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GEOLOGY OF THE TINUI DISTRICT

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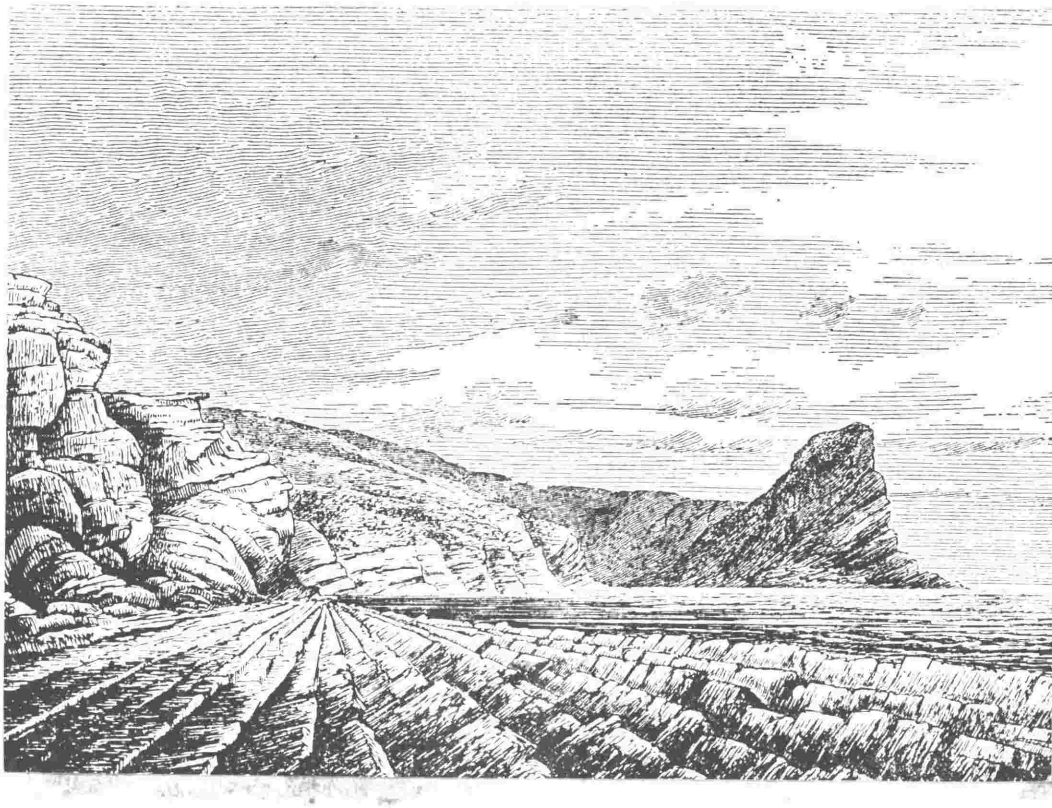

Frontispiece: Shore platform, south of Castlepoint, showing graded beds of the Whakataki Formation; from a sketch by Captain W.M. Smith.

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FIGURE CAPTIONS
(abridged captions)

ABSTRACT

The Tinui District is assumed to be typical of the more deformed part of the New Zealand Mobile Belt. It contains an unusually complete stratigraphic record, rocks representing most stages from Upper Jurassic to Recent being present. Although the rocks are strongly deformed, the complex diapiric structures that occur in the northeast of the mobile belt are absent.

The stratigraphy is described in terms of formations which are then used to infer the paleogeography for eight periods of time.

An attempt is made to treat the structure according to its development with time. The main conclusion is that there was a change in the strike of the fold axes and in the sense of movement of the faults. Strong folds, striking approximately northeast, are Paleocene in age and weak folds, striking approximately north, are post-Miocene. There are two fault trends, one NNE and the other ENE. The ENE striking faults were dominant in the Early Cenozoic and the NNE striking faults were dominant in the Late Cenozoic. The sense of movement on the

NNE faults changed from sinistral to dextral. The change in the direction of the fold axes and in the sense of movement on the faults can be expressed as a change in the direction of maximum horizontal shortening, which is inferred to have changed with time.

It is also found that the rates of tilting, and probably faulting, have not been constant with time, but occurred as bursts (disturbances) in the Paleocene, Early Miocene, Late Pliocene, and Late Quaternary. The Mesozoic part of the geological history of the Tinui District is scrappy and far less complete than the Cenozoic part.

In order to place the Tinui District in a broader setting, the central part of the New Zealand landmass in the Cenozoic, called the New Zealand Mobile Belt, is discussed in some detail. The mobile belt consists of fault blocks which form a geanticline along the New Zealand landmass and a geosynclinal trough between the east coast and the Hikurangi Trench. It is shown that a clear distinction has to be made between tilting and uplift.

A main feature of the New Zealand Mobile Belt is the dextral faulting, on major NNE striking faults, in the Late Cenozoic. A major reversal in the direction of maximum horizontal shortening was found in the Tinui District to have taken place at the beginning of the Miocene or in the Oligocene. The reversal indicates that the dextral faulting of the New Zealand Mobile Belt may have started at that time, and that earlier strike-slip movement had been sinistral. This conclusion contradicts existing reconstructions of the New Zealand landmass with time, and a more complex reconstruction is required to satisfy the tectonics of the Tinui District.

INTRODUCTION - THE PROBLEM

The east coast of New Zealand, from Kaikoura to East Cape, is complexly folded and faulted and can be contrasted with the more stable classical regions of New Zealand such as those in the west and southeast of the South Island. In the classical regions a single major unconformity separates younger, gently dipping, fossiliferous rocks from older, complexly folded, sparsely fossiliferous rocks. In the East Coast Region there is no one single unconformity. Instead there are several. Steep dips, poor exposures, and extensive superficial slumping make the geology difficult to interpret. As compared with most other regions of New Zealand the East Coast Region as a whole is little known, and this gap in geological knowledge prohibits a complete understanding of the stratigraphy, structure and paleogeography of New Zealand.

The Tinui District (Fig. 1) is representative of the East Coast Region. It lies near the centre of the region and is 300 square miles in area and comprises the eastern part of Sheet N158, Masterton, and all of Sheet N159, Tinui, N.Z.M.S.1. (Figs. 2, 3, in pocket at back).

It contains the biggest range of ages from Upper Jurassic to Recent (Fig. 4) of any district in the east coast of the North Island. Several strike-slip faults exist and earthquakes have occurred nearby in historic times. Rates of tilting as high as $30/10^6$ years have been recorded from Upper Pleistocene and Holocene rocks on the coast to the north and south of the district. In the north of the Tinui District fold axes in Cretaceous-Lower Tertiary rocks are at an appreciable angle to the fold axes in Upper Tertiary rocks (Ongley, 1935), indicating that the direction of maximum horizontal shortening has changed. The high tilt rates, different fold directions and the unusually complete record of sedimentation were expected to permit the change of tectonics of the region with time to be determined.

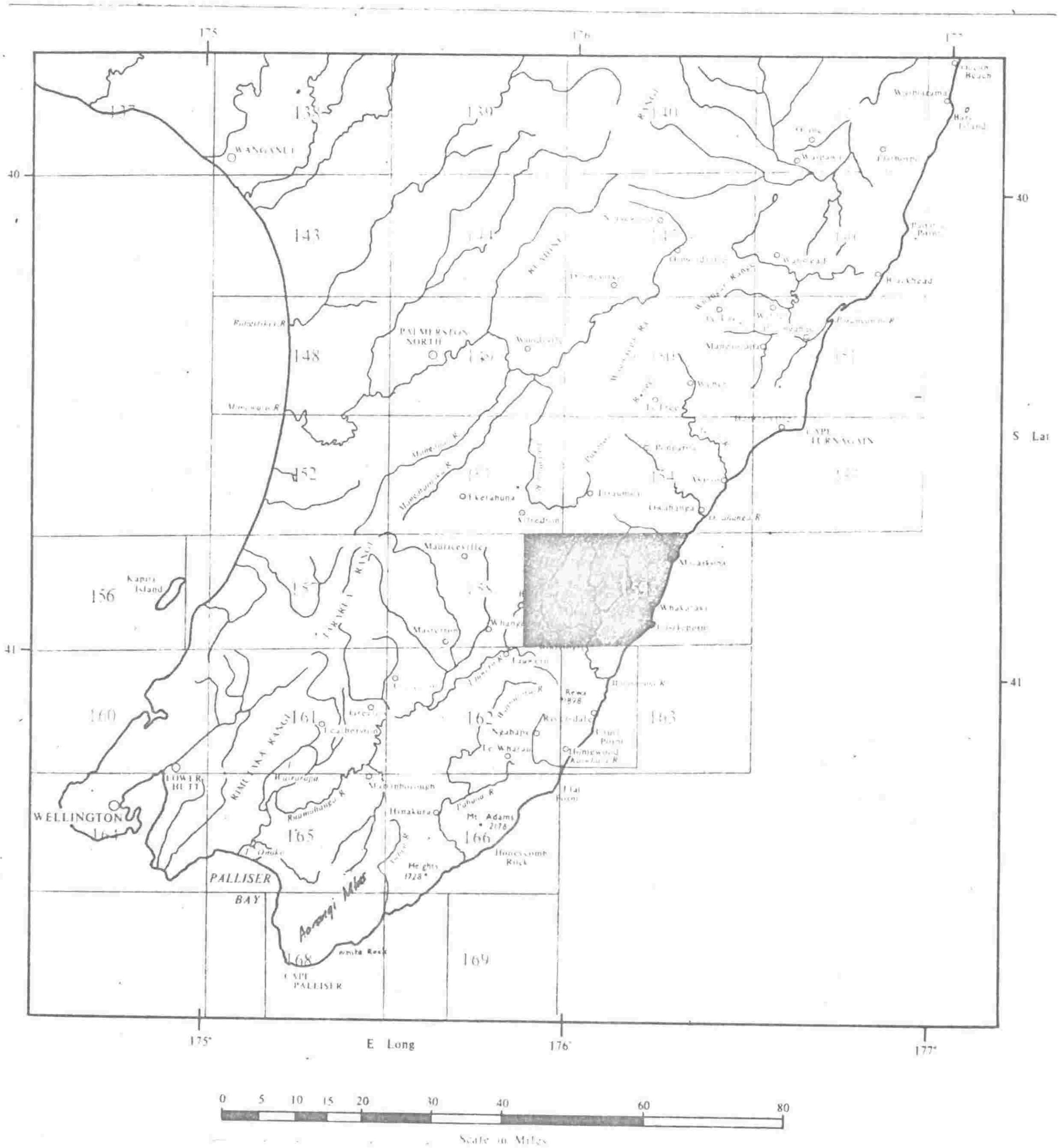


Fig. 1. Map of the southern part of the North Island, showing N.Z.M.S. 1 sheet boundaries and the limits of the Tinui District.

GROUP	FORMATION	STAGE	SERIES			YRS. × 10^6	AVERAGE DURATION OF EACH STAGE
	(SEVERAL FORMATIONS)		HOLOCENE		QUATERNARY		< 1×10^6 yrs
			HAWERA	PLEISTOCENE			
		CASTLECLIFFIAN	WANGANUI				
	CASTLEPOINT	NUKUMARUAN					
		MANGAPANIAN		PLIOCENE	TERTIARY		
		WAIPIPIAN					
HURUPI	RANGIWHAKAOMA	OPOITIAN				3·3	
	WAIHOKI	KAPITEAN	TARANAKI	MIOCENE			4×10^6 yrs
	NGARATA	TONGAPORUTUAN					
	MAUNSELL	WAIAUAN	SOUTHLAND				
		LILLBURNIAN					
ANNEDALE	TAKIRITINI	CLIFDENIAN					
		ALTONIAN	PAREORA			25	3×10^6 yrs
	WHAKATAKI	OTAIAN					
		WAITAKIAN	LANDON				
WANSTEAD	WEBER	DUNTROONIAN		OLIGOCENE			
		WHAINGAROAN					
		RUNANGAN	ARNOLD	EOLENE			
		KAIATAN					
	HUATOKITOKI	BORTONIAN					
		PORANGAN	DANNEVIRKE				
		HERETAUNGAN					
		MANGAORAPAN					
		WAIPAWAN		PALEOCENE			
TINUI	WHANGAI / WAIPAWA	TEURIAN				65	
	TE MAI	HAUMURIAN	MATA	UPPER	CRETACEOUS		5×10^6 yrs
		PIRIPAUAN					
MANGAPURUPURU	GENTLE ANNIE / GLENBURN	TERATAN	RAUKUMARA				
		MANGAOTANEAN					
		AROWHANAN					
	SPRINGHILL	NGATERIAN	CLARENCE				
	MARINGI	MOTUAN					
		URUTAWAN				106	
		KORANGAN	TIATIA	LOWER			
		MOKOIWIAN					
TORLESSE SUPER GROUP	TAIPO / WAEWAEPA	PUAROAN	OTEKE		JURASSIC	146	

Fig. 4. Stratigraphic Outline, Tinui District.

PHYSIOGRAPHY AND STRATIGRAPHY OF THE TINUI DISTRICT

PHYSIOGRAPHY

The Tinui District is bounded in the east by a fairly straight coastline containing only one promontory - the headland and reef at Castlepoint. The district is hilly and is divided into two parts by the valley of the south flowing Whareama River. Hills east of the river reach a height of 1,557 ft at Mt Percy and those west of the river reach a height of 1,704 ft at Mangapurupuru. Many of the hills in the west have strikingly rugged profiles and because of their unusual shape are locally called "taipos". Most of the district is in grass and is used for sheep farming. In the east there are large areas of thick scrub and regenerating bush and some plantations of exotic pines.

The hills are dominantly of Cretaceous and Upper Jurassic rocks. In the Whareama Valley and on the coast the rocks are dominantly Tertiary (Fig. 5).

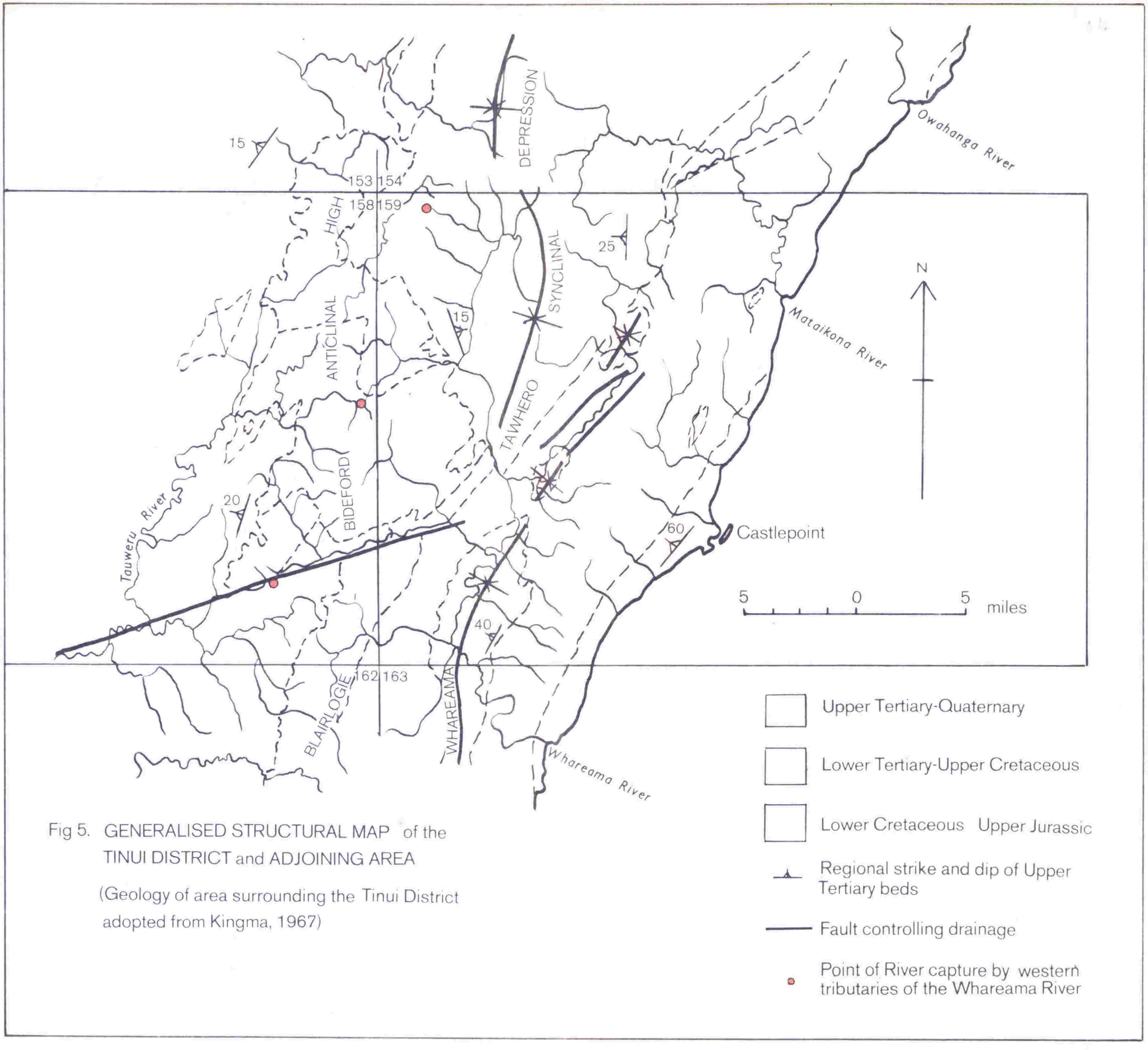


Fig 5. GENERALISED STRUCTURAL MAP of the TINUI DISTRICT and ADJOINING AREA

(Geology of area surrounding the Tinui District adopted from Kingma, 1967)

STRATIGRAPHY

PREVIOUS GEOLOGICAL WORK

The only accounts of the geology prior to 1930 were those by A. McKay (1877), Park (1888), W.A. McKay (1899) and Morgan (1910, 1914). In the early 1930s the northern part of the sheet was mapped in detail by Mr M. Ongley but only a small scale map (Ongley, 1935) and brief descriptions were published (Ongley, 1933; 1934; 1935; 1936a). Some of the Cretaceous rocks are highly fossiliferous and were referred to by Wellman (1959) and a small Cretaceous area was mapped by Haskell (1964). A small area of Tertiary rocks in the north of the district was mapped by Ridd (1967). A late Quaternary tectonic map of the western part (Sheet N158) has been published (Lensen, 1968).

GEOLOGICAL TIME SCALE

The presently accepted sequence of New Zealand Cenozoic stages is that of Finlay and Marwick (1947) with the following modifications:

Scott (in press) has shown that the Altonian Stage overlaps the type Hutchinsonian and the type Awamoan. The Altonian is widespread but the Awamoan and Hutchinsonian are local. The following changes have been proposed. The Pareora Series will contain two stages only: the Otaian (Po) and a new Altonian (Pl). The new Altonian contains the Hutchinsonian, Awamoan and the lower part of the old Altonian. The upper part of the old Altonian is added to the old Clifdenian to form the new Clifdenian. The revision of the Wanganui Series stages by Beu (1969) is adopted in Fig. 4.

The presently accepted sequence of New Zealand Cretaceous stages is that of Wellman (1959). Wellman proposed 12 stages, 10 of them new. The stages with the exception of the Korangan and the Teurian, are based largely on species of Inoceramus. The Teurian was later placed in the lowermost Tertiary Dannevirke Series (Hornibrook, 1962). The remaining Cretaceous sequence was modified by Hall (1963) who showed that the Coverian stage was equal to the Ngaterian and proposed that the Coverian stage be abandoned.

The numerical time scale in Fig. 4 is approximate, being based on only a few accurately dated points (for example see Berggren, 1969). However, it gives the length of stages sufficiently accurately so that rates of tilting can be calculated.

PRESENT MAPPING

The writer spent ten months mapping the Tinui District. Field sheets, prepared by the writer from aerial photographs, were on a scale of 4 inches to a mile. Mapping was based on formations of which 22 are recognised. In Figs. 2 and 3, which are from Johnston (in press a;b), each formation is represented by a mapping symbol consisting of two letters. For most formations the age is reasonably well defined by either foraminifera or macrofossils. Ages given by various species of Inoceramus are based on identifications by the writer. Ages given by other fossils have been provided by those paleontologists acknowledged at the end of this thesis. A list of fossil localities is given in Appendix I.

MESOZOIC STRATIGRAPHY

Torlesse Supergroup

Indurated greywacke and argillite beds, thick greywacke lenses with minor conglomerates, spilites and associated volcanic derived rocks make up the Torlesse Supergroup.

Waewaepa Formation (Waewaepa Series; Ongley, 1935) ew

The Waewaepa Series, named from the Waewaepa Range, was introduced by Ongley (1935) for a thick sequence of dominantly greywacke-argillite beds. It crops out extensively in the west and occurs as a small faulted inlier in the northeast. It consists of severely crushed, graded greywacke-argillite beds, with scattered greywacke and conglomerate beds, rare limestone lenses, and interbedded spilites. Zeolite veins are common. The conglomerates contain well-rounded greywacke pebbles and a few, commonly highly polished, pebbles of extrusive and intrusive igneous rocks.

The formation is at least tens of thousands of feet thick, but because of structural complexity its true thickness is uncertain.

Indeterminable Inoceramus fragments occur rarely. A limestone boulder (N159f435) found in the North Branch of Makirikiri Stream (N159/464818) by Mr M. Ongley and Dr J. Marwick and assumed to have been derived from the formation contained Buchia cf. hochstetteri Fleming (C.A. Fleming, pers. comm.), indicating an uppermost Jurassic (Puaroan Stage) age.

Taipo Formation (Taipo Beds, Hutton, 1872) et

The name Taipo Beds was used by several writers for rocks that form the taipos. The name is here used for thick beds of massive, medium to dark grey greywacke, of pre-Tertiary age. A 3,200 ft thick section from the Mangapokia Valley (N158/447665) to the Mangapakeha Valley (N158/448669) is here designated the type. The line of section crosses several conspicuous taipos and the place is named "The Taipos". Bedding is rarely discernable in most outcrops although the strike can commonly be seen on aerial photographs. The formation contains a few thin lenses of conglomerate, and the conglomerates contain pebbles of the same rocks as those in the Waewaepa Formation. Thin sequences of interbedded greywacke-argillite beds occur locally. The formation is unconformably overlain by the Mangapurupuru Group and almost certainly grades down into the Waewaepa Formation. The maximum observed thickness is 7,200 ft.

No fossils, other than rare plant and *Inoceramus* fragments, have been found. The age of the formation is inferred from its stratigraphic position to be uppermost Jurassic to lowermost Cretaceous.

Mangapurupuru Group

The name Mangapurupuru Series was first used by Mr M. Ongley on his field sheets of the former Eketahuna Subdivision for rocks now known to be largely of Clarence and Raukumara age. The name was never formally defined and is here introduced as a group name. The group unconformably overlies the Torlesse Supergroup and conformably underlies the Tinui Group. It consists of grey, commonly bluish-grey, fossiliferous mudstone, siltstone and graded beds.

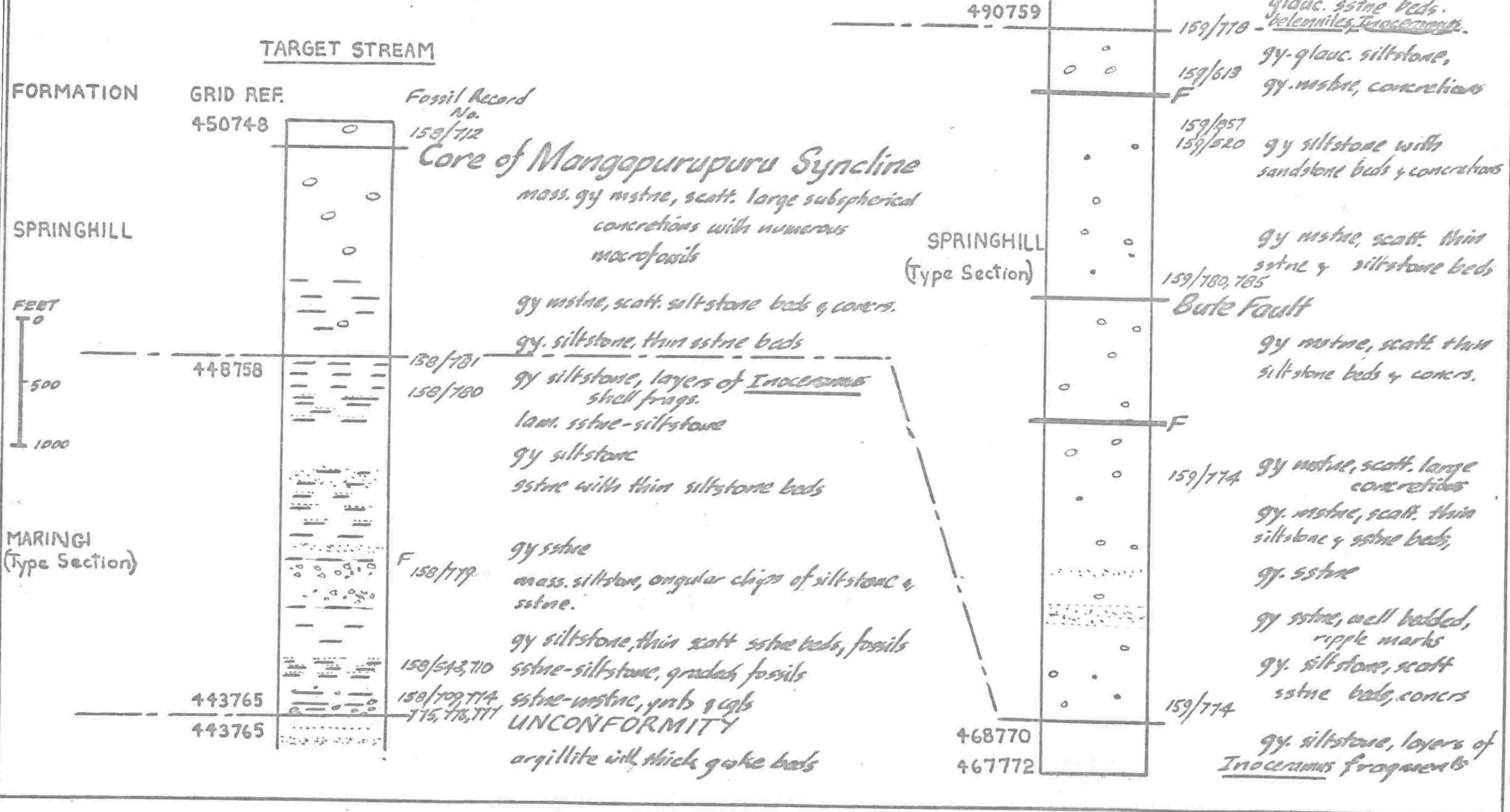
Maringi Formation (new formation) um

The formation is named after Maringi Trig. station (N158/433813), north of Makirikiri Stream. A section 3,100 ft thick exposed in Makirikiri Stream (N158/443765 to 448758) is proposed as the type (Fig. 6). The formation crops out in the west of the district. It consists of a basal conglomerate, 50 ft thick, indurated grey siltstone and occasional graded beds, and layers of *Inoceramus ipuanus* Wellman shells at its top.

In the west the formation grades into a pebbly siltstone named the Bideford Member. A 900 ft thick section exposed along Coopers Road (N158/368756 to 385766) is proposed as the type section for the member. The relations with the overlying and the underlying formations are unknown.

The formation contains numerous fossils, including *Inoceramus* cf. *kapuus* Wellman, *I. ipuanus* Wellman, *Aucellina euglypha* Woods, ammonites, echinoids, nautiloids, belemnites and foraminifera, indicating a ?Urutawan and Motuan age.

Fig. 6. Stratigraphic Columns



Springhill Formation (new formation) us

The formation consists dominantly of massive mudstone or siltstone containing numerous fossiliferous concretions. It crops out extensively in the west and is named after Springhill Station in the south branch of Makirikiri Stream. A 6,000 ft section, between Centre Stream (N159/468770) and Rewa Stream (N159/490759), is proposed as the type (Fig. 6). Its base is defined as the base of massive siltstone conformably overlying the top of the Maringi Formation. Its top is defined as the base of the conformably overlying Te Mai Formation. Between Mt Cameron and Mangapurupuru, lenses of ripple bedded sandstone, upto 450 ft thick, form conspicuous scarps. East of Mt Cameron thin poorly graded sandstone beds crop out. In the Mangapakeha and Mangapokia valleys the formation contains a basal conglomerate and unconformably overlies the Torlesse Supergroup.

The formation is richly fossiliferous. Inoceramus species include I. ipuanus Wellman, I. hakarius Wellman, I. fyfei Wellman, I. nukeus Wellman, I. opetius Wellman, I. urius Wellman, I. pacificus Woods and I. n.sp. aff. concentricus Park. Ammonites are not uncommon as is the belemnite Dimitobelus superstes (Hector). The fossils are of Motuan, Ngaterian, Arowhanan, Mangaotanean, Teratan and Piripauan age.

Gentle Annie Formation (new formation) ua

The formation consists of a chaotic mixture of angular to rounded, dark grey to black chips of sandstone in a fine grained matrix. It crops out in the upper Mangapakeha Valley where a 1,000 ft thick section (N158/400701 to 415708) in Gentle Annie Stream is proposed as the type. The formation unconformably overlies the Torlesse Supergroup and is in thrust contact with the upper part of the Maringi Formation.

Sandstone blocks in the formation contain probable Motuan fossils and many of the chips are highly polished. The formation is interpreted as a breccia caused by the gravity sliding of the lower part of the Maringi Formation during Raukumara time.

Glenburn Formation (Eade, 1966) ug

According to Eade (1966) the Glenburn Formation in the Mt Adams area consists of graded beds, commonly conglomeratic, of Ngaterian and Arowhanan age. The formation is here expanded to include all graded beds of Cretaceous age younger than those of the Torlesse Supergroup. It crops out in the northeast of the Tinui District as a NNE striking strip that extends from the head of the west branch of the Whakataki River into Sheet N153 and as three faulted inliers in Smith Creek. It consists of 800 ft of poorly bedded light grey siltstone and fine sandstone overlain by about 5,000 ft of graded beds. Flute casts indicate a northwest sediment source.

Species of Inoceramus, commonly abundant at the base of many of the graded beds, include I. rangatira Wellman, I. bicorrugatus Marwick, I. opetius Wellman, I. nukeus Wellman, and I. pacificus Woods. No diagnostic microfossils were obtained. The fossils are of Arowhanan, Mangaotanean, Teratan, and Piripauan age.

Tinui Group (Tinui Series; Ongley, 1935)

The Tinui Group, comprising rocks formerly mapped as Tapuwaeroa, Whangai, and Waipawa formations, conformably overlies the Mangapurupuru Group and underlies unconformably the Wanstead Group. Most of the rocks are poorly calcareous; some are non-calcareous, and some are stained yellow by jarosite.

Te Mai Formation (new formation) tt

The formation crops out extensively and consists of well-bedded alternating sandstone and siltstone, commonly cross-bedded with interbedded thick grit and conglomerate beds. A section 3,000 ft thick in the head of Puketewai Stream (N159/671860 to 661864) is proposed as the type. The formation conformably overlies the Glenburn Formation in the east and the Springhill Formation in the west. Conglomerates are abundant in the east, but are known from two localities only in the west. At one, in the lower Whakarora Valley, the conglomerate is at the base of the formation and unconformably overlies the Springhill Formation. In the west a 5 ft thick, red, volcanic derived siltstone crops out in the lower part of the formation. Because of faulting and probable lateral transition into the Whangai Formation the true thickness of the formation is not known, but it is not less than 5,000 ft.

Fossils include *Inoceramus pacificus* Woods, *I. australis* Woods, *I. matatorus* Wellman, *Dimitobelus? ongleyi* Stevens, *D. lindsayi* (Hector), *Ostrea lapillicola* Marwick and foraminifera. The formation also contains *Dimitobelus superstes*

(Hector) which is considered to be derived from the Springhill Formation. The age of the formation is Piripauan, Haumurian, and Teurian.

Whangai Formation (Whangai Series; Quennell and Brown, 1937) tw

The Whangai Formation crops out extensively and consists of light to dark grey, poorly-bedded indurated siltstone with scattered calcareous concretions, and glauconitic sandstone as beds and dikes. The siltstone contains small flakes of hydromica, scattered glauconite grains and is commonly slightly calcareous. Locally it is sufficiently calcareous to be a clayey limestone. In the east glauconitic sandstone occurs as beds upto 40 ft thick and as dikes upto 1 ft thick. In the west the glauconitic sandstone beds are upto 2 ft thick and there are no dikes. The formation weathers to an orange-brown colour and exposed surfaces are commonly covered with a yellow efflorescence of jarosite. It is about 5,000 ft thick in the Tinui District.

Worm tubes, and *Nucula* and *Nuculana* fragments are scattered throughout the siltstones but are useless for dating. Foraminifera are commonly abundant. They indicate a Teurian age with the base of the formation possibly extending down into the Haumurian.

Waipawa Formation (Waipawa Black Shale; Finlay, 1940) tp

The formation consists of lenses of dark siltstone, with high organic content that lie within the Whangai Formation. Two lenses, each less than 100 ft thick are exposed on the Tinui Valley-Whakataki Road. The western lens (N159/581737) is a soft dark grey to brown, carbonaceous siltstone with flattened worm tubes and bands of glauconitic siltstone beds. No fossils were found. The eastern lens (N159/631832) is an indurated dark grey, almost black, fissile siltstone with numerous macrofossil fragments and gypsum crystals. The macrofossils have "Wangaloan" affinites (A.G. Beu, pers. comm.). The Wangaloan stage, based on macrofossils, was the youngest Cretaceous stage in the sequence of New Zealand stages proposed by Finlay and Marwick (1947). It is equivalent to the lower Dannevirke Series but because it could not be fitted accurately into the New Zealand standard stage sequence it was proposed by Hornibrook and Harrington (1957) that the Wangaloan be omitted. Foraminifera, abundant in the eastern lens, are Teurian in age. No fossils were found in the western lens.

TERTIARY AND EARLY QUATERNARY STRATIGRAPHY

Wanstead Group

(Wanstead Series; Ongley, 1936b)

The Wanstead Series, introduced by Ongley (1936b), was redefined as the Wanstead Group by Waterhouse and Bradley (1957). It contains poorly bedded, fine grained sediments that are commonly bentonitic in their lower part.

Huatokitoki Formation (van den Heuvel, 1960) wh

Bentonitic sediments are poorly exposed on either side of the lower Whareama Valley and in addition occur as slivers within or close to the Tinui Fault Zone, and are correlated with the Huatokitoki Formation of van den Heuvel (1960). The formation consists of well to poorly bedded pale grey, greenish grey to dark grey almost black mudstone, grey siltstone and sandstone, glauconitic sandstone, minor conglomerate and bentonite beds. Bentonite crops out only in the north and causes extensive slumping. The thickest bentonite bed, at Ekenui Stream, is 50 ft thick. In the south large blocks of "chalky" mudstone crop out near the base of the formation.

Because of poor exposures no stratigraphic sequence was established and the thickness of the formation is estimated at 1,500 ft. In the Mangapokia Valley a 5 ft thick glauconitic sandstone at the base of the formation rests, probably unconformably, on the Whangai Formation. In the Mangapakeha Valley the formation rests unconformably on rocks of the Torlesse Supergroup. Macrofossils are absent. Foraminifera, with benthic forms dominant, are abundant and show that the Waipawan, Heretaungan and Bortonian stages are present. No Porangan or Mangaorapan foraminifera were found, although the stages are probably present.

