BRITISH ANTARCTIC EXPEDITION 1907–9
UNDER THE COMMAND OF SIR E. H. SHACKLETON, C.V.O.

REPORTS ON THE SCIENTIFIC INVESTIGATIONS

GEOLOGY

PUBLICATIONS OF THE BRITISH ANTARCTIC EXPEDITION, 1907–9, UNDER THE LEADERSHIP OF SIR E. H. SHACKLETON, C.V.O.

REPORTS ON THE SCIENTIFIC INVESTIGATIONS

(Published for the Expedition by William Heinemann, London)

BIOLOGY

Vol. I, Part I. *On Collecting at Cape Royds.* By James Murray, F.R.S.E., F.Z.S. 1s. 6d. net.
II. *On Microscopic Life at Cape Royds.* By James Murray, F.R.S.E., F.Z.S. 5s. net.
III. *Antarctic Rotifera.* By James Murray, F.R.S.E., F.Z.S. 5s. net.
IV. *Musci.* By Jules Cardot. 1s. net.

The above four parts also bound in one volume, 12s. 6d. net.

V. *Tardigrada.* By James Murray. 10s. net.
VI. *Rhizopodes d'eau douce.* By Eugène Penard. 3s. net.
VII. *Fresh-water Algæ.* By W. West, F.L.S., and G. S. West, M.A., D.Sc., F.L.S. 3s. net.
v. 1 Vol. II, Part I. *Mollusca.* By Charles Hedley, F.L.S. 1s. 6d. net.
II. *Antarctic Fishes.* By E. R. Waite, F.L.S. 1s. 6d. net.
III. *Mallophages.* By Professor L. G. Neumann. 1s. 6d. net.
IV. *Astéries, Ophiures, et Echinoides.* By R. Koehler. 5s. net.

GEOLOGY

Vol. I. *Glaciology, Physiography, Stratigraphy, and Tectonic Geology of South Victoria Land.* By Professor T. W. E. David, C.M.G., F.R.S., M.A., Hon. D.Sc. (Oxon), and R. E. Priestley, F.G.S. With Short Notes on Palæontology by T. G. Taylor, B.A., B.E., B.Sc., and Professor E. H. Goddard, D.Sc. Paper boards, £2 2s. net; also in cloth, £2 12s. 6d. net.
Vol. II. Herewith.

No further publications in this series are contemplated.

PUBLICATIONS IN THE PROCEEDINGS OF LEARNED SOCIETIES

Some Results of the British Antarctic Expedition, 1907–1909.
By Sir E. H. Shackleton, C.V.O. *Geog. Journal*, vol. xxxiv, November 1909.

The Tidal Observations of the British Antarctic Expedition, 1907–1909.
By Sir George Darwin, K.C.B., F.R.S. *Proc. Roy. Soc.*, 1911.

An Outline of the Geological Results of the British Antarctic Expedition of 1907–1909.
By Professor T. W. E. David and R. E. Priestley. *Internat. Geol. Congress, Stockholm*, 1910.

Antarctica and Some of its Problems.
By Professor T. W. E. David. *Geog. Journal*, vol. xliii, June 1914.

The Auroral Log of the British Antarctic Expedition, 1907–1909.
Edited and discussed by Dr. D. Mawson. *Proc. Roy. Soc. South Australia*, 1916.

POPULAR NARRATIVES

(Published by William Heinemann, London)

The Heart of the Antarctic.
By Sir E. H. Shackleton, C.V.O. In 2 vols. Crown 4to. Illustrations, Maps, and Portraits, 36s. net. Also an Edition de luxe with special Contributions, vellum, £10 10s. net. Also a New and Revised Edition with Illustrations in Colour and Black and White, Crown 8vo, 6s.

Shackleton in the Antarctic.
By Sir E. H. Shackleton, C.V.O. (Hero Readers Series.) Crown 8vo, 1s. 6d.

BRITISH ANTARCTIC EXPEDITION 1907-9

UNDER THE COMMAND OF SIR E. H. SHACKLETON, C.V.O.

REPORTS ON THE SCIENTIFIC INVESTIGATIONS

GEOLOGY

VOL. II

CONTRIBUTIONS
TO THE
PALÆONTOLOGY AND PETROLOGY
OF
SOUTH VICTORIA LAND

BY

W. N. BENSON, B.Sc.; F. CHAPMAN, A.L.S., F.R.M.S.; Miss F. COHEN, B.A., B.Sc.;
L. A. COTTON, B.A., B.Sc.; C. HEDLEY, F.L.S.;
H. I. JENSEN, D.Sc.; D. MAWSON, D.Sc., B.E.;
Prof. E. W. SKEATS, D.Sc.; J. ALLAN THOMSON, M.A., D.Sc.;
A. B. WALKOM, B.Sc.; Prof. W. G. WOOLNOUGH, D.Sc.

WITH 38 *PLATES AND* 18 *FIGURES IN THE TEXT*
ALSO
INDEX TO VOLUMES I & II

LONDON
PUBLISHED FOR THE EXPEDITION BY WILLIAM HEINEMANN
21 BEDFORD STREET, W.C.
1916

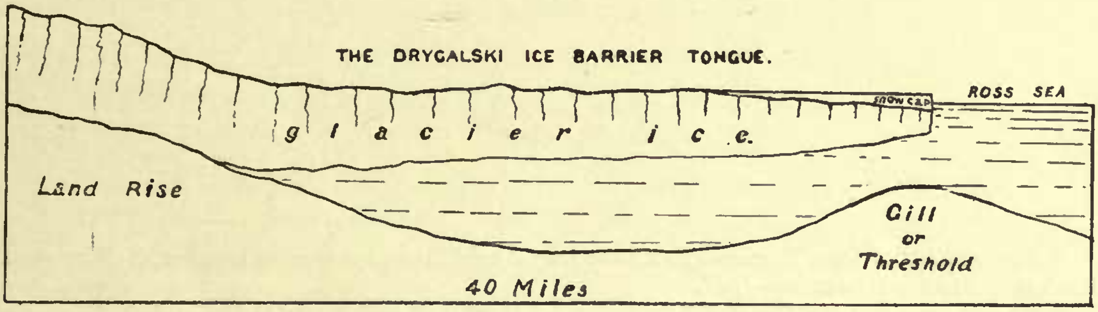
PRINTED AT THE COMPLETE PRESS
WEST NORWOOD
LONDON

PREFACE

The publication of the second volume of the Geology of the British Antarctic Expedition of 1907–1909 has been considerably delayed through several causes, chief among which are the departure of Sir Ernest Shackleton on his present Antarctic Expedition and above all the Great War.

The latter has been such an obsession and has so wholly claimed the active services of both of us * that it has been found to be quite impossible under the circumstances to summarize and modify many of the statements in Vol. I. We must therefore be content with touching on just a few salient points.

First, in regard to the Drygalski Ice Barrier Tongue and the Nordenskjold Ice Barrier Tongue. In the opinion of one of us (Professor David) the sections given on Plate XIV and the plate facing p. 74 are probably incorrect. Instead of both these glaciers being shown as riding on an embankment of their own moraines and subglacial gravels, it is probable that these glaciers are afloat for the greater part of their length, and the longitudinal section, if generalized, should probably be drawn as follows :



This interpretation is suggested (1) by the few soundings around the Drygalski Ice Barrier which show a depth of 300 fathoms close to the extreme end and 668 fathoms at 20 miles back, shorewards, from the end of the Barrier ; (2) by the fact that Glacier Tongue between Hut Point and Cape Evans, a smaller edition of the Drygalski and Nordenskjold Ice Barrier Tongues, actually broke away during the earlier part of Scott's last Expedition; (3) by many interesting sections published by Professor J. W. Gregory in his book on Fiords.

Next, the question has been raised by Frank Debenham, B.Sc., one of the Geologists of Scott's last Expedition, as to whether along the western side of what we have termed the Antarctic Horst the marked westerly descent of the rocks is due to flexing or faulting. On this point we have no definite evidence.

The photographs with which Vol. I is illustrated are the work of several members of the Expedition. In the case of many the identity of the photographer has been

---

* At the eleventh hour this volume was hung up in the press on account of Major (Professor) T. W. E. David and Captain R. E. Priestley being engaged on military service and too fully occupied or out of touch with the printer. The undersigned is engaged in war service in England, and has arranged to take over the work of passing the volume through the press.—D. Mawson.

lost, so that we are unable to mention his name in connection with them. In this matter Mawson * was the largest contributor, supplying forty of those reproduced, including the telephoto view of Mount Erebus.

We are particularly indebted to the authors contributing sections forming this second volume of Geology for their gratuitous and unselfish services in working up the geological results of our Expedition.

We also wish to express our hearty gratitude to Mr. J. A. Tunnicliffe, of the University of Sydney Fisher Library Staff, for his care and patience in preparing the Index to Vol. I.†

The publication of the bibliography of Antarctic Geology prepared by Mr. W. S. Dun, intended for this volume, has been postponed at the last moment, as it is now several years in arrears owing to delay in printing. It is intended that in the near future it shall be brought up to date and published elsewhere.

Finally, this volume is also indebted to the generosity of the Royal Society, who, in addition to the £200 grant towards the printing of Vol. I, have now voted a further £25 to cover the cost of printing the index now appearing.‡

Professor T. W. E. DAVID
R. E. PRIESTLEY

---

* As a matter of fact, I believe Professor David contributed a greater number of photographic illustrations to that volume.—D.M.

† I have extended Mr. Tunnicliffe's Index, so that that appearing at the end of this volume covers both Vols. I and II.—D.M.

‡ All expenses connected with the preparation of matter to form these Geology volumes were defrayed by Professor David from money raised by him in a series of lectures upon the work of the Expedition delivered throughout Australia and Tasmania.—D.M.

CONTENTS

CORRIGENDA TO VOLUME I

Page 37, line 8, *for* Farrar *read* Ferrar.
„ 122, „ 7 from foot, *for* XXXIX *read* XXXIII.
„ 176, Plate XLIX, figure 2, *for* Armytage *read* Mawson.
„ 181, line 19, *for* Brocklehurst *read* Mawson.
„ 231, „ 6 from foot, *for* Lyothyrina *read* Liothyrina.
„ 247, „ 12 from foot, for J. T. Prior *read* G. T. Prior.
„ 266, „ 12 from foot, *for* Blockmann *read* Blochmann.
„ 285, „ 15, *for* Reclus *read* Réclus.
„ 286, „ 3 from foot, *for* funf Sudpolar *read* fünf Südpolar.
„ „ „ 2 from foot, *for* Sudpolar *read* Südpolar.
„ 301, „ 2 from foot, *for* Pass *read* Pas.

PART I

A CONTRIBUTION TO THE STUDY OF ICE-STRUCTURES

(*With Seven Plates and Six Figures in the Text*)

BY

D. MAWSON, D.Sc.

University of Adelaide

CONTENTS

I. INTRODUCTORY

During the winter months much time was spent in investigating the composition, texture, and fabric of the varied ice-forms in the vicinity of Cape Royds.* For this work a Low-temperature Laboratory was constructed in which the temperature was always well below freezing-point. Samples could be treated there in much the same way as other rocks and minerals in an ordinary laboratory. A ready method of studying the crystalline fabric of the specimens was discovered accidentally and happened in this way. It was noted that the large blocks of very cold ice brought into the Hut and piled up in the big melters over the stove quickly became frosted over by the freezing upon them of vapour rising from the bottom of the pot.

In this way, within a few minutes, all the crystal individuals were differentiated to the eye, for the frost additions were microscopic plates developed in optical continuity with the particular individuals upon which they formed. The effect was that every crystal gave a bright reflection when held at a particular angle.

The method of procedure adopted for the investigations was to bring the specimens inside in as cold a condition as possible and place them in the colder portions of the comparatively moist Hut. After a few minutes, upon moving them about in the light, the grain structure could be observed with ease, by reason of the diverse scintillations.

On some moonlight occasions in the winter, depositions of the kind, formed naturally from frost, were observed on the surface ice of the lakes.

With the object of photographing bubbles and other objects contained in the ice, slabs of a fair thickness were first sawn, then reduced to the required thinness by rubbing down on a slightly warm plate, tilted at a small angle to carry off the water.

The Buchanan Hydrometer was used for specific gravity determinations of the thaw water.

For pure water for chemical work freshly fallen snow and some of the *névés* in the vicinity were used, and found to be actually purer than the distilled water brought from New Zealand.

---

* The study of ice and ice-forms was one of my duties on the British Antarctic Expedition, 1907–1909. On return a short popular note to form an appendix to *The Heart of the Antarctic* was forwarded to London on brief notice.

When the *Geological Memoir* was in preparation by Professor David and Mr. Priestley, I was to have co-operated at their request, but preparations for the Australasian Antarctic Expedition, 1911–1914, intervened. Vol. I of Geology has now appeared with excellent chapters on Glaciology, and the notes now submitted are merely fragments in amplification. For several reasons there has been considerable delay in publication of this matter, which was ready four years ago. Since then my observations have been much widened, and will appear shortly in the *Scientific Results of the Australasian Antarctic Expedition*, 1911–1914.

Regret is to be expressed at the loss in transit between Adelaide and Sydney of a consignment of brines and cryohydrates brought back for examination; with them was lost some valuable information.—D.M., *December* 1915.

II. THE LAKE-ICES

1. PRELIMINARY

Ice from the lakelets received most attention. There are many such small basins on Cape Royds Peninsula, as will be noted by referring to the sketch of the neighbourhood prepared from the plane-table survey of Professor David and Mr. Priestley (see *The Heart of the Antarctic*, Vol. I, p. 131).

Much of the interest in the ice from these lakes centres in the fact that the waters of the lakes illustrate various degrees of salinity and consequently the ice shows considerable range of structure. Some of the lakelets are much salter than others, ranging from quite fresh-water basins to others as salt as the sea. In the case of the latter, highly concentrated brine residues are developed in the course of freezing, which themselves eventually solidify after arriving at the cryohydric concentration.

(*a*) *Causes contributing to the Accumulation of Saline Matter in the Lakelets.*

Three contributing causes are likely to have operated in furnishing the salt.

(i) Salts carried on to the land as spray from the sea during gales in the summer and saline snow from the floe blown on to the land during the winter.

(ii) Leaching of salts from the upraised marine muds which, it would appear, at one time covered the whole of the peninsula, and remnants of which are still to be seen.

(iii) Leachings from the alkaline igneous lavas of the neighbourhood.

Without entering into a discussion upon the subject, it will be stated that for obvious reasons these three agencies must be regarded as contributing in the order stated. The contribution blown from the sea is sufficient to account for all the salt. In fact it must actually be held accountable for almost all. The contribution from the third source must be very small indeed, for the prevailing temperature is too low for active chemical decomposition.

(*b*) *Reasons for the varying Salinities of the Lakelets.*

In order to explain the freshness of some of the basins as opposed to the salinity of others, it is necessary to draw attention to many agencies which must have been operative. In the first place, as the winds which carry the saline matter over the land are from the S. and S.S.E., the extremity of the peninsula must receive most of the contributions blown from the sea. The neighbourhood of Blue Lake is more in shadow in this respect, particularly as the head of Back Door Bay is frozen over excepting for a very short period of the year.

The wind distributing the salts over the peninsula is deflected somewhat by the valleys, and so the contour of the land has some determining effect. A situation near to the actual Cape itself, where most of the spray dashes over, ensures salinity. The relative size of the catchment basins and the contained lakelets is important.

The nature of the catchment and its disposition, whether it be rock or snow surface, and whether it be more or less accessible to the sun is a matter of great importance, for in all basins where there is much thaw in summer a considerable annual contribution of saline matter will be brought in with the water. In order that it may become very saline the lakelet itself must be well contained else an exceptional thaw would be liable to sweep out the salts already accumulated.

(*c*) *The Nature of the Saline Accumulations.*

Besides the salt in the lakelets themselves there is always, in summer-time, much saline to be observed over a great part of Cape Royds Peninsula in patches beneath, or in the lee of, stones lying on the surface. In such positions it has the appearance of snow and may be passed by as such. In the winter-time projecting stones arrest a quota of the flying saline snow. As summer approaches, the water from thawing of snow lying about again freezes as soon as the shadow of the rock is entered. Even in the shadow of the rock ablation proceeds rapidly and in time only the salt remains. The presence of the rock acting as a wind-break further protects the accumulation from being carried off by subsequent gales. The illustration (Plate I, Fig. 2) is a view of a pebbly slope high up in the Green Lake basin; small patches of white salt can be seen behind many of the pebbles, easily mistaken for snow.

The saline mineral matter as collected and air-dried contains slightly under fifty per cent. of water, which is driven off at 100° C. It is a mixture of sulphates and chlorides of sodium and magnesium with but traces of other substances.

2. GREEN LAKE

For further information *refer to* Vol. I, p. 148. Green Lake is a shallow lakelet in a rock basin, receiving the drainage of a relatively large catchment area (Plate I, Fig. 1). Its mean diameter is about sixty yards; greatest depth slightly more than six feet, and it is situated some twenty to thirty feet above sea-level. As the water is unusually briny it thaws readily each summer. The common red-brown alga of the Cape Royds lakelets flourishes in the fresher waters of the margin, where thaw-water trickles in from adjacent snow-banks; in the briny central portion there is nothing living excepting bacteria and perhaps other unicellular organisms. The bottom of the latter situation is mantled with a layer of black putrefying mud, from which so much sulphuretted hydrogen is evolved that both the water and the ice have a most disagreeable odour. The gas is doubtless liberated by the action of thio-bacteria, which appear to thrive in the imprisoned waters beneath the surface of the lakelet, existing by reason of their rôle in robbing the sulphates of their oxygen.

Three shafts were sunk by Priestley * in this lake during the winter. The sections exposed in each corresponded very closely in detail. A diagrammatic representation of the July shaft is figured herewith (Fig. 1). In June one foot of brine was found unfrozen at the bottom of the lake. In July there was practically no brine left; none at least where that particular shaft was sunk, distant only twelve feet from the former.

On examination at the Hut, the brine found liquid in the shaft sunk in June was found to contain much sulphate and chloride with a small amount of carbonate and sulphite. With these acid radicles were combined the following bases in order of relative abundance: sodium, magnesium, calcium, potassium, and ammonium. There was present also free sulphuretted hydrogen and carbonaceous matter which charred on evaporating to dryness.

The brine, on standing in a corner of the Hut for a few hours at a temperature of about 30° F. (above its freezing-point), developed a distinctly fluorescent capping layer. From this layer botryoidal masses of a white cloudy substance gradually extended themselves, growing downwards into the liquid at the rate of about half an inch a day. This was noted to take place only in open or loosely corked bottles, and was immediately arrested upon excluding the air. In the course of time the growth extended throughout the liquid, and later settled as a slimy precipitate which proved to be chiefly organic matter. There seems to be no doubt but that the growth was bacterial.

---

* I wish to record my great indebtedness in widening the scope of these observations on ice-structures to Mr. R. E. Priestley and all members of the Expedition who assisted him in the winter programme of sinking shafts through the ice of the lakelets.

The temperature of the brine when bottled at the lake was 22° F. (necessarily the temperature of freezing equilibrium for that particular mixture), further reduction of the temperature caused a separation of H_2O as ice, but there was always a liquid remainder even at temperatures far below zero Fahrenheit.

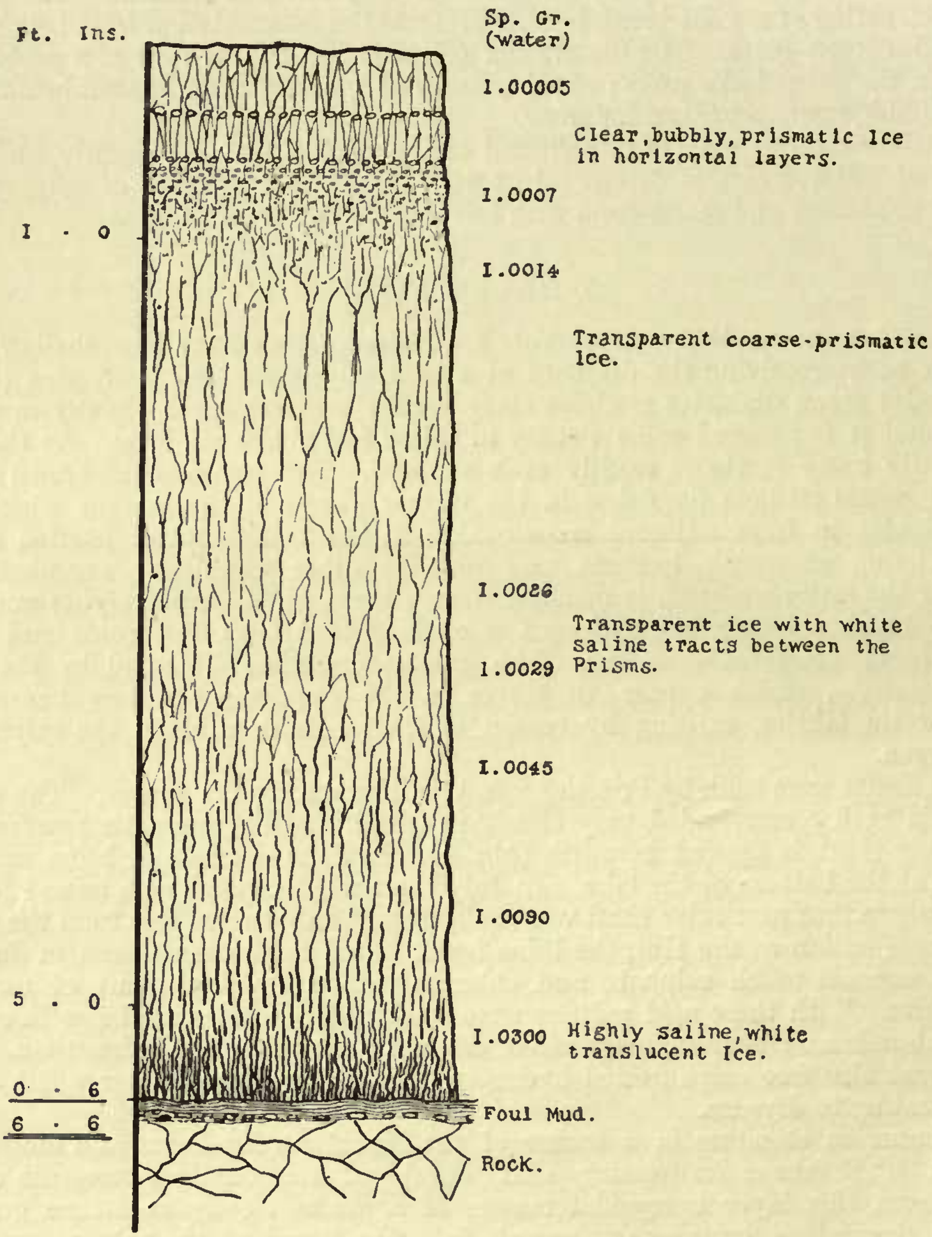


FIG. 1. Diagram illustrating the Ice Section at Green Lake

Two different samples of the liquid brine from the bottom of this lake have been examined by Mr. F. B. Guthrie, F.C.S., analyst to the Department of Agriculture, N.S.W., with the following result:

SAMPLE	1	2
Organic residue settled to the bottom of the bottles (bacterial ?)	per cent. 0·077	per cent. 0·089
Water driven off at 100° C.	87·921	84·761
Water and organic matter expelled by ignition .	0·434	0·750
Saline residue	11·568	14·400

Qualitative tests carried out at the Hut, testing the ice chemically at intervals between the surface and the residual brine, showed the surface fifteen inches to be almost pure water. Below fifteen inches the saline contents rapidly increased. This is well illustrated in the column of densities below.

The following is a table of specific gravity determinations, by the Buchanan Hydrometer, of waters resulting from melting samples of the ice taken at intervals in the July shaft. The second column represents determinations of the temperature of commencement of freezing of the thaw-waters.

SAMPLE	Specific gravity at 4° C.	Commencement of freezing (F.)
Surface to four inches	1·00005	32
Seven inches to ten inches	1·0007	31·95
Twelve inches to fifteen inches	1·0014	31·9
Two feet six inches to three feet	1·0026	31·75
Three feet to three feet six inches	1·0029	31·7
Three feet six inches to four feet	1·0045	31·5
Four feet to five feet	1·0090	30·9
Five feet to five feet three inches	1·0300	29·8

The liquid brine from the June shaft between five feet six inches and six feet had a specific gravity of 1·142 at the same temperature; commencement of freezing 22° F. A sample of the ice from the very bottom, five feet three inches to five feet six inches, of the July shaft was taken to the Hut with others and left in the outer laboratory pending examination. Unfortunately it was contained merely in a bag, as was the usual procedure. When examined it was found to have partially melted and run away, thus indicating the exceedingly low freezing temperature of some of the cryohydrate contained in it.

It is quite probable that, had the earlier shafts not been sunk, there would still have been some liquid brine below the ice in July. As soon as the earlier shafts broke through to the liquid the latter rushed up and rapidly froze as a uniform, somewhat yellowish, enamel-like saline ice.

Crystalline structures. The dominant structure was that of a vertical prismatic arrangement; such as is typical of liquids freezing from above. Each prism was seen to extend in a vertical direction for several inches, some for quite a foot. Near the surface, where the ice was freshest, cross-sections perpendicular to the long prism axis showed the average diameter of the individuals to be about a quarter of an inch, whilst the maximum diameter attained was found to be three-quarters of an inch. At a depth, where the ice was more saline, the structure gradually changed. Upon a glance merely, it appeared as if the individuals in the bottom six inches had been reduced in dimensions, with the production of an aggregate of very even-sized factors averaging one-eighth of an inch across. Closer inspection revealed a more complicated fabric. Instead of the prisms with polygonal cross-sections, which prevailed in the ice near the surface, they were seen to be flattened into the form of plates set vertically, often interpenetrating or twinned. The optical orientation of adjacent plates was often identical. In this way composite flash-faces were met with as much as two inches square.

Saline matter and gas-bubbles, mechanically held within the ice, had taken up positions in vertical tracts between the ice-prisms. Such inclusions were quite obviously elongated in a vertical direction. The saline tracts were more or less opaque and white in colour. Near the bottom of the lake, where, at the time of freezing, the mother-liquor had been very saline, the salt content had materially affected the crystallisation and bulked large in the solidified product. The bottom three inches, which had resulted from the freezing of a liquid containing about fifteen per cent. of solid matter in solution, afforded an excellent illustration. On standing at a temperature still well below 32° F. a specimen of this ice slowly became freed from brine by its draining away. The interspaces once occupied by brine were soon, for the most part, occupied by air, thus affording opportunity of examining the crystalline arrangement of the ice-plates. Upon draining for a while, the specimen showed, in relief, bundles of similarly oriented thin leaves of ice growing vertically downwards. In the crystallisation, as growth continued by lateral expansion of the plates, much brine had become imprisoned, so producing the yellowish enamel-like ice of the deeper zone.

Coming back to the ice forming the first twelve inches below the surface; this appeared on a casual glance to be quite different to that below, for a strongly marked horizontal structure, outlined by layers of somewhat flattened spherical gas-bubbles, caught the eye. The first of the horizontal layers of bubbles was four inches below the surface, the next three inches farther; then the layers came every half-inch, losing distinctness altogether at twelve inches. The contents of the bubbles were, no doubt, chiefly air, but to this it is likely that some sulphuretted hydrogen was added. The prismatic structure best developed at a depth of fifteen inches persisted more or less definitely to the surface, though becoming more confused in the upper layers. Stratified layers, each corresponding to a particular freeze, are a regular feature of lake- and sea-ice. In this case the extreme freshness of the surface layers suggests crystallisation from fresh water. Perhaps abundant snow additions fell upon the surface at the time of freezing. If it were not that the region is disturbed at frequent intervals by violent blizzards, one would be inclined to suggest that when completely thawed the lake, in the short summer, does not regain a state of even salinity. The winter freezing results in pushing the salts downwards, and the extreme density of the lower layers, when thawed the following summer, also tends to keep the salts to the bottom.

3. ROUND LAKE

For further details *see* Vol. I, p. 165. A tarn of very small dimensions near the north-west end of Blue Lake. It averages some thirty yards across, and is only about two feet deep. When trenched in early April it was found to be frozen to the bottom. The water contained much chlorides and sulphates, which were so concentrated in the lower portions as to give it a yellow opaline appearance. The specific gravity of the thaw-water from this latter was 1·009 at 4° C., and the temperature of commencement of freezing was 30·95° F. This yellow ice showed strongly the vertical tracts common to saline ices. These tracts were from one to three inches long in the vertical, and terminated at the lower end in a bulb about a quarter of an inch in diameter. The bulbous extremities were chiefly occupied by gas, but the stems above were almost fully occupied by saccharoidal crystalline matter. The ice itself was in platy form arranged in a vertical direction. The plates averaged an eighth of an inch across, but extended for several inches in the vertical direction. Frequently several adjacent individuals were in optical continuity, producing flash faces up to three-quarters of an inch across.

4. SHALLOW LAKE

Situated in a slight depression in the lee of the ridge immediately north of the head of Pony Gully in proximity to Split Rock. On account of the basin being an imperfect container, much of the thaw-water drains away in the summer-time. The ice-mass is more of the nature of an ice-slab formed by drift accumulations. During the autumn much of the ice from the fresher portions was quarried for domestic purposes. Towards one corner, where the basin was well contained, the ice proved to be very saline. There the ice at the bottom was found to be a completely crystallised concentrated brine, and so presented specially interesting features (Fig. 2). The depth of solid ice was not more than two feet six inches, though irregular accumulations of snow and *névé* were scattered over the surface. No growth of alga was to be seen thereabouts. Doubtless the absence of organic growth accounted for the enamel-white colour of the saline ice from this basin, in distinction to the yellow colour of that from the two

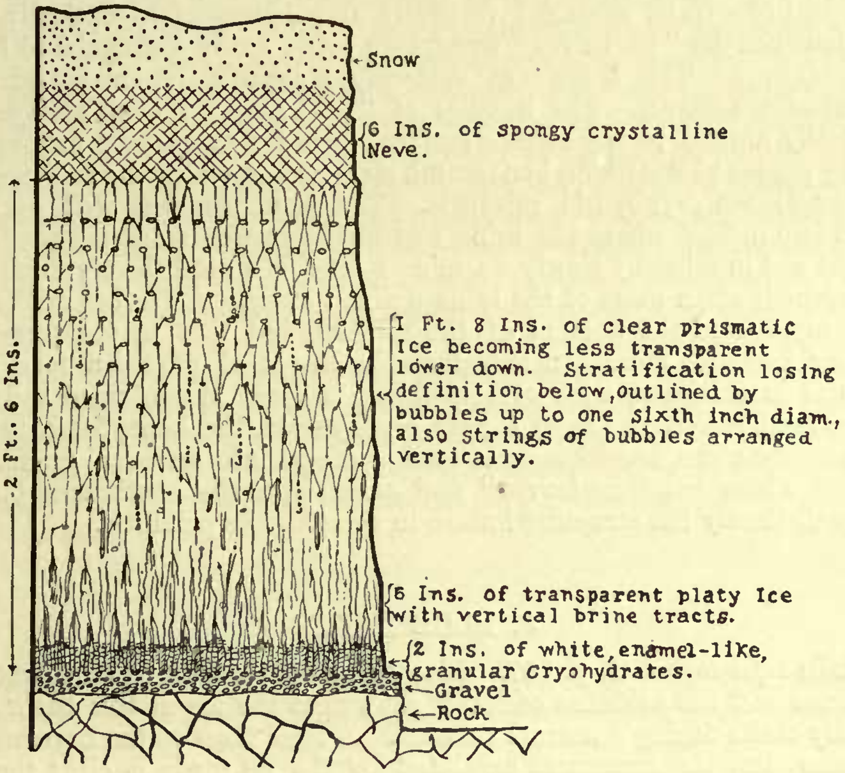


FIG. 2. Shallow Lake Section

preceding. The saline constituents were found to be sulphates and chlorides of sodium, magnesium, calcium, and a small proportion of potassium. The freezing-point of the water obtained by thawing a sample from the bottom was 27·5° F. The bulk of the ice showed horizontal stratification strongly outlined by layers of gas-bubbles, each separated by an average thickness of two inches of clear ice. The bubbles were as much as one-third of an inch in diameter, and were generally elongated upwards in a short stem. This clear stratified ice passes upwards through *névé* into irregular snow-banks. Below it becomes less transparent and whiter. The last two inches in proximity to the bottom were highly saline, resembling white enamel at a temperature of –30° F.—evidently solidified cryohydrates.

The transparent stratified ice of the upper portion of this ice-slab was crystallised in vertical prisms, continuous from one layer to another. Downwards, the dimensions of the prisms dwindled *pari passu* with the increasing salinity; at the same time they assumed a leaf-like form, arranged vertically and developed in optically continuous bundles. Between the "ice-leaves" was frozen brine, easily distinguished by its white, opaque appearance. This brine was evidently mechanically entrapped during the development of the leaves. The bundles of "ice-leaves," though always in vertical planes (actually normal to the cooling surface) were set at varying azimuths, and by intergrowing produced a striking honeycomb structure in which the cells were occupied by liquid or frozen cryohydric mixtures. This structure was well exemplified in the bottom two inches, where the brine was highly concentrated. The "ice-leaves" were brought out in relief by slowly warming a specimen until the cryohydric temperature was reached, when most of the brine drained away. A further critical examination of a sample from the bottom of the slab showed that in the freezing, as the mother-liquor becomes more concentrated, the leaves of pure ice forming the cell walls diminish in thickness with corresponding increase in contained salts. Finally, where the crystallisation was from a pure cryohydrate, the honeycomb type, exhibiting intersertal structure, sometimes was seen to merge into an even granular texture. Sections both along the "ice-leaves" and across optically continuous bundles show more or less distinctly the structure known in petrology as poikilitic.

5. BLUE LAKE

For details *refer to* Vol. I, p. 157. Blue Lake is an extensive fresh-water ice-lake. Our experience and the evidence adduced show that the ice in this basin never more than partially melts during a normal summer. A local thaw at the narrows was noted in midsummer, but the structures exhibited by the ice made it clear that complete thawing takes place only once in a long period of years. This is particularly interesting on account of the fact that Murray found microscopic life amongst the remains of algæ frozen at the bottom, and the minute organisms on being thawed at the Hut again sprang into life.

Qualitative chemical tests showed the ice to be exceptionally pure. Only the faintest trace of chloride could be detected in that between the surface and four feet. At greater depths it was even more free from dissolved mineral matter. The specific gravity of a sample from near the surface gave 1·00005 at 4° C.

Irregular snow-drifts covered the surface of the lake. The particles of such snow and *névé*, during the peculiarly warm conditions of summer and early autumn, "sweat" together, forming a coarser granular mass, very much honeycombed. In the re-crystallisation of snow standing on prismatic lake-ice, there is a strong tendency for the prism structure to be continued above in the developing formation; thus the ice-grains of the new formation are much elongated in the vertical direction. When typically formed in this way the prisms pass downwards, gradually increasing in size until they merge with the prisms of the lake ice. In the upper portions a horizontal section shows clear ice-kernels, the cross-sections of the prisms, separated by much white, opaque, saccharoidal, and honeycombed interspaces (*see* Plate II, Fig. 1). The white interspaces arise from the drawing apart of the grains to fuse with the prism kernels. Successive horizontal sections below show less and less of the honeycombed interspaces, eventually passing into clear ice with only occasional bubbles. The *modus operandi* in the development of this structure is not as clear as it might be, and further information upon the subject is wanting. Cross-sections of such surfaces often show radial patches (*cf.* Plate II, Fig. 2).

Abrasion by wind and snow during the winter produced on portions of the surface of Blue Lake large horizontal polished areas of this kind of ice. An elegant figured pattern was thus developed. Where the vertical prismatic arrangement appears, the term "coralloidal," as used by David and Priestley, aptly describes it. In summer a coralloidal surface tends to become exceedingly rough, for ablation proceeds very rapidly in the spongy mass between the kernels, leaving the latter projecting in relief. The more rapid ablation of the spongy matrix is owing to the fact that it offers less bulk for evaporation, more surface relatively, and has a slightly lower melting-point (for any traces of saline that may have been contained in the snow will be concentrated therein) than in the kernels. The individuals of all ice-formations originating from *névé*, whether they be prismatic or not, always exhibit tortuous interlocking boundaries. The normal prismatic ice of lakes is composed of individuals with straight polygonal boundaries.

The accompanying diagram (Fig. 3) illustrates the section laid bare by Priestley in a shaft sunk in July near the centre of the southern half of Blue Lake.

In descending order the types met with were as follows:

(1) At the surface there was about one foot of hard snow with specific gravity of 0·46, compacted by the winter blizzards; actually a fine grained *névé* as the term is used in Switzerland.

(2) Three inches of a coarse crystalline spongy layer, developed by the recrystallisation during the autumn of the bottom portions of the snow under the influence of warmth below, conducted from the lake-ice, and increasing chill from the autumn conditions above.

(3) Six inches of coralloidal ice in which there were vertical prisms averaging an inch in diameter at their base. These prisms frequently coalesced below in intricate articulating boundaries. This formation doubtless originated from a fall of snow during the summer, or possibly from a fall of the year before.

(4) Eighteen inches of granular, crystalline ice loaded with bubbles. The individuals were very regular in size, averaging a third of an inch in diameter. The texture was hypidiomorphic granular. Occasionally a tendency to short prismatic structure was revealed. Bubbles were distributed irregularly and abundantly throughout, those near the top being largest. In the latter position they were noted to frequently attain a diameter of a quarter of an inch. At a foot below the top of the band eighty-three were counted in an area of seventy-five cubic centimetres, equal to an average of 1·1 to the cubic centimetre. At that spot the average diameter was a sixteenth of an inch.

It will be noted that this layer corresponds closely to the ice of old permanent ice-slabs where there is little movement. It must have originated from the solidification of snow-drifts accumulated upon the lake at least two summers before; in all probability even considerably earlier than that.

(5) Then came ice with a stratified appearance, arising from the distribution of bubbles in sheets. Bands, a couple of inches thick, carrying abundant bubbles alternating with others carrying less bubbles. Here a vertical prismatic structure was moderately well defined and, taken in conjunction with the arrangement of bubbles, is evidence that that ice originated by the freezing of ponded waters.

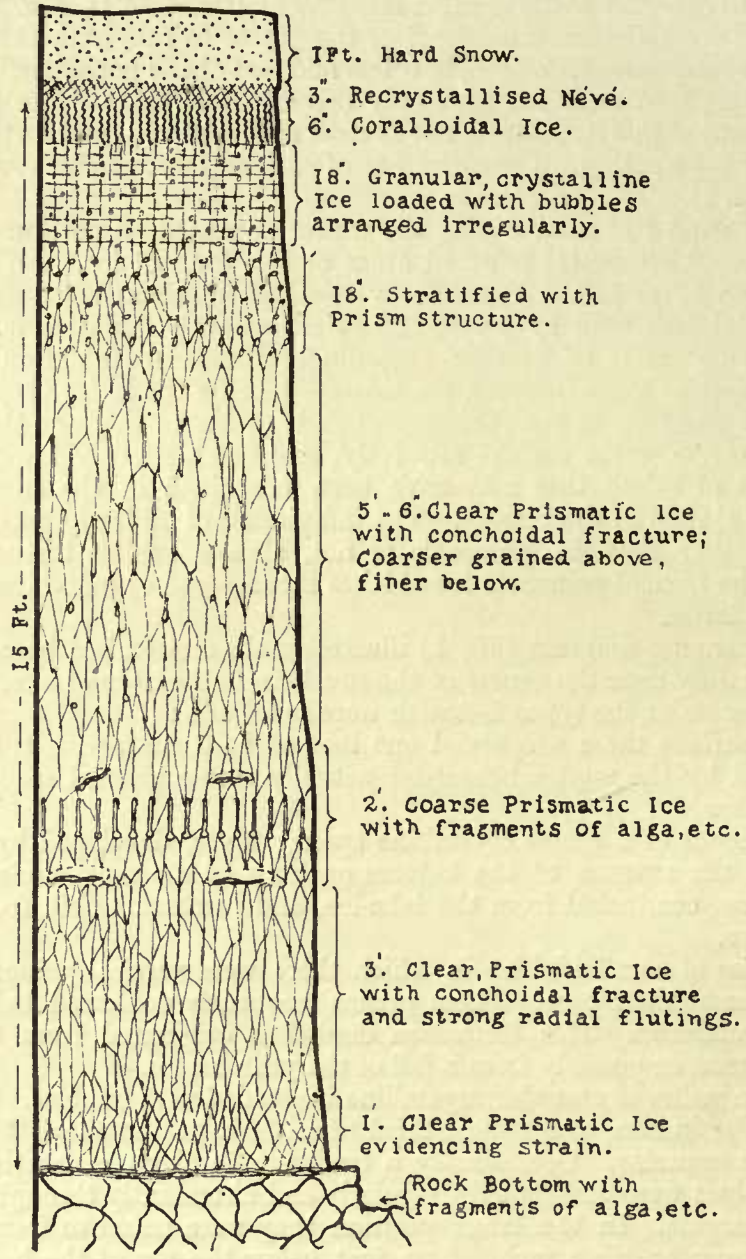


Fig. 3. Blue Lake Section

(6) At about eighteen inches from the top of the stratified bubble-ice the layers became indistinct and the structure was gradually lost, at the same time the ice became

strongly prismatic. In that position patches of tube-like bubbles appeared, usually straight but often winding, averaging a thirty-second of an inch in diameter. At thirty inches below the surface of the stratified lake-ice prisms were met with as much as three inches in cross-section and nine inches long. At that horizon the average cross-diameter was one inch. Occasional bubbles in this part were pear-shaped with the larger end uppermost.

At, and below this level, the ice was very clear and exhibited a well-developed conchoidal fracture with distinct flutings across the sweeping curves. These latter radial flutings became increasingly more strongly marked in the deeper levels. Descending still further, the prisms began to contract in size so that at a depth of eight feet below the surface of the coralloidal ice the grain size was found to average a third of an inch. At that place scattered irregular bubbles were met with, all exhibiting a tendency to elongation in the vertical direction. A block measuring 450 cubic centimetres was found to contain twenty-three bubbles, or one per twenty cubic centimetres.

(7) Between the depths of nine feet and eleven feet below the surface of the coralloidal layer was a band of coarse vertical prismatic ice containing fragments of the red-brown alga on which Murray found living microscopic life. The fragments of alga were each enclosed within disc-like gaseous envelopes, the gas apparently breathed out by the plant and microscopic animals at the time of freezing. As an instance may be mentioned a fragment of alga, half an inch in diameter, surrounded by a gaseous disc five inches in diameter and one-eighth of an inch thick. Adjacent to one of the alga fragments was a bunch of vertical gas-tubes (*see* Plate II, Fig. 3). At the ten-foot level a zone of beautiful tubes was cut through; these had a bulbous extremity below and extended upwards in a regular stem as much as six inches; their diameters ranged from a sixteenth to a twelfth of an inch. A slab of ice from about this level showed tubes from two inches to three inches long and one-eighth of an inch in diameter. On close inspection these were found to be beautiful negative hexagonal crystals. As many as 150 were counted in the slab which, in cross-section, measured 525 square centimetres. Where more sparse they were larger. Examined with a pocket lens they were found to be drusy in the interior.

(8) Below eleven feet there was a change in the ice, so concluding the evidence which indicated that at one time that was the downward limit of thaw for one or more seasons.

From eleven feet onwards bubbles were but occasional. Here and there large irregular ones showed along old fracture planes which had become recemented. The ice was still prism-ice, but no individual longer than three inches was noted. The radial flutings crossing the conchoidal fracture curves were strongly marked.

At fourteen feet to fifteen feet the jarring of the pick developed sets of wavy horizontal cracks, the planes of which crossed each other and resulted in an appearance reminding one of *augen* structure. Evidently the effect of strain induced by the superincumbent weight.

At fifteen feet the rock bottom was reached. There remains of the alga were found. In association with it abundant unicellular chlorophyll-bearing organisms, rotifers, etc., were found still living. The evidence already mentioned goes to show that these organisms must have been imprisoned there in the frozen state for at least three years and probably a great deal longer.

In explanation of the persistence of live organisms in the depths of some of the lakes at Cape Royds, which have remained frozen over in all probability for years, it is suggested that, as sunlight can penetrate through the ice, so long as there is a balance between the plant and animal life all will thrive just as well under a roof of ice as free from it. On account of the lower freezing temperature of saline water, the briny portions of the lakes are the last to solidify and, except in the deepest lakes, are doubtless also the first to thaw. As this is so, the organisms should be able to live on for the greater part of the year in the still liquid deeper zones. At the same time the evidence was clear that in some cases the organisms which came to life on being thawed out had been frozen in such positions for a long time.

6. COAST LAKE

Refer to Vol. I, p. 162. A nearly circular lake averaging about a hundred yards across. Greatest depth met with, four feet one inch. The distribution of algal peat in some of the ice-layers, the character of the crystallisation, and the degree of salinity at various depths, all indicated that a long period had elapsed since the lake had been completely thawed. The usual summer condition does not exceed a partial thaw downwards from the surface.

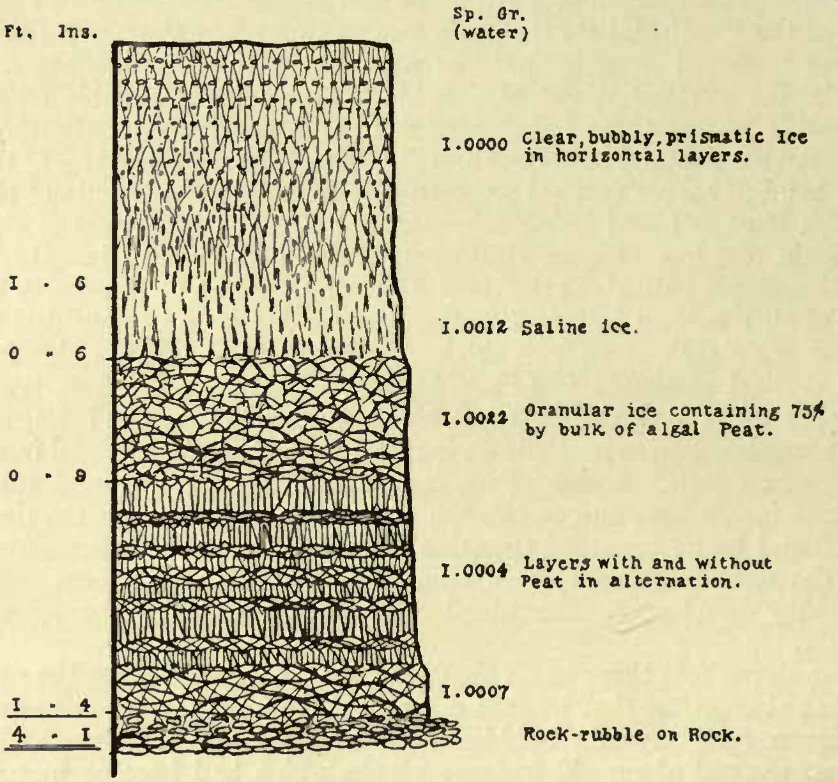


FIG. 4. Coast Lake Section

Specific gravity determinations on the waters obtained by melting samples of the ice gave as follows :

	Sp. gr.
Average bubbly ice between four inches and ten inches . .	1·0000
Prismatic ice between one foot six inches and one foot eleven inches	1·0012
From peaty layer between two feet and two feet nine inches .	1·0022
Between two feet eight inches and three feet eight inches . .	1·0004
From the four-inch peaty layer between three feet eight inches and four feet	1·0007

(1) To a depth of eighteen inches the ice had a strongly marked stratified appearance, owing to the presence of horizontal sheets of gas-bubbles at intervals of half an inch to one inch (*see* Plate III). In the lower portions the layers were closer together and less well defined. The individual crystals were prismatic and of larger dimensions in the deeper layers. They measured half an inch to one inch across and from one inch to two inches, occasionally reaching six inches in length. They were bounded by straight-line faces but showed frequently interlocking junctions. In the deeper layers the bubbles tended to become elongated in the vertical, usually resulting in a tube with a bulbous extremity. The needle-like tubes had a diameter not exceeding one thirty-second of an inch.

(2) Next came a six-inch layer of slightly odoriferous saline ice, with salt tracts between the prisms.

(3) Then there was a nine-inch layer which, in the hand-specimen, had the appearance of jet, and was found to be composed of the peat-like remains of the alga already referred to, with a small admixture of grit, all cemented by twenty-five per cent. in bulk of frozen, somewhat briny water. For many years previously this level must have represented the downward limit of thaw.

(4) Below the main band of algal peat was a belt one foot four inches thick, constituted of layers usually from half an inch to two inches thick, charged with more algal remains alternating with other clear ice-bands. The last four inches of this section were composed of an extra thick band of algal peat and rested on the bottom of the lake. In the layers where organic remains were abundant the ice tended towards an even-sized, granular texture, in which the grains were polygonal, averaging a quarter to a third of an inch in diameter. Where there was little peaty matter the prism structure was preserved and extended from one layer to the other.

7. CLEAR LAKE

Refer to Vol. I, p. 154. An elongated lake about one hundred yards in length and thirteen feet deep where trenched. It was particularly noted for the large area of its surface, formed of handsomely marked coralloidal ice. In other places snow-drifts lay on the surface, and beneath them could be traced stages in the formation of the coralloidal ice. Where the second shaft was sunk, in April, four inches of the figured ice at the surface passed down into prismatic ice in which were vertical columns of bubbles, then bubbles strung like beads, and finally isolated bubbles in vertical lines. Prismatic structure was marked from the coralloidal surface down, but beyond the two-feet level became more prominent, and vertical gas-tubes, some of them negative crystals, appeared. This latter was no doubt ordinary lake ice, but that above was formed in some other way, partially or wholly, from snow-drift accumulations. At five feet four inches there appeared to be another line of demarcation, for the ice below showed only occasional bubbles, was very transparent, and exhibited a conchoidal fracture. At six feet the crystals were still prismatic, bounded by polygonal faces, averaging a quarter of an inch in diameter, but from five inches to six inches long. Often several adjacent crystals were optically continuous, producing faces half an inch or more across.

The total thickness of the ice was nine feet one inch, and there were some four feet of water below it. The specific gravity of that water at 4° C. was 1·0014.

8. GLACIER-ICE (*for comparison*)

For comparison with the textures of the lake-ices a reference to that of glacier-ice from the vicinity is interesting.

A sample of the ice at sea-level, about one hundred feet below the surface of the glacier, one mile south of Cape Barne, was found to be composed of equidimensional grains with interlocking and re-entrant straight-line boundaries. Some of the grains were an inch in diameter. It was loaded with bubbles well shown in the photograph (*see* Plate II, Fig. 4). The bubbles were very irregular in shape, often spherical or dumb-bell-shaped, and sometimes tube-shaped. The spherical bubbles were commonly a sixteenth of an inch in diameter. Where elongated they were found to be leaning at an angle of 45° with the upper end forward in the direction of motion of the glacier.

Nearer the surface the ice of the glacier passed into a finer grained state.

9. CLASSIFICATION OF THE CRYSTALLINE TEXTURES OF THE LAKE-ICES

The crystalline texture of the lake-ices has been shown by the foregoing investigations to depend in the following manner upon the proportion of dissolved salts in the water:

(*a*) Fresh water allows of the formation of coarse prisms.
(*b*) Somewhat saline water yields medium-sized prisms.
(*c*) Highly saline water produces plate structure.
(*d*) Cryohydrates solidify as a fine-grained mass, in which intersertal structure is often prominent.

III. SEA-ICE

Refer to *The Heart of the Antarctic*, Vol. II, p. 337, and Vol. I, p. 180, of this series.

The ice of the first few inches from the surface usually originates as a felting together of small floating crystals. As the freezing in that layer proceeds more rapidly than in the deeper zone, a larger proportion of brine is trapped in the interstices of the feltwork. Below, the ice is prismatic with saline tracts between the prisms. As in the case of lake ices, a horizontal stratification is noticeable throughout the first foot or two below the surface.

