Art. XVII.—*Porirua Harbour: a Study of its Shore-line and other Physiographic Features.*

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Plate XXXV.

Contents.

Introductory.

The inlet known as Porirua Harbour, a landlocked arm of the sea, is a unique geographical feature of the western coast of south-western Wellington (fig. 1). Along this coast all other indentations are the result of marine abrasion acting more effectively than elsewhere on the weaker sections of the coast, the more resistant portions, which are receding less rapidly under wave-attack, being left to form the intervening promontories and headlands. Marine abrasion has played only a minor part in the shaping of Porirua Harbour—a part, however, that was important in connection with the evolution of the shore-line of that inlet.

The outline of Porirua Harbour is characteristic of a drowned area where the sea has penetrated a branching valley-system of somewhat mature topographic development. Two of the principal branches of this valley-system are now occupied by tide-water and constitute the present harbour or inlet, while other former indentations have been reclaimed from the sea by the infilling accomplished by local streams.

One of the first to touch on the physiography of the Porirua area and to correlate it with that of Port Nicholson was Dr. J. M. Bell (1910), who expressed the opinion (*loc. cit.*, p. 539) that the surface of a tilted earth-block dips from near the crest of the scarp of the Wellington fault in the direction of Porirua and forms the slope which originally determined the course of the Porirua as a consequent stream. The validity of the first part of this statement is borne out by the existence of a peneplane surface—evidently referable to the Kaukau cycle of Cotton (1912)—which surmounts the valley of the Porirua Stream and slopes towards sea-level in a northerly direction. In the same paper Bell also referred to certain historical proof that the small uplift which affected the district round Wellington City during the 1855 earthquake extended into the Porirua area, inasmuch as the Pahautanui Stream became noticeably less navigable than formerly.

Dr. C. A. Cotton in a detailed paper on Wellington physiography (1912) referred to the Porirua area at rather greater length. He dissented from the view held by Bell that the Porirua Stream flows down the back slope of a tilted block, on the grounds that the Porirua occupied its present

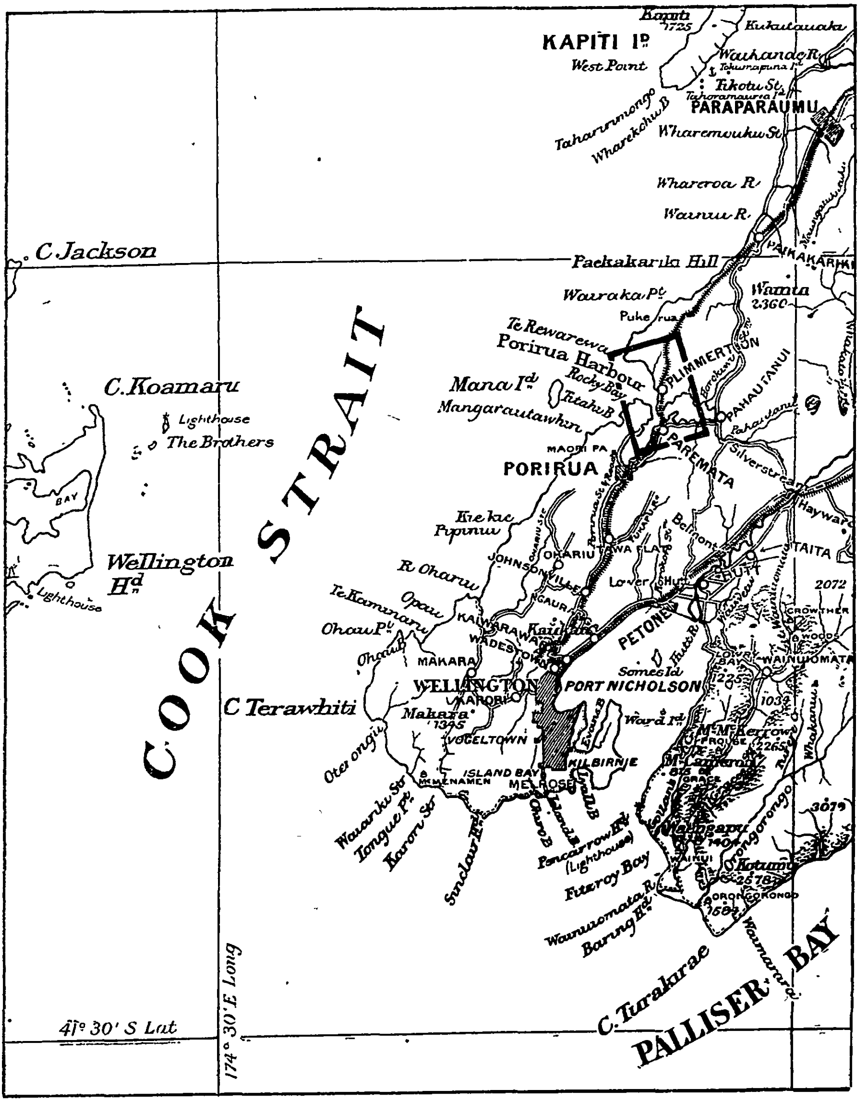

FIG. 1.—Locality map of south-western Wellington, showing places mentioned in text; also the area at Porirua Harbour shown in figs. 4, 5, and 6.

