SEDIMENTOLOGY AND PALEOENVIRONMENTAL ANALYSIS OF CASTLECLIFFIAN STRATA IN THE DANNEVIRKE BASIN

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ABSTRACT

Castlecliffian deposits of the Mangatarata Formation are widespread in the Dannevirke Basin, a fault angle depression on the east coast of North Island, New Zealand. The basin is 80km long and 19-24km wide, is bounded to the east by the upthrust Waewaepa-Oruawharo High and to the west by the upthrust front of the Ruahine Ranges. The basin floor is broken by three major axial-trending anticlinal folds.

Basin development began during early Pliocene times with subsidence continuing into the Nukumaruan. Uplift during Castlecliffian time was accompanied by deposition of the Mangatarata Formation.

Four facies associations are recognised in deposits of the Mangatarata Formation. Facies association one comprises greywacke rubble and gravel deposited in proximal to distal alluvial fan environments. Facies association two is dominated by fluvially deposited, cross-bedded sand and gravelly sand with associated overbank fine deposits. Facies association three is generally a fossiliferous, flaser bedded silt to fine grained sand, deposited in a tidal/estuarine environment. Facies association four is a rarely fossiliferous, fine grained, centimetre bedded silt deposited in a locally subsiding, interfluvial lacustrine environment.

Pumice deposits derived from erosion of unwelded ignimbrite originating in the Taupo Volcanic Zone are significant components of facies association two. They show a range of sedimentary structures associated with rapid deposition. The thickest pumice units, up to 30m, are interpreted to have been deposited in a meandering fluvial environment and display features typical of hyperconcentrated flow and streamflood deposits.

It is possible, using identified pumice units as marker beds, to express the physical and temporal extent of specified sedimentary environments. The boundary between fluvial and tidal/estuarine environments and thus approximate paleoshoreline shows that the overall sea-level trend during the Castlecliffian was one of regression.

Superimposed on this trend are at least ten episodes of transgression related to eustatic sea-level rise. These alternating cycles of tidal/estuarine to terrestrial sediments are interpreted as cyclothems deposited dominantly during 100,000 and 40,000 year long, *c.* 80-130m magnitude, fifth and sixth order orbitally forced glacio-eustatic sea-level cycles and represent Oxygen Isotope stages 21 to 39.

Thinning of pumice tuffs younger than the Rewa Pumice (*c.* 1.0 Ma) toward anticlinal crests suggests that strata younger than this were deformed contemporaneously with deposition, while strata older than the Rewa Pumice show no evidence of syndepositional deformation. This coincides with the restriction of alluvial fan deposits to the west of the study area due to the growing Dannevirke Anticline, between deposition of the Rewa Pumice (*c.* 1.0 Ma) and the Potaka Pumice (*c.* 0.80 Ma).

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INTRODUCTION

1.1 Objective and scope of study

Castlecliffian strata near Dannevirke were first mapped in detail and described by Lillie in 1953. Of prime importance for correlation, six pumice tuffs were recognised within a sequence of both terrestrial and nearshore marine sediments. Recent work identifying and correlating these tuffs within the Dannevirke Basin (Melhuish, 1990) has now provided the stratigraphic basis for a detailed paleoenvironmental reconstruction of the Basin.

The aim of this study was to make a paleoenvironmental reconstruction of Castlecliffian strata in the Dannevirke Basin by integrating tectonic setting, lithofacies and paleocurrent information into a paleogeographic model and to relate the sedimentation history to relative sea level change during the Castlecliffian.

1.2 Location

The study area is located in the Dannevirke district, of southern Hawkes Bay (Fig. 1.1). The area is bounded to the north by the Mangatewainui Stream and to the south by the Mangatera Stream. The western boundary is the Range Front Fault (Melhuish,1990), where Castlecliffian sediments lie adjacent to upthrust Mesozoic greywacke. To the east the boundary is defined by the confluence of the Mangatewainui and Mangatewaiiti streams and further south by the Napier Highway. The Whakaruatapu Stream is the only other major stream to cross the field area. Dannevirke township (Fig. 1.1), situated at the southeastern boundary of the study area, services the surrounding rural community which is involved predominantly in dairy and sheep farming.

