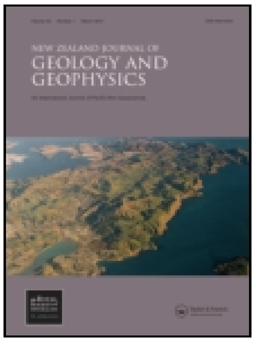

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LATE HOLOCENE MARINE FEATURES ADJACENT TO PORT NICHOLSON, WELLINGTON, NEW ZEALAND

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ABSTRACT

Raised beaches preserved around Port Nicholson and along the southern Wellington coast can be correlated with uplifts that occurred in A.D. 1855 and *c.* A.D. 1460. Records of older movements of base level are also preserved, correlated with either eustatic sea-level fluctuations or tectonic activity. The raised beaches are mapped and described. The evolution of the Hutt Valley and Miramar Peninsula is discussed.

INTRODUCTION

As noted by C. A. Cotton in numerous publications (e.g., 1921b; 1957) the landscape of Wellington Peninsula is largely a product of tectonic activity associated with uplift of the axial ranges of the southern North Island (Rimutaka, Tararua and Ruahine Ranges). Such tectonic activity has had a marked effect on coastal features (e.g., Stevens 1969; Wellman 1967) and a number of localities adjacent to Port Nicholson (Fig. 1) show successions of late Holocene beach ridges. The 1855 earthquake, the most recent of the tectonic events to affect the Wellington Peninsula, caused uplift of the youngest stranded beach ridge, and by analogy, other, higher, ones have probably been uplifted during earlier earthquakes.

In describing the beach ridge profiles all the altitudes have been expressed in terms of the mean sea level (m.s.l.) established by the Department of Lands and Survey, which within Port Nicholson is 0·6 m below mean high water level (tidal range *c.* 0·9–1·2 m). On the open coast of southern Wellington the tidal range is greater: e.g., 1·8–2·1 m at Pencarrow; 1·5–1·8 m at Palmer Head (Fig. 1) and these and other local variations have been taken into account in calculating m.s.l. where appropriate.

The raised beaches studied in this paper are storm beaches, formed some distance above high-tide mark, the exact distance depending on the degree of exposure of the coastline. A distinction has, therefore, been made between beach ridges formed on the open coast and those formed within Port Nicholson, as the former were presumably driven up to a greater height above sea level.

Marine benches have also been studied. These are platforms cut by the sea across bedrock and probably in most instances they were veneered with sediment, now removed by erosion. By analogy with modern shore profiles the benches were cut below the intertidal zone.

Many of the beach ridges have now been destroyed or concealed by shingle removal operations, housing and roading. For example, little evidence

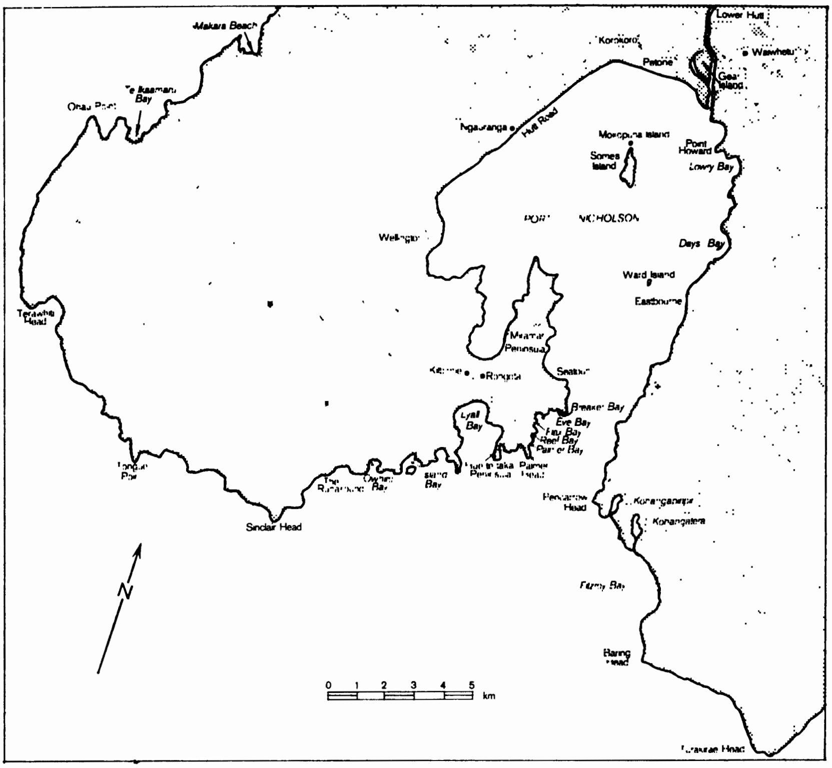


FIG. 1—Map of Wellington Peninsula, showing positions of localities mentioned in the text.

now remains even of the latest earth movement, that of 1855. Use has been made, however, of observations recorded by the late G. L. Adkin, New Zealand Geological Survey, who with great thoroughness surveyed many of the key localities prior to their destruction.

PORT NICHOLSON

Petone (Fig. 2–6)

The surface of the Hutt delta in the Petone area is virtually featureless except for local low-lying areas (formerly swamps) and filled-in or partly filled-in ox-bow lakes, the traces of abandoned courses of the Hutt River. A single well-defined low ridge can however be traced across the delta surface some 150–250 m north of Jackson Street, Petone (Fig. 2). This feature, called locally "The Rise" or "The Hump", has over the years been regarded by local people as the remnant of an old stopbank, built in

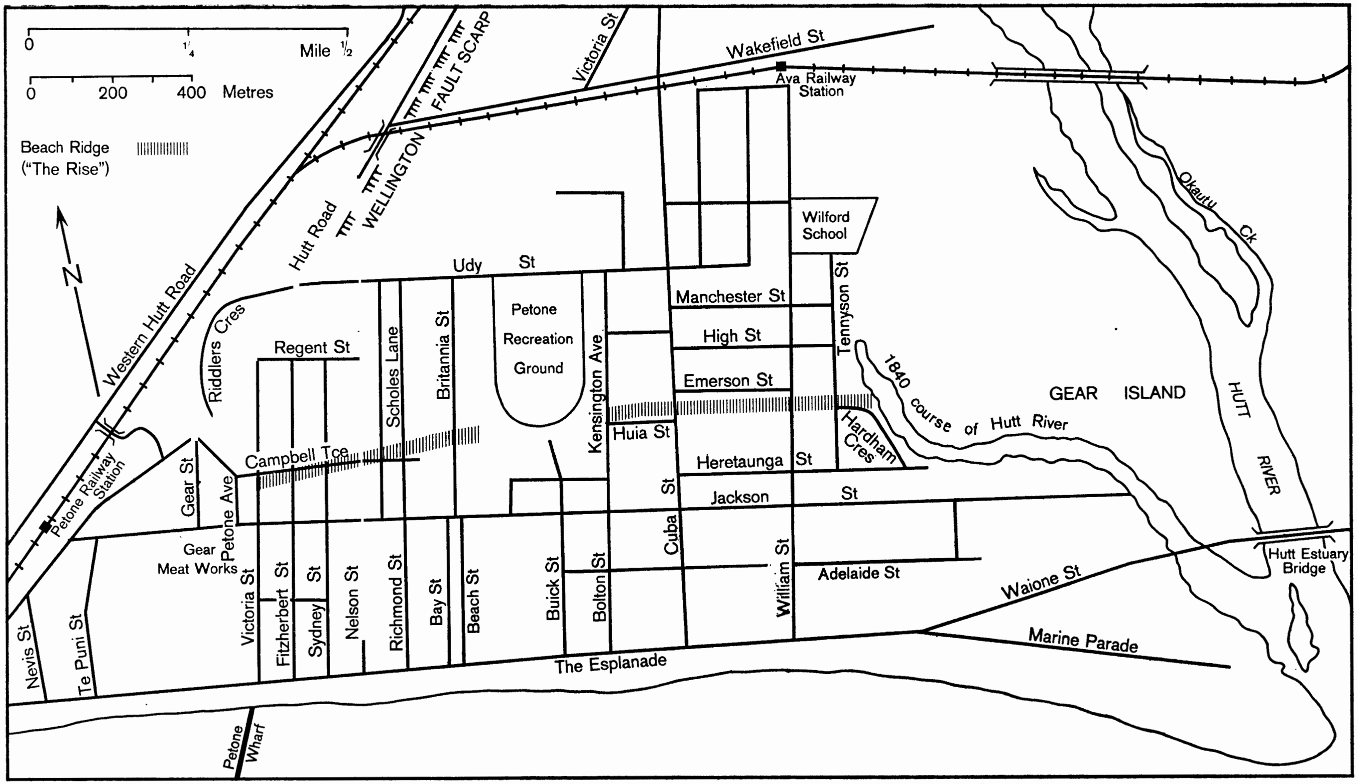


FIG. 2—Map of Petone showing the course across the valley floor of the beach ridge "The Rise", illustrated in Fig. 3–6. Topographic base from NZMS 17 (Hutt Valley), Department of Lands and Survey.

