Pillow-Lavas, Peridotites and Associated Rocks of Northernmost New Zealand.

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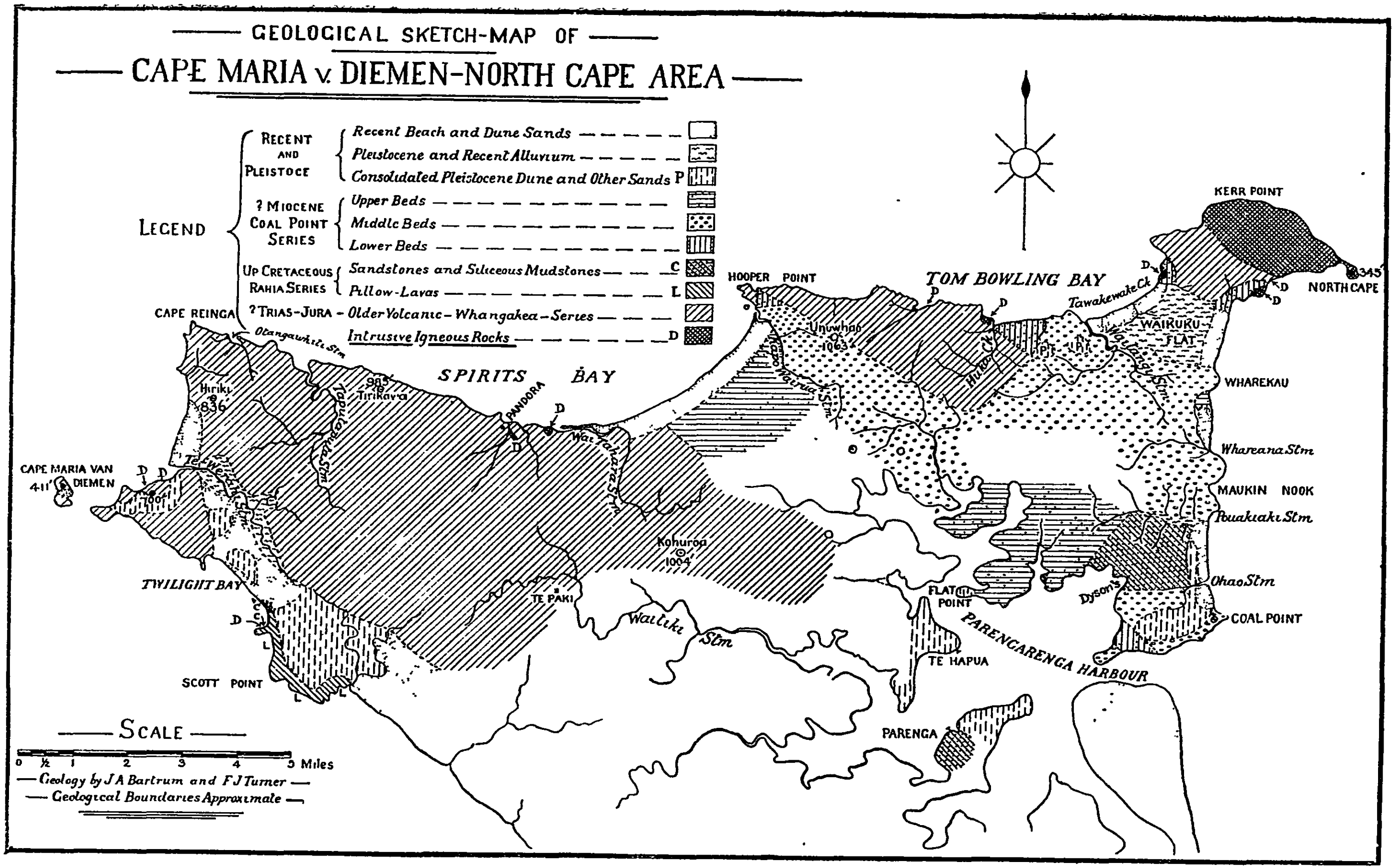
(Plates 20—24.)

Contents.

Introduction.

The authors recently visited the Cape Maria van Diemen—North Cape area of New Zealand with the primary object of studying the peridotites and gabbroid rocks described from there by Bell and Clarke (1910). Owing to the time available being limited, and to


GEOLOGICAL SKETCH-MAP OF
CAPE MARIA v. DIEMEN-NORTH CAPE AREA
LEGEND
RECENT AND PLEISTOCE
Recent Beach and Dune Sands
Pleistocene and Recent Alluvium
Consolidated Pleistocene Dune and Other Sands P
? MIOCENE COAL POINT SERIES
Upper Beds
Middle Beds
Lower Beds
UP CRETACEOUS RAHIA SERIES
Sandstones and Siliceous Mudstones C
Pillow-Lavas L
? TRIAS-JURA - Older Volcanic - Whangakea - Series
Intrusive Igneous Rocks D
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Otangawhiti Stm
SPIRITS BAY
HOOPER POINT
TOM BOWLING BAY
KERR POINT
NORTH CAPE
345'
Tawakewake Ck
WAIKUKU FLAT
WHAREKAU
Whareana Stm
MAUKIN NOOK
Pouakiaki Stm
Ohao Stm
COAL POINT
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Hiriki 836'
Tirikawa 985'
PANDORA
Waitahora Stm
Kohuroa 1004'
CAPE MARIA VAN DIEMEN
411'
TWILIGHT BAY
SCOTT POINT
TE PAKI
Waitiki Stm
FLAT POINT
Dyson's
TE HAPUA
PARENGARENGA HARBOUR
PARENGA
SCALE
0 ½ 1 2 3 4 5 Miles
Geology by J A Bartrum and F J Turner
Geological Boundaries Approximate

the fact that a considerable portion of it was not used to best advantage because the coastal expostures could not be visited during higher phases of the tide, the survey was very far from being thorough. In spite of this fact, however, the observations made have brought to light interesting information, and have shown that erroneous ideas have long been allowed to persist regarding the nature of many of the rocks of the area.

This paper has therefore been prepared in order to remove these misconceptions, and to introduce several fresh facts which have an important bearing upon the geology of this northern region. The authors regret that, owing to force of circumstances, they have had to leave unvisited localities which, judged by the reports of McKay (1894), and Bell and Clarke (1910), would certainly have well repaid investigation. Their thanks are due to Mr. and Mrs. L. Keene, of Te Paki Station, who gave every assistance and kindness within their power, to Mr. H. MacQuarrie for kindly collecting and forwarding rocks from Pandora, to Mr. Manihera, who proved a veritable mine of reliable information regarding routes, and finally to their companions, Messrs. W. E. La Roche and K. A. Allen, who gave valuable help in field work.

Through the courtesy of the late Mr. P. G. Morgan, for many years Director of the New Zealand Geological Survey, several excellent analyses by Mr. F. T. Seelye, of the Dominion Laboratory, are available to support petrographic descriptions of certain igneous rocks.

The authors of this paper would like to place on record their great appreciation of the unfailing assistance which Mr. Morgan has always afforded whenever it lay in his power. His interest and co-operation have been of incalculable benefit to the advancement of geology in this country.

Earlier Work.

The only important reports upon the geology of the North Cape—Cape Maria van Diemen area are those of McKay (1894), Bell and Clarke (1910), and Bell (1909), though Hector visited the district prior to McKay, for it is mapped in his geological maps of New Zealand, and its geology briefly mentioned in an early report (1872), whilst Dieffenbach (1843, p. 199) has made mention of it in his *Travels in New Zealand.* Park (1910), Marshall (1911, 1912), and Morgan (1921) have issued geological maps of the area now described, and with others, such as Bartrum (1925), have made brief reference to certain features of its geology, but have depended for their information entirely upon the work of McKay, Hector, and Bell and Clarke.

Synopsis of Stratigraphy.

The papers of McKay (1894), and Bell and Clarke (1910) have described the present terrain as underlain by sediments of the comprehensive mid-Mesozoic system now known as the Hokonui System. McKay noted that these were invaded by masses of crystalline igneous rocks, and Bell and Clarke added the interesting facts that amongst these latter there were varied series of ultrabasic and gabbroid rocks, whilst amygdaloidal and other igneous rocks intermixed in the so-called sediments were probably contemporaneous lavas (Bell, 1911).

The identification of the rocks in question as sediments of the Hokonui system is erroneous, for they prove to be shattered and locally crushed basic andesitic and basaltic rocks of varied type which include pillow-lavas with which, as is expectable, some marine sediments are bedded. The nearest sediments of Hokonui facies appear to be those at Te Arai Bluff on the west coast, which is over 20 miles south of North Cape. It must be admitted, however, that Bell and Clarke (1910), whilst accepting McKay's designation of the rocks as sediments, appear to have had considerable doubt in their minds as to the correctness of this course.

As will be shown, though many reasons can be advanced for regarding this series of igneous rocks (Whangakea Series of Bell and Clarke, 1910) as mid-Mesozoic (Hokonui System) in age, it may well be uppermost Cretaceous or Palaeocene, for marls laid down in close association with pillow-lavas at Pandora (Whangakea), Spirits Bay, contain numerous tests of foraminifera, amongst which there is a form closely resembling *Orbulina*. These volcanic rocks are the oldest rocks of the Cape Maria van Diemen—North Cape District, and are provisionally classed as contemporaneous flows of the Hokonui System (Trias —? Neocomian) analogous to those of the Whangaroa area (Bell and Clarke, 1909). During the orogeny which terminated Hokonui sedimentation immediately at the close of the Neocomian these flows were intensely shattered, and, probably also at this time, invaded by a mass of gabbroid and ultrabasic rocks in the vicinity of North Cape, for Benson (1920, 1926) has ably shown that ultrabasic intrusions are a characteristic accompaniment of moderately intense crustal compression, whilst, in addition, the intrusive gabbroid rocks include gneisses which are clearly the result of piezocrystallization. On the analogy of Andrews's interpretation of conditions at Broken Hill (1923a) these intrusive bodies probably form a sill-like mass which was injected under considerable pressure. In addition to this major intrusion, there were smaller probably contemporaneous ones of intermediate character. These did not, however, close the cycle of igneous activity, for intrusions in the form of dykes and sills cut mid-Tertiary sediments (Coal Point Series), whilst interbedded with these latter, there are thick masses of andesitic conglomerates and tuff which are products of a phase of vulcanicity which manifested itself far and wide in the northern half of the North Island at this time.

Evidence from other parts of New Zealand clearly demonstrates that the post-Hokonui diastrophism was followed by prolonged erosion prior to the deposition of succeeding Upper Cretaceous beds. These are represented in the present area by steeply folded sediments (Rahia Series of Bell and Clarke) which contain occasional fragments of a large fibrous corrugated shell referable with tolerable certainty to *Inoceramus*. They are the equivalent of the Kaeo Series or Whangaroa (Bell and Clarke, 1909) and probably also of the Otamatea Beds described by Ferrar (1924) from Kaipara Harbour. Unfortunately, the contact of these Cretaceous beds with over-lying strata was not observed by the writers, but many facts indicate that a minor period of pressure, with accompanying emergence and ensuing erosion, intervened between the date of deposition of these strata and that of a varied series of mid-Tertiary sediments (Coal Point Series of Bell and Clarke) which were their immediate successors. These latter strata frequently rest unconformably upon a basement of the Older Volcanic (Whangakea) rocks. At their base there is a conglomerate, which is followed by marine sandstones, then by andesitic conglomerates spread in an extensive sheet at least 600 ft. in thickness, and finally by an upper thick deposit of marine sandstones.

The emergence of these mid-Tertiary beds above the shallow seas in which they accumulated was accompanied by the faulting characteristic throughout New Zealand of this post-Miocene (Kaikoura) orogenic phase. Powerful faults which perhaps passed locally into monoclinal folds, as has happened elsewhere in New Zealand, differentially elevated various blocks of the terrain, which were peneplained after prolonged erosion. This erosion removed great thicknesses of strata from the more elevated blocks and laid bare the peridotites and gneissic gabbros near North Cape. Plateau-like remnants of the peneplain are to-day the most remarkable physiographic feature of the eastern portion of the area described in this paper.

Though incapable of demonstration, it is probable that the uplift mainly responsible for the modern elevation of the plateaus has been accompanied by further differential movement along lines of weakness marked out in the earlier stage, for Waikuku Flat, west of North Cape, is more readily explained as the site of a relatively depressed block than as the sole result of selective erosion following eustatic uplift. This final uplift was considerably greater quantitatively than the present height (between 500 ft. and 600 ft.) of the remnants of the ancient peneplain, for it has been followed by a sub-Recent negative movement of the area which has allowed drowning of the lower portions of many of the streams.

The most recent change of sea-level relative to the land has accompanied a positive movement of about 5 ft. which is demonstrated by raised beaches along many of the coasts of North Auckland, as was early pointed out by Percy Smith (1881).

Long subsequent to the emergence of the North Cape—Cape Maria van Diemen area at the close of Miocene deposition (Coal Point Series), extensive deposits of wind-blown sand accumulated, and to-day Pleistocene and Recent dune-sands here and there mask the older rocks of the coasts.

Physiography.

For completeness of description it has been considered advisable to give a brief account of the physiography of the district now studied, although this has already been well described by Bell and Clarke (1910).

The greater part of the area between Cape Maria van Diemen and North Cape consists of a maturely dissected upland the highest points of which attain a height of a little over 1,000 ft. On the north it is abruptly terminated by the rugged northern coast, but south it merges into a great tombolo which continues south-east for fifty or sixty miles to the ancient mainland at Ahipara.

The drainage pattern is mainly insequent, for the streams show little dependence upon the structure of the area. These latter generally are approaching grade, for they often have swampy valley-floors or else meander over small alluvial flats in their lower reaches. Nevertheless, many of the tributary streams are far from mature and are broken here and there by waterfalls, whilst their valley slopes are generally very steep. Again, although the divides have usually the well-defined nature and softened slopes characteristic of maturity, remnants of an elevated plain of erosion persist at a height of from 500 ft. to 600 ft., and form a very conspicuous feature of the topography, especially in the vicinity of North Cape.

A further element in the topography has been introduced, particularly in the south-west, by the accumulation during Pleistocene and Recent times of great areas of wind-blown sand which are well developed in Tom Bowling, Spirits, and Twilight Bays. These dune-covered areas reach their maximum development south of the district under consideration, and have been described in detail by McKay (1894), and Bell and Clarke (1910). Erosion of consolidated ancient dune-sands by temporary streams draining into Twilight Bay has resulted in developing, near the north end of the bay, a splendid small-scale example of bad-land topography (see Fig. 4).

