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1911-14.

UNDER THE LEADERSHIP OF SIR DOUGLAS MAWSON, KT., D.Sc., B.E.

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VOL. III.

GEOLOGY.

PART III:

THE DOLERITES
OF
KING GEORGE LAND AND ADELIE LAND.

BY
W. R. BROWNE, D.Sc

WITH TWO PLATES.

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BY

W. R. BROWNE, D.Sc.
(*Lecturer in Geology, University of Sydney.*)

WITH TWO PLATES.

CONTENTS.

THE most important section of this collection of basic igneous rocks consists of three specimens of dolerite from the great sill at the Horn Bluff, King George Land. Other dolerite types related to that of the Horn Bluff sill were collected as erratics along the coast of Adelie Land, notably at Cape Denison, where the main collection of the Expedition was made.

At the Horn Bluff the great sill, intrusive into a sandstone formation, rises in organ-pipe formation as gigantic cliffs upwards of five hundred feet in height. The specimens from this important locality were collected by C. T. Madigan's party.

I. THE DOLERITES OF THE HORN BLUFF.

1. Petrography.

The rocks present certain variations in texture, but consist essentially of the same minerals, plagioclase, pyroxene, and iron ore, with a mesostasis of micropegmatite. It will be convenient to preface short descriptions of each of these rocks with an account of the characteristics of the principal mineral constituents.

Plagioclase is as a rule fresh, but occasionally showing slight alteration to sericite. The habit is usually stout prismatic, but in the finest-grained rock (No. 732B) the prisms are more elongated. Zoning is marked, especially in the two coarse rocks (Nos. 732A and 733), and twinning is present on the albite and occasionally on the Carlsbad law, pericline twinning being visible only in the felspars of the coarsest phase (No. 733). The limits of chemical composition are bytownite ($Ab_{20}An_{80}$) to andesine ($Ab_{55}An_{45}$) in the case of No. 732A, and $Ab_{29}An_{71}$ to $Ab_{45}An_{45}$ in No. 733. The felspar of No. 732B shows less strong zoning and is about $Ab_{35}An_{65}$.

The pyroxene is almost entirely monoclinic. It is very pale-grey in colour, sometimes changing peripherally to green or brownish, and without noticeable pleochroism. Some of it is apparently ordinary augite or diopside, but much is of the magnesium-rich variety, known as enstatite-augite or magnesium-diopside, characterised by an optic axial angle which is variable, but always much smaller than that of ordinary augite, approaching 0° in the limit. Extinction angles up to 43° have been observed, but it seems as though extinction and double refraction both decline with the optic axial angle. This is well seen in No. 732A, where two pyroxene individuals often occur in parallel intergrowth, that with the smaller optic axial angle being distinguished by a slightly lighter colour in ordinary light.

In addition to the usual prismatic cleavage, there is often in both pyroxenes an extremely fine basal or salite striation, which, when combined with simple or repeated twinning parallel to (100), gives rise to herring-bone structure. This basal striation is not at all constant in its occurrence, often not extending all the way across a crystal, and being developed in irregular patches. It is often brought into prominence by local yellowish alteration of the pyroxene, with decline in the birefringence. For the most part, nothing definite was observed tending to show that this basal parting betokens twinning, as has been sometimes suggested, (*cf.* Iddings, Rock Minerals, 1906, p. 305), although in one case there was something that looked like simultaneous extinction of alternate lamellæ.

A similar very fine striation is also sometimes observed parallel to (100), and this is likewise often incomplete, and accompanied by alteration. With the development of these salite and diallagic striations, there is often local obliteration of the ordinary prismatic cleavage.

Twinning, when present, is usually of the normal type, parallel to (100), but occasional cruciform twins on (101) are observed.

An almost universal characteristic of the enstatite-augite is its undulose extinction, which is sometimes zonal in character, but generally quite irregular. This is a feature which has often been observed in the pyroxenes of the quartz-dolerites, but has not yet been satisfactorily explained. Benson remarks on something analogous in connection with the rhombic pyroxenes in the dolerites of South Victoria Land[1], comparing it with the similar appearance presented by anorthoclase, and ascribing it tentatively to submicroscopic twinning. It will be remembered that Brögger and Harker[2] believe anorthoclase to be of the nature of a cryptoperthite; and it seems possible that this peculiar form of augite, containing a large proportion of the enstatite molecule, may be a similar cryptoperthitic intergrowth of rhombic and monoclinic pyroxene, a view developed by Elsden[3].

It may be that the monoclinic pyroxene at the temperature of crystallization was able to hold in solid solution a certain proportion of enstatite, more than it could retain at a lower temperature. On cooling, therefore, the excess of enstatite was expelled and took up a cryptoperthitic relation towards the augite, and the volume change, if any, involved in this process possibly set up a state of strain and produced the undulose extinction. Alternatively if the mineral is still a true homogeneous mix-crystal, a state of internal strain may perhaps have been set up owing to a tendency on cooling for the mineral to change its system of crystallization.