Snow piled upon the surface becomes consolidated, and draws up a small quantity of brine from the salt ice below. The following specific gravity determinations were made from samples got in a shaft sunk by Priestley in the frozen surface of Back Door Bay in the winter:

	Specific gravity of thaw-water at 4° C.
First foot	1·0084
Second foot	1·0046
Third foot	1·0043
Fourth foot	1·0026
Fifth foot	1·0061

A sample of the surface sea-water of McMurdo Sound, taken about the same time, on an occasion after a blizzard had cleared the floe out, had a specific gravity at 4° C. of 1·0275.

The reason for the high specific gravity of the first foot of the sea-ice has been mentioned. Below, as the crystallisation becomes slower, expulsion of the salt is increasingly more effective. The fifth foot, which was in contact with the sea-water below, was somewhat cellular and saturated with sea-water, which did not all drain out before part became frozen in the specimen, hence the greater salinity.

IV. ICE-STALACTITES

Besides fresh-water icicles there were to be found along the ice-foot which formed at Cape Royds grottos draped with stalactites of less simple structure. The ice of the ice-foot is in all cases very briny, consisting largely of frozen sea-spray. On account of the fact that the melting-point of brine is very much below that of pure ice, there is a tendency for the former to ooze out of the ice-foot and drip back into the sea. As the freezing of brine solution depends upon its concentration, the brine which drips from the ice-foot at low temperatures is more concentrated than that at high temperatures. In the autumn, with falling temperatures, the brine which oozes from the ice-face becomes somewhat more chilled before it has time to drop, and so leaves behind at that point a little pure ice. In time the dripping-point becomes more pronounced and stalactites, sometimes several feet in length, are built up gradually. A stalactite from the ice-foot at the Penguin Rookery was examined and found to be constructed of alternating concentric rings of compact ice and of cellular ice. The centre was in the form of a somewhat cellular hollow tube. The section figured here is a reproduction of the cross-section traced from the stalactite itself (Fig. 5).

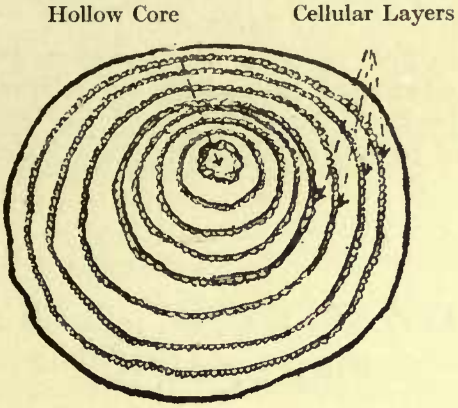


FIG. 5. Cross-Section of Stalactite

On thawing a stalactite the commencement of freezing of the thaw-water was found to be 29·5° F.

A quantity of the drip from stalactites at the ice-foot was collected in the early autumn and found to commence freezing at 8° F. At –5° F. it had assumed the form of a paste—a mixture of unfrozen cryohydrate and fine ice-leaves.

After the sea in the vicinity had become finally frozen over, snow drifting over the floe banked up along the shores, obliterating much of the original ice-foot. Where stalactite-draped caverns remained, the stalactites themselves were found to have developed into grotesque forms by additions of firmly adhering snow (*see* Plate IV, Fig. 2).

A further case worthy of note was that which was presented in a cavern of a large "snow-berg" held in the floe near Cape Barne. The berg, though rather a small one, was originally of the table-topped class. All that was exposed above the sea was fine granular *névé*, firmly consolidated in the lower portions. Owing chiefly to weathering of the summit, it rose somewhat out of the water during the winter, and exposed a large cavern that had formerly been eaten out below sea-level by the wash of the water. Near the water-level, sixty feet below the summit, the berg was composed of fine granular particles averaging one-thirtieth of an inch in diameter, whilst many of the grains reached a twentieth of an inch in diameter. Though well compacted, the *névé* in that part of the berg was sufficiently porous to have been saturated with sea-water. So it happened that, as the berg rose, the brine kept oozing from the roof of the cave, developing well-formed stalactites (*see* Plate IV, Fig. 1).

When the photograph was taken the temperature was −30° F., and there was but a slight drip, which completely froze on the floor as mamillary stalagmites having the appearance of white enamel—evidently frozen cryohydrate. The stalactites showed the usual rings in cross-section, were resinous in appearance, and exhibited a conchoidal fracture. Towards their downward extremities the internal appearance changed to that of a fine granular texture. To what extent this was due to adhering drift-snow or to the freezing of certain cryohydrates with higher freezing-point was not ascertained.

V. A COMPARATIVE STUDY OF ICE-CRYSTALLISATIONS FROM VAPOUR

The amount of water vapour necessary to produce saturation in the atmosphere varies with the temperature. Approaching the freezing-point, 32° F., it sinks to a small fraction of what it is at higher temperatures. Below freezing-point, saturation is attained when there is little more than vestiges of water vapour in the air. In a land where almost all is ice, notwithstanding the fact that at such low temperatures the capacity of the atmosphere for moisture is trivial, great results follow from the offices of the atmosphere in taking up, transporting, and depositing H_2O. For the most part it is evaporation of a solid and deposition as a solid, and is thus a case of sublimation.

An experiment was entered upon with the object of ascertaining whether vapourisation is accelerated in the case of saline ices. A metal mould for casting cylindrical blocks of regular dimensions was made. In it a series of blocks was cast, each about two pounds twelve ounces in weight. There was a block of fresh-water ice, and others with certain ingredients added in molecular proportions : *e.g.* $NaCl$, Na_2SO_4, KCl, $MgSO_4$, and $MgCl_2$. The blocks were suspended on gibbets on the south side of the Hut, as shown in Plate XCI, Vol. I. What with the interference of an occasional blizzard and certain inherent difficulties the experiment was not altogether a success. However, sorting over the results of a large number of weighings, one is struck by a general accordance indicating more rapid ablation in the saline ices.

A theoretical consideration of the case suggests that the presence of salt might accelerate evaporation in the region of the temperature scale not far below the freezing-point of fresh water, but that its effect in this respect would be lost at lower temperatures.

Interesting observations on ice forms developed under varying conditions were made within the precincts of the Hut itself. In explanation of subsequent statements, brief mention of the plan of the Hut is necessary. The Hut was entered by an outer door, then along a short vestibule and through an inner door. The Low-temperature Laboratory was a small, tightly enclosed room outside the main room of the Hut, and was entered by a door in one of the walls of the vestibule. From the Low-temperature Laboratory a scramble on hands and knees under the floor of the vestibule brought one to Wild's Store, another well-enclosed adjunct to the Hut. The cooking-range, the only source of heat, was at the end of the Hut remote from the entrance door. Near the stove the temperature would be well above 32° F. and it fell off regularly *en route* to Wild's Store. The journey to the latter was quite a long and devious one, and along the path there was usually a slight current of air, particularly when the inside door of the Hut was opened. The average winter temperature in Wild's Store ranged from -20° F. to -30° F. As giving some idea of the conditions in the Low-temperature Laboratory, it may be mentioned that on one occasion when the outside temperature was -20° F. that in the Low-temperature Laboratory was -6° F.

Moisture rising from the cooking and from our breath kept the air in the Hut fairly well saturated. Much of this was continually depositing as a fuzzy coating in odd corners where low temperatures prevailed, particularly on the inside of the inside door. All such deposits were, however, of little interest, because they never remained long enough to develop pronounced structure before being destroyed by partial thaw as a result of the wide range of temperature experienced within the Hut.

(*a*) *Crystallisations from Concentrated Vapour.*

In the vestibule snowy growths, usually of a fluffy character, formed on the walls and ceiling so rapidly that it required to be scraped out at very frequent intervals. Thus was exemplified crystallisation from a copious supply of over-saturated atmosphere, at temperatures not greatly below freezing-point. The draught causing rapid carriage of the vapour was certainly a factor in determining its fluffy character.

Similar conditions pertained in the stable, where the breath from the ponies poured forth a copious vapour which froze in beautiful fern-like forms attached to the ceiling and on hanging objects (*see* Plate V, Fig. 1).

The flocculent snow, in delicate flakes, which falls during the Antarctic summer, and more rarely at other times during the year near the sea-board, is of this class.

(*b*) *Crystallisations from an Attenuated Vapour.*

At lower temperatures, even at 100 per cent. humidity, the vapour is attenuated and the precipitation is modified, as exemplified by the formation which appeared in the Low-temperature Laboratory (*see* Plate VI, Fig. 2). Deposition was much slower there than in the vestibule. However, a coating of blade-like forms, standing perpendicular to the walls and ceiling, gradually developed (*see* Plate VI, Fig. 1). In this formation each blade is a composite basal plate built up of innumerable, almost microscopic scales, each with trigonal symmetry as shown in the sketch (Fig. 6).

These small units remind one of forms which compose the precipitation during certain Antarctic winter snowfalls.

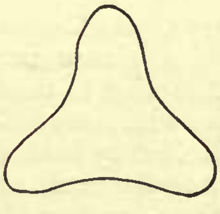


Fig. 6. Ice-Scale with Trigonal Symmetry

Reference to a form of platy crystallisation has been made by David and Priestley (Vol. I, p. 19). The details there mentioned are not quite clear, however, and something more may be added. On that occasion, as we sledged along over the hard *névé* surface of the plateau on a bright sunny day, a carpet of ice-blades began to grow up from the surface *névé*. In a few hours it was just as if we were walking on a velvet-pile carpet. The wind sprang up later on and mowed down the crystal plates. They reminded me at the time of the flakes of flake anthracene. These delicate plates were formed from vapour rising out of the comparatively warm porous *névé* below, and becoming chilled by the air temperature.

The "ice-flowers" of the newly frozen sea are composed of plates similar to those of the Low-temperature Laboratory. Each "flower" is composed of an interpenetrating bunch of these composite plates, and may be so well developed as to reach a diameter of two inches (*see* Plate V, Fig. 2). In the case of a typical crop which formed over Back-Door Bay in the autumn, the thickness of the plates was found to be a two-hundred-and-fiftieth of an inch. Favourable conditions for the growth of ice-flowers are a dead calm and a sudden fall of the temperature to zero or lower. Growth takes place by additions to the plates from atmospheric moisture replenished from the comparatively warm thin ice layer over the sea-water. It was found that, normally, the nuclei for the building up of these rosettes is brine—drops of brine exuded by the hardening sea-ice below. If, therefore, a sample of ice-flowers be collected and thawed, brine and not fresh water is the result. As indicating the degree of salinity may be mentioned determinations of the beginning of freezing of the brine obtained by thawing two samples. One, marked "large old ice-flowers," commenced to freeze at 27·7° F.; the other, distinguished as "small young ice-flowers," gave 20° F. Obviously, as they grow in size, the original brine is continually diluted. A more irregular growth of the kind is that which throughout the winter is seen to form around the margins of cracks in the sea-ice and over newly frozen leads. In such situations the "flowers" are more fluffy and fern-like, and the brine nuclei may be dispensed with altogether, the deposition taking place more or less at random on any exposed objects. Like growths are seen on the surface of sheets of fresh water—in all cases freezing takes place at low temperatures. For instance, on the freezing surface of water exposed by trenching operations in the winter on the lakelets around Cape Royds.

Akin to these plates formed from depositions from rarefied vapour are the leaf-like plates which are typical of ice forming as separations from concentrated brines. Crystallisations of the kind have been mentioned as forming the lowest and most briny zones of Green Lake and of Shallow Lake. Separations of the kind were also well illustrated as developing from sea-water under certain conditions; for example, adhering to ropes left freely suspended in sea-water. An instance of the kind is figured on Plate XXVI of Vol. I. A sample of such plates was allowed to drain at a temperature of about zero F., then thawed, and the freezing-point of the liquid determined. Freezing was found to commence at 31·7° F., illustrating the freshness of the crystals.

(*c*) *Crystallisations from Rarefied Vapour.*

A glance into Wild's Store supplied valuable information in this connection. Adhering to cans of preserved food and on the ceiling were beautiful crystals of clear ice with more or less perfect shape. The ideal form was that of a short hexagonal prism limited by basal planes. In situations where the air current was greater, skeleton forms were the result, and some of these were found so large as to represent portions of hexagons three-quarters of an inch across.

A good example of the same type of formation was met with in the spring on digging up a seal liver which had been buried in the snow during the winter. The lower side of the liver was covered with perfectly formed short prisms of clear ice (*see* Plate VII, Fig. 2).

This form of crystallisation is universal on the walls of crevasses, and in such situations the size of the individuals is often very large. During the winter the moister air from below rises in the crevasse, and as it is chilled nearing the surface, crystals are deposited on the walls. In summer-time, no doubt, additions are made from moist air entering from above. So a spongy mass of crystals is developed which, in time, chokes the mouth of the crevasse.

Frost-ice, which forms at low temperatures, is of this class. The duration of any particular frost-period is usually so short that in cases where the temperature is below zero F. the deposition is scarcely perceptible to the eye, but is readily felt as a sort of sand-paper coating on all exposed objects. Attention was particularly drawn to this frost-ice on account of its interference with the lenses of the spectroscopic camera when exposed for long intervals during the winter night. Plate VII, Fig. 1, is a photograph of the front of the spectroscopic camera on an occasion when it showed an abundance of frost-spicules. Frosts of the kind of which I am speaking took place at temperatures below zero F., that illustrated having formed at −30° F.

Analogous with this class is the precipitation from a cloudless sky occasionally experienced at sea-level during the winter, and even in the height of summer on the plateau. Such falls are composed of minute, well-formed, clear crystals. The mean dimensions of the particles of a fall during the winter at Cape Royds was found to be one-hundredth of an inch. Many of the wonderful optical effects witnessed on occasions in the Polar regions is due to the presence of these particles floating in the atmosphere.

In conclusion it is to be remarked that the subject of vaporisation and redeposition of ice is a most important one, for it is by such processes that snow becomes converted into *névé* and is also largely accountable for the convertion of *névé* into ice. Loosely packed snow holds a large volume of air which is ever taking up and redepositing ice *pari passu* with fluctuations of the temperature and barometric pressure. Thus the individual grains become increased in size and the pore space reduced in accordance with the well-known laws governing recrystallisation under such conditions.

VI. EXPLANATION OF THE PLATES

(All Photographs and Diagrams by the Author)

PLATE I

FIGURE 1.—A winter moonlight view of Green Lake from near High Peak, looking West; the Lake nestling below the figures; the frozen sea in the distance extending to the horizon.

FIGURE 2.—Showing a pebbly slope near Green Lake. In the lee of the pebbles white accumulations of saline matter resembling snow are visible.

PLATE II

FIGURE 1.—Coralloidal ice, Clear Lake. A photograph looking down upon it from three feet above.

FIGURE 2.—The same showing a centric development.

FIGURE 3.—Vertical bubbles in the ice of Blue Lake; ten feet below the surface. (Enlarged.)

FIGURE 4.—Photograph of ice from 100 feet below the surface of a glacier near Cape Barne illustrating the bubbles. (About natural size.)

PLATE III

Stratified bubbly ice from the surface zone of Coast Lake. The top of the block was the actual surface. The white triangular patch on one side is "scar tissue," which formed in a crack from vapour from below. In this way the crack was eventually closed up. (Reduced in size.)

PLATE IV

FIGURE 1.—Stalactites draping a cave in a tilted "snow-berg" near Cape Barne.

FIGURE 2.—Stalactites which have assumed grotesque forms owing to snow additions, in a cavern under the ice-foot at Cape Royds.

PLATE V

FIGURE 1.—Fern-like skeleton crystals adhering to a piece of string in the pony stables. The "fronds" were up to two inches in length.

FIGURE 2.—Ice-flowers on the newly frozen sea, Back-Door Bay. The bunches were about two inches in diameter.

PLATE VI

FIGURE 1.—Looking from a distance of twelve inches into a growth of composite blade-like ice-crystals formed on the wall of the Low-temperature Laboratory.

FIGURE 2.—A distant view of the same.

PLATE VII

FIGURE 1.—Frost-ice formed at −30° F. on the face of the spectroscopic camera.

FIGURE 2.—Hexagonal crystals of clear ice formed by sublimation on a seal liver which had been buried during the winter.

FIGURES IN THE TEXT

PLATE I

FIG. 1. GREEN LAKE VIEWED FROM NEAR HIGH PEAK

FIG. 2. SALINE ACCUMULATIONS (NOT SNOW) IN LEE OF PEBBLES, CAPE ROYDS

[*To face p.* 24

PLATE IV

FIG. 1. STALACTITES OF A CAVE IN A "SNOW-BERG"

FIG. 2. STALACTITES OF GROTESQUE FORM UNDER THE ICE-FOOT

PLATE V

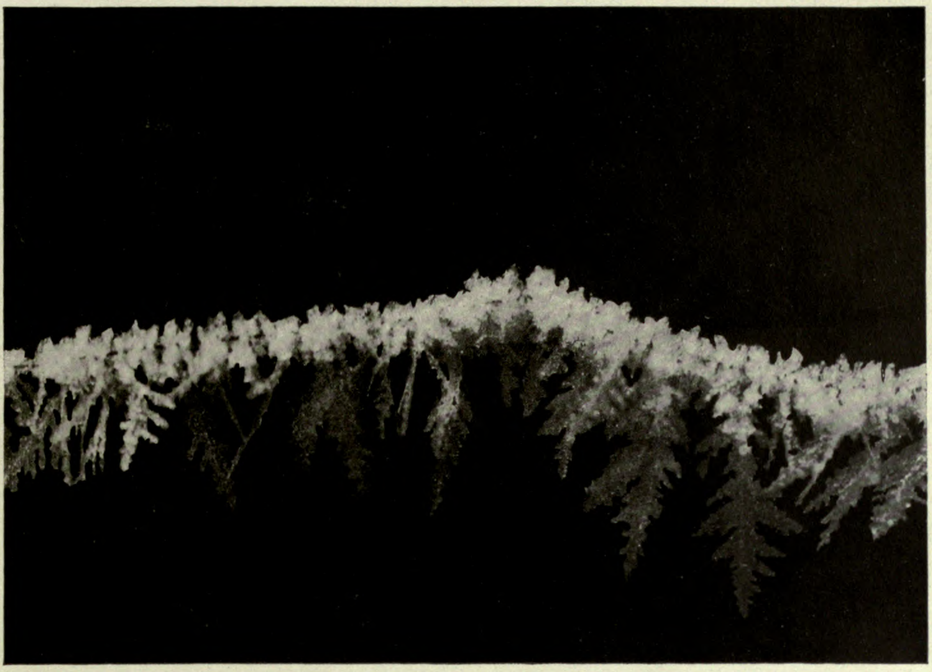


Fig. 1. FERN-LIKE SKELETON CRYSTALS ADHERING TO A CORD

Fig. 2. ICE-FLOWERS ON THE NEWLY FROZEN SEA-ICE

PLATE II

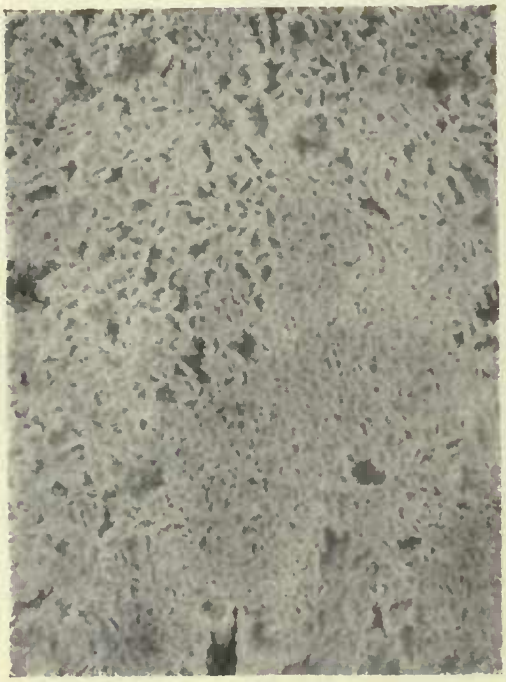
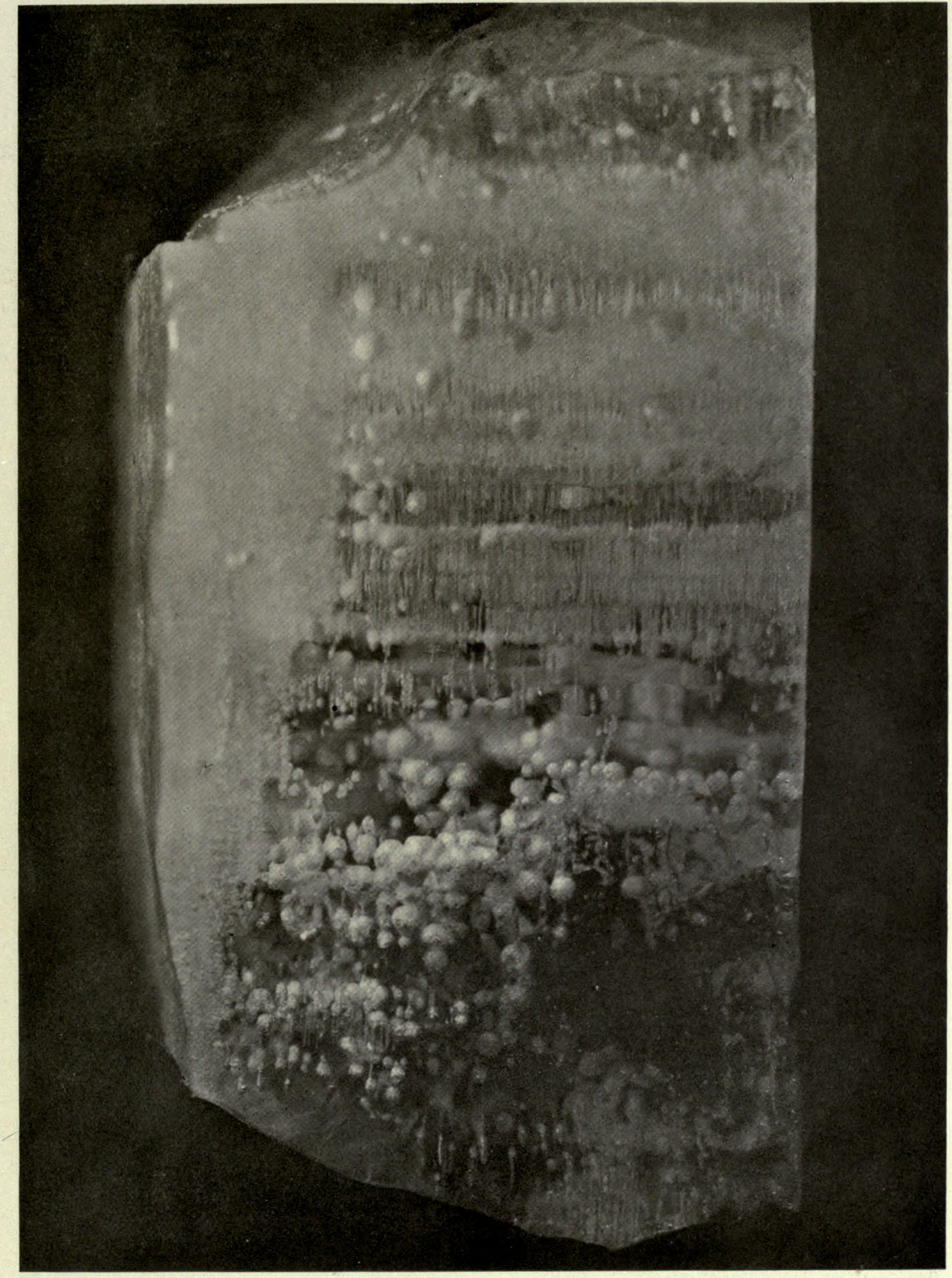


FIG. 1

FIG. 3

FIG. 2

FIG. 4



STRATIFIED BUBBLY ICE FROM THE SURFACE ZONE OF COAST LAKE

PLATE VI

Fig. 1. A CRYSTALLISATION OF PLATY ICE ON THE LABORATORY WALL VIEWED AT A DISTANCE OF TWELVE INCHES

Fig. 2. A DISTANT VIEW OF THE CRUST OF PLATY ICE FORMED ON THE LABORATORY WALL

PLATE VII

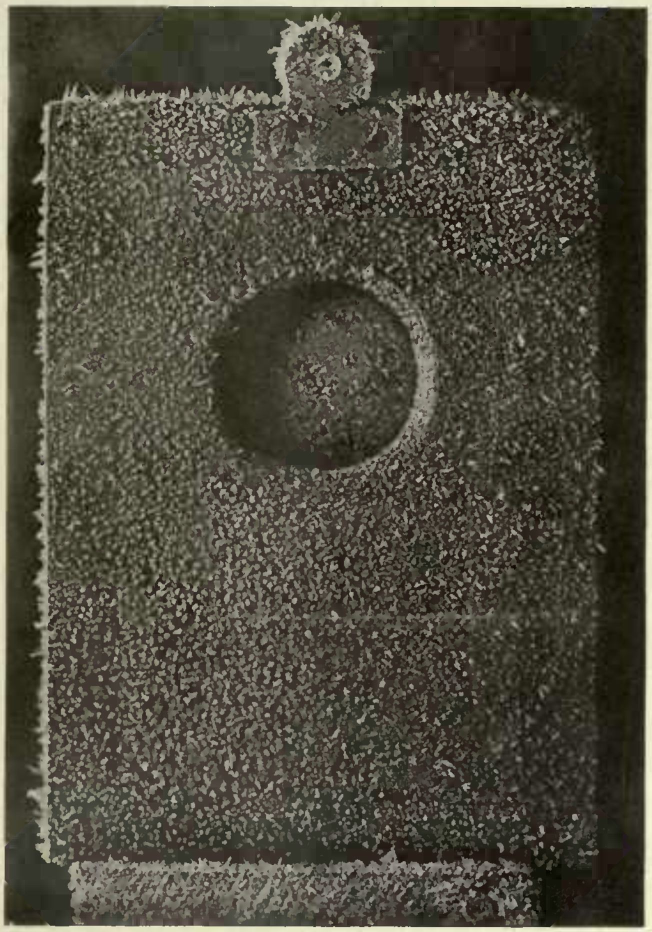


Fig. 1. FROST-SPICULES FORMED AT —30° F. ON THE FACE OF THE SPECTROSCOPIC CAMERA

Fig. 2. HEXAGONAL CRYSTALS OF ICE SUBLIMED ON A FROZEN SEAL LIVER

PART II

REPORT ON THE FORAMINIFERA AND OSTRACODA

FROM ELEVATED DEPOSITS ON THE SHORES OF THE ROSS SEA

(*With Six Plates*)

BY

FREDERICK CHAPMAN, A.L.S., F.R.M.S.

Palæontologist to the National Museum, Melbourne

CONTENTS

Figs. 1, 2. Schlumberger, 1891, *Mém. Soc. Géol. France*, vol. iv, p. 547, Pl. IX, Figs. 48, 49; woodcuts, Figs. 1–5. Chapman, 1907, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 14, Pl. I, Fig. 16. *Idem*, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 313.

This species is the most abundant of the *Biloculinæ* in the present material. A feature of some of the tests is the notching of the carina, but they are not regularly serrated as in *B. serrata*. Others show a transition into *B. lævis* by the salient character of the carina of the penultimate chamber.

B. depressa is a widely distributed form, and is apparently unrestricted as to depth. Sir John Murray gives the bathymetrical range as shore to 3000 fathoms.

Fossil examples, of smaller size than usual, are found in the Tertiary (Balcombian and Kalimnan) beds of Victoria.

Biloculina lævis, Defrance, sp. (Plate I, Fig. 4)

Pyrgo lævis, Defrance, 1824, *Dict. Sci. Nat.*, vol. xxxii, p. 273; Atlas, Pl. LXXXVIII, Fig. 2. *Biloculina lævis*, Defr., sp. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 146, Pl. II, Figs. 13, 14. Goës, 1894, *Kongl. Svenska Vetenskaps Akad. Handl.*, vol. xxv, p. 119, Pl. XXIV, Figs. 914–918. Chapman, 1907, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 14, Pl. I, Fig. 15.

Typical specimens are rare in the present series. *B. lævis* has been recorded by the *Challenger* from two stations in the N. Atlantic at 390 and 1215 fathoms, and in shallow water from Papua.

It is well known as a Tertiary fossil, and has been noted from the southern hemisphere in the Port Phillip Tertiaries (Balcombian series) by the writer.

Biloculina sarsi, Schlumberger (Plate I, Figs. 5*a*, 5*b*)

Biloculina sarsi, Schlumberger, 1891, *Mém. Soc. Zool. France*, vol. iv, p. 553, Pl. IX, Figs. 55–59; woodcuts, Figs. 10–12. Chapman, 1907, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 14, Pl. I, Figs. 1, 2. *Idem*, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 314, Pl. XIII, Fig. 3.

As previously noticed, this species occurs in the "*Biloculina* Clay" of the North Sea, in material obtained at a depth of 2000 fathoms. M. Schlumberger, in describing the species, states it to be there very abundant.

So far as we know at present, *B. sarsi* first appeared in the southern hemisphere; for it occurs in the Tertiary beds of Upper Oligocene or Lower Miocene age (Balcombian) of Port Phillip, Victoria. The fossil shells do not attain such large proportions as the living or subrecent examples.

Biloculina elongata, d'Orbigny (Plate II, Fig. 6)

41 57

Biloculina elongata, d'Orbigny, 1826, *Ann. Sci. Nat.*, vol. vii, p. 298, No. 4. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 144, Pl. II, Figs. 9*a*, 9*b*. Schlumberger, 1891, *Mém. Soc. Zool. France*, vol. iv, p. 553, Pl. XI, Figs. 87, 88; Pl. XII, Fig. 89; woodcuts, Figs. 35, 36. Chapman, 1907, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 15, Pl. I, Fig. 14. *Idem*, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 317.

The tests of this species are very variable in the present collection, but are distinguished from their congeners by the generally elongate form, the comparatively small, almost circular, aperture with definite T-shaped valve, and the rounded periphery. The tests are here unusually large, occasionally attaining a length of 2·25 mm.

B. elongata is a well-distributed species, occurring most frequently in moderately shallow water in temperate seas, and in deeper water in the tropics. In the southern hemisphere it has been recorded off Heard Island, off Kerguelen Island, and south-west of Patagonia, from 20–245 fathoms. Sir J. Murray gives its bathymetrical range as shore to 2025 fathoms. Small examples in the fossil condition have been found in the Tertiary (Balcombian and Kalimnan) beds of Victoria.

Genus—*Miliolina*, Williamson, 1858

Miliolina tricarinata, d'Orbigny, sp. (Plate II, Figs. 7*a*, 7*b*)

Triloculina tricarinata, d'Orbigny, 1826, *Ann. Sci. Nat.*, vol. vii, p. 299, No. 7. *Miliolina tricarinata*, d'Orb., sp. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 165, Pl. III, Figs. 17*a*, 17*b*. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 320.

The distribution of this form is very wide. It extends from the Arctic seas to the Antarctic ice-barrier, and is found at all depths to 2350 fathoms.

The only specimen found here is very small, and suggests a moderately deep water habitat.

Sub-Family—PENEROPLIDINÆ

Genus—*Cornuspira*, Schultze, 1854

Cornuspira involvens, Reuss, sp. (Plate II, Fig. 8) 43

Operculina involvens, Reuss, 1849, *Denkschr. k. Akad. Wiss. Wien*, vol. i, p. 370, Pl. XLVI, Fig. 20. *Cornuspira involvens*, Reuss, sp. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 200, Pl. XI, Figs. 1–3. Egger, 1893, *Abhandl. d. k. bayer. Akad. Wiss.*, cl. ii, vol. xviii, Abth. ii, p. 246, Pl. III, Figs. 18, 19. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 325.

This is another of the species found in the most northerly sounding made by the British North Polar Expedition of 1875–76. It occurs, generally speaking, in shallow to moderately deep water, but has been dredged from one depth as great as 1900 fathoms. Two examples, one fragmentary, occur in the present deposit.

Family—TEXTULARIIDÆ

Sub-Family—BULIMININÆ

Genus—*Bulimina*, d'Orbigny, 1826

Bulimina seminuda, Terquem (Plate II, Figs. 9*a*, 9*b*) 43

Bulimina seminuda, Terquem, 1882, *Mém. Soc. Géol. France*, sér. 3, vol. ii, mém. iii, p. 117, Pl. XII, Fig. 21. *B. elegantissima*, d'Orbigny, var. *seminuda*, Terquem. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 403, Pl. L, Figs. 23, 24.

The specimen now figured under the above name is a juvenile form of the species. The general plan of structure is that of *B. elegantissima*, but the stouter build and sometimes aborally striate shell, especially the first-named characteristic, gives sufficient ground to regard this modification as a well-established form. It is, in fact, a peculiarly southern type of the better-known Arctic, N. Atlantic, and sometimes S. Pacific species, *B. elegantissima*.

The example in the present series also reminds one of *Bulimina contraria*, Reuss, sp., which differs, however, in showing "no real alternation of segments." *

Genus—*Virgulina*, d'Orbigny, 1826

Virgulina schreibersiana, Czjzek (Plate II, Fig. 10)

Virgulina schreibersiana, Czjzek, 1848, Haidinger's *Naturwiss. Abhandl.*, vol. ii, p. 147, Pl. XIII, Figs. 18–20. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 414, Pl. LII, Figs. 1–3. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 291, Pl. XXXVIII, Fig. 6.

Widely distributed both in the northern and southern hemispheres. Its bathymetrical range is from 10 to 3000 fathoms. A small example found, having the aboral end acutely terminated.

Virgulina subsquamosa, Egger (Plate II, Fig. 11)

Virgulina subsquamosa, Egger, 1857, *Neues Jahrb. für Min.*, etc., p. 295, Pl. XIII, Figs. 19–21. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 415, Pl. LII, Figs. 7–11.

This species, like the preceding, has an extensive geographical distribution, and is found in soundings from shallow to deep water alike.

A minute example occurs in the present collection.

Sub-Family—CASSIDULININÆ

Genus—*Cassidulina*, d'Orbigny, 1826

Cassidulina oblonga, Reuss (Plate II, Figs. 12*a*, 12*b*) 43

Cassidulina oblonga, Reuss, 1849, *Denkschr. Akad. Wiss. Wien*, vol. i, p. 376, Pl. XLVIII, Figs. 5, 6. *C. crassa*, d'Orb. (pars). H. B. Brady, 1884, *Rep. Chall.*, vol. ix, Pl. LIV, Fig. 4. *C. oblonga*, Reuss, Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 332.

This species is moderately abundant in the raised beach material. Its more elongated test serves to distinguish it from *C. crassa*, with which it is often confused.

C. oblonga has been dredged off W. Africa, off Cape Town, in the Mauritius, off the West Australian coast, near Kerguelen Island, and north of Enderby Island in the subantarctic group. Other localities might be cited but for the difficulty of discriminating between references to this species and *C. crassa*.

Cassidulina parkeriana, Brady (Plate II, Fig. 13) 43

Cassidulina parkeriana, H. B. Brady, 1881, *Quart. Journ. Micr. Sci.*, N.S., vol. xxi, p. 59. *Idem*, 1884, *Rep. Chall.*, vol. ix, p. 432, Pl. LIV, Figs. 11–16.

This is by far the commonest species occurring in the deposit. The series of specimens selected from the washings shows all stages of the test from the sub-ovoid to the distinctly crosier-shaped shell. The sutures are well impressed, and the aperture is an elongate pyriform orifice. The majority of the examples, however, present the appearance of Fig. 14 of the *Challenger Report* (*loc. cit.*). Hitherto the species has occurred at three stations amongst the islands on the west coast of Patagonia at depths from 45–175 fathoms.

---

* H. B. Brady, in *Rep. Chall.*, vol. ix, 1884, p. 409.

Cassidulina subglobosa, Brady (Plate II, Fig. 14) 44

Cassidulina subglobosa, H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 430, Pl. LIV, Figs. 17*a*–17*c*. Egger, 1893, *Abhandl. k. bayer. Akad. Wiss.*, cl. ii, vol. xviii, Abth. ii, p. 304, Pl. VII, Figs. 41, 42, 52, 53. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 332.

The *Challenger* found this to be a deep water species. It has, however, been obtained in 110 fathoms off Great Barrier Island, New Zealand, and in dredgings at 60 and 85 fathoms round the sub-Antarctic islands of New Zealand.

Two examples only.

Genus—*Ehrenbergina*, Reuss, 1849

Ehrenbergina pupa, d'Orbigny, sp. (Plate II., Figs. 15*a*, 15*b*)

Cassidulina pupa, d'Orbigny, 1839, *Foram. Amér. Mérid.*, p. 57, Pl. VII., Figs. 21–23. *Ehrenbergina pupa*, d'Orb., sp. H. B. Brady, 1884, *Rep. Chall.*, vol. ix., p. 433, Pl. LV., Figs. 1*a*, 1*b*, Pl. CXIII., Figs. 10*a*–10*c*.

One example of this rare species occurs in the upthrust mud. It has been recorded from the N. Atlantic, but typically occurs along the coast of South America. It is a moderately deep water species.

Ehrenbergina serrata, Reuss (Plate II, Figs. 16, 17) 44

Ehrenbergina serrata, Reuss, 1849, *Denkschr. d. k. Akad. Wiss. Wien*, vol. i, p. 377, Pl. XLVIII, Figs. 7*a*–7*c*. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 434, Pl. LV, Figs. 2–7. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 332, Pl. XV, Fig. 2.

This species is not uncommon in the present series, and is represented in every stage of growth. Like the foregoing, it usually affects fairly deep water. It occurred, however, in the exceptionally shallow sounding of 50 fathoms off Bounty Island, south of New Zealand.

Family—LAGENIDÆ

Sub-Family—LAGENINÆ

Genus—*Lagena*, Walker and Boys, 1784

Lagena squamosa, Montagu, sp. (Plate III, Fig. 18)

Vermiculum squamosum, Montagu, 1803, *Test. Brit.*, p. 526, Pl. XIV, Fig. 2. *Lagena squamosa*, Montagu, sp. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 471, Pl. LVIII, Figs. 28–31. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 335, Pl. XV, Fig. 5.

A solitary specimen occurs in the present collection; small, but otherwise typical.

The species is unrestricted as to depth, but is found more usually in shallow water.

Sub-Family—NODOSARIINÆ

Genus—*Nodosaria*, Lamarck, 1816

Sub-genus—*Glandulina*, d'Orbigny, 1826

Nodosaria (*Glandulina*) *lævigata*, d'Orbigny (Plate III, Fig. 19) 44

Nodosaria (*Glandulina*) *lævigata*, d'Orbigny, 1826, *Ann. Sci. Nat.*, vol. vii, p. 252, Pl. X, Figs. 1–3. *Glandulina lævigata*, d'Orbigny, 1846, *Foram. Foss. Vienne*, p. 29, Pl. I, Figs. 4, 5. *Nodosaria* (*Glandulina*) *lævigata*, d'Orb. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 490, Pl. LXI, Figs. 17–22, 32. Goës, 1894, *Kongl. Svenska Vetenskaps Akad. Handl.*, vol. xxv, p. 71, Pl. XIII, Figs. 702, 706. Millett, 1902, *Journ. R. Micr. Soc.*, p. 509, Pl. XI, Fig. 1.

A few typical examples of this species are found in the present series. An intermediate type also occurs, which, in its asymmetrical, oblique test, approaches Reuss's genus *Psecadium.** The affinities of the latter type of shell are with the glanduline forms of *Nodosaria*, and probably merely represent an abnormal condition amounting to deformity induced by injury of the usually symmetrical test. Hitherto these asymmetrical glanduline shells appear to have been confined, with the exception of Goës' example, to a few fossil specimens figured by Reuss and Costa. The aperture in the specimens before us is depressed, and of the stellate type.

This species is yet another of those abundant in northern seas. Goës found it in the Arctic Sea at depths from 20 to 2500 metres. Although widely distributed, it is especially common in the northern parts of the North Atlantic, as at Baffin's Bay and Smith's Sound. In the southern hemisphere *N. lævigata* has been recorded off Patagonia and from the New Zealand area.

Nodosaria (*Glandulina*) *rotundata*, Reuss, sp. (Plate III, Figs. 20*a*, 20*b*) 44

Glandulina rotundata, Reuss, 1849, *Denkschr. d. k. Akad. Wiss. Wien*, vol. i, p. 366, Pl. XLVI, Fig. 2. *Nodosaria* (*Glandulina*) *rotundata*, Reuss, sp. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 491, Pl. LXI, Figs. 17–19. *N. lævigata*, d'Orbigny. Goës, 1894, *Kongl. Svenska Vetenskaps Akad. Handl.*, vol. xxv, p. 71, Pl. XIII, Fig. 707.

This species is by far the commoner of the two *Glandulinæ* found in the Antarctic washings, although usually it is the rarer. Our specimens show the various stages from a simple chamber, indistinguishable from *Lagena globosa*, to the normal three- or four-chambered adult form. The aperture is conspicuous, stellate, and wrinkled on the surface; by oblique illumination under a low power the general surface is seen to be delicately and sparsely striate. The distribution of this form is much the same as that of the foregoing species.

Genus—*Cristellaria*, Lamarck, 1816

Cristellaria convergens, Bornemann (Plate III, Fig. 21)

Cristellaria convergens, Bornemann, 1855, *Zeitschr. d. deutsch. geol. Gesellsch.*, vol. vii, p. 327, Pl. XIII, Figs. 16, 17. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 546, Pl. LXIX, Figs. 6, 7.

A specimen from the present material shows the typical characters of this species. It is not an abundant form, but is fairly well distributed over the great oceanic areas both in the north and south. Dr. Brady points out (*loc. cit.*) that the best specimens have all been taken from very deep soundings.

Sub-family—POLYMORPHININÆ

Genus—*Uvigerina*, d'Orbigny, 1826 44

Uvigerina angulosa, Williamson (Plate III, Fig. 22)

Uvigerina angulosa, Williamson, 1858, *Rec. Foram. Gt. Brit.*, p. 67, Pl. V, Fig. 140. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 576, Pl. LXXIV, Figs. 15–18. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 349.

* *See also* Goës (*op. supra cit.* p. 71, Pl. XIII, Fig. 703), a *Psecadium*-like form.

This species is one of the most abundant of the smaller forms in the present series. The tests are fairly typical, but the inflation of the last few chambers tends to obliterate the usual feature of the trifacial compression of the test, at the oral extremity.

In the living condition *U. angulosa* is found at various depths in the N. and S. Atlantic, the Mediterranean, the Indian Ocean, the N. and S. Pacific, and the Southern Ocean to the Antarctic ice barrier. It was an abundant species in the dredgings from the sub-Antarctic islands of New Zealand. As a Pleistocene fossil it has been recorded from Norway and the N.E. of Ireland.

Family—ROTALIIDÆ

Sub-family—ROTALIINÆ

Genus—*Discorbina*, Parker and Jones, 1862

Discorbina vesicularis, Lamarck, sp. (Plate III, Fig. 23)

Discorbites vesicularis, Lamarck, 1804, *Ann. du Muséum*, vol. v, p. 183; vol. viii, Pl. LXII, Fig. 7. *Discorbina vesicularis*, Lam., sp. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 651, Pl. LXXXVII, Figs. 2*a*–2*c*.

One typical shell was found in the present deposit. As a living species it does not appear to have been found farther south than the Victorian coast of Australia. It inhabits water of moderate depths. It occurs as a Pleistocene fossil in Norway.

Discorbina vilardeboana, d'Orbigny, sp. (Plate III, Fig. 24)

Rosalina vilardeboana, d'Orbigny, 1839, *Foram. Amér. Mérid.*, p. 44, Pl. VI, Figs. 13–15. *Discorbina vilardeboana*, d'Orb., sp. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 645, Pl. LXXXVI, Figs. 9–12; Pl. LXXXVIII, Fig. 2.

A well-formed test of this species having the characteristic brownish-pink coloration of the initial series of chambers was found in the raised beach material. It is a widely distributed form, and mainly affects shallow water. The closely related *D. araucana* was recently recorded from the sub-Antarctic islands of New Zealand.

Genus—*Truncatulina*, d'Orbigny, 1826

Truncatulina refulgens, Montfort, sp. (Plate III, Fig. 25) 45

Cibicides refulgens, Montfort, 1808, *Conch. Syst.*, vol. i, p. 122, 31*e* genre. *Truncatulina refulgens*, Mont., sp. Egger, 1893, *Abhand. k. bayer. Akad. Wiss.*, cl. ii, vol. xviii, Abth. ii, p. 401, Pl. XVI, Figs. 31–33. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 357.

A common shell in the present deposit.

Among the many interesting forms of foraminifera which appear in the northern and southern areas, but are absent from the tropics, this is a noteworthy example. Its bathymetrical limits are wide. As a fossil it has been obtained from the Pliocene; and it occurs also in the Pleistocene deposits of Norway and the N.E. of Ireland.

Truncatulina lobatula, Walker and Jacob, sp. (Plate III, Fig. 26) 45

Nautilus lobatulus, Walker and Jacob, 1798, *Adams's Essays*, Kanmacher's ed., p. 642, Pl. XIV, Fig. 36. *Truncatulina lobatula*, W. and J., sp. Egger, 1893, *Abhandl. k. bayer. Akad. Wiss.*, cl. ii, vol. xviii, Abth. ii, p. 396, Pl. XVI, Figs. 1–3, 10–12. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 358.

Four specimens of the above species occur in the present series. They are all typical, stoutly built tests.

This is a widely distributed form, and is not restricted as to depth, although usually inhabiting moderately shallow water.

Family—NUMMULINIDÆ

Sub-family—POLYSTOMELLINÆ

Genus—*Nonionina*, d'Orbigny, 1826

Nonionina stelligera, d'Orbigny (Plate III, Fig. 27)

Nonionina stelligera, d'Orbigny, 1839, *Foram. Canaries*, p. 128, Pl. III, Figs. 1, 2.
H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 728, Pl. CIX, Figs. 3–5.

It is extremely interesting to find this species occurring in the Antarctic, for it is best known as an Arctic form. In the southern hemisphere it appears to be recorded from only one area at three stations on the west coast of Patagonia, at depths of 125 to 245 fathoms.

EXPLANATION OF PLATES I-III

(*All figures magnified* 29 *diameters*)

PLATE I

FIGURE 1.—*Biloculina depressa*, d'Orbigny. A typical test: *a*, lateral aspect; *b*, peripheral aspect.

FIGURE 2.—*B. depressa*, d'Orbigny. A form with irregularly serrated peripheral flange, and approaching Brady's var. *serrata*. Lateral aspect.

FIGURE 3.—*B. depressa*, d'Orbigny. A variety with narrow peripheral flange and a salient aboral termination. Lateral aspect.

FIGURE 4.—*B. lævis*, Defrance sp. Lateral aspect.

FIGURE 5.—*B. sarsi*, Schlumberger. *a*, Lateral aspect; *b*, peripheral aspect.

PLATE II

FIGURE 6.—*B. elongata*, d'Orbigny. Lateral aspect of a well-grown specimen.

FIGURE 7.—*Miliolina tricarinata*, d'Orbigny sp. *a*, Lateral aspect; *b*, oral aspect.

FIGURE 8.—*Cornuspira involvens*, Reuss sp. Lateral aspect.

FIGURE 9.—*Bulimina seminuda*, Terquem. *a*, Ventral aspect; *b*, dorsal aspect.

FIGURE 10.—*Virgulina schreibersiana*, Czjzek. Lateral aspect.

FIGURE 11.—*V. subsquamosa*, Egger. Lateral aspect.

FIGURE 12.—*Cassidulina oblonga*, Reuss. *a*, Superior lateral aspect; *b*, inferior and oral aspect.

FIGURE 13.—*C. parkeriana*, H. B. Brady. Lateral and oral aspect.

FIGURE 14.—*C. subglobosa*, H. B. Brady. Ventral peripheral aspect.

FIGURE 15.—*Ehrenbergina pupa*, d'Orbigny. *a*, Lateral aspect; *b*, dorsal aspect.

FIGURE 16.—*E. serrata*, Reuss. A full-grown test; ventral aspect.

FIGURE 17.—*E. serrata*, Reuss. An immature test.

PLATE III

FIGURE 18.—*Lagena squamosa,* Montagu sp. Lateral aspect.

FIGURE 19.—*Nodosaria* (*Glandulina*) *lævigata,* d'Orbigny. Lateral aspect.

FIGURE 20.—*N.* (*Gl.*) *rotundata,* Reuss, sp. *a,* Lateral aspect; *b,* oral aspect.

FIGURE 21.—*Cristellaria convergens,* Bornemann. Lateral aspect.

FIGURE 22.—*Uvigerina angulosa,* Williamson. Lateral aspect.

FIGURE 23.—*Discorbina vesicularis,* Lamarck, sp. Superior aspect.

FIGURE 24.—*D. vilardeboana,* d'Orbigny, sp. Superior aspect.

FIGURE 25.—*Truncatulina refulgens,* Montfort, sp. Inferior aspect.

FIGURE 26.—*T. lobatula,* Walker and Jacob, sp. A variety with faintly marked sutures. Inferior aspect.

FIGURE 27.—*Nonionina stelligera,* d'Orbigny. Lateral aspect.

PLATE I

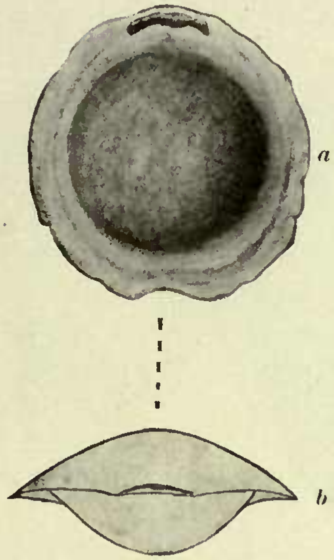


Fig. 1

Fig. 2

Fig. 3

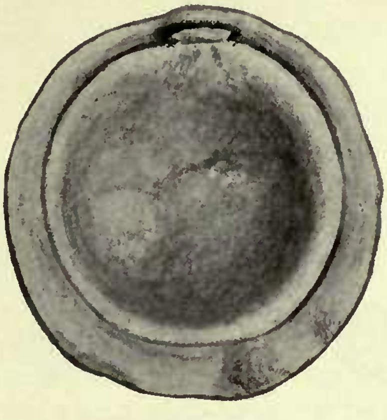


Fig. 4

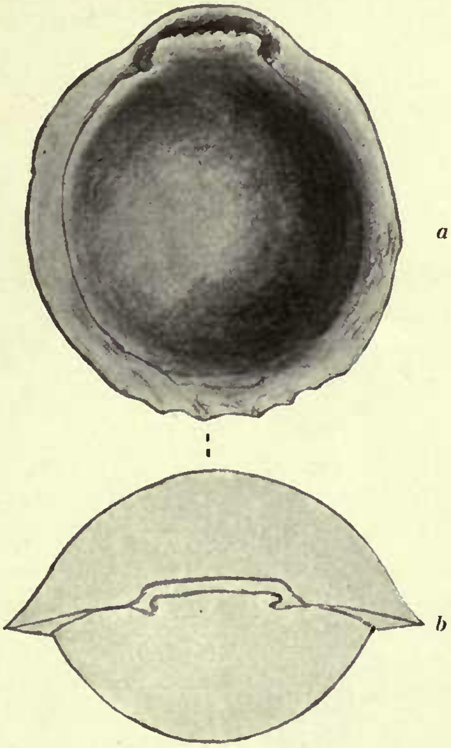


Fig. 5

F.C. ad nat. del.

Foraminifera from Upthrust Muds, S.E. of Mount Larsen. × 29 Diams.

