Geology of the Papakura-Hunua District, Franklin County, Auckland.

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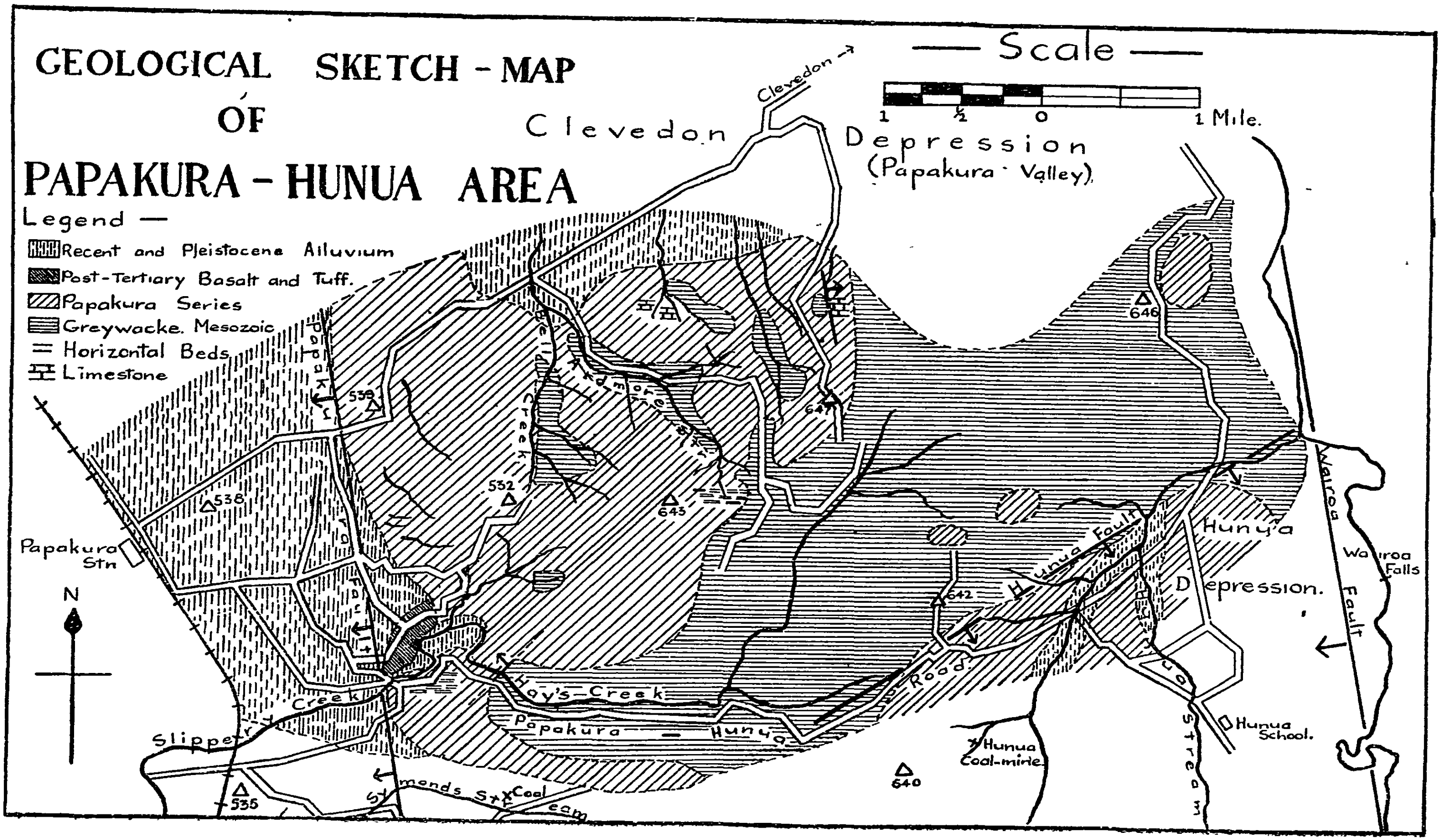
[*Read before the Otago Institute, 13th May, 1930; received by Editor, 3rd July, 1930; issued separately, 31st May, 1931.*]

CONTENTS.

INTRODUCTION AND PREVIOUS WORK.

THE investigation of the district described herein was undertaken in 1924 under the direction of Professor J. A. Bartrum of Auckland University College, who gave the writer a preliminary statement of his conception of the general structure of the district that has proved substantially correct. The results of the work were submitted as a thesis for the Master's degree, and read, in the form of a joint paper with Professor Bartrum, before the Auckland Institute in 1925. The


GEOLOGICAL SKETCH-MAP OF PAPAKURA-HUNUA AREA
Legend —
Recent and Pleistocene Alluvium
Post-Tertiary Basalt and Tuff.
Papakura Series
Greywacke. Mesozoic
Horizontal Beds
Limestone
Scale
1 ½ 0 1 Mile.
Clevedon Depression
(Papakura Valley)
Clevedon
Papakura Stn
N
Hay's Creek
Papakura — Hunua Road
Slippery Creek
Hunua Fault
Hunua Depression.
Wairoa Falls
Wairoa Fault
Hunua School.
Hunua Coal-mine
Coal
Stream
Ardmore
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writer wishes to express his thanks to Professor Bartrum for his readiness in giving assistance and criticism both in interpretation of the geology and in preparation of this paper. He is also indebted to Dr. J. Marwick for identification of fossil mollusca, and to Mr. A. H. Browne who supplied an analysis of coal occurring on his property.

Though many earlier workers have described parts of the area now studied, no full systematic description has previously been attempted. As far back as 1858, Hochstetter (1864) visited the district and separated the coal measures, which he placed in his Brown Coal Formation, from overlying beds which he called the Papakura Series, and correlated with the Waitemata Series of Auckland. He was followed by Hutton (1867), who correlated the limestone of the Papakura Series with a meridional strip of limestone south of Waikato Heads on the west coast of Auckland, placing it stratigraphically above the Brown Coal Formation and grouping both sets of beds as Eocene. In 1871 he agreed with Hochstetter in recognizing an unconformity between the brown coals and the Papakura limestone, but added a further one between the Papakura and Waitemata Series.

A brief report on the beds at Slippery Creek (Hay's Creek) is given by Park (1885), who collected fossils from the Papakura limestone there and noted that recent volcanic material covers the western slopes of Hunua Range. McKay (1888) observed that on its west side the coal beds dip north-east into the range, and recorded the presence in these strata of abundant impressions of fossil leaves, mostly of dicotyledons. He agreed with Hutton as regards the stratigraphic position of the Papakura Series, but claimed that there is no necessity for an unconformity between the limestone and the coal-bearing series, and predicted that work in adjacent areas would probably show that there is a conformable sequence from the coal to the upper surface of the Waitemata Series, and that the apparent unconformities would turn out to be due either to overlap or to dislocation.

More recently Clarke (1905) collected and described fossils from both the Waitemata Series near Auckland and the Papakura Series in the present area, while Bartrum (1922a) referred briefly to the origin of the silts laid down on the lowland around Papakura and northwards, which he regarded as being bounded along its eastern margin by ". . . . irregularly warped uplands of resistant rock due to faulting and flexure." Bartrum (1926) further has incorporated some of the results of the present study in his paper "*On the Western Coast of the Firth of Thames.*"

Owing to lack of time during the preparation of his thesis in 1924, the writer was unable to map in detail several outliers of Tertiary rocks east of Trig. 647, and his subsequent transfer from Auckland unfortunately has prevented his completing the task.

General Description of the Area.

The northern boundary of the district studied is provided by a narrow belt of lowlands constituting Papakura Valley or Clevedon

Depression, which extends east from Papakura to Clevedon. South of this the rugged uplands of Hunua Range rise gradually, and represent structurally a block tilted to the north-west. On the west of the area there is an abrupt rise to the elevated block of the Hunua uplands along a north-north-west–south-south-east scarp believed to be due to a fault here designated the Papakura-Drury Fault. The eastern boundary of the district is determined by natural features that form the eastern margin of Hunua Range, namely the lower course of Wairoa River and the intermontane lowlands here called Hunua Depression, whilst southwards, mapping ceased at an east-west line drawn through a point about a mile south of Papakura.

In the early days of colonisation the district was heavily forested, but the various lowland areas have long been cleared for cultivation, and, except for occasional small remnants, Hunua Range is also divested of its former cover of forest. Unfortunately, deforestation has been followed by abundant growth over large tracts of bracken fern and gorse, while in some places the blackberry has taken full possession, so that the location of outcrops in parts has been a matter of considerable difficulty. In addition, soil creep stimulated by deforestation has undoubtedly hidden outcrops that were available to earlier workers.

Synopsis of Structure and Topography.

The Papakura-Hunua area consists essentially of an uplifted block of Mesozoic rocks, partially covered by rocks of Tertiary age and constituting Hunua Range, which is bounded on the south-west by a strong north-east–south-west fault and on the east by converging fractures which have caused the downthrow of a wedge-shaped block represented by the Hunua depression, and is tilted to the north-west so that it passes below the Pleistocene and Recent filling of a fault-angle depression now occupied by the two-miles-wide Papakura-Clevedon Plain. This plain abuts northwards against the very clearly shown scarp of a strong fault of the north-east–south-west series recognised by Henderson (1924) as the dominant fracture series of the Taupo region.

West of Hunua Range there are lowlands, here called the Papakura lowlands, formed of pumice and other silts covered locally by basaltic débris, which Gilbert (1921) regarded as the filling of a former estuary of the Waikato River.

Nowhere in the area is there evidence of important folding post-dating the deposition of the Tertiary strata, though, as shown above, there is abundant proof of strong faulting. Cotton (1916) has described New Zealand as a "concourse of earthblocks," and the structure of the Papakura-Hunua district certainly accords with this view. This is strengthened by evidence from adjacent areas, for it is generally recognised that the topography of the country between Hunua Range and the east coast of the North Island near Coromandel Peninsula is largely governed by a series of powerful earth-fractures (See Bartrum, 1926). Henderson (1924) maps a series of parallel, alternately depressed and elevated blocks trending north-north-west from the Taupo-Rotorua region towards Hauraki Gulf, and it is the continuation of this series of fractures that has given rise to the upland of Hunua Range with its lateral lowlands. Hunua Range forms a topographic element which has attained the physiographic stage of early maturity, for certain juvenile evidences persist in flat-topped areas suggestive of the original surface. The covering series of Tertiary sandstones is relatively poorly consolidated, so that consequent streams flowing westwards have cut through the cover to impose their courses on the resistant Hokonui greywacke of the basement. Superposed consequents are by no means general, however, for insequent streams have dissected the northern slopes of the range facing Clevedon.

