Raised Beaches and other features of the South-east Coast of the North Island of New Zealand.

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PLATES 75–80.

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INTRODUCTION.

THE district described in this paper comprises the coastline of the southern and south-eastern portion of the North Island of New Zealand. A narrow strip of country inland from the coast itself was also examined, so that the bearing of the rocks of each locality on the type of coastline could be considered. Thus the description of each strip of coast is prefaced by a note on the geological structure, or the rocks of the locality, as it has been found that the type of present-day coastline is profoundly affected by the geological formation of the country.

Literature on the coastal features is fairly complete for the Wellington area, Crawford, Park, Bell, Cotton, Adkin, and Aston having each contributed one or more papers; but the Wairarapa coast has received little attention. Crawford and A. McKay recorded raised terraces but neither described them, though McKay estimated the height of the Palliser Bay platforms. Hence this portion of the work provided a virgin field.

The thanks of the writer are here gratefully extended to all those who have so kindly afforded him accommodation on a much exposed and thinly populated coast, without which help the work would have been extremely arduous. To Mr. Jobberns, of Christchurch, his sincere gratitude for a trip along the Canterbury raised terraces is here expressed. The writer is also indebted to Dr. Cotton for permission to reproduce one of his sketches. (Fig. 4).

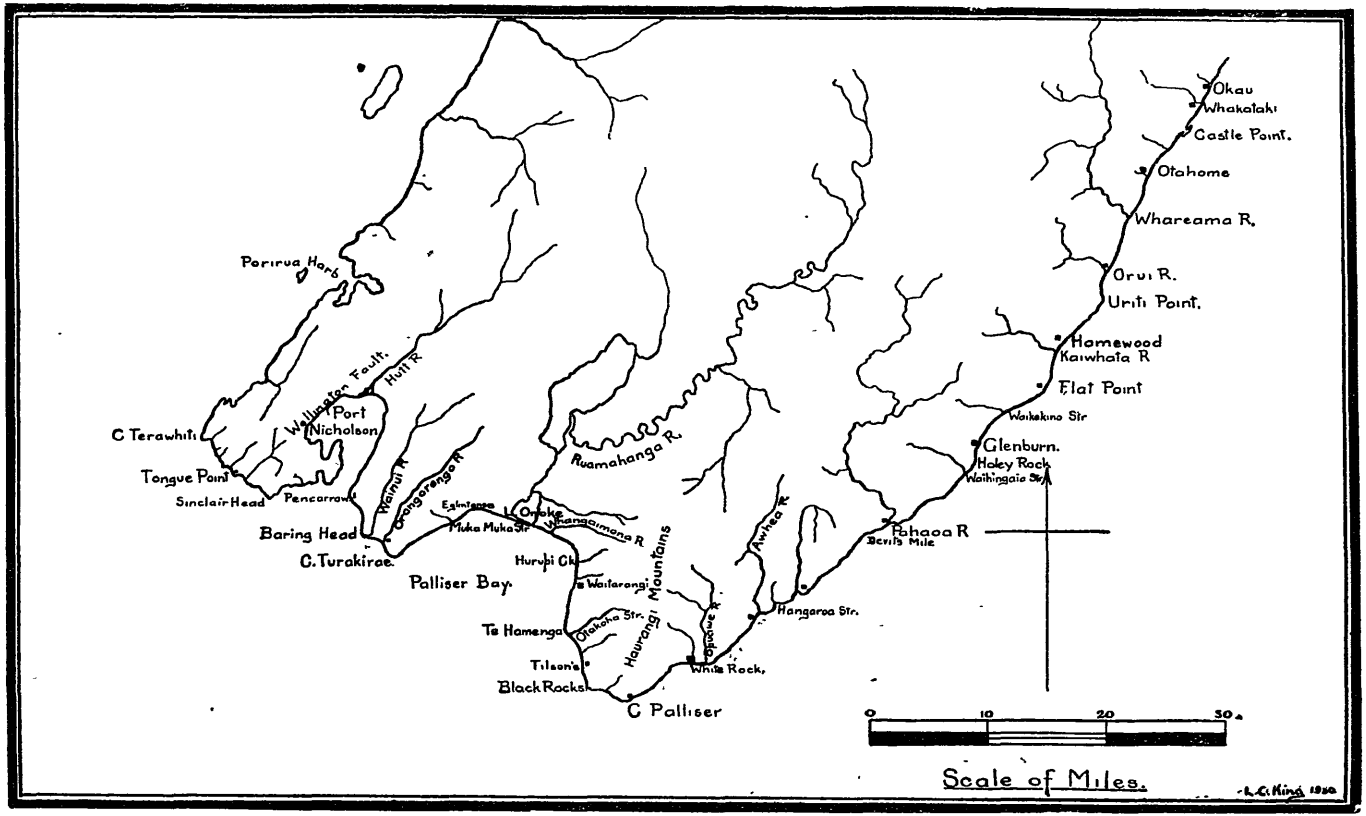

FIG. 1.—Map of Southern Portion of the North Island of New Zealand.

Cape Terawhiti to Port Nicholson. (18 miles).

Geographically, Cape Terawhiti provides a very convenient starting point for this paper, for it is the most westerly point of the south coast of the North Island and so forms the western limit of one of the coasts with which this paper is concerned. Furthermore, it is shown on the majority of maps and so is widely known, in name at least. From Terawhiti east, as far almost as Lake Onoke at the head of Palliser Bay, the rocks consist of a single series of hard, contorted greywackes and argillites across the strike of which, the shoreline cuts, for the main part, at right angles. The coast is bold and rugged, the country rising rapidly to over 1000 ft. Usually, cliffs several hundred feet high front the sea, which, until recent times, has been strongly attacking them. Owing to a comparatively recent movement of the strand the sea no longer reaches quite to the foot of the cliffs. The present shoreline consists of stretches of sand or gravel beach, alternating with wave-cut platforms which project seaward from many of the more prominent headlands.

So far as any discussion on the raised beaches of the district is concerned, Terawhiti is again most suitable, for, just south of the Cape itself is a splendid example of a marine cut platform which has been raised to a height of 125 ft. above sea-level. The surface is smooth; only a few stacks 6 ft. high, now rapidly disappearing under the action of the normal subaerial agencies, still stand above the otherwise level surface. The rear edge of the platform is covered in part by talus, accumulating at a rapid rate from the steep slopes, which rise sharply to a height of 1500 ft. This makes somewhat difficult any accurate determination of the amount of uplift that has taken place, but the mean of a number of estimates gives a value of 125 ft. A covering of six or eight feet of discoidal gravel, up to $\frac{3}{4}$ in. in diameter, may be seen where the protecting grass has been removed. This thinness of the gravel cover is characteristic of all the platforms from Terawhiti to Tongue Point. The explanation may be that, just as the strong swell and current causing the Terawhiti tide rip pass through Cook Strait to-day, so, during the period in which the benches were cut, there was a strong tidal or ocean current which swept most of the debris, derived from the land and resting on the cut shelf, off into deep water, thus keeping the rock surface compartively clean.

A remnant of a higher platform, now 250 ft. above sea level also occurs at Cape Terawhiti. The surface of this platform is almost completely obscured by talus but there can be no doubt of its existence, especially when seen in profile from the other side of Oterongu Bay. (Plate 75, Fig. 1). This prominent higher bench is of the utmost importance as it occurs in every locality along the south coast where the lower or younger platform is well developed; but, just as the lower is present at different heights in different localities, so there is no constant height, or ratio of heights, between the upper and lower platforms. This seems to prove that warping and tilting occurred either during or between the periods of uplift, just as differential warping of a comparatively late age has been

shown by Cotton (1921B, p. 131 *et seq.*) to have governed the form of the Port Nicholson depression.

