Art. XLIV.—*The Post-tertiary Geological History of the Ohau River and of the Adjacent Coastal Plain, Horowhenua County, North Island.*

By George Leslie Adkin.

[*Read before the Wellington Philosophical Society, 5th October, 1910.*]

Plates XV–XIX.

The principal waterway of the central portion of the Horowhenua County is the Ohau River, situated between the Manawatu on the northern boundary of the former, and the Otaki and Waikanae in the south. Though a small stream, with a length of only twenty miles, its valley and the adjacent country present many features of great scientific interest. The total extent of its drainage-area is sixty-four square miles, forty square miles of which is mountainous, the remainder being that portion of the adjacent coastal plain which is drained by the Ohau. Its largest tributaries are the Makahika and Makaretu Streams; others—viz., the Blackwater, Kuku, &c.—though inferior in volume, are by no means inconsiderable. At the point where the Ohau River crosses it the present coastal plain has a width of nine miles, but it is wider toward the north, and narrower in the south.

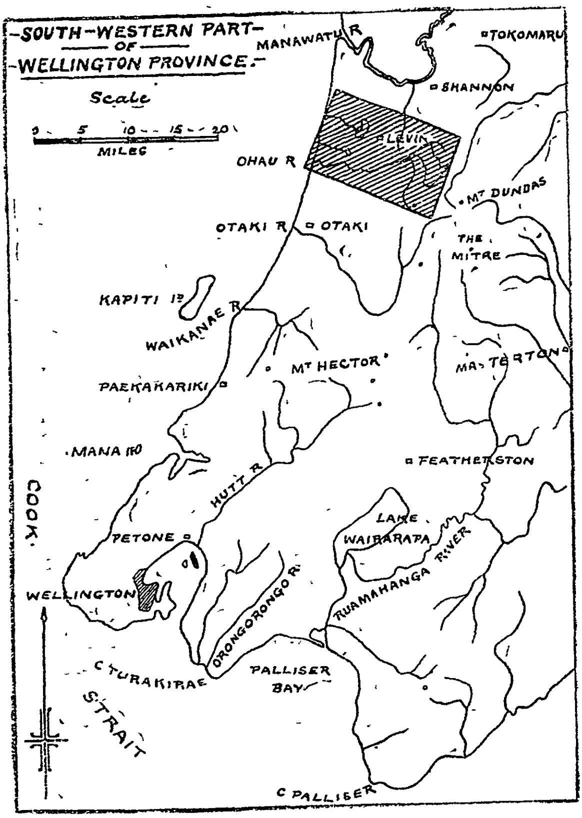


Fig. 1.—Locality Plan of Area described and mapped.

The Upper Ohau River, flowing in a valley which is alternately longitudinal and diaclinal, lies among the western subsidiary ridges of the Tararua Ranges. In this vicinity these latter constitute a wild stretch of country varying in altitude from 500 ft. to over 5,000 ft., and characterized by parallel tectonic ridges, and, in the diaclinal valleys, by tortuous rock-

Face p. 496.]

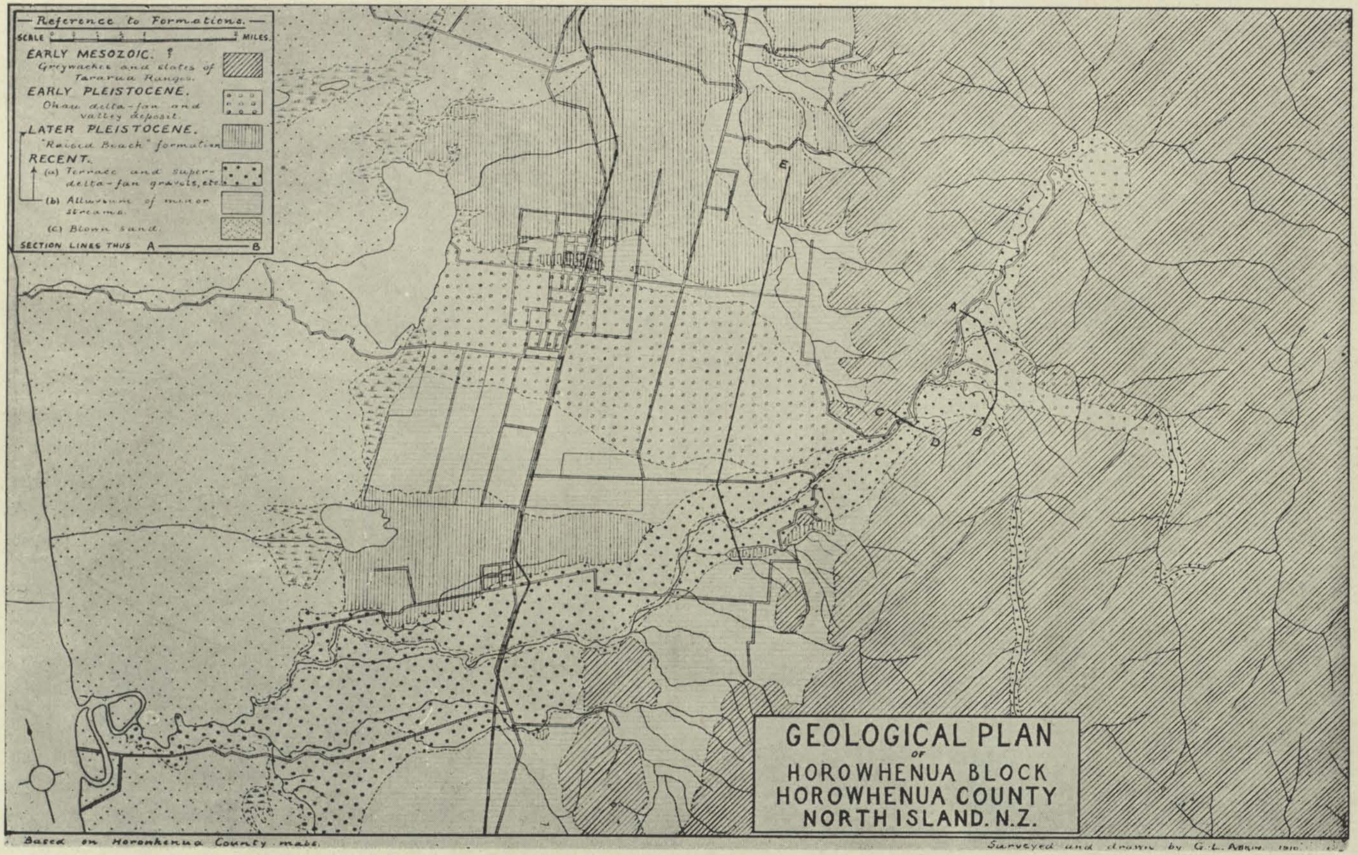
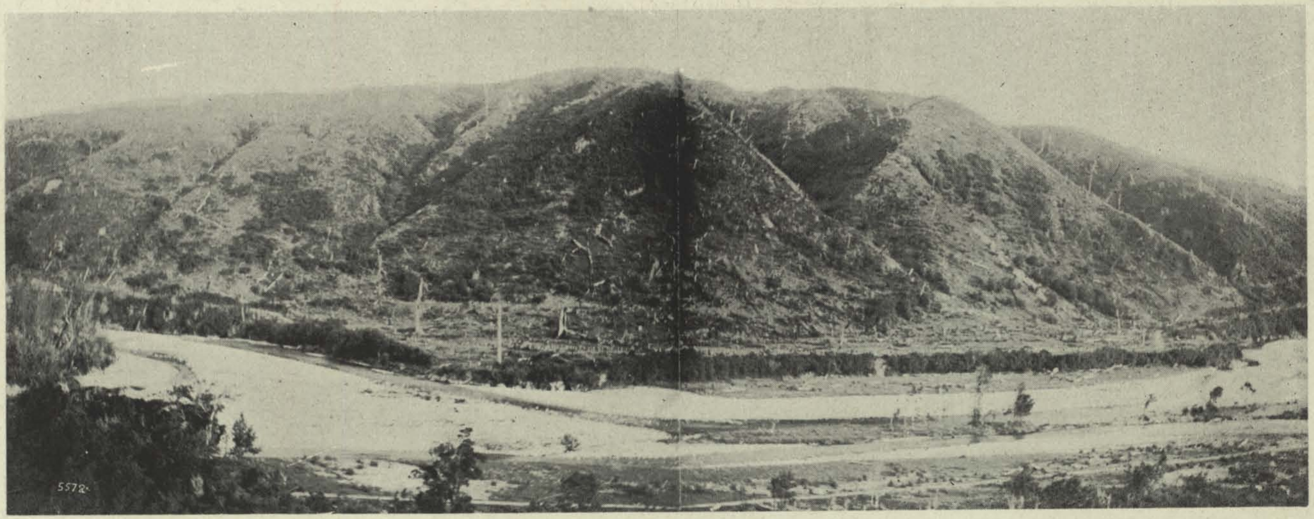


PLATE XV.



THE OHAU VALLEY AND THE ARAPAEPAE RANGE.

The lateral spurs truncated by the Ohau River and its tributaries.

bound gorges. Here may be seen on a very extensive scale the effects of fluviatile erosion. The parallel ridges have been dissected, and their corresponding valleys deepened to an enormous extent by the action of high-grade streams and swiftly flowing rivers.

The culminating peaks of the district are the Mitre, 5,154 ft.; Mount Dundas, 4,944 ft.; and Mount Crawford, 4,795 ft. These are not within or even contiguous to the Ohau catchment-area, but lie near enough to intercept the moisture-laden westerly winds, and thus increase the rainfall within that area. The principal salients of the Ohau water-parting are Mounts Waiopehu, 3,588 ft., and Tawirikohukohu, 3,455 ft. It is near the summit of the latter that the Ohau River proper has its source.

In character the valleys of the Ohau and its two main tributaries differ considerably. As already stated, the Upper Ohau occupies a valley which is alternately longitudinal and diaclinal; the lower portion of the Makahika appears to flow in a deeply incised anticlinal valley, while that of the Makaretu, though diaclinal immediately above its junction with the Ohau, is for the most part longitudinal.

Prior to its occupation by European settlers most of the Horowhenua County was clothed in tangled virgin forest. The zone of heavy mixed bush (almost entirely beech near its upper limits) extends from low altitudes up to the 2,500 ft. contour-line. Above this elevation the bush usually becomes stunted, and is partially—or more often wholly—replaced by shrubs, forming a dense subalpine scrub. In most places at the altitude of 3,000 ft. the scrub terminates more or less abruptly, and the alpine meadow land is reached. The principal components of the latter are tussock-grass, *Astelia*, and alpine flowering-plants, while the subalpine scrub is for the most part *Olearia Colensoi* and *Dracophyllums*.

Though the district under consideration presents many features of interest to the botanist and the nature-lover, it is for the geologist that it reserves its chief attractions. The successive events within its limits have been so varied, and in some cases the action of the several natural agents so complex, that an examination of these events and operations should prove of interest to geological students.