A feature demanding comment is the bench-topography developed in the younger sediments, for frequently several benches form tiers towards the summits of divides, and are almost certainly to be ascribed to inequality in resistance to erosion of various members of the Tertiary sequence. (Fig. 1, Plate 1).

STRATIGRAPHY.

SUMMARY OF STRATIGRAPHY.

As already indicated, Hunua Range is a compound mass of sedimentary rocks. The oldest, which are greywackes of Mesozoic (? Trias-Jura) age, form essentially the core of the range, for they outcrop prominently in the higher and more central zone, though locally covered by caps of Tertiary strata, and have been located at low levels in several of the deeper valleys opening out on to the western lowlands. Along the slopes descending from Hunua Range northwards to the Papakura Valley depression they are exposed at very low altitudes as they pass below the younger deposits of this lowland, and on the east flank of the range they outcrop at the level of Hunua Depression. In addition, at the northern end of the range, an upland diverges eastwards to Wairoa River, and here, as elsewhere, greywacke forms the basement and outcrops along the southern slopes descending to the lowlands near Hunua as well as in the deep gorge by which Wairoa River escapes from the depression.

Earlier geologists referred these greywackes to the Palaeozoic, but later authorities place them in the Hokonui System of approximate Trias-Jura age.* Tertiary strata lie unconformably upon this Mesozoic basement and are extensively developed along the flanks of the Hunua uplands, whilst they form the greater portion of the divides in the neighbourhood of Hay's Creek and Ardmore Valley, and, further north, largely cover the slopes facing Clevedon and Ardmore Townships. They are again exposed in Hunua Depression, and on the high-level terraces between Papakura and Ardmore, which have been carved from the dip slope of the tilted block of the range.

In the lowland areas and in the valleys of Ardmore and Hay's Creeks, beds of the Tertiary sequence pass beneath Pleistocene fluviatile deposits, whilst volcanic lavas and tuffs of Pleistocene age cover them near the debouchure of Hay's Creek.

*For example, Morgan, 1922.

The " hydraulic limestone " beds, called by Ferrar (1920) the Onerahi Series, and by him and many of the earlier workers of the Geological Survey relegated to the Upper Cretaceous*, is absent from the present area, though present not many miles north of Auckland City. Turner and Bartrum (1929) have discussed this fact and conclude that it is a consequence of unconformity between the Onerahi and Tertiary strata, though they have kept in mind (*op. cit.*, p. 884) the possibility that the area north of Auckland was depressed beneath the seas of late Cretaceous and Tertiary times earlier than that south of this city.

1. GREYWACKE OF THE HOKONUI SYSTEM (? TRIAS-JURA).

All exposures of the Mesozoic oldermass reveal a medium-textured greywacke which contains abundant partially-weathered grains of feldspar and fairly plentiful angular grains of quartz. There is no appearance of the argillite so prominently developed in the other similarly-constituted ranges forming the axis of the North and South Islands of New Zealand. Hochstetter (1864, p. 34) speaks of greywackes and " dioritic aphanite " as forming the " Palaeozoic " basement of the present area, but no rocks resembling the " dioritic aphanite " have been located.

In earlier Cretaceous times, at the close of the Hokonui period of sedimentation, strong compressive forces acting throughout the New Zealand area consolidated the sediments and raised them into high mountain folds with a north-north-east trend (Marshall, 1911, p. 38). Gregory (*fide* Marshall, *loc. cit.*, p. 38) claimed that there were two periods of folding in New Zealand, and that the older of them is found in the south-east trending axis of Otago and in North Auckland Peninsula, including thus the folded Trias-Jura rocks of the present district. In this connection Morgan (1922, p. 51) stated that throughout the North Island the strikes are variable, but that south of Auckland a north-north-east trend is most prevalent, whilst north of that city the average strike probably inclines decidedly to the west of north in sympathy with the trend of North Auckland Peninsula.

The original bedding of the greywackes is nowhere discernible, but the rocks are traversed by two systems of closely-spaced, rectangularly disposed joints, and so tend to break down on weathering into a fairly fine rubble of little use commercially even for road metal. They were searched for fossils, but none were found, as is the case in most other parts of New Zealand.

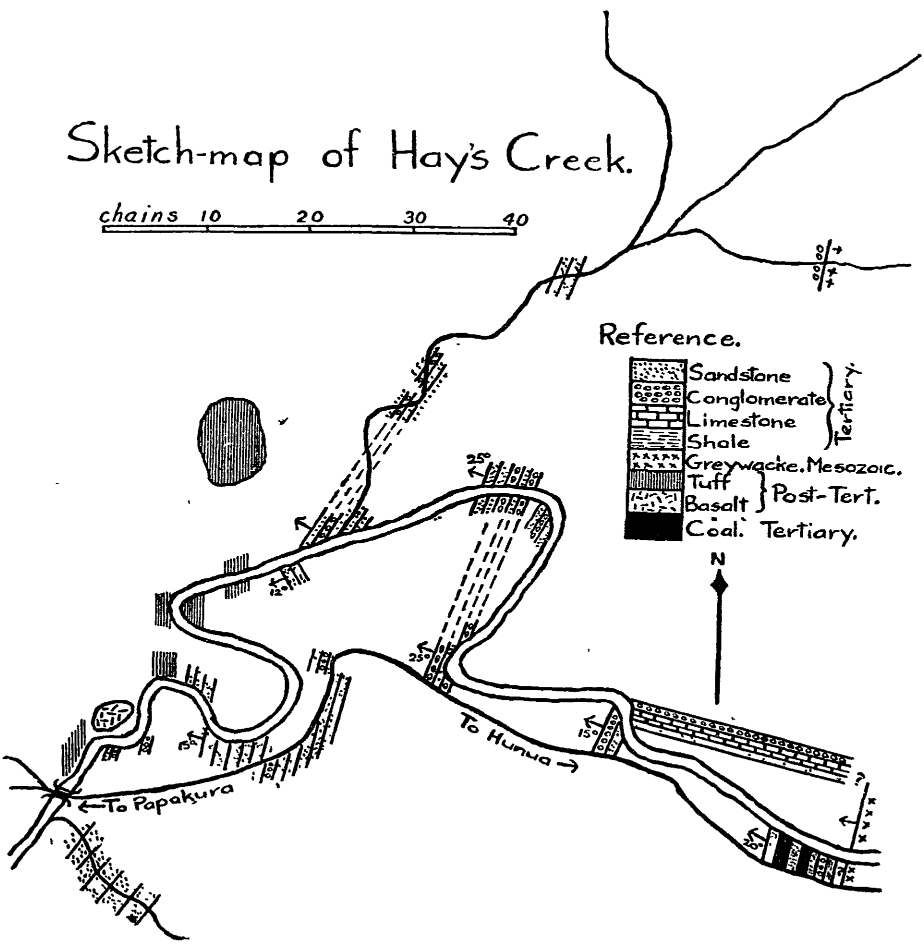
2. THE TERTIARY SEQUENCE (PAPAKURA SERIES).

Introduction.

The nature of the surface on which the Tertiary rocks rest unconformably will be considered in detail in a later section, and for the present it will suffice to state that it was essentially of low relief.

*In a recent paper Henderson (1929a) regards these beds as representing deposits of Danian and earliest Tertiary time.

In the several contacts discovered, the basal Tertiary beds are coarse conglomerates (Fig. 2, Plate 1), succeeded upwards by marine sandstones overlain by coals. The area of deposition of the coal-forming vegetation became more deeply submerged and marine sandstones were again deposited, and were followed by limestone, which was in turn covered by not less than 150 ft. of sandstones, usually with thin intercalated bands of conglomerate, or by beds of more argillaceous material. A minor angular unconformity occurs high in the succession (Fig. 3, Plate 1), and at several other horizons there is evidence of contemporaneous erosion, indicating, along with the intercalated conglomerates, that the area of deposition suffered numerous oscillations of level. In several instances the passage from sandstone to conglomerate and *vice versa* is gradual, but, in others, well-defined bedding planes, representing the diastems of Barrell (1917, p. 797), mark intervals between the times of deposition of successive beds.



Description of Occurrences.

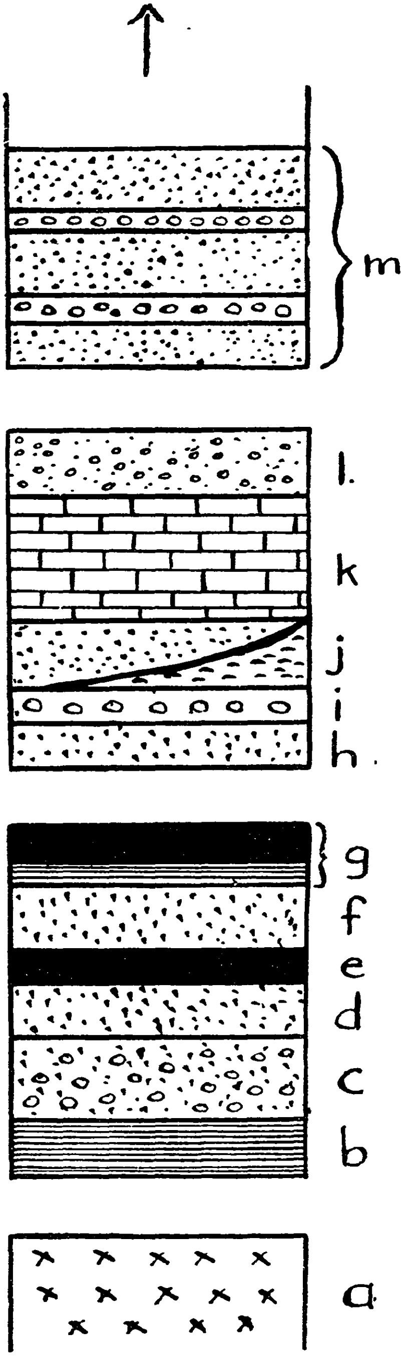
Hay's Creek Area.

In the valley of Hay's Creek there is a fairly complete section of not less than 200 ft. of beds that represent at least the lower portion of the Tertiary cover, beginning upstream from the bridge where the Papakura-Hunua Road crosses Hay's Creek and continuing for a distance of nearly half a mile to where the Hokonui greywacke appears, with its plain-like surface of contact dipping downstream below the younger strata. In this locality the Tertiary rocks have a general uniformity of strike and dip, the latter being constantly at a fairly low angle to the north-west, and suggesting that they have been subjected to a movement of tilting similar to that which has affected the major Hunua Range block.