In contrast with the general insequent drainage, there are one or two instances of streams which have had their courses determined by lines of structure. Such instances will be considered in some detail, for they afford important physiographic evidence as to the structure of the area. The first example of such structural control is furnished at the east end of Spirits Bay, where the tributaries of Kapo Wairua Stream draining from the south-east have adjusted themselves parallel to the strike of a thick series of resistant volcanic conglomerates interbedded with much softer strata. A prominent N.W.—S.E. homoclinal divide (Fig. 6) has been carved from the conglomerate, having steep escarpment slopes on the north-east and somewhat gentler dip slopes on the south-west, whilst less pronounced but quite distinct series of similar cuesta-like divides may be observed in lowlands of soft sandstone west of Kapo Wairua Stream and immediately inland from Spirits Bay. West of these sandstone lowlands there are resistant volcanic rocks which constitute hills which rise abruptly to a height of 1,000 ft. The boundary of the two formations runs south-east from the west end of Spirits Bay beach, and both physiographic and stratigraphic evidence point to this junction being determined by faulting.

There is a second example of subsequent drainage about two miles east of Cape Reinga where the north-west line followed by Otangawhiti Stream is continued beyond its headwaters by a tributary of Taputaputa Stream. Just below its confluence with this tributary, Taputaputa Stream swings around in a semi-circle and flows north-west to the shore. The physiography thus points very strongly to the presence of a fault-zone running in a N.W.-S.E. direction up the valley of this tributary of Taputaputa Stream and down Otangawhiti Valley to the sea.

The facts also suggest that the main valley of Taputaputa Stream is incised along a similar N.W.-S.E. zone of shattering, whilst, going further afield, indubitable evidence of similar control is furnished by the valley of Huka Stream draining into the middle portion of Tom Bowling Bay, for the actual fault-plane is traceable at the shore.

Further physiographic evidence of faulting is afforded by a resistant block about 5 square miles in area of which North Cape forms the most easterly point. This North Cape block attains an altitude of about 750 ft., and is separated from highlands further south-west by a broad undulating flat about 40 ft. above sea-level known as Waikuku Flat, which is covered superficially by alluvium and swamp-filling, and is margined by sand-dunes.

The North Cape block rises so steeply from this flat as to suggest that its south-west face is a dissected fault or fault-line scarp, and, as will be seen from the section appearing later, there is corroborative stratigraphic evidence of a fault running N.W.-S.E. parallel to the north-east border of the lowland. Further south-west the topography again suggests that a fault may separate Waikuku Flat from plateau-like highlands further south-west; if this be so, the north-west trend of Waitangi Stream is subsequent upon such faulting.

This evidence of N.W.-S.E. fracturing is of especial interest in that it shows the continuation of dominant fractures having this trend, along with others roughly at right angles to the first, from as far south as Taupo, where they have been described by Henderson (1924). Bartrum and Laws (MS., 1924) have recognized the dominance of these series near Auckland, and Ferrar (1925, pp. 18-20) in the extensive Whangarei—Bay of Islands area, though Bell and Clarke (1909, p. 23) were able to recognize only an E.N.E.-W.S.W. series near Whangaroa.

The coast-lines of the Cape Maria van Diemen—North Cape district are still in a comparatively youthful stage of development, for they consist in general of rugged stretches, with sea-cliffs as much as 800 ft. in height, where slow retrogression is in progress, which alternate with long sandy bays backed by extensive dune areas which represent the partly filled embayments of the original coast-line of submergence. Probably the most striking feature of the coast-lines is the unusually perfect development of broad, flat, horizontal platforms carved at the base of the cliffs at the height of about 1 ft. above normal high-water level, and perhaps especially prominent in the resistant ancient volcanic rocks of the region. The origin of similar platforms has been discussed in detail by one of the writers (Bartrum, 1926), and need not further be considered here, beyond mentioning that they are believed to be due primarily to the action of storm-waves. These have most effective action at a level slightly above normal high-water level during higher phases of the tide. There appear to be grounds for the belief, however, that subaerial processes active upon the wave-cut platforms have contributed very materially to the remarkably level nature of the benches of the present area, more especially where they have been developed in more shattered rocks.

In contrast with the exposed northern and western coasts, that of Parengarenga Harbour presents outlines of a much less regular kind, for it has originated by submergence of a maturely sculptured area in not far distant times, and, on its northern shores, its initial outlines have not been very greatly modified. Widespread mudflats are witness, however, to extensive infilling subsequent to the submergence, though the recession of the sea-cliffs at headlands does not appear to have been considerable.

The negative movement involved must be taken as the widespread one responsible for the unique embayed coast-lines of almost the whole of the eastern coast of North Auckland. Its amount cannot be calculated with any precision, but was probably about the order of 200 ft.

At a date subsequent to this, however, there have been slight elevatory movements. Broad stream terraces about 30ft. above sea-level are extensively developed along the banks of Waitiki Stream. They are composed of relatively fine-textured alluvium and suggest that, during the period of aggradation which gave birth to the flood-plain from which they were carved, sea-level was distinctly higher than now. Other evidence of sub-Recent positive movement is afforded by beaches about 4 ft. above modern storm-beach level on the northern coast about three-quarters of a mile west of Waitangi Stream, whilst McKay (1894) describes broad flats of marine muds containing recent molluscan species which reach a height of from 10 ft. to 15 ft. above sea-level near the shores of Parengarenga Harbour. Sub-Recent uplift of similar amount can be observed in numerous other parts of North Auckland, especially around the shores of Waiheke Island, Brown Island, Ponui Island and the mainland in the vicinity of Auckland, and has already been remarked by writers such as Smith (1881), Henderson (1924a, p. 582), Ferrar (1925, pp. 53-54) and others. This uplift occurred long after the major submergence described above, at a time when the coast-lines had attained approximately their present outlines.

DETAILED STRATIGRAPHY.

The upward sequence of sedimentary and extrusive igneous rocks appears to be as follows:—

(1) Older Volcanic Series (Whangakea Series of Bell and Clarke)—age? Trias-Jura. Flows of basaltic rock with minor sediments.

(2) Upper Cretaceous Series (Rahia Series of Bell and Clarke). Siliceous mudstones and concretionary green sandstones with *Inoceramus*. Probably also includes basic pillow-lavas.

(3) Middle and Later Tertiary Series (Coal Point Series of Bell and Clarke).

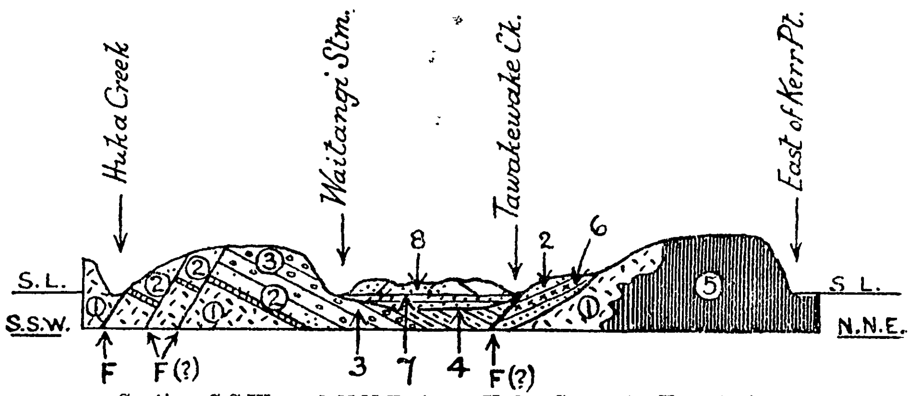
- (a) Lower Beds including sandstones, mudstones, tuffs and fossiliferous basal conglomerate;
- (b) Andesitic conglomerates;
- (c) Upper Beds including sparsely fossiliferous sandstones, mudstones, grits, and minor conglomerates.

(4) Recent and Pleistocene dune-sands, bedded silts and gravels.

1. Older Volcanic Series (Whangakea Series of Bell and Clarke).

Distribution and Lithology.

The name Whangakea Series was first used by Bell and Clarke (1910) to include the extensive series of rocks which is developed in hilly country extending west and south from Pandora (Whangakea) at the west end of Spirits Bay Beach, to Te Paki, Cape Maria van Diemen and Cape Reinga. The same writers also mapped similar rocks exposed along the western part of Tom Bowling Bay between Hooper Point and Huka Creek, as part of the same series, whilst McKay (1894) had previously described and mapped both these areas as comprised mainly of Older Secondary or Palaeozoic sediments. Numerous outcrops of the rocks of this series, which are here



Section S.S.W. and N.N.E. from Huka Creek to Kerr Point.

(1.) Older Volcanic Series. (2.) Lower Beds of Coal Pt. Series. (3.) Middle Beds (andesitic conglomerates) of Coal Pt. Series. (4.) Upper Beds of Coal Pt. Series. (5.) Basic and Ultrabasic intrusives of Kerr Pt. (6.) Sill of quartz diorite. (7.) Pleistocene bedded silts. (8) Pleistocene and Recent dune sands.

designated the Older Volcanic rocks, were also observed by the writers in valleys adjacent to the track from Te Paki to Te Hapua on the western shores of Parengarenga Harbour, so that these rocks evidently extend a considerable distance south-east from Pandora. A narrow strip of similar rocks was also found to connect the east and north coasts along the north-east margin of Waikuku Flat in the vicinity of North Cape, where they are invaded by a large mass of gabbroid and ultrabasic rocks.

The rocks of the Older Volcanic (Whangakea) Series consist of a succession of thick flows of basaltic or andesitic rocks which are intensely shattered, and in thin section show various effects of pressure, whilst, wherever individual flows are recognizable, they appear to be tilted at high angles. Although the main mass of the series consists of normal flows, pillow-lavas are developed in the vicinity of Pandora, and, less perfectly, at various places along the western part of Tom Bowling Bay.

McKay (1894) describes the rocks here recognized as volcanic types as mainly indurated sandstones, shales and slates of Palaeozoic or Older Secondary age which have been intruded by " crystalline rocks" near North Cape and elsewhere. He evidently mistook them for older greywackes and other indurated sediments such as those of the Whangaroa district, which are now referred to the Waipapa Series (Hokonui System) of probable Trias-Jura age.

Marshall (1908, Pl. 13) maps these Older Volcanic rocks and the intrusives of North Cape as diorites and gabbros of uncertain age, presumably on the assumption that McKay made an error in identification similar to that which Marshall (*loc. cit.*, pp. 81-82) found that he made in the case of similar rocks in the Mongonui district. Bell and Clarke (1910), whilst recognizing that a large quantity of igneous material is present in the Whangakea Series,. nevertheless follow McKay's opinion that the series is mainly sedimentary. The microscopic examination of a large number of thin slices representative of the rocks shows that they undoubtedly represent volcanic flows, even though in some localities intense shattering has induced close macroscopic resemblance to indurated sediments. The whole series appears to be volcanic with the exception of a small amount of sedimentary material associated with pillow-lavas at Pandora.

In this connection the section at this latter locality (Whangakea) at Spirits Bay is of especial interest. Almost vertical pillow-lavas are well developed at the extremity of a small headland immediately west of the mouth of the small stream at Pandora, and on a small stack a few yards off-shore from this point. With the pillow-lavas there are basaltic rocks lacking the pillow form and so intensely shattered and crushed that they closely resemble red and green clay-shales. Careful examination reveals, however, that cores of less crushed microscopically identifiable basalt persist in the general shale-like material and strongly suggest the volcanic origin of the whole series. In some places below the pillow-lavas, where the cores of basaltic rock are especially numerous, the rock resembles a conglomerate veined and cemented with calcite. A few yards south from the pillow-lavas towards the beach at Pandora, there is a dyke of pyroxene diorite (N.C. 2) which serves to complicate the section, and, still further on, there are striped red and green rocks which are associated with finely laminated compressed foraminiferal marls. The green material proves on sectioning to be andesitic in character, but the red with which it is intermixed in irregular lensoid manner, is probably sedimentary. The intermixture can be explained as a result of moderately acute shearing.

The pillow-lavas present the usual chilled crust and are almost certainly submarine flows, so that the associated sediments represent deposits formed during an interval between successive outpourings on the sea bottom.

East from Pandora there are two headlands composed mainly of normal older volcanic (Whangakea) rocks. At the second, however, there is an interbedded steeply dipping flow of pillow lava on the line of strike of the similar flow further west. As before, the rocks below the pillow-lava are severely crushed. Still further east at the same headland, there is a mass of hyalopilitic pyroxene andesite (N.C. 25) which apparently belongs to the mid-Tertiary series of extrusions briefly referred to earlier in the Synopsis and described in more detail hereafter in Section 5 of the Lower Beds. (See also Section D for petrographic description.)

The Older Volcanic (Whangakea) rocks appear to have very great thickness and lack fragmental eruptive material interbedded with the flows. These facts and their generally non-porphyritic (or aphyric) nature suggest that the lavas are the product of fissure eruptions in which the magma rose rapidly from considerable depths. Some at least of the flows were extruded under submarine conditions, as is indicated by the existence of pillow-lavas and thin beds of marine sediment associated with them, but the somewhat rare occurrence of such flows is suggestive that this was an exceptional condition.

Age of Older Volcanic (Whangakea) Series.

The age of the rocks described above is uncertain. McKay (1894) referring to rocks which are evidently those occurring with the pillow-lavas at Pandora, states: " From these rocks and from a calcareous red slate, I collected fragments of a fibrous shell apparently *Inoceramus,* and from a mass of grey and reddish limestone on the beach, numerous small shells of which the most abundant appears to be a species af *Halobia.*" On this evidence, and on the supposed lithological resemblance between the older rocks of this area and Triassic and Jurassic sediments of the South Island, McKay placed the rocks here grouped in the Whangakea Series in a series ranging from " Older Secondary" to Palaeozoic in age. Hector (1894) refers to the fossils as "obscure fossils among which are fragments of fibrous shell and a small convex bivalve," and is disinclined to accept McKay's belief that the Pandora rocks are Triassic in age. Bell and Clarke (1910) bring forward no new evidence, and are content to quote McKay and Hector.

Stratigraphic evidence as to the age of the series discussed is meagre, and merely goes to show that there is strong unconformity between it and overlying mid-Tertiary strata, whilst its relations to the Upper Cretaceous Rahia series has not yet been observed.