valley before the faulting and tilting took place. It does not necessarily follow, however, that the excavation of the Porirua Valley has been accomplished since the faulting and tilting, and that it was not in existence prior to those events. The drowning of the lower reach of the Porirua Stream

to form one arm of the present inlet is ascribed by Cotton (*loc. cit.*' p. 257) to a downward movement of 30 ft. or 40 ft. subsequent to the general movement of elevation of the Wellington Peninsula, but no precise cause of the subsidence is proffered. Cotton also states that " at Porirua there appears to have been little or no movement either up or down in 1855. Raised rock platforms similar to those at Wellington are not found." I shall be able to show, however, that raised shore-platforms of wave-planed rock do occur along a very considerable part of the Porirua shore-line, and form one of its most conspicuous features.

The present writer had occasion to refer to the Porirua area in connection with an apparent deformation of the southern end of the Horowhenua coastal plain (Adkin, 1919, pp. 110–12). The deformation of the coastal plain was ascribed to its intersection by the subsiding, or downward tilting, of the earth-block, bounded east and west probably by flexures, which extends from Port Nicholson to Porirua Harbour, and thence northward past Pukerua inside the Island of Kapiti After a detailed examination of a large portion of the Porirua area the writer sees no reason for any modification of this solution of the problems involved.

The Land.

Since the present paper has for its main theme the description and interpretation of shore-line features, only the relevant elements of the land-surface of the Porirua district will be discussed, under two headings, as follow: (1.) Topography and Drainage; (2) Influence of Deformation on the Relief.

(1.) *Topography and Drainage.*

The country surrounding Porirua Harbour is one of moderate elevation but of high relief. This moderately elevated tract rises to a greater height inland, especially in a north-easterly direction, and consists of a series of fairly even-crested hill-ridges, which for the most part have a N.E. by N.–S.W. by S. trend, though a few of them are orientated more nearly north and south. The ridge-tops are commonly broad and undulating, and the ridges themselves are flanked on either hand by long branching lateral spurs that taper off as they descend to the bottoms of the intervening longitudinal valleys. The principal valleys have flood-plains in their lower portions, and graded bottoms extend practically to their heads. In their upper reaches, however, overlapping spurs are still a prominent feature. The valley-sides are well dissected by the numerous lateral gullies, but this dissection has not everywhere extended to the main ridge-crests, where what seems to be a more mature relict topography still prevails.

There is some evidence, in the form of a high-level bench, notably at the head of Taupo Creek and in the valley of the Kahao Stream, of an intermediate partial erosion-cycle, probably corresponding to the Tongue Point cycle of Wellington Peninsula, and in addition to this there are areas of rejuvenation due to coastal recession and other causes. A full consideration of these matters is beyond the scope of this paper, but it may be remarked that, while the topography is undoubtedly composite, indications of the intermediate erosion cycle or cycles have been practically obliterated except in the instances cited above. Broadly speaking, therefore, the topography of the Porirua area may be described as being just past early maturity—that is, in the stage when maximum relief is giving place to more subdued forms.

The main drainage-lines leading to Porirua Harbour have, with one notable exception, the same parallelism, trend, and longitudinal elongation that distinguish the intervening ridges. The one exception is the Pahautanui Stream, which, together with its drowned lower valley—viz., the broad eastern arm of Porirua Harbour—lies transverse to all the other topographical features of the district. The present Pahautanui Valley and its drowned lower portion is too widely-opened and ancient a feature to have had so recent an origin as to belong to a young stream consequent on a bounding flexure of the Port Nicholson–Porirua Harbour tilt-block, and must be regarded as antecedent to the adjacent longitudinal ridges and drainage-lines.

From what is now known of the morphology of other portions of the Wellington district, it is evident that the ridge-tops to the north-east of Porirua Harbour are the residuals of a peneplaned surface, in all probability belonging to the Kaukau cycle of erosion. In the Wellington Peninsula, however, the peneplaned surface of the Kaukau cycle has been uplifted uniformly, whereas the corresponding surface to the north-east of Porirua Harbour has a decided westerly or south-westerly tilt. This is clear evidence of the existence either (1) of one large block having a warped surface which changes from a uniform level in the south-west to a decided upward slope in the north-east, or (2) of two distinct earth-blocks differentially uplifted with respect to each other. The two blocks, or two parts of a single original block, as the case may be, are now divided by the subsided Port Nicholson–Porirua tilt-block already referred to.

