gasworks; and they are in the Tutaekuri as low down as the mouth of the New Cut.

These rough notes are taken mainly from the point of view of a lover of shells and plants; but it would seem that this area would afford a most interesting harvest to those interested in crustacean and insect life, the crustacean life of the salt and brackish water giving place to the insect-life of the fresh, and of the insects themselves the littoral giving place to the inland species. The fauna of the New Cut gives a fair illustration of this. Where this canal joins the channel just below the recreation-ground the hand-net brings up small crabs, shrimps, sand-hoppers, and a crustacean very like a woodlouse with swimming-lobes to its tail-segments. Following up the Cut with the net, the crabs soon disappear, then the water-slater; sand-hoppers and shrimps become scarce; and as one nears the Tutaekuri the larval forms of insects come up in the net—the hideous masked nymphs of a dragon-fly, and lesser relatives, the sand and horny tubes of caddis-worms, with fresh-water shells and drowned land-shells, and the seeds of many inland plants, just such a haul as one may take from a mat of watercress in one of our upland streams.

Art. XXXIX.—*On the Volcanic Grits and Ash-beds in the Waitemata Series.*

By E. K. Mulgan, M.A.

[*Read before the Auckland Institute, 5th August, 1901.*]

Plates XXII-XXVI.

Section I.—Introduction.

The object of this paper is to describe a deposit of volcanic grit which occurs in a Tertiary formation known as the "Waitemata series." This series, of Lower Miocene age, is developed from the Auckland isthmus northwards for upwards of twenty miles, and stretches completely across the Island. The volcanic grits outcrop for the most part along the shore-line, and lie conformably between the sedimentary strata. To trace individual beds in this series is a matter of great difficulty, as these not only thin out and disappear, but are in places considerably disturbed and faulted. Fossils, moreover, occur but sparingly. The grits, however, are amongst the most distinctive beds, and in nearly all cases are fossiliferous. For these reasons they

form a valuable factor in correlating different parts of the series, and hence the importance of determining whether there are several bands of grit or only one, and whether, moreover, the material is due to air-borne or water-borne sediment. It is important also to locate as nearly as possible the position of the vents from which the material originated.

The microscopic appearance of the sections as shown in the plates will facilitate the comparison of the rocks under discussion.

SECTION II.—LITERATURE.

Dr. Von Hochstetter, in 1859, stated that beds of volcanic ashes were interstratified with the sedimentary rocks occurring on the shores of the Auckland Harbour. Subsequently, in 1864, he made the same statements, and also alluded to the remarkable blocks of volcanic rock which occur on the Whangaparaoa Peninsula interbedded with the stratified deposits.

Twenty years later, in 1879, Mr. S. H. Cox, late Assistant Geologist, reported on the country from Auckland northwards. The whole of the Waitemata series as developed round Auckland and to the north of that city he placed as equivalents of the Pareora beds and of Lower Miocene age. In his report he says, "Above these beds (Orakei Bay beds) the Parnell grit comes in interstratified with sandstone and thin beds of sandy marl; and this grit, together with a certain quantity of volcanic ash and occasional angular stones, represents the commencement of the volcanic outburst which, while some of the ash and smaller stones were spread far and wide over the sea-bottom on which the Waitemata series was deposited, attained its greatest development near the Manukau Heads, where beds of breccia at least 700 ft. and probably more in thickness may be seen resting in direct sequence on the marls, &c., of the Waitemata series, the higher beds of this series being notable for the great abundance of volcanic material which is mixed with the sand and clay. It seems probable that the volcanic activity which must have prevailed during the latter part of the deposition of the Waitemata beds, and the consequent rapid accumulation of material on the sea-bottom, may account for the great absence of animal life during the latter part of this period."

In 1881 the same writer, in a second report on the country north of Auckland, endeavours to show that the Parnell grit overlies conformably the Orakei Bay beds.

Two years later Mr. A. McKay, Assistant Geologist, wrote a brief account of the coast-line from Lake Takapuna northwards to the Wade, in which he conjectures that the volcanic ash-bed known as the "Parnell grit" is the southern

extension of the Takapuna ash-beds. He says, "Immediately north of the lake, where the sea-cliffs are higher and the rocks better exposed, they are easily identified as those underlying the Parnell grit. . . . Nearly two miles beyond the lake grey sandy marls referred to the lower beds are overlaid by a volcanic agglomerate which corresponds to the Parnell grit, differing only in the coarser material which composes it, blocks of volcanic rock more than a foot in diameter being common."

In the following year, 1884, Professor Hutton read a paper before the Philosophical Institute of Canterbury on the age of the Orakei Bay beds, in which he reviewed most of the literature bearing on the Waitemata series. He contended—(1) That there is no evidence to show that the Orakei Bay beds are older than the Parnell grit; (2) that on the whole the evidence, both stratigraphical and palæontological, is in favour of Orakei Bay beds belonging to Pareora system (Lower Miocene).

Sir James Hector, in his progress report for 1885, briefly referred to the interstratified volcanic grits in the Waitemata series. He dissented from Mr. McKay's view that the Parnell grit is the southern extension of the Takapuna ash-beds.

In 1885 Mr. James Park, F.G.S., in a report on "The North Shore to Lake Takapuna," wrote, "In the cliffs at the end of Cheltenham Beach occurs the volcanic breccia or grit seen on the coast north of Takapuna. Here it is almost identical with the Parnell grits. At Judge's Bay the strike is north-north-east, which would carry them under the tuffs at the North Head to the place indicated at Cheltenham Beach. These sandstones, although much disturbed in places, have a general dip to the west, and at the first point north of the lake are lying on a volcanic ash-bed or breccia bed containing many large angular fragments of scoriæ and lava, which appear so recent in character that when broken off it would be impossible to distinguish them from the basalts of Mount Eden."

Section III.—Sketch of Geology of District.

The rocks comprising the cliffs and shores of the Auckland Harbour fall readily under four heads, and serve to indicate as many distinct periods of geological time.