Fresh, but somewhat indefinite, evidence of palaeontological nature has been unearthed, during the present expedition, in marly sediment bedded with the Pandora pillow-lavas. In thin section this proves to be a fine-grained calcareous rock compacted and streaked out by pressure and containing numerous tests of foraminifera (See Fig. 3). It appears to be a type of rock hitherto unknown from Hokonui (Trias — ? Neocomian) rocks of the North Island. Mr. W. J. Parr, of Melbourne, very kindly examined the somewhat crushed foraminifera and obtained the valued opinion of Mr. F. Chapman thereon. He writes that the foraminifera are certainly not Tertiary and may even be as old as Carboniferous. The provisional identifications include *Bigenerina, Marginalina, Valvulina, Endothyra,* and possibly *Haplophragmium.* In addition, there are numerous spherical tests of a genus belonging to the Globigerinidae which closely resembles *Orbulina.*

It will be seen that both palaeontological and stratigraphical data fail to furnish very precise information as to the age of the rocks discussed, so that the writers have depended very largely on diastrophic evidence in suggesting that these Older Volcanic or Whangakea rocks are flows erupted contemporaneously with the accumulation elsewhere of normal sediments of the mid-Mesozoic Hokonui

System, and are, in fact, the equivalents of the extensive sheets of basalt described by Bell and Clarke (1909) as interbedded with sediments of this system (Waipapa Series) in the Whangaroa district. This important diastrophic evidence is found in the presence at North Cape of gabbro which has invaded the Whangakea rocks and has primary foliation very strongly developed. It is considered most probable that the injection of this intrusion and its foliation are both the result of the Early Cretaceous orogeny which caused the emergence and folding of the Hokonui sediments from one end to the other of the New Zealand area, and initiated the period of vigorous erosion which preceded later Cretaceous sedimentation. If this be so, the Whangakea rocks must be at least as old as those of the Hokonui System.

There is admittedly a possibility that the series is of Cretaceo-Eocene age, for igneous rocks similar in character to the Whangakea lavas invade Upper Cretaceous sediments (Onerahi Series) in the watershed of Upper Mangakahia Stream and elsewhere in North Auckland, but against this view there are two main arguments. First, there is little evidence that the intensity of pressure involved in the post-Onerahi uplift and folding which preceded general mid-Tertiary sedimentation in North Auckland,* attained sufficient magnitude to develop foliation in the North Cape gabbros, whilst secondly, the foraminiferal fauna of the marl at Pandora is entirely different from that so far discovered in the foraminiferal "hydraulic limestone" of the Upper Cretaceous Onerahi series.†

2. UPPER CRETACEOUS SERIES (RAHIA SERIES OF BELL AND CLARKE).

The rocks included by Bell and Clarke (1910) in their Rahia Series occur at the south end of Rahia or Twilight Bay, in Taupiri Bay four miles north of this, and at Parenga, on what used to be Yates's station, but is now Mr. Chapman's property. McKay (1894) also placed certain "Cretaceo-Tertiary" greensands and siliceous mudstones from Dyson's old station on the north side of Parengarenga Harbour in the same series as the rocks of Yates's station. Though Bell and Clarke omitted the rocks near Dyson's from their Rahia Series, McKay's classification now proves to be correct, and Bell and Clarke's mapping erroneous in this respect. The rocks at Twilight (Rahia) Bay, which are included in this series, contain extensive associated pillow-lavas in addition to marine sediments. Those at Parenga consist of steeply inclined calcareous shales and mudstones alternating with moderately thick beds of concretionary greensands in which there are occasional thin bands of small pebbles. The concretions are often coated by a layer of cone-in-cone limestone and contain occasional fragments of a corrugated fibrous shell which is almost certainly *Inoceramus*, as well as rare casts of a small gasteropod.

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*Benson (1923, p. 54) suggests that the northern portion of New Zealand came within the influence of intense orogenic movements which affected New Caledonia in the early Tertiary.

†Recent advice from Mr. W. J. Parr suggests that this statement may need to be modified.

The rocks mapped by McKay as "Cretaceo-Tertiary" north of Dyson's prove to be highly siliceous mudstones, with green sandstones, which are all considerably shattered and dip at high angles in irregular directions. Good outcrops are plentiful along the divides adjacent to the track from Dyson's to Waikuku Flat. This series of beds extends through to the coast near the south margin of the headland in which Maukin Nook is situated, for a boulder of green sandstone was picked up in the bed of a small stream at this place, in which there was a large fragment of the shell of an *Inoceramus.* This discovery obviously justifies McKay's mapping of the area as "Cretaceo-Tertiary."

Owing to unfavourable tides, the Taupiri Bay outcrops were not examined at beach level. The rocks exposed in the accessible higher portions of the sea-cliff at this locality, and those further north, apparently all belong to the Older Volcanic Series, so that it would appear that the Cretaceous or Rahia beds reported here by Bell and Clarke have very limited extent.

Amongst the most interesting of the beds assigned to the Rahia Series are those at Twilight (Rahia) Bay first recorded by Bell and Clarke (1910). Near the south end of the bay greenish and greyish sandstones dipping due north at 40° outcrop from beneath the sands of an adjoining dune-area. These are followed downward by a flow of pillow-lava about 70 ft. in depth, which has ovoid pillows from 1 ft. to 3 ft. in diameter. Each pillow exhibits small-scale radial prismatic jointing and a somewhat glassy chilled crust. (See Fig. 5). Beneath the lava there are what appear to be finely bedded clay-shales which are almost concealed by beach sands.

At the extreme southern limit of the beach in this bay, pillow-lavas are again developed in the sea-cliffs and shore-platforms; they dip steeply north at an angle of about 50°, the dip being clearly shewn by overfolding of individual pillows (see Fig. 2). Masses of secondary calcareous material and calcite occupy the interstices between the pillows, whilst this latter mineral is also abundant as the filling of joint crevices and vesicles. Above the flow, and apparently in part invaded by it, there are well-laminated indurated greyish mudstones which are exposed on the shore below high-water mark. Beneath the same flow there is a shattered breccia-like mass consisting of vesicular fragments of lava similar to that of the pillows, intermixed with a green matrix of doubtful nature but probably sedimentary. This breccia is interpreted as a scoria formed at the base of the uppermost flow of pillow-lava in this area. Passing further west, the breccia or "scoria" is succeeded in downward sequence by a stratum of green sandstone about 10 ft. in thickness which dips steeply north-east, and then by what appears to be a small mass of "baked" shale. Near this a dyke of dolerite 20 ft. in width is exposed on the shore-platform and is succeeded westward by highly amygdaloidal basalt lacking the pillow form. In the course of a few yards this last basalt passes into typical pillow-lavas which continue south along the rugged shore-line of Scott Point. Near the south end of Scott Point, a non-porphyritic open-grained basaltic rock was discovered a little east of the pillow-lavas in the valley of a small stream cutting steeply down to the shore from the elevated plateau developed along the coast at this locality. It was at first believed to belong to the Older Volcanic Series of rocks, but its petrographic characters are not inconsistent with its description as a phase of the series of flows which nearby have the pillow form.

3. MIDDLE AND LATER TERTIARY BEDS (COAL POINT SERIES OF BELL AND CLARKE).

The area east of a line drawn from the western end of Spirits Bay Beach to Te Hapua, Parengarenga Harbour, exhibits locally thick, extensive sedimentary beds of Middle or Later Tertiary Age. Hector (1872), McKay (1894) and Bell and Clarke (1910) have mapped and described Tertiary rocks from this area, but their work is far from complete. Bell and Clarke grouped the beds in their Tertiary Coal Point Series along wtih rocks on the north side of Parengarenga Harbour which actually belong to the Upper Cretaceous (Rahia) Series.

Although there is no definite evidence of interformational unconformities subdividing the beds of the series, these latter constitute three more or less separate groups or sub-series: an upper group consisting of fossiliferous mudstones, sandstones, grits and minor conglomerates; a middle sub-series of andesitic conglomerates; a lower group which includes sandstones, tuffs, mudstones and a prominent basal conglomerate. These will be considered in ascending order.

(a). The Lower Beds of Coal Point Series.

The lower beds of the Tertiary Series are developed in five localities:—the eastern end of Spirits Bay in the vicinity of Hooper's Point; along the coast east of Huka Creek; on the coast at the east margin of Waikuku Flat; at Parengarenga North Head.

1. *The Hooper Point Section.*

At the east end of Spirits Bay andesitic conglomerates of the middle group are strongly developed on the north wall of the valley of Kapo Wairua stream, and in an islet near its mouth. After an interval, these are succeeded northward by a lower conglomerate which unconformably overlies flows of the Older Volcanic Series (Trias-Jura), and is composed of pebbles and fragments derived from this latter series. It is about 20 ft. thick, and, as already noted by McKay, its lower portion is crowded with the broken remnants of a large cirripede which is probably the same species—*Hexalasma aucklandicum*—as is found in the basal conglomerate of the Waitemata Series on certain islands of Hauraki Gulf near Auckland. Overlying the basal conglomerate there are beds of fine sandstone and mudstone, which are exposed on the steep hill-slopes above the sea-cliffs at this spot. These sediments then pass beneath the andesitic conglomerates of the middle sub-series and, with the basal conglomerate, constitute the lower group of Tertiary beds at this locality.

The section is repeated in the bluff just east of Hooper Point. The cirripede conglomerate, 25 ft. in thickness, is again seen to overlie the Older Volcanic (Whangakea) lavas, and is in turn succeeded by a thickness of from 100 ft. to 200 ft. of fine sandstones and mudstones, which contain concretions of pyrite and dip at 25° south.

Several faults traverse the area, and one has dropped the Tertiary beds described against the mass of Whangakea rocks which forms the extremity of Hooper Point just west of this section.

McKay's (1894) observations at this locality were faulty and led him to place the cirripede conglomerate as the lowest part of his "Manukau Breccias," which are here called the andesitic conglomerates. Bell and Clarke (1910) follow McKay in this error.

2. *The Huka Creek Section.*

Three-quarters of a mile west of the mouth of Waitangi Stream, Tom Bowling Bay, sediments of the lower sub-series of Tertiary strata outcrop at the coast from beneath the andesitic conglomerates of the middle sub-series, and continue to be exposed westward along the coast for a distance of about a mile. At the east end of the section the beds consist of alternate bands of sandstone and mudstone, followed by two beds, 6 ft. and 30 ft. in depth respectively, of fine volcanic grit in which are broken fragments of molluscan shells, and which are separated one from the other by a few feet of mudstone. In downward sequence these in turn are followed by further mudstones and sandstones with shell fragments, which dip east or north-east at an angle of about 20°. For the next 50 yds. the section is obscured, but later, at the mouth of a small creek, there is a very good exposure of fine-bedded mudstones which dip in the same general direction as the preceding beds, but at a lesser angle. A quarter of a mile east of Huka Creek thin tuffaceous beds are interbedded with the mudstones, which then pass down into about 80 ft. of fine-grained volcanic tuffs which dip at about 15° to the north-east and become decidedly coarser at their base. These tuffs rest on a breccia-like mass of crushed slickensided and weathered material, the fragments of which consist largely of the andesitic or basaltic rocks typical of the underlying Older Volcanic Series, but which also include masses, 18 ins. to 2 ft. in diameter, of diorite and of a glassy flow-breccia similar to that locally characterising the Older Volcanic rocks of Cape Reinga and Pandora. This basal material is regarded as the equivalent of the basal conglomerate of other Tertiary sections. Immediately west of the mouth of Huka Creek, the tuff and basal breccia are intersected by a fault with unknown throw which trends north and south and dips at 70° to the east. On the shore-platform the tuffs dislocated by it grade into a rock of "baked" aspect which contains small argillaceous fragments set in a fine argillaceous matrix, and which is invaded by a large dyke of diorite which forms the headland west of Huka Creek. Beyond the dyke, flows of the Older Volcanic Series again appear and continue for some miles westward to Hooper Point.

The extent of the Tertiary beds is evidently limited, for the valleys of the headwater tributaries of Huka Creek were found to be carved in Older Volcanic rocks which outcrop almost continuously in the beds of the streams.

Elsewhere than at this locality, the thickness of the beds of the Lower Sub-Series does not exceed 400 ft.; here their disposition indicates that it cannot be less than 1500 ft., unless (as is indeed highly probable, since one such fault is known to delimit the western margin of the Tertiary beds of the Huka Creek area) there has been repetition of the strata by strike-faults.

3. *The Tawakewake Creek Section, Tom Bowling Bay.*

Tertiary rocks are again exposed at the mouth of Tawakewake Creek at the eastern end of Tom Bowling Bay, and for half a mile north-east along the coast. About 30 ft. of finely laminated sandy indurated mudstones project from beneath dune-sands on the western bank of the creek, and dip south-west at 35°. A sill of diorite, which has caused recognizable induration of the sediments, is in contact with them on their eastern margin, and continues for several hundred yards as a high coastal bluff to where its eastern, lower junction with the Tertiary sediments is clearly visible. These latter consist of about 40 ft. or 50 ft. of finely laminated sandy mudstones which dip south at 25°; some are highly indurated, remarkably fissile and varve-like. At the base of the section about 60 ft. of basal conglomerate unconformably overlies greatly shattered and disordered flows of the basement Volcanic Series. The conglomerate consists for the most part of angular fragments about 3 ins. in diameter derived from the subjacent Trias-Jura Volcanic Series, though fragments of much larger size are abundant. The cement is a highly calcareous material which is crowded with spines of echinoids and remains of bryozoans, while a few joints of a large *Isis* and several fragments of *Hexalasma* were also discovered.

McKay (1894) and Bell and Clarke (1910) do not appear to have visited this locality, for they make no mention of Tertiary rocks either here or at Huka Creek.

4. *The Wharekau Bay Section of Tertiary Beds.*

There is a further outcrop of the lower beds of the Tertiary Series in the sea-cliffs at the north end of Wharekau Bay, which is on the east coast about 2 miles south-east of the section that has just been described. This locality was visited by McKay and Bell and Clarke, but appears to have been rather cursorily examined.