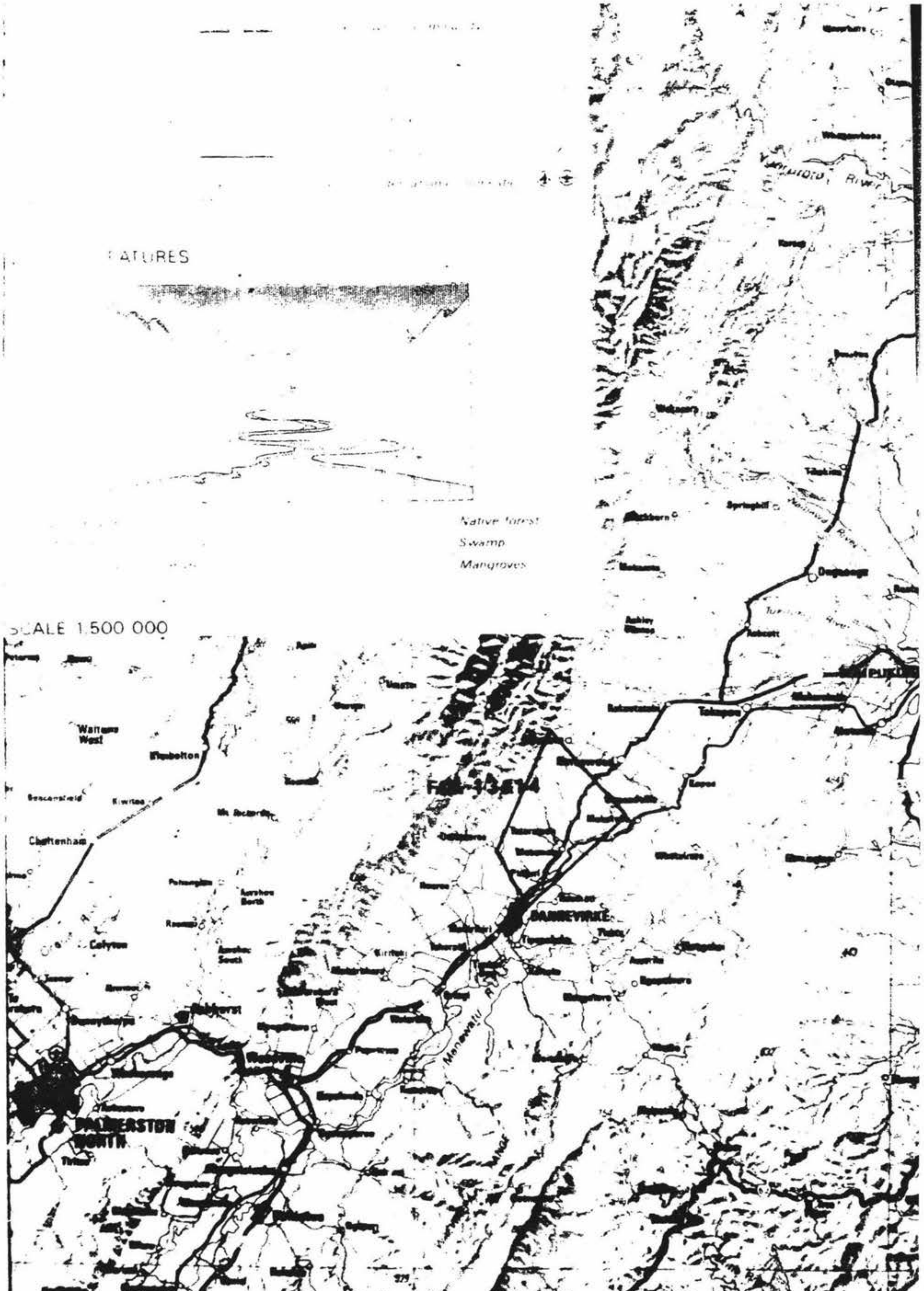

Fig. 1.1 Topographic map of the field area and associated localities (from Department

