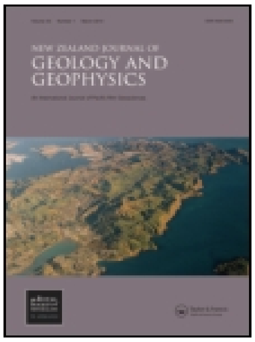

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New Zealand Journal of Geology and Geophysics

ISSN: 0028-8306 (Print) 1175-8791 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzg20

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To cite this article: P. A. Hesp & M. J. Shepherd (1978) Some aspects of the late Quaternary geomorphology of the lower Manawatu Valley, New Zealand, New Zealand Journal of Geology and Geophysics, 21:3, 403-412, DOI: 10.1080/00288306.1978.10424064

To link to this article: http://dx.doi.org/10.1080/00288306.1978.10424064

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N.Z. Journal of Geology and Geophysics Vol. 21, No. 3 (1978): 403–12

Some aspects of the late Quaternary geomorphology of the lower Manawatu Valley, New Zealand

P. A. HESP AND M. J. SHEPHERD

Coastal Studies Unit, University of Sydney, Australia and Department of Geography, Massey University, Palmerston North, New Zealand

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ABSTRACT

The lower Manawatu Valley consists of three topographic units: the Tokomaru Marine Terrace, the Manawatu floodplain, and a coastal dune belt. The floodplain is underlain at depth by river gravels from which a date (NZ 3938B) of 42 700 + 7650 − 3950 years B.P. was obtained. Many box-shaped valleys have developed within the marine terrace adjacent to the eastern margin of the floodplain.

Radiocarbon dating (NZ 3085B) of estuarine mollusc shells (6330 ± 70 years B.P.), and stratigraphic and morphologic studies provide evidence that the lower Manawatu and Oroua Valleys became estuaries during the Postglacial Transgression. During the latter stages of the transgression, two barriers, the Himatangi Anticline and Poroutawhao High, which lie parallel to the present coastline, restricted oceanic influences and facilitated the formation of the estuaries. Valleys cut in the marine terrace during the last glaciation, particularly those lying between Tokomaru and Levin, were partly filled with estuarine sediment to produce the flat valley floors characteristic of box-shaped valleys.

The height and location of estuarine sediment, and the height of beach ridges near Otaki, indicate that there is no evidence in this area and adjacent areas to the south for a Holocene sea level higher than at present.

Rates of uplift in the Levin-Shannon area (*c.* 0·35 m/10^3 yr) are discussed and new evidence for the minimum age of the Levin Anticline (*c.* 60 000 yrs) is presented.

INTRODUCTION

This paper presents the results of an investigation into the origin of the box-shaped valleys which border the Manawatu floodplain in the vicinity of Levin and Shannon. As the geomorphological development of the valleys is intricately related to the Late Quaternary geological history of the lower Manawatu Valley, the wider implications of the results are examined.

GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

The coastal lowland of Western Wellington Land District, which lies between Palmerston North and Levin, and between the Tararua Range and the coast, consists of three basic units (Fig. 1):

(1) The **Tokomaru Marine Terrace** (Cowie 1961) borders the western flanks of the Tararua Range, rising from 30–40 m above mean sea level in the vicinity of Levin to approximately 90 m near Palmerston North. The terrace is underlain by soft sandstones, siltstones, and gravels with a surface cover of loess (1–4 m in thickness), Aokautere Ash (Cowie 1964a; 1964b), and, in places, Pleistocene dune sand (Cowie 1963) and gravel fans. The terrace formation has been described in detail by Oliver (1948) and Rich (1959), and the upper beds have been tentatively placed in the Oturian (Interglacial) Stage by Fleming (1971). The terrace generally has low surface relief and slopes gently away from the range, except where local folding has produced broad anticlines at Levin (Te Punga 1957) and possibly also midway between Levin and Shannon, where a broadly arched divide may be the surface expression of an underlying flexure, tentatively termed "Shannon Anticline" (see Fig. 4). The Tokomaru Marine Terrace has been incised by consequent streams which usually flow in a northwesterly direction. The larger streams, which rise in the Tararua Range (e.g., Kahuterawa Stream), flow across the terrace in valleys with floors and terraces of greywacke gravels transported from the range. Smaller streams, many of which rise within the marine terrace, lack gravel deposits and flow either in V-shaped or box-shaped valleys.

(2) The **Manawatu floodplain** occupies a topographic depression between the Tokomaru Marine Terrace to the east and a wide belt of coastal sand dunes to the west. Rich (1959) postulated that the area now occupied by the southern portion of the floodplain was progressively influenced by marine, estuarine, and fluviatile conditions during the Postglacial Transgression. (The term "Postglacial Transgression" is used in this text to describe the rise in sea level that was initiated after the eustatic minimum about 17 000 years ago and completed about 6 000 years ago.) Bore data supplied to the authors by H. Smith of Taikorea and N. Webb of Levin (well drillers) and the Manawatu Catchment Board indicate that the aggradational gravel terraces of the Manawatu River downstream from the Gorge plunge beneath an increasing thickness of estuarine and swamp deposits in the lower section of the valley. A totara log (probably *Podocarpus totara,* B. Molloy pers. comm.) encountered within a thick gravel

