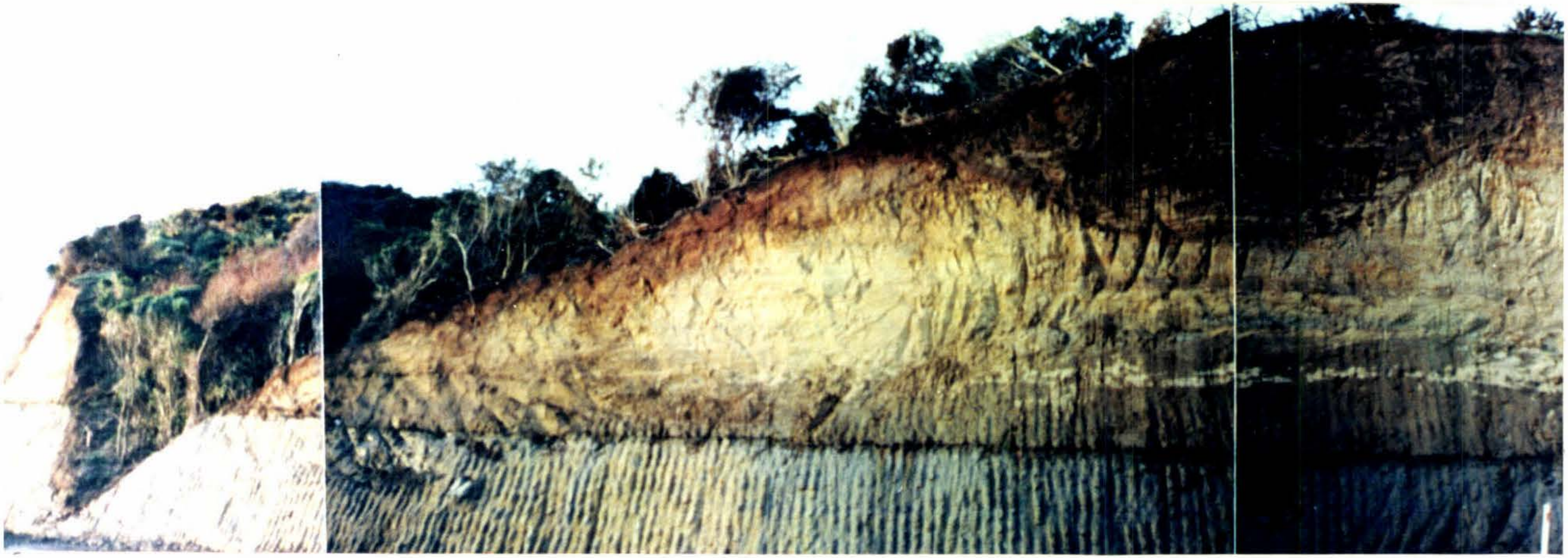
An investigation of the Rapanui and Ngarino marine terraces in South Taranaki: coverbed stratigraphy, distribution and tectonics.

A thesis presented in partial fulfillment of the requirements
for the degree Masterate of Science in Quaternary Science
at Massey University, Palmerston North, New Zealand.

Andrew James Wards

1996



Frontispiece. Rapanui wave-cut surface exposed on S.H.3 *c.* 0.3 km south of the Manawapou River.

Acknowledgements

I would like to thank the following:

My supervisors, Assoc. Prof. V.E. Neall and Dr. A.S. Palmer for their help during the early stages of field work and their encouragement and constructive criticism during the preparation and presentation of this thesis.

Also fellow students from the Department of Soil Science, Massey University; in particular Shane Cronin and Andrew Hammond for assistance in the field during some rather unpleasant Taranaki weather and Scott Keeling for use of his computer and many informal meetings and discussions. Thanks also to Mike Elliot for his review and discussions regarding interpretation of palynological information.

Thanks are due to the Geological Society of New Zealand for the presentation of the 1991 Student Research Award and to the Taranaki Regional Council for kindly supplying borehole data and information on gravel extraction in Taranaki.

Thanks to the numerous landowners who gladly allowed access to their properties and in particular for access to the many recent farm track and oxidation pond cuttings that provided excellent exposures.

My parents Diane and Ian, to whom I am very grateful for their assistance and moral support during this project.

Abstract

Uplifted marine terraces, formed by successive marine onlap during interglacial and interstadial sea level maxima are preserved parallel to the South Taranaki coastline between Kakaramea in the southeast, and Hawera to the northwest.

The objective of this research was to investigate the formation, deformation and subsequent landscape evolution of the Ngarino and Rapanui Terraces in the area between Hawera and Kakaramea. The northwestern part of the study area occupies the southeastern margin of the Egmont ringplain where terraces that extend from the southeast sector are progressively buried by volcaniclastic sediments west of the Tangahoe River. Ages of the wave-cut platforms have been inferred from the coverbed stratigraphy and subsequent correlation to sea-level and oxygen isotope curves. Mapping the height of wave-cut platforms also allowed calculation of marine terrace deformation rates and patterns in this area.

