Geology of the Paekakariki Area of the Coastal Lowland of Western Wellington

By G. L. ADKIN

[*Read before Wellington Branch, August 11, 1949; received by Editor, November 1, 1949.*]

THE subject-matter of this paper includes new data relating to the coastal lowland of Western Wellington. In 1891 McKay (1) wrote: "The low grounds and downs intervening between the coastline and the western slopes of the Tararua mountains [at Shannon and elsewhere] are formed of stratified and slightly compacted marine sands . . ."

The district seems to have escaped further notice until the appearance of the paper on the Ohau River area by the present writer (2) in 1910. Eight years later Cotton (3) published an alternative hypothesis of the origin of the lowland, based principally on theoretical considerations. In 1919 the present writer (4) contributed a second paper pointing out a number of discrepancies between Cotton's theory and the geological realities of the area; emphasis was laid on the longitudinal uptilt of the coastal plain *(sensu stricto)* northward, in addition to its lesser east to west downtilt, as well as demonstrating the *basal* position of the major river-fans (piedmont plain).

In 1948, Oliver (5) dealt in a comprehensive manner with a more extensive portion of the lowland tract—from Paekakariki to Palmerston North. A great body of new data was recorded and the extended area geologically mapped. His main conclusions were in agreement with those of Adkin. Certain formation outcrops, however, at the extreme southern end of the lowland strip were not noted.

GENERAL GEOLOGY AND GEOMORPHOLOGY.

The coastal lowland of Western Wellington reaches its maximum width of 28 miles opposite the Manawatu Gorge. Southward it narrows, along a distance of 58 miles, rather regularly as far as Paraparaumu where its width is two miles. For the remaining 6½ miles a width of only a mile and a quarter finally tapers to the terminating point at the cliffs of Te Paripari, a little over a mile south of Paekakariki village.

The Quaternary formations of the lowland area hitherto recognized are four in number: fluviatile gravels, marine sandstone, stream alluvium, and blown sand. In areal extent the coast-bordering aeolian dune-belt (the Himatangi Formation, 6, p. 271), comes first, covering approximately 50 per cent. of the terrain. The marine sandstone (the Otaki Formation, 3, p. 220) comes next, with stream alluvium, of varying age, a close third. The exposure of the fluviatile gravels (the Ohau Formation, 6, p. 269), the basal member of the group, is of limited extent, occurring only adjacent to the debouchures of the Manawatu, Otaki, and Ohau rivers (see Oliver, 5, Maps 1 and 2). In the present paper three more formations are recorded, all of limited thickness and areal extent but including one of considerable importance geologically.

The geomorphology of the above formations is a matter of importance in the elucidation of the development of the coastal lowland*, which is a feature of some complexity, in origin, structure, and surface configuration.

The basal fans, where exposed, present surfaces of regular and characteristic curvature. The preservation of such surfaces despite subsequent marine submergence must be attributed to conditions in which a superabundance of marine sand neutralized the abrasive action of the waves during sea advance. The covering of the basal fans (piedmont gravel plain) was thus accomplished without any discernible modification of their normal surfaces of deposition.

The blanketing of the fan surfaces by marine sand—the Otaki Formation—during the advance of the sea and the evidence of renewed deposition during its retreat as the coastal plain emerged, were considerations leading to the concept of the probable duplex major structure of the Horowhenua coastal plain (2, p. 507). During the time of still-stand, when the Otaki sea-level was at its maximum on the flanks of the Tararua foothills, the superabundance of marine sand piled up by the waves on the shoreline and immediately off-shore, produced the steeper profile of the innermost part of the subsequently raised coastal plain. The flatter transverse profile of the remainder of the coastal plain surface towards the present coast—a profile (as determined by detailed measurement and levelling in the latitude of Lake Horowhenua) which has a gentle slope of apparently uninterrupted regularity—appears to indicate continuous and nearly uniform uplift, incidental eustatic rises in sea-level not leaving any permanent record here.

The emergence of the steeper innermost marginal strip of the coastal plain appears to have been followed by a temporary phase of marine abrasion and sea-advance during which the steeper initial profile was reduced and bevelled off, along much of its length, to the existing flatter upland surface conspicuous at Shannon, Levin, Otaki, and elsewhere, abutting on the slopes of the Tararua foothills. However, relict outcrops of the sandstone of the initial inner margin occur perched here and there to indicate the position of the original shoreline of maximum submergence.

It seems that it was the juxtaposition of this wave-bevelled inner portion of the coastal plain (altitude 260ft. east of Levin) with adjacent now isolated and more elevated fragments *(in situ)*

---

* The coastal lowland of Western Wellington has been referred to by some writers loosely as a coastal plain. The lowland is, in fact, a complex feature, geologically and geomorphologically, only portion of its area being a true *coastal plain,* using that term in its technical sense. A *coastal plain* is defined, following W. M. Davis and others, as a former sea-bottom of rather fine materials of deposition, raised and emergent as the result of secular uplift or of eustatic change in sea-level. A sea-bed surface is capable of emerging intact and unmodified when the energy of wave-action has been neutralized by a sufficient supply of waste which would have the effect of eliminating abrasion of the emerging surface.

of its constituent sandstone (more particularly that at 530ft. situated 3 miles ENE. of Levin) that led Oliver to postulate a fault at that place (5, p. 11; Fig. 39, p. 31; and Map 2, at end). As shown by the foregoing no such upthrust is necessary to explain the discrepancy in altitude in adjacent exposures of sandstone.

Stream alluvium of the district, usually ranging in age from Mid Pleistocene to Recent, but at the southern end of the lowland apparently coeval with the basal major fans, covers considerable areas of both the Horowhenua coastal plain of Otaki Sandstone and the less generally exposed surface of the piedmont plain of Early Pleistocene gravels. The surface of the alluvium takes the form of distinct minor fans and of coalescent fan-form slopes adjacent to hill-ridges, or of terraces and floodplain strips along river and stream courses. Portion of the later gravel deposits are the product of the incision of the upstream continuation of the major fans—the intermont valley-fill—by the former fan-building rivers, and the deposition of the reworked material on the downstream surface of the fans or in the trench since incised in each of them. Farther downstream where the entrenching finally peters out, a low-gradient secondary fan or fan-like deposit has been built forward by each individual river. Where, as in the case of the Otaki River, the trench incised in the main fan terminates close to the present coast, the shingle and gravels of the secondary fan deposit reach the present shoreline and replace to some extent the normal sand beach of this coast. In a manner similar to this the occasional bands and lenses of gravel observed incorporated in the Otaki Sandstone at Shannon and northward of that place (see Oliver, 5, Figs. 19 and 20, and pp. 20, 21, 39), also at Paekakariki, were carried forward and deposited. Such incorporated gravels by no means necessarily indicate oscillations of the shoreline as suggested by Oliver (*op. cit.*, p. 39).

A Shoreline of Early Human Occupation in Horowhenua.

General considerations indicate that the earlier coast of submergence (Adkin, 2, p. 501; Oliver, 5, p. 37) of Western Wellington commenced to rise and was abandoned by the sea in the Mid Pleistocene (Adkin) or late Early Pleistocene (Oliver)* as the result of secular uplift, orogenic in character, and greatest inland and northward and diminishing seaward and to the south. The uplift produced the Horowhenua coastal plain, lithologically the Otaki Formation. The uplift was continuous and is believed to be in progress at the present day. The rate of uplift no doubt varied from time to time but not to the extent of causing physiographic breaks of sufficient duration to produce anything of the nature of successive distinct shorelines.†

The present writer (7) has briefly recorded evidence of a former shoreline or, more correctly, a series of shorelines, now well

* For reconciliation of this geological time difference, see below, p. 173.