[*To face p.* 36

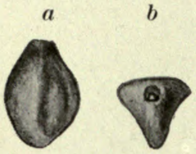


FIG. 7

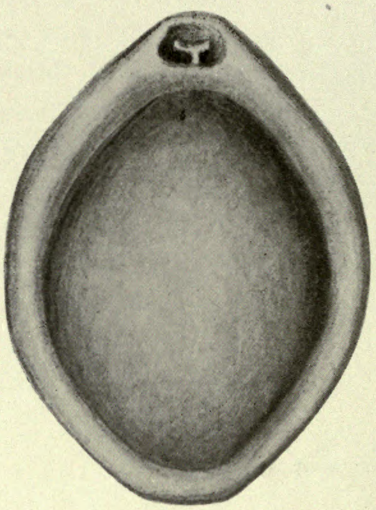


FIG. 6

FIG. 8

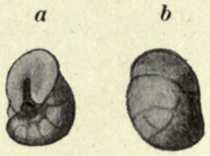


FIG. 9

FIG. 10

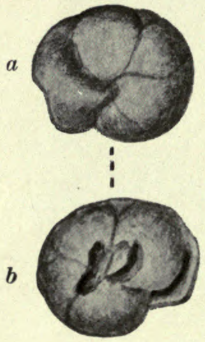


FIG. 12

FIG. 13

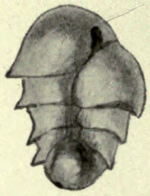


FIG. 16

FIG. 11

FIG. 14

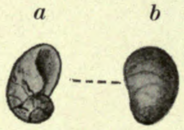


FIG. 15

FIG. 17

F.C. ad nat. del.

FORAMINIFERA FROM UPTHURST MUDS, S.E. OF MOUNT LARSEN. × 29 DIAMS.

PLATE III


FIG. 19

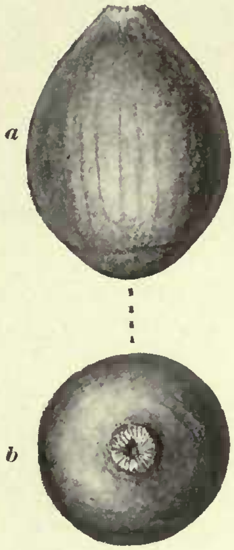


FIG. 20


FIG. 18


FIG. 23


FIG. 22


FIG. 21


FIG. 24


FIG. 25


FIG. 27

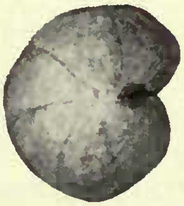


FIG. 26

F.C. ad nat. del.

FORAMINIFERA FROM UPTHRUST MUDS, S.E. OF MOUNT LARSEN. × 29 DIAMS.

SECTION II

OSTRACODA

FROM UPTHRUST MUDS ABOVE THE DRYGALSKI GLACIER, SOUTH-EAST OF MOUNT LARSEN

GENERAL REMARKS ON THE COLLECTION

From amongst the washed débris which yielded the Foraminifera of the accompanying report, there were found a few ostracodal valves. They were all single, showing that the connecting ligament of the hinge-line in every case had been fractured and severed, and that deposition of sediment had not taken place before the carapace was disunited by the action of local currents. This is often seen in recent soundings, where, although at considerable depths, aided by the influence of currents, the valves are frequently found separated.

Five species are herein described, one of which is new, whilst some others help to elucidate already known but imperfectly understood species. They are comprised in the genera *Pontocypris, Cythere, Cytheropteron,* and *Cytherideis.* All the previously described species are Southern Oceanic forms, although one has also been recorded from Torres Strait. One of the species, it is worth noting, shows close alliance with fossil and recent Arctic and sub-Arctic species.

The evidence of these ostracoda as to their bathymetrical distribution is much the same as that of the foraminifera; for they seem to indicate deposits, generally speaking, of at least 100 fathoms, if not of greater depth.

DESCRIPTION OF THE OSTRACODA

Family—CYPRIDÆ

Genus—*Pontocypris,* G. O. Sars, 1865

Pontocypris subreniformis, G. S. Brady (Pl. IV, Fig. 1)

Pontocypris (?) *subreniformis,* G. S. Brady, 1880, *Rep. Chall.,* Zool., vol. i, Pt. III, p. 38, Pl. XV, Figs. 6*a*–6*d* ("*Pontocypris* (?) *subtriangularis,* sp. n.") on plate.

There is a slight confusion in the *Challenger Report* over what appear to be two distinct forms. On p. 38 a *Pontocypris* is described under the name of *P.* (?) *subreniformis,* sp. n. The description there given corresponds with our Antarctic specimens. Reference to Plate XV, Figs. 6*a*–6*d*, of the same *Report,* and given with the description, will show that the species by mistake is there named *Pontocypris* (?) *subtriangularis,* sp. n. Further, another figure, evidently of a distinct species, but named *Pontocypris* (?) *subreniformis,* is to be found on Plate VII, Figs. 5*a*–5*d*. The latter figures, which, by the way, appear to be placed posterior extremity upwards, are closely related to a fossil *Bythocypris* from the Wimmera borings in Victoria; and as Dr. G. S. Brady makes reference to a possible alliance of his *P. subreniformis* with that genus (*loc. cit.* p. 39), Figs. *5a–5d* on Plate VII may be regarded as *B. subreniformis*, G. S. Brady, sp. (form figured but not described).

Three typical valves, one left and two right, of this rather delicate, thin-shelled form occur in the present washings. They are very slightly larger than the type recorded by Brady, our figured specimen having a length of ·65 mm.

The earlier described specimens were from Simon's Bay, S. Africa, 15 to 20 fathoms, and Port Jackson, Australia, 2 to 10 fathoms.

Family—CYTHERIDÆ

Genus—*Cythere*, Muller, 1785

Cythere foveolata, G. S. Brady (Plate IV, Fig. 2)

Cythere foveolata, G. S. Brady, 1880, *Rep. Chall.*, Zool., vol. i, Pt. III, p. 75, Pl. XIII, Figs. *5a–5h*.

It is interesting to note the occurrence of this species in previous soundings in high latitudes. The localities of Dr. G. S. Brady are off Christmas Harbour, Kerguelen Island, at 120 fathoms; and off Heard Island at 75 fathoms. As allied forms Brady cites an Arctic species, *Cythere borealis*, Brady, and *C. œdichilus*, Brady, a species from the Antwerp Crag (Lower Pliocene).

C. foveolata is the commonest form in the present series, and some of the immature valves can be closely matched with Dr. Brady's figure of (?) *Cytheropteron angustatum*,* a form which that author found at Kerguelen Island and Torres Strait; and of which he remarks, "Possibly the genus *Cythere* might have been a more fitting receptacle in this case, but from a few detached valves only it is not easy to arrive at an accurate conclusion" (*loc. cit.* p. 137).

Cythere parallelogramma, G. S. Brady (Plate IV, Fig. 3)

Cythere parallelogramma, G. S. Brady, 1880, *Rep. Chall.*, Zool., vol. i, Pt. II, p. 82, Pl. XV, Figs. 1*a*–1*e*.

The only locality recorded for this species up to the present is Prince Edward Island, Southern Ocean, from 50–150 fathoms.

Two left valves, in splendid condition, of female specimens.

Genus—*Cytheropteron*, G. O. Sars, 1865

Cytheropteron antarcticum, sp. n. (Plate IV, Figs. 4 *a*, *b*)

Description.—Valve seen from the side, subrhomboidal; highest in the middle. Height equal to about three-fifths of the length. Anterior border truncately rounded above, sharply curved below. Dorsal line strongly arched and rapidly sloping backward to meet the subacute posterior end. Ventral edge sinuous and moderately curved. The anterior surface of valve slopes upward from the antero-dorsal region towards the alar prominence, the latter being very pronounced and ending in a moderately sharp point. The surface of the slope along the alar-dorsal area is relieved with irregular, sinuous, and curvilinear excavations. Just beneath the alar beak a small pointed prominence occurs. Edge view of carapace rhomboidal, with acute terminations.

---

* *Rep. Chall.*, Zool., vol. i, Pt. III, 1889, p. 137, Pl. XXXIV, Figs. *5a–5b*.

Measurements.—Length, ·67 mm.; height, ·41 mm.; thickness of carapace, ·52 mm.

Observations.—The general outline of this species is suggestive of *C. abyssorum*, G. S. Brady.* There are, however, marked specific differences in the present form which prevent any reference to that species. The greater relative length; the evenly sloping surface of the alar prolongation; the relatively longer posterior extremity; and the absence of any superficial foveolation, all combine to render it distinct.

Type specimen, a right valve.

Genus—*Cytherideis*, Rupert Jones, 1856

Cytherideis lævata, G. S. Brady (Plate IV, Fig. 5)

Cytherideis lævata, G. S. Brady, 1880, *Rep. Chall.*, Zool., vol. i, Pt. II, p. 146, Pl. V, Figs. 5*a*–5*d*; Pl. XXXV, Figs. 6*a*–6*d*.

We have in the present series two typical valves of this delicate-shelled species. On both examples there are peculiar elongate and contorted markings, seen through the translucent shell, and probably due to remains of visceral attachments within the valves.

This species was dredged by the *Challenger* off Heard Island, Southern Ocean, from mud, at 75 fathoms. Dr. Brady remarks that the specimens were "very few" and seem to be all empty shells."

---

* *Rep. Chall.*, Zool., vol. i, Pt. III, 1880, p. 138, Pl. XXXIV, Figs. 3*a*–*d*.

EXPLANATION OF PLATE IV

(*All figures magnified* 29 *diameters*)

FIGURE 1.—*Pontocypris subreniformis*, G. S. Brady. A right valve.

FIGURE 2.—*Cythere foveolata*, G. S. Brady. A right valve.

FIGURE 3.—*Cythere parallelogramma*, G. S. Brady. A left valve.

FIGURE 4.—*Cytheropteron antarcticum*, sp. n. Right valve.

FIGURE 5.—*Cytherideis lævata*, G. S. Brady. A right valve.

PLATE IV

FIG. 1

FIG. 2

FIG. 3

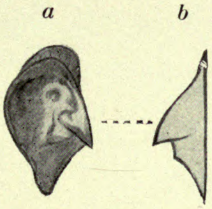


FIG. 4

FIG. 5

F.C. ad nat. del.

OSTRACODA FROM UPTHRUST MUDS, S.E. OF MOUNT LARSEN. × 29 DIAM.

[*To face p.* 40

SECTION III

FORAMINIFERA

FROM ELEVATED DEPOSITS ON THE SLOPES OF MOUNT EREBUS, NEAR CAPE ROYDS

GENERAL REMARKS ON THE COLLECTION

The Foraminifera here described are from some elevated deposits obtained from two localities on the slopes of Mount Erebus at 160 feet above sea-level.

Locality 1.—This deposit is composed chiefly of dark volcanic sand with *Serpulæ* and a few foraminifera and echinoid spines; near Back-Door Bay, about three-quarters of a mile from Cape Royds.

Locality 2.—This deposit contains, with abundant mollusca, polyzoa (*Cellaria* spp. and other genera), ostracoda, and foraminifera, some echinoid test-fragments and spines, and numerous siliceous sponge-spicules (tetractinellid); about one and a half miles from Cape Royds towards Cape Barne.

The last-named locality yielded all the specimens of Ostracoda, and the main portion of the Foraminifera of these two Reports. The valves of the ostracoda were exceptionally well preserved, and must have been floated together and covered up by very gentle sedimentation.

Of the twenty-two species and varieties of Foraminifera here enumerated, twelve are common also to the raised beach deposit south-east of Mount Larsen. They are: *Biloculina elongata, Cornuspira involvens, Bulimina seminuda, Cassidulina subglobosa, C. parkeriana, C. oblonga, Ehrenbergina serrata, Nodosaria* (*Gl.*) *lævigata, N.* (*Gl.*) *rotundata, Uvigerina angulosa, Truncatulina refulgens,* and *T. lobatula.*

Judging from the general foraminiferal fauna of the Mount Erebus elevated deposits, they were also formed in moderately deep water, like the preceding series from south-east of Mount Larsen—viz. at or near 100 fathoms. The presence of many delicate-shelled Ostracoda in the material from Locality 2 indicates, to my mind, a decided clarity of conditions, as distinguished from the more silty or terrigenous deposit of the sample from south-east of Mount Larsen.

DESCRIPTION OF THE FORAMINIFERA

Family—MILIOLIDÆ

Sub-family—Miliolininæ

Genus—*Biloculina*, d'Orbigny, 1826

Biloculina elongata, d'Orbigny

(For references *see* previous Report)

One typical specimen found, nearly equalling in size the large forms here figured from the upthrust muds south-east of Mount Larsen.

Loc. No. 2.

Biloculina bradii, Schlumberger, var. *denticulata*, Brady (Plate V, Fig. 1)

B. ringens, Lam., var. *denticulata*, Brady, 1884, *Rep. Chall.*, vol. ix, p. 143, Pl. III, Figs. 4, 5. *B. bradii*, Schl., var. *denticulata*, Brady, Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 315, Pl. XIII, Fig. 2.

Two tests of this variety, closely resembling the recently figured example from north of Auckland Island, New Zealand, at 85 fathoms, occurs in the floatings of the Mount Erebus material.

Loc. No. 2.

Biloculina irregularis, d'Orbigny (Plate V, Fig. 2)

B. irregularis, d'Orbigny, 1839, *Foram. Amér. Mérid.*, p. 67, Pl. VIII, Figs. 22–24. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 295, Pl. XLI, Fig. 3. Chapman, 1909, *Rep. Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 317.

The present examples are of small size. In the latter feature they agree with the sub-Antarctic specimens dredged twenty miles north of Auckland Island at 85 fathoms.

Loc. No. 1, very rare; No. 2, frequent.

Genus—*Miliolina*, Williamson, 1858

Miliolina circularis, Bornemann, sp. (Plate V, Fig. 3)

Triloculina circularis, Bornemann, 1858, *Zeitschr. d. deutsch. geol. Gesell.*, vol. vii, p. 349; Pl. XIX, Fig. 4. *Miliolina circularis*, Born., sp., Millett, 1898, *Journ. R. Micr. Soc.*, p. 499, Pl. XI, Figs. 1–3. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 318.

This species is not common in the living condition, as regards the Southern Ocean. It was a characteristic form in the dredgings amongst the sub-Antarctic islands of New Zealand. It ranges into moderate depths, keeping generally near the 100-fathom line.

Two small, sub-rotund varieties, having the typical broad aperture, were found.

Loc. No. 2.

Sub-family—HAUERININÆ

Genus—*Planispirina*, Seguenza, 1880

Planispirina bucculenta, Brady, sp. (Plate V, Fig. 4)

Miliolina bucculenta, Brady, 1884, *Rep. Chall.*, vol. ix, p. 170, Pl. CXIV, Figs. 3*a*, 3*b*. *Planispirina bucculenta*, Brady, sp., Schlumberger, 1892, *Mém. Soc. Zool. France*, vol. v, p. 194, Pl. VIII, Figs. 6, 7; woodcuts, Figs. 2–4. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 324, Pl. XIV, Fig. 2.

The gradual extension of the area affected by this striking species is further augmented by its occurrence here in the Antarctic regions. At first known only from the Arctic seas and the North Atlantic, it has since been found off Australia, between there and New Amsterdam Island, and lately in the sub-Antarctic islands of New Zealand. In the northern hemisphere it is a fairly deep water species. Numerous specimens occurred in the washed material from the slopes of Mount Erebus, 160 feet above sea-level.

Loc. No. 2.

Planispirina bucculenta, var. *placentiformis*, Brady, var. (Plate V, Fig. 5)

Miliolina bucculenta, var. *placentiformis*, Brady, 1884, *Rep. Chall.*, vol. ix, p. 171, Pl. IV, Figs. 1, 2. *Planispirina bucculenta*, var. *placentiformis*, Brady, Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 324.

The present occurrence, in a pleistocene deposit, makes the fourth locality for this variety; the previous records being: Culebra Island, West Indies; Kerguelen Island; and the sub-Antarctic islands of New Zealand.

The variety is not so common as the type form in this deposit.

Loc. No. 2.

Sub-family—PENEROPLIDINÆ

Genus—*Cornuspira*, Schultze, 1854

Cornuspira involvens, Reuss, sp. ✓

(For references *see* previous Report)

This species is an important form in the present series, being fairly common and of maximum size, measuring as much as 1·7 mm. in diameter.* The test, in later stages of growth, tends to form a wider tube, and has a more or less corrugated shell-surface. All the specimens noted belong to the microspheric stage, as does the one figured from the raised beach south-east of Mount Larsen.

Loc. No. 2.

Family—TEXTULARIIDÆ

Sub-family—BULIMININÆ

Genus—*Bulimina*, d'Orbigny, 1826

Bulimina seminuda, Terquem (Plate V, Fig. 6) ✓

(For references *see* previous Report)

This species occurs in both of the elevated deposits of the present Report. It is commoner and much better developed in that from locality No. 1, which consists largely of volcanic sand and serpula fragments.

Sub-family—CASSIDULININÆ

Genus—*Cassidulina*, d'Orbigny, 1826

Cassidulina oblonga, Reuss ✓

(For references *see* previous Report)

As in the elevated material from above the Drygalski Glacier, this species is moderately common in the present deposit.

Loc. Nos. 1 and 2.

✓

Cassidulina parkeriana, Brady

(For references *see* previous Report)

This form is here very common, as in the previously reported material from above the Drygalski Glacier, south-east of Mount Larsen.

Loc. Nos. 1 and 2.

---

* Dr. H. B. Brady remarks that this species seldom exceeds 1·26 mm. in diameter.

Cassidulina subglobosa, Brady

(For references *see* previous Report)

This is a rare form in the present deposit. *Loc.* No. 2.

Genus—*Ehrenbergina*, Reuss, 1849

Ehrenbergina serrata, Reuss

(For references *see* previous Report)

Moderately common in the present deposit. *Loc.* Nos. 1 and 2.

Family—LAGENIDÆ

Sub-family—NODOSARIINÆ

Genus—*Nodosaria*, Lamarck, 1816

Sub-genus—*Glandulina*, d'Orbigny, 1826

Nodosaria (*Glandulina*) *lævigata*, d'Orbigny

(For references *see* previous Report)

Only one example was found in the present deposit. *Loc.* No. 2.

Nodosaria (*Glandulina*) *rotundata*, Reuss, sp.

(For references *see* previous Report)

Several examples found in the elevated material from the slopes of Mount Erebus. *Loc.* No. 2.

Genus—*Cristellaria*, Lamarck, 1816

Cristellaria crepidula, Fichtel and Moll, sp. (Plate V, Fig. 7)

Nautilus crepidula, Fichtel and Moll, 1798, *Test. Micr.*, p. 107, Pl. XIX, Figs. *g–i*. *Cristellaria crepidula*, F. and M., sp., Brady, 1884, *Rep. Chall.*, vol. ix, p. 542. Pl. LXVII, Figs. 17, 19, 20; Pl. LXVIII, Figs. 1, 2. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 343.

A fragmentary specimen was found, showing the initial half of the test. It has the outline of *C. lata*, Cornuel, sp., but is not so compressed. It was lately recorded from the sub-Antarctic islands of New Zealand, where it occurred with some frequency. *Loc.* No. 1.

Cristellaria gibba, d'Orbigny (Plate V, Fig. 8)

Cristellaria gibba, d'Orbigny, 1839, *Foram. Cuba*, p. 63, Pl. VII, Figs. 20, 21. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 546, Pl. LXIX, Figs. 8, 9. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 344.

This elongate and compressed modification of *C. rotulata* has been recorded from the South Pacific by Brady, off Western Australia by Egger, and latterly by the writer, from the sub-Antarctic islands of New Zealand (60–85 fathoms). *Loc.* No. 2.

Sub-family—POLYMORPHININÆ

Genus—*Uvigerina*, d'Orbigny, 1826

Uvigerina angulosa, Williamson

(For references *see* previous Report)

Two specimens found in the present elevated deposit.

Family—GLOBIGERINIDÆ

Genus—*Pullenia*, Parker and Jones, 1862

Pullenia quinqueloba, Reuss, sp. (Plate V, Fig. 9)

Nonionina quinqueloba, Reuss, 1851, *Zeitschr. d. deutsch. geol. Gesell.*, vol. iii, p. 47, Pl. V, Figs. 31*a*, 31*b*. *Pullenia quinqueloba*, Reuss, sp., Brady, 1884, *Rep. Chall.*, vol. ix, p. 617, Pl. LXXXIV, Figs. 14, 15. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 324, Pl. LXX, Fig. 5. Chapman, 1906, *Trans. and Proc. N. Zealand Inst.*, vol. xxxviii, p. 101.

This species appears to be more generally met with in soundings from the northern hemisphere; but it is also fairly well distributed in the Southern Ocean. It occurs in the dredgings from Great Barrier Island, off New Zealand, but was not recorded from the sub-Antarctic islands.

Two typical examples were found in the elevated deposit from the slopes of Mount Erebus.

Loc. Nos. 1 and 2.

Family—ROTALIIDÆ

Sub-family—ROTALIINÆ

Genus—*Truncatulina*, d'Orbigny, 1826

Truncatulina refulgens, Montfort, sp.

(For references *see* previous Report)

It is interesting to note that this species is rare in these deposits, whereas in the elevated material south-east of Mount Larsen it is common; whilst in the case of the next recorded form, *T. lobatula*, the reverse obtains. This points to the interrelation of the two forms, probably influenced by bottom conditions rather than depth, as they both have an unrestricted range. In the one case, from near Mount Larsen, the deposit being silty, the high conical form flourishes; in the other, where the deposit is cleaner, sandy, and fragmentary, the low, plano-convex shell is the prevailing form.

Loc. Nos. 1 and 2.

Truncatulina lobatula, Walker and Jacob, sp.

(For references *see* previous Report)

This species is the commonest form in these deposits. It shows some variability, in that the usually flat base tends to become concave in one direction, as though it were endeavouring to build on a cylindrical surface. No attached examples, however, were found.

Loc. Nos. 1 and 2.

Truncatulina haidingeri, d'Orbigny, sp. (Plate V, Fig. 10)

Rotalina haidingeri, d'Orbigny, 1846, *Foram. Foss. Vienne*, p. 154, Pl. VIII, Figs. 7–9. *Truncatulina* (*Rotalina*) *haidingeri*, d'Orb., sp., Egger, 1893, *Abhandl. k. bayer. Akad. Wiss.*, cl. ii, vol. xviii, p. 401, Pl. XVI, Figs. 25–27. *T. haidingeri*, d'Orb., sp., Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 359.

One example found. Typical specimens are not at all common in recent soundings. This species has previously occurred at a few stations in the Southern Ocean. It has lately been recorded from the Great Barrier Island, and off the Snares, sub-Antarctic islands of New Zealand.

Loc. No. 1.

Genus—*Pulvinulina,* Parker and Jones, 1862

Pulvinulina oblonga, Williamson, sp. (Plate V, Fig. 11)

Rotalina oblonga, Williamson, 1858, *Rec. Foram. Gt. Brit.,* p. 51, Pl. IV, Figs. 98–100. *Pulvinulina oblonga,* Will., sp., Brady, 1884, *Rep. Chall.,* vol. ix, p. 688, Pl. CVI, Figs. 4*a*–4*c*.

This species has occurred off the Cape of Good Hope and in the South Pacific (17–275 fathoms), amongst other localities, the majority of which are in the northern hemisphere.

Loc. No. 1.

PLATE V

EXPLANATION OF PLATE V

(*All figures magnified* 29 *diameters*)

FIGURE 1.—*Biloculina bradii,* Schlumberger, var. *denticulata,* Brady. Front or oral aspect. Elevated deposit, between C. Royds and C. Barne.

FIGURE 2.—*B. irregularis,* d'Orbigny. Oral aspect. Deposit, between C. Royds and C. Barne.

FIGURE 3.—*Miliolina circularis,* Born., sp. Lateral aspect. Deposit, between C. Royds and C. Barne.

FIGURE 4.—*Planispirina bucculenta,* Brady. Oral aspect of a specimen with a siliceous sponge-spicule intergrown with the test. Deposit, between C. Royds and C. Barne.

FIGURE 5.—*P. bucculenta,* var. *placentiformis,* Brady. Lateral aspect. Deposit, between C. Royds and C. Barne.

FIGURE 6.—*Bulimina seminuda,* Terquem. Dorsal aspect of a full-grown example. Deposit, near C. Royds.

FIGURE 7.—*Cristellaria crepidula,* Ficht. and Moll., sp. Lateral aspect. Deposit, near C. Royds.

FIGURE 8.—*C. gibba,* d'Orbigny. Lateral aspect. Deposit, between C. Royds and C. Barne.

FIGURE 9.—*Pullenia quinqueloba,* Reuss, sp. Deposit, near C. Royds.

FIGURE 10.—*Pulvinulina haidingeri,* d'Orb., sp. *a,* Peripheral aspect; *b,* inferior aspect. Deposit, near C. Royds.

FIGURE 11.—*P. oblonga,* Will., sp. Superior aspect. Deposit, near C. Royds.

PLATE V

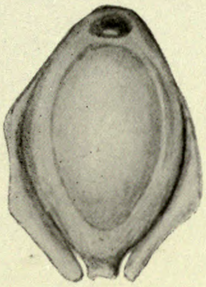


FIG. 1


FIG. 2

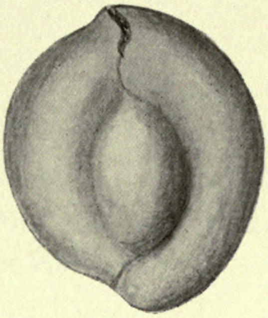


FIG. 3

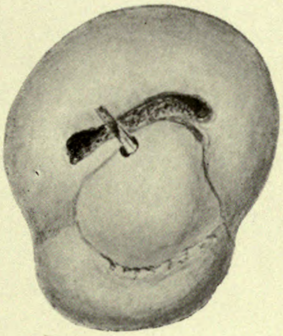


FIG. 4


FIG. 5


FIG. 6


FIG. 7


FIG. 8

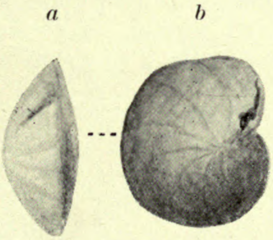


FIG. 10


FIG. 9

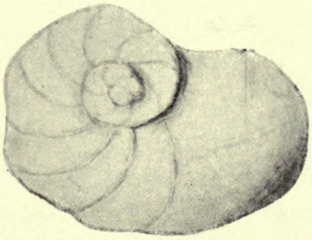


FIG. 11

F.C. ad nat. del.

FORAMINIFERA FROM ELEVATED DEPOSITS, SLOPES OF MOUNT EREBUS, NEAR CAPE ROYDS.
× 29 DIAMS.

[*To face p.* 48

SECTION IV

OSTRACODA

FROM ELEVATED DEPOSITS ON THE SLOPES OF MOUNT EREBUS, BETWEEN CAPE ROYDS AND CAPE BARNE

GENERAL REMARKS ON THE COLLECTION

All the Ostracoda here recorded were obtained from some moderately fine washings floated from the molluscan siftings examined by Mr. Chas. Hedley. The material was obtained from the deposit found 160 feet up the slopes of Mount Erebus, about one mile and a half from Cape Royds towards Cape Barne. The specimens are very abundant, but belong to few species. They range from 20 fathoms in the case of *Cytherura costellata* to 1425 fathoms in *Bairdia victrix.* The occurrence of *B. victrix* tends to show a limiting depth for the deposit of rather more than 100 fathoms, since the least depth for that species hitherto recorded is 120 fathoms. There are eight species in this series, two of which are new forms. They belong to the genera *Bairdia, Cythere, Loxoconcha, Xestoleberis,* and *Cytherura.* In point of abundance *Cythere parallelogramma* comes first, the next in order being *C. polytrema* and *C. normani*; the remainder being somewhat, or altogether, rare. All the previously described species are either known from, or allied to forms of, the Southern Ocean.

DESCRIPTION OF THE OSTRACODA

Family—BAIRDIIDÆ

Genus—*Bairdia,* McCoy, 1844

Bairdia victrix, G. S. Brady (Plate VI, Fig. 1)

Bairdia victrix, G. S. Brady 1867, *Les Fonds de la Mer,* vol. i, p. 152, Pl. XVIII, Figs. 17, 18. *Idem,* 1880, *Rep. Chall.*, Zool., vol. i, Pt. III, p. 56, Pl. X, Figs. 5a–5d.

Some remarkably fine valves occur in the present series. The species has some resemblance to *B. amygdaloides,* which is found as far south as Bass Strait, but the posterior extremity is rounded off instead of tapering to a point. It has a wide range: from the West Indies to Kerguelen Island, and thence to Sydney. It inhabits "chiefly water of a considerable depth" (G. S. B.).

Family—CYTHERIDÆ

Genus—*Cythere,* Muller, 1785

Cythere foveolata, G. S. Brady

(For references *see* previous Report)

Two valves of this species occur here. It has already been noted from the upthrust muds south-east of Mount Larsen, in which deposit it was rather abundant.

Cythere parallelogramma, G. S. Brady

(For references *see* previous Report)

This species is here abundant, whilst in the raised beach deposit south-east of Mount Larsen it was a rare form.

Cythere normani, G. S. Brady (Plate VI, Fig. 2)

Cythere normani, G. S. Brady, 1865, *Trans. Zool. Soc. Lond.*, vol. v, p. 379, Pl. LXI, Figs. 5*a*–5*d*. *Idem*, 1880, *Rep. Chall.*, Zool., vol. i, Pt. III, p. 101, Pl. XVII, Figs. 3*a*–3*d*, and (?) Pl. XXVI, Figs. 4*a*–4*b*.

Dr. Stewardson Brady found this species in the *Challenger* collection between Kerguelen Island and Heard Island, Southern Ocean, at 150 fathoms; and some stouter examples, which he doubtfully referred to the same species, off the west coast of South America, at 1825 fathoms. The latter examples have some light thrown upon them through the present series. I am led to think that the South American specimens belong to the same form; they are of heavier build, with a well-marked subcentral knob on the surface of each valve. In the latter feature this species approaches *C. parallelogramma*, from which it differs, however, in being stouter and anteriorly broader. The species is a very variable one, judging by Brady's original figures of the Abrohlos Bank specimens.

The present examples are of finer texture, the reticulated surface being comparatively delicate, and the anterior and posterior spinulose border more densely armed with fine prickles. The subcentral boss is present in all the specimens, and the submarginal ridge of the ventral border is sharp and thin.

Cythere polytrema, G. S. Brady (Plate VI, Fig. 3)

Cythere polytrema, G. S. Brady, *Trans. Zool. Soc. Lond.*, 1878, vol. x, p. 393, Pl. LXVI, Figs. 1*a*–1*d*. *Idem*, 1880, *Rep. Chall.*, Zool., vol. i, Pt. III, p. 87, Pl. XXI, Figs. 5*a*–5*h*.

This species is represented in the present series by a fair number of valves. They are in a fine state of preservation, and the spines at either extremities are exceptionally long and slender. It has been previously recorded as a fossil from the Antwerp Crag (Lower Pliocene) of Belgium; and in recent soundings by the *Challenger* at 50–150 fathoms off Prince Edward Island, Southern Ocean.

Genus—*Loxoconcha*, G. O. Sars, 1865

Loxoconcha mawsoni, sp. n. (Plate VI, Figs. 4*a*, 4*b*)

Description.—Carapace oblong, tumid. Valve seen from the side, peach-stone shaped, but unusually produced anteriorly. Dorsal margin roundly and evenly curved; ventral strongly convex in middle, sinuously excavated near the anterior, and obliquely rounded at the posterior extremity, where it meets the blunt posterior process. Edge view of carapace subovate, slightly compressed towards the extremities, especially anteriorly; greatest thickness just below the median line. Surface polished, and relieved by a distant, vertical, linear series of elongate shallow pits.

Measurements.—Length, ·76 mm.; width, ·45 mm.; thickness of carapace, ·34 mm.

Affinities.—The nearest related form to this distinct species is *Loxoconcha honoluliensis*, G. S. Brady,* a coral reef form from Honolulu. In shape the latter is broader

---

* *Rep. Chall.*, Zool., vol. i, Pt. III, 1880, p. 117, Pl. XXVIII, Figs. 6*a*–6*f*.

along the median line, not so much produced anteriorly, and with greater compression of the extremities. Its ornament, moreover, consists of scattered circular pittings without linear arrangement.

Genus—*Xestoleberis*, G. O. Sars, 1865

Xestoleberis davidiana, Chapman (Plate VI, Figs. 5*a*–5*c*, 6)

Xestoleberis davidiana, Chapman, 1915, *Zool. Results*, "*Endeavour*," vol. iii, Pt. I, p. 45.

Description.—Carapace in side view, semiovate, bluntly pointed in front and behind; back rounded, slightly angulated at the summit; ventral border gently concave, edge rounded, ventral surface excavate. Edge view, compressed ovate. End view conical, with rounded sides. Surface of shell more or less numerously pitted, each pit or group of pits surrounded by a white spot; probably armed with fine bristles (as in *X. setigera*) in the living state. A few valves of narrower build are present, one of which is figured; they are probably referable to male specimens.

Measurements.—Length of type specimen, ·48 mm.; greatest thickness of carapace, ·3 mm.; height, ·3 mm.

Observations.—At first sight this species reminds us of *X. setigera*, G. S. Brady,* both in the narrow side view of the carapace and the punctate ornament. The latter, however, in *X. setigera* is distinctly papillate. This present species is distinguished by the subacute extremities in side view and the pointed dorsal area of the end view.

X. davidiana, whilst related to *X. setigera*, also a southern form, may be regarded as distinct on the strength of the above characters, which are constant throughout the numerous specimens occurring in the elevated deposit from the slopes of Mount Erebus.

Genus—*Cytherura*, G. O. Sars, 1865

Cytherura costellata, G. S. Brady (Plate VI, Fig. 7)

Cytherura costellata, G. S. Brady, 1880, *Rep. Chall.*, Zool., vol. i, Pt. III, p. 134, Pl. XXXII, Figs. 7*a*–7*d*.

A single valve of this pretty little species was found in the elevated material. It measures ·5 mm. in length, exactly that of the type figured by Dr. G. S. Brady, who obtained his specimens from Balfour Bay, Kerguelen Island, in 20–50 fathoms. This occurrence, therefore, is the second recorded for the species.

---

* *Rep. Chall.*, Zool., vol. i, Pt. III, 1880, p. 125, Pl. XXXI, Figs. 2*a*–*d*, 3*a*–*c*.

EXPLANATION OF PLATE VI

(*All figures magnified* 29 *diameters*)

FIGURE 1.—*Bairdia victrix,* G. S. Brady. Left valve.

FIGURE 2.—*Cythere normani,* G. S. Brady. Right valve.

FIGURE 3.—*C. polytrema,* G. S. Brady. Right valve.

FIGURE 4.—*Loxoconcha mawsoni,* sp. n. Left valve: *a,* lateral aspect; *b,* edge view.

FIGURE 5.—*Xestoleberis davidiana,* Chapman. Type specimen. Left valve: *a,* lateral aspect; *b,* ventral edge view; *c,* front end view.

FIGURE 6.—*X. davidiana,* sp. n. Paratype. Right valve; probably male example.

FIGURE 7.—*Cytherura costellata,* G. S. Brady. Right valve.

PLATE VI

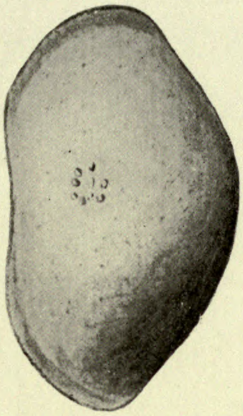


FIG. 1

FIG. 3

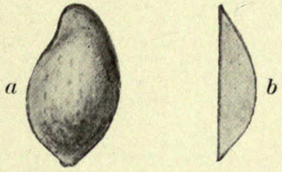


FIG. 4

FIG. 7

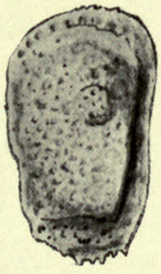


FIG. 2

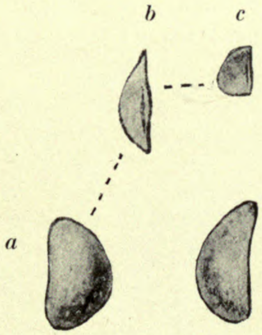


FIG. 5 FIG. 6

F.C. ad. nat. del.

OSTRACODA FROM ELEVATED DEPOSITS, SLOPES OF MOUNT EREBUS, ABOUT 1½ MILE FROM C. ROYDS TOWARDS C. BARNE. × 29 DIAM.

[*To face p.* 52

PART III

REPORT ON THE FORAMINIFERA AND OSTRACODA

OUT OF MARINE MUDS FROM SOUNDINGS IN THE ROSS SEA

SOUNDINGS TAKEN BY CAPTAIN J. K. DAVIS, S.Y. *NIMROD*

(*With Six Plates*)

BY

FREDERICK CHAPMAN, A.L.S., F.R.M.S.

Palæontologist to the National Museum, Melbourne

CONTENTS

INTRODUCTION

THE following report is based on muds collected by Captain J. K. Davis, S.Y. *Nimrod,* from soundings taken in the Ross Sea. The material was courteously placed in my hands by Professor T. W. Edgeworth David, C.M.G., D.Sc., F.R.S. These soundings have yielded most excellent results, not so much on account of the variety of specific forms they contain, as for the information afforded regarding the approximate depths and habitats of the Raised Beach material previously described, which occurred at heights of 20 and 160 feet above sea-level. They also furnish some further interesting data regarding the extension of Arctic species into Antarctic regions,* reference to which will be made in the summary.

Fifteen samples of soundings were examined, and from only two of these were calcareous organisms absent. The range of depth in the samples is from 110 to 655 fathoms. The general nature of the soundings suggests an old shore-line which is undergoing much wear and tear, for the material constituting the deposits is in the main terrigenous, consisting of gritty diatomaceous ooze, green muds, and volcanic sand. As a matter of convenience the soundings are here grouped in rotation according to depth, from above downwards.

SCHEDULE OF SOUNDINGS ARRANGED IN ORDER OF DEPTH
S.Y. *NIMROD* J. K. DAVIS, *Commander*

No.	Date	Latitude	Longitude	Depth in Fathoms	Nature of Sounding	General Contents
1	2.1.09	76° 56′ S.	164° 51′ E.	110	Green terrigenous mud and pebbles of (?) quartz felsite.	A few diatoms (*Coscinodiscus*, etc.). Foraminifera frequent. Sponge spicules abundant. Polyzoa. Ostracoda.
2	12.1.08	76° 55′ S.	164° 55′ E.	113	Black mud.	Foraminifera, as *Cassidulina* and *Uvigerina*, abundant. A few Radiolaria and Sponge spicules.
3	13.1.09	76° 55′ S.	164° 45′ E.	121	Green mud.	Diatomaceæ (*Coscinodiscus*, etc.). Arenaceous Foraminifera (*Saccammina* and *Pelosina* ; numerous hyaline forms in finer portion. Polyzoa.
4	12.2.09	McMurdo Sound, one mile from the outer end of Glacier Tongue, northern side.		153	Volcanic mud and stones.	Diatomaceæ (*Coscinodiscus*, etc.). Foraminifera common. Sponge spicules. Echinoid spines. Ostracoda.

---

* *See also ante,* "Report on the Foraminifera and Ostracoda from Elevated Deposits on the Shores of the Ross Sea."

SCHEDULE OF SOUNDINGS ARRANGED IN ORDER OF DEPTH (*continued*)

No.	Date	Latitude	Longitude	Depth in Fathoms	Nature of Sounding	General Contents
5	11.1.09	77° 1′ S.	165° 5′ E.	171	Dark terrigenous mud.	Diatomaceæ (*Coscinodiscus*, etc.). Few Foraminifera. Sponge spicules. Ostracoda.
6	10.1.09	77° 12′ S.	164° 36′ E.	181	Black mud & sand, with pebbles of granitic rock.	Few diatomaceæ (*Coscinodiscus*, etc.). No Foraminifera. A few Radiolaria.
7	11.1.09	Information missing		225	Black terrigenous mud and sand.	Diatomaceæ (*Coscinodiscus*, etc.). Foraminifera. Sponge spicules. Ostracoda.
8	15.1.09	76° 49′ S.	163° 24′ E.	353	Green terrigenous mud.	Diatomaceæ (*Coscinodiscus*, etc.) abundant. Foraminifera numerous. Echinoid spines. Polyzoa (*Cellaria*). Pteropoda (*Vaginella*). Ostracoda.
9	15.1.09	76° 47′ S.	163° 22′ E.	360	Green terrigenous mud.	Diatomaceæ (*Coscinodiscus*, etc.) abundant. A few Arenaceous Foraminifera and Radiolaria.
10	15.1.09 (label torn)	76° 48′ S.	163° 20′ E.	372	Green terrigenous mud.	Diatomaceæ (*Coscinodiscus*, etc.). Radiolaria. Foraminifera excessively minute and undeveloped.
11	5.1.09	77° 25′ S.	166° 5′ E.	459	Dark, gritty, terrigenous mud.	Diatomaceæ (*Coscinodiscus*, etc.). Radiolaria. No Foraminifera.
12	5.1.09	77° 16½′ S.	165° 55′ E.	460	Green terrigenous mud.	Diatomaceæ (*Coscinodiscus*, etc.) abundant. Radiolaria common. Arenaceous Foraminifera. Sponge spicules.
13	14.1.09 6 A.M.	76° 46′ S.	163° 26′ E.	462	Green terrigenous mud.	Diatomaceæ (*Coscinodiscus*, etc.) abundant. Radiolaria frequent. Arenaceous Foraminifera. Sponge spicules common. Also a few gritty particles of quartz and volcanic débris.
14	4.1.09	Cape Bird (Ross Island) bearing N. 79° E. (true). Distance, 4½ miles.		472	Terrigenous mud with pebbles.	Diatomaceæ (*Coscinodiscus*, etc.) abundant. Radiolaria. Arenaceous Foraminifera.
15	5.2.09	Relief Harbour, N. Drygalski Glacier, about 20 miles off coast.		655	Green terrigenous mud.	Diatomaceæ (*Coscinodiscus*, etc.) abundant. Arenaceous Foraminifera rare.

DESCRIPTION OF THE FORAMINIFERA

Family—MILIOLIDÆ

Sub-family—Miliolininæ

Genus—*Biloculina*, d'Orbigny, 1826

Biloculina depressa, d'Orbigny (for references *see* previous Reports on Foraminifera of Elevated Deposits).

Occurrence.—Sample No. 2, 113 fathoms, very rare.

Biloculina elongata, d'Orbigny (for references *see* previous Reports on Foraminifera of Elevated Deposits).

Occurrence.—Sample No. 2, 113 fathoms, very rare ; No. 3, 121 fathoms, frequent, one of large size ; No. 4, 153 fathoms, rare ; No. 5, 171 fathoms, very rare.

Biloculina bradii, Schlumberger (Plate I, fig. 1).

Biloculina ringens, H. B. Brady (non Lamarck), 1884, *Rep. Chall.*, vol. ix, p. 142, pl. ii, fig. 7. *B. bradyi*, Schlumberger, 1891, *Mém. Soc. Zool. France*, vol. iv, p. 557, pl. x, figs. 63–71 ; woodcuts 15–19. *B. bradyi*, Schlumberger, Chapman, 1907, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 13, pl. i, figs. 7, 8. *Idem*, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 314, pl. xiii, fig. 1.

The distribution of this species is wide, and does not yet seem to be fully worked out, on account of its having been confused with *B. ringens*, Lam. The localities include the Gulf of Gascony, and the sub-Antarctic islands of New Zealand (off the Snares, N. of Auckland Island, and N. of Enderby Island). It has also been recorded as a Tertiary (Oligocene) fossil from Grice's Creek, Port Phillip.

The only example found in the present soundings is a fine specimen measuring 3·75 mm. in length. A variety of this species, viz. *denticulata*, Brady, has been previously recorded from a raised beach at 160 feet, on the slopes of Mount Erebus, between Cape Royds and Cape Barne.

Occurrence.—Sample No. 1, 110 fathoms, one specimen.

Biloculina irregularis, d'Orbigny (for references *see* previous Reports on Foraminifera of Elevated Deposits).

Occurrence.—Sample No. 5, 171 fathoms, very rare ; No. 8, 353 fathoms, very rare.

Genus—*Spiroloculina*, d'Orbigny, 1826

Spiroloculina canaliculata, d'Orbigny (Plate I, fig. 2)

Spiroloculina canaliculata, d'Orbigny, 1846, *Foram. Foss. Vienne*, p. 269, pl. xvi, figs. 10–12. *S. limbata*, d'Orbigny (var.), H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 150, pl. x, figs. 1, 2. *S. canaliculata*, d'Orbigny, Rupert Jones, 1895, *Foram. Crag.* (Pal. Soc. Mon.), pt. ii, p. 108, pl. iii, figs. 39, 40 ; woodcuts, figs. 3*a*, *b* ; Chapman, 1907, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 16, pl. i, figs. 20, 21.

Dr. Brady's figured examples came from the coast of Papua. Rupert Jones states that it is "not uncommon in the Mediterranean, in shallow and moderately deep waters." As a fossil it occurs in the Oligocene of Port Phillip (Kackeraboite Creek); in the Miocene of the Vienna Basin and Malaga; and in the Pliocene of Sutton, Suffolk, England. Its present occurrence is therefore remarkable for its high latitude.

Occurrence.—Sample No. 8, 353 fathoms, very rare.

Genus—*Miliolina*, Williamson, 1858

Miliolina subrotunda, Montagu, sp., var. *striata*, var. nov. (Plate I, fig. 3)

Reference to type species.—*Miliolina subrotunda*, Montagu, sp., H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 168, pl. v, figs. 10, 11.

The present example is a small, neat specimen ornamented with distinct striæ concentric with the curved outline of the shell. It calls to mind Brady's *M. circularis*, var. *sublineata*,* but the type of shell is that of *M. subrotunda*, both as to aperture and contour.

Occurrence.—Sample No. 8, 353 fathoms, one specimen.

Miliolina vulgaris, d'Orbigny, sp. (Plate I, fig. 4)

Quinqueloculina vulgaris, d'Orbigny, 1826, *Ann. Sci. Nat.*, vol. vii, p. 302, No. 33. *Miliolina auberiana*, d'Orbigny, sp., H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 162, pl. v, figs. 8, 9. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 320.

Of cosmopolitan distribution, this species is here extended farther south than any specimens hitherto recorded.

Occurrence.—Sample No. 8, 353 fathoms, one specimen.

Miliolina bicornis, Walker and Jacob, sp. (Plate I, fig. 5)

Serpula bicornis, Walker and Jacob, 1798, *Adams' Essays*, Kanmacher's ed., p. 633, pl. xiv, fig. 2. *Triloculina brongniartii*, d'Orbigny, 1826, *Ann. Sci. Nat.*, vol. vii, p. 300, No. 23. *Miliolina bicornis*, d'Orbigny, sp., H. B. Brady, 1884, vol. ix, p. 171, pl. vi, figs. 9, 11, 12.

A very small, but otherwise well-marked and typical specimen. It is of great interest to discover this species so far south, since it has been hitherto confined to temperate and tropical waters. Hence the small size of the present example. The depth is also a record, the *Challenger* finding it only as low as 120 fathoms.

Occurrence.—Sample No. 8, 353 fathoms, one specimen.

Miliolina agglutinans, d'Orbigny, sp. (Plate I, fig. 6)

Quinqueloculina agglutinans, d'Orbigny, 1839, *Foram. Cuba*, p. 168, pl. xii, figs. 11–13. *Miliolina agglutinans*, d'Orbigny, sp., H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 180, pl. viii, figs. 6, 7. Chapman, 1907, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 20, pl. ii, fig. 36.

As might be expected, the majority of the miliolines in the fine, terrigenous soundings of the Antarctic are mainly arenaceous forms, of which this is amongst the commonest. Its southern distribution includes Cape of Good Hope, 150 fathoms; Prince Edward

---

* *Rep. Chall.*, vol. ix, 1884, p. 169, pl. ix, figs. 7*a–c*.

Island, 1900 fathoms; and off Sydney, 410 fathoms. As a fossil this species has been noted from the post-tertiary clays of Norway and the west of Scotland; and it is fairly common in the Balcombian clays of Port Philip and Muddy Creek, but rarer in the Kalimnan of the latter locality. The present specimens are more neatly built than usual, and the contours are rounder.

Occurrence.—Sample No. 7, 225 fathoms, very rare; No. 9, 360 fathoms, common; No. 12, 460 fathoms, very common; No. 13, 462 fathoms, common; No. 14, 472 fathoms, frequent.

Miliolina oblonga, Montagu, sp., var. *arenacea*, var. nov. (Plate I, fig. 7)

Reference to type species.—*Vermiculum oblongum*, Montagu, 1803, *Test. Brit.*, p. 522, pl. xiv, fig. 9. *Miliolina oblonga*, Montagu, sp., H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 160, pl. v, figs. 4*a*, *b*. Goës, 1894, *Kongl. Svenska Vet.-Akad. Handl.*, vol. xxv, p. 110, pl. xx, figs. 850–850*f*. Chapman, 1907, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 17, pl. ii, fig. 26.

The type species, with a porcellanous shell, has been recorded from the sub-Antarctic islands of New Zealand, from 50–85 fathoms. The present variety differs in the finely arenaceous material of the test. It is quite a constant form, for no porcellanous shells of this species were found in these dredgings. The elongated outline readily serves to distinguish this particular variety from *Miliolina agglutinans*.

Occurrence.—Sample No. 10, 372 fathoms, very rare; No. 13, 462 fathoms, common; No. 14, 472 fathoms, rare; No. 15, 655 fathoms, frequent.

Miliolina tricarinata, d'Orbigny, sp. (for references *see* previous Reports on Foraminifera of Elevated Deposits.)

A species occurring in polar seas, both north and south. It is interesting to note the unusually small dimensions of the present specimens, one measuring only ·346 mm. in length, as compared with a tropical example recorded by Dr. Brady,* measuring 4·45; the average size being rather less than midway between these two extremes.

Occurrence.—Sample No. 3, 121 fathoms, frequent; No. 8, 353 fathoms, very rare.

Sub-family—HAUERININÆ

Genus—*Planispirina*, Seguenza, 1880

Planispirina sphæra, d'Orbigny, sp. (Plate I, fig. 8)

Biloculina sphæra, d'Orbigny, 1839, *Foram. Amér. Mérid.*, p. 66, pl. viii, figs. 13–16. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 141, pl. ii, figs. 4*a*, *b*. *Planispirina sphæra*, d'Orbigny, sp., Schlumberger, 1891, *Mém. Soc. Zool. France*, vol. iv, p. 577, woodcuts 45, 46. Chapman, 1909, *Sub-Antaractic Islands of New Zealand*, vol. i, art. xv, p. 324.

This species occurs sparingly in southern waters. The aperture in our specimens is normal and clearly defined; the labyrinthic opening being confined to deep-water examples.

Occurrence.—Sample No. 3, 121 fathoms, one specimen, very small; No. 4, 153 fathoms, one specimen, typical (figured).

---

* *Rep. Chall.*, vol. ix, 1884, p. 166.

Planispirina bucculenta, Brady (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 3, 121 fathoms, rare.

Sub-family—PENEROPLIDINÆ

Genus—*Cornuspira*, Schultze, 1854

Cornuspira involvens, Reuss, sp. (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 3, 121 fathoms, rare; No. 4, 153 fathoms, very rare.

Cornuspira foliacea, Philippi, sp. (Plate I, fig. 9)

Orbis foliaceus, Philippi, 1844, *Enum. Moll. Sicil.*, vol. ii, p. 147, pl. xxiv, fig. 26. *Cornuspira foliaceus*, Philippi, sp., H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 199, pl. xi, figs .5–9. Chapman, 1907, *Journ. Linn. Soc. Lond.* Zool., vol. xxx, p. 24, pl. iii, fig. 48.

This species does not seem to be a typically southern form, but it occurs as a fossil in the Australian tertiary strata. In the living state it is commonly found in the North Atlantic.

Occurrence.—Sample No. 3, 121 fathoms, very rare; No. 8, 353 fathoms, rare.

Family—ASTRORHIZIDÆ

Sub-family—ASTRORHIZINÆ

Genus—*Pelosina*, H. B. Brady, 1879

Pelosina cylindrica, H. B. Brady (Plate II, fig. 10)

Pelosina cylindrica, H. B. Brady, 1884, *Rep Chall.*, vol. ix, p. 236, pl. xxvi, figs. 1–6.