The oldest rocks of the district are the Palæozoic or Maitai slates (presumably of Carboniferous age), a compact indurated sandstone which covers considerable areas in Waiheke, Motutapu, and several other islands in the Hauraki Gulf, and is continued into the Wairoa Ranges.

Following these slates, lying, indeed, unconformably on them in places (as at Motutapu), are the Waitemata beds, of

Lower Miocene age. These consist of soft or muddy sandstones and friable shales. An average section usually shows bands of sandstone and softer shales alternating with each other. The sandstones are often hard, and vary considerably in texture from fine to coarse. In a few places they are fossiliferous, though as a rule fossils are absent from the great body of strata, though wood in fragments may occur. The strata themselves vary in thickness from a few inches to several feet, the shales or sandy clays forming, on the whole, much thinner layers than the sandstones, seldom, indeed, reaching a thickness of more than a foot. They are, moreover, much softer than the sandstones, and readily crumble away when exposed to the action either of the weather or the sea.

A noticeable feature of the series is the horizontal or gently undulating position which, on the whole, the beds maintain. Here and there, however, great disturbances have taken place, resulting in the rupture and dislocation of the strata, the formation of numerous faults, and the consequent obliteration of connecting-links between individual beds.

To the third group belong Hochstetter's Quaternary beds, consisting of plastic clays and sands, occurring, for instance, along the Tamaki Creek and on the southern shores of the Manukau Harbour.

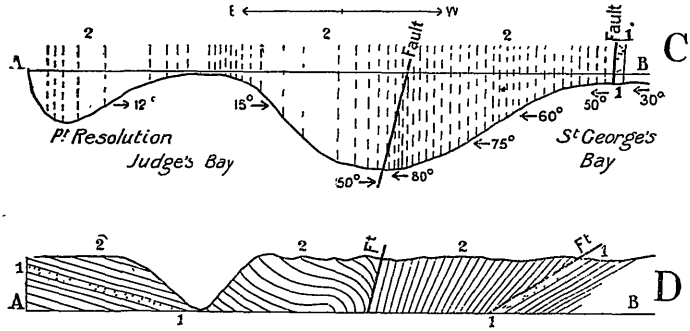
The fourth group comprises the Pleistocene lavas and tuffs which have been ejected from the numerous volcanic vents in the neighbourhood and spread over the greater portion of the isthmus. The lava, consisting entirely of basalt, varies much in texture. It is, on the whole, a hard compact rock, and is always rich in olivine. (See rock section E, Plate XXVI.)

SECTION IV.—GRIT-BEDS ON SOUTH SIDE OF THE AUCKLAND HARBOUR.

On the eastern side of Judge's Bay there occurs a band of volcanic grit some 10 ft. in thickness dipping west at an angle of about 12°. The band consists of fine volcanic material, the fragments ranging from minute specks to particles somewhat larger than a pea. The whole is firmly united together, and forms a reef which runs about 100 yards into the harbour and is exposed at low water, its hard character enabling it to withstand the action of the waves, which have worn away the softer sandstones and shales. It lies conformably between other members of the Waitemata series, is distinctly marked off from the layers both above and below, and can be traced round Point Resolution, where it forms a long outcrop on the western side of Hobson's Bay. About three miles further east, at St. Helier's Point, and again at

Tamaki Point, a similar band appears, almost identical in texture and mineral contents with that outcropping at Parnell. (In point of fact, the only difference is that the St. Helier's Bay beds are slightly coarser at the base.) To the west it appears in St. George's Bay, dipping east at an angle of 30°, the connection between the two bands being shown in section in fig. 1. Between the two exposures the sedimentary strata are much disturbed, in places being thrown on end. There seems to be little doubt that to the same band of grit can be traced the exposures at St. George's Bay, Judge's Bay, St. Helier's Point, and Tamaki Point.

Fig. 1.



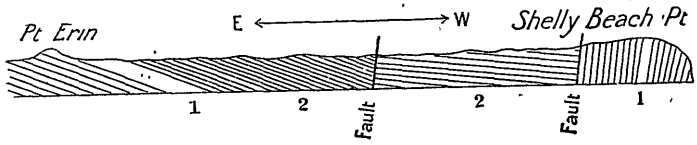
C. Plan. D. Section through AB, showing connection between outcrops of volcanic grit at Judge's and St. George's Bays, known as the "Parnell grit": 1. Volcanic grit. 2. Sandstones and shales.

Following the shores of the harbour westward, a similar band of volcanic grit is met with about a mile and a half further on below Point Acheron. The exposure occurs on the shore-line, and the band appears to dip west at an angle of 10°; but since it cannot be traced into the cliff it is impossible to estimate its thickness or be sure of its dip. Half a mile beyond this, near Point Erin, a similar band, 12 ft. in thickness, outcrops in the cliff and dips west at an angle of 17°. A few hundred yards further on, at Shelly Beach Point, it again appears, lying almost vertically between the other sedimentary strata. (See fig. 2.)

The band of grit strikes north from Shelly Beach Point and sends out a long reef into the harbour in that direction. As in the case of the Parnell grit, the strata between the outcrops are disturbed and faulted. The grit in this exposure is composed of volcanic material similar to that comprising the Parnell ash-beds.

It must be noted that both these and the Parnell ash-beds are of a fairly constant texture, and contain no large included fragments. As previously stated, the Point Acheron outcrop can only be seen as a short platform on the beach. It cannot be connected stratigraphically with the exposures at Point Erin; but the distance separating the two places is not great, and in composition the bands are identical. It seems an obvious conclusion, therefore, that the Ponsonby outcrops are connected.

Fig. 2.



Section from Point Erin to Shelly Beach Point, showing connection between the two outcrops of grit: 1. Volcanic grit. 2. Sandstones and shales.