In the past, studies have tentatively concluded that between Kakaramea and Hawera the younger 120 ka Rapanui Terrace is cut out at the coast along with the 100 ka Inaha Terrace, and that to the west only the Ngarino Terrace is preserved. Examination of coverbed stratigraphy has established that both the Ngarino and Rapanui Terraces (210 and 120 ka respectively) are present in the study area. The terrace coverbed stratigraphy presented here indicates that next to the coast the terrace is younger than 210 ka. On this terrace loess units, corresponding to oxygen isotope stages 2,3,4 and 5 are found and gives a maximum age of 120 ka. Inland, the terrace stratigraphy reveals loess units corresponding to stages 2,3,4,5, and 6, providing a maximum age of 210 ka.

Structural interpretation has demonstrated that underlying tectonics associated

with the Taranaki Fault Zone has subsequently deformed the wave-cut platforms from their shallow angled seaward-dipping profiles. Southeast of the Tangahoe River, uplift rates between 0.3 - 0.55 mm/yr have formed well-defined terraces. The doming of the terrace surfaces is the surface expression of the Patea-Tongaporutu High, which is east of and parallels the Taranaki Fault Zone. The Tangahoe River is interpreted to overlie the Taranaki Fault Zone. This Zone marks the eastern boundary of the Taranaki Basin where uplift rates decrease to below 0.3 mm/yr. Stern *et al.*, (1990) suggest that at this point broad bending of the lithosphere is induced by west-moving thrust sheets within the Taranaki Fault Zone and this is thought to be responsible for the increased uplift rates in this area. The uplift pattern displays the differential between the Patea-Tongaporutu High to the southeast and the Taranaki Basin to the west.

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Chapter One Introduction

1.0 Objective of study

The objectives of this study were to elucidate the distribution of the Rapanui and Ngarino marine terraces in the area between Kakaramea and Hawera in South Taranaki, New Zealand (Figure 1.1a) by:

- investigating terrace coverbed accumulation history and mapping the distribution of important stratigraphic units,
- correlating these stratigraphic units to established sea level and oxygen isotope curves in order to establish age constraints on individual stratigraphic units, and
- determining rates of shore normal and shore parallel terrace deformation by mapping heights of wave-cut platforms and strandlines.

1.1 Introduction

West of Kakaramea the risers separating the Rapanui and Ngarino Terraces become difficult to locate. This may have resulted from factors such as low uplift rates resulting in little relief between terrace treads or coverbed dunesands ramping up against terrace risers and obscuring them.

Erosion of cover beds between the Tangahoe and Manawapou Rivers has made mapping of the strandline between the two terraces difficult. Recent studies by Pillans (1991) and Bussell (1988) have suggested that the Rapanui Terrace northwest of Manutahi is cut out at the coast (Figure 1.1a) and that the younger Inaha Terrace intersects the present coastline *c.* 1.5 km southeast of the Manawapou River.

In this study mapping of the terrace surfaces was acheived using structural interpretation of the wave-cut surfaces (WCS) and coverbed stratigraphy to explain the history of terrace formation, deformation and uplift in the area. Discussed are the effects of near source volcaniclastics and low uplift rates on depositional environments west of the Tangahoe River, and erosion of the terrace coverbeds between the Tangahoe and Manawapou Rivers.

The coverbeds mapped in this study are correlated with the sea level curves of Chappell (1983) and Pillans (1987) and the oxygen isotope curve of Martinson *et al.*, (1987) to ascertain more directly the age of the marine terraces. Correlation of units to the Wanganui region (Pillans, 1981; Wilde, 1978) and to North Taranaki (Alloway, 1989) is presented.

1.2 Study area

The study area is located in South Taranaki, North Island, New Zealand (Figure 1.1a). It covers a northwest-southeast trending coastal strip approximately 30 km in length, with the northwestern boundary at Inaha Stream, west of Hawera and the southeastern boundary being Kakaramea township. The major rivers draining the study area are, from the north: the Waingongoro River which is sourced from Egmont Volcano and which in the past has been the conduit for a number of lahars, and the Tangahoe and Manawapou Rivers in the centre of the study area which drain the Tertiary mudstone hill country inland of the study area (Figure 1.1a). The larger water courses are deeply incised and have small floodplains. Smaller streams such as the Waikaikai and Mangaroa Streams drain the coastal parts of the study area, rising on the Inaha and Rapanui Terraces. Unlike the Tangahoe and Manawapou Rivers these streams have not entrenched deeply into the terrace surfaces, which is probably an indication of their youthfulness. In the past these streams have had their courses impeded by advancing sand dunes, forming swamps and dune-impounded lakes. The study area is bounded by coastal cliffs up to 70 m in height which are currently eroding at approximately 0.7 m/yr (Gibb, 1978). The Waingongoro, Tangahoe and Manawapou Rivers are the only features within the study area that have cut the coastal cliff down to sea level. The smaller streams, yet to incise, plunge over the cliffs as waterfalls, usually in a series of steps formed by resistant lithologic units within the coverbeds.