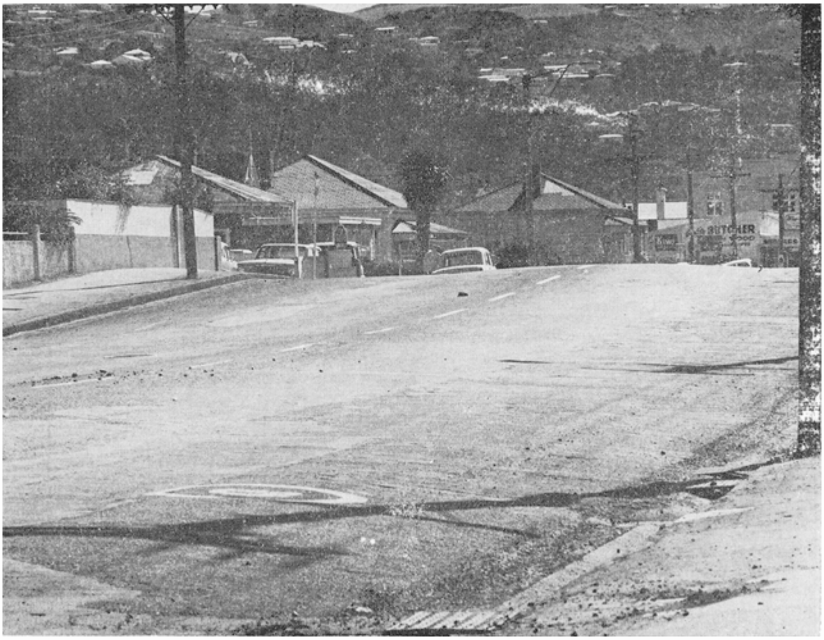


FIG. 3—View of "The Rise" at Cuba Street, Petone, looking approximately northwards.
S. R. Currie photograph

the early days of settlement to protect Petone from flood waters overflowing from the Hutt River (*Evening Post,* 26 December 1970, p. 10; *Hutt News,* 27 January 1971, p. 19).

"The Rise" forms a prominent hump in Cuba and William Streets (Fig. 3, 4). Tennyson Street and Kensington Avenue have been cut through the feature, and Cuba Street will do likewise in the near future. Nicholson (1940, p. 52) recorded that "The Rise" originally extended across the entire width of Petone. Today "The Rise" can be traced fairly readily in the residential areas of eastern Petone, but it has been virtually erased in the many industrial properties in areas towards the west. There is no trace of "The Rise" or any other similar features, on the valley floor east of the Hutt River (i.e., in the Moera district).

"The Rise" commences at Hardham Crescent, at the edge of the 1840 course of the Hutt River (Fig. 2, 16) and can be traced continuously westwards to just short of Kensington Avenue. In this area the relief of "The Rise" varies between 1·5 and 1·8 m.

Westwards from Kensington Avenue "The Rise" has been destroyed by development of the Central Institute of Technology and the Petone Recreation Ground. It appears, however, immediately west of the Recreation Ground, in the grounds of Petone Central School in Britannia Street, and

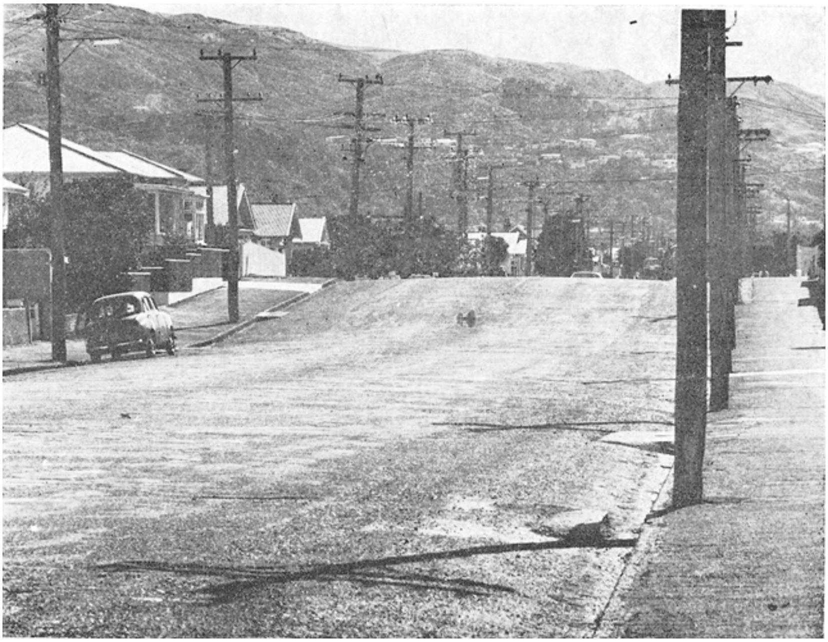


FIG. 4—View of "The Rise" at William Street, Petone, looking approximately northwards.

S. R. Currie photograph

can be traced diagonally across Campbell Terrace as far as Victoria Street and Petone Avenue, where it passes into the flank of an alluvial fan built out across the valley floor by the Te Tuara-whati-o-Te Mana Stream, draining the Korokoro area (Adkin 1959, pp. 89, 126). Near Britannia Street "The Rise" has relief of 0·9–1·2 m and at Campbell Terrace, 0·6–0·9 m.

Excavations for Britannia Court Flats, between Britannia Street and Campbell Terrace, extending some 1·2–1·5 m below the ground surface, showed that "The Rise" in this area is composed solely of imbricated, fairly even-sized pebbles of greywacke sandstone (25–50 mm diameter, but some up to 100 mm). Temporary sections through "The Rise" in the Cuba Street–Tennyson Street area (Stevens 1955 pp. 277–278) showed it to be composed of gravels with concentrations of disarticulated, but otherwise entire, shells of *Chione* (*Austrovenus*) *stutchburyi* (Gray), *Amphidesma australe* (Gmelin) and *Amphibola crenata* (Martyn).

In mid 1971 and early 1972 trenches were cut across "The Rise" in Cuba and William Streets. The Cuba Street trench was 2·4–2·7 m below the surface of the road on the crest of "The Rise", where the ridge is composed of alternating beds of fine gravel (up to 6 mm diameter) and coarse gravel (up to 25 mm diameter). The gravel was rusty but otherwise fresh. The only matrix is a little sand. Bedding dipped clearly down towards the

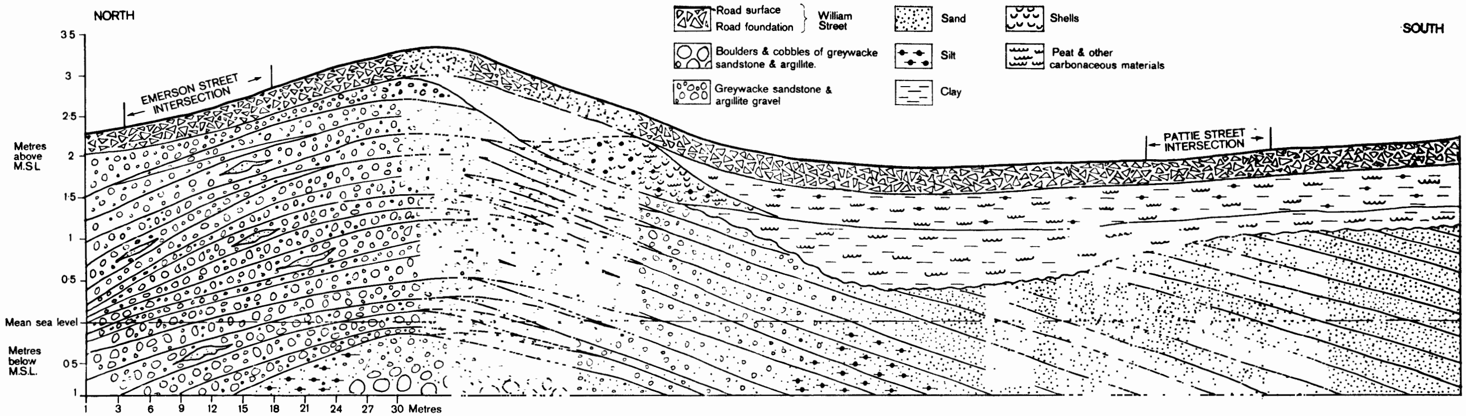


FIG. 5—Diagrammatic view of a section across "The Rise" exposed in a sewerage trench extending along the centre-line of William Street, Petone. Survey details by courtesy of the Petone Borough Council.

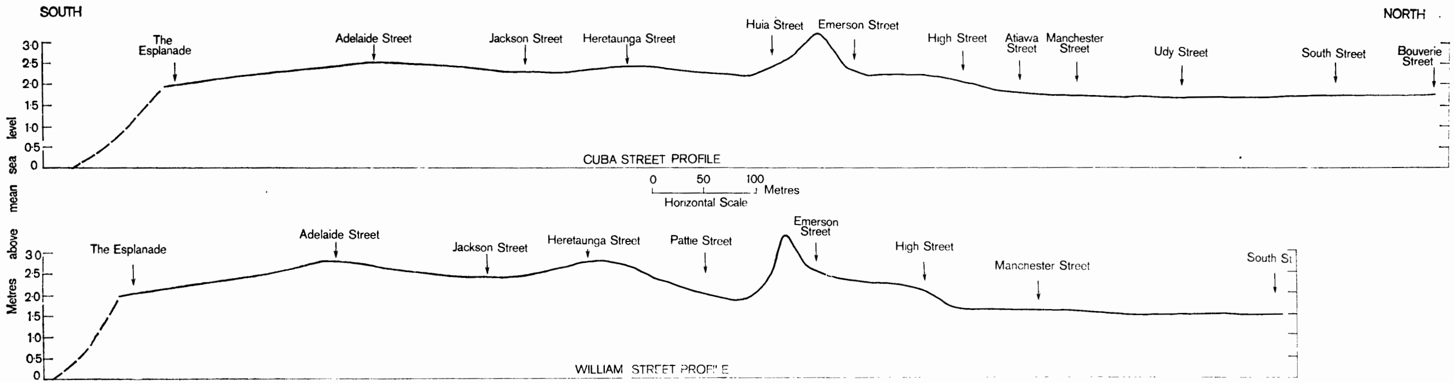


FIG. 6—Surveyed north–south profiles across Petone extending along Cuba Street (upper profile) and William Street (lower profile), refer to Fig. 2. locality map. The arrows along the profiles indicate the centre lines of the streets named. Note the presence of three topographic "highs"—a very marked one to the north ("The Rise"), possibly representing a high sea level; one at Heretaunga Street, interpreted as being a beach ridge left stranded by earth movements accompanying the Hao-whenua Earthquake, *c.* 1460; and one at Adelaide Street, interpreted as being the 1855 storm beach. Based on surveys made by the Petone Borough Council.

south at about 25°. Imbrication was observed in the gravels. Rounded greywacke sandstone cobbles and boulders, up to 300 mm diameter, were encountered in the floor of the trench.