(2.) *Influence of Deformation on the Relief.*

The rocks of the Porirua district are the well-known closely-folded greywackes and argillites usually referred to the Maitai formation of Trias-Jurassic age. The strike of the strata in this vicinity appears to have a general N.E. by E. to E.N.E. direction (N. 55° to 70° E. true = N 38° to 53° E. magnetic), and the dip is for the most part vertical, indicating an isoclinal structure.

As stated above, the trend of the series of subparallel hill-ridges which form the moderately elevated country north-east of Porirua Harbour is usually N.E. by N., while the average strike of the rocks forming them is N. 62° E. (true). With ridges and strike intersecting each other at so large an angle (about 27°) it is difficult to understand the genetic relationship of the hill-ridges to the geological structure so far as the ancient folding is concerned.

Two theories have been advanced to account for the longitudinal features of the orography of the Maitai rocks of southern Wellington as exemplified by the Tararua Range and the lesser hills to the south-west. By one theory the longitudinal ridges and drainage-lines are regarded as being respectively dependent on, and in adjustment to, the original geological structure (Cotton, 1918, pp. 213–14); in the other, secondary deformation is held to be the determining factor in the production of these features (Adkin, 1920, p. 184).

It is extremely likely that both secondary deformation and adjustment to structure were of prime importance, each exercising a predominant influence, but in different localities. In the Wellington Peninsula where the secondary corrugation of the highest peneplaned surface was comparatively weak, and also where its axes appear to have coincided with the strike of the ancient folding, adjustment to structure was probably the factor that determined the trend of the ridges and valleys; but on the more

elevated earth-block now known as the Tararua Range the secondary deformation exercised by far the most potent influence in the determination of the major features of the relief. The marked difference in the drainage-pattern of the Tararua Range and that of the Wellington Peninsula strongly supports this view, and the hilly tract situated to the north-east of Porirua Harbour doubtless forms a transitional area between the north-easterly strongly deformed and the south-westerly less affected surface of the uplifted pre-Miocene peneplain (Bell, 1910, p. 538; Henderson, 1911, pp. 312–13). In the transitional area just referred to, the strike of the ancient folds sweeps round and assumes a more easterly direction than it does in the Wellington Peninsula, and intersects the longitudinal ridges and drainage-lines at an angle of approximately 27°; hence the relief in this locality bears a closer relationship to deformation than to structure, though the influence of the latter may not be wholly wanting.

The Coast-line.

(1.) *The Cliffs.*

The outer coast of south-western Wellington is characterized by a continuous line of bold cliffs rising to heights of several hundreds of feet. At and within the entrance to Porirua Harbour the cliffs are still of imposing aspect, but they diminish in height as the distance from the open sea increases. The cliff-cutting has been effected by marine abrasion mainly under the influence of the prevailing north-westerly wind, while the powerful but less-prevalent southerly wind has produced less extensive but similar results, especially on southward-facing sections of the coast-line within the confines of the harbour.

In itself the cliffed coast-line is a normal feature of marine abrasion, but at the present day it possesses the peculiarity of being beyond the reach of the waves; in other words, the cliffs do not belong to the present but to a former base-line of marine denudation.

With the exception of a few places on the outer coast between the South Head of Porirua Harbour and Titahi Bay, and at two or three headlands in the vicinity of Wairaka Point, where the sea is again undercutting the high land, the former cliffed coast is separated from the present shore-line by a strip of low-lying ground of a width usually from 5 chains to 10 chains, but in certain situations from a quarter to over half a mile. Along the greater part of its length the low-lying strip at the base of the cliffs is a raised rock platform—an uplifted incipient plain of marine denudation (Plate XXXV, and fig. 2, *a*); the remaining portion—situated principally at the seaward ends of the larger valleys opening into Porirua Harbour near its entrance—has been formed by the progradation of the shore brought about by the deposition of a superabundance of coarse waste which has been drifted down the outer coast and into Porirua Harbour and has been piled up above sea-level, in the first instance by the action of the waves, and raised still farther by the earth-movement responsible for the uplift of the adjacent stretches of shore-platform of wave-planed rock.

(2.) *The Raised Shore-platform.*

(*a.*) On the Mainland.

The raised shore-platform (Plate XXXV, and fig. 2, *a*) is one of the most interesting, and in some places also the most conspicuous, of the shore-line features of Porirua Harbour and of the neighbouring coast. The earth-

[Face p. 148.]

The raised shore-platform of the Porirua coast. Inland cliffs on left. The inner part of the shore-platform is covered with blown sand, and its outer margin is being destroyed by the marine abrasion of the current cycle.