Owing to the entire absence, or perhaps non-discovery, of fossil remains in the area under notice, the age of each of the geological formations described in the following has been determined entirely by stratigraphical considerations. Judging, however, from the views held by writers on the Tertiary and post-Tertiary geological history of New Zealand, the recent maximum elevation of the country occurred in the early Pleistocene, and it is upon this conclusion that the chronological divisions in the following are based.

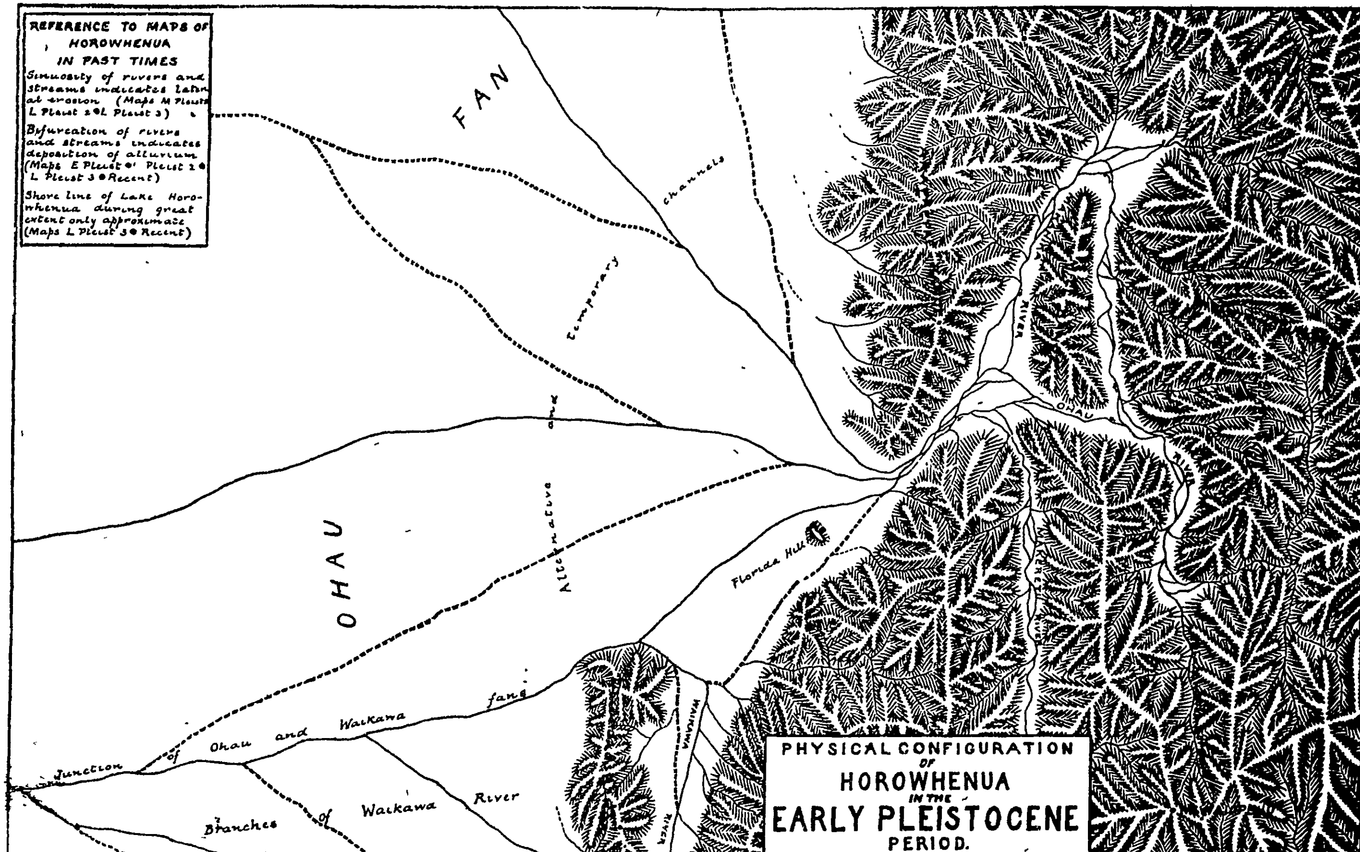
At the close of the Tertiary epoch a plain of the Upper Tertiary, most probably Pliocene, strata was uplifted, and at the cessation of its emergence extended seaward on the western coast of the Wellington Province from the foothills of the Ruahine and Tararua Ranges to far beyond the limits of the present shore. At the termination of this uplift the elevation of our Islands was much greater than now, but, as the movement was more pronounced in the South Island than in the North, the latter Island did not experience so severe a "glacial period" as did the former. The Pliocene (?) plain is now not visible in this district, more recent deposits having completely covered it, and on this account its exact nature cannot be ascertained from observations made in this locality alone, but that the uppermost Tertiary strata had a comparatively plane and gently sloping upper surface is inferred from the configuration and character of the superimposed fluviatile deposit about to be described.

The rivers which at present flow into the sea along the Terawhiti-Egmont coast-line had to traverse the newly uplifted plain, and were then not only of considerable length, but were also of greater volume, due to the greater elevation of the land producing a more abundant rainfall, and incidentally —for the fact does not affect the following considerations—a larger drainage-area. Like the others, the Ohau River crossed the Pliocene plain, and its subsequent history may be traced as follows: Upon leaving its vent in the foothills of the Tararua Ranges the Ohau River began to deposit material upon the Pliocene plain as soon as it was uplifted above sea-level. The deposited material took the form of a fan, and—for a while at least—kept pace with the uplift of the plain, as well as reducing the dissimilar gradients of the river-bed to a more uniform slope. The extent of the fan in a direction radial to its apex or summit is as yet unknown; but it certainly exceeds fifteen miles. Its maximum thickness is also not known, but in this respect it has been found to exceed 700 ft. At the present time the apex of the fan is only 345 ft. above sea-level, the average surface-slope being about 65 ft. in the mile, though the dip of its component layers at some depth below its surface is doubtless greater.

The bulk of this massive and coarse fluviatile deposit consists of somewhat irregular alternations of shingle, gravel, boulders, coarse sand (quicksand when saturated with water at some depth below the surface), and thin bands of clay. The beds of finer detritus are sometimes found in immediate association with the coarser material, any portion of the whole forming an exact counterpart of what may be seen on the Ohau River bed at the present day. The thin layers of clay which were deposited on many successive levels point to a temporary cessation of deposition on such areas, due to the river changing its course to a more or less distant portion of its fan.* During its formation the Ohau fan, with its great wastes of bare shingle stretching far and wide, must have presented a very desolate appearance. Any vegetation which managed to take root upon its barren slopes would, by the river changing its course, as was its unceasing habit, be completely covered by a stony mass. Swamps appear to have existed in hollows on the surface of the fan, probably on many successive levels, an ancient swampy layer 5 ft. in thickness having been met with at a depth of 323 ft. when the first trial artesian bore was sunk on the State farm at Weraroa. Another old land-surface was discovered when a well was dug on Section 38 in the Horowhenua Village Settlement. After passing through from 70 ft. to 80 ft. of gravel and shingle the workmen came upon a swampy layer 1 ft. thick, on the surface of which was found an entire pukatea stump *in situ.*

Driftwood has also been found at various depths in the Ohau fan. After heavy rains, driftwood derived from the bush-clad ranges and washed down by the swollen river would be cast ashore along its margin, and subsequently buried. In several cases when wells have been sunk into the fan this old water-borne timber has been brought to light. Twigs, leaves, and branches were found at a depth of 20 ft. in a well sunk in the Levin Borough about ten years ago. In another well a layer of branches and twigs and also a piece of pukatea timber were found at a good depth. In

* In the artesian wells sunk on the Weraroa State Farm the thin clay-seams were of very frequent occurrence.



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the third trial artesian bore on the State farm at Weraroa a rata log 2 ft. in diameter was found 135 ft. below the present surface. An old well-sinker stated that he had found flax-leaves which still retained their green colour beneath 18 ft. of shingle. This well was situated on Section 46 in Levin Borough.

From its apex to about two miles down its slope the Ohau fan has a fairly regular surface—that is to say, the curve exhibited by a cross-section would be a regular one. Further down its slope, however, its surface is characterized by ridges and hollows, whose strike is parallel to the dip of that surface. In this part the surface-curve, as shown by a cross-section, would be sinuous, though here the fan still retains its hyperbolic contour. The ridges are usually from 5 to 10 chains apart, and, though they seldom have an amplitude exceeding 3 ft., are especially noticeable where a road crosses some of them.

As shown by the coarseness of some of the transported material, and also, by the occurrence of driftwood, the Ohau fan is largely a flood deposit. As material was swept out from the mountain-enclosed valley on to the coastal plain, the river, being more confined to the immediate neighbourhood of its vent, would at first spread that material evenly in every direction. Further out, where spurs were absent and the river had freer play, ridges of deposit would be built up, until it was forced to change its course. While the river was in this state of oscillation—building up, being deflected when its bed became unstable, and eventually returning to its original position, and repeating the process on different parts of its fan—a slight change in the direction of its flow when near the apex of the fan would usually cause a considerable alteration in the position of that portion of its course situated further down the slope, and as a result the low radiating ridges would there be built up.

The Ohau River not only deposited shingle and gravel on the Pliocene coastal plain, but it also filled up with the same materials the deep valley it had cut (in the Tertiary epoch) through the rocks of the Tararua Ranges. This deposition of shingle, &c., in the primary valley of the Ohau was simultaneous with the formation of the fan, the latter being the downward extension of the former.

When the deposit in the valley had attained its maximum thickness it formed a sloping plain bounded by the hills, and traversed by the Ohau River and its two principal tributaries—the Makahika and the Makaretu. Formerly both these tributary streams joined the main river further upstream than they do at the present time; also, the Ohau itself flowed across the shingle plain south-east of, though more or less parallel to, its present channel.

