ON HAÜYNE-TRACHYTE AND ALLIED ROCKS IN THE DISTRICTS OF PORT CYGNET AND OYSTER COVE.

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The igneous rock at Port Cygnet, in Southern Tasmania, has been known for a long time by the name of felspar-porphyry. As the porphyritic crystals of felspar are rather strikingly displayed in the rock, specimens have now and again, through collectors, found their way to different parts of the Colony. Microscopical study of some of these samples made us aware that the handsome porphyries were soda-trachytes, and we classed them as such in our last year's sketch of the igneous petrology of Tasmania.* Since then we have found the felspathoid mineral haüyne or nosean in them, which confirms our previous determination, and a recent excursion to the locality has enabled us to recognise quite a group of these rocks, as well as to fix their geological age.

The country round Lovett and Lymington furnishes several sections which may be used by the geologist, but one of the most valuable of these is, perhaps, that which is afforded by the Livingstone mine. The mine shaft and buildings are on the crest of a hill, 600 feet above sea-level, about two miles N.E. of the township of Lovett. Just before reaching the crest the trachyte may be seen in the road-cutting underlying the sandstones and slaty arenaceous beds which form a large portion of the hill. On the saddle there are some fossiliferous beds of the Permo-Carboniferous System, charged with spirifera and fenestellidae, and a little higher the trachyte appears again. In one form here it has a slabby habit, due to its being largely composed of parallel layers of large tabular crystals of orthoclase felspar, some of which measure as much as two inches in length. The Livingstone mine shaft is close by, and appears to be sunk in banded trachyte and quartz. One hundred and fifty feet below this a tunnel has been driven for 360 feet, passing through

* Trans. Aust. Inst. Mining Engineers, 1898, Vol. V., p 108.

Permo-Carboniferous sedimentary beds, and intersecting several bands of trachyte in its course. First it cuts a 12 ft. layer: subsequently a 2 ft. band of the coarse porphyritic trachyte seen at surface (the miners' name for this is "magpie"), and near the end of the drive 12 to 15 feet of white trachyte rock is passed through, called "diorite" by the miners, and referred to under that name in the published reports of the company. It is important to note that these bands or lava sheets are conformable with the sedimentary strata, and we cannot entertain any doubt of their geological contemporaneity. In this hill, as in the entire region, considerable variety exists in the different flows of these trachytes. Some are coarse in texture, others are fine-grained and compact. Some of them have their counterparts on the Mount Mary Hill rising on the west side of Lovett. In particular the slabby trachyte, distinguished by its large tabular felspars ("magpie") is found again at the Mount Mary mine on the western side of the valley, only there it is much decomposed, and has an abundant development of epidote.

The Mount Mary trachytes may be seen cropping out in the quarry on the hillside in front of Harvey's Hotel at Lovett, where they have been used for road metalling and building purposes. At least two varieties are distinguishable in the quarry face—one a tough dense speckled rock, the other a smooth porphyritic, somewhat fissile, stone of a light bluish-grey hue, suggestive of a sodic lava. The compact type contains a fair amount of epidote. Passing up the hill to the west the rising ground above Mount Mary mine exposes outcrops of several varieties of trachytic rocks, which continue right through the hill to the Lymington-Wattle Grove Road. Opposite Martin's cottage on that road is a bold outcrop of a rather plutonic-looking grey hornblendic rock, at first sight much resembling syenite, but which on microscopical examination we found to be an undoubted trachyte, with beautifully zoned felspars.

There are good exposures of sections on the beach between Lovett and Lymington, where the beds are lying rather flat. On this beach we found additional evidence of the contemporaneity of the trachyte with the Permo-Carboniferous sediments. We discovered some fresh syenite (augite-syenite) along this line, and specimens of a similar rock and of an intrusive micaceous trachyte have since been given us by the Government Geologist (Mr. J. Harcourt Smith, B.A.), who collected them from the shore at low-water, just south of the Lovett regatta-ground. A very remarkable dioritic rock occurs on Mr. Patrick

Cranny's property at Lymington. It consists of hornblende + plagioclase felspar, with the hornblende greatly preponderating. We have placed this dark basaltic looking rock among the dioritic aplites called malchite.

That this petrographical province extends further north we have satisfied ourselves by the discovery of blocks of garnetiferous trachyte at the base of the Sugar-loaf Hill, behind Mrs. Cleary's cottage on the road to Cradoc. It is there also associated with Permo-Carboniferous fossiliferous marine beds. It is well known, moreover, that it extends to Oyster Cove in a N.E. direction.

The word "felspar-porphyry" was applied to the Port Cygnet rocks as a field term, indicating a porphyritic texture. It meant simply that the uniformity of the micro-crystalline ground-mass is interrupted by a profusion of larger crystals which were formed during the intra-telluric period of the history of the rock. The term is only admissible as a temporary expedient for the designation of such rocks prior to definitive examination. It can be discontinued now that the trachytic nature of these rocks is beyond doubt.

It may be useful to trace the lines along which our enquiry has travelled, and show how they lead up to the results now submitted.

As a rule, when the colors are white, yellow, grey, we may take it that a lava does not belong to the basic series of rocks. It will be a member either of the acid series, containing over 66 per cent. silica, or of the intermediate series with 55 per cent. to 66 per cent. As a whole, the Port Cygnet rocks are remarkable for the small quantity of their free silica. They are essentially quartzless rocks. Of course they contain silica in combination, but only sufficient to bring up the SiO_2 per cent. to the limit for intermediate rocks, those lying between the acid granites and rhyolites and the basic gabbros, dolerites, and basalts. The silica per cent. corresponds with the specific gravity, which averages 2·5 to 2·6. These facts help us in locating the rock in a definite division. Now, in this division the andesites and diorites are characterised by plagioclase felspars, while in the trachytes and syenites orthoclase is dominant. In the Port Cygnet rocks orthoclase unquestionably predominates. Trachyte is the volcanic form, syenite the plutonic.