At the north end of the beach the cliffs shew a considerable development of brown volcanic grits which dip gently south. McKay (1894) describes a band of "coralline and foraminiferal limestone" overlying these tuffaceous beds, but, as the tide was high, this could not be examined by the writers of this paper. A short distance further north, white sandstones outcrop high up in the cliffs and dip south above the grits, whilst a few hundred yards still further north there is a disturbed fault-zone in which the tuffaceous beds, the white sandstones and highly fissile sandy indurated shales similar to those of Tom Bowling Bay are all involved. A large mass of diorite about 400 yds. in width here invades the Tertiary rocks, and is exposed in a series of rocky bluffs along the coast. The brown arenaceous character of the weathered rock, and the regularity of its major joints, cause so remarkable a field resemblance to massive sandstone that it was mistaken for such by McKay. The outcrop of the Tertiary sequence is continued beyond the northern edge of the diorite in the sea-cliff about a mile and a half west of North Cape. The basal bed is a heavy breccia, 70 ft. or 80 ft. in depth, which is composed of material derived from the Older Volcanic rocks which it unconformably overlies. It is overlaid by a finely-bedded, white sandstone of unknown though not great thickness, which dips at 20° to the south-south-west, whilst it is displaced by an oblique fault along which a dyke of dolerite is injected. Unfortunately, McKay failed to realise the nature and significance of the basal breccia, which he considered to be the lower part of his " Manukau Breccias."

5. *The Section at Parengarenga North Head.*

It is finally necessary to include in the lower sub-series of the Tertiary succession, carbonaceous green sandstones, mudstones and grits, with irregular lenses of impure lignite, which underlie the andesitic conglomerates of the middle Sub-series, and outcrop along a limited stretch of the shore-line east of Dyson's old station on the north side of the entrance to Parengarenga Harbour, though the beds were left unvisited by the present writers owing to lack of time. Hector (1872) gives a very complete description of the beds of this locality, in which he states that the general dip is about south-west and the total thickness of the beds exposed over 300 ft. On the evidence of plant fossils McKay (1894) correlates these rocks with the lignites and plant-bearing beds of Cooper's Beach, Mongonui, and of St. Paul's, Whangaroa.

Correlation of Lower Beds of Tertiary Series.

Summarizing the evidence disclosed by the sections, the following general upward sequence is recognizable in the Tertiary strata:—

(a) *Lower Beds.*
  1. Coarse basal conglomerate. Marine. Depth generally considerable (up to 70 ft.), but only a few feet at Huka Creek.
  2. Sandstones and mudstones which are largely marine in origin and of shallow water character. Partly terrestrial or lacustrine, for lignites are present at Parengarenga North Head. Depth at least 100 ft. to 200 ft., but may be as much as 1500 ft. in the Huka Creek section. Thick tuffs (100 ft. or more) are interbedded at Huka Creek, and at the north end of Wharekau Beach, at more than one horizon. The sandstones are invaded by a thick mass of diorite at the north end of Wharekau Beach and at Tawakewake Stream, at the east end of Tom Bowling Bay.

(b) *Andesitic Conglomerates,* about 1,000 ft. in maximum thickness, constituting the " Middle Beds."

(c) *Upper Beds.*—Thick sandstones at east end of Spirits Bay, at Wharekau and east of Flat Point, Parengarenga Harbour.

Owing to their misinterpretation of the lithological nature of the basal conglomerates, McKay and Bell and Clarke correlate the Lower Beds with the Andesitic Conglomerates (" Manukau Breccias ") of Auckland district, and with similar fragmental beds at Whangaroa which Bell and Clarke (1909) have named the Wairakau Series. The presence of *Hexalasma* and other Tertiary fossils in the conglomerate suggests, however, that the Lower Beds should be correlated with the

Waitemata Series of Auckland, which lies immediately below the Manukau Breccias.

The contact of the Tertiary beds with the Upper Cretaceous sediments of the Rahia Series has not yet been observed, so that the exact relations of the two series is obscure. Nevertheless, the fact that the former strata rest directly upon the Older Volcanic Series in the vicinity of North Cape, though, on the northern shores of Parengarenga Harbour, at no great distance from North Cape, a great thickness of Rahia beds is developed, is better explained by supposing that near North Cape these latter were eroded from the basement of Older Volcanic rocks prior to Tertiary sedimentation, than by postulating overlap. The steeply folded and intensely shattered nature of the rocks of the Rahia Series, which contrasts with that of the Tertiary strata of the area, also suggests that the former were subjected to an early Tertiary orogeny which later beds were spared. This probability is strengthened by the evidence in favour of unconformity between probable Upper Cretaceous (Onerahi Series) and Tertiary (Waitemata Series) beds in the Whangarei and Auckland districts which has recently been brought forward by Ferrar (1921, 1925) and Bartrum (1924).

(b). *The Andesitic Conglomerates or the Middle Sub-Series of Tertiary Strata.*

The middle beds of the Tertiary Series are coarse andesitic conglomerates which have a maximum thickness of over 600 ft. and, in some places, of probably not less than 1000 ft. These conglomerates occupy the greater part of the area over which the Tertiary beds of the area now described are exposed, and outcrop along a continuous belt from the east end of Spirits Bay, through Munro's station at the north end of Parengarenga Harbour, to the east coast, where they outcrop discontinuously from the North Head of this latter harbour north to Wharekau Bluff. McKay (1894) and Bell and Clarke (1910) also map these rocks as extending in a strip from a short distance inland of the western end of Spirits Bay Beach, through to Waitiki Stream near Te Paki, whilst Bell and Clarke (*loc. cit.*, p. 619) record good exposures of them on the track from Parenga to Te Paki. Earlier maps appear to be incorrect in extending the conglomerate beyond the north bank of Waitiki Stream, for the writers traced the Older Volcanic (Whangakea) rocks for several miles east from Te Paki along the route to Te Hapua.

As will be shown in the section on petrography, the conglomerates consist essentially of well-rounded pebbles of andesite a few inches in diameter, which have been laid down in thick roughly-bedded strata. Their best outcrops are furnished by the occurrences at the east end of Spirits Bay, at the coast west of Waitangi Stream and in the headlands of the east coast such as those at Wharekau, at Maukin Nook, at Coal Point and at Parengarenga North Head.

At Spirits Bay the beds form a prominent cuesta which trends N.W.-S.E. and dips at 20° south-west to Kapo Wairua Creek, and are somewhat coarser in their material than elsewhere. West of Waitangi Stream the conglomerate is in well-bedded strata which dip at 20° to the east. The material there includes a fairly large proportion of diorite in addition to the usual andesitic pebbles, and a number of irregularly shaped bombs with glassy chilled crusts.

On the south side of the headland at Wharekau the conglomerate is covered conformably at high levels by sandstones, and, towards the south, is followed at beach level by a series of sediments which dip south-west at 25° and closely abut against a mass of the conglomerates which is disturbed by faults causing rapid variations of direction of strike and dip. The actual contact of the two sets of beds is not visible, but it seems probable that the sediments belong to the Upper Sub-Series of Tertiary strata.

The direction and steepness of dip vary somewhat rapidly in the conglomerate at Wharekau and southward towards Coal Point, but, west from this latter locality, the dip is prevailingly towards the south-west, generally at angles of 15° or 20°. The synclinal structure recorded by Bell and Clarke (1910) could not be recognized. The beds of the headland in which Maukin Nook is situated have generally a gentle dip to the east, though Bell and Clarke (1910) record from here (= Coal Point of Bell and Clarke's map) a band of interbedded lignite 6 chains long and 1 ft. thick which dips south at 35°. The present writers did not see this bed for they did not visit the shores of the Nook itself, but they observed numerous carbonized and silicified tree-trunks, one not less than 20 ft. in length and 1 ft. in diameter, and noted the abundance of shale and mudstone relative to andesite in the conglomerate, and the much smaller size of the constituent pebbles as compared with those of other outcrops.

At a small headland immediately south of Dyson's at the North Head of Parengarenga Harbour, the conglomerates outcrop in juxtaposition to débris of Upper Cretaceous (Rahia) beds. Their substantial conformity both with the sediments of the Upper Sub-Series of Tertiary beds and with those of the Lower Group below them is undoubted, and conditions of occurrence at Parenga and near Dyson's, taken in conjunction with evidence in favour of unconformity of the Upper Cretaceous to the Tertiary strata elsewhere in Auckland Province, suggest that the conglomerates have overlapped upon resistant erosion-residuals of Cretaceous rock.

On the east shore of a small inlet about a mile and a half east of Flat Point, Parengarenga Harbour, the andesitic conglomerates emerge from beneath a thick south-west dipping series of sandstones with which they appear to be conformable. These latter are mapped by McKay (1894) as *below* the conglomerates, but, in the absence of reliable palaeontological evidence, they are here placed on stratigraphic grounds in the overlying Upper Sub-Series of beds. As, however, the writers could not find time to visit the coastal section eastward towards Dyson's, and other perhaps vital areas immediately north of Te Hapua, they wish freely to admit the possibility that the sequence they have just described may have been inverted by thrust faulting.

(c). *The Upper Beds of the Tertiary Sequence.*

The Upper Beds of the Tertiary Coal Point Series include sandstones, mudstones. grits and minor conglomerates, which are developed extensively inland from Spirits Bay Beach and along the northern shores of Parengarenga Harbour. Similar beds have minor development in sea-cliffs immediately south of Wharekau Bluff on the east coast. The maximum thickness of these Upper Beds may be as great as 1,000 ft.

Inland from Spirits Bay Beach the area underlain by these sediments consists of low hills which contrast strikingly with the much steeper and higher hills carved in the more resistant flows of the Older Volcanic Series to the west and in the andesitic conglomerates to the east, and, like these latter, often reproduce the cuesta type of divide. The strata of this area consist of soft sandstones, alternating with thinner beds of mudstone; they dip approximately south-west at low angles and are practically devoid of fossils. McKay describes them as conformably overlying the andesitic conglomerates, but Bell and Clarke map them as " Older Débris " of Pleistocene age. Their inclined disposition, conforming with that of the andesitic conglomerates, and their lithological difference from the Pleistocene accumulations of the area descibed in this paper, indicate, however, that Bell and Clarke's alteration of McKay's mapping is not justified.

Good exposures of sandstones, grits and mudstones with occasional thin lenses of greywacke-conglomerate, are displayed in the cliffs along the northern shore of Parengarenga Harbour for distances of about a mile north and two miles east of Flat Point, while conglomerates containing, amongst other material, flinty boulders apparently derived from subjacent Upper Cretaceous beds, appear to be interbedded with the finer sediments on the crests of the divides about a mile inland. The beds are fossiliferous, but no collecting was possible in the limited time available. Their dip varies considerably in magnitude, but preserves a fairly constant south to south-west direction. As already stated on p. 116 the writers place these beds *above* the andesitic conglomerates and not *below* them as was done by McKay (1894).

On the south side of Wharekau Bluff sandstones, with thin intercalated beds of mudstone, which lie conformably above the andesitic conglomerates constituting the bluff, are well displayed at high levels. A few chains south of these high-level outcrops there is a fault, and, beyond this, about 150 ft. of sandstones appear at beach level and dip south-west at 25°. Interbedded with them there is a tuffaceous band which contains a few large bryozoa, numerous fragments of crushed molluscan shells, broken echinodermal remains and occasional foraminifera. It appears probable that these are down-faulted representatives of the sandstones overlying the volcanic conglomerates.

4. Pleistocene and Recent Deposits.

Under the heading of Pleistocene and Recent deposits are included all those rocks which have accumulated since the first great uplift of the Kaikoura orogeny, which closed the cycle of Tertiary marine sedimentation in North Auckland approximately in early Pliocene times.

Possibly the oldest beds of this group are those described from the southern end of Twilight (Rahia) Bay by Bell and Clarke (1910) as members of their " Older Débris."

In this locality a horizontal basal bed about 2 ft. thick, composed of small well-rounded pebbles, rests unconformably upon older rocks (Rahia Series) and passes up into about 50 ft. of horizontally-bedded white and yellow sandstones, which, in turn, give place upwards to consolidated dune-sands.

Similarly, two small outliers of white sandstone, which lie above the andesitic conglomerates on the plateau-like divide immediately west of the mouth of Waitangi Creek, shew horizontal stratification and appear to be subaqueous in origin. Such gravels and sands are probably fluviatile deposits of local extent, which belong to the same series of beds as the dune-sands above them.

Drifting dune-sands of Recent age and their consolidated Pleistocene equivalents occur extensively along many of the coastal areas, particularly south of Cape Reinga and in the vicinity of Parengarenga Heads, and have a remarkable development in the giant tombolo south of the area described in this paper. Recent dunes characterise the coastal portions of areas where filling and progradation have followed the widespread and considerable depression, which, as already noted in the Physiography Section, affected the North Cape-Cape Maria van Diemen terrain in common with the rest of North Auckland in Sub-Recent times.

In some localities, notably about three-quarters of a mile east of Cape Maria van Diemen, the consolidated dune-sands contain thousands of shells of terrestrial gasteropods (see Fig. 7), amongst which are the following species:—*Placostylus hongii ambagiosus* Sut., *Rhytida duplicata* Sut., *Realia turriculata* Pf., *Paryphanta busbyi* (Gray), *Serpho kivi* (Gray) and others.*

Similarly, innumerable ancient Maori middens and ovens are exposed in the dune areas of the coasts, and, whilst human bones and chips of obsidian are often very abundantly associated with these, polished implements or ornaments are surprisingly scarce.

As these Recent and Pleistocene sands have been described in detail by previous writers, nothing further need be added in the present description, unless to make mention of the remarkable badland topography carved at the north end of Twilight Bay from ancient dune material (see Fig. 4), and to remark on the fact that, a little east of the sand-dune area of this locality, the deep clays of less elevated portions of the topography are highly suggestive of loess.

In addition to the types of deposit already described there are alluvial gravels and silts which mantle terraces and small flood-plains in the lower reaches of many of the streams and belong to this group of beds, whilst there are also estuarine sands with Recent molluscs, which have been described by McKay (1894) as building extensive flats, such as that at Flat Point, about 10 ft. or 15 ft. above high-water level around the borders of Parengarenga Harbour.

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*The writers are indebted to Mr. A. W. B. Powell for identification of some of these species.

INTRUSIVE ROCKS AND GENERAL PETROGRAPHY.

This section of the present paper is reserved for description of the igneous rocks, which may conveniently be grouped as follows:—

A. Intrusive Rocks.
Rocks intrusive into members of the stratigraphic series already described.
B. The Older Volcanic (Whangakea) Series and Later Pillow-Lavas.
C. The Mid-Tertiary (Coal Point Series) Conglomerates.
D. Igneous Rocks of Uncertain Horizon.

