The Geology of the Riverhead-Kaukapakapa District, Waitemata County, Auckland.

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Plate 6.

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INTRODUCTION.

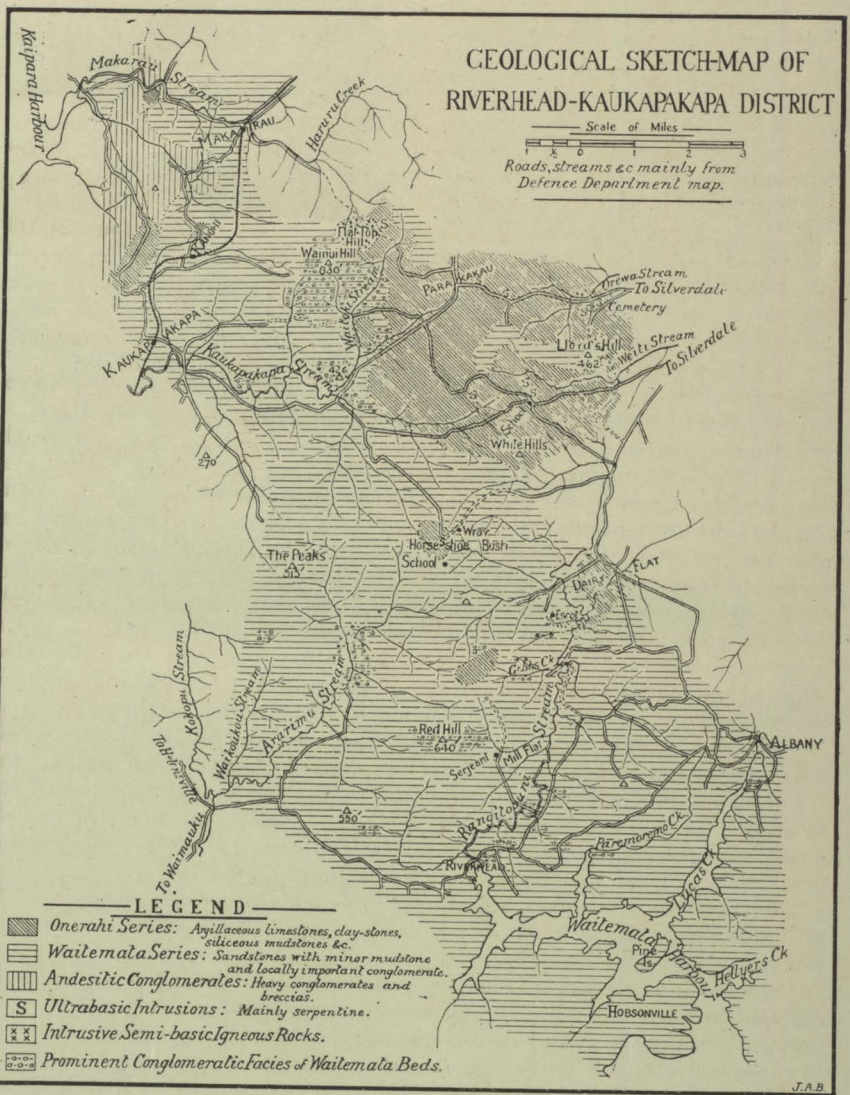
IN the present paper the intention is to describe the stratigraphy of a moderately extensive area of hilly country lying approximately between Riverhead, at the northernmost limit of navigation of Waitemata Harbour, and Kaukapakapa, a township approximately a dozen miles to the north-west. The area is mainly part of Auckland's "gum-lands," deforested open country covered here and there by small patches of forest, but usually clothed only by fern, scanty grasses, and scrub manuka. The country has moderate relief and a fairly intricate insequent drainage-pattern. Resistant rocks are relatively infrequent, so that both longitudinal and cross profiles of the stream-valleys in general are graded, and it is only where a relatively resistant rock is present, or where the streams rise steeply in their uppermost ungraded headwaters portions, that natural outcrops are obtainable. Many other similar areas of deforested country in North Auckland resemble the present one in this respect. Chemical weathering is particularly rapid in the warm, humid climate; there is a considerable depth of completely weathered surface-rock, and, as a consequence of constant burnings and the resulting imperfect cover of vegetation, the floors of the valleys of the smaller streams have become aggraded into swampy areas by soil-wash, aided effectively by various swamp-loving grasses. In such cases there is little chance of outcrops of the underlying rock.

For these reasons it has been found impossible to aid materially, by the results obtained in the study of the present area, in the solution of any of the yet unsolved problems of local geology.

It was found, however, that the district studied was most inaccurately mapped by earlier geologists. The writer is confident that the map he has prepared, though necessarily imperfect by reason of inaccuracy of detail in topography in the only maps available, and by reason of its small scale, will nevertheless help later investigators very materially. Whilst by no means every outcrop obtainable has been visited, yet careful search has been made in nearly all likely localities. Those familiar with the gum-lands of Auckland will recognize readily how impossible it is, without the expenditure of labour entirely disproportionate to the results likely to be obtained, to discover any but the more obvious outcrops.

EARLIER WORK.

It is exceedingly doubtful if members of the early Geological Survey who mapped the area now described visited any but its marginal portions, for it is unlikely that certain phases of the geology could have escaped notice had the interior portions been visited. The only work of any importance is that done in 1879–80 by Cox (1881), who travelled along



the main road northwards from Kaukapakapa, and reported on the geology of that part of the present area which lies between Kaukapakapa and the mouth of Makarau Stream. McKay later (1884, 1888) visited a number of intrusions of serpentine in the vicinity of Silverdale (Wade), and recorded this fact along with some extraordinary observations upon the rocks and their stratigraphic relationships. Some cursory remarks by Hector (1881)

in *Progress Reports* are practically the only other reference to the geology of the district that the writer has come across in the reports of the Geological Survey. He himself has recently described a variety of rocks from conglomerates outcropping near Albany and Riverhead (Bartrum, 1920).