This species varies considerably in shape and texture, according to the material taken up in the construction of the test. It keeps, however, within the definition given by Dr. Brady, and always contains a large proportion of mud in its cylindrical tube. The foraminiferal shells built into the test are thin and small compared with those selected by genera such as *Rhizammina* and *Rhabdammina*. A few sponge spicules are sometimes included in the mud walls, but not to so great an extent as in *Technitella*. The examples found here vary from 28·5 mm. in length.

It is somewhat strange to meet with this species in such comparatively moderate depths, for it has been recognised as a peculiarly deep-water form. The *Challenger* records it from the Antarctic Ice Barrier at 1475 fathoms.

Occurrence.—Sample No. 3, 121 fathoms, rare; No. 5, 171 fathoms, very rare; No. 7, 225 fathoms, very rare; No. 9, 360 fathoms, rare.

Pelosina rotundata, H. B. Brady (Plate II, fig. 11)

Pelosina rotundata, H. B. Brady, 1879, *Quart. Journ. Micr. Sci.*, vol. xix, N.S., p. 31, pl. iii, figs. 4, 5. *Idem*, 1884, *Rep. Chall.*, vol. ix, p. 236, pl. xxv, figs. 18–20. Millett, 1899, *Journ. Roy. Micr. Soc.*, p. 249, pl. iv, fig. 1.

This present specimen is subglobular, and suggests *Technitella* in the abundance of sponge spicules used in the construction of its test; but they are mainly concentrated at two points on the periphery, whilst the wall itself is composed of fine grey mud, with an occasional spicule.

The above species is rare, being sparsely scattered over a wide area. It does not appear to have been previously recorded from the Pacific.

Occurrence.—Sample No. 1, 110 fathoms, one specimen.

Sub-family—SACCAMMININÆ

Genus—*Saccammina*, M. Sars, 1868

Saccammina sphærica, M. Sars (Plate II, fig. 12)

Saccammina sphærica, M. Sars, H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 253, pl. xviii, figs. 11–17. Flint, 1899, *Rep. U. S. Nat. Mus.* for 1897, p. 269, pl. ix, fig. 2.

The tests of the Antarctic specimens are coarsely arenaceous, and are distinguished from *Psammosphæra* by the small, inconspicuous, papillate aperture.* Sometimes two chambers are conjoined very firmly, after the manner of the Carboniferous species, *S. fusuliniformis*, McCoy, sp. (usually erroneously referred to as *S. carteri*).†

S. sphærica is found living within the Arctic Circle, and was only twice recorded by the *Challenger*—once in deep water in the North Pacific, east of Japan, 2050 fathoms, and at the Antarctic Ice Barrier.‡ It has also been noted by Dr. Flint from the South Atlantic, off the Coast of Brazil, at 1019 fathoms. It will thus be seen that, whereas in the higher latitudes it is found in only moderately deep water, in low latitudes it is invariably found at abyssal depths. Its path through the interpolar tracts, whether in the Atlantic or Pacific, has been along the deepest parts of those ocean basins.

Occurrence.—Sample No. 3, 121 fathoms, common; No. 4, 153 fathoms, frequent; No. 5, 171 fathoms, frequent.

Sub-family—RHABDAMMININÆ

Genus—*Hyperammina*, H. B. Brady, 1878

Hyperammina elongata, H. B. Brady (Plate II, fig. 13)

Hyperammina elongata, H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 257, pl. xxiii, figs. 4, 7–10.

H. elongata is chiefly a N. Atlantic form, and has occurred as far north as Franz-Josef Land. It has been previously recorded from the Southern Ocean between the Cape of Good Hope and Kerguelen Island at 1570 fathoms.

Occurrence.—Sample No. 7, 225 fathoms, very rare; No. 9, 360 fathoms, very rare.

Genus—*Marsipella*, Norman, 1878

Marsipella elongata, Norman (Plate II, fig. 14)

Marsipella elongata, Norman, 1878, *Ann. Mag. Nat. Hist.*, ser. 5, vol. i, p. 281, pl. xvi, fig. 7. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 264, pl. xxiv, figs. 10–19. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 270, pl. xii, fig. 1.

---

* Since this description was written, Messrs. Heron-Allen and Earland have published an exhaustive examination of the grounds of separation of *Psammosphæra fusca* and *Saccammina sphærica*, and have dissipated the suggestion that the two forms are identical (see *Journ. R. Micr. Soc.* 1913, pp. 1–26, pl. i–iv).

† Chapman, *Ann. Mag. Nat. Hist.*, ser. 7, vol. i, 1895, p. 215, woodcut.

‡ Brady, *op. supra cit.*, p. 252.

It is of great interest to find this species in the Antarctic Sea, for it is otherwise almost exclusively a North Atlantic form. *M. elongata* has been recorded by Dr. Flint from the West Indian seas, and it has been met with once in the South Atlantic, and occasionally in the South Pacific.

The present examples are typical; the proportion of fine arenaceous mud preponderating, however, over the spicular material in the construction of the test.

Occurrence.—Sample No. 8, 353 fathoms, rare.

Marsipella cylindrica, H. B. Brady (Plate II, fig. 15)

Marsipella cylindrica, H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 265, pl. xxiv, figs. 20–22.

The figured specimen of the present series is a regularly tapering and gently curved variety; whilst another example from the same sounding is enormously large compared with those already known, measuring as much as 13 mm. in breadth at the widest end.

The species is a typically delicate and slender form in the Faroe Channel dredgings at 530 and 542 fathoms. It has also been found in the South Atlantic and South Pacific, generally at great depths.

Occurrence.—Sample No. 14, 472 fathoms, two specimens.

Family—LITUOLIDÆ

Sub-family—LITUOLINÆ

Genus—*Reophax*, Montfort, 1808

Reophax spiculifera, H. B. Brady (Plate III, fig. 16)

Reophax spiculifera, H. B. Brady, 1879, *Quart. Journ. Micr. Sci.*, vol. xix, N.S., p. 54, pl. iv, figs. 10, 11. *Idem*, 1884, *Rep. Chall.*, vol. ix, p. 295, pl. xxxi, figs. 16, 17.

The tests of the Antarctic specimens are short, consisting of few segments, but they are otherwise typical. As an organism showing strong selective power in regard to the material from which it constructs its tests, it is most remarkable. The accompanying arenaceous genera here comprise forms like *Haplophragmium*, and the truly arenaceous species of *Reophax*, as *R. dentaliniformis*, together with arenaceous *Miliolinæ*, all of which employ siliceous sand grains for the walls of the test.*

This species has occurred at Sombrero Island, West Indies, 450 fathoms; Kerguelen Island, 20–120 fathoms; near the Sandwich Islands, 2350 fathoms; off Kandavu, 255 and 610 fathoms; and off Tahiti, 620 fathoms.

Occurrence.—Sample No. 12, 460 fathoms, very rare; No. 14, 472 fathoms, rare; No. 15, 655 fathoms, rare.

---

* The following note, written by Sir John Murray on the same subject, occurs in the *Challenger Report*, Summary of Results, pt. i, 1895, p. 511: "Among the arenaceous species from Sta. 157 there are many interesting illustrations of the mode in which these Rhizopods select and arrange the various particles in the deposit to form their tests. *Astrorhiza crassatina* here forms its test almost exclusively of the spherical Radiolarian *Cromyosphæra Antarctica*; *Storthosphæra* selects the finest mineral particles, with an occasional larger particle of quartz or palagonite; one form selects only the shells of the pelagic Foraminifera, and another only the smallest Diatomaceæ; *Reophax nodulosa* makes use of many large *Coscinodisci*, arranging them flat ways over the surface, and *Rhabdammina abyssorum* forms its tube of the larger angular fragments of quartz, felspar, magnetite, and other mineral particles."

See also Heron-Allen and Earland (*Journ. Quek. Micr. Club*, ser. 2, vol. x, 1909, pp. 403–412, pl. xxxii–xxxv) for an interesting account of the occurrence of a foraminifer, *Technitella thompsoni*, which constructs its test of the plates of *Holothuria* sp.

Reophax dentaliniformis, H. B. Brady (Plate III, fig. 17)

Reophax dentaliniformis, H. B. Brady, 1881, *Quart. Journ. Micr. Sci.*, vol. xxi, N.S., p. 49. *Idem*, 1884, *Rep. Chall.*, vol. ix, p. 293, pl. xxx, figs. 21, 22. Goës, 1894, *K. Svenska Vet.-Akad. Handl.*, vol. xxv, p. 25, pl. vi, figs. 172–175. Millett, 1899, *Journ. B. Micr. Soc.*, p. 254. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 274, pl. xviii, fig. 2.

Tests varying in composition from fine to coarse material in the same sounding, and consisting of angular quartz grains varied by occasional augite granites. The shallowing of deep-water species as they advance to the polar seas is strikingly brought to notice by such forms as the present, which typically inhabit great depths in intertropical regions. Dr. Brady, in the *Challenger Report,* notes only four out of twenty-one stations where it was found in less depths than 1000 fathoms. It is a widely distributed, but generally rare, form.

Occurrence.—Sample No. 4, 153 fathoms, rare; No. 5, 171 fathoms, common; No. 7, 225 fathoms, frequent; No. 9, 360 fathoms, frequent; No. 13, 462 fathoms, very rare; No. 14, 472 fathoms, rare; No. 15, 655 fathoms, rare.

Reophax longiscatiformis, sp. nov. (Plate III, fig. 18)

Description.—Test arenaceous, straight or very slightly curved, consisting of a series of long, ovoid, somewhat irregular segments with deeply incised transverse sutures. Length of test figured (fragmentary), 1·44 mm.; greatest width, ·173 mm.

This species is rare in the Antarctic soundings, being represented by two examples. It is interesting as an isomorphous form, comparable with d'Orbigny's hyaline species, *Nodosaria longiscata,** which is a well-known tertiary fossil.

Occurrence.—Sample No. 9, 360 fathoms; No. 13, 462 fathoms.

Reophax murrayana, sp. nov. (Plate III, fig. 19)

Description.—Test finely arenaceous and spiculose; slender, gently curved and gradually tapering to a blunt point; consisting of numerous segments slightly longer than wide, with sutures nearly at right angles to length of shell. Length of test 1·88 mm.; greatest width, ·115 mm.

This figured specimen, which cannot be matched with already known types of *Reophax,* is isomorphous with a *Nodosaria* (*Dentalina*) of the type of *Nodosaria* (*Dentalina*) *consobrina*, d'Orbigny, var. *emaciata*, Reuss.† The sample of mud from which it was taken was very small, otherwise more examples might have been found.

Named in honour of Mr. James Murray, F.R.S.E., of the British Antarctic Expedition of 1907–9, who superintended the zoological work of the expedition.

Occurrence.—Sample No. 7, 225 fathoms.

Genus—*Haplophragmium*, Reuss, 1860

Haplophragmium canariense, d'Orbigny, sp. (Plate III, fig. 20)

Nonionina canariensis, d'Orbigny, 1839, *Foram. Canaries*, p. 128, pl. ii, figs. 33, 34. *Haplophragmium canariense*, d'Orbigny, sp., H. B. Brady, 1884, *Rep.*

---

* *Foram. Foss. Vienne*, 1846, p. 32, pl. i, figs. 10–12. *See also* Sherborn and Chapman, *Journ. Roy. Micr. Soc.*, 1899, p. 486, pl. xi, figs. 17, 18.

† *Dentalina emaciata*, Reuss, *Zeitschr. d. deutsch. geol. Gesellsch.*, vol. iii, 1851, p. 63, pl. iii, fig. 9.

Chall., vol. ix, p. 310, pl. xxxv, figs. 1–5. Egger, 1893, *Abhandl. k. bayer. Akad. Wiss.*, Cl. II, vol. xviii, p. 261, pl. v, figs. 27–29. Millett, 1899, *Journ. Roy. Micr. Soc.*, p. 359. Chapman, 1907, *Journ. Quek. Micr. Club*, p. 126, pl. ix, fig. 3. *Idem*, 1909, *Sub-Antarctic Islands of N. Zealand*, vol. i, art. xv, p. 327, pl. xiv, fig. 6. *Idem*, 1901, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 400.

Tests small, with very neatly finished walls, generally of a warm brown colour, and consisting of a moderately fine mosaic of sand grains.

A very widely distributed species, which has already occurred, amongst other places, round New Zealand and the sub-Antarctic islands, as well as at Kerguelen and Heard Islands.

Occurrence.—Sample No. 3, 121 fathoms, very common, some specimens excessively minute ; No. 4, 153 fathoms, very common ; No. 5, 171 fathoms, frequent ; No. 7, 225 fathoms, very rare ; No. 13, 462 fathoms, rare ; No. 14, 472 fathoms, very rare.

Haplophragmium latidorsatum, Bornemann, sp. (Plate III, fig. 21)

Nonionina latidorsata, Bornemann, 1855, *Zeitschr. d. deutsch. Geol. Gesellsch.*, vol. vii, p. 339, pl. xvi, figs. 4*a*, *b*. *H. latidorsatum*, Bornemann, sp., H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 307, pl. xxxiv, figs. 7–10, 14. Goës, 1894, *K. Svenska Vet.-Akad. Handl.*, vol. xxv, p. 21, pl. v, figs. 102–120.

This cosmopolitan species is, generally speaking, a deep-water form ; but towards the polar regions affects more moderate depths. A sample of a dredging from the cold-water area of the Faroe Channel, sent me by my friend Mr. A. Earland, consists largely of the tests of the above species.

Occurrence.—Sample No. 9, 360 fathoms, frequent ; No. 12, 460 fathoms, very rar No. 14, 472 fathoms, very rare.

Haplophragmium scitulum, H. B. Brady (Plate III, fig. 22)

Haplophragmium scitulum, H. B. Brady, 1881, *Quart. Journ. Micr. Sci.*, vol. xxi, N.S., p. 50. *Idem*, 1884, *Rep. Chall.*, vol. ix, p. 308, pl. xxxiv, figs. 11–13. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 276, pl. xx, fig. 2.

The *Challenger* localities show this form to be widely distributed, although it is not a common species, ranging over the Atlantic and Pacific Ocean beds from north to south, the most southerly point being on the west coast of Patagonia at 400 fathoms. Dr. Flint records it also from the west coast of Cuba.

Occurrence.—Sample No. 13, 462 fathoms.

Family—TEXTULARIIDÆ

Sub-family—Textulariinæ

Genus—*Valvulina*, d'Orbigny, 1826

Valvulina fusca, Williamson, sp. (Plate III, figs. 23*a*, *b*)

Rotalina fusca, Williamson, 1858, *Rec. Foram. Gt. Brit.*, p. 55, pl. v, figs. 114, 115. *Valvulina fusca*, Williamson, sp., H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 392, pl. xlix, figs. 13, 14.

Dr. Brady records this species as a common North Atlantic foraminifera. It has also occurred in the South Pacific, in the North Pacific, and in the West Indies.

Occurrence.—Sample No. 5, 171 fathoms.

Sub-family—Bulimininæ

Genus—*Virgulina*, d'Orbigny, 1826

Virgulina schreibersiana, Czjzek, p. (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 3, 121 fathoms, rare.

Genus—*Bolivina*, d'Orbigny, 1839

Bolivina textilarioides, Reuss (Plate III, fig. 24)

Bolivina textilarioides, Reuss, 1862, *Sitzungsb. d. k. Akad. Wiss. Wien*, vol. xlvi, p. 81, pl. x, fig. 1. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 419, pl. lii, figs. 23–25; Chapman, 1907, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 31, pl. iv, fig. 79.

This record appears to be new for the Southern Ocean. It is a fairly deep-water form and appears to have been of commoner occurrence in Cretaceous and Tertiary seas.

Occurrence.—Sample No. 3, 121 fathoms ; one specimen, small but typical.

Sub-family—Cassidulininæ

Genus—*Cassidulina*, d'Orbigny, 1826

Cassidulina oblonga, Reuss (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 1, 110 fathoms, very rare ; No. 2, 113 fathoms, very common ; No. 3, 121 fathoms, rare ; No. 4, 153 fathoms, common ; No. 5, 171 fathoms, very common.

Cassidulina parkeriana, H. B. Brady (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 1, 110 fathoms, very rare ; No. 2, 113 fathoms, common ; No. 3, 121 fathoms, frequent ; No. 4, 153 fathoms, common ; No. 5, 171 fathoms, common.

Cassidulina subglobosa, H. B. Brady (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 1, 110 fathoms, frequent ; No. 2, 113 fathoms ; No. 3, 121 fathoms, small specimens, frequent ; No. 4, 153 fathoms, common ; No. 5, 171 fathoms, small, frequent ; No. 7, 225 fathoms, very rare ; No. 8, 353 fathoms, very rare.

Genus—*Ehrenbergina*, Reuss, 1849

Ehrenbergina serrata, Reuss (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 3, 121 fathoms, rare ; No. 4, 153 fathoms, very common ; No. 5, 171 fathoms, very rare.

Family—LAGENIDÆ

Sub-family—Lageninæ

Genus—*Lagena*, Walker and Boys, 1784

Lagena globosa, Montagu, sp. (Plate IV, fig. 25)

Vermiculum globosum, Montagu, 1803, *Test. Brit.*, p. 523. *Lagena globosa*, Montagu, sp., Reuss, 1863, *Sitzungsb. d. k. Akad. Wiss. Wien*, vol. xlvi, p. 318, pl. i, figs. 1–3. Egger, 1899, *Abhandl. k. bayer. Akad. Wiss.*, Cl. II, vol. xxi, p. 102, pl. v, fig. 3 ; Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 333.

A cosmopolitan species, not affected to any great extent by depth or latitude.

Occurrence.—Sample No. 3, 121 fathoms, rare ; No. 8, 353 fathoms, very rare.

Lagena apiculata, Reuss, sp. (Plate IV, fig. 26)

Oolina apiculata, Reuss, 1851, *Haidinger's Naturw. Abhandl.*, vol. iv, Abth. i, p. 22, pl. 1, fig. 1. *Lagena apiculata*, Reuss, 1863, *Sitzungsb. d. k. Akad. Wiss. Wien*, vol. xlvi, p. 318, pl. i, figs. 1, 4–8, 10, 11. H. B. Brady, 1884, vol. ix, p. 453, pl. lvi, figs. 4, 15–18. Chapman, 1900, *Quart. Journ. Geol. Soc.*, vol. lvi, p. 258, pl. xv, fig. 3.

A widely distributed species.

Occurrence.—Sample No. 3, 121 fathoms, one specimen.

Lagena schlichti, A. Silvestri, sp. (Plate IV, fig. 27)

Lagena marginata, Walker and Boys, var., Millett, 1901, *Journ. Roy. Micr. Soc.*, p. 497, pl. viii, fig. 20. *Fissurina schlichti*, A. Silvestri, 1902, *Mem. d. Pont. Acc. Rom. d. Nuovi Lincei*, vol. xix, p. 14 ; woodcuts, figs. 9–11. *Lagena schlichti*, A. Silvestri, sp., Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 337, pl. xv, figs. 7*a*, *b*.

This species appears to be widely distributed, and was formerly confused with *L. marginata*, Walker and Boys. It has already occurred in soundings from the sub-Antarctic islands of New Zealand, at depths of 50–85 fathoms.

Occurrence.—Sample No. 3, 121 fathoms, common ; No. 4, 153 fathoms, frequent ; No. 5, 171 fathoms, very rare.

Lagena marginata, Walker and Boys (Plate IV, fig. 28)

Serpula (*Lagena*) *marginata*, Walker and Boys, 1784, *Test. Min.*, p. 2, pl. i, fig. 7. *Lagena marginata*, Walker and Boys, H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 476, pl. lix, fig. 22. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 335, pl. xv, fig. 6.

This species has a wide range, and is found in both polar seas. It has already been recorded from near the Antarctic Ice Barrier, and from the sub-Antarctic islands of New Zealand. The figured specimen closely approaches the form *L. lævigata*, Reuss.

Occurrence.—Sample No. 3, 121 fathoms, rare ; No. 4, 153 fathoms, very rare.

Lagena orbignyana, Seguenza, sp. (Plate IV, fig. 29)

Fissurina orbignyana, Seguenza, 1862, *Foram. Monotal. Miocen. Messina*, p. 6, pl. ii, figs. 65, 66. *Lagena orbignyana*, Seguenza, sp., Flint, 1899, *Rep. U.S. Nat.*

Mus. for 1897, p. 308, pl. liv, fig. 4. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 337, pl. xv, fig. 10.

This widely distributed species has been recorded off the Falkland Islands at 6 fathoms. It was also found at 60–85 fathoms around the sub-Antarctic islands of New Zealand.

Occurrence.—Sample No. 3, 121 fathoms, one specimen ; No. 4, 153 fathoms, one specimen.

Sub-family—Nodosariinæ

Genus—*Nodosaria*, Lamarck, 1816

Sub-genus—*Glandulina*, d'Orbigny, 1826

Nodosaria (*Glandulina*) *lævigata*, d'Orbigny (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 3, 121 fathoms, very common ; No. 4, 153 fathoms, rare.

Nodosaria (*Glandulina*) *rotundata*, Reuss (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 1, 110 fathoms, one specimen ; No. 3, 121 fathoms, very common ; No. 4, 153 fathoms, frequent.

Sub-genus—*Dentalina*, d'Orbigny, 1826

Nodosaria (*Dentalina*) *communis*, d'Orbigny (Plate IV, fig. 30)

Nodosaria (*Dentalina*) *communis*, d'Orbigny, 1826, *Ann. Sci. Nat.*, vol. vii, p. 254, No. 35. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 310, pl. lvi, fig. 2. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 341, pl. xv, fig. 10.

This common species is another of those usually found in moderately shallow water in high latitudes.

Occurrence.—Sample No. 4, 153 fathoms.

Genus—*Cristellaria*, Lamarck, 1818

Cristellaria crepidula, Fichtel and Moll, sp. (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 3, 121 fathoms, one specimen ; No. 4, 153 fathoms, one specimen.

Cristellaria articulata, Reuss (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 4, 153 fathoms, one specimen.

Sub-family—Polymorphininæ

Genus—*Polymorphina*, d'Orbigny, 1826

Polymorphina oblonga, d'Orbigny (Plate IV, fig. 31)

Polymorphina oblonga, d'Orbigny, 1846, *Foram. Foss. Vienne*, p. 232, pl. xii, figs. 29–31. Egger, 1893, *Abhandl. d. k. bayer. Akad. Wiss.*, Cl. II, vol. xviii, p. 309, pl. xi, figs. 9, 10, 24.

As regards the distribution of this species, the records for the southern hemisphere include Table Bay, Mauritius, and West Australia. It was found by the *Challenger* at Tongatabu at 240 fathoms; and at Raine's Islet, Torres Strait, at 155 fathoms. *P. oblonga* is not uncommon in shore sands near Melbourne (Port Phillip); and typical fossil examples are found in the Balcombian deposits (Oligocene) of Victoria.

Occurrence.—Sample No. 5, 171 fathoms, one specimen.

Genus—*Uvigerina*, d'Orbigny, 1826

Uvigerina pygmæa, d'Orbigny (Plate IV, fig. 32)

Uvigerina pygmæa, d'Orbigny, 1826, *Ann. Sci. Nat.*, vol. vii, p. 269, pl. xii, figs. 8, 9; *modèle* No. 67. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 320, pl. lxviii, fig. 2. Chapman, 1905, *Journ. N. Zealand Inst.*, vol. xxxviii, p. 99.

The range of this generally well-known species is stated by Dr. H. B. Brady * to extend to about lat. 46° S. in the Southern Ocean; and to 79° N. at Smith's Sound and the shores of Franz-Josef Land. It has lately been obtained by the author from soundings off Great Barrier Island, New Zealand at 110 fathoms.

Occurrence.—Sample No. 8, 353 fathoms, one specimen.

Uvigerina angulosa, Williamson (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 1, 110 fathoms, rare; No. 2, 113 fathoms, common; No. 3, 121 fathoms, very common; No. 4, 153 fathoms, very common; No. 5, 171 fathoms, frequent.

Family—GLOBIGERINIDÆ

Genus—*Globigerina*, d'Orbigny, 1826

Globigerina bulloides, d'Orbigny (Plate IV, fig. 33)

Globigerina bulloides, d'Orbigny, 1826, *Ann. Sci. Nat.*, vol. vii, p. 277, No. 1, *modèles* Nos. 17 and 76. Rhumbler, 1900, in K. Brandt's *Nordisches Plankton*, Heft 14, p. 21, figs. 24–26. Wright, 1900, *Geol. Mag.*, N.S., Dec. 4, vol. vii, p. 100, pl. v, fig. 18. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 350.

The present examples are thin-shelled, but otherwise typical. It is somewhat common in the Southern Ocean; a few of the *Challenger* stations being Kerguelen Island, Heard Island, and south-west of Patagonia. It is also of frequent occurrence amongst the sub-Antarctic islands of New Zealand.

Occurrence.—Sample No. 3, 121 fathoms, frequent; No. 8, 353 fathoms, rare.

Globigerina triloba, Reuss (Plate IV, fig. 34)

Globigerina triloba, Reuss, 1849, *Denkschr. d. k. Akad. Wiss. Wien*, vol. i, p. 374, pl. xlvii, fig. 11. Chapman, 1909, *Sub-Antarctic Islands of New Zealand*, vol. i, art. xv, p. 350.

A characteristic specimen, having a thicker test than the examples of the preceding species. Previously recorded from the Southern Ocean.

Occurrence.—Sample No. 10, 372 fathoms, one specimen.

---

* *Challenger Rep.*, vol. ix, p. 575.

Globigerina inflata, d'Orbigny (Plate V, fig. 35)

Globigerina inflata, d'Orbigny, 1839, *Foram. Cuba*, p. 134, pl. ii, figs. 7–9. Rhumbler, 1900, in K. Brandt's *Nordisches Plankton*, Heft 14, p. 19, fig. 19.

The above form is here characteristic and abundant; but it occurs only in one sample. According to Dr. H. B. Brady it is not so common a form in the Arctic and Southern Oceans as in areas of lower latitudes, and that author also notes its southern limit at lat. 53° 55″ S.

Occurrence.—Sample No. 8, 353 fathoms, very common.

Globigerina dutertrei, d'Orbigny (Plate V, fig. 36)

Globigerina dutertrei, d'Orbigny, 1839, *Foram. Cuba*, p. 95, pl. iv, figs. 19–21. H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 601, pl. lxxxi, figs. 1*a–c*.

This species is recorded by Dr. H. B. Brady as a starved representative of *G. bulloides*, in the Antarctic Seas. It has been already recorded from the Antarctic Ice Barrier, both in the surface water and the bottom ooze. It is here very rare, as it was also in the sub-Antarctic island dredgings off New Zealand.

Occurrence.—Sample No. 3, 121 fathoms, one specimen; No. 4, 153 fathoms, one specimen.

Globigerina æquilateralis, H. B. Brady (Plate V, fig. 37)

Globigerina æquilateralis, H. B. Brady, 1879, *Quart. Journ. Micr. Sci.*, vol. xix, N.S., p. 71. *Idem*, 1884, *Rep. Chall.*, vol. ix, p. 605, pl. lxxx, figs. 18–21. Rhumbler, 1900, in K. Brandt's *Nordisches Plankton*, Heft 14, p. 20, figs. 21–23.

A fine typical example. Previously recorded by the *Challenger* as far south as the Cape of Good Hope. This species also occurred around the sub-Antarctic islands of New Zealand, and the present record pushes it still farther southward.

Occurrence.—Sample No. 8, 353 fathoms,

Genus—*Pullenia*, Parker and Jones, 1862

Pullenia quinqueloba, Reuss (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 3, 121 fathoms, frequent; No. 4, 153 fathoms, common.

Family—ROTALIIDÆ

Sub-family—ROTALIINÆ

Genus—*Truncatulina*, d'Orbigny, 1826

Truncatulina refulgens, Montfort, sp. (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 1, 110 fathoms, one specimen; No. 2, 113 fathoms, frequent; No. 3, 121 fathoms, common; No. 4, 153 fathoms, very common; No. 5, 171 fathoms, one specimen.

Truncatulina lobatula, Walker and Jacob, sp. (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 2, 113 fathoms, one specimen; No. 3, 121 fathoms, frequent. No. 4, 153 fathoms, frequent; No. 5, 171 fathoms, frequent.

Truncatulina tenera, H. B. Brady (Plate V, fig. 38)

Truncatulina tenera, H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 665, pl. xcv, figs. 11*a–c*. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 334, pl. lxxvii, fig. 4.

It is extremely interesting to meet with this rare form, which was found by Dr. Brady in soundings at the Canaries, North Atlantic, 620 fathoms ; and at three stations near the coast of Chili and Patagonia at 166 to 1375 fathoms. Dr. Flint has since discovered it off the west coast of Patagonia at 194 fathoms.

Occurrence.—Sample No. 8, 353 fathoms.

Genus—*Anomalina*, d'Orbigny, 1826

Anomalina ammonoides, Reuss, sp. (Plate V, fig. 39)

Rosalina ammonoides, Reuss, 1845, *Verst böhm. Kreid.* pt. i, p. 36, pl. xiii, fig. 66 ; pl. viii., fig. 53. *Anomalina ammonoides*, Reuss, sp., H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 672, pl. xciv, figs. 2, 3. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 335, pl. lxxviii, fig. 4.

The farthest southerly record of this form appears to be that of Dr. Brady, from the west coast of New Zealand at 275 fathoms.

Occurrence.—Sample No. 3, 121 fathoms, one specimen ; No. 8, 353 fathoms, one specimen.

Anomalina polymorpha, Costa (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 8, 353 fathoms, rare.

Pulvinulina elegans, var. *partschiana*, d'Orbigny, var. (Plate V, fig. 40)

Rotalina partschiana, d'Orbigny, 1846, *Foram. Foss. Vienne*, p. 153, pl. vii, figs. 28–30 ; pl. viii, figs. 1–3 ; *Pulvinulina partschiana*, d'Orbigny, sp., H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 699, pl. cv, figs. 3*a–c*, woodcut 21. Millett, 1904, *Journ. Roy. Micr. Soc.*, p. 502.

The present occurrence is apparently new for this part of the Southern Ocean ; the *Challenger* having previously noted it off the Cape of Good Hope (Sta. 142).

Occurrence.—Sample No. 8, 353 fathoms, rare.

Family—NUMMULINIDÆ

Sub-family—POLYSTOMELLINÆ

Genus—*Nonionina*, d'Orbigny, 1826

Nonionina depressula, Walker and Jacob, sp. (Plate V, fig. 41)

Nautilus depressulus, Walker and Jacob, 1798, *Adams' Essays*, Kanmacher's ed., p. 641, pl. xiv, fig. 33. *Nonionina depressula*, Walker and Jacob, sp., Wright, 1900, *Geol. Mag.* Dec. 4, vol. vii, p. 100, pl. v, fig. 23.

This widely distributed species is found in the Arctic Seas. It has been recorded by Dr. Haeusler from the Hauraki Gulf, New Zealand, and by the writer from the sub-Antarctic islands of New Zealand.

Occurrence.—Sample No. 3, 121 fathoms, frequent ; No. 4, 153 fathoms, common.

Nonionina stelligera, d'Orbigny (for references *see* previous Reports on Foraminifera of Elevated Deposits)

Occurrence.—Sample No. 3, 121 fathoms, rare.

Nonionina scapha, Fichtel and Moll, sp., var. *bradii*, var. nov. (Plate V, fig. 42)

Nonionina (?) *scapha*, Fichtel and Moll, sp., H. B. Brady, 1884, *Rep. Chall.*, vol. ix, p. 730, pl. cix, fig. 16.

The specific form, *N. scapha*, has been recorded from, amongst other places, the Hauraki Gulf, New Zealand (Haeusler), and round the sub-Antarctic islands of New Zealand (Chapman).

The present variety was figured by Dr. Brady as a doubtful form of *N. scapha*; and our example exactly resembles it in having an evolute commencement. One of the specimens figured by Dr. Flint,* in his group of *N. scapha* is also comparable to the above variety.

Occurrence.—Sample No. 3, 121 fathoms, one specimen.

Genus—*Polystomella*, Lamarck, 1822

Polystomella crispa, Linné, sp. (Plate V, fig. 43)

Nautilus crispus, Linné, 1767, *Syst. Nat.*, 12th ed., p. 1162–275. *Polystomella crispa*, Linné, sp., Egger, 1893, *Abhandl. k. bayer. Akad. Wiss.*, Cl. II, vol. xviii, p. 432, pl. xx, figs. 20, 21. Flint, 1899, *Rep. U.S. Nat. Mus. for* 1897, p. 338, pl. lxxx, fig. 3.

This ubiquitous species has already been recorded as far south as the sub-Antarctic islands of New Zealand and Kerguelen Island.

Occurrence.—Sample No. 8, 353 fathoms, rare; shells complanate and thin.

DESCRIPTION OF THE OSTRACODA

Section—PODOCOPA

Family—Cypridæ

Genus—*Aglaia*, G. S. Brady, 1867

(?) *Aglaia obtusata*, G. S. Brady (Plate VI, fig. 44)

(?) *Aglaia obtusata*, G. S. Brady, 1880, *Rep. Chall.*, Zool., pt. iii, p. 35, pl. xxx, figs. 8*a–d*. Chapman, 1910, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 426.

This rare species has been found in only three localities, the earlier occurrences being Kerguelen Island, 20–50 fathoms (Brady); and Funafuti, 1050 fathoms (Chapman).

Occurrence.—Sample No. 3, 121 fathoms, one specimen (carapace).

Genus—*Pontocypris*, G. O. Sars, 1865

Pontocypris (?) *faba*, Reuss, sp. (Plate VI, figs. 45*a*, *b*)

Bairdia faba, Reuss, 1855, *Zeitschr. d. deutsch. Geol. Gesellsch.*, p. 278, pl. x, fig. 2. *Pontocypris faba*, G. S. Brady, 1878, *Trans. Zool. Soc.*, p. 382, pl. lxiii, figs. 6*a–e*. *Pontocypris* (?) *faba*, Reuss, sp., *idem*, 1880, *Rep. Chall.*, Zool., pt. iii, p. 37, pl. i,

---

* *Rep. U.S. Nat. Mus. for* 1897 (1899), pl. lxxx, fig. i.

figs. 4*a–d*. *Pontocypris faba,* Reuss, sp., Egger, 1901, *Abhandl. k. bayer. Akad. Wiss.*, vol. xxi, Abth. ii, p. 420, pl. iv, figs. 44, 45. *Pontocypris* (?) *faba,* Reuss, sp., Chapman, 1910, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 427.

Should the specific correlation of this form with Reuss's be correct, the species dates from Cretaceous times. It also occurs in the Pliocene (Antwerp Crag) of Europe. At the present day it is entirely restricted to the waters of the southern hemisphere, being recorded from Bass Strait and Honolulu in shallow water, from Funafuti at the great depth of 1050 fathoms, and from Mauritius in moderately deep water.

Occurrence.—Sample No. 1, 110 fathoms, one specimen (carapace) of an amber-brown colour, with the animal preserved within.

Family—CYTHERIDÆ

Genus—*Cythere,* Muller, 1785

Cythere foveolata, G. S. Brady (for references *see* previous Reports on Ostracoda of Elevated Deposits)

Occurrence.—Sample No. 4, 153 fathoms, one diminutive valve.

Cythere davisi, sp. nov. (Plate VI, figs. 46*a–c*)

Description.—Shell of the female, seen from the side, oblong, subrectangular, with rounded extremities ; highest at the anterior hinge-joint, height more than half the length ; anterior border obliquely rounded at the dorsal angle, strongly curved towards the ventral, with the anterior edge set with numerous short, sharp spines ; posterior border rounded, and armed with some moderately long sharp spines ; dorsal line slightly concave in the centre, and elevated towards the anterior border ; ventral edge nearly straight, but for a broad depression coinciding with an excavated area on the median surface under the subcentral tubercle ; surface tumid in the median area, and covered with fine, polygonal areolæ, each with a central papilla ; the subcentral boss also areolated and pitted ; submarginal flange well developed on the extremities and ventral border ; a sharp salient ridge runs obliquely towards the posterior half of the submarginal flange, abruptly turning at right angles near the posterior margin, and finally thinning away at the post-dorsal angle ; a conspicuous tubercle with fossa over the anterior hinge-joint. Edge view, from below, elongate subcordate, increasing in width from front to back up to the middle of the posterior third of the carapace ; with rounded outline below, irregular above, interrupted by the median depression. End view short, subcordate, almost triangular, but with rounded faces. Carapace of the male more elongate and compressed.

Measurements.—Length of figured example, 1·423 mm. ; greatest height, ·73 mm. ; thickness of carapace, ·7 mm.

The above species was at first tentatively regarded as a variety of *C. wyville-thomsoni,* G. S. Brady,* to which it is related in general form. It differs essentially, however, in having a much thicker carapace, in its rounded posterior extremity, in having a median depression, and in the feeble polygonal surface ornamentation.

This species is named in honour of Capt. J. K. Davis, of the S.Y. *Nimrod,* who collected the present samples of soundings in the Antarctic.

Occurrence.—Sample No. 3, 121 fathoms, frequent ; No. 7, 225 fathoms, one specimen. All the examples are complete carapaces.

---

* *Rep. Chall.*, Zool., pt. iii, 1880, p. 82, pl. xx, figs. 4*a–f*.

Cythere quadriaculeata, G. S. Brady (Plate VI, fig. 47)

Cythere quadriaculeata, G. S. Brady, 1880, *Rep. Chall.*, Zool., pt. iii, p. 86, pl. xxii, figs. 2*a–d* ; pl. xxv, figs. 4*a–d* ; Chapman, 1910, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 432.

Dr. Brady gives two *Challenger* stations for this species, viz. the Inland Sea, Japan (15 fathoms), and off the reefs at Honolulu (40 fathoms). The Funafuti specimens occurred at the great depths of 1050 and 1215 fathoms.

Occurrence.—Sample No. 4, 153 fathoms, one valve of moderately strong build.

Cythere normani, G. S. Brady (for references *see* previous Reports on Ostracoda of Elevated Deposits)

Occurrence.—Sample No. 4, 153 fathoms, frequent ; all single valves.

Genus—*Xestoleberis*, G. O. Sars, 1865

Xestoleberis variegata, G. S. Brady (Plate VI, fig. 48)

Xestoleberis variegata, G. S. Brady, 1880, *Rep. Chall.*, Zool., pt. iii, p. 129, pl. xxxi, figs. 8*a–g* ; Chapman, 1910, *Journ. Linn. Soc. Lond.*, Zool., vol. xxx, p. 435.

This species was found in both deep and shallow water round Funafuti ; and it often occurred in the atoll's lagoon. Dr. Brady's records for the species are Cape Verde, Tongatabu, Fiji, and Noumea.

Occurrence.—Sample No. 4, 153 fathoms, one valve ; No. 8, 353 fathoms, one valve.

Xestoleberis davidiana, Chapman (for description *see* previous Reports on Ostracoda of Elevated Deposits)

Occurrence.—Sample No. 3, 121 fathoms ; one carapace ; No. 4, 153 fathoms, one valve.

Xestoleberis setigera, G. S. Brady (Plate VI, fig. 49)

Xestoleberis setigera, G. S. Brady, 1880, *Rep. Chall.*, Zool., pt. iii, p. 125, pl. xxxi, figs. 2*a–d* ; figs. 3*a–c* ; Egger, 1901, *Abhandl. k. bayer. Akad. Wiss.*, vol. xxi, Abth. ii, p. 456, pl. iii, figs. 37–39.

This species appears to be almost restricted to the Southern Ocean. Brady records it from Kerguelen Island, 120 fathoms ; Heard Island, 75 fathoms ; and Prince Edward's Island, 50–150 fathoms. Egger's specimens came from the coast of Liberia, West Africa.

Occurrence.—Sample No. 3, 121 fathoms, one carapace ; No. 4, 153 fathoms, rare ; No. 5, 171 fathoms, one valve.

Genus—*Cytherura*, G. O. Sars, 1865

Cytherura obliqua, G. S. Brady (Plate VI, fig. 50)

Cytherura obliqua, G. S. Brady, 1880, *Rep. Chall.*, Zool., pt. iii, p. 131, pl. xxxii, figs. 1*a–d*.

The only other locality for this species is that which furnished Dr. Brady with his described specimens, viz., Balfour Bay, Kerguelen Island, 20–50 fathoms. The single valve found in the present series is prominent on the ventral face, but otherwise typical.

Occurrence.—Sample No. 4, 153 fathoms, one valve.

Cytherura rudis, G. S. Brady (Plate VI, fig. 51)

Cytherura rudis, G. S. Brady, 1868, *Ann. Mag. Nat. Hist.*, ser. 4, vol. ii, p. 34, pl. v, figs. 15–17 ; *Cytherura* (?) *rudis*, G. S. Brady, 1880, *Rep. Chall.*, Zool., pt. iii, p. 132, pl. xxxii, figs. 3*a–d*. *Cytherura rudis*, G. S. Brady and Norman, 1889, *Trans. Roy. Dubl. Soc.*, ser. ii, vol. iv, p. 204, pl. xviii, figs. 10–12 ; pl. xix, fig. 21.

The present occurrence of the above species is most interesting from the point of view that it helps to dispel Dr. Brady's doubt regarding the identity of the *Challenger* specimens from the Straits of Magellan (55 fathoms) with the original examples obtained by Brady many years earlier from Davis's Straits. The present Antarctic specimen is nearer the Arctic form in outline ; and the rough polygonal sculpturing is intermediate in character between the southern and northern examples recorded by Dr. Brady. The additional localities for this species given by Drs. Brady and Norman are—Godhavn Harbour, Greenland, 5–25 fathoms ; Ginevra Bay, Spitzbergen ; Smith's Sound, 210 fathoms. Also as a pleistocene fossil at Portland, Co. Maine, U.S.A., and in Scotland, at Loch Gilp.

Occurrence.—Sample No. 7, 225 fathoms, one valve.

SUMMARY OF RESULTS

In the foregoing Report, 64 species and varieties of Foraminifera and 11 species of Ostracoda are described or recorded. Among the Foraminifera the following are new:

Miliolina subrotunda, Mont. sp., var. **striata;**
,, *oblonga*, Mont. sp., var. **arenacea;**
Reophax **longiscatiformis;**
,, **murrayana;** and
Nonionina scapha, F. and M. sp., var. **bradii.**

There is also a new species of the Ostracoda, viz. *Cythere* **davisi.**

A notable feature in the present foraminiferal fauna is the large number of species which are undoubtedly common to the cold areas of the north and south polar regions. Amongst these may be cited: *Saccammina sphærica*, *Haplophragmium canariense*, *H. latidorsatum*, *Virgulina schreibersiana*, *Lagena apiculata*, *L. marginata*, *Polymorphina oblonga*, *Uvigerina pygmæa*, *Globigerina bulloides*, *G. inflata*, *Truncatulina lobatula*, *Nonionina depressula*, *N. stelligera*, and *Polystomella crispa*.

The Ostracoda here recorded are almost peculiarly a southern oceanic fauna; a marked exception is *Cytherura rudis*, already known from Spitzbergen, Greenland, and other localities in the Far North. One or two species, however, have a somewhat extensive range, as will be seen on referring to the distributional notes with each species.
Of the bipolar species of Foraminifera, *Saccammina sphærica* is perhaps the most interesting, since it has been almost exclusively obtained from stations in high latitudes, and only twice in low latitudes, in the North Pacific and South Atlantic, both in deep water. In this, as in other species of bipolar Foraminifera, the following fact is clearly brought out: that these tiny organisms, born and bred in the richer, shallow mud-zones of high latitudes, sink into deeper water areas when spreading out through the tropical and inter-tropical seas, and again graduate into shallower marine conditions as they approach the polar regions. The shallow-water foraminiferal fauna of warmer latitudes, on the other hand, show, broadly speaking, a restricted field. In the two recorded occurrences of *Saccammina sphærica* in inter-tropical seas, it will be noticed that the stations are both situated in main axes of abyssal troughs trending north and south.

The existence of a selective instinct implanted in the Foraminifera is here given further proof in the case of *Reophax spiculifera*; for, although living side by side with *R. dentaliniformis*, a form whose test is an agglutination of comparatively coarse, angular sand grains, it rejects this material in favour of short, siliceous sponge spicules, with which awkward material it constructs fairly neat, long, funnel-shaped chambers, resembling in shape the straw covers of wine bottles.

In the following Table of Bathymetrical Distribution, it will be seen how remarkable a feature is the segregation of many species of Foraminifera within a bathymetrical zone or series of depths within certain limits. This peculiarity of the fauna may, of course, be largely induced by the nature of the sea bottom in supplying suitable food and building material.

LIST OF FORAMINIFERA AND OSTRACODA FROM THE ANTARCTIC SOUNDINGS (S.Y. *NIMROD*)

Species	Bathymetrical Distribution in Fathoms													
	110	113	121	153	171	225	353	360	372	460	462	472	655	Page
FORMINIFERA														
Biloculina depressa, d'Orb. .		X												57
,, *elongata*, d'Orb .		X	X	X	X									57
,, *bradii*, Schl. . .	X													57
,, *irregularis*, d'Orb. .					X		X							57
Spiroloculina canaliculata, d'Orb.							X							57
Miliolina subrotunda, Mont. sp., var. *striata*, var. nov.							X							58
,, *vulgaris*, d'Orb. sp. .							X							58
,, *bicornis*, W. & J. sp. .							X							58
,, *agglutinans*, d'Orb. sp.						X		X		X	X	X		58
,, *oblonga*, Mont. sp., var. *arenacea*, var. nov.									X		X	X	X	59
,, *tricarinata*, d'Orb. sp.			X				X							59
Planispirina sphæra, d'Orb. sp.			X	X										59
,, *bucculenta*, Brady			X											60
Cornuspira involvens, Rss. sp. .			X	X										60
,, *foliacea*, Phil. sp. .			X				X							60
Pelosina cylindrica, Brady .			X		X	X		X						60
,, *rotundata*, Brady .	X													60
Saccammina sphærica, Sars .			X	X	X									61
Hyperammina elongata, Brady .						X		X						61
Marsipella elongata, Norman .							X							61
,, *cylindrica*, Brady .												X		62
Reophax spiculifera, Brady .										X		X	X	62
,, *dentaliniformis*, Brady				X	X	X		X			X	X	X	63
,, *longiscatiformis*, sp. nov.								X			X			63
,, *murrayana*, sp. nov. .						X								63
Haplophragmium canariense, d'Orb. sp. .			X	X	X	X					X	X		63
,, *latidorsatum*, Born. sp. .								X		X		X		64
,, *scitulum*, Brady .											X			64
Valvulina fusca, Will. sp. .					X									64
Virgulina schreibersiana, Cz. sp.			X											65
Bolivina textilarioides, Rss. .			X											65
Cassidulina oblonga, Rss. .	X	X	X	X	X									65
,, *parkeriana*, Brady .	X	X	X	X	X									65
,, *subglobosa*, Brady .	X	X	X	X	X	X	X							65
Ehrenbergina serrata, Rss. .			X	X	X									65
Lagena globosa, Mont. sp. .			X				X							66
,, *apiculata*, Rss. sp. .			X											66
,, *schlichti*, Silv. . .			X	X	X									66
,, *marginata*, W. & B. .			X	X										66
,, *orbignyana*, Seg. sp. .			X	X										66
Nodosaria (*G.*) *lævigata*, d'Orb.			X	X										67
,, (*G.*) *rotundata*, Rss. .	X		X	X										67
,, (*D.*) *communis*, d'Orb.				X										67

LIST OF FORAMINIFERA AND OSTRACODA FROM THE ANTARCTIC SOUNDINGS (*continued*)

Species	Bathymetrical Distribution in Fathoms													
	110	113	121	153	171	225	353	360	372	460	462	472	655	Page
Foraminifera—*cont.*														
Cristellaria crepidula, F. & M. sp.			X	X										67
,, *articulata*, Rss. .				X										67
Polymorphina oblonga, d'Orb. .					X									67
Uvigerina pygmæa, d'Orb. .							X							68
,, *angulosa*, Will. .	X	X	X	X	X									68
Globigerina bulloides, d'Orb. .			X				X							68
,, *triloba*, Rss. . .									X					68
,, *inflata*, d'Orb. .							X							69
,, *dutertrei*, d'Orb. .			X	X										69
,, *æquilateralis*, Brady							X							69
Pullenia quinqueloba, Rss. .			X	X										69
Truncatulina refulgens, Mont. sp. . . .	X	X	X	X	X									69
,, *lobatula*, W. & J. sp. . . .		X	X	X	X									69
,, *tenera*, Brady .							X							70
Anomalina ammonoides, Rss. sp.			X				X							70
,, *polymorpha*, Costa .							X							70
Pulvinulina elegans, var. *partschiana*, d'Orb. var. . .							X							70
Nonionina depressula, W. & J. sp.			X	X										70
,, *stelligera*, d'Orb. .			X											71
,, *scapha*, F. & M. sp., var. *bradii*, var. n.			X											71
Polystomella crispa, L. sp. .							X							71
Ostracoda														
(?) *Aglaia obtusata*, G.S.B. .			X											71
Pontocypris (?) *faba*, Rss. sp. .	X													71
Cythere foveolata, G.S.B. . .				X										72
,, *davisi*, sp. nov. . .			X			X								72
,, *quadriaculeata*, G.S.B. .				X										73
,, *normani*, G.S.B. . .				X										73
Xestoleberis variegata, G.S.B. .				X			X							73
,, *davidiana*, Chapm.			X	X										73
,, *setigera*, G.S.B. .			X	X	X									73
Cytherura obliqua, G.S.B. .				X										73
,, *rudis*, G.S.B. . .						X								74

EXPLANATION OF THE PLATES

PLATE I

FIGURE 1.—*Biloculina bradii*, Schlumberger. Sample No. 1, 110 fathoms. ×13.

FIGURE 2.—*Spiroloculina canaliculata*, d'Orbigny. Sample No. 8, 353 fathoms. × 26.

FIGURE 3.—*Miliolina subrotunda*, Montagu, sp., var. *striata*, var. nov. Sample No. 8, 353 fathoms. × 52.

FIGURE 4.—*M. vulgaris*, d'Orbigny, sp. Sample No. 8, 353 fathoms. × 26.

FIGURE 5.—*M. bicornis*, Walker and Jacob, sp. Sample No. 8, 353 fathoms. × 52.

FIGURE 6.—*M. agglutinans*, d'Orbigny, sp. Sample No. 9, 360 fathoms. × 52.

FIGURE 7.—*M. oblonga*, Montagu, sp., var. *arenacea*, var. nov. Sample No. 13, 462 fathoms. × 52.

FIGURE 8.—*Planispirina sphœra*, d'Orbigny, sp. Sample No. 4, 153 fathoms. ×26.

FIGURE 9.—*Cornuspira foliacea*, Philippi, sp. Sample No. 3, 121 fathoms. × 26.

PLATE II

FIGURE 10.—*Pelosina cylindrica*, Brady. Sample No. 3, 121 fathoms. × 10.

FIGURE 11.—*P. rotundata*, Brady. Sample No, 1, 110 fathoms. × 10.

FIGURE 12.—*Saccammina sphœrica*, M. Sars. Sample No. 3, 121 fathoms. ×20.

FIGURE 13.—*Hyperammina elongata*, Brady. Sample No. 9, 360 fathoms. × 35.

FIGURE 14.—*Marsipella elongata*, Norman. Sample No. 8, 353 fathoms. × 26.

FIGURE 15.—*M. cylindrica*, Brady. Sample No. 14, 472 fathoms. × 20.

PLATE III

FIGURE 16.—*Reophax spiculifera*, Brady. Sample No. 15, 655 fathoms. × 26.

FIGURE 17.—*R. dentaliniformis*, Brady. Sample No. 9, 360 fathoms. × 26.

FIGURE 18.—*R. longiscatiformis*, sp. nov. Sample No. 9, 360 fathoms. × 26.

FIGURE 19.—*R. murrayana*, sp. nov. Sample No. 7, 225 fathoms. × 26.

FIGURE 20.—*Haplophragmium canariense*, d'Orbigny, sp. Sample No. 3, 121 fathoms. × 26.

