PALEOENVIRONMENTAL ANALYSIS OF QUATERNARY STRATA IN THE LEVIN AREA

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ALAN HENRY SEWELL
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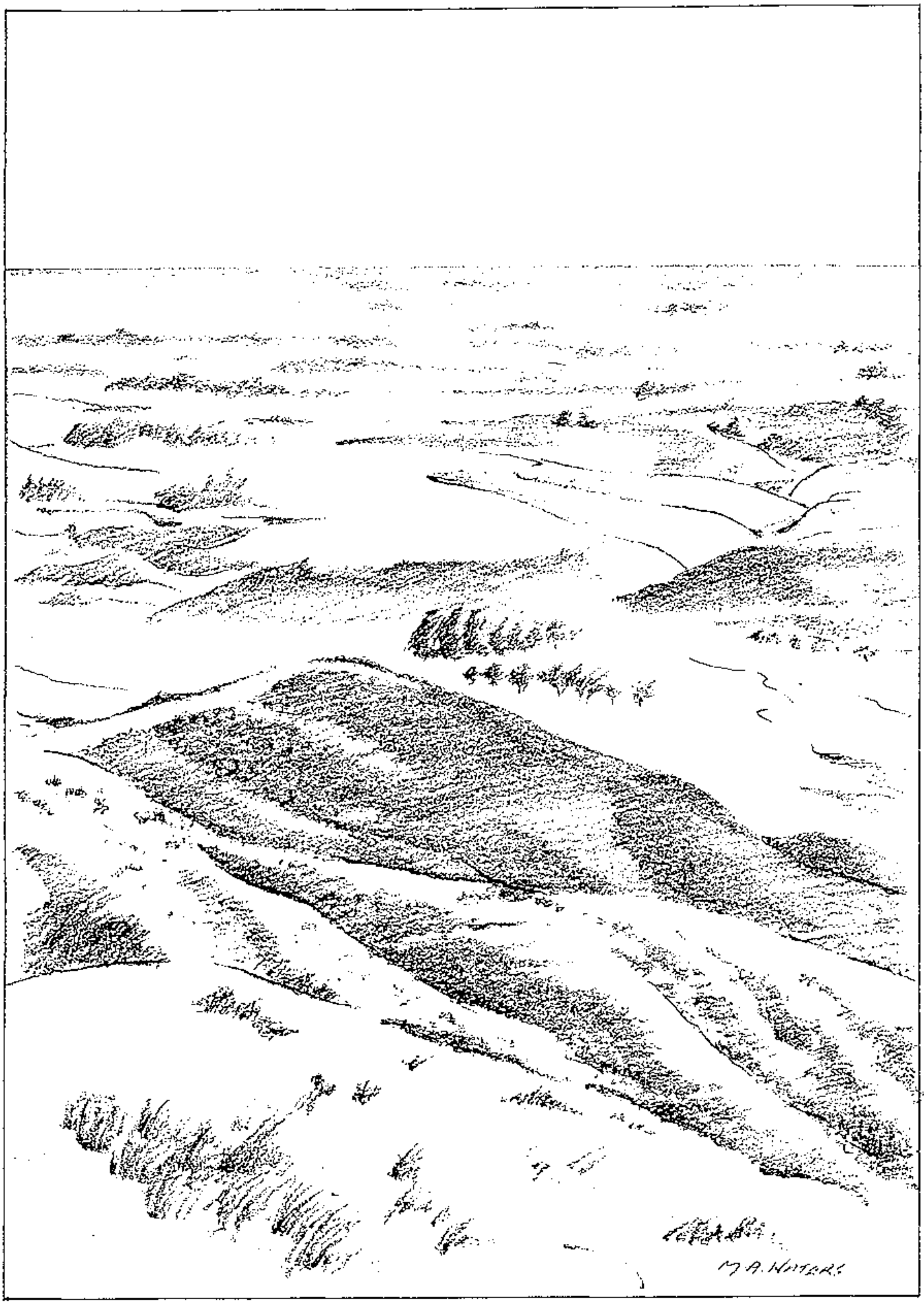

Frontispiece: Pencil sketch looking north from the Tararua foothills, south-east of Potts Hill, across the Tokomaru Marine Terrace and Manawatu River flood plain beyond.

ABSTRACT

Marine transgression during the Last Interglacial resulted in widespread inundation of the southern Manawatu area. The Otaki Formation constitutes the relatively thick blanket of predominantly marine sand deposited at the height of the transgression and is now exposed in a partially dissected marine terrace abutting the Tararua Range.

Sedimentation was controlled by basement block faulting related to a regional strike-slip tectonic regime on the south-eastern margin of the South Wanganui Basin. Wave-induced longshore currents from the north-west supplied abundant sediment to the coast.