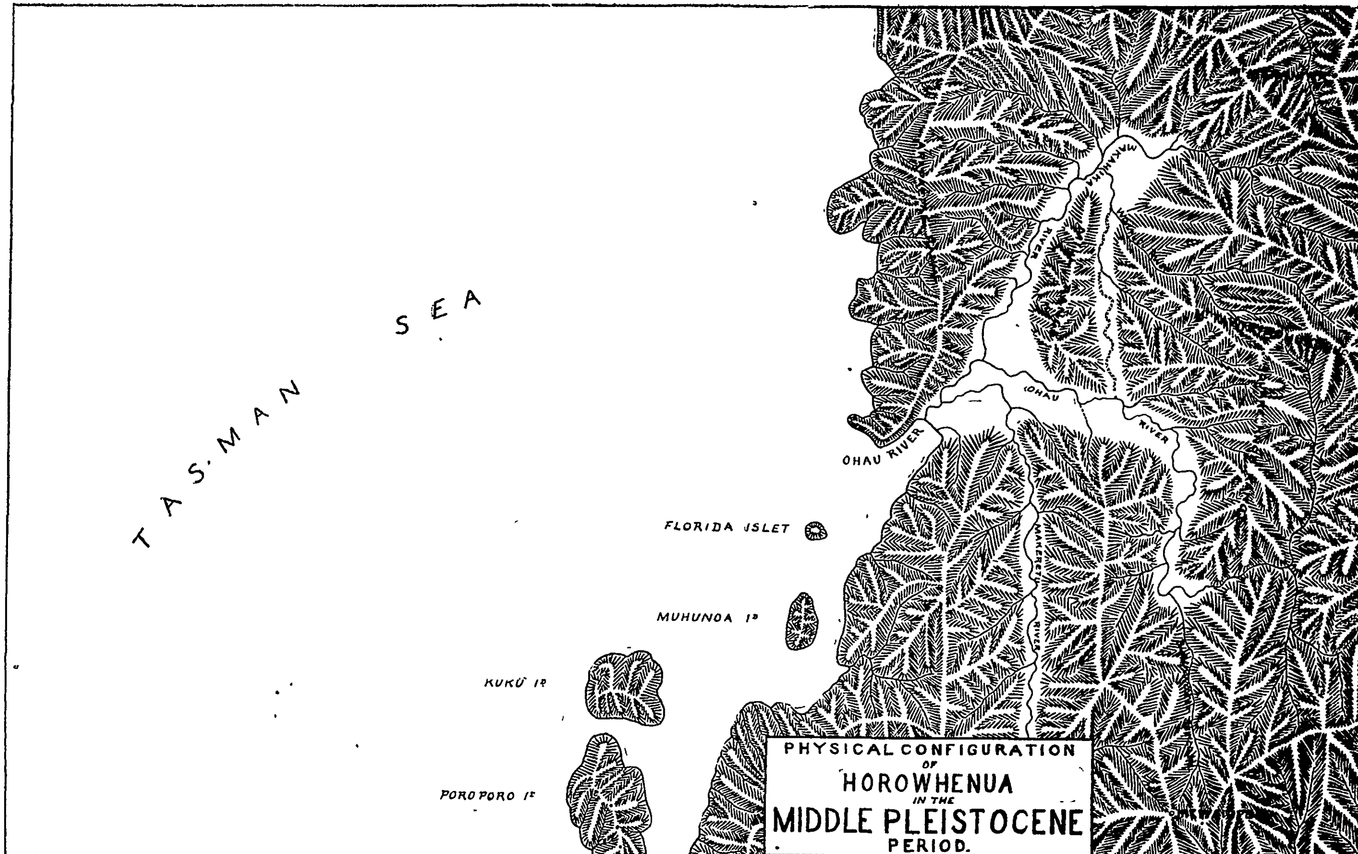
In shape the hill-enclosed alluvial plain which occupied the Ohau Valley bore a close resemblance to a three-fingered hand. The wrist was represented by the narrow strip, varying from 10 to 15 chains in width and three-quarters of a mile in length, which extended up-stream from the fluviatile vent; the palm of the hand was the widest part of the plain, lying round about the junction of the Ohau and its tributaries; and the fingers were the upward extensions of the shingle-beds in the respective valleys of these rivers.

While the "valley plain"—that is, the plain within the hill-enclosed part of the Ohau Valley—was approaching completion the Ohau River appears not only to have debouched upon the "plain" just south of its present channel, but also to have had an alternate course, from its upper gorges, between the Mill and Square Knob Ranges, to the present junction of the Makahika and Wai-iti Rivers, and from thence, in combination with those streams, down the Makahika Valley. Owing to the ruggedness of the locality and to its covering of dense bush, the exact nature and limits of this old suspected course have not been ascertained, but it is probable that it was similar in character to the branch of the "valley plain" which formerly occupied the Lower Makahika Valley. The position of this suspected course has been shown in the maps of Horowhenua in the early and middle Pleistocene periods, but has not been included in the accompanying geological map.

After the Ohau River had graded its bed and built up the surface of its fan and "valley plain" until it had attained its maximum altitude it deposited upon the upward extensions and the widest portion of the latter a superficial layer of clay varying from 10 ft. to 30 ft. in thickness. The precipitation of such fine sediment as clay alluvium was an indubitable indication that the cycle of deposition on the part of the Ohau River was coming to a close, and that very soon it would be flowing at grade—probably for the first time in its existence.

TABLE SHOWING THE SUPERFICIAL DIP OF THE "VALLEY PLAIN" AND OF THE FAN OF THE OHAU RIVER.

Reference to Topographical Map, page 517.	Datum-points.	Altitudes of the Datum-points.	Distances between the Datum-points.	Superficial Dip in Feet per Mile.
		Ft.	Ch.	
A ..	From the upper part of the "valley plain" (near the junction of the Makahika and Wai-iti Rivers)	777	164	95·12
B ..	To the middle part of the "valley plain" (near the junction of the Makahika and Ohau Rivers)	582		
B ..	From the middle part of the "valley plain" (near the junction of the Makahika and the Ohau River)	582	105	163·80
C ...	To the lower part of the "valley plain" (near the head of the Levin water-races)	367		
C ..	From the lower part of the "valley plain" (near the head of the Levin water-races)	367	43	40·93
D ..	To the apex of the Ohau fan	345		
D ..	From the apex of the Ohau fan	345	110	69·09
E .	To the line of the geological section across the Ohau fan	250		
E ..	From the line of the geological section across the Ohau fan	250	64	81·25
F ..	To the Arapaepae Road	185		
F ..	From the Arapaepae Road	185	90	58·6
G ..	To Levin Railway-station	119		
G ..	From Levin Railway-station	119	51	64·31
H ..	To Tirotiro Road (south end)	78		
H ..	From Tirotiro Road (south end)	78	66	50·9
I ..	To edge of Lake Horowhenua	36		



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When the deposition of the clay alluvium had ceased—the rivers having attained a state of equilibrium—lateral erosion came into play, and the Ohau River began to cut into the southern end of the Mill Range at the point where it flows from its upper gorges on to the sloping "valley plain." The river cut away and removed about 20 chains from the end of this range, reducing its constituent rocks to the level of the valley deposit. It was at this time that the Arapaepae Range was shorn of the spurs on its eastern flank.* For the most part these spurs were merely truncated, but in the narrow part of the Ohau Valley, near the fluviatile vent, they were entirely removed. This partial destruction of the Arapaepae Range was the joint work of the Ohau and its two main tributaries, but in the Makahika Valley it was accomplished by that river alone, though, as will be shown later, in a remoter period. As a result of the lateral erosion the area of plain within the Ohau Valley was very considerably increased, and thenceforth consisted partly of the fluviatile deposit, and partly of equally elevated and graded platforms of the country rock. The spurs of the range lying between the Makaretu Valley and the fluviatile vent have also suffered truncation, but in this instance the operation must have occurred either during the excavation of the primary valley of the Ohau River or not later than the period in which the "valley plain" and fan were built up.

As shown by the annexed table, the average superficial dip of the Ohau "valley plain" was much steeper than that of its fan, the dip of the former averaging 110·76 ft. and the latter 64·88 ft. per mile. Though this is so, the progressive diminution of the slope between the upper limits of the "plain" and the lower part of the fan is not regular, but is characterized by declivities of varying steepness. The dissimilar gradients of the "valley plain" are, of course, due to the respective width and narrowness of the valley itself. The gentler surface-slope of the "plain" in the Lower Makahika Valley and in the narrow connection immediately above the apex of the fan (see table) shows that in these places the deposit exactly corresponds to those which sometimes form in valleys of uniform width; but where the Ohau Valley widens out (round about the junction of the Makahika and Makaretu Rivers) the contained deposit endeavoured to assume a fanlike structure, and there the surface-slope is much steeper.

The dissimilar gradients of the fan seem to have been produced in another fashion. They lead one to suspect that the final additions of material to the fan differed in character from the main mass of that formation. In building up its fan the Ohau River transported detritus to positions progressively more distant to the apex of the former. This had the effect of not only raising the surface of the fan, but also of extending its outer edges upon the surface of the Pliocene plain. As the fan approached completion the river's power of transportation diminished, the area of the fan ceased to be extended, and the final additions to its mass were deposited nearer and nearer the fluviatile vent. The alternate steeper slopes of the surface of the fan are the respective limits of detritus laid down in periods of transportation of lessening intensity.

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* The truncated ends of the spurs closely resemble fault scarps, and might easily be mistaken for such. There is, however, no direct or exclusive evidence for such an origin, and fluviatile lateral erosion is a most satisfactory explanation. The origin of the truncation of the spurs is, for the most part, closely connected with the early Pleistocene fluviatile deposits.

When the river had reduced its bed to an easy grade, and had wandered over its completed fan and valley deposit, changing its course perhaps for centuries, the country began to sink. This subsidence affected the whole of New Zealand (which was, immediately prior to this depression, of continental dimensions), and, by reducing the elevation of the country, put an end to any permanent snowfields or glaciers which may have existed in this part of the North Island during the "glacial period." In the North Island this reduction of elevation certainly amounted to more than 500 ft., the base of the Ohau fan deposits being fully that depth below the present sea-level. If during the period of great elevation Cook Strait was occupied by a river, the Ohau must have been one of its tributaries, and the inclined Pliocene plain over which it flowed the side of the old Cook Strait River valley. As Cook Strait is at its southern end (where the mouth of the lost river probably lay) considerably over 100 fathoms in depth, it would seem that an uplift of 1,000 ft. would be necessary to restore it to its original form—*i.e.*, an open and spacious valley. It is therefore safe to assume that the elevation of the southern part of the North Island was reduced by *at least* 1,000 ft.

The downward movement of the land was not sudden or convulsive, but slow, gradual, and perhaps imperceptible. The sea began to inundate the western border of the Pliocene plain, and in the course of time washed the edge of the Ohau fan. The subsidence continuing, the exposed area of the fan became less and less, until it was finally covered, and the sea had advanced a little way up the Ohau Valley. The subsidence then ceased. The usual marginal deposits of sand were laid down against the western flanks of the Tararua foothills, marking the limits of the waves, mud and the finer material being deposited in deeper water at some distance from the shore.

In those days four small islands—Florida Islet, and Muhunoa, Kuku, and Poroporo Islands—lay off the coast of Horowhenua. Their approximate areas were 20, 70, 260, and 670 acres respectively. Their former insularity is shown by the presence upon their flanks of fragmentary patches of uplifted sea-beach deposits. On Florida Islet the latter has been best preserved, and is now elevated 360 ft. above sea-level. At the present time the former islands exist as isolated hills of the ancient rocks of the district. In the early Pleistocene, Florida Islet appears to have projected through the Ohau fan in a manner exactly like the isolated hills of the Upper Canterbury Plain.