Along almost the whole of the coast from Terawhiti to Tongue Point the lower platform is continuous. A few small streams have cut gorges 20 yards wide across it at intervals, but there can be no doubt as to its continuity, even though it is not uniform in height. Observed from the sea, it forms one of the most prominent coastal features, though at no place is it more than 100 yards wide and usually only a few feet across. From a height of 125 ft. at Terawhiti it descends to 110 ft. at the head of Oterongu Bay, though this lesser height may be due to slumping of the rocks which are here traversed by an intense shatterbelt. Thence it rises somewhat abruptly to 145 ft. at the east end of Oterongu Bay. For the next mile it continues horizontally, after which it rises gradually in the course of two

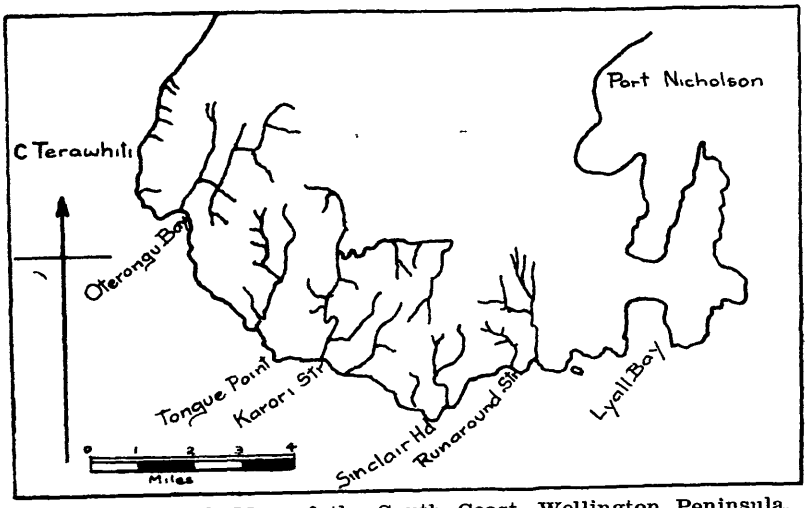

FIG. 2.—Sketch Map of the South Coast, Wellington Peninsula.

miles or so to 270 ft. a little to the west of Tongue Point. It was this change in height that induced Park (1910, p. 586) to say that he had satisfied himself that it was not a marine platform of erosion; but his alternative hypothesis of a glacial origin can hardly be deemed so convincing as the theory that he attempted to overthrow. Throughout its length the platform exhibits the same thin veneer of beach gravels that was noted at Cape Terawhiti. A glance at Plate 75, Figs. 1 and 2 will serve to suggest a relationship between the benches in the two localities and the following of the lower platform continuously from one to the other shows that they are to be correlated in spite of the disparity in height, those at Tongue Point being twice as high as those at Terawhiti.

The Tongue Point platform, undoubtedly the finest west of Port Nicholson, has been described by Cotton (1912, p. 255). Along its base it is over a mile long and it reaches a maximum width of almost half a mile, the height at the rear being 240 ft. As noted by Cotton, even the coarser beds of beach cover attain a maximum thickness of

cnly eight feet. This also bears witness to the strength of a former Cook Strait current. Unlike the other rock platforms, Tongue Point is quite free from any stacks or unconsumed upstanding rock masses. It presents, therefore, a remarkably even surface with an average seaward slope of 5°, which is as yet almost untraversed by streamlets. This may be attributed to the fact that the platform is flanked by two large streams, the Waiariki and the Karori, which effectively drain the country behind the platform so that the only run off is from the surface of the platform itself and the steep cliff at the rear.

At Tongue Point, as at Cape Terawhiti, a second (higher) bench is present at twice the height of the main platform, i.e., at 480 ft. (Plate 75, Fig. 2). It is developed to the same relative extent as that at Terawhiti and although no intervening bench remnant could be found the two must undoubtedly be correlated.

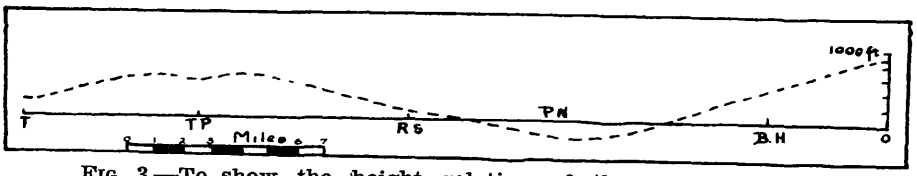

FIG. 3.—To show the height relation of the shoreline of the Tongue Point Cycle (dotted line) to that of the present day.
T. Terawhiti. R.S. Runaround Stream. B.H. Baring Head.
T.P. Tongue Point. P.N. Port Nicholson. O. Orongorongo.

Between Tongue Point and Port Nicholson no other raised marine platforms were observed but most valuable data may be obtained by a consideration of the amount of rejuvenation shown in many of the stream courses. By measuring the heights of the old valley-forms a regular sequence of uplifts was obtained in support of Cotton's "Port Nicholson Warp" theory. Fig. 3, drawn from the above data and showing the relation of the ancient shoreline of the Tongue Point Cycle to that of the present day, demonstrates clearly the nature of the warp as distinct from any faulting. Between Island Bay and Haughton Bay no movement is apparent and then succeeds the drowned region of Lyall Bay and Port Nicholson. The question remains:—Was the Tongue Point shoreline uplifted uniformly (or subuniformly) and subsequently locally downwarped to form Port Nicholson, or was the Port Nicholson district downwarped at the same time as the Tongue Point-Terawhiti coast was arched up? From the fresh appearance of the Wellington Fault Scarp which bounds the depression to the north-west it seems that the drowning movement was separate from and succeeded a more general movement of uplift which concluded the Tongue Point Cycle of erosion. Cotton (1921B, pp. 134-135) inferred, from the fact that the raised marine platforms to the east are parallel or subparallel, that the depression was quite recent. As the present writer is strongly of the opinion that the platforms to the east of Port Nicholson must be correlated with those to the west, and have been produced by the sea during pauses in the same series of movements, discussion of the sequence of orogenic movments is deferred until the Orongorongo platforms have been described.

PORT NICHOLSON TO ORONGORONGO. (6 miles).

About a mile east of Port Nicholson, appear the mouths of two small drowned valleys, both now almost closed by shingle bars. Except for these, the beach is continuous from Port Nicholson to the mouth of the Waiuni-o-mata River, and thence to the Orongorongo. In Fitzroy Bay a raised beach of shingle is present some forty yards from the sea at a height of 20 to 25 ft. Cotton (1921, p. 139) regards this as the pre-1855 storm beach ridge, though it is flat across the top and in places over 25 yards wide. It is thus far too high, wide, regular, and well preserved for a storm beach such as the pre-1855 beach would be. Between the Wainui and Orongorongo rivers, several ancient beach ridges (now confining lagoons on the strand plain) may be recognised but they are not at so uniform a height as their equivalents to the east of the Orongorongo. Along the west bank of the Orongorongo an exposure shows that the 30 ft. level is cut in rock to a considerable width.

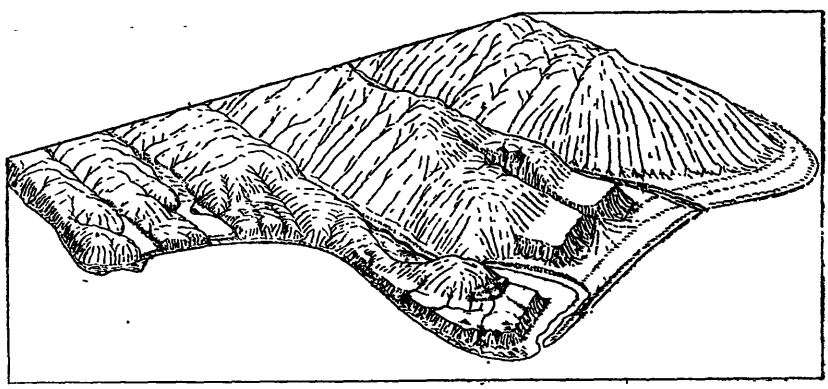

FIG. 4.—Diagram-sketch of the southern end of the tilted area east of Port Nicholson. From left (north-west) to right (south-east) the coastal features shown are: Pencarrow Head, Lake Koangapiripiri, Lake Koangatera, Fitzroy Bay, Baring Head, Wainui-o-mata River, Orongorongo River, Cape Turakirae. (From Cotton).

Throughout its length the beach is backed by high cliffs which exhibit an even crestline formed by the edge of a raised marine terrace. A series of such terraces is present (Cotton, 1921B, p. 135) all tilted to the west, i.e., towards the downwarped Port Nicholson area. These terraces were fully investigated and carefully described by Cotton (*op. cit.*), so little need be repeated here.