Weber Formation (Weber Series; Ongley and Williamson, 1931) ww

The formation consists of massive dark-grey, locally with a greenish tinge, to light-grey almost white mudstone and siltstone, with scattered grit, conglomerate and impure limestone beds. It crops out as fault slivers in or on the west side of the Tinui Fault Zone. The thickest section is about 2,500 ft thick. The base of the formation is unknown, all contacts seen being faulted. Macrofossils are absent. Foraminifera, particularly planktonics, are abundant and indicate a Whaingaroan to Duntroonian age.

Annedale Group

The group is named after Annedale Station in the upper Whareama Valley. It contains the Whakataki Formation, consisting of a thick sequence of graded beds, and the Takiritini Formation consisting of sandstone and algal limestone. It lies between the Wanstead and Hurupi groups.

Whakataki Formation (new formation) aw

The formation consists of thick sequences of graded beds. It crops out extensively in the east and is well exposed near Whakataki. No complete section through the formation was found at any one locality and no single type section can be designated. Instead the base of the formation is defined in the upper Mataikona River (N159/641872) where a sequence of graded beds grades down into the Weber Formation, and the top is defined in the lower Whareama River (N159/529664) where the formation grades up into massive mudstone of the Maunsell Formation. Individual graded beds are from a few inches to several feet thick. Each bed grades from grit or sandstone at the base to mudstone at the top.

The base of each bed commonly contains flute casts. The lower part of each bed is laminated and in its middle part commonly convolutely bedded. In the northeast the formation conformably overlies the Weber Formation. Elsewhere it is unconformable, with a basal conglomerate, on older rocks.

Macrofossils are rare and of no use for dating. Microfossils are sparse and poorly preserved. The age and the thickness of the formation are different in different localities:

Area	Thickness (ft)	Age
Northeast	700	Lw - Po
Lower Whareama Valley	6,000	Pl - Sc
Coast	10,000	Lw - Sc
Southeast	c.500	S?

Takiritini Formation (new formation) at

The formation consists of thick sandstone and thick algal limestone, with interbedded minor siltstone and minor graded bedded sequences. It forms conspicuous outcrops within and on both sides of the Tinui Fault Zone from Takiritini Stream to Maunsell, and as a fault sliver on the west side of the lower Whareama

Valley. A 650 ft thick section in Takiritini Stream (N159/618837) is proposed as the type. The formation disconformably overlies the Whakataki Formation and conformably underlies the Maunsell Formation.

The sandstone is grey, medium to coarse-grained, with bedding planes from a few to many feet apart, and scattered elliptical, rarely fossiliferous concretions. It is 3,500 ft thick at Maunsell but thins northwards and grades into the algal limestone. The limestone is off-white to cream and weathers pink. It contains numerous rounded to elongate, partly worn algal structures of the Lithothamnion group and scattered foraminifera shell fragments.

The age of the formation is Altonian (Pl) to Clifdenian and it is thus the same age as the upper part of the Whakataki Formation in the lower Whareama Valley.

<u>Hurupi Group</u> (Hurupi Series; King, 1933)

The Hurupi Series was introduced by King (1933) for coarse fossiliferous beds at Hurupi Creek, Palliser Bay, that lie between basement "greywacke" and overlying <u>unfossiliferous</u>

means no macro fossils
NZJG 1964: 540

mudstone. It was redefined as the Hurupi Formation by Vella (1954) to include the fossiliferous and unfossiliferous beds. The formation is here raised to group status.

Maunsell Formation (new formation) hm

The Maunsell Formation crops out extensively in the west of the Tinui District. It consists dominantly of massive mudstone and siltstone with minor sandstone and pebbly shell limestone beds and concretions. A section, 9,200 ft thick, in the Tinui Valley (N159/600814 to 563808) is designated as the type. The lower part of the formation grades in the northwest into a thick sequence of graded beds mapped as the Tanawa Member (hmt) and in the northeast into thick sandstone mapped as the Grassendale Member (hmg).

In the Tinui Valley the formation conformably overlies the Takiritini Formation but in the upper Whareama Valley it is unconformable on older formations. In the lower Whareama Valley it is conformable on the Whakataki Formation.

The Tanawa Member (type section N159/615837 to 601838) is named after Tanawa Trig. It is upto 3,500 ft thick and consists of graded beds.

In the Tinui Valley it conformably overlies the Takiritini Formation but further north it rests unconformably on older rocks and contains a basal conglomerate upto 100 ft thick.

The Grassendale Member (type section N159/497790 to 507784) is named after Grassendale homestead. It consists of thick sandstone and thin interbedded calcareous sandstone and conglomerate beds. It is 200 ft thick in the type section and 2,300 ft thick further north. It unconformably overlies older rocks and is disconformably overlain, probably with little time missing, by the Maunsell Formation.

Microfossils are abundant in the massive fine grained sediments of the formation but are rare or absent in other lithologies. Macrofossils are locally abundant in the coarse grained sediments. The age of the Maunsell Formation is Lillburnian, Waiauan, and lower Tongaporutuan. The age of the Tanawa and Grassendale members is Lillburnian to Waiauan.

Ngarata Formation (Neef, in press) hn

The Ngarata Formation was introduced by Neef (in press) for sandstone and overlying fine grained beds cropping out in Sheet N153.

In the Tinui District it is restricted to thick poorly bedded sandstones with scattered conglomerates, shelly limestone beds and concretions. It is 2,400 ft thick and unconformably overlies the Waihoki Formation and the Grassendale Member of the Maunsell Formation in the east, and older formations in the west. Macrofossils, which are poorly preserved and difficult to extract, indicate a Tongaporutuan age. Microfossils are probably present but could not be extracted.

Waihoki Formation (Waihoki Series; Ongley, 1935) hk

The Waihoki Series was introduced by Ongley (1935) for coarse sandstone beds occupying the core of the Tawhero Syncline. It is here used for thick well-bedded, commonly poorly graded, coarse sandstone and siltstone beds, and massive mudstone. The base is defined as the base of the lowest scarp-forming-sandstone bed in the head of Ekenui Stream (N159/559849). No contact with younger beds was seen. The formation crops out between the upper Whareama and Tinui valleys. In the southwest the basal beds are tuffaceous and in the northwest they are commonly glauconitic. The formation is 4,000 ft thick. Except in the northwest, where it probably unconformably overlies the Grassendale Member of the Maunsell Formation, it conformably overlies the Maunsell Formation. Scattered macrofossils and abundant microfossils are middle and upper Tongaporutuan, and Kapitean in age.

Rangiwhakaoma Formation (new formation) hr

The Rangiwhakaoma Formation consists of grey, calcareous siltstone, formerly mapped as the Opoiti Series by Ongley (1935). It takes its name from the Maori name for Castlepoint. An 80 ft thick section on the southeast side of the Castle (N159/662673) is proposed as the type. The formation also crops out on the northwest side of the reef at Castlepoint. Locally it contains concretions and lenses of commonly laminated sandstone. On the northeast side of the Castle there is a thin sequence of sandstone and siltstone beds. The base of the formation is not exposed. It is unconformably overlain by the Castlepoint Formation. Macrofossils are rare. Microfossils are abundant, and are Opoitian in age.

Castlepoint Formation (Castle Point Beds; McKay, 1877) cp

The formation is the youngest in the Tinui District consisting of consolidated sediments. It is composed of well-bedded coquina limestone and shelly calcareous sandstone with scattered pebbles and concretions. It is known definately only from Castlepoint. The limestone is light grey and porous. It contains numerous comminuted shell fragments and scattered complete shells in a calcareous sandy matrix. The sandstone is less porous and contains abundant shell material. Bedding planes are commonly many feet apart. The formation is 450 ft thick on the Castle and 150 ft thick on the reef. On the northeast side of the reef it disconformably overlies the Rangiwhakaoma Formation; elsewhere it rests on it with marked angular unconformity. Macrofossils are very abundant, the most common species being Glycymeris (Grandaxinea) wairarapaensis Powell, Chlamys delicatula (Hutton), Phialopecten triphooki (Zittel), Mesopeplum convexum (Quoy and Gaimard), Venericardia purpurata (Deshayes), Dosina creba (Hutton), Neothyris n.sp. (A.G. Beu, pers. comm.). The age of the formation is Nukumaruan.

A 2 ft boulder of coquina limestone (N158 f650) was found at Maringi Trig. (N158/433813), 15.5 miles northwest of Castlepoint. It is lithologically similar to the limestone at Castlepoint and contains the same Nukumaruan foraminifera. The boulder has either been transported from Castlepoint, or is the last remnant of sheet that once extended over the Tinui District.

LATE QUATERNARY STRATIGRAPHY

Undifferentiated Marine Benches (bf)

Remnants of dissected marine benches at about 270 ft, 400 ft and possibly at 550 ft above sea level are present on the coast at Castlepoint, and are pre-Last Interglaciation in age.

Otahome Formation (new formation) bo

A prominent marine bench, extending from a mile south of the Castle to south of the Tinui District, is capped by weathered fossiliferous marine grits and gravels mapped as the Otahome Formation after Otahome homestead. The type locality is on the cliffs (N159/640665) south of the Castle. King (1930) described the bench as sloping longitudinally from 90 ft above sea level near the Castle to 160 ft above sea level in the south. The fossils (N159f497), collected by Mr M. Ongley, consist of *Cellana radians* (Gmelin), *Zeacumantus subcarinatus* (Sowerby), *Buccinulum (Euthrena) littorinoides* (Reeve) and *Neoguraleus murdochi* (Finlay) and indicate a probable Hawera age. The formation is probably Last Interglaciation in age.

Rorokoko Formation (new formation) h_3

Weathered, poorly sorted greywacke gravel capped by loess underlies an extensive surface in the west of the district and is mapped as the Rorokoko Formation. It is named after Rorokoko Stream (N158/359679). The formation is tentatively considered to be early Last Glaciation in age.

Ngapopatu Formation (new formation) h_2

Fine gravel, grit, sand, silt and clay underlie remnants of an aggradational surface, about 40 ft above the floor of the Mataikona and Whareama valleys. The largest area, covering about 0.5 of a square mile, is in the upper Whareama Valley at Ngapopatu (N159/518775) and is proposed as the type locality. The formation is late Last Glaciation in age.

Whareama Formation (new formation) h_1

Sand, silt and clay fill the floors of the main valleys and are most extensive in the lower Whareama Valley (N159/499617) which is proposed as the type locality. Although the major rivers are incised into the surface capping the formation, an extensive system of drains was required before the surface was suitable for farming. Included in the formation are dune sands forming narrow strips parallel to the coast and locally covering large areas of the adjoining hillsides at Castlepoint, south of the Whakataki River, and north of the Mataikona River. The age of the formation is Holocene.

PALEOGEOGRAPHY OF THE TINUI DISTRICT

Definition of terms

The major problem in paleogeography is to infer the topography at any particular time from the facies of the sediments deposited at that time. It is essential to distinguish between the inferred topography and the known facies and the following terms are defined in order to make the distinction clear:

Geosynclinal trough - a linear topographic feature of regional extent that subsided deeply throughout a long period of time. It consists of an extensive deep water axial part surrounded by a narrow shallow water part on its margins.

Geosyncline - a thick succession of stratified and massive sediments, and possible extrusive volcanics, inferred to have been deposited in a geosynclinal trough.

Basin - a wide topographic feature largely of shallow depth.

Fault basin - an elongated topographic feature bounded on one or more sides by a fault scarp.

Axial facies - stratified, commonly graded and commonly poorly fossiliferous sediments inferred to have been deposited in deep water, such as in the axial part of a geosynclinal trough, or close to a fault bounding a fault basin.

Marginal facies - massive, commonly richly fossiliferous sediments inferred to have been deposited in shallow water, such as in the margins of a geosynclinal trough, a basin, or a fault basin.

Transgression - the advance of the sea over a landmass.

Regression - the withdrawal of the sea from a landmass.

Outcrop maps - maps which show the known distribution of rocks of a particular age and their known and inferred facies boundaries.

Paleogeographic maps - maps in which strike-slip movement and shortening by folding have been allowed for. In practice it is difficult to allow for shortening, and only the inferred strike slip movement has been allowed for.

NEW ZEALAND GEOSYNCLINAL TROUGH

With the formation of the New Zealand Geosynclinal Trough the pattern of sedimentation changed in the New Zealand area at some time between the Devonian and Permian (Suggate, 1965). The axis of the trough extended from the Bay of Plenty south along the western side of the axial ranges of New Zealand (Fleming, 1962; fig. 3). The trough consisted of a deep-water rapidly sinking axial part, in which turbidity currents deposited graded beds, surrounded by a shallow-water marginal part. The Tinui District was near the axis of the trough and the sediments deposited in it are mapped as the Torlesse Supergroup. The supergroup consists of two formations: the Waewaepa Formation (Upper Jurassic) and the Taipo Formation (Uppermost Jurassic to lowermost Cretaceous).

The Waewaepa Formation is composed of many thousands of feet of graded beds, with minor conglomerate beds and lava flows. In the Tinui District bedding-plane shear has destroyed any scour or flute casts that may have existed. In the Aorangi Mountains, 60 miles southwest of the

Tinui District (Fig. 1), linear scour casts, striking NNE-SSW (T.E. Bates, pers. comm.) in the Torlesse Supergroup suggest that sediment transportation was parallel to the inferred axis of the New Zealand Geosynclinal Trough. Diagnostic features for distinguishing between a NNE or a SSW direction are absent. As the geosynclinal trough filled, 7,000 ft or more of coarse sandstone and conglomerate were deposited to form the Taipo Formation.

The pebbles in the conglomerates of the Torlesse Supergroup are of well rounded, indurated greywacke, minor quartz, jasper, and acidic volcanic rocks. Acid igneous pebbles (e.g. granites and porphyries) have been described by Marshall (1903) from the marginal facies of the New Zealand Geosyncline. The pebbles indicate that the Torlesse Supergroup in the Tinui District was derived from older sediments deposited in the geosynclinal trough, rather than directly from an adjacent landmass. Later burial and folding metamorphosed the sediments, the sandstone becoming greywacke and the finer beds argillite.

The folding of rocks of the Torlesse Supergroup was followed by a period of non-deposition estimated at 10-12 x 10^6 years by Fleming (1962) and possibly as long as 20-25 x 10^6 years (Fig. 4).

WAIRARAPA GEOSYNCLINAL TROUGH

Eastern Geosyncline was the name used by Macpherson (1946) and Eastern Basin that used by Kingma (1960), for the Upper Cretaceous and Tertiary rocks in the east of New Zealand. Wellman (1959; fig. 1) inferred that in the Cretaceous a geosynclinal trough extended along the east coast from Marlborough to East Cape. On the west side of the trough, near Gisborne, there was a northeast striking peninsula. Grindley (1961) "eliminated" the peninsula and called the geosynclinal trough the "East Coast Geosyncline". Within the Cretaceous rocks Wellman (1959) recognised three facies:- shelf, transitional and redeposited. Grindley (1961) recognised two facies only, shelf and redeposited. The writer, following the nomenclature of Fleming (1962), has divided the rocks of the geosyncline into a marginal and an axial facies. The marginal facies consists of the Maringi and Springhill formations and the axial facies consists of the Glenburn Formation. All three formations are included in the Mangapurupuru Group.

Because of the usage of "East", "Eastern" and "East Coast" for rocks of different ages and distribution, the name Wairarapa Geosynclinal Trough is proposed for the whole of the geosynclinal trough which extended from Marlborough to East Cape during the Upper Cretaceous.

Marginal Facies

In the west of the Tinui District during the Motuan and possibly the Urutawan, the Maringi Formation, consisting of siltstone with basal fossiliferous conglomerate, and thin graded bedded sequences, was deposited unconformably on the Torlesse Supergroup. In the extreme west of the district the basal conglomerate is very thick and is mapped as the Bideford Member. The conglomerate, which contains shallow water fossils that are not considered to have been transported, is inferred to have been deposited close to a shoreline. The overlying siltstone contains relatively abundant fossils and near its top, fossiliferous, poorly graded, alternating sandstones and siltstones. Flute cast directions show a current direction from the southwest consistent with a shoreline to the west. It is inferred that the sea had transgressed westward.

The outcrop map of Motuan rocks (Fig. 7a) suggests that there was a total of 9 miles of sinistral offset caused by displacement on the Carterton Fault. The displacement has been allowed for in the construction of the Motuan paleogeographic map (Fig. 7b).

During late Motuan to lower Piripauan time the Springhill Formation, consisting of fossiliferous siltstone with numerous fossiliferous concretions and lenses of graded beds and sandstone, was deposited. In the southwest of the Tinui District the formation has a basal conglomerate that unconformably overlies rocks of the Torlesse Supergroup. Elsewhere in the district it conformably overlies the Maringi Formation. The Springhill Formation is inferred to have been deposited as the sea continued to transgress westward. In the Ngaterian, ripple bedded sandstone was deposited locally and some water shallowing is inferred.

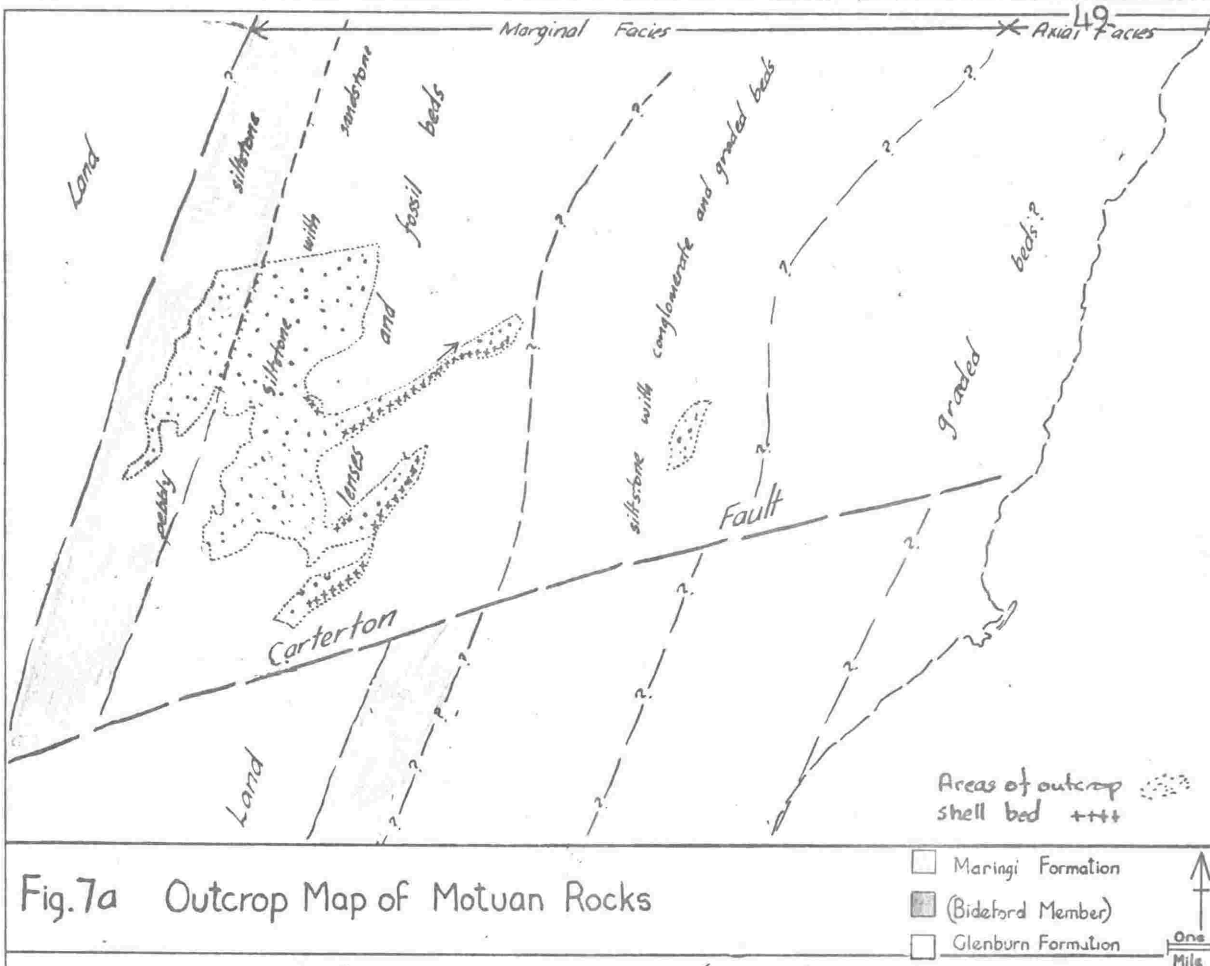


Fig. 7a Outcrop Map of Motuan Rocks

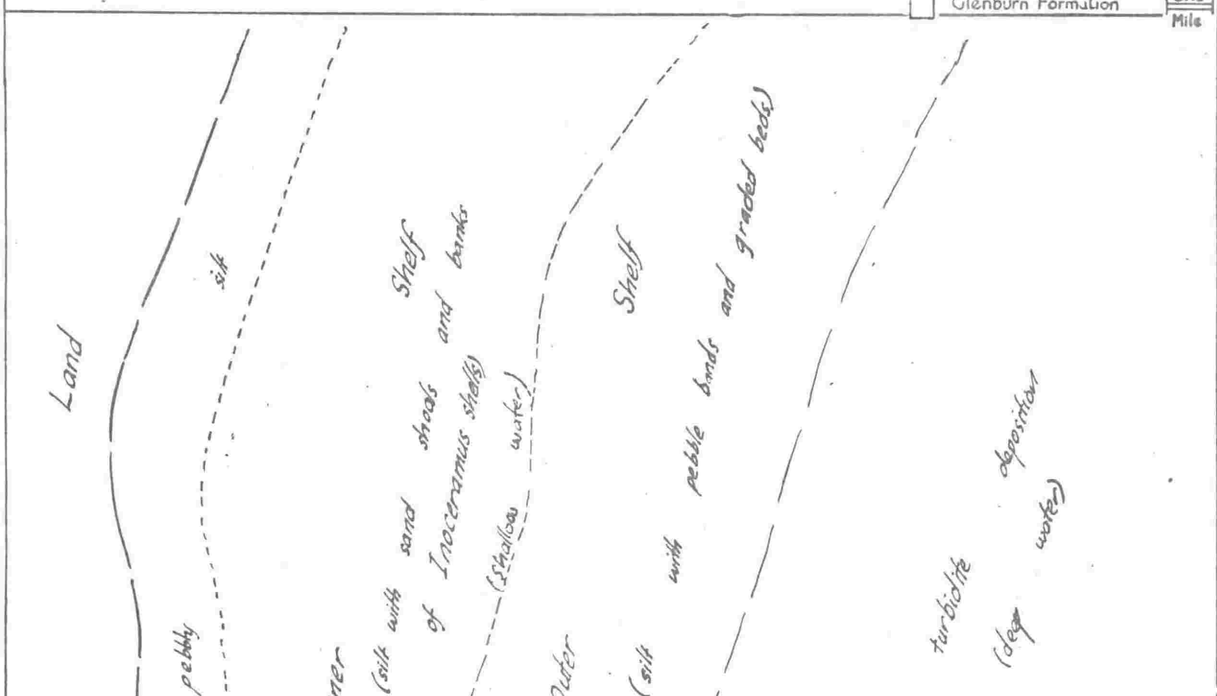


Fig. 7b Motuan Paleogeography

Beds of the marginal facies were deposited in the Dannevirke Subdivision (Raukumara Formation of Lillie, 1953), in the Aorangi Mountains (the upper part of the Whatarangi Formation of Bates, 1969) and in Marlborough (G.J. Lensen, *pers. comm.*). Paleogeographic patterns in the Upper Cretaceous (see below under Tinui Transgression) suggests that an eastern marginal facies existed to the east of the axial facies and to the east of the present day coastline.

Axial Facies

In eastern Wairarapa graded bedded sediments of the Glenburn Formation were deposited from the Ngaterian (possibly from the Motuan) to the lower Piripauan. The base of the formation has not been seen. Flute casts in the Mt Adams area (Eade, 1966), to the southeast of the Tinui District, show that from the Ngaterian to the Arowhanan the currents flowed ESE. Flute casts in the Tinui District show that in the Arowhanan the currents flowed northeast. The formation is interpreted as being deposited by turbidity currents in the axial region of the Wairarapa Geosynclinal Trough.

In Marlborough the Good Creek Formation (of the same facies and of the same age as the Glenburn Formation) was deposited by northeast flowing turbidity currents (G.J. Lensen, pers. comm.). Stratigraphic columns from Marlborough to Hawkes Bay (Figs. 8, 9), have been used to construct a generalised paleogeographic map of the Wairarapa Geosynclinal Trough from the Motuan to Ngaterian (Fig. 10).

Gentle Annie Gravity Slide

The Gentle Annie Breccia is inferred to have formed by the northward sliding and brecciation of the lower part of the Maringi Formation off a rising high of rocks belonging to the Taipo Formation. The high is considered to have formed by the uplift of the north side of the Carterton Fault. The time of brecciation is uncertain but is inferred to be Upper Cretaceous from the degree of compaction of the Maringi Formation and the Gentle Annie Breccia.

Fig. 8.

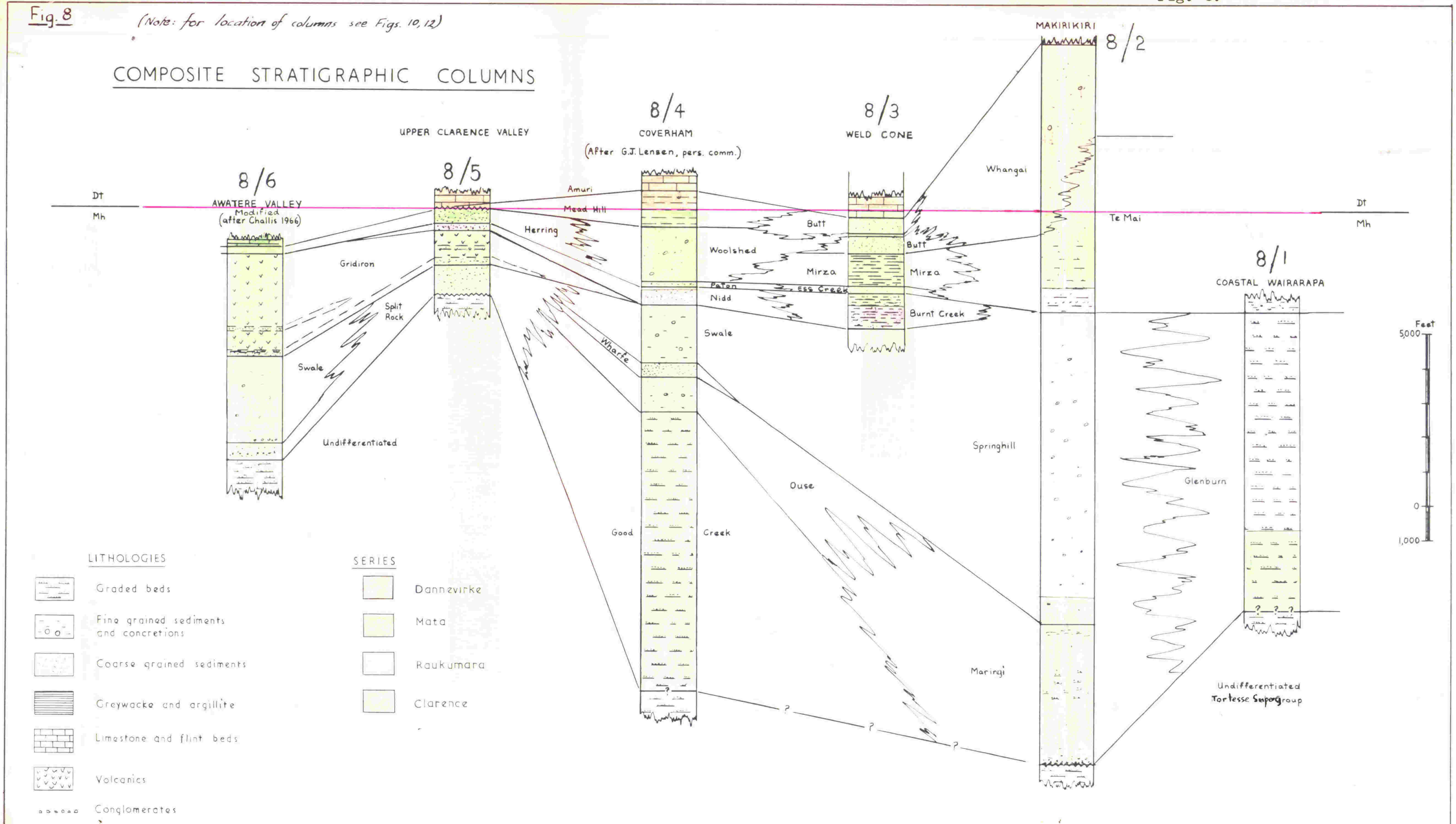
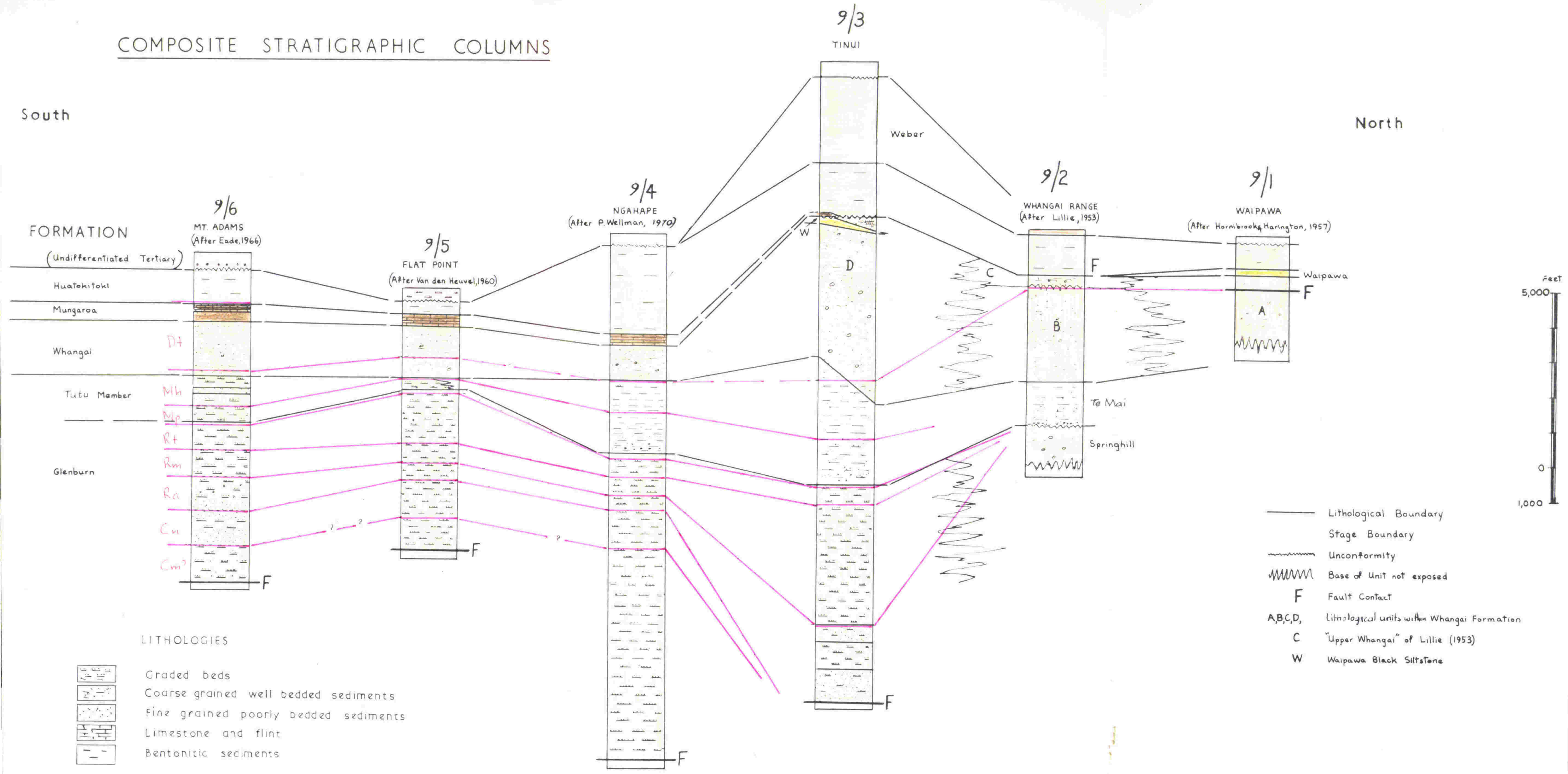


Fig. 8
(Note: for location of columns see Figs. 10, 12)
COMPOSITE STRATIGRAPHIC COLUMNS
8/6
AWATERE VALLEY
Modified
(after Challis 1966)
8/5
UPPER CLARENCE VALLEY
8/4
COVERHAM
(After G.J. Lensen, pers. comm.)
8/3
WELD CONE
MAKIRIKIRI
8/2
8/1
COASTAL WAIRARAPA
Dt
Mh
Amuri
Mead Hill
Herring
Gridiron
Split Rock
Swale
Undifferentiated
Wharfe
Good
Creek
Woolshed
Paton
Nidd
Butt
Mirza
Ess Creek
Burnt Creek
Ouse
Whangai
Te Mai
Springhill
Maringi
Glenburn
Undifferentiated
Torlesse Supergroup
Feet
5,000
0
1,000
LITHOLOGIES
Graded beds
Fine grained sediments and concretions
Coarse grained sediments
Greywacke and argillite
Limestone and flint beds
Volcanics
Conglomerates
SERIES
Dannevirke
Mata
Raukumara
Clarence

Fig. 9. (Note: for location of columns see Figs. 10, 12)



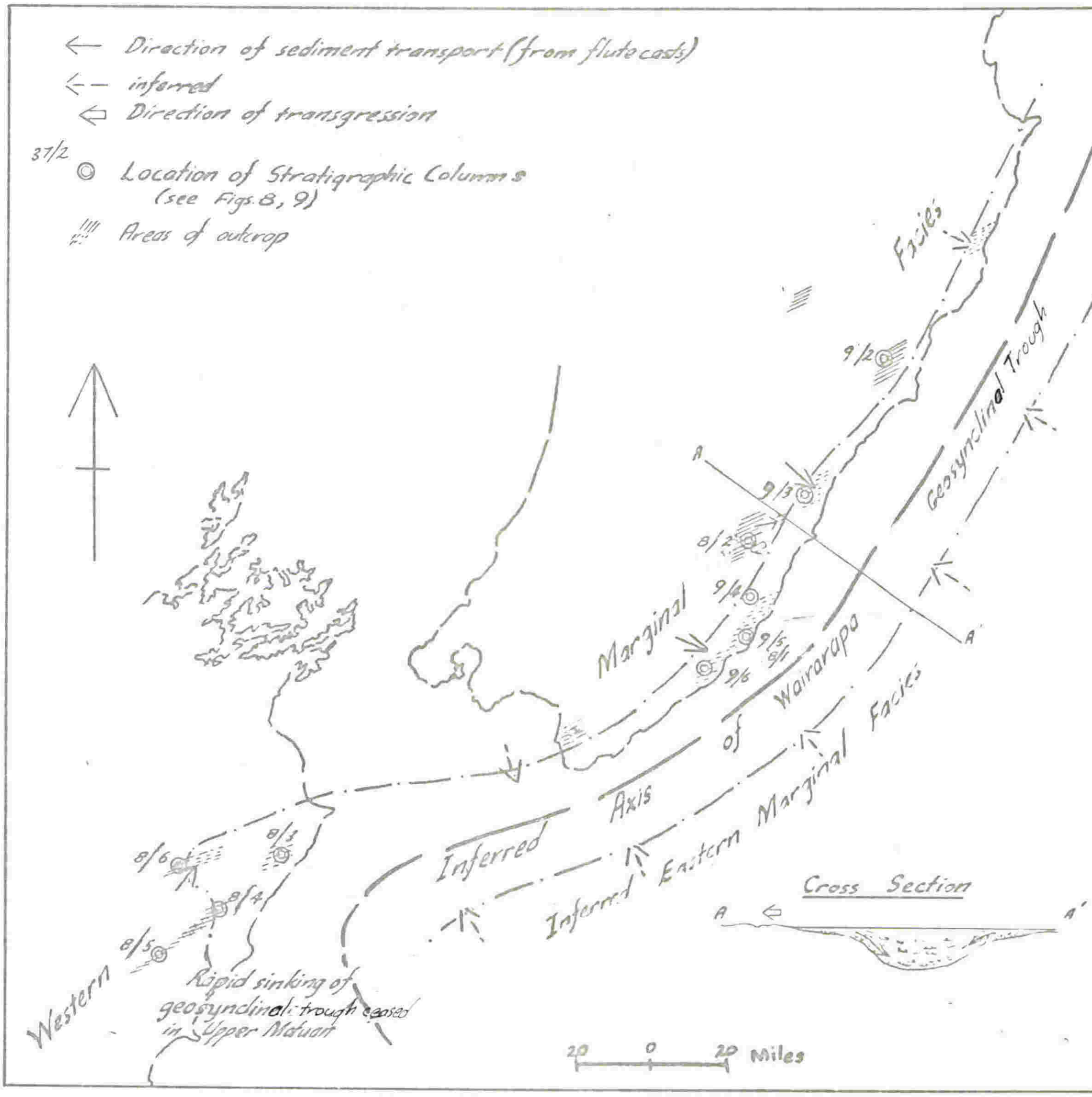


Fig. 10. Generalised map of the Wairarapa Geosynclinal Trough in Motuan-Ngaterian time. Outline of present coast superimposed for convenience of location.