At the top of the sequence sandstones occur at high levels along the flanks of the range both north and south of Hay's Creek, whilst similar rocks again appear at lower levels alongside Papakura-Hunua Road a little east of where it crosses Hay's Creek. Here they include somewhat decomposed fossiliferous greywacke conglomerate with abundant incoherent decalcified molluscan shells. (Fig. 4, Plate 2). With the included well-rounded pebbles of greywacke there are also several large boulders of this rock over 3 ft. in diameter, and, in addition, others of sandstone that seems indubitably Tertiary, along with occasional rounded pebbles of coal. The presence of the pebbles of Tertiary sandstone and coal bespeaks contemporaneous erosion in some adjacent locality, induced, as facts yet to be mentioned will show, by slight elevation of the sea floor, while that of the large boulders of greywacke indicates that the shore-line of the period was very close at hand.

A few chains north-east of this outcrop, near a sharp bend in the road, sandstones of a slightly lower horizon display the minor angular unconformity that already has been mentioned (Fig. 3, Plate 1), and, near at hand, there is a pocket of conglomerate, with a maximum depth of about 5 ft., in which there are, in addition to greywacke, fragments of mudstone derived from the Tertiary rocks. The conglomerate appears approximately at the horizon of the unconformity and gives further evidence that a slight uplift occurred, and allowed the erosion of earlier-deposited Tertiary beds.

Along the road sandstones outcrop for several hundreds of yards, but a section of more varied nature is yielded by exposures in the bed of the adjacent creek, and is illustrated by the accompanying stratigraphical column. At the mouth of the valley, and on the north side, basalt and associated tuff beds outcrop, with sandstone below the tuffs, and, for a distance of about half a mile eastwards, to a point a little upstream from the confluence of a tributary from the north-east, where a log-bridge spans the stream, similar beds with frequent intercalated conglomerate succeed one another with little variation. At the bridge there is a fine-textured conglomerate containing an abundance of brachiopod shells. Several hundred yards upstream from the brachiopod bed, near where the road closely approaches the stream, there is an outcrop of the limestone that is spoken of as the



TEXT-FIG. 1.
Stratigraphical Column to illustrate Succession at Hay's Creek. The breaks in the column indicate where outcrops were not found.

m. Upper portion of Tertiary Sequence. Sandstones and thin conglomerates often rapidly alternating.
l. Fine pebbly conglomerate with occasional brachiopods.
k. Papakura limestone, 8 ft.
j. Grit pinching out to west and giving place to sandstone.
i. Coarse conglomerate with pebbles of coal, 2-3 ft.
h. Sandstone, lower limit not seen.
g. Upper coal bed and its underclay.
f. Unfossiliferous sandstone, 3-4 ft.
e. Lower coaly bed.
d. Unfossiliferous sandstone, 4 ft.
c. Conglomerate with cobbles of Tertiary sandstone, 12 ft.
b. Shale, lower limit not seen.

(l–b: Lower portion of Tertiary Sequence.)

a. Hokonui greywacke (? Trias-Jura).

Papakura limestone dipping at 15° to the north-west, and overlying a soft greyish-white sandstone easily visible from the road (Fig. 5, Plate 2). The limestone is exposed in a bed 8 ft. thick for several hundred yards along the northern wall of the valley, forming part of a precipitous scarp some 20 ft. in height not far back from the stream. Above the limestone there is a thickness of at least 5 ft. of fine pebbly conglomerate containing a few brachiopod and oyster shells. Below it there is a grit bed 9 ft. thick with false-bedded lenses of limestone and sandstone rich in crinoidal remains, and, still lower in the sequence, further thin sandstone which rapidly wedges out eastwards and is replaced by a bed of grit with abundant nodules of iron pyrites. This is followed downwards by a band of conglomerate between 2 ft. and 3 ft. in thickness, and then by sandstone of undetermined but no great thickness.

There is clear evidence here again of the repetition of contemporaneous erosion of earlier-deposited beds of the Tertiary sequence, for this conglomerate contains rounded pebbles of impure lignite, whilst a little below it a rapidly-thinning black layer about an inch in thickness is composed of comminuted coal.

A few chains from these last outcrops, beds of the coal measures appear (Fig. 6, Plate 3), but their description will be reserved for the Appendix. Below them there is 3 ft. to 4 ft. of sandstone underlain by at least 12 ft. of a coarse conglomerate composed of cobbles of Tertiary sandstone; this overlies an exceedingly fine-grained, blue, greasy shale which is here the lowest bed of the sequence and is not 10 yards distant from the basement greywackes, though the actual contact is not visible.

In other sections showing the basal beds of the series, a conglomerate or breccia appears, and its absence in this instance calls for comment. The greywacke rises so steeply that the plane of separation is evidently inclined at a high angle to the horizontal, and, for several reasons, it is believed that the rocks here rest against the younger ones along a fault with a downthrow to the north-west. Examples of the occurrence of basal conglomerates, composed of greywacke débris, at the contact with the greywackes themselves are available in a small tributary of Hay's Creek, at a point about three-quarters of a mile to the north of this locality, and again further north in Ardmore Valley (Fig. 2, Plate 1).

The substitution, therefore, of Tertiary sandstone for greywacke in the Hay's Creek conglomerate shows that this latter probably is not near the base of the series, but that it was derived as the result of erosion of sandstones of the youngermass that had attained considerable thickness and consolidation in some closely-adjacent locality. We may therefore assume the presence, though now disguised by faulting, of a considerable thickness of beds intervening between this conglomerate and the basement rocks. Support of this assumption is afforded by a small stripped portion of the surface of the oldermass that may be observed further upstream for a distance of three or four hundred yards, which descends at an inclination of from 10° to 15° in a north-westerly direction. Its down-valley termination forms a somewhat dissected but nevertheless distinct scarp transverse to the direction of the adjacent portion of Hay's Creek, and hangs a score of feet or so above the stream bed. This structural step is in fact marked by a small waterfall and by rapids, and it appears thus that the stripped greywacke surface is on the upthrow side of a fault, whilst the Tertiary beds under discussion have been down-faulted to the north-west.

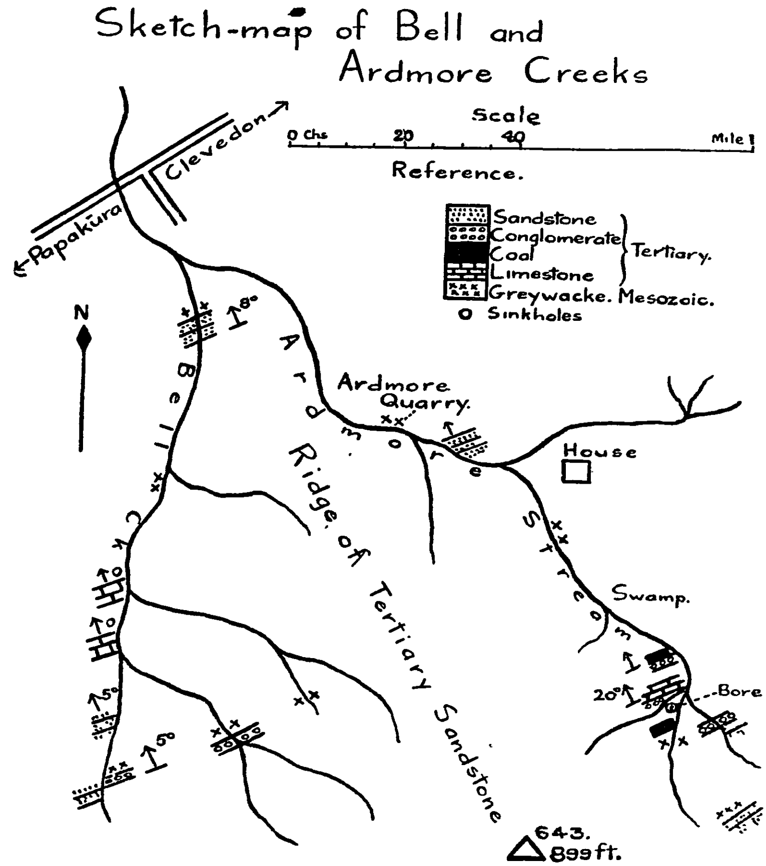
Ardmore Valley Area.

In this locality the Hokonui rocks apparently form a decidedly irregular basement, for their surface rises from 250 ft. at the confluence of the three headwater streams of Ardmore Creek to 700 ft. on the divide immediately south-east of this, where they are capped by sub-horizontal sandstones of the Tertiary sequence. Below the crest of the divide there is evidence strongly suggestive of the probability that the sandstone is part of a series, overlapping upon an irregular basement, for it is in contact with abruptly rising Hokonui rocks. Reference to this fact will be made later in discussion of the nature of the surface of the oldermass.

The lower beds of the Tertiary are exposed near the point of confluence of the three headwaters streams referred to above, and dip about 20° to the north-west. A disused shaft at this locality exposes carbonaceous shales with thin bands of lignite, and it is reported that the Mesozoic basement was encountered below these coaly beds at a depth of 45 ft. below the surface, whilst near at hand a greywacke conglomerate overlies them. Further, a chain north-west from the shaft similar conglomerate, here with fragments of oyster shells, forms the uppermost portion of a flaggy limestone at least 6 ft. thick, which is now rapidly being buried by modern swamp deposits. Measurements show that, in consequence of recent deforestation, the small swamp has been built up a height of at least 4 ft. in four and a-half years. Above the conglomerate there are sandstones with thin intercalated bands of mudstone and richly calcareous sandstone which are exposed almost continuously to a thickness of 650 ft. in passing upwards to Trig. Station 643, distant about half a mile to the south-west. Below the crest of the divide the strike is N.10°W. and the dip 5° to the west.

Bell Creek Area, Ardmore.

The valley in which Bell Creek flows heads south for a distance of about a mile from the junction of Ardmore Quarry Road and Papakura-Clevedon Road. Two points of contact between the older and younger formations were here located, the first in the bed of Bell Creek, about half a mile south of the junction mentioned, where a pocket-like lens of breccia-conglomerate rests on the irregular surface of the older rocks and is undoubtedly a shore-line deposit, possibly derived from an adjacent cliff in the ancient coast-line. A few inches above the basal conglomerate a discontinuous one-inch band, rich in foraminifera, lies just beneath a flaggy calcareous sandstone or arenacous limestone (Fig. 7, Plate 3) with thin bands of mudstone, which strikes S.6°W. and dips at 8° to the north-west. This last bed is current-bedded and contains abundant plates and spines of echinoderms and tests of foraminifera, as well as brachiopods and algae; it thickens downstream, where it includes water-worn pebbles of coal, due no doubt to the contemporaneous erosion of a seam elsewhere, for coal is found below the limestone at other localities in Hunua Range.