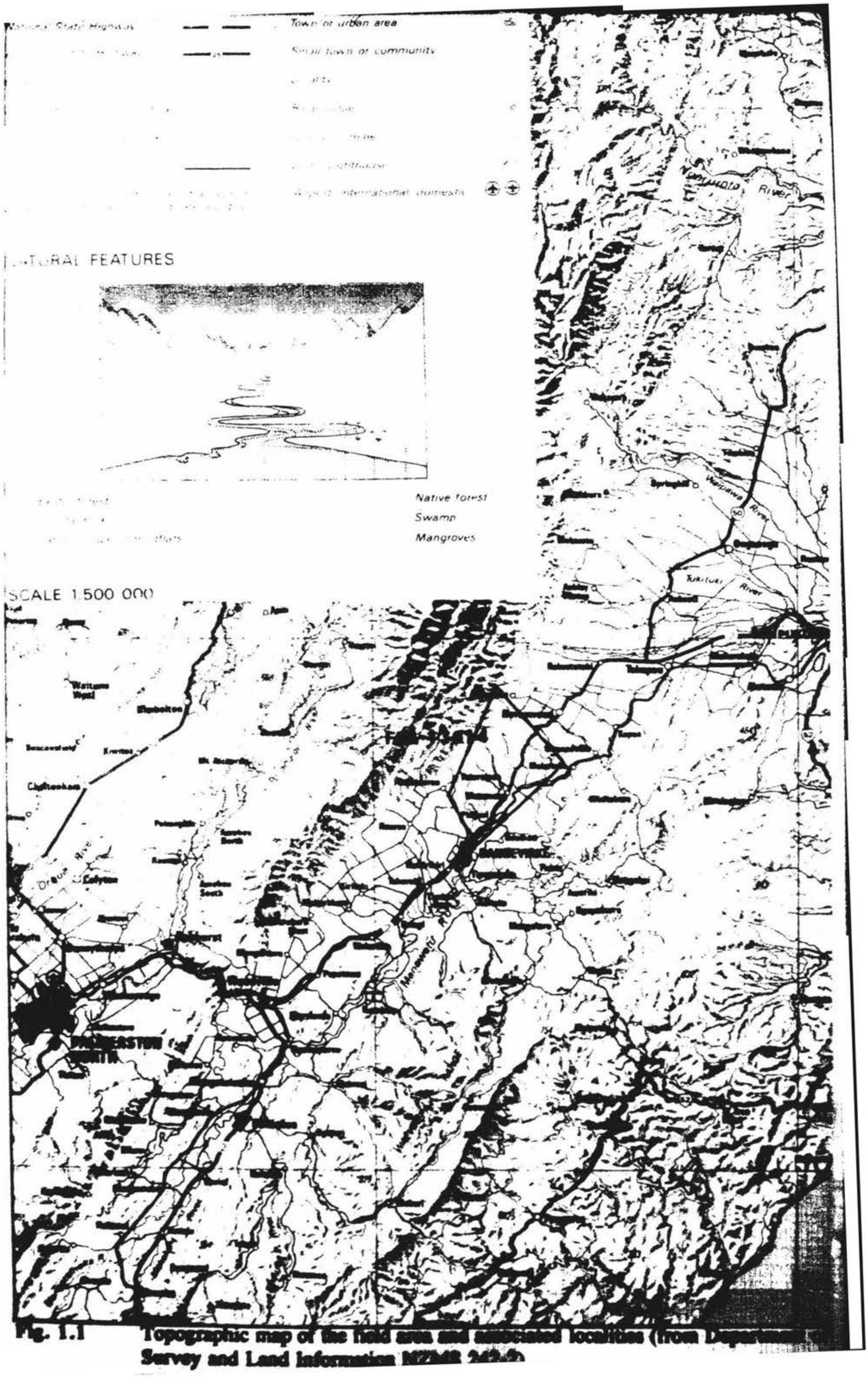

Fig. 1.1 Topographic map of the field area and associated localities (from Department of Survey and Land Information NZMS 242/2)

The field area comprises a relatively well exposed sequence with a variety of terrestrial and estuarine/tidal facies.

1.3 Methods

The four streams mentioned above were mapped using 1:25000 aerial photos. Wherever good outcrop was exposed sections were logged in detail. All available paleocurrent data (Chapter six) and structural data (dip and dip directions) were collected. Samples for grain size analysis and identification of mineralogy, were collected wherever it appeared this information would be useful *e.g.* where there was a change in lithology, grain size or mineralogy. All data collected were plotted on 1:25000 topographic base map and stratigraphic columns (Fig. 2.1, 2.2, 2.3, and 2.4 were drawn showing the distribution of sediments from which facies associations were recognised.