SYNOPSIS OF STRATIGRAPHY.

The following stratigraphic units are recognized: (1) Onerahi series; (2) Waitemata series; (3) Andesitic conglomerate formation; (4) Pleistocene and Recent deposits.

The oldest rocks, which constitute the Onerahi series, include a prominent bed, generally spoken of as the "hydraulic limestone," which is a variably argillaceous, fine-grained, non-crystalline limestone. It most frequently represents an oceanic ooze rich in *Globigerina*, but is associated with fine shaly claystones and indurated siliceous mudstones, which seem in part to represent a local variation of the limestone and in part to be interbedded with it. The series-name selected is that introduced by Ferrar and Cropp (1921) for lithologically identical rocks conspicuous in the Whangarei district. There is no intrinsic evidence of age in the beds themselves, but their provisional generalized assignment to the Cretaceous period may be taken as approximately correct in the light of evidence obtainable in the Kaipara area farther north.

Above the Onerahi rocks—the facts indicate unconformably—there is an extensive series of argillaceous sandstones with minor interlaminated mudstone, which outcrop continuously southwards on the shores of Waitemata Harbour, but much less prominently in the northern part of the Kaukapakapa-Riverhead district. These beds belong to the Waitemata series, which appears from its fossil content near Auckland to be approximately Upper Miocene in age. In the area now mapped there are locally massive green sandstones and thick conglomerates of a most interesting nature forming part of the series. Northwards beyond the present area the massive sandstones are especially well developed.

The next formation in upward sequence consists of andesitic conglomerates and breccias, limited in extent to the north-west corner of the district now described, but traceable northwards, and also southwards where they build the Waitakere Hills, which border the west coast for many miles near Auckland. They appear to lie conformably upon sandstones of the Waitemata series in the few places where fairly clear sections are obtainable, and thus are regarded as approximately Upper Miocene in age. Pleistocene deposits next succeed the Waitemata beds and the andesitic conglomerates. They are represented by occasional terraces of alluvium, sometimes in flights of two or three, but seldom conspicuous. The majority of the stream-terraces do not show an aggradational phase in their history. Recent deposits are limited to linear swamps along the courses of slow-flowing streams. They are a constant feature of most of the valleys, but are by no means extensive. Occasional bog iron-ore deposits of small size, more extensive than elsewhere in small north-east-flowing tributaries of Gibbs Creek, a middle right branch of Rangitopuni Stream, are probably Recent in age.

The synopsis is completed by mention of intrusive igneous rocks. Of these there are two series: one comprises ultrabasic intrusions which now are represented by serpentinous rocks, and the other rocks of semibasic character. The first invade Onerahi beds, and have not yet been observed above that horizon; the others do not constitute a composite series, and differ in age.

DETAILED STRATIGRAPHY.

1. Onerahi Series.

Petrography and Distribution.

The facies of the rocks included in this series ranges from a *Globigerina* ooze containing over 84 per cent. of calcium carbonate to indurated siliceous mudstone in which there is no trace of organic remains, or to buff- and pink-coloured claystones. The component members of the series are therefore peculiarly difficult to diagnose stratigraphically with any certainty. Similar variations are usual in most of the more northerly occurrences of the rocks of the same series. The tests of *Globigerina* are numerous, but usually small, and are accompanied by few other genera of Foraminifera. A specimen collected from the lower course of Waitoki Creek above its confluence with Kaukapakapa Stream exhibits abundant and varied siliceous organisms in the calcareous matrix. Calcareous foraminifera are scarce, but broken spicules of sponges, small free-swimming diatoms, and radiolarians are all fairly plentiful. In addition there are abundant organisms resembling minute unbroken algal filaments, and others which the writer as yet has been unable to classify. Marshall (1916) has previously described similar siliceous marine organic remains from the "hydraulic limestone" near Batley, in the Kaipara district.

It has been found impossible to determine any regularity of structure in the Onerahi rocks. They are exposed comparatively rarely, and the claystones alone show definite bedding-planes. What evidence is available indicates that they are complexly disturbed, and are often crossed by zones of shattering.

In much of the area mapped as belonging to this series the boundaries are conjectural, on account of the paucity of outcrops. In addition there is doubt if the writer is correct in assigning to this, in preference to the Waitemata series, certain highly calcareous mudstones exhibiting no bedding, which are displayed adjacent to the road leading north-westwards from Kaukapakapa to Makarau Stream. They show notable difference in facies from the regularly bedded sandstones of the Waitemata series, which outcrop in juxtaposition southwards alongside the same road, and again northwards at Makarau Valley, where they are conspicuously developed. There are two other isolated outcrops of similar rock: one is about two and a half miles west of Makarau Railway-station, alongside the road following the lower Makarau Valley, whilst the other is visible about a quarter of a mile from Kanohi Railway-station, in a cutting of the road leading to Makarau.

Stratigraphically the inclusion of these areas of rock in the Onerahi series raises difficulties which are non-existent if they are placed with the Waitemata rocks. In a wide examination of undoubted Waitemata strata, however, the writer has not seen any which resemble these at all closely; he has therefore tentatively included them in the Onerahi series, though Cox (1881) does not differentiate such of them as he examined from the Waitemata beds.

The main occurrence of Onerahi beds is to be found south-eastwards of these outcrops of uncertain horizon. It begins immediately east of Wainui Hill, and extends south-eastwards through Parakakau Settlement beyond the limits of the area described in this paper. A few small inliers exist farther south.