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movement responsible for its present position above high-tide level was undoubtedly the uplift that affected the eastern shore of Cook Strait during the 1855 earthquake, as shown by several lines of evidence: (1.) The similarity of the raised shore-platform and the raised beach-ridges of the Porirua area to the raised shore-platform fringing the shores of Miramar Peninsula at Port Nicholson, and to the 9 ft. beach (Crawford, 1869, pp. 320–21; Aston, 1912, p. 209; and writer's observations) of Turakirae Head, respectively; in the latter localities these features have always been attributed to the uplift of 1855. (2.) The historical proof of the shallowing

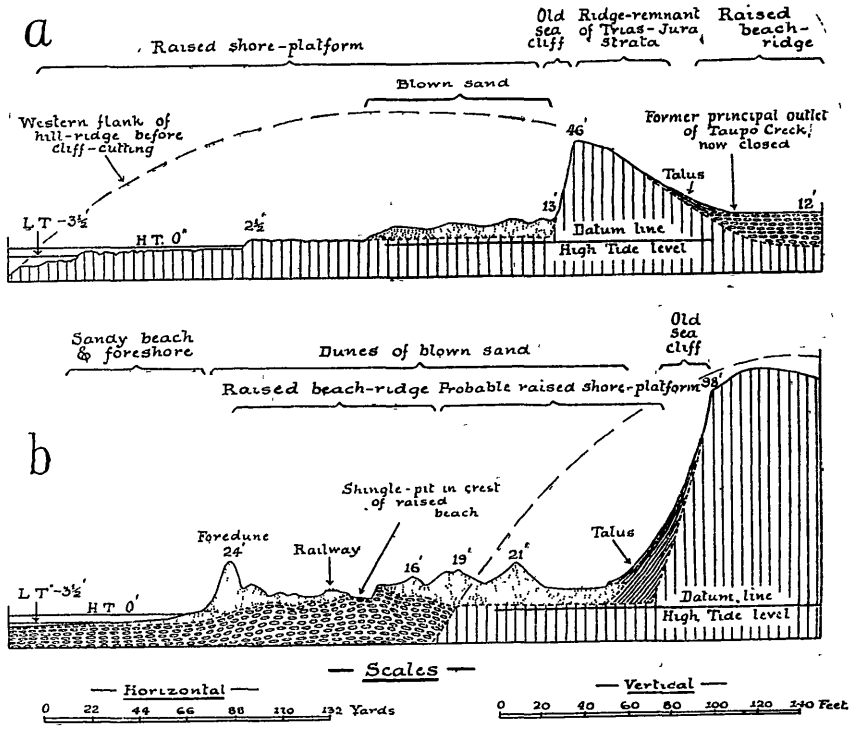

FIG. 2.—Sections of the Porirua coast: (*a*) at Taupo Point, showing the raised shore-platform and inland cliffs; (*b*) half a mile south of Taupo Bay, showing the raised beach-ridge, inland cliffs, and dunes of blown sand. Scale, vertical to horizontal, 3:1.

of the Pahautanui Stream as cited by Bell (*loc. cit.*, p. 538). I have also received details of a statement made by Mr. James Jones, an old Pahautanui settler, to the effect that after the earthquake the tidal flats at Pahautanui were permanently raised above high tide, and were for a time noisome on account of putrefying shell-fish and other marine matter.* (3.) The persistence of a considerable proportion of what is practically the original surface of the raised shore-platform, in spite of the effects of powerful

* Mr. Jones stated that an area of at least 100 acres was raised above sea-level, and his estimate of the amount of uplift was 3 ft. This agrees with my own estimate based on observations of the raised shore-platform. Mr. Jones also referred to the shallowing of the Pahautanui Stream, thus confirming in all details the historical evidence cited by Dr. Bell.

marine abrasion acting under very favourable conditions, points to the extremely recent date of the uplift of the rock platform and of the initiation of the present cycle of marine denudation.

As is well known, the earth-movement of 1855 was of the nature of a tilt to the west or north-west affecting both sides of Cook Strait. The hinge-line of the tilt was evidently situated along the bed of the strait, since its western shore was depressed and its eastern uplifted. The locality of maximum uplift was Cape Turakirae (see fig. 1), the amount being 9 ft. At Port Nicholson the uplift amounted to 5 ft., and at Porirua Harbour entrance 3 ft. Even at Wanganui there was a slight uplift (Field, 1892, p. 573), indicating that the hinge-line of the tilting block did not intersect the coast of the mainland south of that place.

As already indicated, the raised shore-platform is being rapidly demolished by wave-action, so that only a portion of the original surface remains. This rapid demolition is due to several causes, the principal of which are the low altitude of the platform, the thin-bedded character of the rocks forming it, the presence of numerous faults and closely-spaced joints, and—perhaps most potent of all—the very effective tools at the disposal of the waves—viz., a plentiful supply of exceedingly hard greywacke boulders. The raised shore-platform has, naturally, suffered greatest destruction along its outer margin (see Plate XXXV), but in some places, owing to the presence of a broad band or a series of narrower bands of the weaker argillite, it has been entirely removed to within perhaps a few yards of the old sea-cliff, and replaced by a tiny bay. This effect of the weaker strata is often very striking, as also is the influence of bedding, joint, and fault planes which determine the position of deep grooves across the platform.