A summary of the benches present is, however, given for the sake of continuity and for comparison with other benches recorded in this paper. As all the platforms are tilted to the west, correlation is a matter of detailed field work, and a statement of heights alone is deceptive and misleading. The following are Cotton's determinations and correlations:—

Gollan's Valley to Wainui.	Baring Head.	Wainui to Orongorongo.
——	——	Highest Bench.
——	——	Higher Bench.
Wainui Platform.	——	Orongorongo Platform.
——	Baring Head No. 3.	——
——	Baring Head No. 2	——
——	Main Baring Head Platform.	Continuation of Main Baring Head Platform.

The Baring Head Platform, between the Wainui and Orongorongo rivers, where the covering of waste ranges up to 50 ft. in thickness, is at heights, from west to east, of:—385 ft., 500 ft. and 480 ft., while the Orongorongo Platform above it is at heights of:—760 ft., 890 ft., and 870 ft. These observations were made with an aneroid barometer along the rear edge so that the terraces appear parallel within the limits of observation. Both show a marked drop of 20 ft. at the eastern end.

Comparison of the benches to the east of Port Nicholson with those to the west shows that there are no grounds upon which indisputable correlations can be made, but the following are suggested as probably correct.

Terawhiti.	Tongue Point.	Orongorongo.
Upper Bench, 240 ft.	Upper Bench, 480 ft.	Orongorongo Platform, 890 ft.
Lower Bench, 125 ft.	Lower Bench, 240 ft.	Baring Head Platform, 500 ft.

On this basis the analysis of the earth movements is as follows:—

1. A strand line as represented by the highest bench at Orongorongo is the earliest stage recorded.

2. The second highest bench at the Orongorongo indicates an uplift of the order of 125 ft.

3. The cycle of erosion exemplified in the upper platforms at Terawhiti and Tongue Point, the "Wainui" platform and the "Orongorongo" platform was a well marked one of some duration, separated from 2 above by an uplift of some 50 ft. at Orongorongo.

4 and 5. Two short periods of stillstand are represented by the two small benches at Baring Head. They show that uplifts of 240 ft. and 80 ft. have taken place.

6. The main platforms at Terawhiti and Tongue Point, and the Baring Head platform represent Cotton's Tongue Point Cycle of erosion, which apparently was ushered in by an uplift of not more than 80 ft. near Orongorongo.

7. Uplift, probably as a series of movements, brought the coast to a position a little higher than its present level.

8. The Port Nicholson downwarp.

9. Subsequent slight uplift of a few feet to present level.

All the above estimates of uplifts are for the Orongorongo area, where the maximum movement seems to have taken place. Most of the movements in the past seem to have been tilting to the west, thus suggesting the presence of a hinge-line out in Cook Strait about twelve miles west of Cape Terawhiti.

ORONGORONGO TO LAKE ONOKE. (14 miles).

To the east of the Orongorongo River the fringing plain is broader, until at Cape Turakirae it is over 400 yards wide. Along the west side of Palliser Bay, however, its width diminishes gradually until it is only a few yards across. Throughout much of its length well marked ridges of beach gravel are present, four being visible at the mouth of the Orongorongo at heights of: 12, 22, 32, and 44 ft. above high water mark, although the 12 ft. beach ridge was probably formed by the sea while at its present level. At Cape Turakirae, Aston (1912, p. 209) estimated the heights as 9 ft., 40 ft., 60 ft., 80 ft., and 95 ft., but these values appear to be too large, the height of the last being only 70 ft. In addition to the well-marked ridges of beach gravel the plain is strewn with great boulders (" monoliths " of Aston) in the neighbourhood of the Cape, giving an exceedingly rugged appearance to the surface. Along the greater part of the western Palliser Bay coast a 25 ft. raised gravel beach is prominent, in places backed by remnants of a 50 ft. raised cut rock bench covered with coarse detrital deposits (Plate 76, Fig. 1). In the face of the old sea cliff fronting this platform are several ancient marine caves, some of which have been figured by Cotton (*Geomorphology of N.Z.*, p. 423). This bench is of marine origin but farther north, at the mouth of the Muka Muka Stream, the wide 50 ft. terrace may be partly stream cut. The fine gravels covering it show no distinctive characters.

The uplifted platforms of the Baring Head series have been traced only as far as the west bank of the Orongorongo River. On the east side of the river practically no traces of them can be found. The sudden disappearance of such prominent features of the landscape has proved one of the most baffling problems of the district, especially when it is remembered that the later periods of uplift, represented by the shingle ridges and the coastal plain, are better developed to the east than to the west. No satisfactory explanation of the facts has been presented as yet, nor can one be offered here.

In addition to the 25 ft. gravel beach and the 50 ft. rock bench on the western side of Palliser Bay, the profile of the hills facing the sea is suggestive of a high level terrace with a considerable slope towards the Wairarapa Valley. This series of possibly marine remnants is present in two localities south of the Muka Muka Iti Stream at a height of 510 ft. at 335 ft. on the north side of the Muka Muka Iti, and at 225 ft. at the Muka Muka where there are uncon-

solidated covering beds 30 ft. thick. All these high level terraces are of somewhat doubtful origin but the most probable explanation is that they are marine.

At Eglinton's, in the north-west corner of the Bay, a considerable area is even surfaced but it has too great a slope seaward to appear to be a marine bench. It was probably cut by the Ruamahanga River. On account of the slope the writer could give no estimate of its height. A small flat area facing Lake Onoke may, however, be a continuation of the platform which is so prominent to the east of the Lake.

Lake Onoke to Cape Palliser. (23 miles).

Lake Onoke is protected from the sea by a broad gravel beach or bay bar some two miles long, sometimes continuous from side to side and on other occasions broken by a gap through which the surplus waters of the lake escape. The presence of such an outlet is governed largely by the state of the sea, which throws up gravel to block the passage in times of storm, the outflow from the lake being sufficient to clear a channel in good weather.

To the east, along the head of Palliser Bay, the cliffs, cut in soft Tertiary mudstones (Pliocene to the west and Miocene at the eastern corner), rise in places to 200 ft., but are now usually protected from marine undercutting by a beach of coarse sand which extends without a break from the lake outlet to the north-east corner of the Bay. The material for this beach would appear to be derived from the greywacke rocks which outcrop along both sides of the Bay, though, according to Marshall (1929, p. 345), sand is not usually produced by the wearing of gravel on a beach. From the north-east corner of the Bay to the Waitarangi Stream most of the shore is unprotected by beach deposits and so active cutting back of the soft Tertiaries is now in progress, and the cliffs are retreating at a rapid rate. This recession is measurable at the Waitarangi Woolshed, which was built many years ago at some distance from the sea. Now it is in danger of being engulfed; indeed some of the mustering yards are already fast disappearing, the encroachment having been of the order of 25 ft. in the last six years. This portion of the coast receives the force of the south-westerly gales far more than does the head of the Bay and is also nearer the source of the hard greywacke detritus which supplies the abrasive material, so that erosive action is at a maximum in this locality.

Southward of the Waitarangi Stream a broad, uplifted coastal plain makes its appearance and extends almost continuously along the coast for the next 45 miles to the mouth of the Pahaoa River. In only two places throughout this distance was any evidence found of a rock cut base to the platform, the surface in general being thickly covered with gravel, both marine and alluvial. Shingle fans have been formed by most of the streams debouching from the high country to the east, which rises rapidly to a height of 1000 ft. or more, and these fans cover most of the surface of the coastal plain. (Plate 77, Fig. 1). At Black Rocks Point this platform attains a maximum

width of 400 yards and shows four successive subparallel beach ridges all at about the same height. An uplift of 30 to 35 ft. was apparently responsible for the laying bare of this fringing plain.

Midway between Black Rocks and Cape Palliser, hard Tertiary rocks, apparently not hitherto described, though figured by Hochstetter (*Geologie von Neu Seeland, Novara Exped.*, p. 3), outcrop over a small area, striking N. 20° W. and dipping S.W. 60°. They consist of a basal conglomerate 1 ft. thick of well-rounded pebbles; sandstone 50 to 60 ft.; and an arenaceous limestone, 30 to 40 ft., containing fragments of cirripedes, brachipods, polyzoa, echinoids and corals; but the fossils are too poorly preserved and the matrix is too hard to allow collecting.