It is impossible to correlate with certainty the Parnell ash-beds and those occurring at Point Erin, because—(*a*) A great portion of the City of Auckland is built on the land lying between them; (*b*) the intervening strata are much disturbed; (*c*) most of the intervening country is covered with tuff from some of the Pleistocene volcanic vents. But the great similarity in the material composing all these beds; the fact of there being an undoubted connection between the Parnell and St. Helier's Point outcrops on the one hand, and on the other between the various exposures at Ponsonby; and the further fact that, whereas the distance from Judge's Bay to Tamaki Point is upwards of three miles, that from St. George's Bay to Point Acheron is considerably less—would at least point towards the very great probability of the Ponsonby outcrops being extensions of those found at Parnell: —that is, the outcrops of grit occurring along the southern shores of the Auckland Harbour are merely different exposures of the same band.

SECTION V.—GRIT-BEDS ON THE NORTH SIDE OF THE AUCKLAND HARBOUR.

Across the harbour, just below Takapuna Point, at a distance of some two miles and a half from Judge's Bay, there occurs another exposure of volcanic grit. This formation, known as the "Cheltenham Beach beds," consists of a band of about 12 ft. in thickness containing both coarse and fine material. At the bottom is a layer a few inches in thickness of coarse grit or fine conglomerate, the particles being from

1 in. to 2 in. in diameter and slightly waterworn. Above this the material is finer and similar to that met with on the southern side of the harbour, at Judge's Bay and Point Erin. Through the band are scattered numerous angular or sub-angular fragments ranging up to 8 in. or more in diameter. Some of these are close and compact; others, again, are vesicular and amygdaloidal, the infiltrating mineral being principally calcite.

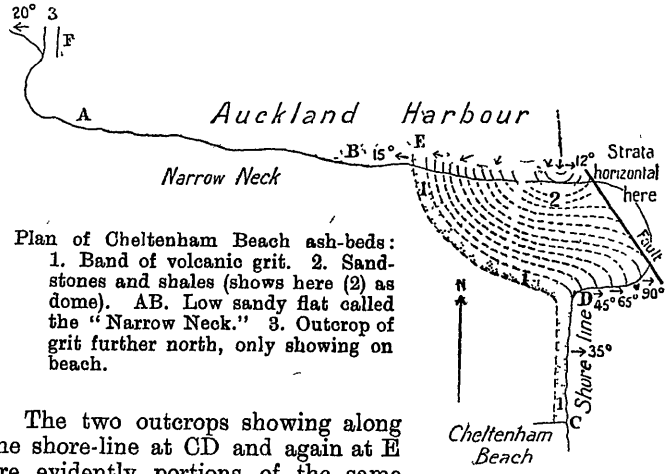
The rocks comprising the fragments are considerably altered and weathered, the feldspar crystals being many of them kaolinised. Large crystals of augite are plainly visible in most of the included fragments.

A section from one of the fragments examined under the microscope showed a microcrystalline ground-mass consisting of a triclinic feldspar, minute augite crystals, and numerous specks of magnetite, with larger porphyritic crystals of feldspar and augite, as well as those of an altered mineral. Many of the feldspars were kaolinised, and most of them contained inclusions of magnetite and augite. They were triclinic, and comprised the varieties andesine and oligoclase. Small augite crystals were numerous, but only a few were idiomorphic. The crystalline form and mode of occurrence of the altered mineral suggested the possibility of its being altered olivine. On the whole, however, the evidence was not sufficient to pronounce definitely on the constituent. The rock is obviously an augite-andesite containing perhaps a little olivine. (See rock section D, Plate XXV.; specific gravity, 2·8.)

The first outcrop of conglomerate and grit met with is at the north end of Cheltenham Beach. The band dips east at an angle of 35°, and, running nearly horizontally for about 200 yards, suddenly disappears, as shown in fig. 3. From this onwards the strata are much disturbed and faulted, in places being thrown on end. Beyond a well-marked dome a little further north the grit again appears in a band some 8 ft. or 10 ft. thick, but the thickness cannot be accurately determined as the band does not show well in the cliff. Here it dips west at an angle of about 15°, and, running out to sea, forms a long reef. From this point northwards for a few hundred yards the cliffs give place to a low sandy flat over which the sea flowed not many years ago, but which has now become dry, the land being raised partly by the wash from the hills and partly by the sand carried in by wind and sea. When the beds (Waitemata) next appear they are dipping west at an angle of 20°. Half a mile or less further north from the outcrop of grit mentioned last another exposure of the same material occurs. Here the band strikes north and presumably dips west; but, as it only shows as a

low platform on the beach, it is difficult to be sure either of the direction or the angle of the dip.

Fig. 3.



Plan of Cheltenham Beach ash-beds: 1. Band of volcanic grit. 2. Sandstones and shales (shows here (2) as dome). AB. Low sandy flat called the "Narrow Neck." 3. Outcrop of grit further north, only showing on beach.

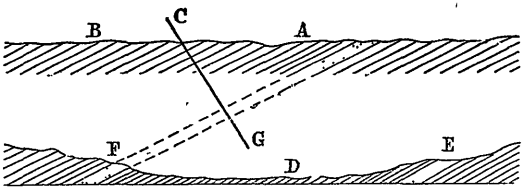
The two outcrops showing along the shore-line at CD and again at E are evidently portions of the same land as shown in above plan. This bed, dipping east at CD, has presumably had its dip changed by the same force which formed the dome, and appears again at E dipping west. The strata at the end of the point are truncated by a fault as shown. To the southern side of the point the dip rapidly increases until at the fault the strata become vertical.

In a paper read before the Auckland Institute in 1889 Mr. Park gave a plan of the Cheltenham Beach ash-beds. In this, however, no notice is taken of the change in the direction of dip in the two exposures, nor is any mention made of the dome. Both of these matters have an important bearing on the question under discussion. Furthermore, the northern outcrop is obtained by producing the line CD (fig. 3), whereas in point of fact it occurs considerably to the west of this position.