Twigs found in the gravel deposited on the seaward flank of "The Rise" at Cuba Street, at about mean sea level, gave a radiocarbon date of 1855 ± 155 years B.P. (N164/f615; NZ 1579).

To the north of "The Rise", extending along Cuba Street, gravel was encountered in the floor of the trench (0·1–0·3 m below m.s.l.) to a point half way between High and Atiawa Street, but further north gravel gave way to blue-grey silt and clay. South of the crest of "The Rise", increasing amounts of sand appeared, mixed with the gravel, but no silt or clay.

The gravel pebbles consist of greywacke sandstone (some veined) and argillite, poorly sorted, round to sub-angular in shape (P.R.L. Browne pers. comm.). The finer material consists of angular weathered rock fragments, angular crystals of quartz, and rare albite, microcline and hornblende crystals.

The William Street trench (Fig. 5) reached 4·2 m below the crest of "The Rise" (0·85 m below m.s.l.) and showed bedded, well-sorted greywacke sandstone gravel, with rare lenses and stringers of sand. The gravel is rusty but otherwise fresh and is composed of well-rounded clasts, ranging between 25–50 mm in diameter. Well-defined bedding dips 25° S on the southern flank of "The Rise" and 15–20° N on the northern flank. Immediately under the crest of "The Rise" the trench bottomed in blue-grey silty sand, that graded downwards and southwards into a concentration of gravel, cobbles and boulders ranging in size up to 300 mm diameter.

On the southward (seaward) flank of "The Rise" at William Street lensoid deposits of sand and shell are developed. The sand deposit is light golden brown in colour, quite loose, well-sorted, and consists predominantly of quartz and minor feldspar crystals and weathered rock fragments (P. R. L. Browne pers. comm.). The sand is up to 0·4 m thick, and the shell bed, which is composed of disarticulated aragonitic shells of *Chione (Austrovenus) stutchburyi* (Gray) and *Amphidesma australe* (Gmelin), is up to 0·7 m thick. The shells are usually entire, randomly orientated, and include both adults and juveniles. They are set in a dark brown matrix (the colour being presumably due to staining by organic matter) of fine evenly sorted loose sand composed of poorly-sorted angular quartz and partly weathered rock fragments (P. R. L. Browne pers. comm.) The sand and shell lenses give way southward to layers of peaty clay and carbonaceous silt, overlying loose blue-grey sand.

The entire rampart-like feature of "The Rise" may be identified as a storm beach ridge relating to a former sea level, probably some 2·5 m above modern m.s.l. The lens of shell material probably formed part of a shelly beach that has now been raised by tectonic movements to a height 2·3–1·5 m above m.s.l.

The shellbed has been stained by organic material, probably associated with soil formation, thus indicating an elapse of time before deposition of the overlying fresh well-sorted sand. The sand may be a patch of dune sand blown inland onto the seaward flank of "The Rise" from the dune belt that was originally immediately adjacent to the 1840 beach (Ward 1928, p. 39).

Samples of *Chione* and *Amphidesma* from the shell bed exposed in the trench gave radiocarbon ages of 2350 ± 70 years B.P. (N164/f613; NZ1577; sample from basal layer of shellbed, 2·1 m above m.s.l.) and 2350 ± 70 years B.P. (N164/f614; NZ1578; sample from uppermost layer of shellbed, 2·4 m above m.s.l.) A sample of the peaty clay, taken from a point immediately on the seaward side of the shell bed, 36 m north of the Pattie Street intersection and 1·0 m above m.s.l. gave a radiocarbon age of 460 ± 55 years B.P. (N164/f616, NZ1580). The shells, as they are of estuarine types, may, because of carbon isotopic fractionation in an estuarine environment, yield a radiocarbon date slightly older than that obtained from wood (T. L. Grant-Taylor pers. comm.).

Between "The Rise" and the sea, a distance of 600 m, the surface of the land has been considerably modified and is virtually featureless. Levelling profiles do however reveal two topographic "highs" (Fig. 6). One, at Heretaunga Street, has its crest 2·8 m above m.s.l. and its base 2·45 m; the other, at Adelaide Street, has its crest 2·7 m above mean sea level and its base 2·35 m. These two "highs" may represent the sites of former beach ridges, now considerably modified, but evidence from excavations is needed before this possibility can be verified.

T. L. Grant-Taylor (pers. comm.) has a record of a gravel beach, now destroyed, in the vicinity of Adelaide Street, east of Cuba Street, and this may correlate with the southernmost "high" in the levelling profile (Fig. 6).

"The Rise" figures in the early history of the Hutt Valley. "Britannia", the first settlement established by the early settlers, was sited at the junction of Moreing's Creek (= Moran's Creek) and the Hutt River (Fig. 16). In March 1840, the settlement was badly flooded by the Hutt River, with the result that many people shifted further south to what was described as "an elevated shingly ridge" (Nicholson 1940, p. 40). The street of houses that was built along the ridge was called "Cornish Row", as most of the inhabitants were of Cornish origin. Cornish Row had a short life however, as it was destroyed by fire on 25 May 1840. To judge from the early settlers' descriptions and maps held by the Hutt Historical Society (the features of which are summarised in the fold-out map in Hall & Toomath 1941), the ridge on which "Cornish Row" was built is the feature now known as "The Rise".

After a particularly disastrous flood in 1893 a stopbank system was built to protect the Petone area, and "The Rise" was incorporated in this system (Nicholson 1940, pp. 66–68). An artificial stopbank was built to the north of Petone, in the Ava area (now incorporated in railway embankments), and from here it extended south-east to join "The Rise". The use of "The Rise" as part of the 1893 stopbank system has undoubtedly given rise to the common assumption on the part of many Petone residents that it is a remnant of an old stopbank and not a natural feature.

The relationship of "The Rise" to the original topography and vegetation of the Hutt Valley can be deduced from a panoramic view of the Hutt Valley painted by Charles Heaphy in 1840 (Stevens 1956a, p. 193, fig 4). Contemporary accounts describe the land between "The Rise" (i.e., "Cornish Row") and the sea as being occupied by sand dunes and swamp (Ward 1928, p. 39). Swamps and "low scrubby coppice wood" (Ward 1928, p. 39) were immediately to the north of "The Rise" and these passed northwards into heavy forest (Stevens 1956a, fig. 5). Nicholson (1940, p. 52) remarks that to the north of "The Rise" there is a marked change in the soil, deep alluvial soil being encountered, and Gibbs (1960 and pers. comm.) has mapped Foxton sand soils south of "The Rise" and Waiwhetu and Waikanae silt loam and sandy loam to the north.

Hutt Road

Stevens (1956a pp. 191–192) recorded rock platforms 2·4–3·0 m above modern m.s.l. and accordant summits of sea stacks on the rock platforms (presumably representing remnants of a still higher and older erosion level) 3·6–4·2 m above m.s.l. The rock platforms recorded here and elsewhere (see below) were presumably cut by the sea some distance below the intertidal zone and probably had an original thin veneer of sediments, now removed.

Stevens (1956a p. 192) also recorded the presence of marine shells and gravels at Ngauranga at a height of 3·0 m above m.s.l.

Somes and Mokopuna (= Leper) Islands

Stevens (1955, 1956a) recorded a ubiquitous shore platform of *c.* 1·5 m encircling both islands. Surmounting this platform are remnants of an older platform, 2·4–3·0 m above modern m.s.l., while above these platform remnants are scattered stacks with accordant summits 6·0 ± 1·5 m above m.s.l.

East Harbour

Raised shore platforms, caves, stacks and bay-head bars have been recorded from Point Howard, Lowry Bay and Days Bay (Stevens 1956a), all a result of the uplift accompanying the 1855 earthquake. No higher features, dating back to earlier movements, have been recorded.

Miramar Peninsula (Fig. 7, 8)

Three gravel bars (or beach ridges) marking successive phases of the infilling of the central valley of Miramar Peninsula were described by Crawford (1873; 1885) and mapped by Adkin (1959, fig. 1, 2). Although the entire area is now covered with houses, factories and roads, fragments of the three features can still be traced (Fig. 7, 8).

The northern ridge, immediately south of Miramar North School, lies at the foot of a truncated valley-side fan. Although rather ill-defined it is linear, attains a maximum relief of about 2 m, and its base is 5·8 m above modern m.s.l.