At the head of Palliser Bay is an extensive terrace which, broken only by the Whangaimona River and its tributaries, stretches from Lake Ferry to the east side of the Bay, where it is continuous with the platform which is so prominent along that portion of the coast. The terrace is not level but rises from 100 ft. at the east side of Lake Onoke to over 300 ft. at the eastern end. At the rear is an even-crested ridge also ascending eastward until it is comparable with the second platform along the eastern side of the Bay, i.e., at 575 ft. Throughout its length this ridge is unbroken, straight and even-crested. The presence of this ridge precludes any possibility of a river origin for the terrace at the head of the Bay unless it be the work of the Whangaimona River which seems now too small to cut such an extensive terrace, a mile and a half wide and five miles long. Further, a river origin leaves unexplained the straightness of the rear edge. No gravel deposits such as might give a clue to the origin were observed. As both the terrace and the even crestline of the ridge at the rear appear to be the continuations of undoubtedly marine platforms along the east side of the Bay, they may for the present, be considered to have been cut by the sea.

Along the whole of the east side of the Bay a well-preserved series of raised platforms affords probably the most striking feature of the coast. When they are seen from a distance the interrelation of the platforms is not very clear for two reasons: (a) There is a general tilt downwards from the opening of the Bay to its head and (b) The benches have a varying development relative to one another at various points along the distance through which they are found. The main platform rises at a gradient of 25 ft. per mile southward, and the higher ones are also tilted to about the same extent. Although the character of the rocks varies from soft Tertiary mudstones at the north end to the hard Trias-Jura greywacke of the Haurangi Mts. at the south end of the Bay, there is little difference in the stage of development reached by the platform in each case.

The terraces are best developed at the following localities:—

(a). Head of Palliser Bay as already described. The heights at the east end are: Terrace, 300 ft.; Ridge crest, 575 ft.

(b). Just north of Hurupi Creek: 425 ft. and 730 ft.

(c). Behind Waitarangi Station: 460 ft., 545 ft., and 800 ft. The 460 ft. terrace is 200 yards wide, the 545 ft. terrace is clear, but only a few yards wide, both being well cliffed and the third, or 800 ft. bench is also well defined. (Plate 76, Fig. 2).

(d). Te Hamenga Point: The top of the point itself is formed by the second lowest terrace (the lowest being cut away south of Waitarangi) and has a strong tilt along its length, rising from 520 ft. at the stream on the north side to 660 ft. at the Otakoha Stream on the south. At the north end this platform shows very plainly 30 ft. of well-worn, even-graded beach gravel. Other terrace remnants are present at heights of 855 ft. and 965 ft., but well-defined cliffs do not show at the rear. The absence of strong cliffing is due to subaerial weathering, which has rounded the formerly steep slopes, though the line of the ancient cliffs is still distinctly traceable.

(e). Black Rocks Series: The heights of the main platform are: 1. One mile north of Tilson's Whare, 675 ft., with a covering of 20 ft. of marine gravel. 2. Opposite Tilson's Whare, 710 ft. 3. At Black Rocks, where there is a covering of 30 ft. of subangular to rounded gravel, 700 ft. There are also forms suggestive of a higher terrace at approximately 950 ft.

As remnants of the same terrace occur at different heights due to tilting of the platforms, some scheme of correlation becomes necessary. The following table is therefore given:

Black Rocks.	Te Hamenga.	Waitarangi.	Hurupi Creek.	Bay Head.
——	965 ft.	——	——	——
950 ft.	855 ft.	800 ft.	730 ft.	575 ft.
700 ft.	600 ft.	545 ft.	——	——
——	——	460 ft.	425 ft.	300 ft.

Towards the south end the terraces are dissected by numerous streams which have cut gorges some hundreds of feet deep through them. The traversing of such an area becomes extremely arduous as it is necessary to descend to sea level each time in passing from one terrace remnant to another. These mountain streams have transported the waste which now covers the surface of the coastal plain, and, considering that some of them descend almost 3000 ft. in four miles, it will be seen that they are capable of carrying an unusually large quantity of detritus. Some idea of the nature of the country may be obtained from Plate 77, Fig. 2.

Cape Palliser to Pahaoa River. (30 miles).

From Cape Palliser to the Pahaoa River the rocks outcropping on the coast are, almost without exception, the greywacke of the Haurangi Mountain Range, similar to that of the Wellington area. At only a few localities are the younger rocks present, where they are usually represented by flaggy limestones. The observed outcrops of the younger series are:—(1). Opposite White Rock Station. (2). At the mouth of the Opuawe River. (3). At the mouth of the Awhea River, and (4). At the mouth of the Hangaroa River. The age of this limestone is in doubt, though McKay (1879, p. 79) regarded it as the equivalent of the Amuri Limestone. It is certainly Notocene

in age as distinct from the Trias-Jura greywacke. To the south of White Rock Station the effect of the disparity between the two rock types is admirably shown in the topography, the greywacke standing up, bounded by precipices 1500 ft. high, above the rounded, subdued forms produced by subaerial weathering on the younger beds. (Plate 78, Fig. 2).

For almost the whole distance under review the coastline consists of the towering greywacke cliffs fringed by a narrow strip of uplifted rock-and-gravel platform such as has already been described. (Plate 78, Fig. 1). Indeed, for the greater part of its length, this coast is wild and rugged in the extreme. To the north, at the Devil's Mile, the rock, as is not unusal in the greywacke series, is crushed and shattered into " rotten rock," an almost unconsolidated fault breccia, so that the sea now reaches to the base of the cliffs except at low water. At the north end of the " Mile " much "rotten rock" comes down to form a talus slope and fan, the seaward edge of which is now strongly cliffed.

A mile or so to the north of Cape Palliser the coast is strewn with gigantic boulders or " monoliths " similar to those at Cape Turakirae, where the character of the country is in every respect akin to that of the locality just studied.

PAHAOA RIVER TO FLAT POINT. (18 miles).

The rocks between Pahaoa and Flat Point are more varied than those farther south. At the mouth of the Pahaoa (north bank), there is a ridge of limestone and between Pahaoa and Flat Point, outcrops of this and a similar limestone are not infrequent. Notably they are present: (1) on the north bank of the Pahaoa; (2) at the mouth of the Waihingaia Stream, where it is strongly shattered and the fissures are filled with calcite; (3) a few hundred yards north of the Holey Rock Lighthouse, where also it is somewhat crushed; (4) in the hills west of Glenburn Station, where stalagmites have been formed below overhanging cliffs; and (5) near the tip of Flat Point itself, where it stands above the beach deposits as a rugged outcrop. Crawford (1868, p. 17, essay) has also noted:—" At Waikekino, six miles south of Flat Point, reefs of Amphibolite are found on the shore or in the sea, penetrating the above named calcareous rocks, and boulders of various trappean rocks are common in the Kaiwhata and other rivers." In his 1869 report (p. 351) he also referred to " Diallage traversing limestone " at Waikekino. This outcrop was not observed by the writer but pebbles of igneous and dyke rocks are very common along the shore in this locality, though no specimens were seen *in situ*. The specimens found were probably transported down the rivers from outcrops known to exist farther inland, thus accounting for the non-observation of any coastal outcrops, while Crawford's original outcrop being " in the sea " in 1868 may have been since demolished. A highly glauconitic sandstone usually underlies the limestone and was noted at nearly all the outcrops of this rock.

At the mouth of the Pahaoa a 35 ft. terrace is strongly in evidence. From its position it might be regarded as of fluvial origin

but for the fact that well-marked beach ridges of sand, now firmly bound by vegetation, occur regularly across it parallel with the present shoreline. These ridges prove that, though the river may have cut the platform the material now covering it was arranged by the sea prior to and during the uplift of 35 ft. On his visit to the locality the writer could obtain no evidence as to which agency originally cut the bench. At places along this uplifted strand small streams, debouching from ravines in the higher country at the rear, have built shingle fans across the inner edge of the platform. These are quite distinct from the old beach deposits and there can be no doubt that river action had little to do with the present appearance of the strand plain apart from the supplying of waste.