Received 5 April 1977, revised 19 September 1977

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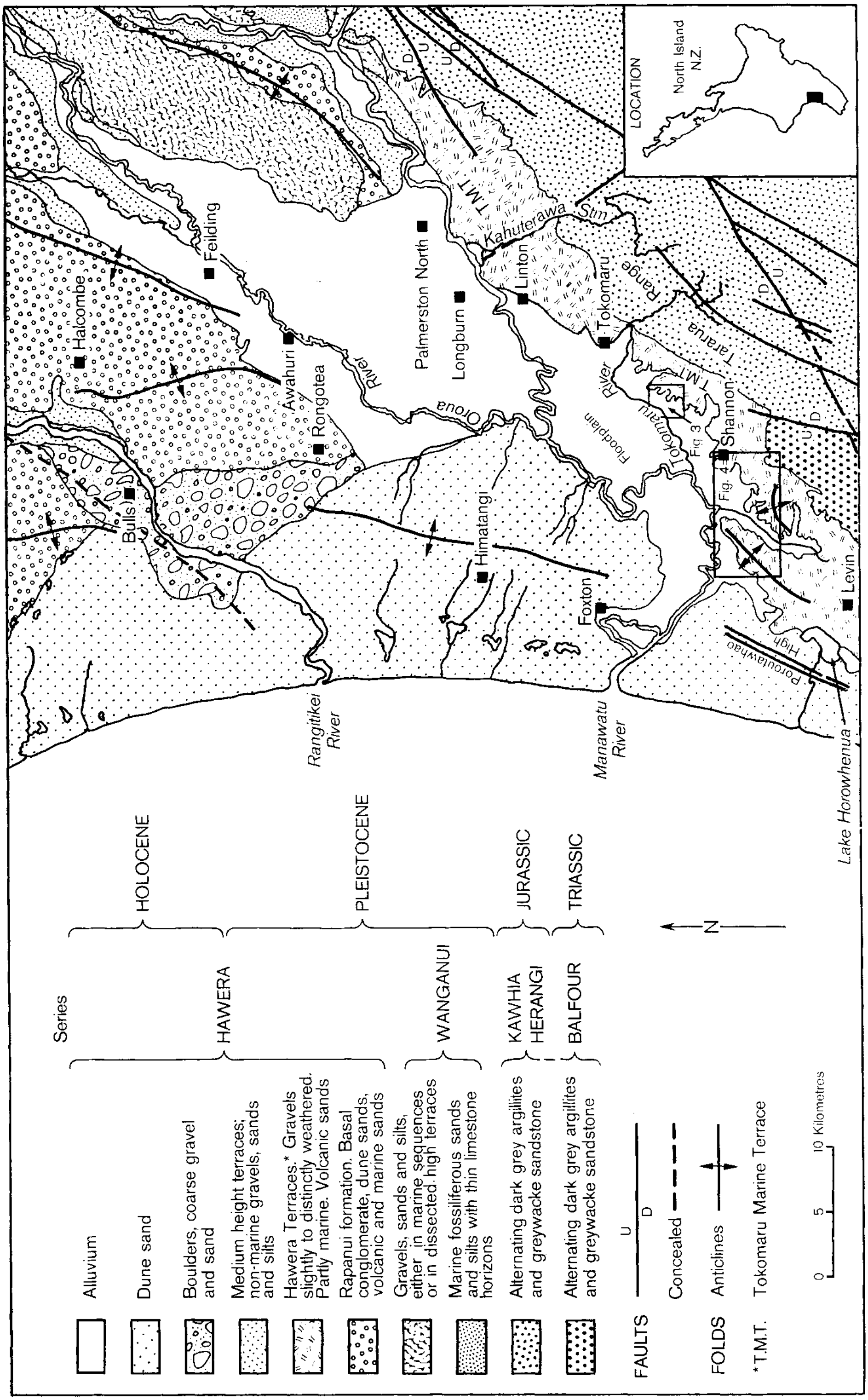

FIG. 1—Geology of the lower Manawatu valley, showing the location of the study area (Fig. 4). Sources: Kingma 1967; Te Punga 1957; Rich 1959; Hesp 1975.

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bed 40 m below the ground surface (34·88 m below m.s.l.) approximately 5 km west of Tokomaru (grid reference N148/957215)* was dated at 42 700 + 7650 − 3950 years B.P. (N.Z. 3938B; see Table 2, Bore 1). The log of wood came from gravels at least 20 m thick which were overlain by 20 m of sand, silt, and peat.

(3) A **dune belt** covering 312 km², and extending as far as 19 km inland exists between the coast and the floodplain. These Holocene dunes have a history of episodal development (Cowie 1963).

BOX-SHAPED VALLEYS DISSECTING THE TOKOMARU MARINE TERRACE

Box-shaped valleys without distinct stream channels, but with swampy floors are particularly common between Tokomaru and Levin where the Manawatu floodplain lies relatively close to sea level. Cotton (1918), who proposed the term "box-shaped" to describe the valleys, noted their characteristically wide, flat floors and steep sides. The width of many valleys appears to be wider than expected in relation to the discharge of the streams which now drain them. Some box-shaped valleys become V-shaped in an up-valley direction, while others are box-shaped throughout their length and terminate within the marine terrace in amphitheatre-like heads. At their western ends the valley floors, which are either flat or have a very low gradient, merge imperceptibly with the Manawatu floodplain (Figs 2A, 2B, and 3).

