the fossils found in the series will bear out this classification. How the pumice band came to be deposited among marl-clays over such a vast area, and quite conformably to the underlying and overlying beds, I am at a loss to explain. I venture, however, to offer a suggestion. Are the blue-clays so common throughout the district simply volcanic ejectamenta, which have been subsequently acted on by aqueous agencies? I am inclined to think so. The blue-grey mud ejected from Rotomahana Lake at the time of the Tarawera eruption, last year, bears a close resemblance to the blue marl-clays in which the pumice band is found. Those who have been over the volcanic district of this island will readily understand that the eruption of mud from Rotomahana is only one of many similar eruptions which have taken place. Hot-water action and steam have played in the past, as they still play, an important part in what is understood as volcanic phenomena. The mixture of clay and pumice-grit and pebbles, of which such a large proportion of the rocks between Mahia and Tologa Bay are seen to be composed, suggests an inquiry as to how a mixture of this sort came about. Clay, equally with pumice, must be set down as a volcanic product; and I see no way to account for a conformity between the pumice and clays, except on some such supposition as stated above. The *moya* of the Central and South Amerian volcanoes is the mud of the Tarawera eruption; and we may suppose that eruptions of mud have been no uncommon event in the history of volcanic phenomena in this island. At least, such is my opinion, and such is the suggestion I offer, as accounting for the pumice band found in the rocks of this East Coast District, and which are classed by the Geological Department as belonging to the Cretaceo-tertiary formation.

The accompanying map (Plate XVIII.) contains all the places mentioned in this paper.

Art. XL.—*Notes on the Volcanic Rocks of the Taupo District and King Country.*

By Professor A. P. W. Thomas, M.A., F.L.S.

[*Read before the Auckland Institute, 14th November*, 1887.]

Mr. Cussen has requested me to identify for him a large number of rock specimens collected during his stay in the Taupo District and the King Country; and the present notes are intended to illustrate the more interesting points in connection with some of them.

Hochstetter travelled through the Taupo District in April, 1859, but his time there was limited, and gave little leisure for the exploration of the country. He states that all the volcanic

rocks collected by him belonged to the family of rhyolites. The rhyolites are a group of lavas which present themselves in an immense variety of structure: they are characterised by the large proportion of silica which they contain, generally so large that the excess separates out in the form of free quartz.

The rocks collected by Mr. Cussen show, however, that a more basic group of lavas, with a lower proportion of silica, are abundantly represented in the Taupo District. The more recent lavas of the giant volcanoes Ruapehu, Ngauruhoe, and probably Tongariro, appear to consist of the basic rocks known as augite-andesites. These are richer in metallic bases and poorer in silica than the rhyolites.

Up to the time of the eruption of Tarawera, in June, 1886, basic rocks were not known to occur in the Taupo volcanic zone.* I have shown elsewhere that the lava of the Tarawera eruption was a form of augite-andesite, and that the same rock occurs at Mount Edgecumbe, the volcanic cone lying 15 miles north-east of Tarawera and in the direction of the Bay of Plenty. It is interesting to find that the same rocks occur as the most recent lavas on the great cones in the south of the zone, and that at so many points along the main line of activity the succession of volcanic rocks has been the same—basic augite-andesite succeeding the acid rhyolites. The country around Lake Taupo is remarkable for the vast quantities of pumice which form the superficial deposits; but it is stated by Mr. Cussen that on approaching Ruapehu and Tongariro the pumice becomes less abundant, and that the surface is formed by a layer of dark brown loam, which is more fertile than is usually the case with the soil of this region. That this is the case is shown by the establishment of sheep-runs near Tongariro. The richer character of the soil appears to be due to its origin from the decomposition of andesitic ashes from the more recent eruptions of the mountains. Speaking generally, the ashes of basic rocks such as the augite-andesites, or basalts, yield by their decomposition a richer, more fertile soil than the acid rocks.

As is well known, the order of succession of the rocks at any given vent, or in a given volcanic district, is such that the more basic follow the acid lavas. The appearance of the basic lavas at such different points in the Taupo zone seems to indicate the opening of a new phase of its volcanic activity, this present stage being characterised by basic lavas. There seems, therefore, a probability that, if the country in the Taupo volcanic zone is ever again covered with great showers of ashes like those which recently fell at the eruption of Tarawera, those ashes will, as

* Hochstetter, however, in "The Voyage of the *Novara*" (Geology: vol. i., p. 104), states that he saw in the Museum of the School of Mines, London, basalts which were said to be from White Island.

they decay, yield a richer soil than barren pumice, now covering so large an area.