† The evolution of the southern end of the lowland was affected and modified by other diastrophic influences and by changes in sea-level, the respective effects of which did not extend to or have marked effect upon the main part of the area to the north. The geological history of the southern portion was therefore, in some respects, at variance with one of virtual normal slow progressive uplift (see below).

inland, defined by relics of an early human occupation. The area supplying the clearest evidence is located between Lake Horowhenua and the sea. There shell middens of two age-belts can be distinguished —a recent outer and an ancient inner belt—with a space of 10 to 15 chains between the two. The outer midden belt lies behind the present foredune and extends back from it for a distance of 80 to 100 yards. These middens are attributed to the local Muaupoko tribe and accumulated as the result of a phase of food-gathering operations up to about a hundred and fifty years ago.

The older middens are scattered over a belt extending from 25 to 100 chains inland. Evidence has been given (*op. cit.*) for the conclusion that these older middens should be assigned to the ancient Waitaha, proved earliest inhabitants of the territory. No well-defined earliest shoreline of human occupation has left its mark, but on the basis of a proper relation to the innermost of the ancient middens, that shoreline has been placed hereabouts at 65 chains inland from the present one.

The advance, in the immediate past, of the present shoreline by uplift and progradation has been shown by recent surveys to have taken place at Waitarere and Waikawa, but no actual figures for the rate of advance are available. The provisional assumption of an advance of about two feet per annum has been adopted as a conjectural approximation to the actual rate of progression.

The final Waitaha shoreline of about 25 chains inland, with progradation at the rate of about two feet per annum, was assessed (*loc. cit.*) at 800 years earlier, that is, prior to 1800 A.D., the approximate terminating date of the Muaupoko independent sovereign occupation and thus the terminating date of the main mass of their midden accumulations within the line of the foredune of the present or near-present shoreline.

Turning to the antiquity of the earliest Waitaha shoreline, 65 chains inland, a calculation on the same basis as the above gives a date of 2,100 years ago, which may be deemed excessive. The date of 1000 A.D. for the termination of the Waitaha occupation of Horowhenua, i.e., about 300 years prior to the advent there of the Muaupoko (a pre-Fleet people), appears to fit into the pattern of known occupations of the area fairly well, since it allows the period of 300 years for the intervening Ngatimamoe occupation. On the other hand the incoming date of the Waitaha (put at 1,300 years earlier—300 B.C.), is open to the objection that this seems too lengthy a period for their sojourn in Horowhenua, but apart from this a very early date for them is by no means unlikely. It is evident that values on which calculations could be based are indeterminate and, almost certainly, variable; for example, the rate of shoreline advance may have altered from time to time as the result of fluctuations in the processes of progradation and/or the rate of orogenic uplift.

The chief geologic interest in the two series of midden-defined shorelines of Horowhenua is the presence in one of them of transported pumice and the complete absence of it in the other. No trace of pumice either in the form of natural fragments or of manufactured artifacts, occurs in the ancient Waitaha middens. The Muaupoko midden belt, on the other hand, lies upon a band, parallel to the present beach, of a sand formation heavily charged with water-worn lumps of pumice of all sizes from small pebbles to boulders a foot or so in diameter. Pumice artifacts also occur, including disc-shaped net-floats and rubstones.

The significance of this pumice-deposit, confined as it is to a band parallel to and not far inland from the present shoreline, was brought to the writer's notice by C. A. Fleming, of N.Z. Geol. Survey (personal communication). His field work in the Wanganui area had disclosed a late pumice deposit ascribed to material derived from a Taupo Shower deposit of the central plateau of the North Island (8, p. 225 and map facing p. 224; 10, pp. 77-8 and map showing volcanic showers, at end). The transport of pumice debris in enormous quantities, far exceeding in amount material derived from the inland deposits by current stream erosion, seemed good evidence of the distribution of the material by the larger rivers draining from the interior *during the progress* of a late Taupo pumice eruption. The Wanganui River, for example, was at that time so choked with floating pumice that masses of it became stranded on the low ground on its lower course. Immense quantities reached the sea and were cast up on, or became waterlogged and were buried in, beaches washed by the southward-flowing littoral marine current. The recording of shore-bordering pumice debris in Horowhenua (7) post-dating shorelines of early human occupation was received with interest since circumstances seemed favourable for determining an approximate date for the Taupo pumice shower. A search for and detailed examination of " marker " deposits of near-shoreline pumice at other points along the coast of Western Wellington was required to throw further light on the problem.

THE PAEKAKARIKI AREA.

The connection of the Paekakariki area (Figs., 1, 5) with the foregoing was brought about by a casual observation made by Fleming in December, 1948, at the beach adjacent to the Centennial Inn (Fig. 1), where he noted "a deposit of decomposed pumice fragments overlying greywacke gravels" (personal communication). In undertaking the obtaining of data of the incidence of this pumice deposit the present writer observed formations underlying the extreme southern end of the coastal lowland that had previously escaped notice.

THE MODERN BEACH.

Southward from Paekakariki the broad sand beach at and north of that place is backed by a high foredune, the toe of which had been undercut and slightly cliffed prior to the building of the modern beach. Cliffing appears to have been somewhat accelerated in recent years, during high tides and coincident stormy seas, as a series of beds of non-aeolian origin at the base of the dunes is now exposed on the seaward side in a number of places. Southward from Paekakariki the sand beach is replaced by a fully-developed shingle beach and the 'tween tides seaward slope steepens. The whole of the shingle beach material is local greywacke. Beach cusps, of characteristic development in coarse and in fine detritus, are present in both local varieties of beach.