Haüy first gave the name of trachyte ($\tau\rho\alpha\chi\acute{\iota}\varsigma$ = rough) to volcanic rocks feeling rough to the touch. In these rocks there is generally very little glass, the ground-mass being more or less crystalline. When they contain plagioclastic felspar it is an acid variety. When this felspar

increases in quantity, and grows more basic, we are led to the andesites; and it is not always easy to understand the meaning of the term trachyte as used by some authors, who extend it in the direction of the andesites till it becomes useless for the purpose of classification. In this connection we cannot do better than bear in mind Rosenbusch's definition of trachyte as implying the dominant presence of a potash felspar and the absence of quartz among the porphyritic constituents. He says :—

"The trachytes are neo-volcanic effusive rocks which may be designated equivalents of the syenitic plutonic rocks and of the palæo-volcanic quartzless porphyries in all their modifications."*

The only modification which we would venture to make in this admirable description would be to include palaeo-volcanic rocks in the trachyte group. Some carboniferous trachytes have been found in Britain, but these have been ranked by the illustrious author just named among "orthophyres" or "quartzless porphyries having completely the habit of trachytes." We cannot see, apart from the question of age, that anything would be gained by calling the Port Cygnet lavas, orthophyres. Many of the felspars are brilliant to the eye and pellucid in thin section. On the other hand, some of them have lost their glassy appearance and acquired a yellowish opaque aspect, sometimes, however, retaining a vitreous interior, to which the peripheral decomposition has not extended. We seem here to have intermediate stages between glassy sanidine and opaque orthoclase. No doubt, the mineralogist would deny the term sanidine to these opaque crystals and call them orthoclase. Of course, those who postulate sanidine as an essential constituent of trachyte will have to call some of these rocks trachytic orthophyres, and reserve trachyte as the name for the varieties with glassy orthoclase. But this seems to us a needless multiplication of classes, and we anticipate that the sanidine variety of orthoclase will not always be regarded as an essential ingredient of trachyte, nor will the name trachyte be confined to rocks of Tertiary age solely.

Assuming, then, that we are now dealing with the trachytic group, we take a further step and define these volcanic rocks as soda trachytes. This is shown by the presence of one or more of the soda minerals, haüyne, analcime, aegirine, aegirine-augite, cataphoritic hornblende, and the green pleochroic augite rich in the acmite molecule ($Na\ Fe\ Si_2\ O_6$). Such trachytes are very closely

* Mik. Phys. d. massigen Gesteine, 1896. p. 738.

allied to phonolites, and become phonolite by the addition of either of the felspathoids, leucite or nepheline. The roughness of ordinary trachytes is characteristically absent, and the disposition of felspar crystals in layers is a marked feature, imparting a certain degree of fissility to the rock. The rock has evidently possessed in its molten state exceptional viscosity, which has impeded free flow and caused crowding of the porphyritic elements. This, again, is not unknown among phonolitic trachytes and phonolites.* The presence of haüyne is considered by some authors sufficient to remove a rock from the trachytes to the phonolytes, and they would call some of the Port Cygnet rocks phonolytes. It is interesting to note that, as nosean (haüyne) in the first British phonolite (Wolf Rock, Cornwall) was discovered by Mr. Allport, in 1871, by means of the microscope, the same instrument has led to the discovery of haüyne and phonolitic trachytes at Port Cygnet.

Though the eruptive rocks of this province are evidently products of one and the same magma, yet different flows at different times show varieties of mineral composition in all probability characteristic of each eruption, in addition to which there are structural differences dependent upon the physical conditions of consolidation. We are able, more or less plainly, to arrange the numerous varieties provisionally, as follows :—

Soda Trachyte Group.

Effusives—

Haüyne Trachyte, with porphyritic haüyne.
Aegirine Trachyte, with aegirine needles and aegirine-augite.
Melanite Trachyte, with abundant melanite-garnet.
Trachyte, with green sodic augite.

These comprise various types, described in detail further on.

Soda Aplite Group.

Intrusives—

Sanidine-augite-haüyne Aplite.
Sanidine-augite-biotite Aplite.
Malchite or dyke-Diorite, (an aberrant member).

Soda Syenite Group.

Plutonics—

Alkali-augite-Syenite, with micro-perthite and analcime.
Alkali-augite-Syenite, with elaeolite, (Little Oyster Cove).

* "We find that acid lavas are very decidedly less mobile than basic ones, and so flow less readily and to smaller distances ; and, further, that certain intermediate lavas, rich in alumina and potash, are remarkably viscous, as is illustrated by the peculiar dome-like forms assumed by some trachytic and phonolitic eruptions." Daubrée "believes that some trachytic domes must have been erupted in a nearly solid, not even pasty, condition." Nat. Hist. of Igneous Rocks. A. Harker. Sc. Prog. Vol. VII. pp. 204–6.

The minerals which we have detected in these rocks may be enumerated as follows :—

	Trachyte.	Aplite.	Syenite.
Essential —	Orthoclase (Sanidine)	Orthoclase (Sanidine)	Orthoclase
	Oligoclase	Augite	Microperthite
	Augite	Biotite	Albite
	Hornblende		Elaeolite
			Augite
			Hornblende
Accessory —	Haüyne	Haüyne	
	Aegirine	Apatite	Melanite-Garnet
	Melanite-Garnet	Sphene	Biotite
	Biotite	Zircon	Apatite
	Apatite		Sphene
	Sphene		Zircon
	Zircon		
	Magnetite		
Secondary —	Analcime	Natrolite	Analcime
	Epidote	Opal	
	Quartz	Quartz	
	Natrolite		
	Actinolite		
	Muscovite		
	Pyrites		
	Limonite		
	Chlorite		
	Clinochlore		

Alkali Syenite (Augite Syenite).

Sp. gr. 2·6.

Found *in situ* on beach south of Regatta Ground, Port Cygnet. No massive exposure, but lying at the water-level.

Macroscopic characters.

Medium grain : brownish grey, syenitic looking ; has an elaeolitic appearance, with greasy feel. With porphyritic tendency by reason of a few large glistening felspars (nearly $\frac{1}{2}''$ long) scattered sparingly. No rhomb-shaped sections of felspars seen. Numerous small brilliant dark garnets appear as specks, which can be well recognised with the pocket-lens ; many of these seem enclosed in the felspars. The rock resists decay well, as shown by the thinness of the weathered crust, decomposition not extending far into the interior of the stone.

Microscopic characters.

