstone and was presumably derived from higher up the alluvial fan.

An ash bed presumed to be the Aokautere-Ngaturi Ash overlies the Pukewhai Gravel near Mangamaire (grid ref 219132) (pers com. Dr W.H. Mathews).

The surfaces overlying the terrace gravels were formed at the culmination of the aggradation phases and have been correlated with late-Quaternary surfaces at Dannevirke and Southern Wairarapa (see Table 1). The ash at Ngaturi can be correlated with a late Quaternary in the Manawatu and at Mangaroa Wellington. In the mapped area the ash has not been found on the Hukanui Surface, which was presumably formed after the ash-fall.

Cowie (1964), has shown that the 4-10 inch thick rhyolitic Aokautere Ash (see table 23), occurs over much of the Manawatu, on all terraces older than the aggradational Ohakea Terrace, and is overlain by loess. The ash overlies solifluction deposits in the Northern Tararua Mountains. A period of formation during a later stage of the last Glacial epoch is indicated. Cowie showed by isopachys that the ash was derived from the Rotorua-Taupo area, rather than from Mt Egmont. Te Punga (1963) described an Ash-Loess sequence near Wellington at Mangaroa (see Table 23). The ash is similar in composition to the Aokutere ash; but is much thicker (9 inches) than the ashes at

Aokautere and Ngaturi. Te Punga considered that the 12-inch-thick yellow-brown clay found below the ash ~~was~~ is probably a soliflucted deposit, and that the overlying material ~~was~~ is loess. Thus the stratigraphic positions of the three ashes at Mangaroa and Aokautere and Ngaturi are identical. It is possible that the greater ash thickness at Mangaroa may be due to some admixture of washed material ~~rather than being all ash fall material~~.

CHAPTER IV

STRUCTURE

Introduction

The structure of the mapped area is dominated by many parallel north-northeast trending active faults, several of which have large late Quaternary dextral components. The others by inference are considered to be basically dextral. Active faults are more common in the south than in the north. An exception is the Wellington Fault which is active along its entire trace in the mapped area (see Lensen 1958). Between the major north-northeast trending faults the Upper Tertiary-Pleistocene strata are tilted to the northwest at 10 to 30 degrees. Upper Tertiary strata are further dislocated by cross faults. Within the fault blocks, folds vary in trend from parallel to about 20 degrees with the major faults; synclines are more common than anticlines but neither extends for more than a few miles. Where the major north-northeast trending faults are closely spaced, the strata between them sometimes dip steeply southeastwards. If these narrow steeply dipping southeastward strata are considered to be faults replacing fold limbs, then the macrostructure is one of assymetrical faulted folds.

The structure of the mapped area is illustrated by a structural contour map, and seven cross sections. The structural contours are drawn at three separate horizons but the horizons usually do not overlap.

North of the Sheet District, at Dannevirke, the structure mapped by Lillie (1953) and Kingma (1962) is broadly similar to that of the mapped area. South-southwest the major faults are thought to coalesce into the wider-spaced north-east-trending Marlborough faults of Suggate (1963). Further southeastwards the Marlborough faults coalesce with the dextral Alpine Fault, perhaps the most important fault in New Zealand. The Alpine Fault, the Marlborough faults and the mapped area all lie within the 200 mile wide active belt of New Zealand which Wellman (1955) called the transcurrent fault zone of New Zealand (see Figure 39). The fault zone is part of the Circum-Pacific mobile Belt. Wellman found that volcanoes and normal faults lie outside the transcurrent fault zone. But Adamson (1966) however, discovered a small basaltic diatreme, which is not older than middle Quaternary, on the east bank of the Glenroy River, (near the Alpine Fault), in south Nelson. well inside the transcurrent zone.

The structure of the mapped area, and much of the east coast of the North Island, resembles part of the wrench fault system of California. The degree of resemblance is closest in areas where the large north-west trending faults are most closely spaced, such as the San Andreas Fault Zone from Soledad Pass to Cajon Pass California mapped by Noble (in Jahns 1954). Part of Noble's map contains cross faults forming a herringbone pattern generally pointing northwest; herringbone fault paterns usually pointing southwest occur in several parts of the mapped area, but especially on both sides of the Rongo Kokako Fault in the Eketahuna area.

Marlborough Faults

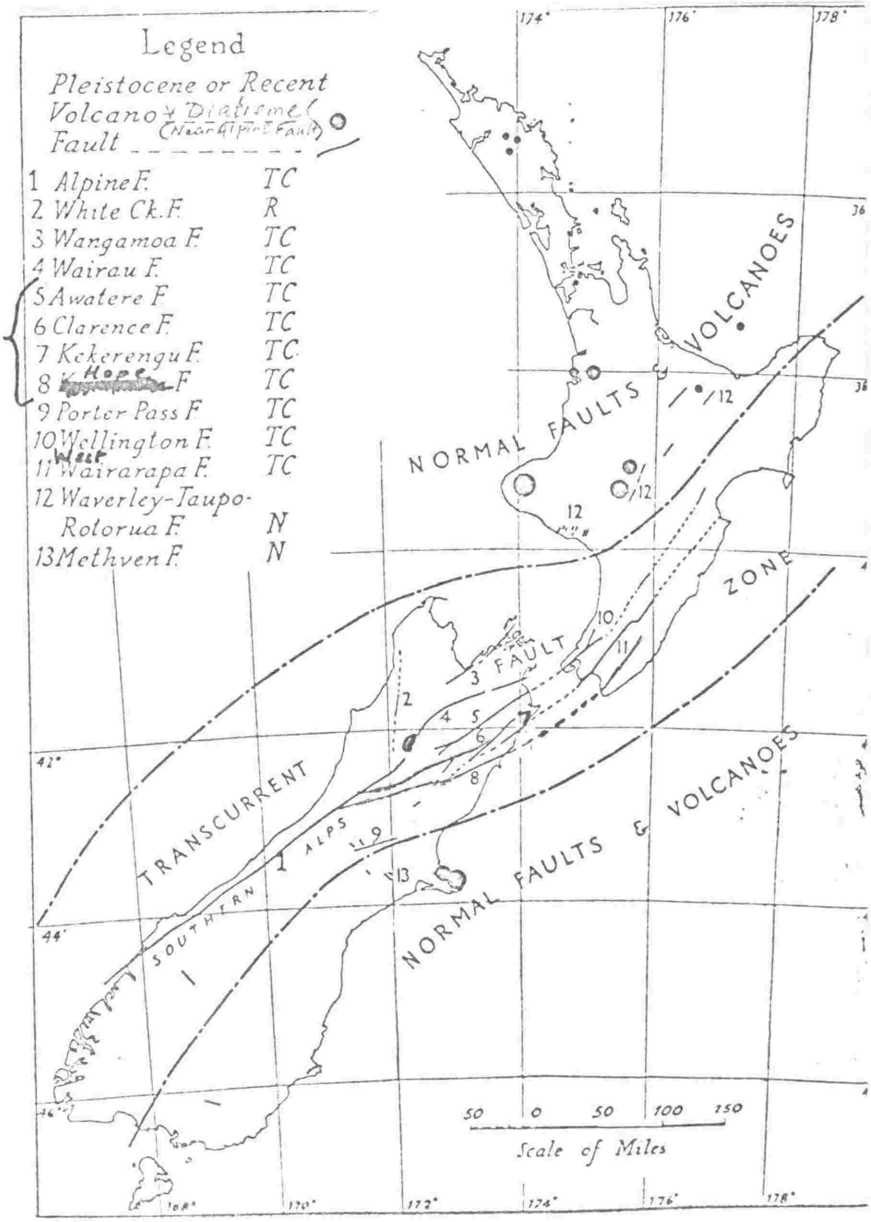


Fig. 39 Map showing active faults and volcanoes active since Pleistocene and relation to the circum-Pacific mobile belt of essentially transcurrent faulting and strong folding.

After Wellman (1955), Suggate (1963) and Adamson (1965).

Earthquakes

Recent destructive earthquakes which had epicentres in or near the mapped area, occurred on August 1st 1942, June 24th 1942, March 5th 1934 and August 5th 1917. Analysis of seismograph data by Bullen (1938) and Hayes (1943) showed that the March 5th, 1934 and August 1st 1942 earthquakes had epicentres within the Sheet District. The epicentre of the August 1st 1942 earthquake is thought to have been along the McKay Fault (see activity on late Quaternary faults), but it is not known which fault was active during the March 5th 1934 earthquake. Ongley (1943b) found that the June 24th 1942 earthquake had an epicentre 27 miles south of the mapped area near Masterton at Taweru. Bullen (1940) found that the epicentre of the August 5th 1917 earthquake was a short distance southeast of the mapped area.

During the earthquakes chimneys in the district were brought down and some brick buildings were destroyed. That no loss of life occurred during the earthquakes was somewhat fortuitous and also due to the wooden construction of most of the settlers houses. Such houses can withstand an earthquake better than brick houses.

Structure - Historical

There have been three phases of the study of the structure of the mapped area and nearby areas. In the first phase, McKay (1877 and 1892b) and Ongley (1935) considered folds to have major importance. In the second phase, Ongley (1943a), Firth and Feldmeyer (1943) and Lillie (1953) mapped many north-northeast trending faults.

In the third phase the dextral nature of the major faults was recognised by Lensen (1957) Orbell (1962) Heine (1963) and Vella (1962b, 1963c).

A geological cross section of the Upper Tertiary strata near Kaiparoro by Hector, illustrating a report by McKay (1877), indicates that Hector thought that the Upper Tertiary strata to be gently folded. McKay's geologic sketch map shows no faults. A cross section at Konini, Mangamaire and Marima by McKay (1892) shows no faults but several anticlines and synclines. Ongley (1935) considered that there was a broad north-northeast trending syncline at Pahiatua, and to the west, the Tararua Mountains were anticlinal. ~~in origin~~. Ongley was aware that the structure near Mt Bruce and in the Upper Ruamahunga River was complex and that fault-angle-depressions containing tilted upper Tertiary strata are common there. Ongley noted that the Eketahuna District differed from most parts of the country in that ~~younger strata~~ the strata became ~~occurred~~ progressively younger ~~westwards~~ from the coast.

Ongley (1943a) attributed fault scarps along the Alfredton, Makuri, Martin, and Mt Buttlers Road faults to the 1855 earthquake. Firth and Feldmeyer (1943) ~~established~~ found several more major north-north east trending faults than had been found by Ongley (1935). They observed that drag folds are often developed adjacent tothe major north-northeast trending faults. They also noted and photographed the angular unconformity between the Tane Sandstone and the overlying P. canaliculata zone near Marima at grid ref. 167133 (see Figure 25).

Lillie (1953) mapped a large number of faults at Dannevirke but considered folds, to be more important than faults. Lillie (1953, p.21) considered that the principle structural elements of the Dannevirke area are from west to east:

"The Ruahine Anticline;

The Dannevirke Composite Syncline;

The Oruawharo-Waewaepa Fault-belt, a faulted anticlinal complex;

The Waipatiki Syncline and the Mangatuna Fault line;

The Whangai-Tangatupara Anticline;

The Akitio Syncline; and

The Porangahau-Porerere Anticlinal Complex"

The four most westerly of these structures are continued south-westwards into the mapped area.

Lillie mapped a north-east trending fault through the town of Woodville, it is considered that this fault is the northward extension of the Huru-Paiwai fault complex.

Lensen (1958), listed the late Quaternary displacements along the important dextral Wellington Fault which trends north-eastwards across the mapped area from Ruapai Stream to a point two miles west of Marima.

South of the central part of the mapped area in the Mauriceville District, Orbell (1962), mapped the major north-northeast trending Alfredton and Mauriceville faults. Vella (1962b) found that the faults converge near Carterton at Carrington. The Mauriceville Fault extends northwards for only a mile in the mapped area; it is then transected by the Hastwells Fault. East of the Mauriceville Fault, Orbell mapped the Mangamahoe Syncline as far south as the Dreyers Fault which transects it. It then extends northwards in the mapped area to be cut off by the Hastwells Fault.

East of the intersection of the Mangamahoe Syncline and the Dryers Fault, Orbell mapped a north-east trending fault, herein named the Martin Fault, that extends north-eastwards to be transected by the Alfredton Fault, 1¾ miles north east of Alfredton. Orbell thought that there were two north-eastward trending faults in the north-western part of his mapped area. These probable faults are considered to be the south-west extensions of the Smiths Line and Hastwells faults.

South of the mapped area near Mt Bruce, Vella (1963c), mapped four north-east trending faults. An unmapped mile-wide belt of country occurs between the mapped area and the area mapped by Vella. The faults can probably be correlated as follows:-

Vella 1963c	This Bulletin
Waitiro	Kaiparoro - Falkner Road
Bruce	Pleckville
Te Mara	Hastwells

Vella (1962b) considered that the major faults within the mapped area are ~~the~~ Wellington, Te Mara, Mauriceville and Alfredton faults.

Heine (1961), thought that the West Wairarapa (Alfredton) Fault was the most important fault in the southern part of the North Island. He attempted to relate the theoretical considerations put forward by Moody Hill (1956), to tectonic features found in the South Wellington Province.

Heine (1964) made a reconnaissance gravity-meter survey of central-northern-Wairarapa; his residual gravity anomaly map contained two north-northeast ~~- south-southwest~~ striking elongated lows which have centres at Masterton and Pahiatua. He suggested that the two lows, ~~had~~ once been adjacent to one another, ~~but~~ had ~~have since~~ been shifted apart about 40 miles, along the line of the West Wairarapa (Alfredton) Fault. Neither Heine's Regional Bouger Anomaly map nor his Residual Gravity Anomaly map indicate the disposition of the major north-northeast trending faults (which often have apparent vertical throws of many thousands of feet), or follow the pattern of the Structural Contour Map. The apparent thick sequence of beds at Pahiatua suggested by the low on Heine's Residual Gravity Anomaly Map may well be correct, but the thickness of Tertiary strata there, is unlikely to be much greater than that on the downthrow side of the Alfredton Fault near Alfredton which on Heine's Residual Gravity Anomaly Map is a high.

In N.Z.M.S. N.154 (Pongaroa) O'Byrne (1963) mapped the north-east trending Mangatiti Fault from near Raukauni (grid ref. 530056) to near Pongaroa; and this fault is thought to be the north-eastward extension of the Saunders Road Fault.

The 1:250,000 Sheet (Dannevirke) Geological map compiled by Kingma (1962) shows that the Rongomai Fault is continuous north of N.Z.M.S.N.153. It trends north-northeast one mile east of

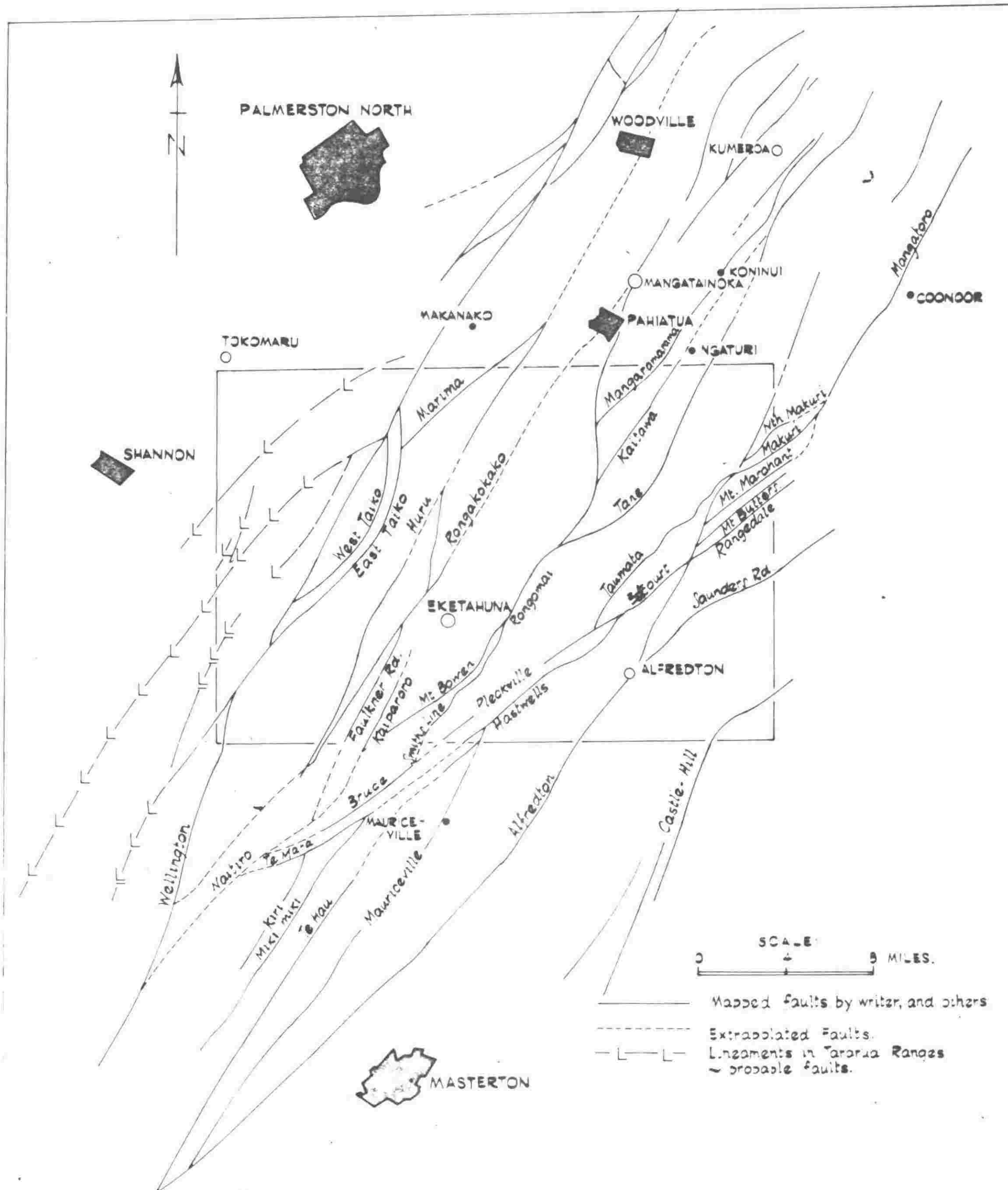


FIG.40 Map showing major faults of the mapped and nearby areas, partly after Ongley (1935), Lillie (1953), Vella (1963c), and Kingma (1962) and (1966)

Pahiatua to the Mangatainoka River, three quarters of a mile downstream of its confluence with the Makuri River.

Vella (1962b) found that the West Wairarapa Fault bifurcates at Carrington into the Alfredton and Mauriceville faults (see Figure 40). The Alfredton Fault branches into a number of faults in the Mt Marchant and Makuri area, that are a southern extension of the important Mangatoro Fault. The fault which Kingma (1962) considered to be the Wairarapa Fault, is the northern extension of the Kaitawa School-Aupapa Road fault complex. Kingma found that this fault complex is continuous some 40 miles northwards to a point 2 miles west of Takapau.

DETAILS OF STRUCTURE

Major Faults

Most of the major faults of the mapped and nearby areas trend north-northeast, a few trend due north (see Figure 40).

The more important faults of the mapped area include: the Wellington; Huru; Rongokokako; Rongomai, Hastwells; Pleckville; Alfredton; & Saunders Road. The faults have long traces and apparent vertical throws of several thousands of feet, and are considered to be more important than the other north-northeast trending faults. To the south of the mapped area the Mauriceville Fault has been considered important by Vella (1962b) and Orbell (1962) but it extends for only a mile beyond the southern margin of the Sheet District. The major faults sometimes branch into two or three closely spaced faults, for example the Huru-Paiwai-

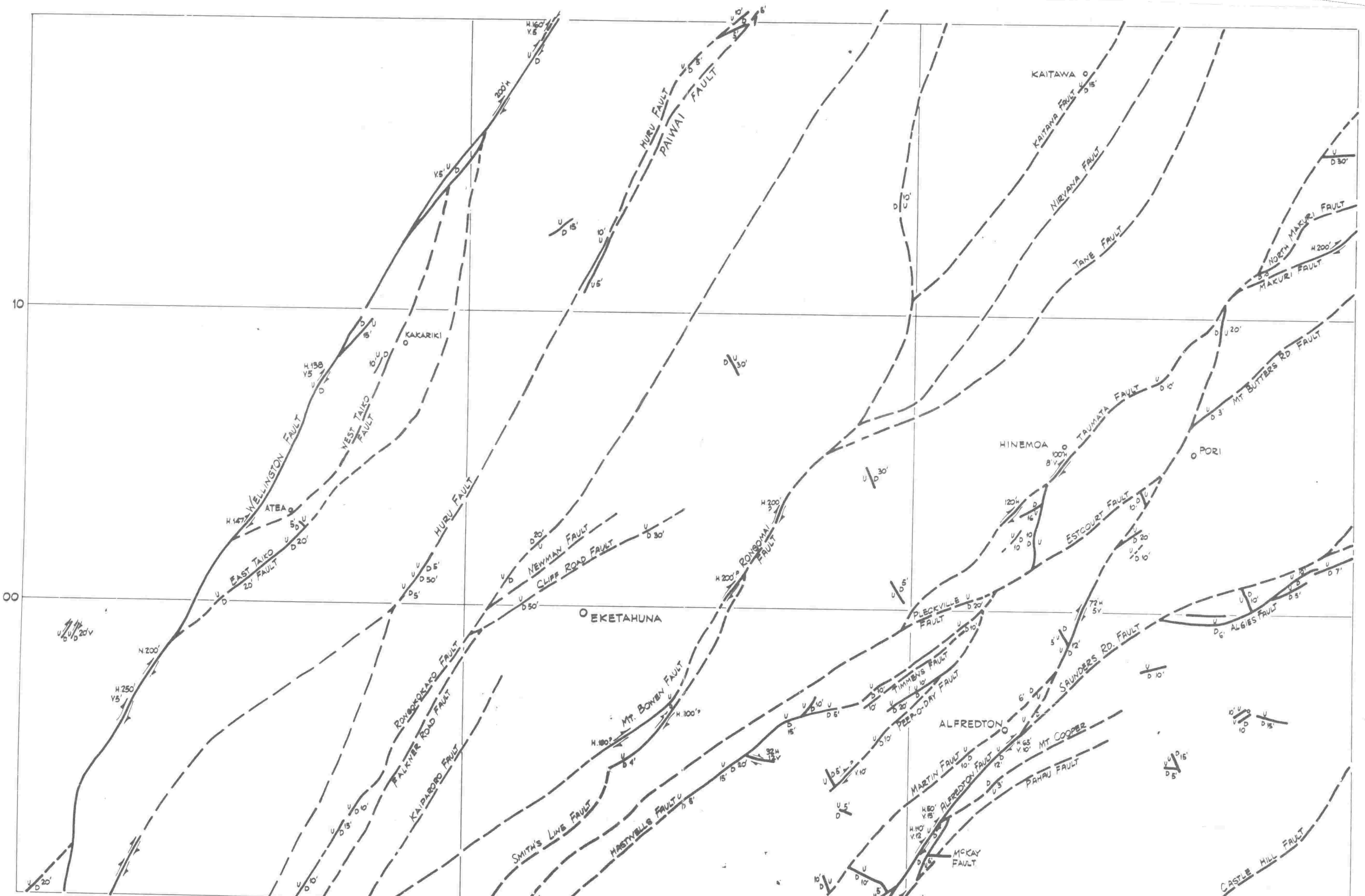
Mangamaira Fault complex near Mangamaire.

Other important major faults, include: the East and West Taiko; the Tane-Nirvana complex; the Taumata; the Estcourt; and the Makuri Fault complex.

The least important north northeast trending faults are the splay faults, they diverge from the major north-northeast trending faults at 10 to 30 degrees. The apparent vertical throw of these faults is greatest near their junctions with the major north-northeast trending faults and decreases away from the junction. Distally the faults are often closed by a "cross" fault.

In the South Wairarapa several workers have found large recent dextral components along the major north-northeast trending faults. The most convincing evidence is the flight of offset late Quaternary terraces which were progressively displaced by the West Wairarapa Fault at the Waiohine River (pers.com. Mr Lensen). Vella (1963c) considered that there has been a 400 ft dextral component along the active Alfredton and Mauriceville faults since the formation of the Waiohine Surface (probably equivalent to the Hukanui Surface of this text). He also thought that there had been a dextral offset of 1,500 ft along the Mauriceville Fault since the formation of the Bruce Surface (probably equivalent to the Hinemoa Surface of this text).

In the mapped area Lensen (1958) showed that there were late Quaternary offsets of about 200ft along the Wellington Fault. The other major north-northeast trending faults are only partly delineated by recent movement (see Figure 41). Previous faulting may be



SCALE:
5 MILES.

FIG. 41 SOLID LINES ACTIVE FAULTS. DASHED LINES, MAJOR NORTH – NORTH EAST TRENDING FAULTS, NOT OBVIOUSLY ACTIVE.

indicated by a lineament along the fault line. Elsewhere the position of the fault plane was inferred from geological mapping. Fault planes of the north-northeast trending faults are rarely exposed. Those which were found are listed below:—

Fault	Locality or grid ref.	Inclination of fault plane
Wellington*	Otangue Stream	78° (north-west)
Cliff Road	153990	vertical
Taumata	379077	vertical
Alfredton	407105	vertical
North Makuri	446139	70° at 140°
Saunders Road	443023	vertical

* Observation by Firth and Feldmeyer (1943 p.26).

The traces of the faults are commonly straight in hilly country, and the fault planes are thought to be generally vertical, or close to vertical. An exception is the Makuri Fault north of the Makuri Gorge which appears to dip northwest at about 70 degrees.

Where Upper Tertiary rocks of the same induration are in fault contact the fault zone is usually only about a quarter of an inch wide; beyond the fault zone there is often little disturbance apart from drag folds and minor faults. An exception occurs near Fernhill Farm at grid ref. 236999, where the R_1 sandstone is strongly deformed in a 40-yard-wide belt east of the Mt Bowen Fault. This locality is close to an abrupt change in strike of the Mt Bowen Fault.

The vertical inclination of most of the fault planes of the major faults, the strike of the Upper Tertiary - Quarternary folds, and the physiographic evidence all indicate that the major North-northeast trending faults are basically wrench. ~~Further~~ Wellman (1966) has considered that "long straight faults have a strong probability of being wrench faults."

Cross faults

Cross faults generally trend northwest between a pair of major north-northeast trending faults. Where the major faults are widely spaced, cross faults developed adjacent to one fault may peter out away from the fault. A few cross faults near Te Hoe Farm do not extend to either of the major faults – Alfredton and Castle Hill – ~~faults~~ which bound the fault block. Cross faults may be either straight or curved. Curved faults are more common where the major north-northeast trending faults are at least 1½ miles apart; the concave sides ~~ones~~ of the curved faults invariably face north-eastwards. The fault planes of cross faults were only found at the two localities, listed below.

cross fault between north northeast trending fault	grid ref.	Inclination of fault plane
Saunders Road and Algie	423008	87^{o}
North Makuri and Makuri	436131	Vertical

The fault planes are thought to be generally close to vertical as the ~~plane~~ trace of faults are ~~not inclined~~ straight in hill country. The width of the fault plane is usually about a quarter of an inch, the same as that of the north-northeast faults. Several of the cross faults have large late Quaternary displacements, indicating, perhaps, that faulting occurred along one fault for some time while other cross faults between a pair of major faults ~~are~~ were relatively inactive. For example (at grid ref 44015) a large late Quaternary displacement of about 30 ft has diverted the upper courses of two small streams making them flow in a direction opposite to which they had previously flowed. The throw on ~~many~~ most of the cross faults is about 100ft. ~~some have smaller throws of between 20 and 100ft, and others have larger throws of about 1,000 ft~~.