A period of repose was followed by one of elevation, a movement which probably continues at the present day. The land rose with the same slow, gradual motion as it had previously sunk This elevation, however, differed from the previous subsidence in that it was local, the uplifted sea-margin lying between Paekakariki and Wanganui. The sea receded and the sandy beach widened, so that in the course of time it formed a plain of marine deposit sloping toward the sea.

At that time the Ohau River flowed in a north-westerly direction across the newly uplifted coastal plain. It flowed in a wide, shallow valley between banks of the soft marine sandstone, and had for its bed the surface of its old fan. After cutting away the soft sandstone, the river formed in the surface of the fan a large number of shallow channels, varying from 1 ft. to 5 ft. in depth, and averaging 1 chain in width. These channels wind about a good deal, but their general trend is to the north-west.

Ohau River, near the Makaretu Junction, showing the Convexity of its Bed.

"Raised Beach" near Shannon, seen from the Tararua Foothills.

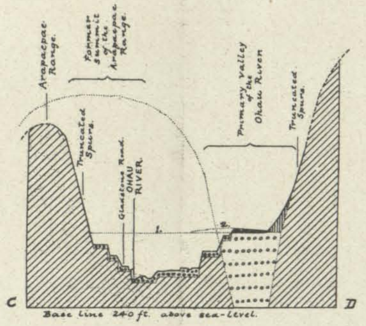
It is now much dissected by small streams and rivers.

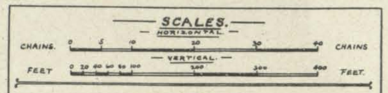
Face p. 504.]

Southern End of the Coastal Plain of Raised Beaches, seen from Paekakariki.

The cliffs which border the sea further south can be seen running inland as a result of the uplift. The dunes of blown sand have completely covered the raised beaches in this locality.

GEOLOGICAL SECTION C-D OF THE OHAU VALLEY
40 CHAINS ABOVE APEX OF FAN.





REFERENCE.

SECTION A-B.

1. Fragment of "valley plain" not on line of section.
2. Probable spur projecting on to "valley plain.
3. Higher terrace not on line of section.

SECTION C-D.

1. Level of lateral erosion of Arapaepae Range.
2. Surface of super-fan gravel

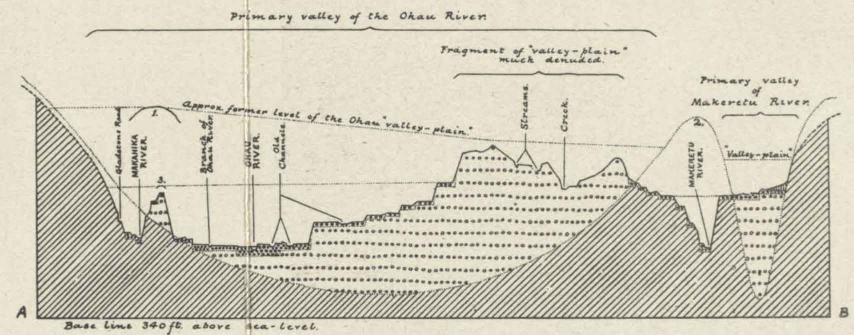
SECTION E-F.

1. Surface of super-fan gravel
2. Surface line of Ohau fan.
3. Floor of valley cut in R-B sandstone by Ohau R.

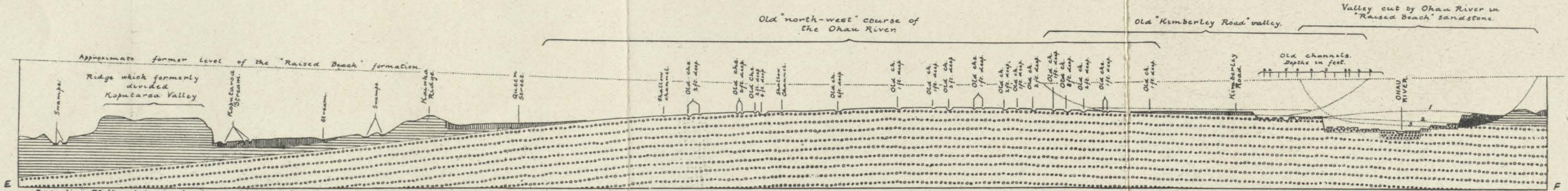
REFERENCE TO FORMATIONS.

AGE.	FORMATIONS.	
EARLY MESOZOIC ?	Greywackes and slates of Tararua Ranges.	
EARLY PLEISTOCENE	Older gravels, etc, of Ohau R. fan and valley deposit)	
LATER PLEISTOCENE	"Raised Beach" formation.	
RECENT	Newer gravels, etc, of the Ohau River	Terrace gravels.
		Super-fan gravels.
LATER PLEISTOCENE RECENT	Alluvium of minor streams. (flood-plains, etc)	

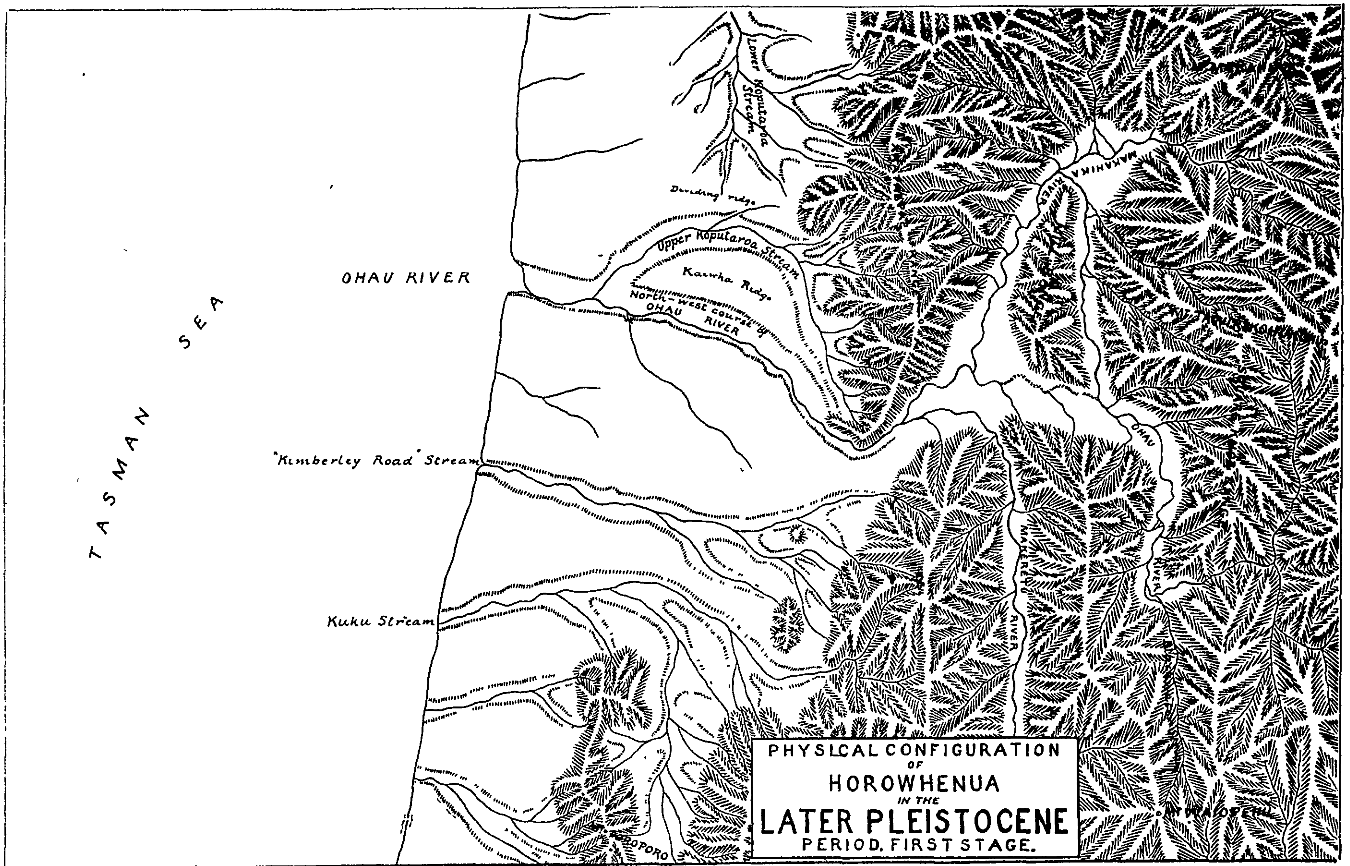
GEOLOGICAL SECTION A-B OF THE OHAU, MAKAHIKA, AND MAKERETU VALLEYS
130 CHAINS ABOVE APEX OF FAN.



GEOLOGICAL TRANSVERSE SECTION E-F OF THE OHAU FAN, THE OHAU VALLEY, AND OF THE SUPERINCUMBENT "RAISED BEACH" FORMATION
115 CHAINS BELOW APEX OF FAN.



Surveyed and drawn by G. L. ADKIN. 1910.



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This old "north-west" course is what may be termed the "intermediate stage" in the recent geological history of the Ohau River. Formerly by the process of aggradation it formed a massive deposit of shingle and gravel, and now by erosion it has excavated a deep valley in that formation. It is hardly likely that these very adverse conditions were abruptly consecutive, but that they were separated by an intermediate stage, which was a period when the river was neither depositing material nor to any great extent scooping out a well-defined channel. The old "north-west" channel was this "intermediate stage."

Though the shallow "north-west" valley of the Ohau River eventually attained a width of about a mile and three-quarters, it was at first much narrower. For a reason which will transpire in the sequel, the river—which originally flowed to the sea near and parallel to the present position of Queen Street (Town of Levin)—continually attacked its left bank, causing it to retreat to the vicinity of Kimberley Road. Prior to this lateral erosion by the Ohau River, the streams from the hills a couple of miles south of the fluviatile vent combined and occupied a wide but shallow valley situated along the line of the present Kimberley Road. The stream formed by this union flowed first into the sea, but afterwards into the southern end of Lake Horowhenua, which was then from 30 ft. to 40 ft. deeper (and consequently more extensive) than now; and when it had excavated its valley through the sandstone formation to the upper surface of the Ohau fan it filled its valley-bottom with alluvium—clay derived from the hills at its sources. By the lateral erosion just described the Ohau River removed the right bank of the "Kimberley Road" valley, tapping it and cutting into the clay alluvium. Though subsequent erosion has removed some of this clay deposit, the remainder can still be seen extending from the intersection of the Arapaepae and Kimberley Roads, through the Weraroa State Farm, toward the southern end of Lake Horowhenua. Originating as a flood-plain, it constitutes one of the most fertile portions of the district.