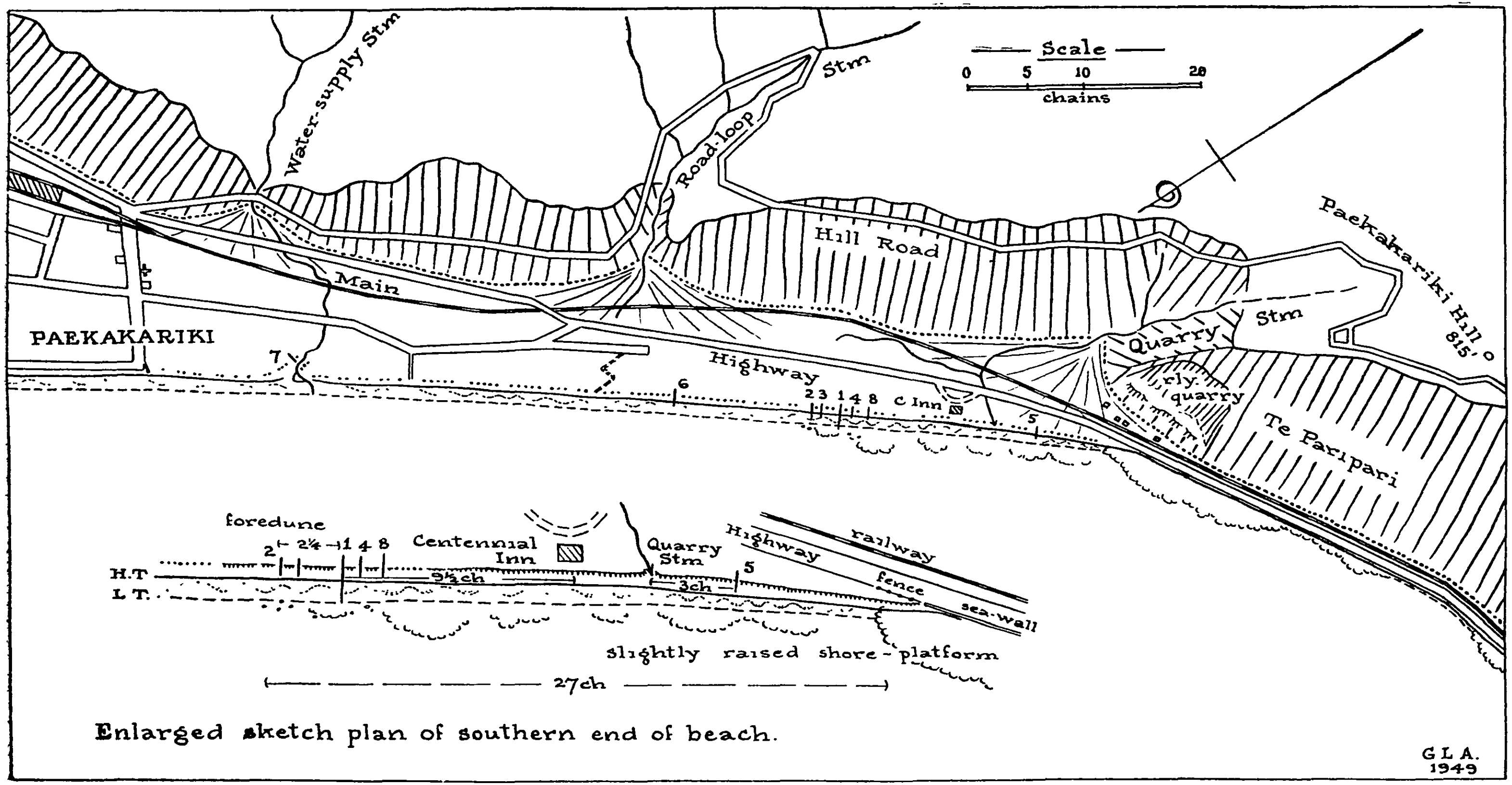

FIG. 1—Map of Paekakariki area showing location of coastal sections, physiographic features, etc.

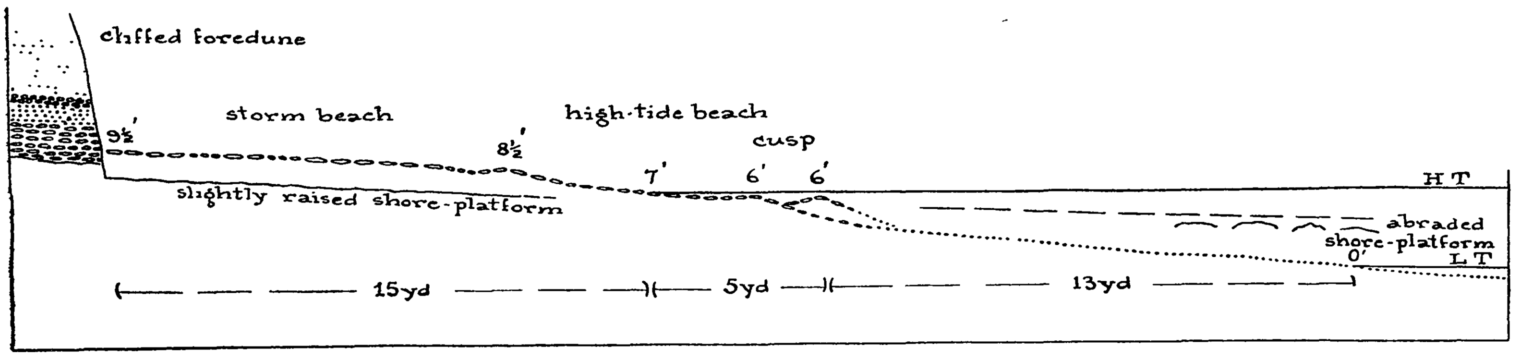

FIG. 2—**Profile of modern beach near Paekakariki (9½ chains north of Centennial Inn).**

Fig. 2 gives the principal features of profile and constituent materials of the shingle beach and its relation to the cliffed foredune. At the outer, lower portion, the slope of the beach for about eleven yards above low-tide line is of sand, and the impression is gained that the inner part—of shingle—is a separate superficial feature overlying the basal beach of sand. High-tide line is surmounted by a storm beach, also of shingle and gravel, which extends inward to and overlaps the base of the slightly cliffed foredune.

The Paekakariki beach terminates (as the coarsest part of the shingle beach) at a point 14 chains south of Centennial Inn (a useful datum point), where it abuts on a rock-platform of marine abrasion, now slightly raised in relation to present sea-level. The slightly raised bench in its nearly intact condition now ends at its junction with the lowland-fringing shingle beach, but it formerly extended (as its remnants do still) 27 chains or more farther north, overlapping the southern end of the lowland strip by that amount. This portion of the shore-platform has been more severely abraded during the period of present base-level as the result of the effects of the contiguous shingle beach.

The Coastal Section.

The apparently recent cutting back and cliffing of the foredune in a number of places at and south of Paekakariki has now revealed the local structure of the lowland strip. The section visible comprises an unexpected multiplicity of local geological formations. For reasons suggested below, none of these well-defined formations is of any great thickness, but all have distinctive characters and thus throw considerable light on varying past relations of sea and land.

The basal formation, showing a thickness up to 3 feet above the inner overlapping margin of the modern storm beach, consists of rather fine sea-worn pebbles and occasional cobbles of greywacke in a (usually) sparse matrix of coarse sand. Intercalated lenses and bands of the same coarse sand occur in the upper part, and the lower part is, to some extent, cemented by oxide of iron. This formation is interpreted as a beach deposit originally laid down at sea-level, and though now above, there is evidence that it had been, at one stage, depressed below sea-level.

The next formation, overlying the last, is a clean, water-laid sand, in places finely laminated, exhibiting delicate cross-bedding, and varying in thickness as the result of subsequent stream erosion from 1½ to about 25 feet; at the places of maximum thickness, however, the base is obscured by talus; the maximum thickness noted in exposures where both upper and lower surfaces are visible was 4 feet. On various grounds—lithology, structure, geographical position, etc.—this marine sand is identifiable as Otaki, and is an attenuated tongue of the extensive coastal plain of marine sandstone of the region northward.

Exposures of Otaki Sand occur in three slightly differing relationships in the coastal section south of Paekakariki. Where first examined by the writer at exposures at the base of the foredune between 9 chains and 11 chains north of the Inn, it

To face p. 164

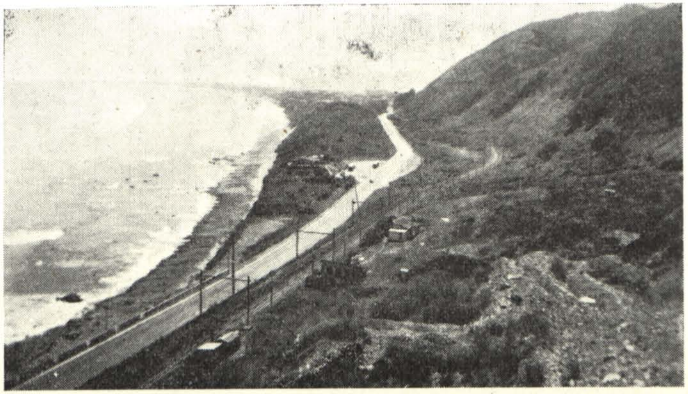

FIG. 5—Southern end of coastal lowland near Paekakariki. Inland cliffs on right; Centennial Inn and dune-ridge at centre; coastal section, modern beach, and fragmentary, slightly raised shore-platform (at approximately low tide) to left. View NNE. from railway quarry in Te Paripari cliffs (see map, Fig. 1).

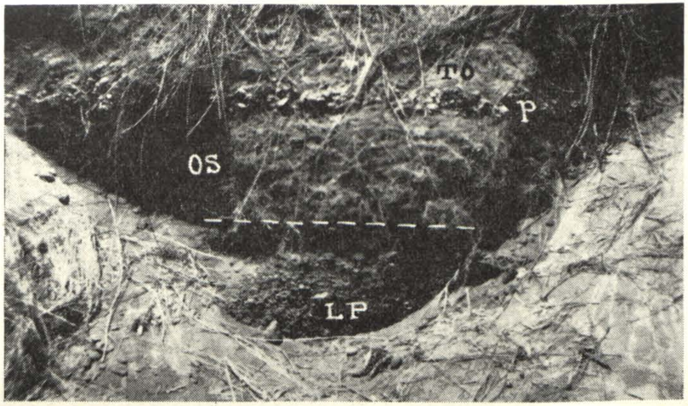

FIG. 6—Coastal Section. Section 1 (map, Fig. 1) showing lower beach-gravels (LP), Otaki Sand (OS), and pumiceous sand (TO) with pumice pebble band (P).