Historic and late Quaternary faulting

Details of the late Quaternary displacements on the major north-northeast trending faults are listed in Table 24; less important north-northeast trending splay faults and ~~also~~ the cross faults are listed in Table 25.

Much of the measured displacements of the late Quaternary faults is in hill topography; the period of formation of the topography varies from as young as Holocene near rivers and streams to about the time of the formation of the Pukewhai Surface.

Vertical components of faulting are generally much more obvious than wrench components. The reason for this ~~are~~ is that the physiographic reference lines required to measure wrench offsets are often absent.

The upthrown side of the major faults is usually on the Western side, the same as that indicated by the Upper Tertiary and Quaternary Strata.

Recent dextral faulting is restricted to the Wellington, and parts of the Rongomai, and Makuri faults (about 200ft) and to the Taumata and Alfredton faults (about 100 ft) (see Table 24). The vertical component of the major faults is usually about ~~the~~ a tenth of the horizontal, but the vertical component of the Wellington Fault is only one fortieth of the horizontal.

Only the East ~~and~~ Taiko, West Taiko, Huru, and Rongokokako faults trend across terrace flights. The terrace edges of the Hukanui and Eketahuna misfit valleys are not obviously offset at the faults. The terrace edges are straight and are good evidence to preclude wrench offsets of more than a few tens of feet.

The Huru Fault however trends across the Hukanui Surface within a pre-Hukanui meander re-entrant, but there is no reference plane to measure the wrench component of this active fault. It is conceivable that it could be large, up to several hundreds of feet.

In listing the details of the late Quaternary faulting the writer has for general uniformity adopted the system used by Wellman (1953) and Lensen (1958). The Symbols used for ~~the~~ "Nature" of feature of fault in ~~see~~ column 4 are listed below:-

R	rent
S	fault scarp
T	fault scarplet
OS	offset stream
I	inferred
P	fault pond

An asterisk with the displacement indicates that the displacement is estimated from air photographs.

"C" in Column 10 indicates that the faulting is dextral.

Wellington Fault

Most of the data on the Wellington Fault is from Lensen (1958). Ridges that were formed prior to the Holocene are displaced 130 - 250 ft dextrally. ~~by the fault~~. There is no evidence of larger older dextral displacements. It should be noted, however, that the Mangatainoka River is underfit and during much of the late Quaternary, the river was spreading gravel on the Nireaha, Hamua, Konini plains. It is conceivable that the valley now occupied by the Mangatainoka was excavated by the Mangahao at a time when it flowed out of the Tararua Range in the valley now occupied by the Mangaroa Stream.

Huru Fault

Most of the late Quaternary faulting along the Huru Fault is near Priests Road at Kerrydale Farm (grid ref. 130003) where there is an abrupt change of the strike of the fault from 020 degrees to 032 degrees. The association of late Quaternary fault-displacements at localities where the strike of the fault changes direction abruptly is a common phenomena of all the major faults in the mapped area. A short distance north-east of Kerrydale Farm the Huru Fault ~~displaces~~ downthrows the Hukanui and Eketahuna Surfaces. ~~The surfaces are downthrown~~ 5 and 50 ft to the south east, but there is no~~t~~ evidence of dextral displacement. The Huru fault is largely concealed beneath the Hukanui Gravels north of the Eketahuna-Hireaha main Highway to near Hukanui Railway Station, ~~some 6 miles~~. Near the Hukanui Railway Station the fault bifurcates ~~to~~ from the Huru-Paiwai fault complex. North of the Hukanui Station parts of both faults have displaced the Hukanui Surface.

South of Priests Road there are no late Quaternary fault displacements.

Rongokokako Fault

Apart from north-west of Parkville where the Rongokokako Fault trends across the Flat Top, Eketahuna, and Hukanui Surfaces there are few late Quaternary fault displacements along the Rongokokako Fault. A short distance south of the Nireaha-Eketahuna main Highway the Newman Road and Cliff Road faults diverge from the Rongokokako Fault. The fault plane of the Cliff Road Fault is exposed near its intersection with the Rongokokako Fault along the course of a large left branch of Ngatahaka Creek at grid ref. 153990. At this locality the Hukanui Gravels are downthrown 6 ft to the east but the top of the Holocene terrace is not displaced. This dates the last vertical displacement as some time ~~since~~ later than the deposition of the lower part of the Hukanui Gravel, but ~~prior~~ earlier than to Early to Mid-Holocene time.

North of the Nireaha-Eketahuna Main Highway the Rongokokako and the Newman faults have displaced the Flat Top Surface. It is downthrown about 20 ft to the south east in both places, but the Eketahuna and Hukanui surfaces are apparently not affected. The terrace edge between the Hukanui and Eketahuna terraces (see Figure 2) is a reference line which indicates that there ~~has~~ have been no dextral displacements of more than a few tens of feet along the Rongokokako or Cliff Road faults since it was formed in the Pleistocene.

The Eketahuna Surface is downthrown 50 ft to the southeast by the Cliff Road Fault at grid ref. 169001, where the fault ~~transects~~ crosses the Nireaha-Eketahuna Main Highway. East of the Makakahi River (grid ref. 210005) the Eketahuna Surface is downthrown about 30 ft to the south east. North of the fault plane the terrace is tilted to the north.

Kaiparoro Fault

South of the mapped area near Mt Bruce, Vella (1963c) found that the Waitiro Fault (Kaiparoro?) has downthrown the Bruce Surface 30 ft to the southeast. In the mapped area there are no late Quaternary fault displacements on the Kaiparoro Fault.

Rongomai - Mt Bowen Faults

Since late Quaternary time the Rongomai and Mt Bowen faults have been active in segments, ~~8¼ miles long~~, from near Soren Trig to Rongomai. It is thought, but it is not certain, that a dextral displacement of about 200 ft has occurred on both faults at several localities.

Hastwells - Pleckville - Taumata faults

Near the southern margin of the mapped area most of the late Quaternary faulting has occurred along the Hastwells Fault. Dextral displacements have not been observed, but it is of interest that a small fault which diverges from the Hastwells Fault at grid ref. 250949 is dextral, (Horizontal 32 ft, vertical 12 ft). The horizontal and vertical displacements rapidly peter out away from the Hastwells Fault. One thousand feet to the southeast at grid ref. 253949 the horizontal displacement is only 12 ft.

The dextral Taumata fault and a few associated cross faults have been active since late Quaternary time.

Alfredton Fault

Ongley (1943a) demonstrated that West Wairarapa Fault was active over much of its southern sector during the Jan 23rd 1855 earthquake. He quotes Mantell in a paper by Lyell (1857) "....La faille est, néanmoins, marquée en beaucoup d'endroits par une fissure ouverte dans laquelle les bestiaux sont venus tomber, sans qu'on ait pu, dans certain cas, les en retirer: quelquefois ces fissures, de 6 à 9 pieds de largeur, sont remplies ça et la de boue et de terre meuble."

Ongley considered that the fault movement extended northwards from South Wairarapa through the Forty Mile Bush as far as Makuri. Faulting along the Alfredton and nearby faults attributed to the 1855 earthquake by Ongley (1943a) is compared with the writer's interpretation, in the table below:-

Ongley p.88	This Bulletin
"Thence it is not traceable for two miles, but again for the half mile it is marked by a 3 ft step".	Mt Butters Road Fault
..."but beyond that it is marked very strongly trending N70°E. for two miles and a half by a trench a chain wide and 20 ft deep".	Makuri Fault, a dextral fault with a displacement of about 200 ft
.."one of the best marked steps crosses the golf links at Alfredton, where the east side is up 6 ft."	Martin Fault
A mile to the north of this west of the Road as shown in Figure 5 the west side is up 6 ft to 10 ft.	Alfredton Fault dextral 100-150ft, vertical 12 ft
Tiraumea River 10 ft	Alfredton Fault dextral + 72ft, ~~ft-~~ vertical 5 ft up to north west.
p.89 Mt Benton of Featherston...., has reported that another fresh fault trends north from the Tiraumea River six miles east of Alffedton towards Pongaroa; but so far this report has not been verified.	still uncertain

It is not known if the faulting attributed by Ongley to the 1855 earthquake occurred or did not, as the northern Wairarapa was either thinly populated or in bush at the time of the earthquake. Several of the fault traces, especially along the Martin and Mt Butters Road faults, are quite fresh and are thought to be younger than 1855.

Southwest of Alfredton, the Alfredton Fault trends across hill country and occasionally across the Hukanui Surface. South of the Mangatakoto Fault at grid ref. 307921 a small stream has been displaced 110 ft dextrally and 12 ft vertically, see Figure 42. Nearby at grid ref. 299913 the lower 4 ft of the fault scarp is much steeper than the upper part indicating a recent displacement of 4 ft. It is probable that the ratio of dextral to vertical displacements remained constant, in which case the 4 ft vertical displacement was associated with a 36 ft dextral displacement. Such a large displacement indicates that perhaps two periods of faulting have taken place relatively recently. Faulting could have occurred during the 1855 earthquake, as has been suggested by Ongley (1943a). It should be noted that there is no obvious dextral displacement on the Alfredton Fault between the Tiraumea River, where a Holocene-cut terrace edge of the Hukanui Surface is displaced at least 72 ft, at the fault and near Mt Marchant. Such an apparent abrupt decrease of 0.2+ per cent is much higher than that found by Lawson (1908) for the 1906 San Francisco earthquake. (0.01-0.001 per cent). It is probable that the Alfredton Fault has been active dextrally in at least half of the segment north of the Tiraumea River, but that displacements are not apparent. The alternative is that the decrease in dextral offset is at least four times more abrupt along the Alfredton Fault than the displacements along the San Andreas Fault during the 1906 San Francisco earthquake. The same argument holds with respect to the Mauriceville Fault which has a dextral offset of 400 ft at Mauriceville (see Vella 1963c), but is not obviously active within the mapped area. It follows that some of the other major north northeast trending faults may also have been active dextrally in late Quaternary time, without the displacement being apparent.

McKay Fault

The McKay Fault has the freshest trace in the mapped area; it trends north-northeastwards between the Pahau Fault at grid ref. 304909 and the Mt Cooper Fault at grid ref 317932. It is subparallel to the Alfredton Fault and 200-400 yds to the east of it (see Figure 42).

The fault is reverse; ~~it~~ dips to the south-east at 58° and the upthrow side is on the east. The scarp at the surface is steep, locally ~~it is~~ about 70 degrees. At grid ref 307917 there is a maximum throw of six ft, the lower three ft of which has a fresher appearance than the upper, indicating that there were probably two recent periods of faulting.

Two fence lines both constructed a long time ago are aligned normal to the McKay Fault. One fence line is sufficiently straight to preclude any recent dextral displacement of less than one foot, but the other, perhaps never very straight cannot ~~preclude~~ exclude a maximum dextral displacement of ~~less than~~ more 2 ft.

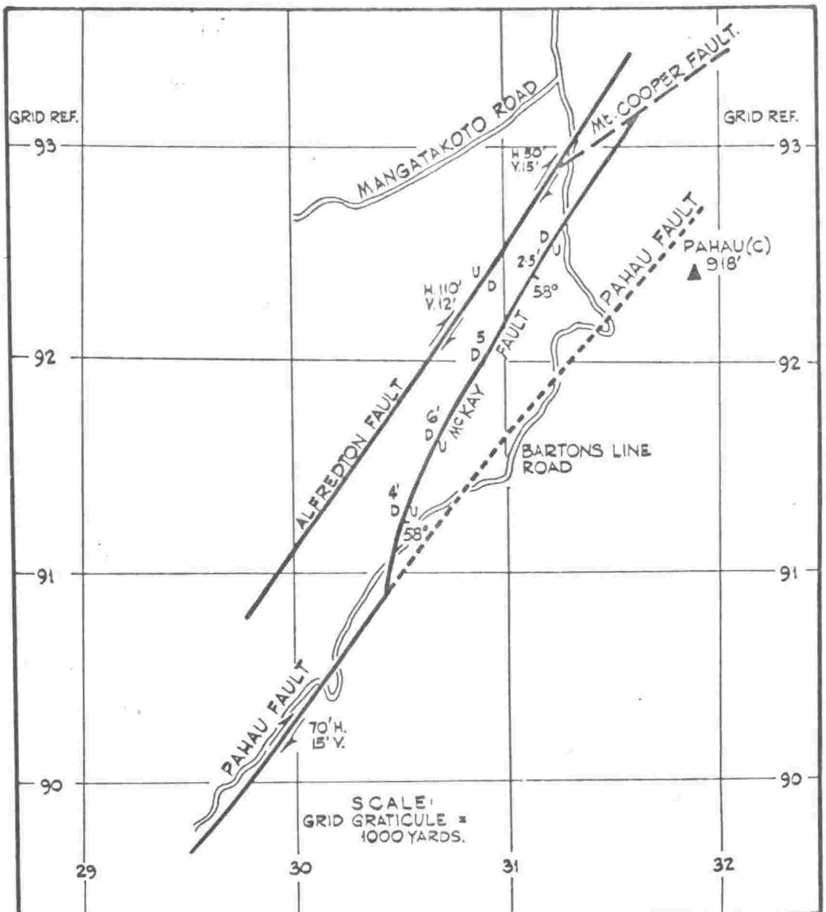


FIG.42 Map shows the relationship of the McKay Fault to the Alfredton, Pahau, and Mt. Cooper Faults. Solid lines, active faults, dotted lines, not obviously active faults.

There is a pencil line on Ongley's Field Sheets along the line of the McKay and Alfredton faults but ~~there are~~ no measurements of throw. This indicates that the scarp of McKay Fault may have been no fresher than the Alfredton Fault at the time of Ongley's examination. Ongley probably mapped the Alfredton area prior to the March 5th 1934 earthquake.

Air photographs taken during 1944, have an off-white ~~coloured~~ line, about ¾ of a mile long along the trace of the fault. This feature and the freshness of the scarp indicate that the last throw of about three feet occurred during the August 1st 1942 earthquake, rather than during the March 5th 1934 earthquake.

Pahau Fault

A 70 ft dextral and 16 ft vertical displacement of a small ridge occurs along the Pahau Fault at grid ref. {301904} (see Figure 42). A fresh scarplet of 3 ft indicates that the fault was active recently.

Drag folds adjacent to major faults

Drag folds are common adjacent and parallel to the major north-northeast trending faults, they are invariably anticlinal on the north west (upthrow) side of the fault and synclinal on the south eastern side (downthrow). The fold axes are not more than 150 yards from the major faults, and the crests are either horizontal or ~~they~~ pitch gently north-northeastwards.

The drag folds are rarely continuous for more than a mile-and-a-half. Within such a distance the strike of the drag fold generally intersects the strike of the adjacent major north-northeast trending fault. Alternatively the fold may be bounded by one or two cross faults.

Lineaments in Lightly Indurated Tertiary Strata

Frequently in thick formations without marker horizons, the mapped structure is one of tilted blocks. From air photographs the blocks can be delineated by lines (lineaments). Degrees of certainly that the line (lineament) is a fault depend on several factors, principally on how well the dip of strata disrupted by the fault is known.

Many of the mapped lineaments occur in the thick Saunders Siltstone, and in the Eketahuna Turbidite.

Fault Patterns

Within the mapped area a number of tectonic patterns are repeatedly developed. North west of Eketahuna a number of splay and cross faults intersect with the Rongokokako Fault to form a herringbone pattern, which points southwest.

In the area between the Huru and School faults, some cross faults are aligned normal to the School Fault and some are at about 45 degrees to the Huru Fault, Together they have dislocated the area into a number of triangular shaped blocks.

Generally the pattern of vertical displacement across cross-faults is random. In the north-eastern part of the mapped area near Tuscan Hills and Ngaturi Creek, however, the downthrow sides of the north trending faults are usually to the east, and the downthrow side of the east trending faults are usually to the north.

South east of Tokomaru the boundary of the hilly Tararua Formation and flattish land of the Tiritea Formation is along straightish segments 300-2,000 yards long, which trend due north and northeast. The segments which trend due north are considered to be faults, and in the northeast trending segments are probably faults.

Often cross and splay faults are collinear within a fault block or even collinear across a major north-northeast trending fault. For example the Cliff Road Fault, an unnamed cross fault, and the Tane Fault occur along a line. But between the faults the upper Tertiary Strata are unfaulted. There are many similar examples; a fault located south of the Hastwells Fault trends in the same direction as the Peep-o-Day Fault but the Mangamahoe Syncline crops out between the faults and is not cut by either. Also the north-east trending Udy Fault trends in the same direction as the Marima Fault, but the faults are transected by the north-northeast trending East Taiko and West Taiko faults.

The match of splay and cross faults across the major north-northeast trending faults is fairly good at several localities. At Rongomai large cross faults such as the Tawatia Fault are often collinear with cross faults west of the fault. Also cross faults in the area between the Taumata and Saunders Road faults are often collinear across the Alfredton Fault.

Major faults, across which the match of cross faults is poor, include the Hastwells-Pleckville and the Saunders Road. The Huru, and Rongokokako faults and their associated cross faults are buried beneath late Quaternary gravels, and their fault pattern is unknown.

It is thought that the good match across certain major north northeast trending faults is fortuitous. If it is not fortuitous it implies a very recent origin of the major north-northeast trending faults.

Minor Faults and Joints

Minor reverse and normal faults with throws measured in inches or feet are fairly common adjacent to the major north-northeast trending faults. They are uncommon at a distance from the major faults except near cross faults. In massive rocks, joints, some perhaps minor faults of unknown throw occur near the major north-northeast trending faults. It is not known if the minor faults have wrench components. The minor faults differ from the major north-northeast trending faults and cross faults in that the fault planes are usually not vertical.

Details of the minor faults developed adjacent to the north-northeast- trending and cross-faults are listed in Appendix 6.

With respect to the major north-northeast trending faults the minor normal and minor reverse faults strike on average 026°, and 055° further east. The faults are thought to be due to drag along the major north-northeast trending faults.

Tilted Tertiary Strata

Tilting of the fault blocks may be due to movement on the two major faults bounding the fault block; or alternatively only one of the faults need be active with the other acting as a hinge.

In Wairarapa Vella (1963c) found that the late Quaternary Waiohine and Ramsley surfaces had an imperceptible westward tilt, and that the westward tilt increased to about 25 degrees at the base of the Upper Miocene. Vella found that, "tilting took place consistently in one direction and at a nearly uniform rate from Hautawan to the present."

The angle of tilt is dependent on three factors:- the number of tilting movements which have occurred since the formation of the reference plane; the average throw during faulting; and the width of the fault block.

The latter is thought to be the most important factor, as strongly tilted strata are characteristic of narrow fault blocks. Vella's uniform rate of tilt hypothesis is considered to be broadly valid though it has been found that occasionally upper Tertiary strata, which were deposited during a period of several million years, do not show a progressive ~~decrease~~ change of tilt.

For example at Putaru, see Column 1 of Table 26, the Middle Tongoporutuan strata are not tilted more than the Opoitian. In cases like these there are two possible interpretations, either there was no faulting during the period when there was an absence of tilting or alternatively that virtually all the faulting was strike-slip. If all the movement was strike-slip it might be anticipated that some of the cross faults associated with the two major faults would have been active, especially where the strike of the major north-northeast trending fault changes.

The average north-west tilt in 13 sections reaches a maximum in the Middle Tongaporutuan. The Kaikoura Orogeny is probably a post-Middle Tongaporutuan event.

When the amount of tilt is plotted against time it can be seen that the rate of tilting has accelerated during the Pleistocene (see Figure 43). Similar conclusions were reached previously by Firth and Feldmeyer (1943 p.41): "In most cases, however, the period of maximum displacement was during the post-Castlecliffian Kaikoura orogeny".

Folds

Considering the amount of post-depositional tectonic deformation, unfaulted large folds are not a common feature of the structure. All the folds trend north-northeast in the same direction as the major faults; they generally pitch gently north-northeastwards. An exception is the Mangamahoe Syncline which pitches south-southwestwards at a low angle.

Synclines may be asymmetrical or symmetrical but the amplitudes of the synclines is usually fairly ~~shallow~~ small. Asymmetrical synclines with highly inclined western limbs such as the Peep-o-Day, the Kamaru and the Kaiparoro synclines are generally developed close to the eastern side of one of the major north-northeast trending faults

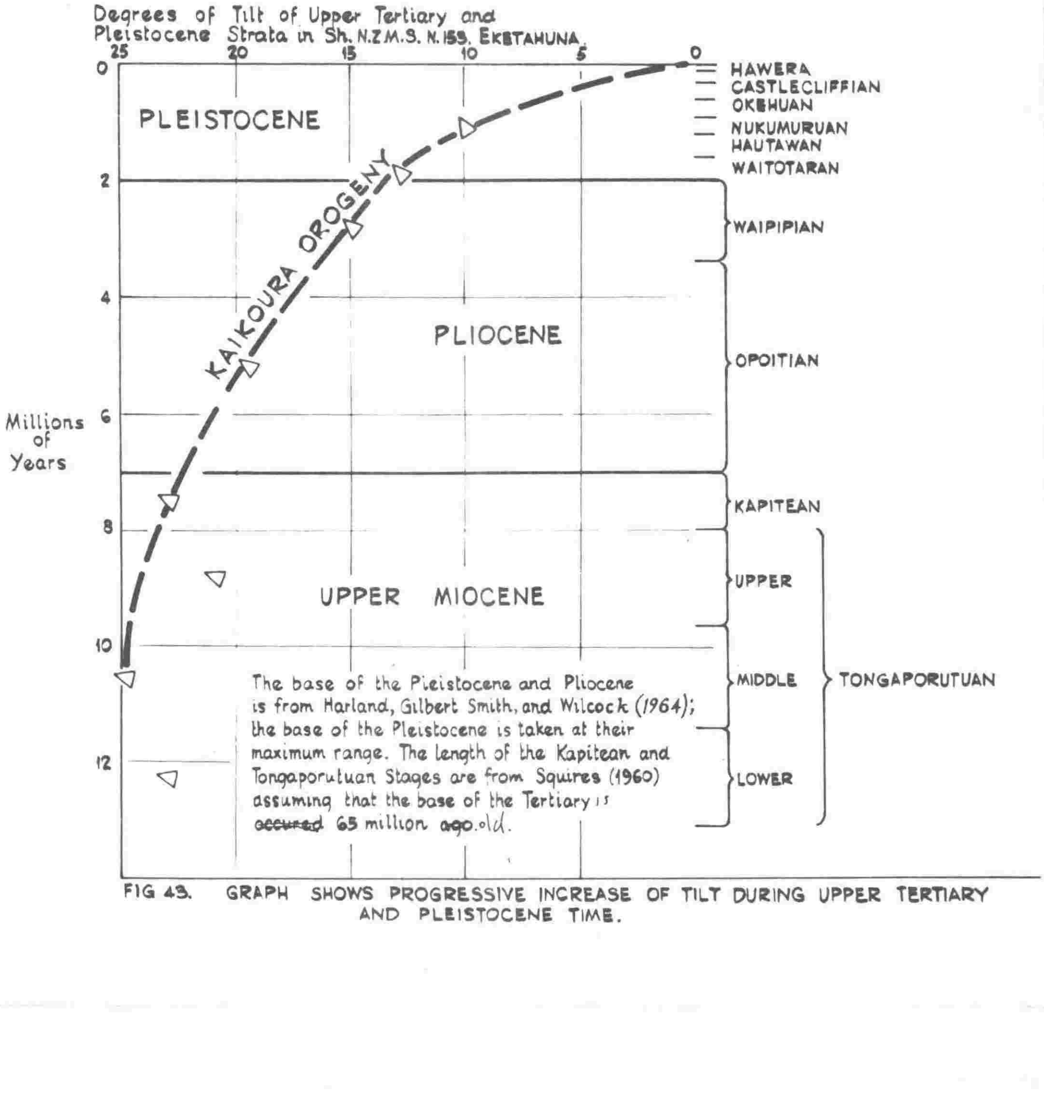


FIG 43. GRAPH SHOWS PROGRESSIVE INCREASE OF TILT DURING UPPER TERTIARY AND PLEISTOCENE TIME.

TABLE 26

TILT OF LOWER TONGAPORUTUAN TO OKEHUAN STRATA IN DEGREES

	EAST OF WELLINGTON FAULT		EAST OF HURU FAULT	EAST OF THE RONGOKOKAKO FAULT			EAST OF THE RONGO-MAI FAULT	EAST OF TANE FAULT	EAST OF HASTWELLS FAULT	EAST OF TAUMATA FAULT	EAST OF RANGEDALE FAULT	EAST OF ALFREDTON FAULT			
	PUTARA	MARIMA (Composite)		EKETAHUNA	RONGOMAI	KONINI			MANGAMAHOE	HINEMOA	WAIPORI STREAM	TE HOE STREAM	TIRAUMEA RIVER	AVERAGE	VELLA (1963c)
STAGE															
CASTLECLIFFIAN															7
OKEHUAN		13												13	
NUKUMARUAN		13				5	12							10	
HAUTAWAN		13												13	15
WAITOTARAN		13												13	
WAIPIPIAN		13		16		18		10	25	20	20	12		15	
OPOITIAN	18	15	18	18	20			15	25	22	20	20	20	19	
KAPITEAN				22	22							25	22	23	
UPPER TONGAPORUTUAN				18	22							23		21	
MIDDLE TONGAPORUTUAN	18			18	35							23	24	25	
LOWER TONGAPORUTUAN												23		23	25

PLIOCENE | PLEISTOCENE

or a splay fault. The axes of the symmetrical Mangamahoe Syncline is parallel to the Mauriceville Fault but is at an angle of thirty degrees or so to the Hastwells Fault. Other symmetrical synclines, such as the Pori Syncline, have been developed within a particularly large fault block.

Unfaulted anticlines occur only rarely; they appear to have been developed under special circumstances. The Rongomai and a anticline north of the Mangamahoe Road (here named the Arakoa Anticline after Arakoa Farm) are the least disturbed by faults. Both anticlines occur about a mile north of large changes of strike of the Rongomai and Martin faults. They are considered to owe their formation to a local compression due to dextral drag along the faults. Anticlines which have developed along the trace of some of the major north-north east trending faults have been subsequently dislocated by later fault movements. The least faulted of such anticlines is the one delineated by the G_1 Limestone along the trace of the Rongomai Fault, about a mile north east of Totaranui Farm.

In cross section the broader assymetric folded nature of the mapped area, often delineated in part by faulted limbs, is more obvious than it is in plan. The ~~macroscopic nature of the~~ folding was previously commented on by Lillie (1953 p.85) who considered "the tectonics are not regarded as being of blocks but essentially of folds accompanied by faults."

CHAPTER V

GEOLOGICAL HISTORY

Little is known about the pre-Miocene events of the mapped area; the Triassic-Jurassic Tararua Formation was deposited in deep water near the axis of the Mesozoic New Zealand Geosyncline. Cretaceous rocks younger than the well indurated Castle Formation are absent in the mapped area, but it is likely that thick sequences were deposited on downwarped Castle and Tararua Formations to cause their induration. Thick sequences of Cretaceous rocks are present further east in the East Coast Ranges. Lower, and lower-mid-Tertiary rocks absent in the mapped area are also well developed in the East Coast Ranges. Southwest of the mapped area at Otaihanga near Papararamu a tiny inlier indicates a brief marine transgression with deposition of Oligocene sediments, (see McPherson 1949).