1.4 Regional setting

1.4.1 Physiography

Two features dominate the physiography of the Dannevirke district. To the east, the NNE-trending Ruahine Range rises to heights of greater than 1500m. Mesozoic rock comprising complexly deformed, highly indurated, flysch sequences with associated spilite and chert make up the strata of the Range and form the regional basement. The second feature dominating the physiography of the Dannevirke district is the sequence of four main terraces. Of the four main terraces recognised (B,C,D, and E, Fig. 1.2) one (B) is younger than the Aokautere Ash (22.5 ky) and three are older (Rhea,1968) Minor terraces younger than Terrace B together with the floodplains of the rivers are grouped under Terrace A. The three older terraces are moderately dissected and gently undulating, and are covered by thick loess. The vertical interval between terrace surfaces varies but it is in the order of 10-20m. Except where disturbed by faulting as at localities 1 and 2 (Fig. 1.2), post-Aokautere Ash terraces are flat with few

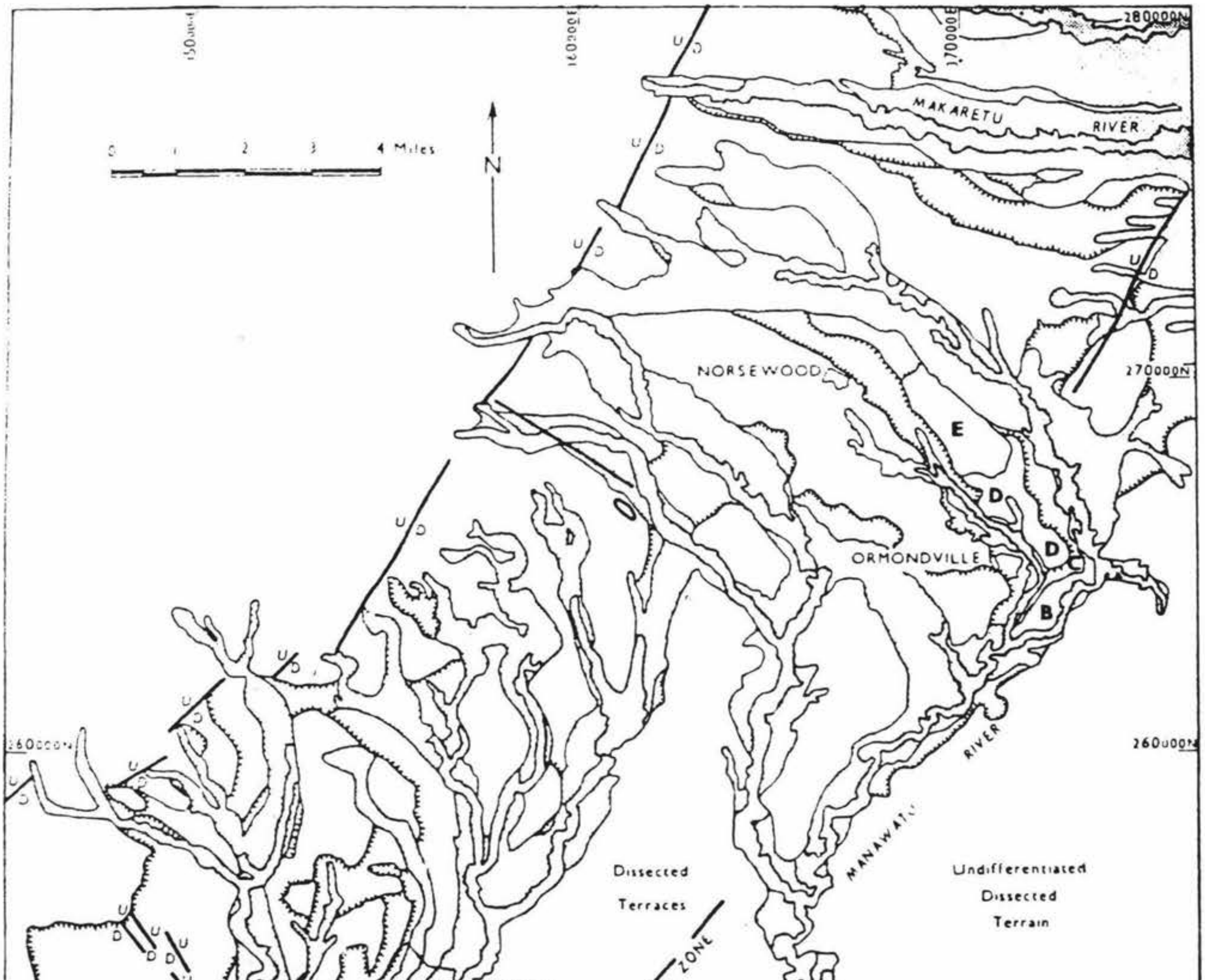

Fig. 1.2 Map of river terraces in Dannevirke district. Young minor terraces and flood plains are finely stipled (A). Terrace B, the oldest post-Aokautere Ash terrace is coarsely stippled. Terraces C, D, and E are pre-ash terraces. Traces of active faults are shown by bold dashes. Numbers in circles mark localities mentioned in text (from Rhea, 1968).