Cotton (1918) considered that box-shaped valleys were formed by stream aggradation following a period of incision, while Oliver (1948) considered that lateral erosion had played a role in the valley widening. All previous authors have explained the valley form in terms of fluvial processes, but as is shown below these processes have not always been dominant.

Stratigraphy

The sediment underlying the floors of a number of box-shaped valleys and the adjacent floodplain of a broad embayment between Shannon and Koputaroa was sampled to 9·0 m with a hand auger (Fig. 4). In the valleys a topsoil (sometimes peaty) generally overlies muds which contain fragments of vegetation and rootlets. Thin peat layers and sandy lenses are often present. The mud becomes sandier and more gleyed with depth. On the flood plain river alluvium (2–3 m thick) of silt/clay grade overlies sand or sandy mud which contains abundant well preserved shells of Bivalvia and Gastropoda. Many of the bivalves have both valves linked (the external ligament is commonly present; many of the gastropods show no signs of wear resulting from transport (delicate protoconchs are commonly present). There can be no doubt that these shells are preserved in the environment in which they lived. The shell horizon extends from a maximum of 1·1 m above mean sea level to at least 3 m below mean sea level (Fig. 5).

The fossil shell fauna extends from the floodplain into box-shaped valleys. The shells are predominantly species characteristic of an estuarine environment with salinities lower than that of the open ocean (Table 1). A. G. Beu, who identified the shells (pers. comm. 1975), considers the assemblages indicate that the salinity increased slightly from the valleys to the flood plain. The finer sediment in the valley fill is an indication of lower energy conditions.

Radiocarbon Dating of Shells

Shells *in situ* collected from a horizon 0·9–1·1 m above mean sea level beneath the floodplain, 3 km southwest of Shannon at N152/900116, were dated at 6330 ± 70 years B.P. (NZ3085B; Bore H. 26, Fig. 5).

Origin of the Box-shaped Valleys

The depth of river gravels beneath the present flood plain surface is taken as evidence that during the last glaciation the lower courses of the Manawatu and Oroua Rivers flowed below present sea level. A reliable reconstruction of sedimentary environments in the lower Manawatu Valley during the Postglacial Transgression awaits detailed stratigraphic analysis and dating of the sedimentary fill. It is assumed that in the Manawatu and Oroua valleys the cold phases of the Otira Glaciation were accompanied by river aggradation. Bore records indicate that the gradients of the Pleistocene river terraces or fans were maintained to the south of Palmerston North and Feilding and that gravel surfaces slope below present sea level. Near Opiki the gravel surface is 15 m below sea level. Near Foxton a gravel surface is about 55 m below present mean sea level (Table 2, Bores 2–4); the overlying sediment is partly estuarine in character and shells from a depth of 46 m below present sea level were dated at 9900 ± 150 years (Te Punga 1958). Bore records show that beds indicative of a marine environment have been encountered at several other localities beneath the flood plain south of Longburn at depths from 55 to 103 m below present mean sea level (Bores 5–8). Te Punga (1954a) has described in detail sediment and shell fauna of possible estuarine origin obtained from a bore in the Awahuri area. At present it cannot be determined whether some of this material was deposited during the Oturi Interglacial or during interstadials of the Otira Glaciation, but the Foxton date confirms that some estuarine beds were deposited during the Postglacial Transgression at depths well below present sea level.

Many tributary streams arising within or crossing the marine terrace incised their valleys to adjust to glacial base levels which were lower than at present. During the Postglacial Transgression the rising sea drowned the lower Manawatu Valley and many tributary valleys between Levin and Tokomaru. Sedimentation occurred initially in estuarine and perhaps lagoonal environments with floodplain alluviation becoming increasingly dominant after sea level stabilised in this area probably about 6000 years ago. V-shaped tributary valleys that extended below sea level were partly filled by estuarine

*Grid reference based on the national thousand-yard grid of the 1:63 360 topographical map series (NZMS 1)