One of the difficulties of elucidating the palaeogeography of the mapped area is in estimating the total amount of dextral displacement that has taken place along the major north northeast trending faults since the Upper Tertiary - Pleistocene Strata were deposited (that is to say, which areas were juxtaposed at any one particular time). Reference planes older than the present topography are absent. Distinctive rocks such as the Stronthn and Foyers granites, which are widely held to have been wrenched apart 65 miles along the Great Glen Fault of Scotland (see Kennedy 1946), are not available as markers of dextral shifts. Perhaps large dextral displacements might be proved or disproved if the Upper Tertiary - Lower Pleistocene rocks of adjacent areas were better known. Abrupt changes of facies of Tongaporutuan strata occur across the Rongokokako and Pleckville faults. Such criteria were ~~was~~ used by Eade (1966) as evidence of transcurrent faulting. There is evidence of vertical components of faulting affecting the thicknesses of Upper Tertiary - Lower Pleistocene strata ~~deposited~~, and it is considered unlikely that dextral components were absent. Uniformitarian principles suggest that dextral displacements of many miles have occurred along the major north northeast trending faults since the deposition of the Upper Tertiary - Lower Pleistocene Strata. Such a probability makes palaeogeographic reconstruction hazardous. The Kaikoura Orogeny, in Wairarapa may have begun during the Tongaporutuan, but the rate of tilting during the Tongaporutuan was much less than during the Upper Pleistocene.

In the mapped area east of the Wellington Fault, downwarping during the deposition of the Tongaporutuan, Kapitean and Opoitian Stages exceeded deposition. Much of the sediment often quite fine grained was deposited in deep water. During this period and also later, structural "highs" sometimes emergent and sometimes below sea level were situated at the site of the Tararua and East Coast Ranges. The "highs" produced part of the detritus which was deposited into the intervening area, which was downwarped almost continuously.

The westward migration of the main axis of Tertiary deposition was noted at Dannevirke (see Lillie, 1953 p.243). Such a Phenomena also occurred in and near the mapped area. At Akitio, O'Bryne (1963) found that sedimentation was continuous from Southland to Taranaki time, while at many other eastern localities there was a period of non-deposition.

In the mapped area maximum subsidence during the mid-Taranakian occurred between Alfredton and Castle Hill. Later during the early Opoitian the axis of the Eketahuna Trough moved westwards to the Eketahuna - Rongomai Valley area; in the Upper Opoitian the axis had moved westward to near Taiko Trig.

The westward migration of the axis of maximum subsidence is paralleled by an apparent progressive westward onlap of Upper Tertiary Sediments onto the Tararua Formation; by the early Opoitian seas had onlapped as far as Atea. Within fault blocks, however, the direction of onlap was southwest rather than due west. It is thought that the apparent progressive onlap is really a south-west one, and that dextral faulting has juxtaposed areas which were originally further apart. Evidence favourable to this contention is from the comparitive rarity of pollen from samples collected from Upper Tertiary Strata in the western part of the mapped area (pers com Mr G. Wilson). Wilson found that the pollen is dominated by Notofagus (fusca) group with secondary podocarp (Podocarpus totara type, P. spicatus ferrugineous type, Dacrydium cupressinum, D bidwillii, Phyllocladus, and Libocedrus; Silver Beech (Nothofagus menziesii) is mostly rare and the now extinct brassi group of Nothofagus very rare. Other angiosperms are few in number. If the onlap was due west, land with a cover of trees should have been present and shedding abundant pollen into the Upper Tertiary sediment.

Alternatively if the onlap was southwest less pollen would be expected in the sediment.

A widespread Lower Tongaporutuan marine transgression containing the distinctive Hurupi macro-fauna occurred over much of the south eastern side of the North Island (see for example Eade 1966).

In the southeastern part of the mapped area, near Castle Hill, seas onlapped southwestwards onto the Castle Formation. Seas gradually deepended; at first sandstones, then siltstones and finally mudstones were deposited. In the mid-Tongaporutuan pumiceous ash fell in both the mapped area and the East Coast Ranges; Kear (1957) considered that the ash had a south easterly source. After the ash-fall, a thick sequence of turbidites were deposited.

In South Wairarapa turbidites of Tongaporutuan and Opoitian age are largely restricted to the Mauriceville and Eketahuna districts. No mention of graded beds was made by Macbeath (1950) at Makara or Campbell (1950) east of Masterton. The seas were, however, deep. Kennett(1966d) has shown that at Palliser Bay, Tt? ~~Taranakian~~, Kapitean, and Opoitian sediments were deposited within the Robulus (1,000 - 2,000 ft), Karreriella (1,000 ft), and Robulus Biofacies. The strata ~~Sediment thicknesses,~~ are not usually as thick as those at Mauriceville and Eketahuna, indicating less rapid downwarping of the basement. The absence of sand and gravel in southern Wairarapa Upper Tertiary deposits indicates that there were no large areas of elevated land nearby. The absence of turbidites indicates that Southern Wairarapa was at a higher elevation than Eketahuna and Mauriceville and that the south southwestward flowing turbidity currents from Eketahuna stalled up a gentle incline towards Southern Wairarapa.

During the deposition of the marine strata at Castle Hill an elevated land was present west of the Pleckville Fault. Initially the land had a relief of at least 1,200 ft. The land was submerged and the relief infilled by non-marine and marine conglomerates and marine sandstones, siltstones and mudstones. The seas transgressed slowly southwards and westwards onto even ~~greater~~ more elevated land. The R_3 sandstone is diachronous; it was deposited at Putara at a time when the R_5 Mudstone was deposited at Eketahuna.

At Alfredton and Eketahuna early Kapitean sediments were identical with ~~to~~ those of the late Tongaporutuan. Later in the Kapitean shallowing of the sea caused a rapid change in the type of sediment deposited east of the Pleckville Fault. At Ngamaia Stream and Morgans Road shallow marine conglomerates were deposited while at Kaipororo a detrial algal limestone was deposited. Further northeast near Eketahuna ~~a~~ widespread sandstone and siltstone was deposited.

It ~~is~~ has been suggested ~~in the text~~ that the Kapitean Stage as defined by Kennett (1966b) actually coincides with a period of worldwide cooling, and that the stage is diachronous being longer in time in the Southern part of New Zealand than in Wairarapa. This contention is similar to that ~~contention~~ put forwarded by Fleming (1944) that there was a slow northward migration of cold-water-indicating mollusca during the onset of the Pleistocene.

North and South of the mapped area the conditions of deposition of the Opoitian Strata were similar to the Kapitean and perhaps part of the Tongaporutuan. Near Dannevirke, Opoitian strata are quite thin and cannot usually be differentiated from the underlying Kapitean. In southern Wairarapa the thick Opoitian strata are not easily differentiated from the Kapitean or Tongaporutuan strata. The culmination of the southwestward Upper Tertiary marine transgression occurred during the Opoitian. Opoitian rocks crop out along the Manawatu Saddle (see Ower 1943) and near Wellington at Makara (see Grant-Taylor and Hornibrook 1964). Lignite fragments occur locally in the Atea Sandstone and Saunders Siltstone in outcrops near the Tararua Range, but are absent further east. It is thought that the Tararua "high" was not entirely inundated by the sea; perhaps some small islands, bearing trees occurred along the crest of the "high". East of the Mangatoro Fault, O'Bryne (1963) found that only 200 ft of Wanganuian blue-grey muddy sandstones ~~occur~~ beneath a limestone, which is thought to be the equivalent of the Lower Pori Limestone. It is not clear if the muddy sandstone should be attributed to the Makuri Sandstone, the Tane Sandstone, or the Saunders Siltstone. At all events Opoitian sediments are not well-developed east of the Mangatoro Fault near Pongaroa and near Akitio. Further southeast at Castlepoint, however, thick massive unfossiliferous Opoitian mudstones were mapped by Kustanowich (1964).

In the mapped area, at least 5,500 ft of Opoitian strata were deposited east of the Alfredton Fault, 5,000 ft between the Rongokokako and Rongomai Faults, and 4,000 ft between the East Taiko and Huru Faults. East of the Pleckville Fault the Eketahuna Mudstone overlies the Te Hoe Turbidite and underlies the Eketahuna Turbidite. The interuption of turbidite deposition may have been due to local downwarping forming a small basin north of the mapped area, which temporarily trapped southward moving sediment. Graded beds found at the centre of the Eketahuna Trough were deposited largely from south-southwestward flowing turbidity currents, on abyssal submarine plains. At the margins of the trough massive siltstones containing archibenthic mollusca were deposited largely as forset beds of basinward aggrading continental slopes. On the west flank of the trough the siltstones overlie lower Opoitian neritic sandstones. Pelagic mudstones accumulated on the lower parts of the continental slopes, at the margin of the abyssal plains. In middle to the late Opoitian a southward moving deep-sea fan deposited a thick sequence of bedded sandstones and siltstones on the previously deposited turbidites siltstones and mudstones. Finally in the late Opoitian the rate of downwarping slowed down and the Eketahuna Trough was infilled with fine sand. Sand was then bye passed, and the sea bottom bored by organisms. Further south-southwest near Masterton deposition was probably continuous from the Opoitian to the Waipipian, as Campbell (1950) mapped 2,600 ft of fossiliferous strata containing *Policinies waipipiensis*, *Mesopeplum crawfordi*, and *Austrofusus pagoda*.

In the early Waipipian, or perhaps in the late Opoitian, the Tararua "high" became substantially emergent and supported a widespread diversified forest. At the Manawatu Saddle, however, an extremely narrow east-west Strait joined the proto-Tasman Sea with the East Coast Strait. It is of interest that fragments of lignite are not uncommon in the Marima Sandstone, but are absent further east in the Makuri Group. The East Coast Ranges rose to near sea level to inhibit the deposition of sediment but generally not high enough to bear a cover of trees. Between the two highs a marine strait, named the East Coast Strait by Grant Taylor (1964) progressively downwarped and received sediment until the Castlecliffian. Vella (1963b) considered, however, that there was a west-north west trending high at Mt Bruce during the Hautawan on which a comparatively thin sequence of limestone was deposited. It is thought that most of the East Coast Strait had an environment of deposition similar to that of the English Channel at the present time; and that much sand and silt moved longitudinally along the sea bottom.

In the mapped area the direction of transport during the Waipipian to lower Nukumaruan was mostly northwards. At the "Pori" some formations such as the Skye Farm and Pori Sandstones were derived from the east.

Post-Opoitian and pre-Nukumaruan faulting had a much more obvious effect on both the lithology and the thickness of strata deposited than previous faulting had. The fault block bounded by the Wellington and Huru faults was downwarped at a slower rate than areas further east; the shallow water, relatively thin, Marima Sandstone was deposited on the block. There was an even slower rate of downwarping west of the Wellington Fault, as only 600 ft of "Waitotaran" and 140 ft of Hautawan Strata were deposited at the Manawatu Saddle (see Ower 1943).

Other faults which were active include the Taumata and Pleckville during the Waipipian, and the Rongomai during Waitotoran and the Hautawan.

Besides the influence of faulting on sedimentation there was also the influence of fluctuations of sea-level; it is not always certain which of the influences was dominant at any particular time.

At Marima, Waipipian (zone of *Pelicaria canaliculata*) seas were warm. The first chill heralding the Pleistocene occurred during the interval between the deposition of the *P*. n.sp.aff. *acuminata* and the *P*. n.sp.aff. *tricarinata* zones. There after climates, and perhaps sea-levels fluctuated; being either warm and high, or cool and low.

In early Nukumaruan time the disposition of land and sea was probably similar to that during the Waipipian, Waitotoran, and Hautawan. It is not known if the East Coast Ranges were emergent but deposits near Ngaturi do not indicate deposition close to land. Vella (1963b) considered that the Mt Bruce "high" became land during the lower Nukumaruan. This contention is considered unlikely because there are widespread marine deposits in the mapped area which were deposited in turbulent shallow water and indicate tidal flow through the "East Coast Strait".

Further the local presence of thick marine gravels are probably due to long-shore drift. In contrast to the thin Waitotoran and Hautawan sediments the Nukumaruan Sediments at the Manawatu Saddle are of the same order of thickness as those east of the Wellington Fault, see Firth and Feldmeyer (1943). It may be that the basement was downwarped more uniformly during the Nukumuruan than previously.

In the mapped area depths of deposition were usually even shallower during the Nukumuruan than in the previous period, much of the strata deposited was at or about sealevel. Barnacle Reefs occurred at two localities, elsewhere massive fine and medium sandstones were deposited, lenses of conglomerate show their derivation was from the northwest. In the Upper Nukumuruan a thick sequence of mudstone, siltstone and sandstone was deposited. It is thought that the continuity of the East Coast Strait had at last been broken, perhaps by the Mt Bruce "high", and that the sedimentation was in a large enclosed bay having a semi-estuarine environment.

During the Okehuan the seas left the mapped area. The Tararua Mountains, previously relatively low-lying, had been eroded as fast as they rose. The rate of uplift increased and the mountains became elevated and were covered by a diversified forest. On one occasion frost-shattering during the culmination of a glacial period mantled the mountain slopes with angular greywacke fragments; the fragments were then spread on the low lying areas east of the Wellington Fault during the following interglacial.

Vella (1963b) has shown that Castlecliffian seas transgressed northwards up the Wairarapa Valley as far north as Mikimiki. West of the Tararua Range continual downwarping occurred and a thick sequence of marine Castlecliffian sediments were deposited. Marine Castlecliffian is absent in the mapped area.

Since the Castlecliffian downwarping has been arrested, and a large positive vertical movement has affected much of the Wairarapa; the land has been raised from about sealevel to 1,000 ft above. It is of interest that the tilt of the Okehuan Mangahao Formation is usually about the same as that of the Waipipian Marima Sandstone indicating that the Huru and Wellington faults have been especially active in late Quaternary time.

During Haweran time the Tiritea Formation was deposited in shallow seas on the west flank of the Tararua Mountains. East of the Tararua Range erosion of the previously deposited Tertiary and Pleistocene deposits continued; at intervals aggradation gravels accumulated, prior to a renewal of downcutting.

A volcanic ash fell on at least a few northeastern parts of the mapped area at the culmination of the penultimate aggradation period.

Since the last period of aggradation, during the last glaciation, chasms as much as 140 ft deep have been cut ~~along the courses of~~ by some of the larger rivers.

CHAPTER VI

ECONOMIC GEOLOGY

Soil

Much of the wealth of the mapped area lies in the productivity of the soil. In recent years mineral deficiencies of the soil, particularly a lack of phosphate, have been corrected by aerial topdressing. But differences in productivity, ultimately reflected in land values remain, and are controlled directly or indirectly by the nature of the underlying rocks. Soils overlying Tertiary sandstones are poor and tend to revert to manuka scrub if not well farmed. Better soils occur on lightly indurated siltstones and mudstones, but this land may become parched during the summer. The Quaternary terraces, Hukanui, Eketahuna, and Flat Top, are first class land. Recent terraces, however, are generally stony because they lack a cover of Pleistocene loess. Hill country underlain by Upper Tertiary limestone is some of the best land within the mapped area. Sheep which graze on such land are large and big-boned, and their wool invariably fetches the highest prices.

Soil Erosion

The stability of the hill country is controlled by the rocks below the surface, the steepness of slopes, and the local structure. Felling of the bush, more than seventy years ago, has increased the rate of run-off and accelerated the formation of slips and gullies in steep country.

Erosion by slips is most prevalent in Tertiary mudstone country, It occurs chiefly during storms. Rainfall causes a local increase in load with a reduction in the strength of the rock due to seepage into joint planes. Consequent rupture causes large scalloped-slips which affect the bedrock as well as soil and turf. Fragments of mudstone clog the streams and the productivity of the land is reduced. Failure of turbidite and mudstone strata is particularly common in certain steep road cuts along the Eketahuna-Alfredton main highway south of the Peep-o-day Trig; slips block the road after almost every heavy fall of rain.

In massive fine-grained Tertiary sandstone erosion is largely restricted to turf slides. During periods of heavy rain the weight of the water-logged turf may become greater than the strength of the grass roots; with a consequent rupture along the turf - sandstone boundary.

Lignite

A few sacks of lignite were quarried from the outcrop of the R_1 Conglomerate in the Rongomai area. Outside the mapped area, lignite was worked on a small scale, near Tiraumea.

The thin lignite beds of the Mangahao Formation at Marima contain 60 per cent ash and 20 per cent water (McKay 1892) and have not been worked.

Road Metal

In the past the roads were constructed with rocks from many small quarries: in basal Tertiary conglomerates at Alfredton and Rongomai;

in limestone at Hastwells, Pori, Mangaramarama; in greywacke at Rongomai and Mangaoranga; and in terrace gravels at Nireaha, Tuscan Hills, and Castle Hill. Major improvements of the highway, and the acquisition of fleets of lorries by the Eketahuna and Pahiatua Borough Councils, has led to ease of working now being more important than proximity to source. A few gravel-pits are now worked on a large scale and most small quarries are falling into disuse. Each year the country borough councils seal a portion of their road system and the need for road metal is being steadily reduced.

Limestone for Agriculture

Although there are vast quantities of pure limestone present within the mapped area (see Morgan 1919) the only quarry being worked on a large scale is alongside the railway at Mauriceville.

Limestone deposits close to the Eketahuna Settlement are either tiny such as the Mesozoic Limestone at grid ref 171936 (see page 54), or are not very pure, as is the limestone from the base of the Makuri Group ~~found~~ at grid ref 183017 which contains only 59.03 per cent of $CaCo_3$ (Morgan 1919, p.153). An analysis of 80 per cent $CaCo_3$ of a limestone sample from Mangamahoe (Morgan 1919 p.155) is thought to be an exceptionally pure sample from the E_7 Limestone. Generally, however, the E_7 Limestone is sandy and it is not likely to be used in preference to the limestone at the nearby Mauriceville Quarry. The S_4 Limestone which is developed south west of Kaiparoro (see page 101) has not been prospected for $CaCo_3$. It is thought to be a fairly pure limestone, but as it is cemented it may not be easily worked.

In the Northern part of the mapped area high-grade limestone deposits are much more plentiful. Seven analyses of limestone listed by Morgan (1919, p.149) contain between 70-96 per cent of $CaCO_3$. These limestones analyses were from samples taken from the Totoranui Limestone at Konini and from the Lower Pori Limestone at the Pori and the Makuri Gorge. The Lower Pori Limestone is particularly pure; one analysis has shown that locally it contains as much as 93.3 per cent $CaCO_3$. At the Pori the loose friable limestone is loaded directly into top-dressing aircraft from pits ~~developed~~ dug alongside landing strips, to be spread across the adjacent countryside.

Water supply

The water supply of the urban area of Eketahuna is piped about seven miles from the middle reaches of the Makakahi River. In rural non-dairying settlements rainwater collected from roofs and stored in tanks is normally sufficient for domestic needs. The larger quantities of water needed by dairy farms (in the western part of the area) is obtained by either pumping water out of creeks, or from shallow bores in late Quaternary gravels.

Streams which have catchments largely in mudstone, siltstone and graded sandstone-mudstone beds, become dry during dry summers. Small agricultural dams have been constructed to ensure a water supply for stock in these areas.

~~Petroleum~~ Hydro-carbons

Since the last war, much of the East Coast of the North Island, where thick sequences of upper Tertiary and lightly indurated Cretaceous rocks are known, has been prospected for oil. A greater part of the search has been concentrated in the Gisborne area where oil seeps and gas springs are known, and the thicknesses of the Cretaceous-Tertiary strata are much greater than in the Wairarapa. Though no oil has been found the search continues.

Within the mapped area two wildcat bores at Tane and Peep-o-day were drilled by Mangaone Oilfields Ltd, prior to the 1914 war. The Tane bore reached a depth of 3,009 ft while the Peep-o-day well was abandoned at an unknown but shallow depth.

An abstract of the Tane bore is given below:-

0-2870 ft	Mudstones with hard streak and occasional thin sandstones
2870-2940 ft	Limestone very hard
2940-3009 ft	Gritty mudstone

A trace of oil at 1,100 ft and frequent traces of gas were reported.

The Tane Bore was not sited on a closure (see cross section K-L and structure contour map) but on the flanks of a tilted block. It could, however, have been drilled at a much more unfavourable position, such as in a syncline or on a fault zone.

No oil seeps have been found either by the writer or by Ongley (1935). In the Dannevirke area, Lillie (1953, p. 113) found that the oil seeps and oil smells are confined to Cretaceous rocks. He considered that no source beds occur west of the Waewaepa-Oruawharo (Mangatoro) Fault belt. Although there is no direct indication that oil is present within the mapped area, it should be noted that oil has been found in large quantities in young basins containing deep-water-deposits similar in many respects to those of the mapped area, for instance in Southern California, particularly at Los Angeles (see Sulwold 1961).

Orbell (1962) reported that inflamable odourless gas, probably methane, was escaping from a saline pool in the Ihurua Valley at grid ref 280886 at a rate of 2 litres per hour. He further reported that a similar pool at grid ref. 268878, now infilled, from which gas had escaped also occurred along the line of the Alfredton Fault.

A chemical analysis of the Ihurua gas by J.S. Maclaurin (Dominion Analyst) in 1911, gave:-

	Per cent
Carbon dioxide	1.60
Olefines	0.40
Oxygen	3.20
Methane	58.96
Hydrogen	9.20
Carbon Monoxide	1.20
Nitrogen	23.40
Total	97.96

The Rongomai and Arakoa anticlines (see Structure Contour Map) could contain natural gas. The Rongomai Anticline is taken as a hypothetical example of just how small the structure containing a gas need be and yet be an economic proposition. If there is a gas reservoir along the crest of the Rongomai anticline it could contain as much as 56,700 million cubic feet of extractable gas. The following assumptions are made in this calculation: That the volume of the reservoir of the R_1 and R_3 members of the Soren Group is about 10,800 million cubic feet; that the porosity of the rock is 15 per cent; that the gas is at a depth of 3,000 ft with a pressure of 70 atmospheres; and that only half of the gas would be extracted. 56,700 million cubic feet of natural gas would meet the requirements of a city with a population of 200,000 for about 250 years.

There is perhaps a greater likelihood of finding gas along the crest of the Arakoa Anticline which has a better closure and is nearer known gas springs than the Rongomai Anticline.

Mercury and Copper

Traces of copper have been found in the Mesozoic greywackes of the Rimutaka, Tararua and Ruahine ranges, and slight traces of mercury (cinnabar) in the Tararua Range.

A ~~cinnabar bearing~~ boulder from near Kakariki containing cinnabar (HgS) was found by Mr W.H. Welsh, a local inhabitant. It was examined and described by Reed (1952), who stated, "The content of mercury varies within the specimen from 3 to 23 per cent, the average being about 13 per cent. Small globules of metallic mercury were detected on the surface of the richer material. Iron sulphide (pyrite) mineralisation has accompanied the deposition of the mercury; the absence of gold and silver was established by assay." The unmineralised part of the specimen is dark green in colour, and was determined by Reed to be a variolitic spilite. Previous occurrences, of mercury, also associated with spilite are restricted to a locality near the headwaters of the Waiohine River, 30 miles to the south-west of Kakariki. Prior to 1962, the outcrop of a thin, steeply dipping jasper body near Taiko Trig (grid ref 136072) was prospected by Mr Welsh. A few spilite boulders were found by the writer but there is no trace of cinnabar in the boulders or in the jasper.

McKay stated in (1888) that "Among these chertose, jasperiod, and diabasic rocks, or in their close vicinity, have been found all the indications of mineral wealth yet discovered within the older rocks of the Wellington District", and subsequent work has fully justified his remarks.

Though considerable money has been spent propecting the "Maharahara Copper Mines", 9 miles north of Woodville in the Ruahine Range, no copper has yet been marketed. MacKay (1888) found that red coloured "chertose" stream boulders contained copper. "Usually a boulder showing evidence of copper at the surface would when broken into, have all its joints more or less coated with green carbonate of copper, enclosing small pieces or crystals of metallic copper." The rock at the workings contains less copper than the stream boulders. Since McKay's investigation many geologists have investigated the prospect. Lillie (1953) considered, "the Maharahara copper is unproved but is not a likely prospect."

Thompson (1914) reported that a little gold was found in a thin pyrites leader traversing a red jasper at the Woodville end of the Manawatu Gorge.

Appendix 1:

Index of Fossil Collections of N.Z.M.S.1. N.153

The following notes explain the details of headings:

Collected by

The initials given refer to the following collectors.

E.T.A.	E.T. Annear
H.E.F.	H.E. Fyfe
N. de B.H.	N. de B. Hornibrook
J.T.K.	J.T. Kingma
A.M.	Alex. MacKay
J.M.	J. Marwick
G.N.	G. Neef
M.O.	M. Ongley
G.O.	G. Orbell
J.T.	J. Torrey
P.V.	P. Vella
P.W.	P. Webb
H.W.W.	H.W. Wellman
C.S.W.	C.S. Wilson

Grid Reference

The reference used is that with the yard grid shown on the Department of Lands and Survey N.Z.M.S. 1 Sheets, using the 1949 Geodetic Datum, and reproduced on the Geological map in this bulletin.

<u>Stratigraphic Position</u>

G_9	=	G_9 Breccia	(Mangahao Formation)
G_7	=	G_7 Conglomerate	" "
G_4	=	G_4 Siltstone	(Totaranui Formation)
G_3	=	G_3 Conglomerate	" "
G_2	=	G_2 Sandstone	" "
G_1	=	G_1 Limestone	" "
T_4	=	T_4 Shell bed	
t_3	=	Zone of *Pelicaria* n.sp.aff. *tricarinata*	(Marima Sandstone)
t_2	=	Zone of *Pelicaria* n.sp.aff. *acuminata*	" "
t_1	=	Zone of *Pelicaria canaliculata*	" "
T_1	=	T_1 Limy Sandstone	" "
F_{21}	=	Kaitawa Sandstone	
F_{18}	=	Chlamys Bed	(Upper Makuri Siltstone)
F_{17}	=	Upper Makuri Siltstone	
F_{16}	=	Koropeke Limestone	
F_{15}	=	Koropeke Sandstone	
F_{13}	=	Lower Sandstone Lens	(Lower Pori Limestone)
F_{12}	=	Lower Pori Limestone	
F_9	=	Skye Farm Sandstone	
F_8	=	Lower Makuri Siltstone	
F_6	=	F_6 Siltstone	(Makuri Sandstone)
F_5	=	Makuri Sandstone	
F_2	=	F_2 Coquinoid Limestone	(Makuri Sandstone)
F_1	=	F_1 Oyster Bed	" "

E_9 = Tane Sandstone

E_8 = Newman Siltstone

E_7 = Tawatia Sandstone

E_4 = Eketahuna Turbidite

E_3 = Eketahuna Mudstone

E_2 = Saunders Siltstone

E_1 = Atea Sandstone

S_2 = S_2 Sandstone (Kaiparoro Formation)

S_1 = S_1 Siltstone " "

R_5 = R_5 Mudstone (Mangaoranga Formation)

R_4 = R_4 Siltstone " "

R_3 = R_3 Sandstone " "

R_2 = R_2 Marl " "

D_2 = Tiraumea Mudstone

D_1 = Te Hoe Turbidite

C_4 = C_4 Mudstone (Ngarata Formation)

C_3 = C_3 Siltstone " "

C_2 = C_2 Conglomerate " "

C_1 = C_1 Sandstone " "

A_7 = A_7 Limestone (Tararua Formation)

A negative suffix means below the base, a positive suffice above the top.

Lithology

The first two numbers refer to the grade range of the sediment, the third, to its induration or cementation, and the fourth to its calcite content.

The small letter refers to the colour, and the final capital letters to minerals and conditions not always present.

Grade and Range

	(1. Boulders	1.)	
	(2. Cobbles	2.)	
	(3. Pebbles	3.)	
Major	(4. Gravels	4.)	Minor
Part	(5. Coarse sand	5.)	Part
	(6. Medium sand	6.)	
	(7. Fine sand	7.)	
	(8. Silt	8.)	
	(9. Mud	9.)	