undulations, and are commonly covered by gravelly soil and marked by shallow branching channels that clearly show on aerial photos. They have well defined and steep risers. Terrace B is underlain by as much as 3m of gravel. At locality 3 (Fig. 1.2) these gravels unconformably overlie strongly iron-stained, non-marine, aggradational, pre-Aokautere Ash, terrace gravel. Terrace B, the terrace immediately younger than the Aokautere Ash, is the most extensive terrace in the district, is well defined, and is correlated with the Ohakea terrace in the Manawatu district (Cowie and Wellman, 1962; Cowie, 1964a,b). The base of the Ohakea loess is dated at 25500 yrs B.P. by radiocarbon dating and the top is older than 9450 yrs B.P. The deposition time of the Ohakea loess corresponds to the latest Quaternary cold period (Milne and Smalley, 1979); also the time of Terrace B aggradation. Terraces B,C,D and E represent significant periods of aggradation. By contrast the recent terraces that are grouped together as "A" are not extensive and mark pauses in the period of river downcutting that is still continuing.

1.4.2 Geology and previous work

The Dannevirke Basin (Fig. 1.3), first outlined by McKay (1877), is essentially a fault-angle depression 80kms long and 19-24kms wide. It is formed by a westward tilted block upthrust along the Waewaepa-Oruawharo High to the east (Turner, 1944) (Fig. 1.4). The High is faulted on its eastern margin with a stratigraphic throw of *c.*2000m (Laing, 1961). A greywacke erosion surface is preserved across the High and on its western boundary. It is covered by Taranaki to Opoitian aged sediment, dipping 20^0 to the west.

In the west Tertiary aged cover beds are drag folded against the upthrust front of the greywacke basement of the Ruahine Range, giving the Basin a general asymmetrical synclinal structure with a short, steeply east-dipping west limb and a long, gently west-dipping east limb. This east limb makes up most of the Basin floor. It is broken by several axial trending faults which repeat the structure of the block as a whole and cause local accentuation of the general westward tilt. In places asymmetrical anticlinal folds