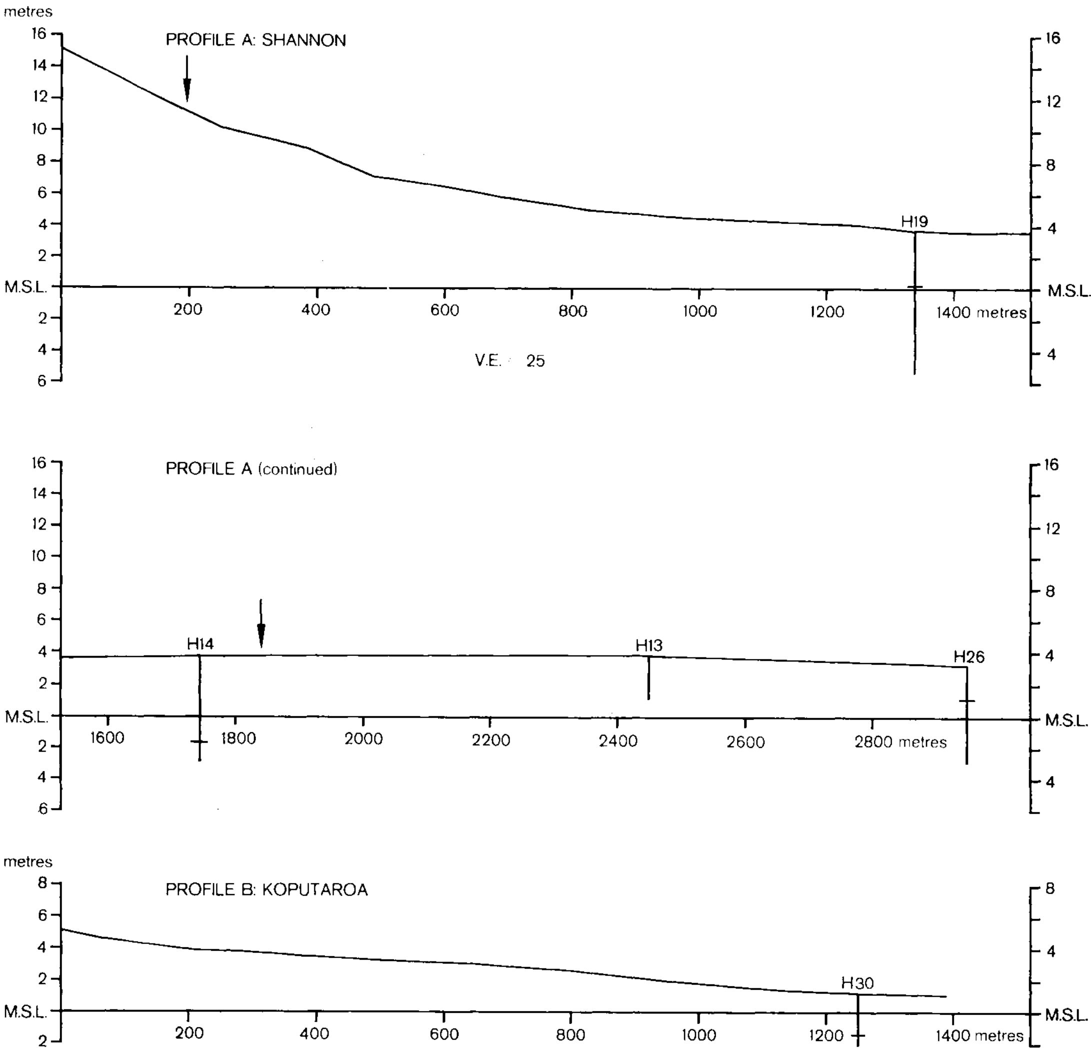

FIG. 2—Longitudinal profiles of two box-shaped valleys. The numbers on the profiles refer to bore holes; the line below the bore site represents the depth of drilling, and the horizontal dash on the line indicates the height at which shells were first encountered. The upper arrow on Profile A indicates the position at which the valley becomes V-shaped; the lower arrow indicates the position of the valley mouth. Location of Profile A is shown on Fig. 4. Profile B runs from N152/830099 to N152/843094.

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FIG. 3—Flat-floored, steep sided, box-shaped valleys within the Tokomaru Marine Terrace (T.M.T.) at Makerua, approximately 5 km northeast of Shannon. Vertical aerial photograph is published with the permission of Department of Lands and Survey.

and later fluvial sediment to become box-shaped, but remained V-shaped where the valley floor had not been incised to below sea level. Box-shaped valleys are not restricted to locations close to sea level elsewhere in the Manawatu: they also occur adjacent to major river terraces where aggradation has followed a period of incision.

TOKOMARU MARINE TERRACE MARGIN

To account for the cliffed margin of the Tokomaru Marine Terrace, a number of authors, including Cotton (1918), Adkin (1919), and Te Punga (1962), have suggested or implied that in this area the terrace faced the open ocean during the final stages of the Postglacial Transgression. However, between Tokomaru and Linton the terrace margin is uncliffed, while to the north of Linton the altitude of the cliff-foot (>20 m) precludes a Postglacial marine origin. Although lateral erosion by former meanders of the Manawatu River and major tributaries has caused some cliffing of the terrace margin between Tokomaru and Levin it is possible that cliffing was initiated at an earlier stage by wave and current action associated with the estuary. The morphology of the terrace margin, including the markedly irregular plan of the cliff, the presence of soft inliers of terrace material which rise from the flood plain near the cliff, and the presence of estuarine beds at the base of the cliff near Shannon, indicate the cliff has developed in a relatively low wave-energy environment. This can be explained by the presence of barriers to the west (see