The habit of the pyroxene is peculiar; there is a suppression of the prism faces and a flattening of the crystal parallel to the (100) pinacoid, so that cross-sections are rectangles with the length about four times the breadth. The prisms are perhaps rather more elongated than usual parallel to the *c* axis, and this characteristic is very marked in specimen No. 733, in the description of which it will be more particularly referred to.

The mesostasis which is present in all three of the rocks is usually of such fine grain as to render the exact determination of its constituents a matter of much difficulty. Under low magnifications it appears colourless but slightly clouded, and sometimes almost isolates the plagioclase laths projecting into it. Viewed with higher magnifications it takes in most places the form of long slender rods of plagioclase arranged in different patterns on a background of another felspar with the optical characters of orthoclase. The rods may be aggregated in groups, each consisting of three or four parallel rods, crossing each other at various angles; or sheaf-like and plumose aggregates, occasionally sprouting from the end of a plagioclase may suggest the effect of frost on a window-pane; or again, the rods may form a confused interlacing network. These phenomena are similar to those described by Osann for the Tasmanian dolerite[4] and by Benson for that of South Victoria Land.

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[1] Report of British Antarctic Expedition, 1907–9, Geology (vol. ii), page 154.
[2] Harker: Natural History of the Igneous Rocks, page 246.
[3] The St. David's Head Rock Series, Q.J.G.S., vol. lxiv, 1908, page 288.
[4] Osann: Central. fur Min., 1907, pp. 701–11.

Elsewhere the intergrowth consists of tiny squares and rectangles and gnomons of felspar in optical continuity with the outer margins of the plagioclase laths, forming a pattern on a larger surface of orthoclase. Other patches of the mesostasis consist of graphically intergrown quartz and orthoclase, the former being recognised by the familiar triangular forms of its skeleton crystals, while again, extensions of the plagioclase laths may be graphically intergrown with quartz. This latter mineral is also found as independent interstitial grains quite evidently primary in many cases, though at times possibly secondary. On the whole, however, quartz plays a very minor part in the mesostasis.

What appears to be minutely granular pale chlorite functions occasionally as an interstitial filling in the two finest grained rocks.

Iron ores, including apparently both magnetite and ilmenite, are not very abundant. They occur mostly embedded either in the peripheral parts of the pyroxenes or else in the mesostasis.

Tiny apatite needles are pretty abundant in the mesostasis of all the rocks, but practically nowhere else, so that the total proportion of apatite in the rocks is insignificant.

Of the two specimens labelled No. 732, the finer-grained, which we may call No. 732B, was collected " 6 feet above the contact of the volcanic rock and the sandstone." The hand specimen shows very marked prismatic jointing on a small scale. The main constituents of the rock are, in volume percentages :

Plagioclase	41
Pyroxene	44
Iron Ore	1
Altered Olivine (?)	3
Mesostasis	11

The plagioclase is mostly in thin to stout laths averaging perhaps ·3 mm.; a few larger individuals apparently slightly more basic than the rest are aggregated in glomeroporphyritic fashion. Enstatite-augite is probably the dominant pyroxene, but an interesting feature is the presence of a very little rhombic pyroxene, very pale-coloured and non-pleochroic, but having negative birefringence. It generally occurs completely enclosed in augite, with which it is in parallel orientation. A very few minute flakes of biotite were detected attached to grains of pyroxene.

A peculiar feature of this rock is the presence of scattered patches of a substance, green to brownish in colour, pleochroic, with a fibrous structure and strong birefringence. The patches are streaked with carbonates and crossed with cracks containing magnetite dust. These characters suggest aggregates of talc, or perhaps iddingsite, after olivine, but this is by no means certain, especially as enstatite or hypersthene might alter in similar fashion. The outlines of the aggregates do not help much in the determination of the original mineral.

The pyroxene is evenly distributed through the rock in typical ophitic relationship to the felspar. (See Plate XXXVIII, Fig. 1.)

The specimen No. 732A was taken from the *débris* at the foot of the Organ Pipes, and is coarser than No. 732B. It is a greyish-black rock in hand-specimen, with occasional pyroxene prisms visible up to 3 mm. in length. The principal constituents are, in volume percentages :

Plagioclase	54
Pyroxene	33
Mesostasis ·	11
Iron Ores	2

This constitution corresponds pretty closely with the norm of the rock, given below, and indicates that the rock has a normative mode.

Plagioclase is in stumpy prisms up to ·5 mm., though a few larger individuals attain a length of 1·5 mm. For the most part the prisms only dent the outlines of the pyroxenes, which are often subidiomorphic, so that typical ophitic fabric is absent. Parallel intergrowths of pyroxenes with different optic axial angles are frequent. There is an absence of rhombic pyroxene, biotite, and the green and brown pseudomorphs so characteristic of No. 732B. (See Plate XXXVIII, Fig. 2.)

The third of this series (No. 733) is coarser in grain than the other two, and differs much from them in other respects. It is a brownish-coloured rock with an average grainsize of about 4 or 5 mm. The dominant characteristic is the presence of many flashing cleavage-planes of pyroxene, slightly curved at times and exhibiting quite a bronzy lustre.