About a mile south of the previous contact, the basal conglomerate is admirably exposed on the right bank of Bell Creek, resting on a worn surface of greywacke (Fig. 2, Plate 1). It contains broken shells of oysters and other molluscs and a few brachiopods, and is overlain by at least 20 ft. of sandstone, with poorly-preserved marine fossils, which dips at 5° to the north-west. These exposures are 230 ft. above sea-level, so that the surface of the Mesozoic rocks rises here in a southerly direction, a fact of importance, for it throws light on the structure of the Papakura Valley depression to the north and will be referred to subsequently.

On the west side of the valley, several hundred yards due north of this second contact, beds of fairly pure limestone, apparently about 30 ft. thick, are exposed in two sinkholes now almost completely masked by a tangle of vegetation. Most of the rock has a crystalline appearance owing to the abundance in it of echinodermal material in addition to other organic fragments; in some parts of it small gritty particles of greywacke are common.

Area North-east of Ardmore Valley.

About half a mile north-east of Ardmore Quarry the valleys of two small streams flowing north-west down the dip slope of Hunua Range towards Papakura Valley contain outcrops of gently-dipping flaggy limestone about 7 ft. thick, which is marked by the somewhat lensoid bedding and lithological characters that distinguish the limestones of the area. The outcrops are limited ones lying below the level of adjacent greywacke, and show only that sandstone with a dip of 5° north-west by west comes in both above and below the limestone. Eastwards from here to Wairoa River, the surface of the Hokonui basement rock is more or less plain-like (Fig. 8, Plate 4), and slopes gently and regularly downwards towards Papakura Valley, capped here and there by sandstones of the Tertiary sequence.

About a mile east of the last-mentioned outcrops of limestone, there is a small valley draining to the north-north-west, in which a bed of sub-horizontal limestone 10 ft. thick, overlain by sandstone, abuts against greywacke exposed in a quarry a few feet from the Tertiary beds. The conditions of occurrence strongly suggest that the hidden contact is along a minor fault of the north-west–south-east series, the valley being excavated along the fault line, and it is indeed possible that the more westerly outcrop of limestone is depressed below the general level of the adjacent greywacke surface by similar faulting.

Stratigraphical Relations and Comparisons.

It has been shown that within the post-Hokonui strata of the Papakura-Hunua area there is no evidence suggestive of unconformity other than that exhibited alongside the road near the debouchure of Hay's Creek, where the upper beds are horizontally disposed upon the planed edges of gently-inclined lower ones, (Fig. 3, Plate 1), whilst shore-line conglomerates also mark the same horizon (Fig. 4, Plate 2). It will be remembered, however, that there is frequent evidence of contemporaneous erosion, especially in the Hay's Creek area, whilst the deposits throughout are distinctly of a near-shore or shallow water facies, so that it is obvious that the area of sedimentation underwent quite a number of rhythmic minor oscillations of level.

The Tertiary sequence in several other parts of the North Island, unlike that in the South Island, is broken by unconformities into several subdivisions, for Henderson and Ongley (1920, p. 31) mentioned at least two unconformities in the Gisborne and Whatatutu Subdivision, whilst in the Mokau district the same writers (1923, p. 16) reported that the Tertiary strata are broken into five series by periods of elevation and erosion. Even in the South Island the observations of Morgan (1916) and others, especially Speight and

Jobberns (1928), indicate that the New Zealand area suffered several transgressions and regressions of shallow seas during the Tertiary.

Reference to Hutton's report on the Lower Waikato (1867) shows that the vertical range of Tertiary strata is there substantially the same as in the present area, for, in each case, the Hokonui basement is overlain by coal beds, above which is limestone followed by sandstones. The same writer (1871, p. 248) made a statement of his views regarding the correlation of Tertiary beds in the Waikato and in the Drury-Papakura district. He regarded the coals of both districts as constituting the one horizon, but inclined to the opinion that the Papakura Series represents the base of a series increasing in thickness southwards which he called the Aotea Series.

In each district he postulated two unconformities in the Tertiary succession, for he believed that beds of the Papakura and Aotea Series rest unconformably on the coals, and that they are in turn covered unconformably by sandstones, those above the Papakura Series being the Waitemata beds of Auckland.

The present writer has found no evidence leading him to believe that the unconformity demanded by Hutton immediately above the coals is actually present, although, as already stated in description of the beds at Hay's Creek, he found pebbles of coal in a conglomerate above the coal, which there is undoubtedly conformable with overlying Tertiary beds. This certainly shows that erosion of the coal was proceeding in an adjoining area, brought about by some change of geographic conditions affecting local erosional processes, so that local unconformity may reasonably be expected, though it can by no means be assumed that widespread uplift and erosion occurred.

With regard to Hutton's other unconformity, Morgan (1916) stated that the unconformity placed by this writer between the Aotea (Papakura) Series and the Waitemata Series had been disproved by Clarke in his 1905 paper; Clarke's conclusion appears to be thoroughly justified.

The well-known "hydraulic limestone" (Onerahi Series of Ferrar), which is near the base of the post-Hokonui strata of North Auckland, and which is believed by many workers to rest unconformably below the Waitemata beds, is absent from the Papakura-Hunua district, for, as Bartrum (1924a) stated, in a report upon the Riverhead-Kaukapakapa district near Auckland, the Waitemata beds rest directly on the Trias-Jura in areas south of Auckland city. He explained this relation by an hypothesis of ". . . progressive subsidence of a Trias-Jura basement that is undergoing accompanying tilting or warping below the seas in which later sedimentation is proceeding." (Bartrum, 1924b).

Conclusions Regarding Correlations.

The writer considers that the relations of the members of the Tertiary series are to be explained by overlap on an unevenly-subsiding basement of Trias-Jura rocks, submergence occurring first towards the south. Expectably, then, beds of the Papakura Series would appear close to the basement at the more northerly points nearer Auckland City, the underlying coals coming in further south, and this is actually seen in the occurrence at Maraetai, some 13 miles east of Auckland City, of the Papakura limestone resting hard on the Trias-Jura rocks as described by Park (1890). On approaching the areas of " hydraulic limestone " north of that city, higher Tertiary (Waitemata) beds rest on the Hokonui rocks, ultimately overlapping unconformably on to the Upper Cretaceous " hydraulic limestone " itself.

In the paper referred to above, Park stated that there is a direct sequence from the Fort Britomart beds of the Waitemata Series at Auckland to the Papakura limestone at Maraetai, and this section is of particular importance in that it is the only one directly connecting the fossiliferous " Orakei Bay beds " of Auckland with the limestone of the Papakura Series. The present investigations certainly support Park's belief (1890) that south of Maraetai conformably lower beds of the Tertiary sequence (Papakura Series) would be found resting conformably on the brown coal measures.

Park remarked that the absence of an equivalent of the Otatara limestone, which characterises the classic North Otago and South Canterbury areas, is a striking feature of the Tertiary sequence in the Waitemata and Papakura districts, but stated (1910, p. 116), however, that a calcareous sandstone or limestone in the Lower Waikato and adjacent localities contains fossils of Ototaran character. Marshall (1916) considered that all the Tertiary limestones of middle or lower Tertiary age throughout New Zealand (including the " hydraulic limestone ") represent the one horizon, believing that they have been deposited at the time of maximum submergence during a widespread diastrophism, for they are all of moderately deep to deep water facies, so that it is not surprising, in view of the shallow water nature of the deposits of the Papakura area, that no comparable limestone horizon is represented there. He later (1924) urged strongly the Lower Tertiary age of the " hydraulic limestone." It is conceivable, however, that certain of the beds of the series may be the near-shore equivalents of deeper-water limestone laid down further off shore. Hutton (1871) remarked that the Papakura Series increases in thickness southwards towards the Waikato area, and, this being so, we may expect to find in that direction, which presumably was more remote from the ancient shore-line of the Tertiary seas, some record of the " missing " limestone. Such limestones do exist, but their relation to those of Papakura is not yet determined. The southward increase of thickness would accord well with the hypothesis advanced above that post-Hokonui sedimentation began and proceeded upon a differentially subsiding basement of Trias-Jura rocks progressively tilted towards the south. An alternative explanation, however, lies in accepting Thomson's (1917) suggestion of the existence of small diastrophic provinces, and assuming that subsidence throughout this entire province at no time attained the depth evidenced in others, especially in the South Island.

The presence of unconformities in the Tertiary naturally leads one to enquire whether they can be made use of in correlating the beds in various districts. If the evidence were such that a general widespread diastrophism could be assumed, this method of attacking the problem would in all probability be highly profitable. But, as shown earlier in this paper, there is much that suggests that various parts of New Zealand have different diastrophic histories, so that one cannot place undue reliance on such a line of evidence, for, although various diastrophic regions may unfold parallel histories, they need not exhibit synchronism in the stages of their development. For the same reason correlations by means of lithology are hazardous, especially in districts, such as the present one, where rapid fluctuations of the shore-line appear to have occurred, and we cannot, therefore, unhesitatingly accept Marshall's (1916) view that there was only one main period of formation of limestone throughout early to mid-Tertiary times.

Finally, then, palaeontology must be considered, but, here again, difficulties arise, for as yet there are insufficient data to permit of any trustworthy correlations.

Hochstetter (1864, p. 43) concluded that the equivalence of the Waitemata beds and the limestone of Papakura cannot be doubted, for he found *Chlamys fischeri* (Zitt.) and casts of the pteropod *Vaginella* both at Orakei Bay, Auckland, and in the Papakura-Ardmore district. His opinion is supported by the work of Clarke (1905), who has been the only subsequent worker to collect and describe fossils from both the Waitemata and Papakura Series.

It may be of interest to mention that Powell and Bartrum (see Turner and Bartrum, 1929, p. 870) have investigated a bed with molluscan fossils which has recently been discovered at Waiheke Island, near Auckland, near the base of the Waitemata Series, and have correlated it with either the Hutchinsonian or Awamoan of Oamaru.

Palaeontology of Tertiary Strata.

Though fossils were collected by the writer from various horizons in the Tertiary sequence, their state of preservation is so unsatisfactory that Dr. Marwick, who kindly examined the molluscan remains, was unable to make much of them; none of the species that probably are new are sufficiently well-preserved for accurate description. Dr. Marwick stated in a letter that, in the absence of characteristic stage-marking fossils, the age of the Papakura-Ardmore beds cannot at present be fixed more closely than Upper Oamaruian.

The following are Dr. Marwick's determinations, as made by him in 1924:—

LAMELLIBRANCHIA.

Venericardia (*Pleuromeris*) n. sp.
Venericardia sp.; may be large specimen of the above.
Protocardia (*Nemocardium*) n. sp., cf. *pulchella* (Gray).
Limopsis sp. cf. *zitteli* Ihering.
Lutraria n. sp.
Pteromyrtea sp.