North of the Pahaoa the plain gradually becomes narrower until the sea reaches the base of low cliffs, some of which are cut in shingle fans. A short stretch of sandy beach covered with large dunes succeeds northwards, presumably as a temporary phase in the general cutting back of the shoreline, and then the 30 ft. platform again makes its appearance, either as bare rock or covered with coarse shingle. Beyond the Holey Rock Light it gradually becomes covered with finer material and about two miles south of Glenburn Station is grassed. All along from the Pahaoa to the Waikekino Stream there thus appear indications that the coast has undergone an uplift of 35 ft., that is, a definite movement of the strand has taken place. The coast north of this point, i.e., the Waikekino Stream, though presenting a strand plain, the inner edge of which is about 35 ft. above sea level, shows no definite evidence of uplift, as sand will easily form dunes 35 ft. above high-water mark. Rock outcrops are not found on its surface, and, as distinct from a plain composed of solid rock with only a comparatively thin covering of soil, the whole coast has the appearance of a strand prograded merely by the accumulation of waste governed by marine agencies. (Plate 79, Fig. 1). It presents a fine beach, inland from which much of the surface is covered either by traces of successive beach ridges or great wandering sand dunes, which, over much of the surface, especially at the north end, have obliterated all trace of the regular ridges, and, finally, the swales between many of the later-formed beach ridges are sometimes marshy. The coast immediately to the south, however, shows no good beach and is a rock bench, either bare or only thinly covered with coarse gravel; a surface from which moisture drains away almost immediately.

The peculiarity of this short stretch of nine miles or so lies in the fact that it has prograded a distance of 500 yards although the coast to the south is subjected to extremely active marine erosion which must have been wearing and cutting the coast for a very long period, producing towering cliffs behind the fringing plain; and to the north the sea now reaches (beyond the Kaiwhata) to the foot of 150 ft. cliffs which are being rapidly worn back. Flat Point itself forms the northern end of the prograded section of the coast but is not sufficiently prominent to deflect coastwise currents and form a backwater in which waste derived from the rest of the coast might accumulate, indeed the point itself is mainly of a prograded nature.

A prominent terrace is continuous at about 500 ft. almost all the way from Glenburn to Flat Point. (Plate 79, Fig. 2). The most southerly remnants may be observed near the Holey Rock Light where they are at a height of 450 ft. and are capped with well-sorted, stratified marine gravel. Towards Glenburn the remnants become more prominent and continuous, and the rear edge rises gradually to 470 ft. North of Glenburn Station there can be no doubt of the continuity of the platform, though small streams cross it in deep ravines. Stratified gravel deposits cap it a mile to the south of Flat Point, where the height is 490 ft. At Flat Point it is approximately 500 ft. and three-quarters of a mile wide but is dissected almost parallel to the coast by two large stream valleys, while at its seaward edge it is cut off by the steep cliffs at the rear of the prograded Glenburn–Flat Point beach. Northward it descends somewhat and grades into the 450 ft. levels at the Kaiwhata.

The origin of the stream-valleys now almost parallel to the coast and dissecting the platform along its length is of interest, as to-day the terrace still slopes seaward. It seems that they must be subsequent, as they are parallel to the strike of the country and opposed to the slope of the plain. They flow into a stream which crosses the plain in an almost straight line from the hills to the sea.

FLAT POINT TO THE WHAREAMA RIVER. (16 miles).

The rocks along the coast from Flat Point to the Whareama River are, almost without exception, soft sandstones and mudstones of Middle Tertiary age, usually in alternating bands about 6 inches thick. These present but little resistance to marine and subaerial agencies, both of which are actively engaged in wearing back the coastline at a rapid rate. So non-resistant are the rocks generally, that it is rare to find a well-developed platform at the base of the cliffs, or a distinct nip where storm waves are most active.

North of Flat Point the prograded coastline abruptly changes to one where rapid cutting back is in progress, and for four miles towards the mouth of the Kaiwhata River a steep beach of boulders is encountered. Just south of the Kaiwhata the cliffs are being attacked and this phase is then continuous as far as Uriti Point, seven miles to the north. Pebbles of igneous rock occurring among the dune deposits at the point are well rounded, indicating that they have travelled a long distance, and as no outcrop of any such rock was found on or near the coast in this locality, this conclusion is strengthened. From Uriti Point onward to the Whareama a well-developed sandy beach is in evidence, at the south end it is fine and hard, at the north coarse and very soft.

At or near the mouth of the Kaiwhata River an extensive series of raised terraces is developed, some of river and some of marine origin.

(1) At 8 ft.—This terrace is merely produced by lateral erosion on the part of the river and there is no evidence that it represents a period of standstill of the strandline. It is poorly developed.

(2) At 30 ft.—This terrace is well exhibited for 600 yards up the stream and its presence on both banks shows that it was originally

of river origin and cut during a period of standstill; for it must be impossible for the sea to cut a terrace only 120 yards wide at the mouth and penetrating 600 yards inland, cut, moreover, not along a weak band in the country rock, but at right angles to the strike of the beds. This terrace is now covered by 4 ft. of marine gravel, above which is 5 ft. of fine deposit crowded with Recent marine molluscan shells, mostly in a good state of preservation, showing that the bench must have been submerged after it was cut by the river.

Further evidence of this submergence is afforded by a mudstone of recent origin, almost certainly contemporaneous with the marine conglomerate and covering beds of the Kaiwhata 30 ft. bench, and crowded with marine mollusca of recent species which outcrops for a short distance up the next four creeks to the north of the Kaiwhata. The outcrops become smaller and smaller towards the north. The most striking evidence of submergence, however, was disclosed on the occasion of the writer's second visit to the district. Great changes had occurred about the mouth of the river. On the first visit it was easy to cross dry shod by means of a high storm beach of gravel thrown up by the sea which damned the river to produce a lake 75 yards wide and 600 yards long; the outflow from which seeped through the gravel to the sea. On the second visit the river mouth was open to the sea. Owing to much rain in the back country the river had broken the dam and built a temporary bar (about awash at high water) 30 yards seaward of the previous high tide mark. Inside the area thus enclosed the river had exercised a scouring action and disclosed the trunks of 22 trees, all upright in the position of growth, previously covered by the sea and marine gravel, just seaward of the beach. That these trees were actually in the position of growth is shown by the fact that many were slender tree ferns without spreading roots, so that if overturned, they would not subsequently regain the vertical position. Another tree stump, which, though not protected by the bar, had been uncovered by the outwash, and overturned by the force of the waves, was also found to the north.

Still other trees with their roots in ancient soil on the Middle Tertiary mudstones projected up through the Kaiwhata conglomerate into the covering shelly beds. (Plate 80, Fig. 1). These are apparently of an age quite distinct from that of the stumps described above, and the oscillations of the strand in this locality, as represented by the two sets of trees, the 30 ft. bench and beds, and the modern shore appear to be:—

(a) The Middle Tertiary rocks were planed by the river and the upper set of trees grew on the area so planed.

(b) Subsidence of ten feet or so during which the Kaiwhata conglomerate and overlying beds with marine shells were deposited.

(c) Uplift of 25 ft. when a marine bench was cut in the soft Tertiary rocks.

(d) Further uplift when trees grew on the bench so cut.

(e) Depression of 2 or 3 ft. more than the previous uplift so that the trees then growing are now below sea level.

Half a mile farther north, at the mouth of a small unnamed creek three more tree trunks (tree ferns), the roots of which are now

below sea level, were exposed by a fresh coming down the creek. It seems impossible that these tree ferns could be in other than their position of growth, for otherwise they would not be standing upright.

(3) and (4) At 42 ft. and 100 ft.—Both of these terraces are confined to the south side of the valley and were almost certainly produced by lateral erosion on the part of the stream.

(5) On the south side a terrace is present at 240 ft. and on the north side at 180 ft. The slope on each of these terraces suggests that they are one and the same, and that northward the 180 ft. level grades into and forms the 150 ft. level of the Homewood area. Thus near the Kaiwhata the platform appears to be tilted with a slope down towards the north.