Structure, normal hypidiomorphic-granular (granitic), with an occasional leaning to the trachytic type by an

idiomorphic columnar felspar here and there. It is essentially a potash-felspar rock, but there is very little proper orthoclase in it, for the orthoclase is intergrown perthitically or rather micro-perthitically with striped felspar, often showing very fine striae indeed, giving the extinction angles of oligoclase or oligoclase-albite. These twinning-lines are generally short, not continuous, and are sometimes interrupted by similar sets at right-angles. Here and there in the slide is water-clear albite, pellucid as quartz; but apart from this, and an exceptionally clear crystal or two of orthoclase, the felspars are turbid.

Some analcime in the felspars points to the former presence of elaeolite, and its existence may be suspected, though we cannot optically demonstrate it.

An important feature is the garnet, which is very plentiful, in brown irregular grains and ill-formed crystals, having a corroded appearance. These are characteristically intergrown or associated with augite, biotite, and apatite, and in their neighbourhood is often seen a yellowish transparent flaky or zeolitic-looking mineral, with low refractive index, and giving in polarised light the appearance of a soda decomposition product. The abundance of garnet warns us that the rock is allied to the elaeolite-syenites.

There is some grass-green augite (malacolite) in granular irregular forms. It has slight pleochroism, and where vertical sections could be found they gave extinction angles of 33° and 34°. The mineral is often bleached in the interior. Besides being specially intergrown with garnet, it is associated occasionally with dark green hornblende. This hornblende is intensely absorptive. Its pleochroism is $\mathfrak{a}$ = yellowish-green, $\mathfrak{c}$ = very dark green. The $\mathfrak{b}$ direction could not be ascertained. A little light brown idiomorphic mica gave $\mathfrak{a}$ = light greenish-yellow, $\mathfrak{b}$ = dark dirty green. Zircon, present in all syenites, occurs in small quantity, likewise a little sphene in elongated wedges. Very little quartz can be definitely recognised.

This syenite cannot be considered quite identical with any of those syenites, rich in alkali, which Rosenbusch has erected into types under the names (after J. F. Williams) Pulaskite, Albany, and (after Brögger) Laurvikite types; but it is evidently related to these and to their allies, the elaeolite-syenites. The syenites which are known in other parts of Tasmania have quite other relationships, being more closely connected with the granite family.

Augite Syenite.

Found *in sitû* on beach between Regatta Ground and Lymington.

Macroscopic characters.

Fine-grained, with numerous lustrous faces of felspars, and specked with green augite. Some of the felspars are idiomorphic. Colour of the rock light grey.

Microscopic characters.

Structure, hypidiomorphic-granular, many of the felspars strongly idiomorphic parallel to 001 and 010. A few of these much larger than the rest, with numerous enclosures of sphene and small felspar crystals. Zoning of felspars quite a feature. Many of the orthoclase felspars are glassy, and have a sanidine habit. There is a good deal of albite-twinned felspar and microperthitic intergrowth of albite-oligoclase with orthoclase, some of the twinning being extremely fine, and cross-twinning is well shown. The extinction angles yielded by different crystals seem to be those of both albite and oligoclase.

A pale green augite (malacolite) is frequent. Its pleochroism is very slight. Its extinction angle in the prism zone is as high as 44°. Wedge-shaped crystals and grains of sphene plentiful. A little idiomorphic apatite and interstitial quartz. We have not noticed any garnet in this syenite.

Hauyne Aplite.

Sp. gr. 2·75.

Found at Port Cygnet, but the precise locality is unknown.

Macroscopical characters.

A medium-grained dark grey rock, consisting largely of small columnar and tabular sanidine crystals, some of which exceed the rest in size. A parallel arrangement of felspars occurs, but is inconstant, the crystals lying mostly in all azimuths. With a hand-magnifier granular augite seems plentiful, and crystals of yellow sphene are seen here and there. Small grey and white spots represent nosean, but this mineral can only be identified microscopically.

Microscopical characters.

The rock is seen to be essentially composed of sanidine, augite, and nosean, with the minerals sphene, apatite, and zircon as accessories. The sanidine is clear, and mostly in columnar forms, with Carlsbad twinning. Some of these

prisms have been dynamically bent. They carry abundant inclusions of haüyne (nosean) decomposed to zeolitic matter of a light yellow colour, giving mottled grey and white interference appearances under crossed nicols. Augite is in prismatic elongated forms, and is a green pleochroic variety with extinction angle of 40°, though as the colour becomes yellowish the angle seems to decrease. $\mathfrak{a}$ = light green, $\mathfrak{c}$ = dark green. Bleaching is common. Grains and rods of augite border crystals of apatite. Large decomposed haüyne crystals are abundant as divergent and fan-shaped zeolites of a pale yellow colour in plain light. Allotriomorphic orthoclase felspar forms a cement uniting the above elements, and this gives the aplitic character to the rock. Yellow crystals of sphene in prismatic and acute rhombic sections are plentiful. Zircon is less common ; magnetite in grains.

Soda Aplite, a Sanidine-Augite-Mica Dyke Rock.

Sp. gr. 2·85.

Locality—On the beach at Port Cygnet, south of the Regatta Ground.

Macroscopical characters.

A hard granular dark glistening rock resembling a minette (mica-trap). Numerous little brilliant faces of dark mica visible. The felspar looks granular and sugary. The green augite is too minute for satisfactory identification.

Mineral constituents.

Sanidine, augite, biotite, apatite, soda decomposition products and pyrite.

Microscopical characters.

The first thing which strikes one on looking at a slide is the panidiomorphic structure of the rock, reminding one at once of aplite. At the same time the prisms of augite and plates of mica follow linear directions like the minerals of a foliated rock.

The felspar is granular and imperfectly prismatic, with its boundaries abridged by neighbouring prisms. Carlsbad twinning is frequent. Where elongated sections are available with some approach to a prismatic character, the extinction is straight. The crystals are pellucid and contain numerous microliths, rods, ovoid and circular grains, perfectly transparent, colourless, and without any definite action on polarised light. Some are light green ; these are augite. The inclusions, which are of large size, are a constant feature.

The augite seems to be diopside, of a dirty green colour, with an occasional disposition to bleach. It is in ill-formed prisms, without perfect terminations. Its extinction angle is about 40°, and it often has perceptible pleochroism. Augite grains, too, are numerous, and large nests or agglomerations of granular augite occur.