The minerals present are :—

Plagioclase	33	per cent. by volume.
Pyroxene	27	,,
Iron Ore	2	,,
Mesostasis	38	,,

The plagioclase forms thick prisms varying in length up to about 6 mm. and giving almost square sections at right angles to (001) and (010). There are also smaller prisms, some of microlitic dimensions. The felspars often show magmatic resorption and embayment of their edges just like the phenocrysts of a porphyritic rock, and inclusions of the mesostasis are fairly frequent. Indeed the mesostasis is so abundant that it gives rise in places to what Iddings would have called porphyritic intersertal fabric, the pyroxene and felspar playing the part of abundant phenocrysts.

The pyroxene is all monoclinic, and, judging by the size of the optic axial angle where it can be observed, is mostly, at all events, enstatite-augite. The salite striation is extremely common, and to a less extent the diallage striation, both accompanied by a brownish decomposition product which gives rise to the bronzy lustre observed in hand-specimen, while herring-bone structure is very characteristic. The alteration associated with the striation is often so arranged as to produce a kind of hour-glass appearance in the sections. A curious feature of these augites is the frequent elongation parallel to the *c* axis, one section parallel to (010) measuring more than 6 mm. in length by about ·7 mm. Some of the crystals show a marked bending into a circular arc, with undulose extinction. This bending causes a tapering in some of the sections, which, combined with the central pinacoidal twinning-line and the herring-bone structure, produces the appearance of a goose-quill, an effect heightened by the curiously serrated edges of the crystals. This serrated effect is possibly a result of the bending of the crystals during their growth, as suggested by Iddings[1] for the curved felspars of the Obsidian Cliff rhyolite. Much of the augite is graphically intergrown with the plagioclase.

The iron ore is mostly ilmenite, in characteristic plates and skeletal forms; there is also much ilmenite and magnetite in tiny granules scattered through the mesostasis.

The rock is much stained with brownish-green and brown decomposition products, which penetrate the pyroxene peripherally and along cracks, and also discolour large portions of the mesostasis. (See Plate XXXVIII, Figs. 3, 4, and 5.)

2. Order of Consolidation.

In the finest-grained rock the felspar has very evidently crystallized first, followed by the augite. In No. 732A this is not so evident; the fabric is subophitic, but the augite is often nearly idiomorphic and only marginally indented by the felspars, as though the former had been the first to start crystallizing and had continued during part of the period of crystallization of the felspar. In No. 733 the graphic intergrowth of felspar and pyroxene indicates much simultaneous crystallization of these two minerals.

It is noteworthy that much of the iron ore has crystallized late, and that the apatite is largely concentrated in the mesostasis. This is often the case in basic rocks[2], and is in harmony with the common experience that the last or pegmatitic products of consolidation of basic magmas are often rich in apatite and iron ore.

Teall, dealing with the Whin Sill dolerite[3], has remarked on the fact that the coarse-grained phases of that rock exhibit graphic or perthitic intergrowths of their constituents. A somewhat similar statement might be made about these Horn Bluff rocks.

3. Discussion of the Petrographical Features.

These three rocks are evidently to be placed among the quartz-dolerites, although quartz does not enter very conspicuously into the constitution of the mesostasis. There is an almost complete absence of biotite and hornblende, which are common minor constituents of the typical hunnediabas and kongadiabas.

[1] Iddings: Igneous Rocks, vol. i, p. 226.
[2] *cf.* for example Elsden, Q.J.G.S., vol. lxiv, 1908, p. 289.
[3] Q.J.G.S., vol. xl, 1884, pp. 640–57.

It is instructive to compare the mineralogical constitutions of the three rocks as given roughly by Rosiwal measurements :

	No. 732B.	No. 732A.	No. 733.
Felspar	41	54	33
Pyroxene	44	33	27
Mesostasis	11	11	38
Iron Ore	1	2	2
Altered Olivine (?)	3	...	...

The rocks are placed in order of increasing average grainsize, and it will be noticed—

(1) That the ratio of light to dark constituents increases with grainsize, and

(2) That the proportion of mesostasis has notably increased in the coarsest phase.

It should be remarked that accurate figures for the mesostasis in the other two rocks were very difficult to obtain, and that a mental note was made, before results had been calculated, that the mesostasis of No. 732B had probably been over-estimated, and that of No. 732A under-estimated at the expense of felspar. Hence there is probably an actual progressive increase in the amount of mesostasis present with the increase of grainsize.

The texture of the mesostasis is likewise somewhat coarser in No. 733 than in the other two rocks, a fact which is in harmony with the observations of Holland[1], Benson[2], and others on the quartz-felspar mesostasis of quartz-dolerites.

It is unfortunately not known from what part of the sill two of these specimens originally came. That labelled No. 732B, from 6 feet above the base of the intrusion, and exhibiting prismatic jointing, probably represents a marginal facies of the rock. No. 732A, being a bit coarser in grainsize, is probably from a more interior portion of the sill.