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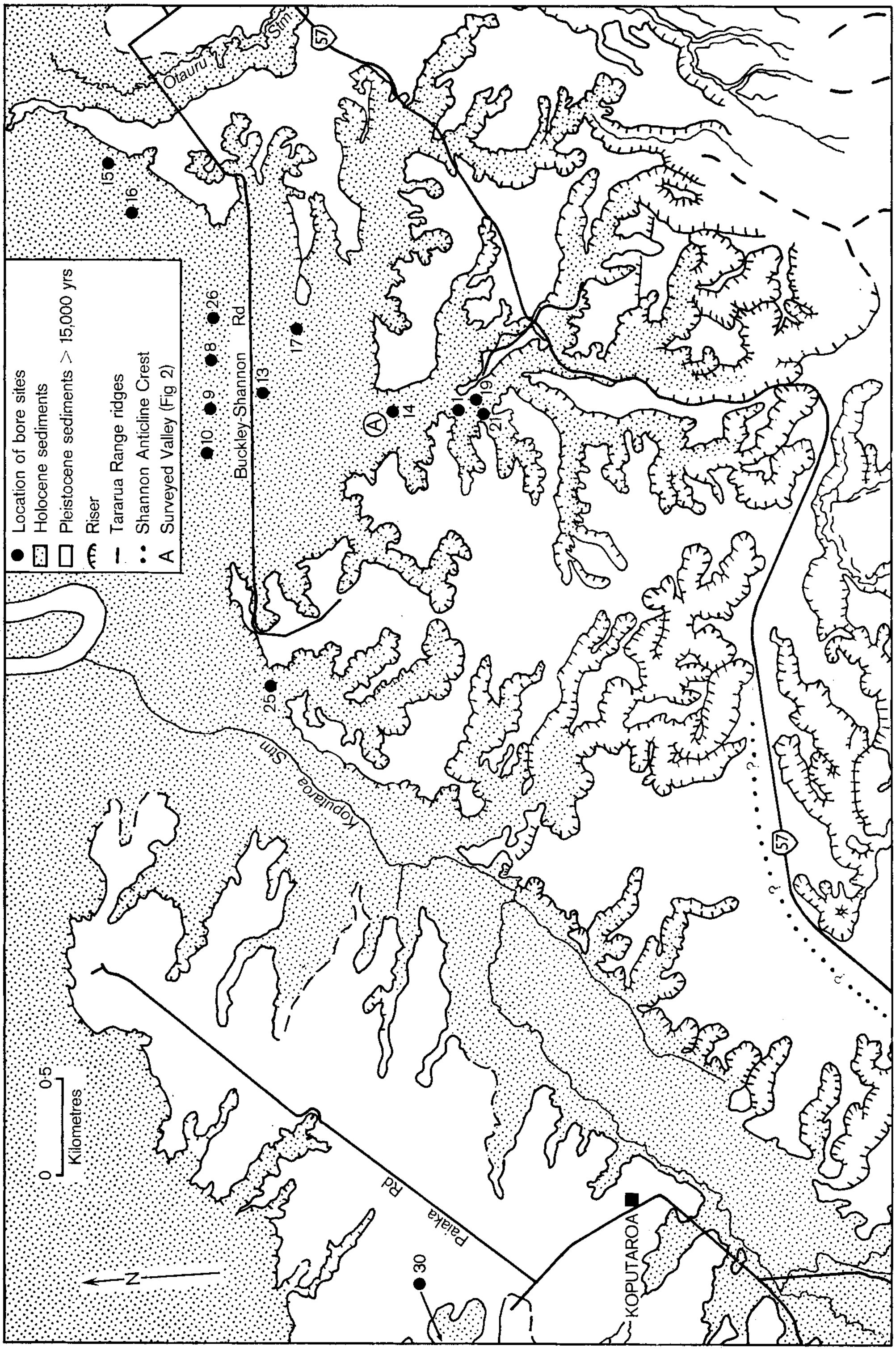

FIG. 4—Location of bores, and morphology of box-shaped valleys in the Shannon-Koputaroa district. Shannon township is just off the right hand edge of the map, near the top corner.

TABLE 1—Fossil Mollusca in samples collected near Shannon (identified by A. G. Beu, N.Z. Geological Survey).

Sample	Location*	Species Present
Sample 1 (Bore H. 26)	N152/900116 +0.914 to +0.573 m. above m.s.l.	Bivalvia: Macomona liliana (Iredale). Chione (Austrovenus) stuchburyi (Gray). Gastropoda: Zeacumantus lutulentus (Kiener). Cominella glandiformis (Reeve).
Sample 2 (Bore H. 26)	N152/900116 +0.573 to +0.085 m. above m.s.l.	Bivalvia : Macomona liliana (Iredale). Cyclomactra sp. Chione (Austrovenus) stutchburyi (Gray). Gastropoda: Potamopyrgus antipodarum (Gray). Amphibola crenata (Gmelin).
Sample 3 (Bore H. 26)	N152/900116 +0.085 m. above m.s.l. to -0.097 m. below m.s.l.	Bivalvia: Chione (Austrovenus) stutchburyi (Gray). Gastropoda : Potamopyrgus antipodarum (Gray). Neoguraleus sp. Amphibola crenata (Gmelin).
Sample 4 (Bore H. 10)	N152/888116 -0.274 to -0.366 m. below m.s.l.	Bivalvia : Xenostrobus securis (Lamarck). Chione (Austrovenus) stutchburyi (Gray). Gastropoda : Potamopyrgus antipodarum (Gray). Xymene plebeius (Hutton). Neoguraleus sp. Chemnitzia sp. ?Amphibola crenata (Gmelin).
Sample 5 (Bore H. 14)	N152/895104 -1.589 to -1.894	Bivalvia : probably Cyclomactra. Arthritica bifurca (Webster). Gastropoda : Potamopyrgus antipodarum (Gray). Amphibola crenata (Gmelin).
Sample 6 (Bore H. 19)	N152/897098 +0.240 to +0.118 m. above m.s.l.	Bivalvia : Cyclomoctra ovata (Gray). Gastropoda : Potamopyrgus antipodarum (Gray). Amphibola crenata (Gmelin).
Sample 7 (Bore H. 19)	N152/897098 -0.918 to -1.040 m. below m.s.l.	Bivalvia : Arthritica bifurca (Webster). Cyclomactra ovata (Gray). Gastropoda : Potamopyrgus antipodarum. Amphibola crenata (Gmelin).
Sample 8 (Bore H 21)	N152/895097 -3.098 to -3.190 m. below m.s.l.	Bivalvia: Cyclomactra ovata (Gray). Gastropoda: Amphibola crenata (Gmelin).