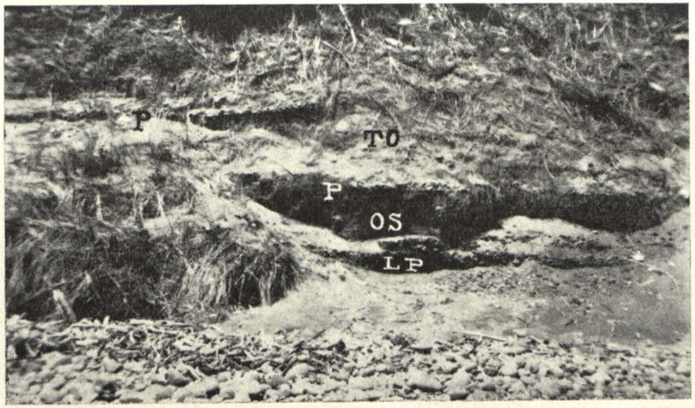

FIG. 7—Coastal Section. Section 4 (map, Fig. 1) showing pumiceous sand (TO) with pumice pebble bands (P, P) overlying Otaki Sand (OS) and lower beach-gravels (LP). Inner margin of modern beach, foreground.

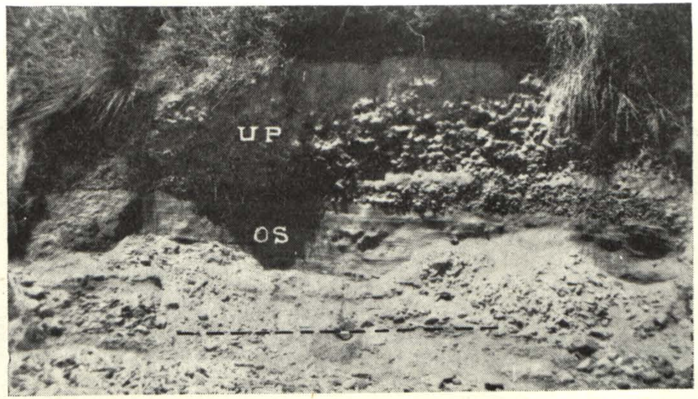

FIG. 8—Coastal Section. Section 5 (map, Fig. 1). Otaki Sand (OS—base indicated) overlain by upper beach-gravels (UP), with alluvial silt of minor stream-fan at top.

overlies the lower beach gravels and is overlain by a second water-laid sand formation (described below). About 7½ chains south of the Inn, it overlies the lower beach gravels, has a thickness of 4 feet, is strikingly laminated and cross-bedded, and is overlain by a second marine beach-gravel formation, which in turn is capped by the alluvial fan deposit of the Quarry Stream (Figs. 1, 8). At the debouchure of the Water-supply Stream (Fig. 1, and Fig. 3, Section 7), 15 chains south-west of Paekakariki village, the Otaki Sand is cemented by iron oxide into a coherent sandstone, equal in hardness to anything outcropping in the Horowhenua area. The base of the outcrop in the stream bank is below stream-bed level and may rest, at some depth, on an earlier fan of the Water-supply Stream. Its upper surface is overlain by the second water-laid sand, here 32 inches thick, which merges upward into light-coloured, fine alluvial silts forming the toe of the present minor fan (now incised) of the Water-supply Stream.

Between the local streams the present upper surface of the Otaki Sand stands at a higher level on the seaward dune-face than at places where it was eroded off and lowered to a still greater extent by the local streams within the range of their flow; its level in the inter-stream-course positions is 25 feet (or more) above the inner edge of the modern beach (which is approximately 9½ feet above low-tide level).

In addition to fine lamination and current-bedding of the laminae (in places prominent), the Otaki Sand in the Paekakariki area is characterized by its clean, even texture and the complete absence of pumice pellets and pebbles. It frequently, however, contains sporadic pebbles and cobbles of greywacke, and, in places, thin discontinuous layers and lenses of the same material. The latter occur in the vicinity of the debouchures of the local streams, but the former, the sporadic fragments, may occur anywhere in between, by lateral migration along the prograding beach of the period.

Coming now to the upper water-laid sand overlying the Otaki Sand, we find it the local equivalent of the narrow, pumice-loaded sand-belt deposit of the Horowhenua coast. The Paekakariki pumice-pebble sand is characterized by its pumiceous composition and texture, and by the presence of well-defined but discontinuous bands of pumice pebbles at more than one horizon, and by pumice fragments promiscuously scattered through it. The relative position of the pumice-pebble bands varies from place to place, the intervening sand charged with smaller and scattered fragments varying from 6 inches to perhaps 12 feet or even more. Frequently, however, a band of pumice pebbles (with, in places, an occasional pebble of greywacke) caps the underlying Otaki Sand; in other places the plane of contact between Otaki Sand and pumice sand can be placed only by the difference in composition. The upper limit of the pumice-pebble sand is difficult to fix as it seems to grade into the overlying dunes of wind-blown sand.

The upper beach-gravel formation that can be seen overlying the Otaki Sand south of the mouth of the Quarry Stream is of similar origin to the lower beach-gravel formation, but it differs from it chiefly in being composed of coarser, poorly-sorted material

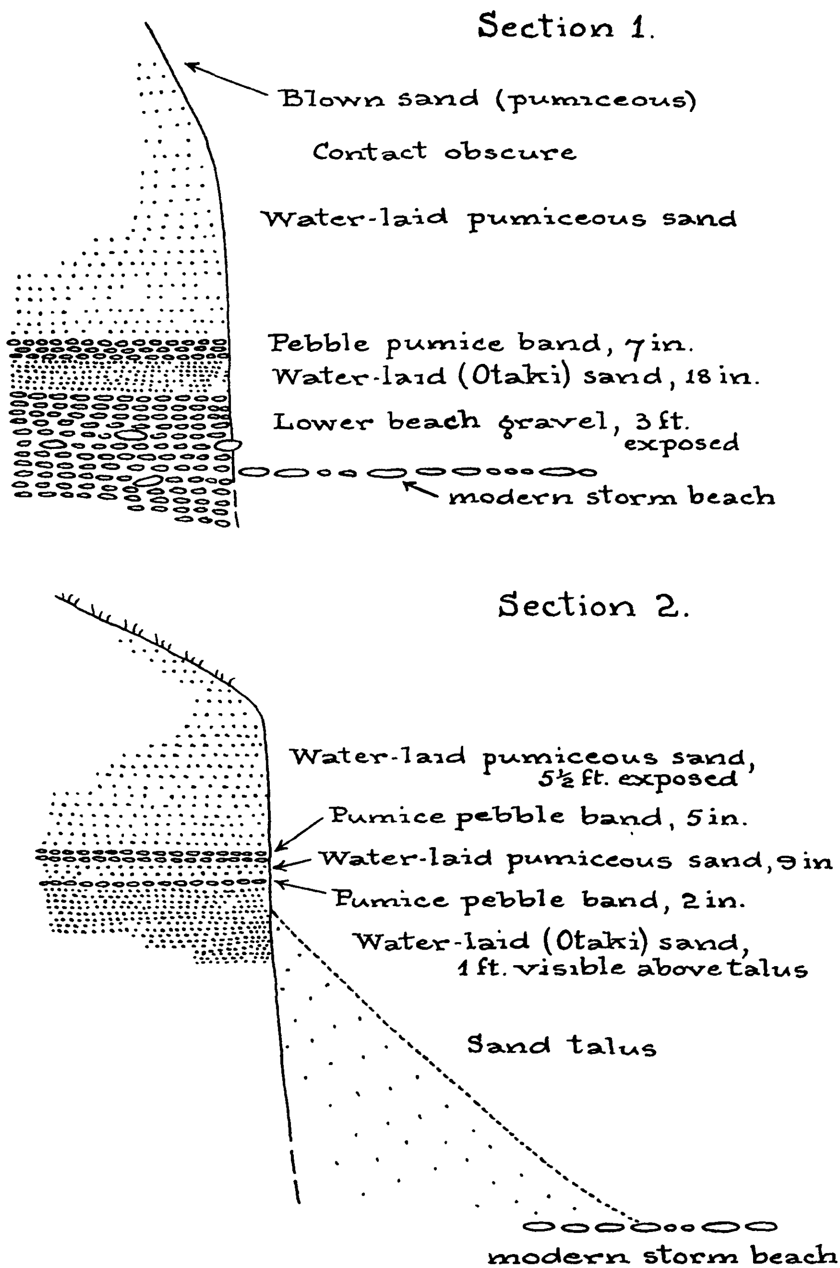

Fig. 3—Details of Coastal Section at points 1 and 2 shown on map, Fig. 1.

with a notable proportion of angular fragments. Angular detritus was not seen in the lower beach-gravel formation.