The third constituent in order of frequency is a yellowish-brown biotite with strong basal cleavages, showing in sections perpendicular thereto. Rays vibrating parallel to a undergo least absorption, c being opaque-brown, and a yellowish-brown. There is a little apatite in stout short prisms and large irregular grains. Some decomposition material similar to the yellow products after haüyne is present. The rock contains neither quartz nor hornblende, and is altogether an unusual one. We do not know of any similar occurrence with which it can be compared. It appears to belong to the group of aplitic dyke rocks (Rosenbusch), but the absence of aegirine and the abundance of a high-angled augite shut it out from the tinguaitic set. Still, we feel tolerably certain that its place is in the soda-trachyte series, and among the dyke rocks in that series.

HAÜYNE-TRACHYTE.

Sp. gr. 2·55.

Occurs near the shaft on hill at Livingstone Mine, near Lovett.

Macroscopical characters.

A bluish-grey porphyritic rock with crowded layers of glistening tabular sanidine felspars. The smaller porphyritic elements are hornblende, augite, brilliant dark garnets, and numerous soft white sections of haüyne. This is the only rock which we have found with comparatively fresh or unaltered haüyne (nosean).

Microscopical characters.

The felspars are clear in section. The fragments in the slides are generally too imperfect for reference to particular zones. The orthoclase is much intergrown with oligoclase: there are fragmentary sections of Carlsbad twins with albite twinning on one half, sometimes with a cross striation. Partial twinning frequent in orthoclase crystals, but sometimes very faintly visible. Some felspars seem to have been enlarged by a subsequent addition of material, which surrounds the original crystals as a fringe. This must have taken place prior to the final consolidation of the rock.

Garnet.—This is plentiful. When it occurs in such rocks it is usually referred to the variety of calcium-iron garnet known as melanite. It is in forms of the trapezohedron and dodecahedron, and sometimes zoned. In thin section the colour is yellowish to reddish brown. Its sections are margined brown, and traversed by irregular iron-marked fissures. It is quite common to find it intergrown with and enclosing crystals of hornblende and augite.

Haüyne (Nosean).—This mineral is abundant, and gives sections approximating to faces of the cube (100), dodecahedron (110), and trapezohedron (211). Hexagonal sections are common ; no trigonal ones. Rounded grains very frequent, and crystals with a mutilated and corroded appearance. The mineral is sometimes colourless, but generally characterised by a soft slate-grey tint in the peripheral parts, shading off towards the interior. The colour is deepest at the border. Dark striae are often seen proceeding from the faces inwards, sometimes in sets at intersecting angles. There is none of the blue tint which is seen in some haüynes. The interiors are full of granular microlites ; nearly all are undergoing decomposition into natrolite or other soda products represented by divergent scaly aggregates. Crystals of haüyne are often enclosed in the large felspars.

Nosean and haüyne are classed together by Rosenbusch under the group name haüyne. They are both silicates of alumina and soda, but in the haüyne there is the addition of lime. Dana* gives the percentage composition of the two minerals as under :—

	Silica.	Sulphur trioxide.	Alumina.	Lime.	Soda.
Haüyne...	32	14·2	27·2	10·0	16·6 = 100
Nosean ...	31·7	14·1	26·9	—	27·3 = 100

Haüyne often has a blue tint. Where this tint is absent and no lime separates out during decomposition, it is impossible to distinguish the two optically. These facts have to be borne in mind when considering authors' references to either of these two minerals.

Hornblende.—This is a somewhat peculiar variety. It has the black colour of arfvedsonite to the eye, and is deep green, sometimes nearly opaque in thin section. If the section is at all thick it is opaque. The pleochroism is strong. $\mathfrak{a}$ = yellowish green ; $\mathfrak{b}$ = very dark green, sometimes opaque ; $\mathfrak{c}$ = very dark green, sometimes opaque. This absorption scheme $\mathfrak{c} \geqq \mathfrak{b} > \mathfrak{a}$ agrees with

* System of Mineralogy, 1898, pp. 431–2.

that of common green hornblende, and not with that of arfvedsonite, which is $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$. But the startling opacity suggests something out of the common, and in some sections the absorption varies to $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$, which characterises the black alkali-iron hornblende of certain phonolitic trachytes and linguaites which Brögger has called cataphorite. It seems to us possible that the hornblende is of a cataphoritic nature, though its extinction angle is rather low for that species. $\mathfrak{c} : c = 14°$ to $17°$, whereas in cataphorite it varies from $23°$ to $60°$.

A bright green slightly pleochroic augite occurs in prisms and grains. $\mathfrak{c} : c = 34°$ or thereabouts. Apatite in grains. The groundmass consists of small sanidine prisms in fluxional arrangement, interspersed with small grains of augite. The whole is rather obscured by decomposition.

Tertiary haüyne-trachytes occur in France (Auvergne); haüyne-phonolites in Germany, Portugal, the Canaries, Colorado; the nosean-phonolite of the Wolf Rock, Cornwall, is the nearest related rock in Britain.

Haüyne-Trachyte.

Found on the crest of the Livingstone Hill, and in the mine tunnel 150 feet below. Also in the trench at Mount Mary Mine, west of Lovett.

Macroscopical characters.

A soft light grey rock, easily recognised by its large tabular orthoclase felspars lying thickly in parallel layers, causing the rock to split more easily in that direction. These felspars are mostly between $\frac{3}{4}''$ and $1\frac{1}{2}''$ in length, and from $\frac{1}{8}''$ to $\frac{1}{4}''$ thick, and can be often chipped out from the matrix, making good specimens for the cabinet. They are tabular $\parallel 010$, and the cleavage parallel to this plane is perfect. The crystals are opaque externally, light yellow, but occasionally the interior is glassy, sanidine-like. Mr. Frank Rutley has aptly described them to us as having a biscuit-like appearance. The miners call this rock "magpie." The only other pronounced macroscopical element is limonite in hexagonal and other sections after some cubic mineral, probably garnet. The same rock occurs at the Mount Mary Mine, where it is more decomposed, and contains much epidote.

Microscopical characters.

The orthoclase is often intergrown with a striped felspar. It encloses numerous hexagonal and other sections of haüyne, replaced by liebenerite (?). The rock is full of

porphyritic pseudomorphs of liebenerite (?) aggregates after haüyne in rectangular and rounded sections.