The first number indicates the grade of the major part of the sediments and the second the minor part. Well graded sediments with a small grade range show a small numerical difference between the first two numbers.

Induration or cementation

1.	Unconsolidated	
2.	Very soft	falls to pieces when handled
3.	Soft	easily crushed by hand
4.	Moderately soft	with difficulty crushed by hand
5.	Moderately hard	cannot be crushed by hand
6.	Hard	edges broken with difficulty
7.	Very hard	as very hard limestones, etc.

Amount of Calcite

		Per Cent Calcite
0	non-calcareous	0 - 1
1	slightly calcareous	1 - 5
2	moderately calcareous	5 -20
3	very calcareous	20-50
4	Impure limestone	50-80
5	Pure limestone	80-100

Colour

a	almost white	g	dark brown grey
b	very light grey	h	green grey
c	light grey	i	yellow brown
d	medium grey	j	reddish
e	dark grey	k	green brown
f	medium brown grey		

Supplementary

	Slightly	Moderately	Very
Tuffaceous	T	TT	TTT
Glauconitic	G	GG	GGG
Micaceous	M	MM	MMM
Pyritic	P	PP	PPP
Carbonaceous	C	CC	CCC
Weathered	W	WW	WWW
Concretionary	O	OO	OOO
Quartzose	Q	QQ	QQQ

Phosphatic	F	FF	FFF
Shell beds	S	SS	SSS
Borings	B	BB	BBB

Facies by Foraminifera

(See Appendix 2, Table 2)

Collection Number	Year Collected	Collected by	Locality	Grid Ref. N.Z.M.S. N.153	Strat Position (Ft)	Lithology	Age by Forams	Facies by Forams	No. of Macrofossil species	Age by Macrofossils	Geological Survey macrofossil No.	Climate by Plant Microfossils	Remarks
478	32	JM	Timmins Ck	?	?	concretionary sandstone			9		1609		Pelicaria Biofacies A type locality Zeacolpus delli vellai Marwick and Notocallosta (Stir-acallista) multi-striata (Sowerby)
479	33-34	M.O.	Te Hoe Stm		Upper C_1	argillaceous con-cretionary sandstone			5		2000		Hurupi macrofauna
480		M.O.	Bartons Line			shelly limestone			10		2001 2002		
481		M.O.	2 miles W. of Alfredton		E_3?	light grey mud-stone			1		2003		Mantellium. aff. marwicki Pow
482	34	M.O. 10 M	$\frac{1}{4}$ mile E. of Trig	253122	F_2	limestone					2007		
483	34	M.O.	Railway cutting 50ch S. of Bowen Rd.	192973	S_2	sandstone			2		2008		Neothytis. cf. ovalis common
484	34	J.M.	Marima Rd $\frac{3}{4}$ mile S.W. of Kareara			fine argillaceous sandstone					2232		
485	34	J.M.	Tainui Stm $\frac{1}{4}$ mile upstm of ford						1		2233		
486	45	C.S.W.	N.E. Road cutting 90 ch S. of Tane Trig								3532		
487	31	M.O.	Road cut $\frac{3}{4}$ mile W.S.W. of Kareareo Trig			mudstone			1		2236 4456		A locality of Stiracolpus delli vellai Marwick
488	31	M.O.	Road cut 90 ch W of Trig Karearea								4457		
489		M.O.	Road cut 10 ch from Pahiatua Trig								4458		

490	31	M.O.	Tainui Rd ¼ mile upstream of ford					4459	
491		M.O.	Makuri Rd, 1 mile S.W. from Jargen			fossiliferous fine sand		4493	
492	32	M.O.	Tiraumea Rd 5-10 ch N. of Ngaturi Creek?					4496	
493	49	E.T.A.	Top of Mt Ben 1¾ miles N.N.E. of Mona Homestead				11 T_t lower	4869	Hurupi macrofauna
494	49	E.T.A.	Creek 1½ mile N.N.E. of Mona Homestead			pebby conglomerate	3	4870	fossiliferous basal conglomerate
495	49	E.T.A.	Creek 1½ mile N.N.E. of Mona Homestead			sandstone	3	4871	concretionary boulders in creek
496	32	J.M. / M.O.	Kaitawa Rd 4 miles S. of Mt Marchant					7049	
497	32	M.O.	½ mile S.W. of trig 7 Onehua			fossiliferous sandstone		7051	
498	32	J.M. H.E.F. M.O.	Te Aupapa Rd ½ mile S. of Te Aupapa Trig	376176		fossiliferous shell Limestone		7052	
499	32	J.M. H.E.F. M.O.	Road cut Te Hoe Road	394922	20 ft above greywacke			7053	
500	31	M.O.	Road cutting 30 chs S.E. of Karearea Trig			mudstone		7059	
501	49	E.T.A.	1½ miles N.N.E. of Mona Homestead			6762 fo	4	4871	concretionary boulders
502	49	E.T.A.	1¾ miles N.N.E. of Mona Homestead			7852 fw		4869	
503	49	E.T.A.	1½ miles N.N.E. of Mona Homestead			3761 do		4870	collection discarded poorly preserved
504	47	M.O.	Pahiatua-Makuri W. end of Gorge		F12	limestone			No fauna (micro-fossils)

505	57	M.O. H.E.F. J.M.	1 mile S. of Trig 924						No fauna (micro- fossils)
506	47	M.O. H.E.F. J.M.	30 ch at 220° from Makikikaka Trig				Wo		
507	47	M.O. H.E.F.	Kaitawa-Alfredton Rd cut E. of Watta Trig						No fauna (microfossils)
508	47	M.O. H.E.F. J.M.	Kaitawa-Alfredton Rd cut E. of Watta Trig			mudstone	Wo?Ww		Poor fauna (microfossils)
509	47	M.O. H.E.F. J.M.	Saddle along Eketahuna- Alfredton high- way 1 ml N.W. of Hansen Trig				Wo		
510	47	M.O. H.E.F. J.M.	Eketahuna- Alfredton Rd cut 5 ch W. of Rd Cnr.						No fauna (microfossils)
511	47	M.O. H.E.F. J.M.	Eketahuna- Alfredton Rd cut at prominent cnr.						No fauna (microfossils)
512	47	M.O. H.E.F. J.M.	Quarry in coarse conglom. W. of Mangaone Alfred- ton Rd.	239005	R_1	conglomerate			No fauna Microfossils)
513	47	M.O. H.E.F. J.M.	Rd cut - Alfred- ton-Mangaone Valley main highway ½ way uphill				Wo		
514	47	M.O. H.E.F. J.M.	Rd cut 10 ch S. of Peep-o-Day Hmst. 1 ml N.E. of Ash Hill				Tt		
515	47	M.O. H.E.F. J.M.	Te Hoe Stm 2 mile N.W. of Castle Trig				Tt		
516	47	M.O. H.E.F. J.M.	Te Hoe Rd 1 mile N.W. of Castle Trig		a few feet above greywacke contact			5	

517	47	M.O. H.E.F. J.M.	Castle Hill Rd $\frac{1}{4}$ ml E. of Alfredton								No fauna (microfossils)
518	47	M.O. H.E.F. J.M.	Rd cut Alfredton-Tiraumea main highway	391984	E_2		Wo or Ww prob Wo				
519	47	M.O. H.E.F. J.M.	$1\frac{1}{2}$ mile N.W. of Trig Ulic			soft sandstone					No fauna (microfossils)
520	1887	A.M.			A_7	marble					
521		M.O.	30 ch N. of Mahakikatea Trig		E_9				1	2230	A type locality of <u>Stiracolpus</u> <u>pro-collosus</u> Marwick
522	32	M.O.	Coach Rd - Rt bk trib of Makakaki R, $3\frac{1}{2}$ miles S. of Eketahuna.		A_7	marble			1	5917	<u>Aucella-Aucellina</u>
526		M.O.	Mangaone Stm, see 49 Block 16			indurated sand-stone 4461 gT			1	7067	River boulder con-taining (R.V.) <u>Buchia</u> aff. <u>malay-omaorica</u>
527	59	G.N.	Mangaone Stm 150 yd N.E. of bridge along Rongomai Valley Rd.	256026	E_4	9931d	Wo	upper Bathyal			Possibly some shallow water sp.p carried in.
528	59	G.N.	Rd cut Woodville -Masterton Highway 75 yds N. of Bridge	185966	S_2	7931c					Poor fauna
529	59	G.N.	Rd cut Castle Hill Rd. 300 yds E.S.E. of Terrace Trig.	406918	C_1	7830 Ww					No fauna (microfossils)
530	59	G.N.	Drainage Ditch Castle Hill Rd. 40 yds N. of Bridge	398922	C_3	8930d	Tt	fairly shallow			No pelagics
531	59	G.N.	Te Hoe Stm 30 yds upstm of disused bridge	389929	D_1	9-40d W	N.D.	N.D.			No fauna (microfossils)
532	59	G.N.	Cut Castle Hill Rd at centre of S. bend	367946	E_3	9-830d W	Wo	mid to outer bathyal			

533 59	G.N.	Cut Castle Hill Rd	352950	E_9	9-30d Ww			No fauna (Microfossils)
534 59	G.N.	Cut 160 yds W. of Eketahuna -Alfredton Highway Bridge	327957	C_4	9-51e	Tk	mid-outer bathyal	from base of concretionary horizon
535 59	G.N.	Cut Eketahuna-Alfredton Highway. 330 yds W. of intersection with Bartons Line Road	313956	E_4	9831d "turbidite"	Wo	outer neritic	Poor fauna (microfossils) pelagics moderately good.
536 59	G.N.	Cut Eketahuna-Alfredton Highway. 700 yds E. of Saddle	301952	E_3	9-831e	Wo		Very poor fauna - does not appear to be a shallow water fauna.
537 59	G.N.	Drainage Ditch centre cnr. on Alfredton-Eketahuna main Highway	274973	E_4	8-953d com calc nodules	N.D.	N.D.	
538 59	G.N.	Cut Eketahuna main Highway 1200 yds slightly E. of N. of Ash Hill.	268973	E_4	8793 d	N.D.	N.D.	Secondary cementation obscures microfossils.
539 59	G.N.	Cut Eketahuna -Alfredton Highway	239998	R_3	7874dsss			
540 59	G.N.	Cut Eketahuna -Alfredton Highway	239998	R_3	7842dS		Upper neritic	
541 59	G.N.	Cut Eketahuna -Alfredton Highway	224996	R_4	8730c	N.D.	N.D.	
542 59	G.N.	From south pt of bend, Eketahuna main Highway, 1000 yds N. N.E. of Mt Turner Trig.	211994	Uppermost R_5	9830c	up Tt-Tk or Wo	moderately deep water	Probably not Wo because *I inflata* is absent but pelagics are not common.

543 59	G.N.	Rt bk of Lge Lt br of Te Hoe Stm. 200 yds S.W. of Terrace Trig.	398921	Uppermost C_1	7830eW			5	L.Tt	
544 59	G.N.	Lt. Bk. of Gorge 100 yds E.N.E. of No. 1 Trig.	389917	C_1	7830c	N.F.	N.F.			
545 59	G.N.	Lt.br. of Te Hoe Creek		C_1		N.F.	N.F.			
546 59	G.N.	Lt.br. of Te Hoe Creek by sml W/fall	Sheet N158 392897	C_1	8742d	N.F.	N.F.	2		
547 59	G.N.	Lt.br. of Te Hoe Creek	C_1			N.F.	N.F.			
548 59	G.N.	Lt.br. of Te Hoe Creek	C_1			N.F.	N.F.			
549 59	G.N.	150 yds upstm of trib. of main creek	424938	C_3	siltstone					No fauna (microfossils)
550 59	G.N.	Te Hoe Stm 200 yds S. of West Base 591 Trig.	372942	E_4	turbidite 8931d	Wo-LWw	Bathyal			Poor fauna - all moderately deep water app. probably bathyal.
551 59	G.N.	Track 550 yds S.W. of West Base 591 Trig.	371937	E_4	turbidite	Wo-LWw	Bathyal			
552 59	G.N.	Track 550 yds S.W. of West Base 591 Trig.	371937	-2 feet 551 E_4	turbidite	Wo-LWw	Upper Bathyal			Identical to 551.
553 59	G.N.	Te Hoe Stm below farm bldgs	375935	E_3	9830	lower Ww upper Wo?	deep water			No pelagics possibly upper Tt-Tk
554 59	G.N.	Te Hoe Stm 350 yds W.S.W. of east Base Trig.	380933	E_3	9830e	uTt-Tk	upper Bathyal Lower neritic			
555 59	G.N.	Te Hoe Stm. 5 yds upstm of fence	382932	D_1	turbidite	Mid Tt possibly upper Tt	upper Bathyal lower Neritic			

556	59	G.N.	Te Hoe Stm 450 yds S.E.S. of E. Base Trig.	384931	D_1	turbidite	Tt-Tk prob.Tt			<u>Globorotalia</u> <u>conomiozea</u> & <u>G</u>. cf. <u>miozea</u> are the most abundant pelagics.
557	59	G.N.	Te Hoe Stm 250 yds upstm of Lge trib.	397928	C_4	983 g0	mTt	upper bathyal-mid bathyal		
558	59	G.N.	Te Hoe Stm. 700 yds N.W. of W. Base Trig	365944	E_3	9831 d	Wo	mid bathyal		Rather restricted fauna pelagics dominant, but little more than 50 per cent.
559	59	G.N.	Trib. of W. Flowing Ck.	356913	E_4	turbidite	basal Wo	semi pelagic-mid bathyal		Globs moderately abundant nearly as many as benthics
560	59	G.N.	Conflu. of trib. with W. flowing ck.	358910	E_3	9831 f	Tt-Tk	mixed u neritic and bathyal		Very poor fauna.
561	59	G.N.	200 yds N.E. of No. 1 1071 Trig.	389916	C_4	9131e	Tt	mid-upper bathyal		Globs not common.
562	59	G.N.	Rd cut 450 yds S.W. of Mt Cooper	331943	F_5					
563	59	G.N.	Rd cut 450 yds S.W. of Mt Cooper	331943	F_5	7822dM	Top Ww	Upper Neritic	2	Shallow shelf environment moderately warm.
564	59	G.N.	Lt.Bk of Ihuraua Stm 420 Alfredton-Eketahuna Highway	329952	C_4	9930eWw	Tt-Tk	Neritic		
565	59	G.N.	Cut Alfredton-Masterton Highway, 200 yds S.E. of Alfredton Fault	333950	E_9	very fine sandstone	N.D.	N.D.		
566	59	G.N.	Cut, Flat Bush Rd 200 yds N. of Bridge	337921	E_9	7821eMM	Top Wo	lower neritic	3	

567	59	G.N.	Ck 250 yds N.E. of Farm Bldgs. 1850 yds S.W. of Mt Marsh Trig	342913	E_2	9831eM	Wo	Redeposited Neritic & mid-upper bathyal			Rare Ostracods
568	59	G.N.	Ck 1200 yd S.W. of Mt Marsh	350916	E_4	turbidite	Wo-Ww	"			Rare Ostracods
569	59	G.N.	Small exposure inrt br, Te Hoe Stm.	399929	C_4	9831eW	N.D.	N.D.			
570	59	G.N.	Rt br, Te Hoe Stm, 750 yds S.E. of Knights (X) Trig.	410928	C_1	7831 Ww			9	L.Tt	Fallen blocks in stream
571	59	G.N.	Rd cut 1000 yds S.W. of Peep-o-Day Trig	297956	E_7	8932cMM	High Wo Ww	- Upper Bathyal			Globs not common
572	59	G.N.	Top of Hillside slip 300 yds N.W. of Alfredton Fault	297915	C_4	9830d	N.D.				Weathered
573	59	G.N.	Gully at head of S flowing Stm 30 yds S.W. of Alfredton Fault	298909	C_4	8930eWw	N.D.	N.D.			V. poor fauna. Many small spheroidal siliceous bodies.
574	59	G.N.	Spillway at Agricult Dam. 1700 yds S.W. of Mangatakoto & intersection Bartons Line	301921	C_1	fine sands with a few pebbles	N.F.	N.F.			
575	59	G.N.	Quarry 2050 yds S.W. of Pahau (c) Trig. 200 yds W. of Alfredton Fault.	301915	C_2	233-s	Wo-Ww		2		
576	59	G.N.	Rd cut Bartons Line 70 yds S. of Crest of hill.	300903	F_5	7832dS	upper Ww	Shallow water	1		
577	59	G.N.	Lt.bk of Lge Trib. of Tiraumea R. 50 yd N.W. of Culvert on Mast.-Weber Highway.	448968	C_4	9832					Notorotalia taranaki

578	59	G.N.	Lt. br. Tiraumea R. 3 yds downstm of sml W/fall	444974	basal D_1	9832	UTt-Tk prob.up Tt	Deep water fauna	Kapitean species not seen
579	59	G.N.	Rt. br. Tiraumea R. 1050 yd upstm at small W/fall	423993	E_2	9830eWe	N.F.	N.F.	
580	59	G.N.	Lt. bk. Tiraumea R. 1550 yd S.W. of Saddle Trig.	426083	Lower E_2	8931 eWw	Tk- Wo		Splintery weathering interbedded sands and silts.
581	59	G.N.	Rd cut 1150 yd E.N.E. of Kaitawa Trig	408072	E_2	8932e	Tk-LWw		
582	59	G.N.	Waipori Ck 40 yds below Pori Rd Bridge 5 ft below large concret.	389998	E_2	8931eT	Ww		
583	59	G.N.	Pori Rd cut 350 yds W. of R806 Trig.	389093	E_2	8732eM			
584	59	G.N.	Rt.bk. of Lt. br. of Punga Stm 250 yds E. of intersect. of Cent. Mangamahoe & Mangamahoe roads.	247900	E_7	8932e	Wo		
585	59	G.N.	Ck 300 yds W. of intersect. of Baker & Mangamahoe roads	251911	E_4	9833e	Wo	deep water	
586	59	G.N.	Rd cut Mangamahoe Rd 250 yds S.E. of intersect. with Baker Rd.	256909	E_4	muddy turbidite	N.F.	N.F.	
587	59	G.N.	Rd cut Mangamahoe Rd 700 yds S.E. of Intersect. with Baker Road	258904	E_4	muddy turbidite	Wo-Ww		Probably Wo
588	59	G.N.	Rd cut Mangamahoe Rd 1050 yds S.E. of intersect. with Baker Road	263903	E_4	"	N.F.	N.F.	Weathered
589	59	G.N.	Sml stm. 15 yds upstm of bridge on Mangamahoe Rd.	271903	E_4	"	Wo-Ww Prob.Wo	deep water	Small fauna - many pelagics.

590	59	G.N.	Rd cut 650 yds S.E. of IM Trig	224997	50 ft + 541 R_4	8930c	N.F.	N.F.	
591	59	G.N.	Rt.bk.of lt.br. trib.of Mangaone R., 750 yds N.E. of 15M Trig.	242979	E_4	8932e	Wo-Ww		Poor fauna
592	59	G.N.	Lt.bk.lt.br. of Mangaone R.	253960	E_4	983--Ww	N.F.	N.F.	Weathered
593	59	G.N.	S of sml track 10 yds from Fault trace	254957	E_7	7831dM	Ww	Upper neritic	A few minute microfossils
594	59	G.N.	10 yds E. of Coach Rd - 1st exp E. of Fault trace	293958	E_7	8932eP	Wo	deep water	
595	59	G.N.	Rd cut Eketahuna -Alfredton main Highway	292959	E_4	8932e	Ww		Poor fauna
596	59	G.N.	Stm 70 yds W. of Farm	288964	E_3	9830eWw	N.D.	N.D.	
597	59	G.N.	Rd cut at top of bk	283973	E_3	9830gW	N.F.		Weathered
598	59	G.N.	Below small W/fall	348972	E_2	7830MWW	N.F.		
599	59	G.N.	Lt.bk Mangaone R, 700 yds S.W. of 7M Trig.	251010	E_4	8932c	Wo		
600	59	G.N.	Rt.bk Mangaone R, 400 yds S.W. of 7M Trig.	252013	E_4	9832cB	Wo-LWw		Borings
601	59	J.K.	Cut Masterton-Woodville State Highway	191961	E_4	8942d	Wo		
603	61	P.W. N.de B.H.	Main Rd ¼ mile S of Eketahuna in twisting bends.	?	E_4	8832gMcc			Rich in carbonaceous fragments. Also Nannoplankton
701	59	G.N.	W/fall 400 yds N.E. of 19M trig.	269010	E_4	9832cB	Lower Ww pos. Wo		Worm borings.
702	59	G.N.	Lt.bk.Rt.br of Mangaone R. 1000 yds W. of 19M Trig.	257007	E_4	8932C	Wo-LWw		

703	59	G.N.	20 yds W. of Central Mangaone Road Bridge across Makakahi R.	202053	E_8	very fine sandstone			5	
704	59	G.N.	Rd cut 20 yds E. of Central Mangaone Rd Bridge across Makakahi R.	202052	E_8	7833c	Wo-Lww		1	
705	59	G.N.	Makakahi Rd cut 500 yds N.E. of intersect. with Central Mangaone Road	218053	E_4	8932cC	Wo			
706	59	G.N.	Track 30 yds E. of Central Mangaone Rd 1050 yds N.W. of 4M Trig	218045	E_4	8931cM	Wo-LWw			
707	59	G.N.	Rt.bk.of stm. 30 yds N. of Central Mangaone Rd, 640 yds N.W. of 4M Trig.	224043	E_4	9833c	Wo			
708	59	G.N.	Track 300 yds N. of Hawera-Mangaone valley highway intersect.	270057	E_7	9832cW	Wo	deep water		very rich in Pelagics poor in benthics.
709	59	G.N.	Rd cut Hawera Rd 2100 yds N.E. of 8M trig	253069	E_4	8922cM	L.Ww			
710	59	G.N.	Rd cut 200 yds S.E. of 54M Trig.	245073	E_4	8922c	Wo			
711	59	G.N.	Nr confluence of two sml stms 500 yds S.E. of Old Coach Road	177935	R_3	7831e	N.F.	N.F.		Common broken shell fragments
712	59	G.N.	Loose blocks from stm channel S. of Old Coach Rd 1500 yds N. of Mt Munroe	171936	A_7	Limestone			3	<u>Aucellina</u> <u>Inoceramus</u> sp. fragments fish tooth.
713	59	G.N.	Stm 300 yds S.W. of intersection of Railway & Rd, 450 yds N.W. of 13 M Trig.	193035	E_8	8732c	L.Ww			

714	59	G.N.	Track 8 yds from Stm 2150 yds W.S.W. of 13M Trig.	174026	E_3	8931cWW	Wo-LWw				
715	59	G.N.	Rd-cut 150 yds N.W. of Rongo-kokako Fault 1950 yds N.W. of 14M Trig.	173022	E_3	8931cW	Wo				
716	59	G.N.	Rd-cut 400 yds N.W. of Rongokokako Fault	169023	E_3	8931c					
717	59	G.N.	Upstm of W/ fall in small stm 250 yds N.W.N. of Manga-tainoka bridge	118042	10 ft-E7 E_3	9831c	Wo				
718	59	G.N.	Rt bk Mangaroa Stm 550 yds S.E. of Well-ington Fault, 600 yds upstm of Lge Lt br trib.	075015	E_2	7830c	Wo prob.WO				
719	59	G.N.	Lt bk of L. br of Mangaroa Stm 500 yds upstm of con-fluence with Mangaroa Rd stm.	085028	E_1	7831cC	Wo-Ww	neritic	5	Wo	
720	59	G.N.	Lt bk of L. br of Mangaroa Stm 700 yds up stm of confluence with Mangaroa Stm 400 yds S.E. of Wellington Fault	083028	E_1	7831C			7		
721	59	G.N.	Stm 5yds upstm of fence line, 20 yds N. of Al-fredton-Eketahuna Main Highway, 300 yds S. of 1M Trig	218096	R_5	9832d	TK				Rare <u>Globorotalia miozea</u> no sign of <u>G. inflata</u>
722	59	G.N.	½ way up hillside 300 yds E. of Tawatia Rd	283019	E_4	8931CM	Wo				

723	59	G.N.	Track, N. of large pond	280045	E_7	8932cM	Wo		
724	59	G.N.	Track, N. of large pond	280045	E_7	7631cS	Wo		Graded bed, common foraminifera and shell fragments.
725	59	G.N.	Cut Pa Va.Main Highway 1650yds S. of intersection with Mangaone Valley Main Highway	325053	E_2	8932c	Wo		
726	59	G.N.	Rd-cut Pa Valley Highway 1800yds S. of intersection with Mangaone Valley Highway	326052	E_2	calcareous very fine grained sand			_Nemocardium_ _pullchellum_ common.
727	59	G.N.	Rd-cut Pa Va. Highway 700yds N.W. of Mara Trig, 300yds N.W. of Taumata Fault.	328031	E_4		Wo		
728	59	G.N.	Rd-cut Pa Va. Highway 400yds N.E. of Estcourt Stn, 1350 yds S. of Mara Trig.	334014	E_4		N.F.	N.F.	Weathered
729	59	G.N.	Rd-cut Pa Va. Highway 300yds N.E. of Estcourt Stn 300yds N.W. of Estcourt Fault	335013	E_4		Wo	deep water	
730	59	G.N.	Rd-cut Quarry Rd 150yds E. of Rongokokako Fault	165115	E_3	8932c	Wo	moderate depth	
731	59	G.N.	Rd-cut Eketahuna-Nireaha Highway 1200 yds S. of intersection with Quarry Rd 400yds N.W. of Huru Fault	138024	E_3	8932cW	Wo		Very abundant _Plectofrondicularia_ _pellucida_
732	59	G.N.	Rd-cut Eketahuna-Nireaha Main Highway	139017	E_4	9830c	N.F.		Weathered

733	59	H.W.W. P.V. G.N.	Rd-cut Mangaone Valley Highway, 1400 yds S. of intersection with Hinemoa Rd. 200 yds S.E. of Kaitawa Fault.	352168	F_{21}		upper Wo Upper Ww		5		
734	59	H.W.W. P.V. G.N.	Rd-cut Mangaone Valley Highway 1050 yds N. of intersection with Hinemoa Rd	345192	F_{21}		prob U.W.w				
735	59	H.W.W. P.V. G.N.	Rd-cut Mangaone Valley Highway 600 yds S.W. of No.2 Trig, 300 yds N.W. of Mangaramarama Fault	344195	F_{21}		Top Ww- basal Ww	shallow water			Ostracods present
736	59	H.W.W. P.V. G.N.	Rd-cut, 600yds S.W. of Ruatea Stn.	385037	F_8		Upper Wo Upper Ww				
737	59	H.W.W. P.V. G.N.	Rd-cut, 1200yds S.W. of Ruatea Stn.	382031	F_8		Upper Wo Upper Ww				
738	59	H.W.W. P.V. G.N.	Rd-cut, Pori Rd 650yds N. of intersect. with Saunders Rd 250 yds N.W. of Saunders Rd Fault	390003	E_2		Ww-Wn		2		Excellent fauna of small species _N._ _pullchellum_ _Caryophyllia profunda_ Moseley
739	59	H.W.W. P.V. G.N.	Rd-cut, Mangaone Valley, Highway 650yds W. of No. 2 Trig.	Sheet N149 340201	G_1				1		
740	59	H.W.W. P.V. G. N.	Rd-cut, Mangaone Valley highway 950yds N. of intersect. with Hinemoa Rd 50 yds S. of Mangaramarama Fault.	344190	near base F_{21}						
741	59	G.N.	Lt bk Mangahao R. 500yds downstm of bridge	196172	t_3	sandstone			9	t_3	Nests of _Zenatia_ Pelicaria Biofacicies