The raised wave-cut shore-platforms of south-western Wellington are especially suggestive and instructive in connection with the subject of intermediate incipient or partial erosion-cycles which go to make up the composite topography characteristic of many New Zealand landscapes. At Porirua Harbour the raised shore-platform, which, as elsewhere, represents a small interruption in the geographical cycle, is being rapidly destroyed. In many cases a pronounced interruption in the geographical cycle may well be the sum of a series of small interruptions each of which has been obliterated in turn, thereby giving the whole the false appearance of a single great interruption. This is probably the key to the origin of occasional isolated hillside or shore-line benches and other similar indications of intermediate erosion-cycles—fragments preserved in exceptionally favourable localities long after all other traces of the cycles to which they belong have been obliterated.

(*b.*) The Reef.

The Reef is the name given to a pair of interesting rock shoals situated in mid-channel at the entrance of Porirua Harbour. At high tide the higher rocks reach uniformly to 3 ft. above sea-level. This uniform level corresponds in every respect to the surface of the raised shore-platform that fringes the mainland. The Reef marks the former site of an island, or pair of islands, which were completely planed off by marine abrasion prior to the uplift of 1855. At low tide the two groups of higher rocks are surrounded by a much more extensive area of low rocks just awash. This lower surface is the present plane of marine denudation, and is the level to which the 3 ft. surface has been cut down since 1855. The evidence furnished by the Reef is supplementary to and confirmatory of that afforded by the raised shore-platform on the mainland

(*c.*) Potholes formed by Wave-action.

An interesting minor phase in the destruction of the raised shore-platform is the formation of potholes by wave-action. I have nowhere come across a reference to the formation, in any part of the world, of potholes by wave-action, and, though this phenomenon may have been previously noted, its occurrence is probably very rare.

The conditions requisite for the formation of such potholes are: (1) The presence on the shore-line of a fairly level surface of relatively soft rock; (2) waves of sufficient power to perform the work required; (3) cobbles of relatively hard rock to act as the cutting instruments.

The necessary combination of conditions and factors as above occurs at Porirua Harbour near Plimmerton (see Plate XXXV and fig. 1). At Plimmerton, because of the low altitude of the hills and their mature topography, the shore-platform is composed of comparatively soft weathered rock. Other important factors are the thin-bedded character and the vertical attitude of the rocks forming the platform, and the strike of the strata, the trend of which is here approximately at right angles to the shore. Being lines of weakness, the bedding-planes of the vertical strata have been hollowed out by the waves. Upon being washed into one of these grooves a travelling cobble or boulder of the extremely hard greywacke is propelled landwards until it becomes immovably wedged in a fissure or meets an obstruction preventing its farther progress. In the latter case its forward motion is changed to a circular one, and a pothole is initiated. This may grow to a considerable size unless interrupted by the breaking-away of one of the walls of the hollow. The largest pothole noted measured 3 ft. 6 in. by 2 ft. in diameter and 2 ft. in depth.

(3.) *The Raised Beach-ridges.*

The raised beach-ridges of Porirua Harbour have a narrower range than the uplifted shore-platform, being confined to the eastern coast at the harbour's entrance from near Te Rewarewa Head to the vicinity of the Paremata railway-bridge, and to the outer coast from Te Rewarewa Head northward to Pukerua Bay. Along these stretches of coast-line two conterminous series of shingle and boulder beaches may be distinguished: (1.) An older series which was in existence prior to the 1855 earthquake and was uplifted during that event, so that it is now beyond the reach of the waves and is not in the course of accumulation. This series of beaches is referred to herein as the raised beach-ridges. (2.) A younger series still being deposited along portions of the present shore-line within the limits defined. This is undoubtedly the post-earthquake equivalent of the older series.

The most northerly point of origin of the material of both series of beach-ridges is the coast at Pukerua and Wairaka Points, where great outcrops of intensely hard greywacke form headlands abutting on this very exposed portion of the coast. Some of the detritus derived from the abrasion of these greywacke headlands is carried eastward into Pukerua Bay, but the greater part is swept southwards down the coast-line by powerful waves acting under the influence of the prevailing north-westerly wind.

Immediately south of Wairaka Point (see fig. 1) there is a great embayment, which on account of its general appearance and for convenience of description I have named Desolate Bay. Along its entire length the

shore-line of Desolate Bay is backed by an unbroken line of cliffs, probably 600 ft. to 700 ft. in height, and remarkable for the development of extensive screes. These, which consist of angular blocks of greywacke of all sizes, descend to the tide-level line and add greatly to the quantities of detritus which the sea is carrying down the coast.