The upper beach formation is of limited lateral extent and apparently extends forward a lesser distance from the base of the

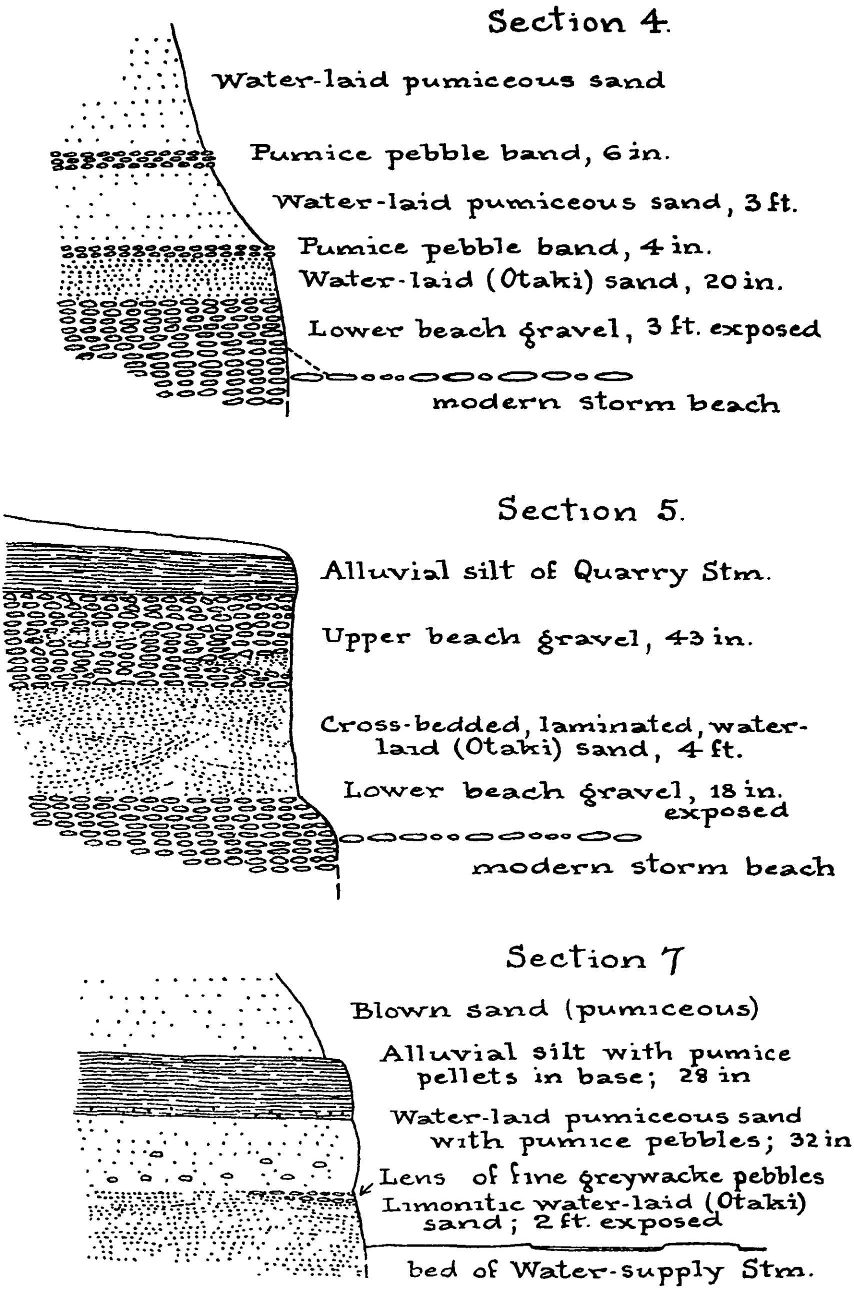

FIG. 3a—Details of Coastal Section at points 4, 5 and 7 shown on map, Fig. 1.

now inland cliffs than does the lower gravel deposit. This indicates a shorter period of still stand (or of very slight uplift) at this stage, as also does the presence of angular debris. South of the

Quarry Stream the toe of its present alluvial fan—a clayey silt 16 inches in thickness at the shoreline—caps the upper beach-gravel formation (Fig. 3, Section 5, and Fig. 8).

Of the local dunesands little need be said. They overlie in this vicinity the water-laid pumice-sand formation and portions of the recent alluvial fans of the local streams. The blown sand of the dunes was derived from a former seaward extension of the water-laid pumice-sand; hence the difficulty in defining the plane of contact between the pumiceous water-laid sand and the aeolian sand. The recent advance of the sea (prior to the late progradation of the modern beach) cut back the exposed pumiceous sands (also the underlying beds) thus removing the source of the blown sand, and the dunes are now stable except for talus on their slightly undercut seaward face*.

Summarizing, and supplying data not yet given of the measured parts of the general coastal section (see map, Fig. 1, nos. 1-7), details are as follows:—

Section 1 (Fig. 3, Sect. 1, and Fig. 6).

	Wind-blown pumiceous sand (at top)	
5 ft. 7 in. +	Water-laid pumiceous sand - - - - -	5 ft. +
	Pumice-pebble band - - - - - - - - - -	7 in.
	Water-laid (Otaki) sand - - - - -	1 ft. 6 in.
	Lower beach-gravels (showing) - - - - -	3 ft.

Section 2 (Fig. 3, Sect. 2).

	Wind-blown pumiceous sand (at top)	
3 ft. 4 in. ±	Water-laid pumiceous sand - - - - -	2 ft. ±
	Pumice-pebble band - - - - - - - - - -	5 in.
	Water-laid pumiceous sand - - - - - -	9 in.
	Pumice-pebble band - - - - - - - - - -	2 in.
	Water-laid (Otaki) sand (base hidden) -	9 ft. 6 in.

Section 3.

	Wind-blown pumiceous sand (at top)	
3 ft. 2 in. ±	Water-laid pumiceous sand - - - - -	2 ft. ±
	Pumice-pebble band - - - - - - - - - -	7 in.
	Water-laid pumiceous sand - - - - - - -	6 in.
	Single line of greywacke and pumice pebbles -	1 in.
	Water-laid (Otaki) sand (base hidden) -	9 ft. 6 in.

Section 4 (Fig. 3, Sect. 4, and Fig. 7).

	Wind-blown pumiceous sand (at top)	
6 ft. 1 in ±	Water-laid pumiceous sand - - - - -	5 ft. ±
	Pumice-pebble band - - - - - - - - - -	6 in.
	Water-laid pumiceous sand - - - - - -	3 ft.
	Pumice-pebble band - - - - - - - - - -	4 in.
	Water-laid (Otaki) sand - - - - -	1 ft. 8 in.
	Lower beach-gravels (showing) - - - - -	3 ft.