North-east of Levin the Kairanga Trough, occupying a north-east-trending structural depression between uplifted basement blocks, formed the centre of an embayment during the transgression. Tide-dominated depositional processes predominated around the margins of the embayment. In the Forest Lakes area, the absence of seaward barriers resulted in an open wave-dominated coastline. Between Ohau and Shannon mixed wave/tide processes predominated. Stabilisation of sea level resulted in shoreline progradation which was especially marked south of Levin where a dune belt formed, mantling the coastal cliff and later migrating inland.

Retreat of the sea was followed by differential uplift and dissection of the newly exposed marine terrace. Two later marine transgressions cut treads in the earlier marine terrace, their strandlines being controlled by the previously established drainage pattern. Ameliorating climate associated with the major sea level regression of the Last Glacial was accompanied by several phases of loess and minor dune sand accumulation on the exposed marine terraces. At the same time large areas of the terrace coverbeds were removed due to river aggradation. Final truncation of the Last Interglacial marine terraces occurred during the Holocene transgression.

Tectonic warping of the marine terraces is continuing along pre-existing basement faults.

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CHAPTER 1

INTRODUCTION

1.1 PURPOSE AND SCOPE OF STUDY

In recent years there have been major advances in the understanding of the evolution of the South Wanganui Basin including a well documented chronology of Quaternary sea level fluctuations. Much of this information has arisen from studies carried out both onshore and offshore in the Wanganui and south Taranaki areas.

Little stratigraphic and sedimentological investigation of late Quaternary strata in the southern Manawatu area has been undertaken since Oliver mapped the Otaki Formation in 1948. Thus, in the light of present knowledge, it is timely to apply modern techniques of sedimentary basin analysis in making a detailed study of the late Quaternary strata of the southern Manawatu district.

The aim of this study is to elucidate the stratigraphy, distribution, environment of deposition and post-depositional history of the Otaki Formation that underlies the Tokomaru Marine Terrace in the Levin area and to relate this to the late Quaternary history of the Wanganui Basin.

1.2 LOCATION OF STUDY AREA

The study area is located in the Horowhenua district, south-western North Island, and forms a rectangular strip of elevated coastal plain (c.200 sq. km.) between Otaki River in the south and Tokomaru River in the north (Fig. 1.1). The area is bounded to the north by the Manawatu River flood plain. The western boundary is concealed by Holocene coastal sand dunes within 3km of the coast. The Tararua Range forms the eastern boundary. Other major rivers draining the Range which cross the study area include (from south to north) Waitohu Stream, Ohau