(6) At 450 ft.—Here a flight of terraces, now strongly dissected, is present tilted in the same manner as the lower bench, so that, on the evidence available, it seems that this terrace is the continuation of the 500 ft. Flat Point terrace, and that it slopes down northward to form the 350 ft. Homewood level.*

In the Homewood District flat terraces are present at various levels over a distance of eight miles, from the Kaiwhata to the Orui River, and their breadth throughout much of the distance is over two miles. Streams crossing the lower marine terraces have cut broad flat valleys (up to half a mile wide), between which are left the older flat interfluves giving a most complicated series of levels when viewed for the first time. Some of the terraces (the higher levels) are almost certainly marine but the lowest or 30 ft. is undoubtedly of river origin, as will be shown later.

The coastline itself, as before mentioned (p. 510), is now being actively cut back by the sea; the soft Tertiary strata being too incoherent for much undercutting to occur. Slips are frequent, the material being removed by the sea almost as fast as it is supplied. In view of this rapid present-day retreat of the cliffs, the question arises as to what agency or accident has preserved such a wide terrace (two miles wide) along the coast immediately to the rear, for it seems that unless the uplift of 150 ft. was very recent the whole of the terrace should now be cut away. Furthermore, to the north towards Orui, the 150 ft. level is absent but the 350 ft. and 220 ft. platforms, which are not notably developed in the Homewood area, are well exhibited. The explanation apparently lies in the structure of the country.

The rocks strike N.E. and dip inland at angles of 20° to 30°, while the trend of the coast is almost N.E., so that the rocks run out at a slight angle with the coast. Also a reef of very hard rock projects from the headland just to the south of the Kaiwhata mouth. Owing to the state of the sea and tide the writer did not find it possible to examine the reef, but the probability is that it is a hard shell limestone. This reef in former days must have presented a very strong barrier to the sea, as the reef at Castle Point does now, and, although, geologically speaking, such a feature is of only a most

*The name Homewood area is here applied to all that district which lies between the Kaiwhata and Uriti Point.

temporary nature, yet it is certain to leave some effects that will be apparent for a short period after its destruction and it is probably due to the existence of this reef that the erosion of the 150 ft. platform at Homewood has been so long delayed. To the north it is farther from the land (about half a mile to seaward opposite Homewood Station), and as we proceed northward it recedes progressively from the present shore. This is to be expected as that portion would be earlier exposed on the coast and would be attacked first. Thus at Orui, the remnants of the reef are two miles from the shore, and rapid cliff retreat from this former position has completely destroyed the 150 ft. level. The reef may also have aided in the preservation of the 350 and 220 ft. benches when the 150 ft. platform was originally cut at Orui. To-day all that remains of the reef is a few small, upstanding rocks or reefs awash at high water, stretching along the strike of the main reef at the Kaiwhata, and becoming less and less pronounced farther north. In its day, however, it must have presented to the sea a magnificent front similar to that now shown on a smaller scale by the reef at Castle Point.

Furthermore, as will be shown later, a pronounced 30 ft. terrace is present as broad flood plains up all the streams of any size in the district. For all the stream beds to exhibit such marked accordance of a former level, which is so remarkably developed, requires a period of standstill of the strand to be postulated. If such is the case, why is there no record of a marine bench at that height in the district, though such is present further south? If we assume, as indeed there is every reason for so doing, that the sea was engaged at that particular time in cutting back a cliff of hard limestone which retarded its advance very considerably, then the absence of any pronounced bench is accounted for. Since that time it has had only soft Tertiary strata to erode and so has obliterated with ease any marine traces of a period of standstill.

Synopsis of the Terraces in the Homewood and Orui Districts.

(1) At 30 ft.—The terraces in this group are of undoubted river origin. They do not appear as a continuous platform but as a number of flat areas sunk in the general 150 ft. terrace. In plan they are usually horse-shoe shaped, with the open end to the sea. This shape alone makes it practically certain that they are to be ascribed to lateral planation by streams, and not to marine agencies, as the tendency of the sea is to straighten a coastline and not to cut a mile into the land at one place and leave the neighbouring portion untouched, especially when the strike of the rocks is almost parallel to the coast. Moreover, streams in entrenched courses now flow across these plains of lateral planation.

For all the streams to exhibit this 30 ft. plain requires a considerable period of standstill, as many of these basin-like flats are half a mile wide and penetrate a mile or so inland. In some cases two of these plains have coalesced, some distance from the sea, by one stream or other cutting through the interfluve. Both streams, however, still enter the sea on opposite sides of the remaining interfluve

downstream. For this to occur without actual stream capture taking place, both the adjacent plains of planation must have been at exactly the same level when the interfluve was broken down, and the river which obliterated the interfluve must have swung back across its own plain, unless, after capture, the streams separated again. Thus, three miles north of Homewood Station, a broad flood plain is crossed by two rivers which pass to the sea on opposite sides of a remnant of upstanding divide between their mouths, though upstream they appear to flow on the same flood plain. As these remnants are themselves flat-topped (forming part of a higher bench), the effect is to give " hills of planation " somewhat analogous to those described by Gilbert (1877, p. 130). A difference arises in that the flat top on the New Zealand examples may be attributed to marine action in place of normal river planation, the lower, surrounding plain being due to river action alone. These hills are about 50 ft. high (the seaward edge of the older terrace being approximately 70 ft., and the river plain 30 ft.), and form a peculiar feature possible only under the exceptional circumstances described.

The questions arise:—1. Are the higher platforms also plains of lateral river planation? 2. May some of the terraces in other areas be also due to river corrasion?

1. Such forms, when well-developed, may simulate marine terraces so closely as to be indistinguishable and yet the height of a marine bench must be measured at the rear edge, i.e., at the base of the former cliffs, if such are present, while that of a plain of river origin must be taken as near to the sea as possible. Altogether, the problem seems so important that a special section will later be devoted to it (see Appendix p. 520).

2. So far as the raised platforms dealt with in this paper are concerned, the writer considers the 30 ft. Homewood level the only one of undoubted river origin though several others may be taken as of a similar nature.

(2) At 150 ft.—A prominent terrace extends from the Kaiwhata nearly to Uriti Point. This is the widest of all the platforms present, reaching a breadth of over two miles; and, except where crossed by streams and their flood plains, it now reaches the sea-shore; the present cliffs being contraposed in it. The origin of this terrace is somewhat in doubt. The cliffs at the rear are not sharp but are, nevertheless, clearly defined. They are not straight in plan, however, and their general appearance suggests that they were cut by rivers emerging from gorges in the higher terraces. The possibility of such an extensive terrace being cut by small streams is a doubtful point, and the gravels found upon it hardly contribute any definite evidence, though inclining to an alluvial appearance with a suggestion of imbricated structure in an exposure at the side of the road near Uriti Point. The capability of the small rivers which exist in the locality to plane off such a bench is more than doubtful, and the fact that (except for the sharp upwarp at the Kaiwhata end) the inner edge is level for about five miles suggests a marine origin. In the absence of definite evidence the writer inclines to the belief that it is marine.

(3) At 220 ft.—A series of terrace remnants was observed behind the 150 ft. terrace about midway between Homewood and Uriti Point, and an extensive though somewhat dissected platform is present between the Homewood Road and the Orui River. The line of cliffs at the rear is sharp and clearly marked, but the gravel cover is usually obscure. On its general appearance it is classed as marine.

(4) At 350 ft.—In the Homewood District fourteen terrace remnants occur at heights of about 350 ft. Though, owing to the strong dissection of the country, all were not examined, many showed in places a covering of marine gravel similar to that visible on the coast to-day. The deposits range up to ten feet in thickness, and the individual pebbles up to one inch in diameter. Altogether, the alignment of the rear portions and their correspondence in height, together with the character of the gravels seem to indicate a marine origin. At the Orui end, the 350 ft. bench is exhibited as a broad flat top on the hills behind the 220 ft. platform. Like the 220 ft. it is better developed here than at Homewood and it may be here also be regarded as marine.

Whareama River to Okau. (20 miles).

North of the Whareama River, to Castle Point, the soft Plio-Miocene strata (alternating mudstone and sandstone bands a few inches in thickness) outcrop along the coast, forming a series of low cliffs at the foot of most of which is a fringe of present day beach. In many localities there is a prominent " 'tween tide " rock platform, which is left bare at low water and forms a flat area crossed by slightly raised bands where relatively harder layers outcrop. These " between tide " platforms are sometimes well developed and form a notable feature of this section of the coast. Their prominence may perhaps be attributed to the lack of angular waste with which the sea could abrade them. Another noticeable feature which may also be attributed to the lack of hard waste is that the cliffs are commonly less steep than when cut in hard greywacke. With the reduced cliff-cutting efficiency of the sea, and its lag in abrading the bottom, due to the lack of suitable waste before referred to, subaerial weathering becomes more important, and so the cliffs crumble and the angle is prevented from being steepened, while the sea merely pulverises the soft clayey detritus and removes it.