At High Rock Point, which is the southern horn of the crescentic Desolate Bay, the last of the naked screes carries its quota of angular blocks to sea-level, and south of this spot the screes are "fixed" by vegetation. Here also the raised beach-ridge makes its first appearance, and extends as a flat-topped terrace at the foot of the cliffs as far as Te Rewarewa Head. North of Te Rewarewa the raised beach-ridge evidently rests upon the surface of the raised shore-platform; south of that headland it appears to follow the outer margin of the latter.

The most interesting development of the raised beach-ridges is found just within the entrance of Porirua Harbour, on its eastern shore. In its progress southward (prior, of course, to the uplift of 1855) the older accumulation of travelling shingle extended in the form of detached beaches or shingle-spits, piled up to 7 ft. above sea-level, right across the former

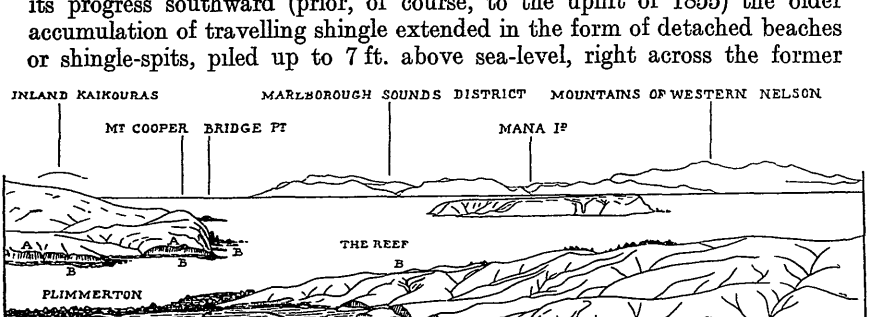

FIG. 3.—Panoramic view of the entrance of Porirua Harbour, looking south-west and west, showing the general topography and the relationship of the shore-line features. A, inland cliffs; B, raised shore-platform; C, deltaic flat of Taupo Creek; the line of houses at Plimmerton marks the position of the detached beach or spit which cut off the former Taupo indentation.

indentations now represented by the flat-bottomed lower valleys of Spring Creek, the Motuhara Stream, and Taupo Creek. (Compare figs. 4 and 5.) Continuing southward, the travelling shingle was piled up by the waves about sea-level and carried forward until it had reached the vicinity of the present Paremata railway-bridge. Here its farther progress was arrested by the strong currents caused by the ebb and flow of the tide in the extensive Pahautanui arm of Porirua Harbour.

The formation of this inner beach-ridge, which prior to the 1855 earthquake reached a maximum height of 8 ft. above high-tide level, was succeeded by the formation of an outer detached beach or shingle-spit (see fig. 5, at "The Narrows"), which branched off from the inner beach at a spot half a mile south of Taupo Bay, and was built forward by the waves as far as the present Paremata Point, when its farther progress was again arrested by the tidal currents. Unable to extend longitudinally, the spit was increased in breadth by additions of the travelling shingle until it presented the appearance of three parallel ridges, the highest of which was piled up to a height of 8 ft. above high-tide level.

The uplift of 1855 raised the shingle beach-ridges and spits, together with the other coastal features in this vicinity, a farther 3 ft. The uplift also raised the shallow shingly sea-bed between the inner and outer shingle-beaches at Paremata Point slightly above sea-level; and subsequently the formation of the younger series of beach-ridges added two more shingle-ridges to the outer margin of the raised Paremata Point spit.

(4.) *Deltaic Flats.*

The cutting-off from the open sea of some of the lateral indentations of Porirua Harbour in its initial form (fig. 4) by the formation of detached shingle-beaches across their entrances, and the conversion of these indentations into lagoons (see fig. 5), has led to the production of a considerable area of fertile flat land. This newly formed land comprises the flats of deltaic origin in the lower portions of the valleys that open on to the eastern shore of Porirua Harbour at its entrance.

In the valley of Taupo Creek, where the largest tract of deltaic flat occurs (see fig. 3), the sea formerly penetrated inland at least three-quarters of a mile farther than it does now, as is shown by the presence of old sea-cliffs of small size at that distance from the present sea-beach. The space between these inland cliffs and the raised beach-ridge upon which the village of Plimmerton has been built has since been reclaimed by the outward growth of the deltaic deposits of Taupo Creek and its tributaries. Other deltaic flats occur in the neighbouring valleys of Spring Creek and of the Motuhara Stream (see fig. 5). Flats of a somewhat similar deltaic character also occur in the lower valley of the Kahao Stream, as well as at the heads of the main arms of Porirua Harbour; but it is unlikely that deltas would have been formed, in the absence of the detached beach-ridges, in the more exposed lateral valleys nearer the entrance of the harbour.