Since outcrops are relatively scarce it is perhaps desirable to record where they can best be examined. Good exposures of argillaceous limestone exist abundantly in the upper and middle portions of the valley of Waitoki Stream eastwards of Wainui Hill. Again, in cuttings of the Parakakau–Silverdale Road a shaly red and grey claystone facies appears. It is steeply tilted, and strikes approximately north-east and south-west. Near White Hills, especially along the road leading south-east from the school towards Dairy Flat, there are excellent exposures of the white siliceous mudstone phase of the beds. North-westwards of the school, at the distance of about a mile along the track to Parakakau, a massive relatively resistant limestone is exposed, whilst about three miles westward of White Hills School a pure limestone is exposed in a quarry opened up for agricultural lime about a quarter of a mile north of the road to Kaukapakapa.

Onerahi beds probably occupy most of the district east of the Silverdale – Dairy Flat Road as far south as Dairy Flat, where limestone outcrops at the road near where it crosses the upper north-east branch of Rangitopuni Stream and also south-westwards in grass-lands on the right bank of this tributary.

It can next be found, continuing in a south-west direction, in Rangitopuni Stream below its confluence with the tributary just mentioned. Near Escot's house it is represented in the material dug from a well, though Waitemata sandstones shortly appear in a rill about 10 chains south of the house. South and south-westwards of Escot's there are two inliers of white indurated mudstones which must be referred to the Onerahi series. One is inconspicuously exposed in a trench cut many years ago for a mill-race on the right bank of Gibbs Creek about 300 yards above its confluence with Rangitopuni Stream. The other is represented by a number of outcrops in a belt over a quarter of a mile in width on the divide at the head of the same creek. Siliceous replacements of wood are common on the gum-track following this divide.

Finally, a small isolated area showing not only limestone but other phases is recognizable by fragments turned up in some post-holes, and by actual outcrops in the headwater basin of a small north-west-flowing stream a little south-west of Wray's house at Horseshoe Bush. Waitemata beds are extensively exposed in the upper portions of several small streams at no great distance eastwards, and can shortly be recognized northwards from the Onerahi limestone in imperfect outcrops furnished by slips adjacent to the road giving access to Wray's property.

Relations to other Series.

Actual contacts between the Onerahi strata and the overlying Waitemata rocks have not been discovered, though in several instances rocks of the two series have been found in close contiguity to what must be the actual surfaces of contact. In some instances the Waitemata beds apparently next above the Onerahi rocks are sandstones, in others they are conglomerates, a condition that might be expected with deltaic beds. The conglomerates contain a large assortment of rocks both igneous and sedimentary, and it is not unusual to find pebbles of a *Globigerina* ooze microscopically indistinguishable from similar material composing Onerahi limestones, whilst fragments of other sediments comparable with other phases of the Onerahi beds often abound. Cox (1881) states that Hector

observed similar relations between the beds of the two series near Matakana North Head. Similarly, in a railway-cutting a short distance north of the cement-works at Portland, near Whangarei, pebbles of what appears certainly to be Onerahi limestone are present in a fine conglomerate of the succeeding series. These conditions are so widespread as to suggest unconformity rather than mere disconformity between the Waitemata and Onerahi series. This is in accord with conclusions reached by Ferrar (1922) as a result of recent field-work in the Whangarei and Bay of Islands Subdivision. Insufficient data are available to allow exact estimate of the nature of the surface of Onerahi rocks covered by the Waitemata series. In some localities it is obvious that it now is highly irregular, but it is impossible to be sure that such irregularity is not the result of diastrophic movements of more recent date than the period of deposition of the covering beds.

In this connection it is important to consider the relations of the calcareous mudstones north of Kaukapakapa (which have been mapped tentatively as Onerahi) to the andesitic conglomerate formation. At the roadside about a mile and a half north-north-west of Kaukapakapa the volcanic rocks overlie sandstones of the usual Waitemata facies, which have a slight westerly dip. In a very few yards the calcareous mudstones appear devoid of bedding-planes at a slightly higher level. Half a mile farther northwards these last beds are covered by volcanic material. Precisely similar relations obtain alongside the Lower Makarau Valley Road.

The evidence does not justify any hard-and-fast conclusions, since it is based on insecure lithological identification, but the deductions which seem to be necessary as a consequence of it are certainly instructive. If the white marls are correctly placed in the Onerahi series, either of the two following hypotheses will explain the facts:—

(*a.*) Assuming conformity between the volcanic and the Waitemata series, it is essential to postulate not only unconformity between the latter and the Onerahi rocks, but also a nicely adjusted emergence of small low islands of the earlier rocks through the Waitemata rocks prior to the covering of both series by volcanic fragmental beds.

(*b.*) If unconformity between the volcanic series and the underlying Waitemata beds be admitted, the facts are explicable whatever the relations between these latter and the Onerahi rocks, but more readily if unconformity exists, since otherwise diastrophic movements must necessarily have preceded the erosion that caused the uncovering of the two sedimentary series before the deposition of the volcanic strata.

The first hypothesis has little to recommend it, for so nice a balance of events as the conditions of field occurrence would require is unlikely to be attained.

In spite of the fact that the andesitic conglomerate formation is generally accepted as conformable to the Waitemata series, it seems advisable to keep in view the possibility of the truth of the second hypothesis, which is contrary to this belief.

2. Waitemata Series.

Petrography, Distribution, &c.