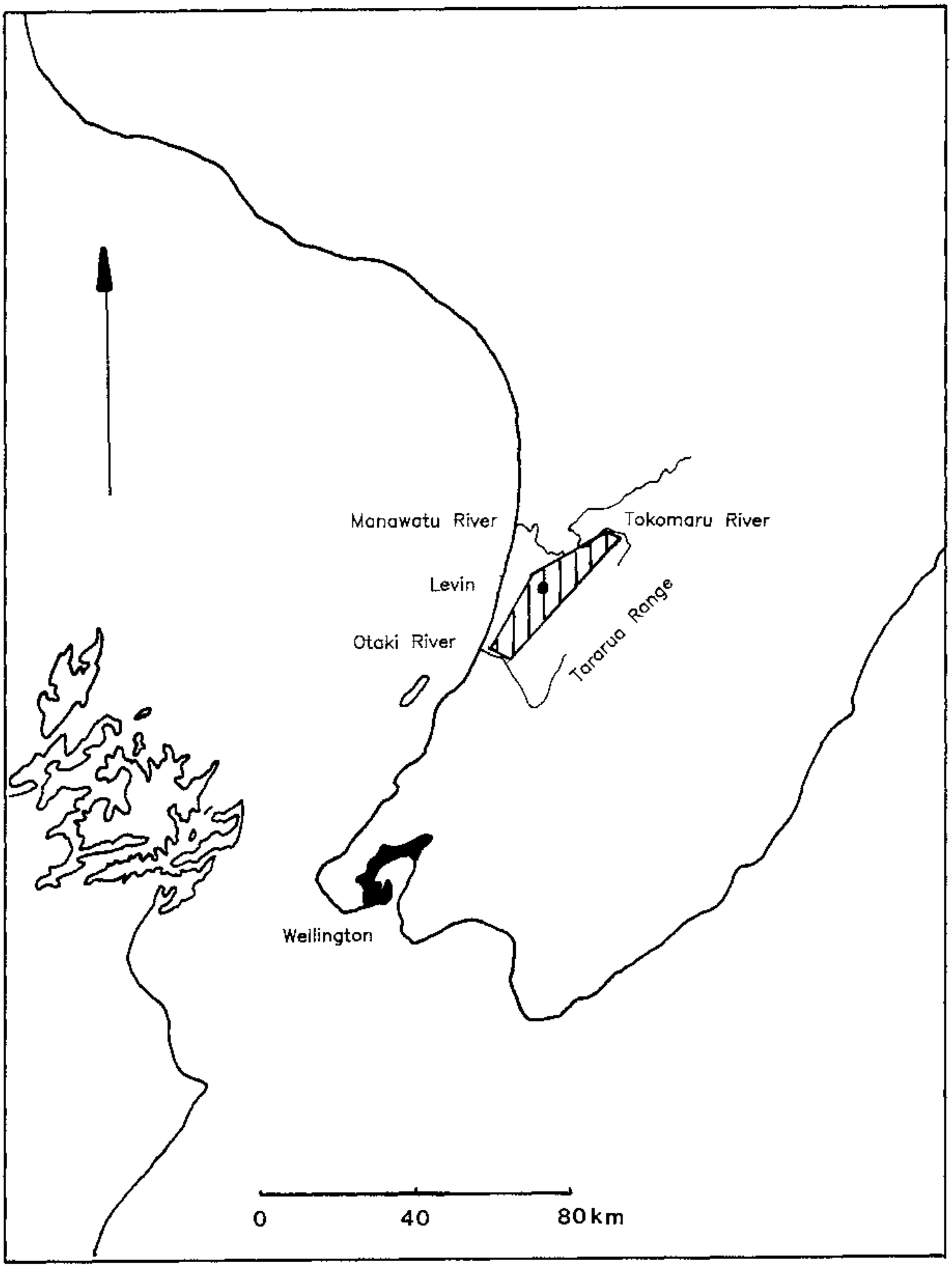

Fig 1.1   Location map of study area.

River and Mangaore Stream (Fig. 1.2).

Levin township (population 15,000), situated in the centre of the study area, services the surrounding rural community which is involved predominantly in dairy farming.

1.3 METHODS

Primary data was gathered through field reconnaissance with samples being collected for more detailed analysis. Additional information, supplied by the Manawatu-Wanganui Regional Council, provided subsurface data from 82 bore logs of water wells drilled directly into the Tokomaru Marine Terrace. Bore hole locations are plotted on Maps 1-4 with grid references from the NZMS 260 series along with other relevant information, tabulated in Appendix A.

1.3.1 Field Work

The extent of the Tokomaru Marine Terrace between Otaki River and Tokomaru River was delineated through aerial photographic interpretation and ground survey. Well exposed sections were described and measured in detail with the aid of a Brunton compass and Abney level. Their locations are plotted on Maps 1-4 with measured section descriptions and NZMS 260 series grid references given in Appendix B.

Exposure in the field area is generally poor, consisting of many small outcrops of several metres in thickness. The best outcrops occur in farm tracks, road cuttings and silage pits. Stream valleys alone yielded few good exposures.

Geological maps were prepared showing the distribution of the Otaki Formation including structural and geomorphic features along with measured section and bore hole locations (Maps 1,2,3,4).

1.3.2 Sampling Methodology

Sampling of the unit was carried out with the following intentions:

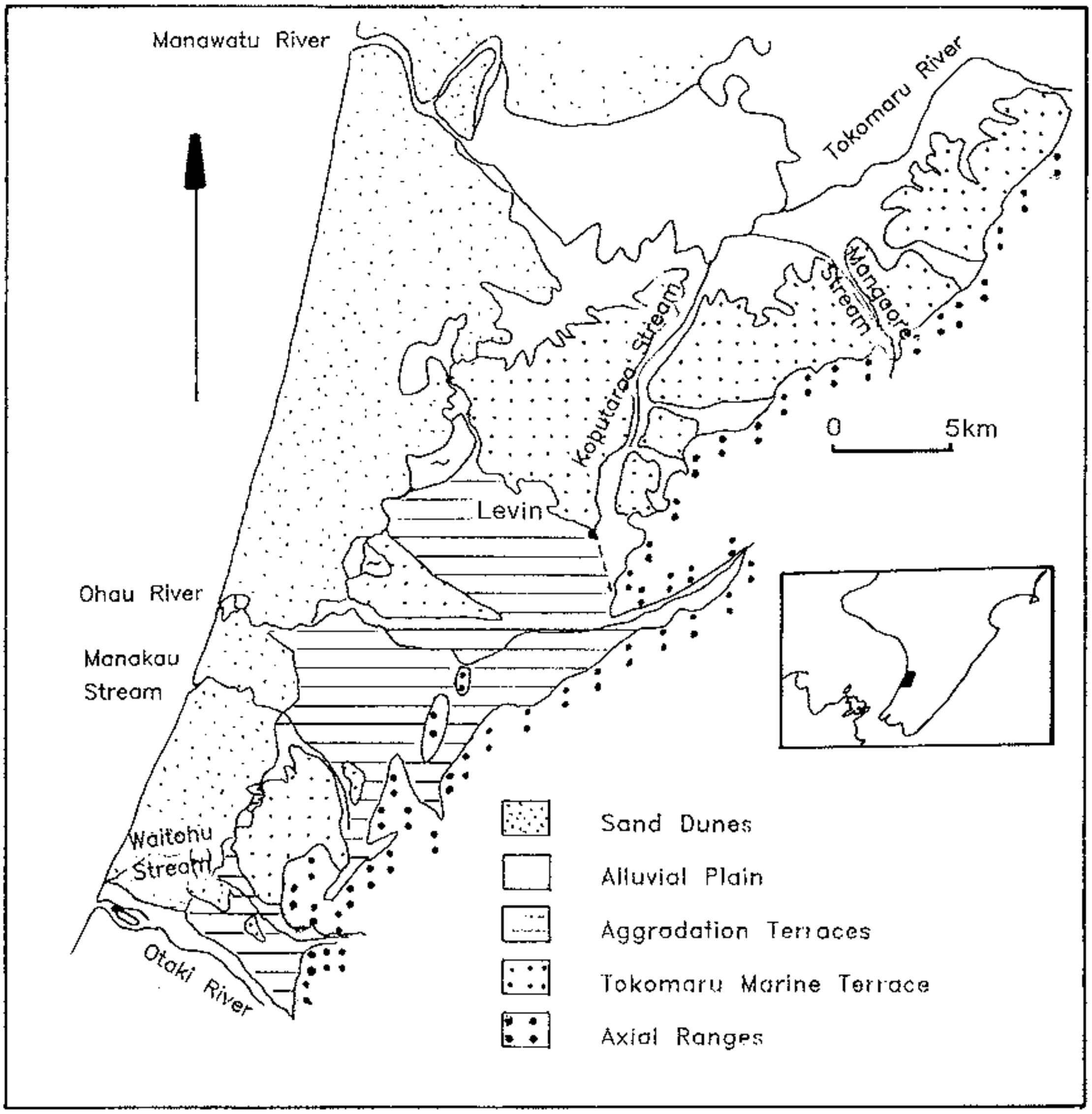

Fig 1.2
Physiography of southern Manawatu district.

1. grain size analysis

a) to delineate variations in overall grain size characteristics of the sandstone both vertically and laterally through the unit;

b) to provide descriptive data to aid in interpreting depositional environment;

2. to provide data on provenance from the petrography of detrital grains;

3. to provide paleoclimatic information from fossil pollen analysis.

Where sections of good vertical exposure were encountered sampling was carried out systematically up the sequence. In areas of poor exposure spot samples were taken with their relative position in the sequence noted. Samples of more indurated sandstone were obtained less selectively from across the study area for thin sectioning and petrographic analysis. Palynological analysis was carried out on two samples of peat by D.C. Mildenhall (DSIR Geology and Geophysics). Both peat samples came from the single occurrence of peat encountered within the Otaki Formation in the study area.

1.4 REGIONAL SETTING

1.4.1 Physiography

Four main physiographic features dominate the Horowhenua and southern Manawatu districts (Fig. 1.2). To the east, the NNE-trending Tararua Range sub-parallels the coastline and rises abruptly to heights of more than 1500m. Mesozoic rocks comprising complexly deformed, highly indurated, flysch sequences with associated spilite and chert make up the strata of the ranges and form the regional basement.

An uplifted and partially dissected marine terrace abuts the western flanks of the Tararua Range and slopes gently seaward. It is a composite structure composed of several recognisable benches comprising Pleistocene marine strata overlain by a sequence of loesses. Typically the uplifted plain forms flat topped interfluves separated by "box-shaped" swampy valleys (Fig. 1.3).[1]

River aggradation surfaces associated with the Ohau and Otaki rivers fan out westward from the ranges bisecting the older marine terraces with broad corridors of coarse alluvium leaving occasional inliers prominently preserved. The most extensive aggradation surface is correlated with the end of a widely recognised phase of river aggradation in the southern North Island attributed to the last glaciation (Milne 1973a,b). The deposits of the aggradational episode are mapped as Ohakean gravels from which Ohakean loess is derived. The upper surface of the gravels is mapped as the Ohakean terrace. To the west, the marine terraces and Ohakean terrace are truncated by the cliff formed during the Holocene high sea level (*c*.6.5kyr B.P.) giving way to a prograding coastal plain.

North of Levin the prograding coastal plain is dominated by the Manawatu River floodplain which overlies Holocene estuarine beds at shallow depth (Hesp and Shepherd 1978). A broad belt of coastal dune sands exists between the floodplain and the coast. South of Levin, coastal dunes often mantle the marine cliff which truncates the old coastal plain with dunes resting on the Ohakean terrace or older marine terraces. Elsewhere a narrow swampy area, in places developed into large lagoons, separates the cliff from the dune belt.

1.4.2 Geology

The study area forms part of the south-eastern margin of the South Wanganui Basin which is bounded to the east and north-east by the Tararua, Ruahine and Kaimanawa ranges and to the south by the Marlborough Sounds. The northern boundary is obscured by volcanics of the central plateau and the western

[1] Cotton (1918) proposed the term "box-shaped" to describe the characteristically wide, flat floored, but steep sided valleys occurring in the uplifted coastal plain in southern Manawatu. Hesp and Shepherd (1978) note: "The width of many (box-shaped) valleys appears to be wider than expected in relation to the discharge of the streams that now drain them".