The outcrop at F (fig. 3) may have reached its present position owing to being horizontally displaced by a strike fault running east and west. The low swamp occurring between the higher cliffs on either side may well indicate some faulting of the strata, in consequence of which the sea has been able to effect an entrance and erode the narrow valley, now become a dry sandy flat. Additional force is lent to this theory by the fact that a line drawn across the narrow neck east and west would pass through low mud-flats and the waters of

Shoal Bay, and could be continued for upwards of two miles before reaching high ground. The following diagram will furnish a further explanation of this theory :—

Fig. 4.



Suppose CG to be the line of fault. Then if the downthrow occurred on side A, and subsequent denudation planed the whole surface level, the band would appear displaced at E and F as shown, the surface at D representing the low ground between the two outcrops. Furthermore, the amount of lateral displacement would increase and that of vertical displacement decrease with the angle of hade. A normal strike fault hading at a large angle would cause the necessary lateral displacement with a relatively small amount of throw.

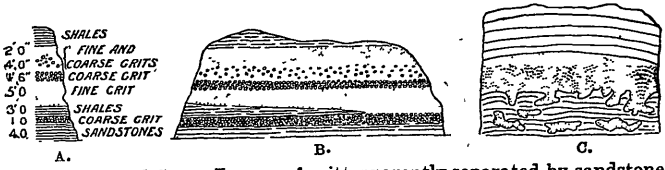
It would seem, therefore, that the exposure occurring at Cheltenham Beach, marked CD (fig. 3), is undoubtedly connected with that marked E, which is almost to a certainty the same band as the one outcropping further north at F.

Mr. Park states (page 5) that the strike of the Judge's Bay bed would carry it to Cheltenham Beach. This may be so, but the bed at Judge's Bay dips west, whereas that at Cheltenham Beach dips east. Besides, the strata at Cheltenham Beach are so disturbed as to render their correlation with those occurring at Parnell a matter of extreme difficulty; indeed, no stratigraphical connection can be established between the beds on the opposite sides of the harbour. Considerable difference, moreover, is to be found in the material composing the beds at the two localities. At Parnell the deposit shows plenty of Maitai slate, contains no larger fragments and extremely few fossils; whereas at Cheltenham Beach the grit is coarser in character, in places merging into conglomerate, is distinguished by numerous blocks of andesite, and is fossiliferous throughout.

From Cheltenham Beach north the strata consist of the ordinary sandstones and shales, these being overlaid at Takapuna Beach by a stream of basaltic lava from the old crater which is now occupied by Lake Takapuna. About a mile north of this crater-lake the ash-beds again appear in the seacliffs, lying, as before, conformably between other beds of the

Waitemata series. At this point, however, they present the curious appearance indicated by the accompanying section (fig. 5). Portions of the volcanic grit outcrop in irregular patches and detached bands on the weathered surface of the cliff in such a way as to suggest at first sight a number of different layers. After a careful investigation of the locality, I am of opinion that only one bed is to be seen, and that the appearance of different bands has resulted from portions of the grit being squeezed in between the softer sandstones and shales. The appearance has been produced subsequent to deposit. This belief is further strengthened by the fact that in places the shales between the grit are arranged in lenticular masses, thinning out and disappearing in the course of 50 or 60 yards or even less.

Fig. 5.



Appearance of cliff: A. Layers of grit apparently separated by sandstones and shales. B. Grit continuous. Sandstones and shales thinning out. C. Grit appearing in detached masses through softer strata.

The grit here presents much the same appearance as that at Parnell and Point Erin, except that in places there are coarser layers with fragments up to $\frac{3}{4}$ in. in diameter. Scattered through the ash-beds are angular and subangular volcanic fragments, some of them being upwards of 12 in. in diameter. These consist of a vesicular lava of augite-andesite showing large augite crystals and numerous amygdules of calcite and the zeolite chabazite. A section made from one of these blocks showed under the microscope a microcrystalline ground-mass similar to that seen in the Cheltenham Beach section, except that a good deal of it was composed of an altered product—probably chlorite. As in the case of the other section, the porphyritic constituent consisted of large crystals of andesine, oligoclase, and augite, and a small amount of altered olivine. The feldspars showed broad as well as fine lamellæ, and contained numerous inclusions of augite and magnetite. In some of the crystals the curious phenomenon appeared of the direction of extinction being different in different parts of the crystal. The edges and central portions extinguished at different angles, owing to the outer zone being less basic in character. Large and small augite crystals were numerous, and many of the former showed well-marked crystalline form. Specific gravity, 2·7.

The rock, it will be seen, is similar in all essentials to that found at Takapuna. (See rock section A, Plate XXII.)

Note.—The large crystal shown in the section was the only undoubted olivine crystal present. Without this explanation the section would seem to belong to a rock rich in olivine. This is not the case.

The only description of the included fragments of rock in these deposits is that given by Mr. Park, who states that the rock composing the included fragments could not be distinguished from Mount Eden basalt. It is important to distinguish at the outset between the megascopic characteristics of the two rocks. The Mount Eden lava is a well-defined basalt, rich in olivine, whereas the rock included in the deposit of grit is an undoubted augite-andesite. In some of the fragments from Takapuna ash-beds a very few olivine crystals do occur, but they are much altered, and can only be identified by the aid of the microscope.

The rocks in the neighbourhood of the grit are much contorted and disturbed. Indeed, this disturbance seems to characterize most of the sedimentary rocks in the immediate vicinity of the volcanic grits.

The ash-beds here reach a thickness of from 10 ft. to 14 ft., and can be traced for about 100 yards north. They dip landwards, or towards the west, at an angle of 15°, and show just before disappearing in the cliff an outcrop approximately horizontal. Fine and coarse grits seem to be associated without any obvious method of arrangement, shading into one another without any distinct lines of demarcation. The particles vary from the finest material up to angular or subangular fragments 2 in. in diameter. The sandstones and shales here and there thin out and disappear, and the grit shows the irregular arrangement mentioned previously. This thinning-out of the strata is probably another indication of the pressure to which the beds have been subjected. Fossils are here relatively abundant as compared to Cheltenham Beach.