Sharply defined sections of a cubic mineral decomposed to limonite are plentiful. The determination of the original mineral is difficult, as we have not much beyond the forms to guide us.

Dana says*—"Garnets containing ferrous iron often become rusty and disintegrated through the oxidation of the iron, and sometimes are altered more or less completely to limonite, magnetite, or hematite." In one of our sections we detected a crystal of melanite-garnet undergoing this change, but we have not been able to discover any further instances of partial change. Haüyne also suffers a somewhat similar change, and the choice here appears to be between the two minerals, haüyne and garnet, with probabilities stronger in favour of the latter.

The groundmass is rather obscure, but appears to consist of prisms of straight extinction felspar. Iron ore in minute grains.

Haüyne-Trachyte.

This is another trachyte from the top of the Livingstone Hill. It is a grey rock, with the faint bluish tinge, which in the Port Cygnet trachytes we have found associated with the presence of haüyne. Groundmass compact lava-like, with numerous porphyritic crystals of dull white orthoclase $\frac{1}{4}''$ to $\frac{1}{2}''$ in length. These crystals are tabular in habit. The other visible porphyritic constituent is the limonite to which we have alluded above as being probably pseudomorphous after melanite-garnet. This is in hexagonal and other familiar sections of the isometric system.

Mineral constituents.

Orthoclase : secondary limonite, muscovite, iron oxide.

Microscopical characters.

The large orthoclase crystals are turbid, and enclose occasional sections of nosean, now replaced by micaceous aggregates in confused flakes, polarising in the vivid colours of the second order. These remind one of the secondary muscovite (liebenerite) in liebenerite-porphyry. Mingled with them is a mineral giving soft grey interference tints, and this may be natrolite. The same aggregates are frequent throughout the rock, filling up the interiors of the porphyritic haüyne (nosean) crystals which

* System of Mineralogy, 1898, p. 446.

have preserved their characteristic contours. The groundmass is much decomposed, but seems to consist essentially of small sanidines. Numerous black needles obscured by ferrite may represent acmite or aegirine.

Aegirine-Trachyte.

Sp. gr. 2·61.

There are two or three varieties of trachyte, with needles of the soda-pyroxene aegirine entering largely into the composition of the groundmass. The most striking of these is a greenish rock, markedly porphyritic and fissile by reason of parallel layers of tabular sanidine crystals, found on the beach at Port Cygnet south of the Regatta Ground. The only other porphyritic mineral is augite. The plates of sanidine lie preponderatingly in one direction in layers, giving rise to divisional planes, along which the rock cleaves more easily than in a direction perpendicular thereto.

Microscopical characters.

Inclusions of minute needles of augite (or aegirine) are frequently arranged in zonal form round the periphery of the sanidines, and the margins of the large felspars often melt imperceptibly into the groundmass, the magma of which has apparently corroded them. A crop of microlites is usual along these imperfect edges. The sanidines are clear, and enclose crystals and fragments of augite, besides indefinable microlites and glass inclusions.

Augite.—Sections in the zone of 001 and 100 are common.

The colour of these porphyritic pyroxenes is a rather deep green ; they are distinctly pleochroic. The extinction angles are very variable, and the character of extinction is undulose, probably in consequence of mixtures of normal and soda pyroxene. The extinction of the central portion of a crystal will be 38°, while that of the margin will be straight or nearly so. Sometimes a crystal is found extinguishing at about 5° or 6° in one direction, with a pale yellowish fringe extinguishing at the same angle in the opposite direction. Inserting the quartz wedge with its axis of least elasticity covering the elasticity axis of the pyroxene nearest to the vertical crystallographic axis of the latter, we notice that the colour falls till it is replaced by darkness. In petrographical language, compensation has set in. By this we know that the axis of elasticity in the two crystals (the quartz and the augite) are dissimilar. As the direction in question is that of least elasticity in the quartz, it follows that it is that of

greatest elasticity in the pyroxene. This is an important optical test for distinguishing soda pyroxene from normal augite. The groundmass is a remarkable feature of the rock. Small laths of sanidine, often with fluxional arrangement, form a ground-work, with which are entangled pale green rods and needles of the soda-pyroxene aegirine. These are slightly pleochroic, and might be mistaken for augite, but that they uniformly extinguish nearly parallel to their long axis, which direction of extinction the quartz wedge shows to be that of the a axis of optical elasticity. The rods are sometimes acicular at one or both extremities, sometimes curved. They occasionally attach themselves end on like a fringe to the borders of crystals of augite. They call to mind the aegirine needles in the aegirine- (formerly called acmite-) trachyte of the Kühlsbrunnen in the Siebengebirge.

In one of our slides is an equilateral hexagonal section of a small water clear mineral in the groundmass, greatly resembling a section of nepheline ; but it is not perfectly isotropic between crossed nicols, and we have failed to obtain a dark cross in convergent polarised light. It has peripheral and central inclusions of colourless to pale green pyroxenic microlites. It has no border such as is common in noseans. If it is nepheline, it would remove our rock from the trachyte to the phonolites ; for the present we must leave the determination doubtful. In the groundmass there is a good deal of isotropic zeolitic matter, apparently of the nature of analcime.

Another variety of the same rock is found on Mount Mary, just above the mine. There it is a compact green rock, often laminated, strongly resembling a metamorphic rock. A few isolated scattered crystals of sanidine occur in it, together with an occasional small black garnet. Under the microscope we see that the green colour is due to the felted network of aegirine needles, and that the rock is essentially identical with the one just described, only with the porphyritic felspars reduced to a minimum. The garnet is the usual melanite variety, brown in thin section. This rock contains pyrites.

Aegirine Trachyte.

Sp. gr. 2·61.

Occurs on Mount Mary, just above the mine.

Mineral constituents.

Sanidine, augite, melanite, titanite, aegirine, biotite, apatite.

Macroscopical characters.

A compact greenish grey rock, with large isolated glistening tabular crystals of sanidine. Numerous small black garnets embedded in the rock, and dark augite prisms visible under hand-lens.

Microscopical characters.