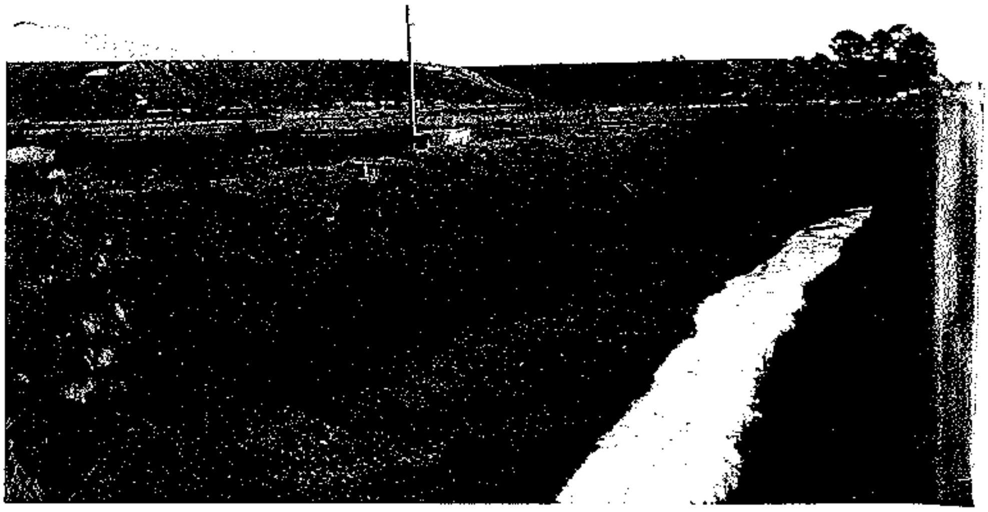

Fig 1.3

A flat topped interfluve typical of the partially dissected marine terraces in the Horowhenua district. This photograph was taken approximately 2km north of Shannon and looks south.

boundary is marked by a zone of major faults (Taranaki, Manaia) which separate it from the much older and deeper Taranaki Basin (Fig. 1.4).

Anderton (1981) describes the Wanganui Basin as a broad half graben structure trending NNE which contains up to 4km of marine Plio-Pleistocene sediments developed by progressive subsidence and onlap to the south combined with emergence and offlap to the north.

The oldest Cenozoic sediments in the South Wanganui Basin consist of two small faulted outliers of Oligocene marine sandstone within basement rock at Otaihanga and Picton. They are thought to be remnants of an extensive cover predating the formation of the basin. Elsewhere, Plio-Pleistocene strata crop out over most of the onshore part of the basin and consist of shallow marine and terrestrial sediments originally grouped into the Wanganui and Hawera Series (Fleming 1953). Recently, the Hawera Series has been deleted from the New Zealand chronostratigraphic scheme and replaced by the Haweran Stage of the Wanganui Series (Beu *et al.* 1987). In the Horowhenua district no Cenozoic strata older than Haweran age have been recognised.

North-west of the study area four oil exploration wells drilled in the South Wanganui Basin encountered basement beneath sediments no older than Pliocene (Anderton 1981). Basement consists of rocks similar to those of the axial ranges described above, being part of the Torlesse Terrane (Korsch and Wellman 1988).

Structural trends in the South Wanganui Basin comprise gentle regional dips toward a depocentre south of Wanganui cut by NE-NNE-trending faults (Anderton 1981). Along the south-eastern margin of the basin NNE-trending faults parallel the axial ranges. Here, block faulting of basement has given rise to a series of topographic highs where overlying strata have been deformed into a number of gentle anticlines described by Te Punga (1957a), some of which are still growing. In some cases basement has been thrust to heights just above present