FIGURE 21.—*H. latidorsatum*, Bornemann, sp. Sample No. 14, 472 fathoms. × 26.

FIGURE 22.—*H. scitulum*, Brady. Sample No. 13, 462 fathoms. × 26.

FIGURE 23.—*Valvulina fusca*, Williamson, sp. : *a*, side view ; *b*, oral aspect. Sample No. 5, 171 fathoms. × 26.

FIGURE 24.—*Bolivina textilarioides*, Reuss. Sample No. 3, 121 fathoms. × 56.

PLATE IV

FIGURE 25.—*Lagena globosa*. Montagu, sp. Sample No. 8, 353 fathoms. × 52.

FIGURE 26.—*L. apiculata*, Reuss, sp. Sample No. 3, 121 fathoms. × 52.

FIGURE 27.—*L. schlichti*, A. Silvestri. Sample No. 3, 121 fathoms. × 52.

FIGURE 28.—*L. marginata*, Walker and Boys. Sample No. 3, 121 fathoms. × 52.

FIGURE 29.—*L. orbignyana*, Seguenza, sp. Sample No. 4, 153 fathoms. × 52.

FIGURE 30.—*Nodosaria* (*Dentalina*) *communis*, d'Orbigny. Sample No.4, 153 fathoms. × 52.

FIGURE 31.—*Polymorphina oblonga*, d'Orbigny. Sample No. 5, 171 fathoms. × 26.

FIGURE 32.—*Uvigerina pygmæa*, d'Orbigny. Sample No. 8, 353 fathoms. × 26.

FIGURE 33.—*Globerigina bulloides*, d'Orbigny. Sample No. 3, 121 fathoms. × 52.

FIGURE 34.—*G. triloba*, Reuss. Sample No. 10, 372 fathoms. × 52.

PLATE V

FIGURE 35.—*Globigerina inflata*, d'Orbigny. Sample No. 8, 353 fathoms. × 52.

FIGURE 36.—*G. dutertrei*, d'Orbigny. Sample No. 3, 121 fathoms. × 52.

FIGURE 37.—*G. æquilateralis*, Brady. Sample No. 8, 353 fathoms. × 52.

FIGURE 38.—*Truncatulina tenera*, Brady. Sample No. 8, 353 fathoms. × 52.

FIGURE 39.—*Anomalina ammonoides*, Reuss, sp. Sample No. 3, 121 fathoms. × 52.

FIGURE 40.—*Pulvinulina elegans*, var. *partschiana*, d'Orbigny, var. Sample No. 8, 353 fathoms. × 52.

FIGURE 41.—*Nonionina depressula*, Walker and Jacob, sp. Sample No. 3, 121 fathoms. × 52.

FIGURE 42.—*N. scapha*, Fichtel and Moll., sp., var. *bradii*, var. nov. Sample No. 3, 121 fathoms. × 52.

FIGURE 43.—*Polystomella crispa*, Linné, sp. Sample No. 8, 353 fathoms. × 52.

PLATE VI

FIGURE 44.—(?) *Aglaia obtusata*, G. S. Brady. Right valve. Sample No. 3, 121 fathoms. × 40.

FIGURE 45.—*Pontocypris* (?) *faba*, Reuss, sp. : *a*, right valve ; *b*, ventral aspect. Sample No. 1, 110 fathoms. × 26.

FIGURE 46.—*C. davisi*, sp. nov. : *a*, left valve ; *b*, ventral edge view ; *c*, posterior end view. Sample No. 3, 121 fathoms. × 26.

FIGURE 47.—*Cythere quadriaculeata*, G. S. Brady. Left valve. Sample No. 4, 153 fathoms. × 52.

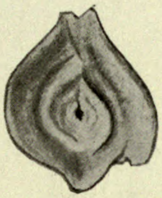
FIGURE 48.—*Xestoleberis variegata*, G. S. Brady. Left valve. Sample No. 4, 153 fathoms. × 52.

FIGURE 49.—*X. setigera*, G. S. Brady. Left valve. Sample No. 3, 121 fathoms. × 26.

FIGURE 50.—*Cytherura obliqua*, G. S. Brady. Left valve. Sample No. 4, 153 fathoms. × 42.

FIGURE 51.—*C. rudis*, G. S. Brady. Left valve. Sample No. 7, 225 fathoms. × 52.

PLATE I

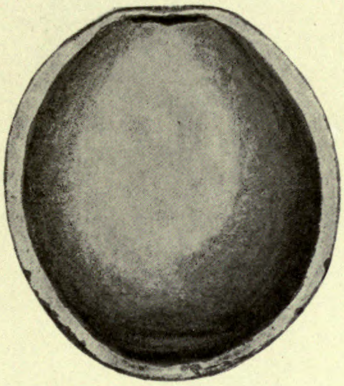


×26
FIG. 2

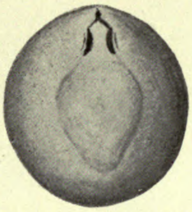
×52
FIG. 3

×26
FIG. 4

×52
FIG. 6.

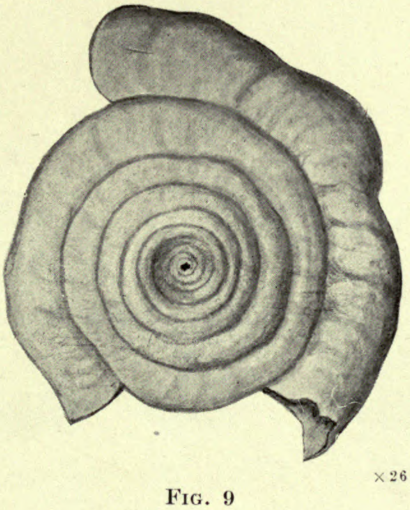


×13
FIG. 1



×26
FIG. 8

×52
FIG. 5



×26
FIG. 9

×52
FIG. 7

F.C. ad nat. del.

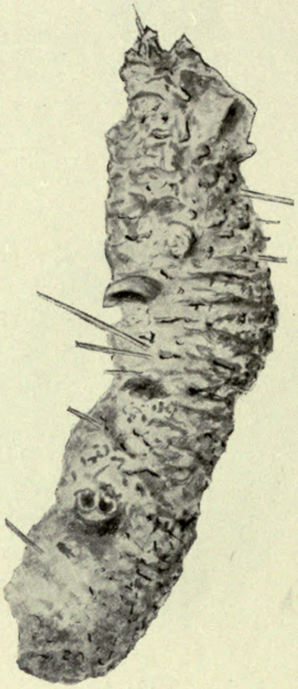
ANTARCTIC FORAMINIFERA.—S.Y. *NIMROD*, 1909

[*To face p.* 80

PLATE II

× 35

Fig. 13



× 10

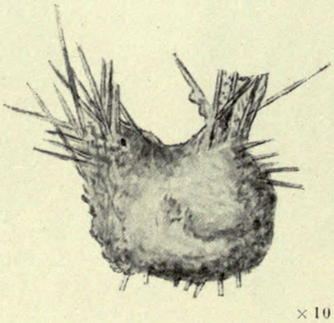
Fig. 10

× 20

Fig. 15

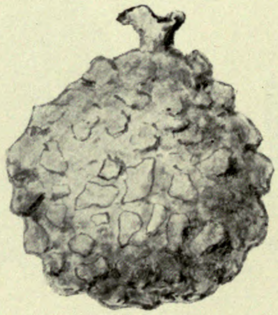
× 26

Fig. 14



× 10

Fig. 11



× 20

Fig. 12

F.C. ad nat. del.

ANTARCTIC FORAMINIFERA.—S.Y. *NIMROD*, 1909

PLATE III


×26
FIG. 16


×26
FIG. 17

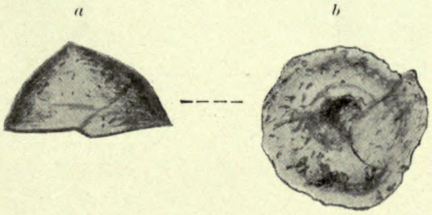

×26
FIG. 18


×26
FIG. 21


×26
FIG. 19


×26
FIG. 20


×26
FIG. 22



×26
FIG. 23

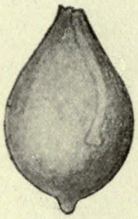

×56
FIG. 24

F.C. ad nat. del.

ANTARCTIC FORAMINIFERA.—S.Y. *NIMROD*, 1909

PLATE IV

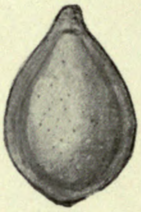
× 52
Fig. 25



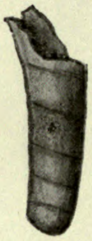
× 52
Fig. 26

× 52
Fig. 27

× 52
Fig. 29



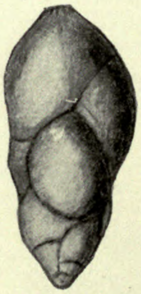
× 52
Fig. 28



× 52
Fig. 30

× 26
Fig. 32

× 52
Fig. 33



× 52
Fig. 31

× 52
Fig. 34

F.C. ad nat. del.

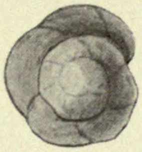
ANTARCTIC FORAMINIFERA.—S.Y. *NIMROD*, 1909

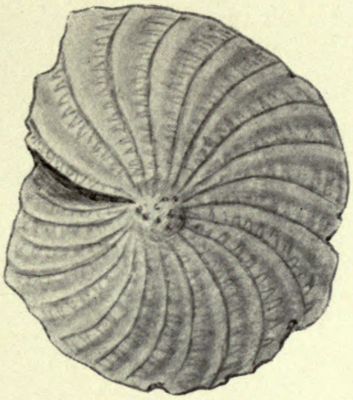
PLATE V


×52
Fig. 36


×52
Fig. 35

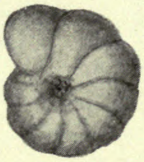

×52
Fig. 37


×52
Fig. 38


×52
Fig. 43


×52
Fig. 39


×52
Fig. 40


×52
Fig. 41


×52
Fig. 42

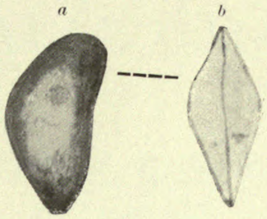
F.C. ad nat. del.

ANTARCTIC FORAMINIFERA.—S.Y. *NIMROD*, 1909

PLATE VI

×40

Fig. 44

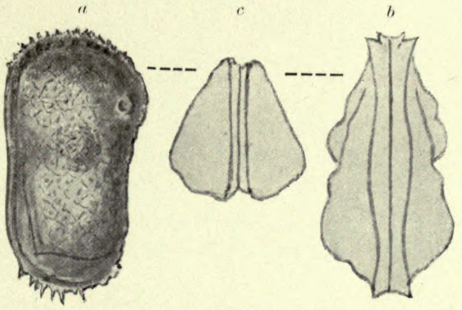


×26

Fig. 45

×52

Fig. 47



×26

Fig. 46

×52

Fig. 48

×42

Fig. 50

×52

Fig. 51

×26

Fig. 49

F.C. ad nat. del.

ANTARCTIC OSTRACODA.—S.Y. *NIMROD*, 1909

PART IV

REPORT ON A PROBABLE CALCAREOUS ALGA

FROM THE CAMBRIAN LIMESTONE BRECCIA FOUND IN ANTARCTICA AT 85° S.

(*With Plate*)

BY

FREDERICK CHAPMAN, A.L.S., F.R.M.S.

Palæontologist to the National Museum, Melbourne

INTRODUCTORY

SEVERAL distinct types of fossil remains in Cambrian limestone from various parts of the world have been referred, and probably rightly so, to the calcareous algæ. Notably amongst these are *Confervites primordialis* of Bornemann* (from Sardinia), also recorded by Von Toll† (from Siberia); *Epiphyton flabellatum*, Bornemann‡ (from Sardinia); and *Siphonema* [= *Girvanella*] *incrustans* § and (?) *arenaceum*, Bornemann || (from Sardinia).

The genus *Confervites* above mentioned has generally been made a dumping-ground for all organisms resembling modern seaweeds having a simple or branching thread-like thallus. It seems tolerably certain that many of these simple seaweed-like forms, to whatever botanical group they may belong, existed in prodigious abundance in the earliest known rocks; the evidence being strengthened by the fact that a large number of these forms cannot be referred to trails, stains, or cracks in the sediments, nor do they come within the definition of any group of animal organisms. Regarding *Confervites*, Seward ¶ remarks: "Numerous fossils have been referred to this genus by different authors, but they are for the most part valueless and need not be further considered." That author subsequently says (p. 178): "It is possible that this [*Confervites Chantransioides* of Bornemann] is a fragment of a Cambrian alga, but the figures and description do not afford by any means convincing evidence."

The present specimens form a considerable proportion of the limestone. They

---

* "Die Versteinerungen des cambrischen Schichtensystems der Insel Sardinien," *Kais. Leop.-Carol Deutsche Akad. Naturforscher*, vol. li, 1887, p. 16, pl. ii, figs. 5, 6.

† "Beiträge zur Kenntniss des sibirischen Cambrium, Pt. I," *Mem. Acad. Imp. Sci. St. Petersb.*, Ser. VIII, vol. viii, No. 10, 1899, p. 47, pl. viii, figs. 1c, d, text fig. 9.

‡ Bornemann, *loc. supra cit.*, p. 16, pl. i, figs. 9, 10.

§ *Idem, loc. cit.*, p. 18, pl. ii, figs. 1, 2. *See also* Chapman, *Rep. Aust. Assoc. Adv. Sci. Adelaide Meeting*, 1907, p. 7 (sep. copy), foot-note *j*, where it is stated that Bornemann's species is synonymous with *Girvanella problematica*, Nich. and Eth. fil.

|| *Idem, loc. cit.*, p. 19, pl. ii, fig. 3.

¶ *Fossil Plants*, vol. i, Cambridge, 1898, p. 177.

show a marked feature of growth as a living organism, since they appear normally attached to shell fragments and what seem to be the remains of crinoid ossicles. They possess a distinct wall to each thread-like cell, and the character of the wall is such that it could not possibly have resulted from infiltration. These tubular and tufty organisms occur in a series of slides cut from the pebble of a limestone breccia containing *Archæocyathinæ*, and are closely related to the before-mentioned *Epiphyton flabellatum*, Born. These specimens also bear some resemblance to Von Toll's figure of *Confervites primordialis* (*loc. supra cit.*), but there the (?) thallus is not distinctly spreading in radial fashion, the tubular structure being more or less parallel; in which feature it further differs from Bornemann's type figure. Von Toll's text figure of the Siberian organisms also shows a series of transverse connecting-rods which bind the thallus together, but which are absent in Bornemann's specimens, and are exhibited to a slight degree in the present examples.*

A very close resemblance exists between the present form and Bornemann's generic type, *Epiphyton*. In the species figured by that author (*E. flabellatum*) the thallus is fan-shaped and irregularly, alternately grouped to form comparatively large spreading masses. In the Antarctic species—which specimens, by the way, are all of smaller dimensions—the thallus is less complex, nearly always consisting of isolated tufts. It has a habit of nestling within or growing upon calcareous organisms similar to that of Bornemann's species.

The only other organism with which the genus *Epiphyton* could be reasonably compared is *Solenopora*; which has of late years been shown to have a strong claim to relationship with the calcareous algæ.† In fact, at first sight, it seemed nearest allied to that genus. In some features the two genera show certain resemblances, as in the fascicular grouping of thread-like cells and their division by sparsely distributed horizontal partitions; but the parallel or elongately radial character of the former affords a distinctive feature between the two kinds of organisms. *Solenopora*, moreover, never shows, so far as known, the short radial, fascicular habit of *Epiphyton*.

DESCRIPTION OF THE SPECIES

Genus—*Epiphyton*, Bornemann, 1887 (? *Confervites*, Von Toll, 1899)

Epiphyton fasciculatum, sp. n. (Plate I, Figs. 1–3)

Thallus fasciculate and fan-shaped; consisting of radial and branching tubes; often occurring in isolated tufts, but normally growing in alternate clusters of two or many more.‡ Tubes irregularly cylindrical, constricted at intervals and interrupted by more or less horizontal partitions, disposed in fan-shaped groups; the constrictions impart a digitate character to the thallus. Extremities of the tubes sometimes widening and bluntly truncated. Thallus often flat or subconvex at the base, owing to its habit of attaching itself to hollow surfaces; rounded or dome-shaped on the distal surface. A transverse section of the thallus shows it to be thick and radial in structure. Cells in cross-section massed, closely adpressed, subrounded to polygonal.

---

* It is probable that Von Toll's so-called *Confervites primordialis* is really referable to *Epiphyton*, and not to *Confervites*, considering the habit of growth shown in his pl. viii, figs. *c* and *d*, and his description that it grows in tufty masses on the *Archæocyathinæ* of the Cambrian limestone of Torgoschino.

† "On the Structure and Affinities of the Genus Solenopora," *Geol. Mag.*, Dec. 4, 1894, p. 145.

‡ The habit of growth makes it appear a microscopic facsimile of the Cambrian *Oldhamia antiqua*, Forbes.

Cell-walls of clear granular calcite ; interior infilled with a dark grey granular material. Where massed together the individual cell-walls can always be singled out by a dark line separating each tube.

Measurements.—Average height of thallus, single tufts, about 5 mm. Aggregated tufts about 4 mm., or even more, in diameter. Average width of cells, ·05 mm.

Observations.—The Sardinian species, *E. flabellatum*, shows the same general habit of growth as the Antarctic form, but the organism is of stronger and larger growth, the tubular cells are stouter, and the plan of dichotomy is different; since *E. fasciculatum* is characterised by the forked terminals of the cells being more slender and more regularly cylindrical than in *E. flabellatum*, whilst their extremities, seen in section, present a tuning-fork shape by the forked tips tending to become parallel.

The dimensions of *E. flabellatum* are in every way greater than in *E. fasciculatum*, as the following table will show :

Diameter of tubes . . .	*E. fasciculatum* . . .	0·05 mm.
	E. flabellatum . . .	0·08 mm.
Average length of tufts . .	*E. fasciculatum* . . .	0·5 mm.
	E. flabellatum . . .	0·7 mm.

Occurrence.—In a pebble of Cambrian limestone breccia, containing Archæocyathinoids, oolite grains, and ostracods. Obtained by Wild on the Southern journey, 85° S. An important organism, constituting a large proportion of the limestone.

Notes on the more important occurrences in the slides.—No. 2.—A good, typically thin section, showing some fine examples of *Epiphyton*, which exhibit the general characters (Paratype). No. 69.—Globular masses of the organisms, drifted into a recess. No. 111.—Good rounded masses, not so digitate as usual. No. 114.—Small flocculent masses of the organism. No. 115.—Finest example of *E. fasciculatum*, showing good detail (Type). No. 119.—Capitate specimen. No. 122.—Pellet-like masses, seen in a rather thick section.

EXPLANATION OF THE PLATE

FIGURE 1.—*Epiphyton fasciculatum,* sp. nov. Showing the fine ramified (?) thallus attached to a quadrate fragment, probably a crinoid ossicle. Paratype. Slide No. 2. × 28.

FIGURE 2.—*E. fasciculatum,* sp. nov. A group of the organism, showing well-preserved walls. Cut mainly in a transverse or oblique direction to the tubes. Type. Slide No. 115. × 28.

FIGURE 3.—*E. fasciculatum,* sp. nov. The same more highly magnified, showing the double structure of the cell-walls. Slide No. 115. × 180.

PLATE I

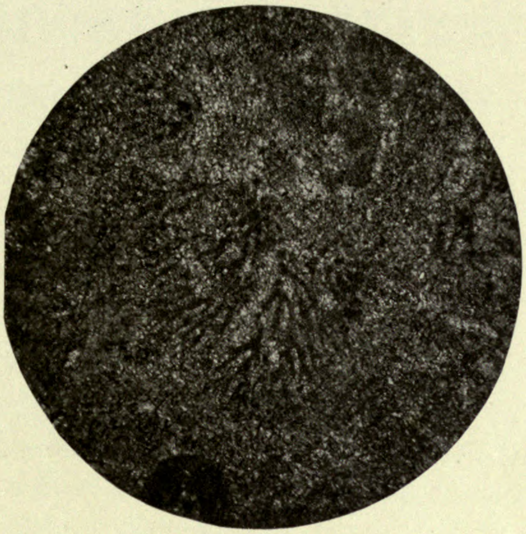


Fig. 1 × 28

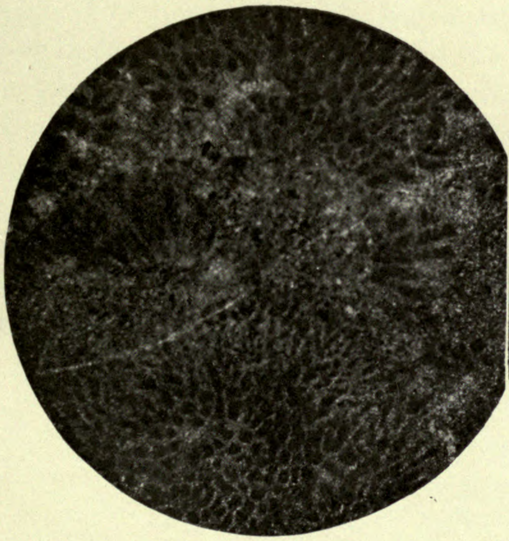


Fig. 2 × 28

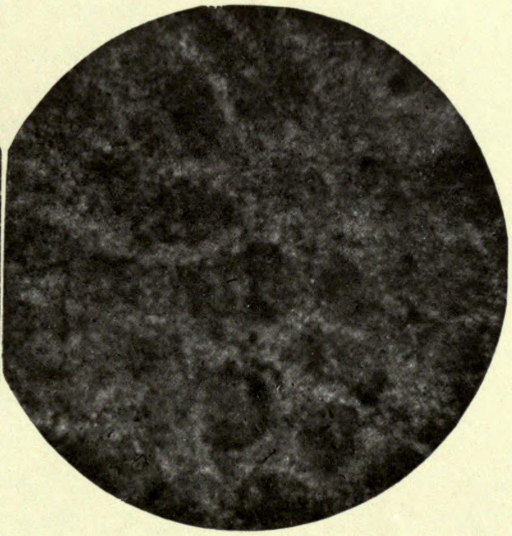


Fig. 3 × 180

F.C. photomicr.

Epiphyton fasciculatum, sp. nov. in Cambrian Limestone from Antarctica at 85° S.

[*To face p.* 84

PART V

REPORT ON MOLLUSCA
FROM ELEVATED MARINE BEDS, "RAISED BEACHES," OF McMURDO SOUND

(*With Three Figures in the Text*)

BY

CHARLES HEDLEY, F.L.S.*

From the mud of the "Raised Beach" Mr. R. E. Priestley carefully collected a large series of shells, mostly of small size. These specimens are so fresh and glossy that they appear to have come direct from the sea, rather than to be fossils. Probably the low temperature has assisted to save them from that decay which in a mild climate and a similar situation might have overtaken them. Still, it seems safe to assume that their geological age is of the slightest, and that all will ultimately be found to still exist in McMurdo Sound.

Comparing this collection with the shells dredged by the expedition, on which I have already reported, a difference is noticeable in the presence, absence, and relative abundance of various shells. The explanation may be that the "raised beach" was upheaved from a deeper horizon than the dredgings represent. Mr. Murray† has explained that shell beaches are not permitted by the ice to accumulate in the Antarctic. It follows that the deposit under examination is not a "beach" in the ordinary acceptance of the term.

Only the *Belgica* Expedition has hitherto collected *Scissurella euglypta*, Pelseneer,‡ which is therefore a gain to this hemisphere.

In the following list of these subfossil shells a star (*) indicates that it was recorded among the recent shells of the Expedition.

GASTEROPODA

Scissurella euglypta, Pelseneer.
**Valvatella refulgens*, Smith.
* *crebrilirulata*, Smith.
minutissima, Smith.

---

* This paper was written in October 1910 and proofs sent to the writer in January 1916. During five years' editorial custody, the conchological nomenclature has been extensively revised, so that to bring the article up to date it would be necessary to restudy the subject and rewrite the article. Only ordinary press corrections have been made.—C. H.

† Murray, *ante*, vol. i, "Biology," 1909, p. 2.

‡ Pelseneer, *Moll. "Belgica" Exped.*, 1903, p. 17, ff. 43–45.

Lacuna macmurdensio, Hedley.
*_Rissoa adarensis_, Smith.
* _fraudulenta_, Smith.
* _glacialis_, Smith.
deserta, Smith.
* _gelida_, Smith.
sp.
*_Capulus subcompressus_, Pelseneer.
*_Lovenella austrina_, Hedley.
* _antarctica_, Smith.
*_Vermicularia murrayi_, Hedley.
Turbonilla polaris, Hedley.
Eulima convexa, Smith.
*_Thesbia innocens_, Smith.
*_Trophon longstaffi_; Smith.
Trophon priestleyi, Hedley.
*_Odostomiopsis major_, Hedley.
Retusa frigida, Hedley.

Lamellibranchiata

*_Adacnarca nitens_, Pelseneer.
*_Philobrya limoides_, Smith.
*_Pecten colbecki_, Smith.
*_Lima hodgsoni_, Smith.
*_Thracia meridionalis_, Smith.
*_Cardita astartoides_, Martens.
*_Kellya nimrodiana_, Hedley.
Tellimya antarctica, Smith.

The novelties are described as follows :

Turbonilla polaris, sp. nov. (Fig. 1)

Shell long and slender, constricted between the whorls. Adult whorls eight, well rounded. Protoconch glassy, not immersed, of one and a half whorls at right angles to the adult shell, its length slightly exceeding the breadth of the subsequent whorl. Sculpture : smooth, vertical, round-backed ribs, parted by smooth and rounded furrows of equal breadth ; on the last whorl these amount to twenty. A strong basal keel receives and ends these vertical ribs ; its upper edge is visible above the suture on the spire. Base smooth. Aperture rhomboid, columella straight. Length, 3·75 ; breadth, 1 mm.

A single specimen, slightly fractured at the aperture, which may not be adult. The genus had not previously been traced so far south.

Trophon priestleyi, sp. nov. (Fig. 2)

Shell small, very solid, narrowly fusiform. Whorls five, including a smooth pointed protoconch of a whorl and a half, suture marked by a narrow groove. Sculpture: there are two prominent keels on the periphery, another much smaller just above the sutural groove, and another small one on the shoulder; these reach the outer edge of the lip. On the base of the last whorl are three more spirals, successively diminishing anteriorly. These keels have thin, pinched, rather wavy edges, and are separated by shallow furrows twice or thrice their breadth. Both keels and interspaces are overridden by fine radiating threads. Aperture ovate, outer lip bevelled within, inner lip slightly excavated. Canal short, broad, and slightly recurved. Length, 5·5; breadth, 2·8 mm.

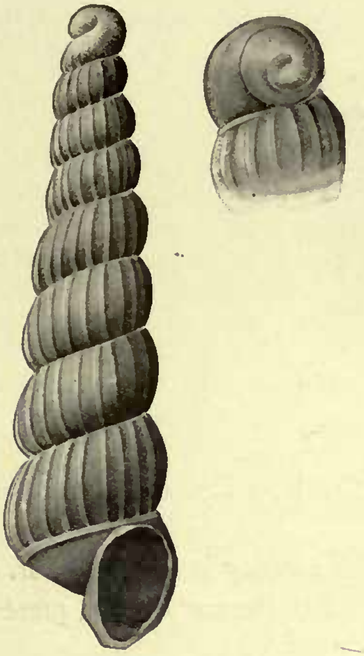


FIG. 1

FIG. 2

One entire specimen and a few fragments. It is unusual in *Trophon* for the radial sculpture to be subordinate to the spiral. Such forms as *T. petterdi*, Crosse, and *T. plebius*, Hutton, form a passage to the present form. I presume that *Sipho antarctidis*, Pelseneer,* is related to the species now introduced.

* Pelseneer, *Moll. "Belgica" Exped.* 1903, p. 22, f. 60.

Retusa frigida, sp. nov. (Fig. 3)

Shell small, oval, slightly contracted at the waist, rounded below, gradate above. Whorls three, the earlier prominent, with a half-turned-over tip. Suture deeply furrowed. Surface glossy, smooth, except some almost imperceptible spiral grooves on the shoulder. Aperture large, pyriform more than two-thirds the total length of the shell, rounded in front, narrowly arched posteriorly. Outer lip advanced and sinuate medially, inner lip slightly curled over the long and deep umbilical furrow. Length, 2·25; breadth, 1·25 mm.

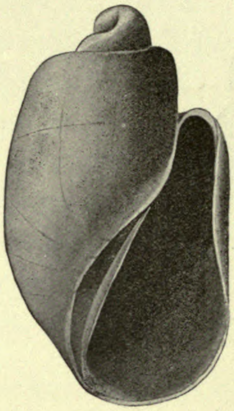


FIG. 3

One whole and another broken specimen. The novelty is nearest to *R. antarctica*, Pfeffer,* from South Georgia, from which the axial furrow of the present species clearly distinguishes it.

---

* *Jahrb. wiss. Anst. Hamburg*, III, 1886, p. 189, pl. 3, f. 5.

PART VI

REPORT ON ANTARCTIC SOILS

BY

H. I. JENSEN, D.Sc.

THESE Antarctic soils, forwarded by Dr. Douglas Mawson, were submitted to me in my official capacity as Assistant to the Chemical Branch of the Department of Agriculture, New South Wales, by my chief, Mr. F. B. Guthrie, F.C.S. Dr. Mawson supplied the following introductory note in explanation :

INTRODUCTORY NOTE

" These four samples of ' soils ' were the nearest approach to true soil afforded by the region of South Victoria Land visited by us. The first three samples were collected by myself, the last one by Mr. R. E. Priestley.

" Numbers 1 and 2 were got from the bottom of a slight depression, some seventy feet above sea-level, a quarter of a mile north-east of the Hut at Cape Royds. At that spot, before reaching the coarse gravels and kenyte lava below, there is about a foot of what might be called soil. The actual surface was mantled with a thin layer of very uniform gravel of particles about one-eighth of an inch in diameter. The gravel is the residue left after the wind has carried off the finer stuff. It appears that after the gravel has accumulated to a depth of about a quarter of an inch the fine material below is protected from further deflation. Samples 1 and 2 were from the same spot, the former representing layers several inches below the latter.

" Sample 3 came from a moraine mound two hundred yards nearer Blue Lake.

" Sample 4 was collected by Priestley on the mainland of South Victoria Land, in Dry Valley, on the western side of McMurdo Sound.

" In no case was there anything in the nature of subsoil in the general acceptation of the term.

" Earth is quite a rare occurrence in South Victoria Land, for almost everywhere that ice is absent, rock alone is met. Generally speaking, the earthy matter is only rock-flour from ice abrasion ; thus mechanical disintegration is the rule. At the same time there appears to be some chemical decay. It would appear that when depositions of rock-flour have been exposed for long, that an appreciable amount of chemical decomposition is effected.

" Referring to the water-soluble constituents of these soils, however, it is to be remembered that the coastal regions are likely to be impregnated with sea salts in the manner detailed in other sections of this volume.

" Some wheat was sown in a potful of a mixture of Nos. 1 and 2 of the described samples.* In this experiment the wheat germinated earlier than usual and showed unusual vigour and growth, demonstrating the suitability of the soil as a plant food.

" More than usual interest attaches to the examination of these soils, coming as they do from a land where practically no vegetation exists."

GENERAL ANALYSIS

These " soils " proved of great interest, and the results of the analyses are given in the Tables A and B.

---

* Experiment conducted at Adelaide.

GENERAL NATURE OF THE SAMPLES

NUMBER 1. Black soil; mechanically a light loam. Largely derived from kenyte lava, the prevailing rock of the neighbourhood. From a position six inches below the surface at Cape Royds, Ross Island, Antarctica.

NUMBER 2. Dark soil; mechanically a very sandy loam. Largely derived from kenyte lava, the prevailing rock of the neighbourhood, but with some admixture of ice-carried morainic mud. Taken between the surface and a depth of three inches, but not including the half-inch of surface gravel; Cape Royds.

The water-soluble constituents form little acicular crystals in the soil, and are probably combined in the form of chlorides of sodium, potassium, and magnesium; sulphates of magnesium, calcium, and potash; and carbonate of soda.

NUMBER 3. Black soil; mechanically a very sandy, gravelly loam. Partly derived from kenyte lava and partly from morainic matter. From between one and four inches below the surface, on the top of a moraine mound, Cape Royds.

NUMBER 4. Light-coloured irregular and indefinite soil. Moraine silt derived largely from Gneisses and Schists. From Dry Valley, South Victoria Land.

TABLE A. MECHANICAL ANALYSES OF ANTARCTIC SOILS

Number	Water Capacity	Absolute weight lbs. per acre 6 in. deep	Capillary power (inches in 4 hours)	Root Fibres	Stones over $\frac{1}{4}$ in. diam.	Coarse Gravel over $\frac{1}{10}$ in. diam.	Fine Gravel over $\frac{1}{50}$ in. diam.	Sand	Clay*
	%	lbs.	inches			%	%	%	%
1	25 (low)	1,866,853	over 9 (excellent)	nil	nil	20·7	22·1	20·5	36·7
2	25 (low)	1,798,965	over 9 (excellent)	nil	nil	23·3	38·6	16·8	21·3
3	28 (low)	2,040,000	over 9 (excellent)	nil	nil	30·3	45·8	15·4	8·5
4	35 (fair)	n.d.	5 (good)	Sample insufficient					

COMMENTS

In the table on p. 92 I have compared the above with

(*a*) a soil derived from alkaline lavas at Mittagong, N.S.W.;
(*b*) a soil derived from basalt, Tweed Heads, Queensland; and
(*c*) a granite soil from the south coast (Moruya, N.S.W.).

From this table (p. 92) it appears that in spite of the abundant moisture from melting snows the leaching out of mineral plant food does not take place with anything like the rapidity of this process in moist soils of less frigid climate.

Rock weathering in Antarctica is much more a process of mechanical disintegration than of chemical change into a normal soil. Zeolitic minerals form by slow hydration; carbonates also form very slowly, but the solution and removal of these acid soluble minerals are much slower processes than their formation. So these minerals accumulate in the sand grains without being leached away and thus breaking up the grains into finer particles.

---

* Impalpable matter, chiefly clay.

TABLE B. CHEMICAL ANALYSIS* OF ANTARCTIC SOILS

No.	Reaction	Moisture	Volatile	Nitrogen	Ammonia	Lime†	Potash†	Phosphoric† Acid	Remarks
		%	%	%	%	%	%	%	%
1	Strongly alkaline	2·13	2·09	·028	·040	1·080 (excellent)	3·293 (excellent)	·554 (very good)	*Water soluble* Chlorine (Cl) . . . ·75 = 1·21% common salt (NaCl) Sulphuric anhydride (SO_3) . ·052 Lime (CaO) . . . trace Magnesia (MgO) . . . ·171 Potash (K_2O) . . . ·156
2	Strongly alkaline	3·28	3·27	·028	·040	1·033 (excellent)	2·703 (excellent)	·394 (good)	*Water soluble* Chlorine (Cl) . . . 1·052 = 1·699% common salt (NaCl) Sulphuric anhydride (SO_3) . ·146 Lime (CaO) . . . ·015 Magnesia (MgO) . . . ·227 Soda (Na_2O) . . . 1·010 Potash (K_2O) . . . ·128 Humus . . . nil Total solids . . . 2·333
3	Strongly alkaline	3·68	3·50	·028	·040	1·520 (excellent)	3·220 (excellent)	·650 (very good)	*Water soluble* Chlorine (Cl) . . . ·628 = 1·01 5% common salt (NaCl) Sulphuric anhydride (SO_3) . ·079 Lime (CaO) . . . trace Magnesia (MgO) . . . ·086 Potash (K_2O) . . . ·606
4	Strongly alkaline	1·29	1·62	·028	·040	1·907 (excellent)	·765 (excellent)	·313 (good)	*Water soluble* Chlorine (Cl) . . . ·179 = ·290% common salt (NaCl) Sulphuric anhydride (SO_3) . ·044 Lime (CaO) . . . trace Magnesia (MgO) . . . trace Potash (K_2O) . . . ·081

---

* Analysis of the fine soil.

† Constituents soluble in hydrochloric acid, specific gravity 1·1.

	No. 1 (Cape Royds)	No. 2 (Cape Royds)	No. 3 (Cape Royds)	No. 4 (Dry Valley Antarctica)	A Alkaline lava (Mittagong)	B Basalt (Tweed Heads)	C Granite (SouthCoast)
Reaction . .	Strongly alkaline	Strongly alkaline	Strongly alkaline	Strongly alkaline	Alkaline	Very strongly acid	Acid
Water capacity .	25% (low)	25% (low)	28% (low)	35% (fair)	50%	64% (high)	33% (low)
Capillary power .	Over 9″ (excellent)	Over 9″ (excellent)	Over 9″ (excellent)	5″ (good)	—	5¾″ (good)	6″ (good)
Clay . . .	36·7%	21·3%	8·5%	—	43·0%	85%	24·2%
Moisture . .	2·13%	3·28%	3·68%	1·29%	1·75%	8·40%	1·32%
Volume . .	2·09%	3·27%	3·50%	1·62%	3·70%	18·99%	5·23%
N. . . .	·028% (def.)	·028% (def.)	·028% (def.)	·028% (def.)	·151% (good)	·392% (good)	·126% (satisfy.)
CaO . . .	1·08% (excellent)	1·033% (excellent)	1·50% (excellent)	1·907% (excellent)	·173% (satisfy.)	·162% (satisfy.)	·173% (satisfy.)
K_2O . . .	3·293% (excellent)	2·703% (excellent)	3·22% (excellent)	·765% (excellent)	·103% (satisfy.)	·029% (bad)	·047% (indif.)
P_2O_5 . . .	·554% (vy. good)	·394% (good)	·65% (vy. good)	·323% (good)	·058% (fair)	·102% (satisfy.)	·049% (indif.)

Rock weathering under normal conditions consists, first, of the mechanical disintegration of the rock into gravel and sand; next, the formation of veins of secondary minerals in veins within these grains; and, lastly, the solution of the secondary minerals in organic acids causing further disintegration.

Only the first two of these processes are of importance in Antarctic weathering. Consequently the accumulation of zeolites makes the soils appear chemically rich.

The cause of the absence of the third process lies in the absence of organic acids. Organic matter in these soils is remarkably low. This is due to dearth of plant life, the cause of which I propose to touch upon.

First, carbon dioxide is much lower in the air of frigid climates than in our climate. Secondly, the cold regions of the earth have no thunderstorms, hence the precipitation is not nitrified with nitric acid as in regions where thunderstorms are frequent. The discharges of the aurora are probably not intense enough to make nitrogen combine with oxygen. The want of the acids CO_2 and HNO_3 partly accounts for the small amount of leaching. The want of nitric acid, together with the coldness of the climate, account for the want of plant life, and hence of organic acids which would dissolve carbonates and zeolites. Nitrifying bacteria, which can produce nitric acid and ammonia from the air, cannot live in the cold, and plants do not thrive in the absence of nitrates.

The Antarctic soils are alkaline, which fact is due to the accumulation of salts, carbonates, and zeolites, and the absence of organic acids.

In two of the soils (1 and 2) crystals of Glauber's salt (*mirabilite*) existed in the dried soil. The soil water is probably charged with this salt, which may probably be derived from the decomposition of nosean in the alkaline lavas. Common salt is also abundantly present, and is in the soils examined partly derived from marine spray, but may partly be formed by the decomposition of sodalite.

The small percentage of nitrogen obtained in each estimation probably exists in the form of ammonia salt from wind-blown penguin guano, or droppings from skua gulls.

PART VII

REPORT ON THE PETROLOGY OF THE ALKALINE ROCKS OF MOUNT EREBUS, ANTARCTICA

(With Five Plates)

BY

H. I. JENSEN, D.Sc.

THROUGH the kindness and courtesy of Professor David, F.R.S., C.M.G., Sir Ernest Shackleton, and Mr. R. E. Priestley, F.G.S., of the South Pole Expedition of 1907–9, I have been able to examine and classify the alkaline eruptive rocks of Mount Erebus and Ross Island. In this work I have been greatly assisted by Mr. R. E. Priestley. He cut sections and made a preliminary examination of a much larger number of specimens of these rocks than I had time to devote attention to, and all the most important types which he discovered he transferred to me for further investigation and classification.

The eruptive rocks of Ross Island have microscopically, with very few exceptions, strongly alkaline affinities. The exceptions consist entirely of olivine basalt, which, though not an alkaline rock and commonly associated with calcic magmas, may yet be a differentiation product of an alkaline magma. The olivine basalts do, I understand, burst through the kenytes and other alkaline types, and are, where found, the final products of volcanic activity. The other basic rocks, poor in alkali, such as limburgite and magnetite basalt, are nevertheless types which are so commonly associated with alkaline magmas and so rarely with calcic magmas that they are generally looked upon as normal differentiation products of the former.

All the rocks dealt with in this part may be regarded as differentiates of a magma of the composition of intermediate kenytes. The origin of the kenyte itself is a more difficult problem.

In my paper on "The Distribution, Origin . . . of Alkaline Rocks,"[*] I infer from the sequence of Australian alkaline lavas that "basic lavas may rise along fractures and intrude themselves into the alkaline zone" of the earth's crust (for the supposed existence of which several reasons were put forward in the same paper). "Here they will assimilate alkali, and also help to bring about a refusion of the whole alkaline zone." In this paper therefore the origin of basic alkaline rocks is ascribed to stoping, assimilation, and solution of alkaline sedimentary and metamorphic rocks by a basaltic magma from the zone of basic igneous rock, which is supposed to underlie the whole of the earth's crust.

Reginald A. Daly, in a paper on "The Origin of Augite-Andesite . . ."[†] published

---

[*] *Proc. Linn. Soc. of N.S.W.*, vol. xxxiii, pt. iii, 1908.

[†] *Jour. of Geol.*, July–August 1908.

simultaneously with mine, ascribes most igneous magmas to assimilation of crustal rocks by an olivine basalt magma. According to these views olivine basalt is the primary magma. Through assimilation of alkaline sedimentaries of the earth's crust the kenyte mother magma has been formed. This, again, may produce olivine basalt by differentiation.

In a more recent paper, entitled "The Origin of Alkaline Rocks," * Professor Daly supposes these rocks to be differentiates from a normal basalt magma following interaction with limestones at a depth. This hypothesis seems a very probable one in theory, chemically, physically, and mineralogically sound, but unfortunately the field evidence in Australia lends it so far only little support. Yet I think it highly probable that many alkaline and subalkaline bodies have originated in this way, and others in the way I have suggested.

G. T. Prior has assigned the term "Atlantic type" to all rocks which might under the Rosenbusch classification be considered differentiates of a foyaitic magma. For reasons given in my paper on "The Distribution, Origin . . . of Alkaline Rocks," I prefer to call the type to which they belong "Katepeiric."

The lavas of Ross Island are in this report treated under the following headings:

1. Trachyte.
2. Acid Kenyte.
3. Intermediate to Basic Kenytes.
4. Trachydolerites (porphyritic basalts with alkaline affinities).
5. Leucitophyres, Tephrites, and Basanites.
6. Basalts without Olivine.
7. Olivine Basalts.
8. Limburgites. Magma Basalts.
9. Magnetic Basalts.

Generally speaking, this order of treatment is one of decreasing acidity and alkalinity, but a strictly natural arrangement is impossible, for the following reasons:

(*a*) The trachydolerite group passes insensibly into that of the limburgites and *vice versa.*

(*b*) Some of the tephrite-basanite group are more basic than the basalts with or without olivine.

(*c*) The limburgites have stronger affinities with the trachydolerites and basanites than with the basalts.

(*d*) The magnetite basalts sometimes have affinities with the kenytes.

The following schematic representation gives some idea of the relationships of these rocks as far as petrological investigation can decide (*vide* p. 95).

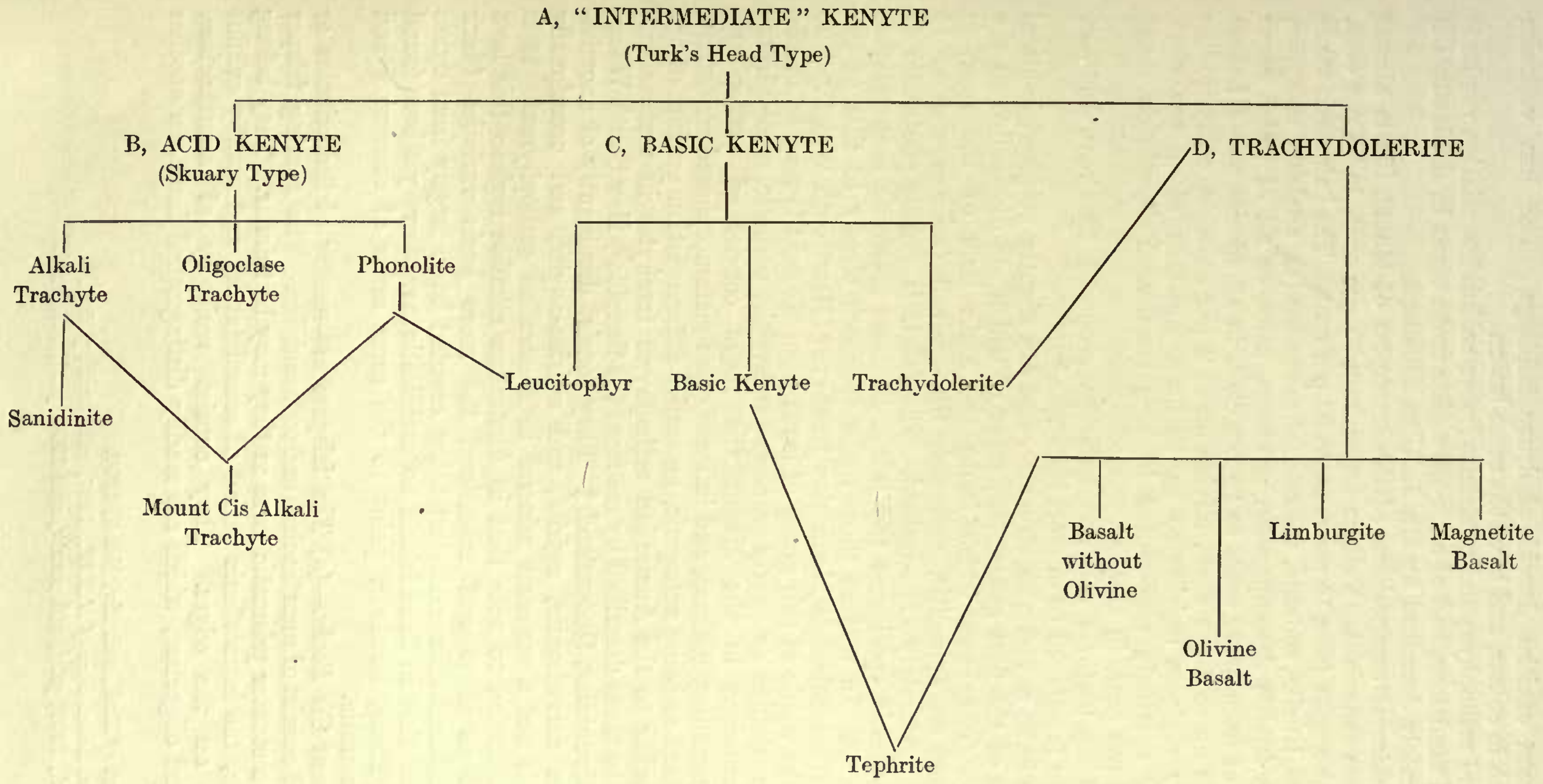
1. THE TRACHYTES

Localities.—Most of the trachytes which were collected came from a parasitic cone to which the name of Mount Cis has been given. Other trachytes were collected at Observation Hill, Hut Point, Mount Bird, Turk's Head, and a tuff cone on Ross Island. In miscellaneous collections of erratics from Cape Royds and other parts several trachytes were also contained.

(*a*) *Mount Cis Trachytes.*—Those from Mount Cis were the most typical trachytic rocks collected. They belong to the group of phonolitic trachytes. The dominant variety is a dark grey or greenish-black vesicular rock with a glistening sheen, at once suggesting the presence of an abundance of sanidine or anorthoclase. The

---

* *Bull. Geol. Soc. of America*, vol. xxi, May 1910.



A, Intermediate Kenyte (Turk's Head Type).

General characters : Moderately high TiO_2, much acid plagioclase and alkaline pyroxene, some olivine, and magnetite.

B, Acid Kenyte (Skuary Type).

Low TiO_2, much anorthoclase and pure alkali-pyroxene ; a little olivine and magnetite ; ground-mass as in trachyte.

C, Basic Kenyte (Turk's Head and Cape Barne).

High TiO_2, acid plagioclase felspar, titaniferous alkali-pyroxene, much olivine and magnetite ; ground-mass tephritic.

D, Trachydolerite (Mount Erebus, Cape Royds, etc.).

Very high TiO_2, acid to medium plagioclase, titaniferous augite, much olivine and magnetite, frequent apatite ground-mass as in basanitic basalt.

vesicles are empty steam cavities devoid of drusy infillings. The less vesicular varieties are dark greyish in colour, and have the same lustre.

Included fragments of orthophyre and sanidinite (more acid differentiation products of the same magma), of sandstone, and of older granulitic rocks occur in the Mount Cis lavas. These are separately described by Mr. J. Allan Thomson.

Composition.—The mineral composition of the trachytes of Mount Cis is almost the same in all specimens examined. Felspar forms from 60 per cent. to 75 per cent. of the mass, and ægirine-augite from 10 per cent. to 25 per cent. The balance is made up of olivine, magnetite, leucite, sodalite, interstitial nepheline (?), analcite, cossyrite, riebeckite, and various ferritic decomposition products, some or all of which occur together to the extent of from 5 per cent. to 10 per cent. in all specimens. Of these magnetite usually forms up to 5 per cent., olivine up to 2 per cent. A cossyrite-like hornblende occasionally replaces ægirine so as to form upwards of 5 per cent. Apatite is occasionally sparingly represented in long needles. Felspathoids range from 1 per cent. to 10 per cent. in amount.

Texture.—In describing textures the nomenclature proposed by Cross, Iddings, Pirsson, and Washington is adhered to in most instances.*

Most of these rocks have a vesicular structure, and are slightly porphyritic-hiatal with stray phenocrysts of the first generation, most of which are discernible to the naked eye (phaneric). The base, which forms the main bulk of the rock, is holocrystalline, or almost so, aphanitic, extremely fine-grained (microcrystalline to cryptocrystalline), and moderately even-grained. The fabric is usually pilotaxitic or trachytic. In the pilotaxitic specimens the fabric becomes trachytic near vesicles, inclusions, and xenocrysts. In texture these rocks approach closely to that of the phonolitic varieties of Warrumbungle Mountains trachyte † (New South Wales). The textural characters of the whole of this group of lavas from Mount Cis may be briefly expressed thus: holocrystalline or nearly so, megaporphyritic, perpatic, mediophyric.

Inclusions.—The inclusions in the Mount Cis rocks consist of orthophyre, sanidinites, pyroxene-granulites, diabase, and in some cases metamorphosed sandstone. The first type is important as being autogenic, an earlier differentiation product of the same magma; it is similar to the Australian orthophyric trachytes in texture and composition, especially to those described by me from the Canoblas, New South Wales, and the Glass House Mountains, Queensland.‡ They consist dominantly of anorthoclase with subordinate arfvedsonite, ægirite, and ægirine-augite, and occasionally a little olivine, which is not a common mineral in Australian orthophyres. It is interesting in this connection to note that in Australian alkaline regions this lava type was first erupted as plugs and mamelons, the more basic varieties (dark trachytes, phonolitic and andesitic trachytes) being erupted later, largely from dykes and fissures. It appears that in Ross Island no sanidinitic lavas have yet been found except as inclusions. These, however, point to the same order of succession and differentiation as in Australia.