*Repeated visits to the Paekakariki area show that, though the stratigraphical relationships are constant (though of varying proportions from point to point), continuous minor changes in exposure recur and beds and features may be successively obscured or laid bare. The modern beach, also, fluctuates in minor surface form and in composition from time to time according to the influence of periods of calm or stormy weather, rainfall, force and direction of wind, etc.

Section 5 (Fig. 3, Sect. 5, and Fig. 8).

Clayey silt (alluvium) - - - - - - -	1 ft. 4 in.
Upper beach-gravels - - - - - - - -	3 ft. 7 in.
Water-laid (Otaki) sand - - - - - - - -	4 ft.
Lower beach-gravels (showing) - - -	1 ft. 6 in.

Section 6.

Wind-blown pumiceous sand (at top)	
Water-laid pumiceous sand - - - - - -	5 ft. ±
Water-laid (Otaki) sand (base-hidden) - -	4 ft.

Section 7 (Fig. 3, Sect. 7).

Wind-blown pumiceous sand (at top)	
Clayey silt (alluvium) - - - - - - -	2 ft. 4 in.
Water-laid pumiceous sand with pumice pebbles - - - - - - - - - - - -	2 ft. 8 in.
Unconformity, with lense of fine, water-worn greywacke pebbles - - - - -	3 in.
Water-laid cemented (Otaki) sand (base hidden) - - - - - - - - - - - - -	2 ft.

INTERPRETATION, AND FORMATION NAMES.

The lower beach-gravel formation is interpreted as being an early marine abrasion product, localized at the Te Paripari cliffs of the Paekakariki area, of the late Early Pleistocene to Mid Pleistocene shoreline of Western Wellington. The deposit accumulated as an incipient strand-plain during an interval of stillstand or of very slow uplift. For it the local formation name of "Lower Paripari" is suggested

Submergence interrupted the accumulation of the Lower Paripari Formation and by carrying it below sea-level, allowed the deposition on it of the overlying marine sand. On similarity of lithology and internal structure, as well as geographical position and relationship to the "old land," this sand is correlated with the established Otaki Formation in Horowhenua and northward. The name "Otaki Formation" is therefore retained for the Paekakariki portion.

Overlying the Otaki Sand is another sand formation of similar marine sedimentary origin but of different lithology. The distinctive lithology connects it with, on the hypothesis of its derivation from, a Taupo pumice shower; it is a waterborne facies of the product of a Taupo pumice eruption Despite its limited thickness and areal extent, the geographical range and distinctive lithology of this pumiceous sand stratum makes it an important horizon marker. As a formation name, "Taupo Outwash," or, in full, "Taupo Outwash Pumice-pebble Sand" has been adopted.

The upper beach-gravel formation, derived from renewed abrasion of Te Paripari cliffs, was also built forward as an incipient strand-plain during another interval of stillstand. It rests directly on a degraded surface of the Otaki Formation. The pumiceous sand is absent here, and as the upper gravels are regarded as slightly older than the pumiceous sand, the former is presumed to have been raised above sea-level by renewed uplift just prior to the deposition of the sand. The pumiceous sand was then deposited on a shoreline seaward of the gravels at this place, and later completely removed here by the final sea advance. " Upper Paripari Formation " has been selected as a suitable local formation name for these gravels.

Diastrophic Factors.

To interpret correctly the sequence of Quaternary events that have left their mark in the Paekakariki area, it seems necessary to recognize and correctly assess the interaction of diverse diastrophic processes that have affected the terrain as a whole and that vicinity in particular. The working hypothesis already advanced by the present writer (4, p. 111; 10, pp. 146-8) may here be restated and developed in more detail.

The general concept is the extended contemporaneity of both epeirogenic and orogenic movements, the latter comprising two linked but opposing stresses, a major and a lesser, in operation simultaneously. The land-surface affected by these movements was the "pre-Miocene peneplain" (so called) to which the land had been reduced. Large areas of this subdued surface were submerged by Tertiary seas, other portions were gently upwarped and remained emergent. Evidence from the Port Nicholson area indicates that the Kaukau erosion-surface was part of the initial surface of the axial highland belt from which, in the North Island, the Tararua-Rimutaka collinear ranges have been carved. The whole forms part of the emergent portion of the "pre-Miocene peneplain," or, more correctly, subdued matureland.

The Kaikoura orogenic uplift and deformation progressed to its climax at the close of the Pliocene. The drainage consequent on the uplift developed as the orogeny proceeded, the axial belt reaching a state of deep dissection at, or even prior to, the beginning of the Pleistocene. At this stage epeirogenic uplift supervened and at its maximum the glacial episode occurred. During this uplift, extra-axial areas were likewise elevated, and during pauses, the benches of partial erosion-cycles—Table Hill, Mana, Tongue Point, etc—were successively developed, each at the expense of the graded surface of the preceding epicycle.

With dissection proceeding, the initial surface of the axial belt was uplifted, tilted, and flexured into a secondary anticlinorium, finally faulted and upthrust on its eastern flank (11). Separating this deformed belt from the more uniformly uplifted and relatively gently warped superficies of the Wellington Peninsula "block," there intervenes a long, narrow, subsiding (or relatively lagging) tectonic strip. This is the Port Nicholson-Porirua-Pukerua " sunkland " strip. Its lateral boundaries appear to be monoclinal flexures and, in part, normal faults facing inwards (Fig. 4).

The particular diastrophic movements outlined, other than the epeirogenic movement, are visualized as being varying manifestations of the crustal forces behind the Kaikoura orogeny. The general