742	59	G.N.	Lt bk Mangahao R. from base of cliff, 400yds N.N.E. of Marima-Mangamaire bridge	198171	t_3	7632cOS	Ww-Wn		13	t_3		Pelicaria Biofacies
743	59	G.N.	Rt bk Mangahao R. W.N.W. of Karearea Trig, 1300 yds N.E. of Marima Mangamaire Rd Bridge	209173	uppermost t_2	7822cM	uppermost Ww-basal Wn	upper neritic	6			<u>Pinna-Offadesma</u> assemblage
744	59	G.N.	Rt bk Mangahao R. 850yds N.W. of Karearea Trig, 50yds W. of Clifton Fault.	210180	t_3	massive very fine sandstone			8			
745	59	G.N.	Base of cliff above low tce, 950yds S.E. of Nikau, 500yds S.E. of Parinui Trig.	217187	t_3	very fine sandstone			7	t_3		Pelicaria Biofacies
746	59	G.N.	Rt bk Mangahao R. 1350yds N.E. of Parinui Trig	Sheet N149 227201	t_3	7841c	upper Ww		2			
747	59	G.N.	Cut Marima-Nikau Rd 850 yds N.N.E. of Marima bridge	196176	t_3	7832C	upper Ww	upper neritic	2			
748	59	G.N.	Rt bk Mangahao R. base of 50 ft cliff, 250yds S.E. of Marima bridge	199166	Lower t_3	very fine sandstone			6			Nests of <u>Stinacolpus</u> sp.
749	59	G.N.	Sml Tce remnant, Lt bk Mangahao R. 950 yds E.S.E. of Marima Sch. 1200yds S.W. of Marima Bridge	191157	t_3	fine sandstone			6	t_3		Pelicaria Biofacies, nests of <u>Stiracolpus</u> and <u>Neomocardium pullchelum</u>
750	59	G.N.	Lt bk Mangahao R. 1100yds S.E. of Marima Sch. 2000yds N.W. of Koti (2) Trig.	191153	lower t_3	7841c	prob. upper Ww		11	t_3	similar or some what warmer than present day	

751	59	G.N.	Slip, Rt bk Mangahao R. 1450yds N.E. of Koti (2) Trig	192147	10' below Chlamys bed $\underline{t}_2$	fine sandstone			26	$\underline{t}_2$	Pelicaria Biofacies
752	59	G.N.	Rt bk Mangahao R. 2000yds S. of Marima Sch. 1050yds N.E. of Confl. with Otangane Stm.	184144	uppermost $\underline{t}_2$	very fine sandstone			4		
753	59	G.N.	Rt bk Mangahao R. 700yds S. of confl.with Otangane Stm.	174138	$\underline{t}_2$	fine sandstone			7		
754	59	G.N.	Rt bk Mangahao R. 700yds S. of confl. with Otangane Stm.	173133	$\underline{t}_1$	7832c	u.Ww	upper neritic	4	$\underline{t}_1$	Zeacolpus. sp. fairly common
755	59	G.N.	Rt bk Mangahao R. below uncon-form. 1150yds N.E. of Mikaera Trig, 1600yds N.W. of Whetu Trig.	168124	E_9	7830cM	Wo-LWw	mid-upper neritic			
756	59	G.N.	1ft above uncon-form. Rt bk Mangahao Rv. 30 ft up bk.	165124	basal $\underline{t}_1$	7830c	Ww		1		
757	59	G.N.	Lt bk Mangahao R. most S. expos-ure from Kopikopiko -Marima Rd.	165128	Lower $\underline{t}_1$	7622c	u.Ww	upper neritic	21		Ostracods
758	59	G.N.	Near Hilltop, 1150 yds N.W. of Koti Trig. 250yds S.E. of Mangahao R.	192142	basal $\underline{t}_2$	concretionary fine sandstone			5	$\underline{t}_2$	
759	59	G.N.	Head of Canyon, 650yds upstm of Confl. with Mangahao R.	182138	$\underline{t}_2$	7832c	Ww-Wn	very shallow water			

760	59	G.N.	W/fall 1500yds upstm of Confl.with Mangahao R. 1950 yds S.W. of Koti (2) Trig.	183132	T_1	5433	Ww-Wn		1			<u>Cardium</u> <u>spatiosum</u>
761	59	G.N.	Lt bk Mangahao R. 400yds E. of Confl.with Otangue Stm.	165128	$\underline{t}_1$	sandstone			5			
762	59	G.N.	Lt bk Mangahao R. 200 yds S.E. of Marima-Kopikopiko Rd.	165129	$\underline{t}_1$	7830c	Ww-Wn	upper neritic	16	$\underline{t}_1$	Slightly cooler than present	Ostracods
763	59	G.N.	Below concr. horizon at base of cliff Rt bk Mangahao R 200yds N.E. of Mikaera Trig	160121	E_9	7831c	Wo	Outer neritic				
764	59	G.N.	Base of cliff, Mangahao R. 1 mile E. of Makaera Trig, 300yds S.E. of confl. with Lt br Ck.	142109	$\underline{t}_2$	7622c	upper Ww-Wn	upper neritic to sub-litoral	2			Zethalia Biofacies
765	59	G.N.	Base of cliff in abandoned meander, 850yds S.E. of Wellington Fault	129108	$\underline{t}_1$	7622c	U.Ww-Wn	sub litoral	5			Nests of <u>Struthiolaria</u> fragments of lignite Pseudononion Biofacies
766	59	G.N.	Gully to Rt of N.W. flowing Stm, 1050yds N.N.W. of Whetu Trig.	172119	E_9	7831cM	Wo					
767	59	G.N.	Gully, 200yds N. of Whetu trig, 1 mile N.E.of Hukanui Rlwy Stn.	174111	E_7	7831cM	Wo					Robulus biofacies - rare pelagics
768	59	G.N.	Rd-cut. Henderson's Rd. 500yds S.E. of Karearea Trig.	220170	$\underline{t}_2$	732cSSS	basal Ww Ww	mid-upper neritic				fragile fossils - bryozoans

769	59	G.N.	Rd cut Henderson's Rd 50yds S. of 768	219169	t_2	7830cM	Upper Wn		2			compare with 742-759
770	59	G.N.	Gully 300yds W. of Puka (T) Trig	287153	uppermost F_{21}	Sandstone						
771	59	G.N.	Gully, 200yds N.of Puka (T) Trig	287153	uppermost F_{21}	7940cM	Upper most Ww Basal Wn		4+			rich microfauna
772	59	G.N.	Ck bed, 10yds W.of Farm bldg 400yds N.W. of Puka (T) Trig	284153	F_{21}	7831c	Upper Ww	mid-lower neritic				
773	59	G.N.	Gully nr S.W. flowing Stm. 1000yds S.W. of Puka (T) Trig	279146	F_{15}	7841cM	upper Ww	Lower neritic				
774	59	G.N.	Head of Ck, 15 ft below 1st 400yds E. of Makakahi Rd	274140	15' below limestone F_8	7931c	Top Ww					
775	59	G.N.	Above bryozoa hzn, 10yds up stm of Tainui Stm Narrows, 15 ft up Rt bk 2000 yds upstm of con-fl. with Mangahao R.	181180	26' above base G_2	7831cM	Ww	upper neritic			At least as warm as present day	
776	59	G.N.	15ft above Lt bk Tainui Stm, 50yds upstm of 775	181181	G_2	fine sandstone	Wn	upper neritic	3			
777	59	G.N.	Lt bk Tainui Stm, 50yds E. of Rd to Henderson's Farm	178182	G_3	3422	Top Ww basal Wn	upper neritic				<u>Notorotalia</u> <u>mangaoparia</u> biofacies - abundant ostracods.
778	59	G.N.	Rt bk Tainui Stm 800yds S.E. of Wellington Fault	177182	G_4	7832cS	Ww-Recent		3	1	Warmer than present day	Restricted marine fauna 3 shell beds each one shell thick - <u>Tawera</u> sp.common and one <u>Ostrea</u> and one <u>Austrofusus</u> shell.
779	59	G.N.	Rd cut Pukohai Rd 250 yds W. of E. Taiko Fault	144110	T_1	weathered limestone 2.5' thick and soft loose friable sandstone						

780	59	G.N.	Sml Tce remnant lt bk Mangahao R.1050yds E. of Kaerarea Trig.	205172	uppermost $\underline{t}_2$	7832OW			8	$\underline{t}_2$		Pelicaria Biofacies
781	59	G.N.	Extreme E.pt of Stm cut Canyon 600yds upstm of confl. with Mangahao R.	205187	$\underline{t}_3$	7622c SSS			2			
782	59	G.N.	Canyon below W/ fall 30yds down dtm of Marima-Nikau Rd Bridge	202189	$\underline{t}_3$				2			
783	59	G.N.	Rd cut, 800yds W. of Rlwy at Mangamaire	220160	$\underline{t}_3$	7840c	u.Ww	lower neritic				A few thin shelled pelecypods & gastropods - too fragile to coll - (<u>N. kingma</u> zone)
784	59	G.N.	Rd cut Marima-Mangamaire Rd 1000yds W. of Rlwy.	218159	$\underline{t}_3$	7831cS	Top Ww basal Wn	neritic prob. Upper				
785	59	G.N.	Rd cut Marima-Mangamaire highway, 300yds E. of intersection with Henderson's Farm, Rd.	216159	Upper $\underline{t}_1$	7832c	U.Ww	mid-upper neritic	4	upp-er $\underline{t}_1$	Simil-ar to pres-ent day or a little cooler	some ostracods
786	59	G.N.	Rt bk of Wah-aoteika Stm, 250yds upstm of confl. with Mangahao R.	158127	$\underline{t}_1$	7822c			4			
787	59	G.N.	Rt bk of Wahaot-eika Stm, 600 yds upstm of confl. with Mangahao R.	155128	uppermost $\underline{t}_1$	7622c	Upper Ww-Wn	upper neritic -sub litoral	7	$\underline{t}_1$		common ostracods
788	59	G.N.	Base of Lst, 300yds S.W. of Henderson's Hmstd, 300yds S.E. of Karearea Trig.	218171	basal G_1	54---			4			

789	59	G.N.	Rt bk of Stm, 200yds S.W. of Parinui Trig	222187	uppermost G_1	34---			3	Bryozoan <u>Ostrea</u>
790	59	G.N.	Rt bk of Stm, 300yds N.E. of Parinui Trig	224190	G_1				6	<u>Chlamys delicatula</u>
791	59	G.N.	Gully downstm of w/fall 900 yds N. of Karearea Trig	214182	$\underline{t}_3$	7822			12 $\underline{t}_3$	
792	59	G.N.	Lst, 900yds N. of Karearea Trig halfway uphill	215182	T_5	shell bed gdg to limestone			7 $\underline{t}_3$	
793	59	G.N.	Track, at slip 500yds E. of Masterton-Woodville state Highway	279174	F_{21}	7832	Ww		5+	Molluscs suggest a depth of deposition of 200-400 metres - some sponge spicules.
794	59	G.N.	Track, 800yds E.N.E. of Pahiatua Trig	280173	F_{21}	mainly very fine sandstone				Nests of <u>Nemocardium pullchellum</u>
795	59	G.N.	Gully 1000yds E.S.E. of Pahiatua Trig	283170	F_{21}				6+	Nests of <u>Nemocardium pullchellum</u>
796	59	G.N.	Gully, 1100yds E.S.E. of Pahiatua Trig	283170	30'-G_1 F_{21}	7931M	top Ww basal Wn	mid-upper neritic	3+	
797	59	G.N.	Gully, 900yds E.S.E. of Pahiatua Trig	282168	F_{21}	very fine sandstone			5+ $\underline{t}_3$	
798	59	G.N.	Gully, 900yds E.S.E. of Pahiatua Trig	281168	20' below 797, F_{21}				5+ $\underline{t}_3$	
799	59	G.N.	Sml Stm, 1200 yds S.E. of Pahiatua Trig	282163	F_{21}				4+	Shell bed
800	59	G.N.	Rt bk Makakahi R, 700yds downstm of Hawera Rd bridge	231103		8930cMW				
801	59	G.N.	Rt bk Makakahi R.	237107	8731cMB					

802	59	G.N.	Farm track, 30 yds E. of Makakahi R.	248121		7830cMO	N.F.	N.F.		
803	59	G.N.	Temporary exposure near base of hill-side 1200yds E. of Tutaekara-Masterton-Woodville Rd. intersection.	260143	F_{15}	very fine sandstone			4	
804	59	G.N.	Canyon below w/fall upstm of ft bridge, 650yds upstm from confl. with Otangue Stm.	166139	$\underline{t}_2$				1	
805	59	G.N.	Lt bk stm 550 yds upstm of confl. with Otangue Stm.	167139	$\underline{t}_2$				4	Nests of <u>Struthiolaria papulosa</u>
806	59	G.N.	Lt bk Otangue Stm 450yds upstm of confl. with Mangahao R.	171141	$\underline{t}_2$	fine well sorted sandstone			5	
807	59	G.N.	Rt bk Otangue Stm, 800yds upstm of confl. with Mangahao R.	167141	$\underline{t}_3$	massive sandstone			4	<u>Offadesma</u> and <u>Pinna</u> assemblage
808	60	G.N.	Rt bk Mangara-upiu Stm 600yds upstm of Mang-araupiu Rd Bridge	103052	E_1	7842cC	Wo-LWw	Lower neritic	5+	Many mollusc fragments - pelagics rare
809	60	G.N.	Hillside 30ft above Lt bk Man-garaupiu Stm 700yds upstm of Mangaraupiu Rd bridge	102052	E_2	8930c	Wo-LWw	inner bathyal		Fairly common <u>Stira-colpus</u> shells casts of small pelecypods.
810	60	G.N.	Rt bk Manga-raupiu Stm 1000 yds upstm of Mangaraupiu Rd Bridge	100 050	E_1	7842cMC	Wo		1	Abundant <u>Uvigerina pliozea</u> but little else

811	60	G.N.	Rt bk Mangaraupiu Stm 750yds S.E. of Wellington Fault	097051	650' + E_1, E_2	891cMPC	Wo	Upper bathyal	5			Molluscs-echinoderm spines, a few ostracods
812	60	G.N.	Lt bk of Lt br of Mangaraupiu Stm 450 yds upstm of Mangaraupiu Rd Bridge	105058	E_2	8732c	Wo	Lower neritic				Many mollusc fragments
813	60	G.N.	Lt br of Mangaraupiu Stm, 850 yds E.S.E. of Wellington Fault	103063	$\underline{t}_1$	7332cSS			4	$\underline{t}_1$		Zethalia Biofacies
814	60	G.N.	Lt br of Mangaraupiu Stm, 1000 yds upstm of Mangaraupiu Rd bridge	105064	E_2	8732cC	Wo	Upper bathyal				
815	60	G.N.	Lt br of Mangaraupiu Stm, 800 yds upstm of Mangaraupiu Rd bridge	106064	E_2	8942cC	Wo	Upper bathyal				One deep water Ostracod.
816	60	G.N.	Cliff, base of rt bk Mangahao R. 700yds S.E. of Wellington Fault	121096	$\underline{t}_1$	7630cSC		Sub litoral	4			Zethalia-Pseudononion Biofacies many ostracods present
817	60	G.N.	Lt bk Mangahao R. 300yds S.E. of Wellington Fault	122107	G_7	carbonaceous silt						Not processed
818	60	G.N.	30ft from top of cliff along Rt side of Mangahao R.	128104	$\underline{t}_1$	shell bed			8			
819	60	G.N.	Base of cliff, Rt bk Mangahao R. 1800yds slightly E. of N. of Kakaraki Trig.	127105	$\underline{t}_1$	73--s			8	$\underline{t}_1$		<u>Austrofusus</u> <u>pagoda</u>
820	60	G.N.	"	127105	8' below 819 $\underline{t}_1$	73--cSS			4			
821	60	G.N.	"	127105	15' below 820 $\underline{t}_1$	720cC	Ww-Wn	Sub litoral	8		Similar to present day & wetter	very similar to 816 - <u>Pseudononion parri</u> common.

822	60	G.N.	Rt bk Mangaroa Stm, 500yds S.E. of Wellington Fault	075016	E_2	8742cG	Wo	outer neritic-inner bathyal	3+		some shallow water <u>Pseudononion</u> sp. showing signs of transportation.
823	60	G.N.	Gully 100yds S.E. of East Taiko Fault	089017	E_3	8742c	L.Wo	outer neritic			
824	60	G.N.	Gully, below line of concret. 150 yds S.E. of E. Taiko Fault.	089016	E_3	8931cM	Wo	outer bathyal			compare 815 - possibly a little deeper pelagics not common
825	60	G.N.	Lt br of Mangaroa Stm, 1300 yds upstm of confl. 1400yds S.E. of Wellington Fault	090042	E_2	7832c	Wo				
826	60	G.N.	Lt br Mangaroa Stm, 1150yds up stm of Rd bridge	091042	E_2	8741c	Wo	outer neritic			Molluscan fragments - <u>Stiracolpus</u> <u>Chlamys</u> - Micantapex - pelagic foraminifera not common.
827	60	G.N.	Lt br Mangaroa Stm 700yds upstm of Rd bridge	096041	E_1	7831cC	Wp-Ww	mid-outer neritic			
828	60	G.N.	Lt bk Ngamaia Stm 500yds upstm of confl. with Mangatainoka R.	047964	R_3				2		2 shell bands present
829	60	G.N.	Rt bk Ngamaia Stm. 550 yds upstm of confl. with Mangatainoka R.	047964	above 828 R_3	7830c	N.F.	N.F.	4	uTt	<u>Sectipecten</u> <u>grangei</u>
830	60	G.N.	Base of cliff lt bk Mangatainoka R. 500 yds N.E. of Putara Sch.	076985	R_3	7841cC	TK	upper neritic			Shell beds - a few ostracods
831	60	G.N.	Base of cliff Lt bk of Mangatainoka R.	076986	R_3	sandstone			9		<u>Sectipecten</u> <u>granei</u>
832	60	G.N.	"	075987	c50ft above 831 R_3	7841cSC	Tk				

833	60	G.N.	Lt br of Manga-raupiu stm, 800yds upstm of Mangaraupiu Rd bridge	106068	E_2	8930cGP					Numerous pyrite casts of forams - many Globigerinids unidentifiable.
834	60	G.N.	Lt br of Manga-raupiu stm, 650 yds upstm of Mangaraupiu Rd bridge	108067	E_2	8932cCP	Wo				Pyrite replacing fossil wood.
835	60	G.N.	Lt br of Manga-raupiu stm 450 yds upstm of Man-garaupiu rd Bridge	110065	E_2	8932cMc	Wo could be Ww	outer neritic	6		Zeacolpus relatively common, trace siderite
836	60	G.N.	Gully 800 yds W. of Mangaraupiu Rd.	113047	E_1	7820cC	N.F.	N.F.	1		Weathered
837	60	G.N.	Head of Gully 900yds W.N.W. of Mangaraupiu Rd bridge	111074	E_2	8932cMC	Wo	upper bathyal			
838	60	G.N.	Rt bk of Manga-hao R. halfway up cliff	129107	$\underline{t}_1$	sandstone			1	$\underline{t}_1$	
839	60	G.N.	Shellbed near top of cliff along Rt bk of Mangahao R.	130106	$\underline{t}_1$	sandstone			5	$\underline{t}_1$	Struthiolaria papulosa common
840	60	G.N.	Rt bk Puketi Ck 5yds N. of Taumata Fault, 300yds up stm of Kaitawa Rd bridge	373074	E_2	8942c	Wo or Tk	neritic			Hauserella Biofacies very few Globrotalia sp.
841	60	G.N.	Lt bk Puketi Ck just downstm of large lt br 5 yds S. of Taumata Fault	376075	F_5	7832d	Wo	upper neritic			
842	60	G.N.	At confl. of lge lt br and Puketi Ck.	376075	F_5	7831d	Wo	upper neritic	5		Offadesma-Pinna assemblage Pseudononion Bio-facies - several ostracods.
843	60	G.N.	Rt bk of Lt br of Puketi Ck, 350yds S.E. of Taumata Fault	378073	F_5	sandstone			8		Fauna similar to Pelicaria Biofacies

844	60	G.N.	Lt bk of lt br of Puketi Ck 900yds S.E. of Taumata $F_a$ult.	384069	E_9	7832c	Tk	lower neritic		
845	60	G.N.	Rt bk of lt br of Marino Ck,300 yds upstm of confl. with Rt br.	372099	E_2	8742c	Wo	mixed neritic & bathyal		
846	60	G.N.	Lt bk of Lt br. of Marino Ck, 800 yds upstm of confl. with rt. br.	378098	E_2	8742c	Wo	mixed neritic and upper bathyal	3	Mollusc fragments
847	60	G.N.	Lt br.Marino Ck, 1600yds upstm of confl. with rt. br.	386098	E_2	8932c	Wo-Ww	lower neritic	3	Probable sandy turbidite bed
848	60	G.N.	Sml stm 550yds N.E. of Nelson Farm.	372082	E_2	8932c00	Wo	upper bathyal possibly mixed	2	
849	60	G.N.	Sml stm, 450 yds N. of Nelsons Farm	367385	E_2	8743cM	Wo	upper bathyal - mid bathyal	1	
850	60	G.N.	Hirinakitu Stm, halfway between bridge and confl. with Tiraumea R.	367369	E_2	8743c	Wo	upper bathyal		
851	60	G.N.	Lt bk Hirinakitu Stm 600yds upstm of Kaitawa-Hinemoa Rd bridge	373367	basal shell bed F_5	fine sandstone			3	
852	60	G.N.	Outflow of Agricult. Dam.1400yds S.W. of confl. of Mangaone & Tiraumea R's.	340158	F_{17}	8740c	N.D.	N.D.		
853	60	G.N.	Rt bk of sml. trib. 3100yds E.N.E. OF Koropeke Trig.	333171	Uppermost F_{17}	8731c	upper Ww	upper neritic		
854	60	G.N.	Halfway up hill-side 100yds N. of Mangaramarama Fault.	326180	Uppermost F_{21}	8741c	U.Ww pos Wn	upper neritic		

855	60	G.N.	Near top of hill, 100yds S.W. of native bush 100yds N.W. of Mangaramarama Fault.	326181	G_1	sandy limestone			3	<u>Pelicaria fossa</u>
856	60	G.N.	Rt bk Mangaone R.10yds E. of Kaitawa Fault	337147	F_{15}	7832cM	LWw	mid-upper neritic	1	<u>Nemocardium pullchellum</u>
857	60	G.N.	Rt bk Mangaone R, 100yds S.E. of Kaitawa Fault	338150	F_{17}	7832c			2	<u>Nemocardium</u>; <u>Ostrea</u>
858	60	G.N.	Rt bk Mangaone R.700yds upstm of confl.with Tiraumea R.	348152	F_{17}	8742c	prob LWw		1	<u>Nemocardium</u>
859	60	G.N.	Rt bk Mangaone R.100yds upstm of ft bridge	337137	uppermost F_8	8732c	prob. u.Ww	Lower neritic		Moderately large echinoid spines
860	60	G.N.	Rt bk Mangaoae R.1050yds S.E.S. Koropeke Trig.	328131	Lowermost F_8	7832c	U.Ww	upper neritic	1	<u>Mesopeplum crawfordi</u> common
861	60	G.N.	Rt bk Mangaone R. 1100yds S.E.S. of Koropeke Trig.	328130	uppermost F_5	shellbed			1	Shell bed composed entirely of <u>Mariocrypta</u> sp.
862	60	G.N.	Lt bk Mangaone R. yds S.E.S. of Koropeke Trig.	328127	F_5	78---			2	<u>Mesopeplum</u> common
863	60	G.N.	3ft below concret. hzn at confl.of trib.with main stm 950yds S.W. of Te Aupapa Trig.	368178	uppermost F_{17}	8731cMMOO	U.Ww-Wn			Moderately shallow water fauna, prob. enclosed basin, reduced salinity
864	60	G.N.	Lt bk Makuri R. 100yds W. of Quarry 500yds S.W. of Tuscan Hills Farm.	398144	E_9	7832d	Wo	upper neritic		
865	60	G.N.	Rt bk Makuri R. 550yds W. of Tuscan Hills Farm	397149	basal F_5	7632d	Wo-Ww	upper neritic		Pseudononion Biofacies
866	60	G.N.	Rt bk Makuri R. 150yds N.W. of Tane Fault	388159	uppermost F_5	7832c	L.Ww	Deep neritic or upper bathyal	2	Type locality <u>Melonis zeobesus</u> Vella. Deep water <u>Terebratula</u> sp. and oyster.