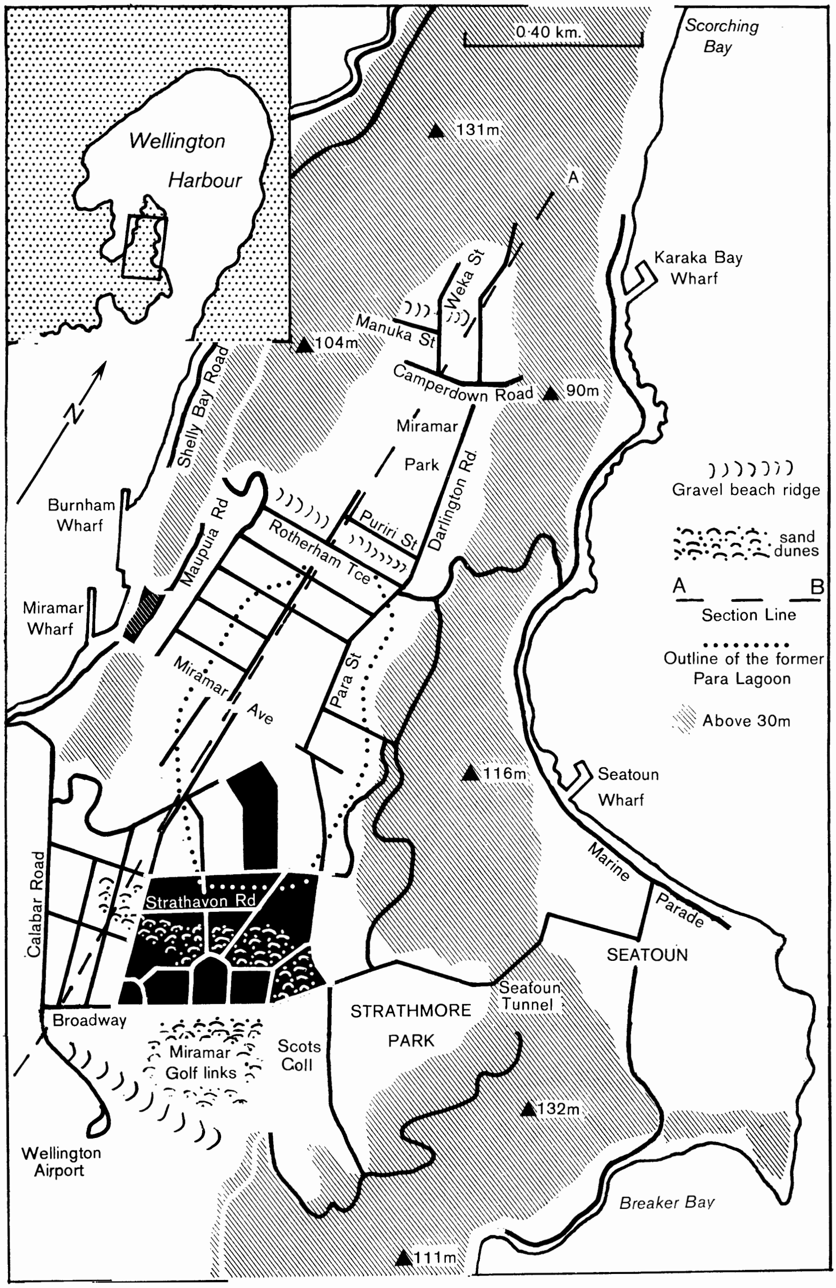


FIG. 7—Map of the central valley of Miramar Peninsula, showing the distribution of beach ridges and related features. The topographic base has been obtained from NZMS 17 (Wellington), Department of Lands and Survey.

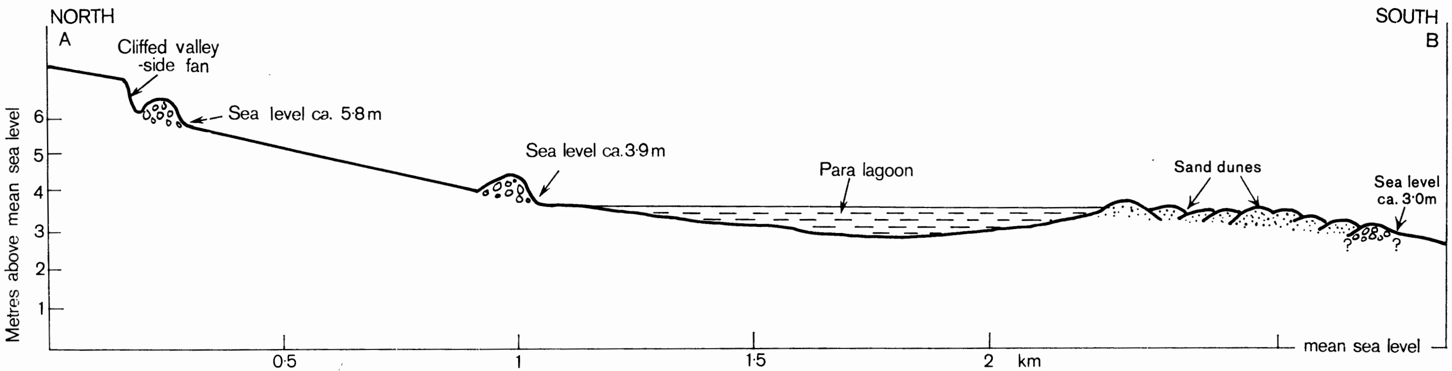


FIG. 8—Profile of the central valley of Miramar Peninsula, showing the distribution of beach ridges and related features. Levels obtained by Wellington City Council have been used in the preparation of the figure.

The second ridge, running between Rotherham Terrace and Puriri Street, although somewhat modified by urban development, is reasonably well-defined. It has about 1·8 m of relief and its base is 3·9 m above modern m.s.l. Along Rotherham Terrace it is composed of boulders and cobbles of greywacke sandstone and coarse gravel (I. W. Keyes pers. comm.)

The third and southernmost of the beach ridges recognised by Crawford and Adkin cannot be easily identified in the present-day topography. Adkin mapped it as extending across the entrance of Miramar valley, in the area now occupied by Wellington airport and the Miramar golf links. Earth-moving activities associated with the construction of Wellington airport have destroyed any traces of the beach ridge in that area, but low hillocks cross the Miramar golf links, extending from near the golf club pavilion in the direction of Scots College (Fig. 7). As these lie on the same line as Adkin's ridge (1959, Fig. 2) they are probably remnants of the once continuous beach ridge observed by Crawford and Adkin. This part of the golf links is about 3·0 m above m.s.l., which probably represents the approximate base of the beach ridge (Fig. 8).

Immediately to the north of the Miramar golf links a number of small ridges traverse that part of the floor of the Miramar valley west of Strathmore Park (e.g., in the vicinity of The Quadrant, Crawford Green, Strathavon, Kedah, and Caledonia Roads). However, all appear to be sand dune ridges, of irregular pattern, and are interpreted as together forming a dune belt, derived from the former shoreline adjacent to the beach ridge seen in the golf links (Fig. 7, 8).

Ponding of drainage between the dune belt and the Rotherham Terrace–Puriri Street beach ridge created a large lagoon, covering some 85 ha: Te Rotokura, or as the European settlers called it, Para Lagoon or Burnham Water. A tunnel to drain Para Lagoon was constructed in 1849 (Crawford 1873; Adkin 1959, p. 61).

SOUTH WELLINGTON COAST

Turakirae Head (Fig. 9)

The succession of raised beaches at Turakirae Head has been described by Wellman (1967; 1969) and Stevens (1969; 1973). To aid comparison with the other beach ridges described in this paper two adjustments have been made to Wellman's results: 1. As Wellman's measurements referred to the crest of each beach ridge, rather than the sea-cut notch at its foot, the beach heights have been adjusted to allow for their relief. The lowermost beach ridge, that stranded by the 1855 uplift, is generally low and for the purposes of this study its relief is regarded as negligible. The other, higher, beach ridges are however massive ramparts some 2 m high. 2. As Wellman's original measurements were based on mean high water level, adjustment to m.s.l. has been necessary, using 1·1 m as the tidal range for Turakirae (Wellman 1967, p. 125).

In Fig. 9 the beach heights have been adjusted to allow for their relief and relation to m.s.l.

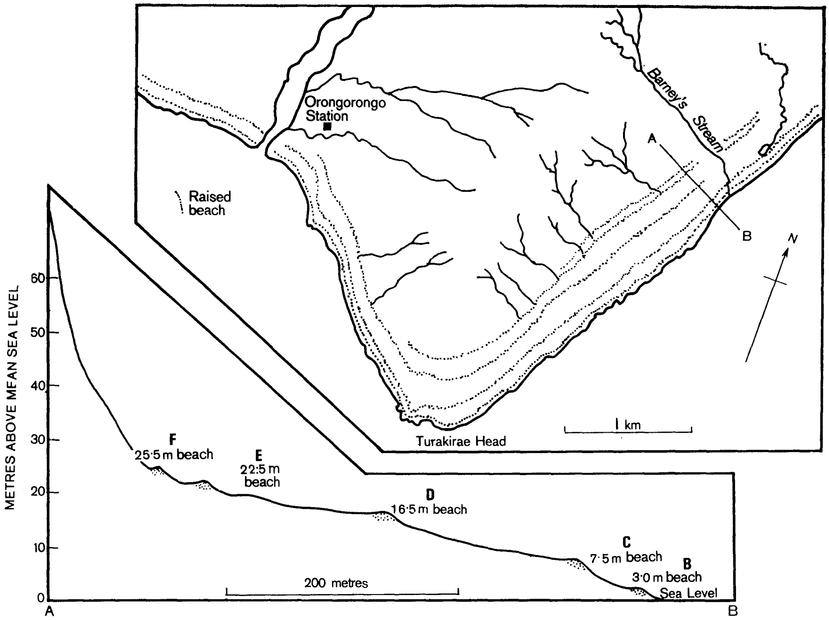


FIG. 9—Representative profile across the succession of raised beaches at Turakirae Head. Based on Wellman (1967). Topographic base from NZMS 2, Sheet N164/9, Department of Lands and Survey. The letters B–F refer to the notation applied by Wellman to the beach ridges.