TINUI TRANSGRESSION

At the beginning of the Piripauan the rate of sinking of the Wairarapa Geosynclinal Trough had decreased and the degree of infilling had advanced to such an extent that by the end of the lower Piripauan the trough had ceased to exist. New Zealand was then a mature landscape over which the sea transgressed. The transgression in the Wairarapa is named the Tinui Transgression. During the transgression rocks of the Tinui Group (Te Mai, Whangai and Waipawa formations) were deposited.

Lower Piripauan to lower Haumurian

Except locally, the Te Mai Formation was deposited conformably both on the marginal and on the axial facies of the Wairarapa Geosyncline. In the east the formation consists of conglomerates, grits and coarse sandstones. Cross-bedding in the coarse sandstones indicates that the formation was derived from the east (Fig. 11). The conglomerates and grits contain *Ostrea* cf. *lapillicola* Marwick and belemnites. One of the

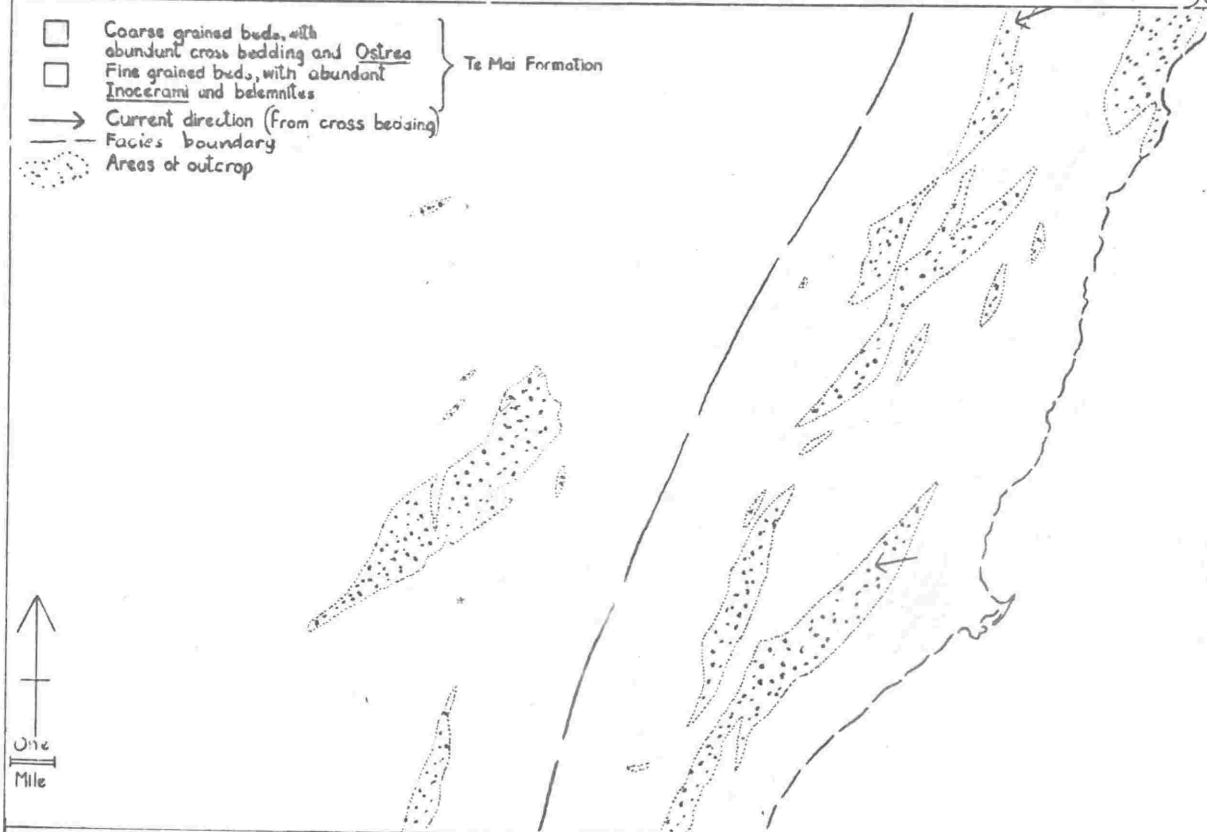


Fig. 11. Outcrop Map of Piripauan Rocks

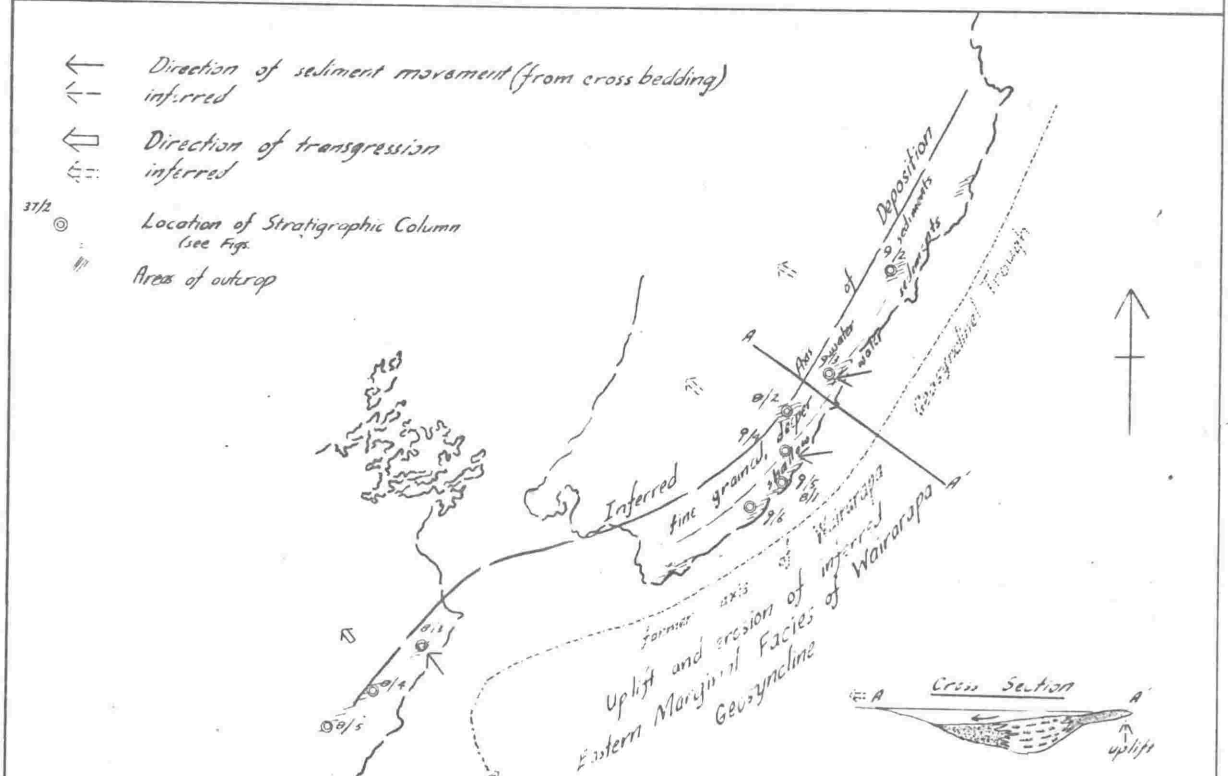


Fig. 12. Distribution of Piripauan – Lower Haumurian Rocks (Outline of Present East Coast Superimposed)

belemnites is Dimitobelus superstes (Hector) which, being Motuan to Mangaotanean in age (Stevens, 1965), is assumed to have been derived from the eastern marginal facies of the Wairarapa Geosyncline (Fig. 10). In the west the formation contains fewer conglomerates and grits. Cross-bedding and Ostrea lapillicola Marwick, which is generally restricted to coarse sediments, are absent. It contains, however, sandstone beds with numerous fragments of Inoceramus pacificus Woods, I. matatorus Wellman, and Dimitobelus lindsayi (Hector). Planktonic foraminifera are more abundant in the west than in the east.

In southern Hawkes Bay, Upper Cretaceous sediments coarsen eastwards (Kingma, 1962). In the Dannevirke Subdivision, conglomerate at the base of beds equivalent to the Te Mai Formation suggests a local unconformity, although Lillie (1953; p. 78) stated that there was no major folding at this time. Stratigraphic columns (Figs. 8, 9) are used to construct a map (Fig. 12) showing the distribution of Piripauan and lower Haumurian rocks in Marlborough, in Wairarapa and in Hawkes Bay.

Upper Haumurian to Teurian

During the upper Haumurian dark well bedded mudstones and siltstones were deposited to form the upper part of the Te Mai Formation. Macrofossils other than abundant worm borings are absent. It is inferred that over the whole of the Tinui District deposition was uniformly in deep water. In the late Haumurian and Teurian poorly bedded siltstone, in which calcareous concretions now occur, was deposited to form the Whangai Formation. At most places it rests conformably on the Te Mai Formation. Locally it is the lateral time equivalent of the Whangai Formation. In the east of the Tinui District layers of commonly glauconitic sandstone were deposited. In the upper Teurian, lenses of dark siltstone, with gypsum and a high organic content, accumulated to form the Waipawa Formation.

In southern Hawkes Bay, deposition of the Whangai Formation began in the lower Haumurian, as did sediments of the same facies - Woolshed Formation - in Marlborough.

Conditions of deposition of the Whangai and Waipawa Formations

Kingma (1967) reported pumice fragments and glass shards in the Whangai Formation in eastern Wairarapa and inferred extensive rhyolitic volcanism to the east of the present day coastline at the end of the Cretaceous. In spite of an extensive search, no pumice or glass shards were found in the Tinui District or in samples from the type locality of the formation in the Whangai Range, southern Hawkes Bay. The intrusion of basic igneous rocks near Ngahape (Grapes, 1970) is the only known igneous activity in the Wairarapa and southern Hawkes Bay at this time.

The formation contains quartz, montmorillonite, illite and kaolinite; minerals that form after prolonged weathering. Their source was probably from a landmass to the west that was approaching senility. The land to the east (Fig. 12), which earlier supplied the bulk of the Piripauan sediments does not appear to have provided a significant amount of sediments. In the east, conditions were favourable for the formation of glauconite.

Locally in the Tinui District, sediments with a very high organic content were deposited and are mapped as the Waipawa Formation. Hornibrook and Harrington (1957) suggested that in Hawkes Bay the formation was deposited in stagnant lagoons. However, the plant fragments and coal seams that would be expected in such an environment are completely absent, indicating that the formation was deposited in deep water.

PONGAROA BASIN

In Wairarapa and southern Hawkes Bay the basins (or basin) that formed in the Lower Tertiary are collectively called the Pongaroa Basin. In it was deposited the Wanstead Group comprising the Huatokitoki (Waipawan to Runangan) and Weber (Whaingaroan to Duntroonian) formations. Little is known, particularly in the Wairarapa, of the paleogeography.

The Huatokitoki Formation, from the Tinui Valley to the coastal part of southern Hawkes Bay, contains thick bentonite deposits. The origin of the bentonite is uncertain. Fyfe (1934), following overseas workers, suggested that the bentonite is derived from the weathering of acidic volcanic material but did not infer any source for the volcanic material. Kingma (1967) inferred rhyolitic volcanoes at an unspecified distance to the east of the present day coastline. However, there is no recognisable volcanic material in rocks of the Tinui and Wanstead groups and hence no evidence for nearby volcanoes.

Siliceous limestone, mapped as the Mungaroa (Waterhouse and Bradley, 1957) or Kaiwhata (van den Heuvel, 1960) formations, were deposited in the south of the basin (Fig. 13) and represent the northernmost limit of the Amuri Limestone of Marlborough and North Canterbury (Fig. 8). In Whaingaroan and Duntroonian time planktonic foraminiferal ooze accumulated to form the light grey coloured Weber Formation.

WHAKATAKI FAULT BASIN

In the Tinui District, the Whakataki Fault Basin formed in Waitakian and the Whakataki (Waitakian to Clifdenian) and the overlying Takiritini (Altonian to Clifdenian) formations

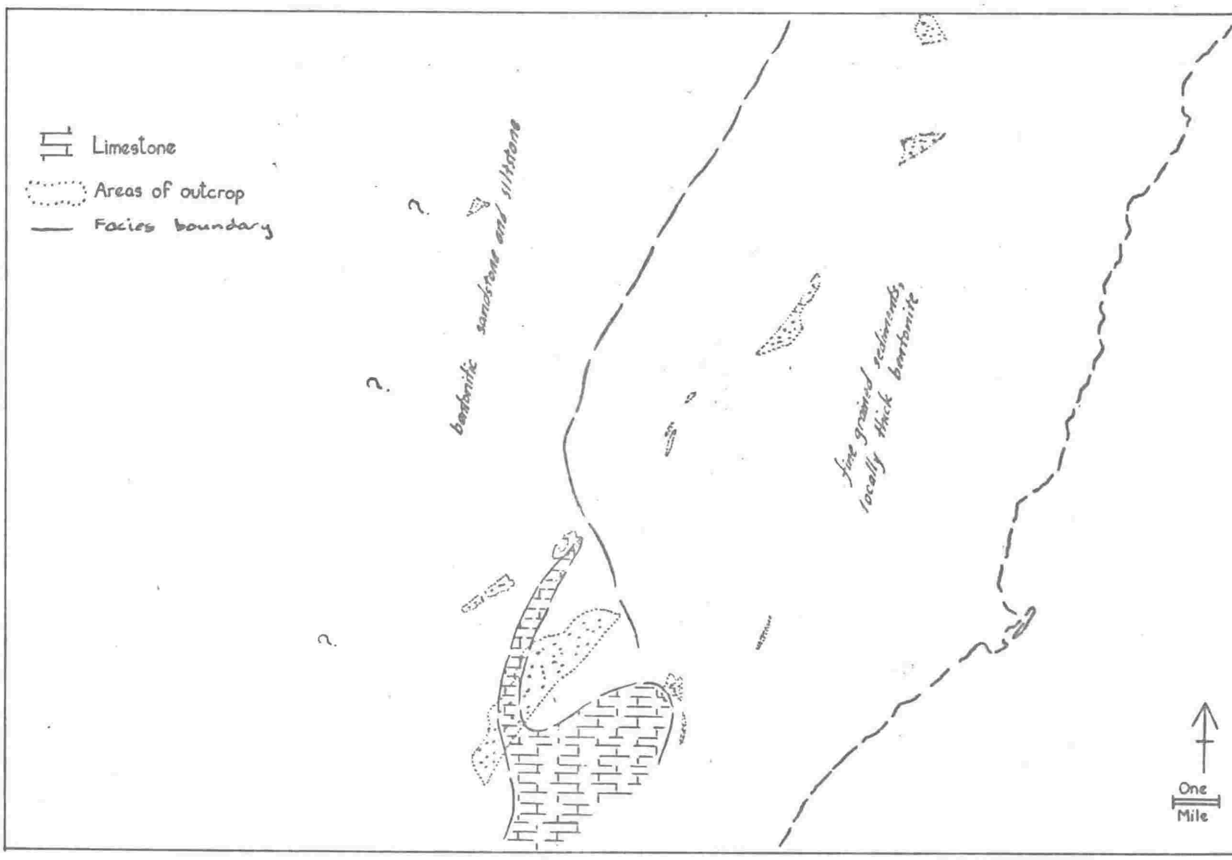


Fig. 13. Outcrop map of Waipawan to Bortonian rocks (Huatokitoki Formation).

were deposited in it. In the east of the district the Whakataki Formation, consisting of a thick graded bedded sequence with basal conglomerate, was deposited unconformably on older rocks. Near Te Mai the conglomerate is absent and the graded bedded sequence conformably overlies the Weber Formation. The Whakataki Formation is thicker in the east than in the west and in the west it contains massive siltstone. Widespread flute casts show that currents flowed from the east and south.

It is inferred that the Whakataki Fault Basin was formed by the sudden downthrow of the west side of a fault to the east of the present day coastline (Fig. 14a). Erosion of the fault scarp formed the basal conglomerate. As erosion of the scarp decreased, graded beds (axial facies) were deposited by turbidity currents flowing eastwards towards the axis of the basin and by turbidity currents flowing north along the axis of the basin. In the west, massive siltstone, containing a rich fauna of benthic foraminifera, was deposited in shallow water close to a landmass (marginal facies). The offset of the shoreline of the landmass is

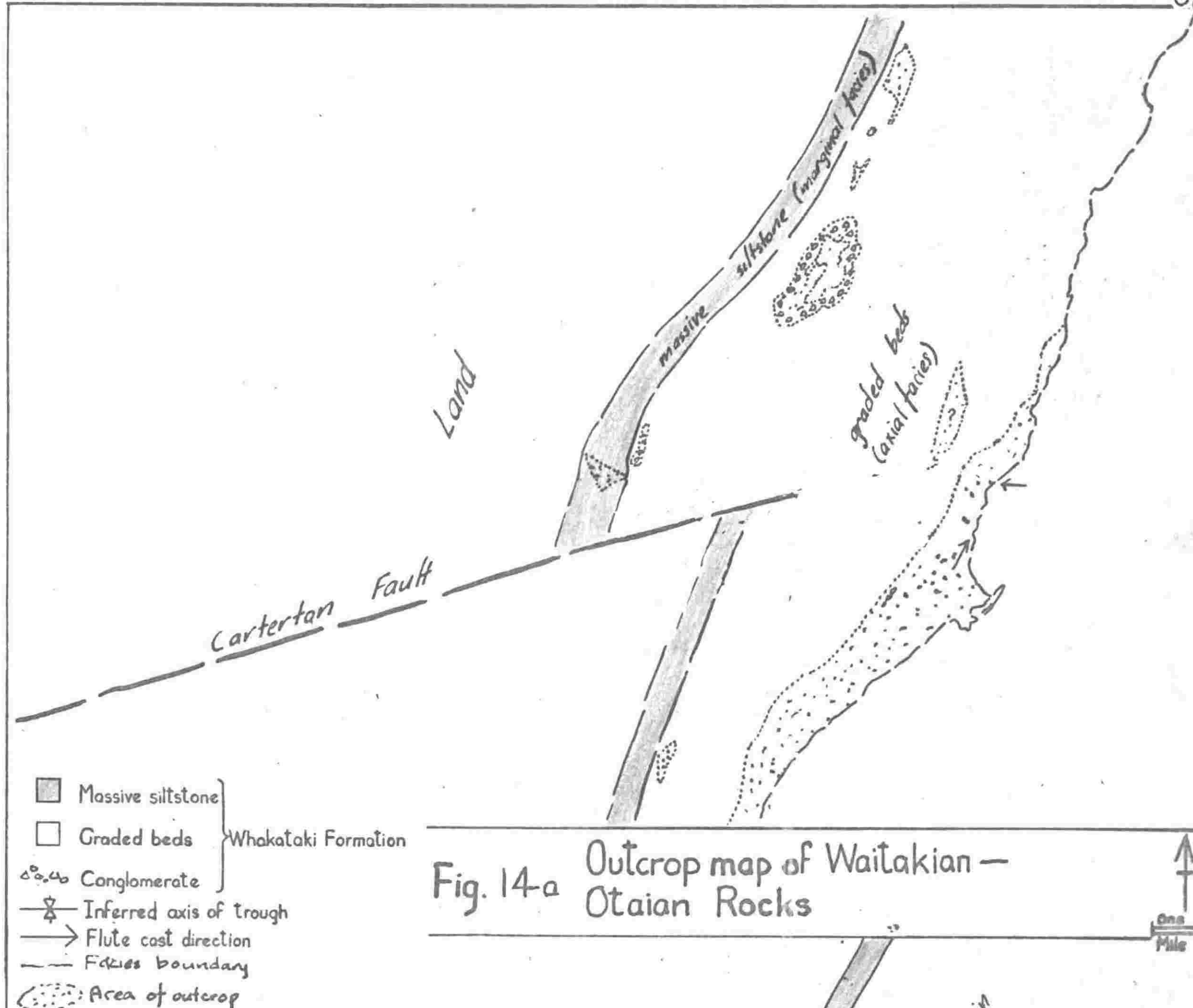


Fig. 14-a Outcrop map of Waitakian — Otaian Rocks

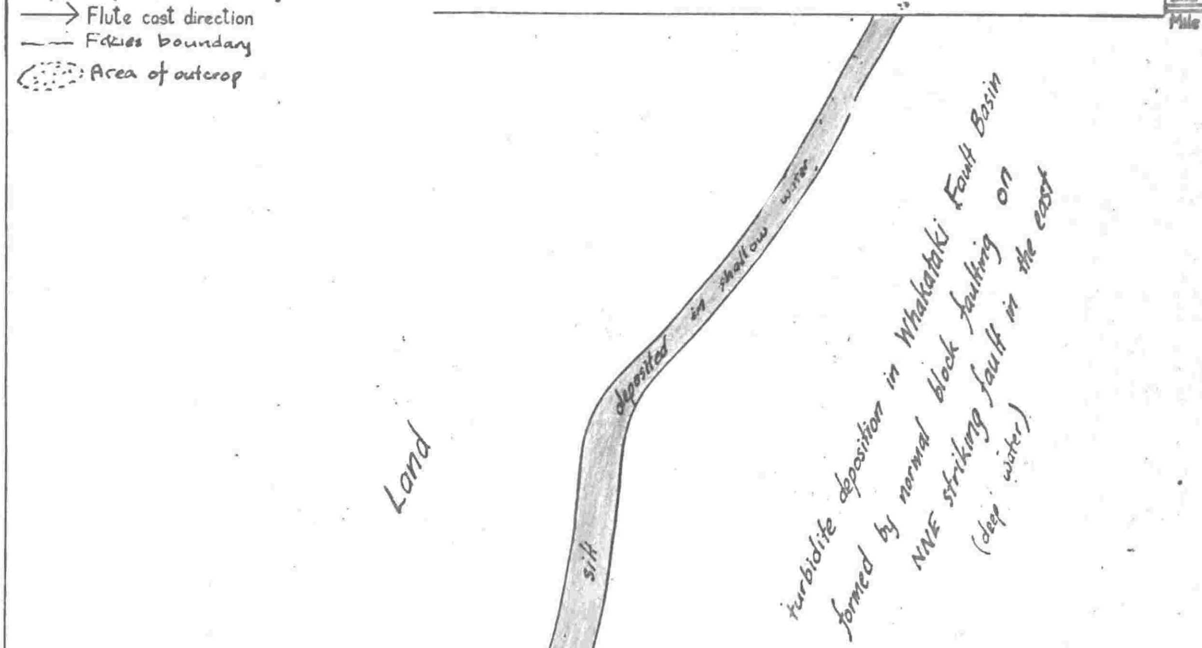


Fig. 14 b. Waitakian—Otaian Paleogeography inferred to have been caused by movement on the ENE striking Carterton Fault and this is allowed for in the paleogeographic map (Fig. 14b) and the block diagram (Fig. 14c). The offset (apparent strike-slip displacement) of the shoreline by the Carterton Fault is sinistral (Fig. 14a). However, the shoreline would initially have been a gently east dipping reference plane and any vertical movement on the fault would produce a large apparent horizontal displacement. Real and apparent horizontal displacements by faulting are discussed further under Structure.

In the Altonian, the Whakataki Fault Basin broadened and graded beds continued to accumulate. In the northwest the sea shallowed and sandstone and algal limestone of the Takiritini Formation were deposited disconformably on the Whakataki Formation (Fig. 15a). From the distribution of the Takiritini Formation it is inferred that the south side of the Carterton Fault was downthrown. On the upthrown side of the fault, shoal areas formed in the margin of the fault basin. A fault sliver in the lower Whareama Valley (Fig. 2) is inferred to have been dragged southwards into its present position by dextral strike-slip movement on a fault on the west limb of the Whareama Syncline.

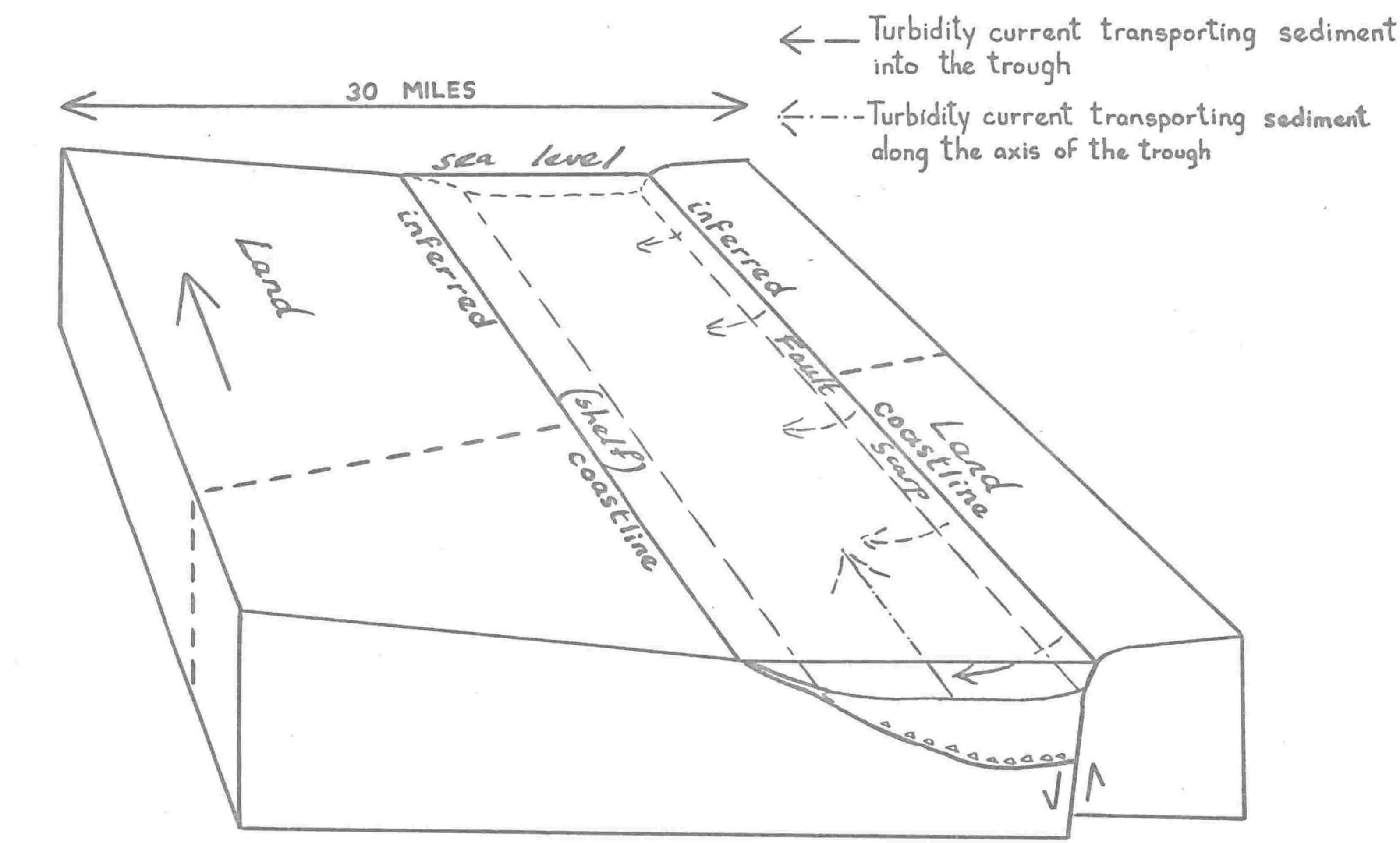


Fig. 14 c. Block Diagram of the Whakataki Fault Basin at the end of the Otaian (Deposition of the Whakataki Formation)

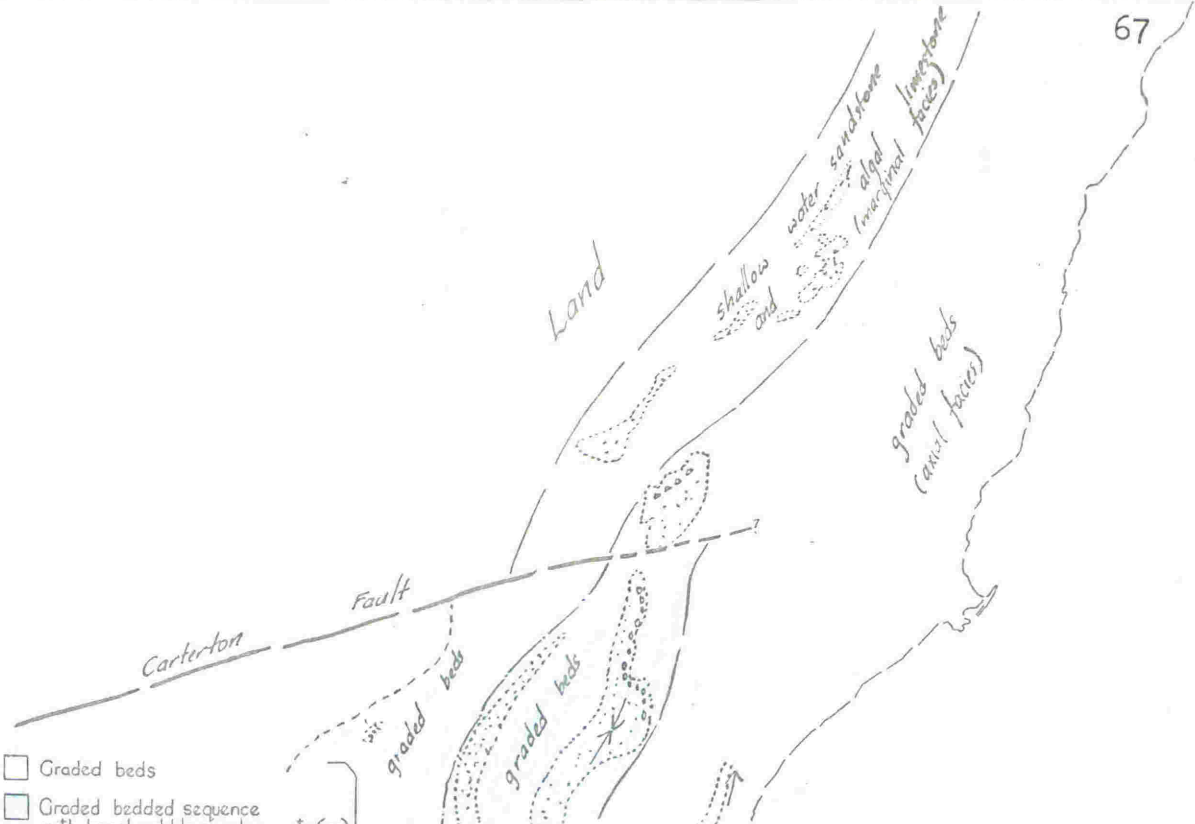


Fig. 15a. Outcrop Map of Altonian — Clifdenian Rocks

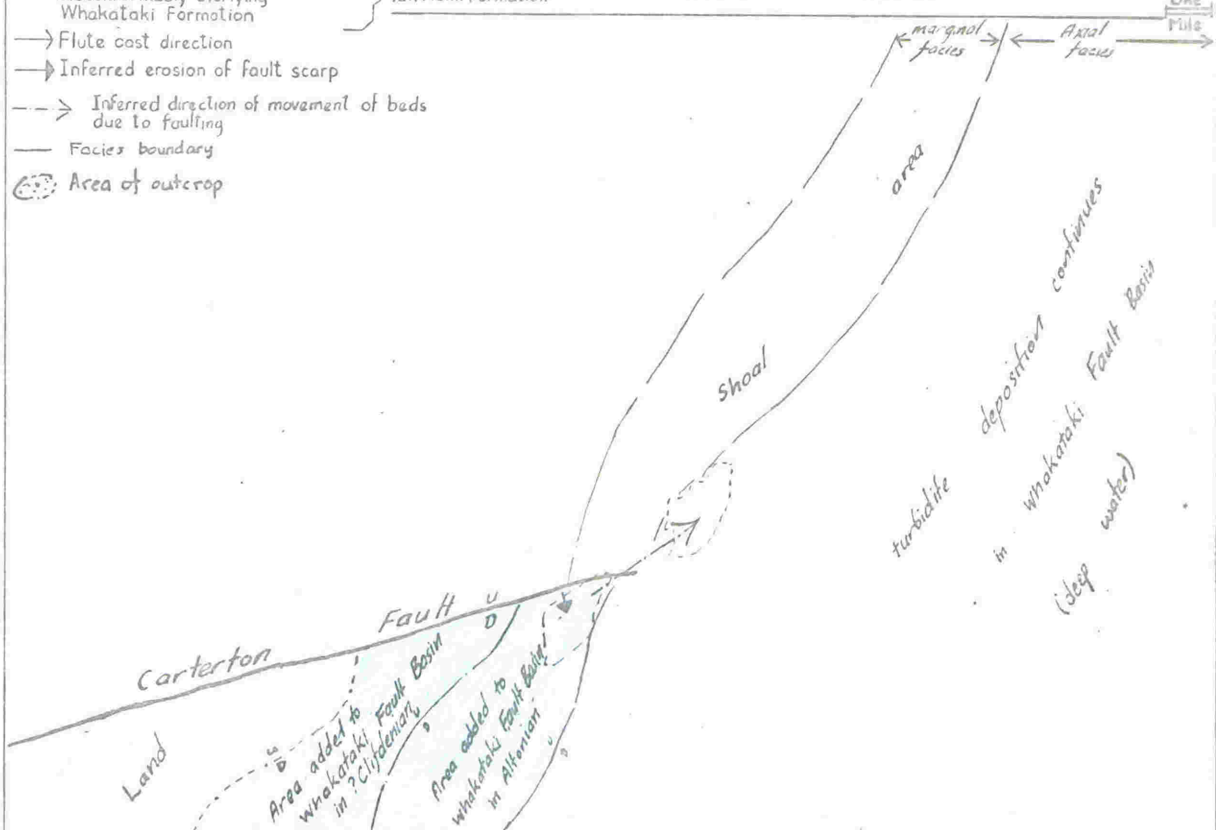


Fig. 15 b. Altonian — Clifdenian Paleogeography

On the south side of the Carterton Fault, the area of deposition of the Whakataki Formation increased in the Altonian and it probably increased again in the Clifdenian. The increase was probably caused by block faulting. In the new areas of deposition, graded beds with a basal conglomerate, were deposited. The conglomerate is angular close to the Carterton Fault and is inferred to have been derived from the fault scarp. Elsewhere it contains rounded pebbles considered to have been derived from the erosion of littoral deposits on the southeast edge of the basin. Flute casts in the graded beds show that most currents flowed from the SSE, and a few from the north. It is inferred that the currents from the SSE flowed along the axis of the basin after originating from a landmass to the east (Fig. 15c). The north flowing currents are considered to have originated from the Carterton Fault scarp. The later interaction of the Carterton Fault and the NNE striking faults is thought to have displaced an area of graded beds northeastwards (Fig. 15a). This displacement is allowed for in the paleogeographic map of lower Southland time (Fig. 15b). By the end of