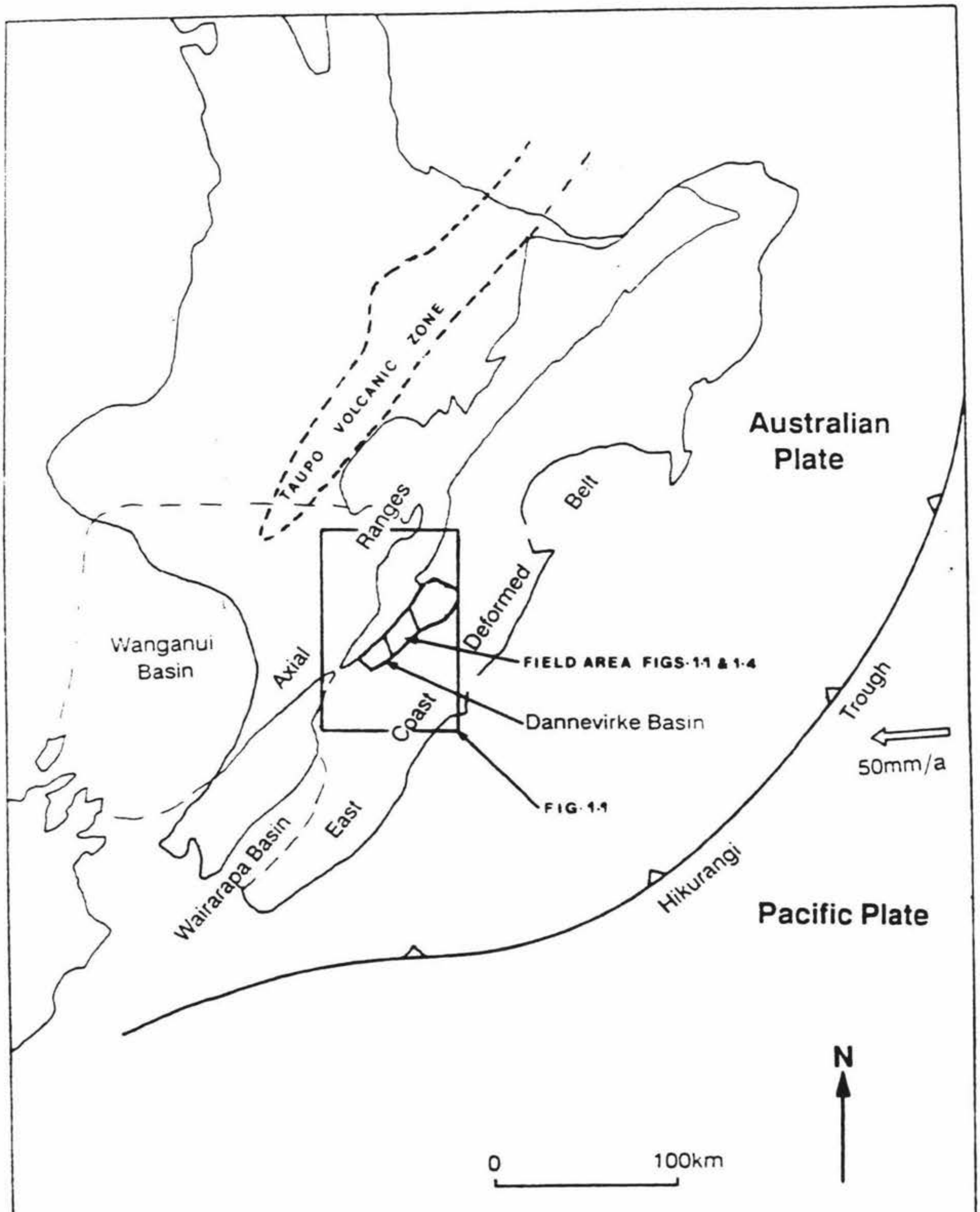

Fig. 1.3 Tectonic setting of the Dannevirke Basin (modified from Melhuish, 1990).

are superimposed which are probably the surface expression of further faulting in the basement (Firth and Feldmeyer, 1943; Melhuish, 1990).

The greywacke basement has been stripped of Tertiary cover beds at several places exposing a line of basement "highs" which form a natural eastern limit to the Basin. A similarly upthrust basement "high" is exposed within the Basin near Kumeroa, northeast of Woodville (Fig. 1.1). This basement high conveniently divides the Basin into a northern or Dannevirke section, and a southern or Pahiatua section (Firth and Feldmeyer, 1943).

The Kumeroa greywacke "high", first mentioned by Thomson (1914) forms the prominent Morgan's Hill and is steeply dipping with an erosion plane on its western edge covered by basal Tertiary conglomerates. At its northern extremity there are several splinter faults considered to run with decreasing throw into the Dannevirke Anticline, and along its eastern edge a prominent scarp overlooking the Manawatu River marks the line of the Kumeroa Fault, which is contiguous with the Dannevirke Anticline.

1.5 Dannevirke Basin tectonic history

During the early Pliocene the sea extended across most of the southern part of the North Island (Lillie, 1953). At this time a basin of sedimentation began to form to the east of the present axial range, with the west flank of the basin extending towards the present range crest. The strike of this basin appears to have been nearly north-south. A number of faults developed at this time and some were active during the whole period of basin development (Lillie, 1953). Development of the basin continued during the Waipipian (3.0-2.5 Ma) with sediments deposited consisting mainly of sands, mud and local gravel. The area of the present range crest was largely still submerged. Basin subsidence associated with faulting continued into the Mangapanian (2.5-2.0 Ma).