Augite-andesites.—The most interesting of these rocks are undoubtedly those which occur at the great volcanic cones to the south of Lake Taupo. The most recent lava stream on Ngauruhoe, said to be that of the eruption of 1869, is a black scoriaceous rock of somewhat resinous lustre. A fresh fracture shows to the naked eye small crystals of white felspar and dark augite. Thin sections for the microscope show that the rock contains numerous crystals of felspar and augite, which measure up to ·16 inch in diameter; but olivine is wholly absent. The felspars are almost entirely plagioclases, but one or two sanidines can be detected. The former are remarkably rich in inclusions of brown glass, sometimes so numerous as to obscure all the clear substance of the felspar, except a narrow rim which is free from inclusions. In some crystals all the glass of the inclusions is devitrified by the appearance of globulites; in others the glass is still pure. Sometimes the inclusions are arranged in zones, showing the stages of growth of the felspar crystal. A few felspars contained numerous vapour cavities, and augite grains, in addition to the glass. The augite crystals also contain glass inclusions, but they are far freer from them than the felspar. The ground-mass of the rock is a yellowish-brown glass, containing microliths. The glass is abundant, and the microliths of all stages of development, but most of them whilst appearing as simple rods are sufficiently large to polarise slightly. The ground-mass also contains a few grains of magnetite.

Other specimens from Ngauruhoe belong to the same type of rock. In one of these the glass of the ground-mass is colourless, but contains a fine black dust, which renders the ground-mass very dark, except in extremely thin sections. The glass inclusions of the felspar crystals, however, are many of them of the same brownish colour as in the previous rock, showing that the glass was originally of the same colour in both rocks. A rock obtained from a considerable altitude on the western slope of Ruapehu is nearly of the same variety; the ground-mass of the rock, however, is more finely microlithic.

Other augite-andesites were obtained from near the crossing of the Whanganui River, a stream flowing into the west side of Lake Taupo. In one of these the ground-mass was composed of microliths, cemented by a very small amount of colourless glass. It remained dark between crossed nicols, save for a few small crystals of felspar and augite, and some scattered microliths sufficiently developed to polarise. In another variety no glass could be detected in the microlithic base, but it included a considerable number of felspars, augite grains, and magnetites. An augite-andesite from Whangamata Bay has a ground-mass intermediate between the last two varieties.

Near the Karutau Stream, on the west of Lake Taupo, was found a very black rock of resinous lustre, and showing only a few small crystals to the naked eye. The microscope shows that the larger crystals—the first separated in the cooling of the rock—are principally plagioclases, though a few augites are present. The plagioclases have very numerous inclusions of glass, which is sometimes brownish, but usually greyish and partly devitrified. The ground-mass consists of a grey glass, containing numerous microliths and magnetite grains; but here and there patches of brownish glass, free from microliths, are to be seen. It contains, also, numerous ledge-shaped sections of small plagioclase, which show a flow-structure by their arrangement.

The curious peak of rock on the summit of Titiraupenga, which forms so conspicuous a landmark when viewed from the country north of Taupo, is composed of a rock which must be considered as an augite-andesite. It is a rock of interesting appearance, having a dark-grey ground-mass, in which are embedded abundant greenish-black augite crystals, measuring up to $\frac{1}{3}$rd of an inch in diameter, and more numerous felspars up to $\frac{1}{8}$th of an inch in diameter. There is no olivine. The felspars are chiefly plagioclases; they are much fissured, and have fairly abundant glass inclusions. The augites have very few inclusions, their borders in some cases being sharply defined, but, as a rule, they are bordered by a single row of crystalline augite grains, which form, as it were, the outermost layer, or zone, of the crystals. The ground-mass is distinctly micro-crystalline, being composed of augite grains, felspar, and magnetite, with only a small proportion of amorphous matter between.

It should, perhaps, be mentioned that augite-andesites were found by Hochstetter in the country lying further to the north-east of Lake Taupo—as, for instance, at Kakepuku and Pirongia, extinct volcanic mountains lying on the right and left banks respectively of the Waipa.

Rocks collected by Mr. Cussen at Maungakawa are also augite-andesites.

Rhyolites.—The rhyolites occur in a greater variety of structural forms than perhaps any other species of rocks. Some of the varieties are eminently glassy (forms of obsidian, pumice, etc.). Another group—the Rhyolites proper of Zirkel, but named by v. Richthofen and others the Liparites—includes felsitic and porphyritic varieties. Both these groups are represented by numerous varieties in the Taupo District. A third group, the Nevadites or granitic rhyolites of v. Richthofen, appear to the naked eye to consist mainly or entirely of crystals of quartz, sanidine, etc., the ground-mass being present in small quantity. This last group is not represented in the district, so far as I am aware.