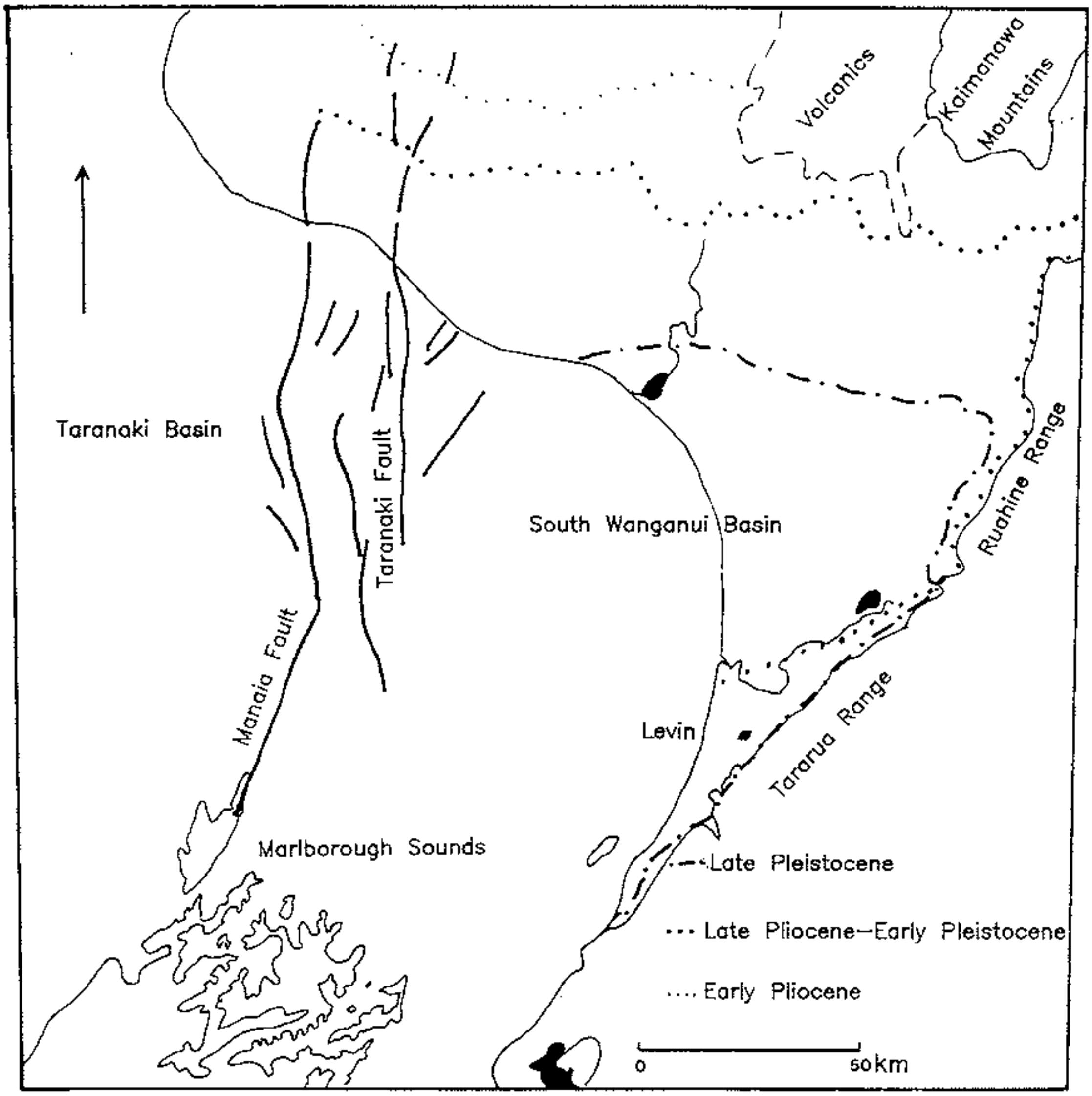

Fig 1.4

Map of the South Wanganui Basin showing basin boundaries and present distribution of early Pliocene, late Pliocene - early Pleistocene and mid-late Pleistocene sediments (after Anderton 1981).

sea level.

Bekesi (1989) studied the Poroutawhao High immediately west of Levin where wave cut basement is found 5 metres above sea level. A 2.5km. wide up-thrown block controlled by a NNE-trending high angle fault on its eastern margin was delineated and named the Levin Fault. Fleming and Hutton (1949) noted a similar fault on the eastern side of Kapiti Island. Rich (1959) recognised the Himitangi Anticline which extends for nearly 21km northwards from Foxton and probably represents the northern extension of the Poroutawhao High. To the east the Manawatu River flows along the Kairanga Trough (Rich 1959) which represents a deep downfold between the line of basement highs to the west and the axial ranges to the east. Hesp and Shepherd (1978) noted the effect of these structures on Holocene sedimentation in the lower Manawatu valley and how they have controlled its river course.

Eustatic sea level fluctuations during the Pleistocene have had a major influence on sedimentation and stratigraphy in the Wanganui Basin. During glacial maxima the coastline lay about 100km to the west of its present position and a land bridge existed across Cook Strait (Lewis and Eade 1974). Ensuing periglacial conditions led to river aggradation on the coastal plain accompanied by loess accumulation on older surfaces to the east. Milne (1973a,b) described an extensive sequence of aggradational terraces in the Rangitikei Valley and Milne and Smalley (1979) formulated a standard coverbed stratigraphy for the sequence based on associated loess deposits. This has enabled confident correlation with similar deposits in the Otaki district (Barnett 1984).

Pillans (1983) recognised a flight of twelve marine terraces in south Taranaki formed during high sea level stands over the last 0.7 million years. Quantitative dating of coverbed strata coupled with a deformation model have enabled a detailed chronology of sea level fluctuations for the late Quaternary to be established (Pillans 1990). In southern Manawatu levelled spurs and planed surfaces occur sporadically in the foothills of the Tararua Range and attest to a similar history, though chronological control is poor.

The uplifted coastal plain in the Horowhenua district has, until recently, been ascribed to one marine terrace representing shallow marine deposits laid down upon a wave cut surface during a major sea level maximum. Locally named the Tokomaru Marine Terrace (Hesp and Shepherd 1978), it has been inferred as a likely correlative of the Rapanui Terrace at Wanganui (Palmer *et al.* 1988). Pillans (1983) gives a date of 120kyr B.P. for the Rapanui strandline based on amino acid dating of wood fragments and correlation with a major worldwide high sea level event.