A. INTRUSIVE ROCKS.

The intrusive rocks of the district may be considered to fall broadly into two main groups which are based upon both field and petrographic characters. One of these lends itself to further subdivision.

1. Peridotitic and Gabbroid Rocks of the Kerr Point-North Cape Mass. Probably Early Cretaceous in age.
2. Minor Intrusions.
   (a) Dykes of diorite and dolerite of pre-Miocene age.
   (b) Dioritic intrusions in the Coal Point sediments. Probably Miocene in age.

1. *Peridotitic and Gabbroid Rocks of the Kerr Point-North Cape Mass.*

General Description.

A most interesting series of ultrabasic and gabbroid rocks was discovered by Bell and Clarke (1910) at the coast near North Cape and Kerr Point. Whilst the present authors cannot claim to have made a thorough examination of the area, they consider, nevertheless, that Bell and Clarke overestimate the importance of noritic or gabbroid rocks in relation to the peridotitic. The coast at North Cape, and thence north-west for half a mile and south-west for over a mile, consists, it is true, wholly of gabbroid rocks, but at Kerr Point ultrabasic rocks were followed continuously from both the west and the east margins of their occurrence for distances aggregating well over half a mile, and preponderated in quantity over the gabbroid. The dominant rocks proved to be peridotites and pyroxenites which are generally in relatively unaltered state, though sometimes considerably serpentinized. These have been intersected by numerous small discontinuous lensoid bodies or larger dykes of gabbroid rocks, which shew considerable variety both in mineralogical constitution and texture, and are especially prominent on the western margin of Kerr Point. At this last locality they include an extremely coarse norite containing hypersthene, hornblende and diallage, in which the crystals are sometimes over 4 ins. in largest dimension. It is almost impossible to separate the various ultrabasic rocks one from another in the field, for partial serpentinization of olivine completely masks the character of many types. Microscope sections demonstrate, however, that they differ rather markedly in the proportions of the olivine and pyroxenes present, and range from dunite-serpentine to lherzolite and wehrlite. One section of serpentine (N.C. 19) shews that the rock from which it was cut may have been derived from harzburgite of which the original enstatite is now represented by "bastite," but not one of the 31 slices cut from various portions of the gabbroid and ultrabasic intrusions shews any identifiable enstatite, though numbers possess hypersthene which contains relatively so little iron that its pleochroism is scarcely distinguishable. The optical character of the mineral was tested time and time again, and proved always to be negative, whilst the curvature of the hyperbolic brushes in interference figures indicated an optic axial angle less than that of either enstatite or bronzite. It thus appears probable that the mineral recorded by Bell and Clarke (1910, p. 623) as enstatite should be called hypersthene.

As already remarked, it is difficult to estimate exactly what part harzburgite-serpentine or dunite-serpentine plays in the make-up of the main intrusion, for insufficiently numerous sections of the general serpentine, of which most other types appear to be subsidiary phases, were made to do more than establish the presence of both facies.

Wehrlite (N.C. 18, 18a) possessing different degrees of coarseness of grain is very abundant on the west edge of Kerr Point, whilst on its eastern border, a little north-west of North Cape, there is a considerable mass of lherzolite, as already described by Bell and Clarke (*loc. cit.*). Pyroxenites similarly are occasionally prominent, as is exemplified by a websterite (N.C. 52) on the western portion of the Kerr Point promontory, and by a lherzolitic rock (N.C. 14) immediately west of the North Cape lherzolite that has just been mentioned.

Detailed Description of Ultrabasic Intrusive Rocks.

In the rock described as wehrlite (N.C. 18, 18a), diallage, and serpentinized olivine associated with the usual strings of magnetite, are sub-equal in amount, the large rather rounded crystals of the former being enwrapped by the latter (see Fig. 8). In section N.C. 18a the lamellar twinning of the diallage is made obvious by what appears to be incipient alteration to some unidentified product. In the lherzolite (N.C. 1, 38) the grain-size is large, for crystals ½ in. or more in length are not uncommon. The proportions of olivine to pyroxene vary, but the former mineral is at least equal in amount to the latter. The olivine is partially serpentinized and has given rise to dense strings and masses of secondary magnetite. In one section (N.C. 38) the pyroxene is mainly hypersthene which exhibits fine-scale lamellar twinning and poicilitically encloses chondri of olivine, but there is also a little colourless monoclinic pyroxene which appears to be augite. In the other section (N.C. 1) the augite is perhaps more abundant than the hypersthene, though in much smaller crystals. A little interstitial altered basic plagioclase is present, whilst small amounts of bastite, talc and uralite are associated with the pyroxene. The lherzolitic rock (N.C. 14) recorded from near the typical lherzolite just described, contains a greatly reduced quantity of olivine (25 per cent.). There is no feldspar and the pyroxene is mainly augite, though polysynthetically-twinned hypersthene is represented by a few crystals. Some of the pyroxene is permeated by minute vermiform markings which seem to be elongated fluid inclusions, though their appearance strongly resembles that obtained with micrographic intergrowth. Brownish-green hornblende occurs in ragged crystals which are chiefly concentrated along a narrow shatter-zone; with it there is a quantity of secondary bladed actinolite, whilst chlorite and talc are found elsewhere as derivative of the pyroxene.

The websterite (N.C. 52) recorded above is essentially a diallage rock, though hypersthene is also an important constituent; incipient alteration has again caused the lamellar twinning of the diallage to be especially obvious.

In addition to the pyroxenites described, there are occasional small dykes of an altered diallage rock (N.C. 11) in which a small quantity of greenish hornblende, tinged here and there by brown, is the only constituent besides the diallage.

This latter mineral is often altered to an almost opaque whitish product in which the high birefringence of the original mineral is still recognisable.

Gabbroid Rocks of the Minor Intrusions Associated with the Ultrabasic Complex.

Gabbroid dykes invade the peridotites and allied rocks described in the last section, especially on the west margin of the mass. In hand-specimen the rocks of these dykes are generally normal coarse-grained types. Their varieties include granophyric quartz gabbro; anorthosite or anorthositic gabbro; olivine norite or gabbro; gabbros and norites with occasional hornblende in addition to both monoclinic and orthorhombic pyroxenes; and finally gabbros in which the usual pale-green augite is largely converted to uralite.

The granophyric quartz gabbro and the olivine gabbros or norites were not located *in situ,* but were identified from sections cut from large beach boulders at the west margin of Kerr Point. The quartz gabbro (N.C. 53) has a most unusual structure. Uralite is an abundant constituent; it is associated with cores of almost colourless greenish augite and a small amount of probable hypersthene and is in slightly less quantity than plagioclase (basic labradorite). The latter mineral is in two generations, for there are crowded nests of lath-like crystals about 0.4 mm. in length around which large crystals of plagioclase have crystallized (see Fig. 11). Meanwhile, the uralitized pyroxene ophitically enwraps the feldspar and occasional large masses of iron ore. Finally, there is a moderate quantity of interstitial micrographically intergrown material, which consists of quartz and an albite-twinned feldspar possessing an index of refraction greater than that of Canada balsam.

Generally the feldspars present very clean-cut idiomorphic borders to the micropegmatitic material, but in a few instances the margins of the larger crystals are somewhat ragged. Dr. W. N. Benson has suggested in explanation of the unusual relations between the two generations of feldspar, that the larger crystals began crystallization at an earlier date than the smaller, but later continued the process contemporaneously with the latter, and thus finally were moulded upon them.*

*Personal communication.

The more typical gabbros vary rapidly in facies as a result of differences in the proportions of the constituent minerals. More leucocratic phases are represented by anorthositic rocks which occur as narrow dyke-like portions of larger gabbroid masses with the usual abundant ferromagnesian minerals. One such rock when sectioned (N.C. 39) proved to be composed of about 80 per cent. of plagioclase (? basic labradorite), with a little over 15 per cent. of colourless monoclinic pyroxene (? diopside) and a relatively large amount of rather strongly pleochroic sphene. This last mineral occurs as small wedge-shaped crystals, which are collected in bar-like aggregates in close association with the pyroxene, and possibly represent original ilmenite. The feldspar is somewhat shattered, so that exact determination of its variety proved impracticable. Another unusual leucocratic rock forms conspicuous veinlets, a few inches wide, in the lherzolite north-west of North Cape. It is a coarse-grained rock with dark ferromagnesian crystals as much as 1 in. in length, and quite a number of small amber-coloured grains of sphene visible in hand-specimen. Whitish material constitutes about 75 per cent. of the rock and proves in section (N.C. 76) to be plagioclase which is now largely converted to scales of a moderately highly refractive and strongly birefringent mineral. This has positive optical character and negative elongation, so that it is probably prehnite. With the prehnite there are minute ramifying veinlets of actinolite, whilst the large dark crystals of ferromagnesian mineral are brown hornblende or a pale-green variety fringed with brown. The sphene recognised macroscopically is not plentiful in section.

Amongst other gabbros, mention may be made of an irregular lens-like intrusion of hornblende gabbro (N.C. 42) which penetrates the serpentine near its extreme westerly margin at Kerr Point. Its feldspar (basic labradorite) varies from point to point in its proportions relative to hornblende, but appears generally to be in excess of this latter. It is associated with derived rosette-like groups of prehnite and minute spherulitic growths of chlorite. There is a large amount of pale-green to bluish-green primary hornblende, and abundant fibrous secondary amphibole, wedged in between crystals of plagioclase, whilst in parts of the section there are relatively large masses of sphene and magnetite. The structure is coarsely holocrystalline and frequently ophitic. Hypersthene and pale-green augite or diallage are the most plentiful ferromagnesian constituents, and, though all have been more or less converted to uralite, augite is the first to suffer such alteration. The hypersthene generally exhibits the usual multiple twinning, and frequently is minutely intergrown with monoclinic pyroxene disposed along the composition planes of the twin. Hornblende generally accompanies the pyroxene, usually forming intergrowths with this latter. It is doubtful whether or not it is primary; it may be magmatically derived from pyroxene as so often appears to be the case with the amphibole of gabbroid rocks. Usually it is greenish-brown in colour, but may be pale-green.

Hypersthene and monoclinic pyroxenes (both augite and diallage) are present in nearly all the varieties of gabbroid rocks, and in such nearly equal proportions that the latter must be classed as noritic gabbros. There is no hypersthene, however, in a uralite-augite gabbro (N.C. 50) which forms a 20 ft. dyke on the extreme west border of the peridotites. Olivine norite-gabbro was identified only from large beach boulders. About 8 per cent. to 10 per cent. of olivine is present in the rocks sectioned (N.C. 49, 58); it is in moderately unaltered crystals which accompany the other ferromagnesian minerals usual in these rocks.

The Noritic Gabbro of North Cape.

An extensive mass of gabbroid rock forms the coast for about half a mile north-west and over a mile south-west from North Cape. The rock is typically a fine-grained basic type, but is subject to variations in texture, and, near North Cape itself, is strongly gneissic in structure (see Fig. 9). The foliation is believed to be due to piezo-crystallization; it is very regular in orientation and trends approximately N.W.-S.E. with a dip of 20° to the south-west. Locally it is on a very fine scale, but more generally it is coarse and regular, exhibiting laminae about ⅛ in. in depth which are alternately rich in feldspar and ferromagnesian minerals. West of North Cape this gneissic rock is associated with lherzolite, but the mutual relations were not determined.

It is difficult to conceive how the variations of structure and certain alternations of texture and mineralogical differences shewn by different parts of the main gabbroid intrusion can be due to divergences in the rates of cooling of different portions of a single injected magmatic body, and, although no supporting evidence was obtained in the field, it appears more probable that the intrusion was not a single event, but partook of the nature of a multiple injection of bodies of almost identical magma, probably at closely spaced intervals of time. On this hypothesis, the gneissic portion of the gabbro is capable of two interpretations. In the first place it may be considered the earliest phase of the invasion of magma. If this be so, the unilateral pressure responsible for its foliation must largely have found relief before later injections occurred, for the only suggestion of oriented stress furnished by other rocks of the mass lies in granular pyroxene and ragged, bladed uralite illustrated by two of the sections prepared from representative rocks.

As an alternative, it is conceivable that the gneissic gabbro was the last phase of the intrusion, and that the earlier associated gabbros had been intruded in advance of an epoch of severe pressure which accompanied the injection of the gneissic body. Following this view, the foliation of this latter, lacking in the earlier gabbros, was possible only because of high temperature (the temperature of solidification) acting in conjunction with pressure. The first of these interpretations, namely, that the foliated portion of the gabbroid intrusion represents the earliest phase of the injection, appears to the writers to be the more probable.

The gabbroid rocks prove microscopically to be more or less ophitic noritic gabbros in which the femic minerals are generally in excess of the feldspar (either basic labradorite or bytownite). The ferromagnesian minerals are generally augite, hypersthene and uralite, which is extensively developed from both pyroxenes, though more especially from the augite. In one or two rocks (N.C. 8, 10) conversion to uralite has almost been completed (see Figs. 12, 13). In most instances augite has been present originally in greater quantity than hypersthene. In one slide (N.C. 10) a little probable quartz is present, though it does not lend itself to ready identification. In this same rock, there is also a little minutely micrographic material and a small quantity of an interstitial mineral, in fibrous radial sheaf-like aggregates, which appears to be a feldspar. In another rock (N.C. 9), brownish-green hornblende is plentifully associated with pyroxene as if intergrown with it, and appears to be derived from the latter mineral. The pyroxene is in small granular crystals about 0.2 mm. in diameter, whilst the plagioclase has especially ragged outlines as a result, it is believed, of unilateral pressure. (See Fig. 10).

A number of narrow holocrystalline dykes of lighter colour than the general rock penetrate the gabbro south-west of North Cape. Of those sectioned, one (N.C. 40) is very similar to the diopside-sphene-rich rock described by Bell and Clarke (1910, p. 623) as forming dykes in the lherzolite near North Cape, but differs in possessing a greater amount of feldspar. The rock here described is an even-grained holocrystalline type with about 50 per cent. of colourless pyroxene (? diopside), between 1 per cent. and 2 per cent. of sphene and the remainder basic labradorite. The rock of another such dyke (N.C. 4) was found to be a quartz-augite diorite. The feldspar (acid labradorite) is in rather lath-shaped crystals and dominates over almost colourless partially uralitized augite. There are groups of sphene and iron-ore, though these minerals are not unusually abundant, whilst quartz constitutes about 10 per cent. to 15 per cent. of the rock. Still another type (N.C. 24) is dominantly feldspathic, with only about 15 per cent. of pyroxene (? diopside) and with about.2 per cent. of sphene. The feldspar is greatly altered and weathered, and is replaced here and there by large clear masses of a zeolite which resembles natrolite.