Holocene sand dunes extend inland up to four kilometres between the Manawapou and Wanganui Rivers (Fleming, 1953), but within the study area reach a maximum of 2 km inland (Figure 1.2).

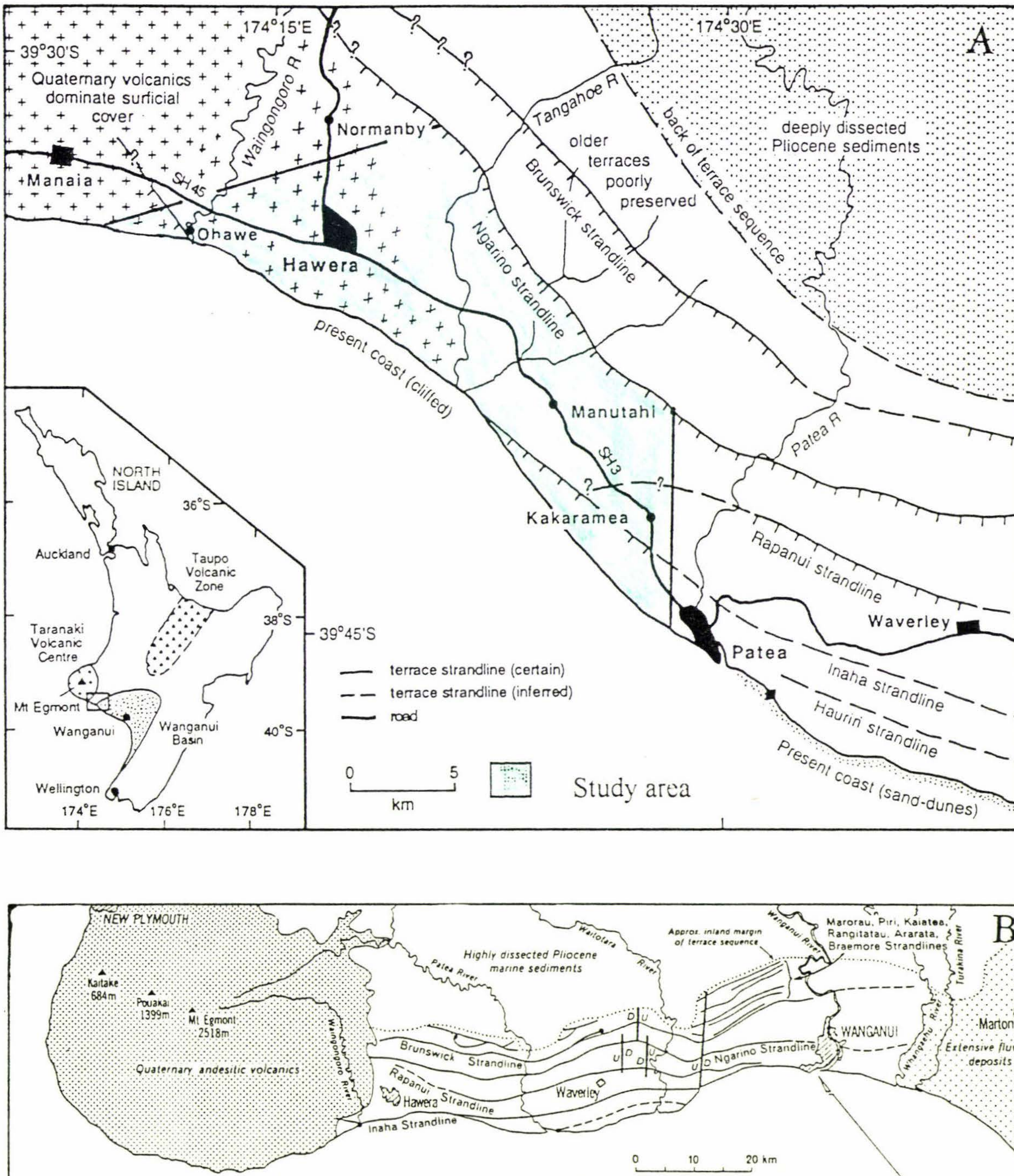


Figure 1.1 **(A)** Location of the study area in relation to the Wanganui and Taranaki Basins and the Taupo Volcanic Zone. Uplifted marine terraces in the southeast sector of the study area become progressively buried west of the Tangahoe River beneath Quaternary volcanics of the Egmont ringplain. West of Kakaramea the distribution of the Rapanui and Ngarino Terraces is uncertain but it is believed that the Rapanui Terrace either cuts out west of Kakaramea (after Bussell, 1993), or as shown in (b) widens towards the west. **(B)** Distribution of Quaternary marine terraces between Wanganui and Hawera (after Pillans, 1983).