The large sanidine crystals are clear and fresh-looking. Dodecahedral sections of brown-zoned garnet in simple and compound forms enclose prisms of augite. These large garnets are a feature in the rock slice. Green pleochroic augite in imperfect forms of the prism occurs in nests. The extinction angle is as high as 37°, and the mineral often encloses crystals of apatite. a yellowish green, b yellowish, c green. Some sphene is present porphyritically. A little pale yellowish brown biotite is associated with the nests of augite crystals. It can be picked out in the slide by its strong pleochroism—a yellowish brown, c opaque.

The groundmass consists of small lath-shaped sections of sanidine with fluxional arrangement and pale green pleochroic rods of aegirine extinguishing parallel to their length. Granules and small crystals of sphene are plentiful. There is some isotropic material of a zeolitic nature.

MELANITE-TRACHYTE.

Stones of this rock were found at the back of Widow Cleary's cottage on the road to Cradoc, about 2 miles N.W. of Lovett, at the foot of the green conical hill which rises there from the road. The hill exposes permo-carboniferous mudstones a few hundred feet up, with abundant marine fossils. This is the most northerly extension of the trachyte which we examined, but we could not find it *in sitû*.

Macroscopical characters.

Light brown in colour, granular in texture, studded with brilliant black crystals of melanite-garnet. This mineral is such a constant and abundant accessory that the rock may well be called a melanite-trachyte.

Mineral constituents.

Orthoclase, perthite, melanite, augite, apatite, biotite, sphene, analcime, chlorite, limonite (manganese ?).

Microscopical characters.

The most frequent porphyritic element is melanite-garnet, light and yellowish-brown, in thin section, in the

usual forms, and strongly zoned in successive layers. The garnet crystals are habitually intergrown with, and enclose augite. The next most important phenocrysts are those of a green pleochroic augite, with an extinction angle not exceeding 33°. a light green, c deep green, often encloses apatite. There are occasional large porphyritic crystals of fresh orthoclase and perthite, with zonal tendencies. The holocrystalline groundmass comprises orthoclase laths and allotriomorphic felspar; sphene in crystals and grains; some normal biotite; chlorite in scales as a pseudomorph; a little analcime and limonite, with purplish iron oxide (manganiferous ?).

Trachyte.

Sp. gr. 2·7.

On Lymington Road, opposite Martin's cottage.

Macroscopical characters.

A bold exposure on the west bank of the road of a pearl-grey granitoid rock resembling a fine-grained syenite, but essentially trachytic in nature. The groundmass is of even granular texture, with a few larger crystals of glassy felspar, with 010 faces and idiomorphic outlines. Felspar makes up the bulk of the rock; prisms of hornblende numerous; augite is present also, but cannot be distinguished macroscopically from the hornblende. The rock weathers little, but, when affected, the felspars become yellow and opaque.

Mineral constituents.

Sanidine, oligoclase (albite ?), hornblende, augite, sphene, apatite, zircon, magnetite, quartz.

Microscopical characters.

Those of a typical trachyte, somewhat near andesite, the main feature being tabular phenocrysts of zoned felspar in a granular felspathic groundmass. The hornblende phenocrysts are numerous enough to be considered as essential constituents. The augite recedes in quantity to an accessory value. It is difficult to locate this rock in any special position in the trachyte group. The forms of felspar are similar to those prevailing in andesitic trachytes, and there is a good deal of oligoclase; but there is no development of glass, and the rock is not lava-like in appearance.

Felspars.—Isometric forms prevail. Carlsbad twins with 010 faces are frequent, and zonal structure is

characteristically developed. In no other rock in Tasmania have we seen the concentric zonal markings so beautifully exhibited. Striped felspar is present in quantity, its extinction angles being those of oligoclase-andesine. We have not been able to measure an angle high enough for albite on an 010 section, but a strip of felspar, intergrown with a crystal of sanidine, gave an angle of 20°, and this may be albite. The felspars are uncommonly free from inclusions of the other minerals of the rock.

Hornblende.—Next to felspar, this is the most prominent constituent in dark green columnar forms. The olive-green color is often so deep as to make the mineral opaque, and occasions difficulty in reading off the extinction angle. The absorption scheme is $\mathfrak{b} \geqq \mathfrak{c} > \mathfrak{a}$, and the pleochroism $\mathfrak{a}$ yellowish-green, $\mathfrak{b}$ very dark green, $\mathfrak{c}$ dark green, sometimes opague. The extinction angle is unusually high, the values which we obtained being 20°, 21°, 25°, 26°, 28°, 30°, 31°, 32°. These agree very well with Professor Brögger's cataphoritic hornblende, though the absorption scale does not correspond ; it is evidently a hornblende with cataphoritic tendencies.

Augite is not frequent ; it occurs mostly in forms of the prism. Extinction angle 38°, very pale green, non-pleochroic : crystalline sphene, apatite and zircon are constant accessories. The groundmass is not fluxional, but crystalline-granular. In it are a few rounded blebs of quartz, aurrounded by a fringe of re-crystallised felspars, and containing some moving bubbles ; magnetite grains in no great quantity, and no mica discernable.

Malchite.

Sp. gr. 2·79.

This rock was found on Mr. Cranny's property, adjoining Coad's farm, at Lymington. It occurs on the side of the hill, but its geological relations were not further examined. Locally it is called "basalt."

Macroscopical characters.

Those of diorite, granular in texture, dark green in colour, owing to the green hornblende which forms the bulk of the rock. It is iron-stained along short irregular cleavage planes.

Mineral constituents.

Hornblende, biotite, augite, plagioclase, apatite, sphene.

Microscopical characters.

Essentially dioritic. What is remarkable is the decided dominance of hornblende as a constituent of the rock. This mineral forms irregular hypidiomorphic plates, often reduced to a granular condition by dynamo-metamorphism. It is intergrown with biotite, which often accumulates in nests or aggregations of flakes. In the hornblende $c : \mathfrak{c} =$ about 14°. $\mathfrak{a}$ pale yellowish green, $\mathfrak{b}$ dark brown green, $\mathfrak{c}$ dark green. The biotite is the ordinary type. Some of the felspars are larger than the rest, and these are hypidiomorphic, while the smaller felspars of the pseudo-groundmass are allotriomorphic. Many felspars are simply twinned on the Carlsbad plan, others albite twinned. A good deal of the felspar appears to be labradorite. The other constituents are apatite, sphene, quartz, and pale augite in small quantities.