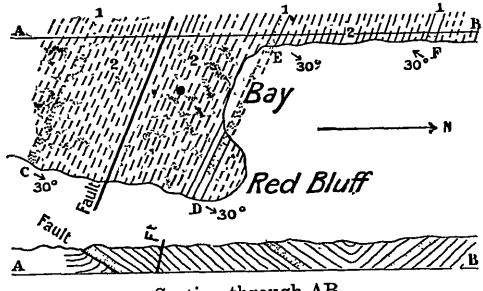
Both Mr. McKay (*l.c*) and Mr. Park (*l.c.*) assert that these ash-beds are portions of the band seen at Cheltenham Beach. But no stratigraphical proofs in support of this contention are attempted; in point of fact, none are available. The Waitemata beds are obviously shallow-water deposits. None of the strata as a rule persist for any great distance. Hence the difficulty of establishing any stratigraphical connection between outcrops separated from each other by a distance of from three to four miles. The probability is, however, that such a connection does exist.

About a mile further along the beach, at a place called Red Bluff—the headland being stained by red and brown oxide of iron, suggestive of its volcanic origin—the volcanic grits

again appear in a band about 12 ft. in thickness, and can be traced northwards for a few hundred yards. Between the exposures of grit just described and those at the Red Bluff the sedimentary strata are considerably disturbed and faulted, so much so that it is almost impossible to establish any satisfactory connection between them. It is a noteworthy fact, however, that nowhere do these volcanic ash-beds show more than one outcrop—*i.e.*, nowhere do they outcrop as a number of bands distinctly separated by sedimentary strata.

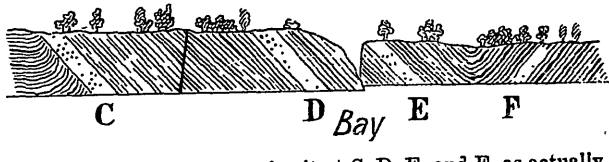
At the Red Bluff the grits become coarser, in some places passing into conglomerates, with fragments, slightly waterworn, 2 in. to 4 in. in diameter. The coarser texture of the beds in this neighbourhood would seem to indicate greater proximity to the old seat of activity. Scattered through the beds are large volcanic blocks corresponding in size, texture, and composition to those previously described; and, as in the case of similar exposures elsewhere, these ash-beds lie conformably between the Waitemata sandstones and shales. Here, however, the direction of dip is north-east, and the angle at which the beds are inclined approximately 30°.

Fig. 6.



Section through AB

Plan and section showing connection between outcrops of volcanic grit at the Red Bluff: 1. Bands of volcanic grit. 2. Sandstones and shales. C, D, E, F. Four outcrops of grit.



Sketch showing four outcrops of grit at C, D, E, and F, as actually seen on the ground.

The two outcrops at the Red Bluff, C and D, are caused by a fault which has parted the band and displaced one portion horizontally (see section). Beyond outcrop D the band disappears in a little bay, but reappears again a short distance further on at E, where it has been bent into a syncline showing as a fourth outcrop at F. These are the only exposures of the grit in this locality. As in the case of the Takapuna ash-beds, they are fossiliferous throughout.

That these ash-beds were laid down in water is abundantly proved by the included fossils (*Bryozoa*) they contain. The angular character of the whole of the material, both large and small, would point to its being deposited at no great distance from where it originally fell; whilst the fact that the bands lie conformably between the other members of the Waitemata series tends to indicate that these grits were laid down horizontally and subsequently tilted by the same forces which caused the inclination of the other sedimentary beds.

As already mentioned, these grits in several places are fossiliferous. Indeed, the fossils are abundant and can be readily seen standing out from the weathered surface. In the softer strata above and below they hardly occur at all, the gritty floor having been evidently more favourable for their growth, and the calcareous nature of the grit having aided in their preservation. Mr. S. H. Cox says that these deposits of grit represent the commencement of the volcanic outbursts which culminated in the formation of the volcanic breccia at the north Manukau Head, and further adds that this volcanic activity may account for the great absence of life during the latter part of this period. This explanation, however, does not seem satisfactory, since it is in the volcanic beds that fossils are most numerous; whilst, moreover, many of the *Polyzoa* and *Bryozoa* occur in the positions they occupied whilst living.

This brings us to a consideration of how the material reached its present position. It is hardly conceivable that it was ejected into the air and fell as the product of a single shower, for in that case one would expect to find the fossils either at the top or bottom of the beds—possibly in both places—whereas some, at any rate, of the exposures are fossiliferous throughout their entire thickness. The more probable explanation is that the material was furnished gradually, and carried along the bottom by currents working out from the sources of supply. In this way a large amount of volcanic material could be spread over the bottom with sufficient slowness to admit of the growth of marine organisms, yet rapidly enough to mark off the deposit from other members of the series.

SECTION VI.—GRIT-BEDS OF THE WHANGAPARAOA PENINSULA.

The next important outcrops of these volcanic grits are on the Whangaparaoa Peninsula, where they occur in considerable numbers and exhibit great variety of texture. As elsewhere, they lie here conformably between the other members of the series, which have been much disturbed in their vicinity.

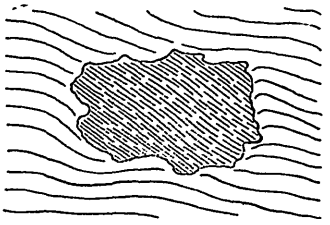
Starting from the northern side and travelling east, the ash-beds are first met with in a place called Coal-mine Bay. Here the grit occurs as a well-marked band dipping north at an angle of 8°. In composition and appearance this bed corresponds with those described previously, being perhaps, on the whole, a little coarser in texture. It varies from fine to coarse, the coarser material being below, shading into a fine conglomerate. The exposure at this place is not large, but about half a mile further on the same band outcrops again and forms a reef running for some distance into the sea. The included blocks, which are numerous, consist of a hard, compact, fresh-looking andesite, with large porphyritic crystals of augite and a triclinic feldspar. Examined microscopically a section from one of these blocks showed a ground-mass and porphyritic constituents almost identical with those already described. The feldspars comprise the varieties andesine and oligoclase, and, as in the other sections, show numerous inclusions of augite and magnetite. The augite crystals are perhaps larger than those in the other rocks described, whilst the olivine, although showing crystalline form, is much altered, and is not present in sufficient quantities to form an essential constituent. Chlorite, evidently an alteration product, occurs in several places in abundance. (Specific gravity, 2·8.)