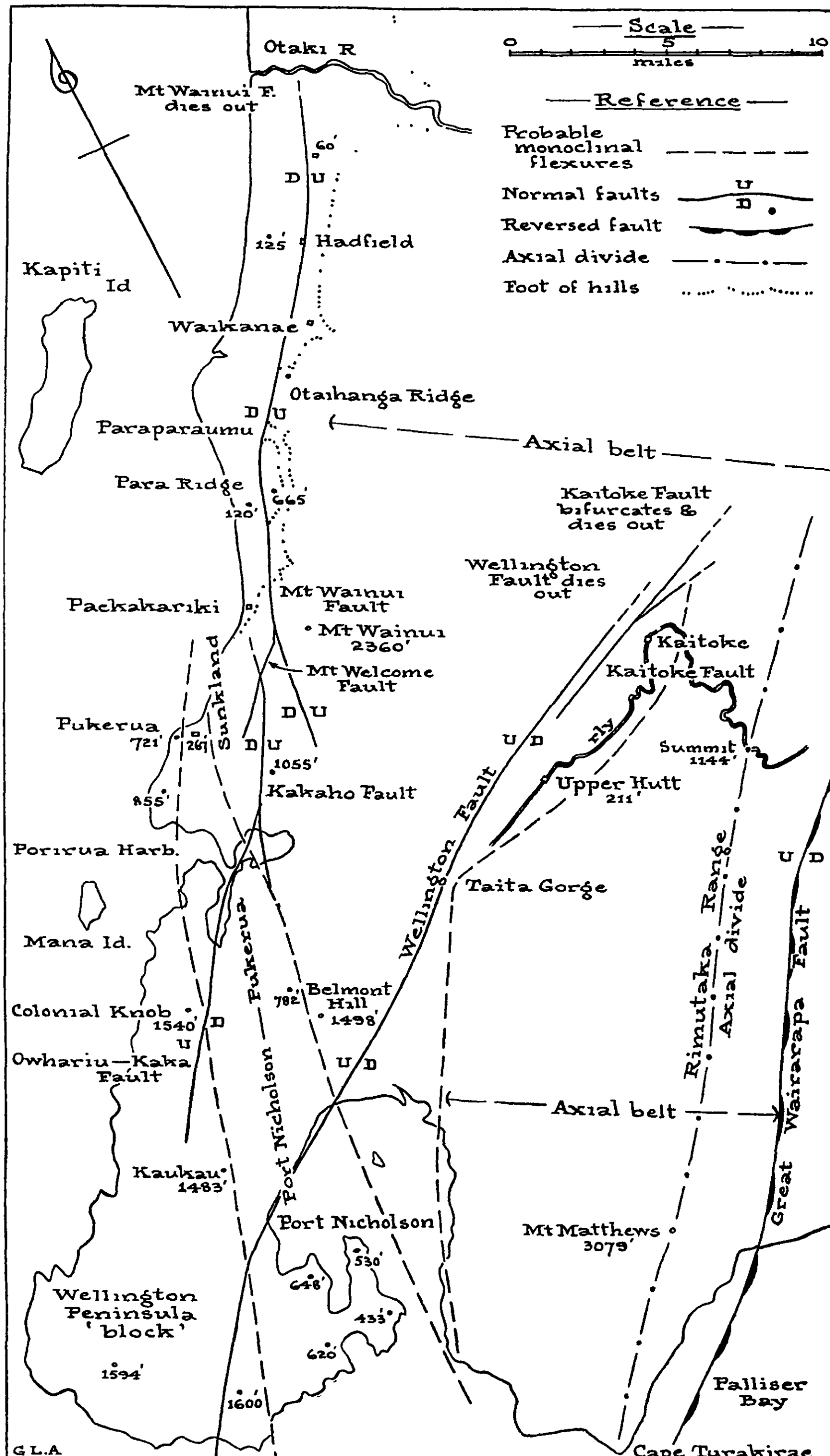

FIG. 4—Map showing details of structural lineaments of South-western Wellington.

movement was one of uplift. It was of greatest intensity along the axial belt: stresses of lesser intensity elevated the Wellington Peninsula " block "; the interaction of these two units with perhaps some rotation of the axial segment, apparently produced a down-drag along the hinge-line of the contact, and by slowing up the uplift along that zone, gave it the semblance of a *relatively subsiding* strip.

The most recent effects of crustal stress in this relatively subsiding sunkland strip are three normal faults that cross it obliquely. These are respectively known as: the Wellington Fault (Cotton), the Owhariu-Kaka Fault (Quennell and Ferrar), and the Mount Welcome Fault (Adkin); their trend is sub-parallel. The inbreak of the Wellington Fault accelerated the local subsiding tendency very considerably and produced the fault-angle and, in part, the more strongly downwarped area of Port Nicholson and the Hutt Valley (Fig. 4). The Owhariu-Kaka fault-trace exhibits features of very recent movement but in part it coincides with an older fault-scarp, especially on the eastern side of Colonial Knob. Northward, the recent trace of the Owhariu-Kaka Fault intersects the older Kakaho Fault (see Fig. 4) at an acute angle, and recent movement on the northern part of the Kakaho Fault was probably due to movement on the Owhariu-Kaka line. The Mount Welcome fault-trace (Fig. 4) is one of the most recent of the local crustal fractures and there is little, if any, evidence of earlier movement on this line. It is probable, however, that the most recent movements on the northern part of the Mount Wainui Fault (Fig. 4) were produced by the northward extension of movement on the Mount Welcome Fault. The latter intersects the former at an acute angle (cf. the Owhariu-Kaka-Kakaho intersection, Fig. 4), and rejuvenation of the northern part of the older Mount Wainui Fault is indicated by notched spurs and by the postulated disruption of the Otaki Sandstone towards its (this fault's) extreme northern end, as submitted on a later page of this paper. About the end of the Early Pleistocene a second epeirogenic movement—this time of subsidence took place. This probably involved the whole of the South Island and the southern part of the North, and may have been uniform over that area, or of the nature of a slight tilt, possibly from north to south.

With sea-level thereby brought to a relatively higher altitude in relation to the diminished New Zealand land-mass (thus reduced to separate islands as now), the effects of ensuing orogenic movements together with apparent eustatic changes in sea-level became obvious. Continued orogenic uplift of the Tararua-Rimutaka axial range caused the sea to leave its late Early Pleistocene to Mid Pleistocene shoreline along the Tararua foothills and lay bare the Horowhenua coastal plain. The lesser complementary but opposing orogenic movement—i.e., the down-drag or lag of the Port Nicholson-Pukerua tectonic strip—slowed up the general upward movement, enabling eustatic changes in sea-level to produce occasional submergence of the narrow southern end of the coastal lowland.

NOTES ON LOCAL GEOLOGICAL HISTORY.

The piedmont alluvial plain of coalescing major fans of Horowhenua in the Early Pleistocene* extended southward as far as Waikanae. These fans were the product of the larger rivers draining from the Tararua Range during its second-cycle uplift and were deposited on an extended lowland surface reaching far to the west.

There is evidence for the belief that the smaller but conspicuous fans fringing the foothills between Te Horo and Waikanae and from south of Paraparaumu to Paekakariki, were coeval with the major fans and thus formed part of the piedmont apron of basal gravels. As the product of comparatively small streams, the lesser fans have gradients of values greatly in excess of those of the larger and flatter fans of the principal rivers, and the apexes and upper slopes of the former stand at higher levels, making them striking features of the landscape. Truncation of the toe of most of these steep southern fans by faulting took place (see Fig. 4), a derangement of equilibrium that caused them to be breached and trenched by their originating streams. Later, a renewal of fan deposition resulted in some complexity of structure and surface configuration. Over the whole lowland area, however, stability and a cessation of fan-building had been reached for a lengthy period prior to the peripheral submergence that followed that aggradation.

The period of greater elevation, marked by the episode of Early Pleistocene glaciation, was followed by this regional subsidence. In the Paekakariki area the Lower Paripari Formation is taken as being related to the new coast of submergence. The submergence gave rise, in Western Wellington, to the highest Otaki shoreline, which is assigned to times extending from late Early Pleistocene to Mid Pleistocene. A slightly qualified concept of the date of the Otaki shoreline is introduced here. In the Paekakariki area coastal abrasion and the building forward of an incipient strand-plain took place at a rather earlier date than the abandonment of the earliest Otaki shoreline at the inland hill-region of the "old land" northward in Horowhenua. A late Early Pleistocene date (Oliver, 5, p. 37) for the former and an early Mid Pleistocene one (Adkin, 2, p. 502) for the latter may well apply in the respective localities, and cover the evident time lag between the two.

The submergence of the Lower Paripari strand-plain apparently by a eustatic rise in sea-level allowed the deposition upon it of the overlying Otaki Sand. In the Paekakariki area this sand deposit was more limited in thickness and lateral extent than in the region to the north. Uplift, on a restricted scale, then laid bare the sandy sea-bed to form a narrow strip of coastal plain—the southern wing of the Horowhenua coastal plain—originally extending southward past the present lowland terminus.

---

*The divisions of the Pleistocene (and of the Quaternary as a whole) as used by the present writer (see also, Oliver, *op. cit*), are tentatively based on diastrophic data and on estimates of the relative space of geological time required for the several geomorphologic and geologic changes that have taken place within the area dealt with.

The most southerly exposure of Otaki Sandstone known until recently is that at Otaihanga, a mile and a half north of Paraparaumu (Oliver, *op. cit.*). The present writer has demonstrated (on the basis of the rather uniform longitudinal downtilt of the Otaki shoreline southward, see graph, 4, p. 111), the theoretical original extension of the coastal plain (*sensu stricto*) as far south as a little beyond Porirua Harbour entrance. It may be assumed, however, that on account of its extreme narrowness and the unconsolidated nature of its make-up, such former extension would be very vulnerable to wave-attack and quickly removed by marine abrasion.

In the part that survived north of Te Paripari the emergent surface was channeled by local streams. A pronounced submergence then took place, entirely drowning (at the southern end of the coastal lowland only) the whole of the then eroded and irregular surface of this narrow and slightly embayed coastal plain. Upon the uneven surface renewed deposition of material washed down coastwise from the north, introduced the final component of the coastal plain strip, namely, pumiceous sand charged with pumice pebbles (the Taupo Outwash Pumice-pebble Sand). Complete local submergence is indicated by the fact that water-laid pumiceous sand overlies *unconformably* not only the lowest but also the highest eroded surface of the Otaki Formation to be found at and south of Paekakariki.