(5.) *The Sandy Beaches.*

The sandy beaches, of which Taupo Beach at Plimmerton is the largest, are of very recent origin. The source of the sand appears to be the sediments of Porirua Harbour. After the formation of the tidal flats in the upper reaches of the harbour a bar was formed just within its entrance. On the bar the maximum depth of water is only 5 ft., while on either side of it the depth is 9 fathoms (Admiralty chart). The bar appears to have been formed by the checking of the sediment-laden ebb tide drawing out of the harbour by the waves raised by the prevalent north-westerly winds. Part of the deposited sediment would then be cast back upon either of the adjacent shores, and would accumulate at the heads of embayments to form sandy beaches. Dunes of blown sand derived from the sandy beaches cover small areas at several places along the shore of the harbour.

THE ORIGIN OF THE HARBOUR AND THE EVOLUTION OF ITS SHORE-LINE.

The deposition of the Trias-Jurassic sediments and their subsequent folding and uplift followed by peneplanation appear to have been the earliest diastrophic and physiographic events in the area under notice. These conditions held until the advent of a second period of diastrophism (the Kaikoura deformation). The peneplaned land-surface was first uplifted and then block-faulted on a large scale, the squeezing of the earth-blocks by the compressive forces within the earth's crust being in all probability

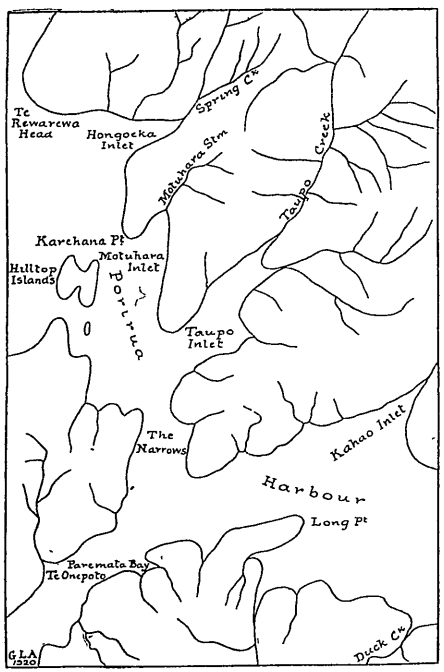

FIG. 4.

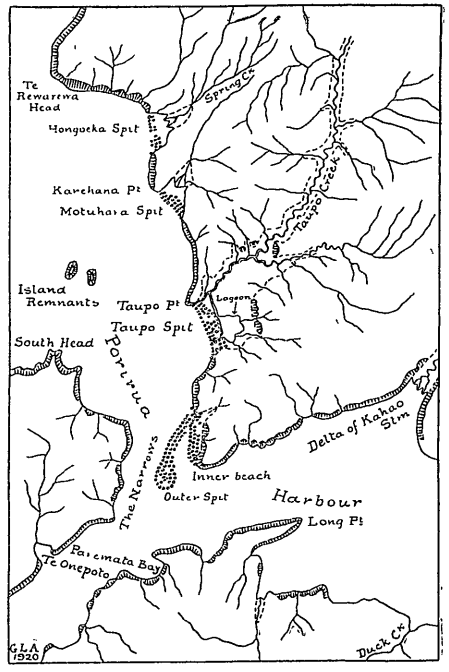

FIG. 5.

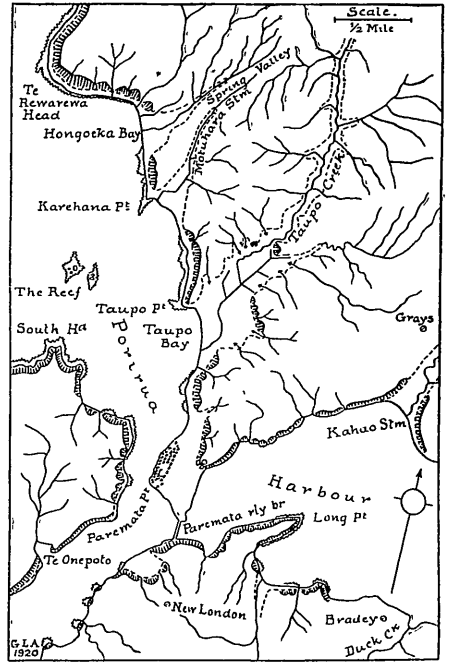

FIG. 6.

FIG. 4.—Evolution of the Porirua coast-line. Stage 1, a young drowned coast, caused by the drowning of the Pahautanui–Porirua valley-system.

FIG. 5.—Evolution of the Porirua coast-line. Stage 2, a submature coast, resulting from the cliffing of the headlands and the closing of the embayments by spits of shingle (detached beaches). The complete filling of the embayments with deltaic deposits and the formation of the outer shingle-spit at "The Narrows" took place towards the close of this stage.