Lakes Kohangapiripiri and Kohangatera (Fig. 10, 11)

Beach ridges are developed on the coast line of Fitzroy Bay, to the east of Pencarrow Head (Fig. 1) and, although extensively modified by removal of gravel, the succession is particularly well marked adjacent to Lakes Kohangapiripiri and Kohangatera (Fig. 10). Both lakes occupy the lower ends of drowned valleys. Caves, wave-cut cliffs, and sea stacks found along the valley sides indicate that the valleys were originally long narrow inlets of the sea. The presence of the drowned valleys was cited by Cotton (1921a; b) as part of his evidence for the formation of Port Nicholson by transverse deformation.

The drowned valley inlets were cut off from the sea, initially by the formation of shingle spits, but eventually by the accumulation of continuous gravel bars, that were widened by successive uplifts. Thus Kohangapiripiri and Kohangatera are now fresh-water lakes, normally draining to the sea by seepage through the shingle bar, but in times of flood sometimes flowing directly into the sea. An abandoned outlet stream of Lake Kohangatera is shown in Fig. 10, 11.

The levels and distinctiveness of the individual ridges at Kohangatera and Kohangapiripiri differ because the former is at a salient in the coastline and the latter at an embayment. The beach ridges at Lake Kohangatera

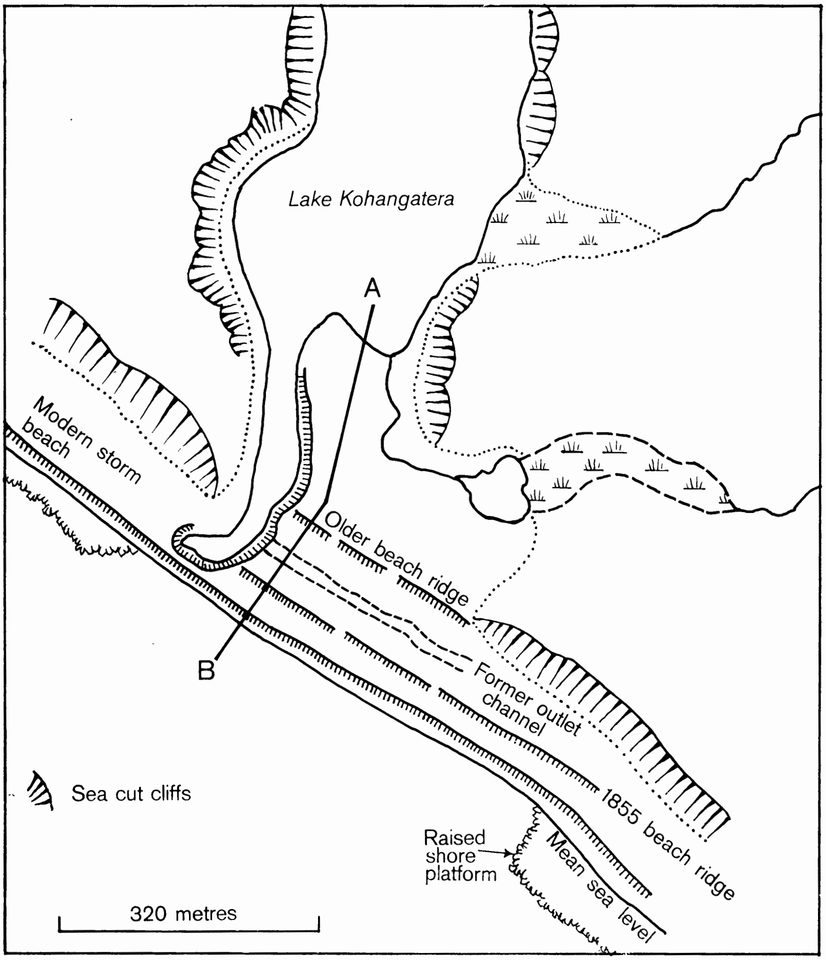


FIG. 10—Map of the raised beaches at Lake Kohangatera, as mapped by G. L. Adkin, 1956. A–B marks the line of section shown in Fig. 11.

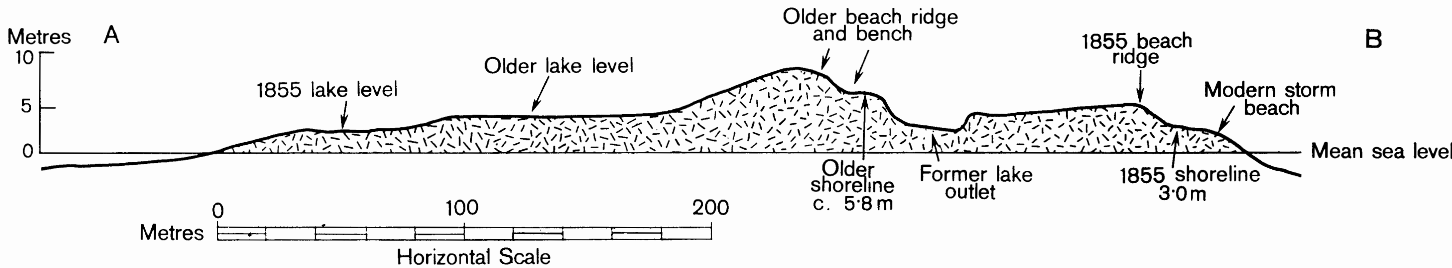


FIG. 11—Cross section of the raised beaches at Lake Kohangatera, as determined by G. L. Adkin, 1956, along the line A–B shown in Fig. 10. A survey by P. M. Otway in 1969 confirmed the essential features of the cross section.

(Fig. 11) are the better developed. The modern storm beach ridge is backed by a very high dome-shaped beach ridge that accumulated prior to the 1855 uplift. The base of the 1855 beach ridge is about 3·0 m above modern m.s.l. and its crest 4·5 m. Inland, another equally impressive beach ridge is present, separated from that of 1855 by an abandoned outlet channel of Lake Kohangatera. The base of this older beach ridge is 5·8 m above m.s.l. and its crest 7·6 m.

Baring Head, Fitzroy Bay, Pencarrow Head

Small remnants of raised beaches, presumably stranded by the 1855 uplift, are present at these localities and their heights above m.s.l. have been calculated, assuming m.s.l. to be 0·75 m below high tide level: Baring Head 2·85 m; eastern side of Fitzroy Bay 2·75 m; Pencarrow 2·55 m (cf. Fig. 18).

Breaker, Eve, Flax and Reef Bays (Fig. 12, 13)

A spectacular beach ridge along the south-east coast of Miramar Peninsula was stranded by the 1855 uplift. It has now been entirely destroyed by roading and housing. Before its destruction however, the beach ridge was recorded and photographed by G. L. Adkin (notebooks deposited in New Zealand Geological Survey; photo albums deposited in the Turnbull Library and National Museum) and photographed by C. A. Cotton (e.g., 1921a; 1922, fig. 412, 413; 1949, fig. 413; negatives held at New Zealand Geological Survey). Some of the photos taken at that time were published in Stevens (1973 fig. 13·8–13·6) and two are reproduced as Fig. 12, 13 of this paper. Adkin recorded the base of the beach ridge as being 2·4 m above m.s.l.

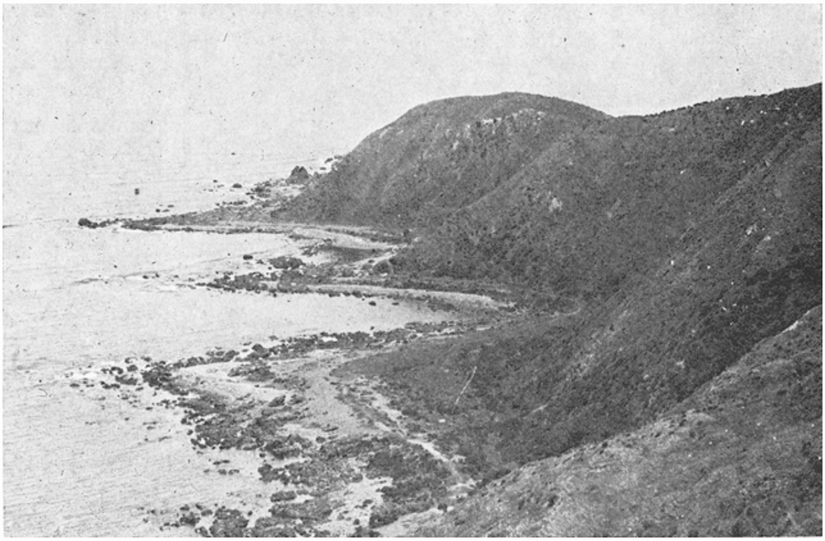
No higher beach ridges, apart from that of 1855, were recorded by Adkin or Cotton.