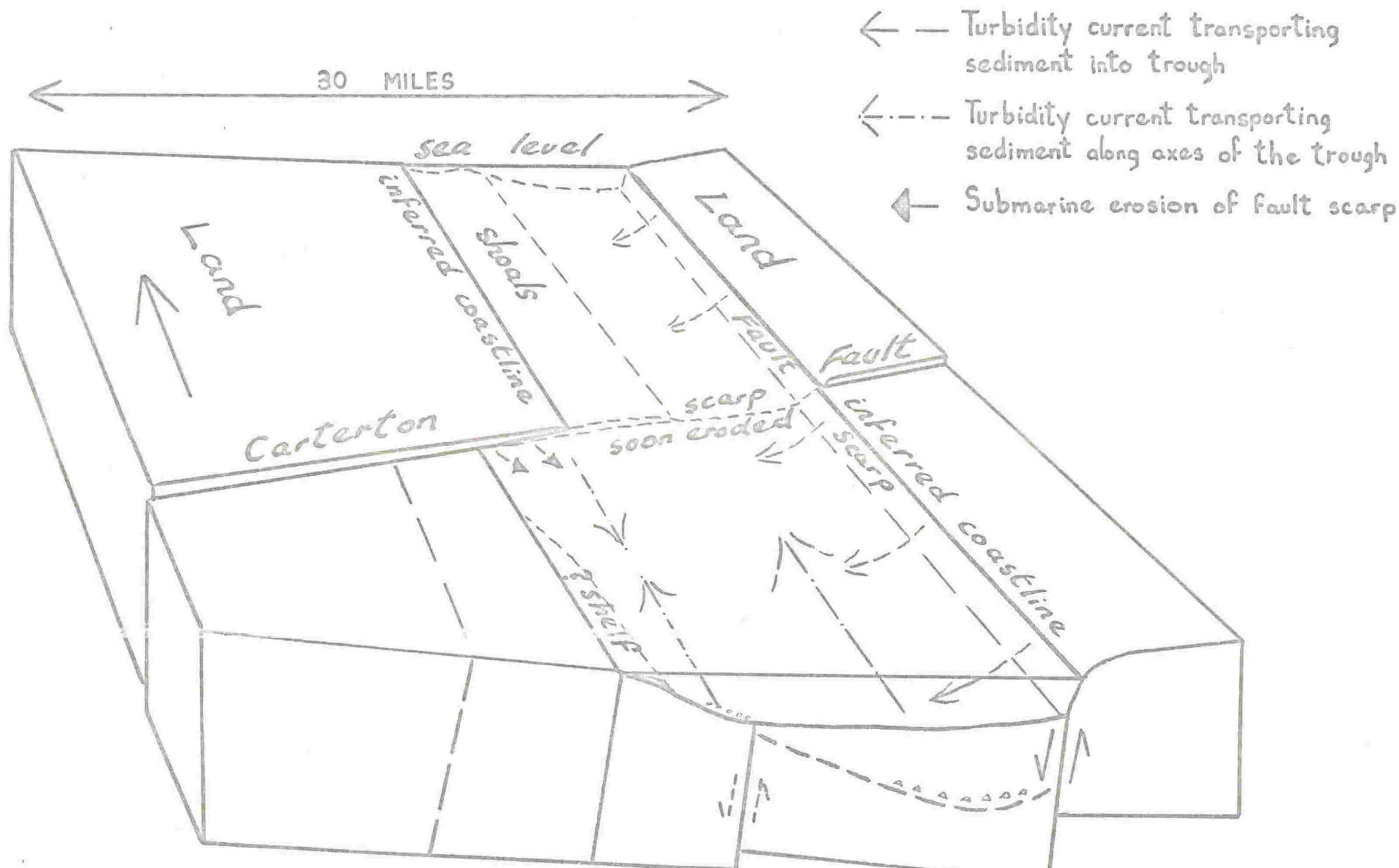


Fig. 15c. Block Diagram of the Whakataki Fault Basin at the beginning of the Lower Southland. (Deposition of Whakataki and Takiritini Formations)

Clifdenian time, subsidence of the Whakataki Fault Basin slowed down and the sea began to transgress westward.

HURUPI TRANSGRESSION

A westward transgression of the sea in the Wairarapa in upper Southland and Taranaki time, when the sediments of the Hurupi Group were deposited, is termed the Hurupi Transgression. In the west the group was deposited unconformably on Mesozoic rocks and as indicated by Lower Tertiary foraminifera, rocks of the Wanstead Group made up part of the source rocks. In the centre of the Tinui District in Lillburnian time, massive, fine-grained sediments of the Maunsell Formation were deposited conformably on the Whakataki and Tekiritini formations. To the west, coarse fossiliferous sediments of the Grassendale Member of the Maunsell Formation were deposited unconformably on older sediments. In the northeast, graded beds of the Tanawa Member of the Maunsell Formation were deposited unconformably, with basal conglomerate, on the Whakataki and older formations. The graded beds are interpreted as a deep water deposit (axial facies) deposited by turbidity currents. Flute casts in the graded beds show that the currents flowed from the SSW and from the southeast (Figs. 16a, 16b). It is inferred that the eastern part of the Tinui District was uplifted by movement on one of the NNE striking faults. Erosion of the fault scarp produced the basal conglomerate. The currents that formed the flute casts are thought to have flowed off the landmass and then parallel to the fault. In the west, as the sea transgressed westward, littoral sediments and then massive siltstone were deposited as a marginal facies.

In the Waiauan (Fig. 17) graded beds (of the Tanawa Member) are thinner and contain a greater number of interbedded mudstone beds than do the Lillburnian graded beds. In the west a disconformity lies at the top of the Grassendale Member and it is inferred that there was a temporary eastward regression. Following the regression the sea began to transgress rapidly westward depositing the Maunsell Formation.

By the middle Tongaporutuan the only land was in the northwest of the district (Fig. 18). In the north the Waihoki Formation, consisting of

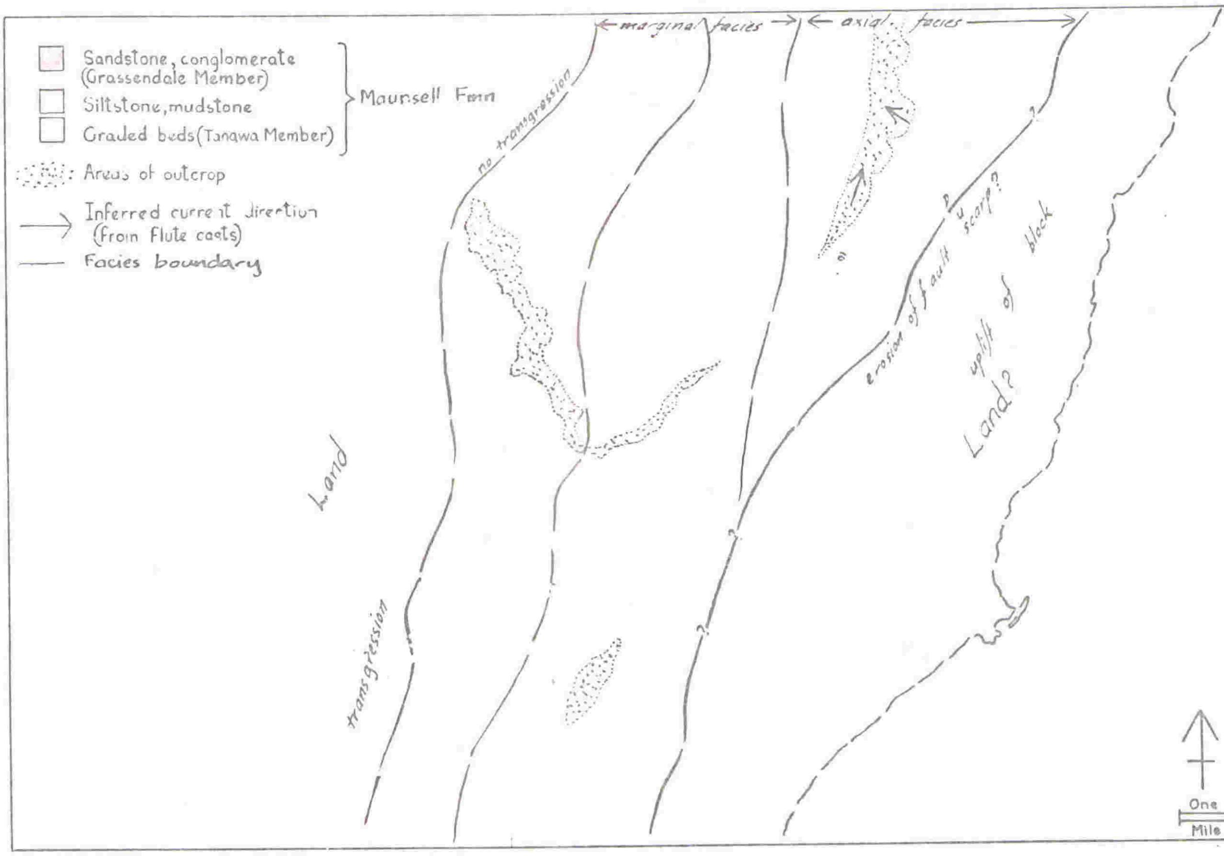


Fig. 16a. Outcrop map of Lillburnian rocks.

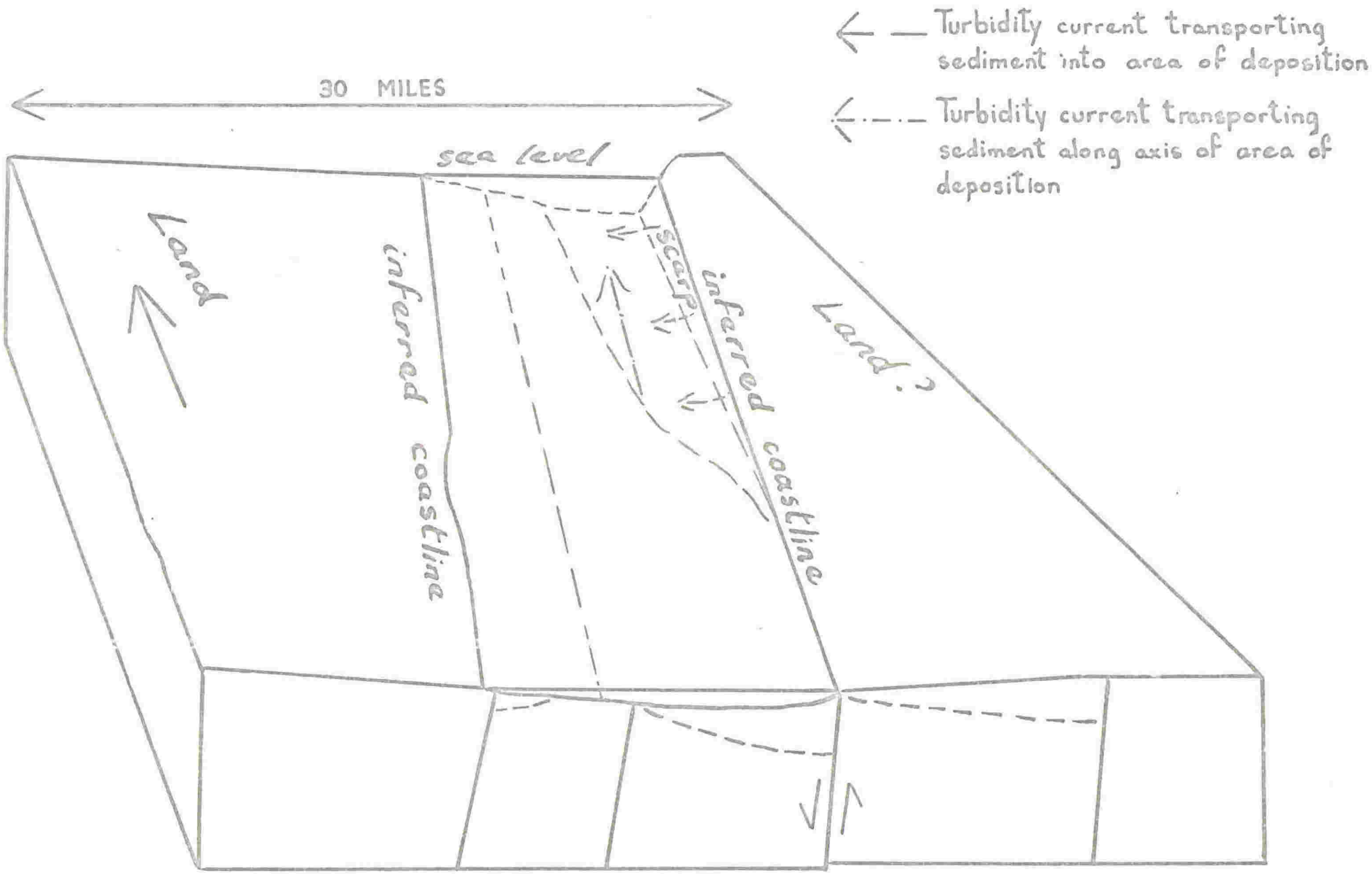


Fig. 16 b. Block Diagram showing the Hurupi Transgression in the Lillburnian (Deposition of the Maunsell Formation)

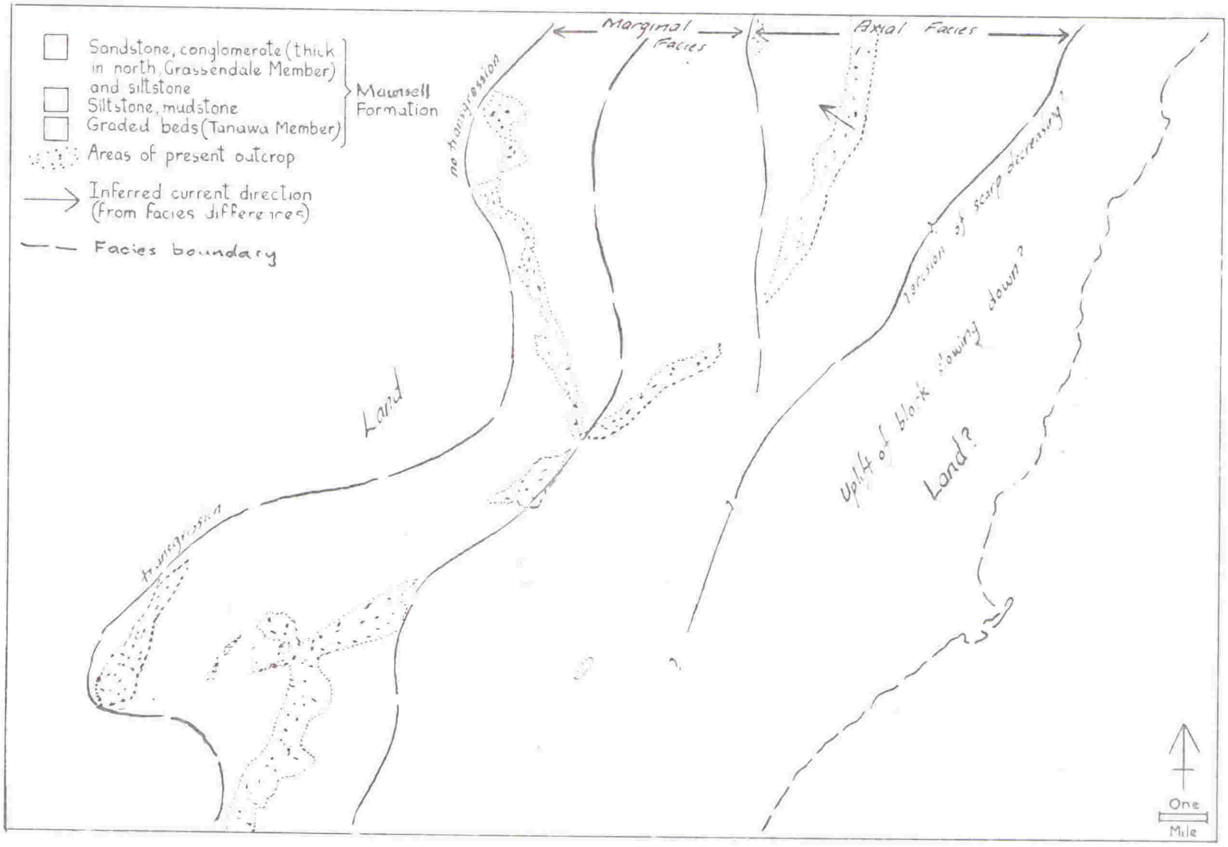


Fig. 17. Outcrop map of Waiauan rocks.

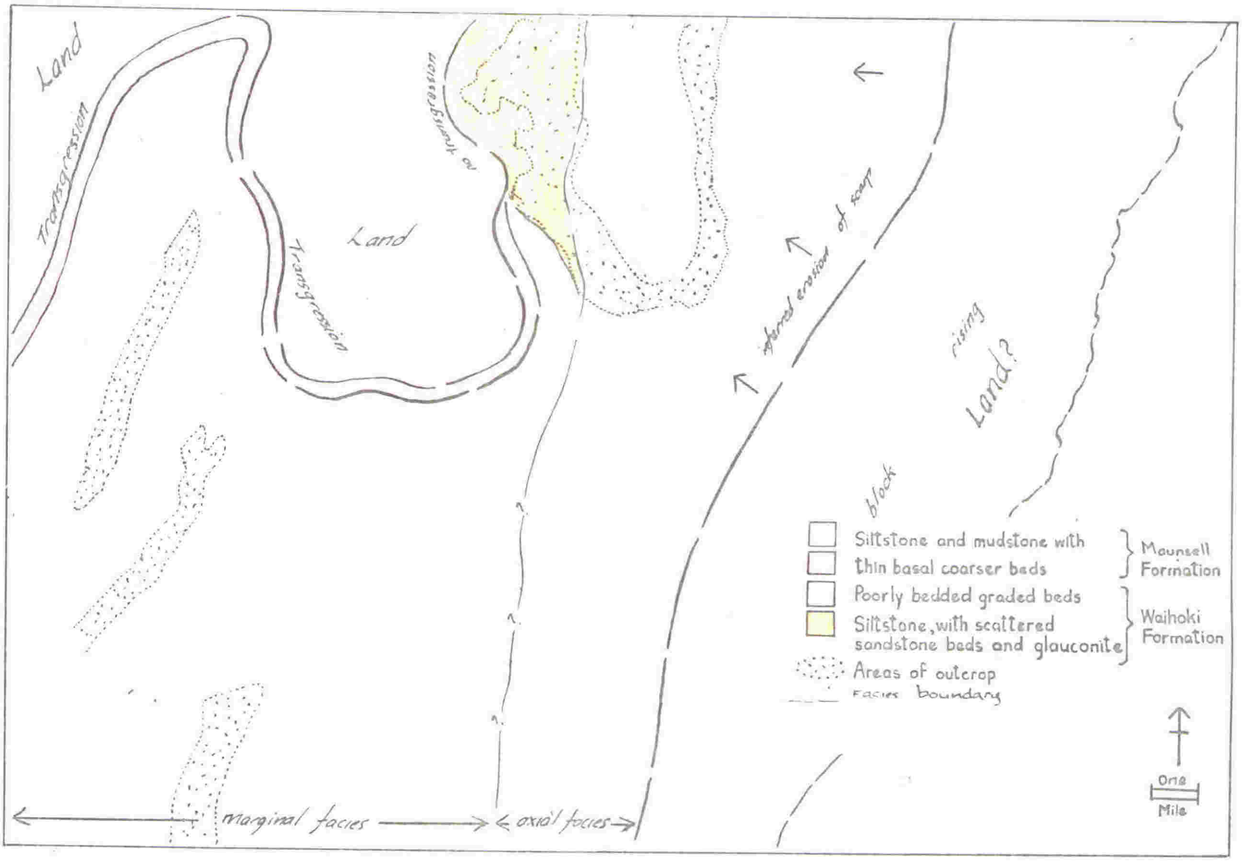


Fig. 18. Outcrop map of middle Tongaporutuan rocks.

poorly graded sandstone-siltstone beds with interbedded mudstone, was deposited conformably on the Maunsell Formation. In the west the Waihoki Formation is finer grained and more massive than in the west. Locally it contains glauconitic sandstone. It is inferred that there was uplift and erosion in the east. In the west there was little sedimentation. In the southwest the base of the formation is a tuffite, the origin of which is uncertain. Kear (1957) inferred that it came from a "south-eastern volcanic zone". However, tuffite is abundant in the upper Miocene Mapiri Formation of northern Hawkes Bay and Poverty Bay and it is more likely that it originated from the "Coromandel andesite zone" where volcanism of Upper Tertiary age is known (Grindley et al., 1959).

In the northeast of the Tinui District coarse sediments of the Ngarata Formation were deposited during the middle or upper Tongaporutuan. In the west the formation is unconformable on the Torlesse Supergroup and in the east it is unconformable on the Waihoki Formation (Fig. 19). Deposition of the Ngarata, Waihoki and Maunsell formations continued in Kapitean time. In the Opoitian, siltstone of the Rangiwhakaoma Formation

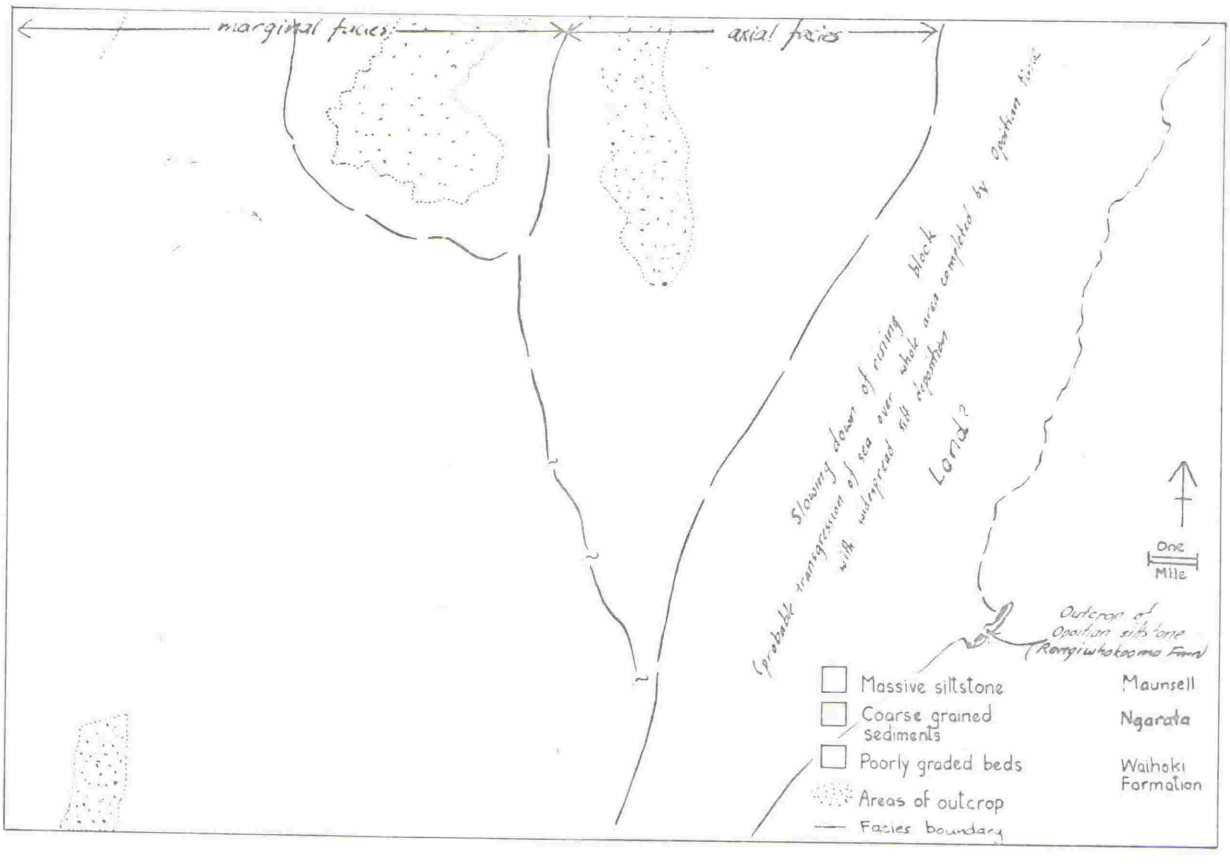


Fig. 19. Outcrop map of upper Tongaporutuan and Kapitean rocks.

was deposited at Castlepoint and it is inferred that the siltstone was once much more widely deposited than it is now.

CASTLEPOINT TRANSGRESSION

Shelly sandstone and coquina limestone of the Nukumaruan Castlepoint Formation is known in place only at Castlepoint. A 2 ft boulder of coquina limestone was found at Maringi Trig. 15.5 miles northwest of Castlepoint. If the boulder is substantially in place and not man-transported, it indicates that the limestone once rested directly on Cretaceous rocks at this locality. The Hurupi Group, inferred to have been deposited at this place (Fig. 19), must have been eroded prior to the deposition of the limestone. West of the Tinui District deposition continued apparently without interruption from the Opoitian to the Castlecliffian. During Nukumaruan and Castlecliffian times deposition changed from marine to non-marine (Kingma, 1967).

It is inferred that during Waipipian and Mangapanian times the Tinui District became land. In the Nukumaruan the sea transgressed onto the district (Castlepoint Transgression). During the transgression shallow water sediments were deposited unconformably on deeper water older sediments. The formation contains Chlamys delicatula (Hutton) - a cold climate indicator. Therefore the transgression was caused by the tectonic lowering of the land below a sea level already lowered because of the cold climate. Vella (1963) included the formation in his Te Ahitaitai Cyclothem, the second oldest of four he recognised in the Wairarapa. He inferred that the cyclothems were deposited while the Wairarapa was sinking tectonically at a decelerating rate. The basal beds of the cyclothem contain cold water faunas which he inferred were probably deposited during glacio-eustatic sea level fluctuations.

PRESENT DAY RELIEF

The present day relief of the Tinui District is dominated by depressions along the Whareama and Tawhero synclines (Fig. 5). The two major rivers, however - the Whareama and the Mataikona - do not flow for any great distance along the depressions. Instead, to reach the coast they flow in gorges cut through hills to the east. It is considered that headward erosion of rivers draining eastward from the hills captured the rivers that once flowed in the depressions. Later uplift produced the hills, and continued river erosion the gorges. In turn western tributaries of the Mataikona and Whareama rivers captured the eastern tributaries of the Tauweru River (Fig. 5).

Three periods of aggradation, followed by degradation, formed three sets of terraces in the floors of the Mataikona and Whareama valleys. On the coast, marine benches have been cut at 100 ft, 270 ft, 400 ft and possibly at 550 ft.

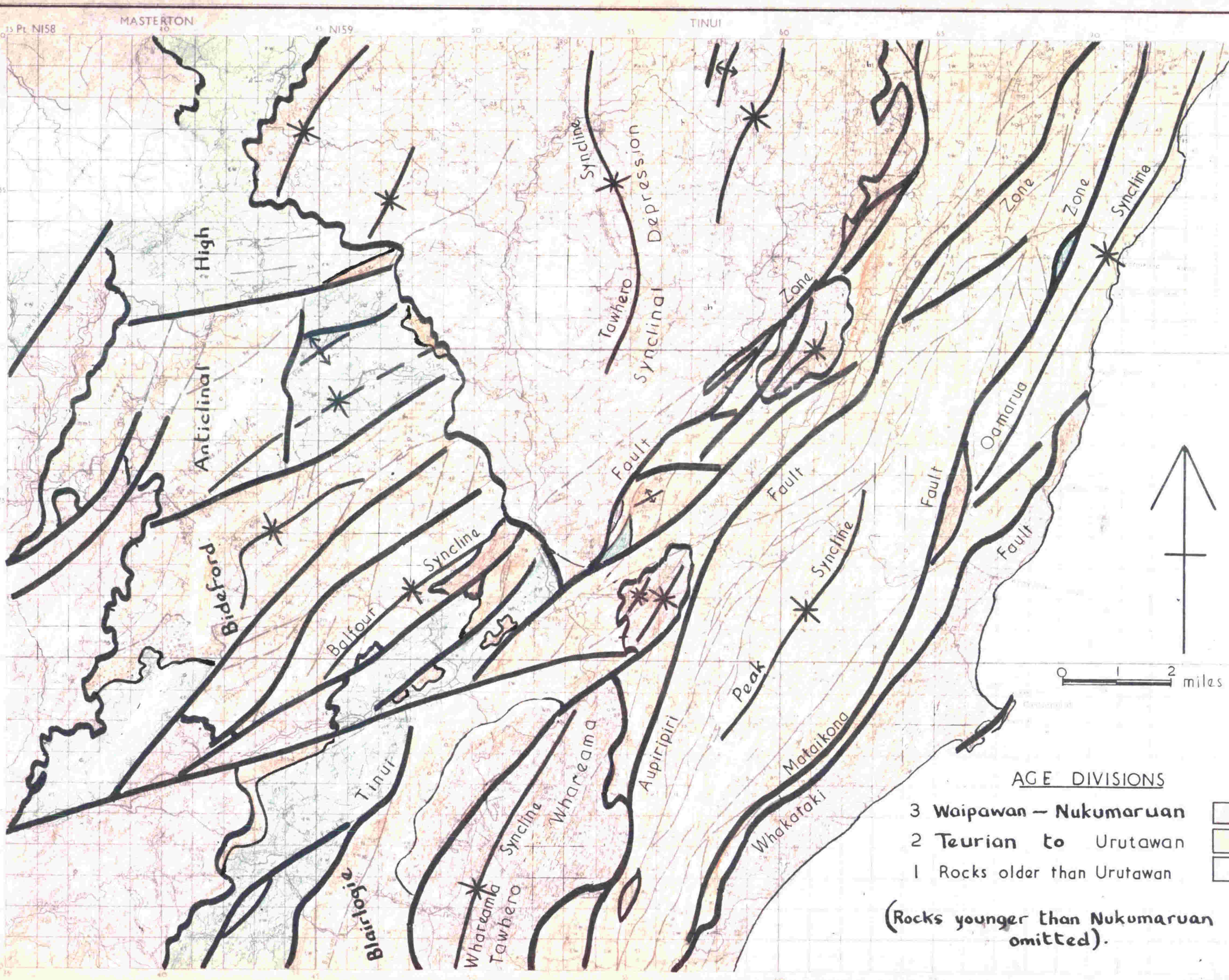
TECTONIC DISTURBANCES IN THE TINUI DISTRICT

It will be shown that the rate of tectonic movement with time was not uniform but varied widely. During short intervals of time, rates of tilting rose from about $1^{o}/10^{6}$ years to as high as $30^{o}/10^{6}$ years and then declined. The intervals of rapid tilting are called disturbances. Four disturbances are recognised in the Cenozoic: in the Paleocene; in the Early Miocene; in the Late Pliocene; and in the Late Quaternary.

Paleocene Disturbance

Teurian rocks of the Tinui Group are unconformably overlain by Waipawan rocks belonging to the Wanstead Group. The rocks of the Tinui Group are strongly folded about northeast striking axes whereas rocks of the Wanstead Group are not folded in this direction (Fig. 20). The strong folding therefore took place in a short interval of time equal to about a Lower Tertiary stage (i.e. about 3×10^{6} years; Fig. 4). The strong folding is called the Paleocene Disturbance. The Wanstead Group is too poorly exposed to provide a meaningfull tilt rate for the disturbance.