Palmer *et al.* (1988) noted the occurrence of two narrow treads cut in the seaward margin of the Tokomaru Marine Terrace (TMT) a few kilometres north of Otaki and suggested possible correlation with two terraces dated at *c.*100kyr and *c.*80kyr north of Wanganui. North of Potts Hill a lower tread cut in the TMT can be traced intermittently as far as Tokomaru River. These treads have been mapped in detail in the course of this study (Maps 1,2,3,4).

A summary of the late Quaternary stratigraphy for the southern North Island based on work done in several different areas is outlined in Table 1.1.

1.5 PREVIOUS WORK

Early studies of the area were carried out by Adkin (1910, 1919) and Cotton (1918) on what was loosely described as the old coastal plain or coastal plain formation. Each proposed quite different interpretations for its origin. Adkin (1910) considered the strata in the Levin area, which he called the Horowhenua Sandstone, to represent a double raised beach formation. He based his conclusions on the occurrence of two sandstone beds separated by a zone of yellow clay, the latter not present close to the ranges. Adkin interpreted this assemblage as a basal sand bed laid down upon a transgressive

ERA	NZ Stages after Beu etal (1987)	N.Z. Substages	Estimated age B.P. kyr	Marine Terraces Wanganui Pillans(1990)	River Terraces Rangitikei Milne (1973)	Loess Deposits Rangitikei Milne (1973)	Waikanae Fleming (1972)
(UPPER) QUATERNARY	HAWERAN		<0.2				Waitarere Sand
			1				Motuiti Sand
			1.8				Taupo Sand
		Aranuian	5.5				Foxton Sand
			10				Paraparaumu Peat
			12				Kena Kena Fm
			14				
			16		Ohakea	Ohakea	Te Waka Sand
		Otiran	18				Parata Gravels Judgeford Loess Matenga Fanglomerate
			19				
			25				
			30		Vinegar Hill		
			35		Rata	Rata	Tini Loess Older gravels
			40				
					Putorino		Waimahoe Lignite (>35)
			60	Rakaupiko			
			70		Porewa	Porewa	
			80	Hauriri			
							Otaki dune sand)
		Oturian	100	Inaha	Cliff		Awatea Lignite)Otaki
							Otaki beachsand)formation
			120	Rapanui	Greatford		
			125		Marton	Marton	
		Waimean	140				
			170		Burnand	Burnand	
			180				
		Terangian	210	Ngarino			
			230				
		Waimaungan	240		Aldworth		
			245				

Table 1.1

Summary of late Quaternary stratigraphy for the southern North Island.

shoreline followed by a second sand bed deposited as the sea retreated, the interbedded clay representing deeper water deposits.

Cotton (1918) designated the name Otaki Series for the strata of the old coastal plain from its southern end, north of Paraparaumu, to the Manawatu River. He considered it to be an entirely aeolian deposit, in places interfingering with gravels of adjacent alluvial fans. Cotton attributed the yellow clay noted by Adkin to be formed in swamps or lakes impounded by dunes.

Oliver (1948) mapped the distribution of the coastal plain formation and discussed its composition and origin in some detail. He distinguished two lithologic units, wind deposited soft sandstone and water deposited soft sandstone, in what he renamed as the Otaki Formation, although no type section was designated. He also noted minor occurrences of conglomerate, silt and clay. In comparing the texture and composition of the Otaki Formation with the present day coastal deposits to the west, Oliver made the following observations:

1. sand in the Otaki Formation is generally more rounded than present day beach and dune sand;
2. Otaki Formation has a higher ferromagnesian content than present day beach and dune sand.

Oliver considered the Otaki Formation to be a predominantly shallow water marine deposit with minor dune sands laid down above coalescing alluvial fans.

Rich (1959) studied Late Cenozoic stratigraphy around Palmerston North and designated the name Tiritea Formation to coverbed strata that were lateral equivalents to the Otaki Formation (Oliver 1948) to the south. He described similar lithologies to Oliver and noted the predominance of conglomerate toward the mouth of the Manawatu Gorge with sand becoming dominant further south. He also noted the occurrence of micaceous and carbonaceous silts and pebbly sands containing some pumice. He attributed the depositional environment to be a shallow water marine to subaerial complex influenced by "frequent shifting of both strandline and stream courses along the base of the western flank of the axial ranges". Rich considered the Tiritea Formation to be coeval with the Halcombe Conglomerate and Mangaone sandstone (Te Punga, 1952) to the north-west.

Cowie (1963) distinguished the much younger Koputaroa Phase dune-sands[2] from what Oliver had previously included as part of the Otaki Formation in the Levin area. He noted a strongly weathered clay separated the two units which indicated a period of intense and prolonged weathering. Cowie (1963) considered the Koputaroa dune-sands to be of fluvial origin primarily on the grounds that they accumulated during the Last Glaciation when sea level was considerably lower. Shepherd (1985) studied the heavy mineral content and roundness of the Koputaroa dune-sands and suggested a marine rather than fluvial origin.