867	60	G.N.	Rd Cut Kaitawa-Pahiatua Highway 100yds N.W. of Mangaramarama Fault	344191	F_{21}	massive very fine sandstone	Top Ww -Wn	mid-upper neritic	2	$\underline{t}_3$	
868	60	G.N.	Head of Gully 850yds upstm of confl. with Tiraumea R. 100yds E. of Kaitawa Fault	367195	F_{21}	shell bed	Top Ww-basal Wn	mid-upper neritic			Lenticular 27" thick shell bed containing many <u>Terebratula</u> shells and bryozoans.
869	60	G.N.	Bulldozed Track 150yds N.W. of Tiraumea R.	371199	G_2	7632C			6		
870	60	G.N.	Bulldozed track near top of hill 150yds E. of Kaitawa Fault.	370199	G_2	7832C			5		
871	60	G.N.	Shell bed and 5ft below, at head of Gully 200yds W. of Lge N. flowing stm, 250yds E. of Mangaramarama Fault.	321172	F_{21}	shell bed			8+	$\underline{t}_3$	2' thick <u>Chlamys</u> shell bed in otherwise massive very fine sandstone.
872	60	G.N.	Lt bk Mangaone R. 700yds N.E. of Tane Trig.	323105	E_7	7842cHH	Wo-LWw	upper neritic			
873	60	G.N.	Rt bk Mangaone R.200yds S.W. of Nirvana Trig.	332114	upper E_7	7833c	Wo-LWw				
874	60	G.N.	Lat.30yds W. of Mangaone R.750 yds N.W. of Nirvana Trig.	332123	F_2	53451			5		
875	60	G.N.	Rt bk Mangaone R. 1150yds S.E. of Tane Trig.	327095	E_9	7830d	N.D.	N.D.			Tiny spheriodal siliceous organisms common
876	60	G.N.	Lt bk Mangaone R.900yds S.E. of Tane Trig.	325096	E_7	8742c	Wo	lower neritic	2		Echinoids common

877	60	G.N.	Rd cut Mangaone Valley Highway 500yds S.W. of intersect. with Tane Rd 20yds S. of Ft. bridge	321083	E_9	7831c	Wo-LWw	upper neritic	1	<u>Stiracolpus</u> fairly common very shallow upper neritic
878	60	G.N.	Lt bk Kaitawa Ck downstm of rapids & w/fall, 1600yds W.S.W. of Tuscan Hills Farm	386142	3 ft+F_2 F5	fine sandstone			9+	
879	60	G.N.	Stm rapids, 40yds upstm of 878 - base of F_2 Limy Sst.	"	F_2	coarse sandstone			3	
880	60	G.N.	Rt bk Kaitawa Ck 400yds N.E. of Kaitawa Fault, 1600yds S.W. of Tuscan Hills Farm	389139	E_9	7822dSS	Wo-Ww	neritic		Pseudononion Biofacies
881	60	G.N.	Rt bk Kaitawa Ck 1600yds S.W. of Tuscan Hills Farm	394134	F[illegible]	7832c	Wo-LWw	shallow upper neritic		Ostracods common
882	60	G.N.	Rt bk Kaitawa Ck 300yds N.W. of Tane Fault	380147	uppermost F_5	7832c	L.Ww	mid-lower neritic	2	Haeuslerella Biofacies <u>Neomocardium pullchellum</u>. Large echinoid spines
883	60	G.N.	Lt bk Lt br of Kaitawa Ck 30 yds upstm of confl.	377164	F_{15}	8942c	U.Ww	mid neritic		Haeuslerella Biofacies
884	60	G.N.	Bluff, 100yds N. of Koropeke Fault 350yds N.E. of Koropeke Trig.	328144	30' above base, F_{16}	4551			4+	Type locality <u>Nonionella</u>? sp. Vella
885	60	G.N.	Gully 300yds upstm of confl. with Mangaramarama Stm. 500yds N.W. of Koropeke Trig.	323144	F_{15}	shell bed in very fine sand			3+	
886	60	G.N.	Gully 300yds upstm of confl. with Mangaram-arama Stm 1350 yds N.W. of Koropeke Trig.	315148	F_{15}	7832c	LWw	upper neritic	1	A few thin shelled plcy

887	60	G.N.	Base of Lst. 500yds W. of lge N. flowing Stm, 1700yds N.W. of Koropeke Trig.	313150	F_{16}	7643i					*Echinocardium* sp. common
888	60	G.N.	Gully near head of Rt br. of Mangaramarama Stm.	318169	F_{21}	7830c	post Wo	upper neritic	2	t_3	Type locality *Pacinonion* cf. *parki* Hornibrook, *stiracolpus* fairly common and ostracods present.
889	60	G.N.	Farm track 100yds S.E. of No. 2 Trig	347199	G_2	coarse sandstone			4+		
890	60	G.N.	Stm 1050yds S.W. S. of 3M Trig. 900yds N.E. of 2M Trig	228011	R_5	9832c	Tk	mid-outer bathyal			Abundant pelagic forminfera
891	60	G.N.	1300yds W.S.W. of intersection of Central E. & Rongomai Valley Rds.	234008	R_3	7853dSS.CC	TK	upper neritic			
892	60	G.N.	2000yds N. of Mangaone Va. Highway	281078	E_3	8942c		upper bathyal			Benthic foraminifera rare
893	60	G.N.	Bulldozed track 600yds N. of Mangaone Valley Highway	280065	E_7	7841cM	L.Ww	lower neritic			Probably redeposited microfauna.
894	60	G.N.	From post hole dug in about 1910	246035	R_3	concretionary sandstone					Many shells and a whale's vertebra
895	60	G.N.	Rd side exposure on central Mangaone Rd	241028	R_3						Sample lost
896	60	G.N.	Stm exposure along trib. of Tiratahi Stm.	247049	R_5	9851c	UTt-Tk	Outer bathyal			Type locality *Neouvigerina eketahuna* Vella *Pacinonion neefi* Vella Pelagics rare
897	60	G.N.	From post-hole 20yds N. of Central Mangaone Rd	239029	uppermost R_3	sandstone			1		*Struthiolaria praenutia*
898	60	G.N.	Farm track 400 yds W. of bridge across Mangatainoka River.	099006	uppermost R_3	7842c	UTt	lower neritic	4		rare ostracods

899	60	G.N.	Gully 2000yds S. of Atea	089010	E_3	8942c	Wo	upper bathyal			Globs moderately common but far out-numbered by benthics.
900	60	G.N.	Lt br of Daven-port Stm, 100yds S.E. of Wgtn Fault.	058994	E_2	8932c	Wo	lower neritic			
901	60	G.N.	Confl. of Lt br. with Davenport Stm.	060990	E_2	8932c					
902	60	G.N.	Lt bk Davenport Stm. 500yds up-stm of confl. with Mangatainoka R.	067088	E_1	7832cCC	Wo-Ww	neritic	6	Wo	Probably mixed upper and lower neritic foraminifera
903	60	G.N.	Lt bk Davenport Stm 200yds upstm of confl. with Mangatainoka R.	070087	basal E_1	sandy shelled			9	Wo	Wave sorted shells, <u>Spisula aequilateralis</u> Deshays particularly common
904	60	G.N.	Hillside, 700yds W. of Mangaone R.	305078	E_7	7830cMM	N.F.	N.F.			
905	60	G.N.	50yds W.of Hill summit,3ft below base of Tawatia Sandstone	337064	3'below E_7, E_2	9832c	Wo	mid bathyal			Semipelagic fauna - Globs abundant, near 50% of specimens
906	60	G.N.	Spillway of Farm dam 900yds N. of Eketahuna-Alfred-ton Highway	265982	E_4	9842c	Wo	outer bathyal-abyssal			Globs about 80% of specimens.
907	60	G.N.	Lt bk of Stm, 900 yds S. of Central E. Rd, 900yds E.N.E. of 9M Trig.	257997	E_4	9842c	Wo	lower bathyal-abyssal			Type locality <u>Haeuslerella finlay</u> Vella.
908	60	G.N.	Rt bk. of Makakahi R.300yds N.W. of Soren Trig.	184961	R_5 5.5' below ash bed	9851c	TK				Possibly moderately deep fauna, but odd.
909	60	G.N.	Lt bk Makakahi R. 50yds S. of Masterton-Wood-ville Highway	174955	S_2	8732c	Tk				No foram depth indicators Restricted fauna - lacks Globs.
910	60	G.N.	Rt Bk Makakahi R. 1000yds S.W. of Soren Trig.	179952	R_5 very near base	9832c	Tk	mid to Upper bathyal			Type locality <u>Bolivinita pliobliqua</u> Vella <u>Hofkeruva (Tereuva) lutorum</u> Vella, pelagic forams common not abundant.

911	60	G.N.	Rt bk Makakahi R.1400yds E.S.E. of Smiths Rdge Trig.	176947	Upper R_3	7831cC	TK	upper neritic	14	TK?	Secti pectin grangei Plant fragments common
912	60	G.N.	Rt bk Makakahi R. 30yds up stm of Masterton-Woodville Highway bridge	184965	S_2	very fine sandstone					Common brachiopods - sample lost - no shells present in outcrop October 1962.
913	60	G.N.	Rt bk Makakahi R. 600yds W.S.W. of Eketahuna Cemetery	187981	uppermost E_3	9832c	Wo	mid bathyal			Microfauna Semipelagics Globs moderately abundant
914	60	G.N.	Lt bk Makakahi R. halfway between Rd and Rlwy bridges	199016	E_4	9832c	Wo	mid bathyal			
915	60	G.N.	Rt bk Makakahi R. 800yds E. of Masterton-Woodville Highwy	206022	E_4	8931c	Wo	very deep			Redeposited shallow water foraminifera
916	60	G.N.	Stm, 7yds dwnstm of w/fall 1200yds S.E.S. of Mt Heale Trig.	269083	uppermost E_3	9833c	Wo	lower bathyal			Type locality Sigmoilopsis zeaserus Vella Hofkeruva (Trigonouva) pliozea - Vella - Noviuva zealandica Vella - Globs more 50% of sample.
917	60	G.N.	Rt bk Mangaoranga Stm 500yds E. of Quarry site on Mangaoranga Rd.	217964	R_5	9843c	Wo-LWw prob LWo	lower-mid bathyal			Some fishscales and fish teeth abundant pelagic foraminifera
918	60	G.N.	Mangaoranga Stm 100 yds W. of Rlwy.	194986	lowermost E_4	8932c	Wo	about mid bathyal			
919	60	G.N.	Mangaoranga Stm 800yds W.S.W. of Mt. Turner	200983	lowermost E_3	8932c	Wo	mid-upper bathyal			Uvigerina sp. indicates Tk but Glob inflata indicates Wo age.
920	60	G.N.	Rt bk Mangaoranga Stm 100 yds upstm of lge lt br trib.	205973	upper R_3	7831c0	TK	outer neritic to upper bathyal	2	UTt	Callusaria obesa Hutton a few scattered macrofossils and ostracods
921	60	G.N.	Rt bk Mangaoranga Stm.	205972	R_3	7630c			15	UTt	Shells common very carbonaceous

922	60	G.N.	Rt bk Mangatainoka R. 1200yds N.E. of Rlwy bridge	190074	upper E_7	7832c0	upper Ww	outer neritic		Robulus Biofacies? Poor fauna
923	60	G.N.	Rt bk Manga-tainoka R. 100 yds N. of Kamaru Trig.	193079	E_8	8932c	Wo-LWw	upper bathyal		Globs relatively uncommon
924	60	G.N.	Stm. 1100yds upstm of Rd bridge	363031	E_2	8932cM	Up.Ww	lowermost neritic-upper bathyal		Globs rare
925	60	G.N.	Stm. 1200yds S.W. of Pori Rd.	378018	F_8	8933c	U.Ww	mid neritic		Globs rare
926	60	G.N.	Confl. of Lt.br. trib. with Main Stm 1600yds W.S.W. of Rutea Stn.	374037	E_2	8933c	LWw	mid-lower neritic		<u>Astrononion</u> cf. <u>nova zealandica</u> abundant
927	60	G.N.	Hirinakitu Stm. 2000yds upstm of Kaitawa-Hinemoa Rd bridge	386060	E_2	8732cM	Wo	mid-upper bathyal		
928	60	G.N.	Lt br of Hirin-akitu Stm 150yds upstm of confl. with rt.br.	398064	F_5	sandstone			2	
929	60	G.N.	Rt br of Hirin-akitu Stm 250yds upstm of confl. with lt.br.	396066	F_5	7831cM	preWw	Pseudo-nonion sub litoral		Several ostracods
930	60	G.N.	Rt.br. of Hirin-akitu Stm 950yds W. of Intersect. of Mt Marchant & Pori Rds.	401070	F_5	7832c	U.Ww	very shallow upper neritic		
931	60	G.N.	W/fall 650yds S.E.S. of Watta Trig 1150yds from stm-Tiraumea R. confluence	352064	lower E_4	8942c	Wo	mid bathyal		Globs mod abundant
932	60	G.N.	Confl. of L.& R. br.trib.,900yds upstm from confl. with Tiraumea R.	364017	E_2	9840c	Wo	mid-upper bathyal		Rather poor fauna

933	60	G.N.	Rt.bk.Tiraumea R.600yds upstm of confl.with Te Hoe Stm.	348013	E_2	8942cM	Wo-LWw			
934	60	G.N.	Rt.bk.Tiraumea R.800yds dwnstm of confl. with Te Hoe Stm.	345019	E_2	8732c	Wo-Ww			
935	60	G.N.	Stm,100yds dwn stm of confl. with lt.br.trib.1500 yds N.W. of Ruatea Stn	378045	E_2	8932c	Wo	upper bathyal to lower-most neritic		Globs mod abundant
936	60	G.N.	Stm 1000yds E.S.E. from Makakikatea (L) Trig	385111	E_2	8732cBB	Wo	upper bathyal		
937	60	G.N.	Stm 400yds upstm of Kaitawa-Hinemoa Rd	365057	F_5	7832c	LWw	upper neritic		Type locality <u>Astron-onion</u> <u>vadorum</u> Globs very rare
938	60	G.N.	Lt.br.of Makuri R.1 mile upstm of confl.	439127	F_5	sandstone			1	
939	60	G.N.	Rt.br.stm 400yds upstm from confl. with lt.br.	434129	F_5	7821c		Pseudo-nonion facies shallow		
940	60	G.N.	Culvert Pahiatua-Pongoroa Highway	422130	E_2	8742c	Wo LWw	neritic		Ostracods common Haeuslerella Biofacies
941	60	G.N.	Rd Cut 100yds east of Makuri R.	408139	E_2	8732c	Wo	neritic		Haeuslerella Biofacies
942	60	G.N.	Cut, Puketoi Rd 900yds E.S.E. of Farmhouse	450062	E_9	7831c	Wo? (Tk-Ww)	shallow water		Haeuslerella Biofacies
943	60	G.N.	Cut Puketoi Rd, 750yds W.N.W. of Skye Farmhouse	435068	F_9	7833c	Wo	shallow neritic		Type locality <u>Pacinon-ion novozealandicum</u> Vella and <u>Pacinonion poriensis</u> Vella. Abund-ant ostracods - echinoid spines - specimens ex-tremely abundant & many species but many some-what worn.

944a	60	G.N.	Rd cut Puketoi Rd 1000yds N.W. of Skye Fm	434070	F_9	very fine sandstone				
944b	60	G.N.	Cut Mt Butters Rd 700yds N.E. of intersect. with Puketoi Rd	424087	F_{13}	67351	Wo-LWw	upper neritic		Ostracods abundant Haeuslerella Biofacies
945	60	G.N.	Cut Mt Butters Rd 550yds S.S.E. of Makuri Bridge	SheetN154 45111	F_{12}	sandy limestone	Wo-LWw	neritic		Haeuslerella Biofacies
946	60	G.N.	Culvert, 40yds N.W. of Bridge across Makuri R.	448117	F_9	8733h	L.Wo	neritic		Fauna might be derived from Miocene beds - many ostracods Haeuslerella Biofacies
947	60	G.N.	Ngaturi Ck 50yds dwnstm of confl. with Rt.br.	427174	E_2	8931c00	Wo	lower neritic		Haeuslerella Biofacies many mollusc fragments (thin shelled)
948	60	G.N.	Ngaturi Ck 300 yds dwnstm of confl. with rt. br.		E_2	7832c00M	Wo	outer neritic	1	Haeuslerella Biofacies ostracods prisms of <u>Pinna</u>
949	60	G.N.	Rt.br.Ngaturi Ck at 1st local where stm bed is incised	449173	E_2	8731c	Wo	inner bathyal	4	Robulus Biofacies
950	60	G.N.	Rt.br.Ngaturi Ck at confl. with small lt.br.ck.	439176	E_2	8731c	Wo-LWw	outer neritic-bathyal		<u>Nemocardium pullchellum</u>, ostracods rare - Globs rather rare mollusc fragments abundant.
951	60	G.N.	Rt.br.Ngaturi Ck, 550yds upstm of confl. with Ngaturi Ck.	433175	E_2	8932c	L.Ww	upper bathyal		Robulus Biofacies
952	60	G.N.	Ngaturi Ck 50yds dwnstm of confl. with major trib.	435166	E_2	8931c	LWw	upper bathyal		Robulus Biofacies fragments of thin shelled pelecypods
953	60	G.N.	Ngaturi Ck 300yds dwnstm of ft bridge	417184	E_2	8932c	LWw	innter bathyal	1	Type locality <u>Hofkeruva (Laminiuva) rodleyi tutamoides</u> Vella
954	60	G.N.	Rt.bk.Ngaturi Ck below concret.hor.	411189	E_9	7833c	UWw	lower neritic	1	Mollusc fragments Haeuslerella Biofacies <u>Nemocardium pullchellum</u>

955	60	G.N.	Ngaturi Ck upstm of rapids & w/fall	407190	F_5	7831c	Ww-Wn prob Ww	lower neritic	1	Haeuslerella Biofacies
956	60	G.N.	Ngatiri Ck dwn stm of rapids and w/fall	404196	F_5	76---			1	Pecten
957	60	G.N.	Ngaturi Ck - rt bk.	Sheet N149 401201	F_8	8732c	Ww-Wn prob Ww	lower neritic		Haeuslerella Biofacies
958	60	G.N.	Kaitawa Ck 1700yds E.N.E. of Makahikaro Trig.	398127	E_2	8732cM	Wo-LWw	outer neritic		Pyramidellid (<u>Odostomia</u>?) sp. <u>Stiracolpus</u> sp.
959	60	G.N.	Kaitawa Ck 10 yds below w/fall 1600yds E. of Makahikatea Trig	398119	E_2	8932cM	Wo	upper bathyal		
960	60	G.N.	Kaitawa Ck 5yds E. of Alfredton Fault	407104	F_5	7830d	N.D.	Pseudononion		Extremely poor fauna - possibly a beach sand - broken shells present.
961	60	G.N.	Rt bk Makuri R. 50yds N. of Makuri Fault	425118	E_2	8941c	Wo	Lower neritic upper bathyal		
962	60	G.N.	From Bartons Line Rd 138yds S. of hilltop	298902	F_5	sandstone			3	<u>Ostrea</u> <u>Phialpecten triphooki</u> <u>Mesopeplum crawfordi</u>
963	60	G.N.	"	298902	F_5	sandstone			2	<u>Phialopecten</u> <u>Panopea</u>
964	60	G.N.	From Bartons Line Rd 52yds S. of hilltop	299903	F_5	sandstone				
965	60	G.N.	From Bartons Line Rd	302907	F_5	sandstone			1	
966	60	G.N.	Rd cut Mangatakoto 1st bend W. of Bartons Line intersect.	304928	C_4	9842c	UTt	mid-upper bathyal		Globs area small percentage of fauna
967	60	G.N.	Nr top of hill-800yds E. of Bartons Line Rd	310906	F_5	shellbed			4	
968	60	G.N.	Rd cut along Bridle track 2200yds S.E. of Mt Baker Trig	275931	E_3	9832c	UTt-Tk	prob mid bathyal		

969	60	G.N.	Rd cut along Bridle track 900yds S.E. of Mt Baker Trig.	263937	E_4	9832c	Wo	outer bathyal-abyssal		Microfauna indicates greatest depth yet found - 90% pelagic foraminiferal species
970	60	G.N.	Gully below w/fall 1800yds S.W.S. of 94 Trig	432942	uppermost C_1	7831d	L-mid Tt	upper neritic	12 L.Tt	Well preserved Hurupi macrofauna
971	60	G.N.	Lt.bk. of Happy Creek 20yds dwnstm of fence 1500yds S.W. of 94 Trig	427949	C_4	9832c	mid Tt	upper bathyal		Type locality *Parafrodicularia wairarapa* Vella
972	60	G.N.	Rt.bk. of Happy Creek 100yds upstm of a lt. br.ck. 1500yds S.W. of 94 Trig	425951	6" above 973, D_1	mud fraction	Tt			
973	60	G.N.	"	425951	6" below 972, D_1	9832c	mid Tt	about mid bathyal		Semipelagic Biofacies
974	60	G.N.	Rt.bk. Happy Creek 2ft below ash bed 900yds upstm of Alfredton-Tiraumea Rd bridge	412965	lowermost E_3	9832c	Tk or basal Wo	mid bathyal		Odd *Globorotalia* looks intermediate between *inflata* & *miozea*.
975	60	G.N.	Rt.bk.Tiraumea R.1100yds W. of Green Ridges Trig	360998	E_2	9832c	Wo-LWw	mid bathyal		Globs about 50% of species.
976	60	G.N.	Rt.bk. Tiraumea R. 650yds S.E. of Moroa Track Trig.	363985	E_2	8732c	LWw	upper bathyal-lower neritic		Possibly a mixed fauna
977	60	G.N.	Rt.bk.550yds upstm of rt.br. of Waipori Stm 1250 yds S.S.E. of Pori (S) Trig.	415030	E_9	7831d	Wo-LWw	mid-upper neritic		Pelagics rare
978	60	G.N.	Lt.bk.750yds upstm of a rt. br. of Waipori Stm. 1000yds S.S.E. of Pori (S) Trig.	414033	F_5	7829d				

979	60	G.N.	From hillside, 800yds S.W. Pori (S) Trig	416035	F_5	fine sandstone			2	<u>Phialopecten triphooki</u> <u>cardium</u> sp.
980	60	G.N.	Stm channel above w/fall Waipori stm 50yds upstm of a lt.br.trib.	425035	E_2	8931cO	Age?	Pseudo-nonion Bio-facies		Sample probably switched with 978.
981	60	G.N.	100yds dwnstm of w/fall in Waipori Stm 1400yds S.E. of Pori (S) Trig.	424034	E_2	siltstone			1	<u>Brissopsis</u> sp.
982	60	G.N.	Lt.bk. Waipori Stm, 1750yds S.S.E. of Pori (S) Trig	418026	E_2	8931cM	Top Wo Lower Ww	Lowest neritic upper-most bathyal		Globs are rare
983	60	G.N.	Rt.bk. lt.br. of Ihuraua Stm, 400yds E. of Alfredton-Masterton Highway	334912	E_9	very fine sandstone			3	
984	60	G.N.	Cut Pori Rd, 1000yds N.N.E. of Pori-Saunders Rd intersect.	391007	E_9	very fine sandstone	N.F.	N.F.		
985	60	G.N.	Lt.bk.nr. head-waters of Mangaone Rd, 150yds N. of Alfredton-Eketahuna Highway	257976	E_4	9833c	Wo	mid-upper bathyal		Very abundant pelagics
986	60	G.N.	Outflow of Pond, 50yds N. of Alfredton-Eketahuna Highway, 700yds W. of 16M Trig.	261973	E_4	9832cM	Wo	Lower-mid bathyal		
987	60	G.N.	Rd cut Alfredton-Eketahuna Highway 50yds E. of 16M Trig	268974	E_4	9832c	LWw	upper bathyal		Robulus Biofacies

988	60	G.N.	Cut Alfredton-Eketahuna Highway 650 yds E. of 16M Trig.	274973	E_4	9832c	LWw	upper bathyal		
989	60	G.N.	Waipori Stm, 2200yds S. of Pori (S) Trig	412020	E_2	8731cMBB	Wo-LWw	lower neritic	5	Globs not common
990	60	G.N.	Rt.br.460yds upstm of confl. with Waipori Stm	402021	E_9	7833c	Wo	neritic		
991	60	G.N.	Tiny stm near source 1800 yds S. of Mangatakoto Rd 400 yds N.W. of Alfredton Fault	294909	Lowermost D_1	9851c	T	upper neritic, & deep water species		Very poor fauna
992	60	G.N.	500yds upstm of confl. at lge stm & Te Hoe Stm, 750yds N. E. of Bee Hill.	348971	E_2	8932c	Wo	upper bathyal-lower neritic		Globs not common
993	60	G.N.	Stm 950yds upstm from confl. with Tiraumea R,600 yds E.N.E. of Green ridge Trig	380000	E_9	7832c		upper neritic		
994	60	G.N.	Lk.bk.lt.br. of Waipori Stm, 900 yds N.E. of Green Rigges Trig	377104	F_5	sandstone			2	Panopea
995	60	G.N.	Lt.bk. Tiraumea R. 1000yds N. of Kaitawa Trig	397982	E_2	8930cM	Wo	Lower neritic-& bathyal		
996	60	G.N.	Lt.bk.Tiraumea R. 750 yds N.E. of Kaitawa Trig	401977	E_2	8942c	Wo prob upper Wo	mid-upper bathyal		Globs much less than 50% of specimens
997	60	G.N.	Lt.bk. Tiraumea R. 1500yds N.E. of Kaitawa Trig	409980	E_2	8930c	Wo-LWw	bathyal		Poor fauna
998	60	G.N.	Lt.bk.Tiraumea R.1200yds E.N.E. of 97 Trig	421980	E_2	8932c	Wo-Ww	mid neritic		

999	60	G.N.	Dozed track 750yds N.W. of Camp Trig, 1200 yds W. of Kempthorn Trig	318966	E_2	8932c		Up Wo	lower neritic		
1000	60	G.N.	Farm track, S. of saddle, 2000 yds N.W. of Alfredton	316972	E_7	8932c		Wo	inner bathyal		Robulus Biofacies
1001	60	G.N.	Farm track 1900 yds W. of Timahanga Trig, 300 yds N.W. of Peep-o-day Fault	313083	uppermost E_3	8932c		Wo	inner bathyal		Robulus Biofacies
1002	60	G.N.	Cut Faulkner Rd nr.base of Hill, 200yds S.E. of intersect. with Priests Rd.	142000	E_4	8920cC		N.F.	N.F.		
1003	60	G.N.	Farm track, 1300 yds N.N.E. of intersect. of Priests Rd & Eketahuna-Nireaha Highway 200yds S.E. of Huru Fault	139065	E_4	8730c		N.F.	N.F.		
1004	60	G.N.	Culvert by cliff, 3yds E. of Masterton-Woodville St Highway 100yds N.W. of Te Awe Awe Rd. intersection	211080	E_9	7831cM		N.F.	N.F.		
1005	60	G.N.	Gully, 1100yds S. of Kamaru Trig, 150yds E. of rlwy bridge, Mangatainoka R.	196067	E_7	7833cB		Wo	mid bathyal		
1006	60	G.N.	Rt.bk.Makakahi R.300yds upstm of confl. with Bruce Ck.	144928	R_5	9832c		Tk	outer bathyal Abyssal		No pelagics, almost barren of pollen
1007	60	G.N.	Rt.bk.Makakahi R,300yds N.W. of KaiparoroRd-Masterton-Woodville-Highway intersect.	135927	S_2	7822		Tk		1	Sample lost

1008	60	G.N.	Lt.bk.Makakahi R.700yds N.W. of intersect. of Kaiparoro Rd with Masterton -Woodville St. Highway	131928	E_3	9832c	L.Ww	mid-outer bathyal		
1009	60	G.N.	Lt.bkof Stm, 700yds upstm of confl. with Bruce Stm	127914	20' below S_4, S_2	7832c	Tk	mixed neritic-bathyal	1	<u>Neothyris</u> cf. <u>ovalis</u>
1010	60	G.N.	Gully 2450yds NE.of Makakahi (J) 300yds S.E. of Huru Fault	119968	E_4	8740cC	Wo-LWw			
1011	60	G.N.	Lt.bk.of stm, 1900 yds N.E. of Makakahi (J) Trig,250yds S.E. of Huru Fault	116962	E_3	9842c	Wo	mid bathyal		Pelagic foraminifera abundant
1012	60	G.N.	Lt.bk.of stm, 2850yds N.W. of intersect. of Morgan & Faulkner rds	122964	E_3	9832c	Wo	upper-mid bathyal		Robulus Biofacies
1013	60	G.N.	Cut Faulkner Rd 1100yds S. of intersect. with Parkville Central Rd	143972	E_4	8930cC	N.D.	N.D.		Decorticated pyrite casts of foraminifera
1014	60	G.N.	Cut, Kaiparoro-Hastwells Rd, 250yds S.E. of intersect. with Masterton-Woodville Highway	162924	R_5	9831c	UTt-TK prob TK	mid upper bathyal		
1015	60	G.N.	Cut Kaiparoro-Hastwells Rd, 150 yds N. of Mt Munroe intersect.	170907	E_4	9832c	Wo	lower bathyal-abyssal		Pelagic foraminifera 80-90 percent of total foraminifera
1016	60	G.N.	Rd-cut Bowen Rd 9yds S. of Rlwy bridge	206921	E_4	9832c	Wo	upper-mid bathyal		Type locality <u>Neouvigerina</u> <u>bellula</u> Vella <u>Melonis</u> <u>lutorum</u> Vella Pelagics abundant but less than 50% of the specimens.