By the time the Ohau had gained access to the old "Kimberley Road" valley, however, the latter had been deserted by the stream which formed it. The "Kimberley Road" stream seems to have been divided from the streams which drained the hills still further south by a low ridge of the soft marine sandstone; and, having aggraded its bed with the clay alluvium, lateral erosion commenced, by which means it cut through the dividing-ridge, and allowed itself to be captured by one of the aforementioned neighbouring streams.

These small watercourses have their sources in the outlying Poroporo Range, in the adjacent Tararua foothills, and in the intervening valley. They flowed round the northern end of the Poroporo Range, entering the sea directly opposite. One of them, the Kuku Stream, afterwards raised its bed by depositing alluvium, and flowed over a low col—situated near the northern end of the outlying range—subsequently cutting the small ravine which it still occupies.

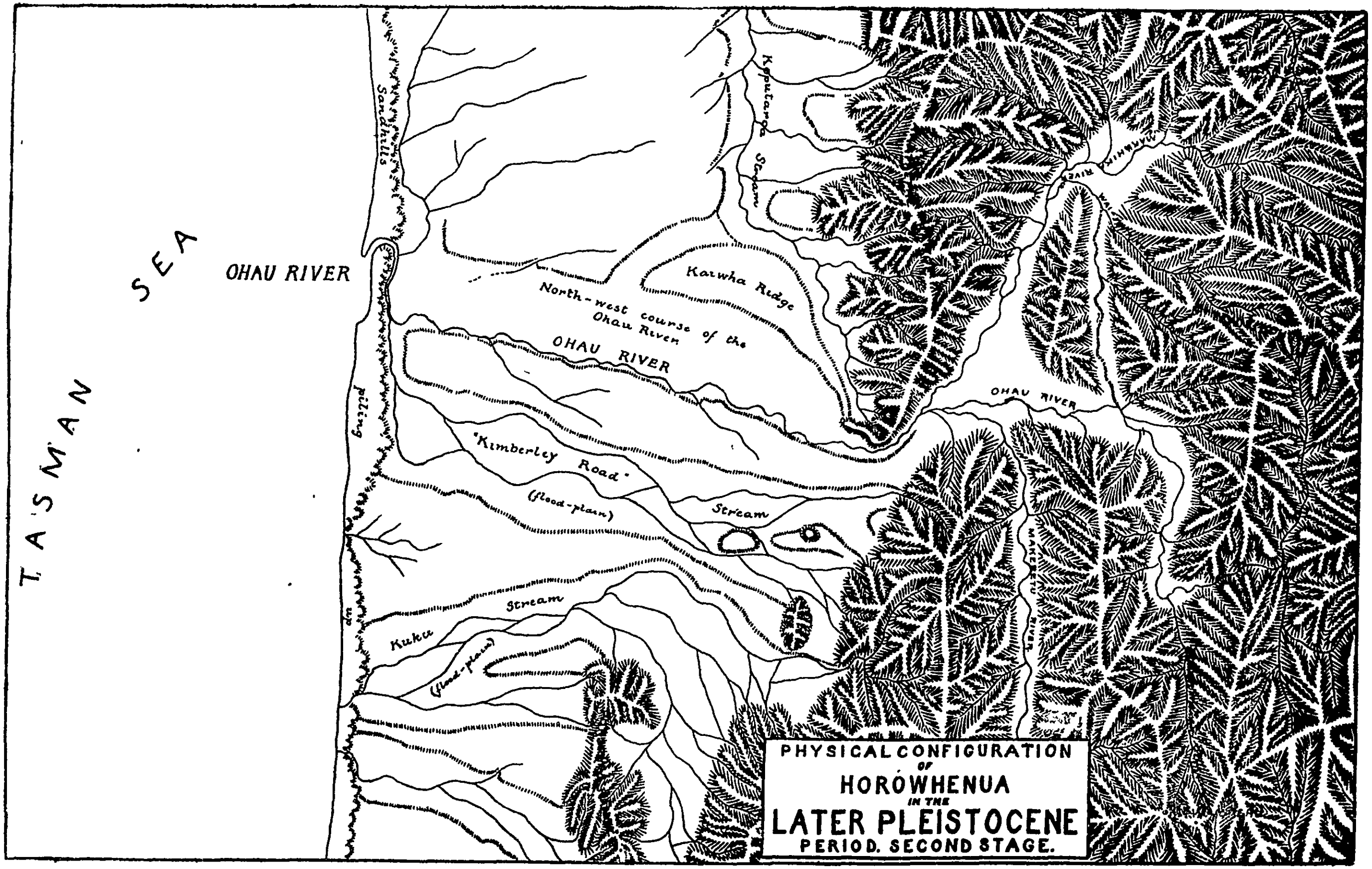
Though there is no direct evidence that the "Kimberley Road" stream vacated its original valley before the Ohau had gained access to it, for two reasons such is believed to have been the case. One is that the clay alluvium has not been channelled in the manner it probably would have been had the stream flowed into the Ohau; and the other, and more important, is that had the deviation not taken place the original valley of the stream would have formed an insurmountable barrier to the Ohau River when the course of the latter was changed in the manner to be described later.

The structure and lithological character of the material of the inclined plain of marine deposit (raised beaches) may now be examined. I am indebted to Mr. John Young for a hint as to the origin of this formation. From original observations made while travelling up and down the railway he concluded that it was nothing more or less than an extensive series of raised beaches, and I have since proved—to my own satisfaction at least—that such is indeed the case. At the foot of the ranges the raised-beach formation is composed of sandstone, but further out from them—in Levin Borough, for example—the formation consists of an upper bed of sandstone, a middle zone of yellow clay, and a basal layer of sandstone, the first and last being identical in all respects. Along the lower slopes of the Tararua foothills especially, the thickness of the raised-beach formation varies according to its remoteness from or proximity to the summits of the Ohau, Otaki, and other fans. Two miles south of Shannon the sandstone lies on the lower northern slope of the Ohau fan, and there has a thickness exceeding 500 ft. Opposite Levin its thickness was originally 200 ft. to 240 ft., but has since been much denuded.

The raised-beach formation is evidently a double one. When the country sank (terminating the early Pleistocene elevation), and the sea advanced over the land in this locality, sandy beaches were formed, only to be submerged and superseded by others as the subsidence continued. When the subsequent uplift took place, the sea while receding repeated the process of deposition, and formed a second series of sandy beaches above the first. The intercalated masses of clay represent, of course, the finer sediment laid down while the sea was advancing and receding, and also when this portion of the country was at its recent minimum elevation—*i.e.*, when the sea washed the Tararua foothills.

The sandstone of the formation is usually rudely stratified, and generally finely laminated, the laminae sometimes exhibiting false bedding. Its colour varies from light and dark grey to various shades of red and yellow. Quartz grains, which constitute the greater part of the sandstone, are coated with iron-oxide in the red and yellow varieties, and associated with black particles in the grey. Ripple-marks are of frequent occurrence in the sandstone, usually at some little distance from the upppermost sea-margin at the foot of the hills, and are without doubt due to the friction of fairly deep water, and not to the action of wind.

In this district both the clay and the sandstone are quite destitute of fossil remains. This deficiency is probably due to the seas which then washed these shores being too turbid to be favourable to the life of shell-fish and similar creatures which were likely to be preserved in the fossil state; or it may be that shells which were originally preserved have since been removed by dissolution. In some places, especially at the foot of the Arapaepae Range, the sandstone outcrops are seen to be riddled, or even honeycombed, with tubular holes, usually from ½ in. to 1 in. in diameter. The absence of fossil remains within these holes renders it difficult to determine whether they were the homes of marine worms or borers, or have merely been made by land-insects since the uplift. The size of the perforations and certain other characteristics seem, however, to disfavour the latter suggestion.



Restored and drawn by G L Adkin

The southern extremity of the newly uplifted coastal plain just described lies about two miles south of Paekakariki. The cliffs which border the sea further south begin at this point to run inland. These cliffs attain in some places a height of 800 ft., and do not rise perpendicularly from the sea-margin, but form precipitous scarps, fringed at the foot with jagged rocks which lie slightly above high-water mark. As these cliffs strike inland (as a result of the uplift), and recede more and more from the present shore, they are, by the formation of talus slopes and other effects of subaerial denundation, gradually transformed into steep hills, which present comparatively unbroken faces. The best examples of the former sea-cliffs are to be seen near Otaki and Ohau. Although the flat land (marine sediment) first appears near Paekakariki, there are abundant signs of uplift, and also of prior depression, of the country as far south as Porirua Harbour.

The coastal plain of marine deposit varies in the different localities between Paekakariki and Wanganui in both width and elevation. The uplift was probably greatest midway between the two extremities, and the altitude of the upper edge of the sandstone increases at the southern end apparently with some irregularity as that point is approached. This irregularity may really be only apparent and not actual, for in some cases it is certain that subaerial denundation has proceeded so uniformly that, though the original surface of the sandstone has been considerably lowered, the original superficial slope remains unaltered, and the denuded surface is liable to be mistaken for the original one.

The projection of the coast (Kenakena) near Waikanae is, with the exception of the numerous river-mouths, the only irregularity in the grand sweep of the present beach lying between Paekakariki and Wanganui. This projection, which lies exactly opposite the Island of Kapiti, has doubtless been formed by the flow of the tides round the ends of that island. The meeting of the tidal currents on its lee has caused the suspended sediment to be precipitated, thus forming a sandy ridge, partly sub- and (by the rise of the land) partly supra-marine. Should the uplift of the land continue, Kapiti, by the extension of this ridge, will eventually become a peninsula.

In the immediate neighbourhood of the Ohau River the principal stream which dissected the coastal plain of marine sediment was the Koputaroa. Taking its rise in the southern end of the Arapaepae Range, and receiving many affluents from the western slopes of the same, it flows northwards into the Manawatu River. During its, geologically speaking, short life the Koputaroa has passed through many vicissitudes, and, though the stream is rather insignificant, a review of its life-history will perchance serve to indicate the nature of similar sediments and operations of larger watercourses, the conditions under which such sediments were deposited, and the manner in which their actions and operations were effected. When seen in miniature, origins, modes of action, and cause and effect are more easily studied and understood than when the same phenomena occur on a larger scale.