Fig. 20a. MAJOR STRUCTURAL FEATURES, TINUI DISTRICT



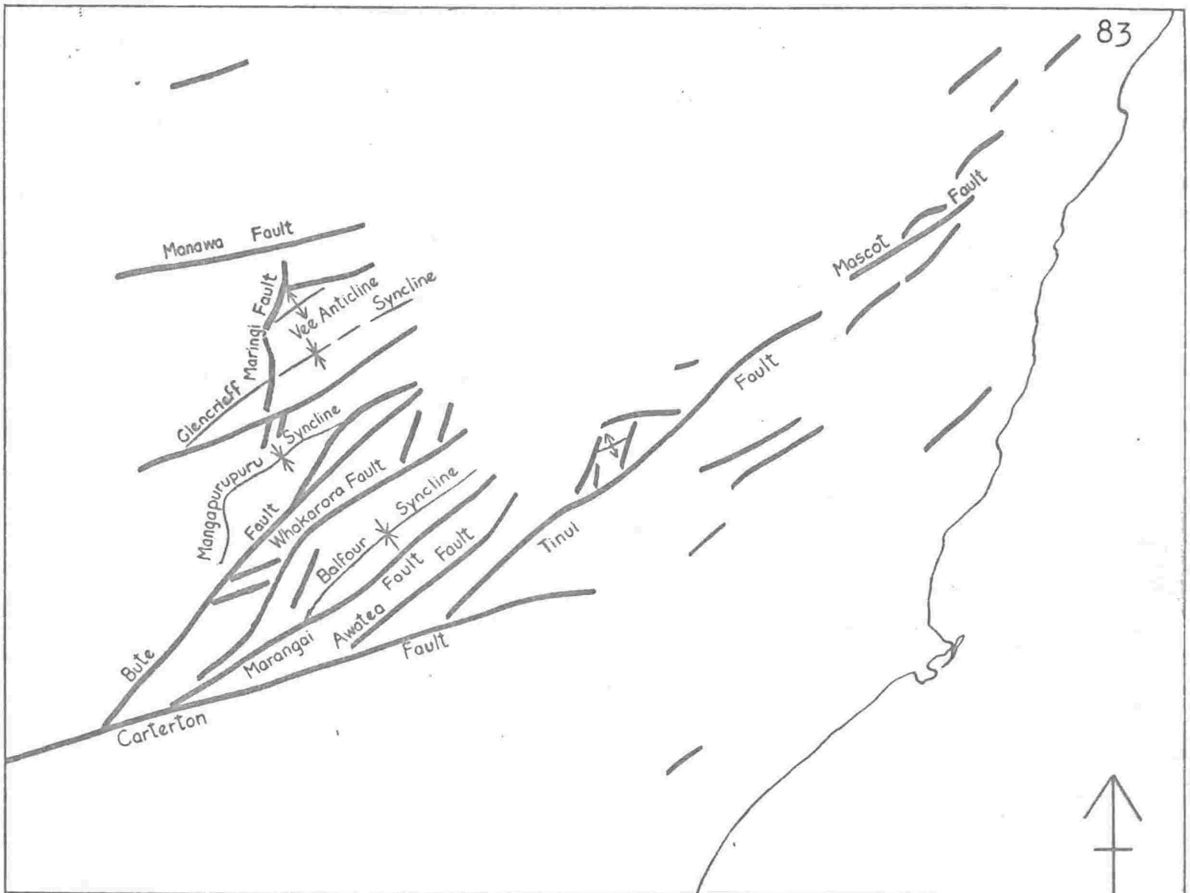
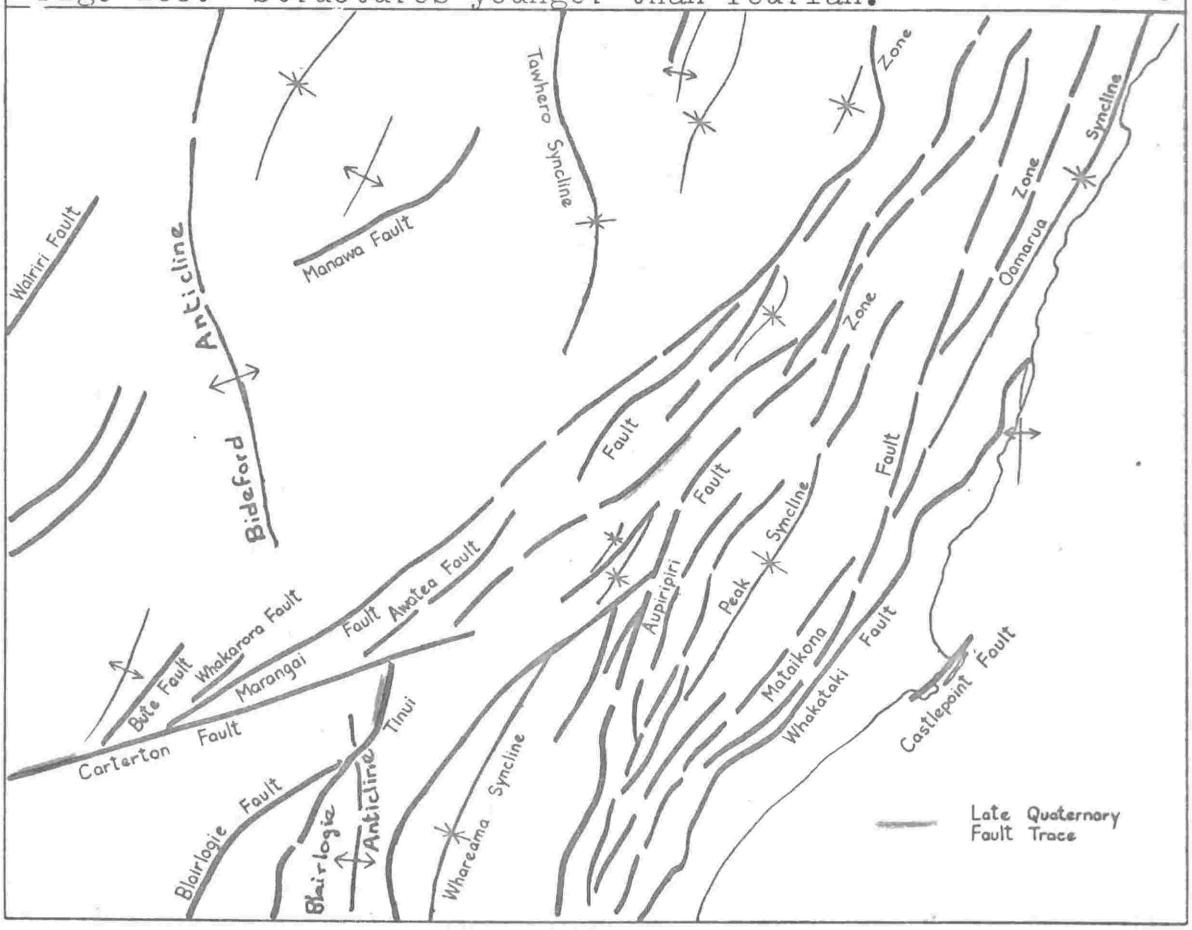


Fig. 20b. Structures younger than Urutawan but older than Waipawan.

Fig. 20c. Structures younger than Teurian.



Early Miocene Disturbance

The slow uniform deposition of the Wanstead Group ceased in the Duntroonian, to be followed by rapid, variable deposition of the Annedale Group in the Waitakian. The Annedale Group, with a basal conglomerate, unconformably overlies the Wanstead and older groups except in the upper Mataikona Valley where the two groups are conformable. From the lithological change at the conformable contact it is inferred that the unconformity - called the Early Miocene Disturbance - represents a period of time of about a stage in duration (say 3×10^6 years). No fold axes can be related to this disturbance.

Late Pliocene Disturbance

It has already been mentioned that at Castlepoint the Nukumaruan shallow water Castlepoint Formation rests with angular unconformity on the deep water Opoitian Rangiwhakaoma Formation, the Waipipian and Mangapanian stages being absent. On the Castle, the angular difference between the two formations is about 12°. The unconformity represents Waipipian and Mangapanian time, assumed to be no more than 1 x 10^6 years giving a tilt rate of at least $12^o/10^6$ years. The interval of rapid tilting is called the Late Pliocene Disturbance.

Late Quaternary Disturbance

In the Wairarapa there are a number of places where the amount that Upper Pleistocene and Holocene rocks have been tilted has been determined. King (1930) mapped uplifted marine benches on the Wairarapa coast, noted that uplift had not been uniform, and inferred tilting. Wellman, 1967 surveyed six Holocene raised marine beach ridges which extend along the west flank of the southern end of the Rimutaka Range at Cape Turakirae. He showed that uplift and tilting took place suddenly at intervals of about 1,000 years over the past 6,000 years. He concluded that the range has been rising at an average rate of about 12 ft/10^3 years. The average rate of tilting on the western side of the range is about $30^o/10^6$ years. Tilt rates in terrace deposits in eastern Wairarapa (Singh, in press) and Holocene marine sediments off

Hawkes Bay (Lewis, in press) are about $20^{\circ}/10^{6}$ years.

The Rimutaka and Tararua ranges have strongly concordant summit heights that are interpreted (Wellman, 1948) as marking the present altitude of an old peneplain. The peneplain is folded into an anticline and the dip of the peneplain surface on the western side of the range is about 6°. The age of the surface is not known, but Wellman suggested that it is younger, rather than older, than rocks of the Wanganui Series which crop out on the flanks of the ranges. It is assumed that the Rimutaka Range peneplain was formed near sea level during a period when there was no uplift, and that the uplift and tilting at Cape Turakirae represent the last part of the uplift of the ranges. The present tilt rate is $30^{\circ}/10^{6}$ years and the tilt of the peneplain is about 6° demonstrating that tilting at the present rate cannot have started more than 0.20×10^{6} years. The present interval of high tilt rates is called the Late Quaternary Disturbance.

DISTURBANCES AND THE REST OF NEW ZEALAND

An attempt is now made to determine if the four disturbances recognised in the Tinui District in the Paleocene, in the Early Miocene, in the Late Pliocene and in the Late Quaternary took place elsewhere in New Zealand.

Paleocene Disturbance

In the Dannevirke Subdivision Lillie (1953; p. 35) noted that "previous to the deposition of these lower Tertiary beds [Wanstead Group] the Cretaceous was very considerably folded and most of the Whangai rocks [Whangai Formation] removed by erosion". In the Gisborne area Stoneley (1968) recognised a "local unconformity" at the base of the Waipawan. In the Waipara District of North Canterbury, which "exposes the most complete fossiliferous sequence through the Dannevirke Series in North Canterbury" (Hornibrook in Wilson, 1963), Wilson (1963) noted that the Dannevirke Series is separated from the Teurian stage by minor breaks representing no great interval of time. However, he stated "but local tectonic movements had already caused local erosion".

It would appear that rates of tilting were sufficiently rapid to cause short breaks in deposition over most of the eastern part of New Zealand, but only in southern Hawkes Bay and in the Wairarapa, were the rates of tilting high enough to form noticeable unconformities.

Early Miocene Disturbance

In the Dannevirke area there was a major change in sedimentation at this time and the Pareora Series is absent (Lillie, 1953; Kingma, 1960) although in many places the stratigraphic sequence appears to be continuous (Lillie, 1953). The absence of the Pareora Series is not now as important as it was previously considered to be because of the recent recognition that the series represents only a relatively short period of time (Scott, in press). Lillie (1953) stated that the Ihungia Formation (Altonian to Clifdenian) is often difficult to distinguish from the underlying Weber Formation although at some localities there is a marked unconformity.

For example in Mototaria Survey District, the base of the Ihungia Formation is a fossiliferous conglomerate, several hundred feet thick, which unconformably overlies a reduced thickness of Wanstead Group rocks. In the Akitio Syncline the basal bed of the Ihungia Formation is a limestone containing pebbles derived from the Weber Formation. It is therefore concluded that the major change in sedimentation was accompanied by uplift and erosion.

North of the Dannevirke area there are many diapiric structures and a possibility of large scale gravity sliding (Stoneley, 1962, 1968) and the geology is confused. The most southerly known diapiric structure is the Elsthorpe Anticline, south of Hastings, which developed in the Early Miocene (Kingma, 1957). Stoneley (1968) showed that there was an unconformity within the Waitakian east of Gisborne, which, although representing only a short period of time, marks a major change in sedimentation. He inferred that the area about immediately east of Mt Hikurangi was uplifted with extensive décollement.

In North Canterbury a disconformity between the lower Landon Amberley Limestone and the upper

Landon Weka Pass Stone (also a limestone), although representing only a short period of time, is apparently important, for Wilson (1963) stated that "a sudden regression, caused, perhaps by earth movements in the Alpine region, took place before the deposition of the Weka Pass Stone".

On the west coast of the North Island in the Waikato Coalfield there was a major change in sedimentation during the Waitakian. The change is at the contact, at most places an unconformity, between the Te Kuiti Group and those overlying: the Waikawau Group in the north and the Mahoenui Group in the south (Kear and Schofield, 1959). Kear and Schofield stated that "deposition of the Te Kuiti Group finally ceased when tectonic activity produced (1) an angular unconformity between it and younger sediments and (2) uplift of the source province from which the subsequent clastic sediments were derived". The unconformity does not represent a great length of time and at one locality it can be shown to be within the Waitakian Stage.

In north Westland, between the end of the Oligocene and the end of the middle Miocene (Gage, 1949; Wellman, 1949), the sites of Lower

Tertiary deposition became mountain ranges and Lower Tertiary mountain ranges became sites of Upper Tertiary deposition because of reversal of movement on major faults.

Late Pliocene Disturbance

In the Dannevirke Subdivision there is an unconformity similar to the one already described from the Tinui District, except that the shallow-water limestone above the unconformity, the Te Aute Limestone, is older and Mangapanian in age. The base of the limestone was described by Lillie (1953) as an important erosional break which affected all areas of Mangapanian sedimentation. The limestone commonly contains greywacke pebbles, with composition similar to the greywacke forming the Ruahine Range. The pebbles increase in abundance westward towards the range, and show that the range was being uplifted. The Te Aute Limestone is unconformably overlain by the Nukumaruan Petane Limestone (Kumeroa Formation of Lillie, 1953). Lillie recorded an angular discordance that indicates westward tilting between 2° and 15° between the two limestones.

In the Gisborne area diapiric structures developed (Stoneley, 1962; Ridd, 1964) and décollement took place. Ridd considered that the climax of tectonic movements was reached in the Early Pliocene. At Waerengaokuri, Tongaporutuan beds are the youngest part of a diapiric intrusion and are overlain by undeformed Castlecliffian lacustrine beds (Bishop, 1968).

In the South Island widespread gravel formations (e.g. Moutere Gravel, Old Man Gravel, Kowhai Gravel) show that rapid uplift of the Southern Alps took place in late Pliocene time immediately prior to the Nukumaruan. That the uplift of the Southern Alps was sudden is shown in the Moutere Depression of Nelson, where Waitotaran coal measures (Glenhope Formation), are conformably overlain by the Moutere Gravel. The Glenhope Formation is locally derived from rocks on the west side of the Alpine Fault but the Moutere Gravel is derived from the Southern Alps on the east side of the fault (Johnston, 1971).

Late Quaternary Disturbance

The high rates of tilting determined from marine ridges and marine benches in the Wairarapa and southern Hawkes Bay have already been discussed. Ridges and benches are known elsewhere in New Zealand, such as one in Westland giving a tilt rate of 15 $^{o}/10^{6}$ years (Suggate, 1968), but few rates of tilting have been determined. Active fault traces are present throughout most of New Zealand (Lensen, 1965) and some show horizontal movement averaging 0.5 in/year (Clark and Wellman, 1959).

DISTURBANCES WITHIN NEW ZEALAND AS A WHOLE THAT CANNOT BE CORRELATED WITH THOSE IN THE TINUI DISTRICT

In addition to the disturbances described above, which correlate with those in the Tinui District, other disturbances have been recognised. Lillie (1953; p. 80) described the deposition of the upper Southland Tutamoe Formation in the Dannevirke Subdivision as being tectonically important. According to him new sites of deposition formed and new areas were uplifted and eroded. In the Tinui District the topographic change may be represented by the Hurupi Transgression. In the Gisborne area, Stoneley (1968) recognised that the main movements in a Tertiary décollement took place in Pareora time. It was followed by the widespread deposition of Altonian (Pl) or younger sediments unconformably on older sediments. The uplift of the Kaikoura Ranges is well dated by the formation in Southland time of the Great Marlborough conglomerate (Lensen, 1962).

It would be inappropriate to discuss here all the disturbances within New Zealand, but it is likely that sudden disturbances similar to those that took place in the Tinui District occurred in all parts of New Zealand but they were not necessarily synchronous with those that took place in the Tinui District.

STRUCTURE OF THE TINUI DISTRICT

In order to discuss folding and faulting in the Tinui District with time, it is convenient to consider the stratigraphic sequence to be divided into three major age divisions (Fig. 20a):

Division 1: rocks older than Urutawan (Torlesse Supergroup)

Division 2: rocks between Urutawan and Teurian in age (Mangapurupuru and Tinui groups)

Division 3: rocks between Waipawan and Nukumaruan in age (Annedale and Hurupi groups and Castlepoint Formation).

It is also convenient to consider first the area west of the Tinui Fault Zone, and then the area east of it.

West of the Tinui Fault Zone

Folds

Rocks of division 1 are strongly and complexly folded, the only well defined fold being the Vee Anticline which is parallel to the folds in Division 2 (Fig. 20b). Division 1 is not considered further. Rocks of division 2 are strongly folded, with dips of about 50° to 70° whereas rocks of division 3 (Fig. 20c) are relatively weakly folded, with dips of generally less than 50° and commonly between 10° and 25°. The weak folding in division 3 almost certainly affected the rocks of divisions 1 and 2, but as the rocks had already been fairly strongly folded its effect was negligible. Similarly, the strong folding which affected rocks of Division 2, had, with the exception of the Vee Anticline, negligible effect on the strongly deformed rocks of division 1. The axes of the strong and of the weak folding have different strikes. The strong folds strike approximately northeast, the weak folds approximately north. The strong folding is Early Cenozoic (Paleocene) in age, and the weak folding is Late Cenozoic (Post-Miocene) in age.

Faults

The faults are grouped according to the age of the rocks they displace. Within rocks of divisions 1 and 2 the major faults strike between ENE and northeast, and minor faults strike NNE. These faults are not well developed in division 3. In division 3 the major faults strike approximately NNE, parallel to major Late Cenozoic faults in the Wairarapa. They extend through rocks of divisions 1 and 2, but are relatively unimportant there. Hence the ENE faults are inferred to have been dominant in the Early and the NNE faults are inferred to have been dominant in the Late Cenozoic.

East of the Tinui Fault Zone

The strike of the fold axes, faults, and the dip of the rocks is the same in division 2 as it is in division 3. Consequently it is impossible to distinguish between Early and Late Cenozoic folding and faulting. Early Cenozoic folding about ENE striking axes is inferred for the district west of the Tinui Fault Zone. ENE folding to the east of the fault is thought to have been obliterated by the later faulting and folding along NNE trends.

Early Cenozoic Folds and Faults (Fig. 20b)

Folds

Early Cenozoic folds are mostly determined by opposing dips some distance apart, and only rarely are the fold axes themselves exposed. Four folds are mapped: the Vee Anticline in the northwest, and the Glencrieff, Mangapurupuru, and Balfour synclines in the southwest. All the folds are separated by faults and there are no complementary anticlines between the three synclines in the southwest. The synclines plunge northeast and the single anticline southwest. The age of the youngest beds in each syncline becomes progressively younger in a southeast direction indicating that the "synclines" are the northwest limb of a larger syncline (Fig. 3) that has been faulted and folded.

Faults

The major faults are the ENE striking Carterton, Target and Manawa faults. A number of faults striking northeast to ENE branch off towards the Target Fault. The only NNE striking fault of importance is the Maringi Fault between the Target and Carterton faults. Because of poor exposures and wide zones of crushing, it is impossible to observe the dip of many of the faults directly. However, as the surface trace of each fault is linear across hilly topography, the fault planes are inferred to dip steeply. For convenience, the faults with unknown dip are shown as being vertical in Fig. 3.

Late Cenozoic Folds and Faults (Fig. 20c).

Folds

Folds in the Late Cenozoic rocks usually have exposed axes. Where the axes are not exposed the folds are determined from opposing dips and from the slope of exhumed erosional surfaces on Early Cenozoic or older rocks. Folds are more numerous in the west than in the east, and only the major folds are named in Fig. 20c. In the west there is a major upfold, the Bideford-Blairlogie Anticlinal High, made up of the Bideford Anticline north of the Carterton Fault and the Blairlogie Anticline south of the fault. To the east of the high there is a major downfold, the Tawhero-Whareama Synclinal Depression, made up of the Tawhero Syncline in the north and the Whareama Syncline in the south. Between the synclinal depression and the coast there are two major synclines, the Oamarua and Peak synclines. The folds are described in turn, beginning in the west.

The axis of the Bideford Anticline is defined in the north of the Tinui District by the crest of an exhumed erosional surface cut across Cretaceous and older rocks. In the south the surface has been largely destroyed and the position of the axis is uncertain. The Blairlogie Anticline is poorly defined by an exhumed erosional surface which shows that most of the eastern limb of the anticline is faulted out by the Tinui Fault Zone. North of the Tinui District the Bideford Anticline, defined by opposing dips in Upper Tertiary beds, can be traced as far as Pongaroa. South of the district it the Blairlogie Anticline crosses the coast near Pahoa.

The axis of the approximately north-striking Tawhero Syncline is well defined by dips in Late Cenozoic rocks. The axis of the NNE striking Whareama Syncline is concealed by alluvium but is inferred to be parallel to the Aupiripiri Fault Zone and to the Buxton Fault (Fig. 2). Vertical drag on the faults may have caused the dips in the Whareama Syncline to be 15° to 20° steeper than dips in the Tawhero Syncline. The northern end of the Whareama Syncline has been offset by dextral faulting.

The Tawhero Syncline can be traced for a short distance north of the Tinui District where it disappears, or has been obliterated in a complexly faulted area south of Pongaroa. The Whareama Syncline extends south to cross the coast at Flat Point (Fig. 1).

In the east the axes of the Oamarua and Peak synclines strike NNE and are parallel to major faults. The complementary anticlines are absent but their axes are approximately represented by the Aupiripiri and Mataikona fault zones; the rocks dipping away from the fault zones towards the synclinal axes. The axes of the synclines are parallel with the faults and it is inferred that the folding is controlled by the faulting. This contrasts with the situation at most other parts of the Tinui District where the faults and folds are not parallel, and the folds are inferred to have formed by compression.

Faults

The major NNE striking faults are, from west to east: the Wairiri Fault, the Tinui Fault Zone, the Whakataki Fault, and the Castlepoint Fault Zone.

The Wairiri Fault, east side downthrown, has brought the Waewaepa Formation into contact with the Maunsell Formation. It dips vertically, and north of Wairiri Road has a sliver of Whangai Formation infaulted along it.

The Tinui Fault Zone is the most important fault in the Tinui District. North of Tinui Village the fault zone is 1.5 miles wide and contains active traces. The downthrown side is to the west. South of Tinui Village the fault zone is narrow. The east side is downthrown, and as its dip is 70° west it has a reverse component. Several faults branch off the fault zone, the most important being the Blairlogie Fault in the southwest. North of the Tinui District the fault zone extends north into southern Hawkes Bay. Southwards it probably joins the Adams Fault of Eade (1966) which reaches the coast near the Pahoa River.

The Whakataki Fault extends from Reef Point to south of the Tinui District. The curve of the fault trace across hill country suggests a westerly dip of about 60°. It is downthrown to the east and is thus inferred to have a reverse component. The fault disappears out to sea at Reef Point, and probably reappears as the fault, on the coast near the Owahanga River, which continues northwards into the Dannevirke Subdivision (Lillie, 1953). South of the Tinui District it reaches the coast at Flat Point.

The Castlepoint Fault Zone is exposed at

Castlepoint. Associated with it are the only definite outcrops of Opoitian and Nukumaruan rocks in the Tinui District. The fault dips steeply, and is downthrown to the east. A collinear steeply dipping fault at Cape Turnagain is probably its northern continuation.

So far it has been tacitly assumed that new faults appear and old faults become inactive. The true situation is more complex and a particular fault may change its rate of movement or even its sense of movement with time. However, in order to determine the history of a particular fault, many well dated reference lines (Fig. 21) or reference planes are required. It is important to distinguish between reference lines and the outcrop of reference planes. In the general case, a fault displaced inclined reference plane shows on a map as an outcrop line which is "offset" by the fault (Fig. 22). The offset has a horizontal length, which in general does not represent the horizontal (strike-slip) displacement of the reference plane by the fault.

To determine the amount of horizontal displacement the dip of the reference plane at the time of faulting must be known, and also the sense of movement in one direction. In

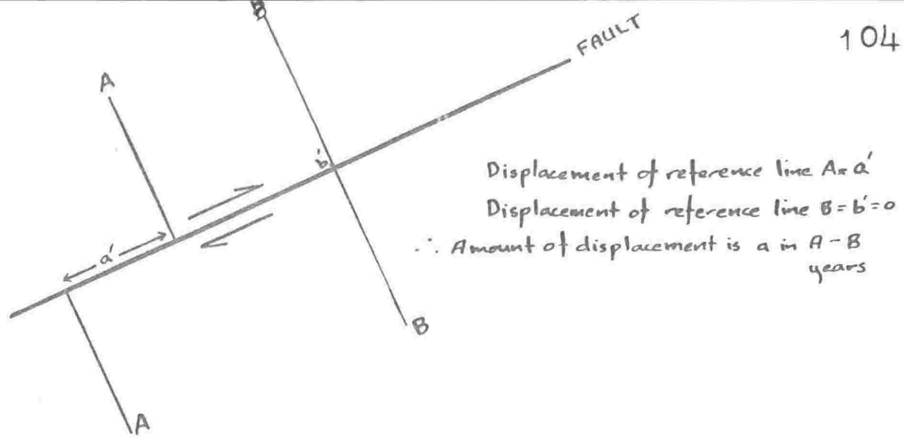


Fig. 21. Reference lines (or vertical reference planes) offset by a fault.

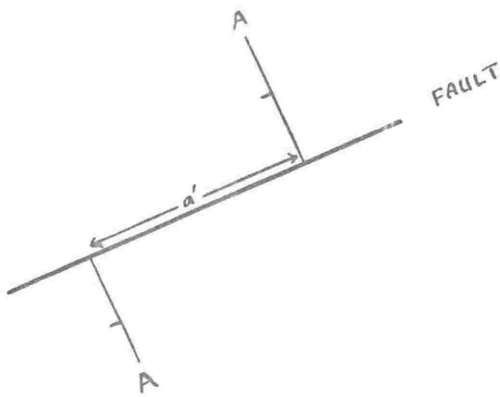


Fig. 22. Dextral offset of an inclined reference plane (A).

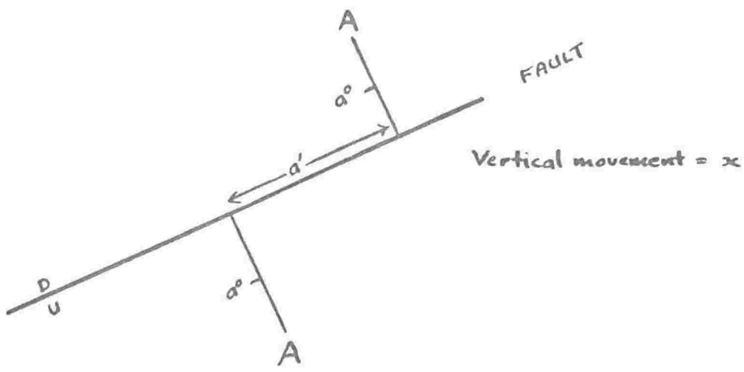


Fig. 23. Plan showing vertical displacement of a reference plane (A).

Fig. 22 the dextral offset (a') of an inclined reference plane A could have been entirely caused by vertical fault movement. The lower the angle of dip, the greater the horizontal offset. If the amount of vertical movement, and the downthrown side are known, then the true horizontal displacement of reference plane A is a'. The amount of horizontal displacement (y) by vertical movement (x) can be calculated by using the following solution

$$\tan. a^\circ = \frac{y}{x}$$

if y equals a' then there has only been vertical movement on the fault. If it is more, then y - a' equals the amount of sinistral movement on the fault and if it less then a' - y equals the amount of dextral movement on the fault.

Horizontal movement on a fault may have all been in the same direction or in different directions, and in all cases the total displacement is the algebraic sum of the movements on that fault. Movements on the major faults in the Tinui District are considered in terms of the previous discussion and an attempt is made to determine the amount and sense of movement at different times in the past. The NNE striking faults are discussed first.

Horizontal Movement on the NNE Striking Faults

The NNE striking Tinui Fault Zone truncates the ENE striking Carterton Fault and associated faults (Fig. 2). ENE striking faults immediately north of the Tinui District (Kingma, 1967), and on the opposite side of the fault zone to the Carterton Fault, are assumed to have been the continuation of the Carterton Fault and associated faults. The ENE striking faults are inferred to have been sinistrally displaced by about 16 miles by the Tinui Fault Zone (Fig. 24).

In the Mt Adams area, Eade (1966) mapped a facies discontinuity in his Kaiwhata Formation (Teurian) across the NNE striking Tutu Fault. The fault is almost collinear with, and may be the continuation of, the Tinui Fault. Eade suggested that the change was due to strike-slip faulting of at least 12 miles, although the sense of movement was not specified. P. Wellman (1970) showed that if movement had been strike-slip then it would have been sinistral, that is, in the same sense as the movement inferred on the Tinui Fault Zone. Further evidence is provided by glauconitic sandstone dikes in the Whangai Formation (Teurian)

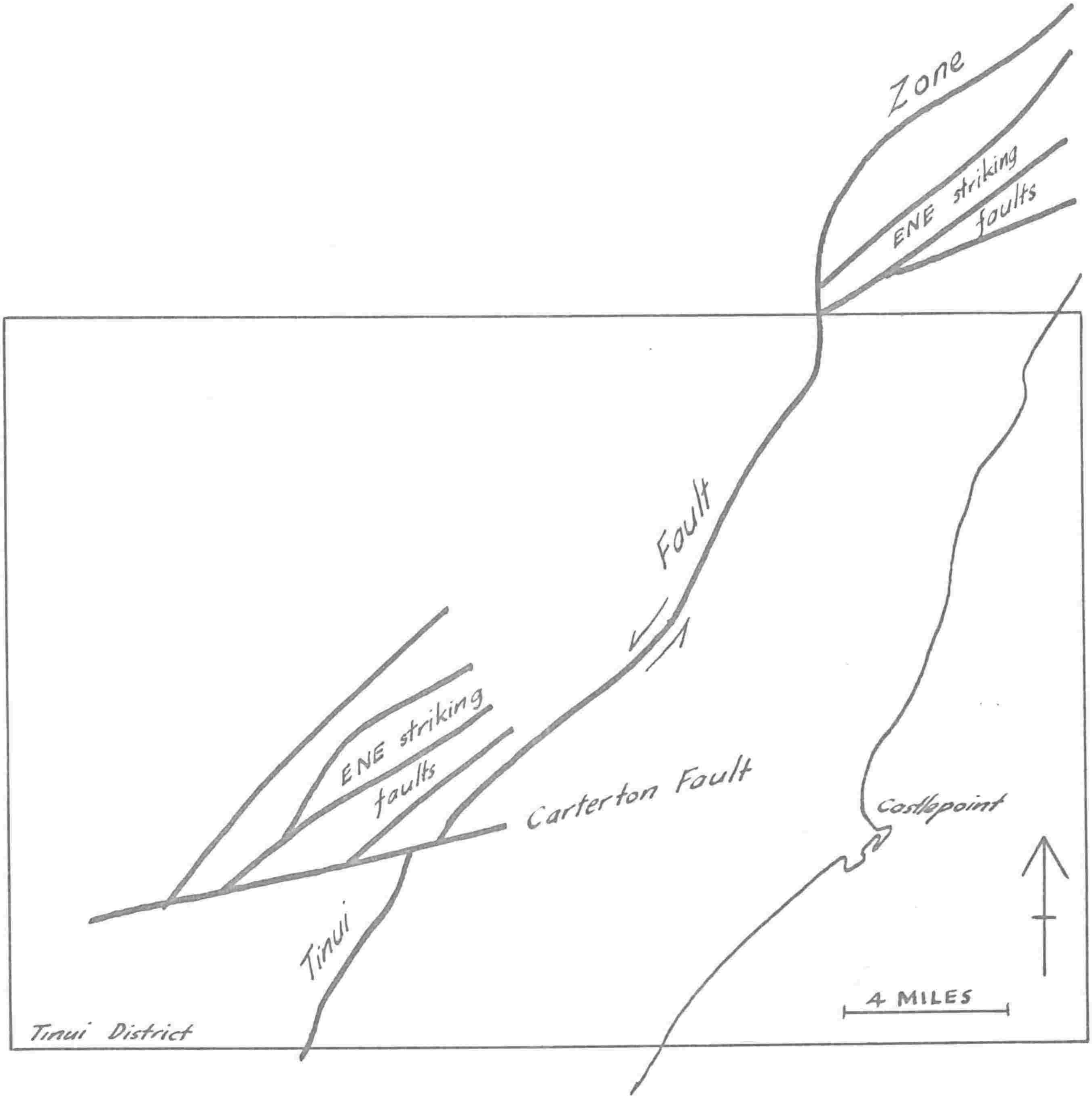


Fig. 24. Inferred sinistral displacement of ENE striking faults by the Tinui Fault Zone.

exposed on a coastal platform south of the Awhea River (Professor H.W. Wellman, pers. comm.). Wellman has recorded small sinistral offsets on northeast to NNE striking faults which displace the dikes.

In the Tinui District a NNE striking fault on the west limb of the Whareama Syncline has a sliver of the Takiritini Formation (Lower Miocene) along it. The sliver is 8 miles south of similar rocks in the Tinui Valley. At least 8 miles of dextral movement on the fault is thus possible. Ridd (1967) inferred that the northeast to NNE striking Pongaroa Fault continued southwards, beneath Upper Miocene sediments, to join the Tinui Fault Zone. From paleogeographic patterns on either side of the Pongaroa Fault, Ridd inferred that there was about 8 miles of dextral movement on the fault during the Miocene.

In conclusion, all the NNE striking faults for which there is any information, have moved in a dextral sense since the Miocene. However, there is evidence for sinistral movement on some of the faults prior to the Miocene. Therefore it is inferred that movement on all the NNE striking faults prior to the Miocene was sinistral.

For some faults the early sinistral movement was greater than the late dextral movement.

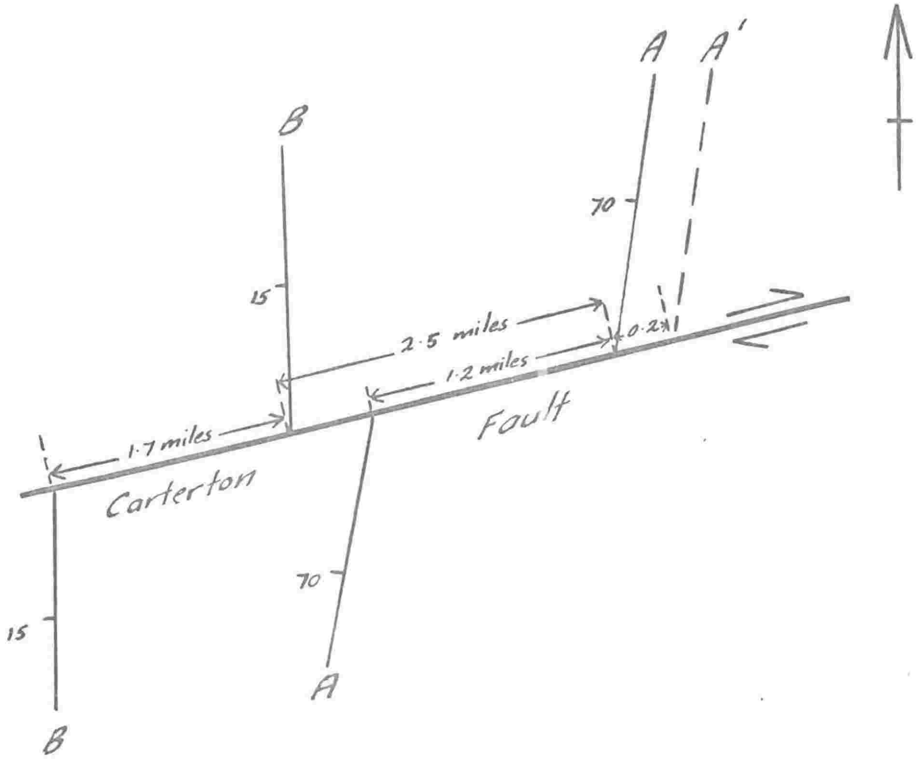
Vertical Movement on the NNE Striking Faults

Within the Tinui Fault Zone in the Tinui Valley a well defined active fault trace, 4 miles long, is downthrown 12 ft to the west for part of its length. The Whakataki Fault has downthrown the Lower Miocene Whakataki Formation on its eastern side. The fault plane dips 60° west and the sense of movement is reverse. In the southeast of the Tinui District the Tinui Fault Zone dips 70° west and the sense of movement is reverse.

Horizontal Movement on the ENE Striking Faults

According to Lensen (1968) the Carterton Fault immediately west of the Tinui District dextrally displaces by 45 ft the edge of gravels which are here mapped as the Rorokoko Formation of early Last Glaciation age. The 70° westerly dipping Tinui Fault Zone has an offset of 1.2 miles across the fault. The offset is partly due to vertical movement and partly due to dextral displacement. The vertical movement would have produced sinistral offset of the Tinui Fault Zone of about 0.2 miles. The true dextral movement on the fault is therefore about 1.4 miles (Fig. 25). The 15^{o} westerly dipping base of the Maunsell Formation is dextrally offset by 1.7 miles across the Carterton Fault. However, the dip of the formation was initially gently east (Fig. 17) and has since rotated to 15^{o} west. During vertical movement the sense of apparent horizontal movement would therefore have changed from dextral to sinistral.