Just to the south of Castle Point, the " 'tween tide " platforms are not present but they reappear to the north between Castle Point and Whakataki where the strata can be observed running out on them at a small angle with the coast. A sand beach is also present. To the north of Whakataki, the rock platforms become more prominent than ever and the outcrops in them afford a splendid opportunity for unravelling the structure of the country. (Plate 80, Fig. 2).

Midway between the Whareama and Castle Point is an extensive flat area, in places over half a mile wide and 5½ miles long. This may be called the Otahome Flat, after the homestead of that name on it. Though it forms such a prominent feature of the landscape, its origin is a matter of considerable doubt. The only drainage con-

sists of a few small creeks, and the nearest river (the Whareama) is separated from it by a considerable range of hills (the Trooper) in which there is no break to suggest that the river ever flowed nearer Otahome than it does now. Thus a fluvial origin seems out of the question.

On the other hand, the surface, which slopes longitudinally northward from 160 ft. at the Otahome homestead to 90 ft. at its last appearance 1½ miles south of Castle Point, is not sufficiently level to be a plain of marine erosion. Furthermore, no trace of marine gravel has been found upon it. (This, however, may be attributed to the softness of the rocks, the absence of typical beach deposits being merely due to the rock crumbling, instead of forming pebbles, and giving a deposit now indistinguishable from residual clay produced by subaerial weathering). Again, there is a noticeable absence of cliffs, or any suggestion of cliffing, at the rear of the platform. Once more this may be attributed to the softness of the country rock, which rapidly disintegrates with the loss of all bold lines in the topography and the production of rounded contours. There is thus considerable difficulty in determining the origin of the Flat, but for the present it may be regarded as marine.

At Castle Point a number of even crested ridges occur but there is no justification for attributing their form to marine agencies, especially as their heights are discordant.

The lighthouse reef at Castle Point is of interest, not only as a fossil locality, but also as a physiographic study. The structure is simple. The Plio-Miocene sedimentaries run out at small angle with the coast and dip inland at 15°. A hard band of limestone has produced a resistant barrier to the sea and caps a small sea cliff which rises northward. At the north end arenaceous deposits form the uppermost layer (on which the lighthouse is built) but at the seaward edge these have been cut away by the spray which dashes with great violence against them as the waves strike the limestone below. A stripped upper surface is thus produced on the limestone which therefore stands seaward as a platform sloping slightly inland. Behind the reef is a lagoon, which has an opening to the sea at the south end, where the limestone stratum inclines down towards sea level. Along the outer margin of the reef the finest marine views on the coast may be obtained in rough weather, the sea dashing with great violence against the almost vertical surface of the limestone and hurling spray high in the air against the arenaceous deposits behind. Beneath the lighthouse a large cave pierces completely through the reef. Due to percolating waters much travertine has been deposited in it and small stalactites hang from projections on the roof.

It requires little imagination to visualise a reef such as this, on a much grander scale, previously protecting the Homewood coast north of the Kaiwhata; and the existence of such a reef in former times in that region has already been discussed.

For some distance along the Matai Kona Road, north of Whakataki, a series of roughly stratified sand deposits containing Recent marine Mollusca occurs. They may possibly represent a period of

standstill when the strand was 50 ft. higher than now or may be correlated with the Recent mudstone deposits and Kaiwhata conglomerate of the Homewood area. In the latter case the movement may have been almost uniform along the coast and the intervening evidence eroded away. There is, however, no definite basis of correlation.

The Correlation of Platforms in Different Areas.

It seems advisable here, in view of the fact that excellent suites of platforms occur only in widely separated localities, to give a summary of the bases on which these suites may best be correlated, if any such correlation is possible.

1. *Similarity in height.*—If uplift movements were uniform from place to place it would be possible to correlate benches in different localities on the evidence of height alone. Furthermore, if only a slight tilt or warp is present, and the sets of benches not very far apart, calculations of slopes and gradients can be used as a basis of correlation. This method was employed herein with the benches along the east side of Palliser Bay where the gaps between sets of terraces are not great and where all the terraces have a general slope to the north. It is frequently necessary, however, to treat each platform in one vertical set separately to allow for the effects of warping or tilting in between the various stages. This method has proved of great service when employed over limited areas but is insufficient in itself when applied to benches in widely separated localities.

Jobberns (1928) in his study of the north-east coast of the South Island, found practically continuous marine terraces for considerable distances along the coast at almost constant elevation and used a pure height correlation very extensively in comparing benches in different areas. It must be emphasised, however, that his is an exceptional case and well supported by field evidence of almost strictly uniform uplift. In the southern portion of the North Island benches are rarely found parallel to sea level but are strongly tilted and warped. Any correlation based on actual height is therefore not only useless but misleading.

Henderson (1924, p. 589) bases most of his correlations purely on height data, and divides the benches of the New Zealand coast into four groups: (a) Awakino Cycle, up to 120 ft.; (b) Tongue Point Cycle, 200-300 ft.; (c) Charleston Cycle, 350-600 ft., and (d) Kaukau Cycle, above 600 ft.

This arbitrary division on such a basis, though it may be true in a broad sense for New Zealand as a whole, cannot be applied to a limited area because a continuous tilted platform may, at one extremity, fall well within the limits of one group and at the other end be quite as definitely comparable in height with the representatives of a much younger or older cycle. Thus Terawhiti 125 ft. platform would approach most closely the Awakino Cycle, while the Tongue Point 240 ft. platform, a continuation of the Terawhiti platform, is actually the type locality of the earlier Tongue Point Cycle; also the second Terawhiti remnant (250 ft.) is, according to the height correlation, of Tongue Point age, but its equivalent, the

Tongue Point upper remnant is 480 ft., and therefore to be classed with the Charleston platforms. Again, the main platform of the east side of Palliser Bay is, at its southern extremity, 700 ft., and therefore should be equivalent to the Kaukau Cycle, while at Te Hamenga and Waitarangi it is 600 ft. and 545 ft. respectively, thus being definitely within the limits of the Charleston Cycle.

It seems, then, that strict correlation of platforms on the basis of height alone is attended by very grave dangers of error. Admitting that in the broad sense New Zealand has moved as a whole during late Tertiary and Recent times, yet differential movement has also been strong in some localities, and the complications arising from the correlation of benches which, though at similar levels, are nevertheless of different age are likely to become formidable if height data are relied upon exclusively.

Furthermore, many of the earlier estimates of terrace levels are merely eye measurements, and it is extraordinarily difficult, even with constant practice, to judge the heights of terraces with any degree of accuracy. Jobberns (1928, p. 531) records an instance where an estimated height (by Hutton) was " only a little more than half the actual height." McKay also erred in the same direction in his estimates of the Palliser Bay benches. In consequence, therefore, of the excessive warping and tilting of the platforms under review no correlations on height alone are attempted here.

2. *Similarity in stages of development and appearance.*—In some cases this forms a very reliable guide for the classification of terraces. A better example could hardly be found than the profiles of Terawhiti and Tongue Point. In spite of the disparity in heights previously referred to, a comparison of the profiles renders correlation almost certain, and in this case there is the continuous presence of the lower platform between the two points to place the identity beyond doubt. It was found in the field that by this method, the comparison of sets of benches was not only much simplified but also fairly reliable. The relative extent of successive terraces, combined with their relative heights, gives a general impression of them which is of the utmost value for correlative purposes. A precaution which must be observed lies in noting the geological structure of the country, as in different sets of beds quite different appearances may be assumed by the same platform. Notably the ratio of height to width varies.

3. *The covering beds.*—In some instances a characteristic rock type may be found among the deposits on a certain bench but not on the terraces either above or below. Fragments of rotted pumice, for example, may be frequently found on a particular terrace and so provide a guide to the correlation of platforms in neighbouring areas. As a general rule, however, the character of the rocks and pebbles forming the cover varies so considerably (a) with the distance transported and (b) with the rock of which they are composed that a small distance may be responsible for a great change in the type of cover, especially when the beds were deposited close to the supply of waste.