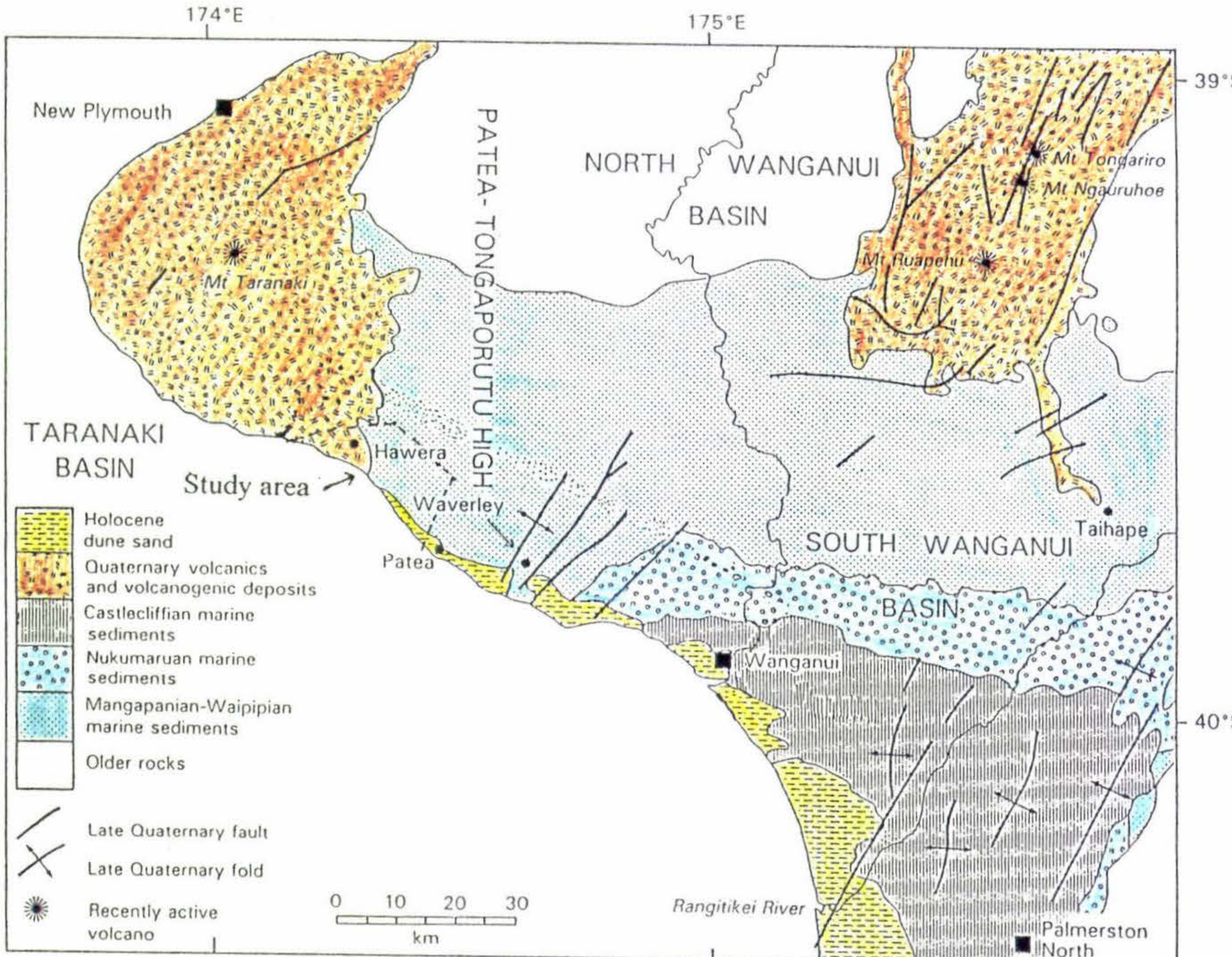


Figure 1.2 Regional geology and study area location in relation to the South Wanganui Basin, Patea-Tongaporutu High and South Taranaki Basin to the west. Northeast-trending faults east of Patea mark the Nukumaru Fault Zone along the eastern margin of the Patea-Tongaporutu High. The Taranaki Fault Zone (a series of high angle reverse faults) marks the eastern margin of the South Taranaki Basin and is interpreted to underlie the study area. Quaternary volcaniclastics from the Taranaki Volcanic succession have infilled the South Taranaki Basin, forming the Taranaki Peninsula (after Pillans, 1990).