When traced north-west from Auckland along the shores of Waitemata Harbour, the beds of the Waitemata series preserve for many miles a marked regularity of type, and are predominantly somewhat feldspathic

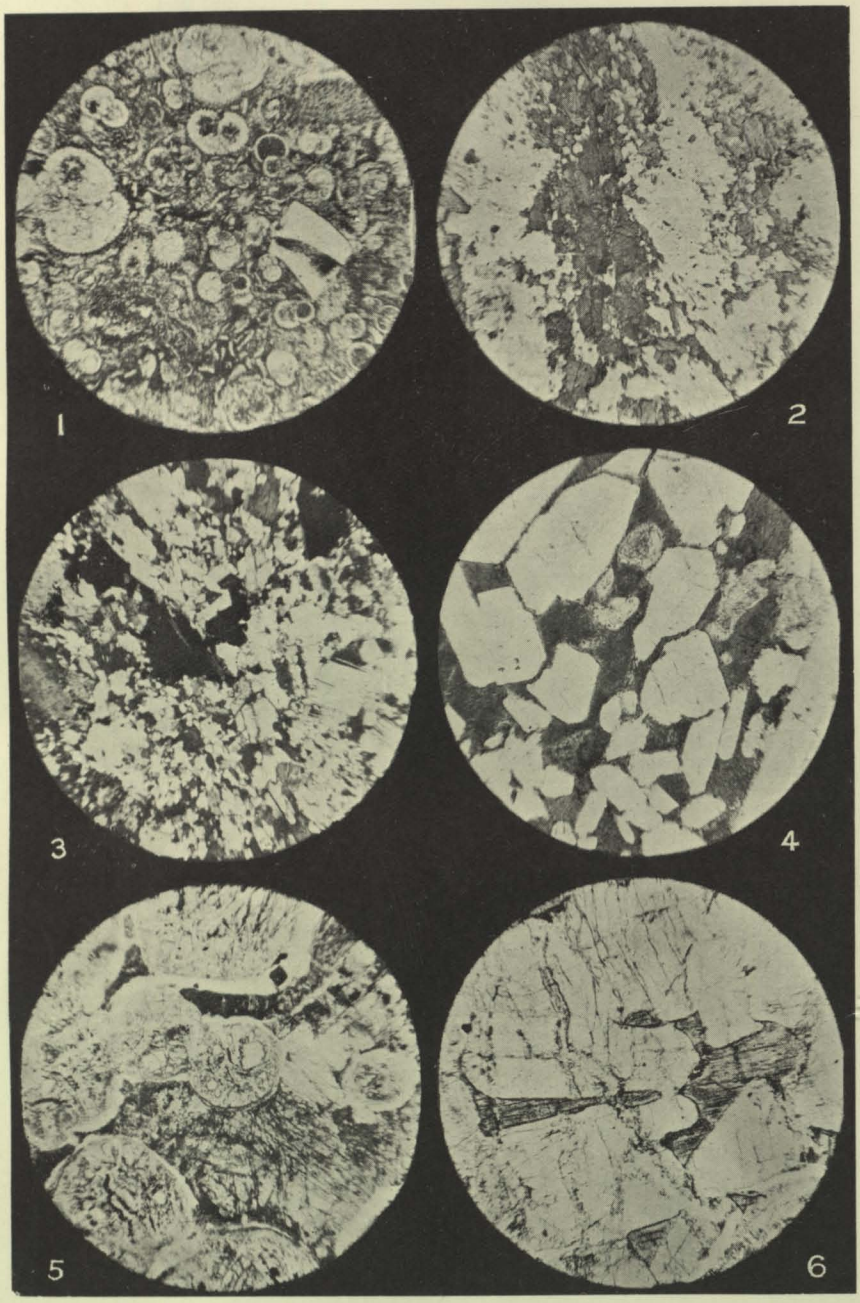


FIG. 1.—Crystalline limestone rich in foraminiferal, polyzoan, and echinodermal remains. Conglomerate in Waitemata beds, lower Rangitopuni Stream.

FIG. 2.—Gneissic hornblende diorite. Typical of many such diorites in the Waitemata conglomerates.

FIG. 3.—The same gneissic diorite viewed under crossed nicols.

FIG. 4.—Greenish-brown hornblende enclosing basic labradorite in an ophitic hornblende-gabbro from the Waitemata conglomerates.

FIG. 5.—Plagioclase and derived saussurite poecilitically enclosing partially serpentinized olivine in feldspathic peridotite from the "serpentine" quarry at Parakakau.

FIG. 6.—Anorthositic phase of the same "serpentine." Highly basic labradorite is enwrapped by accompanying diallage.

Face p. 144.] Magnification in all figures 35 diameters.

sandstones interbedded with frequent thin layers of mudstone. Carbonized remains of vegetation abound, but otherwise organic remains are scarce. The beds in this part of their extent are often complexly disturbed by small-scale folds and by faults which generally have unimportant throw. It is difficult amid this complexity to determine the major structure, but observations tend to show that the general strike is approximately N. 55° E., and that the beds rise successively in the series as followed north-west, at all events as far as Riverhead. At this latter place beds of conglomerate are intercalated in the sandstones and constitute a conspicuous feature of the geology for at least twelve miles northward.* Since his first description of their occurrence and petrographic interest, the writer has found them in numerous localities, and has recognized several fresh rock-varieties represented amongst the pebbles (Bartrum, 1920). His first impression was that they represented a definite horizon—at a higher level in the series, however, than the basal conglomerates near Papakura, and at Motu Tapu, Kawau Island, Cape Rodney, and other places where the Waitemata beds rest hard upon the mid-Mesozoic basement exposed in those localities. This view is almost certainly incorrect, for there are several bands of conglomerate exposed near Red Hill and elsewhere, which are separated by variable thicknesses of sandstone. Acute disturbance is the keynote of the structure, and there is the additional handicap of infrequent outcrops, so that accurate identification of horizon is difficult, if not impossible.