Palmer Head and Hue-te-taka Peninsula* (Fig. 14, 15)

Beach ridges preserved at the southern extremity of Miramar Peninsula (at Palmer Head and Hue-te-taka Peninsula) were mapped by G. L. Adkin (unpublished field notes at New Zealand Geological Survey); they have now been greatly modified by roading, housing and shingle removal operations. At Palmer Head (cross-section A–B, Fig. 15), a modern gravel storm beach with its crest at about 1·9 m and its base 1·2 m above m.s.l. is well-developed. Further inland the gravel storm beach left stranded by the uplift accompanying the 1855 earthquake has its crest at about 4·5 m and its base 2·4 m above m.s.l. Further inland again, at the rear of the coastal platform, a boulder beach, some 3·8 m above m.s.l., and wave-cut stacks lie at the foot of a cliff whose base has been trimmed by wave action.

At Hue-te-taka Peninsula (Section C–D, Fig. 15) the coastal profile shows a modern storm beach with its crest at about 1·8 m above m.s.l., and 1855 storm beaches, with their bases at about 2·4 m above m.s.l., encircling a large stack, which is thought to have been trimmed at the same time as the boulder beach at the back of the coastal platform at Palmer Head (Section A–B, Fig. 15).

*Hue-te-taka Peninsula is a local Maori name (see Adkin 1959, p. 22).



C. A. Cotton photograph

FIG. 12—Photograph, taken about 1919, of Eve Bay (foreground), Flax Bay (centre) and Reef Bay (background), on the southeastern extremity of Miramar Peninsula (Fig. 1). The gravel beach left stranded by the uplift accompanying the 1855 earthquake shows as a white strip parallel to the modern coastline (cf. Fig. 13). Note the rocky sea-cut coastal platform that was exposed at the same time. Houses and the Breaker Bay Road now cover and obscure both the coastal platform and the storm beach (cf. Stevens, 1973, fig. 13·8–13·16).

Thus, at Palmer Head and Hue-te-taka Peninsula the 1855 beach is well developed, and remnants of a higher, older beach are preserved. The 1855 beach, with its base 2·4 m above m.s.l., is composed of gravel and sand and is a storm beach, formed slightly above the then existing high tide level. The older beach remnants, on the other hand, are boulder accumulations that probably were deposited between tide marks or below. They, therefore, probably represent boulder beaches that, at the time of their formation, were largely covered by high tide at least. If this assumption is correct, the sea level to which they relate was probably 3·8 to 4 m above modern m.s.l. This pre-1855 beach, although of similar altitude to the beach between Rotherham Terrace and Puriri Street, Miramar (Fig. 8, 17), may correlate with the beach ridge in the Miramar golf links (see above, Fig. 8), with the 0·8 or 1·0 m difference between the two representing variation in beach levels on exposed and sheltered coastlines.

Lyall Bay

Crawford (1873) records the presence of a large raised beach, presumably the one left stranded by the 1855 uplift, facing Lyall Bay. Adkin, in his notebooks (presumably on the basis of observations made in the 1920s), recorded the height of the 1855 beach as *c.* 1·8 m above m.s.l. This beach has now been completely destroyed.

C. A. Cotton photograph

FIG. 13—Photograph, taken about 1919, of the 1855 gravel storm beach and exposed sea-cut rock platform. Reef Bay, Miramar Peninsula (cf. Fig. 1, 12).

The Runaround

The southern Wellington coast extending some 4–5 km to either side of Sinclair Head is spectacularly cliffed, and in many places extensive talus slopes extend from the hill-crests down into the sea. Although similar in this respect to the Turakirae coast, a high rate of tectonic uplift at Turakirae has led to the creation of a broad coastal plain (Cotton 1969), whereas in the Sinclair Head region a régime of active cliff-cutting has continued. Raised beaches are, therefore, not easily preserved. However, in 1947 Adkin recorded (unpublished note books, New Zealand Geological Survey) a fragment of cemented beach gravel, now destroyed, attached to the cliff face in the vicinity of The Runaround (grid ref. N164/305142). Assuming m.s.l. to be 0·75 m below high tide level, the beach gravel was about 3·75 m above m.s.l. Rock platforms in the area show two levels: 1·95 m and 2·85 m above m.s.l. The lower level probably relates to the 1855 uplift. The upper level may represent the rock-cut bench on which the fragment of cemented beach gravel was originally deposited.

Tongue Point and Terawhiti Head

Remnants of shingle beaches developed above modern high tide level are found in the vicinity of Tongue Point and Terawhiti Head. The bases of the beaches appear to be respectively some 2·0 and 1·5 m above m.s.l. but possible confusion with the modern storm beach is difficult to resolve.

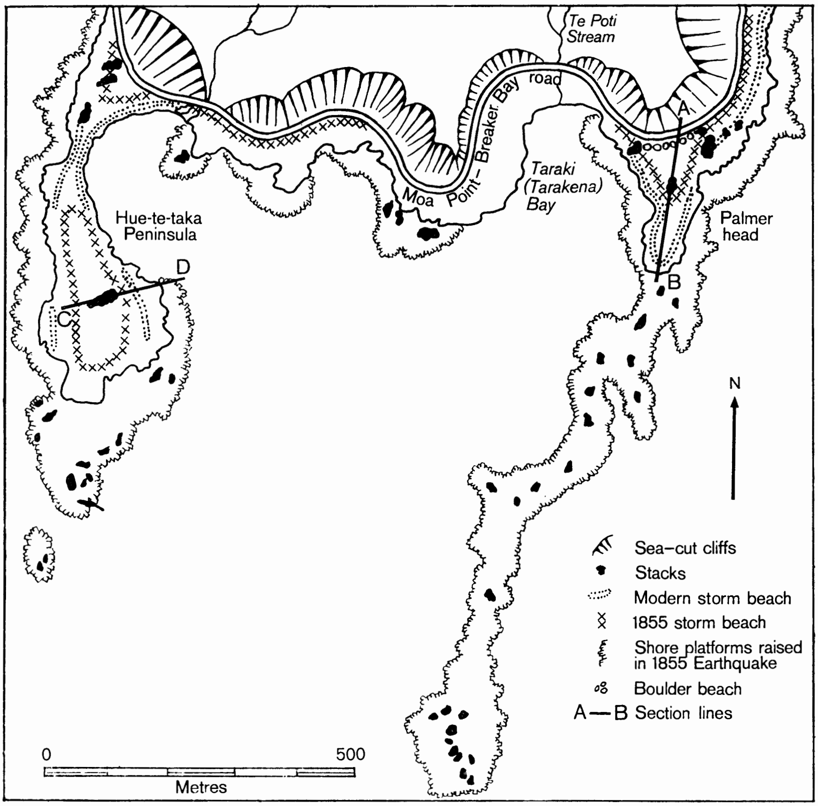


FIG. 14—Sketch map of beach ridges and other topographic features developed in the vicinity of Palmer Head, at the southern extremity of Miramar Peninsula (Fig. 1). Topographic base from NZMS 2, Sheet N164/5, Department of Lands and Survey. Based on unpublished observations by G. L. Adkin (1947, 1955, 1956), supplemented by the author. Many of the raised beach features shown on this map have now been destroyed or considerably modified. Cross sections A–B and C–D are illustrated in Fig. 15.

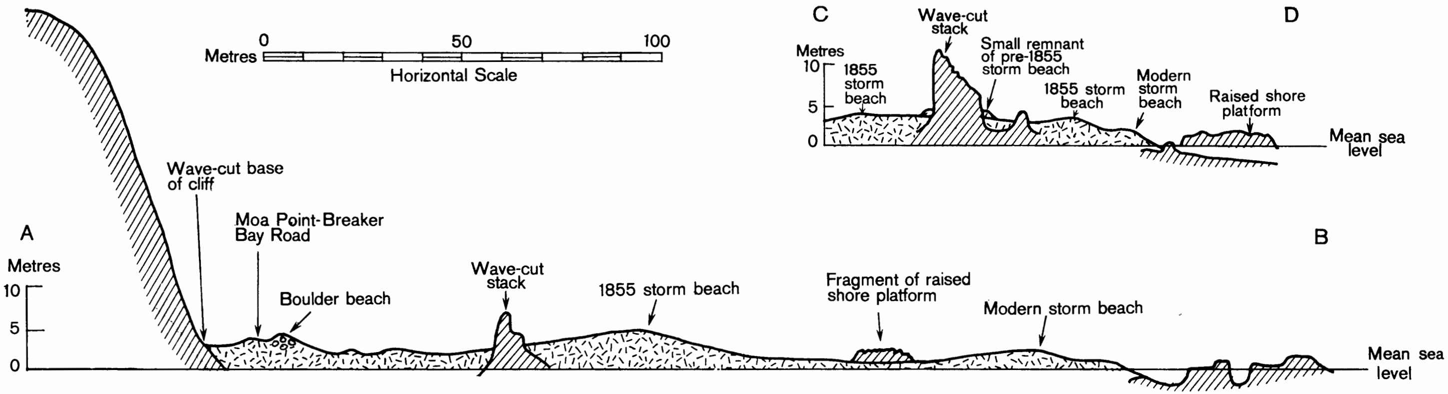


FIG. 15—Cross sections through the coastal platforms at Palmer Head (A–B) and Hue-te-taka Peninsula (C–D). See Fig. 14 for location of section lines. Based on unpublished observations by G. L. Adkin (notebooks held by N.Z. Geological Survey).

The heights of 2·0 and 1·5 m are used in Fig. 17, as they appear to agree with the trend line extrapolated from the other localities on the south Wellington coast.