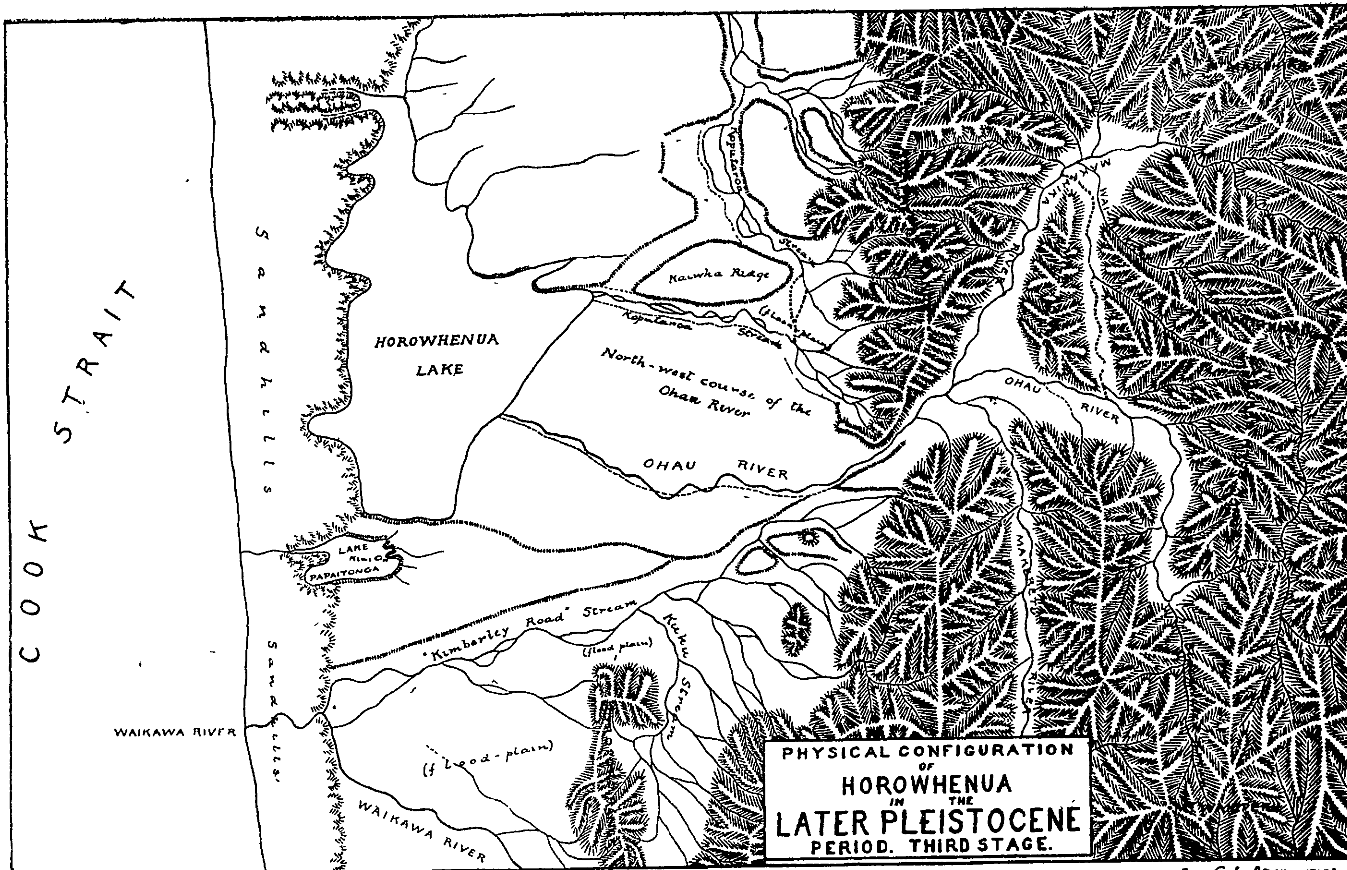
Towards the termination of the Pleistocene period—that is, when the Ohau River flowed in the shallow "north-west" channel, and this portion of the country was at a somewhat lesser elevation than at the present day —the valley which is now occupied by the Koputaroa Stream was transversely divided by a low sandstone ridge. This ridge lay directly between its two remaining extremities, which may still be seen — one near the northern end of the Koputaroa Road, and the other a little north of the north-east corner of Levin Borough.

North of this ridge the drainage was then the same as now, but on the southern side a considerable change has occurred. The Upper Koputaroa Stream—*i.e.*, the portion south of the dividing-ridge, took its rise in the southern extremity of the Arapaepae Range, flowed parallel to it as far as the present position of Queen Street, and then, bending north-west and west, flowed into the Ohau River near the point where it then entered the sea. The Upper Koputaroa was divided from the Ohau River by another low sandstone ridge extending from near the source to the junction of the former with the latter. The " Kaiwha " ridge (such being the name by which it was known to the old-time Maoris) varied from a quarter to half a mile in width, and its summit was about 25 ft. above the beds of the Upper Koputaroa and Ohau Rivers, though later it was in some parts considerably lowered—apparently by pluvial erosion.

While deepening and widening its valley the Upper Koputaroa removed part of the ridge which divided it from the lower part of its present valley, and, deserting its connection with the Ohau, formed a continuous stream, which poured its waters into the Manawatu River. A base-level of vertical erosion having been established, lateral erosion became important, so that the Koputaroa attacked and removed the upper portion of the " Kaiwha " ridge, thereby gaining access to the old " north-west " channel of the Ohau River, which was by that time vacated, and therefore dry. The surface-slope of the Ohau fan preventing an overflow of the Koputaroa to the south-west or west, deflected it toward the north-west and caused it to hug the southern side of the " Kaiwha " ridge, and by lateral erosion to cut back its bounding scarp. The sandstone of the ridge was, however, not so entirely removed as to expose the underlying fan.

After attaining the base-level of erosion as mentioned above, the Koputaroa began to fill its valley with alluvium derived from the Arapaepae Range. This deposition of material was probably the result of a similar process on the part of the Manawatu River—the one keeping pace with the aggradation of the other. Being in a state of stable equilibrium, the Koputaroa (when the pivot of its motion was in the breach of the " Kaiwha " ridge) by repeated oscillations from one side of its course to the other flowed and deposited material, sometimes on the south side, and sometimes in its valley proper, on the northern side of the " Kaiwha " ridge. This process was continued until the alluvium had reached its present thickness and structure.

During its recent outflowings along the line of Queen Street to the centre of Levin a second bifurcation of the Koputaroa Stream occurred, this time near the Horowhenua Butter-factory. At this point the stream by building up its bed was able to cross a low portion of the " Kaiwha " ridge, and after an interval, and again by aggradation, this time of its newly-acquired channel, it entered the shallow valley of a small stream which formerly flowed westward into Lake Horowhenua. Taking possession of this small valley, the Koputaroa deposited material in it for the remainder of the time of its outflow in this direction, thrusting forward its alluvium as far as the intersection of Queen Street and Tirotiro Road. Both the first and second branches of the westward outflow of the Koputaroa Stream reached and entered the then more extensive Horowhenua Lake.



Restored and drawn by G L Adkin

Since the excavation of the shallow channel it now occupies the Koputaroa has, of course, been confined to its principal valley, and again pours the whole of its waters into the Manawatu River.

The alluvium of the Koputaroa and its tributaries, being fairly typical of the deposits of the other streams which convey the drainage of the Tararua foothills across the coastal plain, is worthy of some notice. In surface form there is a marked contrast between the deposits of the Koputaroa and those of its tributaries. This difference is due to the dissimilarity in the gradients of their beds, the bed of the trunk stream having at that time, as now, a much gentler slope than had those of its tributaries. The Koputaroa spread its alluvium from one side of its valley to the other in gently sloping sheets, while its tributaries formed laterally coalescing fanlike deposits, each deposit having its apex in the gully of the stream to which it owes its origin. The deposits of the tributary streams are not true fans, because they were modified by the presence of the lateral spurs of the Arapaepae Range, which separated their upper portions.

Besides having a gentler surface-slope, the alluvium of the Koputaroa differs from that of any one of its tributaries in other respects; the area it occupies is greater, though its thickness is less; and its contained rock *débris* consists of well-rounded pebbles and boulders, and not, as do the tributary deposits, of angular fragments. The alluvium of the Koputaroa itself consists of masses of gravel, grit, and boulders, surmounted by patches of yellow clay. The total thickness probably does not anywhere exceed 30 ft., and, though the thickness of the lower portion is fairly constant, the upper clayey division varies—in some places swelling out to a depth of 5 ft. or more, and in others thinning away to the upper surface of the underlying gravel. These masses of superficial clay frequently contain numbers of sporadic stones of various size. Of these the largest observed was a greywacke boulder, roughly rhomboidal in form, but nevertheless well water-worn. It lay just below the surface of the clay, and was found to weigh 320 lb., its greater diameter being 28 in., its lesser 20 in.

From recent observations made in Victoria by Mr. Guppy it has been found that muddy water, having a greater specific gravity than that which is free from suspended particles, is able, even when flowing at a moderate velocity, to transport boulders of considerable size. From this it will be seen that the presence of large sporadic stones in a deposit of fine silt, and their transportation, by a stream of no great magnitude, to positions some miles from the parent rock, are phenomena not difficult to be accounted for. These facts seem to indicate that when the Kuputaroa Stream first began to deposit material it was a muddy torrent washing down large numbers of various-sized stones; but after it had raised its bed by deposition its flood-waters spread, in the absence of any well-defined channel, over the whole of the floor of its valley, and, while depositing clay, also rolled down and disturbed the comparatively few pebbles and boulders which happened to come within the range of its action.