Te Punga (1962) described in detail a *c*.12m sequence of Otaki Formation resting unconformably on a greywacke wave cut platform near Waikanae. Radiocarbon dating of a wood fragment from a lignite horizon yielded an age >45,000 years but no attempt was made to correlate the sequence laterally. Paleoenvironmental inferences were limited to discussion concerning the significance of marine sponge spicules in a muddy sand bed near the base of the sequence.

Fleming (1972) expanded Te Punga's work by suggesting a paleoenvironmental history for the same sequence and incorporated it into an emerging late Quaternary stratigraphy for the Waikanae area. He recognised three informal members in the Otaki Formation; (basal) Otaki beach sand, Awatea lignite, and (upper) Otaki dune sand. He attributed the sequence to marine beach gravels and sands of a transgressive high level sea followed by beach derived dune sands that advanced as the sea retreated with lignite deposited in swamps ponded by the dunes. Chronologically, Fleming placed the Otaki Formation in

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[2] Koputaroa Phase dune-sands are here on referred to as "the Koputaroa dune-sands".

the Oturian Stage (Last Interglacial) of the Hawera Series based on geomorphologic and lithologic criteria (see Table 1.1).

In the Otaki area, Palmer *et al.* (1988) recognised a Last Interglacial marine cliff truncating Martonan aggradation gravels deposited during the preceding (Penultimate) glacial period. Aeolian Otaki Formation abuts and mantles the cliff extending inland across the Martonan surface for 1.5km. Palmer *et al.* (1988) recognised up to four loess units mantling the Otaki Formation near Otaki.

1.6 TERMINOLOGY

Marine terrace nomenclature follows that of Pillans (1990), (Fig. 1.5).

The Tokomaru Marine Terrace in this study refers to the gently sloping, uplifted coastal plain underlain by marine, fluvial and aeolian sediments (coverbeds) that rest on the Tokomaru wave cut platform cut during the Last Interglacial sea level maximum (*c.* 120kyr B.P.).

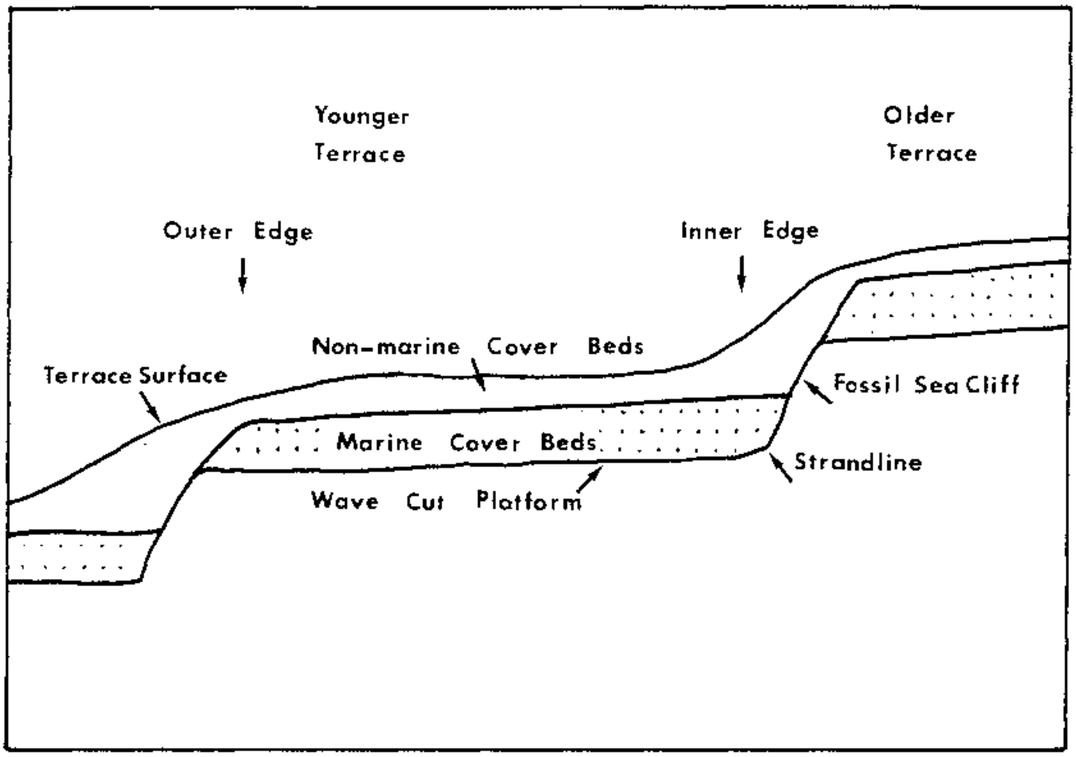

Fig 1.5
Marine terrace nomenclature (based on Pillans 1990)