1.3 Geological setting

1.3.1 Subsurface geology

The study area lies directly above a basement horst called the Patea-Tongaporutu High (Figure 1.2). This structural high separates the Taranaki Basin to the west from the South Wanganui Basin to the east. The study area lies on the boundary of these two basins. Therefore to provide a suitable geologic background to the study area, a brief history of each basin follows.

The South Taranaki Basin

The South Taranaki Basin (STB), has an extensive distribution offshore and onshore is now deeply buried beneath Quaternary volcanics and volcaniclastics. Its history as an independent geological province began approximately 80 ma (Haskell and Palmer, 1984). The eastern margin of the STB is bounded by the Taranaki Fault Zone (Figure 1.2) which may be a splay of the Alpine Fault (Knox, 1982). The Taranaki Fault Zone is interpreted as a 50 km-wide zone of stacked thrusts (Haskell and Palmer, 1984). Immediately adjacent to the east is the Patea-Tongaporutu High (Figure 1.2), which separates the STB from the South-Wanganui Basin (SWB).

The STB is comprised of two major structural blocks, the western platform to the west and the Taranaki graben to the east (Pilaar and Wakefield, 1978). The western platform is bounded to the east by the Cape Egmont Fault Zone which separates it from the Taranaki graben (Haskell and Palmer, 1984). The Taranaki graben is estimated to be 7 km thick (McBeath, 1977) and contains a sequence of Late Cretaceous (80 ma) to Recent sedimentary rocks. These sediments overlie basement rocks of Paleozoic and early Mesozoic age (120-240 mya). Within the study area only the Pliocene and Pleistocene sediments are exposed above sea level.

The South Wanganui Basin

The South-Wanganui Basin is an elliptical-shaped basin that contains approximately 4 km of shallow water marine sediments. Development of the SWB took place largely during the Pliocene and Pleistocene with regional tilting causing submergence to the south and uplift to the north (Anderton, 1981). The SWB is bounded to the west by a series of en echelon oriented basement highs (eg. the Patea-Tongaporutu High). The margin of the high is marked by the Nukumaru Fault Zone (Figure 1.2). The eastern basin margin is marked by the southern North Island axial ranges.

To the north is the North Wanganui Basin (NWB). The boundary between the two is taken as a line between Mt. Egmont in the west and Mt. Ruapehu in the east. Basin growth has been from north to south and since the early Pliocene the SWB depocentre has migrated in a southeastwards and then southwestwards direction (Figure 1.3). The Late Pleistocene depocentre of the SWB is located 50 km south of Wanganui (Anderton, 1981) and coincides with the greatest negative gravity anomaly (-165 milligals) in the New Zealand region. Sediments were laid down in a shallow marine environment as sedimentation kept pace with subsidence. Subsidence alone however cannot explain the large thickness of sediments in the Basin. Watts *et al.*, (1982) state that on isostatic grounds the greatest thickness of sediment that can accumulate in a basin is unlikely to exceed 2.5 times the original water depth. As the large thickness of shallow water sediments in the Basin were deposited in approximately 100 m of water, the sediments in the SWB cannot be attributed to sediment loading alone, and an additional driving force for the formation of the SWB must be proposed (Stern *et al.*, 1993). The Basin is now thought to be related to lithospheric downwarping (Stern *et al.*, 1993) proceeding in a southwards direction (Figure 1.4) with sediments younging towards the south. Within the Nukumaru Fault Zone faults offset the sediments (Figure 1.2). The majority of these faults are reverse faults that strike northeast, and show a small downthrow to the east. However normal faults have also been reported (Fleming , 1953; Whitten, 1973; Pillans, 1993) which are related to surface stretching associated with the growth of young anticlines (Pillans, 1990).