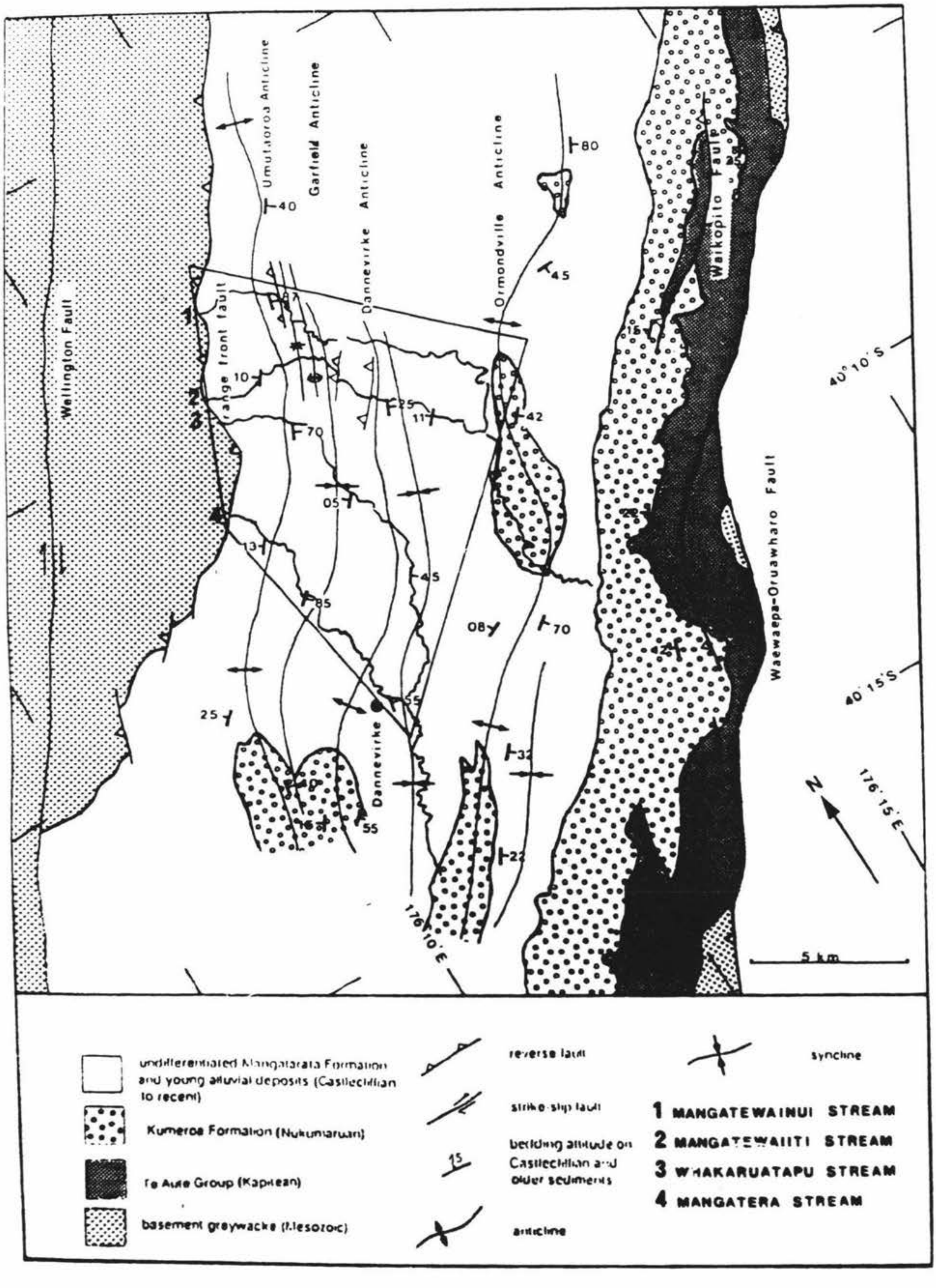

Fig. 1.4 **Simplified geological map of the southern part of the Dannevirke Basin (modified from Melhuish, 1990).**

During the Hautawan and Nukumaruan (2.0-1.26 Ma) the Dannevirke-Pahiatua Basi continued to deepen, but sedimentation was confined to the area west of the Waewaep Oruawharo High.

In latest Pliocene - early Pleistocene times the seaway extending from Hawkes Bay the Wairarapa became constricted in the vicinity of Mt. Bruce and about 1.5 M independent drainage basins developed, with the Dannevirke-Pahiatua Basin to the no and the Masterton Basin to the south (Kamp and Vucetich, 1982).

The sudden incoming of floods of pumice, derived chiefly from erosion of unweld pyroclastic flow deposits originating from the Taupo Volcanic Zone (Kamp, 1981), in the Basin during the Castlecliffian (1.0-0.4 Ma) marked a lithological change fr marine mudstone to laminated, interbedded estuarine muds, silts and sands of Mangatarata Formation (Firth and Feldmeyer, 1943).