SUMMARY OF EFFECTS OF THE 1855 EARTHQUAKE

The tectonic effects accompanying the 1855 earthquake have been documented by Travers in Hector (1875), Field (1892), Bell (1910), Adkin (1921), Ongley (1943), Stevens (1956a, 1973) and Leamy (1958). Much of the deformation in Wellington was due to movement along the southern part of the West Wairarapa Fault in the Wairarapa valley. Movement amounted to a maximum of 2·7 m vertical and 12 m horizontal and the entire Wellington region west of the fault was uplifted, the amount of uplift decreasing westwards (Stevens 1956a; 1969; 1973) (Fig. 17).

The uplift drained much of the low-lying land adjacent to Port Nicholson, in both Wellington City and the Hutt Valley, exposed the shore platforms around the entire harbour coastline, and extended the front of the Hutt delta for a distance from 30 to 100 m, depending on the shore profile, related to the distance from the mouth of the Hutt River, the major source of sediment (Stevens 1956a) (Fig. 16). Prior to the uplift, the Hutt River was navigable as far as Maoribank (Upper Hutt) and shipyards were sited on both the Waiwhetu Stream (at White's Line) and the southern tip of Gear Island (Fig. 16A). The uplift considerably shallowed the Hutt River and Waiwhetu Stream and made them unsuitable for navigation. Judging from pre-1855 survey plans (Nicholson 1940, p. 32; fold-out map in Hall & Toomath 1941), the 1855 shoreline was in the vicinity of Adelaide Street (Fig. 2), coinciding with the topographic "high" noted in Fig. 6 and the gravel beach recorded in this paper. Adelaide Street is taken as being the approximate position of the shoreline immediately before the 1855 earthquake.

CORRELATION OF BEACH RIDGES AND CHRONOLOGY OF PRE–1855 EARTH MOVEMENTS

1. *Beach Ridge C and Correlatives*

At Turakirae Head, Wellman (1967; 1969) interpreted each of four pre–1855 raised beaches as resulting from discrete uplifts within the past 5600 years. Ward (1971), however, has interpreted the raised beaches as recording continuous uplift, combined with fluctuations in sea level.

Above the 1855 beach ridge, Wellman mapped a beach ridge (Beach Ridge C) (Fig. 9) that he inferred to have been stranded by an uplift 600 years ago. Wellman's Beach Ridge C is the only beach ridge at Turakirae Head containing Taupo pumice (last eruption A.D. 130; Healy *et al.* 1964), lumps 0·30 m in diameter are fairly common. In view of the size of the lumps, and the rocky nature of the strips of exposed sea floor between the beach ridges (forming effective barriers to movement of materials between beach ridges) it is assumed that the pumice was deposited sometime during the formation of Beach Ridge C, and not cast up from a later, lower beach line.

The topographical "high" at Heretaunga Street, Petone (Fig. 2, 6) is correlated with Beach Ridge C. Support for this possibility comes from the radiocarbon date of 460 $\pm$ 55 years (see Port Nicholson, above) obtained from peaty materials, presumably formed in a swamp between "The Rise" and the Heretaunga Street "high", and the presence of lumps, up to 120 mm in diameter, of Taupo pumice in gas main trenches at the intersections of Jackson Street with Bay and Beach Streets (Fig. 2) (identified by B. P. Kohn, Victoria University of Wellington). These records of pumice are the only confirmed ones from Petone, but pumice may underlie the Shandon golf course, close to the eastern end of Jackson Street (Stevens 1955, p. 233). Thus in Petone pumice seems to be confined to a belt between the Heretaunga Street and Adelaide Street topographic "highs".

The southernmost of the Miramar beach ridges (i.e., that crossing the Miramar golf links; Fig. 7,8) is also tentatively correlated with Turakirae Beach Ridge C. As far as can be determined, the golf links beach ridge is the next highest beach above that of 1855 (identified as lying between Lyall and Evans Bays (see above). Crawford (1873; and in Smith 1881, p. 400) recorded the presence of pumice at the entrance to Miramar Valley, at a height close to that of the golf links beach ridge, and seawards of the beach ridge. The situation at Miramar appears similar to that at Petone: the site of deposition of Taupo pumice being apparently restricted to between the 1855 beach and the next highest (i.e., next oldest) beach.

It is concluded that the Turakirae Beach Ridge C can be identified at various localities along the southern Wellington coast (Fig. 17) and within Port Nicholson, at Miramar and Petone. Wellman (1967; 1969) has, by extrapolation from uplift rates, dated the movement that stranded Beach Ridge C as having occurred about 600 years ago. If it is assumed that the Miramar golf links beach ridge was uplifted during an earthquake, then that earthquake was probably the *c.* A.D. 1460 Hao-whenua earthquake, reported by Best (1918, 1919, 1923) from Maori genealogies, and accepted by Stevens (1955; 1956a; 1973; see also Eiby 1968, p. 20; Lensen, 1970; Dibble & Lensen 1970). Wellman's and Best's dates for the earthquake immediately prior to that of 1855 are thus in reasonable agreement.

The uplift associated with the 1855 earthquake tilted the Wellington shoreline by 20″ arc in a westerly direction. To judge from the above shoreline correlations, similar tilting, but about 1·5 times the angle, accompanied the Hao-whenua uplift (Fig. 17). Figure 17 suggests that the Hao-whenua uplift like that of 1855, was probably a result of movement along the West Wairarapa Fault. The stepped nature of the scarplet developed along the fault line (Ongley 1943) and progressive displacement of river terraces (Lensen & Vella 1971) provide evidence of earlier movements. This differs from the view of Wellman (1967; 1969), who postulated a different axis of tilting for the uplifts before 1855 (cf. Cotton 1969).

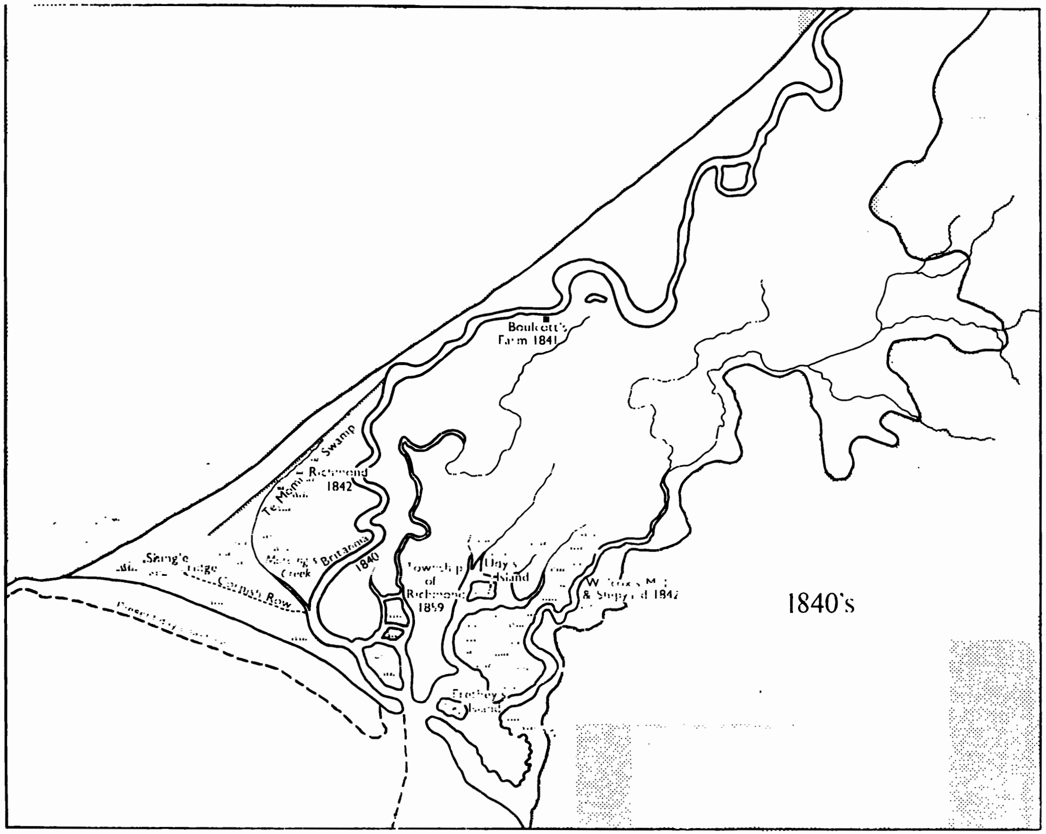
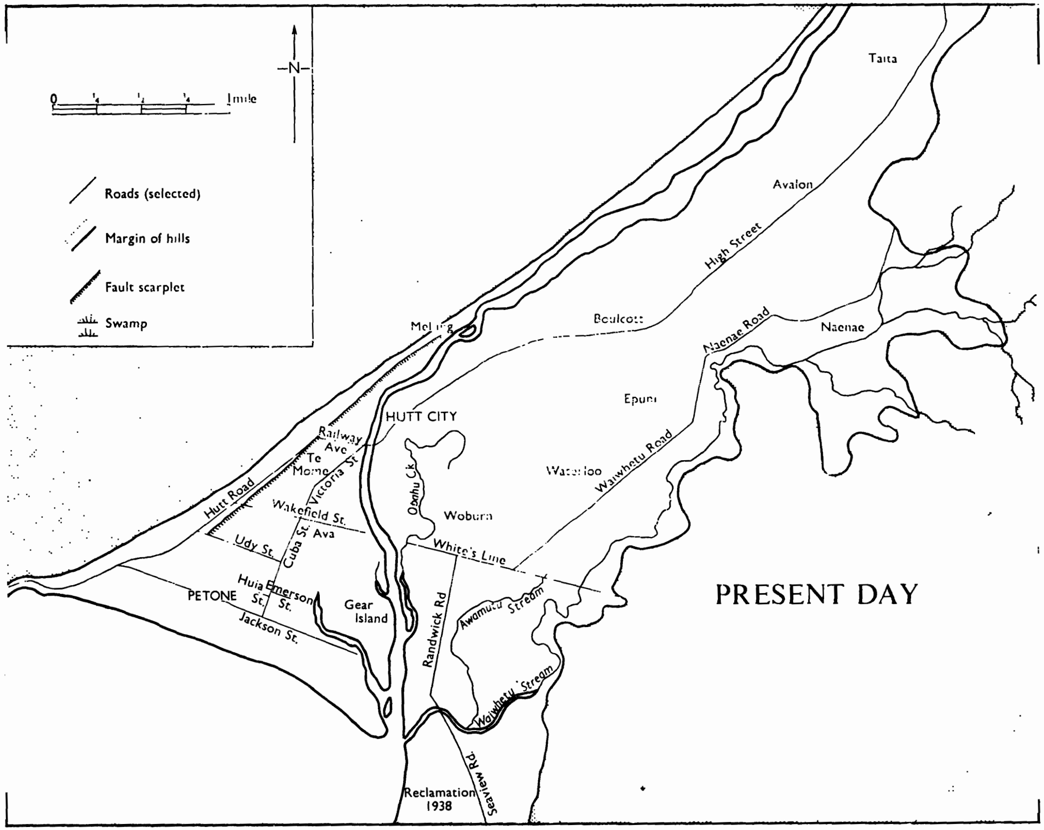