Petrographically the conglomerates are characterized by an abundance of dioritic pebbles along with various greywackes and argillites, andesites and other rocks. Their texture varies considerably. Not infrequently there is a gradual passage from sandstone through grit to fine conglomerate in which the pebbles average about ½ in. in diameter. Generally, however, there are numbers of coarse boulders, 3 in. or 4 in. in diameter, along with finer matrix, whilst exceptionally there are incorporated rock-masses 7 ft. and more in diameter. The dioritic boulders seldom exceed 1 ft. in diameter, whilst the especially large ones are invariably andesitic. In the majority of the exposures the freshness of all types of rock incorporated is very noticeable, but this statement is not applicable to those outcrops at the higher levels where conditions have favoured deep weathering.

Isolated large boulders of impure jasper, veined freely by small comby and drusy veins of quartz, are to be found here and there in areas of Waitemata beds. One noted in an easterly headwaters branch of the creek draining the north-east slope of Red Hill is unusually large and measures at least 25 ft. in diameter. None of these masses was discovered *in situ*, and the only explanation that the writer can offer of their occurrence is that they are local silicifications of the Waitemata beds. It is possible that siliceous springs furnished the silica required.

The distribution of the Waitemata beds is shown on the accompanying map, and need not be detailed in full. Their location has often been a matter involving an element of speculation because of the scarcity of outcrops. This is particularly the case for an area shown extending west from Lloyd's Hill, in the north-east of the map. Waitemata sandstones are indicated by soil, topography, and occasional outcrop; but much of the central portion of this area is clothed in dense forest, and was not examined.

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* Cox (1881, p. 27) notes at Riverhead the discovery of "several specimens of volcanic rocks from boulders which appear to be included in the sandy marls."

The conglomerates are exposed near Riverhead Wharf in several places. Alongside the road to Albany, about a mile and a half north-eastwards of Riverhead, outcrops are visible in the beds of two small streams crossing the road, and immediately north of the more easterly of these last outcrops there is a thin band showing on the banks of Rangitopuni Stream at the uppermost limit of tide-waters. Farther north-east in the same stream, and in a cutting adjacent to the stream near where the road to Serjeant's crosses by bridge to the right bank, a heavy conglomerate at least 40 ft. in depth has prominent outcrop. Eastwards from Riverhead similar beds appear in Paremoremo Creek and at the roadside a little north-west of that stream. This band possibly is continuous in a north-easterly direction, reappearing as a strong stratum which outcrops near the lower wharf at Albany, on Lucas Creek, and from there for nearly two miles is traceable onwards by means of boulders shed by it.

North of Riverhead several bands outcrop in an area around Red Hill, and there is an exposure of similar conglomerate on one of the gum-tracks leading from the Riverhead–Helensville Road about two miles south-west from Red Hill. Some of these bands are only a few feet in depth, but others exceed 60 ft. In most of the branches of Gibbs Creek north-east of Red Hill the conglomerate is again found, but it is poorly developed beyond the areas already mentioned, until the Ararimu Stream is reached, where an extensive outcrop occurs. It can be traced northwards to The Peaks in divides west of Ararimu Stream, and was examined *in situ* in several small streams draining west to Kokopu Stream.

It is reported that there is an outcrop of conglomerate at Horseshoe Bush, but the writer did not locate it.

Continuing north, there is no sign of conglomerate until near the Kaukapakapa–Parakakau Road, where it outcrops in unmistakable fashion, probably covering nearly all the area between its mapped extent at Wainui Hill and its southern outlying outcrops adjacent to the Kaukapakapa–Parakakau Road. This is by far the most important development of the conglomerate, and its thickness, including minor beds of sandstone, cannot be much less than 700 ft.

About a quarter of a mile north of Makarau Railway-station a thin bed, less than 1 ft. in depth, with small dioritic and other pebbles, appears on the right bank of Makarau Stream in the massive sandstones typical of the Waitemata series as developed in that district. It serves as an indication that others of similar character are to be expected throughout such beds.

Whilst it is impossible to gain any accurate information on the subject, the facts indicate that the beds of conglomerate throughout the Kaukapakapa-Riverhead district are discontinuous and essentially lensoid in nature. Thin bands are probably of common occurrence, for characteristic boulders are to be found over wide areas other than these where definite outcrops are obtainable.

Relations to Associated Series.

The evidence of certain pebbles enclosed in conglomerates of the Waitemata series has already been shown to suggest widespread erosion of the Onerahi beds during Waitemata sedimentation. Onerahi strata do not outcrop in the mid-Auckland district south of the area which they have been shown to occupy at Dairy Flat, and the Waitemata beds rest, wherever the contacts are visible, upon a surface of Trias-Jura sediments. This

surface seems to have possessed very low relief at the time of its burial, if one may judge from the portions of it now bared for inspection near Papakura and at Waipu and other parts of North Auckland. It must be admitted that the fact of the Waitemata beds resting successively upon Trias-Jura and Onerahi ones can reasonably be explained by an hypothesis of progressive subsidence of a Trias-Jura basement that is undergoing accompanying tilting or warping below the seas in which later sedimentation is proceeding. Cotton (1916) invokes a comparable hypothesis in explanation of similar conditions in other parts of New Zealand. Nevertheless, this evidence, combined with that of the pebbles, furnishes a very strong case in favour of the existence of unconformity between the Waitemata and Onerahi series. There is further support of unconformity in the fact that Onerahi limestones appear immediately to underlie coarse Waitemata conglomerates in Waitoki Creek and a little east of the junction of Kaukapakapa–Parakakau and Kaukapakapa–Silverdale Roads. This abrupt change of facies from marine ooze to near-shore conglomerate implies very considerable marine regression, which must have introduced a greater or less degree of disconformity. This conception of the existence of unconformity is by no means a new one. Unconformity was described many years ago in places not far distant from the present district by both Cox (1881) and McKay (1884A, p. 104), but all fresh evidence is valuable, since some cases of such apparent unconformity are explicable by faulting.