Immediately prior to or in part contemporaneous with the deposition of the pumiceous sand, the shoreline had again reached the base of Te Paripari cliffs. A coarse beach-deposit (Upper Paripari Formation) was built forward to form a second narrow strand-plain, but this did not attain the breadth of the earlier one.

It will be evident that a multiplicity of changes in base-level affected the Paekakariki coast and shore as slow orogenic uplift was neutralized at least twice by eustatic rises in sea-level. Following the foregoing, further slight uplift occurred and by laying bare the light pumiceous sands, provided a wind-erodable surface from which the existing dunes were derived. Sea-advance by wave-attack then took place and the shoreline was cut back to the base of the present foredune. Finally a small amount of uplift brought about the progradation of the existing beach, the shingly portion of which was derived from erosion of the earlier strand-plain deposits.

Attention is now directed to the coastal lowland north of Paekakariki where the Mount Wainui Fault (see Fig. 4) was a factor in the evolution of the present topography. The southern (known) part of this fault-line, topographically forms a prominent scarp marked by faceted spurs on the western face of Mount Wainui, and its northern extension is one of the faults bounding, in part, the Port Nicholson-Pukerua " sunkland " strip. North-north-west of Mount Wainui this fault leaves the hill country and crosses the lowland. At this point it transected the fan of the Rongo-o-te-wera Stream, downfaulting its seaward segment. Farther north, its scarp bounds the western side of the outer hill-ridge located immediately south of Paraparaumu (a hill-ridge nameless but herein referred to, for convenience of reference, as Para Ridge). Continuing northward, it similarly defines the western side of Otaihanga Ridge (Macpherson, 12, map Fig. 1, section BB Fig. 2, and p. 72). At Waikanae, a gap of four miles of low ground shows no trace, but northward again, the fault truncates the older units of the series of steep minor fans previously referred to (together with the Rongo-o-te-wera fan) as being coeval with the Early Pleistocene major fans of Western Wellington. Still farther north Mount Wainui Fault transects the (major) fan of the Otaki River, downthrowing a seaward segment, and it dies out, as a topographic lineament, close to the lower course of the Otaki River.

There is good evidence of the late movement on this fault but as a crustal break it probably dates back to the Kaikoura orogenic climax. Prior to its transection of the older minor fans but subsequent to its determination of the outer hill-faces south and north of Paraparaumu, the initial Otaki shoreline had been established following the epeirogenic subsidence. A few miles north of Waikanae (e.g., at the former railway station of Hadfield*—near Fraser's Hill Road), this shoreline was certainly inland of, that is, east of, the line of Mount Wainui Fault. This is shown by the fact that Otaki Sandstone capping older minor fans there, is cut and downthrown to the west on the line of this fault by a renewal of differential movement. This is taken as indicating that the fault, in the later stages of its inbreak, extended its length northward as a topographic break, over terrain previously intact and overlain by an unbroken formation of emergent Otaki Sandstone.†

The sea had retired as a result of the emergence of the Horowhenua coastal plain but its southern wing was re-submerged by what appears to have been the greatest of the eustatic rises in sea-level. This occurred after the downfaulting of the outer segments of the older minor fans. It was at this juncture that the fault-scarped fan of Rongo-o-te-wera Stream was cut back by the sea to about 5 chains beyond the line of the Mount Wainui Fault. Proof of this cutting back by wave-action is given by similar wave-truncaiton of fans located immediately south-west of the Rongo-o-te-wera fan; these cliffed fans are not transected by the line of the Mount Wainui Fault and the line of their truncation trends at approximately at right angles to it.

The fault-scarped western face of Para Ridge was also part of the shoreline during this later sea-advance, but owing to its more resistant nature (greywacke, as compared with stream gravels) it was but slightly (if at all) modified by marine abrasion. The same qualification applies to the fault-defined western boundary of Otaihanga Ridge farther north. It also applies—rather unexpectedly

---

*Thus previously referred to, in 4, p. 112.

† Oliver (5, Table I, p. 5) gives details of a well (Fig. 10, D, p. 12) sunk on the low ground to the west of the scarp at Hadfield. The beds passed through are given as: Dune-sand, 57ft, on hard solid rock. At this place the scarp shows Otaki Sandstone and it is extremely likely that the greater part of the 57ft of sand formation on the downthrown side is Otaki Sandstone also, and not blown sand as surmised by Oliver. Prior to the faulting movement here, the two sand bodies (if identical as suggested) would be contiguous and continuous.

at first sight—to the fault-truncated series of fans at Hadfield. But there the gravel fans are protected by an exposed platform of greywacke basement on which they rest (forming an uplifted contraposed shoreline) which checked abrasion and has preserved them from deeper truncation under wave-attack than would otherwise have taken place. Northward of this locality the maximum shoreline of secondary sea-advance (by re-submergence of the coastal border) was apparently too transitory to allow further advance by abrasion to be effected to any notable degree.

ACKNOWLEDGEMENTS.

The writer wishes to express his thanks for helpful suggestions to several members of the staff of the N.Z. Geological Survey, especially the Director (Mr. M. Ongley) and Mr. C. A. Fleming, Palaeontologist; also for the latter's acquiescence in the writing up and presentation of this paper.

LITERATURE CITED.

1. McKAY, ALEX. 1894 On the prospects of Finding Coal near Shannon on the Wellington-Manawatu Railway-line, 1891. *Rep. Geol. Explor. during 1892–93*, Geol. Surv N.Z., p. 1.

2. ADKIN, G. L., 1910. The Post-Tertiary Geological History of the Ohau River and of the Adjacent Coastal Plain, Horowhenua, North Island, *Trans. N.Z Inst*, vol 43, pp. 496-520.

3. COTTON, C. A., 1918. The Geomorphology of the Coastal District of South-west Wellington, *Trans. N.Z. Inst*, vol. 50, pp. 212-22.

4. ADKIN, G. L., 1919. Further Notes on the Horowhenua Coastal Plain and the Associated Physiographic Features, *Trans. N.Z. Inst.*, vol. 51, pp. 108-18.

5. OLIVER, R L., 1948. The Otaki Sandstone and its Geological History, *N Z D S I.R. Geol. Mem.*, *No. 7*, 49 pp.

6. ADKIN, G. L, 1948. On the Occurrence of Natural Artesian Springs in the Horowhenua District, *N.Z. Journ. Sci. Tech.*, vol. 29, no. 5 (sect. B), pp. 266-72

7. ADKIN, G. L, 1948. *Horowhenua: Its Maori Place-names and their Topographic and Historical Background*, Wellington, Department of Internal Affairs, 446 pp.

8. GRANGE, L. I, 1929. A classification of the Soils of Rotorua County, *N.Z. Journ. Sci. Tech.*, vol. 11 (1929-30), pp. 219-28.

9. GRANGE, L. I., 1937. The Geology of the Rotorua Subdivision, *N.Z. Geol. Surv. Bull. No. 37*, p. 138.

10. ADKIN, G. L., 1921. Porirua Harbour: A Study of its Shoreline and other Physiographic Features, *Trans. N.Z. Inst.*, vol. 53, pp. 144-56.

11. ADKIN, G. L., 1949. The Tararua Range as a Unit of the Geological Structure of New Zealand, *Trans. Roy. Soc. N.Z.*, vol. 77, Pt. 5, pp. 260-72.

12. MACPHERSON, E. O., 1949. The Otaihanga Faulted Outlier and Notes on the Greensand Deposit, *N.Z. Journ. Sci. Tech.*, vol. 30, no. 2 (Sect. B), pp. 70-83.

NOTE—Several geographical names have been used in this paper to facilitate brevity of description; these have not been submitted for approval to the New Zealand Geographic Board.