An analysis of a typical moderately coarse-grained noritic gabbro (N.C. 48) from near the southernmost margin of the gabbroid mass is given in Column 1, Table 1. The rock is somewhat ophitic, with about 40 per cent. of modal plagioclase, and is relatively free from decomposition or alteration. Augite is slightly in excess of hypersthene, and has been the later of the two to crystallize, for it is often moulded upon the hypersthene. The analysis calls for no special comment apart from its high percentage of lime, which is co-ordinated with a high proportion of normative anorthite.

Age of the North Cape-Kerr Point Intrusives.

West of Kerr Point, and also on the east coast a short distance south of Whiriwhiri Stream, the peridotites and gabbros appear to invade the flows of the Older Volcanic Series, which are intensely shattered and crushed near the contact, and frequently are impregnated with pyrite, which is also found in some of the intrusive rocks themselves. They thus definitely post-date the Older Volcanic Series, and, as already indicated in a previous section, though the date of intrusion may therefore possibly be Eocene (p. 109), the gneissic nature of some of the rocks in question strongly supports the probability that they were injected in Early Cretaceous times, and broadly speaking, accompanied the great orogenic movement which closed the Hokonui period of sedimentation in New Zealand.

2. MINOR INTRUSIONS.

In addition to a closely related series of intrusions forming part and parcel of the Kerr Point ultrabasic and gabbroid mass, there are a number of injections which fall fairly completely within two groups so far as date of intrusion is concerned.

The earlier group has invaded rocks of the Older Volcanic (Whangakea) Series of probable Trias-Jura age at a date prior, it is believed, to the conclusion of the orogeny which terminated the prolonged Trias-Jura sedimentation, for the rocks of several of the intrusions indicate by bent lamellae of plagioclase, and other signs, that they have been subjected to considerable pressure during or since their consolidation.

If the Older Volcanic Series is correctly assigned to the Hokonui System, it would then appear most probable that the early Cretaceous orogeny not only affected the lavas of this series but also the rocks of intrusions which were themselves an accompaniment of the early phases of the orogeny.

The second group of intrusions referred to intrudes into the sediments of the Coal Point Series (? Miocene).

(a). *Pre-Miocene (? Early Cretaceous) Intrusive Rocks.*

Most of the dykes included in this group are placed there because, as has just been stated they intrude into the older volcanic rocks and shew evidence of having been subjected to intense pressure since their consolidation. Though the intrusions are quite small, their rocks have plutonic facies, thus indicating that considerable depths of the original cover have been removed since the injection of the dykes. It is by no means improbable that the period of intrusion of the majority was the same as that of the Kerr Point ultrabasic and gabbroid mass.

The examples recorded could doubtless have been increased considerably if thorough examination of the northern coast had been practicable.

They are:—

1. A wide dyke of micrographic pyroxene-quartz diorite (N.C. 61) outcropping at the shore about 1 mile east of Cape Maria van Diemen.
2. A narrow dyke of pyroxene diorite (N.C. 2) discovered in the sea-cliff near the mouth of the stream at Pandora, Spirits Bay.
3. An intrusion, probably of limited size, represented by large blocks on the east wall of the valley at Pandora about 300 yards south from the shore-line. Its rock is an augite diorite containing brown hornblende (N.C. 41).
4. A doleritic dyke, 21 ft. wide, trending N.65° W., associated with pillow-lavas at the southern end of Twilight (Rahia) Bay. There is no evidence of pressure having affected the rock of this intrusion, but its petrographic similarity to the pillow-lavas suggests that it is the hypabyssal equivalent

of these latter, which the writers have included in the Upper Cretaceous Rahia Series.

Macroscopically this rock closely resembles à greensand upon casual inspection, but the rocks of the other dykes in this group are typical fine-grained dioritic types.

Examined microscopically the pyroxene-quartz diorite (N.C. 61) recorded from 1 mile east of Cape Maria van Diemen proves to be a moderately even-grained holocrystalline rock containing approximately 60 per cent. of plagioclase (acid labradorite) in lath-like crystals which seldom exceed 1 mm. in length, and which are built around about 25 per cent. or more of sub-idiomorphic slightly titaniferous pyroxene and about 10 per cent. of ilmenite in large crystals. Here and there are masses of minutely micrographically or spherulitically intergrown material enclosing large crystals of plagioclase or other earlier mineral. The spherulites appear to be almost wholly feldspathic; the micrographic intergrowths are on so fine a scale that exact identification of the constituent minerals is not possible, yet a small amount of quartz was detected elsewhere in the section and it is probable that both quartz and feldspar (? orthoclase) are present in the intergrowths. There is no evidence that the material is myrmekite. It appears rather to be a product of end-stage crystallization as described by Colony* for similar intergrowths in noritic rocks from Sudbury, Ontario, and elsewhere.

The pyroxene diorite from Pandora (N.C. 2) is a weathered fairly coarse-grained rock with abundant very pale green augite in granular aggregations which suggest shattering by pressure. Larger, less plentiful crystals of hypersthene accompany the augite. Secondary amphibole and chlorite abound in some parts of the slide and may be in stellar and sheaf-like forms. The pyroxene-hornblende diorite from the Pandora valley is similarly an altered and weathered type with prominent kaolin and chlorite. The femic minerals are subidiomorphic deep-brown hornblende with a less amount of pink titaniferous augite and 4 per cent. or 5 per cent. of ilmenite. There are numerous small sharp prisms of apatite and a very little radially fibrous mineral which appears to be a feldspar. Plagioclase constitutes about 60 per cent. of the rock by volume but is so weathered that its variety was not determined with certainty; it is apparently basic andesine.

The last of the rocks described in this group—the dolerite from Twilight Bay (N.C. 33)—is a coarse-grained ophitic rock which has been greatly altered and weathered. Pinkish, faintly pleochroic augite (about 25 per cent.) and ilmenite (about 5 per cent.) in long irregular rods are the only primary femic minerals, unless rare chloritic pseudomorphs preserving cracks and form suggestive of olivine actually represent that mineral. The plagioclase sometimes encloses close-spaced needle-like prisms of brown hornblende or of pale-green augite. Needles of apatite are ubiquitous. Weathering again militates against exact determination of the variety of the plagioclase. It is, however, at least as basic as acid labradorite. The

*R. J. Colony, The Final Consolidation Phenomena in the Crystallization of igneous Rocks, *Journ. of Geol.*, vol. 31, 1923, pp. 169-178.

secondary minerals include chlorite, a little opal, chalcedony in radially built masses and a poorly refractive and poorly birefringent mineral in radial or divergent fibres which is associated with the chalcedony. It generally is very deeply clouded, or even rendered almost opaque as a result of some form of decomposition, and is referred with considerable doubt to some or other zeolite (? stilbite).

The classification of this rock as a dolerite is perhaps open to doubt in view of the uncertainty of the variety of the plagioclase. Its strongly ophitic structure, however, points to this being its correct position.

(b). *Intrusions in the Coal Point Sediments (? Miocene).*

Three important intrusions were located in sediments of the Coal Point Series (? Miocene) not far from Kerr Point and North Cape. One of the largest is a sill of quartz-augite diorite (N.C. 5), 300 ft. or 400 ft. in depth, which intrudes into fine-grained sandstones near the base of the Coal Point Series as developed at the east margin of Tom Bowling Bay. Its lower surface is distinctly chilled and accords perfectly with the stratification of the laminated sandy mudstone beneath it. The mudstone exhibits no sign of metamorphism other than slight marginal induration at the western margin of the sill near the mouth of Tawakewake Creek.

In hand-specimen the diorite is a compact fairly finely crystalline rock which weathers deeply to a sandstone-like mass which can only be determined as igneous in relatively fresh examples. It contains about 45 per cent. of feldspar (acid labradorite), 15 per cent. of quartz and a very small quantity of micrographically intergrown quartz and orthoclase; the balance of the rock is mainly pale green augite with a moderate quantity of uralite, some greenish-brown hornblende, and magnetite in normal quantity.

A second member of this group of intrusions outcrops on the east coast a little north of Waikuku Flat. It is a mass of micrographic quartz diorite (N.C. 23) similar to the preceding one, but its relations to the intruded strata are not discernible and its thickness is greater than that of the sill just described. In its weathered condition at its outcrop it so closely resembles a sandstone as to have been described as such by earlier workers. In section the rock is dominantly feldspathic, the feldspar (acid labradorite) being in stout lath-shaped crystals which are accompanied by about 15 per cent. of quartz, and a lesser quantity of chlorite which is associated with occasional ragged remnants of brownish green hornblende and a little magnetite. There are, in addition, a fairly large proportion (10 per cent.) of micrographically intergrown quartz and feldspar which enwrap earlier minerals (see Fig. 17), and a few needles of apatite.

The third intrusion of this period intersects heavy basal conglomerates of the Coal Point Series outcropping on the coast 1½ miles west of North Cape. It proved to consist of a most interesting coarse-grained doleritic rock (N.C. 30) which includes alkaline varieties amongst its feldspars. These latter minerals constitute 50 per cent. of the rock, and are generally in lath-shaped crystals about 1 mm. in length; basic labradorite is the dominant variety, but there are also occasional crystals of albite, others of probable orthoclase and several fairly large anhedral ones of an unidentified alkali feldspar closely crowded with vermiform growths of chlorite. It has a refractive index considerably lower than that of Canada balsam, and shews faint, highly irregular sub-microscopic twinning reminiscent of that of anorthoclase. An additional section was made from the only duplicate available, but failed to shew any trace of the mineral in question, and it is therefore believed to be present as xenocrysts. There is a possibility that this feldspar is albite, for lath-shaped crystals of this mineral were detected by their low refractive index and positive optical character, but the irregular outline of the (?) anorthoclase suggests that its origin, in any case, differs from that of the more tabular albite. The analysis of this rock (No. 2 of Table 1, p. 131) shews its relative basicity. The content of alkalis, though not high, is above the average and is clearly due to the presence of modal alkali feldspar.

Immediately west of Huka Creek, Tom Bowling Bay, there is a massive intrusion which outcrops at the shore-line for several hundred yards, and which, though intersecting the Older Volcanic Series, has been injected along the course of a fault which dislocates the basal tuffs of the Coal Point Series in this locality. This mass thus belongs to the same period of intrusion as the others of this section and is, moreover, a micrographic quartz-augite diorite (N.C. 59) closely similar to other intrusive rocks of this period. The micrographic material is in comparatively small amount, whilst the augite is accompanied by a very little brownish hornblende.

In view of the fact that all four of the intrusions just described definitely post-date the Lower Beds of the Coal Point Series, it may be affirmed with safety that they were injected in later Miocene times, during the period of igneous activity which gave rise to semi-basic lavas from which the andesitic conglomerates of the Coal Point Series were derived.

B. Older Volcanic (Whangakea) Series and the Pillow-lavas.

Normal Whangakea Lavas.

One of the ubiquitous characters of the lavas classed here as the Older Volcanic Series is their poverty in phenocrysts. Rarely indeed is it possible to detect these latter in hand-specimens. It is unusual to find a succession of flows spread over a comparatively wide area which shew such uniformity in this respect, and this fact suggests that the uprise of the magma to the surface from considerable depths was a rapid process.

The lavas of this series have suffered extensive shattering and locally have been comminuted by shearing to such an extent that their true nature is completely masked, and only made decipherable by the discovery of cores of uncrushed igneous rock in the general shale-like material. Veinlets composed mainly of calcite, but with subsidiary zeolite, occupy the interstices between the fragments resulting from this shattering.

McKay (1894) was excusably misled by their aphyric character, into regarding this series of rocks as consisting of greywackes and shales. Bell and Clarke (1910), whilst shewing obvious doubt as to

Fig. 1.—View looking west to Cape Reinga, whence according to Maori tradition the spirits of the dead depart for the next world. Older andesites. Note the characteristic wave-cut platforms (tide nearly full).

Fig. 2.—Pillow-lavas at south end of Twilight Bay. The flow dips steeply to the left.

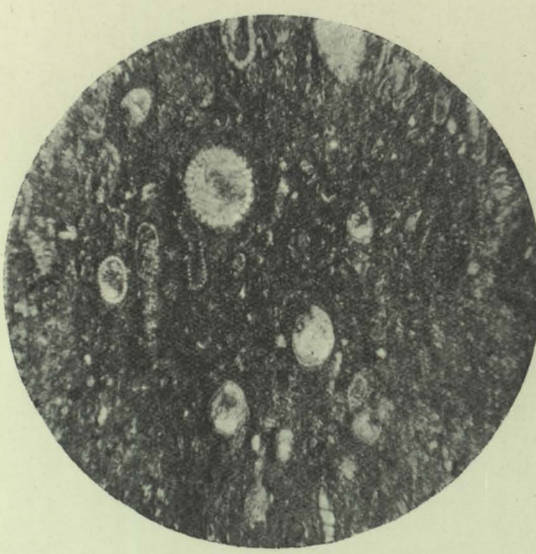

Fig. 3.—Photomicrograph of foraminiferal marl associated with pillow lavas of the Older Volcanic Series at Pandora (Whangakea), Spirits Bay; magnification 45 diameters.

FIG. 4.—Bad-land topography developed in consolidated dune sands, Twilight Bay.

FIG. 5.—Pillow-lavas unconformably overlain by Pleistocene bedded gravels and sands, near the south end of Twilight Bay.

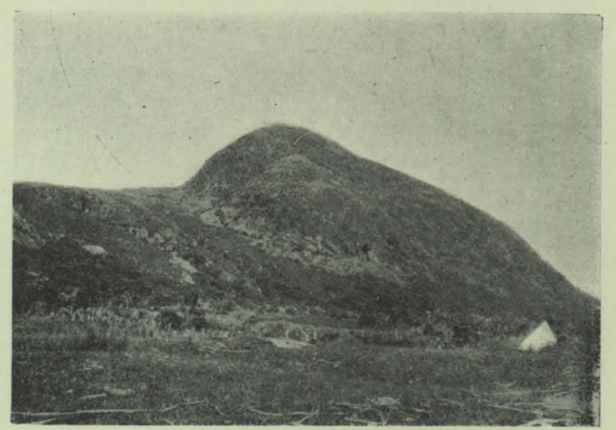

FIG. 6.—Homoclinal ridge of andesitic conglomerate overlying Tertiary sandstones and mudstones, east end of Spirits Bay.