Minerals of the Mount Cis Rocks.—(*a*) The felspars are mostly of the acicular or lath-formed habits, and consist of anorthoclase and sodasanidine. The sparing felspar phenocrysts may have a stouter prismatic form or they may be tabular. They belong to an earlier generation, the intratelluric period of consolidation, and usually exhibit corrosion phenomena on the edges. They consist variously of anorthoclase, sodasanidine, albite, and oligoclase, which are readily distinguished from one another

---

* *Jour. of Geol.*, vol. xiv, No. 8, 1906.

† *Proc. Linn. Soc. of N.S.W.*, 1907, vol. xxxii, p. 557.

‡ *Ibid.*, 1909, pt. i, vol. xxxiv, and 1906, pt. i, vol. xxxi.

by their characteristic properties, such as extinction angles, refractive indices, cleavage angles, and modes of twinning.

The microlites of the base, being of minute size, were not so readily identified, yet the following properties point to their being anorthoclase: the refractive index was but slightly below that of Canada Balsam, twinning was mainly on the Carlsbad plan, but shadowy extinction of the moirée type indicated the presence of ultramicroscopic polysynthetic twinning in some crystals, the sanidine cross cracking or parting was fairly common, cleavage almost rectangular, and extinction angles varied from 0° to 8° with the length of the laths.

(*b*) The pyroxenes consisted chiefly of ægirine-augite, though in some specimens true ægirine, and in others colourless diopside accompany the ægirine-augite. The ægirine-augite is of a greenish-yellow colour, and occurs in prismatic laths, needles, and grains. Often a group of crystals of this mineral is optically continuous, so that the pyroxene may be regarded as embracing the penetrating felspar needles ophitically. The ægirine-augite seems usually to have continued to crystallise out longer than the felspar. It commonly extinguishes at angles lying between 20° and 35°, and occurs in two generations, the earlier of which is usually less alkaline than the later.

Cossyrite-like amphiboles occur only sparingly in most specimens or not at all. They may be scattered about in grains or form ophitic aggregates of a deep coffee-brown colour, pleochroic from olivine-brown to deep brown opaque in sections across the length. In some slides these amphiboles show a deep purplish-blue absorption colour on rotating the stage, indicating affinities with riebeckite or some species of kataphorite. These hornblendes are seldom seen with any tendency to idiomorphism, though in one slide a few small idiomorphs were noticed. Often they form the nucleus of an ægirite growth or a fringe round magnetite. The cleavage when noticeable was at about 65°.

Riebeckite occurs only very rarely in deep blue ragged grains, sometimes fringing cossyrite-like amphibole, or forming the nucleus of ægirine-augite. Arfvedsonite is occasionally secondary after ægirine-augite (a uralitic decomposition product), occurring around the pyroxene (or replacing it) together with ferrite decomposition products.

Olivine occurs only sparingly, and only as phenocrysts, which belong to the intratelluric period of consolidation. The crystals are usually rounded grains and have been strongly resorbed at the edges by the magma. It can only be considered a rare or accessory constituent in these rocks.

Magnetite in idiomorphic grains is a common accessory in some of the slides, in others soda hornblendes take its place. It is not improbable that in some of the rocks the cubic and octahedral black isotropic grains provisionally identified as magnetite may be a black variety of perofskite, knopite, or geikielite.

Felspathoids are not uncommon, but only present in small amounts. Usually they are interstitial and were the last minerals to crystallise. In addition to filling smaller interstices these minerals may form larger patches into which felspar needles penetrate. The commonest felspathoids are sodalite and analcite.

Order of Consolidation.—There are two generations of minerals, each of which has its own order of crystallisation. In the first generation magnetite is formed first, for it occurs included even in the cores of olivine and pyroxene phenocrysts, and it finished crystallising before the others commenced to separate. The olivine came next, and is very corroded by the magma. Felspar followed, and was likewise strongly resorbed at the rim on reaching surface conditions, and the ægirine-augite probably formed at the same time.

As regards the second generation, magnetite and other accessories formed first, then felspar commenced and at the same time cossyrite. Riebeckite followed, and after that ægerite commenced to separate. Felspar then finished crystallising, after that ægirite, which partly is later than felspar. Lastly the felspathoids formed, and occur mainly in interstices as sodalite and analcite.

Chemical Composition.—Table I gives the analyses of pumice * from the top of Mount Erebus and of the trachyphonolite J. 13. For comparison the analyses are recorded of phonolitic trachyte, Cape Adare; phonolitic trachyte, Mount Terror (Cape Crozier); hornblende trachyte, Observation Hill; and trachyandesite from the Warrumbungle Mountains, New South Wales.

TABLE I.—ANALYSES OF TRACHYTIC ROCKS

Substance	A J. 13 Trachyte, Mt. Cis (Hogarth)	B Pumice, Mt. Erebus (Burrows and Walkom)	C Phonolitic Trachyte, Cape Adare (Schofield)	D Phonolitic Trachyte, Mt. Terror (Prior)	E Hornblende Trachyte, Observation Hill (Prior)	F Trachyandesite, Timor Ledges, Warrumbungle, Mts., N.S.W. (H. I. Jensen)	G Cumal Phlegrose, Cuma type (Washington)
SiO_2 . .	58·94	55·95	61·01	57·95	55·47	58·95	59·79
TiO_2 . .	1·40	0·98	—	0·40	1·32	0·76	0·56
Al_2O_3 . .	16·33	22·53	16·62	20·43	20·67	17·04	19·05
Fe_2O_3 . .	2·48	0·99	3·55	3·43	2·83	2·80	2·95
FeO . .	5·54	4·54	2·81	1·35	1·86	4·66	1·08
MnO . .	0·21	tr.	0·55	0·07	0·02	0·05	nd.
MgO . .	1·03	tr.	0·06	0·26	1·43	0·57	0·36
CaO . .	2·10	3·21	3·27	1·90	3·43	2·49	1·19
Na_2O . .	5·54	7·42	5·92	8·32	8·33	4·51	6·79
K_2O . .	5·25	3·97	5·22	5·96	4·86	6·39	7·10
H_2O (100°+) .	0·42	0·00	Loss on ignition 1·13	0·79	0·12	1·28	0·24
H_2O (100°−) .	0·44	—		0·23	0·08	0·59	—
P_2O_5 . .	0·57	0·02	—	0·07	0·03	abs.	0·10
CO_2 . . .	0·05	—	—	—	—	0·06	none
SO_3 . . .	0·16	—	—	—	—	tr.	none
ZrO_2 . .	0·22	—	—	—	—	0·17	—
NiO.CoO . .	—	—	—	—	—	0·01	—
BaO . .	—	—	—	—	—	abs.	—
SrO . . .	—	—	—	—	0·01	abs.	—
Li_2O . .	abs.	—	—	—	—	abs.	...
Cl . . .	—	—	—	—	—	tr.	0·53
Sum . .	100·68	99·61	100·14	101·16	100·46	100·33	99·74

In Table VI (p. 123) the magmatic names of the rocks are given.

It will be seen that the pumice from the summit of Erebus is closely allied in composition to the hornblende trachyte of Observation Hill, described by Prior.† Our specimen, J. 3 (1913), is almost identical with Prior's, so that his analysis probably represents the composition of J. 3. These rocks are closely allied on the one hand to the tephritic trachytes, as that of Farodada, Columbretes, described by Becke ‡ and

---

* The pumice analysed is the ground-mass of a very beautiful kenyte which forms the latest lava extravasation of the present active crater of Mount Erebus. Some specimens contain abundant, large, handsome, twinned crystals of anorthoclase.—D. M., Ed., 1916.

† *National Antarctic Expedition*, 1901–4, "Petrology."

‡ Tschermak's *Min. und Petr. Mitth.*, 1906–7, Bd. xvi, p. 174.

placed by Rosenbusch * in the Trachydolerite group. On the other hand, the presence of basalt hornblende, kaersuetite and high titania indicate affinities with the Kulaites. Though so closely allied in chemical composition the Erebus pumice and the Observation Hill trachytes are very different in appearance, the former being a hemicrystalline kenyte with huge anorthoclase phenocrysts, the latter an even-grained holocrystalline trachyte in which only hornblende occurs as phenocrysts. The Observation Hill trachytes are apparently kenytes in chemical composition, *cf.* Table I, B and E (p. 98) with Table II, A, B, and C (p. 110).

The Mount Cis trachyte, J. 13, is in mineral composition and microscopic structure similar to the phonolitic trachytes from Cape Adare and Cape Crozier, of which analyses are given for comparison. The first of these was described by David, Smeeth, and Schofield (*Proc. Roy. Soc. of N.S.W.*, 1895), and the latter by Prior (*op. cit.*). This rock type is also akin to the phonolitic trachytes of Dunedin, New Zealand, described by Marshall (*Q.J.G.S.*, vol. lxii, 1906), and the trachyandesites of the Warrumbungle Mountains. It will also be seen that Washington's Cumal Phlegrose is an almost identical rock.

The Mount Cis trachyte is in the American system of classification a monzonose, in which class the Warrumbungle trachyandesites also fall, but the margin between these rocks and the phlegroses is very slight. High titania and the presence of some zirconia are characteristic features of these rocks.

J. 1 (1911) is in hand-specimens a dark basalt-like rock, which nevertheless has a silky sheen that discloses its trachytic nature. Under the microscope it is seen to be porphyritic-hiatal in phaneric first generation phenocrysts and perpatic. The ground-mass is holomicrocrystalline and varies in fabric from true trachytic near the vesicles and inclusions to pilotaxitic away from them.

The sparing phenocrysts in this slide consist of green ægirine-augite and small nephelines, which in this rock type antedate the felspar. The nephelines are idiomorphs, and possess a low double refraction, a hexagonal cleavage and refractive index of 1·54. It appears that this rock prior to its extrusion has had many nepheline idiomorphs, most of which have changed to aggregates of sodalite and analcite. These masses preserve the outlines of nepheline, and hence are regarded as pseudomorphous after that mineral.

The ground-mass consists of lath-shaped felspar microlites with the properties of anorthoclase, and ægirite or acmite (both with straight extinction), which occur in hypidiomorphic prisms and allotriomorphic aggregates behaving ophitically to felspar. Magnetite occurs as an abundant minor constituent in allotriomorphic grains; brownish glass occurs as a minor interstitial substance; zircon needles occur sparingly in minute needles in the felspars and may be looked upon as an early consolidation product.

In addition there are a few grains of deep brownish-green arfvedsonite amphibole enveloping deep blue riebeckite grains. The latter are pleochroic from deep purplish-black to dark brownish-green in elongated sections, and has a cleavage of 55½°. Brown cossyrite-like hornblende seems also to be present in minute amount. Sometimes this occurs as a nucleus of ægirine. Its pleochroism ranges from bluish-green to greenish-brown in sections at right angles to the length of the grains.

The rock as described must be regarded as a phonolitic trachyte allied to Cumal Phlegrose (*see* Washington, *The Roman Comagmatic Region*, p. 27).

Plate I, figs. 1 and 2.

J. 13 (1922). This rock resembles J. 1 both in hand-specimen and under the microscope. It contains the same felspars together with ægirine-augite, ægirine,

---

* *Gesteinlehre*, zweite Auflage, p. 355.

soda-hornblendes, etc., occurring in the manner described in the previous slide. Some of the ægirite grains exhibit a tendency to uralitic alteration to arfvedsonite. The main point of difference between this slide and the previous lies in the fact that the former contains a considerable amount of colourless isotropic interstitial material which is quite amorphous and frequently studded with inclusions. This has the characteristics of nosean or sodalite, gelatinises with dilute acids and stains readily. The fabric of the rock is pilotaxitic, and the texture may be described in general terms as holocrystalline, megaporphyritic, perpatic, mediophyric. The specimen and slide bear close resemblance to some pseudoleucite and nosean trachyphonolites from the Warrumbungle Mountains. (For Analysis *see* Table I, A, p. 98.)

J. 27 (1936). In texture and composition this rock is very similar to J. 1 and J. 13. It differs mainly in containing sparing phenocrysts of olivine. The yellowish-green ægirine-augite behaves ophitically to the felspar and shows frequent decomposition to uralitic arfvedsonite and serpentine. Ferrite is also a common decomposition product. The dominant felspars show faint polysynthetic twinning in addition to Carlsbad twinning under the high power, and have an extinction angle of 8°, which shows them to be anorthoclase fairly rich in the oligoclase molecule. Several other specimens, J. 29 and J. 30, exhibit the same characteristics in micro-section.

J. 32 (1742). This is a similar rock in texture and composition. It contains a number of isotropic patches, penetrated by felspar laths in a stellate (divergent radial) manner, giving parts of the slide a strahlenkörnig structure. The patches seem to consist of sodalite. The inclusion in this specimen proved to be an olivine ægirine orthophyre or sanidinite. Another rock, J. 43, is similar. A little nepheline and minute interstitial crystals have also been identified in these rocks by staining methods.

All these typical Mount Cis rocks are dark and silky, vesicular, and slightly porphyritic as viewed megascopically. Under the microscope they preserved a texture described as holocrystalline or nearly so, megaporphyritic, perpatic, mediophyric, with a pilotaxitic to trachytic fabric. They contain usually a fair amount of felspathoid, which may exist as any of the minerals nepheline, nosean, or sodalite. They are therefore trachyphonolites or phonolitic trachytes, and are all closely allied to Washington's Cumal Phlegrose (see *The Roman Comagmatic Region*, also Table I, G, p. 98).

Other Trachytes.—Of these the most interesting types were:

J. 7 (1916). An oligoclase trachyte included in kenyte breccia from a parasitic cone on Mount Erebus.

Megascopic characters.—Light grey compact porphyritic rock; felspar phenocrysts about 2 mm. long of tabular and prismatic habit.

Microscopic characters (*see* Plate I, fig. 6).—Hypocrystalline, megaporphyritic to microporphyritic serial, dosemic; ground-mass about 30 per cent., consisting of anorthoclase, oligoclase, lilac augite, apatite, magnetite, other iron ores, nepheline, cancrinite, brown glass. The fabric is of a vitrophyric intersertal type, the phenocrysts consisting chiefly of megascopic, prismatic, and tabular oligoclase-andesine, and smaller microscopic anorthoclase and olivine crystals, both of which species vary in size from almost megascopic to the minute size of the nepheline augite and magnetite crystals of the base.

Oligoclase occurs chiefly as phenocrysts which are highly corroded and which show both optical and mechanical zoning. Twinning, Carlsbad, albite, and pericline. The refractive index is greater than that of Canada Balsam, and the extinction angles are those typical of oligoclase-andesine.

Anorthoclase.—Both as large and small microscopic phenocrysts with the characteristic shape of sanidine. This felspar is less corroded and not so commonly zoned. Its refractive index is less than Balsam, and the extinction angles agree with those of anorthoclase. The twinning is Carlsbad, and sometimes faint lamellar twinning accompanies it.

Augite.—This mineral is of a peculiar lilac or bistre colour, and has idiomorphic outlines. It usually extinguishes at from 38° to 45°. Corresponds closely with the bistre-coloured pyroxene described by J. Allan Thomson in an eclogite from Kakanui, New Zealand. (See *Geol. Mag.*, May 1907 ; Dec. 5, vol. iv.)

Nepheline.—Nepheline occurs as small idiomorphic crystals in the base. Secondary cancrinite also occurs sporadically scattered in patches throughout the rock. Other felspathoids also occur interstitially. Olivine exists as corroded phenocrysts only. Apatite and magnetite as small crystals in the base. Secondary iron ores constitute an important accessory. Brownish glass forms the balance of the rock.

J. 3 (1913). *Kaersuetite* (?), *Ægirine-augite Trachyte*, Observation Hill.—Megascopic characters.—Very fine-grained aphanitic rock of dark grey colour and containing reddish inclusions.

Microscopic characters.—Holocrystalline, even-grained pilotaxitic; consisting of lath-shaped and acicular felspars, brown hornblendes, green soda pyroxene, and a little opacite. Of these constituents the first two are partly microporphyritic serial, miniphyric.

The felspar laths have straight extinction and appear to be anorthoclase. Green pyroxene was last to crystallise; it occurs in grains and acicular prisms, which have an extinction angle of 34°. A brown amphibole, pleochroic in colours from dark reddish-brown to yellowish-brown, occurs as numerous scattered idiomorphic grains and also as clusters of grains (Plate I, figs. 3 and 4). These clusters represent the remains of almost completely assimilated fragments of a camptonitic rock, inclusions of which remain in the specimen. The brown camptonitic amphibole has the properties of kaersuetite, and this mineral has not been resorbed by the magma, but numerous grains and microphenocrysts of it lie scattered through the base together with opacite grains. (For Analysis *see* Table I, E, p. 98.)

J. 50 (1959). *Baked Alkali-trachyte*, Ross Island, Tuff Cone.—This specimen is a very weathered or baked rock of reddish colour and even grain-size. It has a microholocrystalline, pilotaxitic fabric and consists of anorthoclase, oligoclase-andesine, iron-stained ægirine-augites with an extinction of 35° in phenocrysts, (*see* Plate II, fig. 6), laths, and grains, magnetite and iron ores largely secondary, and interstitial felspathoids (nosean or sodalite).

J. 51 (997). *Anorthoclase Trachyte.* A compact grey specimen marked old lake deposit.—This is typical trachytic trachyte consisting mainly of anorthoclase which shows Carlsbad and Baveno twinning. The other minerals are interstitial rods of ægirine-augite (and its decomposition products, epidote, iron ores, etc.), and idiomorphic magnetite grains. The texture is best described as holomicrocrystalline, uneven, seriate, trachytic.

J. 62 (1961). *Anorthoclase Trachyte.* An erratic from Cape Royds.—This was very similar to J. 51. Megascopically, porphyritic-hiatal in felspars of the first generation. Microscopically, porphyritic-serial in felspar of the second generation, apparently a soda sanidine. The texture of the rock is holocrystalline, megaporphyritic, perpatic, mediophyric, with a pilotaxitic fabric in the ground-mass. The order of consolidation was, first magnetite, then felspar, lastly ægirine-augite.

J. 52 (1466). *Phonolitic Trachyte.* Another erratic from Cape Royds.—This rock is of an aphanitic appearance and vesicular in nature. It is porphyritic-hiatal, and has a hyalopilitic base approaching strahlenkörnig intersertal. It consists of anorthoclase, yellowish-green ægirine, and dendritic and pectinate aggregates of grains and rods of iron ore (both magnetite and hæmatite). Magnetite also occurs sparingly in scattered independent grains, and hæmatite as scales. The ægirine occurs sparingly as small phenocrysts of the first generation, and more abundantly as idiomorphic microlites, which are commonly bunched together in groups of parallel individuals. This pyroxene is decomposing to ferrite. Interstitially occurs a colourless glassy substance, probably of felspathoid composition (*see* Plate II, fig. 5).

J. 53 (1960). *Phonolitic Trachyte.* Erratic from Cape Royds.—This has a texture that may be described as microporphyritic-serial, dosemic, vitrophyric. The phenocrysts are equant and prismatic, consisting mainly of anorthoclase, but a fair number of smaller phenocrysts of pseudoleucite occur in the base. The pseudoleucites are polygonal or rounded, and consist of a mosaic of orthoclase and nepheline. Other similar pseudospherulitic aggregates seem to consist of natrolite and to be secondary after sodalite. The base is a greenish-brown glass, devitrifying with the production of cryptocrystalline characters. Hence this rock is phonolitic trachyte allied to leucitophyre.

J. 54 (1841). *Anorthoclase Trachyte.* Erratic from Ferrar Glacier.—This was megascopically an extremely fine grained bluish-grey rock with phaneric phenocrysts.

Microscopically it is holocrystalline, megaporphyritic-hiatal, perpatic, and magnocumulophyric (*see* Plate I, fig. 5). The phenocrysts of the first generation are in groups, and consist of anorthoclase crystals which may envelop subordinate ægirine, arfvedsonite, and olivine. The base is coarsely microcrystalline, consisting dominantly of an allotriomorphic granular mass of anorthoclase, the grains of which embrace microlites of albite and ægirite as inclusions, and have ægirine filling the interstices between them. The structure is similar to that noticed in a Fassifern (Queensland) Trachyte (*Proc. Linn. Soc. N.S.W.*, vol. xxxiv, March 1909). Evidently the cause of the peculiar fabric is that after the albite and ægirite had separated out a pasty glass of the composition of anorthoclase was left, and this devitrified in irregular crystal grains which embrace poikilitically the earlier form of minerals.

P. 254 (5830). *Biotite Hornblende Trachyte.* Erratic, Cape Royds.—The texture of this rock is porphyritic-serial.

The phenocrysts consist of biotite and idiomorphic prismatic hornblendes belonging to the normal brown variety, and also lath-shaped sanidine felspars. The base consists of sanidine, greenish needles of ægirine-augite, and sparingly magnetite scattered through the rock in idiomorphic grains.

J. 21 (1930). *Phonolitic Trachyte.* Inaccessible Island.—This is a reddish baked rock of hypocrystalline pilotaxitic texture. It contains large-zoned anorthoclase phenocrysts. The other minerals are zoned anorthoclases and albites with shadowy extinction due to strain, and Carlsbad, Baveno, and albite and Manebach twinning; pyroxene undergoing decomposition to ferrite and serpentine; magnetite and ilmenite; and much colourless isotropic glass (probably of analcite or nosean composition), and also a dark glass. The structure may be described as microporphyritic, sempatic to persemic in prismatic and equant phenocrysts.

J. 16 (1925). From the same locality.—This is a holocrystalline, microporphyritic-serial, persemic rock with pilotaxitic fabric. It consists of lath-shaped anorthoclase, with oligoclase, ægirine-augite, magnetite, and ferritic decomposition products.

J. 15 (1924). Also from Inaccessible Island.—This rock is very similarly constituted, but contains a few megaphyric corroded olivine crystals. The texture is hypocrystalline trachytic. The minerals are anorthoclase, oligoclase, olivine, and ægirine-augite, with a clear colourless isotropic base probably of felspathoid composition.

The trachytes from Inaccessible Island have in hand-specimen the appearance of aphanitic andesite, and in mineralogical composition too they form a transition phase between the trachyphonolites and augite andesites.

Remarks.—The felspars in all this miscellaneous series of trachyte greatly predominate in amount, forming always 80 per cent. or more of the total. Olivine is rare or absent; magnetite is not common; ægirine is the chief dark constituent.

It is of particular interest that two types of inclusions dominate in the trachyte, viz. sanidinite (orthophyre) in the phonolitic and orthoclase ægirine trachytes and camptonite in the oligoclase trachyte.

THE TRACHYDOLERITE AND KENYTE GROUP

The kenytes are usually considered to be a facies of trachydolerite. For the rocks of the Erebus series I prefer to create three groups of the trachydolerite family, viz. the Acid Kenytes, the Basic Kenytes, and the Trachydolerites proper, to be distinguished by the nature of the phenocrysts and ground-mass, thus:

Kenytes (Acid and Basic). *Phenocrysts*, anorthoclase (almond-shaped), ægirine.
Acid Kenytes. *Phenocrysts* of type; *ground-mass*, structure and composition of alkaline trachyte.
Basic Kenytes. *Phenocrysts* of type, also tabular oligoclase; *ground-mass*, structure and composition as in basic phonolites and tephrites.
Trachydolerites. *Phenocrysts*, titaniferous augite and olivine as in dolerite; *ground-mass*, structure and composition of tephritic and basanitic basalt.

The kenytes are all rough-looking rocks, varying from light grey to black in colour, and usually markedly porphyritic in plate-like or almond-shaped felspars. They are conveniently divided into two types: the *acid type*, obtained from the Skuary, Mount Erebus, Cape Royds erratics, and Cape Barne; and the *basic type*, derived typically from Turk's Head, Mount Erebus, and Cape Royds erratics.

Composition of Kenytes.—The phenocrysts of the first generation consist of felspar, alkaline pyroxene, and more sparingly magnetite and olivine. Rarely leucite occurs as a product of intratelluric crystallisation. The felspar phenocrysts of the typical acid kenytes are almond-shaped anorthoclases (as in rhombenporphyr), and of the basic type rounded oligoclases of tabular habit. Both felspars contain olivine, pyroxene, and magnetite inclusions.

The pyroxene phenocrysts vary from true ægirine in the most acid and alkaline rocks of the series to a brown titaniferous pyroxene in the most basic. Both the felspars and pyroxenes just mentioned occur also as constituents of the base and smaller phenocrysts of a second generation.

Olivine occurs as corroded phenocrysts, very rarely as a constituent of the base.

Magnetite belongs partly to the first and partly to the second generation. Other iron ores (hæmatite, limonite, ferrite, opacite) occur chiefly as secondary products. Ilmenite frequently takes the place of magnetite.

Leucite occurs in some of these rocks as idiomorphic phenocrysts, rarely of the first, but usually of the second period of crystallisation. It is rarely quite fresh. Commonly it is replaced more or less by zeolites and pseudoleucite (orthoclase and nepheline).

Other felspathoids, chiefly nosean, sodalite, and analcite, occur occasionally in the interstices of the base.

Apatite occurs both as small first generation phenocrysts, and as a constituent of the base.

The other minerals recorded and described under the Trachytes are also present in variable amount, especially the soda amphiboles.

Texture.—The structure of these rocks is usually vesicular and always porphyritic, namely, porphyritic hiatal, megaphyric, and usually they are dosemic, though dopatic types do occur. The crystallinity varies from holocrystalline to hemivitreous. The base may be anything from glassy to holocrystalline with phenocrysts ranging from microporphyritic to magniphyric in size. The fabric of the base may be trachytic, pilotaxitic, hialopilitic, or vitrophyric.

Inclusions.—Inclusions of a white rock determined by Mr. J. Allan Thomson to be sanidinites and microtinites occur in some kenytes. In others (kenytic breccias on Parasitic Cone of Erebus) we have inclusions of an oligoclase trachyte. The more basic kenytes have frequently inclusions of the more acid types.

Order of Consolidation of the Minerals.—The minerals belonging to the intratelluric period of crystallisation crystallised in the following order:

(*a*) Orthoclase in rounded fragments included in the anorthoclase phenocrysts. This may be xenogenic in origin, the remains of partially resorbed country rock.

(*b*) Magnetite as grains included in phenocrysts of other minerals; and also as independent grains.

(*c*) Pyroxene, both as independent crystals and inclusions in felspar.

(*d*) Anorthoclase as corroded almond-shaped phenocrysts.

(*e*) Leucite occurs occasionally as a first-generation mineral in the more basic facies of kenyte.

All these minerals belonging to the first generation exhibit great corrosion by the magma, and in the case of the felspars strain phenomena.

The minerals of the second generation crystallised with few exceptions in the following order: (*a*) magnetite; (*b*) olivine; (*c*) apatite; (*d*) titaniferous pyroxene and ægirine-augite; (*e*) felspar; (*f*) ægirite, glass, and felspathoid.

Habit of Felspar.—The felspar of the kenytes consists of three kinds:

(1) Almond-shaped corroded anorthoclase crystals, grading into microcline microperthite, and moirée microcline;
(2) The idiomorphic prismatic and tabular soda sanidine or anorthoclase of the base; and
(3) The tabular corroded phenocrysts of acid plagioclase in many of the basic kenytes.

The anorthoclase phenocrysts are often zoned both optically and mechanically, the former being due to varying composition, the latter a corrosion effect. They show good Carlsbad twinning usually combined with cross-hatching due to fine lamellar twinning in directions which cannot be assigned definitely to any of the common twinning laws (*see* Plate II, fig. 3).

The ground-mass felspar seldom shows this fine twinning, though occasionally it has distinct albite and pericline twinning, as well as Carlsbad. The plagioclases are likewise frequently zoned, and have well-marked Carlsbad, albite, and pericline twinning. They belong chiefly to the oligoclase species, though they may range to the basicity of acid labradorite.

The other minerals have already been described to a sufficient extent.

2. GROUP OF ACID KENYTES

General Characteristics.—Hand-specimen, light grey to reddish with large felspars, forming about half the mass. The texture and general composition have already been indicated. The large anorthoclase and microcline microperthite phenocrysts, forming from 30 per cent. to 50 per cent. of the mass, have in addition to the properties already mentioned a refractive index very near that of Canada Balsam; their peculiar microperthitic and polysynthetic twinning only become visible near the position of extinction: included in them we have rounded quartz and orthoclase grains, apatite, olivine, magnetite, pyroxene shreds of glass and iron ores.

The other phenocrystalline minerals are, ægirine and ægirine-augite, which are usually uncorroded, but sometimes slightly resorbed; magnetite in idiomorphic or more or less corroded crystals; apatite in stout diomorphic rods; olivine in corroded grains. The base varies from holocrystalline, either pilotaxitic (strahlenkörnig) or trachytic, to hypocrystalline (hyalopilitic), hemicrystalline (vitrophyric), and holohyaline. The minerals of the base are often porphyritic-serial, and consist of felspar microlites, ægirine, soda amphiboles, apatite, magnetite, and glass. In a few cases colourless felspathoid or other isotropic material which gelatinises with dilute acid is also present; this may be sodalite, nosean, or analcite; the analyses indicate a frequent abundance of nosean.

The most typical acid kenytes were got from the Skuary.

J. 47 (1956). The Skuary.—Hand-specimen, grey, rough with coarse crystals.

Texture.—Porphyritic hiatal in phaneric rhomben-felspars, sempatic, magnophyric. The base is holocrystalline, pilotaxitic, approaching panidiomorphic granular or diabase structure.

Composition.—Anorthoclase of the habits described above forms about 35 per cent. in phenocrysts, and 35 per cent. of the rock in the base. The phenocrysts contain numerous included zircon needles. They have each a dark zone near the rim, consisting of included granules of the materials of the base, and into this zone the crystals of the base often project. The phenocrysts are highly resorbed and rounded by corrosion, yet of very large size, reaching a length of half an inch.

Magnetite, olivine, apatite, and pyroxene occur in the manner described under general characteristics. The pyroxene phenocrysts consist of ægirine-augite of greenish colour, faint pleochroism and high extinction angle (38°).

The base is a pilotaxitic mass consisting of felspar laths, with Carlsbad and sometimes very faint lamellar twinning, probably anorthoclase; acicular prismatic microlites of ægirine-augite similar to that of the phenocrysts; laths of a brown hornblendic mineral which is pleochroic from deep brown along the length to opaque transversely (species of cossyrite); idiomorphic grains of magnetite; apatite and zircon needles and a little interstitial dark glass. The base is therefore like the trachyte of Observation Hill, Hut Point, though the brown hornblende is most nearly allied to that of the Cape Crozier trachyte described by Prior (*cf.* Table I, D and E, p. 98).

J. 25 (1934). *Vitrophyric Kenyte* (Analysis, Table II, C, p. 110), same locality.—Hand-specimen, reddish.

Texture.—Coarsely porphyritic, dopatic, megaphyric with vitrophyric fabric, the base being almost holohyaline.

Composition.—The chief constituents are lozenge-shaped anorthoclase (microcline microperthite) phenocrysts, some ægirine phenocrysts (Plate II, fig. 4), and red glass. The latter constituent fills corrosion cavities in the phenocrysts (Plate II, fig. 3). The other phaneric minerals are corroded lumps of magnetite and smaller grains of red iron ore. The red glassy base contains some microporphyritic laths of anorthoclase and non-refracting cryptocrystalline needles (belonites) immersed in the reddish-yellow tachylitic matrix.

J. 5 (1712). *Kenyte,* same locality.—This rock is similar to J. 47, but more coarsely grained, quite holocrystalline, and contains some secondary epidote replacing the original ægirine-augite to some extent, and also aggregates of dusty soda hornblende. Interstitially colourless idiomorphic material consisting of nosean, and full of riebeckite inclusions, is present.

For Analysis *see* Table II, B, p. 110.

J. 40 (1948). *Kenyte,* same locality.—Very similar to J. 47. It differs from J. 47 chiefly in the greater abundance of olivine phenocrysts, and in the greater alkalinity of the pyroxene, which is here a true ægirine. The base is holocrystalline stahlenkörnig. It differs from J. 47 in the absence of cossyrite-like hornblende, and the presence instead of scattered grains of a purplish opaque, very pleochroic hornblende, which changes colour from dark blue opaque to purple on sections parallel with the length, and reddish-brown opaque on sections at right angles to the length. This amphibole is probably a kataphorite closely allied to riebeckite.

Flakes of hæmatite are abundant in this rock. This specimen is clearly of a more alkaline type than those already described.

Photo. Plate II, figs. 1 and 2.

J. 63 (1962). *Specimen* P. 103. An erratic from Cape Royds.—Similar to the foregoing. Kenytes of the acid type were also obtained on Mount Erebus, at Cape Barne, and as erratics at Cape Royds. Many Cape Royds erratics correspond closely with the Skuary types. Decomposition of the ægirine to epidote and the formation of secondary magnetite were noticeable features.

The typical Mount Erebus and some Cape Royds kenytes are different from those just described (*see* Plate III, fig. 1). They occupy a position intermediate between the Skuary and the Turk's Head types. The phenocrysts are those of the acid kenytes, and the base is that of the basic kenytes and tephrites. The phenocrysts consist of the characteristic rhomben felspars, sparing olivine, pyroxene, ilmenite, and sphene.

The base is hypocrystalline, microporphyritic serial, hyalopilitic, and consists of miniphyric phenocrysts of leucite (with characteristic outlines, central and marginal inclusions of dusty magnetite), microlites of felspar, brown glass, and colourless isotropic glass (possibly of the composition of nosean, sodalite, or analcite). The brown glassy material contains minute magnetite needles (incipient skeleton crystals), and brownish belonites of titaniferous augite just commencing to devitrify out of the glass. Pyroxene belonites and glassy felspathoids were clearly the last products of consolidation.

The leucites possess the characteristics of the leucite from the Cape Royds kenyte described by Dr. G. T. Prior*; they are often feebly birefringent because of alteration to pseudoleucite. The felspar microlites consists of anorthoclase.

Prior gives an analysis and photo of a similar specimen. For Analysis *see* A, Table II, p. 110, or Analysis No. 3, p. 119, vol. i, *National Antarctic Expedition of* 1901–1904. For illustration *see* Plate III, fig. 1, and Plate VIII, fig. 3, *National Antarctic Expedition*, 1901–1904, vol. i.

J. 64 (1963), P. 54. Half-way between Cape Royds and Cape Barne, one mile south of Back-Door Bay.—This rock is similar to the Erebus specimen, but contains some titaniferous pyroxene phenocrysts.

P. 55.—This is also very similar to the Erebus kenyte. The pyroxene of the first generation is a titaniferous ægirine-augite, and the base contains abundant leucites. The specimen exhibits striking similarity to the kenyte from Cape Royds examined and analysed by Prior.

J. 44 (1953). *Kenyte*, Turk's Head.—This is a dark grey, almost black, somewhat porous lava, porphyritic in large phaneric crystals of felspar with almond shape. These crystals are very dark in colour from abundant inclusions. The hand-specimen is very like the Erebus type just described.

Texture.—Porphyritic, sempatic, magnophyric in anorthoclase of the first generation. The base is hemihyaline and hyalopilitic.

Constituents.—The phaneric felspars are of the species of microcline-microperthite. Apatite, magnetite, olivine, and ægirine also occur as representatives of the first generation. The base is quite isotropic under the low power, but the high power reveals felspar microlites, brown grains and belonites whose nature cannot be determined, and yellow glass.

J. 48 (1957). *Vitrophyric Kenyte*, Cape Barne.—This rock is very similar to J. 25 from the Skuary. The almond-shaped microcline-microperthites studded with inclusions are of the typical habit and kind. The base is vitrophyric tachylite, and contains corroded phenocrysts of magnetite, olivine, and ægirine-augite; also rods of apatite and microlites of a sanidine-like felspar. (*See* Plate II, fig 4.)

3. THE GROUP OF BASIC KENYTES

General Characteristics.—Phenocrysts, anorthoclase and acid plagioclase; base, phonolitic or tephritic. The hand-specimens of oligoclase kenytes show the tabular plagioclases to possess a planophyric arrangement.

Excepting for the presence of plagioclase in lieu of microperthite phenocrysts, and the greater abundance of felspathoid, the minerals are the same as those of the acid kenytes.

The fabric is as variable as in the previous group, but there is a stronger tendency for the base to remain glassy.

All members of this group contain abundant macroporphyritic phenocrysts of felspar, and smaller amounts of corroded augite, olivine, and magnetite visible to the

---

* *National Antarctic Expedition*, 1901–1904, Natural History, vol. i, "Geology."

naked eye. They are mostly sempatic, the large phenocrysts amounting to from 40 to 60 per cent. of the mass.

Rocks of this type come chiefly from Turk's Head, Cape Royds, and the Dellbridge Islands.

J. 11 (1920). *Plagioclase Kenyte,* Turk's Head. (*See* Analysis D, Table II, p. 110.)—This is a grey rock with very large tabular phenocrysts, the thicker of which are occasionally made almond-shaped by corrosion.

Texture.—Megaporphyritic, sempatic, magnophyric. The grey aphanitic base is pilotaxitic, and varies from micro- to crypto-crystalline. (*See* Plate III, figs. 2 and 3.)

Constituents.—The most abundant constituent is plagioclase of the species oligoclase, often surrounded by a zone of albite or anorthoclase. This occurs only as phenocrysts. The other phenocrystalline minerals are olivine, magnetite, and brown titaniferous augite in corroded grains, and stout rods of apatite. The pyroxene has an extinction angle of 25°, and is probably a titaniferous ægirine-augite.

The base is practically holocrystalline, the only isotropic constituent being a clear colourless interstitial residuum, which probably consists of analcite or sodalite together with some nosean as indicated by analyses. The other constituents are:

(1) Felspar laths with Carlsbad and fine lamellar twinning, and the refractive index near that of Canada Balsam, probably anorthoclase.
(2) Ægirine-augite in minute stunted rods and grains.
(3) Black grains of magnetite.
(4) A few idiomorphic nephelines.
(5) A brown barkevicitic hornblende in scattered grains, and also in mossy aggregates, composed of minute rods.
(6) Allotriomorphic leucite crystals with characteristic inclusions.
(7) A few riebeckite grains.

Of these constituents the felspar is predominating in amount.

This rock, which may be termed oligoclase-kenyte, is closely akin to the anorthoclase-kenyte (J. 44), though in macroscopic structure and appearance there is a notable difference, especially in the habit of the porphyritic felspars.

J. 55 (500), P. 66. Erratic, Cape Royds.—*Texture.*—Porphyritic serial and glomeroporphyritic serial, sempatic, minophyric. The base is a hemicrystalline, decomposed, vitrophyre.

Constituents.—Oligoclase in small phenocrysts, still smaller phenocrysts of magnetite with hæmatite and limonite as decomposition products, light brown titaniferous augite with an extinction angle of 34°, very corroded grains of enstatite, hæmatite secondary after a brown basaltic hornblende, and a few idiomorphs of nepheline. These form the phenocrysts; the base is very decomposed, and contains abundant felspar microlites and skeletons of secondary iron ores. Felspathoid minerals appear to have been originally present.

This rock has close affinity with phonolitic oligoclase trachyte, and with the Kulaites described later.

J. 46 (1955). *Kenyte Agglomerate,* Turk's Head.—A dark fragment in the agglomerate was sectioned. It was serial porphyritic in oligoclase of prismatic habit, and with Carlsbad, albite, and pericline twinning. Optical anomalies, such as shadowy extinction, occur in the phenocrysts, and are due to strain. Small olivine phenocrysts are also present. The base is mostly non-crystalline, and consists of innumerable dusty magnetite grains in a colourless glass. A number of black and brown opacite masses suggest the original presence and subsequent disintegration of hornblende.

Another fragment in this rock is a black vitrophyre containing phenocrysts of oligoclase magnetite and augite in a black opaque matrix.

No. X. *Shonkinitic Kenyte Porphyry,* erratic, Cape Royds.—This rock is a remarkable kenyte in which the phenocrysts are those minerals which constitute the usual constituents of teschenite and shonkinite, while the ground-mass is a normal trachyte.

The phenocrysts are:

(1) Labradorite felspar with extinction angle 30° corroded at the same time in the centre and around the rim.

(2) Bistre-coloured to purplish augite in small slightly corroded phenocrysts sometimes surrounded by a corrosion rim of magnetite.

(3) Large corroded phenocrysts of brown basalt hornblende with sapphire (?) inclusions. In many cases the whole or a large part of the hornblende is pseudomorphosed to magnetite, usually with a core of hypersthene.

(4) Broken nepheline crystals and pseudomorphous aggregates of orthoclase and sodalite after nepheline.

(5) Groups of large idiomorphic soda orthoclase crystals. Veins consisting of an intermixture of orthoclase and fluorspar traverse the rock.

The ground-mass consists of a very fine-grained holocrystalline base of anorthoclase ægirine-augite, riebeckite, and dusty magnetite in isometric grains and stunted rods.

4. GROUP OF TRACHYDOLERITES

The name trachydolerite is most suitably retained for those rocks which have the phenocrysts of porphyritic basalt or dolerite, and a ground-mass of a tephritic nature.

Texture.—These rocks have porphyritic, megaporphyritic structure, and are usually vesicular. The phenocrysts may be serial or hiatal. The ground-mass is a variable from holocrystalline to glassy, with fabric ranging from pilotaxitic, doleritic, ophitic or strahlenkörnig to hyalopilitic or vitrophyric.

Composition.—(1) *Phenocrysts.*—Olivine occurs in abundance as large corroded crystals. Titaniferous augite, often enveloped by an outer zone of secondary deposition, is also abundant and attains large size. Apatite and magnetite or ilmenite occur as smaller phenocrysts, the former idiomorphic, the latter corroded. Enstatite is not infrequent. Large felspar phenocrysts, ranging from oligoclase to basic labradorite, may be present.

(2) *The Ground-mass.*—The base consists of acid plagioclase, anorthoclase, magnetite, purplish augite, more rarely green ægirine-augite, felspathoids, and glass.

The characters which all these minerals present are so typical as to need no further description. The order of consolidation is the normal one for dolerites. The pyroxene may precede or follow the felspars.

In hand-specimen these rocks all resemble porphyritic basalt. They are very dark, almost black, in colour, and very rough in fracture from the unevenness of the grain size.

J. 12 (1921). *Trachydolerite Breccia.* Parasitic cone on Erebus.—*Hand-specimen.*—Typical breccia with large and small fragments of lava.

Micro-structure.—The section includes portions of both the fragments and the tuffy base.

Texture.—The inclusion is a porphyritic serial, vitrophyric trachydolerite, with a pilotaxitic flow arrangement in the microphenocrysts; sempatic; mediophyric to miniphyric. The tuff portion has typical aschen-structur. (Plate III, fig. 4.)

Included fragment. This contains large first-generation phenocrysts of acid labradorite, and smaller corroded phenocrysts of titaniferous augite, olivine, apatite, and magnetite. All these range in size from phaneric to aphanitic. Smaller patches of isotropic material possess the characteristic form and inclusions of leucite. The base contains felspar laths with the properties of anorthoclase forming one-third of its bulk, and the remainder consists of glass. The tuff portion of the slide contains the same kinds of mineral.

The rock is therefore a leucitic trachydolerite.

J. 56 (1124). This is a somewhat similar rock to the inclusion in the preceding. It is, however, megaporphyritic hiatal, dopatic, hyalopilitic. The acid labradorite phenocrysts of this rock are frequently surrounded by a deposition of magnetite belonging to the effusive period of crystallisation.

J. 41 (1950). *Trachydolerite,* Inaccessible Island.—This rock is similar. The felspar phenocrysts are somewhat more acid, being oligoclase andesine, and a little biotite is present.

TABLE II. ANALYSES OF KENYTES

Substance	A	B	C	D	E
	Kenyte, C. Royds (Prior)	J. 5 Kenyte, The Skuary (Hogarth)	J. 25 Vitrophyric Kenyte, The Skuary (Hogarth)	J. 11 Plagioclase Kenyte, Turk's Head (Hogarth)	Dunklere ältere Aufscheidung, Tephritic Trachyte, Columbretes, *vide* Rosenbusch
SiO_2 . . .	56·09	55·62	54·84	47·56	46·39
TiO_2 . . .	1·23	1·35	1·34	2·60	0·72
Al_2O_3 . . .	20·79	19·07	18·57	18·77	19·03
Fe_2O_3 . . .	1·54	6·06	6·26	1·66	9·79
FeO . . .	3·84	nil	0·47	7·13	0·96
MnO . . .	0·05	0·20	0·21	0·20	—
MgO . . .	1·26	1·20	1·06	2·82	5·33
CaO . . .	3·18	2·72	3·00	7·82	7·02
Na_2O . . .	7·33	7·56	6·96	5·15	5·47
K_2O . . .	3·91	4·59	4·51	2·68	2·47
H_2O (100° +) . .	0·19	0·12	1·20	1·27	2·04
H_2O (100° −) . .	0·39	0·14	0·62	0·82	
P_2O_5 . . .	0·38	0·47	0·85	0·07	0·88
CO_2 . . .	—	0·03	0·05	trace	—
SO_3 . . .	—	0·97	0·56	0·06	—
ZrO_2 . . .	—	0·15	0·20	—	—
NiO, CoO . .	—	abs.	—	—	—
BaO . . .	—	—	—	—	—
SrO . . .	—	0·28	—	0·21	—
Li_2O . . .	—	—	abs.	—	—
C	0·17	—	—	—	0·38
Sum . .	100·35	100·53	100·70	9882	100·48

The close relationship of the normal kenytes to the hornblende trachytes of Observation Hill has already been referred to. The analyses of the Skuary kenytes are of interest as being of rocks almost devoid of ferrous iron. In J. 5 (Table II, B, p. 110), magnetite must be absent; the dark grains resembling magnetite must be riebeckite. J. 25 (Table II, C, p. 110) is also a riebeckite-bearing rock. The norm of both these rocks (*see* Analyses IV and V, Tables V and VI, pp. 122, 123) indicates presence of both nephelite and noselite molecules. The kenytes differ from the trachytes, as regards chemical composition, in the following respects: they contain less silica, more alumina, more lime, and more phosphoric acid. Zirconia is usually present.

The rocks here designated plagioclase kenytes are of a much more basic nature. Iron minerals are more plentiful, also magnesia. In alkali percentage as well as general composition they correspond to the Tephrites and Basanites of Rosenbusch, but the texture is so typically that of the kenytes that it is as well to regard them as a basic kenyte. The norm gives their position in the American classification as being in the subrang *Salemose*, which brings out relationships with camptonite from Maine, nephelite basalt, dolerite and other rocks (cf. *Chemical Analyses of Igneous Rocks*, by Washington, Professional Paper No. 14, U.S. Geol. Surv.). The basic inclusions in tephritic trachyte, Forodada, Columbretes, are almost identical in chemical composition with the plagioclase kenyte (*cf.* Analysis 36, p. 355, *Gesteinlehre*, 2nd ed.). This is additional evidence that this rock type is a basic differentiate of the kenytic magma.

5. THE GROUP OF LEUCITOPHYRES AND TEPHRITES

In hand-specimens these rocks resemble dark grey or reddish-brown basalts. Vesicles are often arranged in a planophyric manner.

Texture.—Porphyritic hiatal or glomeroporphyritic; sempatic; mediiphyric to mediophyric. Vesicles abundant or absent: fabric of base, hypohyaline, pilotaxitic, occasionally ocellar.

Constituents.—The constituent minerals are those of the trachydolerites, but leucite is relatively much more abundant, forming one of the chief constituents, and felspar is less abundant. Leucite occurs as mediophyric and minophyric phenocrysts, which are frequently altered to pseudoleucite. The other phenocrysts attain a smaller size.

J. 57 (1499). *Leucitophyre.*—The chief crystalline constituents of this rock are tabular oligoclase-andesine crystals, idiomorphic leucites and pseudoleucites, and corroded prisms of ægirine-augite. The base consists mainly of red glass, which contains fine microlites of felspar and ægirine-augite.

This rock is therefore an oligoclase leucitophyre. (Plate IV, fig. 6.)

The other leucite-bearing rocks are of a more basic character, and belong rather to the group of tephritic basalts.

J. 31. *Leucite Tephrite.* Loc.: Top of Crater Hill.—This is a reddish porous rock, the vesicles of which are arranged in planes or bands. The core of the specimen is dark basaltic-looking, and has small leucite and nosean phenocrysts of minophyric size studded through the aphanitic base. The leucites are, under the microscope, seen to be altered to a mosaic of orthoclase and nepheline (pseudoleucite), and vary in size from just megascopic to microscopic (minophyric to miniphyric). Their rounded outlines are due to resorption. Other corroded microscopic phenocrysts are present in ragged grains composed of olivine, light brownish hypersthene secondary after hornblende, idiomorphic cumulophyres of uncorroded augite with hour-glass twinning, and large corroded magnetite grains.

The pseudoleucite and nosean crystals contain inclusions of black magnetite and of honey-yellow to deep brown wohlerite. (Plate IV, figs. 3 and 4.)

The base is a miniphyric vitrophyre consisting of colourless glass in which minute needles of alkali-felspar, microlites of titaniferous augite and dusty magnetite are scattered broadcast. The texture of this rock is porphyritic serial in leucite and nosean with ocellar fabric. From the chemical composition the colourless glassy material of the base should have the composition of nosean.

6. CLASS OF BASALTS POOR IN OLIVINE

These rocks possess the usual textures and mineral composition of basalts. Cape Barne was a particularly prolific source of them. They vary from fine-grained to aphanitic in grain size.

J. 6 (1915). *Intersertal Augite Andesite*, Cape Barne.—*Hand-specimen.*—Vesicular brownish rock with the appearance of andesitic basalt, no phaneric phenocrysts.

Microscopic Texture.—Porphyritic serial in felspar which is irregularly distributed in prismoid and equant microscopic phenocrysts, consequently very uneven-grained; hypocrystalline with intersertal fabric tending towards ophitic, groups of augites being present which extinguish together. The phenocrysts consist of oligoclase, but the smaller laths seem to be anorthoclase, the composition of the felspar varying between these two according to the size of the crystals. The other minerals are idiomorphic magnetite grains, a few stray olivines, hypidiomorphic grains and rods of brown titaniferous augite and interstitial glass.

The pyroxene was the last mineral to crystallise. The position of this rock is intermediate between trachyte, andesite, and basalt.

All the other basalts poor in olivine are likewise from Cape Barne.

J. 2 (1912). *Aphanitic vesicular rock with ocellar structure.*—*Texture.*—Hypocrystalline, hyalopilitic. (*See* Plate V, fig. 3).

Constituents.—Labradorite in laths, 50 per cent.

Faint brown augite and brown glass, 40 per cent.

Magnetite, 7 per cent. Olivine, 2 per cent. Apatite, 1 per cent.

J. 4 (1914) is a similar rock, but contains slightly more olivine. (*See* Analysis, Table III, D, p. 114, and Table V, No. X, p. 122.)

J. 10 (1919). This rock has a higher felspar percentage, and has numerous prisms of olive-brown to reddish-brown hypersthene interspersed with the augite laths and magnetite of the base. Phenocrysts are rare, but dark patches of opacite occur, which are decidedly suggestive of derivation from basaltic hornblende. The hypersthene of the base also points that way.

J. 58 (1358). This rock is intermediate between J. 4 and J. 10.

J. 19 (1928). *Texture.*—Microporphyritic serial, vitrophyric, with vesicles shaped and arranged so as to give an ocellar structure to the rock.

Composition.—This rock differs from those just described mainly in containing a higher percentage of magnetite and black glass. Small olivines are sparingly present, and are highly corroded. Brownish augite occurs as small phenocrysts in the devitrifying base.

Various irregularly shaped dark patches profusely rich in magnetite represent either disintegrated xenoliths or the degradation products of basaltic hornblende.

In **J. 20 (1929)**, a very similar rock, the fine dusty magnetite of these dark areas was clearly seen to be imbedded in a brownish isotropic matrix. The magnetite is clearly of secondary origin, and it seems most likely that these rocks originally contained basalt hornblende.

J. 24 (1933). This is a microporphyritic serial basalt without olivine, the phenocrysts being a basic labradorite. In this slide, too, occur black augite-opacite aggregates secondary after hornblende. The base is intersertal, almost panidiomorphic, hypocrystalline, consisting of felspar in needles, augite prisms, magnetite grains and apatite in stout rods, with a trace of interstitial glass.