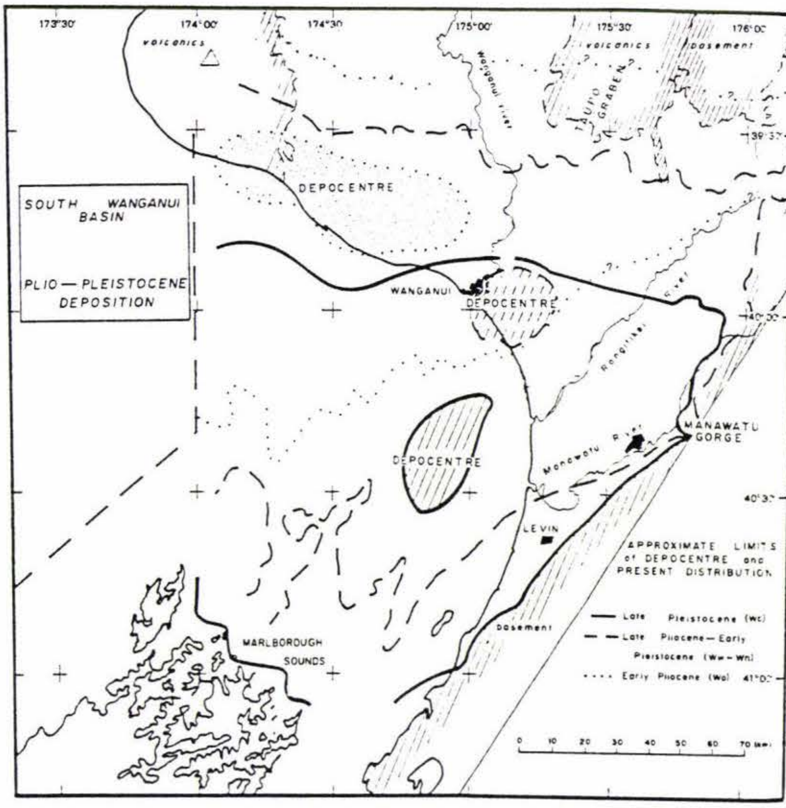


Figure 1.3 Southeasterly migration of South Wanganui Basin depocentre from Early Pliocene to Late Pleistocene and southward younging of uplifted marine sediments (Anderton, 1981).

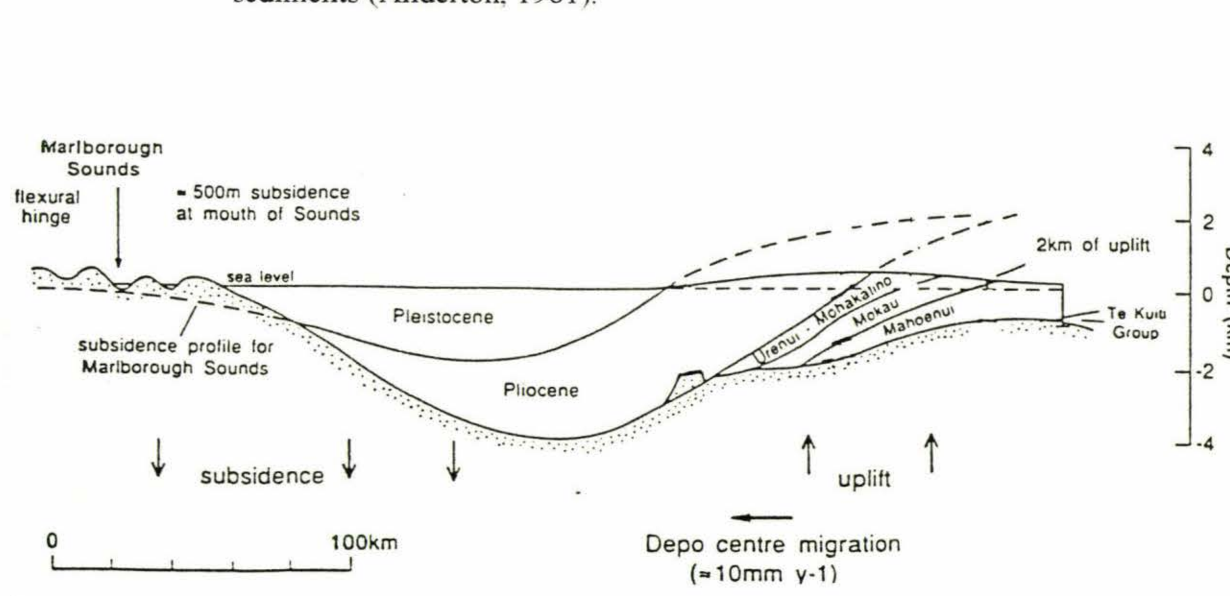


Figure 1.4 SSE - NNW cross section of South Wanganui Basin showing depocentre migration progressing as a lithospheric downwarp with subsidence occurring in the south and uplift in the north (after Stern *et al.*, 1993).

1.3.2 Surface geology

The Taranaki Peninsula is constructed mainly of materials derived from the chain of andesitic stratovolcanoes, extending north-northwest from Mt. Egmont. In order of decreasing age they are Paritutu and Sugar Loaf Islands (1.75 ma) in the north, then Kaitake (0.5 ma), Pouakai (0.25 ma) and Egmont to the south, the latter classed as an active volcano formed during the last 0.13 ma (Smith *et al.*, 1994). These volcanoes are of a high K calc-alkaline type characterised by hornblende-andesite lavas (Smith *et al.*, 1994).

Andesitic stratovolcanoes are potentially unstable landforms and they tend to quickly build up thick sequences of detrital volcaniclastics to form ring plains which surround the mountain. The extensive ring plain comprises coalescing aprons of reworked volcaniclastic deposits forming a relatively undissected sloping surface that grades away from the edifice (Palmer and Neall, 1991). These ring plain deposits are then capped with a variable thickness of tephra and loess. Tephra deposits generally decrease in thickness with increasing distance from source while volcanic loess deposits increase in relative thickness away from the edifice, at least out to 100 km from source.