FIG. 7.—Fossil shells of *Placostylus hongii ambagiosus* and other terrestrial gasteropods in consolidated dune sands, south-east of Cape Maria van Diemen.

FIG. 8.

FIG. 9.

FIG. 8.—Wehrlite (N.C. 18) from Kerr Point intrusion, shewing slightly altered lamellar diallage, and partially serpentinized olivine.

FIG. 9.—Gneissic norite-gabbro (N.C. 55) from near North Cape, with bands alternately rich in pyroxene and plagioclase.

FIG. 10.

FIG. 11.

FIG. 10.—Fine-grained phase of norite-gabbro (N.C. 9) from southwest of North Cape, shewing plagioclase and granular pyroxene. Nicols crossed.

FIG. 11.—Granophyric quartz gabbro (N.C. 53) from beach boulder on the western margin of Kerr Point. Nests of small laths of plagioclase are enwrapped by large crystals of the same mineral, the whole being enveloped by pyroxene. Nicols crossed.

Magnification of figures, 38 diams.

FIG. 12.

FIG. 13.

FIG. 12.—Noritic gabbro (N.C. 8) from south-west of North Cape, shewing plagioclase, and secondary amphibole replacing pyroxene. Nicols crossed.

FIG. 13.—Finer phase of noritic gabbro (N.C. 10) from south-west of North Cape. The pyroxene is almost completely converted to uralite.

FIG. 14.

FIG 15.

FIG. 14.—Subophitic andesitic basalt (N.C. 12) from Older Volcanic Series in bed of Huka Creek. Laths of plagioclase enwrapped by partially chloritized augite. Nicols csossed.

FIG. 15.—Picritic basalt (N.C. 17); pillow-lava from 3 miles east of Hooper Point. Phenocrysts of plagioclase are enclosed in a (?) hyalopilitic groundmass of chloritized augite and laths of plagioclase.

Magnification of figures, 38 diams.

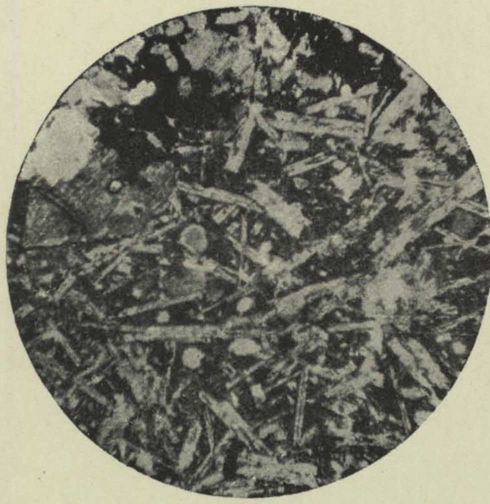

FIG. 16.

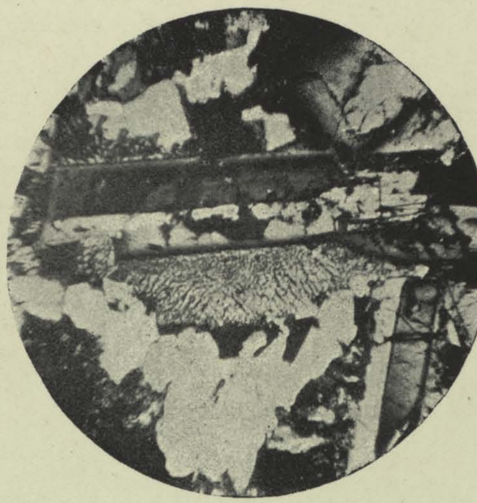

FIG. 17.

FIG. 16.—Pillow lava (N.C. 29) from south end of Twilight Bay. A pseudomorph after olivine enclosed in a plexus of laths of plagioclase.

FIG. 17.—Quartz diorite (N.C. 23) from east of Waikuku Flat, east coast, shewing plagioclase and quartz enwrapped by a micrographic intergrowth of these two minerals. Nicols crossed.

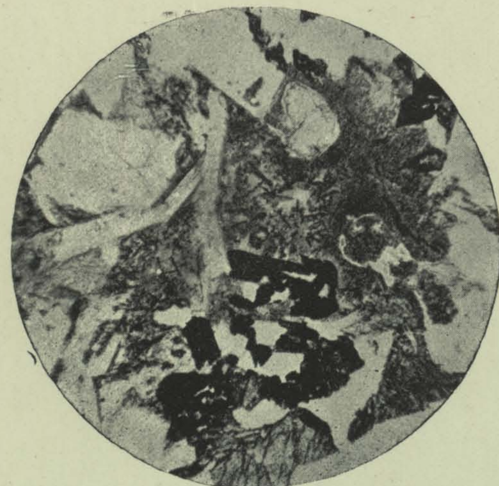

FIG. 18.

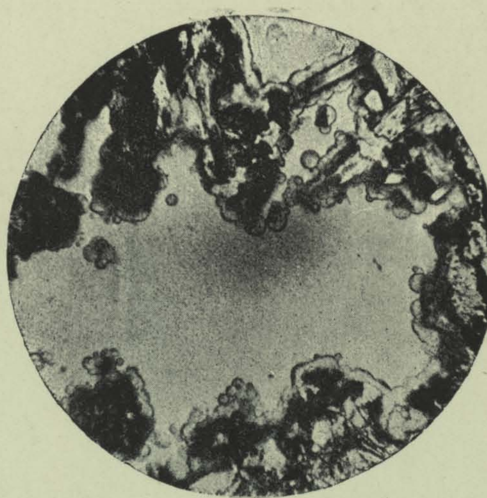

FIG. 19.

FIG. 18.—Andesite (N.C. 26b) from conglomerates of Coal Point Series, west side of mouth of Waitangi Stream, Tom Bowling Bay. Phenocrysts of plagioclase, ilmenite and augite in a groundmass of plagioclase enclosing radially grouped needles of hornblende.

FIG. 19.—Andesite (N.C. 43a) from conglomerates of Coal Point Series, west of Waitangi Stream, shewing a vesicle filled with concretionary opal and zeolite (central part).

Magnification of figures, 38 diams.

their true nature, followed McKay's lead, but brought to light some interesting details of intrusives injecting the series, and also noted the "orbicular" structure of some of the flows comprising it, which are, in actual fact, perfect examples of pillow-lavas.

These latter are best seen in two outcrops near Pandora at Spirits Bay, but they are also exposed on the shores of a cove three miles east of Hooper's Point and doubtless in other places which the writers were unable to visit. At Scott's Point there is a most extensive outcrop of highly characteristic pillow-lava, but there are grounds for believing that it belongs to a later period of extrusion than other flows of this type.

The exact microscopic determination of the members of the Older Volcanic Series is difficult on account of chloritization and other alteration. All are semi-basic or basic in character, and range from quartz andesites to fairly basic basalts which are free from modal olivine in all but the pillow-lavas. The rocks generally consist microscopically of a plexus of rather small laths of plagioclase quite devoid of fluxional arrangement, along with variable proportions of more or less chloritized pale-green or pale-brown augite and some iron-ore. In a few instances, notably in a mass (N.C. 12) comparatively little affected by shattering which outcrops in the wide-spread valley of Huka Creek, Tom Bowling Bay, ophitic and sub-ophitic structure appears. (See Fig. 14).

The variety of plagioclase is andesine-labradorite in the more acidic, and is as basic as Ab_{40} An_{60} in the more basic members of the series. The laths are very often bent in response to severe pressure which doubtless has also caused the shattering already referred to. The proportion of iron-ore varies from about 1 per cent. to about 7 per cent.; both magnetite and ilmenite are represented.

Quartz-augite andesite was collected from the shore at the west margin of the Kerr Point ultrabasic and gabbroid mass; it is a much-altered type with very abundant chlorite, some epidote and comparatively little identifiable quartz. A quartz-uralite andesite with about 10 per cent. of quartz was sectioned, but unfortunately its locality was omitted in the field-labelling.

A rock kindly forwarded with others by Mr. H. MacQuarrie from the shore a few yards south of the pillow-lava at Pandora, has small lenses of dark-reddish-brown material in a greenish altered lava which proved in section (N.C. 80) to be a fine-grained non-porphyritic olivine-free basalt. It is traversed by veinlets of zeolites and by occasional narrow crush-zones.

Microscopically examined, the reddish lenses (N.C. 79) are found to consist of an indecipherable shale-like material closely traversed by veinlets of calcite associated with a zeolite. If the rock were actually shale entangled in the associated lava, it expectably should shew some sign of mineral reorganisation. It does not do so, however, and it is perhaps possible to regard it as comminuted and completely altered portions of the associated basalt. There is support for this latter suggestion in somewhat similar alteration traceable adjacent to the pillow-lavas a few yards away. Sections of these latter have such dense oxidation products that the original structure of the rocks is considerably obscured.

In a small rill entering the sea at the north end of the first sandy beach south of Cape Reinga, a blackish glass was found which had entangled large blocks of the normal lava, and had so created a flow-breccia. Similar material was noted at the base of the Tertiary sequence at Huka Creek, Tom Bowling Bay, and amongst specimens forwarded by Mr. MacQuarrie from the shore ¼ mile west of Pandora, Spirits Bay. In thin section the glass is a deep-brown almost opaque variety. It encloses scattered, rather small crystals of augite and plagioclase.

Bell and Clarke (1910, p. 622) describe an altered augite andesite from Darky Hill (Tirikawa), west of Spirits Bay; it has moderately large phenocrysts of augite and plagioclase and a groundmass which apparently has been hyalopilitic. A similar rock (N.C. 83) was collected by Mr. McQuarrie from the shore ¼ mile west of Pandora. It has idiomorphic phenocrysts of both plagioclase and augite, the former in elongated altered crystals about 0.8 mm. in length and the latter a colourless variety quite unaffected by alteration or decomposition. The groundmass is in considerable excess of the phenocrysts, and its structure greatly obscured by weathering. The augite present in this matrix is in minute prisms which are often grouped side by side to form fringes to the larger laths of plagioclase.

The remainder of those of the Older Volcanic rocks which have been examined microscopically either fall on the border-line between andesites and basalts as defined by Washington,* or are more definitely basalts, for the percentage proportions of modal femic minerals range from about 35 to as much as 65. Two examples of more basic basalts are yielded by a rock (N.C. 80) out-cropping a few yards south of the pillow-lava at Pandora, and by a hyalopilitic type from a small cove 3 miles east of Hooper's Point. This last basalt (N.C. 6) contains numerous small phenocrysts of augite along with a few of plagioclase, and, following Washington (*loc. cit.*), is to be classed as a picrite-basalt. (See Fig. 15).

An analysis of the rock from Taputaputa, a little over 2 miles east of Cape Reinga, is appended in Column 3 of Table 1, whilst its norm is in the corresponding column of Table 2.

In section this type is an olivine-free, non-porphyritic andesitic basalt, consisting essentially of a plexus of unoriented laths of plagioclase (Ab_{45} An_{55}) enclosing about 40 per cent. of almost colourless augite sub-ophitically related to the plagioclase. (Compare Fig. 14). The analysis demonstrates that the rock unquestionably is a basalt, though with a leaning towards the andesites as defined by Washington (*loc. cit.*). The variety of plagioclase determined in section is more basic than that shewn by the norm, whilst the normative olivine in actual fact has separated out as pyroxene.

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*H. S. Washington, Petrology of the Hawaiian Islands; I. Kohala and Mauna Kea, Hawaii. *Am. Journ. Sc.*, vol. 5, 1923, pp. 465-502.

ANALYSES OF IGNEOUS ROCKS.

TABLE 1.

ANALYSES.

	1.	2.	3.
SiO_2	48.12	49.82	49.76
Al_2O_3	14.07	17.61	15.72
Fe_2O_3	3.85	0.96	2.31
FeO	5.38	4.66	6.52
MgO	7.03	9.78	7.15
CaO	8.62	14.67	9.85
Na_2O	2.68	1.23	3.68
K_2O	1.44	0.10	0.34
H_2O+	3.29	0.56	2.55
H_2O-	3.51	0.19	0.56
CO_2	None	0.04	Trace
TiO_2	1.92	0.25	1.04
ZrO_2	—	None	None
P_2O_5	0.07	0.03	0.10
S	0.01	0.03	0.12
Cr_2O_3	None	0.03	0.03
V_2O_3	0.04	—	—
NiO	—	0.04	0.03
MnO	0.16	0.15	0.22
SrO	0.04	None	Trace
BaO	None	Trace	Trace
	100.23	100.15	99.98

Analyses by Mr. F. T. Seelye.

TABLE 2.

NORMS.

	1.	2.	3.
Quartz	0.60	—	—
Orthoclase	8.34	0.56	1.67
Albite	23.06	10.48	31.44
Anorthite	21.96	42.26	25.30
Diopside	16.55	24.43	18.41
Hypersthene	13.58	17.72	5.02
Olivine	—	1.98	9.28
Magnetite	5.57	1.39	3.02
Ilmenite	3.65	0.46	1.98
Pyrite	—	—	0.23
Apatite	—	—	0.34

1. Dolerite N.C. 30) from dyke in basal Tertiary beds, 1½ mile west of North Cape.
2. Noritic gabbro (N.C. 48), southern margin of gabbroid mass, North Cape.
3. Basalt from Older Volcanic Series (N.C. 51), Taputaputa, east of Cape Reinga.

The Pillow-Lavas.

As has been noted elsewhere in this paper, it is believed that not all of the pillow-lavas of the Cape Maria van Diemen-North Cape area belong to the Older Volcanic Series, but they are so closely allied petrographically that it is convenient to describe all together. They resemble the rocks of this last-mentioned series in being severely shattered and altered. The individual pillows vary in diameter from 1 ft. to 3 ft., and, in their best development, shew a more or less distinct radiate, finely prismatic structure and a chilled crust which is clearly illustrated in Fig. 5. Some are decidedly overturned and elongated in the direction of flow. (See Fig. 2).