It would be interesting to know the precise mode of occurrence of the relatively coarse-grained type No. 733. This rock is strikingly similar in texture and constitution to a coarse phase of the Tasmanian dolerite from the Domain, Hobart, similarity extending even to the curvature of the flattened and elongated pyroxene prisms. This rock, according to Professor Sir Edgeworth David[3], occurs as *schlieren* or pegmatitic segregation veins in the normal fine-grained dolerite. In a specimen in the collection of the Geological Museum of the University of Sydney, the pyroxene individuals at times exceed an inch in length, and the mesostasis forms a large proportion of the rock.

[1] Holland, Q.J.G.S., vol. liii, 1897, p. 408. [2] Benson, *op. cit.*, p. 155. [3] Verbal communication.

A search of some of the literature of the quartz-dolerites reveals the fact that the peculiar habit and curvature of the pyroxene has often been noted. It is true there is no mention of it, for example, in Harker's description of the Carrock Fell intrusion[1], or Elsden's account of the St. David Head Rock series[2], or in J. V. Lewis's report on the diabases of New Jersey, U.S.A.[3].

But Teall, examining the dolerite of the Whin Sill[4], noted a coarse-grained variety occurring " only where the rock attains a very considerable development," in which " crystals of pyroxene measuring an inch in length are not uncommon." The crystals are flattened parallel to (100), and the cleavage planes are " bent and undulating," pinacoidal twinning is present, also a fine basal striation, absent when the rock is fresh but present in the most altered specimens. The coarser rock occurs apparently in irregular veins, the junctions of which with the fine-grained dolerite are " remarkably abrupt."

A. H. Phillips[5] noted in the trap of Rocky Hill, New Jersey, a coarse-grained phase whose relation to the other phases is not mentioned, except that it is regarded as occupying a central position in the intrusion. The pyroxene crystals " constantly increase in length as we pass in from the border " of the intrusion; in the very coarsest varieties of the rock they measure " often an inch and occasionally 2 inches in length." A schistose arrangement was sometimes seen, and slight curvature of the long axis was observed, but this is evidently attributed by the author to the pressure which gave rise to the schisosity.

The internal characters of the pyroxenes are similar to those described for the Adelie Land rock, but the basal striation is attributed to polysynthetic twinning parallel to (001). Undulatory extinction was observed of a zonal nature.

The " plumose diabase " occurring as a phase of the trap sheet of Holyoke, Massachusetts[6], appears to be a particularly coarse-grained variant of the basalt of which the sheet is composed. The pyroxenes of this rock, up to 4 inches in length, are curved, twinned on the pinacoid, and basally striated; and in addition the vertical sections show notched or serrated edges due to " the development of unit faces." These coarse-grained patches occur as lenticular masses or *schlieren* in the trap.

The similarity on many points of the Adelie Land rock with those just mentioned is very clear, and it seems as though the characteristics emphasised, especially those of the pyroxene, are peculiar to certain pegmatitic phases of the dolerites, so that the rock No. 733 may with some degree of confidence be assigned to this category.

4. Chemical Composition and Relationships.

To indicate the chemical characters of the Horn Bluff dolerite a chemical analysis, for which I am indebted to Mr. G. D. Osborne, B.Sc., and Miss M. L. Graham, B.A.,

[1] Q.J.G.S., vol. l, 1894, pp. 311–336. [2] Elsden, *op. cit.* [3] Annual Report of State Geologist of New Jersey, 1907. [4] Teall, *op. cit.*, p. 643. [5] A.J.S., 4th series, vol. viii, 1899, pp. 267–285. [6] Emerson, Bull. Geol. Soc. Amer., vol. 1904, pp. 91–130.

was made of the rock No. 732A, the results of which are given in column I below, the analyses of three other quartz-dolerites from Antarctica and one from Tasmania being added for comparison :—

	I.	II.	III.	IV.	V.
SiO_2	53·05	54·17	54·16	53·26	52·49
Al_2O_3	16·95	14·90	15·08	15·64	16·44
Fe_2O_3	0·79	1·09	0·79	0·24	2·60
FeO	6·69	7·74	8·08	7·44	5·30
MgO	6·91	10·66	7·14	8·64	6·18
CaO	11·56	8·79	10·57	12·08	11·71
Na_2O	2·05	1·26	1·60	1·25	2·06
K_2O	0·97	0·54	1·11	0·58	1·09
H_2O + ...	0·49	0·53	0·36	0·41	1·42
H_2O —	0·43	0·17	0·20	0·35	0·15
CO_2	......	Trace.	Trace.	......	......
TiO_2	0·65	0·64	0·70	0·70	0·62
P_2O_5	Trace.	Trace.	Trace.	0·04	Trace.
MnO	0·07	0·15	0·14	0·11	Trace.
	100·61	100·65	99·93	100·74	100·06
Analysts	Osborne and Graham.	? Walkom and Burrows.	? Walkom and Burrows.	Prior.	Dittrich.

I.—Horn Bluff Dolerite No. 732A;

II and III.—Erratics from Cape Royds, South Victoria Land. Geology (Vol. II), British Antarctic Expedition, 1907–9, p. 157.