To the south, Quaternary airfall deposits cover the marine terrace surfaces. The coverbeds are usually composed of materials derived from the volcanic chain to the northwest that has been reworked to leave a complex array of marine, littoral, and dune-sand sediments interbedded with tephra. The inland margin of the study area is dissected Tertiary hill country where volcanic airfall material is restricted to a thin veneer on the steep mudstone landscape and thus often prone to shallow landsliding.

The northwestern part of the study area is situated on the southeastern margin of the Egmont ring plain. The ring plain has a radial drainage pattern with a high density of stream channels close to source, the density decreasing with increasing distance from the mountain. The central and southern parts of the study area are situated on coastal marine terraces. The terraces are probably present closer to the mountain but have been deeply buried beneath the volcanic deposits. On the marine terraces the drainage pattern is denedritic with streams and rivers flowing normal to the coast. All watercourses in the study area, except the Waingongoro and Patea Rivers (which are sourced on Mt. Egmont), drain the inland mudstone hill country which has a high potential for erosion. These rivers therefore tend to carry a much larger amount of suspended sediment (Taranaki Regional Council, 1991) and this is reflected in the colour and nature of the stream channels and their associated floodplains.

1.4 Present climate

Rainfall in the area is related to elevation and hence exposure to the predominant rain-bearing westerly winds. Mt. Egmont affects weather both locally and regionally; rainshadow effects caused by the mountain are recorded as far southeast as Waikanae and Levin. The study area receives *c.* 1200 mm rainfall that is distributed evenly throughout the year with the coastal plains receiving less rain than the inland terraces at higher elevations (Figure 1.5).

The coastal regions experience a warm temperate climate with few extremes; the highest and lowest temperature recorded being 30°C and - 1.5°C respectively. Annual temperatures in inland areas are cooler than average with common frosts and fogs. The region experiences predominantly west and northwest winds (Thompson, 1981). Relatively strong winds occur in late spring and early summer, mostly from the westerly or southerly quarter.

1.5 Past and present vegetation

Very little of the original native forest remains on the ring plain or the coastal terraces. Isolated pockets now remain in gullies and on land too steep to be farmed. The coastal strip was the first area to be cleared by the Maori and by the time of European settlement, it consisted of fern and shrub (Dieffenbach, 1843). Near to the coast the forest contained a low canopy consisting of *Dysoxylum spectabile, Beilschmiedia tawa, Hedycarya arborea, Corynocarpus laevigatus, Elaeocarpus dentatus, Alectryon excelsus, Rhopalostylis sapida* and *Myoporum laetum*. The understorey contained *Dodonaea viscosa, Macropiper excelsa, Melicytus ramiflorus, Cyathea spp. and Geniostoma rupestre var. crassa.* Within 4 km of the coast black topsoils are predominant. This is thought to be due to the original native scrub vegetation containing *Phormium tenax* and *Pteridium acquilinium* var. *esculentum* (Stewart *et al.*, 1977). Farther inland brown topsoils dominate and these were formed under a podocarp-hardwood forest dominated by *Beilschmiedia tawa* and podocarps such as *Dacrydium cupressinum, Podocarpus totara and Dacrycarpus dacrydioides*. The present landscape is now dominated by pasture with farm or paddock boundaries comprised of boxthorn hedges as well as small stands of *Pinus radiata* and macrocarpa.

1.6 Soils

The present day soils in this region are formed largely from Late Quaternary tephra of hornblende-andesite composition derived from Egmont Volcano (Palmer *et al.*, 1981) with the tephra mantle progressively thining and becoming finer away from source. The soils at the southeastern margin of the Egmont ring plain and the northern end of the coastal marine terraces belong to the Egmont series (Allophanic Soils) on flat and rolling terrane.

On the flat to rolling ring plain and terrace surfaces the Allophanic Soils generally have a very high amorphous clay (allophane) content with silt loam textures. The subsoils contain fine volcanic ash and volcanic loess, and it is this that gives these subsoils their characteristic waxy feel. The allophane imparts many desirable qualities such as friable consistence, high macroporosity and thus good drainage to the soils, making them some of the most productive or potentially productive soils in the country. High phosphate retention values also characterise these soils; this is overcome by heavy applications of phosphate fertilisers. Often the topsoils close to the coast have a sandy texture derived from wind blown sand imparting a lower phosphate retention.