*All locations refer to grid references based on the national thousand-yard grid of the 1:63 360 topographical map series (NZMS 1), Sheet N152—Levin.

section below). In contrast, between Otaki and Waikanae erosion by higher energy ocean waves, in the absence of seaward barriers, produced a regular, gently curved, Postglacial cliff which is parallel to the present coastline (Te Punga 1962).

WESTERN MARGIN OF THE ESTUARY

If the Manawatu River flowed into an estuary during at least the closing phases of the Postglacial Transgression, a land barrier must have existed to the west. Te Punga (1953) described a bedrock high to the south of Foxton which he named the Poroutawhao High (Fig. 1). Five bore logs (9–13) made available by N. Webb, indicate that this feature, presumably a Mesozoic greywacke contact, extends at least as far south as Hokio, to the west of Lake Horowhenua, and is up to 5 m above mean sea level. This rise would have protected the terrace margin in the Levin-Shannon area from the direct influence of ocean waves.

Rich (1959) described the Himatangi Anticline which extends for approximately 21 km northwards from Foxton (Fig. 1). He considered that the Holocene dune sand overlies upwarped marine beds which were equivalent in age to the beds comprising the Tokomaru Marine Terrace Formation. (Rich found silt containing a marine microfauna in a pit 7·2 km northeast of Himatangi—N148/848367.) Bore records supplied by H. Smith indicate that beds of sand, silt, and clay extend to depths of 100 m beneath the surface of the anticline, but that coarse sand and shells typical of Holocene littoral deposits occur only within a few kilometres of the coast. Near the Manawatu flood plain to the east of the anticline, river gravel is present at depth beneath the Holocene dunes, but does not extend westwards beneath the anticline. This indicates that during the aggradational phases of the Otira Glaciation the Manawatu and Oroua Rivers were flowing to the east of the anticline. Furthermore, from the location of river gravels and estuarine facies it would appear that the lower courses of the Oroua and Manawatu Rivers have not differed markedly from their present position during late Pleistocene and Holocene times.

From the evidence above, it appears that the Himatangi Anticline and Poroutawhao High formed barriers behind which estuarine deposits accumulated in a sheltered environment. Connection with the sea was probably between the Poroutawhao High and the Himatangi Anticline in the vicinity of the present mouth of the Manawatu River. The barrier also formed a base for subsequent coastal progradation, which probably occurred rapidly after about 6000 years ago, when sea levels stabilised and an offshore equilibrium profile was established (Shepherd 1974).

TECTONISM AND FORMER SEA LEVELS

The average altitude of the Tokomaru Marine Terrace (excluding the cover beds) increases in a northerly direction, indicating a northerly increase in the rate of regional uplift. If it is assumed that the last interglacial sea level maximum (120 000 years ago, Bloom *et al.* 1974) was 5 m above present mean sea level, and the surface of the terrace (including cover deposits) is 8 m above the horizon marking the last interglacial mean sea level, then the Tokomaru Marine Terrace in the Shannon area, with an average height of 55 m, has been uplifted at an average rate of 0·35 m per 1000 years.

Assuming constant uplift at this rate, the top of the estuarine beds dated at 6330 ± 70 years B.P. (now at a height of 1·1 m above m.s.l.) will have been uplifted by about 2·2 m since deposition. Accordingly, at the time of deposition the top of the beds would have been 1·1 m below mean sea level, or slightly higher if subsequent compaction occurred. If the Postglacial sea level in this area about 6000 years ago was very close to its present level, as indicated above, this appears to conform to the Australian model rather than to European and North American models, where sea levels do not appear to have reached the present level earlier than 3700 years ago. Major differences in Holocene sea level curves from