The relations of the Waitemata to the overlying volcanic series have been discussed in some detail in earlier pages (see pp. 141, 143–44). It is sufficient to state that the evidence available in the area now described is inconclusive.

Origin and Petrography of the Waitemata Conglomerates.

The conglomerates generally comprise polished and well-rounded pebbles and boulders firmly cemented by finer matrix of more angular nature. The shape and well-polished nature of the boulders, and the occasional discovery with them of broken marine molluscan remains, indicate that the beds accumulated near the shore-line of the Waitemata seas, but no conclusion has been attained as to the exact location of the latter. Though no facts have been disclosed which can throw light upon the possibility of the material being a rewash of earlier conglomerates, its general freshness, and the rarity of similar conglomerates in older series, are against such a supposition.

In an earlier paper upon the conglomerate at Albany (Bartrum, 1920) the writer described many rocks of igneous origin. He has not made special effort to increase the list, for it is a matter of difficulty on account of the abundance of dioritic rocks which present considerable variety in hand-specimen, though microscopically they are closely allied. Though it has added very few fresh types, his additional work has demonstrated the essential uniformity of the dioritic batholites from which a great proportion of the pebbles of the conglomerates was derived. The general type has perhaps been an augite-diorite, though hornblende-diorites also are common. The augite of the augite-bearing types has been converted almost wholly to uralite, whilst more intense unilateral pressure here and there has developed granulation along with closely-spaced twinning-planes in the feldspars and even prominent gneissic and schistose structures.

Less-frequent acid phases of the magma have crystallized as granodiorites and quartz-monzonite, which seem to show more intense

metamorphism than the diorites, for they are very commonly gneissic. More basic facies are found as ophitic rocks which structurally and mineralogically approach dolerites and epidiorites. The variety of feldspar that they contain is, however, seldom more calcic than andesine-labradorite, and is usually basic andesine, so that the writer's earlier designation of such rocks as dolerites is objectionable in spite of the dominance of ferro-magnesian mineral over plagioclase. It does not appear contrary to general usage to employ the term " epidiorite " for those types characterized by uralite, but the others are best called " diorite-porphyries." With them may also be included a few less basic rocks which have a structure approaching the trachytic. They are fairly coarse and non-porphyritic, and are built of dominant plagioclase in large irregularly disposed laths accompanied by uralite.

In addition to diorites, but probably derived from different intrusions, there are occasional gabbroid types represented amongst the pebbles. They include an anorthosite which already has been described (Bartrum, 1920). Other varieties are highly ophitic hornblende gabbro, with or without olivine. The hornblende has apparently been derived magmatically from hypersthene or augite, for these minerals survive as occasional remnant-grains amidst the hornblende.

The volcanic rocks of the conglomerate are predominantly andesites. They have not been closely studied, but are known to include hypersthene and hornblende types along with pyroxene-andesite containing both augite and hypersthene. Several trachytes were described amongst the Albany rocks, and locally are included abundantly in the conglomerate. Since describing them, however (Bartrum, 1920), the writer has had the opportunity of studying similar rocks from the Whangarei district, for which analyses are available. These showed unexpected acidity, and ranged from slightly calcic rhyolites to dacites. Trachyte-like rocks showing most minute resemblance to dacites of the Whangarei district have recently been found amongst the pebbles of the Waitemata conglomerates now described, and it seems probable that the types described as trachytes in the earlier paper are incorrectly classified. It is inadvisable, however, to attempt reclassification in the absence of exact knowledge of their chemical characters.

Rhyolitic material of rather felsitic nature is the main igneous constituent of some bands of finer conglomerate near Riverhead, but it is particularly scarce elsewhere, and only one specimen was collected from northern occurrences. It proved to be a type with phenocrysts of acid plagioclase and a little biotite surrounded by an abundance of turbid rather glassy base.

The source of the frequent masses of fresh andesite which are found in huge blocks as much as 8 ft. in diameter in several occurrences of the conglomerate has not yet been discovered. They are especially well displayed in a small tributary of Waitoki Stream, which drains the south flank of Wainui Hill. It is inconceivable that they have travelled far from their parent mass, yet no outcrops of similar andesites have been located, unless a greatly-weathered massive rock outcropping in a road-cutting a short distance west of the bridge over Rangitopuni Stream, on the road to Serjeant's, happens to be one. Flat-top Hill, immediately north of Wainui Hill, is an intrusive mass of semi-basic character, but its rock is quite unlike any of the andesites in the conglomerates.

Possible Unconformity in Tertiary Strata.

The writer found a fragment of crystalline limestone about 3 in. in diameter in the conglomerate which outcrops a short distance below the bridge over Rangitopuni Stream, on the road to Serjeant's. It contains *Globigerina, Rotalia,* and other foraminifers, along with crinoid stems, echinoid plates, polyzoans, and other calcareous organic remains. *Globigerina* is especially abundant. The limestone closely resembles many of the Tertiary limestones of the Auckland Province, of which the writer has examined a considerable number in microscopic section. Crystalline limestones certainly appear as thin bands closely associated with the hydraulic limestone near Pahi, in the Kaipara district, but, apart from this and what is perhaps a similar occurrence at Kawakawa, the crystalline limestones of that and the Whangarei district are usually considered to occupy the same horizon as the so-called Whangarei limestone, which Ferrar and Cropp (1921), as a result of their recent detailed survey, relegate to the Tertiary.

South of Auckland City the crystalline limestones have long been regarded as mid-Tertiary.