GASTEROPODA.

Sigapatella sp.

Polinices n. sp. cf. *kawhiaensis* (Marwick) and *unisulcatus* (Marwick).

Polinices cf. *scalptus* (Marwick).

The polyzoa were sent to Dr. G. H. Uttley, who has not so far found time to proceed with investigation of them.

Mr. F. Chapman of Melbourne University very kindly identified the following foraminifera (See Chapman, 1926, p. 20):—

Truncatulina haidingeri d'Orb.

Amphistegina lessoni d'Orb.

Clarke (1905) listed the following fossils recorded by Hochstetter (1864), himself and others from the Papakura Series. His lists have not yet received the revision necessitated by the intensive studies that have been made of the brachiopods and molluscs during recent years, but they are inserted here for convenience of reference, with the molluscan and brachiopod nomenclature brought up to date.

COELENTERA.

Flabellum laticostatum Ten.-Woods.
Flabellum papakurense Clarke.
Echinoderma.
Schizaster rotundatus Zitt.
Brachiopoda.
Tegulorhynchia nigricans (Sow.)
Terebratella novae-zelandiae Iher.
Terebratella sanguinea Leach.
Liothyrella gravida (Suess).

MOLLUSCA.

Pelechypoda.
**Limopsis zealandica* Hutton.
Glycymeris huttoni Marwick.
Crassostrea nelsoniana (Zitt.)
Gigantostrea wuellerstorfi (Zitt.)
Anodonta elliptica Hutt.
Pallium (*Felipes*) *burnetti* (Zitt.)
Chlamys fischeri (Zitt.)
Pallium (*Felipes*) *polymorphoides* (Zitt.)
Lentipecten hochstetteri (Zitt.)
Parvamussium zitteli (Hutt.)
Parvamussium papakurense (Clarke).
Limatula maoria Finlay.
Venericardia awamoaensis Harris.
Scaphopoda.
Dentalium solidum Hutt.

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*Several years ago specimens of *Glycymeris* from Hay's Creek, Papakura, were sent to Dr. Marwick, who remarked in a private communication that these specimens do not agree exactly with any species so far described, and would appear to be nearest to a new species from Manaia Beach, Taranaki, which has a wide distribution in the Lower Wanganuian (*G. manaiaensis* Marw.).

Gasteropoda &c.
Sigapatella sp.
Polinices ovuloides (Marwick).
Maoricolpus cavershamensis (Harris).
Vaginella aucklandica Clarke.

Plants.

Several impressions of dicotyledonous leaves were collected by the author, but, up to the time of writing, it has been found impossible to attempt identification of them. Von Ettingshausen's work (1891) on New Zealand Cretaceous and Tertiary flora, though not accepted by New Zealand geologists, has not yet been revised, and the same applies to the short list of species collected by Hochstetter in 1859 from the Papakura district.

3. Post-Tertiary Deposits.

The post-Tertiary deposits include those both of sedimentary and igneous origin, the former being confined mainly to the structurally depressed areas, although recent alluvium is also found in the valleys of Hay's Creek and Ardmore Stream.

On the lowlands around Papakura and northwards towards Otahuhu, railroad and road cuttings expose incoherent pumiceous silts, placed by Hochstetter (1867, p. 272) in his Lignite Formation of the Manukau Flats. They are believed by Gilbert (1921, p. 101) to have been brought down by the Waikato River from the pumice lands of the centre of the North Island, and deposited in a former estuary of that river, whilst the lignites accumulated in associated swamps.

In the lowlands of Hunua Depression recent silts of fluviatile origin rest on the eroded surface of Tertiary sandstones, forming extensive terraces many feet above the present level of adjacent streams.

Rocks of igneous origin are locally developed along the western edge of the Hunua Range and came from a vent near the debouchure of Hay's Creek, where both lava (Fig. 9, Plate 4) and tuffs (Fig. 10, Plate 5; Fig. 11, Plate 5) outcrop prominently, the tuffs in particular forming a lofty remnant of the earlier cone (Fig. 10, Plate 5). There appear to have been at least two major episodes of explosive activity, separated by one characterised by outpouring of lava. Basaltic lavas of similar type, with associated fragmental beds, also occur in the north-eastern portion of Hunua Depression, just outside the area selected for study.

Hochstetter (1864, p. 54; 1867, p. 268) evidently included these volcanic rocks with the volcanic " conglomerate " and flows of Drury and the Lower Waikato in his " Basaltic Boulder Formation," which he distinguished as distinctly older than the basalts of Auckland, for there the flows occupy the present valleys and are almost completely undecomposed, whereas those of the Waikato are considerably weathered and streams have cut deep trenches in them. He recorded the fact that the basalts overlie the Lignite Formation with its associated pumiceous silts, so that obviously the rhyolitic eruptions of the Taupo region preceded the basaltic ones of the Lower Waikato Basin.

GEOLOGICAL HISTORY OF PAPAKURA–HUNUA AREA.

Beds of the Hokonui System form the oldest surface rocks yet discovered in the North Island, though there is evidence of a pressure-affected earlier terrain, for Bartrum (1921a, pp. 120-21) recorded the presence of granulites in conglomerates intercalated in the basement Mesozoic shales and greywackes of Great Barrier Island, whilst he found similar evidence in another conglomerate near Whangarei (1921b, p. 128). Later the same writer (1924a) stated his conclusions that the granulated and sheared plutonic rocks of various conglomerates represent a now-buried terrain existing before and during the deposition of Trias-Jura sediments, and that this terrain apparently persisted into Tertiary times, for mid-Tertiary conglomerates with similar material appear not to be a re-wash of mid-Mesozoic ones.

In the present area, however, the conglomerates of Tertiary age that have been described entirely lack material of the kind recorded by Bartrum.

Benson (1923, pp. 37, 41) mapped the coastline of the land-mass that supplied the Trias-Jura sediments as trending approximately north and south adjacent to the west coast of New Zealand, and stated (*op. cit.*, p. 39) that this continent, which extended westwards over the present Tasman Sea and united New Zealand with Australia, remained above sea level until near the close of Jurassic times. At the close of the Trias-Neocomian period of sedimentation, however, the New Zealand area was elevated to form dry land, and the sediments were folded into mountain ranges, of which the "oldermass" of this paper forms the worn-down relics, for, as Cotton (1916) showed, long-continued erosion followed this orogeny.

Over the region now represented by North Auckland the truncated folds of this land-mass were next submerged beneath the Upper Cretaceous seas, where they were covered unconformably by ammonite-beds and the limestones, claystones and other beds of the Onerahi Series. In their turn, these Upper Cretaceous strata appear to have been uplifted and exposed to erosion and to have been removed from extensive areas. As a result of this emergence, and the longer one that preceded it, the land-mass had attained a very advanced stage in the cycle of erosion when depressional movements supervened, and it descended beneath the Tertiary seas to receive a cover of younger sediments. At first, basal conglomerates and associated marine beds were laid down, and then, during a temporary pause in the movement of depression, extensive swamps or lagoons came into existence near the coast. Over the present Lower Waikato area the coal-forming vegetation flourished more abundantly and the swamps assumed greater proportions than elsewhere, so that the seams of brown coal of that district attain considerable thickness and have considerable commercial importance. Near Papakura and Hunua, however, they are comparatively poorly developed and gradually thin out to the north, until near Auckland they have disappeared entirely. Subsequent progressive subsidence obliterated these low-lying swamps, and the coals became covered by the marine strata that now constitute the Papakura and Waitemata Series.

It is demonstrated by the characters of the sediments of the youngermass, and by the constant evidence of contemporaneous erosion they display, that the area was at no time deeply submerged and that the general movement of subsidence was of an oscillatory nature. Finally elevation ensued, and the compound mass became subject to normal subaerial denudation. Block-faulting, totally unaccompanied by folding so far as can be determined, then affected the area, and this was evidently a phase of the Kaikoura orogeny (Cotton, 1916, p. 248) which began probably in Pliocene times.

The subsequent history of the district is traceable only by reference to events near Auckland, which have been discussed by Bartrum (1922; 1929) and Turner and Bartrum (1929). Those of major importance include the filling of the downthrown block west of Hunua Range by the pumiceous silts brought by the Waikato River, and the subsequent sharp uplift by which deep trenches were excavated. These latter were later drowned by a submergence, sub-equal in amount to the uplift, which seems to have been the last diastrophic event of any real importance. Cotton (1916, p. 318) stated that these concluding movements, which he termed the post-Kaikoura movements, were epeirogenic rather than orogenic in character, and that there was evidence of a long period of rest between them and the earlier Kaikoura orogeny, during which the current cycle of erosion reached an advanced stage of development.

The upland block of Hunua Range has been sub-maturely dissected, but rejuvenation is shown in the fact that locally the streams have recently entrenched themselves to the extent of 6 ft. to 8 ft. below earlier flood-plains. Sub-Recent uplift has affected the whole Auckland area, for there are raised platforms and beaches, sometimes as much as 9 ft. above sea-level, around the shores of Hauraki Gulf, but it is doubtful if the rejuvenation can be a result of this movement; for it can scarcely have been reflected to so considerable an extent at parts of the stream courses that are relatively distant from the sea.

THE SURFACE OF THE OLDERMASS.

The pre-Tertiary surface carved upon the oldermass of the area examined appears in general to possess very slight relief (Fig. 8, Plate 4), and thus conforms with Cotton's (1916, p. 246) view of the nature of this surface throughout New Zealand. It is shown by adjacent regions that this condition is not merely a local phase, for the ranges north of the depression of Papakura Valley and the lofty uplands east of Hunua Depression are all marked by a striking accordance of summit levels and occasional plateau-remnants, and, although these areas were not examined, one strongly suspects that they are both structurally and stratigraphically akin to Hunua Range, though their elevation is such that all Tertiary beds have probably been stripped from their surface, whilst in Hunua Range this is not so.