IV.—Erratic from Knob Head Moraine, South Victoria Land. National Antarctic Expedition, 1901–4, Natural History, Vol. I., Geology, p. 137.

V.—Enstatite-augite-bearing Diabase from Launceston, Tasmania. Osann, Central. fur Min. 1907, pp. 701–711.

An inspection of these analyses shows that of all the South Victoria Land rocks No. III is most closely related to the Horn Bluff rock, and that there is a distinct chemical resemblance between them, but that a very much closer and very remarkable agreement exists between the Horn Bluff dolerite and the Tasmanian diabase. The only points of apparent difference are in the higher Fe_2O_3 and H_2O of the Tasmanian rock, which are possibly to be attributed to surface alteration. The norms of the three rocks in question emphasise the closeness of the relationships :—

	I.	III.	V.
Quartz...	1·96	6·18	4·50
Orthoclase	6·12	6·12	6·67
Albite	17·29	13·62	17·29
Anorthite	33·92	30·86	32·25
Diopside	19·01	17·50	20·83
Hypersthene	18·93	22·54	12·06
Magnetite	1·16	1·16	3·71
Ilmenite	1·22	1·37	1·22
Water	0·92	0·56	1·57

This is particularly true in the case of Nos. I and V. In the latter as compared with the former there is an increase in normative quartz and magnetite, which is offset by a decrease in hypersthene. This is due to the oxidation of the FeO into Fe_2O_3, which causes more of the FeO to be required for normative magnetite, decreasing the amount available for diopside and hypersthene, and consequently liberating SiO_2 for normative quartz.

It is interesting to note, in passing, the possible effect of slight weathering on the norm, and perhaps too on the magmatic designation of a rock. It is quite conceivable that by the oxidation of the FeO, and the consequent liberation of normative SiO_2, a rock which actually contains modal olivine may show normative quartz. Further, the diversion of this SiO_2 from the femic to the salic portion of the norm would disturb the relative proportions of salic and femic constituents and of normative quartz and felspar' putting the rock into a more salic class and a more quaric order.

In the present instance the disturbance has not been sufficient to change the magmatic position of V relatively to I, and both rocks belong to III. 5. 4. 3 Auvergnose. No. III, is placed in III.4.4.3.

Conclusion.

The wonderful similarity between the quartz-dolerites of South Victoria Land and those of Tasmania has been pointed out by Benson[1] and Thomson[2]. The present writer has had the opportunity of examining some of the Tasmanian rocks microscopically, and of comparing them with the Adelie Land rocks, and the resemblance is certainly remarkable. Chemical and mineralogical investigation indeed show that the rocks at present under discussion are very closely related to those of Tasmania, and that they are, beyond reasonable doubt, co-magmatic with the dolerites of South Victoria Land encountered by the Scott and Shackleton Expeditions.

II. DOLERITE ERRATICS FROM THE MORAINES, CAPE DENISON.

The collections made from the moraines near the Winter Quarters at Commonwealth Bay have yielded a number of specimens that have features in common with the dolerites described above, and should be grouped with them.

Specimen No. 837, of which No. 838 is a duplicate, appears in hand-specimen as a dark, fairly compact rock, somewhat pitted on the weathered surface, and showing occasional small phenocrysts of felspar. Under the microscope the rock is seen to be a typical fine-grained dolerite, wherein the pyroxene is predominant over the felspar, and resembling No. 732B in many respects. The felspar is present in two generations,

[1] *Op. cit.* [2] Jour. & Proc. Roy. Soc. N.S.W., vol. xliii, 1911, p. 312.

the earlier being in thick tabular crystals, up to 3 mm. in length, and zoned ($Ab_{25}An_{75}$ to Ab_{45} An_{55}). Schiller inclusions are arranged along the pinacoidal cleavage-planes. The later plagioclase laths, averaging ·5 mm., have a composition about Ab_{35} An_{65} (Plate XXXIX, Fig. 2).

The pyroxene is all monoclinic, pale-grey to pale purplish-grey, and is, in part at least, enstatite-augite; it is ophitic towards the felspar. Olivine is represented by abundant small individuals pseudomorphed by brown iddingsite (?), but a few aggregates are found representing original olivine nodules now changed to a pale-green strongly birefringent substance, suggestive of talc, and sometimes accompanied by carbonates. The marginal passage of this into a brown-coloured substance suggests that the material doubtfully referred to above as iddingsite may really result from the staining of this green talc-like mineral by iron (Plate XXXIX, Fig. 1).

The iron ore is skeletal ilmenite with a little magnetite; it is usually moulded on felspar but enclosed in pyroxene. A little pyrites has made its way along cracks in the felspar.

There is a small proportion of mesostasis in the rock, consisting of a greyish mineral that appears to be orthoclase, sometimes in parallel intergrowth with what is probably another felspar, and often crowded with magnetite granules and tiny apatite (?) needles. Very occasionally quartz fills the little interstices between the felspar laths.