From Coal-mine Bay east the grits and fine conglomerates are numerous, cropping out at intervals all along the coast. They are similar in appearance to the one just described, except that they become distinctly coarser towards the point to the east The beds here have been so disturbed and the exposures in places are so small that it is impossible to establish any stratigraphical connection between individual outcrops. In both grits and conglomerates fossils occur from top to bottom. The included fragments here reach a diameter of from 1 ft. 6 in. to 2 ft., and occur in greater abundance than in the grits nearer Auckland.

Towards the end of the point great blocks of andesite appear, measuring in one case at least 18 ft. across. This huge mass must have fallen on the bottom and been covered up with sediment. The force with which the mass fell may have displaced the strata, causing the appearance presented in the figure in the margin. It may, moreover, have fallen in water.

But the strata round and about the block are considerably weathered, one bed shading into another without any clear line of division, hence the difficulty of explaining satisfactorily what has actually taken place.

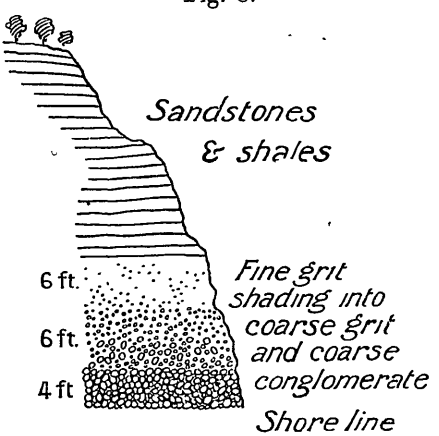
Fig. 7.



Included block of andesite, 18 ft. across, imbedded in sandstone and shale at Whangaparaoa.

In the case of other included masses the beds do not seem to be in any way displaced, and in no case has any alteration in the sedimentary strata been brought about at their junction with these masses. This phenomenon is not easily explained. The rocks are not in the least dyke-like in character. They have effected no alteration in the surrounding beds. They cannot, therefore, be explained as being the remains of intrusive masses. They must have reached their present position when cool, and cannot have fallen with much violence on the soft yielding sandstones and shales, which otherwise would show more signs of being displaced. Moreover, such huge masses cannot have been hurled for any great distance through the air, and the fact that they are not water-worn forbids the assumption that they have been transported far by the action of water; and yet there is no indication of any volcanic vent in their neighbourhood further than that furnished by the presence of the blocks themselves. It may have been that they were deposited quietly on a relatively hard firm bottom and subsequently covered with sediment.

Fig. 8.



Section at end of point, Whangaparaoa.

At the extreme eastern point of the peninsula is a series of volcanic deposits some 16 ft. in thickness, with horizontal

outcrop, as shown in accompanying sketch. Below is a coarse conglomerate, merging into breccia, containing subangular fragments up to 3 ft. in diameter, none of the blocks being much waterworn. Above, the conglomerate gradually becomes finer, passing into coarse and then into fine grit, the whole being capped by sandstones and shales. Throughout the grit angular volcanic fragments up to 1 ft. in diameter are scattered, and the whole, as elsewhere, is fossiliferous.

The rock of which these blocks are composed is hard and compact, with very large augite crystals and crystals of feldspar showing plainly. Under the microscope the rock appeared to be identical with that found at Coal-mine Bay, except, perhaps, that the ground-mass was almost holocrystalline and the olivine more difficult to identify.

From the presence of such large masses of volcanic rock it would appear that the vent from which they were discharged was somewhere in the immediate neighbourhood, though I could find nothing to show in what direction it was likely to be discovered. Possibly its site may be further north or east beneath the waters of the Hauraki Gulf.

On the southern shores of Whangaparaoa similar bands of grit occur at intervals, but the outcrops are not so well marked as those on the northern side, and the material of which they consist is finer than that met with on the opposite shore. There is little doubt that these outcrops are merely the southern extension of those found on the northern side of the peninsula.

SECTION VII.—GRIT-BEDS OF THE MANUKAU HARBOUR.

Along the northern shores of the Manukau Harbour there occur numerous outcrops of volcanic grit, both fine and coarse deposits being abundant. In several places connection can be traced between the outcrops, but more frequently this is not possible. There is, however, with one exception, to be mentioned presently, absolutely no evidence to show that the bands are distinct.

The same formation prevails here as that found along the shores of the Auckland Harbour, and in every case the grit lies conformably between the sandstones and shales of the Waitemata series. In many places the strata show evidence of having been subjected to much disturbance, and faulting is common all along the coast-line.

The first outcrop of grit appears on the beach about a quarter of a mile from the Village of Onehunga. It consists of angular fragments ranging from very fine particles to those the size of a pea, but in this place the outcrop is so weathered that it is difficult to determine its composition. It here disappears underneath the shore-line.

A few hundred yards further on a similar band outcrops, having at its base a layer of fine conglomerate (the particles being about 2 in. in diameter) some 3 ft. in thickness.