There is, however, local conspicuous irregularity of the surface of the oldermass at the headwaters of Ardmore Stream, where, as already has been stated, the Trias-Jura greywacke rises into pronounced crag-like inliers, abutting against the Tertiary beds. This naturally suggests the possibility that the abrupt contact is the result of faulting, especially as displacements of this nature are found elsewhere in the district, but no direct evidence has been found in support of this suggestion, although it could very readily explain the sharp difference in level of the basal Tertiary beds not far distant in the same valley, near the disused shaft referred to earlier in the paper, whilst similar steep contacts have been noted on the northern slopes of Hunua Range near Ardmore Village. The writer is therefore forced to consider the possibility that this crag represents a monadnock which was unreduced by the vigorous normal erosion that broadly levelled most of the surrounding surface. As depression continued, and as the Tertiary seas crept further landwards, the residual could then have persisted as a much-reduced island-remnant or stack, until it finally was completely submerged and buried by sandstones that now almost surround it, rising to a considerable height above it. There is, in fact, strong indication, along the course of a headwaters branch of Ardmore Stream flowing to the north-west, that such overlapping of the Tertiary beds upon the mid-Mesozoic basement as is here suggested actually has occurred, whilst the presence of large boulders of greywacke several feet in diameter in the basal conglomerates of the younger series exposed in the valley of a small tributary of Hay's Creek, as well as at higher horizons (as near the debouchure of Hay's Creek), shows that the advancing Tertiary seas locally developed greywacke cliffs of no mean height.

DETAILED STRUCTURE.

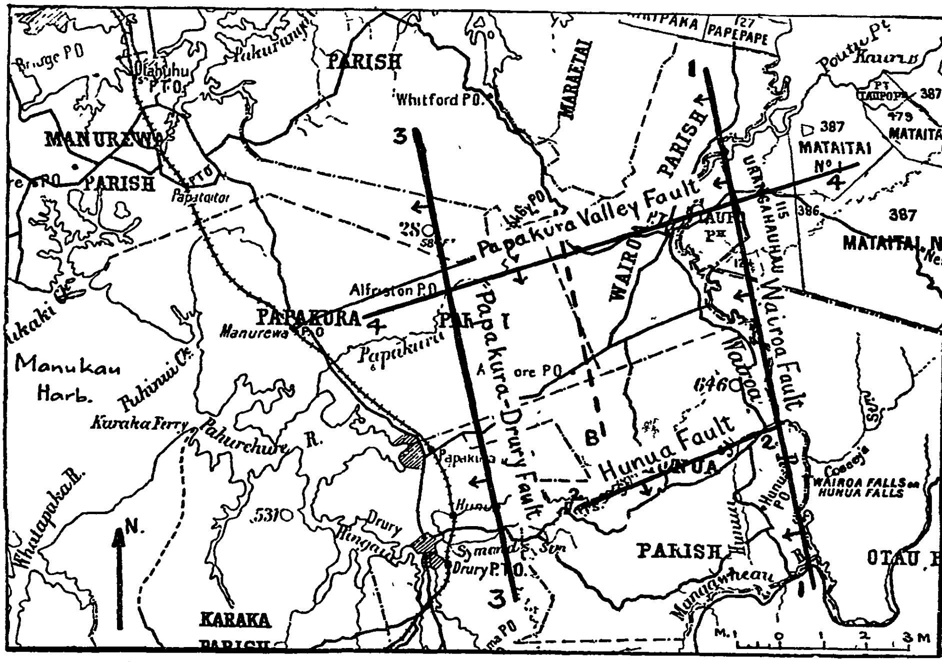
Fault Systems.

Inspection of the accompanying index-map will show that the present topography is largely governed by earth-fractures of two systems, which have variously uplifted and tilted adjacent earth-blocks. In all cases the scarps along the fault-lines are submaturely dissected; in some instances they are certainly true fault-scarps, but in others either fault-line scarps or composite fault-scarps, as defined by Cotton (1922, p. 172), for they seem largely, if not wholly, to be the result of selective erosion along fault-lines.

Wairoa Fault.

The most prominent fault of the district is that determining the eastern side of Hunua Depression, where its scarp delimits the high country to the east (the northerly continuation of Pakaroa Range). This fault trends north-north-west and south-south-east, and along its line Wairoa River has cut a deep subsequent gorge about three miles in length by which it escapes from the lowlands near Hunua. An upland that rises on the western side of the river at the northernmost angle of Hunua Depression, and constitutes an easterly extension of the northern portion of Hunua Range, with which it accords generally in altitude, has its general summit level fully 400 ft. below that of the high-level uplands on the other side of Wairoa River. This indicates that there has been a downthrow to the west of about 400 ft.

The continuation of this fault can be followed north-north-west beyond Papakura Valley lowlands by a prominent scarp, and accompanying discordance of level of approximately 400 ft. between surfaces of the relatively upthrown and downthrown blocks. As its line is followed south-south-east, however, from the outlet gorge of Wairoa River, the displacement is probably rather along a monoclinal flexure than along a fracture, for there seems here little trace of any true scarp in the long ridges running up from the lowlands to the high-level country eastwards towards the Firth of Thames.



INDEX MAP OF FAULTS.—1, Wairoa Fault; 2, Hunua Fault; 3, Papakura-Drury Fault; 4, Papakura Valley Fault. AB: Line of section across Clevedon lowland to show fault angle depression.

The Wairoa fault is possibly a continuation of a fracture mapped by Henderson (1924, p. 272) further south in the Waikato district. Whether this be so or not, major faults of similar trend characterise the adjacent regions, as instanced by the fractures that are responsible for the graben occupied by Hauraki Plains and Firth of Thames (See Henderson and Bartrum, 1913, p. 59; Bartrum, 1926), and by the Papakura-Drury Fault shortly to be described, which is the western limit of Hunua Range.

The suggested southern passage of Wairoa Fault into a monoclinal fold also finds parallel in the belief of Professor Bartrum* that the scarp on the east side of Hauraki graben, which is clearly due to fracture over the greater part of its length, gives place to monoclinal flexure where the railway to Rotorua ascends eastwards from the floor of the graben to the elevated plateau north of Rotorua.

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*Private communication.

Hunua Fault.

The intermontane basin that has been called by the writer Hunua Depression represents a down-thrown block, more or less triangular in plan, with its apex directed towards the north. The down-throw has been brought about by the concerted action of Wairoa Fault and another, here called Hunua Fault, transverse to it, with a trend approximately east-north-east and west-south-west, which has its maximum displacement towards the north-east and appears to die out to the south-west. At the base of the scarp marking the line of this fault the lower portion of Hunua Stream flows north-east to join Wairoa River near the upstream end of its outlet gorge, its bed here being carved in Mesozoic rocks, though further to the south-west Tertiary sandstones rest at low levels against steeply-rising greywacke. Not far upstream from the confluence of this stream with Wairoa River, an isolated conical hill rises from the adjacent lowland almost at the foot of the scarp, and arouses interesting speculations as to its origin. One possibility is that it may represent a step, down-thrown by step-faulting; but its relative isolation and shape and the topographic characters of the adjoining scarp suggest that it more probably is a kernbut, or displaced rock-mass associated with rift-faulting, so named by Lawson (1903, p. 331; see also 1927, p. 248).

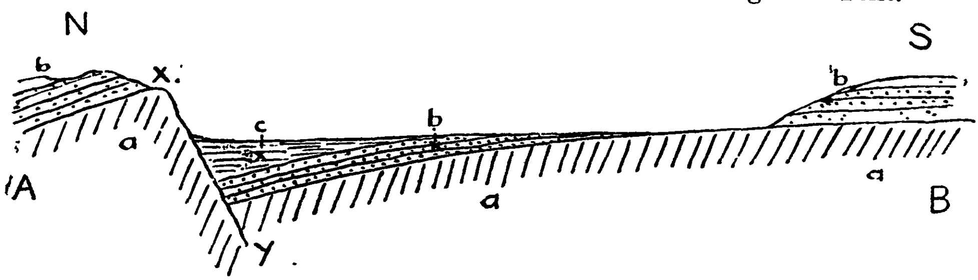
Papakura-Drury Fault.

The Papakura-Drury Fault is a prominent fracture of the north-north-west series at the western margin of Hunua Range; the low-land on which Papakura and Drury are situated is believed to be a block down-thrown by it to the west, whilst the steeply-rising slopes of the range represent a scarp, probably a composite fault-scarp (Cotton, 1922, p. 172), due to the fracture.

From his examination of the coal beds exposed on the lower slopes of the upthrown Hunua block east of Drury, Cox (1882, p. 34) realised that the dip of the strata would not carry the coal below the flats to the west, but suggested that a fault may well do so, and recommended boring as the only means of ascertaining the facts. Long previous to this, at the instigation of Hochstetter (1864), the Auckland Provincial Government had put down two bores, but neither was sufficiently deep to reach the expected "Brown Coal Formation," and even in the deeper of two, which penetrated 65 ft., they encountered only surface clays and basaltic conglomerate and lava. Professor Bartrum has, however, drawn the writer's attention to the fact that several years ago the *New Zealand Herald* reported that the coal had been reached below the basalt in a bore near Drury Railway Station, so that there is now direct evidence of the relative down-throw, either by faulting or flexure, of similar horizons on either side of what is here believed to be a fault-line, though the extent of such down-throw is not ascertained.

Papakura Valley Fault.

The northern edge of the alluvium-floored Papakura Depression rests against a steeply inclined, fairly rectilinear scarp trending east-north-east and west-south-west, which is ascribed for several reasons to the presence of a fault. The topographic evidence in favour of such interpretation is very strong, but even more cogent is the fact that the attitude of the Tertiary beds on the south side of the depression is continued in the hills about three miles north-east of Manurewa, where, as in the Ardmore area, the Tertiary beds rest upon a dip slope of greywacke inclined to the north-west. It is thus clear that, prior to the inception of the block-faulting that is postulated, the uplands both north and south of the Papakura-Clevedon lowland were united structurally as one great unit, the disruption of which by east-north-east–west-south-west faulting has produced a low-lying fault-angle depression into which the Tertiary beds have been lowered, as is illustrated by the diagrammatic section of Fig. 2 in Text.



TEXT-FIG. 2.—Diagrammatic section on the N.N.W.–S.S.E. line A B of Index Map of Faults. XY is the Papakura Valley Fault trending N.E.–S.W. The elevated country to the right represents the northernmost portion of Hunua Range. a: The oldermass. b: The Tertiary covering beds. c: Pleistocene and Recent fluviatile deposits.

It has been shown that the faults of the Papakura-Hunua district form a pattern that is approximately rectangular, in which the main fractures are those of the north-north-west–south-south-east series that are shown by Henderson (1924) to control the structure of the central portion of Auckland Province, diverging from the major north-east–south-west series of the Taupo zone. In a recent paper Henderson applies to New Zealand the view of Bailey Willis that the major faults are due to thrust, and, near the surface, develop steep curved fronts upon the blocks affected, which are tilted away from the frontal fault, whilst in advance there is an area of depression. The facts brought to light by the present investigation do not definitely support this hypothesis, though it may be noted that Bartrum (1926) considers that the continuation of Papakura Valley Fault bends from a east-north-east direction to a northerly one as it passes Clevedon.