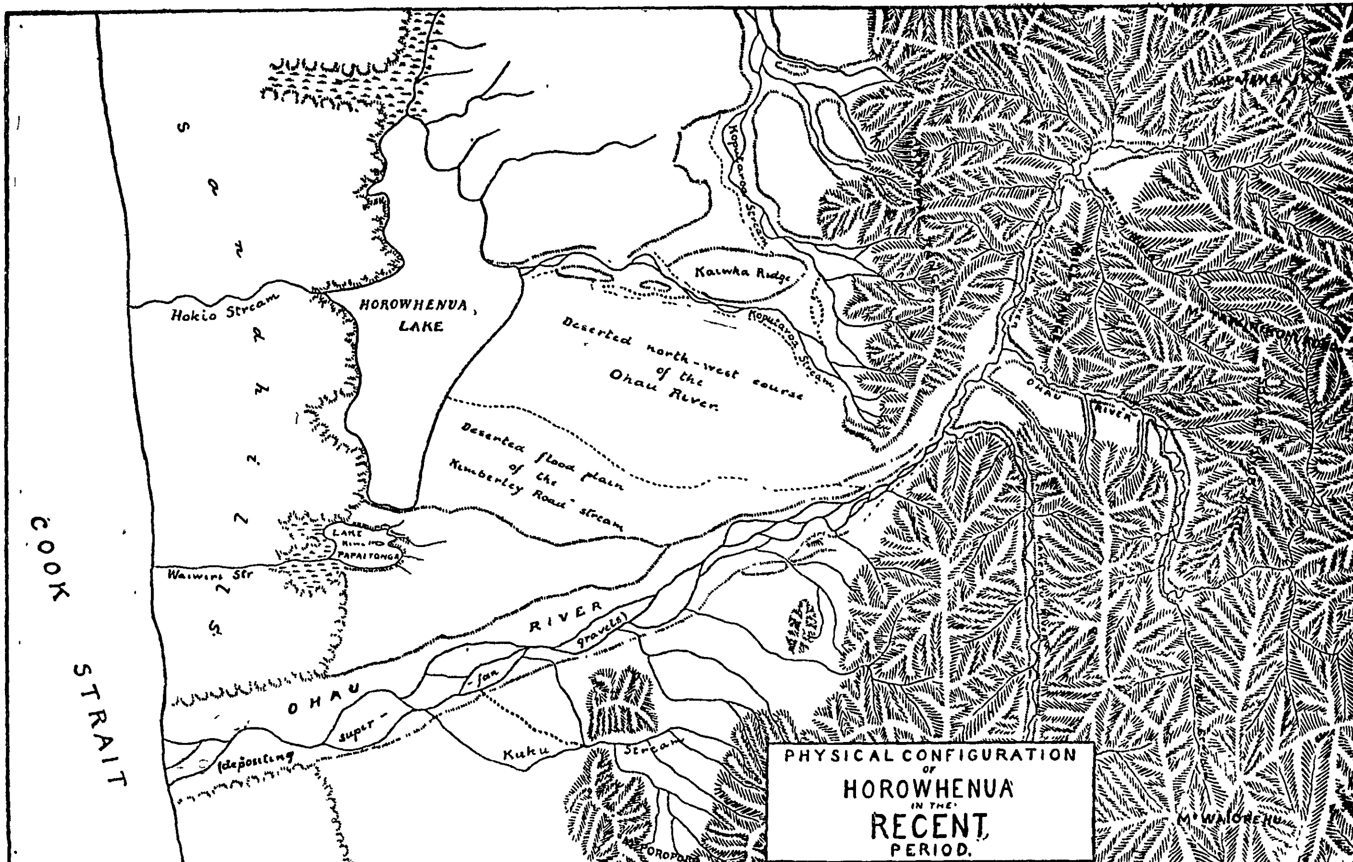
The Ohau River flowed in, and gradually widened, its "north-west" valley, until the sea had receded, in this vicinity, to about five miles from the ranges, when a bar, or perhaps sandbanks, were formed at the mouth of the river. By the action of wind and waves, combined with the uplift of the land, the bar or sandbanks were raised above sea-level, and sand-dunes were piled up, at first obstructing and afterwards completely blocking the river at the point where it entered the sea.

In this manner the Horowhenua Lake was formed. The waters of the river gradually banked up behind the sandy barrier, finally filling the wide channel as far up as the present site of Levin. At the time of its maximum extension the Horowhenua Lake must have had an area of between five and six square miles, its former eastern and south-eastern margins being indicated by the presence of a black soil on the surface of the shingle of the Ohau fan. The uppermost edge of the area of black soil extends from Levin to Weraroa, and from thence along the Beach Road to the State farm, and is, of course, a relic of the swamps which fringed the former successive margins of the lake. During its maximum extension the greatest depth of the lake was about 100 ft., the level of its waters being for a while kept fairly constant by an overflow between the sandhills to the sea. When, however, by the enlargement of this outlet the Hokio Stream came into existence, the surface of the lake was more or less gradually lowered until it reached its present level, thereby reducing its area by three-fourths, and diminishing its depth by more than 70 ft. The irregular swamps at the north and south ends of the lake are the relics of arms of that sheet of water when it had attained its greatest extent, or are abortive attempts to gain an outlet to the sea, or perhaps both.

Former levels of the Horowhenua Lake are indicated by the position and elevation of the extremities of the alluvial deposits of streams which at one time flowed into it. The previously mentioned "Kimberley Road" stream flowed into the southern end of the lake when its level was rising. The Koputaroa has also left memorials of the former higher levels of the lake. The first branch of its western outflow reached the lake when the surface of the latter had attained its maximum altitude—about 110 ft. above the present sea-level; while the second branch entered the lake when its surface had been lowered to about 70 ft. above that datum-line.

At the present time the Horowhenua Lake has an area of 900 acres, its surface is 36 ft. above sea-level, and its greatest depth probably does not exceed 30 ft. The lake derives its water-supply from the overflow of the adjacent swamps and from their interfluent streams, and its only outlet is the Hokio Stream, the sluggish waterway which meanders between the sandhills to the sea. The six islands situated near the western and southern shores were artificially constructed by the Maoris in the early part of the last century to serve as fortresses in their intertribal wars. Some are now, however, more or less submerged through the wasting-away of the perishable vegetable matter of which they were partly constructed.

The sandhills which enclose the Horowhenua Lake on its western and southern shores have kept pace with the uplift of the land, so that they now cover the strip of country, three miles wide, which borders the sea. On the southern boundary of the county the belt of sandhills is also three miles in width, but at its northern end the blown sand has spread inland for over six miles. The most advanced inroad of blown sand is situated near the northern end of Lake Horowhenua, where a comparatively thin stratum extends from the main belt of dunes to the Heatherlea cross-roads. This tongue of land has long ceased to drift, but it can be distinguished from the underlying raised-beach sandstone by its finer texture, its less regular structure, the absence of parallel laminae, and its hummocky upper surface. The superimposition of the blown sand upon the raised-beach sandstone can also be seen about one mile south of Lake Horowhenua.



Restored and drawn by C L ADKIN.

The general arrangement of the sandhills is in ridges at right angles to the coast-line. Their culminating point between Paekakariki and the Manawatu River is Moutere, 288 ft., and situated between the northern end of Lake Horowhenua and the sea. The surrounding sandhills have a general altitude of 170 ft., and vary in character considerably. Great wastes of bare drifting sand border the coast-line, but further inland the dunes are covered with manuka scrub and grass, so that in these parts the accumulation has now ceased.

The hollows between the older ridges and hills of drifted sand are occupied by grassy flats, swamps, or lagoons. The last named are very numerous, though their area seldom exceeds a few acres. Papaitonga, the largest of the lagoons, is situated in the wedge-shaped sandstone area lying between the former and the present course of the Ohau River. It occupies a hollow (the former valley of a small stream) on the junction-line of the raised-beach sandstone and the hills of blown sand. Extensive swamps border the western shore of Papaitonga, and a stream connects it with the sea. The smaller island, Motu Ngarara, is artificial, but Kiwi Island is an isolated mound of raised-beach sandstone.

The Ohau River flowed into the Horowhenua Lake until the latter had attained its maximum area. At this juncture the deflecting force which had caused it to continually erode its left bank compelled the river to vacate its "north-west" channel, and to flow across the plain of raised-beach sandstone in its present position, but on a much higher level. A moment's consideration will show that the deflection was southwards, which in a river flowing west is from its right bank towards the left. This fact gives some indication as to the nature of the force which impelled the Ohau River to continually attack its left bank during the occupation of its "north-west" channel. Ferrel has shown that moving bodies on the earth's surface, in the absence of other controlling forces, are deflected to the left in the Southern Hemisphere. This law has already been applied to the Canterbury rivers,* and there is no doubt that the deflective force produced by the earth's rotation was the agency which caused the Ohau River to alter the direction of its flow. Having reached its present position, the deflection of the river ceased, owing to the retardation and suppression of the deflective force, partly by superficial obstacles—*i.e.*, the unfavourable configuration of the land-surface, viz., the Poroporo Range —and partly by the awakening of other forces which introduced a new cycle of action into the history of the Ohau River—viz., the excavation of the valley it now occupies.

Upon attaining its present position the first act of the Ohau River was to make for itself a valley in the raised-beach sandstone, and to deepen it until the surface of the underlying fan was again denuded, and also slightly incised. This erosion was due to the sandstone having a gentler surface-slope than had that part of the "valley plain" which lay above its limits, and to the tendency of the river to equalize the gradients of the different portions of its bed. Soon after this erosion of the sandstone the Ohau River began to channel its former deposits.

The gradual diminution in the slope of the surfaces of the fan and "valley plain" had an important effect upon the subsequent action of

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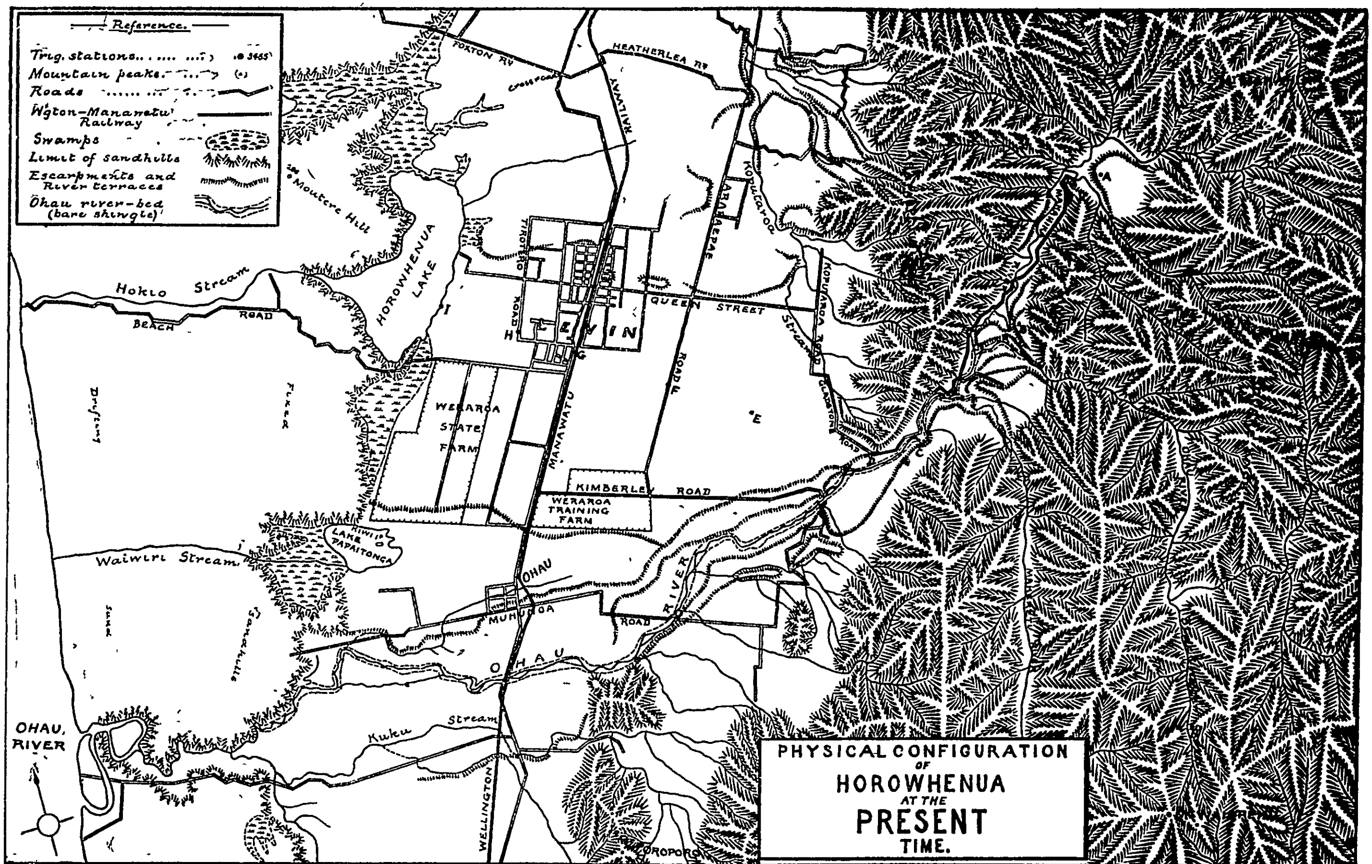
* F. W. Hilgendorf: "The Influence of the Earth's Rotation on the Course of the Rivers on the Canterbury Plains," Trans. N.Z. Inst., vol. 39, p. 206.