A tentative correlation of the benches of the South Coast is here given. In each case two benches are very prominent, all others being

distinctly subsidiary, and in every locality the lower of the two more prominent platforms is the better developed. They are therefore taken as the basis of correlation from district to district.

Terawhiti.	Tongue Point.	Baring Head.	Orongo-rongo.	Black Rocks.
——	——	——	1100 ft.	——
——	——	——	925 ft.	965 ft.*
250 ft.	480 ft.	760 ft.	870 ft.	950 ft.
——	——	Two small terraces.	——	——
125 ft.	240 ft.	385 ft.	480 ft.	700 ft.

From this it will be seen that the two main terraces, which are found in each case, correlate fairly well, rising in each instance the farther east that they appear, suggesting a general axis of tilting somewhere in Cook Strait. Just as the Tongue Point shoreline is downwarped in Port Nicholson at the present day, so, apparently, there was warping between previous uplifts producing slight anomalies in the relative heights. In every case the platforms are carved in hard greywacke.

The terraces of the Homewood area, excavated in soft Tertiary strata, present features not comparable with those cut in greywacke and have been already correlated among themselves so that no attempt is made as yet to compare their various ages with those of the greywacke suite.

Correlation of lower raised beaches.

Beaches at 25 ft. to 35 ft.—This is present from Baring Head to Orongorongo, whence it follows around Cape Turakirae and appears as the wide 25 ft. beach along the west side of Palliser Bay. Where the Tertiary rocks outcrop at the head of the Bay it is now entirely cut away by the sea operating at its present level, but is prominent farther on as the 35 ft. uplifted plain fringing the coast from Waitarangi to the Pahaoa. Farther north, it is probably represented in part by the prograded coast south of Flat Point and then by the 30 ft. uplift at Homewood and the Kaiwhata. Thus one of the latest movements of the coast appears to have been a general uplift of approximately 30 ft. throughout almost the whole length of coast described in this paper.

Appendix.

Criteria for the Determination of Marine or Alluvial Origins.

In any discussion involving quantitative estimations of uplift, the origin of the particular terrace on which calculations are based must of necessity be one of the most important points to be deter-

*The 965 ft. bench is not at Black Rocks but at Te Hamenga; this is equivalent to a height of 1060 ft. at Black Rocks Point.

FIG. 1.—Terawhiti showing (in profile) the remnants of two marine terraces.

FIG. 2.—Tongue Point (profile). Compare with Fig. 1.

FIG. 1.—The 25 ft. shingle beach (enclosing lagoon), 50 ft. rock bench, and possible 510 ft., remnant western Palliser Bay.

FIG. 2.—The 460 ft., 545 ft. (on right) and 800 ft. levels at Waitarangi, east side Palliser Bay, looking north.

FIG. 1.—The fan-covered surface of the 35 ft. beach north of Black Rocks. Te Hamenga in the distance.

FIG. 2.—Showing the dissection of the 675 ft. terrace opposite Tilson's Whare. The gullies are 650 ft. deep.

FIG. 1.—The 35 ft. bench, looking north from Cape Palliser. The cliffs at the rear are nearly 1000 ft. high.

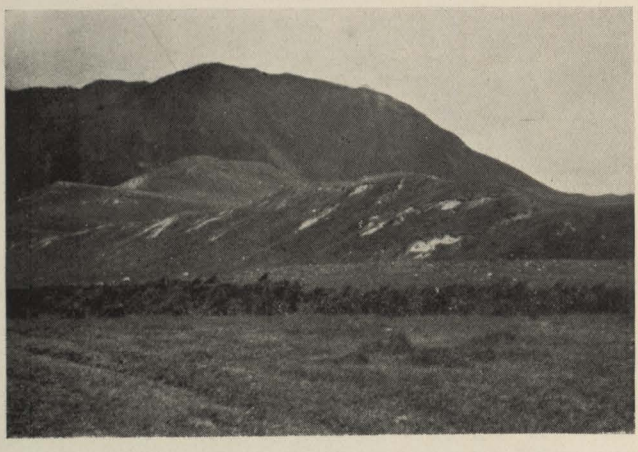

FIG. 2.—Tertiary (subdued forms) Mesozoic (strong relief) contact south of White Rock.

FIG. 1.—The prograded coast south of Flat Point, from the 500 ft. terrace, looking south.

FIG. 2.—30 ft. uplifted coastal plain near Glenburn, showing also the 500 ft. platform from Glenburn to Flat Point.

FIG. 1.—Upper old land surface as shown by trees at the mouth of the Kaiwhata.

FIG. 2.—"Tween-tide" rock platforms north of Whakataki.

mined, for, in the case of a marine terrace the previous shoreline must have been at the rear edge of the terrace, where a line of cliffs may or may not be present; whereas an alluvial plain must be measured at its seaward edge for the bed of a stream near the sea is practically at sea level and if the stream be well graded, as indeed it must be to produce a plain of any dimensions, then we may take that height nearest the sea as giving us the best measure of uplift. To quote an instance: the platform at Homewood whose height has been given in a previous section as 30 ft. has a height at the rear edge of 100 ft. Thus if, by any mischance, it were classed as of marine origin, then the uplift represented would be over three times the real measurement. The importance, then, of correct determinations cannot be over-estimated and it is with the object of explaining the criteria employed in the field work for the present paper that the following remarks are appended.

1. *General appearance, extent, position and relative proportions of the terrace.*—These are all *qualities* to be observed from one suitable standpoint, and usually provide the strongest impressions that one receives. The surface must be considered, whether it is even or irregular, whether any irregularity is due to unconsumed stacks, to slipping of the covering beds, or to disused stream channels. A finely sinuous rear edge to a terrace may be taken as indicative of a river origin just as a straight or gently curved one implies a marine origin. In this connection it should be noted that the inner edge of an uplifted terrace is commonly rather more embayed than is the later coastline. Generally speaking, the greater the distance along a coast through which a terrace extends the greater are the possibilities that it is marine, as few New Zealand rivers flow parallel to the coast for a considerable distance. Broad terraces facing the sea near the mouths of even small rivers are always open to grave doubt, especially if no terraces are found farther along the coast, for, though originally cut by one agency, they may be subsequently modified with ease by the other.

2. *Character and distribution of the covering deposits.*—Discoidal gravels are not always found in beach deposits, indeed they are exceptional, but beach gravels are commonly better sorted and less bound together with fine material than are their alluvial equivalents and with practice a nice discrimination between the two types can be made in the field. Apart from the composition of covering deposits much information may be obtained from a consideration of their distribution. For example, at the mouth of the Conway River, South Marlborough, the terrace now uplifted 40 ft. above high water mark is crossed parallel to the present shoreline by a series of gravel ridges formed during the retreat of the sea and proving the marine origin of the terrace. (Jobberns, 1928, p. 532). The remains of former dune deposits may also throw light on earlier shorelines. If the character of the gravel only is relied on, it must be borne in mind that a bench may be river cut, depressed and covered by marine gravel.

3. *The slope of the rear edge of the terrace.*—No river cut terrace will exhibit a perfectly level inner edge if followed along parallel

to the coast, unless it has been tilted back through exactly the angle at which it was cut. This case is extremely improbable, and so level terraces must be, almost without exception, marine.

4. *Presence or absence of cliffing at the rear.*—Good cliffing seems to be more characteristic of the marine type, though river cut terraces sometimes exhibit quite sharp cliffs.

5. *Presence of "island" interfluves,* as described earlier in this paper, is always indicative of a stream origin, on an uplifted coast.

6. *Marine shells* have been recorded from some raised coastal terraces though they are not of frequent occurrence.

Conclusion.

Broadly speaking, the coastline, throughout the length examined, is a coastline of emergence, the only exceptions being Port Nicholson (a local downwarp) and Palliser Bay (a fault angle depression). Along much of the distance uplifted terraces of undoubted marine origin testify to the amount of uplift from place to place and demonstrate that the movements were not uniform but consisted of a series of interstage warpings and tiltings. Small movements of subsidence have also taken place within comparatively recent times at the Kaiwhata and may have affected other regions, but no definite evidence in support of a general lowering of the land was obtained.

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