The association of olivine and quartz in the same rock, though not unknown, is rather exceptional. Certainly the olivine is now completely altered, but the identity of the original mineral is beyond doubt. The quartz for the most part has the appearance of being primary, acting as an interstitial filling in which are embedded apatite needles and the ends of plagioclase prisms. A possible explanation is that the olivine grains and nodules represent early intratelluric crystallizations from the dolerite magma, which had sunk to the bottom of the magma-reservoir and were caught up in the still liquid portion of the magma at the time of its injection.

Specimen No. 456 is a medium-grained rock in which felspar (Ab_{35} An_{65}) and pyroxene are present in about equal proportions, and ilmenite of semi-skeletal habit is unusually abundant. The pyroxene is, in part at least, enstatite-augite, showing the salite striation at times and altering into chlorite enclosing tiny sphene granules, and into brownish uralite, the felspar showing sericitic and calcitic alteration. For the most part the pyroxene is moulded on the felspar, but occasionally the reverse relation holds. Quartz occurs interstitially in very small amount and never in pegmatitic intergrowth, and a very little apatite and biotite are also noticed. A feature of the rock is the presence of irregular interstitial patches of finer grain than the main body of the rock, consisting, as far as can be made out, largely of plagioclase, with subordinate augite largely altered to uralite. Ilmenite and magnetite are fairly plentiful in close association with augite; also elongated, tiny needles of what appear to be apatite, often with parallel arrangement. Little flakes of biotite are not uncommon, and there is a mesostasis consisting apparently of a felspar (? orthoclase) crowded with confused radiating aggregates of very tiny brown rods of some intermediate substance, possibly rutile[1]. The last phase of consolidation of the rock has been the introduction of pyrites, often along cracks in the felspar.

A very fine-grained type is represented by Specimens Nos. 449 and 457, which are really duplicates. The rock is hard, compact, and aphanitic, with a subconchoidal fracture in places, and showing tiny dendritic patches of pyrites on joint planes. It is holocrystalline, intergranular in fabric, and of notably uniform grainsize.

Felspar (acid labradorite) is arranged in little bundles of parallel laths up to ·3 mm. long, the bundles being oriented in all directions. The pyroxene is very plentiful in tiny light-green prisms and granules. It is predominantly if not solely monoclinic, but though the presence of enstatite-augite is suspected the small size prevents conclusive proof. Quartz is in fairly abundant interstitial patches, and an interstitial felspar of low R.I., probably orthoclase, also occurs, but never in intergrowth with quartz.

Magnetite is quite plentiful, and minute shreds of biotite and needles of apatite are fairly common. Infrequent vesicles are filled with chlorite. (Plate XXXIX, Fig. 3.)

A different type of rock is No. 459, which is close-grained and slightly vesicular in hand-specimen. It contains two generations of felspar prisms, both about Ab_{35} An_{65}, somewhat zoned, and often showing only Carlsbad twinning. Enstatite-augite, the dominant mineral, is moulded on the felspar, but typical ophitic fabric is not developed, the pyroxene being in small grains. Iron ores include both ilmenite and magnetite, and a little pyrites has been introduced subsequently to consolidation. Frequent patches of a fox-red pleochroic mineral (? iddingsite) may represent pseudomorphs after olivine, and a good deal of greenish and brownish chloritic material is present, sometimes forming cores to the felspar crystals. (Plate XXXIX, Fig. 4.) The abundant small interstitial spaces of the rock are filled with material of a light brownish-green colour, thickly charged with microlitic magnetite. This has a feeble polarization and may represent the devitrification of a glassy base.

All these rocks possess certain characteristics which link them with each other and with the quartz-dolerites, the most important being the presence of enstatite-augite and of quartz and orthoclase. Textural and mineralogical variations are such as might be expected in a differentiation series, and such indeed as have been described as resulting from the crystallization of quartz-dolerite magmas.

It is doubtful whether the rock labelled No. 208 should be grouped along with the dolerites just described. It is a dominantly felspathic rock, with prisms of labradorite averaging about 1·75 mm. in length, another felspar, probably orthoclase, being present in minor amount. Pyroxene is for the most part moulded on the plagioclase, and plays

[1] *cf.* J. V. Lewis, Annual Report of State Geologist of New Jersey, 1907, p. 117.

an interstitial role. This pyroxene is entirely monoclinic, and has a violet, or rather rose, colour, with distinct pleochroism, betokening the presence of titanium. Biotite is abundant, likewise ilmenite in semi-skeletal forms and rods. Apatite is scarce, and there are a few irregular patches of pyrites.

The rock is considerably altered, the felspar being spangled with sericite flakes as well as with calcite and chlorite; in some places it appears to be altering to a zeolite.

Augite is much changed to a fibrous uralite, pleochroic as follows:—

X = Pale yellowish-green.
Y = Green.
Z = Bluish-green.

With $Y > Z > X$.

With the uralite change, there has been separation of iron oxide. Chlorite is another alteration product of the pyroxene. Biotite is irregularly bleached. Some of this mineral is probably primary, but much appears to be an alteration product of the augite. The section of an augite crystal is often covered over with tiny scraps of biotite, many of which are optically continuous and simulate the appearance of a graphic intergrowth with the augite. Some of the biotite and uralite contain pleochroic haloes surrounding tiny indeterminate colourless minerals. A number of irregular patches of yellow-green chlorite are seen, sometimes associated with little granules of carbonates and of secondary sphene; these may represent the ultimate alteration products of augite.