The predominance of hornblende and the allotriomorphic felspars may be looked upon as exceptional for diorite pure and simple. Our rock is certainly dioritic, but its structure is rather aplitic than plutonic, consequently belonging to the dyke series of diorites. It is somewhat schistose in thin section, though not so macroscopically. It seems allied to the plagioclase hornblende aplites described by Osann from the Odenwald, and called by him malchite. Of our slides of the malchitic rocks—orbite, luciite, and malchite—luciite most resembles ours, but we do not grasp the essential distinctions intended to be expressed by these divisions. The quartz in our variety is present in very small quantity.

It is not easy to understand the occurrence of a dioritic rock in this plexus of trachytes ; and, in view of the fact that Professor Rosenbusch in his recent "Elements of Petrology" (p. 135) has stated that diorites not only have no chemical or mineralogical relationship with the alkali syenites, but have never been found integrally associated with them, we would reserve the present peculiar rock for the additional examination which it merits and requires.

DISTRICT OF LITTLE OYSTER COVE.

Alkali Syenite, with accessory Elaeolite.

This is represented by a piece of rock from Mr. Innes's property, a mile back from Oyster Cove. We have not been able to examine the occurrence *in situ*, and from the small quantity of material at our disposal we can only give a general account of the characters of the rock.

Macroscopically it is a very light-coloured stone, weathering easily, and resembling a coarse trachyte rather than a syenite. It may be compared with those elaeolitic syenites which have a tendency to trachytic structure.

Under the microscope this pseudo-trachytic appearance shows itself by the larger felspars (sometimes idiomorphic) being cemented or surrounded by a holocrystalline groundmass of smaller hypidiomorphic and allotriomorphic felspars. There is, however, great variation in the size of the latter. There is a remarkable absence of coloured constituents. A flake or two of biotite is the only ferro-magnesian mineral which we can detect. Sphene, zircon, and apatite are accessories.

Orthoclase felspar preponderates. It is fresh and often zonal. Oligoclase is freely intergrown with it. Some of it is streaky, like the orthoclase of the Norwegian elaeolite syenites, and has an undulose extinction. There is much residual felspar (albite) in its clearness resembling quartz.

In the rock are certain irregular and imperfect forms of elaeolite, a few basal sections being isotropic. This determination was confirmed by digesting the rock in HCl and obtaining a fair quantity of gelatinous silica.

There is not sufficient of the felspathoid to constitute the rock a true elaeolite syenite, besides which the pyroxene and hornblende so abundant in elaeolite syenites are here conspicuously absent. It is rather one of those alkali syenites which occasionally carry subordinate elaeolite.

Trachyte.

We have examined three varieties of trachyte rock from Little Oyster Cove. They all appear to belong to the igneous complex, which embraces both the Port Cygnet and Oyster Cove Districts. They carry identical minerals, viz :—sanidine and oligoclase, cataphoritic hornblendes, green augite, sphene, zircon, and apatite ; and, from garnetiferous gold-bearing sand found in the neighbourhood, we know that melanite-garnet is also an ingregient. From the few specimens which we have seen, it is likely that, as in the Port Cygnet series, these also are rich in varieties.

On the whole they exhibit a tendency to vary in the direction of the andesites, the dominant porphyritic felspar being plagioclastic, and an increase of iron ore in the groundmass showing itself. The small felspars of the groundmass are often minutely granular or allotriomorphic, but where prismatic they show straight extinction, which

may mean sanidine or oligoclase. The porphyritic felspars are large and scattered; zonal structure common. A large orthoclase crystal, giving a section parallel to the clino-pinacoid, showed a characteristic extinction angle of 22°. The hornblende is green, basal sections brownish green; extinction angle about 14°, and the absorption that of cataphoritic hornblende, $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$.

The preceding form a complete series of a unique set of rocks so far as Tasmania is concerned. To the geologist they are important as being the youngest matrix of gold in the colony. The trachytes appear to have shed the gold which has been won on the alluvial field at Lymington and found in the gullies on Mt. Mary. They are in places veined with quartz, but it is not at all clear that the quartz itself is auriferous, and the veins have not the characteristics of true fissures. We have seen some sand collected from a creek about a mile back from Little Oyster Cove towards Port Cygnet, which contains flaky gold, more or less waterworn, with numerous melanite garnets, zircons, and small crystals of sphene. It is a sand which is evidently the detritus of the garnetiferous trachytes, and the occurrence in it of gold associated with the minerals just named supports the idea that the trachytes are the source of the gold throughout the whole province. There is nothing intrinsically inconsistent in the occurrence of gold in the quartz veins of trachytes. It is found in various parts of the world in much younger trachytes and andesites than these, though the gold-bearing reefs in the rest of Tasmania are of older date and traverse Silurian slates and sandstones. But, so far as we can see at present, there is no trustworthy evidence to show that the Port Cygnet quartz veins are auriferous, while, on the other hand, there is some reason for believing the trachytes themselves to contain sparingly disseminated gold, especially where they are silicified and brecciated. The miners are pursuing the right course in selecting these tuffaceous and siliceous zones for exploration. Unfortunately the mining work which is being carried on has not so far proved the existence of the precious metal in the matrix in anything like payable quantities. Whether the gold has been concentrated anywhere to a greater extent than in the parts hitherto exploited, remains for future search to decide. The pyrite in these rocks has so far proved non-auriferous.

Conclusion.

We have abstained from referring to several additional minor varieties of trachytic rock which we have collected, and which differ slightly from the foregoing, but their minute description in this connection would serve no practical purpose, and we doubt not the discovery of further types will reward the diligent collector. The results of our enquiry may be conveniently summarised as follows :—

1. All round the arm of the Huon, known as Port Cygnet, there is an extensive development of porphyritic rocks, which are phonolitic or soda-trachytes containing haüyne, aegirine, analcime, and cataphoritic hornblende. Some of these furnish the finest examples of orthoclase felspar crystals to be found in the island.

2. The trachytic area extends to Little Oyster Cove on the N.E., to the N. of Lovett as far as Sugar Loaf Hill, to the S. of Lovett as far as Lymington and the Huon, but requires further exploration beyond these limits.