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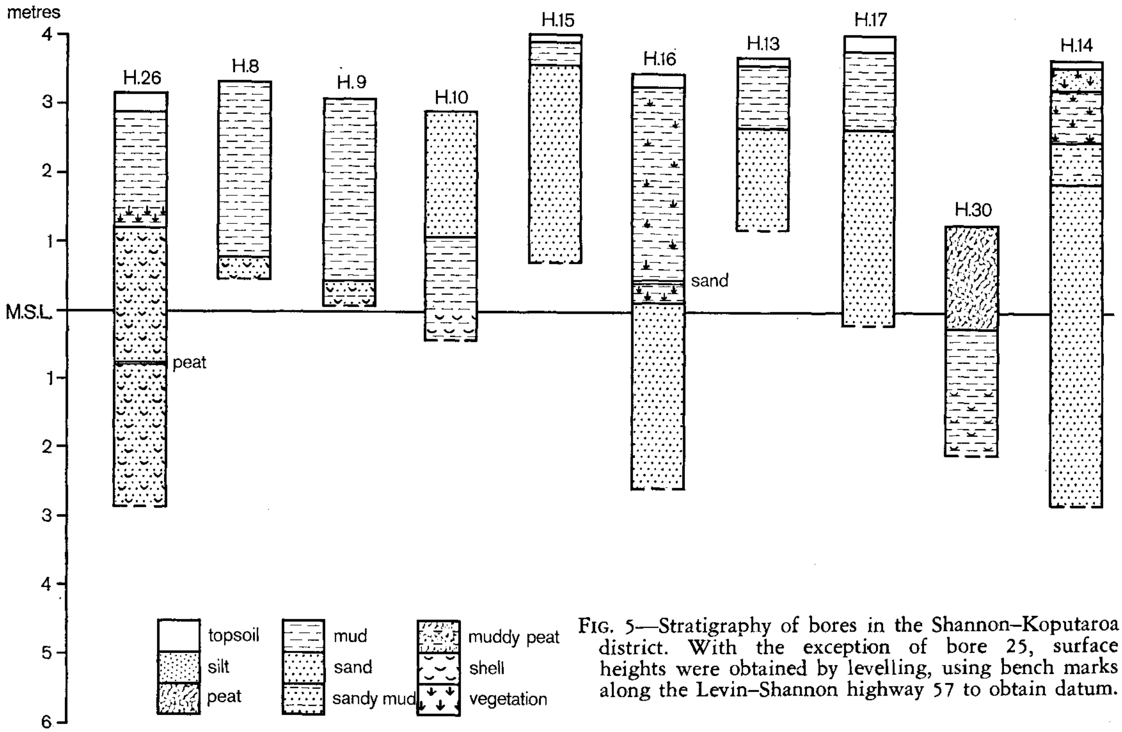

FIG. 5—Stratigraphy of bores in the Shannon–Koputaroa district. With the exception of bore 25, surface heights were obtained by levelling, using bench marks along the Levin–Shannon highway 57 to obtain datum.

TABLE 2—Location and stratigraphy of deep bores. Grid references relate to Sheets N148—Tangimoana, N149—Palmerston North, and N152—Levin, of the topographical map series (NZMS 1).

BORE NUMBER 1: N148/957215
Surface 5.12 m above m.s.l.

Depth (metres)	
0 – 6.09 metres	alternate layers of peat and clay.
6.09 – 19.8	sand with small layers of clay.
19.8 – 40.23	shingle.
40.23 – 41.0	log of wood: (42,700 $^{+7650}_{-3950}$ years B.P.; N.Z. 3938 B).
41.0 – 43.58	shingle.
43.58 – 54.56	sand.
54.56 – 59.44	clay.
59.44 –	sand.

BORE NUMBER 2: Whitebait Creek, Foxton Beach. Approx. N148/762218
Surface 5 m above m.s.l.

Depth (metres)	
0 – 2.7	sand.
2.7 – 9.1	sand, silt.
9.1 – 28.6	sand, shell.
28.6 – 33.3	sand, gravel.
33.3 – 37	sand, gravel, shell.
37 – 37.3	metal.
37.3 – 57.1	sand, shell.
57.1 – 59.8	gravel.
59.8 – 60	blue clay.
60 – 64.2	metal.

BORE NUMBER 3: N148/796206
Surface 3 m above m.s.l.

Depth (metres)	
13.1 – 34.5	sand, shell.

BORE NUMBER 4: N148/763214
Surface less than 15 m above m.s.l.

Depth (metres)	
54.3 – 60	shingle/silt/clay mixture, shells.

BORE NUMBER 5: N152/843193
Surface approx. 6 m above m.s.l. (± 1.5 m)

Depth (metres)	
31.40 – 46.32	clay bound sand and shells.

BORE NUMBER 6: N149/038808
Surface approx. 19 m above m.s.l.

Depth (metres)	
88 – 92.1	sand, silt, shell.

BORE NUMBER 7: N149/020298
Surface approx. 15 m above m.s.l.

Depth (metres)	
76.4 – 76.1	sand, wood, pumice.

BORE NUMBER 8: N149/018284
Surface approx. 12 m above m.s.l.

Depth (metres)	
at 84.3 – 96.0	sand, shell. Whole *Chione* valves well preserved; *Macomona* sp. fragments.

BORE NUMBER 9: N152/784093
Surface approx. 21 – 24 m above m.s.l.

Depth (metres)	
0 – 99.1	sand.
99.1 –	blue rock.

BORE NUMBER 10: N152/784102
Surface approx. 21 – 24 m above m.s.l.
Solid rock encountered at 40 m.

BORE NUMBER 11: MOUTERE ROAD, LEVIN. N152/748046 – N152/754066
Surface approx. 15 – 18 m above m.s.l.

Depth (metres)	
0 – 0.6	sandy topsoil.
0.6 – 1.2	clay, gravel.
1.2 – 1.8	peat.
1.8 – 2.7	clay, gravel.
2.7 – 14.6	sand.
14.6 – 15.2	sand, stones.
15.2 – 15.8	clay, gravel.
15.8 –	shattered rock.