The rock may be termed an essexitic dolerite. (Plate XXXIX, Fig. 5.)

EXPLANATION OF PLATES.

All photographs have been taken in ordinary light unless when otherwise stated.

Plate XXXVIII.

Fig. 1. Fine-grained quartz-dolerite from Horn Bluff (No. 732B). Note typical ophitic fabric. Patches of mesostasis are to be seen at the centre of the picture and elsewhere. x 27.

Fig. 2. Quartz-dolerite from Horn Bluff (No. 732A). The felspars, which act as a matrix, may be seen indenting the periphery of the pyroxene. The augite crystal on the left is cut parallel to (100), and shows indistinct basal striation. The mesostasis in which the felspars are set is well shown. x 17.

Fig. 3. Part of the pegmatitic quartz-dolerite (No. 733) from Horn Bluff. To the right of the vertical diameter is part of a long pyroxene individual twinned on (100) and showing serrated edges. The dark longitudinal band on it represents an alteration area in which the exceedingly fine basal striation is developed. The rectangular sections coming out horizontally from the top of this crystal are cross-sections of augite. At the right-hand side of the long pyroxene some granophyric mesostasis may be seen. Note the variation in the size of the plagioclase. x 17.

Fig. 4. Basic plagioclase, cut normal to (010) and (001), in graphic intergrowth with augite, in No. 733. Chlorite-stained granophyric mesostasis at top and sides. x 17.

Fig. 5. No. 733. Most of the field is occupied by mesostatic material, some in the position of extinction, consisting largely of felspar with rod-like or acicular development. To the left this is in contact with a twinned plagioclase crystal whose broad lamellæ are extinguished. Crossed nicols. x 59.

Plate XXXIX.

Fig. 1. No. 837. Showing part of a nodule composed of olivine grains with some associated felspar and pyrites. The olivine has been altered to talc (?), the colour of which changes from very pale-green on the left to a greenish-brown on the right side of the nodule. x 17.

Fig. 2. No. 838. Showing part of a glomeroporphyritic aggregate of plagioclase. Crossed nicols. x 17.

Fig. 3. No. 449. Containing plagioclase, with granular augite and magnetite. A few small white patches represent interstitial quartz. x 27.

Fig. 4. No. 459. Showing on the left part of a glomeroporphyritic aggregate of plagioclase crystals whose central portions have been replaced by chlorite. x 27.

Fig. 5. Essexitic dolerite (No. 208). There may be seen augite, plagioclase, ilmenite (sometimes in rods) and chlorite (light irregular patches at top and right-hand side). x 17.

Sydney: Alfred James Kent, Government Printer—1923.

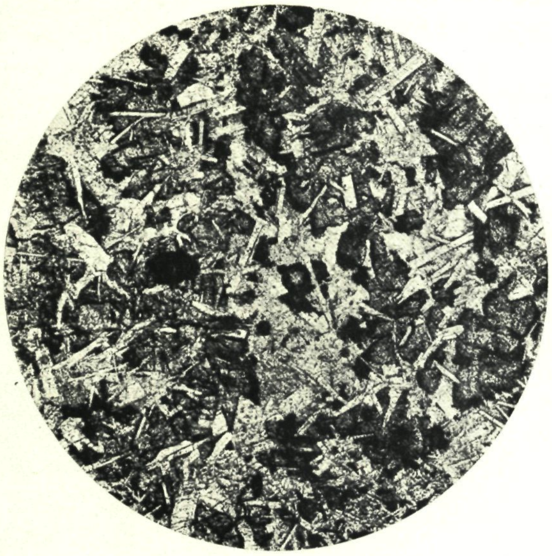


Fig. 1.

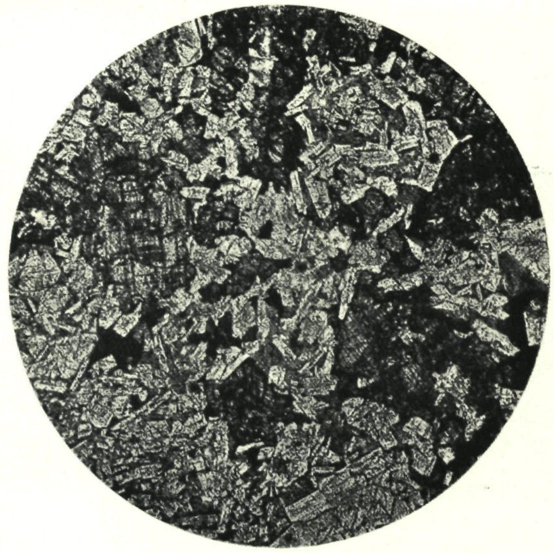


Fig. 2.