So little of a definite character is known of the geological history of the Auckland area during Tertiary times that it is as well to consider the possibility of the limestone pebble in the conglomerate having been derived from a Tertiary bed. This identification would suggest an unconformity in the Tertiary succession, which would have to be located somewhere above the limestone horizon. An alternative suggestion, however, is that the fragment of limestone was upthrown with other material from a subjacent limestone stratum by volcanic eruption, and later became incorporated in the conglomerate.

3. ANDESITIC CONGLOMERATE FORMATION.

The rocks of this formation are limited to the north-west portion of the Riverhead-Kaukapakapa district, but they can be traced almost continuously south to the Waitakere Hills, west of Auckland, which are a resistant range composed on its eastern flank mainly of tuffs and on its western of andesitic fragmental rocks of coarse and varied kind. Beyond the Makarau Stream the same beds have an important northerly extension. The relations of these volcanic beds to the Waitemata series have been sufficiently discussed on pages 141 and 145. Where undoubted Waitemata beds and the volcanic rocks were seen in contact there was no indication of unconformity.

The petrographic nature of the constituent material of the conglomerates and breccias was not examined microscopically. In the Waitakere Hills mass pyroxene-andesites are exceedingly common.

4. PLEISTOCENE AND RECENT DEPOSITS.

A synopsis of the nature and occurrence of these beds sufficient for the purpose of this paper has been given on page 141. The origin of the small deposits of iron-ore, which are represented by irregularly nodular masses of impure limonite 1 ft. and more in diameter, which are scattered plentifully upon the surface in a few localities, is debatable. Such deposits are frequent throughout northern Auckland, and have varied relations to topography, for they occur upon tops of plateaux and on benches high on the walls of valleys as well as upon their floors. The limonite has undoubtedly originated

in some instances, though not in others, as a deposit in former swamps. It was noted that the nodular masses often lie upon the exposed surface of a relatively impervious stratum near its contact with more pervious overlying material, and it is probable that seepage of water rich in iron salts along such junctions has given rise to their formation.

Igneous Rocks.

It is unnecessary to add further description to such mention as already has been made of the igneous rocks represented in the Waitemata conglomerates, and this section will therefore be reserved for a brief statement of such other igneous rocks as have been found. The majority occur as intrusions of ultrabasic character penetrating Onerahi rocks, and are described in the next paragraph. In addition there are several other less important occurrences which will be described.

Ultrabasic Intrusives.

This series of rocks, which can broadly be called "serpentines," abundantly intrude Onerahi limestones and claystones.* The rocks themselves are not sufficiently resistant to form outcrops in any way conspicuous in their relation to topography, and they are therefore discoverable only by patient search.

The following are the main occurrences :—

(*a.*) On the east and north-east slopes of Flat-top Hill.

(*b.*) Alongside the Parakakau–Silverdale Road, a short distance from its junction with the Parakakau–Kaukapakapa Road, there is a large interesting mass which has been extensively quarried. A small intrusion of serpentine can also be seen on the same road, near where it gains the summit of the divide between the Orewa and Kaukapakapa drainage basins.

(*c.*) Farther along the Parakakau–Silverdale Road serpentine outcrops near the cemetery shown on the map. The main body has been quarried west of the short branch road giving access to the cemetery, but it can be traced in much-weathered state farther east.

(*d.*) East of White Hills School there is an outcrop adjacent to the Silverdale Road on Mr. Davidson's farm, but it was not examined by the writer.

(*e.*) Near White Hills School there are several exposures representing apparently the one intrusion. The rock is exposed in the road-cutting near the school, and in several places north-westwards. At one of these latter outcrops a quarry has been opened up.

(*f.*) About a mile west of White Hills School.

(*g.*) On the valley-slopes of a small stream separating Wray's house from the school at Horseshoe Bush.

Most of the intrusions recorded are represented on the accompanying map in their approximate positions.

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* Since this was written a short report by Mr. H. T. Ferrar upon the Silverdale district (*17th Ann. Rep. N.Z. Geol. Surv.* (n.s.), 1923, p. 8) has appeared, in which it is stated that the serpentines underlie the Onerahi beds. The evidence submitted is unconvincing, and the supposition raises many more difficulties than it attempts to remove.

The list given cannot be regarded as by any means exhaustive: many unobtrusive occurrences have doubtless been passed by unobserved.

In reality the "serpentines" differ considerably in their true character one from another. The majority vary between wholly serpentinized dunite with subsidiary bastite, and rocks in which the bastite has increased so considerably in proportion to serpentine that the name "harzburgite" is merited. Usually the crystallization is not particularly coarse, but in parts of the intrusion east of Wainui Hill the bastite forms crystals as much as 1 in. in largest dimension. The "serpentine" near the cemetery adjacent to the Parakakau–Silverdale Road, though mainly derived from original dunite, has portions which have a very different character. One such is mainly chlorite along with epidote and sphene.

The Parakakau quarry has opened up a rock possessing very great interest. Not all phases are now obtainable actually *in situ*, though they may be collected from quarried rubble, so that the field relationships between the phases are not observable. Much of the material is crushed and slickensided; and is penetrated by numerous narrow veins of chrysotile, but there is a quantity of less-completely altered rock which varies from typical troctolite to a greenish-black rock which shows successive gradations towards dunite-serpentine. The dark rock is built of chondri of partially serpentinized olivine enwrapped poecilitically by a moderately refractive, colourless, altered mass, which is only faintly birefracting, and which is probably referable to saussurite, since there are occasional remnants of basic plagioclase associated with it. The troctolite is evidently a relatively acidic variation of the feldspathic peridotite, for the proportions of the saussurite and plagioclase to original olivine vary greatly in the sections examined.