FIG. 6.—Evolution of the Porirua coast-line. Stage 3, an uplifted coast. The uplift which took place during the 1855 earthquake produced the raised shore-platform (shown by the irregular line along the shore), inland cliffs, and uplifted beach-ridges which form conspicuous features of the present coast-line.

a factor in the elevation of the higher blocks. In what is now the southern part of the Wellington district the main earth-blocks have a N.N.E.–S.S.W. direction, this being the general trend of the principal fractures. The present high-standing blocks were in some cases uplifted uniformly, but more commonly tilted, the usual direction of the tilt being towards the west. The compression that accompanied the block-faulting and contributed to the uplift of the high-standing blocks was also responsible for the warping of the upper surfaces of these. The warping took the form of a series of broad anticlinal and synclinal flexures disposed longitudinally with respect to the N.N.E.–S.S.W. elongation of the earth-blocks. These longitudinal flexures, which determined the lines of the present longitudinal drainage, in some places coincide with the strike of the ancient folding, and in others intersect it at a considerable angle. The latter fact is accepted by the writer as unequivocal evidence that the secondary folding or warping, where operative, was the predominant factor in the determination of the present longitudinal drainage.

The degree of secondary folding sustained by the surfaces of the high-standing blocks was doubtless variable: in some instances it was pronounced; in others, again, perhaps insufficient to shape the initial drainage-pattern. In the latter cases the longitudinal drainage is possibly the result of adjustment to the ancient structure.

In the highest-standing block—viz., that from which the Tararua Range has been carved—the compressive forces acted in two directions at right angles to each other, with the result that the principal longitudinal folds were accompanied by transverse folds, or perhaps the latter were represented in part by dips in the main axes of folding. This accounts for the occurrence of the zigzag and trellis drainage-pattern solely characteristic of the Tararua Range in the area under notice. On some of the high-standing blocks of lesser elevation only longitudinal flexures were developed, and in others the warping appears to have been practically absent.

The last diastrophic event prior to the historical period was the inbreak of the Wellington fault and the resultant northerly tilt of the Port Nicholson–Porirua Harbour earth-block. This subsidence was the cause of the drowning of the maturely developed Pahautanui–Porirua valley-system, and of the creation of Porirua Harbour. In its initial stage the shore-line of the newly formed inlet had all the characteristics of infancy, such as are present when a drowned land-surface of the mature stage of topographic development is involved: the hill-slopes descended to the water's edge and continued without interruption below the level of the water-plane; in plan the outline of the shore was one of great irregularity, the projecting spurs forming prominent salients, and the drowned lateral valleys acute tapering indentations. Near the entrance of the inlet a few hilltop islands—the higher parts of a nearly submerged spur—lifted their rounded summits above the new sea-level. The general configuration and the outstanding topographic features of Porirua Harbour at this stage of its development are shown in fig. 4.

The initial stage of the Porirua shore-line was a very transient one. Under wave-attack, even in sheltered positions well within the harbour's entrance, the cliffing of the partially submerged hill-slopes was rapidly effected, and in addition detached beaches or shingle-spits were thrown across the mouths of certain of the indentations on the eastern shore, converting them first into tidal and later into brackish or fresh-water lagoons.

Fig. 5 shows the Porirua shore-line (at high tide) at a later stage of development than that represented in fig. 4: the coast-line has been straightened by cliff-cutting and by the closing of the bays by shingle-banks; delta deposits are rapidly filling the bays thus cut off; and the hilltop islands near the entrance of the harbour have been reduced to island remnants. The shore-line at this period appears to have reached a submature stage.

Before the interruption referred to below, the above processes were carried to an even more advanced stage than that depicted in fig. 5. The lagoons in the former embayments were completely filled with deltaic deposits, and converted into salt and, later, into fresh-water marsh. The island remnants also disappeared, having been cut down to sea-level by continued marine abrasion; at low tide their former sites were marked by rock reefs.

The progress of the shore-line towards complete maturity was interrupted by the earthquake of 1855. The narrow shore-bench or incipient plain of marine abrasion, to the between-tides level of which the hill-slopes of the initial shore-line had been cut down in the process of cliff-cutting prior to 1855, was raised on that date to a height at Porirua Harbour of 3 ft. above high-water level (see Plate XXXV, and fig. 2, *a*).

The above considerations clearly indicate that the Port Nicholson and the Porirua areas belong to one and the same physiographic district, since it has now been demonstrated that even the last diastrophic event—viz., the small uplift of 1855—was common to both.* The principal divergence in the parallelism of the life-histories of the two areas is the difference in form and origin between their respective harbours: one of these is of tectonic origin—a complicated graben-like depression subsequently modified by the various mechanical agents of change; the other is the result of the partial drowning of a normal valley-system modified since the submergence by the several phases of marine abrasion and deposition.

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* Contrary views have been held by some—*e.g.*, Sir Charles Lyell, quoted by C. A. Cotton (1912, p. 257).