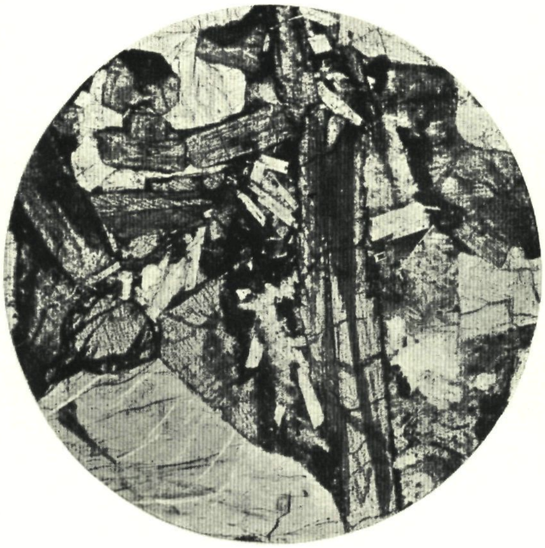
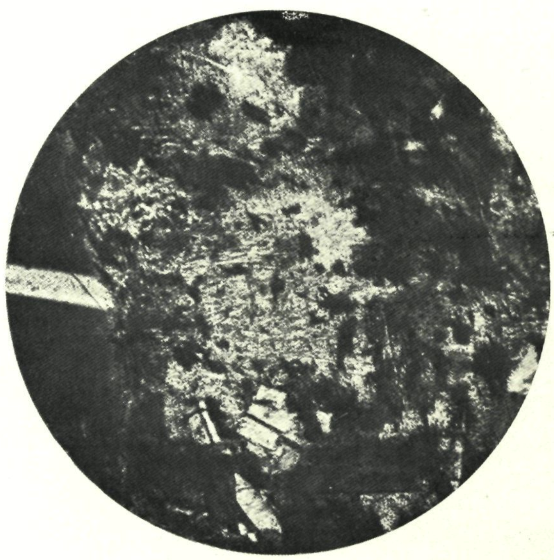


Fig. 3.

Fig. 4.



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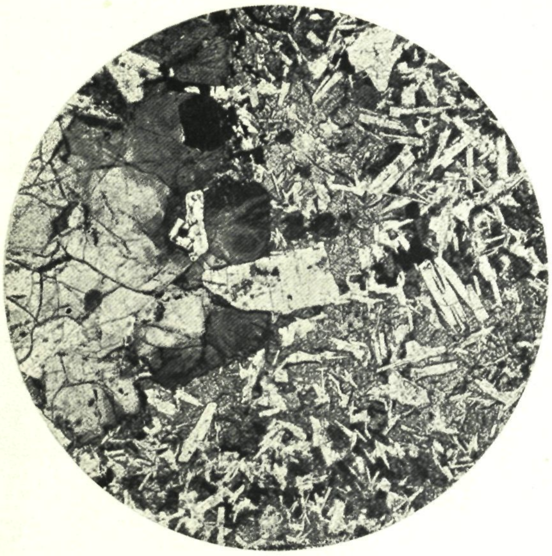

Fig. 1.

Fig. 2.

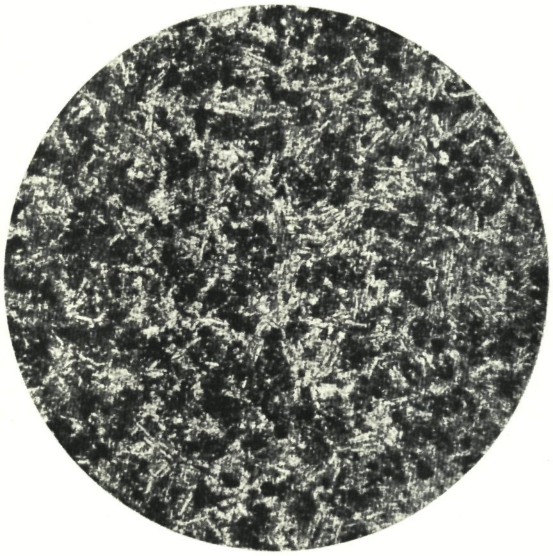

Fig. 3.

Fig. 4.

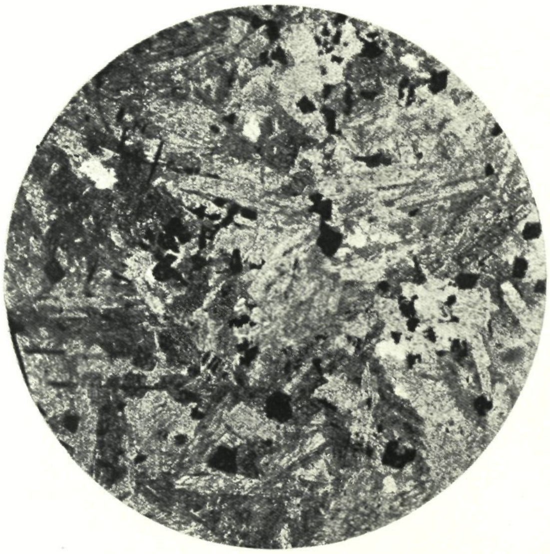

Fig. 5.