The rock of the pillow-lava at the northern margin of Scott's Point is finely vesicular, and exhibits in hand-specimen a moderate number of red pseudomorphs of carbonate and haematite after olivine. A little below what appears to be the uppermost flow of the series exposed at the south end of Twilight (Rahia) Bay, and immediately west of a dyke of green dolerite, there is a massive aphyric amydaloidal rock of similar nature to the pillow-lava, but devoid of olivine, which is soon followed westwards by further pillow-lavas which form the sea-cliffs for about two miles at Scott Point, but which were not examined microscopically. The pillow-lava at the south-end of Twilight Bay and the associated amygdaloid are probably best classed as basic andesites and andesitic basalts, for they are intermediate between andesites and basalts. In the present writers' sections of the pillow-lava (N.C. 29), pseudomorphs after olivine are the only phenocrysts, though Bell and Clarke (1910, p. 622) have noted occasional labradorite in addition to the olivine in their slides. About 70 per cent. of the rock consists of laths of weathered plagioclase, which form an unoriented open-textured matrix (see Fig. 16) in which are a little very pale green augite and about 5 per cent. of rod-like ilmenite. The amygdaloidal olivine-free aphyric basalt has a less proportion (about 60 per cent.) of plagioclase. There is a large quantity of pink augite with densely crowded ilmenite and magnetite. The augite is generally in curious closely appressed minute sub-parallel prisms, though sometimes in divergent or radial groups. No exact determination of the variety of plagioclase proved possible. In most instances the extinction angles obtained with albite twin-lamellae were small. Albite was suspected, but, so far as the weathered condition of the mineral allowed determination, refractive index tests negatived any possibility of the occurrence of this mineral.

Bell and Clarke (1910, p. 622) compare the pillow-lavas at Pandora with those at Scott Point, but state that the crystals of olivine are free from alteration, more frequent, smaller and corroded, whilst there are no phenocrysts of plagioclase. The present writers' sections are so obscured by hematitic and other oxidation products as to render determination of olivine impracticable. A small mass of lavas having imperfect pillow form, which outcrop at a small cove 3 miles east of Hooper Point, consist of an olivine-free chloritized basalt possessing numerous phenocrysts of almost colourless augite accompanied by a few groups of small crystals of plagioclase. There is abundant pyroxene in the groundmass, with about 25 per cent. of plagioclase in diversely arranged relatively long laths, and a moderate amount of iron-ore which is mainly ilmenite.

Summing up the facts, it is evident that there is no petrographic reason for separating the pillow-lavas from other members of the Older Volcanic (Whangakea) Series. The Twilight Bay-Scott Point pillow-lavas have been grouped with the Cretaceous Rahia Series, and thus separated from other similar flows, only because of their association with sediments which are quite dissimilar from any of Trias-Jura age yet known from New Zealand, but closely resemble Cretaceous beds at Parenga.

C. THE PETROGRAPHY OF THE MID-TERTIARY (COAL POINT SERIES) CONGLOMERATES.

The conglomerates of the mid-Tertiary Coal Point Series preserve a dominantly igneous character throughout their wide extent of outcrop, and somewhat rarely contain any noteworthy proportion of pebbles of sedimentary rocks. Bell and Clarke (1910, p. 619) record sedimentary material in the conglomerate outcropping on the trail between Parenga and Te Paki, whilst the present writers found it in moderate abundance at Maukin's Nook on the east coast.

A very large number of microscope sections were cut from constituent fragments of the conglomerate west of Waitangi Stream and at the east end of Spirits Bay, but little important variation was discovered. Bell and Clarke describe the prevailing type as a hyalopilitic augite andesite with a large amount of glass, and remark on the lack of importance of hypersthene which is so ubiquitous in the pyroxene andesites of the similar conglomerates and breccias of the Waitakerei Ranges near Auckland. The present study shews, however, that hypersthene is no whit less abundant than in the southern rocks; there is, however, greater lithologic variety in the northern than in the Waitakerei conglomerates.

Boulders of dioritic, and more rarely, of gabbroid rocks, which have been derived from intrusions such as those described in an earlier section, though never very plentiful, can nearly always be found after brief search, whilst, as is to be expected, representatives of the earlier (? Trias-Jura) volcanics are also discoverable.

Hyalopilitic pyroxene andesites with both augite and hypersthene, usually with plagioclase as the most abundant phenocryst as well as the most important constituent of crystalline portions of the groundmass, are apparently the prevailing types. Phenocrysts and matrix are sub-equal in amount. The matrix shews all gradations from a variety with comparatively little glass (e.g. N.C. 34, o) to distinctly vitrophyric types in which the minerals of the second generation are represented only by tiny microlites. The rocks are remarkably free from signs of alteration, though rare chloritic pseudomorphs after possible olivine were noted in one or two of them. The phenocrysts are idiomorphic and seldom exceed 1 mm. in length. Those of plagioclase very often contain numerous minute glass or mineral inclusions, and generally vary in variety from andesine-labradorite to acid labradorite, though, in one more basic rock (N.C. 34, c), the feldspar is labradorite-bytownite. This particular rock is one of the few with pseudomorphs of chlorite after olivine, and further exhibits abnormal basicity in possessing proportionally more pyroxene as compared with feldspar than the andesites associated with it, for the two minerals are sub-equal in amount.

Other types of andesite identified include the following:—vitrophyric augite-hornblende andesite with quite a number of small phenocrysts of brown hornblende in addition to those of plagioclase and augite; fine-grained varieties with imperfectly crystallized matrix and few phenocrysts; hyalopilitic augite andesite with curious sheaf-like grouping of the plagioclase in the groundmass (N.C. 70, a); a special type of andesite (N.C. 26, b) with augite and some green hornblende. About 75 per cent. of this last rock consists of large idiomorphic crystals of plagioclase (Ab_{40} An_{60}) as much as 1.5 mm. in length and numerous smaller ones (about 0.2 mm. in length) of the same mineral, with a greatly subordinate quantity of very pale greyish augite and a little ilmenite. The balance of the rock is a "matrix" consisting partly of clear colourless glass and partly of feldspar in large irregular crystals which enclose numerous minute needles of green hornblende, these latter very often being grouped in stellar fashion. (See Fig. 18).

The same envelopment of earlier prismatic hornblende by later plagioclase is exhibited by two other rocks sectioned, both of them highly feldspathic, though with a little augite. One is almost identical with the rock just described, but for the fact that the texture is even-grained. Large stumpy laths of labradorite are more or less ophitically enwrapped by a minor proportion of augite, whilst the last-crystallized feldspar, as before, is crowded with minute prisms of deep-green hornblende.

In addition to the hyalopilitic andesites described, there are closely allied perlitic vitrophyric rocks (N.C. 34, k, m, n, p) which bear very close similarity in section to certain rocks from the Whangarei-Bay of Islands area described by one of the present writers in a chapter of a recent Geological Survey bulletin (Ferrar, 1925). These proved on analysis to be andesitic dacites. About 60 per cent. of the bulk of these perlitic rocks is a glass colourless in section and containing numerous lath-shaped crystals (about 0.2 mm. in length) of plagioclase, and prisms of hypersthene and augite, the former in greater profusion than the augite, whilst there is also a variable though important quantity of deep-brown hornblende. The glass itself is crowded with trichitic microlites; in some slides these have so increased in size as to be mineralogically determinable, though in such cases the glass has lost its clarity and become more opaque.

The older andesitic rocks sectioned (N.C. 34, h; 43, a) resemble the rocks typical of the series (Whangakea Series) to which they belong, and are largely composed of laths of basic labradorite which make an open-textured unoriented mesh. There is about 4 per cent. or 5 per cent. of ilmenite in relatively large crystals whilst about 10 per cent. of pale-greyish-green partially chloritized augite is entangled in the mesh of plagioclase and, at times, ophitically enwraps this last mineral. In one of the two slides (N.C. 43, a) large prisms of secondary quartz have crystallized in drusy spaces in company with opal, a radially fibrous zeolite, chlorite and a little pyrite. Chlorite has lined the cavities and has then been followed by the opal which has crystallized as tiny radially built concretions. (See Fig. 19).

The gabbroid and dioritic rocks sectioned have their prototypes in the similar pre-Tertiary intrusive rocks which already have been described. The gabbros (N.C. 34, d; 34, e) are a uralite-augite variety and another containing uralite with both hypersthene and augite.

The diorites have plagioclase (labradorite) dominant over ferromagnesian minerals; they include an augite diorite with a little brownish-green hornblende and some micropegmatite (N.C. 72), and quartz diorites containing uralite associated with plentiful cores of augite (N.C. 15, b), or else augite with a little greenish-brown hornblende (N.C. 15, c).

West of the mouth of Waitangi Stream, Tom Bowling's Bay, the Tertiary conglomerates contain numerous small fragments of black chilled igneous rock which in section prove to consist of a brown glass with a few small phenocrysts of augite and plagioclase. These represent the chilled crust of andesitic bombs.

D. IGNEOUS ROCKS OF UNCERTAIN HORIZON.

An andesitic rock (N.C. 25) which outcrops on the shore-platform about half a mile east of Pandora, Spirits Bay, proved on sectioning to be an unaltered hyalopilitic hypersthene-augite andesite identical with the similar rocks of the conglomerates of the Coal Point Series. It is adjoined by typical members of the Older Volcanic Series, but unfortunately its petrographic separation from these latter was only determined when microscopic slides had been prepared, so that its field relations were not carefully observed. It was believed to be a small intrusion, but the distinct parallelism of its numerous lath-shaped phenocrysts of plagiolcase and certain other characters suggest rather that it is an extrusion. If this rock actually represents a lava, the explanation of its occurrence presents many difficulties which are otherwise non-existent, so that, in the absence of more precise knowledge, it has provisionally been classed as a dyke rock in the section on stratigraphy.

A number of boulders of a white volcanic rock were discovered at the mouth of Pandora Creek, Spirits Bay. It consists of an irresolvable light-grey "earthy" matrix which encloses numerous small idiomorphic phenocrysts of plagioclase, and great numbers of much smaller lath-shaped crystals of the same mineral, along with scattered small euhedral crystals of deep-brown hornblende and a little magnetite. The plagioclase is very finely zoned and is relatively free from lamellar twinning. The rock is microscopically indistinguishable from many of the trachytic dacites which have been described by one of the writers (Bartrum, 1925) from the Whangarei Heads district. Its chemical nature could only be determined by analysis, but it was considered that the labour of analysis was scarcely justified whilst nothing was known of its field relationships.

Acidic dyke rocks were also located by the writers at Mt. Camel in the Hohoura district, 29 miles south-south-east from North Cape; several of them exhibit phenomena indicative of severe strain, so that their injection probably occurred before the commencement of the Early Cretaceous deformation which terminated Hokonui sedimentation. The Pandora rock, on the contrary, lacks any evidence of strain and is therefore probably an early Tertiary effusive approximately contemporaneous with similar acidic rocks in the Whangarei-Bay of Islands Subdivision (Ferrar, 1925).

THE STRUCTURE OF NORTH AUCKLAND PENINSULA.

In discussion of the structure of the Whangarei-Bay of Islands Subdivision, Ferrar (1925, p. 18) has recently summarized many of the various opinions with regard to the structure of North Auckland Peninsula, but has found the distortion of the basement Hokonui (Waipapa Series) rocks of his area too great to permit of any safe generalization of fold-directions therein. He suggests, however, on the basis of the trend of certain greywacke ranges, that " . . . the Mesozoic earth movements were in the nature of folds along north-west to south-east axes, the folds bending over eastward toward a submerged area." However correct this conclusion may prove, it must be observed, nevertheless, that the trend of these ranges is probably largely governed by the N.W.-S.E. fracture-system accompanying later Tertiary emergence of the New Zealand area, and believed by Park (1921) to determine the framework of the peninsula.

As already remarked, these fractures can be clearly followed from an originating source in the Taupo region, where they meet the immense fractures of a N.E.-S.W. system (Henderson, 1924), through Auckland to Whangarei and the Bay of Islands (Ferrar, 1925, pp. 18-21), until they finally reach North Cape.

Benson (1924, p. 132) remarks how, in the New Zealand region, these fracture-systems generally cross the trend-lines obliquely, as had been noted earlier by Cotton (1916) for the southern part of North Island, and states the possibility of regarding the New Zealand-Kermadec ridge " . . more as a complex fault-horst than as a fold-anticline," though Brouwer, he states, believes " that a geanticline growing at depth is represented by a fractured ridge."

Bell and Clarke (1909, pp. 42-43) find the general trend of a major anticlinorium in the inland portion of the Whangaroa area to be E.N.E.-W.S.W., though nearer the coast the folds approximate a W.N.W.-E.S.E. direction. They are in agreement with Marshall (1908; 1911, p. 5), who found a dominant north or north-east trend in the Bay of Islands and in localities further north, that the arrangement of the basement rocks of Whangaroa Subdivision shews no relation to the alignment of North Auckland Peninsula. In the north of Great Barrier Island, however, the strike of rocks of the same system is approximately N.W-S.E. (Bartrum, 1921), though near Coromandel it is approximately meridional (Fraser Adams, 1907, p. 26.).

In view of the frequent disparity of direction between the axis of the peninsula and the fold-axes shewn by these observations, it is surprising to find that the foliation of the gneissic gabbro at North Cape, in common with the folding of the sediments at Great Barrier, accords in direction with the backbone of North Auckland. It is well known by those familiar with the Hokonui rocks, as developed in North Auckland, that stratification is seldom distinct, except in areas characterised by complex minor folding such as would tend to obscure the general trend of the strata. It is therefore probable that an erroneous conception of the direction of the major folds has been gained, as appears to be the opinon of Morgan (1922), and that, in the present state of our knowledge, it is unwise to accept Benson's (*loc. cit.*) generalization concerning the obliquity of intersection of fracture-lines with trend-lines in the New Zealand area, as applying unreservedly to North Auckland.

The evidence at Great Barrier Island and North Cape undoubtedly supports Suess's (1913) view that fold-axes open out to the north and north-west from the main structural axis of New Zealand, and pass through North Auckland as an integral part of his "Third Australian Arc." Following Brouwer's suggestion (*fide* Benson, *loc. cit.*) the N.W.-S.E. fractures of the late Tertiary orogeny (Kaikoura orogeny of Cotton) are perhaps the result of geanticlinal folding following the early Cretaceous axis along which the Hokonui rocks were up-arched. This is the "closing Tertiary" Australasian crustal undulation of Andrews (1923, p. 2) progressing "from the continental nucleus to the Central Pacific, the prominence of the forms and the relative youth of the activities being accentuated with progressive approach to the main ocean itself."

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