1017	60	G.N.	Lt.bk.of Stm 30ft. below Bowen Rd, 850yds S. of Routley Trig	215933	E_4	9832c	Wo	mid bathyal outer bathyal		Semi pelagic Biofacies
1018	60	G.N.	Cut Bowen Rd 650yds N.N.E. of Routley Trig	216948	uppermost E_4	8930cC	N.F.	N.F.		
1019	60	G.N.	Cut No.1 S. Rd 600 yds W. of intersect. with Masterton-Woodville Highway. 900yds N.E. of Smiths Ridge Trig	168955	E_4	9832c		outer bathyal-abyssal		
1020	60	G.N.	Lge Rt.br.stm. 10yds upstm from confl. with Ngatahaka Stm.	163971	E_4	9832c	Wo	mid-outer bathyal		Globs fairly abundant nr. 50% of specimens
1021	60	P.V. G.O.		293906	D_1	8942dM.C.B.				
1022	60	H.W.W. P.V. G.N.	Lt.bk.Mangahao R. 350yds N.E. of bridge at Marima, 100yds dwnstm of 742	199170	$\underline{t}_3$	fine concretionary sandstone			8 $\underline{t}_3$	Three persistent lines of concretions
1023	60	H.W.W. P.V. G.N.	"	199170	0-3.5' + 1022, $\underline{t}_3$	shell bed 3.5' thick			10 $\underline{t}_3$	
1024	60	H.W.W. P.V. G.N.	"	199170	0-60' + 1023, $\underline{t}_3$	muddy very fine sandstone			20 $\underline{t}_3$	
1025	60	H.W.W. P.V. G.N.	Rt.bk. Mangahao R,650yds N.W. of Karearea Trig	210175	uppermost $\underline{t}_2$	massive very fine sandstone			3	<u>Offadesma</u>-<u>Pinna</u> faunal assemblage
1026	60	H.W.W. P.V. G.N.	Rt.bk.Mangahao R. 650yds N.W. of Karearea Trig 100yds dwnstm of 1025	210175	10' above base $\underline{t}_3$	massive very fine sandstone			6	5' above shell bed
1027	60	H.W.W. P.V. G.N.	Near top of hill 900yds N. of Karearea Trig	216182	10-20' G_1 $\underline{t}_3$	very fine sandstone			2	<u>Neomocardium pulchellum</u> abundant

1028	60	H.W.W. P.V. G.N.	Track, at Hukanui Tce edge, 600yds S.W. of Karearea Trig.	211169	uppermost $\underline{t}_2$	concretionary very fine sandstone		5	$\underline{t}_2$		Pelicaria Biofacies
1029	60	H.W.W. P.V. G.N.	Wahaoteika Stm 1800yds upstm from confl. with Mangahao R. 850 yds S.E. of Wgn Fault	143132	40' below 1095, G_7	thin carbonaceous silty clay				cooler than pres-ent	Material of non marine aspect 175' above Ostrea bed.
1030	60	H.W.W. P.V. G.N.	"	143132	50' above 1097, G_9	"				cooler & drier than pres-ent	
1031	60	H.W.W. P.V. G.N.	Wahaoteika Stm 100dys S.E. of Kopikopiko Rd, 20yds S.E. of Wgtn Fault	142143	G_7	1' thick carbon-aceous silt					
1032	60	H.W.W. P.V. G.N.	Hillside 30ft above lt.bk. Daven-ports Stm 1000 yds upstm of confl. with Mangatainoko R.	062990	E_2	sandy siltstone	unwashed	13			Many Pelecypoda and Gastropod species
1033	60	G.N.	Lt.bk. Mangatain-oka R.350yds dwnstm of Davenports Ck.	075987	R_3	fine concretionary sandstone		2			Not in place, decorticated _S_ _obesa_
1034	60	G.N.	S. flowing stm, 1500yds S.E. of 10M trig	253106	E_9	massive muddy micaceous very fine sandstone	unwashed				
1035	60	G.N.	R.br. of Manga-ramarama Ck 750yds N.W. of Mt Heale Trig	256097	E_9	from fossiliferous concretion - not in place		3			
1036	60	G.N.	Lt.bk. of lt. br.of Mangaram-arama Ck 200yds upstm of confl.	292119	E_9	massive very fine sandstone	unwashed				
1037	60	G.N.	Base of Lst, 900yds E.N.E. of Pahiatua Trig.	281173	G_1	coquinoid limestone		2			

1038	60	G.N.	Nr base of Lst. 900yds E.N.E. of Pahiatua Trig.	282173	G_1	soft rubbly limestone		4	
1039	60	G.N.	Hillside east of lge Lt.br. of Pohehe Ck, 2500yds E. of Pahiatua (A) Trig	298968	50'-G_1, F_{21}	massive light blue grey sandy silt, some concretions	unwashed	3+	Ostrea sp, Atrina Nemocardium pullchellum
1040	60	G.N.	E. of Rt.br. of Pohehe Ck, at top of low hill	304172	G_1	fossiliferous limestone many Balanus fragments		3	Pelicaria fossa, Aeneator sp. Chlamys delecatula
1041	60	G.N.	Gully at head of W.flowing Stm. 1100yds S.W. of Taiepa Trig, 150yds N.W. of Tota-ranui Fault	297178	F_{21}	massive, weathered fine sandstone			
1042	60	G.N.	Lt.bk.Manga-oranga Stm, 500yds N.W. of Quarry	210968	R_2	983--			No pollen in sample
1043	60	G.N.	"	210968	5' above 1042 R_2	2 inch thk carbon-aceous horizon			
1044	60	G.N.	Lt.bk.Otangane Stm, from shell bed, 1 mile upstm of confl. with Mangahao R.	159149	G_1	sandy concret-ionary shell bed		10	
1045	60	G.N.	Base of Lst. 1400yds S.W. of Marima-Mangamaire Rlwy crossing	217150	G_1	36--		5	
1046	60	G.N.	Sdy.lst.rt.bk. S. flowing trib. of Mangamaire Stm.900yds N. of Koti (2) Trig	203144	T_1			1	
1047	60	G.N.	Gully 850yds N. of Koti Trig	203145	$\underline{t}_1$	concretionary fine sandstone		3	

1048	60	G.N.	Lt.bk.Mangatainoka R.1950yds E. of Taiko (T) Trig.	096062	E_3	mudstone, 3 concretionary horizons	unwashed				Some lignite gragments
1049	60	G.N.	Shell bed 20 ft above bed of lt. br.trib.850yds upstm of confl. with Mangahao R.	189161	$\underline{t}_3$	1' shell band in otherwise massive very fine sand	"	6		Probably a little cooler than the present day	P. rugosa shell bed
1050	60	G.N.	5 ft above stm bed	189161	15' below 1049, $\underline{t}_3$	massive fine sandstone		1		"	
1051	60	G.N.	Lt.bk.Mangahao R.100yds dwnstm of750 (fosloc) 1200yds S.E. of Marima Schl.	191152	basal $\underline{t}_3$	very fine sandstone & sandy siltstone		4	$\underline{t}_3$		
1052	60	G.N.	Rt.bk.Mangahao R. 1600yds S.E.S. of Marima Sch.	187143	above T_3 $\underline{t}_2$	massive very fine sandstone		1			
1053	60	G.N.	Lt.bk.Mangahao R.1250 yds S. of Marima Sch.	181147	$\underline{t}_3$	concretionary fine sandstone		4			
1054	60	G.N.	Nr head of ck, 1400yds N.W. of Central Mangamahoe Rd-Mangamaire Rd intersec-	230918	basal F_8	muddy siltstone	unwashed				
1055	60	G.N.	Rt.bk.rt.br. of Ngatahaka Ck,1500yds N.N.E. of Smiths Ridge Trig	160963	E_4	Composite turbidite bed		1			Caryophyllia coronatus (coral)
1056	60	G.N.	Rt.bk.of Ngatahaka Ck,800yds dwnstm of Faulkner Rd bridge	147163	E_4	Thin pelagic mudstone overlying turbidite bed		1			3 deep water pelecypods N.sp.aff. Procardia
1057	61	G.N.	Lt.bk.Ngamaia Stm, 300yds S.E. of Wgtn Fault.	044969	E_1	pebbly fine sandstone		5			

1058	61	G.N.	Lt.bk.Ngamaia Stm,200yds up stm of confl. with Mangata-inoka R.	047962	R_3	Concret. horizon in fine sandstone			
1059	61	G.N.	Lt.br.Ngatahaka Cr,1050yds E. N.E. of Rongokokako Dairy Factory	151091	E_3	mudstone	not washed		
1060	61	G.N.	Rt.bk.Mangaora Stm.1050yds up stm of confl. with Mangatain-oka R.	109036	E_3	massive silty mudstone	"		
1061	61	G.N.	Rt.bk.of rt.br. of Ngatahaka Ck 450yds S.of W. end of Morgan Rd	122938	E_3	mudstone	not washed		
1062	61	G.N.	Stm. W.of fence, 350 yds N.W. of W. end of Morgan Rd.	119944	E_2	silty very fine sandstone			
1063	61	G.N.	W.flowing trib. of lge S.flowing Stm. mile S.E. of rlwy bridge	221900	F_6	muddy siltstone	not washed		
1064	61	G.N.	100yds dwnstm of 1063	6"below uncon-formity 221900	E_9		not washed		
1065	61	G.N.	Lt.bk.of lt.br. of Mangaoranga Stm 900yd upstm of confl.	201967	R_3	fine sandstone with concretion-ary horizons		1	
1066	61	G.N.	Lt.bk.of lge lt. br of Waipori Stm 950yds up stm of confl. 1000yds E.N.E. of Rata (M) Trig	441013	E_2	muddy siltstone	not washed		
1067	61	G.N.	350yds N.E. of Tiraumea (2) Trig.	449993	basal E_3	mudstone	not washed		Almost barren of pollen
1068	61	G.N.	Rt bk Makuri R. 1550yds dwnstm of bridge	433113	F_9	fine sandstone		2+	<u>Pelicaria</u> sp.

1069 61	G.N.	200yds upstm of 1068	435114	uppermost F_9	silty fine sandstone	3+		
1070 61	G.N.	Hillslope 1050 yds W.S.W. of Skye Farm	431063	uppermost F_9	fine sandstone	4+		
1070a 61	G.N.	500yds S.W. of Rangedale Farm 150yds N.W. of Rangedale Fault	418073	F_{18}	silty mudstone	2		*Chlamys* bed, 2' thick
1072 61	G.N.	Lge rt.br.of Makuri R.850yds upstm of Pahiatua-Akitio via Pongaroa main highway	398166	F_2	fossiliferous limy sandstone	7		
1073 61	G.N.	Tainui Stm lt. bk. 400yds dwn stm of G_1 Lst.	185177	upper $\underline{t}_3$	massive fine sandstone	4	$\underline{t}_3$	Common nests of *Stiracolpus* sp.
1074 61	G.N.	Tainui Stm Lt. bk. 1200yds up stm of Mangahao R.	188174	$\underline{t}_3$	massive fine sandstone	4	$\underline{t}_3$	
1075 61	G.N.	Tainui Stm, 15 ft above stm 100yds W. of 1076.	187173	$\underline{t}_3$	concretionary shell bed	3	$\underline{t}_3$	Pelicaria Biofacies
1076 61	G.N.	Tainui Stm lt. bk. base of cliff 1050 yds upstm from Mangahao R.	188173	$\underline{t}_3$		4		
1077 61	G.N.	Tainui stm rt.bk. base of cliff at confl. with ft. br.100yds S.W. of 1073	184176	$\underline{t}_3$	massive blue grey sandstone	2	$\underline{t}_3$	
1078 61	G.N.	Mangahao R. lt. bk. 450yds upstm of Otangue Stm	173135	$\underline{t}_1$	very fine sandstone	1	$\underline{t}_3$	
1079 61	G.N.	Mangahao R. lt. cliff lwr sh.bed 1150yds upstm of Otangue Stm	167132	$\underline{t}_1$	fine sandstone	9	$\underline{t}_3$	
1080 61	G.N.	Sml.rt.br. of Mangahao R.rt. bk.100yds upstm of confl.	169128	$\underline{t}_1$	weathered rusty brown fine sandstone	3	$\underline{t}_1$	*Cardium spatiosum*

1081	61	G.N.	Mangahao R.rt. bk.350yds dwnstm from Otangue Stm	178142	$\underline{t}_2$	massive silty very fine sandstone		$\underline{t}_2$	
1082	61	G.N.	Mangahao R. base lt.cliff 1300yds S.W. of Marima Sch.	178147	$\underline{t}_3$	massive fine sandstone		$\underline{t}_3$	
1083	61	G.N.	Sml rt.br.gully of Owhaia Ck 2000yds S.W. of Puka (T) Trig	273137	50'-G_1 F_8	shell bed in very fine sandstone			2' thk <u>Chlamys</u> bed occurs above sands, with <u>Marama</u> <u>murdochi</u>
1084	61	G.N.	Rt.bk.lge nth flowing Stm,1600 ydsN.E. of Nirvana Trig	347125	F_5	massive very fine sandstone	5		Some broken fossils
1084 A	61	G.N.	Stm 800yds S.W. of Mt Marchant	401077	uppermost F_5	fossiliferous very fine sandstone			
1085	61	G.N.	Hirinakitu Stm 150yds N.W. of Mt Butters Rd	401069	F_5		2		
1086	61	G.N.	Hirinakitu Stm, above w/fall 20 yds E. of Alfredton Fault.	396066	F_5	massive very fine sandstone	3		
1087	61	G.N.	1350yds S. of Skye Farm	442051	F_1	coquinoid limestone	1		Oysters and oyster fragments form the $\underline{F}_1$ Coquinoid limestone.
1088	61	G.N.	R.br. Ngaturi Ck 450yds upstm of confl.	425180	E_2	massive muddy siltstone	5		
1089	61	G.N.	R.br.Ngaturi Ck 1350yds upstm of confl.	433183	E_2	massive muddy silts	5+		
1090	61	G.N.	Hillside 1400 yds S.W. of Tuatea Stn	384028	uppermost F_8	sandy siltstone	5	$\underline{t}_2$	
1091	61	G.N.	Hdwaters trib. Waipori Stm 1350 yds.S.of Ruatea Stn	393027	F_8	muddy siltstone	1		
1092	61	G.N.	Rd cut 5 ft below tce, 550 yds E.of Mangahao Bridge, Mangamaire-Marima Rd.	204167	uppermost $\underline{t}_2$	massive fine sandstone	6	$\underline{t}_2$	Pelicaria Biofacies common crab fossils

1093	62	G.N.	Cut Mangamaire -Marima Rd 100yds W. of (1092)	203167	uppermost $\underline{t}_2$	massive fine sandstone	8	$\underline{t}_2$		
1094	62	G.N.	Cut Mangamaire -Marima Rd 450 yds E. of Mangahao Bridge	202167	$\underline{t}_3$	massive very fine sandstone	2	$\underline{t}_3$		
1095	62	G.N.	Wahaoteika Stm 1800yds upstm of confl. with Mangahao R.	143132	40'+(1029) G_7	fine sandstone and pebbles			poor flora, similar to present day	
1096	62	G.N.	W/fall 50yds upstm of (1095)	143132	25'+(1095) G_7	light blue grey carbonaceous silty mudstone			similar to (1097)	
1097	62	G.N.	Gully 250yds N.E. of Wahaoteika Stm	145133	120'+(1096) G_7	"			cooler than present, but warmer than (1098) & (1030)	15 ft below G_9
1098	62	G.N.	Gully 250 yds N.E. of Wahaoteika Stm	144135	155' +(1030) G_7	light blue grey carbonaceous silty mudstone			cooler & drier than present	
1099	62	G.N.	Sml.rt.br. Mangahao R. 100yds upstm of confl. 1000yds,dwnstm of Mangahao Bridge	195157	$\underline{t}_3$	massive fine sandstone	2	$\underline{t}_3$		
1100	62	G.N.	100yds upstm of (1099)	195156	$\underline{t}_3$	massive very fine sandstone	4	$\underline{t}_3$		
1101	62	G.N.	75yds upstm of (1100)	196155	$\underline{t}_3$	massive fine sandstone	1	$\underline{t}_3$		
1102	62	G.N.	Makuri R.rt. bk. 1250yds E. of Te Aupapa Trig.	389182	uppermost F_{15}	massive very fine sandstone	6	$\underline{t}_3$		

1103 62	G.N.	Makuri R.rt.bk. under Ft bridge	390187	uppermost F_{15}	sandy siltstone	1		
1104 62	G.N.	Makuri R.rt.bk. 550yds dwnstm of Ft bridge	388192	F_{17}	shell bed	9	L.Tt	Macrofossils collected above 4.5° angular interformational unformity
1105 62	G.N.	Lge lt.br. [illegible] of Tiraumea R. 1650yds S.E. of N94 Trig.	449945	C_1	massive fine sandstone	5		Hurupi Macrofauna
1106 62	G.N.	100yds dwnstm of (1105)	449946	C_1	massive fine sandstone	3	LTt	" "
1107 62	G.N.	Farm track 700 yds N.E. of Ngarata Farm Bldgs	448940	C_1	concretionary fine sandstone	13	LTt	" "
1108 62	G.N.	Lt.bk.Patup-aiarehe Stm 20yds W. of Rd	139122	$\underline{t}_2$	shell bed	3		
1109 62	G.N.	50yds upstm of (1108)	139122	$\underline{t}_3$	fine sandstone	4		
1110 62	G.N.	Mangahao R. 800yds W. of Mikaera Trig	150120	$\underline{t}_1$	massive very fine sandstone	4	$\underline{t}_1$	
1111 62	G.N.	Gully 900yds N.W. of Kaikaera Trig	150124	$\underline{t}_1$	massive fine sandstone	5		
1112 62	G.N.	Track 1700 yds N.N.E. of Green Ridges Trig.	376014	F_8		3+		
1113 62	G.N.	Gully 700yds W. of Tiraumea Bridge	344183	F_{17}	massive very fine sandstone and some siltstone	2+	$\underline{t}_3$	
1114 62	G.N.	L.br.Manga-raupiu Stm 950yds upstm of Mangoraupiu Rd bridge	101150	E_1		1	Wo	<u>Struthiolaria obesa</u>

1115	62	G.N.	75yds upstm of (1114)	100151	E_1		2	Wo	Struthiolaria obesa
1116	62	G.N.	50yds upstm of (1115)	100150	E_1	siltstone	4	Wo	Struthiolaria obesa Coluzea spectablis Powell
1117	62	G.N.	Gully 50yds N. of v.sml lt. br. of Mangahao R.	173147	$\underline{t}_3$	sandy siltstone	1	$\underline{t}_3$	
1118	62	G.N.	Cut Kopikopiko Rd 300yds N. of Otangue bridge	175142	$\underline{t}_3$	very fine to fine sandstone	2	$\underline{t}_3$	Dosinula zealandica
1119	62	G.N.	Cut Kopikopiko Rd 5ft below tce 800yds S.W. of Otangue Bridge	169134	$\underline{t}_2$	massive fine sandstone	1	$\underline{t}_2$	
1120	62	G.N.	Lt.br.Otangue Stm 800yds up stm of confl.	164139	$\underline{t}_3$	massive fine sandstone	1		
1121	62	G.N.	R.br. Makuri R.1050yds up stm of confl.	428134	E_2				
1122	62	G.N.	150yds upstm of (1121)	429136	E_2		1		
1123	62	G.N.	Head of Lge rt. br.of Makuri R.900yds S.W. of Makuri (D) Trig	436142	E_2	muddy siltstone	1		
1126	62	G.N. H.W.W.	Tiraumea R. Rt.bk.1900yds upstm from confl.Mangaone R.	358153	F_8	muddy siltstone		$\underline{t}_3$	
1127	62	J.T.	Bruce Stm, rt. bk.250yds up stm from Makakahi R.	147928	R_3		3		Platyhelia distans Tension woods Common (coral)

1128	63	G.N.	Hillside 950yds N.E. of confl. of Otangue Stm and Mangahao R.	183143	basal $\underline{t}_3$	fine sandstone	3	$\underline{t}_3$	*Pelicaria* sp. identical to those of fossil locality (1094) from fine sand 2-3 inches thick.
1129	63	G.N.	Wahaoteika Stm 200yds upstm of confl. with Mangahao R.	159127	$\underline{t}_1$	fine sandstone	3+		
1130	63	G.N.	200yds upstm of (1129) 650 yds N. of Mikaera Trig	158126	$\underline{t}_1$	" "	9	$\underline{t}_1$	
1131	63	G.N.	300yds upstm of (1130)	156126	$\underline{t}_1$	" "	3	$\underline{t}_1$	
1132	63	G.N.	200yd upstm of (1131)	154127	$\underline{t}_1$	" "	3	$\underline{t}_1$	

<u>Appendix 2</u>: by P. Vella

Foraminiferal Age and Depth Determinations,

Eketahuna District.

Microsamples from Eketahuna district were examined from the points of view of geological age, and paleoecology with special reference to depth of deposition. The bases for most of the age and paleoecological determinations have been set out in a discussion of foraminifera faunas from Mauriceville district, immediately south of Eketahuna (Vella, 1962, Biostratigraphy and Paleoecology of Mauriceville district, New Zealand. Trans. Roy. Soc. New Zealand: Geology, Vol. 1 No. 2 pp. 183-199).

Geological ages were based on the zones shown in Table 1, the zones being assumed to have time-stratigraphic value within the area concerned. The lowest two zones shown in Table 1 were not described in the Mauriceville account but were mentioned by Hornibrook (in Fleming ed. 1959, Lexique Stratigraphique International, fasc. 9., New Zealand). Foraminifera are less reliable than Mollusca in the late Pliocene and Pleistocene zones, and ages of strata within this range have been largely determined by Mr Neef himself.

Since examination of the Eketahuna and Mauriceville microsamples the Tongaporutuan and Kapitean stages have been subjects of detailed micropaleontology studies by G.W. Gibson and J.P. Kennett (Ph.D. theses Victoria University of Wellington). Two species of foraminifera vis. <u>Bulimina aculeata</u> and <u>Textularia kapitea</u>, both of which had previously been regarded as important key species of the Kapitean stage, were discovered by Gibson to occur in the Tongaporutuan Stage considerably lower than Kapitean. Kennett was able to recognise the Kapitean Stage on the basis of other species; and he revised downwards to upper Tongaporutuan some of the Eketahuna strata which had been determined by the writer as Kapitean. Amongst these strata were those in the southern part of region containing the Mollusc Sectipecten grangei.

Depths of deposition were based on the interpretations of biofacies shown in Table 2. These interpretations have been used in other contexts by the writer, and also by Kennett (loc. cit.) and so far there has been no reason to revise them significantly.

Table 1

	Zones in shallow water facies	Zones in deep water facies
Nukumaruan	Zelandica Zone	not represented
Hautawan	Rotunda Zone	————
Waitotaran?	Mangaoparia Zone	————
Waitotaran	Kingmai Zone	————
Waipipian	————	Molestus Zone
Opoitian	Olsoni Zone	Inflata Zone
Kapitean	————	Zeaserus Zone
U. Tongaporutuan	————	Schlumbergeri Zone
M. Tongaporutuan	————	Pohana Zone
L. Tongaporutuan	(Mollusca)	Quadrilatera Zone

Table 2

Biofacies	Inferred Environment	Approximate depth-Range in feet
1. Streblus	estuarine	0 to ?
2. *Zeaflorilus	sublittoral	20
3. Elphidium	upper neritic	20 to 200
4. Haeuslerella	lower neritic	200 to 1,000
5. Robulus	upper bathyal	1,000 to 2,000
6. Semipelagic	mid bathyal	2,000 to 4,000
7. Eupelagic	lower bathyal	4,000 - ?

* Originally named Pseudononion Biofacies.

Appendix 3: Identifications and Notes by H.B. Fell

Echinodermata

This Appendix is subdivided into two parts.

Many samples of lightly indurated upper Tertiary marine strata, originally collected to study the contained foraminiferal fauna, were also found to contain spines and plates of Echinodermata. A study of the spines and plates is contained in Part I.

Part II is concerned with whole or larger fragments of Echinodermata tests.

Part I

Unrolled Spatangoid spines and plates are common in sediments which were deposited under soft bottom conditions, especially in deep water mudstones and siltstones. Spatangoid spines from sandstones are generally more rolled, than those from finer grained sediments, and are considered to have been transported along the sea floor prior to deposition.

Cidaroids and Temnopleurids (Echinodermata) are common in association with mollusca at neritic cepths. Fragments of Echiodermata from the Eketahuna and Te Hoe Turbidite formations are of both spatangoid and Cidaroids and Temnopleurids types.

NGARATA FORMATION

C_1 Sandstone

Fossil Locality

970 Fragments of *Spatangoids*, rolled.

C_4 Mudstone

966 *Spatangoid* spines and *Pseudechinus*-like spines, the latter much eroded and evidently derived from hard-bottom elsewhere (shell-bed perhaps).

971 inderterminable fragments of cidarids, tiny fragments of *Pseudechinus*-like forms (*Brochopleurus*?) and tiny fragments of spatangoids somewhat rolled. Material not identifiable owing to lack of knowledge of Tongaparutuan macrofossils to which these spines might belong.

TE HOE GROUP

TE HOE TURBIDITE

555 Spatangoid spines (soft bottom) and rolled *Pseudechinus*-like spines, suggesting some derivation of material from hard-bottom environment.

SOREN GROUP

MANGAORANGA FORMATION

R_3 Sandstone

911 No trace of echinoderms

Fossil Locality	
	R_5 Mudstone
917	Spatangoids present.
910	No trace of echinoderms.
	KAIPARORO FORMATION
	S_2 Sandstone
1007	Traces of spatangoids and temnopleuroids, indent.
	EKETAHUNA GROUP
	ATEA SANDSTONE
902	Obscure rolled spatangoid spines.
	SAUNDERS SILTSTONE
814, 815 837, 933	Abundant spatangoid spines, soft substrate.
811, 950 959	Abundant though eroded spatangoid spines.
825	Some spatangoid spines and partly dissolved *Pseudechinus* spines, (simulating *Holopneustes*, but not this littoral genus, I think the effect is due to some differential corrosion of the bases).
901	Fragmentary rolled spatangoid spines.
934, 982	Traces of spatangoids.
832, 927 932	No traces of echinoderms.
	EKETAHUNA MUDSTONE
717 731,824	Abundant spatangoids soft substrate.
558	Spatangoid indent, cidarid indent.

Fossil Locality	
968	Indeterminable fragments of cidarids, tiny fragments of _Pseudechinus_-like forms (_Brochopleurus_?) and tiny fragments of spatangoids. All too rolled for identification.
974	Traces of spatangoids and temnopleuroid spines like _Pseudechinus_.
708, 714	No trace of echinoderms.

EKETAHUNA TURBIDITE

1017	Spatangoids abundant.
701, 985	Spatangoids present.
709, 710 727	Sparse spatangoids.
722, 914	Spatangoid spines indicating soft bottom, but a sparse proportion of rolled spines of a regular echinoid, very probably _Pseudechinus_, indicates some derivation of material from hard bottom environment.
706, 915	No evidence of echinoderms.

TAWATIA SANDSTONE

704	Spatangoid plates with crenulate tubercles. Crenulation biased, about 5 large crenulations on one side and about 5 small ones on the other, spines of the same type as at fossil locality 558 evidently associated with plates; crenulation pattern does not match _Echinocardium_, (which has a continuous margin on the side away from the largest crenulations), and I think the material is all to be referred to _Brissopsis_.

Fossil Locality	
872	Much rolled spatangoid plates and spines.
873	Rolled spatangoid spines.
723	Sparse spatangoid spines, soft substrate.

NEWMAN SILTSTONE

876	Rolled spatangoid spines.

TANE SANDSTONE

766	Abundant fairly fresh spatangoid spines, soft substrate.
954	Abundant spatangoid fragments, but rolled.
942	Spatangoids present.
738	Rolled spatangoid spines.
865	Sparse smashed redeposited spatangoids.
881	Sparse rolled redeposited spatangoids.

<u>MAKURI GROUP</u>

MAKURI SANDSTONE

882	First known occurrencefossil of cidaroid _Ogmocidaris_. Full account of genus and its depth range in Pal. Bull. 23 The New Zealand deep-water cidarid, _Ogmocidaris benhami_ may be compared to this species (see illustration of spine on p.28 of same Pal. Bull), but the present species is coarser and more thorny than the living species, and may represent a second species of the hitherto monotypic genus. Known range hitherto Bay of Plenty to Cape Kidnappers.
937	Spatangoids present.

Fossil
Locality

LOWER MAKURI SILTSTONE

925 Abundant spatangoids.

SKYE FARM SANDSTONE

736 Some spatangoid spines, rolled material.

LOWER PORI LIMESTONE

F_{13} Sandstone lens

944b A few fragments of spatangoids.

KOROPEKE SANDSTONE

886 Cidarid *Ogmocidaris* cf. 882 but even coarser spectimen. It may represent a second species, as it appears to intergrade morphologically with deep-water *Goniocidaris*.