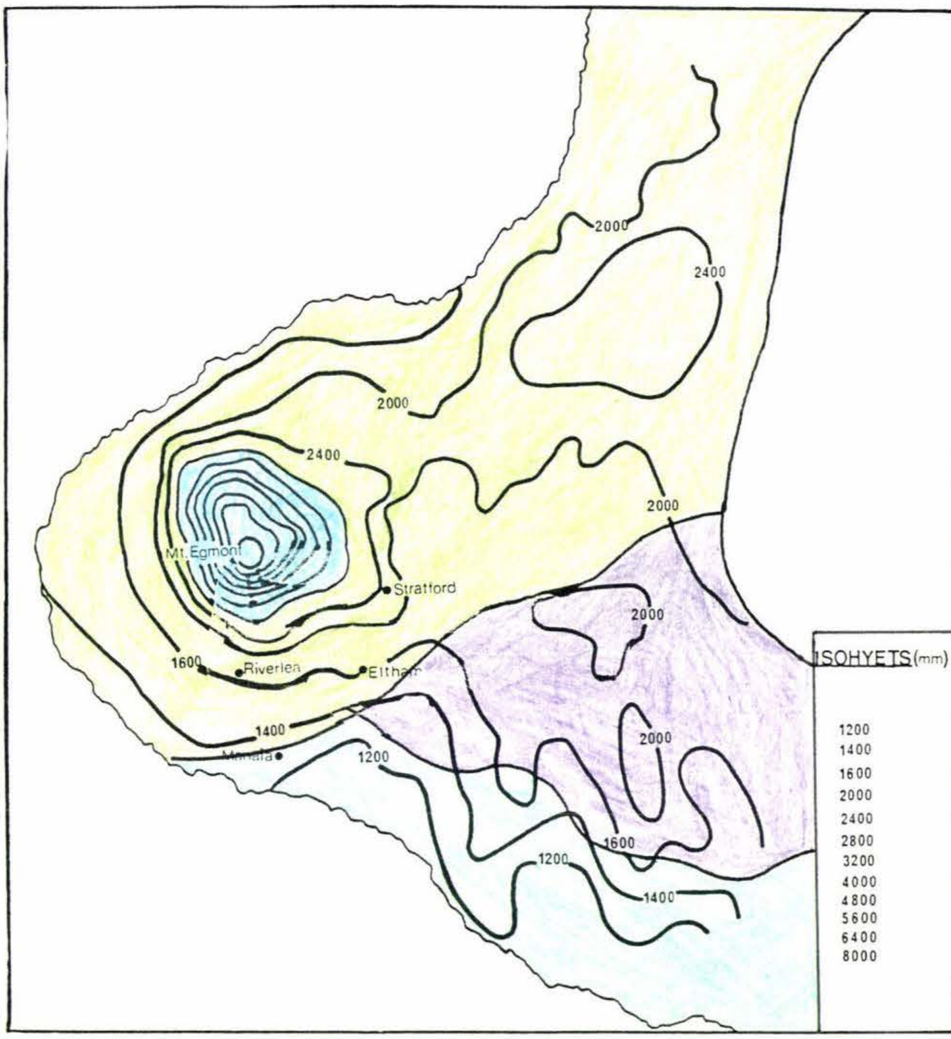
Farther inland and southeastwards on the dissected marine terraces the underlying Tertiary sedimentary strata are often exposed. The landscape becomes progressively more dissected as uplift rates and terrace age both increase inland. In the river valley systems where moderately steep to steep slopes dominate the landscape, the soil pattern is related to the different lithologies exposed to weathering. In places composite soils have formed which have very well developed pedological features and are classed as Granular Soils. In contrast, undissected flat to rolling interfluve terrace surfaces have a mature and stable landscape history with little of no erosion of coverbed units. With increasing terrace age the the marine sediments on each wave-cut surface (WCS) are mantled by progressively older volcanic ash and volcanic loess deposits.

A narrow coastal strip of Holocene sand dunes, sand plains, peaty swamps and lakes that extend from Wanganui to Cape Egmont, form the sand country of the Wanganui-South Taranaki region (Wilde, 1979). Between Wanganui and Patea, Wilde

(1979) mapped the sand country soils and described eight soil series (3 on the dunes and 5 on the associated sand plains) with differences being mainly attributed to drainage conditions and landform age.

1.7 Landuse

The landuse in the area centres around livestock farming; dairy farming being dominant. Sheep and beef farming is the second largest activity, generally in the hill country. Horticulture in the region is represented by a few orchards and commercial gardens in the vicinity of Hawera and Normanby where up to *c.* 200 ha of asparagus are grown (Water and Soil Misc. Publication No. 110).



Climatic types

A2	Warm humid summers, mild winters. Annual rainfall 1500 to 2500 mm with a winter maximum. Prevailing wind southwest.
C3	Warm summers. Very heavy rain at times from south and southeast. Annual rainfall mainly 1500 to 2500 mm.
D1	West to northwest winds prevail with relatively frequent gales. Annual rainfall 900 to 1300 mm. Rainfall reliable and evenly distributed throughout the year. Warm summers and mild winters.
M	High rainfall mountain climates. Conditions vary greatly with altitude and exposure.

Figure 1.5 Mean annual rainfall isohyets and climatic regions of the Taranaki region (Official New Zealand Meteorological Office data, 1941-1970).