FIG. 16—Evolution of the lower Hutt valley, 1840 to present day.

Figure 16A shows the situation before the 1855 earthquake. At this time much of the seaward edge of the Hutt delta was occupied by swamp and tidal inlets. The Hutt River and Waiwhetu Stream were navigable for some distance and shipyards were established on their banks (Willcox's Shipyard on the Waiwhetu Stream; Meech and Oxenham's Shipyard on the southern part of what is now Gear Island).

Figure 16B shows the valley after the 1855 earthquake raised the Hutt delta some 1·0–1·5 m, drained the swamps, reduced the depth of the rivers, and extended the shoreline southwards.



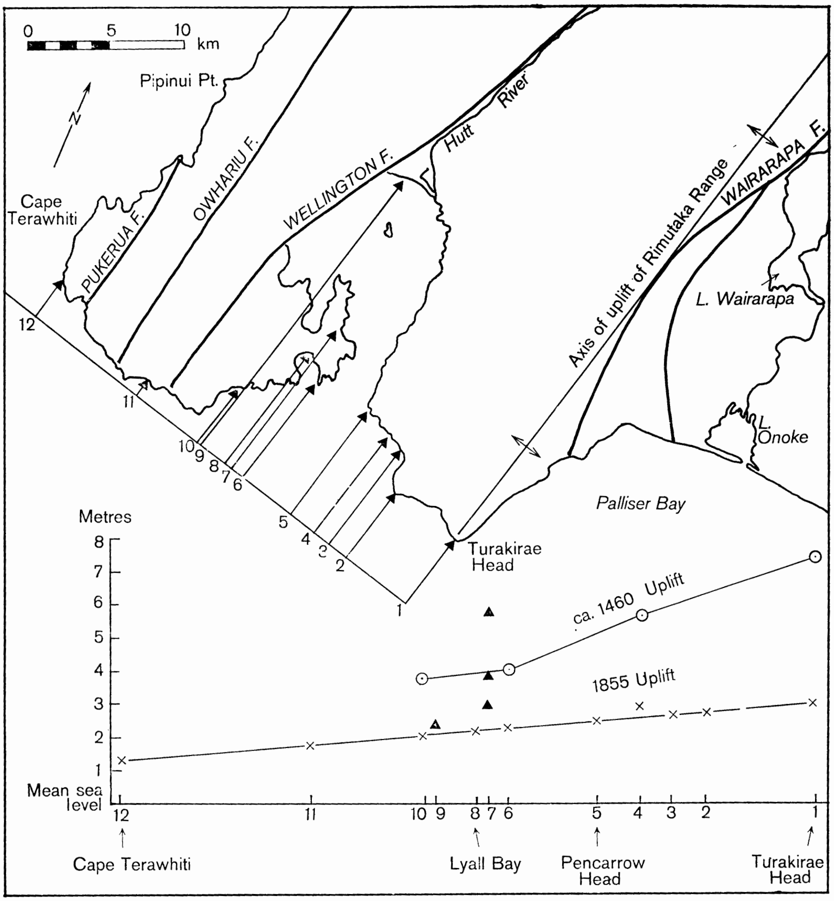


FIG. 17—Diagram summarising the data on raised coastal features presented in this paper. Fig. 1 should be consulted for locality details.

Most of the features used in the compilation of this diagram are storm beaches, formed some distance above high-tide mark, the distance depending on the degree of exposure of the coastline. Thus a distinction has been made between beach ridges formed on the open coast (crosses and open circles) and those formed within Port Nicholson (triangles), as the former were presumably driven up to a greater height above sea level. The triangles represent information from Petone (9) and Miramar (7). In each instance the plotted position represents the present elevation of the *base* of the beach ridge above present mean sea level.

An arbitrary base line has been taken as the distance from the main anticlinal axis (Rimutaka–Tararua Range). The 1855 beach ridge at Lake Kohangatera (4) may have been formed at a slightly higher level than that at Turakirae Head (1), the former being developed on a gravel shore, the latter on a rocky shore (cf. Wellman 1967, p. 126).

2. *"The Rise" and Correlatives*

"The Rise" at Petone has previously been identified as a beach ridge stranded by the Hao-whenua uplift (Stevens 1955; 1956a; b; 1973), but it is clear from the radiocarbon dates and the levelling profiles reported in this paper that it is a very much older feature. Exactly how old is difficult to determine because the date obtained from the shellbed on "The Rise" may not necessarily date the stranding of the beach ridge.

Northwards from "The Rise", the floor of the Hutt Valley is marked by large depressions, the sites of former swamps (e.g., the Te Mome swamp, Hall & Toomath 1941; Adkin 1959, p. 42, map 7), but there is no sign of further beach ridges. Older beach ridges, if they existed, have probably been removed by lateral swinging of the meander belt of the Hutt River.

A remnant of the terrace that was apparently built up to a high sea level some 4000 years ago (Stevens 1956b; cf. Grant-Taylor 1967) extends from Melling southwards along the western edge of the Hutt Valley, and is cut by a scarplet of the Wellington Fault (Grant-Taylor 1967). The scarplet cannot be traced southwards beyond a point about 120 m north of Udy Street (Fig. 2, 16) and it has been presumed by Grant-Taylor (1967) and Stevens (1973) that the Petone beach was about here at the time of the last movement on the fault. G. J. Lensen (pers. comm.) believes on the basis of an unpublished radiocarbon date (NZ707), obtained from swamp peats along the Wellington Fault, that the last movement on the Wellington Fault in the Wellington district occurred about 868 $\pm$ 99 years ago, implying that the Petone beach may have been close to Udy Street some 900 years ago (Grant-Taylor 1967; Stevens 1973). Radiocarbon dates NZ1577–1579, reported on in this paper, and the distribution of Taupo pumice in the Petone area indicate, however, that "The Rise" is older than at least 1800 years, and may be some 2350 years old.

This suggests that either the last movement on the Wellington Fault is substantially older than 2350 years, or is about that age or younger, in which case the southern extension of the scarplet has been obscured by the fan of the Te Tuara-whati-o-Te Mana Stream, and other streams. Correlation of "The Rise" with Wellman's (1967) Turakirae beach ridge succession is not immediately obvious, as on the basis of radiocarbon dates (which do not necessary date the stranding of "The Rise"), it apparently falls between Beach Ridge C, formed *c.* 600 years ago, and D, formed *c.* 3100 years ago. However, it might correspond with one of the periods of high sea level (e.g., Miranda-9 or Miranda-10) recorded by Schofield (1960; 1964) from the Firth of Thames (Hauraki Gulf, Auckland), and thought to be eustatic in origin.

The central valley of Miramar, sheltered from the effects of both marine and river erosion, has two beaches higher than that attributed to uplift accompanying the Hao-whenua earthquake (viz 3·9 m and 5·8 m, Fig. 8). Elsewhere in the Port Nicholson area these two beaches have evidently been destroyed by either river action, or coastal erosion, or obscured by urban development. Sea-cut rock benches preserved on Somes and Mokopuna Islands, and formerly present along the Hutt Road (see above), appear to show approximately the same levels as those of the Miramar raised beaches, when allowance is made for the difference between benches cut into bed rock on the one hand and raised beaches on the other.

As no information is available on the age of the two oldest Miramar beach ridges, their correlation remains doubtful. Two possibilities exist: either they may be related to two of Schofield's high sea levels (e.g., Miranda-13, 3900 ± 90 years; Miranda-12, 2730 ± 70 years) (Schofield 1960, 1964; Ward 1971); or to Wellman's Beach Ridges D and E (3100 and 4900 years ago respectively) (Wellman 1967, 1969) (Fig. 9).

If correlation with Turakirae beach ridges D and E is sustained, further doubt is cast on the existence of Wellman's axis of tilting in the entrance to Port Nicholson (Wellman 1967, fig. 1; and see above).

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