BORE NUMBER 12: Surface approx. 15 – 18 m above m.s.l.
Located within 200 m of Bore No. 11.

Depth (metres)	
0 – 7.0	sand, clay, peat.
7.0 – 9.1	sand, gravel.
9.1 – 9.4	gravel.
9.4 – 10.6	blue clay, gravel.
10.6 – 10.9	gravel, sand.
10.9 –	solid blue rock.

BORE NUMBER 13: SAND ROAD, HOKIO. Approx. N152/744029
Surface approx. 9 – 15 m above m.s.l.

Depth (metres)	
0 – 32.1	sand.
32.1 –	blue rock.

NOTE: Over 200 bore records were examined. Those included above illustrate specific points in the text. Mr H. Smith provided the records for bores 1 and 4; the Manawatu Catchment Board for bores 2, 3, and 5–8; and Mr N. Webb for bores 9–13. A more comprehensive description of bore logs can be seen in Hesp (1975).

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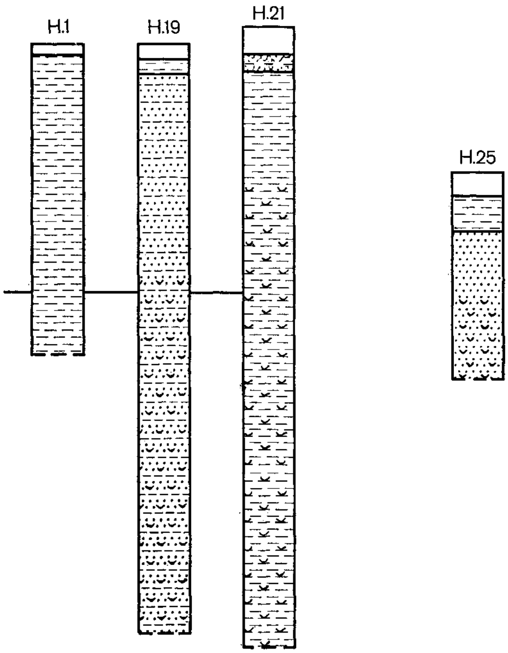

different areas of the world have been discussed by Thom & Chappell (1975) who consider that these differences are caused by "global isostatic processes".

The absence of Holocene estuarine beds in the southern Manawatu area at altitudes above the present high-tide level offers no support for the idea that sea levels have been appreciably higher than at present during the Holocene. In the light of this conclusion, we re-examined the Holocene marine cliff extending southwards from the Otaki River which has been described by Te Punga (1962) as providing evidence for a +3 m Holocene sea level. By levelling and drilling a profile from the sea, (N157/626847) to the cliff (N157/656837) the authors determined that the gravel beach ridge at the foot of the Holocene cliff and all subsequent gravel beach ridges are lower than the active gravel storm ridge behind the present beach. This evidence invalidates Te Punga's (1962) claim that Holocene sea levels have been higher than present in this area.

Age of the Levin Anticline

Te Punga (1954b, 1957) considered the Levin Anticline to be of "extreme youth" because it lacked the development of buckshot gravels which cap anticlines in northern Manawatu. One box-shaped valley (near Koputaroa, Fig. 2B) extends from the floodplain to within approximately 250 m of the axis of the Levin Anticline, (20 m above mean sea level at this location) and lies at right angles to the fold axis. It was considered that a longitudinal profile of the valley floor would provide an indication of maximum uplift rates. In a distance of 1·4 km from the floodplain to the abrupt valley head, the valley floor rises only 4 m, and at least the uppermost 2 m of fill are alluvial deposits. (Other longer box-shaped valleys in the Shannon area rise only about 1 m in their lowermost 1·4 km, although more filling has occurred near their heads.) Assuming the valley floor was flat 6000 years ago, (i.e., filled to about the high tide level), maximum local uplift of only 0·33 m per 1000 years near the axis of the anticline is indicated. If the assumptions upon which this calculation is based are correct, the Levin Anticline is at least 60 000 years old.

CONCLUSION

During the last glaciation the lower portions of the Manawatu and Oroua Rivers appear to have deposited coalescing gravel fans which were subsequently drowned and buried by sediment during the Postglacial Transgressions. A major estuary existed in the present Manawatu flood plain, while many valleys within the Tokomaru Marine Terrace became branches of the estuary. Subsequent filling with estuarine and fluvial sediment led to the formation of the flood plain and adjacent box-shaped valleys.

ACKNOWLEDGMENTS

The authors wish to thank Dr J. L. McArthur (Geography Department, Massey University, Palmerston North), for his help and advice during the course of this work, and Dr V. Neall (Soil Science Department, Massey University, Palmerston North), for his comments on the manuscript. We also thank Dr A. G. Beu (N.Z. Geological Survey, Wellington), for the identification of shell species and discussion of their environments; Dr B. P. J. Molloy (Botany Division, DSIR, Christchurch), for identification of the dated log of wood; the Manawatu Catchment Board, Mr H. B. Smith (Taikorea), and Mr N. Webb (Levin), for the provision of bore logs; the Department of Geography, Massey University, for equipment; and Mrs V. J. Hesp, Mr W. McGuire and Mr D. Grinlington for their invaluable assistance in the field.

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