The Motuan shoreline (Fig. 7a) and the Waitakian shoreline (Fig. 14a) are sinistrally offset by the Carterton Fault. As the dip of the shorelines would be gently east for a considerable time after their formation, a small amount of vertical movement would produce a large horizontal offset and there is no evidence for any horizontal displacement. It is inferred that the NNW side of the fault was upthrown in the Upper Cretaceous to initiate the Gentle Annie gravity slide and again in the Otaian when the Takiritini Formation was deposited.



A = Tinui Fault Zone

B = base of Maunsell Formation

Fig. 25. Diagrammatic representation of apparent and real horizontal offsets on the Carterton Fault.

Such vertical movement would cause dextral offsetting of the shorelines. It is therefore inferred that there was sinistral movement on the Carterton Fault prior to the Late Cenozoic. It is impossible, without further information on the amount and direction of vertical movement on the fault, and the dip of the shorelines at the time of vertical movement, to determine the true amount of sinistral displacement.

Vertical Movement on the ENE Striking Faults

The Carterton Fault vertically displaces the edge of the early Last Glaciation Rorokoko Formation by up to 15 ft. The downthrown side is different at different places. In the east, opposite Awatoitoi, it is the SSE side, whereas further west it is the NNW side. In the Pliocene the SSE side of the fault was downthrown. It is inferred that the SSE side was also downthrown in the Otaian and in the Upper Cretaceous. The dip of the fault is unknown, but is greater than 70° from its linear trace. Vertical movements on other faults are unknown.

Intersecting Strike-slip Faults

Two fault trends, one striking NNE and the other striking ENE, have existed in the Tinui District during the Cenozoic. Although it is inferred that the NNE trend was dominant in the Late Cenozoic and the ENE trend was dominant in the Early Cenozoic, some interaction between the two trends has occurred throughout the Cenozoic. The horizontal displacement of the ENE striking faults by the Tinui Fault Zone (Fig. 24) is shown diagrammatically in Fig. 26. Such offsetting would form the numerous fault slivers, striking ENE, that exist within the Tinui Fault Zone (Fig. 2).

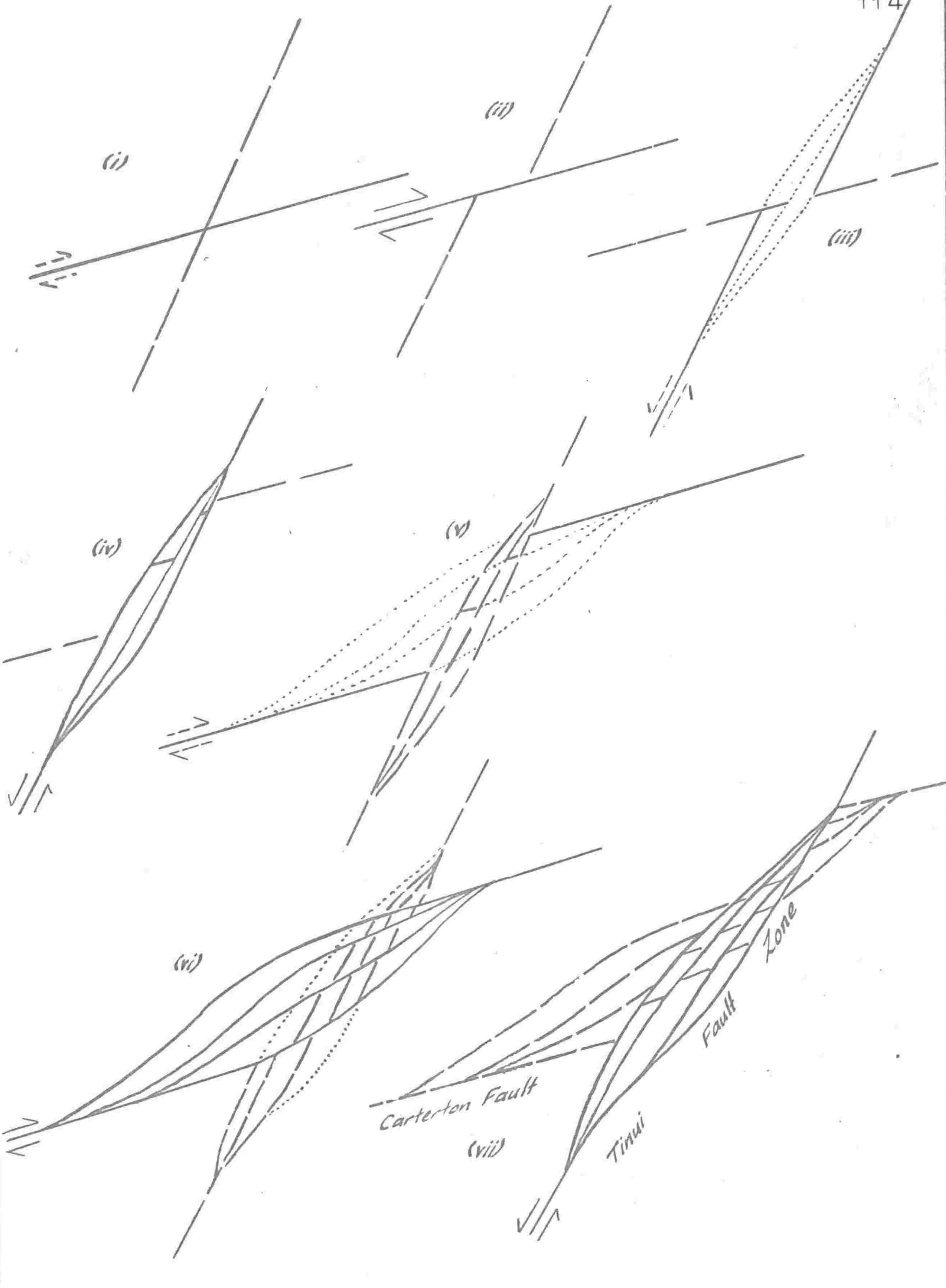


Fig. 26. Diagrammatic representation of formation of Fault Slivers

THE NEW ZEALAND MOBILE BELT

It has already been mentioned (p. 9) that the Tinui District forms part of a complexly folded and faulted region which extends from Kaikoura to East Cape. The region, along with the rest of the central part of the New Zealand landmass, contains strongly tilted Late Cenozoic rocks. This is in contrast to the southeast of the South Island and the northeastern half of the North Island where dips in Late Cenozoic rocks are gentle. For convenience, the central part of New Zealand is termed the New Zealand Mobile Belt (Fig. 27). There are many features in common to all parts of the belt in the New Zealand landmass, and in order to more fully understand the structure of the Tinui District, they will be discussed and a simple model proposed.

The New Zealand Mobile Belt is elongated approximately NNE-SSW with a major trench, the Hikurangi Trench, along its northeastern side. The landmass can be regarded as the crest of a major upfold or geanticline and the sea bed to the east as a major downfold or geosynclinal trough. Approximately parallel to the sides of the mobile

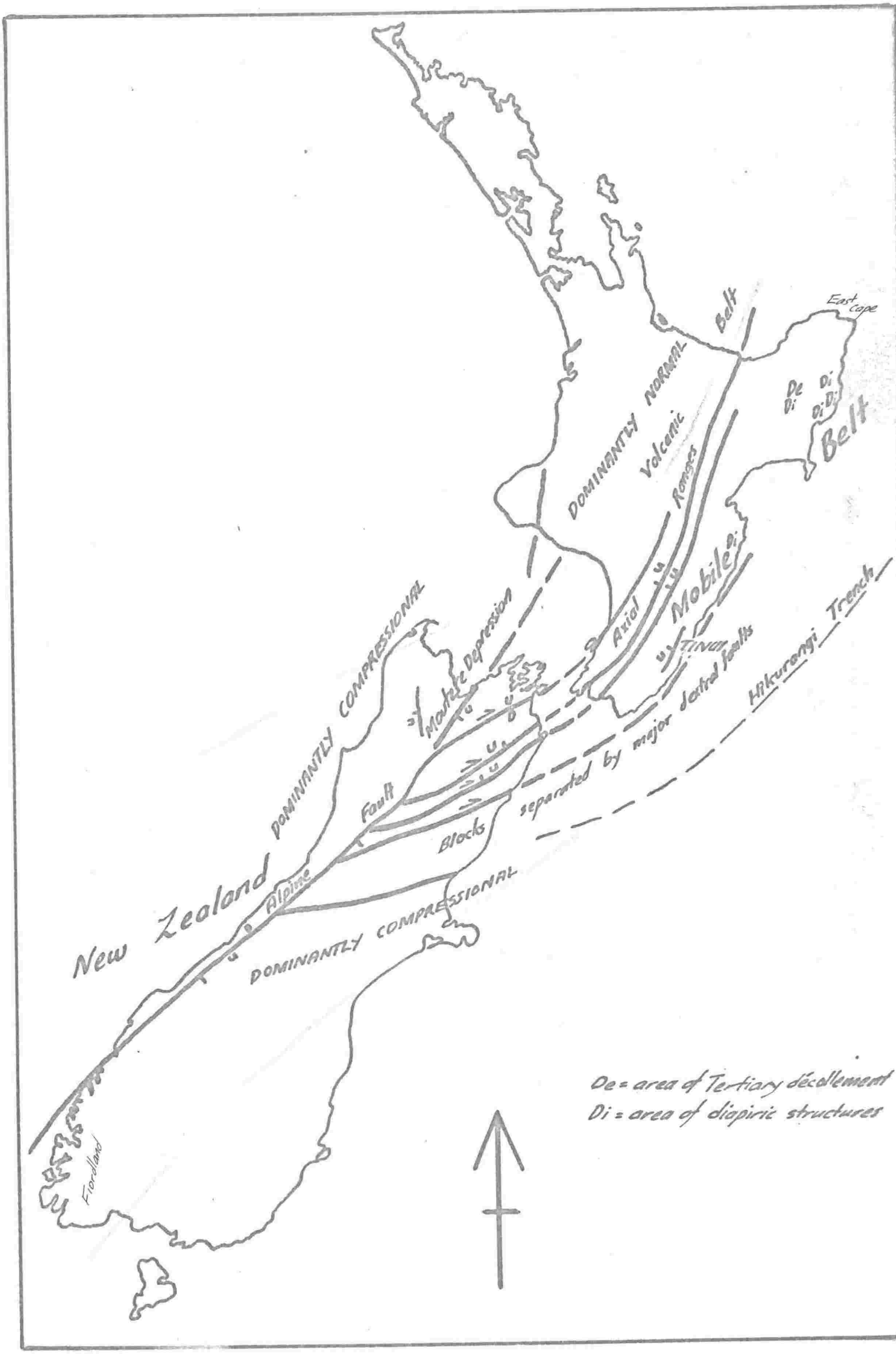
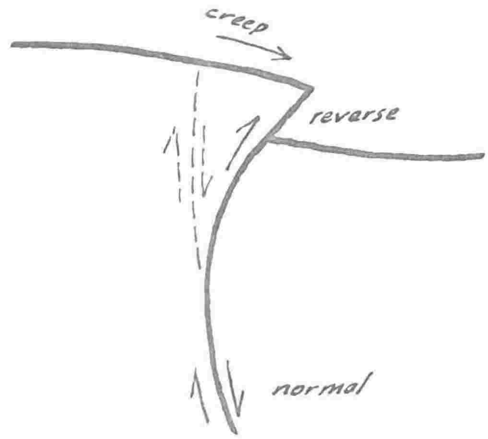


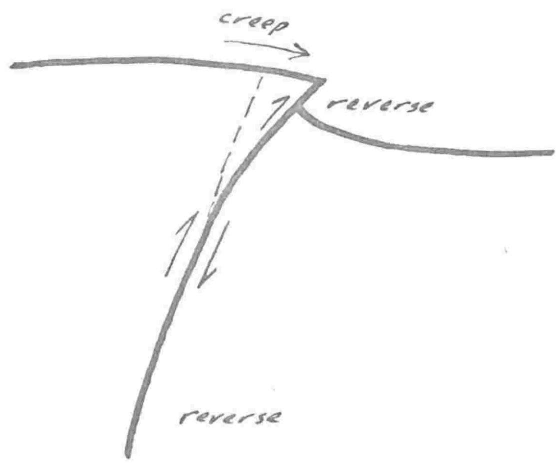
Fig. 27. New Zealand Mobile Belt.

belt are major dextral faults. The faults diverge from the Alpine Fault in the northern end of the South Island and cross Cook Strait into the east of the North Island (Fig. 27). The best known feature of the faults is the hypothesis, first introduced by Wellman in 1949 (Bensen, 1952), of a postulated 300 miles dextral displacement by the Alpine Fault of several major structures in the South Island. Although the displacement is accepted by most New Zealand geologists there is little agreement as to when it occurred. In the south of the South Island the dip on the fault is eastward, the western side is downthrown, and the sense of movement is reverse. In the north of the South Island and in the North Island the dip on the faults branching off the Alpine Fault is westward, the eastern side is downthrown, and the sense of movement is reverse.

The possibility that the dip on many of the faults is decreased by gravity creep of the upthrown side must be considered (Fig. 28). However, it is inferred that the faults remain reverse at depth because retriangulation surveys across the Alpine Fault in Marlborough (Wellman, 1955), across the White Creek Fault before and



(a) normal fault



(b) reverse fault

Fig. 28. Cross sections showing alternative explanations of a fault with a reverse component at the surface.

after the 1929 movement on the fault (Henderson, 1937), and in Hawkes Bay before and after the 1931 Napier earthquake (Professor H.W. Wellman, *pers. comm.*), and recently in the Wellington area (P.M. Otway, *pers. comm.*), show that the New Zealand Mobile Belt is undergoing shortening as well as strike-slip displacement.

Between the major dextral faults are a large number of elongated fault blocks (Cotton, 1916; Houtz *et al.*, 1967), at an acute angle to the strike of the major dextral faults (Fig. 29). It is assumed that the blocks are separated by reverse faults and that blocks and faults rotate together so that the total width of the mobile belt decreases with time.

Within each fault block, asymmetrical synclines developed in the lows and asymmetrical anticlines developed in the highs (Fig. 30a, b). As rotation of the block advanced, faulting sometimes removed the steep limb of the fold (Fig. 30c) and growing folds will form. Such growing folds are typical features of the east coast of the North Island, were first described from New Zealand by Macpherson (1946), and are independent of uplift or depression of the mobile belt. The

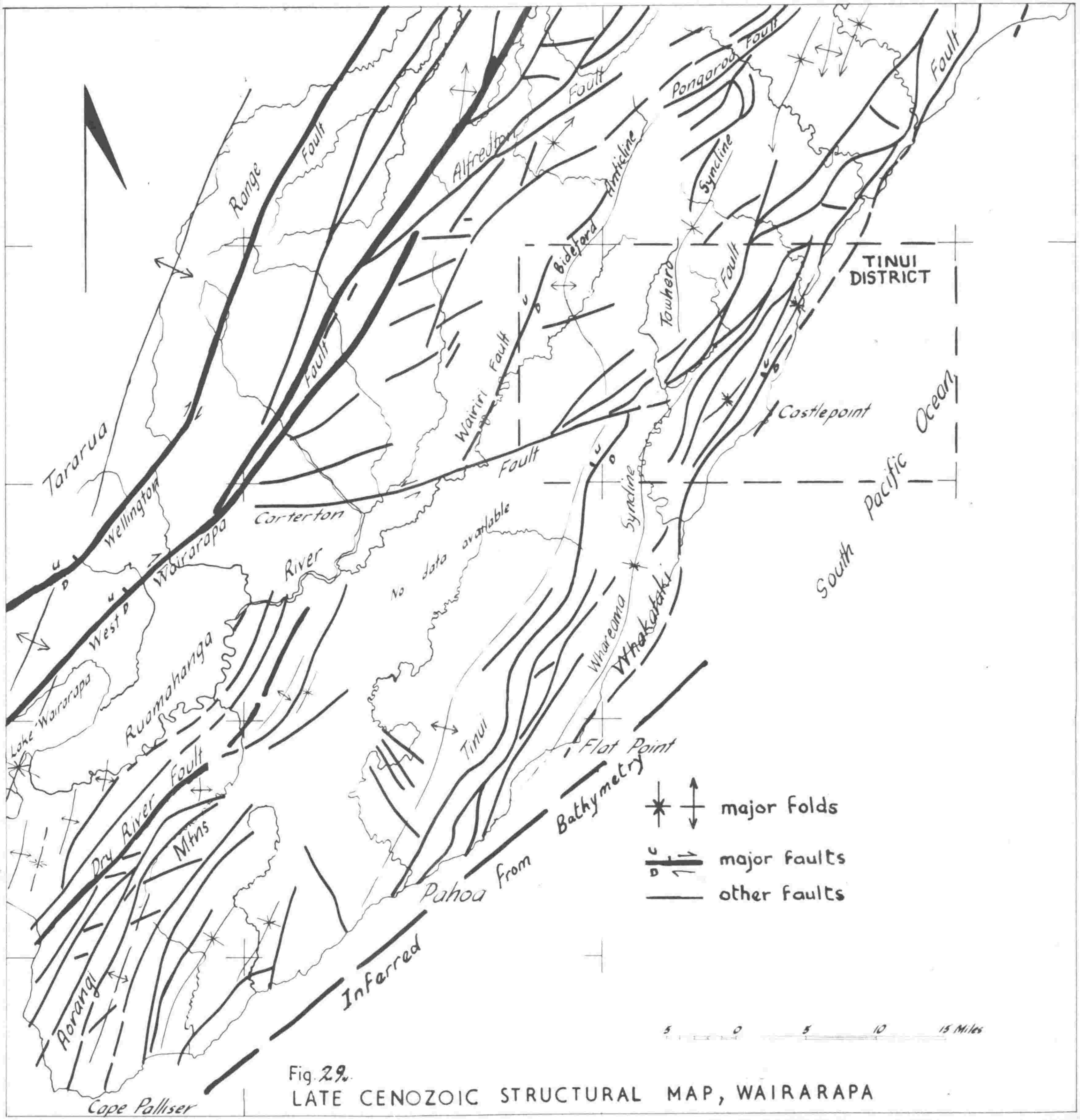


Fig. 29.
LATE CENOZOIC STRUCTURAL MAP, WAIRARAPA

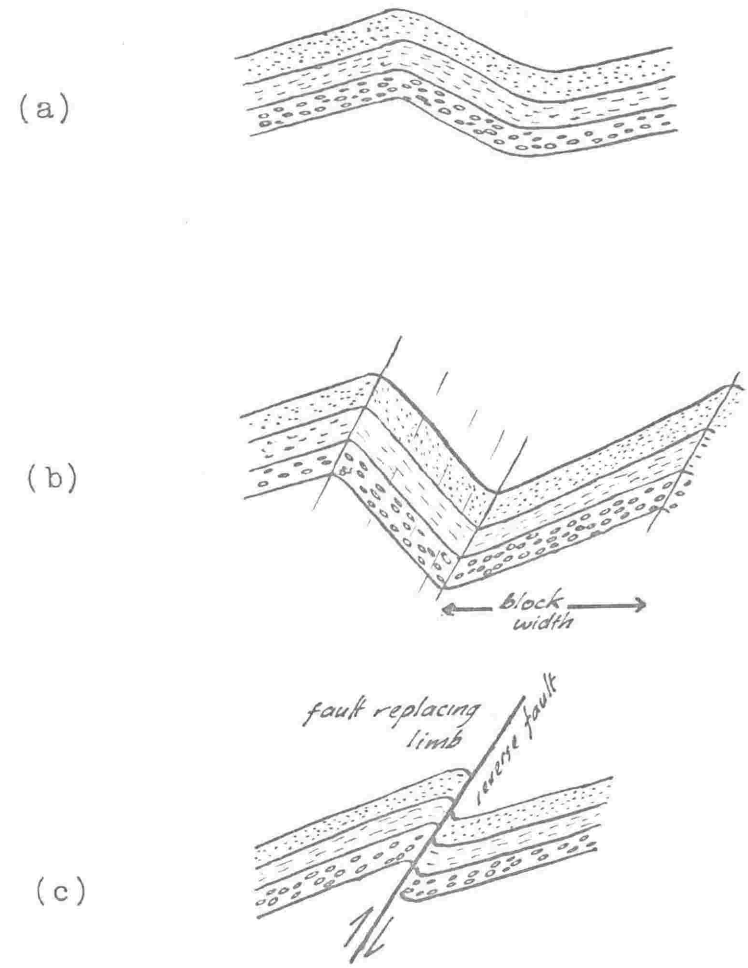


Fig. 30. Cross sections showing asymmetrical folds and fault replacing limb.

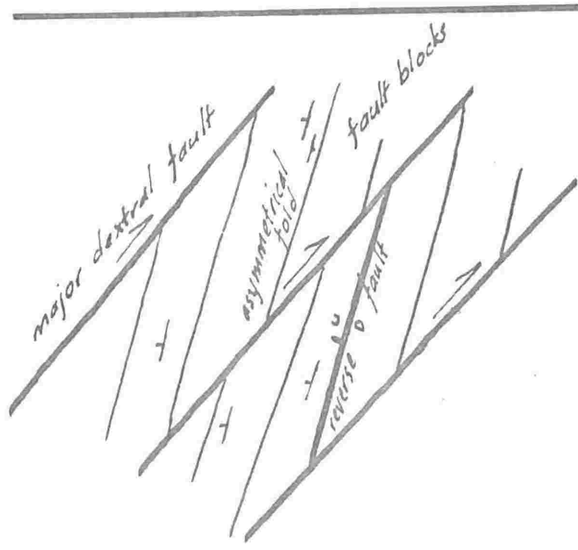


Fig. 31. Plan showing major dextral faults and fault blocks.

Late Cenozoic major dextral faults, fault blocks and folds, in the Wairarapa are shown in Fig. 31.

The amount of rotation of fault blocks in the past can be measured by (a) tilt rates and (b) faulting.

(a) Tilt rates can be determined from:

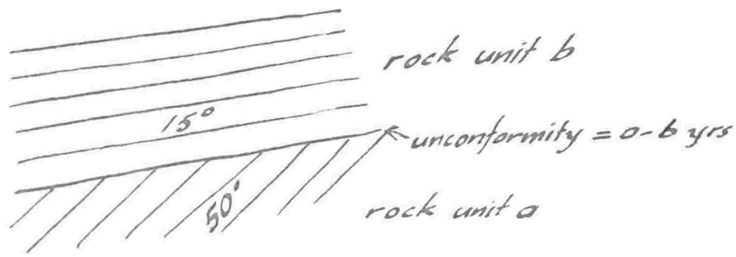
(i) Unconformities

The difference in dip, in degrees, divided by the age difference, in years, between two rock units separated by an unconformity (Fig. 32) gives the tilt rate.

The meaningfullness of the result depends on the uniformity of the rate of tilting and on the accuracy of dating the time interval represented by the unconformity. For instance if the tilting takes place in short bursts of time equal to only a few million years, and the unconformity represents scores of millions of years, the average tilt rate will be less than the maximum rate.

(ii) Isopachs

Provided that the sediments at any particular time were deposited at the same depth below sea level, then isopachs drawn from sediments deposited between two time planes will give the amount of tilt that has taken place (Fig. 33).



Tilt rate = $\frac{\text{dip difference}}{\text{time represented by the unconformity}} = \frac{35}{\text{a-b yrs}}$

Fig. 32. Unconformity.

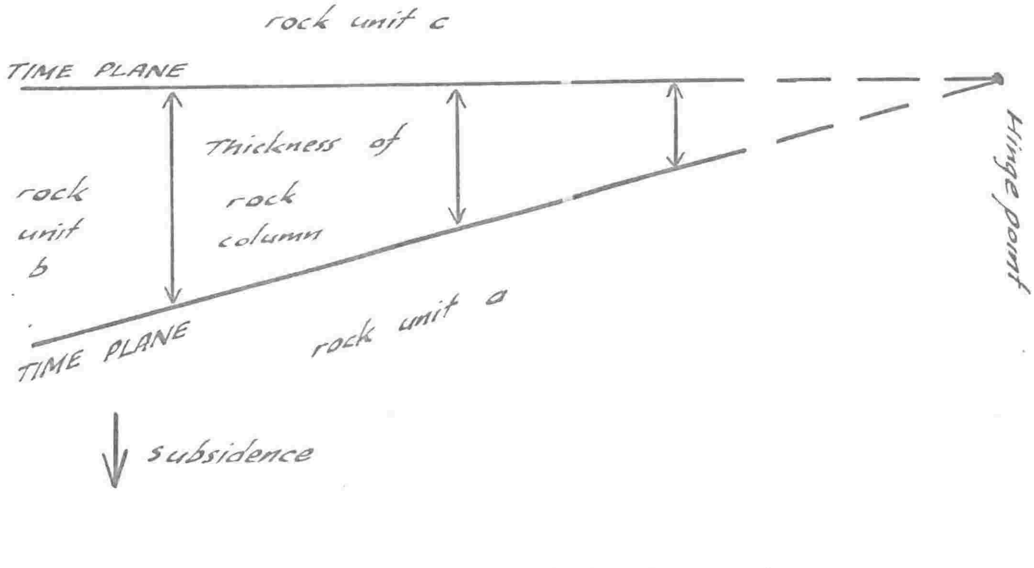


Fig. 33. Cross section normal to isopachs

The following tilt rates are indicated by the change in sediment thicknesses within individual basins in the Tinui District:

Urutawan to Piripauan	$\frac{1}{2}$-$1^{o}/10^{6}$ years
Waitakian to Otaian	$1^{o}/1-2 \times 10^{6}$ years
Middle Tongaporutuan to Kapitean	$1^{o}/10^{6}$ years

The tilt rates, although very low compared with tilt rates during the disturbances, are an order of magnitude higher than tilt rates in continental regions.

(b) Faulting

That faulting has taken place in the past is inferred from coarse conglomerates with a nearby source that are considered to have been eroded from the upthrown side of an active fault and to have been deposited on the downthrown side.

In the Tinui District the basal conglomerate at the base of the Whakataki Formation (Waiktakian to Clifdenian) is interpreted as having been deposited in a fault basin (Fig. 14). On the west coast of the South Island the coarse breccia of the Eocene Omotumotu Formation is somewhat similar and according to Gage (1952) was derived from a fault coast.

THEORETICAL AND OBSERVED FAULT MOVEMENTS

An attempt will be made to determine the changes in the sense of fault movements with time in the Tinui District. The fault movements are directly related to the direction of maximum horizontal shortening which is assumed to be at right angles to the axes of growing folds (Fig. 34).

The position and strike of the folds have already been described in detail. The northeast striking folds formed during the Paleocene Disturbance indicating a southeast direction of maximum horizontal shortening (Fig. 35). The north-south striking folds formed during the Late Pliocene and Late Quaternary disturbances indicating an east-west direction of maximum horizontal shortening (Fig. 36). No folds have been recognised as forming during the Early Miocene Disturbance but it is inferred, from fault movements, that the direction of maximum horizontal shortening was about northeast.

Having determined the direction of maximum horizontal shortening it is possible to infer the theoretical sense of movements, that is whether sinistral (S), dextral (D), reverse (R), or normal (N) (Fig. 34), on the faults that

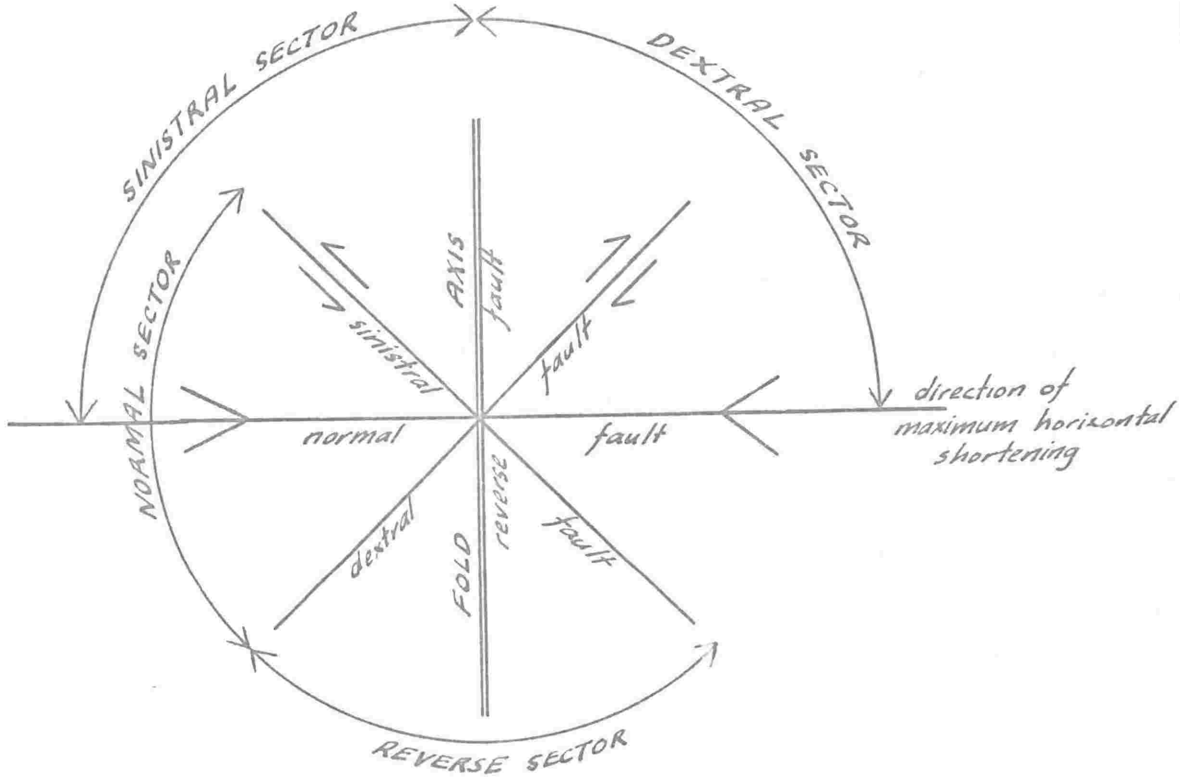


Fig. 34. Inferred relationship between fold axes, faults and the direction of maximum horizontal shortening.

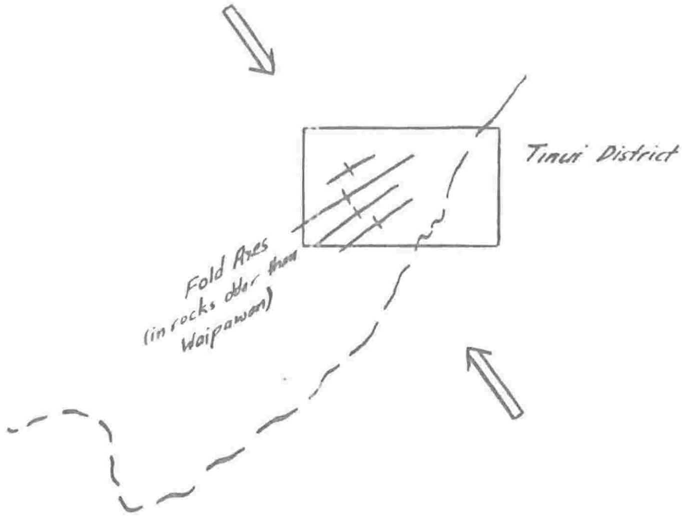
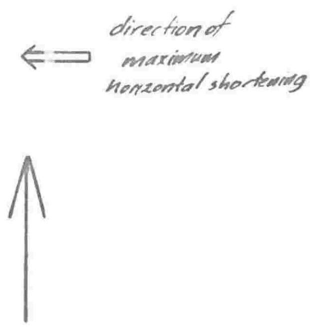


Fig. 35. Inferred direction of maximum horizontal shortening during the Paleocene Disturbance.



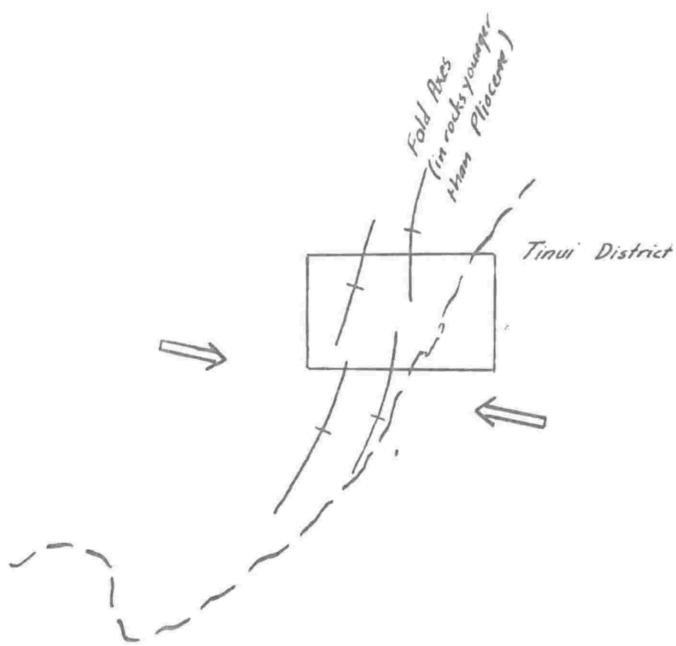


Fig. 36. Inferred direction of maximum horizontal shortening during the Late Pliocene Disturbance.

were active at those times, and to compare the theoretical with the observed movements (Fig. 37). It should be noted that Figs. 34 and 37 give the ideal solution in determining the sense of movement on a fault but in practice only when a fault lies well within a sector (Fig. 33) is it possible to assume its sense of movement with reasonable certainty.

Reversal of Movement

Provided the fault movements retain their sense with time (dextral faults remaining dextral faults, reverse faults remaining reverse faults etc.) the tectonic pattern remains the same irrespective of the change in the rate of movement and irrespective of the formation of similar new structures.

However, reversal in the sense of movement of the faults, that is from dextral to sinistral and reverse to normal, represents a basic change in the tectonic régime. Such changes have taken place and they provide critical information for the interpretation of the tectonic history of New Zealand as a whole.