In dump-heaps of the same quarry there are frequent fairly coarse fragments of a white pyroxenite which consists in the main of two minerals; the more important is a colourless monoclinic pyroxene, which from casual inspection seems to be diopside, and with it is a fairly large amount of diallage. The full study of this and several others of the rocks has not yet been attempted.

Quartz-porphyrite of Flat-top Hill.

This rock forms a neck consisting partly of lava, partly of fine well-consolidated tufaceous breccia, which penetrates Onerahi beds and forms the elevation of Flat-top Hill. The eruption seems to have preceded the deposition of the Waitemata series, for the porphyrite shows evidence of pressure in bent laths of plagioclase and other points of entire dissimilarity from the post-Waitemata eruptions of the Auckland Province. Petrographically the rock is an open-grained non-porphyritic type built of a plexus of laths of plagioclase (andesine) which enwrap subordinate pale-green, partially chloritized augite, and a little magnetite. There are numerous small rounded areas of quartz built in an irregularly intergrown and radiate fashion. Often they enwrap or enclose the plagioclase. Thus, unless they replace some earlier mineral, of which action there is no evidence, they have crystallized before complete solidification of the porphyrite. As there is every reason to believe that the quartz is a pneumatolytic precipitate from the original magma, the rock has been classed as a quartz-porphyrite.

Doleritic Rocks.

The rocks described under this heading are believed to represent masses intrusive into the Onerahi beds. Certain of them have been found only as boulders, but there may be actual outcrop in the headwaters of Orewa Stream. All are to be found within a short distance of the cemetery adjacent to Parakakau–Silverdale Road.

The dolerite from Orewa Stream is discoverable only with difficulty. It occurs as small fragments in the low right bank of the stream, about a quarter of a mile west of the cemetery. One large block partially bared in a small excavation appears to represent the actual outcrop of a dyke. If so, the dyke is likely to be a narrow one, for the rock is much more resistant than the surrounding beds, and if in moderate quantity would certainly give topographic indications, which are now lacking, of its presence.

Petrographically the dolerite is a relatively coarse, holocrystalline, poorly ophitic rock, made up of about 75 per cent. plagioclase along with almost colourless partially-uralitized augite, a little ilmenite, and rare crystals of green hornblende. Frequent narrow, white, secondary veinlets have not been closely studied, but appear to consist of opal with a little radiating zeolite.

A little east of the cemetery there are numbers of boulders lying on the surface which have very uniform macroscopic appearance, but which when sectioned show some variety, though perhaps not greater than is to be expected in specimens from different parts of the same intrusion. One of the coarser specimens proves to be a basic dolerite, or an epidiorite, with only about 25 per cent. of plagioclase (labradorite) in slender laths. The rest is pyroxene, or uralite derived from that mineral, with a little magnetite and occasional picotite. Some small crystals of unaltered though marginally resorbed hypersthene are present, but the main mass of the pyroxene has been pale augite now almost completely converted to uralite except in a few parts of the section. A fine-grained, non-porphyritic epidiorite shows perfect fine-scale ophitic structure, with some fluxional arrangement of the plagioclase (basic labradorite), which here forms nearly three-quarters of the rock. The pyroxene is completely uralitized.

Mr. H. T. Ferrar, of the Geological Survey, kindly supplied the first specimen that the writer obtained of these epidioritic boulders. In a report furnished to Mr. Ferrar it was suggested that the boulders had been shed from conglomerates in the pre-existing Waitemata cover. Later collecting, however, has established a comparative uniformity of type which contrasts with the diversity usual in the conglomerates, and there can be little doubt that the rocks are actually intrusives which penetrate the Onerahi claystones of the vicinity.

Basalt near Wray's House, Horseshoe Bush.

About 150 yards north-east of Wray's house at Horseshoe Bush the writer found some fragments of basalt in a small gulch on the south side of the track leading to Dairy Flat. The rock differs considerably from the Quaternary basalts of Auckland, Lower Waikato, and North Auckland, for it contains much less plagioclase (not more than 25 per cent.), and exhibits prominent zonal structure in the augite which is abundantly present. Olivine is fresh, coarse, abundant, and in euhedral crystals. The augite is in numerous sharply idiomorphic zoned crystals, and with it are associated very plentiful small flakes of deep-brown biotite. There is a moderate quantity of magnetite, whilst apatite is in very long sharp needles. The matrix is constituted by weathered laths of plagioclase.

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Descriptions of Two New Species of Gasteropod Shells.

By ALBERT E. BROOKES.

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Plate 7.

TATEA, Ten.-Woods, 1879, *Proc. Roy. Soc. Tasm.*, p. 72.

Tatea hedleyi n. sp. (Plate 7, figs. 1–3.)

Shell small, elongate, conical, with rounded nucleus, and without any perceptible sculpture except a few faint growth-lines. Colour pale buff, with narrow ochraceous bands below suture. Whorls 5½, convex, with rather deeply impressed sutures. Body-whorl more than half the height of all preceding ones taken together. Protoconch depressed, consisting of one turn. Spire about 1½ the height of aperture. Aperture ovate, angled above, base rounded, descending. Peristome discontinuous, with margins united by a thin parietal callus. Basal lip thickened, outer lip thin. Columella short and rounded. Umbilicus consisting of a narrow chink. Operculum thin, horny, transparent, paucispiral, with nucleus subcentral, slightly raised and nearer base, upon which are several broad shallow grooves.

Diameter, 1·7 mm.; height, 2·5 mm.

Animal unknown.

Holotype and paratypes in my collection, and paratypes also in the collection of the Australian Museum, Sydney.

Habitat.—Rangitoto Island, Hauraki Gulf, Auckland.

Situation.—Under decaying *Zostera*, near high-water mark.

Numerous specimens were obtained. It adds a genus and a species to our fauna.

Distribution.—Tasmania (genotype); Australia; Macquarie Island.