Very numerous specimens of rhyolites were collected by Mr. Cussen, more especially on the western side of the lake. I do not propose to deal with all the varieties found, but merely to mention some of the leading forms.

A rhyolite from Whangamata Bay has a distinctly granitoid appearance, showing numerous white crystals, with angular granules of darker substance between. A little closer observation, however, suffices to show that the darker portions are merely the ground-mass of a dark-grey glass in which the crystals are embedded. The latter consist of cracked glassy blebs of quartz and sanidines, with some plagioclase. The rock contains, besides, a few small augites. The ground-mass is a nearly pure glass, alternating with a glass densely crowded with long slender pellucid microliths which do not polarise. The alternation of bands of these two varieties of glass in wavy lines makes evident the fluidal structure of the rock.

Another rock from the same locality is grey in colour, the macroscopic crystals are few in number; they are mostly sanidines, with a smaller proportion of plagioclase. Quartz seems to be absent, and the rock contains accessory crystals of dark-brown hornblende and pale augite; both are scarce. It may be added that augite, in small amount and in small crystals, is a very frequent mineral in the rhyolites of the neighbourhood of Lake Taupo; in other parts of the Taupo zone I have found it much less frequently. The ground-mass in the rock is sphærolitic, consisting of granules, and greyish non-polarising granules, arranged in small spherical masses, the fibres radiating from the centre of the spheres. In this case the sphærolites show no tendency to separate from one another, and are not visible to the naked eye.

A grey rock from the same place contains a large number of macroscopic crystals, mostly quartz and sanidine, with a considerable proportion of sanidine; but both hornblende and augite are present in very small amount. The ground-mass is microfelsitic, with a strong tendency to form axiolites in which the fibrous material diverges, not from a point as in the sphærolites, but from along a line or axis. It may be noted here, that, whilst in the typical rhyolites the orthoclase felspars (sanidines) predominate, plagioclase being present in much smaller proportion, yet in some of the varieties of the Taupo volcanic zone the proportion of plagioclase rises occasionally so as to equal that of the sanidine, and, possibly, surpass it, suggesting the idea that the rock is a dacite. Nevertheless, on the whole, the sanidine exceeds the plagioclase in amount in these rocks.

A rhyolite from Western Bay has a ground-mass which is a mixture of wavy fluidal bands and streaks of lilac and bluish-black stony substance. The crystals contained in the ground-mass are mainly sanidines, quartz is absent, and plagioclase and

augite are present in small quantity. The ground-mass is partly micro-felsitic, and consists of dark bands of micro-felsite which alternate with bands, clearer bands, in which the micro-felsitic matter passes into a finely micro-crystalline aggregate with red granules.

The rock which forms the island of Motutaiko is a bluish-grey laminated lava, with semi-vitreous glaze along the surface of the joints. The thin parallel laminæ of which the rock is composed are often very distinct, and are alternately more or less glassy, but in other parts the laminæ blend together, as the glass becomes more fully devitrified. The macroscopic crystals are not numerous, and are chiefly sanidines; plagioclase is, however, also present, as well as augite, magnetite, and apatite. The ground-mass is chiefly a pale-glass, crowded with slender microliths and black granules, but it is marked here and there by dark-brownish patches and streaks of indefinitely granular or micro-felsitic matter, giving a banded character to the rock.

It is unnecessary to mention here the pumice, which occurs in such vast quantities in the district. A nearly pure obsidian was obtained by Mr. Cussen on Ngauruhoe. It has a perfect conchoidal fracture, and no macroscopic crystals. In thin flakes it shows a greenish-smoky colour and bands of a darker shade. The general mass of the rock is quite free from microliths, but the bands derive their darker appearance from the presence of multitudes of parallel microliths.

ART. XLI.—*Notes on the Rocks of the Kermadec Islands.*

By A. P. W. THOMAS, M.A., F.L.S., Professor of Natural Science in the Auckland University College.

[*Read before the Auckland Institute, 14th November*, 1887.]

THE following notes are descriptive of the various rocks collected by Mr. Percy Smith during the recent visit of the *Stella* to the Kermadec Islands. Most of the specimens were obtained from Sunday Island, the largest of the group.

The rocks, with one curious exception, are unmistakably of volcanic origin, and consist of fragmental materials in the form of scoriæ and fragments from the tuffs, and of lavas from the streams which alternate with the tuffs, or from the dykes which intersect the islands, and bind the loose beds and lava streams together.