856, 859 Abundant spatangoids, soft bottom.

883 Spatangoid spines present.

773 Traces of spatangoids.

UPPER MAKURI SILTSTONE

853 Abundant spatangoids, soft bottom.

863 Sparse smashed redeposited spatangoids.

852 No trace of Echinoderms.

KAITAWA SANDSTONE

733 Abundant spatangoid spines and sparse rolled cidaroids, probably *Goniocidaris*, and some other regular echinoids, indicating derivation from some hard bottom elsewhere.

Fossil Locality

735 Abundant *Pseudechinus* spines and plates, probably *P. albocinctus*. Some rolled indent cidaroid fragments. Spatangoid spines, rather rolled. Asteroid marginal and ambulacral plates, very rolled and indent. General aspect is that of a mixed soft and hard bottom on the outer part of the shelf or beyond it.

734, 867 Abundant spatangoid spines, soft substrate.

888 Spatangoids present.

771 Sparse spatangoids.

MAREMA SANDSTONE

P. Canaliculata zone

754, 757 Traces of rolled spatangoid spines doubtless redeposited.

762 As above, but including some less rolled material.

P. n.sp.aff. *acuminata* zone

743 Some rolled spatangoid spine fragments. Looks redeposited disturbed material.

P. n.sp.aff. *tricarinata* zone

768 Severely rolled *Pseudechinus*, of distant hard bottom origin, and some traces of spatangoid spines; also a little rolled sorted cidaroid material. Suggests outer part of shelf.

746 Some spatangoid spines, soft substrate.

742, 747 No trace of echinoderms.

Fossil Locality

MANGAMAIRE GROUP

G_3 Conglomerate

777 No trace of Echinoderms.

Part II MACROFOSSILS

NGARATA FORMATION

C_3 Sandstone

570 Fragment of arachnoidid, probably Fellaster Durham. Indicates sandy substrate in upper region of shelf.

EKETAHUNA GROUP

SAUNDERS SILTSTONE

811 Araeosoma cf. thetidis (H.L. Clark). After treatment with a clearing lacquer enough characters became visible to show that it is a part of the aboral surface of the echinothuroid Araeosoma; in addition, a number of perfectly preserved spines with their cross-sections are visible. The spine-character, and also the general aspect of the tuberculation, suggests a close affinity with the existing North Island and Queensland species Araeosoma thetidis, though the complete infilling of the axial lumen of the spine distinguishes it from thetidis (where the spine is almost, but not completely, infilled).

Araeosoma ranges from 130 to 1,500 metres. The New Zealand species has been taken at stations on the continental slope between 120 and 400 fathoms; some other stations cover bottom trawls ranging over 40-125 fathoms, and 100-130

Fossil
Locality

fathoms, so that it is not known whether the trawl content came from the upper or lower limit of the range, or from the intermediate depths. However, the Terra Nova reported a specimen from 70 fathoms, and this may probably be considered the upper limit, the species being essentially a slope form, and probably indicating soft-bottom, though the related genus Asthenosoma is reported on hard-bottom in Japanese waters.

Very few fossil records of echinothurioids are known, a few occurring in the Danish chalk and one from the Jurassic of Europe, (the earliest known appearance of the group).

In Recent seas the echinothuroiods are well represented, and their absence from the fossil record may be attributed to their extreme fragility and the sparseness of suitable facies in the Tertiary formations of most parts of the world.

In New Zealand waters the species Araeosoma thetidis ranges from North Cape to Bay of Plenty, but one spine almost certainly referable to the species was taken at a Victoria University Cook Strait Station (VUZ 87) in 400 fathoms. It may be regarded as a clear indicator of the bathyal bottom fauna, and its presence at fossil locality 811 must imply a depth within the range indicated above. The specimen is illustrated in the Treatise on Invertebrate Palaeontology, Vol. U. Echinodermata 3(1) page U.347 Figure 256 (1a and 1b)

981 Brissopsis. sp.

One large internal mould fragment of a specimen that would be about 80mm long, which is insufficiently preserved for species

Fossil Locality

determination. Large <u>Brissopsis</u> of these dimensions occur at the present day only at depths of 250 to 550 fathoms, though smaller immature specimens are occasionally taken when trawling between 70 to 200 fathoms. <u>Brissopsis</u> is a soft bottom indicator.

MAKURI GROUP

KOROPEKE LIMESTONE

884 <u>Apatopygus</u> sp.

This specimen seems closer to <u>Apatopygus papillosus</u> Zittel of the Landon, than to the late Tertiary species; but the material does not permit a precise determination. It is a soft bottom indicator, probably sand or shell sand.

MARIMA SANDSTONE

<u>F</u>.n.sp.aff. <u>acuminata</u> zone

758 <u>Pseudechinus novaezealandae</u> Mortensen, the recent species ranges in distribution from rock pools to the edge of the continental shelf; it has a northern boundary on the East Coast near Napier.

Appendix 4: by J.C. Yaldwyn

Fossil Crabs

Apart from the unidentified crab fragments found in the Newman Siltstone (fossil locality 1035), and the crab finger from the G_1 Limestone (fossil locality 790), all the crab fossils were collected from the Marima Sandstone.

EKETAHUNA GROUP

NEWMAN SILTSTONE

Fossil Locality

1035 Eleven fragments of a Crustacean, two distorted crab fingers

MARIMA SANDSTONE

zone of *Pelicaria canaliculata*

753 A poorly preserved carapace of a goneplacid crab most probably *Carcinoplax* sp.

zone of *P.* n. sp. aff. *acuminata*

751 A complete carapace of a goneplacid crab most probably *Carcinoplax* sp.

An almost complete carapace of *Ommatocarcinus* cf. *macgillivrayi*, with fingers of presumably the same species.

A nearly complete carapace of *Jacquinotia edwardsii*

780 A complete right hand of *Cancer novaezealandiae* and two other fragments of presumably the same species.

Fossil Locality

1093 A well preserved carapace, shaped like a majid crab, with distinctive multi-papillated tubercles.

zone of P. n. sp. aff. tricarinata

1049 The opposing finger tips of Cancer novaezealandiae, and a fragment from presumably the same hand.

742 A well preserved carapace and both hands of a goneplacid crab most probably Carcinoplax sp.

1109 An isolated finger of Ovalipes. cf. punctatus

MANGAMAIRE GROUP

TOTARANUI FORMATION

G_1 Limestone

790 One isolated finger about 2 inches long similar to Jacquinotia including the little parallel ridges on the inner edge, but identification cannot be certain as certain features, such as the swelling on the inner (broken) edge, do not match recent material.

Notes on the distribution, geographical and preferred depth of water, of the recent species and close relatives of the crab fossils.

Family MAJIDAE

Jacquinotia edwardsii (Jacquinot)

This is certainly a southern form; it occurs intertidally at the New Zealand "Subantarctic Islands" (Auckland and

Campbell) and in deep water (down to 250-300 fathoms) off Otago.

Family CANCRIDAE

Cancer novaezealandiae (Jacquinot)

This species occurs interidally and down to at least 60 fathoms at the "Subantarctic Islands" and at the mainland at least as far north as Auckland. However, it attains its maximum size hence we assume it lives in its optimum conditions, off the subantarctic Islands and in Foveaux Strait.

Family GONEPLACIDAE

Ommatocarcinus macgillivrayi White

It is found off the coast of both islands of New Zealand from about 5 to about 40 fathoms, but appears to be more abundant in the south, especially off Otago.

Carcinoplax sp.

I do not think the Marima specimens belongs to C. victoriensis Rathbun, a deep water species from off Southern Australia and off New Zealand (Chatham Rise, 220 - 320 fathoms). They appear to be close to another Southern Australian species, C. meridionalis Rathbun, recorded from about 50 to 150 fathoms, but not known from New Zealand as yet.

Appendix 5:

Dye Staining of Lightly Indurated Upper Tertiary Rocks

Pantin (1960) has shown that when semi consolidated sediments are treated with a dye, such as Methylene Blue or Gentian Violet many small scale features become apparent, after the surface has been pared with a razor blade.

The technique can also be used on many lightly indurated sediments which are still slightly porous, and which exhibit local variations in porosity corresponding to sedimentary structures. The dye is able to make these structures move apparent by soaking further into the more porous areas than into those parts not so porous. At the start of the process the rock is dyed with Methylene Blue. Then the surface is gently pared with a razor blade. At first the whole surface is blue and on further paring non-porous areas of the undyed sediment are increasingly revealed. When there is maximum contrast from deep blue, through various shades of blue to the grey colours of the rock, the paring is stopped.

Fifty-eight samples of lightly indurated upper Tertiary sandstones, siltstones and mudstones were treated with Methyl Blue dye, in each case about three square inches of a flat surface was treated.

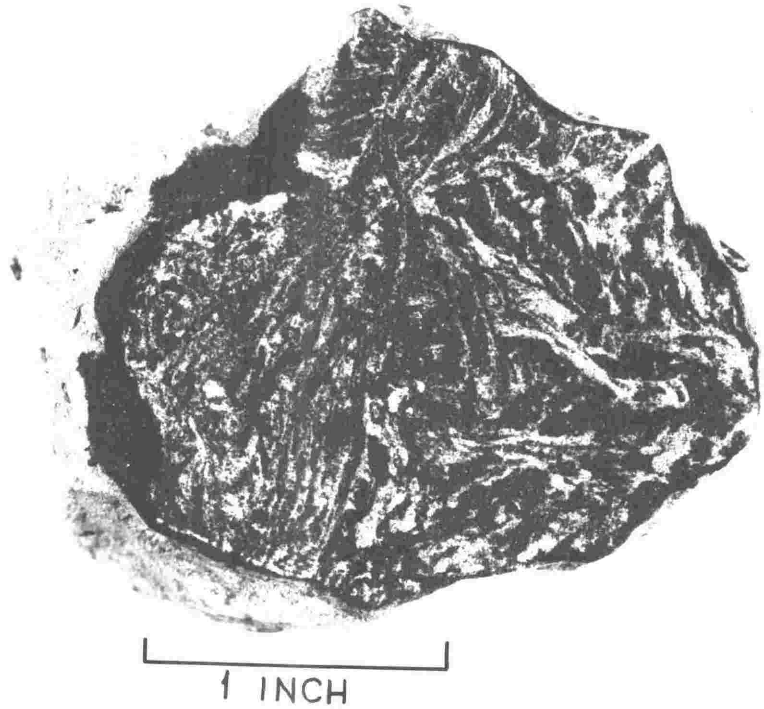
It might have been anticipated that the massive sediments on dyeing would show little except rare primary depositional features. It was found that siltstone and mudstone which was deposited in deep water and was not a turbidite bed generally showed either a granular structure (such as that shown by the left side of Figure 47) or had little or no internal differentiation and contained no identifiable lamination or animal burrows. Such sediment gives no clear indication whether burrowing had taken place or not; it is only when burrows are infilled with sediment of a different grain size that the burrows become apparent. However, as lamination would be anticipated in the absence of organic disturbance, it is probable that extensive burrowing had taken place.

Some of the shallow-water siltstones show the same uniformity of structure as the deep-water non-turbidite sediment. The remaining siltstones and most of the shallow-water sandstones are either mottled or reveal recognisable organic burrows.

The classification of burrow patterns, and the identification of animals which made them, is clearly a new line of research. The most obvious burrows found are figured (Figures 44 - 49).

Reference

Pantin, H.H. 1960: Dye-Staining technique for Examination of Sedimentary Microstructures in Cores. J. Sediment. Petrol: (3) 314-316.



M.D. King photograph

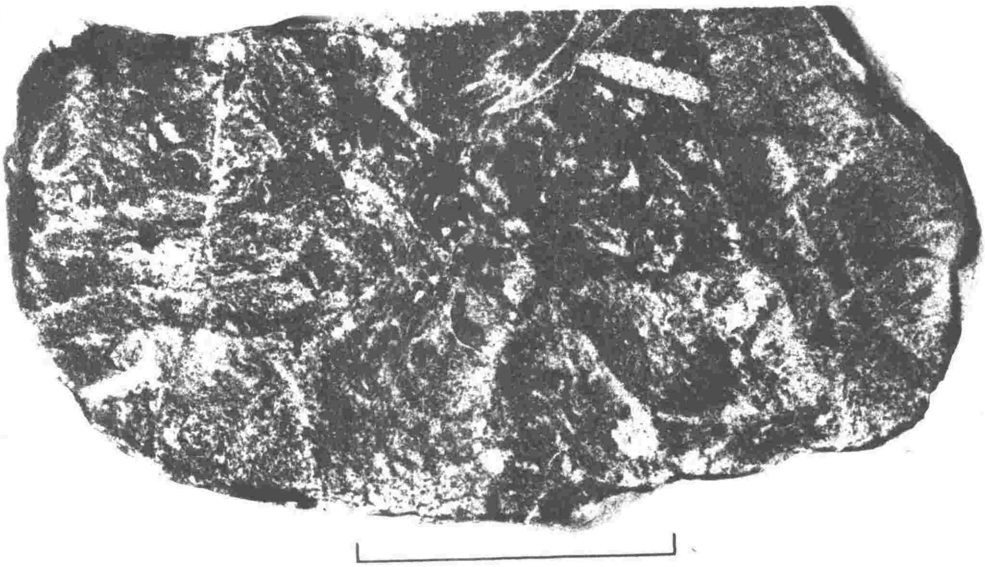
Figure 44: Section parallel to bedding.

From Fossil Locality 769, zone of *Pelicaria* n. sp. aff. *acuminata*.

Biofacies: Neritic.

Lower Left to top centre

Many horizontally aligned burrows. Sand filled burrows rather indistinct perhaps due to multiple boring. Such multiple boring can produce features similar to bedding.



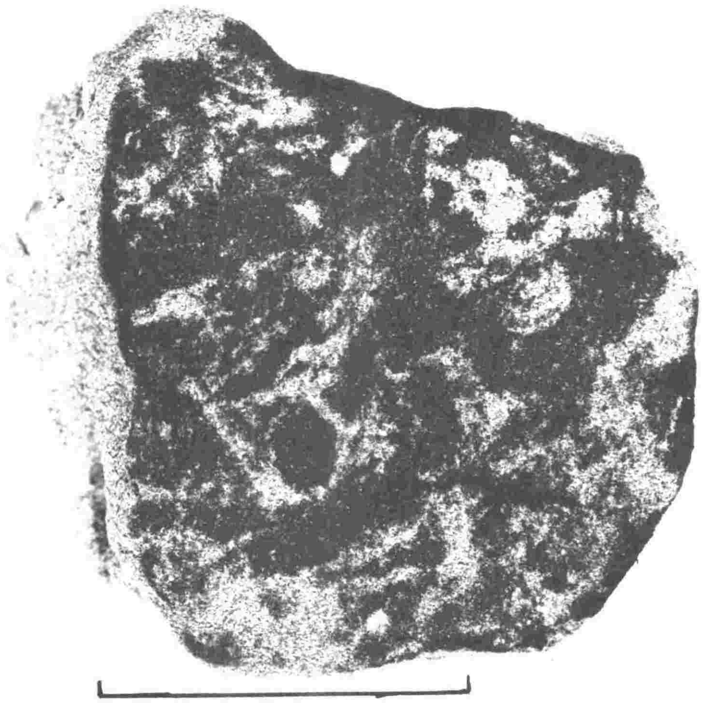
M.D. King photograph

Figure 45: Section probably normal to bedding.

From fossil Locality 563. Makuri Sandstone.

Deposited in fairly shallow water.

Sediment completely disturbed, due to animal burrowing. Diffuse dark coloured areas due to an animal "eating out" patches of sand.



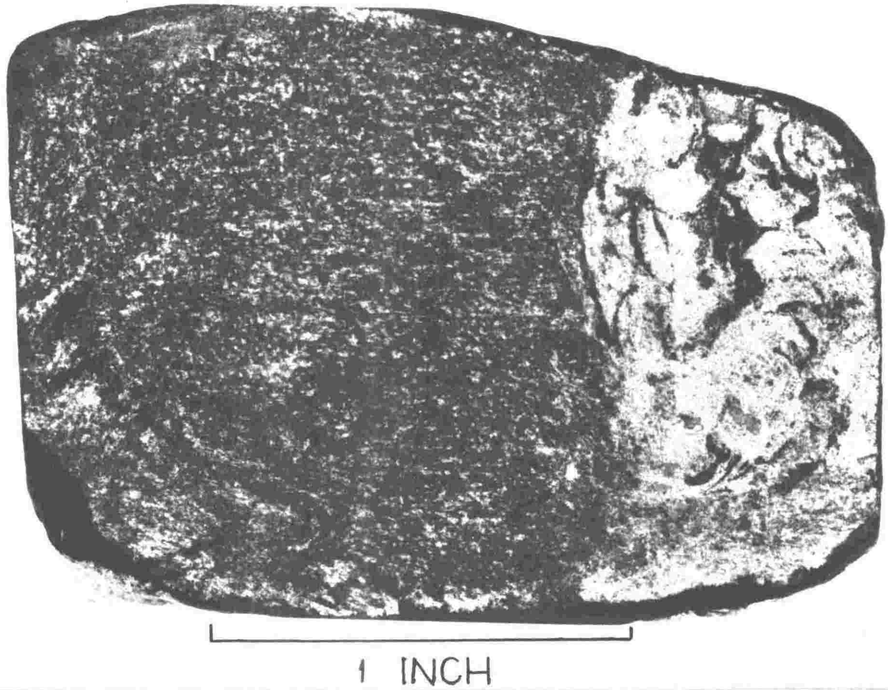
M.D. King photograph

Figure 46: Section parallel to bedding.

From fossil Locality 978. Makuri Sandstone.

Biofacies. Neritic.

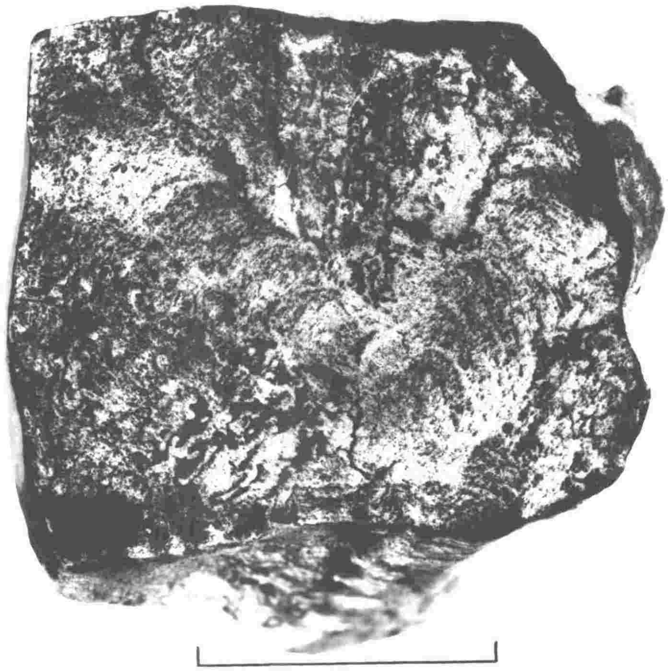
Dark coloured areas, about ¼ inch in diameter are "sandy relict burrows", these are curved in a horizontal plane, one burrow left centre however, trends vertically.



M.D. King photograph

Figure 47: Section probably approximately normal to bedding. from fossil locality 566 - Tane Sandstone. Biofacies - Lower Neritic.

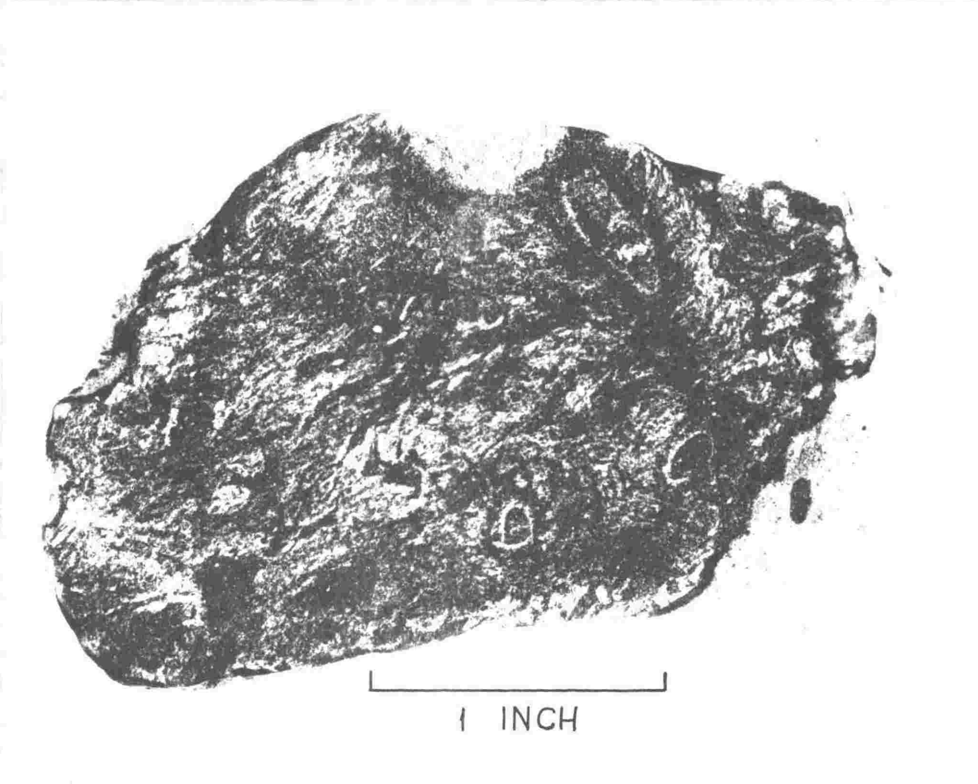
Left Centre Clay dispersed in small particles (light coloured areas about the size of a pin), sand in diffuse areas about 3 times the size of the clay particles, (dark coloured areas). Right Clay faecal material deposited in meniscus structures in a vertically aligned burrow about .16 of inch in diameter. The animal ingested material and passed it out as it moved through the sediment.



M.D. King photograph

Figure 48: Section cuts bedding at about seventy degrees. From fossil locality 876 - Tawatia Sandstone. Biofacies. Lower Neritic.

Burrows about ½ inch in diameter infilled with clayey faecal material deposited in fine meniscus shaped structure, the latter are made apparent by the concentration of different grain sizes by the animal. Lower Left and Lower Right Sandy relict burrows with some clayey faecal material left within the centre of the burrow.



M.D. King Photograph

Figure 49: Section cuts bedding at about 15 - 20 degrees. From fossil locality 873. Tawatia Sandstone. Deposited in fairly deep water.

Right centre Three cross sections of subvertical clay lined burrows. The following events are deduced.

(1) Muddy material removed beyond burrow by animal.

(2) Construction of a semi-rigid clay wall.

(3) After the animal died, or left its burrow the void was filled with sandy material.

Upper Centre Indistinct sandy relict burrows with some clayey faecal material. Lower left Sandy relict burrows.

Appendix 6:

Tables of Minor Faults and Joints

Minor faults and joints from near the major north-northeast trending faults, both in the mapped area and from two localities a short distance to the north and south are listed in Table 1. Minor faults and joints from near cross faults are listed in Table 2.

TABLE 1

JOINTS AND MINOR FAULTS, NEAR THE NORTH NORTHEAST TRENDING FAULTS

Grid Ref.	Type of Minor fault, or Joint	Strike of Minor Fault	Inclination and Bearing of Fault Plane	Throw in Feet	Distance of the Minor Fault From the Associated nearby North Northeast trending Fault (in yds) and strike of the North Northeast fault (in brackets)	Angle Between the Strike of the Faults
144145	Normal	050	60 at 140	?	100, W. of Wellington (040)	10
127124	Joint	{350 / 025	{30 at 260 / 85 at 290		100, W. of Wellington (029)	39
178143	Reverse	120	45 at 030	0.5	50, W. of School (022)	89
	"	065	25 at 165	1.0		43
139114	Joint	045	65 at 315		200, E. of Huru (030)	15
216160	Joint	{040	{85 at 310		200, E. of Paiwai (021)	71
	"	080	85 at 350			31
	Reverse	340	28 at 250	0.5	5 - 50, E. of Cliff Rd from top	76
	Normal	030	10 at 035	0.1	increasing in distance from the	21
	Reverse	355	30 at 085	0.33	Cliff Road Fault (056)	29
153990	"	050	40 at 140	2.0		84
	"	065	70 at 155	?		99
	"	010	35 at 100	0.5		44
	Normal	015	75 at 105	1.25		49
143973	Reverse	045	70 at 135	c 1	50, W. of Faulkner Road (030)	15
161968	Reverse	130	70 at 140	0.5	150, E. of Kaiparoro (027)	103
170907	Reverse	100	{85 + 75 at 010	all c 1	400, E. of Smiths Line (036)	64
			35 at 190			
253013	Joint	060	80 at 330		600, E. of Rongomai (030)	30
188903	Normal	030	{60 at 120	c0.5	50, W. of Hastwells (047)	17
			80 at 300	c0.5		
387207 (N.Z.M.S. N.149)	Reverse	350	38 at 260	c3.0	450, W. of Nirvana (028)	38
205800 (N.Z.M.S. N.158) See Orbell 1962)	Reverse	c060	30 at c330	c20.0	900, E. of Mauriceville (040)	20
340005	Joint	335	70 at 55		650, S. of Estcourt (055)	90
350985	Joint	070	Vertical		200, W. of Alfredton (025)	45
402082	Joint	105	near Vertical		[illegible]	[illegible]
382040	[illegible]					

TABLE 2

JOINTS AND MINOR FAULTS NEAR CROSS FAULTS

Grid Ref.	Type of Minor Fault, or Joint	Strike of Minor Fault or Joint	Inclination and Bearing of Fault Plane	Throw in Feet	Distance (in yds) From Cross Fault	Remarks
102051	Joints	090	34 at 180		100, S. of unnamed fault	Subparallel to unnamed fault
		305	65 at 35			
076987	Normal	050	85 at 140	2.0	100, S.E. of Putara School	
167127	Joint	070	45 at 340		600, E. of Pukohai Road	
161122	Joint	095	35 at 005		150, W. of Pukohai Road	
253103	Joint	070	45 at 250		600, S.W. of unnamed fault	Subparallel to two unnamed faults
218053	Normal	345	c70 at 065		Near several faults	
326952	Joint	290	Vertical		100, S. of unnamed fault	Subparallel to unnamed fault
343078	Reverse	040	80 at 130	c 1	250, S. of unnamed fault	
382933	Joint	085	c70 at 175		200, N. of Te Hoe Farm Fault	Parallel to Te Hoe Farm Fault
383930	Joint	010	55 at 020		200, S. of Te Hoe Farm Fault	
386931	Joint	000	60 at 90		100, S. of Te Hoe Farm Fault	Subparallel to unnamed fault
390927	Joint	335	60 at 65		400, W. of unnamed fault	Subparallel to unnamed fault
436981	Normal	090	60 at 180	c 1	350, S. of unnamed fault	
424953	Joint	285	73 at 025		5,E. of unnamed fault	Parallel to R. Trig Fault
422178	Normal	030	68 at 100	10	50, S.E. of unnamed fault	
425181	Joint	020	Near Vertical		200, S. of unnamed fault	
451952	Normal	322	70 at 52	2.9	100, E. of Whaitawhiti	Parallel to Whaitawhiti Fault
"	?	300	72 at 210	+ 10	100, E. of Unnamed fault	Subparallel to Whaitawhiti Fault
450952	Joint	305	Vertical		50, E. of unnamed fault	" " "
451949	Joint	060	65 at 150		100, E. of unnamed fault	

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