The majority of the olivineless basalts have, it will be seen, the following general characters:

(*a*) Felspar, usually basic labradorite, forms 50 per cent. of the bulk or less.
(*b*) Black patches crowded with dusty magnetite inclusions probably represent disintegrated hornblende phenocrysts.
(*c*) Olivine is only sparingly represented.
(*d*) Apatite is less abundant than in the kenytes.
(*e*) The glassy base consists largely of dark brownish-black glass undergoing devitrification to magnetite, titaniferous pyroxene and hypersthene. It is full of black magnetite grains both of primary and secondary origin.
(*f*) No felspathoids detected in this group.

7. THE GROUP OF OLIVINE BASALTS

The general characters of this group are so well known as to need no detailed description. The peculiarities of the Antarctic olivine basalts examined by me seem to be that they are usually coarsely porphyritic, and approach the limburgites on the one hand and the basanites on the other. Felspathoid minerals are of common occurrence as a minor constituent. The felspar of these rocks consists of basic labradorite, and the pyroxene is a deep brown titaniferous augite. The olivine is usually in large corroded phenocrysts. Felspar does not usually occur as phenocrysts, but may do so in some types. The texture is usually holo- to hemi-crystalline, porphyritic hiatal, dopatic or sempatic, megaphyric, and the fabric hyalopilitic.

J. 59.—*Porphyritic Felspar Olivine Basalt,* Cape Royds.—This rock is a black porphyrite full of tear-shaped vesicles (drawn into that form by flow during the plastic condition).

The phenocrysts consist of basic labradorite, olivine, highly titaniferous augite, magnetite, and apatite. The holocrystalline pilotaxitic base consists of acid labradorite in laths, and augite and magnetite in idiomorphic grains.

J. 28 (1937). *Enstatite-olivine Basalt or Basanite,* loose block, foot of Crater Hill.—*Texture.*—Porphyritic serial, dopatic, mediiphyric. Ground-mass holocrystalline, intersertal.

Constituents.—Felspar, consisting of acid labradorite, occurs only as laths and microlites of variable size belonging to the effusive period of crystallisation. The olivine and enstatite form corroded microphenocrysts belonging to the intratelluric period. The intersertal base consists of a granulite mass of brown titaniferous augite and magnetite in almost idiomorphic grains, giving the whole rock almost a panidiomorphic structure. A little interstitial, colourless, and isotropic material is present, probably sodalite or analcite.

J. 26 (1935). *Limburgitic Basalt,* Hut Point.—*Texture.*—Microporphyritic hiatal, dopatic; hyalopilitic fabric near to diabase structure.

Composition.—Magnetite forms about 30 per cent., titaniferous augite about 45 per cent., and alkali-felspar about 15 per cent. These minerals belong to the second generation, and in the interstices between them we have fillings of analcite or sodalite. About 10 per cent. of the rock consists of olivine in small hypidiomorphic phenocrysts. Nepheline also appears to be present.

The rock is a very basic one, and may be called limburgitic basalt allied to basanite.

Two rocks, viz., J. 49 from Cape Barne and J. 36 from Mount Bird, are allied to kulaite, but must be put in this group as felspar olivine basalts.

J. 49 (1958), Cape Barne. This is a black rock, porphyritic in white phaneric felspars.

Texture.—Porphyritic hiatal, sempatic, megaphyric, with aphanitic hyalopilitic base.

TABLE III. ANALYSES OF BASIC ROCKS

Substance	A Hornblende Basalt, Sulphur Cones (Prior)	B J. 68 Limburgite, Mt. Erebus (Burrows and Walkom)	C Rossweinose, Rosswein, Saxony (*vide* Washington's *Analyses of Igneous Rocks*)	D J. 4 Olivine Basalt, Cape Barne (Hogarth)	E Olivine Basalt, The Gap (Prior)	F Limburgitic Basalt, Winter Quarters (Prior)	G Leucite Tephrite, Crater Hill (Hogarth)	H Nepheline Basalt, No. 13, p. 372, Rosenbusch, *op. cit.*
SiO_2	43·92	45·63	48·29	43·54	42·14	42·10	41·64	40·53
TiO_2	4·19	2·42	—	5·03	4·90	4·93	4·36	1·80
Al_2O_3	17·42	10·43	10·00	16·08	14·95	14·87	13·80	14·89
Fe_2O_3	4·09	1·20	2·93	2·63	2·90	3·26	7·93	1·02
FeO	8·83	8·93	5·46	10·14	9·71	9·76	5·41	11·07
MnO	0·09	0·17	—	0·20	0·12	0·07	0·19	0·16
MgO	4·89	15·01	17·22	6·44	9·47	8·88	8·78	8·02
CaO	9·53	12·89	11·80	8·09	10·32	10·63	11·16	14·62
Na_2O	4·60	2·04	2·78	3·61	3·27	3·20	2·14	2·87
K_2O	2·17	0·74	0·45	1·67	1·80	1·80	1·40	1·95
H_2O (100°+) . .	0·11	0·16	1·95	0·36	0·16	0·12	0·47	1·44
H_2O (100°−) . .	0·06	0·21		0·08	0·12	0·11	0·62	
P_2O_5	0·67	0·43	—	1·29	0·40	0·58	0·96	1·32
CO_2	—	0·12	—	0·15	—	—	0·05	0·17
SO_3	—	—	—	—	—	—	1·70	—
ZnO_2	—	—	—	—	—	—	abs.	—
NiO.CoO . .	—	—	—	—	—	—	—	—
BaO	—	—	—	—	—	—	abs.	—
SrO	—	—	—	1·46	—	—	—	—
Li_2O	—	—	—	—	—	—	abs.	—
Cl	—	—	—	—	—	—	—	—
Sum . .	100·57	100·38	100·88	100·77	100·26	100·31	100·61	99·86

Composition.—The phenocrysts consist of oligoclase, usually exceeding 5 mm. in size, titaniferous augite 3 to 4 mm., smaller olivines and magnetite. Black opacite pseudomorphous after hornblende also occurs (*see* Plate V, fig. 2), and are of mega-porphyritic size. The base is hemicrystalline and consists of anorthoclase microlites, brownish idiomorphic grains of titaniferous pyroxene, magnetite grains, and a yellow devitrifying glass studded with inclusions. There are also colourless isotropic areas studded with inclusions, and they have probably the composition of nosean or analcite.

J. 36 (1944), Mount Bird.—This is described in the section dealing with Cape Bird rocks (*post*, p. 125).

Both the basalts rich in olivine and the limburgites described hereafter are similar to the olivine basalts and limburgites described by David, Smeeth, and Schofield in *Proc. Roy. Soc. N.S.W.*, vol. xxix, 1895, and those described by Prior in the *National Antarctic Memoir.*

Chemical analysis shows that the basalts from Cape Barne and, in fact, all the basaltic rocks of Ross Island differ from normal basalts and can be divided into two classes, one of which has limburgite affinities, the other of which contains hornblende or pseudohornblende phenocrysts and is related to the Kulaites (Table IV, p. 120). The olivine basalt from Cape Barne, J. 4, is a typical member of the second group, and one which does not display its affinities by pseudomorphs after hornblende. The felspar molecules (*see* Table VI, p. 123) (high alumina) are sufficiently abundant to place this rock in the Salfemane class, while the typical limburgitic basalt has a lower Al_2O_3 percentage, and belongs to the class Dofemane.

J. 10, J. 19, and **J. 20** are basalts similar to those described by Prior from Sulphur Cones, and his analysis (Table III, A, p. 114) gives their composition approximately. Their relationship to Kulaite is evident both from mineral and chemical composition.

The analysis of J. 4 corresponds closely with Prior's olivine basalt from the Gap and his limburgitic basalt from Winter Quarters.

The leucite tephrite, Crater Hill (*see* J. 31, *also* Analyses G, Table III, p. 114, and XI, Tables V and VI, pp. 122 and 123), is allied to the limburgite J. 68 (*see* Analysis B, Table III) on the one hand and to the basanites on the other. The amount of sulphuric anhydride in the rock is very large, and shows that much of what was originally considered leucite is in reality nosean. The norm (*see* Table VI) differs remarkably from the mode, especially in the development of felspathoid in place of felspar.

The normative composition of the limburgite, J. 68 (Table VI, No. IX, p. 123) bears out the microscopic determination of the remarkable pseudomorphous aggregates after felspar. It is a typical Kossweinose, as a comparison with the analysis of the Rosswein type rock (Table III, C, p. 114) shows.

8. GROUP OF THE LIMBURGITES

In this group felspar is absent, or only subordinate in amount. They closely resemble the porphyritic basalts in hand-specimen, and are usually coarsely porphyritic in olivine and augite. The pyroxene is generally of two generations. The order of consolidation was normal.

The usual texture is porphyritic hiatal, sempatic, magnophyric with intersertal base, which may be hyalopilitic, diabasic, or strahlenkörnig (divergent radial).

J. 60 (523 ?). *Limburgitic Basalt.—Texture.*—Porphyritic hiatal, dopatic, magnophyric ; ground-mass diabase grained.

Composition.—The phenocrysts are corroded olivine, enstatite, magnetite, and a few idiomorphic labradorites full of magnetite inclusions. The base, which is almost panidiomorphic in structure, contains brown titaniferous augite in prismatic grains, magnetite, and a smaller amount of basic labradorite microlites.

J. 9 (1918). *Limburgite,* Observation Hill.—*Texture.*—Microporphyritic serial, dopatic, magnophyric.

Fabric.—Intersertal, diabase structure.

Composition.—This rock consists of hypidiomorphic grains of titaniferous pyroxene (about 50 per cent.), labradorite microlites (about 35 per cent.), idiomorphic magnetite (about 10 per cent.), and olivine in microscopic phenocrysts (about 5 per cent.).

J. 23 (1932). *Basanitic Limburgite,* Cape Barne.—This is a similar rock to J. 9, but more deficient in felspar, which amounts to less than 20 per cent.

Texture.—Porphyritic hiatal, dopatic, panidiomorphic.

Composition.—Magnophyric phenocrysts of olivine and hypersthene imbedded in a base consisting of titaniferous augite, very basic plagioclase, magnetite, and a colourless interstitial substance with the refractive index and double refraction of nepheline.

J. 61 (537). *Limburgite.*—*Hand-specimen.*—Very vesicular grey rock, porphyritic in magnophyric corroded olivine grains. (*See* Plate IV, figs. 1 and 2.)

Texture.—Porphyritic hiatal, dopatic, megaphyric, with divergent radial fabric in base (strahlenkörnig).

Composition.—The phenocrysts consist of olivine and light green pyroxene, both highly corroded. They are bordered with a rim of magnetite granules.

The base is holocrystalline, and consists of white prismatic pseudomorphs shaped like large felspar laths, which are arranged in a divergent radial manner like the felspar of ophitic diabase, and between these mineral groups lie intersertal masses of titaniferous augite and magnetite in minute idiomorphic grains.

The divergent radial aggregates appear to be made up of minute idiomorphic pyroxenes, quite colourless and non-pleochroic, with a slight interstitial amount of nepheline. The pyroxene may be wollastonite, and the whole may be secondary after an unstable anorthite or soda anorthite. The aggregates are at first sight suggestive of the pinite pseudomorphs after labradorite in liebnerite porphyry, but the secondary mineral is pyroxenic in habit and properties, not micaceous.

9. MAGNETITE BASALTS

These rocks are some of the most differentiated portions of the parent kenyte magma. They are dark, heavy, more or less vesicular basalts, sometimes megaporphyritic, sometimes aphanitic. The chief localities for these rocks are Cape Barne and Tent Island.

Texture.—They are usually microporphyritic hiatal, dopatic, hypo- or hemi-crystalline vitrophyres.

Constituents.—The phenocrysts are usually extremely corroded, and consist of felspar varying from oligoclase to basic labradorite, more rarely anorthoclase, corroded olivines, augite varying from green ægirine-augite to brown titaniferous augite, magnetite, and idiomorphic apatite in stunted rods. The ground-mass consists mainly of magnetite, though the high power may in places reveal the presence of brown glass interstitially in a mass of dusty magnetite.

J. 34 (1942). *Magma Basalt*, Tent Island.—*Hand-specimen.*—Black and vesicular.

Texture.—Porphyritic hiatal, dopatic, dominantly magniphyric, though a few mediophyric phenocrysts occur. Fabric vitrophyric.

Constituents.—Phenocrysts—zoned, corroded oligoclase and labradorite felspar filled with apatite and glass inclusions, light greenish-brown ægirine-augite (titaniferous), corroded olivine, sparing apatite rods. These phenocrysts are imbedded in a black opaque mass which has by reflected light the steel-grey colour of magnetite, and probably consists mainly of iron ore. (*See* Plate IV, fig. 5.)

J. 35 (1943), from Gap Moraine, Hut Point.—This contains corroded phenocrysts of enstatite and olivine and no other phenocrystalline mineral. The base consists of a brown to black mass, containing plagioclase microlites with feathery and pronged ends (keraunoids and swallow-tailed microlites), imbedded in acryptocrystalline matrix of black magnetite, brown, almost isotropic, pyroxene crystallites and brown pyroxenic glass. In texture this rock is a porphyritic hiatal, sempatic basalt vitrophyre.

J. 17 (1926), Tent Island.—This is a red vesicular lava, and contains phenocrysts of oligoclase-andesine and of greenish-brown augite. The former are corroded and zoned, while the latter are idiomorphic in rods. Corroded olivines are also present. These phenocrysts are imbedded in a reddish-brown, opaque, glassy base, consisting largely of iron ores.

J. 22 (1931). *Magnetite Basalt*, Cape Barne.—*Hand-specimen*, dark compact bluish-black rock, with small vesicles and slightly porphyritic in felspar.

Texture.—Porphyritic hiatal, vesicular, dopatic, mediophyric to microphyric, with vitrophyric fabric in base.

Constituents.—The felspar phenocrysts consist of basic labradorite twinned on Carlsbad, Baveno, and Manebach laws, as well as on the albite and pericline laws, several types of twinning occurring together in each crystal. This felspar occurs sparingly as megascopic, but plentifully as microscopic phenocrysts. Small augite rods forming interpenetrating twins and corroded olivines also occur as microscopic phenocrysts. The base is made up mainly of magnetite and dark isotropic glass.

The most remarkable thing about the magnetite basalts is the reversal of the order of consolidation, the magnetite having been one of the last minerals to form.

GENERAL DISCUSSION ON DIFFERENTIATION

One of the most striking points about the Antarctic lavas examined is the highly differentiated nature of the effusive products. The abundance of limburgites, magnetite basalts, olivine nodules, sanidinite inclusions, etc., and the occurrence of basalts without olivine, felspar basalts and olivine basalts in different interbedded flows, show that differentiation was very complete, and that the eruptions tapped now one, now another portion of the magma.

Specific gravity played a most important part in the differentiation. This is shown by the occurrence of felspar basalts and augite andesites which R. A. Daly has demonstrated to be formed by gravity differentiation (*Jour. of Geol.*, July–August 1908). The formation of the magnetite basalt is probably due to gravity; just as magnetite has in one specimen, P. 60, formed a secondary deposit round felspar phenocrysts, so have phenocrysts of various minerals become enveloped in a clump of magnetite and dragged down by the weight of the secondary deposit into the heavier magnetite layer. In this way the phenocrysts of the magnetite basalts probably originated.

Prior has shown that these highly differentiated ferriferous basalts and limburgites abound in many Antarctic islands. Such rocks occur also in Greenland and Spitzbergen, and on basaltic volcanoes arising out of deep ocean.

It is not unlikely that the greater proximity of the Polar regions of the earth, and of the magma caverns on the floor of the ocean, to the earth's centre may stimulate gravitative differentiation. So evenly are the various forces producing differentiation balanced that a comparatively slight change in the conditions under which cooling takes place may cause one force to greatly predominate over all others.

The same highly differentiated nature of Antarctic eruptive rocks is evidenced by the alkaline, subalkaline, and basic lavas obtained by Borchgrevink at Cape Adare, and described by David, Smeeth, and Schofield (*cf.* J. 1, and *Proc. Roy. Soc. N.S.W.*, 1895).

There seems to be but little difference, if any, between the alkaline volcanic rocks of Ross Island and those of the mainland.

The sequence of these lavas appears to have been the same as that which is so characteristic of the Australian alkaline province—that is, from acid to basic.

The fact that the crater on the summit of Erebus is still erupting kenyte, while at Cape Barne basalts are the latest effusive products, I do not take to indicate that these lavas come from different magmas, but rather that the vent which gave the Cape Barne lavas was supplied from a deeper source than the Erebus crater. The molten magma has differentiated in the magma reservoir, and probably tongues of differentiated rocks have been thrust into surrounding formations. Fissures may tap one or all of the differentiation products, but the more elevated vents situated over the centre of the magma chamber will tap the lavas in the order of their specific gravity, and will continue to pour out each type of lava much longer than the subsidiary vents and fissures. Thus if Cape Barne represents lavas poured from the fissure which has tapped sill-like offshoots of the main reservoir, the whole sequence might be completed in this locality while the summit of Erebus is still in the kenyte phase of eruption. The summit may become extinct before emerging from this stage, the forces being insufficient in the final stages of eruption to raise the subjacent basic lavas to the summit, so that these may never reach the surface except by side fissures.

Yet the order of eruption would be from acid to basic wherever several lavas have flowed from the same vent, and where flows from different vents have not intermingled or overlapped. Such seems to have been the sequence of the lavas of Ross Island as far as can be determined on present knowledge.

THE VOLCANIC ROCKS OF CAPE BIRD

The Cape Bird rocks of the Expedition's collection were, according to Mr. Priestley and Professor David, mostly water-worn and ice-carried specimens collected at the foot of Cape Bird, which is a seaward projection of Mount Bird. None were obtained *in situ.**

Being derived from an independent focus of eruption, a special interest attaches to them and to their comparison with the rocks of Mount Erebus.

The Cape Bird rocks are intimately related to those of Erebus, being alkaline in facies. Their distinguishing feature is, however, in all varieties, the abundance of brown basaltic hornblende and alteration products after this mineral.

The alteration products consist of magnetite, colourless augite, red hypersthene, and apparently in some cases a red titaniferous hornblende, which may be a kaersuetite.

---

* Several of the specimens collected were *in situ* from the agglomerate formation at the landing-place.—D. M., 1916.

In some cases magnetite is the sole alteration product recognisable in the pseudomorphs. In other cases several of the above-mentioned minerals are present.

The formation of red secondary hypersthene by the molecular change of hornblende has been ably described by Washington * in several papers dealing with the rocks of Kula, in Syria.

The Cape Bird rocks consist of:

(1) Trachytes of a strongly alkaline facies, which generally contain pseudomorphs after basaltic hornblende in greater or smaller amount.

(2) Kulaites or trachydoleritic rocks with the peculiar pseudomorphs after basaltic hornblende which characterise kulaite.

(3) Subalkaline basalts and dolerites, some enstatite-bearing, some olivine-bearing.

The rocks of the kenyte series are absent in the Cape Bird rocks which have come under my notice. It is, however, very probable that the complete Erebus series will recur on Mount Bird, with this difference alone, that basalt hornblende and its pseudomorphs will be present in all the rock species in varying proportions.

In most of the Cape Bird rocks examined the basalt hornblende has been altered by the magma in such a manner that there can be little doubt that it is not a normal differentiation product of the rocks in which it occurs. The subalkaline magma has differentiated in the first place into an alkaline magma and a basic one, in the latter of which hornblende was a normal consolidation product. The basic magma has then been injected into the alkaline, and has been mixed with it in varying proportions whilst differentiation of the alkaline magma was in progress, the hornblende undergoing partial resorption and alteration. Then the differentiated alkaline lavas were extruded and rapid cooling caused the final metamorphosis of the hornblendes.

P. 314 (622). Hand-specimen missing. *Alkaline Trachyte*, Cape Bird.—This is a beautiful microcrystalline trachyte showing under the microscope a well-marked flow structure.

Texture practically holocrystalline, dopatic, porphyritic serial in small felspar phenocrysts, some of which are visible to the naked eye. There are also stray phenocrysts of corroded magnetite pseudomorphs after rod-shaped hornblende crystals. These are minophyric.

The porphyritic felspar (magniphyric) consists of anorthoclase, as shown by the fine multiple twinning and moirée accompanying a sanidine habit. The fine acicular felspars of the base are probably also anorthoclase. The other minerals consist of corroded grains of magnetite and ægirine-augite. A little isotropic felspathoid occurs interstitially.

The rock, but for the hornblende pseudomorphs, is identical with some Mount Cis trachytes.

P. 341 (653). This is a fluidal fine-grained hemicrystalline trachyphonolite containing, in addition to the minerals of P. 314, nepheline and corroded olivine grains, as well as a number of grains of camptonitic minerals appertaining to the inclusion described in this rock by Mr. J. Allan Thomson.

J. 18 (1205). *Altered Phyro-hornblende Trachyte*, Cape Bird. (For Analyses *see* Table IV, A, p. 120; Table V, No. VI, p. 122; and Table VI, No. VI, p. 123; Photo, Plate III, fig. 5). Megascopically this is a light grey rock dotted with black rod-shaped phenocrysts. The structure is porphyritic hiatal, and slightly vesicular.

---

* *Jour. of Geol.*, vol. viii, 1900; *Am. Jour. of Sci.*, vol. xlvii, 1894; *The Volcanoes of the Kula Basin in Lydia.*

Microscopically, holocrystalline, megaporphyritic (hiatal), dosemic, magnophyric. Fabric of ground-mass, trachytic. The phenocrysts have the outlines of hornblende, but seem under the low power to consist of magnetite, but under the high power there is seen to be present, in addition to the magnetite, a colourless augite (diopside), some greenish augite (ægirine augite) and a reddish-brown mineral with hornblende cleavage and straight extinction. The last mentioned has the pleochroism of kaersuetite, but may be a hypersthene similar to that formed in similar pseudomorphs in kulaite.*

Larger remains of a highly pleochroic reddish-brown to greenish-brown (basaltic) hornblende constitute the nuclei of several of the pseudomorphs, and may be original. It is quite possible that this is a complex amphibole which has split up in some instances into an aggregate of magnetite, diopside, ægirite and a simpler titaniferous hornblende (kaersuetite).

The grains are too minute to allow one to be confident of the determination.

That the black phenocrysts are psuedomorphs after hornblende is certain. (*See* Plate III, fig. 5.)

TABLE IV. ANALYSES OF CAPE BIRD ROCKS

	A	B	C	D	E
	J. 18 Phyrohornblende Trachyte, C. Bird (Burrows & Walkom)	No. 648 Kulaitic Basalt, C. Bird (Burrows and Walkom)	Leucite Kulaite, Kula, Syria (Washington)	Kulaite, Kula, Syria (Washington)	Basalt, Siebengebirge (E. Kaiser)
SiO_2	52·54	48·26	49·90	48·35	48·93
TiO_2	1·44	0·88	0·93	0·12	trace
Al_2O_3	19·41	22·67	19·89	19·94	22·63
Fe_2O_3	2·90	3·22	2·55	2·48	8·84
FeO	5·31	4·56	4·78	5·25	1·97
MnO	0·23	0·11	trace	trace	0·50
MgO	1·91	3·73	5·05	5·15	3·54
CaO	4·60	8·68	7·21	7·98	7·27
Na_2O	7·50	4·03	5·60	5·47	4·23
K_2O	3·49	2·15	3·74	3·99	2·04
H_2O (+)	0·16	0·32	0·19	0·22	0·36
H_2O (−)	0·08	0·30	0·13	0·16	—
P_2O_5	0·26	1·01	trace	trace	trace
CO_2	0·20	trace	—	—	—
	100·03	99·92	99·97	99·95 †	100·31

The trachytic base consists of soda-sanidine, ægirine augite, arfvedsonite, and smaller amounts of magnetite and hæmatite. The felspar and pyroxene are idiomorphic, the arfvedsonite occurs in allotriomorphic grains, and the magnetite is mostly secondary (opacite). Another slide made from a different specimen, P. 315 (626), is similar, but the pseudomorphs contain larger nuclei of the original unaltered hornblende.

---

* Washington, *op. cit. ante*, p. 119.

† Summation here includes chlorine and other constituents estimated by Washington but not incorporated in this table.

Igneous Inclusions in Beacon Sandstone. Mr. Priestley left in my hands for examination two microsections of Beacon sandstone with somewhat decomposed inclusions of igneous rock. At first it was thought that the included lava fragments were kenyte, to some of which they bore strong resemblance in texture. The minerals were somewhat decomposed, so that identification was rendered difficult. A closer examination of the slides revealed that the fragments bore a more strongly marked resemblance to the kersantites described by Prior, and figured fig. 4, Plate IX, of his report. These rocks, being intrusive into the basement rocks of Victoria Land, would be more likely to occur in sandstone than would kenyte.

The trachyte with pseudomorphs after hornblende from Cape Bird is much more basic than the normal trachytes tabulated in Table I (p. 98), and even more basic than the kenytes. Yet it is a typically trachytic rock in hand-specimen and under the microscope but for the abundant pseudohornblendes. It is these inclusions which account for the basicity of the rock, raising the percentages of ferrous iron, magnesia, alumina, and lime at the expense of silica. Comparison with analyses C and D, which with E are quoted from Washington's *Analyses of Igneous Rocks* shows that this trachyte is not a kulaite, for magnesia and lime are not as high and the alkalies higher than should be the case in this group.

The kulaitic basalt (numbered 648) also varies in composition from typical kulaite and is almost identical in composition with a basalt (Analysis, Table IV, E, p. 120) from the Siebengebirge, which is also a noted alkaline province. The close chemical relationship of the basic kenytes to the kulaitic basalts has already been referred to (*cf.* Table II, p. 110), as has also the similarity in composition of this rock to the basic autogenic inclusions in tephritic trachyte from Columbretes.

Calculated in the American classification the kulaitic basalt is in the subrang Hessose, where its true affinities are quite obscured, and the trachyte J. 18 falls in the subrang Essexose, which is also an unnatural group for a rock of its mineralogical features to fall into. (*See* Table VI, p. 123.)

THE KULAITE SERIES

J. 36 (1944). *Kulaite*, Mount Bird.—The hand-specimen is a rough-fractured, grey, andesitic-looking rock, megaphyric in larger felspars and smaller pyroxenes.

The texture is porphyritic hiatal, dopatic, magnophyric with a hypocrystalline hyalopilitic fabric inclined to the diabasic structure.

The phanerocrystalline constituents consist of labradorite felspar, large phenocrysts of bistre augite, smaller crystals of light-brownish augite, and occasional grains of corroded olivine. There are also numerous dark patches whose outlines suggest that they are pseudomorphs after hornblende. These are resolved by the high power into a mixture of magnetite, colourless diopside, hypersthene needles, and felspar as described by Washington.* (*See* Plate III, fig. 6.)

The ground-mass consists of acicular labradorite crystals, augite, enstatite, and magnetite. The augite belongs to the same species as that of the phenocrysts. Many of the finer constituents are simply fragmentary portions of broken-up pyroxene, felspar phenocrysts, and of the pseudomorphs, and belong, strictly speaking, to the first generation.

The second-generation minerals are, with the exception of the pseudohornblende, identical with those of the first generation. In addition, rod-shaped enstatites are present.

An isotropic glass, probably of leucitic composition, occurs interstitially.

---

* *Jour. of Geol.*, April–May 1896.

TABLE V. ANALYSES OF ROCKS OF THE EREBUS SERIES

By J. W. Hogarth, G. F. Burrows, B.Sc., and A. B. Walkom, B.Sc.

Substances Estimated	I Felspar, Summit of Erebus (Burrows and Walkom)	II J. 13 Trachy-phonolite, Mt. Cis (Hogarth)	III Pumice, Mt. Erebus (Burrows & Walkom)	IV J. 5 Kenyte, The Skuary (Hogarth)	V J. 25 Vitrophyric Kenyte, The Skuary (Hogarth)	VI J. 18 (1205) Phyro-hornblende Trachyte, Cape Bird (Burrows & Walkom)	VII J. 11 Plagioclase Kenyte, Turk's Head (Hogarth)	VIII (648) Kulaitic Basalt, Cape Bird (Burrows & Walkom)	IX J. 68 (537) Limburgite, Mt. Erebus (Burrows & Walkom)	X J. 4 Olivine Basalt, Cape Barne (Hogarth)	XI J. 31 Leucite Tephrite, Crater Hill (Hogarth)
SiO_2	60·83	58·94	55·95	55·62	54·84	52·54	47·56	48·26	45·63	43·54	41·64
TiO_2	0·36	1·40	0·98	1·35	1·34	1·44	2·60	0·88	2·42	5·03	4·36
Al_2O_3	23·92	16·33	22·53	19·07	18·57	19·41	18·77	22·67	10·43	16·08	13·80
Fe_2O_3	0·11	2·48	0·99	6·06	6·26	2·90	1·66	3·22	1·20	2·63	7·93
FeO	2·14	5·54	4·54	nil	0·47	5·31	7·13	4·56	8·93	10·14	5·41
MnO	—	0·21	trace	0·20	0·21	0·23	0·20	0·11	0·17	0·20	0·19
MgO	0·07	1·03	trace	1·20	1·06	1·91	2·82	3·73	15·01	6·44	8·78
CaO	3·39	2·10	3·21	2·72	3·00	4·60	7·82	8·68	12·89	8·09	11·16
Na_2O	6·11	5·54	7·42	7·56	6·96	7·50	5·15	4·03	2·04	3·61	2·14
K_2O	2·96	5·25	3·97	4·59	4·51	3·49	2·68	2·15	0·74	1·67	1·40
H_2O (100° +) .	0·07	0·42	0·00	0·12	1·20	0·16	1·27	0·32	0·16	0·36	0·47
H_2O (100° −) .	0·12	0·44	0·09	0·14	0·62	0·08	0·82	0·30	0·21	0·08	0·62
P_2O_5	—	0·57	—	0·47	0·85	0·26	0·07	1·01	0·43	1·29	0·96
CO_2	0·00	0·05	0·02	0·03	0·05	0·20	trace	trace	0·12	0·15	0·05
SO_3	—	0·16	—	0·97	0·56	—	0·06	—	—	—	1·70
ZrO_2	—	0·22	—	0·15	0·20	—	—	—	—	—	abs.
NiO.CoO . . .	—	—	—	abs.	—	—	—	—	—	—	—
BaO	—	—	—	—	—	—	—	—	—	—	abs.
SrO	—	—	—	0·28	—	—	0·21	—	—	1·46	—
Li_2O	—	abs.	—	—	abs.	—	—	—	—	—	abs.
Sum . .	100·08	100·68	99·61	100·53	100·70	100·03	98·82	99·92	100·38	100·77	100·61

TABLE VI. CALCULATED NORMATIVE COMPOSITION OF THE ROCKS ANALYSED

Minerals	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
	Felspar * Mt. Erebus	J. 13 Trachy-phonolite, Mt. Cis	Pumice, Mt. Erebus	J. 5 Kenyte, The Skuary	J. 25 Kenyte, The Skuary	J. 18 (1205) Trachyte, Cape Bird	J. 11 Basic Kenyte, Turk's Head	(648) Kulaitic Basalt, Cape Bird	J. 68 Limburgite, Mt. Erebus	J. 4 Olivine Basalt, Cape Barne	J. 31 Leucite Tephrite
Quartz . .	1·200	1·920	—	—	—	—	—	—	—	—	—
Orthoclase .	17·792	30·580	23·91	27·244	26·688	20·57	16·024	12·23	4·448	10·008	8·340
Albite . .	57·116	44·016	39·82	43·492	45·588	31·96	24·628	28·82	7·336	14·148	17·816
Anorthite .	16·958	4·726	15·56	7·784	8·062	8·90	20·016	31·97	16·958	22·796	23·908
Nephelite .	—	—	12·21	0·284	1·136	17·04	10·224	2·84	5·396	8·804	—
Sodalite, Noselite }	—	Nos.1·338	—	Nos.8·697	Nos.4·683	—	—	—	—	—	{ Sulphate of lime) 2·856
Corundum .	3·328	—	0·31	—	—	—	—	2·14	—	—	—
Zircon . .	—	0·366	—	0·183	0·366	—	0·183	—	—	—	—
Diopside .	—	1·888	—	—	1·392	8·96	8·536	4·29	34·904	17·872	8·952
Hypersthene .	3·368	7·448	—	—	—	—	—	—	—	—	5·100
Olivine .	—	—	4·49	2·100	1·680	4·27	7·682	8·46	23·336	11·416	9·240
Magnetite .	0·232	3·712	1·39	—	1·624	2·74	2·552	4·64	1·856	3·712	11·368
Ilmenite .	0·780	2·736	1·98	—	2·584	4·18	5·016	1·67	4·560	9·576	3·952
Hæmatite .	—	—	—	6·080	2·400	—	—	—	—	—	—
Rutile . .	—	—	—	0·560	—	—	—	—	—	—	—
Apatite .	—	1·240	—	1·240	1·860	0·61	2·790	2·17	0·930	2·790	2·170
Calcite .	—	0·100	0·10	0·100	0·100	0·50	0·260	—	0·300	0·400	0·100
Titanite .	—	—	—	1·960	—	—	—	—	—	—	5·684
Water . .	0·190	0·860	0·09	0·260	1·820	0·24	2·090	0·62	0·370	0·440	1·090
Sum .	100·960	100·930	99·86	99·984	99·983	99·97	100·001	99·85	100·39	101·962	100·576
		Dosalane	Persalane	Persalane	Persalane	Dosalane	Dosalane	Dosalane	Dofemane	Salfemane	Salfemane
		Germanare	Russare	Canadare	Canadare	Norgare	Norgare	Germanare	Hungarare	Portugare	Gallare
		Domalkalic	Domalkalic	Domalkalic	Domalkalic	Domalkalic	Alkalicalcic	Docalcic	Hungariare	Docalcic	Docalcic
		Sodipotassic	Dosodic	Dosodic	Dosodic	Dosodic	Dosodic	Dosodic	Domagnesic	Presodic	Presodic
		Monzonose	Viezzenose	Laurvikose	Laurvikose	Essexone	Salemose	Hessose	Rossweinose	—	Auvergnose

* This felspar (anorthoclase), being full of inclusions, has the composition:

(1) Felspar (as above)	92·0%
(2) Iron ore . .	0·8%
(3) Hypersthene .	3·4%
(4) Quartz . .	1·2%
(5) Corundum . .	3·4%
(6) Water . .	0·2%

The rock is therefore a limburgitic basalt almost identical with kulaite.

The pseudomorphs of this rock, by the presence in them of felspar, strongly suggest that the molecular alteration of the original hornblende was accompanied by replacement of its molecules by molecules of the ground-mass.

P. 324 (648). *Kulaite*, Cape Bird.—This rock is similar to J. 36, but the alteration of the hornblende has not progressed so far.

The texture of this rock is hypocrystalline and porphyritic, with phenocrysts, partly idiomorphic and partly broken and corroded, scattered about as in vitrophyric texture.

The phenocrysts consist of felspar belonging to the labradorite and andesine families, faintly pleochroic augite (light green to light brown), unaltered barkevicitic hornblende in idiomorphic crystals, and pseudomorphosed basalt hornblende in corroded crystals. Apatite occurs as inclusions in all the minerals, and magnetite is very abundant as a secondary constituent and both primary and secondary in the base.

The pseudomorphs consist of a granular mixture, chiefly magnetite, with colourless augite and red hypersthene in some cases: in other cases the main alteration product is a red hypersthene phenocryst with a rim of secondary magnetite and augite. It is possible that this hypersthene is an original mineral, but both the association and the occurrence in it at times of traces of hornblendic cleavage suggest that it is secondary.

Some of the felspar phenocrysts have tuning-fork ends.

The base consists of idiomorphic felspar laths, magnetite titaniferous augite, and an isotropic glass. The magnetite of the base is largely secondary.

P. 325 (648). (For Analysis *see* Table IV, B, p. 120; and Table V, No. VIII, p. 122.) This rock slice is similar to the foregoing. It is markedly porphyritic in faintly pleochroic augite and basalt hornblende, undergoing the alteration described previously. Some pseudomorphs consist mainly of a large crystal of red hypersthene with a magnetite-augite rim. Others consist mainly of an aggregate in which magnetite predominates over augite and hypersthene. The original phenocrysts of hornblende were highly idiomorphic, but they have been largely broken and corroded in their metamorphosis. This idiomorphism is noticeable too with the felspar and augite phenocrysts, some of which have been fragmented and corroded. (*See* Plate V, fig. 1.)

P. 317 (630). *Kulaite.*—This rock is of a similar texture and constitution to P. 325 but differs in the base, being much more evenly fine-grained in texture—practically none of its constituents exceeding cryptocrystalline size and most of the material is hyaline. The rock is *sempatic* and the phenocrysts are corroded and broken as in the previous slide. The pseudomorphs are of exactly the same type, but the proportion of unaltered hornblende is greater. The pleochroic augite is undergoing chloritic decomposition, and magnetite in this slide occurs as a primary phenocrystalline constituent as well as in the ground-mass, where it is developed both as a primary and secondary mineral.

Felspar is a minor constituent so that this rock so if a somewhat more basic type than the previous.

The four rocks just described are porphyritic hiatal with phaneric phenocrysts. The texture is hypocrystalline inclining to vitrophyric in fabric. The phenocrysts of hornblende in each show a remarkable variety of forms of alteration, depending, it would seem, on the amount of iron in the original hornblende. The glassy base of each contains a felspathoid, probably leucite.

These rocks lie in the trachydolerite group and have affinities with the camptonites, the limburgites, and the tephrites. The Kulaite of Kula, described by Washington, agree with them in its characters, so that this name has been chosen for them. (For Analysis *see* Table IV, p. 120.)

Closely allied to this group of rocks, but deficient in the hornblende and its pseudomorphs, are the tephritic and basanitic dolerites of the next group.

From the close similarity of the two groups it would seem that the kulaïtes are derived by a mixture of a camptonitic with an alkaline doleritic magma.

THE CAPE BIRD DOLERITES

P. 334 (654). *Olivine Basanite,* Cape Bird.—This is a compact, dark porphyritic rock, megaphyric in olivine. It has a porphyritic hiatal structure, and its base is very fine-grained, hypocrystalline and hyalopilitic in fabric.

Olivine occurs as broken and corroded phenocrysts. Felspar occurs sparingly as phenocrysts, also of broken and very corroded outlines. The felspar phenocrysts consist of albite. In addition, we have rounded and corroded nepheline phenocrysts and patchy masses of cancrinite after nepheline.

The base consists of pyroxene, magnetite, lath-shaped felspars, and glass.

The larger pyroxene crystals of the base are idiomorphic and consist of a brownish to greenish pleochroic ægirine-augite.

This rock is a very alkaline type of dolerite. The low felspar percentage puts the rock in this basic division, but it has strong affinities with the tinguaites and phonolites.

P. 327 (649). *Alkaline Dolerite.*—This rock has close affinities with the kulaites but is devoid of the basalt hornblende and its alteration product.

The structure is porphyritic, serial, sempatic, minophyric, with a tendency to a flow arrangement. The texture is hypocrystalline with a variety of pilotaxitic fabric.

The main phenocrystalline constituents: augite, consisting of a faintly pleochroic greenish to brownish pyroxene as in the kulaites; zoned and corroded plagioclase, ranging from oligoclase to acid labradorite; and magnetite.

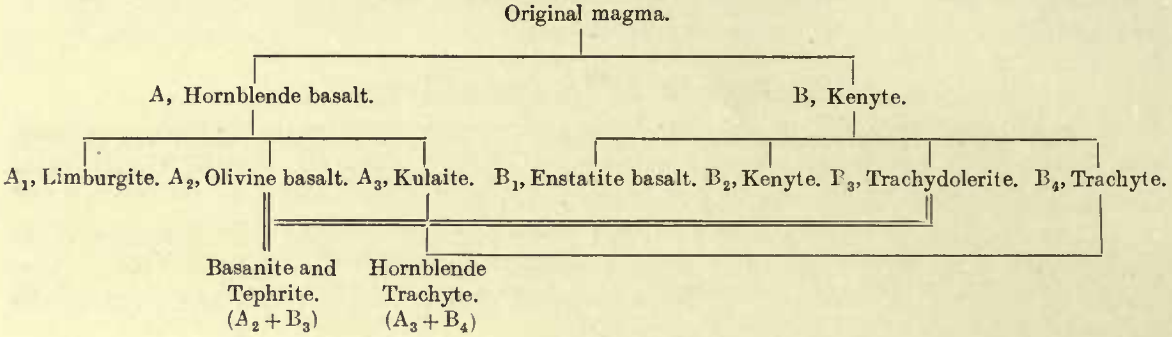
The base consists of brownish augite, magnetite, ilmenite, plagioclase, and a felspathoid (probably leucite), and glass.

In both texture and composition this rock exhibits a great divergence from normal dolerites and an approach to the basic kenytes and kulaites. Felspar and pyroxene are about equal in amount.

P. 322 (642). *Limburgitic Dolerite.*—This rock is the most basic rock examined for this locality. It is coarsely porphyritic—serial, in olivine ranging from magnophyric size downward, and in enstatite ranging of minophyric size. These phenocrysts are always broken and corroded, and sometimes invaded by the ground-mass, and clearly belong to the intratelluric period. The first augite of the effusive period was only faintly titaniferous and forms light-brownish idiomorphic crystals, but the finer augites are deep in colour, being more highly titaniferous. Broken magnetite phenocrysts occur, but, in addition, there is second generation of magnetite in the base. The felspar percentage is very small and this mineral occurs only as fine microscopic needles of labradorite. A small amount of interstitial glass occurs in the base. The order of consolidation was: (1) magnetite, (2) olivine, (3) enstatite, (4) augite, (5) magnetite, (6) felspar, (7) glass.

The most remarkable feature of the three basic rocks described is the dearth of apatite, which is usually an abundant mineral in basic rocks. This feature clearly links them to the kenytes and other alkaline rocks in which phosphoric acid is, as a rule, very deficient.

The Cape Bird rocks indicate that at this reservoir of magma there was an early differentiation into a hornblende basalt magma and an alkaline kenytic magma, each of which has again further differentiated and the final products obtained were mixtures of the differentiates of these two magmas.



The rocks of Cape Bird suggest that an examination of Mount Bird will reveal a much more complete series of acid alkaline eruptives than has been poured from the Erebus vent.

The abundance of basalt hornblende and pseudomorphs after this mineral in the Cape Bird rocks, and their comparative absence in those of the Erebus series (except at Cape Barne), in spite of the similarity in other respects of both series of rocks, is a fact of some significance. It may, perhaps, be an indication that differentiation of the Cape Bird magma commenced in much more deep-seated regions of the earth than the Erebus magma, and the mixing of differentiation products, as already suggested, might have taken place in the process of eruption.

The basaltic hornblende occurs, according to Prior, in certain basalts of Cape Bird and in certain trachytes from Hut Point and Observation Hill. I also found pseudomorphs after hornblende in some Cape Barne basalts.

As may be gathered from the foregoing notes the nature of the pseudomorphs varies considerably. In some cases they consist wholly of magnetite, in others principally of hypersthene; in some of a mixture of grains of magnetite, hypersthene, and colourless augite; in some nuclei of the original basalt hornblende occur; in some a secondary deep red to opaque pleochroic hornblende occurs with magnetite, augite, and felspar; this secondary hornblende has been referred to by Prior as a cossyrite-like hornblende, but in my slides it has typically the characteristics of kaersuetite, though in some cases it is very like cossyrite. The most extreme stage of alteration of hornblende seems to be into a mosaic of magnetite augite and felspar, and where this occurs chemical interaction between the constituents of the hornblende and of the matrix has probably taken place.

Hornblende, more or less pseudomorphed, has also been described by Prior in rocks from Mount Terror, so that this mineral seems to be widely distributed in all the rocks except those of Erebus. That the volcanic rocks collected by Borchgrevink and by the Scott expedition at Cape Adare are closely analogous to those of Ross Island is a fact which is of great interest, and is further emphasised by the important collection of erratics described by Woolnough.

EXPLANATION OF THE PLATES

(Photos by H. Gooch, University of Sydney)

PLATE I

FIGURE 1.—*Trachyte, Mount Cis,* No. J. 1 (× 35, nicols uncrossed), showing trachytic fabric near vesicle in left top quadrant, also a hexagonal pseudomorph after nepheline to the right of the vesicle, and the pilotaxitic fabric of the rest of the slide.

FIGURE 2.—*Trachyte, Mount Cis,* No. J. 1 (× 45, nicols crossed), showing fabric.

FIGURE 3.—*Kaersuetite* (?), *Ægirine-Augite Trachyte, Observation Hill,* No. J. 3 (× 35, nicols uncrossed). In the left top quadrant is seen a dark mass consisting of a cluster of grains and rods of reddish-brown camptonitic hornblende.

FIGURE 4.—No. J. 3 (again) (× 45, nicols crossed). Near centre of slide is seen a small idiomorphic brown hornblende crystal. Other grains and rods of the same mineral are scattered throughout the slide.

FIGURE 5.—*Anorthoclase Trachyte, Erratic, Ferrar Glacier,* No. J. 54. (× 35, nicols crossed.) This photo shows a group of anorthoclase phenocrysts (cumulophyre), some of which are at extinction. The base shows along to top and left side of the slide.

FIGURE 6.—*Oligoclase Trachyte, Parasitic Cone of Erebus,* No. J. 7 (× 35, nicols crossed). Slide showing bistre-coloured augite, olivine, mechanically zoned oligoclase and anorthoclase, phenocrysts.

PLATE II

FIGURE 1.—*Acid Kenyte (holocrystalline), The Skuary,* No. J. 40 (× 35, nicols crossed), showing microline-microperthite phenocryst near extinction.

FIGURE 2.—Same as Figure 1. Showing strahlenkörnig texture of base.

FIGURE 3.—*Vitrophyric Kenyte, The Skuary,* No. J. 25 (× 35, nicols crossed), showing part of very large rhomb-shaped anorthoclase phenocryst and a smaller microperthitic felspar near extinction.

FIGURE 4.—*Vitrophyric Kenyte, Cape Barne,* No. J. 48 (× 35, nicols uncrossed), showing an ægirite phenocryst and crystallites in vitreous base.

FIGURE 5.—*Phonolitic Trachyte, Erratic, Cape Royds,* No. J. 52 (× 35, nicols uncrossed), showing vesicular structure and texture.

FIGURE 6.—*Baked Alkali Trachyte, Tuff Cone, Ross Island,* No. J. 50 (× 35, nicols uncrossed), showing a large ægirine phenocryst.

PLATE III

FIGURE 1.—*Leucite Kenyte, Mount Erebus* (type specimen) (× 46, nicols uncrossed), showing anorthoclase phenocrysts and structure of leucitic base. Note the rounded leucite crystals.

FIGURE 2.—*Oligoclase Kenyte, Turk's Head,* No. J. 11 (× 35, nicols crossed), showing twinned oligoclase phenocrysts.

FIGURE 3.—Same as Figure 2 (nicols uncrossed), showing leucitic base similar to Erebus rock, Figure 1 (× 46, nicols uncrossed).

FIGURE 4.—*Trachydolerite Breccia*, *Parasitic Cone*, *Erebus*, No. J. 12 (× 35, nicols uncrossed), showing anorthoclase and plagioclase phenocrysts and the *aschenstructur*.

FIGURE 5.—*Phyro-pseudohornblende Trachyte*, *Cape Bird*, No. J. 18 (× 35, nicols uncrossed), showing huge magnetite phenocrysts replacing hornblende in trachyte base.

FIGURE 6.—*Kulaite*, *Cape Bird*, No. J. 36 (× 35, nicols uncrossed), showing pseudomorph (largely magnetite and felspar) replacing hornblende.

PLATE IV

FIGURE 1.—*Limburgitic Basalt*, *Mount Erebus*, No. J. 61 (× 45½, nicols crossed), showing olivine and pyroxene phenocrysts with kelyphitic borders, and a vesicle.

FIGURE 2.—Same slide showing divergent radial arrangement of the secondary laths after felspar and nepheline.

FIGURE 3.—*Leucite-Nosean Tephrite*, *Crater Hill*, No. J. 31 (× 35, nicols slightly crossed), showing rims of secondary felspathoid round vesicles.

FIGURE 4.—Same slide, nicols not crossed.

FIGURE 5.—*Magnetite Basalt*, *Tent Island*, No. J. 34 (× 35, nicols uncrossed), slide cracked; note small felspar phenocrysts in magnetite base.

FIGURE 6.—*Leucitophyr*, loc. uncertain, No. J. 57 (× 35, nicols uncrossed). The interiors of the large pseudoleucites have been ground away in making the slide.

PLATE V

FIGURE 1.—*Kulaite*, *Cape Bird*, No. P. 325-(648) (× 35, nicols uncrossed), showing magnetite pseudomorphs of magnetite after hornblende and also a hypersthene pseudomorph with magnetite rim.

FIGURE 2.—*Olivine Basalt*, *Cape Barne*, No. J. 49 (× 35, nicols uncrossed), showing magnetite pseudomorph after hornblende.

FIGURE 3.—*Andesitic Basalt*, *Cape Barne*, No. J. 2 (× 35, nicols crossed), showing hyalopilitic vesicular ocellar texture.