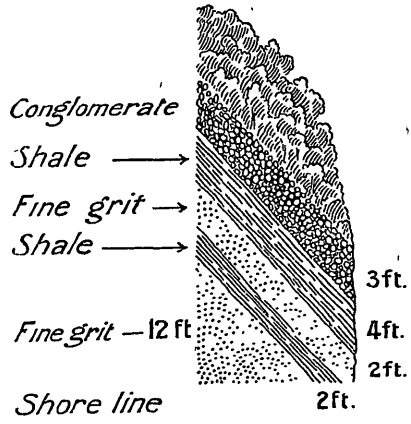
A quarter of a mile west of this spot another exposure occurs, distinctly coarser than that first met with. The whole band, about 10 ft. thick, is composed of fragments of scoriæ and volcanic ash up to $\frac{3}{4}$ in. in diameter, and contains a great deal of wood in minute pieces converted into lignite. This bed can be traced for some distance, but finally disappears in the cliff. It reappears, however, half a mile further on, maintaining the same thickness and texture. Scattered through the band at this spot are a considerable number of angular volcanic fragments, many of them being 1 ft. or more in diameter. They are imbedded in the grit, and seem to have been thrown out when that material was deposited. The rock is a hard fresh-looking andesite, with minute steam-cavities, showing microscopic crystals of augite and feldspar. (Rock section C, Plate XXIV.)

Examined microscopically an average section showed a microcrystalline ground-mass similar to that appearing in the other sections described, though containing perhaps a little more feldspar. The porphyritic constituents were identical with those in the other sections, except for the absence of olivine, no traces of which were to be found. In some of the feldspars appeared the same peculiarity as that seen in the section from the Takapuna ash-beds, successive zones of the material of the crystals extinguishing at different angles. Augite and magnetite were very plentiful, the former appearing in both large and small crystals, and showing well-marked crystalline form. (Specific gravity, 2·7.)

From this on westwards for a couple of miles there are frequent outcrops of these ash-beds. In several places they contain large angular included fragments similar to those just described. Here and there they pass into conglomerates whose particles are in some cases considerably waterworn. The conglomerates for the most part, when traced upwards, pass into finer grits. The coarser portions do not contain fossils. In some of these conglomerate beds I found pebbles of Maitai slate. These, about 1 in. in length, were flattened and much more waterworn than the volcanic material. None of this slate has yet been found nearer than Motutapu, an island in the Hauraki Gulf about five miles north-east of Auckland. The inference is that these pebbles have either been derived from beds of slate in the immediate neighbourhood underlying the Waitemata series, or they have been brought into their present position by the agency of rivers or currents, which have carried them from more distant localities.

After passing this spot, about a mile beyond a headland called "The Horn," the outcrops of grit disappear, and are not met with until about five miles further on, when they again become plentiful. They are similar in every respect to those already described. One exposure, however, deserves special mention. It occurs at Shag Point. As shown in sketch (fig. 9), this consists of a band of conglomerate composed of fragments of a close-grained andesite, 6 in. to 8 in. in diameter, much waterworn and rounded. This bed, 3 ft. in thickness, rests on beds of shale some 4 ft. thick; and this, again, is underlaid by a layer of grit 2 ft. in thickness. A small layer of shale separates this from another band of grit 12 ft. thick, which extends to and passes under the shore-line. The strata here dip into the hill and disappear. To the west the coast-line curves round to form a bay, whilst to the east the cliffs give place to a low gently sloping bank covered with vegetation; hence this is the only section available. Above, the vegetation extends down to the conglomerate and the rocks are completely decomposed, so that it is impossible to say what may overlie the band—most probably the ordinary Waitemata sandstones and shales. It would appear from the section that there are at least two, and possibly three, distinct bands, one of conglomerate and two of grit, separated by layers of shale. This conjecture is rendered all the more probable from the fact that the conglomerate overlies the grit. Here, however, we are approaching a country where in early Tertiary times there was great volcanic activity; hence it is not surprising to find an increase in the amount of volcanic material interstratified with the ordinary sedimentary deposits.

Fig. 9.



Sketch at Shag Point, showing distinct bands of conglomerate and grit.

The country from Puponga Point northwards consists of coarse volcanic conglomerate intersected by dykes and lava-streams of andesite and beds of volcanic tuff. Masses of Waitemata beds occur in places mingled with the conglomer-

ate, as though the volcanic explosions of former times burst through and ruptured the sedimentary strata, fragments of which were eventually enclosed with the conglomerate.

The lava-streams of this district are, on the whole, very much alike. They consist of a hard compact rock slightly vesicular, showing abundant augite and feldspar crystals. The augite is plentiful, but none of it is very large. I have examined a considerable number of rock sections from these lava-flows, and have found the rocks similar—indeed, almost identical—with those already described from the fragments in the volcanic grits. They differ from these only in the absence of olivine; but, as this mineral is not an essential constituent, its presence or absence is a matter of but small importance.

Section VIII.—Summary and Conclusion.

It will be seen from the foregoing that these volcanic grits are spread over a considerable area on both sides of the Auckland isthmus, and that they invariably lie conformably between the sandstones and shales comprising the Waitemata series. It is clear, moreover, that the material, although arranged by water, has not been brought from any great distance; at least, the larger fragments could not have been carried far. A careful comparison of the sections described—and these, it must be remembered, were taken from exposures separated by considerable distances—shows that the rocks differ only in the presence or absence of olivine, and that this difference is one not between separate exposures on the same side of the isthmus, but between those on opposite sides. Moreover, this difference is so slight that it hardly deserves to be considered at all, the rocks being identical in all essential mineral contents and in specific gravity.

Stratigraphically there is no evidence to show that all the outcrops belong to one and the same band; but the close correspondence between the fragments of rock included in them, their similarity in texture, in bedding, in arrangement, and in fossil contents, and, further, the fact that in no case, except at Shag Point, is there any exposure showing more than one band, whereas in several cases a connection can be traced between separate outcrops, all furnish evidence which points towards the probability of the various exposures being connected together. There seems little doubt that this is the case with the exposures on the southern side of the Auckland Harbour. Between the ash-beds at Cheltenham Beach, Takapuna, and Red Bluff the connection has not been established; but the great similarity presented by these exposures, and the fact that the several outcrops showing at Cheltenham Beach can be correlated, as can also those ap

pearing at Red Bluff, adds considerably to the likelihood of a single band being accountable for the whole of the exposures along the northern shores of the harbour, perhaps—though this is not so certain—as far as Whangaparaoa Peninsula. If this be the case, and there seems to be much evidence in support of the contention—that is, if a band of grit maintaining an average thickness of 10 ft. or 12 ft. persists for upwards of six miles in a northerly direction—the inference does not seem an extravagant one that the same band, which, it is to be borne in mind, shows no signs anywhere of thinning out, should extend two or three miles towards the south. This distance would bring it across the water as far as Judge's Bay, and so connect the exposures on the opposite sides of the harbour. This, however, is only a conjecture, though by no means an unreasonable one.