As all the faults described have displaced Tertiary beds, they are certainly to be referred to the Kaikoura orogeny of Cotton (1916). There is, however, nothing to show at what date the greater portion of the movements was completed locally. Recent earthquakes in the Morrinsville district indicate that complete stability has not yet been established.

Summary and Conclusion.

The Papakura-Hunua district comprises a broadly truncated surface of folded Mesozoic rocks overlain by a youngermass of

Tertiary age, which evidences minor interruption of deposition at several horizons, though not general unconformity, as postulated by Hutton, between the coal beds near the base of the Tertiary sequence and the overlying Papakura Series.

As a result of important faulting post-dating the deposition of the Tertiary strata, the area is divided into topographic divisions. The central portion is occupied by Hunua Range, a sub-maturely dissected upland block, which on its east, north and west sides is bounded by depressed areas often underlain by Tertiary beds freely mantled by alluvium of Pleistocene and Recent date.

The palaeontological evidence now available is insufficient to enable correlation of the Tertiary strata with stages of the Oamaruian elsewhere to be attempted or an estimate obtained of the relative importance of such indications of minor unconformity as have been observed. So far as local geology is concerned, it is concluded that the Papakura Series represents lower horizons of the Waitemata Series.

APPENDIX.

1. PETROGRAPHY.

(a) *Greywacke of the Hokonui System (? Trias-Jura)* (Fig. 12, Plate 6).

Megascopically the greywackes show some slight variation in grain-size, but, in other respects, samples from different localities agree fairly closely. The mineral grains form a firmly welded equidimensional mosaic with little trace of finer interstitial material. Microscopically they consist of very abundant, decomposed, cloudy feldspar (both orthoclase and plagioclase), a moderate amount of chlorite and subordinate, irregularly shaped, angular grains of quartz. Anhedral fragments of opaque iron-ore (magnetite) are moderately plentiful, whilst there are many scattered granules of epidote. Some samples contain numerous small crystals of green hornblende and a few of augite, often displaying definite crystal outlines. In addition there are sometimes fragments of fine-grained sediment and of various andesites. It is worthy of note that Bartrum (1917, p. 422) reports having found andesitic pebbles in the rocks at Port Waikato which are the uppermost deposits of the Hokonui System.

(b) *Papakura Limestone (Tertiary).* (Fig. 13, Plate 6; Figs. 14 and 15, Plate 7; Fig. 16, Plate 8).

The limestones from Hay's Creek, Ardmore Valley, Bell Creek and from the area north-east of Ardmore Quarry are all essentially similar in texture, in content of calcium carbonate and in their contained organic remains. The great bulk of the rock consists of organic débris cemented by abundant interstitial calcite, whilst there are also small angular grains of quartz and a few of very fine-grained greywacke. Grains of glauconite fill the minute cavities of echinodermal plates (Fig. 15, Plate 7), and other organic material of the limestone at Bell Creek (Fig. 14, Plate 7), and microscopic particles of magnetite occur sparingly in another sample from the same locality.

All the limestones contain some calcareous algae (Fig. 13, Plate 6), but that from the upper part of Bell Creek has them so abundantly that it may be called an algal limestone. In general, however, the Papakura limestone may be more fitly described as a polyzoan limestone, for, with the exception of the algal facies just noted, polyzoa constitute the bulk of the incorporated organic remains (Fig. 16, Plate 8), but there are, in addition to algae and polyzoa, numerous foraminifera with spines and plates of echinoids, corals and occasional fragments of the shells of brachiopods. It thus appears to be closely similar to the polyzoan limestones of Waiwiku Island, Kawhia, and of Gibraltar Rocks, Kaipara Harbour, described by Marshall (1916, p. 91).

(c) *Basalt (Post-Tertiary).*

1. *Boulders on the Western Slopes of Hunua Range.* (Figs. 17, 18, Plate 8).

These boulders litter the western scarp-face of Hunua Range, and are probably the remnants of flows such as those better exhibited further south at Bombay and Pokeno. They are composed of holocrystalline, sub-ophitic rock, in which there are large laths of plagioclase (acid labradorite) partially enwrapped by a somewhat coarse-grained groundmass of abundant irregular crystals or grains of colourless augite. The rock is not markedly porphyritic, though phenocrysts of olivine do occur (Fig. 17, Plate 8), and flow-orientation of the laths of feldspar is lacking. The sections examined show little trace of weathering or alteration, beyond slight serpentinization of the olivine along fractures or the margins. Ilmenite is moderately plentiful in interstitial patches or as occasional rods.

There are numerous small spherulitic masses of radially fibrous calcite, which in places fills the interstices between crystals of the groundmass, so that it is often partially penetrated by laths of feldspar (Fig. 18, Plate 8). The general absence of weathering shows that this calcite cannot have been formed by secondary processes from the rock itself. In addition aggregates of aragonite and other carbonate partially or wholly fill many of the larger vesicles, and it is almost certain that these carbonates and the interstitial calcite of the groundmass have a common origin. Lewis (1912, p. 727) said of zeolites in the Newark igneous rocks of New Jersey that they were formed by magmatic and not meteoric waters, and therefore originated during the final phase of consolidation of the magma, whilst Browne (1923) gave a similar explanation of calcite in basalt at Maitland, N.S.W., and Bartrum (See Ferrar, 1925, pp. 69-70) of carbonates in basalts near Whangarei. There can be no doubt that the carbonates of the boulders near Papakura originate in this manner.

Comparisons with slides of several of the Lower Waikato basalts show that these latter are very similar to that just described.

2. *Basalt from Quarry near the Debouchure of Hay's Creek.*

This rock has a groundmass that is almost pilotaxitic in structure, for it consists largely of exceedingly small, fluxionally arranged laths of plagioclase, which are embedded, along with very numerous tiny crystals and grains of magnetite and colourless augite, in a small amount of colourless glass. There are abundant, entirely undecomposed, idiomorphic phenocrysts of augite (sometimes schillerized) also olivine and less numerous ones of plagioclase.

2. DESCRIPTION OF COAL BEDS (TERTIARY).

Although not strictly within the area forming the subject of this paper, outcrops in Symond's Stream, a little south of Hay's Creek, and at a coal mine in the Hunua district were examined in the hope that they would assist in the study of the coal measures within the area.

There is a good outcrop in the bed and banks of a small tributary entering Symond's Stream from the north-east, near the bridge on the old Hunua Road. As shown in a drive, the coal is about 3 ft. thick and in parts is a good quality lignite, though towards the bottom of the seam there is admixed fireclay in thin lenses. The "overclay" is about 1 ft. in thickness, and is a very fine-grained sandstone containing some pyrite and broken plant remains and striking N.50°W. with a dip of 70° to the south-west. The "underclay" is a carbonaceous shale, which is exposed for a depth of about 3 ft., though its total thickness could not be ascertained.

Irregularly rounded concretions of ferrous carbonate, partially or wholly oxidized to limonite, are scattered in the bed of the stream. Similar concretions of siderite occur at the Hunua mine, and have been described by Bartrum (1922).

Mr. A. H. Browne, on whose property the coal at Symond's Stream occurs, kindly supplied the following analyses of coal and fireclay which were performed by the Wilson Cement Company:

Coal (Lignite).	
Moisture	18.12
Volatile hydroc.	32.31
Fixed carbon	31.75
Ash	17.82
	100.00
Sulphur	1.97
Fireclay (White).	
Loss on ignition	7.44
Silica	46.94
Alumina	38.12
Oxides of iron	trace
Oxides of zinc	trace
Magnesia	trace
Sulphur trioxide	0.43
Alkalies and undet.	7.07
	100.00

The fireclay has been used with eminent success for the manufacture of fire-bricks.

In the Hunua district, coal crops out in several places close to where it has been mined in recent years on the banks of a small stream flowing north-north-east into Hunua Stream, but the mine alone was closely examined. Here the seam is from 5 ft. to 6 ft. in thickness and has a strike of N.35°W. and a dip of 12° to the north-east. Judged by the material stacked nearby, the coal is a highly friable lignite containing abundant small masses of resin and with films of pyrite in the joint crevices. The overclay is a puce-coloured shale containing the concretions of siderite described by Bartrum (1922) and plentiful impressions of plants, which could be collected only with difficulty owing to the friability of the rock. A little up-stream from the coal, there is an outcrop of fossiliferous marine sandstone, stratigraphically below the coal; this locally has abundant shells of lamellibranchs, though so crushed and decalcified as to be useless for determination.

In Hay's Creek, on the western side of Hunua Range from the coal-mine at Hunua, there are two sets of coaly beds, separated by a fireclay and several feet of sandstone. The upper bed is 2 ft. thick (Fig. 6, Plate 3), and has at its base a one-inch layer of fairly good lignite, whilst the remainder of the bed is highly impure and poorly coherent. The overclay is not visible, but the associated underclay carries abundant impressions of the leaves of dicotyledonous plants, though again collection is exceedingly difficult on account of the fissility and friability of the shale. The lower coaly bed is in reality merely a carbonaceous shale.

In Ardmore Valley the coal was obtained in an old shaft on the property of Mr. Craig. At a depth of 45 ft., an adjacent bore revealed the underlying greywacke, but unfortunately no detailed log is available. In the accessible portion of the shaft the overclay—a typical fireclay—is underlain by a coal bed 1 ft. to 18 ins. deep, in which there is a band 4 ins. in thickness of good brown coal, though the rest of the layer contains much argillaceous impurity. The series of beds dips at 20° to the north-west and contains very imperfect traces of vegetation. It is understood that the bore disposed of all hope of the coal attaining sufficient thickness to be valuable commercially. A chain or so away from the bore, a portion of the same bed appears almost at the level of the adjoining swamp, and, although no fireclays are here in contact with the coal, there are fairly coarse-textured conglomerates apparently little above it.

Hochstetter (1864, pp. 34, 37) referred to the Hunua Coalfield, by which he evidently meant the area mined at Drury, and stated that it was discovered in 1858 by the Rev. Mr. Purchas and worked in the same year. He placed these Drury coals in his Tertiary Brown Coal Formation and obtained from the beds of this formation, at various places nearby, somewhat imperfect leaves determined by Unger as *Myrtifolium lingua, Phyllites ficoides, P. laurinium, P. purchasi, P. novae zelandiae, Fagus ninnisiana* and *Laranthophyllum dubium,* whilst he also recorded a large bivalve (? *Anodonta*).