The Mangatarata Formation was first used by Quennel (1937), for a group of pumiceo silts with lignites and sands interbedded with gravels which occur in the Mangatara Valley southeast of Waipukurau (Fig. 1.1). Quennel described these beds as gen tilted to the west and resting on all underlying formations from the Whangai Formati upwards. Quennel (1938) also included in the Formation pumiceous silts, sands a gravels which conformably overlie Nukumaruan beds in the Takapau and Norsewo survey districts. Bands of white pumice sand, cemented gravel, and lignite are uniq to the formation, and were assigned Castlecliffian age (Lillie, 1953). In t Mangatewainui Stream the uppermost beds of the Nukumaruan aged Kumer Formation show the change from offshore marine sedimentation to estuarine and fluv conditions that characterise the Mangatarata Formation. Thick mudstones contain bands of lignite and shellbeds are indicative of mudflat conditions with swam vegetation. *Austrovenus stutchburyii* is the dominant species. It is small shel (suggesting stunting through low salinity), thin shelled (suggesting acid conditions), flat (suggesting lack of wave action) (Lillie, 1953).

Shane (1989) and Melhuish (1990), have distinguished several different rhyolitic tuffs in the Mangatarata Formation of the Dannevirke Basin. It is these tuffs which aid in basin wide correlation by creating stratigraphic marker beds which give time planes across the entire basin allowing approximate rates of sedimentation to be calculated. Tentative correlations can also be made with tuffs in the Rangitikei Valley and in the southern Wairarapa on the basis of mineralogy, glass chemistry and palaeomagnetism (Shane, 1989).

The Mangatarata Formation was tilted and folded by the Kaikoura Orogeny. The beds in general strike N 25 E and dip 6-10 degrees to the NW (Lillie,1953; Piyasin, 1966). Due to the tilting and folding there is usually marked unconformity between the Mangatarata and younger strata (Lillie, 1953). The thickness of the formation decreases southward from Norsewood (Fig. 1.1), (Leslie and Hollingsworth, 1972). At Norsewood the thickness is at least 600m (Lillie 1953), but thins to less than 100m, 5km south of the Manawatu Gorge (Fig. 1.1) where Piyasin (1966) considered the whole of the Mangatarata Formation was represented. Farther south in the Eketahuna region (Fig. 1.1), Ongley (1935) and Neef (1984) found the Mangahao Formation, the equivalent of the Mangatarata Formation, to be less than 60m thick.

1.6 Structures within the Dannevirke Basin

The general synclinal structure of the Dannevirke Basin is broken by three strongly asymmetrical anticlines, all with steep eastern limbs and gentle western limbs. All three structures have a general plunge to the north, with the result that Castlecliffian strata dominate the surface exposures north of Dannevirke, Nukumaruan strata dominate the area south of Dannevirke, while Waitotoran strata crop out in the south of the basin at Kumeroa (Firth and Feldmeyer, 1943).

The western or Umutaoroa anticline (Fig. 1.4) maintains a northerly plunge and it is clearly defined throughout the field area in Castlecliffian beds. Its strike carries it closer to the western margin of the basin, until at the Makaretu River north of the field area it is only 1km from the Range Front Fault (Melhuish, 1990).

The central or Dannevirke anticline (Fig. 1.4) is traceable north over a distance of 19km to the Norsewood area. At Dannevirke it converges on the western anticline until their axes are only 1.5km apart. The high dips on the east limbs of both structures in this locality suggest the possibility that both folds may be grading into faults here and to the south.

The eastern or Ormondville anticline (Fig. 1.4) is well defined over a distance of 40km from the Makaretu River west of Takapau (Fig. 1.1) in the north, to Kumeroa in the south (Firth and Feldmeyer, 1943). To the north of the field area a small, north plunging anticline lies between the western and central anticlines. It appears to die out to the south but it is not known whether this is due to closure or whether it grades into a fault.

The only fault apparent at the surface in the field area is a reverse fault with an offset of *c.* 100m. It lies *c.* 2 km west of the Dannevirke anticline in the Mangatewaiiti Stream (Fig. 1.4). Melhuish (1990) has identified other subsurface faults in the field area using seismic profiles and tuff correlation.