DISTURBANCE	STRIKE OF FOLDS	INFERRED SHORTENING DIRECTION	THEORETICAL (1) AND OBSERVED (2) MOVEMENT ON NNE FAULTS		ENE FAULTS	
			1	2	1	2
LATE QUATERNARY	NORTH	EAST	DR	D	DN	D
LATE PLIOCENE	NORTH	EAST	DR	DR	DN	D
EARLY MIOCENE	-	NORTHEAST*	DN	D	SN	S
PALEOCENE	NORTHEAST	SOUTHEAST	SR	S	DR	

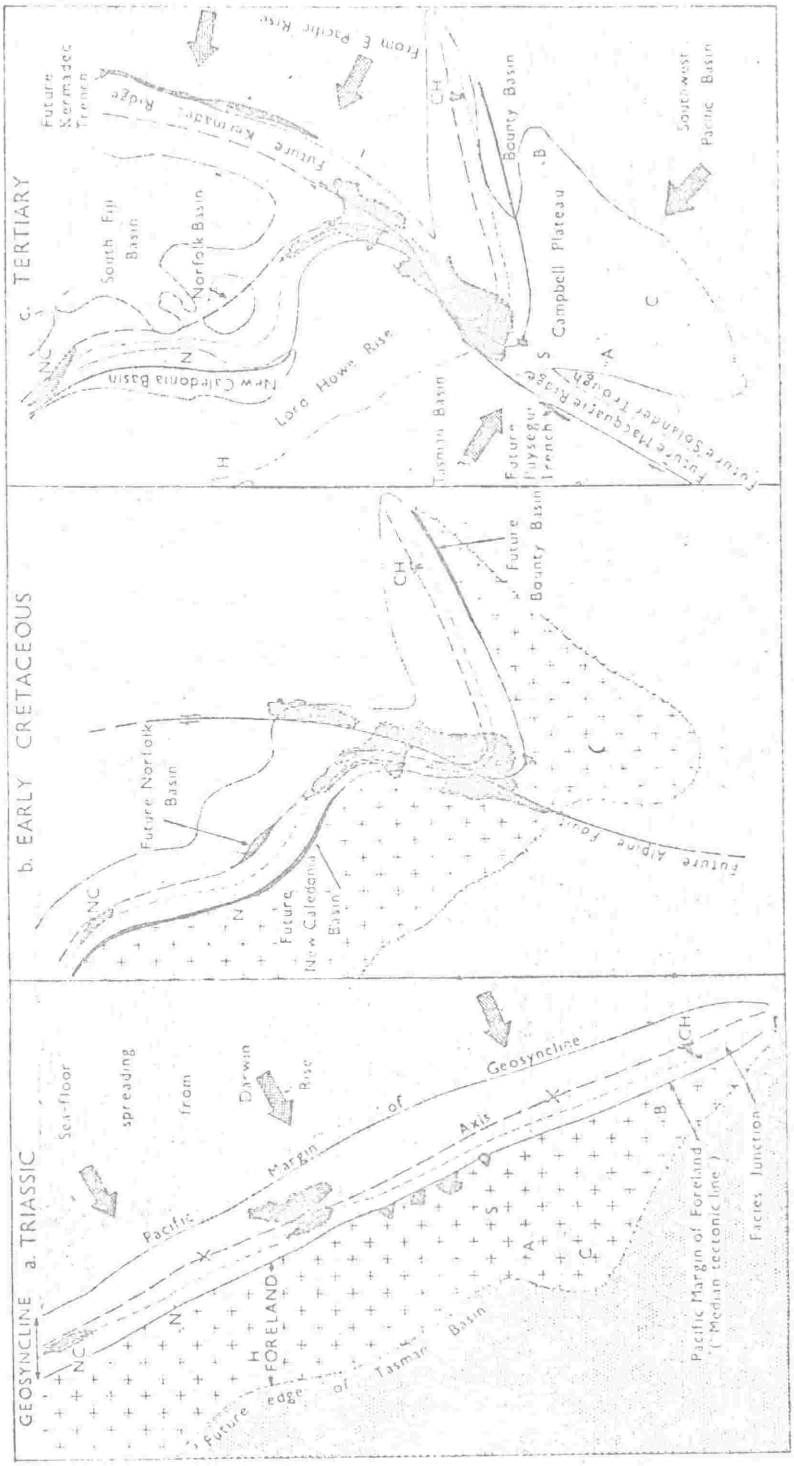
*Inferred from columns 2

Note: horizontal movement given first; dextral (D), sinistral (S), normal (N), reverse (R).

Fig. 37. Theoretical and observed sense of movement on the NNE and ENE striking faults.

In the Tinui District the sense of movement of the NNE striking faults changed from sinistral in the Early Cenozoic to dextral in the Late Cenozoic. The reversal in the sense of movement was accompanied by a change in the direction of maximum horizontal shortening from southeast in the Early Cenozoic to east in the Late Cenozoic. A similar reversal has been observed on the west coast of the South Island where in the Oligocene highs became lows and lows became highs. During the reversal, faults changed their sense of movement, from normal to reverse (Wellman, 1956) and from sinistral to dextral (Grindley, et al., 1959), and the direction of maximum horizontal shortening changed from NNE to ESE (Laird, 1968).

The timing of the reversal is directly related to the timing of the beginning of the dextral movement on the Alpine Fault which shows a 300 mile dextral displacement. Fleming (1970) in his most recent reconstruction of the New Zealand landmass considered that the beginning of the displacement was in the Early Cretaceous (Fig. 38). If, as the simplest model, it is assumed that the displacement continued in the



Palaeogeographical reconstructions of the New Zealand region from Triassic to Tertiary. (*a*) Triassic (New Zealand Geosyncline); (*b*) Early Cretaceous (early Rangitata Orogeny); (*c*) Tertiary (after rupture of Alpine Fault).

A—Auckland Islands. B—Bounty Islands.
C—Campbell Island. CH—Chatham Islands.
H—Lord Howe Island. N—Norfolk Island.
NC—New Caledonia.

Oceanic crust stippled; continental crust of foreland, crosses; sites of future marginal ocean basins, black. Facies boundary and axis of geosyncline, light and heavy dashed lines. Arrows inferred directions of sea-floor spreading.

Fig. 38. Reconstructions of the New Zealand landmass (Fleming, 1970).

same sense but not necessarily at the same rate until the present day then the direction of maximum horizontal shortening will remain the same. On the other hand if the direction of shortening is found to differ from that of the present day at any particular place then the model proposed by Fleming needs modification.

In the Tinui District and on the west coast of the South Island it has been shown that the expected direction of maximum horizontal shortening (about east-west) has existed only since the beginning of the Miocene. Both areas are close to the major dextral faults and it can be assumed that over the New Zealand landmass the east-west direction of maximum horizontal shortening has existed only since the beginning of the Miocene. Therefore, strike-slip movement on the Alpine Fault would have been dextral only since the Oligocene.

Clark and Wellman (1959) recognised that if the rate of movement on the fault (0.5 in/yr) that they calculated for the Late Quaternary was extrapolated back in time then the "...300 mile shift could have accomplished since the Oligocene..."

The Alpine Fault dextrally offsets a number of reference lines which may include a belt of mylonite by 145 miles and a belt of lamphrophre dikes by 80 miles. The age of mylonite and dikes is no younger than Lower Cretaceous (Wellman and Cooper, 1971) giving a possible dextral displacement of 80 miles since the Lower Cretaceous. However, in discussing the various reference lines offset by the fault, Wellman (1964) considered the dikes to be a "poor" reference line, and concluded that the Alpine Fault was post-Miocene in age. Hattori (1966) has postulated an "Older Alpine Fault" striking about NNE, which is dextrally displaced about 300 miles by the Alpine Fault and which could have formed the mylonite zones. Therefore any reconstruction of the New Zealand landmass will have to consider whether an "Older Alpine Fault" existed and also if there have been any reversals in the tectonic regime prior to the Cenozoic. Such a reconstruction is well outside the scope of this thesis.

CONCLUSIONS

The detailed mapping of the Tinui District has provided critical information on the rate of folding and faulting of part of the New Zealand Mobile Belt in the Cenozoic. In the east of the mobile belt, from Marlborough to East Cape, tilt rates averaging $10^{\circ}/10^{6}$ years have occurred for the whole of the Holocene (10,000 years). Tilting at this rate has not occurred throughout the Cenozoic but has taken place at this rate for short periods of time, equal to or less than a stage in duration, called disturbances. Disturbances have been recognised in many parts of New Zealand but are not everywhere synchronous. Tilting has taken place between disturbances, to allow deposition to continue, at a much slower rate of about $1^{\circ}/10^{6}$ years (Fig. 39).

During the Oligocene or Early Miocene there was a major change in the tectonic regime with dextral movement beginning on the major NNE striking faults. At this time the direction of maximum horizontal shortening changed from southeast to about northeast or east.

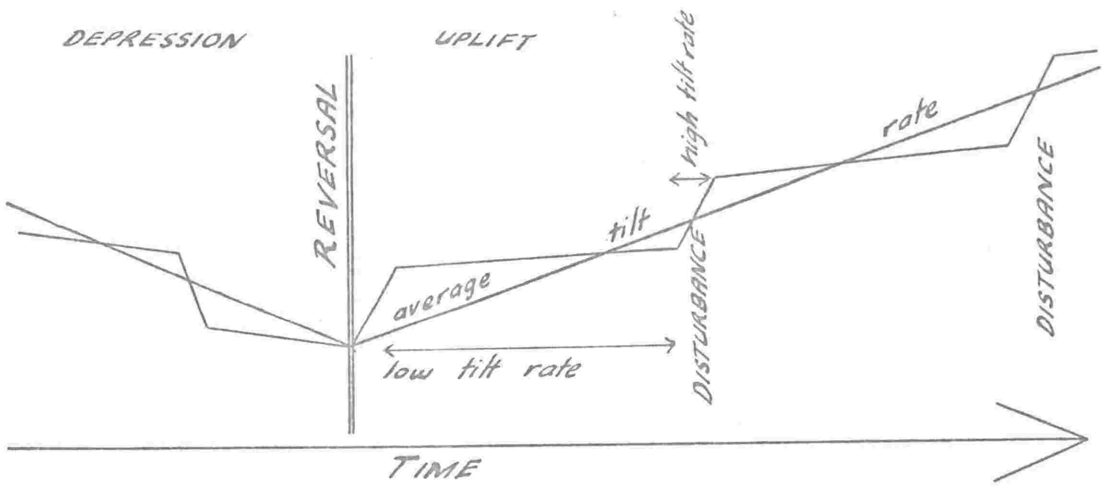


Fig. 39. A simple model showing tectonic reversal and the amount of tilting during and between disturbances.

ACKNOWLEDGMENTS

The writer is indebted to many staff members of Victoria University of Wellington, and the New Zealand Geological Survey, Lower Hutt, for fossil determinations. Dr. I.G. Speden identified Cretaceous molluscan fossils other than cephalopods and *Inocerami*. Dr. A.G. Beu identified Tertiary macro collections. Dr. G.R. Stevens identified many of the belemnites and Dr. R.A. Henderson identified the ammonites. Tertiary foraminiferal determinations were made by Mr. G.H. Scott, Dr. N. de B. Hornibrook and Professor P. Vella. Dr. P.N. Webb identified the Cretaceous and Teurian microfaunas.

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LITERATURE CITED

BATES, T.G. 1969: The Whatarangi Formation (Lower Cretaceous), Aorangi Range, Wairarapa, New Zealand. Transactions of the Royal Society of New Zealand, Geology, 6 (11): 139-42.

BENSON, W.N. 1952: Meeting of the Geological Division of the Pacific Science Congress in New Zealand. Proceedings of Geological Society of America, 1950: 11-15.

BERGGREN, W.A. 1969: Cenozoic chronostratigraphy, planktonic foraminiferal zonation and the radiometric time scale. Nature, 224: 1072-5.

BEU, A.G. 1969: Index macrofossils and New Zealand Pliocene and Lower Pleistocene time-stratigraphy. New Zealand Journal of Geology and Geophysics, 12 (4): 643-58.

BISHOP, D.G. 1968: The geology of an area of accelerated erosion at Wairengaokuri, near Gisborne. New Zealand Journal of Geology and Geophysics, 11 (3): 551-63.

CHALLIS, G.A. 1966: Cretaceous stratigraphy and structure of the Lookout area, Awatere Valley. Transactions of the Royal Society of New Zealand, Geology, 4 (5): 119-37.

CLARK, R.H; WELLMAN, H.W. 1959: The Alpine Fault from Lake McKerrow to Milford Sound. New Zealand Journal of Geology and Geophysics, 2 (3): 590-601.

COTTON, C.A. 1916: The structure and late geological history of New Zealand. Geological Magazine, 6: 314-20.

EADE, J.V. 1966: Stratigraphy and structure of the Mount Adams area, eastern Wairarapa. Transactions of the Royal Society of New Zealand, Geology, 4 (4): 103-17.

FINLAY, H.J. 1940: New Zealand foraminifera: key species in stratigraphy. Transactions of the Royal Society of New Zealand, 69 (4): 448-72.

FINLAY, H.J; MARWICK, J. 1947: New divisions of the Upper Cretaceous and Tertiary in New Zealand. New Zealand Journal of Science and Technology, B28 (4): 228-36.

FLEMING, C.A. 1962: New Zealand biogeography - a paleontologist's approach. Tuatara, 10 (2): 53-108.

__________ 1970: The Mesozoic of New Zealand: chapters in the history of the Circum-Pacific Mobile Belt. Quaterly Journal of the Geological Society of London, 125 (2): 125-70.

FYFE, H.E. 1934: Bentonite and its occurrence in New Zealand. New Zealand Journal of Science and Technology, 15 (6): 386-94.

GAGE, M. 1949: Late Cretaceous and Tertiary geosynclines in Westland. Transactions of the Royal Society of New Zealand, 77 (3): 325-37.

______ 1952: Greymouth Coalfield. New Zealand Geological Survey Bulletin (n.s.) 45.

GRAPES, R.H. 1970: A petrological study of the Kaiwhata Sill, Ngahape, east Wairarapa. Transactions of the Royal Society of New Zealand, Earth Sciences, 7 (10): 177-96.

GRINDLEY, G.W. 1961: Mesozoic orogenies in New Zealand. Proceedings of 9th Pacific Science Congress, 12: 71-5.

GRINDLEY, G.W; HARRINGTON, H.J; WOOD, B.L. 1959: The geological map of New Zealand, 1:2,000,000. New Zealand Geological Survey Bulletin (n.s.) 66.

HALL, W.D.M. 1963: The Clarence Series at Coverham, Clarence Valley. New Zealand Journal of Geology and Geophysics, 6 (1): 28-37.

HATTORI, H. 1966: The metamorphic belts of New Zealand and their ages. Journal of the Japanese Geological Society, 72 (5): 233-43.

HASKELL, T.R. 1964: The Cretaceous geology of the Whakarora area, Wairarapa, New Zealand. New Zealand Journal of Geology and Geophysics, 7 (3): 554-60.

HENDERSON, J. 1937: The West Nelson earthquakes of 1929 (with notes on the geological structure of West Nelson). New Zealand Journal of Science and Technology, 19 (2): 65-144.

HOUTZ, R; EWING, J; EWING, M; LONARDI, A.G. 1967: Seismic reflection profiles of the New Zealand Plateau. Journal of Geophysical Research, 72 (18): 4713-29.

HORNIBROOK, N. de B 1962: The Cretaceous-Tertiary boundary in New Zealand. New Zealand Journal of Geology and Geophysics, 5 (2): 295-303.

HORNIBROOK, N. de B; HARRINGTON, H.J. 1957: The status of the Wangaloan Stage. New Zealand Journal of Science and Technology, B38 (6): 655-70.

HUTTON, F.W. 1872: Synopsis of the younger formations of New Zealand. New Zealand Geological Survey, Report on Geological Explorations, 1871-2, (7): 182-4.

JOHNSTON, M.R. 1971: Pre-Hawera geology of the Kaka District, North-west Nelson. New Zealand Journal of Geology and Geophysics, 14 (1): 82-108.

__________ (in press a): Sheet N159 - Tinui and part Sheet N158 - Masterton. "Geological map of New Zealand, 1:63,360". New Zealand Department of Scientific and Industrial Research, Wellington.

__________ (in press b): Geology of Castlepoint Headland and Reef, Wairarapa, New Zealand. New Zealand Journal of Geology and Geophysics.

KEAR, D. 1957: Pumice chronology in New Zealand. New Zealand Journal of Science and Technology, B38 (8): 862-70.

KEAR, D; SCHOFIELD, J.C. 1959: Te Kuiti Group. New Zealand Journal of Geology and Geophysics, 2 (4): 685-717.

KING, L.C. 1930: Raised benches and other features of the south-east coast of the North Island of New Zealand. Transactions of the New Zealand Institute, 61 (3-4): 498-523.

________ 1933: Tertiary molluscan faunas from the southern Wairarapa. Transactions of the New Zealand Institute, 63 (3): 334-54.

KINGMA, J.T. 1957: The North Island Geanticline in the Hawke's Bay Sector. New Zealand Journal of Science and Technology, B38 (6): 496-9.

________ 1960: Outline of the Cretaceo-Tertiary sedimentation in the Eastern Basin of New Zealand. New Zealand Journal of Geology and Geophysics, 3 (2): 222-34.

________ 1962: Sheet 11 - Dannevirke. "Geological Map of New Zealand 1:250,000". New Zealand Department of Scientific and Industrial Research, Wellington.

________ 1967: Sheet 12 - Wellington. "Geological Map of New Zealand 1:250,000". New Zealand Department of Scientific and Industrial Research, Wellington.

LAIRD, M.G. 1968: The Paparoa Tectonic Zone. New Zealand Journal of Geology and Geophysics, 11 (2): 435-54.

LENSEN, G.J. 1962: Sheet 16 - Kaikoura. "Geological Map of New Zealand 1:250,000". New Zealand Department of Scientific and Industrial Research, Wellington.

__________ 1965: Active faults and major earthquakes in New Zealand (map). New Zealand Journal of Geology and Geophysics, 8 (6).

__________ 1968: Sheet N158 - Masterton. "Late Quaternary tectonic map of New Zealand 1:63,360". New Zealand Department of Scientific and Industrial Research, Wellington.

LEWIS, K.B. (in press): Growing folds on the Hawke Bay coast and continental margin. In "Recent Crustal Movements and associated Seismicity". Royal Society of New Zealand Bulletin 9.

LILLIE, A.R. 1953: The geology of the Dannevirke Subdivision. New Zealand Geological Survey Bulletin (n.s.) 46.

McKAY, A. 1877: Report on country between Cape Kidnappers and Cape Turnagain. New Zealand Geological Survey, Report of Geological Explorations, 1874-6, (9): 43-53.

McKAY, W.A. 1899: Report on the geology of the Trooper Range, Castlepoint District, Wellington. Appendix to Journal of House of Representatives, N.Z.C. - 9: 33-6.

MACPHERSON, E.O. 1946: An outline of Late Cretaceous and Tertiary diastrophism in New Zealand. New Zealand Geological Survey Memoir 6.

MARSHALL, P. 1903: Boulders in Triassic conglomerate, Nelson. Transactions of the New Zealand Institute, 36: 467-71.

MORGAN, P.G. 1910: Report on probable occurrence of petroleum and other minerals in eastern Wairarapa districts. Appendix to Journal of House of Representatives. N.Z.C. - 16: 6.

__________ 1914: Petroleum prospects in Southern Hawke's Bay and eastern Wellington. New Zealand Geological Survey 8th Annual Report (n.s.): 131-5.

NEEF, G. (in press): Sheet N153 - Eketahuna. "Geological map of New Zealand 1:63,360". New Zealand Department of Scientific and Industrial Research, Wellington.

ONGLEY, M. 1933: Eketahuna Subdivision. New Zealand Geological Survey 27th Annual Report (n.s.): 4-5.

ONGLEY, M. 1934: Eketahuna Subdivision. _New Zealand Geological Survey 28th Annual Report (n.s.)_: 2-3.

________ 1935: Eketahuna Subdivision. _New Zealand Geological Survey 29th Annual Report (n.s.)_: 1-6.

________ 1936a: Blairlogie Gas Vent. _New Zealand Geological Survey 30th Annual Report (n.s.)_: 9-12.

________ 1936b: Dannevirke Subdivision. _New Zealand Geological Survey 30th Annual Report (n.s.)_: 1-4.

ONGLEY, M; WILLIAMSON, J.H. 1931: Eketahuna Subdivision. _New Zealand Geological Survey 25th Annual Report (n.s.)_: 3-5.

PARK, J. 1888: On the probable discovery of oil and coal in Wairarapa North County. _New Zealand Geological Survey Report of Geological Explorations, 1887-88, 19_: 20-4.

QUENNELL, A.M; BROWN, D.A. 1937: Dannevirke Subdivision. _New Zealand Geological Survey 31st Annual Report_: 1-6.

RIDD, M.F. 1964: Succession and structural interpretation of the Whangara-Waimata area. New Zealand Journal of Geology and Geophysics, 7 (2): 279-98.

________ 1967: Miocene transcurrent movement on the Pongaroa fault, Wairarapa, New Zealand. New Zealand Journal of Geology and Geophysics, 10 (1): 209-16.

SCOTT, G.H. (in press): Revision of Hutchinsonian, Awamoan and Altonian Stages (lower Miocene, New Zealand). New Zealand Journal of Geology and Geophysics.

SINGH, L.J. (in press): The Whareama Syncline: a growing fold on the Wairarapa coast. In "Recent Crustal Movements and associated Seismicity". Royal Society of New Zealand Bulletin 9.

STEVENS, G.R. 1965: The Jurassic and Cretaceous Belemnites of New Zealand and a review of the Jurassic and Cretaceous Belemnites of the Indo-Pacific region. New Zealand Geological Survey Paleontological Bulletin 36.

STONELEY, R. 1962: Marl diapirism near Gisborne, New Zealand. New Zealand Journal of Geology and Geophysics, 5 (4): 630-41.

STONELEY, R. 1968: A Lower Tertiary décollement on the east coast, North Island, New Zealand. New Zealand Journal of Geology and Geophysics, 11 (1): 128-56.

SUGGATE, R.P. 1965: The tempo of events in New Zealand geological history. New Zealand Journal of Geology and Geophysics, 8 (6): 1139-48.

__________ 1968: The Thirty Foot raised beach at Rapahoe, North Westland. New Zealand Journal of Geology and Geophysics, 11 (3): 648-50.

VAN DEN HEUVEL, H.B. 1960: The geology of the Flat Point area, eastern Wairarapa. New Zealand Journal of Geology and Geophysics, 3 (2): 309-20.

VELLA, P. 1954: Tertiary mollusca from south-east Wairarapa. Transactions of the Royal Society of New Zealand, 81 (4): 539-55.

_______ 1963: Plio-Pleistocene cyclothems, Wairarapa, New Zealand. Transactions of the Royal Society of New Zealand, Geology, 2 (2): 16-50.

WATERHOUSE, J.B; BRADLEY, J. 1957: Redeposition and slumping in the Cretaceo-Tertiary strata of SE Wellington. Transactions of the Royal Society of New Zealand, 84 (3): 519-48.

WELLMAN, H.W. 1948: Tararua Range summit height accordance. New Zealand Journal of Science and Technology, B30 (2): 123-7.

__________ 1949: Geology of the Pike River Coalfield, New Zealand. New Zealand Journal of Science and Technology, B30 (1): 84-95.

__________ 1955: New Zealand Quaternary Tectonics. Geologischen Rundschau, 43 (1): 248-57.

__________ 1956: Structural outline of New Zealand. New Zealand Department of Scientific Research, Bulletin 121.

__________ 1959: Divisions of the New Zealand Cretaceous. Transactions of the Royal Society of New Zealand, 87 (1,2): 99-163.

__________ 1964 [i.e. 1970]: Age of Alpine Fault, New Zealand. International Geological Congress. India. 22nd. Compte Rendus. Part 4, Section 4. Rock deformation and tectonics: 146-62.

WELLMAN, H.W. 1967: Tilted marine beach ridges at Cape Turakirae, N.Z. Journal of Geoscience, Osaka City University, 10 (1): 123-9.

WELLMAN, P. 1970: Geology of the Ngahape area, eastern Wairarapa. Transactions of the Royal Society of New Zealand, Earth Sciences, 8 (11): 157-71.

WELLMAN, P; COOPER, A. 1971: Potassium-Argon age of some New Zealand lamphrophyre dikes near the Alpine Fault. New Zealand Journal of Geology and Geophysics, 14 (2): 341-50.

WILSON, D.D. 1963: Geology of Waipara Subdivision. New Zealand Geological Survey Bulletin (n.s.) 64.

APPENDIX I

Appendix I gives a brief summary of nearly a thousand fossil localities in the Tinui District.

Collectors

AA	A.D. Allen	SK	S. Keston
AB	A.G. Beu	IK	I.W. Keyes
WB	W.M. Briggs	JK	J.T. Kingma
DC	D. Campbell	TK	T. Kotaka
DJ	D.J. Cullen	ML	M. Lehner
RC	R.A. Cooper	JM	J. Marwick
AC	R.A. Couper	JMc	J. McKay
JE	J.V. Eade	KM	K.J. McNaught
CF	C.A. Fleming	GN	G. Neef
GG	G.W. Grindley	MO	M. Ongley
MG	M. Gage	HP	H.M. Pantin
MH	W.D.M. Hall	MP	M. Pick
RH	R.F. Hay	IS	I.G. Speden
TH	T.R. Haskell	GS	G.R. Stevens
JH	J. Hector	PV	P. Vella
NH	N. de B. Hornibrook	HW	H.W. Wellman
MJ	M.R. Johnston	JW	J.E. Wellman
	PW	P. Wellman	

Abbreviations

c	grid reference approximate
( )	grid reference (amended to 1949 geodetic datum) or age adopted direct from the fossil record form
F	microfaunal collection held at Victoria University of Wellington
F 17891	microfaunal collection held at N.Z. Geological Survey
F ——	microfaunal collection discarded
V	macrofaunal collection held at Victoria University of Wellington
GS	macrofaunal collection held at N.Z. Geological Survey
NL	collection not located
—	collection not in place
?	data unknown
der	derived
rec	recollection
ND	no determination

SHEET N158 MASTERTON (east of grid 35)

Sheet Fossil Number	Register Number	Grid Reference	Age	Adopted Age	Formation	Collector
456	GS 7948	420635	Cm-Rm	Cm-Cn	us	MO
	F 9506		C			MO
466	GS 1843	430694	Cm	Cm	um	MO
467	GS 1850	374683	NL	Sw-Tt	hm	MO
468	GS 1851	379696	Cm	Cm	ua	JM, MO
469	GS 1852	436703	Cm	Cm	um	JM, MO
470	GS 1853	426673	Sl-Sw	Sw	hm	JM, MO
471	GS 1854	c 384718	NL	Sw-Tt	hm	JM, MO
472	GS 1854b	c 384718	Sc-Tt	Sw-Tt	hm	JM, MO
473	GS 1865	450778	NL	C	um	JM, MO
474	GS 1866	446774	ND	Cm	um	JM, MO
478	GS 1875	443765	Cm	Cm	us	JM, MO
479	GS 1876	442754	? Cm	Cm-Cn	us	JM, MO
480	GS 1877	447760	Cm, C	Cm	um+s	JM, MO
488	GS 2017	c 402756	low Tt	low Tt	hm	MO
491	GS 2020	398753	Tt	Tt	hm	MO
492	GS 2021	414763	? C	Cm-Cn	us	MO
493	GS 2022	408760	C	Cm	us	MO
503	F 7115	354662	Sw	Sw	hm	DC

506	F 7118	360618	upp Tt	upp Tt	hm	DC
507	F 7119	(380627)			hm	DC
512	F 7300 F rec	355645	Tk-Wo upp Tt-Tk	Tk Tk	hm	DC ?
537	GS 5895 F ———	435643	Mp NF	Mp	us+t	MG, MO MG, MO
538	GS 1843 F 9494	430694	NL upp C	Cm	um	HW, JW HW, JW
539	GS 6088	430693	Cm	Cm	um	HW, JW
540	GS 6089 F 9495	435698	Cm upp C	Cm	um	HW, JW HW, JW
541	GS 6090	416709	Cm	Cm	um	HW, JW
542	GS 6091 F 9496	426709	Cu?-Cm upp C	Cu?-Cm	um	HW, JW HW, JW
543	GS 6439	444763	?Cu-Cm	?Cu-Cm	um	RH, HW
544	GS 6440	444767	Cu?-Cm	?Cu-Cm	um	RH, HW
545	GS 6443	446755	Cn	Cn	um+s	RH, HW
546	GS 6447	435641	Cn?	Cn	us	HW
547	GS 6448	(435643)	NL	Sw	hm	HW
548	GS 6131	c 421690	Cm	Cm	um	HW
631	F 17633	445745	C	Cn	us	MJ
632	F 17634	420677	Mh	Mh	tt	MJ
633	F 17635	415677	Cm-Cn	Cm-Cn	us	MJ
634	F	426677	M-D	Mh	tt	MJ
635	F 17742	399770	Cm-Cn	Cm	um	MJ

636	F 17743	395770	Cm-Cn	Cm	um	MJ
637	F 17744	391774	Cm-Cn	Cm	um	MJ
638	F 17745	404786	Cm-Cn	Cm	um	MJ
639	F 17746	398778	Cm-Cn	Cm	um	MJ
640	F 17747	422803	C-?R	Cm	um	MJ
641	F 17748	409794	Cm-Cn	Cm	um	MJ
642	F	379810	low Tt	low Tt	hm	MJ
643	F	370785	low Tt	low Tt	hm	MJ
644	F	357764	low Tt	low Tt	hm	MJ
645	F	376695	low Tt	low Tt	hm	MJ
646	F	352717	mid Tt	mid Tt	hm	MJ
647	F	365735	Sw-Tt,Tt?	mid Tt	hm	MJ
648	F 17749	400760	C-R	Cm	um	MJ
649	F	359754	ND	low Tt	hm	MJ
650	F	433813	Wn	Wn	cp?	MJ
651	F	430670	Sw-Tt,Tt?	Tt	hm	MJ
652	F	357645	upp Tt-Tk	upp Tt-Tk	hm	MJ
653	GS 9942	386715	Cm-Rm	Cm	um	MJ
657	GS 9943	398728	Cret	Cm	um	MJ
658	GS 9944	405738	Cm-Rm	Cm-Cn	um	MJ
659	GS 9945	410788	Cret	Cm	um	MJ
660	GS 9946	419805	pre-Cn	Cm	um	MJ
661	GS 9947	410740	Cm-Cn	Cm	um	MJ

691	F 17850	412647	S1-Sw	Sw	hm	MJ
692	GS 9997	373754	Sw?	Sw	hm	MJ
693	GS 9998	367754	S1-Sw	Sw	hm	MJ
694	F 17900	430704	Cm-Cn	Cn	us	MJ
695	GS10020 F 17901	417710	Cm-Cn Cm-Cn	Cm	um	MJ MJ
696	F 17902	422710	Cm-Cn	Cn	us	MJ
697	F 17929	350647	Sc-Tt	Sw	hm	MJ
698	F 17930	352645	Tt-Wo?	Tk	hm	MJ
699	F 17931	359679	Sc-Tt?	Sw	hm	MJ
700	F 17932	359676	?S1-Tt	Sw	hm	MJ
701	V ?	430693	<u>Cm</u>	Cm	um	RC
702	V ?	c 431694	<u>Cm-Cn</u>?	Cm	um	JE
704	V 1609	442811	<u>Cm</u>	Cm	us	MJ
705	V 1611	447803	<u>Cm</u>?	Cm	um	MJ
706	V 1612	438798	ND	Cm	um	MJ
707	V 1613	435799	<u>Cu?-Cm</u>	Cu?-Cm	um	MJ
708	V 1614	441776	Cu?-Cm	Cu?-Cm	um	MJ
709	V 1626	441769	Cu?-Cm	Cu?-Cm	um	MJ
710	V 1627 F ———	444763	Cm ND	Cm	um	MJ MJ, IS
711	V 1998	446721	<u>Cm</u>	Cm	um	MJ
712	V 1628	449756	<u>Cn</u>;<u>Cn</u>; Cm-Rm	Cn	us	MJ

713	V	1629	442754	Cm?;Cm?; Cm;Cm?	Cm	um+s	MJ
714	V	1631	441750	Cm-Rm;Cn	Cn	us	MJ
715	V	1634	434751	Cm	Cm	us	MJ
716	V	1635	434746	Cn	Cn	us	MJ
717	F	17750	424757	Cm-Cn	Cn	us	MJ
718	V	1637	420795	Cm?	Cm	um	MJ
719	V	1638	414802	Cm	Cm	um	MJ
720	V	1986	c 445732	Cm?	Cm-Cn	us	MJ
721	V	1987	444723	Cu?-Cm	Cu?-Cm	um	MJ
722	V	1988	441722	Cm	Cm	um	MJ
723	V	1989	443717	Cm	Cm	um	MJ
724	V	1991	448702	Mp; Mp	Mp	tt	MJ
725	V	1992	406710	ND;Cu?-Cm	Cu?-Cm	ua	MJ
726	V F	1993 ———	415707	Cm? NF	Cm Cu?-Cm	um ua	MJ MJ
727	V	1994	427693	Cm;Cm;Cm?	Cm	um	MJ
728	V	1995	433694	Cm	Cm	um	MJ
729	V	1996	449731	Cu?	Cu?-Cm	um	MJ
730	V	1997	442728	Cm?	Cm	um	MJ
731	V	?	421688	Cm	Cm	um	WB, RH
732	V	?	(416686)	Cm	Cm	um	RH, TK, HW
733	V	?	(c 427694)	Cm	Cm	um	HW
734	V	2011	424735	Cn?	Cn	us	MJ

735	V 2012 F 17636	422722	C ? Cm-Cn	Cm	um	MJ MJ
736	V 2013	427743	Cm?, Cm	Cm	us	MJ
737	V 2014 F 18021	405748	Cm? C-R	Cm	um	MJ MJ
738	V 2018	437667	Cm?; Cm	Cm	us+t	MJ
739	F 17637	445704	Mp-low Mh	Mp	tt	MJ
740	F 17638	444705	Cm-Cn	Cm-Cn	us	MJ
741	F 17639	419712	R	Cm-Cn	us	MJ
742	F 17640	409733	Cm-Cn	Cm	um	MJ
743	F 17641	427720	Cm-Cn	Cm-Cn	us	MJ
744	F	401603	Sw?	Sw	hm	MJ
745	F ———	428623	?-S?	Sa-Sc	aw	MJ
746	F 17642	424763	Cm-Cn	Cn	us	MJ
749	F	397652	mid-upp Tt	mid Tt	hm	MJ
750	GS 9948 F 17751	408737	ND Cm-Cn	Cm	um	MJ MJ
751	F 17752	403750	Cm-Cn	Cm	um	MJ
752	F	398753	low Tt	low Tt	hm	MJ
753	F	392751	mid-upp Tt	Tt	hm	MJ
754	F 17753	389707	Cm	Cm	um	MJ
755	F	382716	low Tt	low Tt	hm	MJ
756	F 17754	390712	Cm-Cn	Cm	um	MJ
757	F	385724	mid-upp Tt?	Tt	hm	MJ

758	F 17755	389729	C	Cm	um	MJ
759	F 17756	401755	C,Cm?-Cn?	Cm	um	MJ
760	F 17757	410766	C	Cm	um	MJ
761	F 17758	413765	Cm-Cn	Cm	um	MJ
762	F ——	415761	ND	Cm	um	MJ
763	F 17759	375751	C	Cu?-Cm	umb	MJ
764	F 17760	372759	C	Cu?-Cm	umb	MJ
765	F ——	360684	NF	Tt	hm	MJ
766	F 17928	420642	?S1-Tt?	Sw	hm	MJ
767	F ——	431663	NF	Cm-Cn	us	MJ
768	F ——	433872	NF	Tt	hm	MJ
769	F ——	438869	ND	Tt	hn	MJ
770	F ——	438868	ND	Tt	hn	MJ
771	F ——	416705	NF	Cu?-Cm	ua	MJ
772	F 17956	355795	M?	Mh-Dt	tw	MJ
773	F 17957	355794	Tt	Tt	hm	MJ
774	GS10059	441768		Cu?-Cm	um	MJ, IS
775	GS10060	441769		Cu?-Cm	um	MJ, IS
776	GS10061	442766		Cu?-Cm	um	MJ, IS
777	GS10062 F 18016	442765	Cu? ND	Cu?-Cm	um	MJ, IS
778	F 18017	444763	ND	Cu?-Cm	um	MJ, IS
779	F 18018	444762	C	Cu?-Cm	um	MJ, IS
780	F ——	448758	NF	Cm	um	MJ, IS