3. The trachytes are lava sheets contemporaneous with Permo-Carboniferous sandstones and mudstones.

4. Associated with these trachytic lavas and their tuffs are allied plutonic and dyke rocks, also of a sodic nature ; viz., alkali-syenite (containing elaeolite) and haüyne-aplite.

5. There is an interesting development of melanite-garnet in the trachytes and syenite. This garnet seems to run through the whole series, and is a constituent of the auriferous sands of the district.

6. The dark green rock of the locality described in the older literature as "metamorphic," and looking such to the naked eye, is shown by the microscope to be ægirine-trachyte, full of minute acicular crystals of the green soda pyroxene ægirine.

7. Gold has been found at Lovett, Lymington, and Little Oyster Cove, mostly alluvial, a minute quantity *in situ*. It is highly probable that the alluvial gold has been derived from the trachyte, disseminated therein in small quantities. The few quartz veins in the trachyte do not seem to have collected this gold to any special extent, though what gold has been found in the matrix has occurred in their neighbourhood. The quartz is so closely associated with, and banded with, trachyte that the assay results are inconclusive. Appearances are against these quartz veins being true lodes.

8. This highly interesting, though small, peculiar petrographical province is a purely local one, confined, so far as

we know, to this part of Tasmania. Its unexpected discovery may be placed to the credit of the young and expanding science of microscopical petrology.*

* Since writing the above we have seen Prof. Rosenbusch's new work on the Elements of Petrology (Elemente der Gesteinslehre, 1898), in which he groups the trachytes and quartzless porphyries (orthophyres) in one family. He says, (pp. 265–6), "Orthophyres differ from trachytes only in their greater age and consequent inferior preservation, viz., in the more frequent red and brown color, diminished porosity of the ground-mass, dull aspect of the felspars and extreme decomposition of the colored constituents. Fresh orthophyres cannot be distinguished from trachytes." Referring to the sanidine in orthophyres, he adds, (p. 266) :—"In the quartzless porphyries sanidine has mostly, though by no means always, surrendered its glassy habit, and possesses the habit and often the red color of orthoclase."

EXPLANATION OF PLATES.

FIG. 1.—Section of trachyte showing zoned crystal of orthoclase. Mount Mary, S.W. Lovett. × nicols. × 16.

FIG. 2.—Section of melanite-trachyte with zoned crystal of melanite-garnet. Cleary's Hill, N.W. of Lovett. Plain light. × 16.

FIG. 3.—Section of haüyne-aplite or haüyne-trachyte dyke rock, with large Carlsbad twins of sanidine carrying included crystals of haüyne. Groundmass = crystals of green augite and haüyne with allotriomorphic orthoclase felspar. From Port Cygnet. × nicols. × 16.

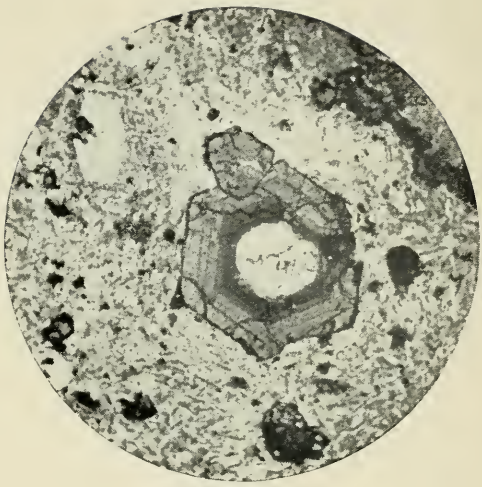
FIG. 4.—Section of trachyte from back road, two miles N.W. of Lymington. Porphyritic crystals = sanidine in Carlsbad twins and zoned, plagioclase, green hornblende and augite. × nicols. × 16.

FIG. 5.—Section of haüyne-trachyte from Livingstone Hill, N.E. of Lovett, showing large porphyritic sanidines. The dark hexagon on the left represents melanite-garnet; the smaller crystal below it is green augite. Surrounding these two crystals are small forms of haüyne. × nicols. × 16.

FIG. 6.—Section of green aegirine-trachyte from beach S. of Lovett. Porphyritic sanidine and augite. Groundmass = rods of pale green aegirine and prisms of sanidine with fluxion structure. Plain light. × 16.

FIGS. 7 AND 8.—Megascopic photographs of dull tabular orthoclase (decomposed sanidine) crystals in haüyne-trachyte on Livingstone Hill, N.E. of Lovett. Natural size.

1.

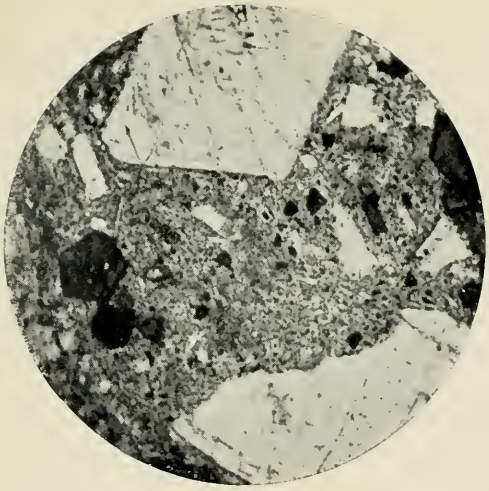


2.

3.

4.

TRACHYTE FROM PORT CYGNET.



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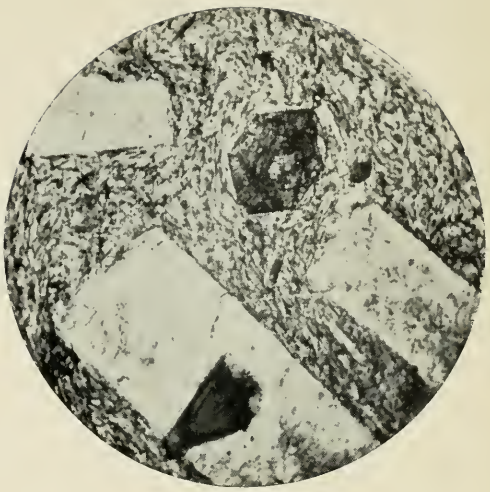

6.

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TRACHYTE FROM PORT CYGNET.