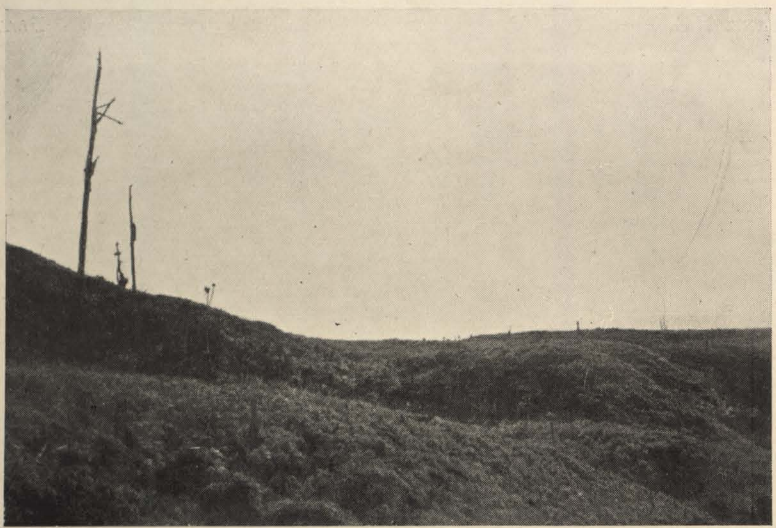


FIG. 1.—Bench topography in Tertiary sandstones on the divide S.E. of the headwaters of Ardmore Stream.

FIG. 2.—The more southerly of the two contacts at Bell Creek showing basal Tertiary conglomerate resting on the eroded surface of the greywacke of the oldermass. [*Photo. by J. A. Bartrum.*

FIG. 3.—Angular unconformity along the roadside about a quarter of a mile E.N.E. of the bridge at the debouchure of Hay's Creek, showing horizontal beds of sandstone resting discordantly on inclined sandstones. [*Photo. by J. A. Bartrum.*

Face p. 64.

FIG. 4.—Sandstones of the Tertiary along the roadside a few chains east of the debouchure of Hay's Creek, succeeded upwards by a shoreline greywacke conglomerate containing decomposed molluscan and other remains.

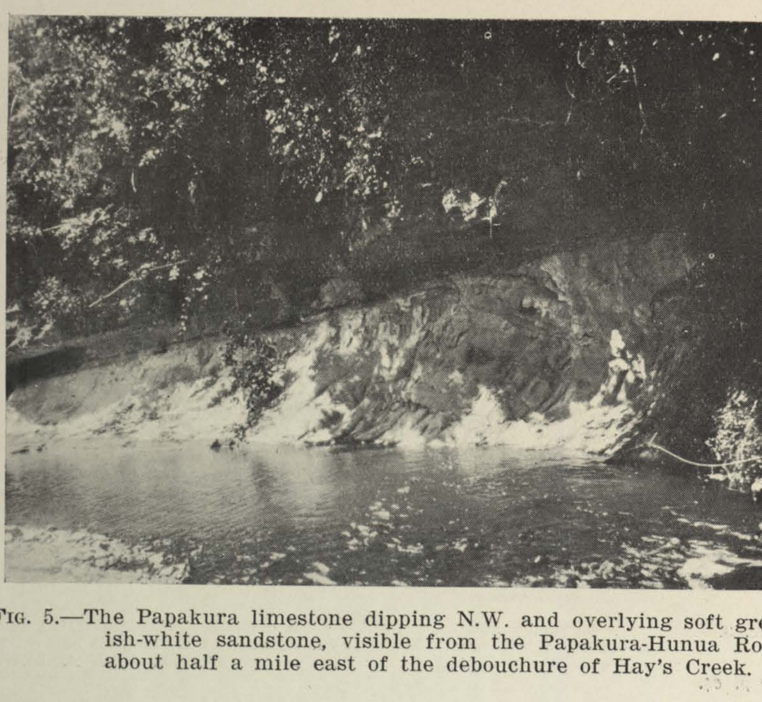


FIG. 5.—The Papakura limestone dipping N.W. and overlying soft greyish-white sandstone, visible from the Papakura-Hunua Road about half a mile east of the debouchure of Hay's Creek.

FIG. 6.—The upper coal bed at Hay's Creek overlain by Recent alluvium charged with boulders of greywacke. The underclay is also visible.

FIG. 7.—Root-wedging in flaggy limestone at Bell Creek, near the more northerly of the two contacts between Mesozoic and Tertiary rocks.

[*Photo. by J. A. Bartrum.*

FIG. 8.—N.W. slopes of Hunua Range. The foreground and right of the picture show a stripped surface of Trias-Jura rocks characteristically closely dissected. The divide in the background consists of Tertiary sandstone, which has slipped and shows the typical hummocky surface caused by such dislocation.

FIG. 9.—Columnar basalt in the quarry near the debouchure of Hay's Creek.

FIG. 10.—Beds of tuff on the divide north of and near the debouchure of Hay's Creek.

FIG. 11.—A block of Tertiary sandstone causing depression of bedding of the tuffs shown in Fig. 10.

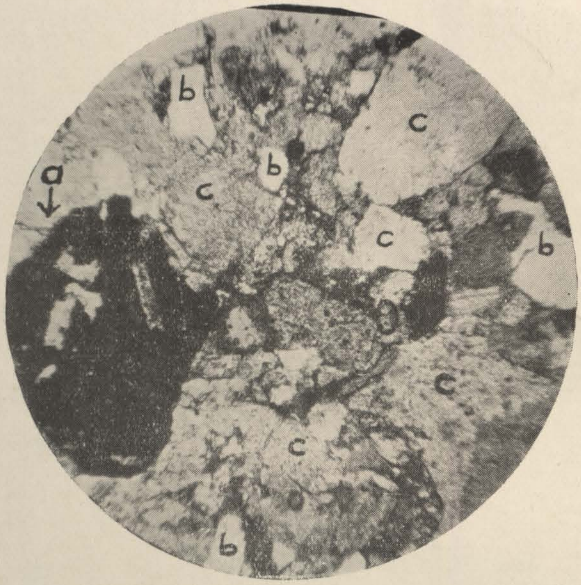


FIG. 12.—Greywacke from Hay's Creek. Fragments of andesite (a), and grains of quartz (b), and of felspar (c) set in a more or less equidimensional mosaic. The remainder of the material comprises chloritised and kaolinised minerals, the original characters of which cannot be determined. Ordinary light. Magnification, 45 diams.

[*Photomicrographs, J. A. Bartrum.*

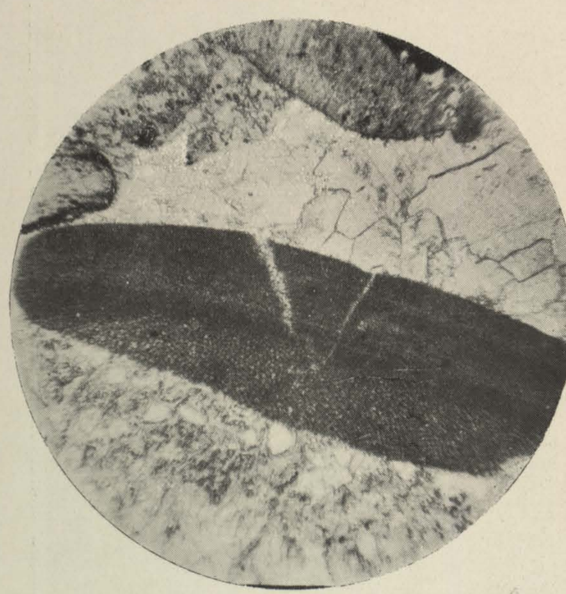


FIG. 13.—Papakura limestone from N.W. slopes of Hunua Range, facing Papakura Valley. Lithothamnium across the centre of the photo, small grains of quartz seen below this and secondary crystalline calcite above. Magnification, 45 diams.

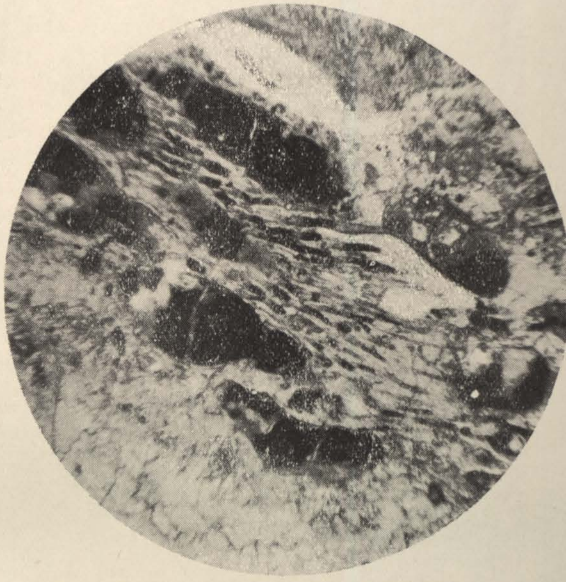


FIG. 14.—Longitudinal section of a polyzoan filled with glauconite. Papakura limestone, Bell Creek. Magnification, 45 diams.

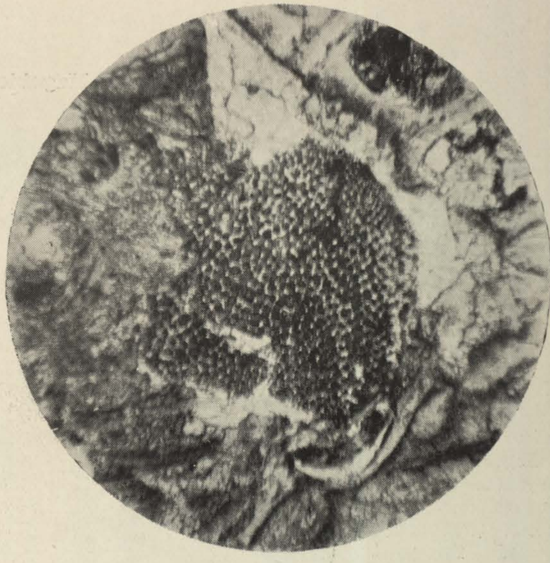


FIG. 15.—Fragment of an echinodermal plate, the interstices filled by grains of glauconite. Papakura limestone, Bell Creek. Magnification, 45 diams.

FIG. 16.—Typical section of Papakura limestone with abundant remains of polyzoa and occasional foraminifera. Magnification, 45 diams.

FIG. 17.—Basalt of a boulder on the west flank of Hunua Range. The photograph shows olivine serpentinized along fractures and around borders, laths of felspar (white), and irregular crystals of augite (grey). The black material is partly serpentine and partly rod-like ilmenite. Ordinary light. Magnification, 45 diams.

FIG. 18.—Basalt from the same locality as that of Fig. 17, showing irregular crystals of olivine (a), and augite (grey, high relief). Calcite (b) occupies interstices and is partly penetrated by laths of felspar. Ordinary light. Magnification, 45 diams.

The collections examined by von Ettingshausen (1891) do not appear to have included material from this area.

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