SHEET N159 TINUI

Sheet Fossil Number	Register Number	Grid Reference	Age	Adopted Age	Formation	Collector
434	GS 1879	513892	Tk	Tk	hk	MO
435	GS 1867	464818	O	O	ew	JM, MO
436	GS 1873	459764	Cm	Cm	um	JM, MO
437	GS 1874	459765	Cm?	Cm	um	JM, MO
438	GS 1817	682895	Rt?	Mp	tt	MO, KM
439	GS 1813	690894	Rm	Rm	ug	MO, KM
440	GS 93	c 538737	Sc?	Sc	at	JH
441	GS 201	?	NL	Sw-Tt	hm?	JMc
442	GS 4477	538737	Pl-Sc	Pl-Sc	at	JM
443	GS 4439	538737	Pl-Sc	Pl-Sc	at	JM
444	GS 5,844	?	NL	?	?	JH
445	GS 37	?	(Wn?)	Wn	cp	JMc
446	GS 81	?	Wn	Wn	cp	JMc
447	GS 1811	684793	ND	Dt	tw	MO
448	GS 1814	649834	Rt	Rt	ug	MO, KM
449	GS 1816	663849	Rt?	Mp	tt	KM
450	GS 1819	662675	Wn	Wn	cp	MO, KM
451	GS 1820	663675	Wn	Wn	cp	MO, KM
452	GS 1827	632731	ND	Dt	tw	KM
453	GS 1828	635724	NL	Dt	tw	KM

454	GS 1829	682769	ND	Dt	tw	KM
455	GS 1830	686763	ND	Dt	tw	KM
456	GS 1831	677730	ND	Lw-Po	aw	KM
457	GS 1832	c 631754	NL	Dt	tw	KM
458	GS 1833	548721	NL	Sa	aw	KM
459	GS 1834	608797	NL	Ph-Sa	at	KM
460	GS 1835	607799	NL	Ph-Sa	at	MO, KM
461	GS 1836	c 551757	Mp	Mp	tt	KM
462	GS 1837	550746	Cm?-Rm?	Cm-Ra?	us	KM
463	GS 1838	561738	NL	Mh-Dt	tt?	KM
464	GS 1839	609791	NL	Pl	at	KM
465	GS 1840	608787	NL	Lw-Po	aw	KM
466	GS 1841	604775	(Cret)	Mp-Mh	tt	KM
467	GS 1842	c 593777	NL	Dt	tt	KM
468	GS 1855	484851	Tt	Tt	hn	MO
469	GS 1856	485856	Tt	Tt	hn	MO
470	GS 1857	513892	ND	Tt-Tk	hk	MO
471	GS 1858	497859	Sl-Sw	Sw	hmg	MO
472	GS 1859	463823	Rt	Rt	us+t	MO
473	GS 1860	?	NL	Tt	hm?	MO
474	GS 1861	524794	NF	mid Tt	hk	JM, MO
475	GS 1862	?	NL	?	?	?
476	GS 1863	477791	NL	Cm	um	JM, MO

477	GS 1864	510726	Mp	Mp	tt	JM, MO
478	GS 1868	493757	Mp	Mp	tt	JM, MO
479	GS 1869	489759	Mp	Mp	tt	JM, MO
480	GS 1870	486759	ND	Cn-Ra	us	JM, MO
481	GS 1871	468770	Cm	Cm	um	JM, MO
482	GS 1872	564713	ND	Sa	aw	JM, MO
483	GS 1878	479806	Cret	Cu?-Cm	um	JM, MO
484	GS 1880	c 534728	S1-Sw	S1-Sw	at+h?	JM, MO
485	GS 1881	c 532727	ND	?	?	JM, MO
486	GS 1882	659673	Wo?	Wo	hr	JM, MO
487	GS 2821	664677	Wo?	Wo	hr	KM, MO
488	GS 2822	676762	ND	Dt	tw	KM
489	GS 2823	671795	ND	Dt	tw	KM
490	GS 2824	594737	ND	Dt	tw	KM
491	GS 2825	630733	ND	Dt	tw	KM
492	GS 2826	631732	low D?	Dt	tp	KM
493	GS 5341	672685	NL	Wn	cp	CF, JM
494	GS 6996	538737	P1?	P1-Sc	at	MO
495	GS 6997	c 534747	P1-Sw	Sc-S1	at+h	MO
496	GS 7040	(686803)	ND	Dt	tw	
497	GS 7050	c 640665	H-R	H-R	bo	MO
498	F 7092	673687	(Wo?)	Wo	hr	ML
499	F ———	466681	NF	low Cret?	ew	ML
500	GS 5241	672685	NL	Wn	cp	CF, JM

501	F	8371	464617	Mh-Dw, D mixed	Mh-Dt	tt?	MP
502	F	8372	(486657)	ND	Dt	tw	MP
503	F	8373	501652	(Pl)	Pl	aw	MP
504	F	8374	552642	(M-D)	Dw-Ab	wh	MP
505	F	8375	553642	(Lw?)	Pl	aw	MP
506	F	8376	546653	(Pl?)	Pl	aw	MP
507	F	8377	577613	(Pl)	Pl	aw	MP
508	GS	6041	694893	Rm?	Rm	ug	HW
509	GS	6040	690894	Rm	Rm	ug	HW
510	GS	6039	c 684900	(Mh)	Mp-Mh	tt	HW
511	F	9037	527619	Pl	Pl	aw	MP
512	F	9038	536627	Pl-Sc	Pl	aw	MP
513	F	9039	528669	Sl	Sl	hm	MP
514	F	9040	529665	S, ?Sc-Sw	Sl	hm	MP
515	F	9041	534621	Pl	Pl	aw	MP
516	F	9042	535627	Pl	Pl	aw	MP
517	F	9043	513658	Sl-Sw	Sl	hm	MP
518	GS	6444	462760	(Cn)	Cn	us	RH, HW
519	GS	6445	483759	(Rm)	Ra	us	GG, HW
520	GS	6446	486759	Ra?	Ra	us	GG, HW
521	GS	6441	462761	(Cm-Cn;Ra)	Cn; Ra	us	RH, HW
522	GS	6442	464757	Ra ?	Ra	us	HW

523	V	?	606798	Pl	Pl	at	SK, HW
524	F	11648	660673	Wo	Wo	hr	SK
525	F	——	658674	NF	Lw-Po	aw	SK
526	F	——	676731	NF	Lw-Po	aw	SK
527	F	——	700794	NF	Mh-Dt	tw	SK
528	F	——	601679	NF	Mh	tt	SK
529	F	——	671767	NF	Mh-Dt	tw	SK
529a	F	13660	671767	Mh	Mh-Dt	tw	SK
530	F	——	630733	NF	Dt	tp	SK
530a	F	13661	630733	Dt	Dt	tp	SK
531	F	11649	606798	Pl	Pl	at	SK, HW
532	F	11650	604798	Po-Pl	Lw-Po	aw	SK, HW
533	F		668722	(R)	(R)	hl	SK
534	F		500789	(Sw?)	Sl?-Sw	hmg	PV, HW
534	F	13663	673688	Wo	Wo	hr	SK
535	F	13662	667724	ND	Lw-Po	aw	SK
536	F	13664	(675735)	Lw-Sw?	Lw-Po	aw	SK
537	F	13665	608795	Lw-Po?,S? mixed	Lw-Po	aw	SK
537a	F	13689	607796	(Lw-P, P?)	Lw-Po	aw	JK, SK
538	F	13666	625706	Mh	Mh	tt	SK
539	F F	13667	(607795)	Po+contam upp Po-l	Lw-Po	aw	SK

540	F	——	642722	NF	Mh	tt	SK
541	F		(608797)	(Pl-Sc)	Pl	at	SK
542	F		597799	(Dt?)	Mh	tt	SK
543	F	——	(626817)	NF	Mh	tt	SK
544	F		?	(P?)	Lw-Po	aw	SK
545	F		628652	L-P	Lw-Po	aw	SK
546	F	——	(627785)	NF	Dt	tw	SK
547	F	——	625798	NF	Mh	tt	SK
548	F	——	643727	NF	Mh	tt	SK
549	F		607797	(Pl-Sc)	Pl	at	SK
550	F	13679	607798	Pl	Pl	at	SK
	F	rec		Pl		at	MJ
551	F		608794	ND	Pl	at	SK
552	F		608794	?Pl	Pl	at	SK
553	F		?	Pl	Pl	at?	SK
554	F		609818	(?Lwh-Ld)	Lwh-Ld	ww	SK
555	F		(590800)	(S?)	Sl-Sw	hm	SK
556	F		(591800)	Ab	Ab	wh	SK, PV
557	F		593803	(Lwh-Ld)	Lwh-Ld	ww	SK, PV
558	F		594802	NL	Sl-Sw?	hm?	SK, PV
559	F		(592757)	(Mh-Dt)	Dt	tw	SK, PV
560	F		597800	P-S?	?	a?	SK, PV

561	F 13797	594801	Dw	Dw	wh	SK, PV
562	F	?	(P?)	?	a?	SK, PV
563	F ——	598800	ND	?	?	SK, PV
564	F F 17903	596799	Dh Dh	Dw-Ab	wh	SK, PV MJ
565		No form				
566	F	(567750)	(Dw-Dh)	Dw-Ab	wh	JK, SK, HP
567	F 13680	(566751)	Dt	Dt	tt	JK, SK, HP
568	F 13681	566751	Dt	Dt	tt	JK, SK, HP
569	F 13682	548721	Pl	Pl	aw	SK, PV
570	F	(614787)	(Mh-D)	Mp-Mh	tt	SK
571	F	?	(A)	Dw-Ab	wh	SK
572	F	588810	(S-T)	Sw	hmt	SK
573	F	606807	(P?)	Po	aw	SK
574a	F	(584799)	(Sl-Tt)	Sw	hm	SK
574b	F	(592788)	(P)	Lw-Po	aw	SK
575	F	(592803)	(Po)	Po	aw	SK
576	F	(616842)	(Sl-Sw)	Sl-Sw	hmt	SK
577	F	589804	(Sl-Sw)	Sw	hm	SK
578	F	603813	(Po)	Po	aw	SK
579	F	608819	(Sl-Sw)	Sl-Sw	hm	AC, SK, PV
580	F	611818	(Po)	Po	aw	AC, SK, PV
581	GS 5367	608797	Po-R	Pl	at	AC
581	F	c 614815	NL	Pl.	at?	AC, SK, PV

582	F		c 608808	(P)	Po	aw	AC, SK, PV
583	F		c 594804	(Dm-Dh)	Dm-Dh	wh	SK
584	F		599789	(Pl?)	Po	aw	SK
585	F		(595790)	(Po)	Po	aw	SK
586	F		615795	(Po)	Lw-Po	aw	SK
587	F		c 620797	NL	Mp-Mh	tt	SK
588	F		574787	(Sl-?)	Sl-Sw	hm	SK
589	F		575787	(Lwh-Ld)	Lwh-Ld	ww	SK
590	F		584793	(upp S?)	Sl-Sw	hm	SK
591	F		585792	(Lw-P)	Po	aw	SK
592	F		574778	(Pl)	Pl	at	SK
593			574778	(Pl-Sc)	Pl	at	SK
594	F		c 584787	Lwh-Ld	Lwh-Ld	ww	SK
595	F		c 584785	Sl-?, Sw-low Tt?	Sl-Sw	hm	SK
596	F		c592810	(upp S?)	Sw	hmt	SK
597	F		598845	Sl-?, Sw-low Tt?	Sw	hm	SK
598	F		620844	Lwh-Ld?	Lwh-Ld	ww	SK
599	V	1313	617793	Mp	Mp	tt	SK
600	F		(592804)	(S?)	Sl-Sw	hm?	SK
601	F	13683	535711	Dt	Dt	tw	JK
602	F	13684	583753	Mh-Dt	Dt	tw	JK

603	F	13685	604738	Dt	Dt	tw	JK
604	F	13686	618737	Dt	Dt	tw	JK
605	F	13687	630733	Dt	Dt	tp	JK
606	F	13798	(519757)	Sc-Ww?	Sw-Tt	hm	JK
607	F	13799	(485853)	Sl-Sw?	Tt	hm	JK
608	F	13800	608797	Pl	Pl	at	JK
609	F	13801	608797	Pl ?	Pl	at	JK
610	F	13802	608797	Lw-P	Po	aw	JK
611	F	13803	(459611)	Mh	Mh	tt	JK
612	F	13945	(493844)	Sw?	Sw	hmg	JK
613	F	17695	491758	ND	Mp	tt	WB, RH
614	F	17696	493757	Rt-Mp	Mp	tt	WB, RH
615	V	2033	483802	Cu?-Cm?	Cu?-Cm	um	MJ
616	V	2034	490797	Cu?-Cm?	Cu?-Cm	um	MJ
	F	18023		C-R			MJ
	F	——		ND			
617	F	——	603799	ND	Lw-Po	aw	MJ
618	F	17697	556746	Cm-Cn	Cm-Cn	us	MJ
619	F		561760	Ak?-Lwh?	Dw-Ab	wh	MJ
620	F	18019	468624	Dt	Dt	tp	MJ
621	F	——	581736	NF	Dt	tw	MJ
622	F	18030	667687	Lw-Po	Lw-Po	aw	MJ
701	V	1021	463786	ND	low Cret?	ew	JE

702	V 1022	458759	Cn	Cn	us	AA, MH
703	V 1024	489761	Ra	Ra	us	AA, MH
704	V 1025	463758	Cn?	Cn	us	AA, MH
705	V ?	480717	(Mp?)	Mp-Mh	tt	RC, JE
706	V 1027	450783	Cu?-Cm	Cu?-Cm	um	HW
707	V 1028	472741	ND	Cn	us	RC, JE
708	V 1029	479737	Cu?	Cn	us	RC, JE
709	V 1030	c 479765	Cm-Cn	Cn	us	HW
710	V 1031	463735	Cm	Cm	us	JW
711	V 1208	473744	Cn?	Cn	us	HW
712	V 1209	470742	ND	Cn	us	HW
713	V 1210	459739	Cm	Cm	um	JE
714	V 1211	485740	Cm	Cm	us	JE
715	V 1212	485740	ND	Cm-Cn	us	JE
716	V 1213	458771	ND	Cm-Cn	um+s	JE
717	GS 7929	665848	Mp	Mp	tt	GS, IK
718	GS 7930	664849	Mp	Mp	tt	GS, IK
719	GS 7931	662850	Mp	Mp	tt	GS, IK
720	GS 7932	661851	ND	Mp-Mh	tt	GS, IK
721	F 14783	660851	Rt-Mp	Mp	tt	GS, IK
722	GS 7933	660851	Mp-Mh	Mp-Mh	tt	GS, IK
723	GS 7934 F 14784	660851	Mp Rm-Mp	Mp	tt	GS, IK GS, IK

724	GS 7935 F ———	666848	ND ND	Mp	tt	GS, IK GS, IK
725	GS 7936 F 14785	682895	Rt? Rt-Mp	Mp	tt	GS, IK GS, IK
726	F 15379	673688	Wo	Wo	hr	NH
727	A G B#	674688	Wo-Wn	Wn	cp	AB, PW
728	A G B	674687	Wn	Wn	cp	AB, PW
729	A G B	669679	Wn	Wn	cp	AB, GN
730	A G B	665676	Wn	Wn	cp	AB, CF, PW
731	A G B	665675	Wn	Wn	cp	AB, CF, PV, PW
732	V 1023	489763	Ra	Ra	us	TH
733	V 1039	460764	Cm	Cm	us	RC
734	V 1040	459765	ND	Cm	um	TH
735	V 1207	488785	Cm?	Cm	um	TH
736	GS 9610	c 664676	Wn	Wn	cp	JM
737	GS 9611	674687	Wn	Wn	cp	JM
738	GS ?	463823	Mh?	Mp-Mh	us+t	MO
739	F 17231	c 696773	Lw?-Po?	Lw-Po	aw	DJ
740			vacant			
741	V 1682 *	660676	ND	Lw-Po	aw	WB
742	V 1683	672682	ND	Wn	cp	WB
743	V 1684	674687	ND	Wn	cp	WB
744	V 1685	674687	ND	Wn	cp	WB
745	V 1686	674687	ND	Wn	cp	WB

746	V	1687	674687	ND	Wn	cp	WB
747	V	1688	674687	ND	Wn	cp	WB
748	V	1689	674687	ND	Wn	cp	WB
749	V	1690	674687	ND	Wn	cp	WB
750	V	1691	674687	ND	Wn	cp	WB
751	V	1692	674687	ND	Wn	cp	WB
752	V	1693	674687	ND	Wn	cp	WB
753	V	1694	674687	ND	Wn	cp	WB
754	V	1695	674688	ND	Wn	cp	WB
755	V	1696	672686	ND	Wn	cp	WB
756	V	1697	659674	ND	Wn	cp	WB
757	V	1698	665675	ND	Wn	cp	WB
758	GS	9734	535710	ND	Dt	tw	SK
759	V	1608	454775	Cm-Cn;Cn	Cm-Cn	us	MJ, HW
760	V	1610	450805	Cret	Cm-Cn	us	MJ
761	V	1615	491783	Cm	Cm	us	MJ
762	V	1616	481796	pre Cn	Cu?-Cm	um	MJ
763	V	1617	c 481805	C; ?Cm-Rm?	Cu?-Cm	um	MJ
764	V	1618	490794	ND	low Cret?	ew	MJ
765	V	1619	475782	Cm	Cm	um	MJ
766	V	1620	458818	Rm; Mp?	Rm-Mp	us+t	MJ
767	V	1621	459771	Cu?-Cm	Cu?-Cm	um	MJ

Collection held by A.G. Beu
* V 1682 - V 1698 microfaunal samples

768	V	1622	462769	Cm?	Cm	um	MJ
769	V	1623	459763	Cm?	Cm	us	MJ
770	V	1624	458759	Cn	Cn	us	MJ
771	V	1625	480785	C?	Cu?-Cm	um	MJ
772	V	1630	462762	Cm-Cn;Ra?	Cn, Ra	us	MJ
773	V	1632	467772	Cm; Cm	Cm	um	MJ
774	V	1633	468770	Cm-Cn;Mp?	Cm-Cn;Mp	us;tt	MJ
775	V	1640	499768	Rt	Rt	us	MJ
776	V	1641	485767	Cn?	Cn	us	MJ
777	V	1642	488765	Cn	Cn	us	MJ
778	V	1643	491758	Mp	Mp	tt	MJ
	F	17643	494757	Rt-Mp,Mp?			MJ
779	V	1644	487759	Ra;Ra	Ra	us	MJ
	F	17644		Ra			MJ
780	V	1645	480761	Cn	Cn	us	MJ
781	V	1646	495749	Mh?	Mh	tt	MJ
	F	17645		Mp-Mh,Mh?			MJ
782	V	1647	483743	Cn	Cn	us	MJ
	F	17646		?C-R			MJ
783	V	1648	476747	Cn	Cn	us	MJ
	F	17647		Cm-Cn			MJ
784	V	1649	472752	Mp	Mp	tt	MJ
785	V	1650	478758	ND	Cn	us	MJ
786	V	1651	482750	Cn	Cn	us	MJ
787	V	1652	477740	Cn	Cn	us	MJ

788	V 1653	471742	Cn; Cn	Cn	us	MJ
789	V 1654	467744	Cn	Cn	us	MJ
	GS10058		ND			MJ
	F 17648		Cm-Cn			MJ
790	V 1655	460772	Cu?-Cm	Cu?-Cm	um	MJ
791	V 1656	510726	Mp	Mp	tt	MJ
792	V 1657	492742	Mh	Mh	tt	MJ
793	V 1982	462724	Cm-Rm	Rt?-Mp	tt	MJ
	GS10000		Cm-Rm	Rt-Mp		MJ
	F 17904		Rt-Mp;	Rt-Mp,		
			Cm-Cn	Cm-Cn	tt;us	MJ
794	V 1983	459742	Cm; Cm	Cm	us	MJ
795	V 1984	455728	Cm?	Cm	um	MJ
796	V 1985	452722	Cm	Cm	um	MJ
797	V 1990	453710	Mp	Mp	tt	MJ
798	V 1999	468720	pre-Tert	Cm-Cn	us	MJ
799	V 2000	683823	Rm	Rm	ug	MJ
800	V 2001	712881	Rm?	Rm	ug	MJ
801	V 2002	679874	Rt; Mp	Rt-Mp	ug;tt	MJ
802	V 2003	671860	Mp;Mh?	Mp-Mh	tt	MJ
803	V 2004	687891	Rm;Rt;R	Rm-Rt	ug	MJ
804	V 2005	678886	Mp?	Mp	ug	MJ
805	V 2006	674886	Cm-Mp?	Mp	tt	MJ
806	V 2007	682895	Rt?	Mp	tt	MJ
807	V 2009	681849	Ra	Ra	ug	MJ

808	V	2010	673839	Ra	Ra	ug	MJ, HW
809	V	1658	499707	low Cn	low Cn	us	MJ
810	V	2015	637818	Rt	Rt	ug	MJ
811	V	2016	662850	Mp	Mp	ug	MJ
812	V	2017	620797	Mp	Mp	tt	MJ
813	V	2019	673828	Mp	Mp	ug	MJ
814	V	2020	674832	Rm	Rm	ug	MJ
815	V	2021	658810	Mh?	Mh	tt	MJ
	F	17649		Mh, low Mh?			MJ
816	V	2022	653815	Mp-Mh	Mp-Mh	tt	MJ
817	V	2023	655821	Ra	Ra	ug	MJ
818	V	2024	657831	Rm	Rm	ug	MJ
819	V	2025	646834	Rt	Rt	ug	MJ
820	V	2026	652838	Rt; Mp?	Rt; Mp	ug	MJ
821	V	2027	669856	Mp	Mp	ug	MJ
822	V	2028	718867	Mh?	Mh	tt	MJ
823	V	2029	680830	Rt	Rt	ug	MJ
824	V	2030	679812	Rt; Mp	Rt;Mp	ug;tt	MJ
825	V	2031	644827	Rt	Rt	ug	MJ
826	V		554752	?Cm-Rm?	Cm-Ra?	us	MJ
	F	17650		?C-R, low R?			
827	V	2032	553744	?Cm-Rm?	Cm-Ra?	us	MJ
828	V	1040b	459765	ND	Cm	um	MJ
829	F	17651	460698	Rt-Mp	Mp	tt	MJ
830	F		641871	upp Lw-Po, Po?	Lw-Po	aw	MJ

831	F		641873	upp Lw-Po, Po?	Lw-Po	aw	MJ
832	F		640873	Po	Po	aw	MJ
833	F		635881	Lw	Lw	aw	MJ
834	F	17652	645888	Dt	Dt	tw	MJ
835	F		614889	Sl-Tt,Sw-low Tt?	Sw	hm	MJ
836	F		574898	mid-upp Tt, upp Tt?	upp Tt	hm	MJ
837	F		629853	Ab	Ab	wh	MJ
838	F		517735	Lwh-Ld	Lwh-Ld	ww	MJ
839	F	17653	676900	Dt-Mh	Mh	tt	MJ
840	F		497794	Sl-Tt?,Sw?	Sl?-Sw	hmg	MJ
841	F		528683	mid-upp Sa	Sa	aw	MJ
842	F	——	452689	ND	Tt	hm	MJ
	F	rec		low Tt, der D			MJ
843	F		620836	low Lwh	Lwh	ww	MJ
844	F		504766	ND	Sl?-Sw	hmg	MJ
845	F	17654	501767	Mp-Mh	Mp	tt	Mj
846	F	17655	484740	R-Mp	Mh	tt	MJ
847	F	17656	482738	Cm-Cn	Cm-Cn	us?	MJ
848	F	17657	495743	Mp-Mh	Mh	tt	MJ
849	F	17659	466708	?Cm-Cn	Cm-Cn	us	MJ

850	F	17660	460713	Rt-Mp	Mp	tt	MJ
851	F	17661	503764	Rt-Mp	Mp-Mh	tt	MJ
852	F	17662	504765	Rt-Mh	Mp-Mh	tt	MJ
853	F	17663	496767	Rt-Mp	Rt	us	MJ
854	F	17668	500758	Mp-Mh	Mh	tt	MJ
855	F	17664	496757	Mp-Mh	Mp	tt	MJ
856	F	17665	495757	R-D	Mp	tt	MJ
857	F	——	489759	ND	Ra-Rm	us	MJ
858	F	17666	458751	Cm-Cn	Cn	us	MJ
859	F	17658	652824	Mh-Dt	Mh	tt	MJ
860	F		564776	Lwh?	Lwh-Ld	ww	MJ
861	F		548754	low Lwh	Lwh	ww	MJ
862	F		612793	upp Lw-P, upp Po?	Po	aw	MJ
863	F		483646	D	Dw-Ab	wh	MJ
864	F	17698	582764	Dt	Dt	tt	MJ
865	F		586781	Ar?	Dw-Ab	wh	MJ
866	F		596828	S1-Sw	Sw	hm	MJ
867	F		591809	S1-Sw	Sw	hmt	MJ
868	F		590805	Sw-Tt	Sw	hmt	MJ
869	V	2163	673689	Ww-Wn	Wn	cp	AB
870	F		559841	Tt	mid Tt	hm	MJ
871	F		563776	ND	Sw	hm	MJ
872	F		581768	Dt?	Dt	tt	MJ

873	F	544755	Sw?	S1-Sw	hm	MJ
	F 17958		S1-Sw			MJ
874	F	549754	Lwh?	Lwh-Ld	ww	MJ
875	F	603813	Lw-Po	Lw-Po	aw	MJ
876	F	600817	Sw?	Sw	hm	MJ
877	F	591802	Sw-Tt, Sw?	Sw	hm	MJ
878	F	593802	upp Po-Pl, Po?	Po	aw	MJ
879	F 17699	618795	Mh-Dt	Mh	tt	MJ
880	F	610818	low Lwh	Lwh-Ld	ww	MJ
881	F	615822	upp Po	Po	aw	MJ
882	F	597797	Lw-Po, upp Po?	Po	aw	MJ
883	F	583793	upp S-T	Sw	hm	MJ
884	F	595779	ND	Dt	tt	MJ
885	F 17703	598781	Dt	Dt	tt	MJ
886	F	609788	Pl	Lw-Po	aw	MJ
887	F	576823	upp Tt	mid Tt	hmt	MJ
888	F	597799	ND	Lw-Po	aw	MJ
889	F	564823	S1-Tt	upp Tt	hk	MJ
890	V 2035	535730	pre Cn	Cm	um	MJ
891	V 2036	551602	Mp	Mp	tt	MJ
892	V	573677	Mp	Mp	tt	MJ
893	GS 9910	500789	P-low S	S1?-Sw	hmg	PW

894	F 17761	566774	Dt	Dt	tw	MJ
895	F	557766	Sw-low Tt, Sw?	Sw	hm?	MJ
896	F	498845	Sw	Sw	hmg	MJ
897	F	550768	Lwh?	Sw	hm	MJ
	F 17959		Sw			MJ
	GS 9995		Sl-Sw			MJ
898	F	574778	Pl	Pl	at	MJ
899	F	594792	Lw-Po	Po	aw	MJ
900	F	536831	Sw-upp Tt, Sw?	Tt-Tk	hk	MJ
901	F	549722	Pl	Pl	aw	MJ
902	F 17762	548725	Dt	Dt	tw+wh	MJ
903	F	544740	Lwh?	Lwh-Ld	ww	MJ
904	F	543739	Po	Po	aw	MJ
905	F 17767	535731	Lw-Po	Po	aw	MJ
906	F 17768	527732	Lw-Po	Po	aw	MJ
907	F 17769	621781	Dt	Dt	tw	MJ
908	F 17773	629744	Dt-Dw	Dt	tw	MJ
909	F	583801	Sw	Sw	hmt	MJ
910	F	564807	upp Tt-Tk	upp Tt	hk	MJ
911	F	565807	mid Tt-upp Tk	mid Tt	hm	MJ
912	F	552705	Pl	Pl	aw	MJ
913	F 17763	567751	Dt	Dt	tt	MJ
914	F 17764	566752	Dt	Dt	tt	MJ

915	F		568728	Pl	Pl	aw	MJ
916	F		563729	Pl	Pl	aw	MJ
917	F		635692	D,Lwh-Po	Lw-Po	aw	MJ
918	F		531748	Sw?-Tt?	Sw	hm	MJ
	F	17961		Sc-Tt	Sw		
919	F	17765	556600	Mh-Dt	Mp-Mh	tt	MJ
920	F		535630	Pl	Pl	aw	MJ
921	F		552627	Lw-Po	Lw-Po	aw	MJ
922	F		550641	D-Ab?	Dw-Ab	wh	MJ
923	F		529664	Sc	Sc	aw	MJ
924	F	17770	545656	Dm, Sw	Dw-Ab	wh	MJ
925	F		547652	Pl - ?	Pl	aw	MJ
926	F	17771	577675	Dw-?Sw	Dw-Ab	wh	MJ
927	F		584625	L,Lwh?	Lw-Po	aw	MJ
928	V	2038	607678	Mh	Mh	tt	MJ
929	V	2039	583655	Mp	Mp	tt	MJ
930	F		548689	Pl	Pl	aw	MJ
931	F		530872	Sw-low Tt?	Tt	hk	MJ
932	F		511876	mid Tt	mid Tt	hk	MJ
933	F		499881	mid Tt	mid Tt	hk	MJ
934	F		499843	upp Tt-Tk	upp Tt	hk	MJ
935	F		508900	mid Tt-Tk	upp Tt-Tk	hk	MJ

936	F	526897	upp Tt	upp Tt-Tk	hk	MJ
937	F	561887	mid-upp Tt	upp Tt	hk	MJ
938	F	484873	upp Tt-Tk	Tt	hk	MJ
939	F	564891	Tt-Tk	mid Tt	hm	MJ
940	F	494862	ND	Sw	hmg	MJ
	F 17891		Sw-Tt			MJ
	GS 9986		Po-Sw			MJ
941	F	496861	Sw?-low Tt?	Sw	hmg	MJ
942	F	490873	ND	Tt	hk	MJ
943	F 17969	485870	Sc-Tt, upp S?	Sl-Sw	hmg	MJ
944	F	463698	upp S?	Sw-Tt	hm	MJ
945	F 17766	582768	Dt	Dt	tt	MJ
946	F	620782	NF	Dt	tw	MJ
947	F	455680	Sl-Sw,Sw?	Sw	hm	MJ
948	F	475829	Ab	Ab	wh	MJ
949	F	486831	Sw-Tt,Sw?	Sw	hm	MJ
950	F	485833	Sw-Tt?	Sw	hm	MJ
951	F	510836	Sw-Tt,Tt?	Tt	hm	MJ
952	F	497830	mid Tt	mid Tt	hk	MJ
953	F	511799	low Tt	low Tt	hm	MJ
954	F	500785	Sl-low Tt	Sl?-Sw	hmg	MJ
955	F	518749	low Tt?	Sw	hm	MJ
	F 17960		?Sa-Tt?			MJ

956	F		620810	Lw-Po, Lw?	Lw-Po	aw	MJ
957	F		619818	upp Lw-Po, Po?	Po	aw	MJ
958	F		617820	Pl	Po	aw	MJ
959	F		636884	A-Lwh, Lwh?	Lwh-Ld	ww	MJ
960	F		642861	Lwh-Ld	Lwh-Ld	ww	MJ
961	F		628853	D-Ab	Dw-Ab	wh	MJ
962	F	17808	608812	S1-Sw	S1	hmt	MJ
963	F	17809	612823	S1-Sw	Sw	hm	MJ
964	F	17810	608797	Pl	Pl	at	MJ
965	F	17811	606799	Pl	Pl	at	MJ
966	F	17812	612824	Lw-Po	Po	aw	MJ
967	F	17813	602800	Lw-Po	Po	aw	MJ
968	F	17814	599799	Lw-Po	Lw-Po	aw	MJ
969	F	17815	597799	Lw-Po	Lw-Po	aw	MJ
970	F	17816	637892	Dh	Dh	wh	MJ
971	F	17817	632897	Lw-Po	Lw-Po	aw	MJ
972	F	17818	631896	Lw-Po, Lw?	Lw-Po	aw	MJ
973	F	17819	628880	Lw-Po	Lw-Po	aw	MJ
974	F	17820	629880	Lw-Po, Lw?	Lw-Po	aw	MJ
975	F	17821	630881	Lw-Po	Lw-Po	aw	MJ
976	F	17822	631881	Lwh-Ld	Lwh-Ld	ww	MJ
977	F	17823	632880	Ab	Ab	wh	MJ

978	F 17824	629852	Ab	Ab	wh	MJ
979	F 17839	634852	Dm-Dh	Dm-Dh	wh	MJ
980	F 17840	625855	S1-Sw	S1	hmt	MJ
981	F 17841	627854	Lw-Po	Lw-Po	aw	MJ
982	F 17842	615839	S1	S1	hmt	MJ
983	F 17843	616837	Pl -S1	P1 -Sc	at	MJ
984	F 17844	617837	Sc-S1	P1 -Sc	at	MJ
985	F 17845	618837	P1	P1	at	MJ
986	F 17846	618837	Pl	Lw-Po	aw	MJ
987	F 17847	618837	Lw-Po	Lw-Po	aw	MJ
988	F 17848	619837	Lw-Po	Lw-Po	aw	MJ
989	F 17849	597847	S1-Sw	S1-Sw	ah	MJ
990	F 17851	516677	Dh	Dh	wh	MJ
991	GS 9987	623829	Mh?	Mh	tt	MJ
992	F 17890	627881	S1-Sw	S1-Sw	hmt	MJ
993	F 17905	473684	low Mh	Mh	tt	MJ
994	F 17892	486849	S1?-Tt?	Tt	hn	MJ
995	F 17893	512851	Tt	Tt	hk	MJ
996	F 17894	508853	Tt	Tt	hk	MJ
997	F 17895	504855	Tt	Tt	hk	MJ
998	F 17896	500858	Tt	Tt	hk	MJ
999	F 17897	497859	?S1-Tt	S1-Sw	hmg	MJ
1000	F 17898	492863	S1-Sw	Sw	hmg	MJ

1001	GS 9996	527750	low S	upp S	hm	MJ
1002	F 17933	487832	Sw-Tt	Sw	hm	MJ
1003	F 17934	489832	Sw-Tt	Sw	hm	MJ
1004	F 17935	490832	low Tt	low Tt	hm	MJ
1005	F 17936	492832	low-mid Tt	low Tt	hm	MJ
1006	F 17937	495831	mid Tt	mid Tt	hm	MJ
1007	F 17938	573894	mid Tt	mid Tt	hm	MJ
1008	F 17939	573893	mid Tt	mid Tt	hm	MJ
1009	F 17940	576889	Tt,mid Tt?	upp Tt	hmt	MJ
1010	F 17941	579890	S1-Sw?	Sw	hmt	MJ
1011	F 17942	584882	S1-Sw	Sw	hmt	MJ
1012	F 17943 GS 9999	504793	?S1-Tt Lw-S1	S1 S1	hm	MJ
1013	F 17899	667680	Po-Pl	Po-Pl	aw	MJ
1014	F 17962	549765	?S1-Tt	S1-Sw	hm	MJ
1015	F 17963	552765	Lw-Po?	Lw-Po	aw	MJ
1016	F 17964	548755	Lw-Po?	Lw-Po	aw	MJ
1017	F 17965	544751	S1-Sw	S1-Sw	hm	MJ
1018	F 17966	537749	upp Sa-Sw, ? S1-Sw	S1	hm	MJ
1019	F 17967	536748	?S1-Sw	S1	hm	MJ
1020	F 17968	531745	?S1-Sw	S1	hm	MJ
1021	F 18024	485689	Dw	Dw	wh	MJ
1022	F 18029	490796	R-C	Cu?-Cm	um	MJ

1023	F 18025	586746	Dt	Dt	tt	MJ
1024	F ——	587746	NF	Dt	tt	MJ
1025	F 18026	563667	Mh	Mh	tt	MJ
1026	F 18027	559685	Dt	Dt	tt	MJ
1027	F 18028	466721	C	Cm-Cn	us	MJ
1028	F ——	464723	NF	Cm-Cn	us	MJ