the Ohau River. As has been shown in the appended table, this slope is very similar to a *thalweg*, or erosion-curve, being relatively steep in its upper parts, but gradually becoming flatter (with some irregularity) as it is descended. At that time the chief endeavour of the river was apparently to *reduce* the steepness of its bed; and on this account, and as a result of the general progressive *diminution* of the superficial dip of its former deposits, the upper and middle parts of the "valley plain" were the first to be incised. The material from this excavation was washed down, and spread over the surfaces of the lower part of the "valley plain" and the upper part of the fan; and it was also deposited to the depth of some 20 ft. on the floor of the valley in the raised-beach sandstone. Lateral erosion on the part of the river then came into play, and in the last-mentioned locality the sides of the valley were cut back—down to the level of the material just previously deposited. This lateral erosion was effected in such a manner as to cause the resultant flood-plain to have a convex surface when viewed longitudinally. In forming this part of the flood-plain the river cut sideways, on its right bank, not only through the sandstone side of the valley, but it also notched (laterally) the slope of the underlying fan. Vertical erosion again attaining an ascendency, another flood-plain was formed somewhat below the level of the first, and this time extending from the upper edge of the "valley plain" to some distance down the slope of the fan. Subsequently, periods of lateral erosion and the formation of successive flood-plains alternated with periods of vertical erosion, and in cases when the flood-plains were not totally destroyed by the further action of the river their fragments were left to form the terraces which are now so common in the several portions of the Ohau Valley.

Owing to its straightness and uniform width, the Lower Makahika Valley, at the commencement of the erosion of the early Pleistocene deposits, was extremely liable to be swept from side to side by floods, so that, with the exception of two or three fragments which now indicate the altitude of the original surface, the Makahika branch of the "valley plain" was destroyed and washed away. As the excavation progressed—lateral erosion being in part superseded by vertical—the lower flood-plains were less affected by the action of the river than the original surface was, and are therefore more extensively preserved. The truncation of the spurs in the Makahika Valley appears to have been effected in the Tertiary epoch, since thick masses of early Pleistocene deposits can be seen abutting upon their truncated ends.

An examination of the escarpments of the terraces which have been cut in the "valley plain" shows that there are of the latter two distinct types. In one the terrace-face consists either of shingle, gravel, &c., from summit to base, or has a considerable thickness of these materials resting on the country rock, while in the other type the country rock is surmounted by only a comparatively thin layer of water-worn detritus. The first type of terrace shows that the Ohau has incised its Pleistocene deposits (which fill the primary, or pre-Quaternary, valley of the river) either in the middle or at one side of the valley, while those of the second type indicate that the river has cut laterally and then vertically into the bounding hills, and, in forming the subsequent flood-plains, deposited a veneer of gravel and shingle upon the successive platforms which it carved in the ancient base rocks.



Based on Horowhenua county maps — Surveyed and drawn by G L. ADKIN

Scale, two miles to an inch.

The gravels, &c., of the Ohau fan and valley deposit, and also of the recent terraces, consist of greywacke, soft slates, fragments of conglomerate, and red and green quartzose material in corresponding proportion to their occurrence in the country rock of the district.

Since the excavation of its present valley the Ohau River, along the lower part of its course, has raised its bed by the deposition of fine sediment in much the same manner as the Waimakariri River has done in the neighbourhood of Kaiapoi. These alluvial flats, which constitute the fertile lands about the Lower Kuku Stream, have their origin where the terraces of the Ohau merge upon the surface of its fan, and extend from thence to the coast, though there, as elsewhere, their limits are hidden by blown sand. The establishment of these aggraded alluvial flats has prevented the inroads of the dunes on a narrow strip bordering the left bank of the Ohau River. This is the only place within the area shown on the accompanying maps where the fertile land, which elsewhere lies contiguous to the foot of the ranges, approaches to within one mile of the sea-beach.

The question now presents itself, What caused the Ohau River to excavate its present valley? A cursory examination of the locality would doubtless lead the observer to the conclusion that the present terraced valley of the Ohau River is the direct result of the (geologically) recent plication of the folds, and consequent slow upheaval, of the Tararua Ranges, and also of the adjacent sea-bed. Such, however, was not the case. It is true that upheaval has taken place, as shown by the occurrence of raised beaches, and it is highly probable that such was due to crustal movements in the Tararua and Ruahine Ranges; but there is evidence to show that the uplift and the formation of the present Ohau Valley were not coincident, and therefore the former was not the direct cause of the latter. The river did not *commence* the excavation of its valley until the land had well-nigh reached its *present* elevation.* The Ohau flowed in its north-west channel until the land was within 30 ft. of its present elevation, and after that again it flowed in the same direction as it does now long enough to excavate the sandstone to a depth of about 100 ft.—all before it *commenced* to incise the upper portion of its "valley plain."

These facts point to a very considerable lapse of time between the beginning of the uplift and the commencement of the erosion of the Ohau Valley, so that a more satisfactory explanation of the latter operation must now be sought for.

The theory recently put forward by an eminent Canterbury geologist† appears to conform with the facts of the case under notice. He considers that one of the causes which will enable a river to excavate its channel is "the failure of the supply of waste"—that is, the failure of the supply of detritus with which the river is aggrading its bed or which it is transporting to lower levels. Concisely, the theory is as follows: Other factors remaining constant, a cessation or diminution of the supply of transportable

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* By "the excavation of its valley" is meant the erosion by the Ohau River of its former deposits—*i.e.*, the "valley plain" and fan accumulations. Being due to causes other than those now being considered, the origin of the second valley in the raised-beach sandstone does not come into the present discussion.

† R. Speight: "Some Aspects of the Terrace-development in the Valleys of the Canterbury Rivers," Trans. N.Z. Inst., vol. 40, p. 16.

rock *débris* within a catchment-area will cause the contained river to deepen its channel. In this district the ascertainable facts appear to support and confirm this view.

Though at the present time the basin of the Ohau River contains only a few insignificant areas rising above the timber-line, in the early Pleistocene, when the river was building up its fan, a very considerable proportion of the mountains among its sources and upper reaches was bare of arboreal vegetation. The former lower altitude of the timber-line in relation to the sources and upper reaches of the Ohau River was, of course, due to the greater elevation of this part of the country at that time.

A covering of dense forest acts as a shield and filter—controlling the impetuosity of the water following heavy rain; binding the soil together and protecting the underlying rocks; allowing only the finest silt to be transported to lower levels; and, perhaps most important of all, preventing the formation of landslips. A striking, though by no means rare, example of the last-mentioned attribute of a forest covering was observable from Levin on Friday, the 3rd September, 1909. Dry weather followed by rain — a very favourable series of circumstances — produced their usual effects on the mountains; but, though innumerable slips were visible on those ridges of the Tararuas lying above the limits of the bush, not more than half a dozen were to be seen upon the nearer forest-clad ranges.*

It follows, then, that in the early Pleistocene, when the land hereabouts stood at least 1,000 ft. higher than now, the areas bare of forest suffered severely from the action of the elements—rain-storms swept away the soil; the alternate action of sun and frost shattered the rocks thus exposed; and landslips and freshets carried the resultant rock *débris* to the valley-bottoms, furnishing the Ohau and its tributaries with an abundant supply of "waste" wherewith to build up its deposits in the lowlands.

This state of affairs was brought to a gradual close by the following subsidence of the land. It would appear that the upward extension and growth of the forest did not keep pace with the subsidence, because, had it done so, the excavation of the present Ohau Valley would have commenced in the middle Pleistocene—the period of recent minimum elevation of this part of the country. It seems, therefore, that the forest was slow in adapting itself to, and taking advantage of, the new conditions, and by failing to check the supply of "waste" delayed the excavation of the valley to the Recent geological period—almost to the present day.

In the foregoing an attempt has been made to account for the varied physical features of the district, the various geological formations, and the peculiarities of surface-configuration. As previously stated, the absence of fossils will no doubt force investigators to fall back on stratigraphical evidence and the evidence of the slow crustal movements—first epeirogenic, then orogenic—when attempting to place the formations of the district in their correct position in the geological scale. The problems of the district are by no means exhausted, but, as those still unsolved apparently do not affect the continuity of the chain of events, their non-solution is in the present instance of no great importance.

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* That the nearer ranges are not immune from landslips is shown by the fact that when the bush is felled they are particularly liable to be disfigured by these hideous scars.

TABLE OF FORMATIONS DESCRIBED IN THE ABOVE PAPER.

Formations.	Composition of Formations.	Origin.	Age.	Alternative Name.
Rocks of Tararua Ranges	Greywacke, slates, &c.	Marine (?)	Early Mesozoic (?)	..
Pre-existing plain (lateral slope of Cook Strait valley)	(?)	(?)	Pliocene (?) ..	..
Ohau Valley deposit and fan	Boulders, shingle, sand, and clay-seams	Fluviatile	Early Pleistocene	Period of uplift, great elevation, and subsidence.
..	..	..	Middle Pleistocene	Period of minimum elevation.
Raised beaches ..	Soft sandstone and clay	Marine..	Later Pleistocene to Recent	Period of latest uplift.
Alluvium on the latest coastal plain. [Flood-plains, &c., of the minor streams]	Gravel, boulders, clay	Fluviatile (minor)	Recent ..	
Terrace gravels, &c., in the Ohau Valley	Shingle and clay	Fluviatile	Recent ..	
Blown sand ..	Sand	Aeolian	Recent to present day	

ART. XLV.—*Some Notes on the Marlborough Coastal Moraines and Waiau Glacial Valley.*

By Professor JAMES PARK, F.G.S., Otago University.

[*Read before the Otago Institute 4th October, 1910.*]

Plates XX–XXII.

THE Marlborough coastal moraines extend from the shores of Cook Strait near Cape Campbell southward to Shades Creek, a distance of twenty-six miles. I have elsewhere* spoken of the three greatest of these glacial deposits as the Cape Campbell Moraine, the Kekerangu Moraine, and the Shades Creek Moraine, but a recent examination of the maritime belt in which they occur has led me to the belief that these moraines, although now more or less detached, at one time constituted a continuous deposit, having

* James Park: "The Geology of New Zealand," 1910, p. 201.