In a previous portion of the paper I referred to Mr. Park's statement that the strike of the grit at Judge's Bay would carry it to Cheltenham Beach, a statement which in itself is perfectly correct, but which does not meet the difficulty of correlating the two exposures. Though there is much in favour of the contention, and though it is possible to imagine conditions under which the existing outcrops could be connected, yet the presence of large masses of lava in one set of beds and their entire absence in the other is not easily accounted for. The whole matter, in short, is one whose solution is beset with considerable difficulty. It was this I wished to bring out in referring to Mr. Park's statement.

From the evidence adduced it would appear, so far as the northern side of the isthmus is concerned, that we may conclude the exposures on the southern side of the harbour to be connected; that a very strong probability exists of the Cheltenham Beach, Takapuna, and Red Bluff outcrops being connected; and that there is much to be said in favour of the theory that the Cheltenham Beach and Parnell exposures belong to the same band.

Along the shores of the Manukau Harbour the beds may not correspond to those met with on the opposite side. There are no exposures on the land between the two seas, and the distance as the crow flies from the Parnell ash-beds to those nearest to Onehunga is about six miles, hence the impossibility of connecting the two stratigraphically. But, whether connected or not, these beds are identical with those found on the opposite side, and, like them, have every appearance of belonging to the same band. The outcrop at Shag Point, near Puponga, showing the separate beds, is certainly an exception; but it must be remembered the exposure was not large, and no very definite conclusions need be based on it. It may be that the lower layer of grit is a western extension of that

found nearer Onehunga, and the interbedded shales merely lenticular masses between which the grit has been squeezed, the thinning-out being obscured by the formation of the ground and the vegetation covering it. In this case the conglomerate at the top would represent a later deposit. But the presence of conglomerate on the outskirts of a conglomerate country is not surprising.

From the similarity between the fragments included in the grits and the composition of the grits themselves it is not unreasonable to conclude that they were ejected by vents which had some connection with each other. Moreover, that there were several vents there is not the slightest doubt. It is quite inconceivable that fragments of rock such as those found at Whangaparaoa, Takapuna, Cheltenham Beach, and in the ash-beds along the northern shores of the Manukau Harbour, could have been hurled for any great distance through the air; and the fact that they are not much waterworn shows that they have not been transported far by the agency of water. Hence we may conclude that there were several centres of eruption and several showers of ashes, some coarser than others, as in several places, notably at Takapuna (see Section V., above), the coarser ash overlies the fine. Moreover, the eruptions which caused the ash must have occurred about the same time, and the showers themselves must have taken place at relatively short intervals.

All traces of the localities of these old centres of activity have long since disappeared; but the evidence furnished by the material composing the grit enables within certain limits the loci of some of them to be established. One volcanic centre undoubtedly existed at or near Whangaparaoa. Such huge fragments as those found there must certainly have been derived from a vent in the immediate vicinity of their present position. Another centre evidently lay not far from the Takapuna ash-beds, the fragments in the grits there being too large to have been derived from Whangaparaoa, a distance of about ten miles. Another vent probably had its site at or near Cheltenham Beach. But in the case of the two latter it is not possible to do more than conjecture. It may have been that a single vent situated somewhere between them furnished the material for the deposits in both places, as well as that for those on the southern shores of the harbour. That it probably existed nearer to Takapuna and Cheltenham Beach than to the southern side of the harbour is shown by the difference in texture of the material in these places, that found in the beds of the former being much coarser than the other. There is, however, nothing to indicate either the precise locality or the number of these vents. It is quite conceivable that much of the material was derived from vents in the

country now occupied by the andesitic ranges of Waitakerei. The Parnell grit may well have had its origin there, and have been brought down by rivers and currents operating at a time when the physical features of the district were altogether different. But the whole question, either of locating precisely these old vents or of estimating with certainty their probable number, is one which offers but a feeble chance of ever being satisfactorily solved.

Note.—The Waitemata series can be traced further north than Whangaparaoa, good sections showing along the cliffs at Waiwera and round the Mahurangi Harbour, where the volcanic grits again appear. North of this the sedimentary rocks change considerably in character, the numerous layers which distinguish the sandstones on the Auckland isthmus giving place to thicker bands of a more highly indurated sedimentary rock darker in colour and closer in texture. The grits at Waiwera and Mahurangi are very similar both in appearance and texture to those already described, and, like these, contain numerous angular and subangular fragments of augite-andesite, some of which reach upwards of 1 ft. in diameter. Their mode of occurrence, however, does not throw any additional light on the questions raised in this paper.

ART. XL.—*Notes on some Andesites from Thames Goldfield.*

By Professor JAMES PARK, F.G.S., Director, Otago University School of Mines.

[*Read before the Otago Institute, 12th November, 1901.*]

HORNBLENDE-ANDESITE.

FROM the Mata Stream southward, the deeply eroded surface of the crumbling Palæozoic slaty shales, which form the basement rocks of the Hauraki Peninsula, are covered with a great pile of andesite lavas, tuffs, and breccias. From the Mata northward the coast-line is occupied by the slaty shales for a distance of eight or nine miles without interruption. Between the Mata and Waikawau Streams the slaty shales are intruded by seven massive dykes of igneous rock which are well exposed in the deep road-cuttings winding around the indentations of the rocky shore-line. The general trend of the dykes is east and west, but, so far as I could discover, they do not appear to reach the valley of the Waikawau, which runs parallel with the coast-line for some