PLATE I

FIG. 1

FIG. 2

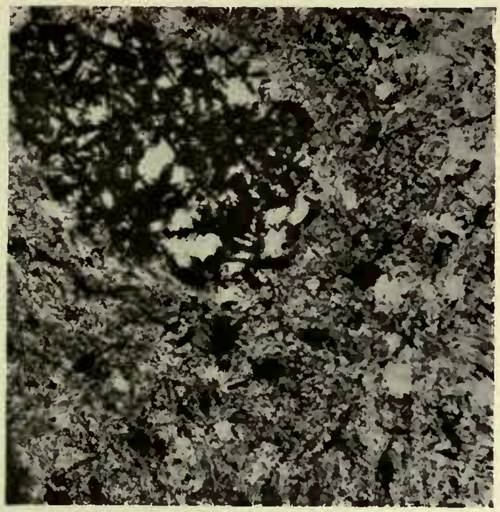


FIG. 3

FIG. 4

FIG. 5

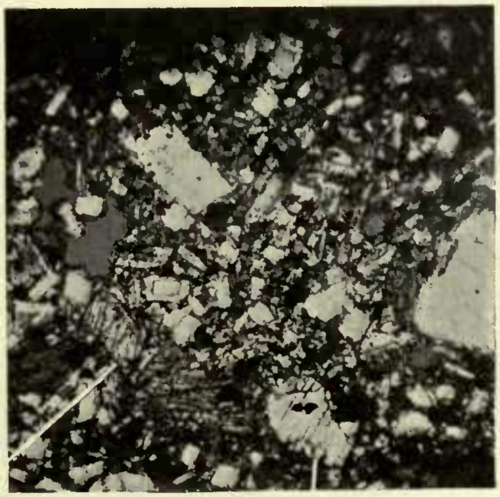


FIG. 6

[*To face p.* 128

FIG. 1

FIG. 2

FIG. 3

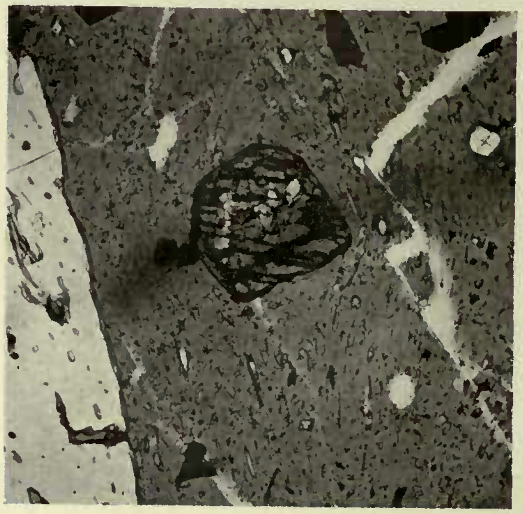


FIG. 4

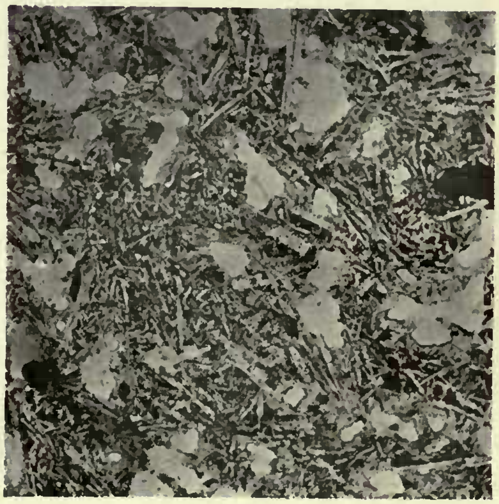


FIG. 5

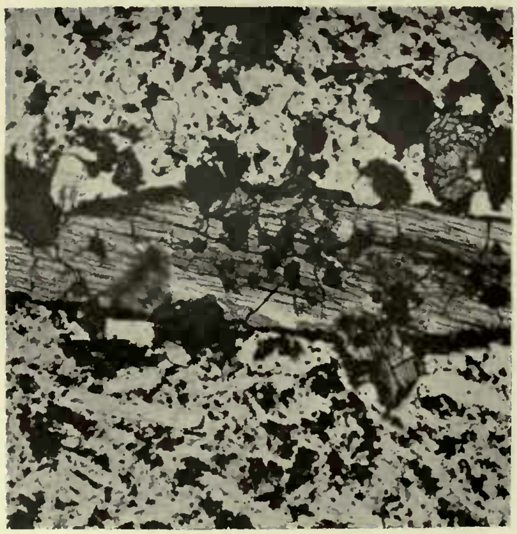


FIG. 6

PLATE III

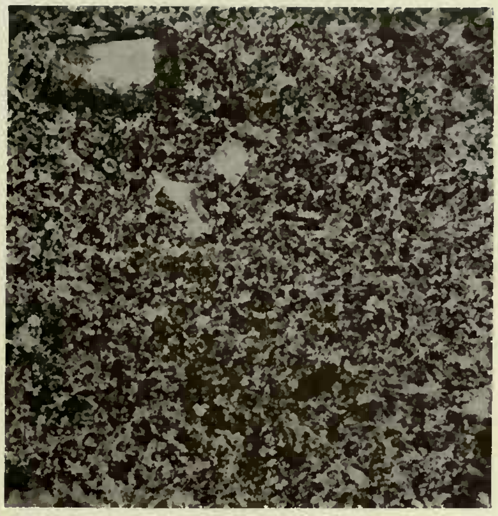


Fig. 1

Fig. 2

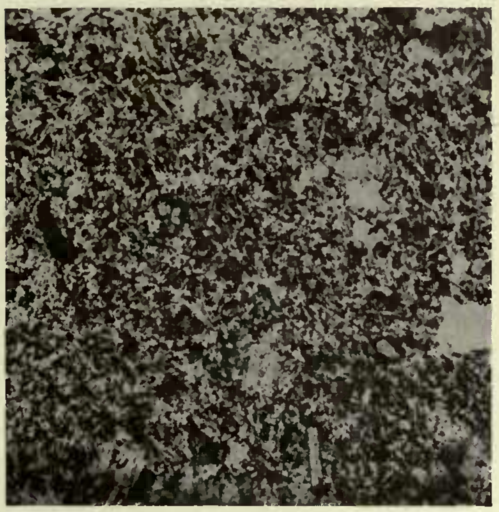


Fig. 3

Fig. 4

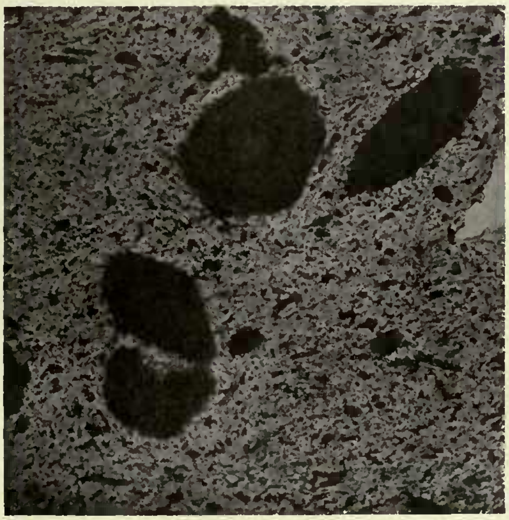


Fig. 5

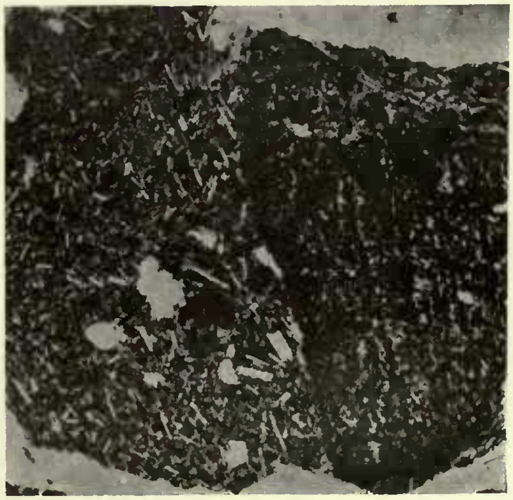


Fig. 6

PLATE IV

Fig. 1

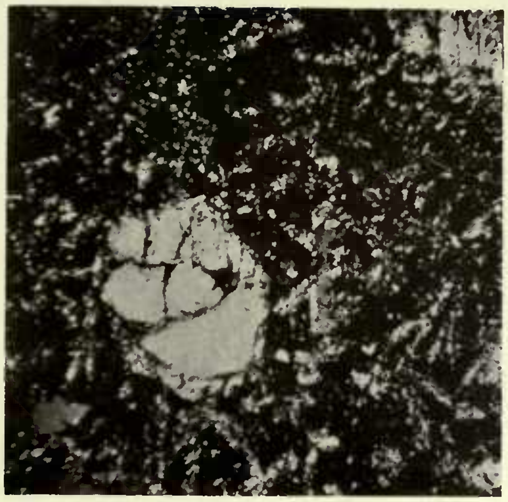


Fig. 2

Fig. 3

Fig. 4

Fig. 5

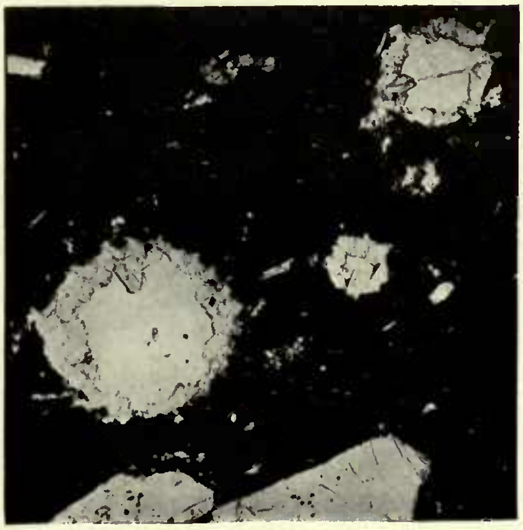


Fig. 6

PLATE V

FIG. 1

FIG. 2

FIG. 3

PART VIII

REPORT ON THE INCLUSIONS OF THE VOLCANIC ROCKS OF THE ROSS ARCHIPELAGO

(*With Three Plates and Three Figures in the Text*)

BY

J. ALLAN THOMSON, M.A., D.Sc., F.G.S.

CONTENTS

REPORT ON THE INCLUSIONS OF THE VOLCANIC ROCKS OF THE ROSS ARCHIPELAGO

(*With Three Plates and Three Figures in the Text*)

BY

J. ALLAN THOMSON, M.A., D.Sc., F.G.S.

APART from the information that inclusions may give as to the sequence in age of volcanic rocks and the constitution of the underlying terrane, their petrological study may throw important light on petrogenesis. Lacroix, who has made a speciality of these studies for many years, declared in 1893, after the examination of over three thousand specimens: "Cette richesse en matériaux nouveau me permet de tirer quelques conclusions générales de mes observations, bien que j'aie jugé nécessaire d'être fort prudent sur un sujet semblable, pour lequel les faits d'observation ne seront jamais trop nombreux."*

The inclusions of a province petrographically so interesting as that of Ross Island thus possess more than a local interest, and the geologists of the Shackleton Antarctic Expedition are to be congratulated on the extent of their collections.

Although there is a general agreement as to the nomenclature of certain groups of inclusions, their classification as a whole is still a subject of disagreement among petrologists. The various groups will therefore be first described and their origin discussed before the attempt is made to show their place in a general classification.

Several types of inclusions have previously been collected by Ferrar and the officers of the Scott Expedition, and described by Prior.† Of these all but two were found in the basalts and limburgites near Winter Quarters, and were of the nature of olivine and gabbroid nodules. The two exceptions were enclosed in trachytes, the one being a felspathic nodule or sanidinite, and the other consisting mainly of hornblende. All the types described by Prior are included in the present collection with the exception of the sanidinite from the trachyte of Cape Crozier.

I. OLIVINE, PYROXENE, AND GABBROID NODULES IN THE BASIC ROCKS

A large number of olivine, pyroxene, and gabbroid nodules were collected from the basalts and limburgites of Hut Point. In some few cases the specimens were enclosed in the volcanic rock, but more often they were loose, so that the exact nature of the host could not be determined. Owing to the difficulty of preparing thin sections of these loosely compacted rocks, but few slides were made, and the mineralogical composition was ascertained by crushing small fragments under oil on a glass slip and examining the powder under the microscope. A more permanent preparation may be

---

* Lacroix, A., *Les Enclaves des Roches volcaniques*, Mâcon, 1893, p. 13.

† Ferrar, H. T., and Prior, G. T., *National Antarctic Expedition*, 1901–4; *Natural History* vol. i; *Geology, Brit. Mus. Rep.*, London, 1907, pp. 11, 12, 14, 106–9, and 114.

made by mounting the powder in a solution of Canada balsam and xylol. With a little practice very rapid examination may be made by this method, and in particular it is more easy to distinguish olivine and pyroxene thus than in a thin section. Any mineral present in small amount may, however, easily escape detection.

These nodules consist of associations of two or more of the following minerals: olivine, a pale green augite (chrome-diopside), rhombic pyroxenes, brown hornblende, biotite, a basic plagioclase, and a spinel. The associations are shown in the following table:

Number of Specimen	Olivine	Chromite	Brown Hornblende	Biotite	Augite	Enstatite	Hypersthene	Pleonaste	Plagioclase	Magnetite	Name of Inclusion	Corresponding Plutonic Rock
1209	×	×										Dunite.
1227	×	×										
1193	×	×	×								Olivine and Pyroxene Nodules.	Hornblende Dunite.
1195	×	×	×									
1208	×	×	×									
1250	×	×	×									
1255	×	×	×									
1252	×	×		×								Biotite Dunite.
1210	×	×		×	×							(?) Biotite Lherzolite.
1222	×	×		×	×							
1226	×	×				×						Lherzolite.
1841	×						×					
1225	×	×	×		×							
1230	×		×		×	×						
1185	×		×		×				×	×	Gabbroid Nodules.	Hornblende Gabbro.
1189			×		×				×			
1900			×		×				×			
1904			×		×				×			
1905			×		×				×			
1906			×		×				×			
1907			×		×				×			
1908			×		×				×			
1909			×		×			×	×			
1910	×		×		×	×		×	×	×		
1216					×				×			Gabbro.
1232	×				×				×			
1234					×				×			
1279					×				×			
1842	×				×				×			
1901					×				×			
1902					×				×			
1903	×				×				×			

The olivine is pale green in colour and very free from inclusions. The impregnation with magnetite, described and figured by Prior* in some of his specimens, does not appear to be represented in the present collection. A few of the nodules, however, are of a reddish colour ("rubifié") owing to the separation of limonite from the olivine. The

---

* *Loc. cit.*, p. 108.

augite, on the other hand, is seldom free from ferruginous inclusions, both magnetite and limonite are sometimes scattered irregularly throughout the mineral, and sometimes so disposed in small rods as to produce a schiller structure parallel to the vertical axis, while rows of negative crystals occasionally run parallel to the base. Hypersthene and enstatite show a similar schiller structure in a plane parallel to the vertical axis. There appears to be no difference between the augite of the pyroxene and gabbroid nodules, both giving extinction angles of over 40°. The felspar is a very basic variety with extinction angles, on symmetrically cut albite lamellæ, as high as 37° (labradorite-bytownite).

As regards the quantitative relationships, in the olivine nodules olivine predominates greatly over the other ferromagnesian minerals, which are generally present in quite subordinate amount. In a few cases, however, augite occurs in such abundance that the rocks may well be termed pyroxene nodules. The rhombic pyroxenes are never present in large quantity, a feature which Lacroix has noted as common when hornblende is present.* In the gabbroid nodules the ratio between felspar and ferromagnesians varies somewhat widely, as also does that between augite and hornblende. It will be noticed that the spinel of the olivine nodules is chromite, whereas that of the gabbroid types is pleonaste. Mr. W. N. Benson, of Sydney University, has pointed out to me that the same law of association prevails in the inclusions of a large neck at Dundass, near Sydney.

The structural relations call for little mention. Most often the rocks are quite massive, but in one specimen (1909)† there is a well-marked banding of felspathic and ferromagnesian minerals. The olivine nodules are typically granular rocks, neither olivine nor augite showing definite crystalline form (Fig. 1, Pl. I). Hornblende and biotite, if present, are always the last elements of consolidation. In one specimen (1193) there is a small veinlet of brown hornblende traversing the nodule, recalling on a minute scale the association of hornblendites with the lherzolites of the Pyrenees.‡ In the gabbroid nodules also the order of crystallisation is not well marked, although olivine is clearly anterior to augite. There is no suggestion of ophitic relation of pyroxene to felspar, but sometimes the augite appears to be intergrown with the felspar on its edges. The brown hornblende surrounds the augite, and in one case is found chiefly between the plagioclase and the olivine, probably in consequence of a magmatic resorption of the latter, but there is no radial orientation of the hornblende as in the well-known reaction rims, nor is the hornblende found in parallel position on the augite.

Although hornblende is a frequent constituent of the above inclusions, it does not appear as the main constituent of hornblende nodules, such as are often found in hornblende basalts. The collection includes, however, one large cleavage fragment of brown hornblende measuring 3 by 1·5 cm. in its greatest diameters. It shows in places a rounding and polishing that may be ascribed to magmatic corrosion.

As regards the origin of these inclusions, there is no doubt that they are closely

---

* *Loc. cit.*, p. 486.

† The numbers attached to the specimens in this paper require some explanation. When the paper was written, in September 1910, many rock specimens collected by the Expedition had not been given registered numbers, and microscopic slides made from such specimens were labelled T. 1 2, etc., when made to my order, P. 1, 2, etc., when made by Mr. Priestley, and E. 1, 2, etc., when belonging to the general collection of slides. I understand that the specimens of which slides were prepared were deposited, with others, in the Museum of the Geological Department of Sydney University, but that a duplicate collection was sent to Professor Lacroix at the Musée d'Historie naturelle, Paris.—J. A. T., January 1916.

‡ Lacroix, A., " Les roches basiques accompagnant les lherzolites et les ophites des Pyrénées," *Compt. Rend. viii, Cong. Géol. Inter., Paris*, 1900, p. 806.

connected genetically with the rocks in which they occur. The origin of olivine nodules has been the subject of a voluminous discussion into which there is no need to enter here. The fact that the inclusions themselves form a differentiation series comparable with that which would have been expected had the various basic volcanic rocks enclosing them consolidated under plutonic conditions, suggests that they are actually fragments from such a series which has arisen from the differentiation and consolidation in depth of a portion of the primary basic magma.

II. SANIDINITES AND MICROTINITES IN THE TRACHYTES AND KENYTES

Sanidinite is the name given by Lacroix* to the coarse-grained miarolitic rocks consisting predominatingly of sanidine or anorthoclase which are so often found as inclusions of trachytes and certain kinds of phonolites. Similar rocks of more compact grain and finer texture he has designated as " micro-sanidinites." Both types are represented in the present collection. The analogous term " microtinite "† is used for similar inclusions consisting mainly of plagioclase felspar.‡

Prior § has described a coarse-grained inclusion in the trachyte of Cape Crozier which consists of an aggregate of stout felspar-prisms with some pleochroic (yellow to grass-green) ægirine-augite and a little cossyrite-like hornblende; the felspars are partly oligoclase with symmetrical extinctions of about 8° and partly anorthoclase. This rock appears to be a sanidinite, but differs considerably from those now to be described.

Sanidinites and Microsanidinites in the Trachyte of Mount Cis

By far the larger number of the felspathic inclusions have been found at Mount Cis, a small parasitic cone 700 feet above sea-level on the foot of Erebus, about half-way between Cape Royds and Cape Barne. The cone is composed of a dark grey highly jointed rock determined by Dr. Jensen as a phonolitic trachyte.

The sanidinites vary in dimensions from fractions of an inch to several inches, and are more or less rounded in outline. Their immediate contact with the host is, however, not smooth because of the injection of the ground-mass into the druses of the inclusion. The rocks are seen in hand-specimens to be made up mainly of large platy felspar prisms, more or less interlaced; the spaces between the felspars are partly filled up with a brown glass, partly with the dark grey vesicular ground-mass of the trachyte, but are seldom completely filled, so that the whole mass has a most distinctly miarolitic aspect. Numerous black iridescent crystals are seen in the druses and to a less extent within the felspars themselves, and these prove on crushing under oil to consist of a very yellow olivine. Less frequently small dark prisms (sometimes twisted) of ægirine-augite are found with the same mode of occurrence, and occasionally apatite and magnetite are also noted. The length of the tabular felspars varies between a few millimetres and 3·5 cm., their thickness in general being about one-fifth of their length.

Although on a general inspection the felspars appear to be of the same nature, microscopical examination shows that in most specimens they consist of sanidine, but in a few cases of anorthoclase. Cleavage fragments of the former show no twinning, while a fine albite lamellation may be observed in the latter. This is in accord with their properties in thin sections, the sanidine showing only Carlsbad twinning, the anortho-

---

* *Les Enclaves*, etc., p. 352.

† From microtine, a term proposed by Tschermak for the glassy plagioclases.

‡ Lacroix, A., " Conclusions à tirer de l'étude des enclaves homœogènes pour la connaissance d'une province pétrographique—Santorin," *Compt. Rend. Acad. Sc.*, cxl, 1905, p. 973.

§ *Loc. cit.*, p. 114.

clase on the other hand exhibiting the fine cross-hatching typical of the mineral as well as sometimes only fine albite twinning (Fig. 2, Pl. I). Both varieties have refractive indices less than those of Canada balsam and clove oil ($\mu = 1{\cdot}536$) but when fragments are immersed in monochlor-benzene ($\mu = 1{\cdot}525$) the indices of the sanidine are mostly below that of the liquid, γ alone being of about the same amount, while those of the anorthoclase are mostly above 1·525, α alone being about the same. In habit the anorthoclase appears to form stouter and shorter prisms.

The following table gives the mineralogical composition observed by crushing selected fragments of the rocks in suitable liquids:

Number of Specimen	Sanidine	Anorthoclase	Olivine	Ægirine-Augite	Magnetite	Apatite	Brown Glass
1728	×		×	×	×		×
1730		×	×	×	×		
1731	×		×	×	×	×	
1734	×		×	×	×		
1735	×		×		×		
1737		×	×	×			
1744		×	×	×	×	×	×
1747		×	×	×	×		×
1748		×	×		×		×
1749		×	×		×		×
1751	×						
1756	×		×	×			×
1757	×		×	×	×	×	×
1760	×		×	×	×	×	×
1761	×			×	×		×
1767	×		×	×	×		×
1771	×		×	×			×
1772	×		×	×	×		
1776	×		×				
1777	×			×	×		
1821	×		×	×			
1843		×	×				
1844	×		×				
1845		×	×		×		
1846	×				×		
1976	×	×	×	×	×	×	
659 } Erratic, probably Mt. Cis.		×	×				
827		×	×				
1424		×	×	×	×	×	×

So fragile are the rocks that the sections obtained do not give much further information about the structure. The felspars when lying free in glass have perfect crystal outlines (Fig. 2, Pl. I), but most often partially interfere with one another. Opaque inclusions are somewhat abundant and are generally scattered irregularly through the mineral, but occasionally lie in vertical planes in the crystal. The ægirine-augite is a strongly coloured yellow-green variety with a slight pleochroism. Cleavage flakes give extinction angles of 37°–39°, whilst the largest extinction angle measured in section (not quite parallel to 010) is 43°. In part, at least, the mineral has crystallised after the felspar, on which it is moulded (Fig. 3, Pl. I). Fig. 4, Pl. I shows a crystal of ægirine-augite lying in a druse of the rocks partly filled with ground-mass. The olivine, though abundant in hand-specimen in well-formed crystals, is poorly represented in section. It occurs frequently in the trachyte in the neighbourhood of the inclusions, and is there perfectly idiomorphic except for the inclusion of stout crystals of magnetite. Apatite and magnetite are abundant in stout crystals, either in the druses or included in any of the above minerals.

The interstitial glass and ground-mass possess interesting characters. Very often there is a pale brown glass remarkably free from microlites, and in such cases there is a gradual passage from the base of the inclusion into the ground-mass of the trachyte by a gradual increase in the number of felspar microlites. In other cases the ground-mass of the sanidinites is more coarsely crystalline than that of the host, from which it differs also in the absence of flow structure (Fig. 5, Pl. I).

The microsanidinites differ considerably from the sanidinites in outward appearance, for they are typically compact, fine-grained rocks whose felspathic nature is not always clearly evident at first sight. They are generally light-coloured, but sometimes contain darker, coarser-grained, and miarolitic centres, whilst one specimen (1753) is altogether dark grey and vesicular.

In section they prove to have a mineralogical composition similar to that of the sanidinites, but they differ notably in structure. They are composed for the most part of small quadrate prismatic felspars of which by far the majority are untwinned, or show only Carlsbad twins and are to be referred to sanidine. The refractive indices are, however, slightly higher than those of the sanidine of the sanidinites and are seldom lower than that of monochlor-benzene ($\mu = 1{\cdot}525$) so that presumably they belong to soda-sanidine. A few of the larger prisms show typical anorthoclase twinning, while occasionally more elongate plagioclase (oligoclase-albite) is also found. Besides these small quadrate felspars there are generally present much larger pseudoporphyritic plates of anorthoclase, which partially envelop the sanidine. A yellow olivine is very abundant in grains of similar size to those of the felspar mosaic, and is in places distinctly ophitic in structure. Ægirine-augite also occurs, but is more idiomorphic. Magnetite in small grains is widespread, whilst apatite is rare. Fig. 6, Pl. I, gives a general view of the rock.

The dark miarolitic centres approach more nearly in structure to the coarse sanidinites, but are much darker in colour owing to the predominance of ægirine-augite in small prismatic crystals. Miss F. Cohen, of Sydney University, kindly undertook a goniometrical examination of these, the results of which are appended to this paper.

The microsanidinites appear in most cases to pass insensibly into the ground-mass of the host. The dark variety (1753) forms an exception, as it is sharply delimited from the trachyte by a thin zone of large anorthoclase and olivine crystals.

A fragment of rock showing holocrystalline structure, specimen (1146), found as an erratic at Cape Royds, may possibly be an inclusion from a trachyte. It is a mottled yellowish grey and black rock of medium to fine grain, which bears some resemblance to the sanidinites in one corner, where it is more felspathic and more coarsely crystalline. It consists of anorthoclase prisms arranged in orthophyric fashion, with abundance of interstitial ægirine-augite and olivine largely replaced by magnetite, with a smaller amount of barkevicitic hornblende in typically allotriomorphic forms. Apatite and magnetite are richly present. The rock is thus a basic type of alkaline trachyte or orthophyre. Whether it was brought to the surface as an inclusion or is a fragment of a dyke remains uncertain.

Sanidinites and Microtinites in the Kenytes

Five felspathic inclusions have been obtained in the kenytes; with them will be described two others found as erratics at Cape Royds on account of their similarity. The mineralogical composition of these rocks is shown in the following table:

Number of Specimen	Locality and Host	Sanidine	Anorthoclase	Plagioclase	Biotite	Magnetite	Hæmatite	Augite	Olivine	Apatite	Glass
1971	Kenyte, Cape Royds . .	×	×		×	×					×
1972	Kenyte, Cape Royds . .	×	×		×	×		×			×
1793	Kenyte, Inaccessible Island .	×	×	×	×	×					
1847	Erratic Kenyte, Cape Royds	×	×	×	×	×					×
1848	Kenyte, Tent Island . .		×	×	×	×	×	×	×	×	×
1155	Erratic, Cape Royds . .	? ×	×			×					×
1710	Erratic, Cape Barne . .		×		×	×					×

The specimens from the Cape Royds kenyte are small fragments, from which it is impossible to infer the size of the whole inclusion. They are of moderate grain and are more compact than the sanidinites of Mount Cis. In section they show large, somewhat rounded phenocrysts of anorthoclase in a ground-mass of radially disposed microlites, which from their straight extinction appear to be sanidine (Fig. 1, Pl. II). A pale brown glass is very abundant, and from its occurrence in irregular patches and not in the interstices of the rock structure it appears to result from remelting of part of the rock. Irregular grains of magnetite are abundant within the phenocrysts and in the ground-mass. A clear biotite occurs sparingly in large plates and also in clusters around the magnetite. On the exterior of the inclusion, the microlitic character disappears; large and small rounded plates of anorthoclase with a little brown augite and small magnetite grains form an irregular mosaic like that of a sandstone (Fig. 2, Pl. II).

The inclusion in the kenyte of Inaccessible Island is a spherical mass about 5 cm. in diameter. It is only slightly miarolitic, and consists of large platy twinned felspars in a brownish felspathic matrix. In section the large felspars are seen to be andesine with both Carlsbad and albite twins, and in opposition to those of the ground-mass they are clear and glassy. The latter have a peculiar stippled appearance owing to the separation of opaque matter (limonite) along both sets of cleavage planes. They show only Carlsbad twins, and are to be referred to sanidine on account of their refractive indices, but they occasionally contain clear kernels of anorthoclase. For the most part they have stout columnar habit with an approach to orthophyric arrangement, but there are smaller miarolitic areas partially filled by much more slender microlites together with iron ores. Magnetite is abundant both as enclosures in the felspars and in the interstices of the ground-mass. With it is associated a very little biotite, and a greater amount of a yellowish green mineral of high refractive index.

The inclusion in the erratic black kenyte found at Cape Royds is a biotite microsanidinite. It contains large pseudoporphyritic plates of anorthoclase lying in a matrix of small quadrate prisms of sanidine, anorthoclase, oligoclase, and glass. Well-shaped large and small crystals of magnetite and more or less rounded plates of biotite are abundant.

The inclusion in the kenyte of Tent Island is a large mass 8 × 5 × 6 cm. The hand-specimen shows large platy felspars with a miarolitic brownish red cement, in the midst of which iridescent black crystals of olivine may be recognised. The large felspars are zoned and twinned in a complex manner (Fig. 3, Pl. II) and prove to belong to oligoclase and andesine. In their interstices another felspar may be detected in small lath-shaped prisms. From its refractive indices between those of monochlor-benzene ($\mu = 1{\cdot}525$) and clove oil ($\mu = 1{\cdot}536$) it is determined as anorthoclase. It is accompanied by large crystals of olivine and titaniferous augite enclosing apatite, small apparently shapeless plates of hæmatite and biotite and much magnetite in large and small grains.

The two erratics (1155 and 1710) are presumed to be inclusions from the fact that they bear a general resemblance to the sanidinites and differ from plutonic rocks in containing a considerable amount of clear brown glass. They are further presumed to be inclusions from the kenytes from the abundance of magnetite that they contain, and in the case of (1710) from the presence of biotite. They have not been studied in section.

OTHER SANIDINITES

Microsanidinite in a Basic Rock from Hut Point (1238). The host is a reddish brown, somewhat earthy basic rock, and the inclusion a small friable white rock. The powder of the latter examined in oils shows that it is composed almost entirely of anorthoclase, with zircon as the only other constituent in numerous stout prisms. The grain size and general appearance recall the clearer microsanidinites of Mount Cis.

Erratic Sanidinite, Cape Royds (1357). This is a large angular rock which bears in some places considerable superficial resemblance to the sanidinites, but is not miarolitic like them, and is distinguished by the occurrence of large lustrous patches of black glass. Microscopic study suggests that it is a sanidinite that has been partly remelted. The most abundant mineral is a clear sanidine, partly in large plates with numerous enclosures of glass and leucite, and partly as a fine mosaic. An augite of peculiar yellowish colour is fairly abundant, also partly in large plates full of the same inclusions and partly as small rounded grains clustered together. It has a colour more nearly yellow than green, is very feebly pleochroic, gives extinction angles of 45°, and has strong dispersion of the bisectrices with an axial angle of nearly 90°. Perhaps the yellow colour is due to the reheating which the rock appears to have undergone. Apatite is also an abundant constituent in stout prisms with sharp pyramidal terminations where it lies in glass, a feature which suggests a late crystallisation for the mineral. The glass, brown in thin section, occupies relatively large areas of the rock. It has a refractive index slightly lower than that of monochlor-benzene ($\mu = 1{\cdot}525$). Rosenbusch gives the indices of artificial syenite glass as 1·520, and of monzonite glass as 1·550.* Douglas † obtained results still higher for syenites and even more acid rocks. The refractive index of the brown glass in the sanidinites of Mount Cis is also less than 1·525, so that the glass of the rock under description agrees well with what would be expected from the remelting of a sanidinite.

Within the glass there are two minerals besides the apatite that have clearly separated from the glass on cooling (Fig. 5, Pl. II). One is magnetite in quadrate sections of large and small octahedra, in whose immediate vicinity the glass is decolorised. The abundance of the magnetite is probably connected with the melting of olivine or biotite, although why the former did not recrystallise is difficult to understand. The other mineral is still more abundant in small sharp colourless perfectly isotropic crystals with low relief. They have sometimes quadrate forms, occasionally truncated at the corners, and sometimes hexagonal forms. A few cleavage traces are observed on both forms,

---

* *Mikr. Phys.*, i, ii, Tabelle I, 1905.

† Douglas, J. A., "Changes of Physical Constants in Minerals and Igneous Rocks, on the Passage from the Crystalline to the Glassy State," *Q.J.G.S.*, lxiii, 1907, p. 153.

and in each case run parallel to the dominant faces, *i.e.*, the cleavage net is respectively rectangular or triangular, and therefore probably dodecahedral. The refractive index, superior to that of xylol ($\mu = 1 \cdot 494$), excludes analcite and sodalite, so that the mineral must be leucite. This too is what would be expected in the melt of a rock consisting largely of sanidine.

There is no clue as to the rock in which this inclusion was remelted, but the above description renders it probable that the sanidinite originated in a trachyte.

Origin of the Sanidinites and Microtinites

The origin of sanidinites in trachytes appears at first sight very simple. They consist in general of the same minerals as the phenocrysts of the rock, and appear to have arisen by a simple aggregation of these minerals; another plausible view is that they represent a complete crystallisation in depth of a portion of the trachytic magma, perhaps as a wall to the magma basin, and have been broken off and included in the still unconsolidated magma on eruption. Lacroix, in his earlier work,* considered the latter the more probable mode of origin; but subsequently he has shown that sanidinites may arise in many different ways. For instance, trachytes appear to have the power of converting inclusions of such rocks as older trachytes, gneisses and granulites into sanidinites † and this may have happened in many cases where the intermediate steps can be no longer traced. A still more curious origin is put forward for some sanidinites in the basic leucitic tuffs of Somma.‡ Besides the sanidinites the tuffs contain blocks of metamorphosed limestones which have locally the constitution of sanidinites, and the isolated sanidinites are assumed to be fragments broken off from the limestone blocks. The origin of the sanidine in the cavities of the limestone is ascribed to contact alteration accompanied by an exudation of soda into the limestone under pneumatolytic conditions. It is obvious, therefore, that the explanation of the origin of the sanidine in any rock must be carefully scrutinised.

The peculiar feature of the Mount Cis sanidinites is the predominance of olivine over ægirine-augite, in opposition to its rarity in the trachyte. A further mineralogical difference between the two rocks is the absence of the alkaline amphiboles in the former and their presence in the latter. Chemically expressed, the sanidinites are richer in iron and magnesia than the trachytes and poorer in lime. They cannot therefore be regarded as simply a deep-seated crystallisation of a part of the trachyte magma, unless some differentiation is admitted. One specimen might suggest that they are simply aggregations of phenocrysts (Fig. 4, Pl. II), but phenocrysts of sanidine are not at all common in the trachytes, and the specimen might be interpreted equally well as a sanidinite that had been partly broken up by movement in the trachyte.§

The microsanidinites present the same mineralogical differences from the trachytes as the sanidinites. From their orthophyric structure they point more clearly to deep-seated crystallisation, with a slight amount of differentiation. The development of a thin zone of coarse crystals around one of them (1753) perhaps gives the clue to the origin of the sanidinites. The latter may have been originally inclusions of orthophyric trachyte which the trachyte magma has by the power of its mineralising vapours trans-

---

* *Les Enclaves*, etc., pp. 353 *et seq.*

† Lacroix, A., "Sur deux nouveaux groupes d'enclaves des roches éruptives," *Bull. Soc. fr. Min.*, xxiv, 1901, pp. 488–504.

‡ *Loc. cit.*

§ This specimen was sent away to the International Geological Congress at Stockholm, so that the writer has not been able to re-examine it.

formed into the coarse-grained rocks we now see. The negative evidence against this view is, however, stronger than the positive, and it is perhaps best, in the present state of our knowledge, to consider them also as fragments of deep-seated rocks of close genetic connection with the trachyte magma.

The materials for the study of the felspathic inclusions of the kenytes is, unfortunately, very meagre, but it is of interest to find that both sanidinites and microtinites can originate in kenytic magmas. The most noticeable mineralogical difference from the kenytes lies in the presence of biotite, a mineral not recorded at all from the volcanic rocks. It is well known that a dry melt of orthoclase and biotite in certain proportions will recrystallise under slow cooling as a mixture of olivine and leucite. The two last minerals are found occasionally as phenocrysts in the kenytes, so that it appears that the biotite, and therefore the rocks containing it, crystallised under different conditions of pressure from those which prevailed during the formation of the phenocrysts of the kenyte. The inclusions cannot therefore be simple aggregations of phenocrysts.

There is a close correspondence between the natures of the hosts and of the inclusions. Sanidinites are found in the acid kenyte of Cape Royds which contain anorthoclase as phenocrysts, while microtinites are found in the basic kenytes of the Delbridge Islands, which contain phenocrysts of oligoclase. The augite of both types of inclusion is titaniferous and not ægirine-augite as in the sanidinites of the trachytes. From this correspondence it may be safely inferred that the inclusions originated from the same magmas as the rocks enclosing them. Further inquiry as to whether they are fragments of already consolidated portions of the magmas or foreign fragments that have been reconstituted by the influence of the magmas cannot be profitably followed on the evidence available. The microlitic structure of the ground-mass points to the former view.

III. HORNBLENDIC INCLUSIONS IN THE TRACHYTES

Inclusion in the Trachyte of Observation Hill. Prior has already noticed the rounded brownish enclosures in the trachyte of Observation Hill : " Under the microscope they consist of a dense mesh of interlacing prisms of basaltic hornblende, similar to that in the trachyte, with magnetite grains and only a little interstitial felspar. The hornblende in these enclosures and in the trachytes has the characters of barkevicite." *

This type is represented by only one specimen in the present collection. It agrees in general characters with those described by Prior, but it may be noted that besides the fine interlacing prisms of hornblende there are a few larger and proportionately stouter prisms which stand to the former as phenocrysts to ground-mass, and thus give the rock a lamprophyric character. The untwinned felspar has refractive indices slightly lower than that of Canada Balsam, and probably belongs to anorthoclase.

Inclusion in the Trachyte of Cape Bird. A specimen of a dark green phonolitic trachyte from the beach pebbles of Cape Bird proves to be rich in small hornblendic inclusions. They are more coarsely crystalline than the Observation Hill type, and are markedly vesicular with minute crystals of analcite in the vesicles. Under the microscope hornblende, augite, olivine, felspar, magnetite, apatite, calcite, and analcite may be recognised. The structure is distinctly porphyritic ; colourless olivine in prismatic forms with acute pyramidal terminations and pale lilac titaniferous augite in long prisms with obtuse pyramids terminated by the basal plane appear to have formed the earliest phenocrysts, since hornblende is occasionally moulded on both minerals. A considerable amount of magmatic resorption has affected the augite in cases where it is enclosed with

---

* *Loc. cit.*, p. 118 and Fig. 66.

rounded forms within the hornblende along with grains of magnetite. Fig. 1a shows the normal course of the resorption and Fig. 1b an unusual case where it has taken place on one side of the augite only, with the development of the hornblende in parallel position. The hornblende is a common brown variety with pleochroism from brown to yellow-brown, and is perfectly euhedral where it does not impinge on olivine or augite, with the faces M (110), B (010), A (100), and dome terminations. Felspar occasionally forms large lath-shaped crystals comparable in size to the above-named minerals, but cannot be considered a phenocryst, since it includes abundantly the fine hornblende needles of the ground-mass. It shows simple albite twins with low extinction angles, but too few opportunities of measurement present themselves to determine the maximum, nor can the refringence be compared with that of balsam since the mineral is always surrounded by analcite. The latter occupies large areas of the ground-mass, of which the chief constituent is hornblende in small prisms crossing one another in all directions. The amygdules are generally completely filled with analcite and calcite, the former being the earlier mineral in sharp crystals (Fig. 6, Pl. II).

Fig. 1a

Fig. 1b

On the assumption that a calcic felspar has been replaced by analcite and calcite, the rocks agree in all respects with olivine camptonites.

Origin of the Hornblendic Inclusions of the Trachytes

Lacroix has found that inclusions more basic than their host, although not so common as inclusions of sanidinites, have nevertheless a wide distribution in trachytes, especially in those rich in ferromagnesian minerals. They are for the most part of the nature of porphyrites. In phonolites the analogous inclusions are generally camptonites, rocks which, he points out, frequently accompany nepheline syenites, the plutonic representatives of phonolites. He considers them, nevertheless, as basic segregations from the phonolitic magma.*

While the Observation Hill inclusions might easily be considered as segregations, since the same hornblende is so abundant in the trachyte, the Cape Bird camptonites cannot be so regarded. The alteration they have undergone could scarcely have taken place had they never existed but within the trachyte, since the latter is a relatively fresh rock. It is simpler to conceive of them as fragments of true camptonites which were completely consolidated and partly altered before they were enclosed in the trachyte magma.

The fact that the basic inclusions of the Ross Island trachytes are camptonites and not porphyrites is a further confirmation of the phonolitic affinities of these trachytes.

* *Les Enclaves*, etc., p. 416.

IV. ORBICULAR AUGITE-SYENITE : PROBABLY AN INCLUSION

An Erratic from half-way between Cape Royds and Cape Barne, near Mount Cis. The reasons for assuming that this rock is an inclusion of some volcanic rock are, first, the alkaline affinities of the rock, and secondly, the abundance in it of a brown glass similar to that described in so many of the above inclusions.

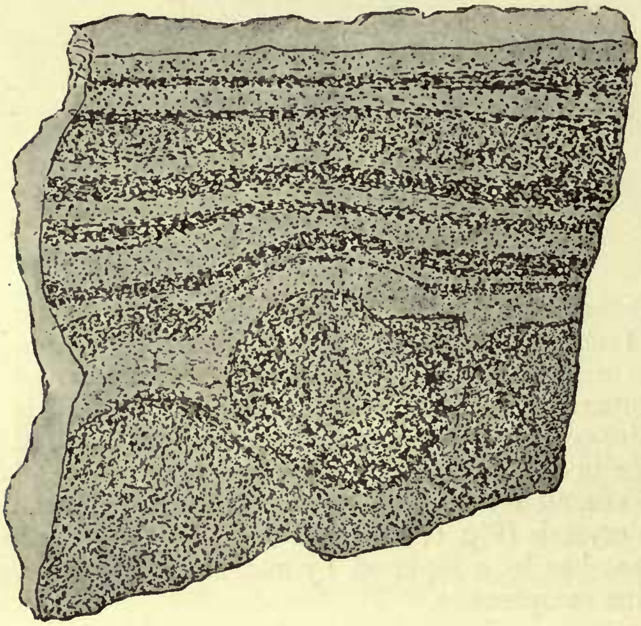


FIG. 2

The hand-specimens (1974 and E33) are small angular fragments which show for the most part a banded character, and only in one case a complete spherule. The accompanying sketch (Fig. 2) of a polished surface, kindly drawn by Mr. W. N. Benson, of Sydney University, gives a clear idea of the macrostructure. The dark bands and the centre of the spherule owe their colour in part to an augite, but more particularly to magnetite. The clear bands consist predominantly of felspar.

The augite is a brownish green variety without marked pleochroism. The dispersion of the bisectrices is so strong that the mineral often does not completely extinguish, but the extinction angle $Z \wedge c$ is approximately 32°. The axial angle is nearly 90°. From the brownish colour and strong dispersion the mineral must be classed with the titaniferous augites. It occurs in anhedral elongate plates, which are relatively large when they are found in the centres of the spherules or between the dark bands, and in these cases are set more or less radially. Occasionally in the small clear bands it occurs in small rounded grains. In the dark bands it is generally in much smaller crystals and elongated tangentially to the spherules. In both cases it is rich in magnetite inclusions, arranged perpendicularly to the elongation, and occasionally encloses a brown glass.

The felspars show a great diversity of twinning; untwinned forms are abundant, and so are forms with cross-hatchings of various degrees of sharpness from mere moiré extinctions to twinning scarcely to be distinguished from microcline twinning; simple albite twinning with low extinction angles is comparatively rare. The refractive indices of all these lies not far from that of Canada balsam. More exact determinations in liquids of known indices show that none lie below 1·525, and most lie between 1·536 and 1·540. A plagioclase in cleavage flakes shows one index below 1·540 and one above; it therefore belongs to oligoclase; the rest of the felspar appears to belong to anorthoclase with unusually high refractive indices, and probably therefore rich in the anorthite molecule. Like the augite, the felspars vary in size according to their position. Within or near the dark bands they form a fine-grained polygonal mosaic; between the dark bands and in the centre of the spherules they have a tendency to an elongate radial habit. They enclose small magnetite grains and an abundance of fine colourless needles, too small for exact determination. Some larger prisms with cross-fractures are certainly apatite, but the majority of the needles are probably sillimanite.

A brown glass is found somewhat abundantly in certain bands, both as inclusions in the felspar and augite and as an interstitial base. In the latter case it encloses well-shaped octahedra of magnetite and is crowded with arborescent crystallites, In addition there is occasionally a clear mineral of moderate refringence and low birefringence, which is biaxial with a moderate axial angle and optically negative. In crushed fragments of the rock this mineral is seen to be well crystallised and appears to be orthorhombic, with pinacoids, basal plane, and dome faces. It has not been definitely determined.

If the presence of glass be neglected, the rock has the mineralogical composition of an augite syenite (of the soda syenite family) and may be termed an orbicular augite syenite. The glass included in the minerals might have arisen by remelting, and in one of the specimens has very much the appearance of having arisen in this way; that occurring interstitially, however, appears to be the result of a normal stoppage of crystallisation due to sudden cooling. The alkaline affinities of the rock ally it to the volcanic series of Ross Island, and the hypothesis is put forward that it was torn from its place before consolidation was complete, and brought to the surface either in a lava or a volcanic breccia.

V. PLAGIOCLASE-PYROXENE INCLUSIONS IN THE TRACHYTE OF MOUNT CIS

Among the fine-grained compact inclusions from Mount Cis there are four characterised by a mottled greenish grey appearance. These prove on microscopic examination to consist of a basic plagioclase and pyroxene with subordinate magnetite and sphene, and in one case calcite. The plagioclase generally occurs in large tabular plates with both Carlsbad and albite twins, and is referable from extinction angles to labradorite. The pyroxene in three of the specimens (T 7, P 33, and 1969) is a pale green monoclinic variety with oblique extinctions up to 44° and a high axial angle. In the other (E 35) it is an almost colourless variety with straight extinctions and is optically negative and therefore referable to bronzite. The pyroxenes generally have an ophitic relation to the felspars, but in parts of the rocks the structural relations have been more or less broken down, and the pyroxene is found as small grains intermixed with and included in small felspar plates (Fig. 1, Pl. III).* In places a brown glass appears, either as inclusions in the felspars, or as an interstitial matrix in which small euhedral felspars are embedded (Fig. 2, Pl. III). In one rock (E 35) the felspar is accompanied by a colourless, more strongly refringent mineral which appears to be wollastonite. In the same rock there is a vesicular glassy selvage against the trachyte, in which large plates of anorthoclase are developed.

These inclusions must be interpreted as fragments of dolerites that have been partially melted and recrystallised, with a slight admixture of trachytic material on the edges. The dolerites appear to have no alkaline affinities, and can scarcely be derived from the trachytic magma or its allies.† They are probably fragments of sills intrusive into the Beacon sandstones such as occur on the mainland.

---

* From the resemblance of these apparently granulitic parts of the rock to some of the pyroxene granulites that are found as erratics at Cape Royds, the writer was at first inclined to regard these rocks as inclusions of granulites, and this view was published in the preliminary account of the Geology by Professor David and Mr. Priestley, *Compt. Rend. Congr. Geol. Inter. Stockholm*, 1910. The absence of the characteristic clove-brown wedges of sphene and the ophitic character of the least disturbed parts of the rock are against this view.

† They present little resemblance to the gabbroid nodules described above.

VI. QUARTZ-BEARING INCLUSIONS

Quartz-Pyroxene Inclusions in the Trachyte of Mount Cis

These are small, rounded, compact, greyish white inclusions, at first sight similar to some of the microsanidinites, but distinguished from them on close examination by the presence of small grains of quartz. With them must be included a number of very vesicular brown inclusions, since in some cases the latter contain a kernel of the former.

Under the microscope the first type is seen to consist mainly of numerous large grains of quartz separated by smaller grains of the same mineral and of a pale yellow-green augite (Fig. 3, Pl. III). Occasionally the pyroxene has a sieve-like or poikilitic development, enclosing grains of the other minerals indifferently. In some specimens a turbid plagioclase (labradorite) also occurs in large grains, but never in amount equal to the quartz. Wollastonite can be definitely identified in one section (E 14) in long prisms enclosing small granules of augite, and is suspected in others. Magnetite appears in most specimens in irregular blotches and small grains, and sphene is found in a few in large rounded forms. Calcite appears in only two specimens. In all a greater or less amount of a clear brown glass is present.

Sometimes the structure of the inclusion remains unaltered right to its contact with the host, but where the quartz grains abut against the trachytic ground-mass there is an ingrowth of a green augite, near ægirine in its properties, from the host.

This phenomenon is still better exemplified in cases where sporadic xenocrysts of quartz have swum in the trachytic magma (Fig. 4, Pl. III). At other times a different form of contact is observed; the inclusion becomes slaggy and vesicular towards the edge, and in section is predominantly glassy with an occasional development of large anorthoclase crystals besides the sharp augite prisms, some partially molten quartz grains still remaining.

There is little doubt that the wholly slaggy and vesicular inclusions represented melted rocks of the same nature as those which gave rise to the quartz-pyroxene type. The rocks are excessively fragile, and no satisfactory sections were obtained, but examination of crushed fragments in oil shows that they consist chiefly of a clear brown glass with a variable amount of quartz, augite, magnetite, and numerous prismatic crystals of a mineral which could not be definitely determined. It has refractive indices superior to those of wollastonite, which it resembles in its straight extinction and moderate birefringence. It is biaxial with a low optic axial angle, is negative and has positive elongation of the prisms.

One specimen (E 17, T 5) merits separate description. It has a vesicular contact zone with the host of about 1·5 cm. in width. The kernel (4 cm. in diameter) has a thin white shell, but is much darker in the centre than is usual in this type of rock (Fig. 5, Pl. III). The contact zone is similar in general characters to the above described rocks, containing the quartz, augite, and the undetermined mineral all lying in a brown glass. The outer part of the kernel resembles the more compact inclusions. The dark colour of the centre is due to the prevalence of finely distributed magnetite dust. Large clear quartz grains are still present, but they are fewer and farther apart, and there are in addition a few grains of an intermediate plagioclase. These minerals are all enclosed in large interlocking plates of a mineral which resembles cordierite both in habit and in the abundance of magnetite inclusions. It is biaxial with a moderate axial angle, and optically negative and may thus be cordierite or a felspar of the orthoclase-anorthoclase series. No twinning was observed. On the margin between the dark centre and the clearer exterior there are numerous granules of strongly pleochroic hypersthene, often developed at the edge of large quartz grains.

All these inclusions, from the abundance of quartz they contain where not extensively melted, may be safely referred to fragments of impure sandstone. The presence of augite, wollastonite, and calcite shows that there must have been some lime present, possibly as a calcareous cement.

Quartz-bearing Inclusions in the Kenytes

Two specimens only of this nature have been collected. The one was included in the kenyte of Cape Royds, the other in that of Sentinel Hill. The former is a fine-grained brownish grey banded rock, with large rounded cavities. In section it is seen to consist of quartz in small angular grains, with lesser amounts of felspar, augite, and magnetite. The brownish colour is due partly to a glassy base, and partly to limonite staining. The felspar occurs in short rectangular forms giving symmetrical extinction on albite lamellæ of 33°, and is therefore labradorite, although more acid species may also be present. The augite, on the other hand, is found in highly irregular embayed forms and freely includes quartz.

The other inclusion (E 20) is a slightly reddish streaky rock with a sintery appearance which microscopic examination shows to be due to an abundance of glass. The clear streaks are composed mainly of small rounded quartz grains lying each isolated in the glass. Occasionally, however, they are accompanied by thin needles of a colourless mineral, which from its straight extinction, positive elongation, and moderate birefringence appears to be sillimanite. Where there is the richest development of these needles there are also some small clear hexagonal overlapping plates of tridymite. There are a few larger prisms and rounded plates of another clear mineral, with refringence and birefringence much superior to those of quartz. It is uniaxial or almost so, and optically positive.

The more turbid streaks are almost opaque in section, and appear to consist largely of glass with smaller amounts of the above-named minerals, together with much fine opaque dust. In a few patches they are excessively rich in minute needles, probably of sillimanite. Magnetite and hæmatite are abundant in both parts of the rock.

This rock, like the last, is clearly an altered sandstone.

VII. CLASSIFICATION OF THE INCLUSIONS

From the above descriptions and discussions it will be obvious that the inclusions can be sharply separated into two categories, the one including all those rocks which are genetically connected with the volcanic hosts, the other comprising those that have no such connection and have been broken off from the sedimentary or older igneous rocks through which the volcanic lavas ascended. This underlying distinction has been made the basis of all the classifications that have been proposed. As early as 1884 Sauer proposed the terms "endogene" and "exogene" for the two classes, and his terms are still applied by some German writers.* Lacroix in 1893 rejected them for the terms "homœogène" (from ἕναλλος, analogous, and γενναω, I beget) and "énallogène" (from ὅμοιος, different, and γενναω), since the genetic relationship is not necessarily one of direct parentage, such as is implied in the term endogene.† Sollas in 1894 proposed the terms "xenocryst" and "xenolith" for foreign

---

* Sauer, *Erlaut. Preuss. Geol. Landsanst,* Sect. Wiesenthal, 1884, p. 70.

† *Les Enclaves,* etc., p. 7.

crystals and rocks respectively without discussing the genetic origin, and these terms have come into general use in English.[*] Harker in 1900 proposed to replace Lacroix's terms by the terms "cognate xenoliths" and "accidental xenoliths" respectively, on the ground that Lacroix relied on analogies of composition between inclusion and host and not upon analogies of origin.[†] Holland the same year suggested the term "autolith" in antithesis to "xenolith," rejecting Lacroix's term owing to a mistranslation of "homœogène" by "homogeneous."[‡] In the subsequent year Lacroix pointed out that Harker's criticism was based on a misunderstanding:

"Le principe énoncé par M. Harker est précisément celui qui m'a guidé dans l'établissement des deux groupes d'enclaves en question et dans leur nomenclature ?"[§]

Harker in 1909 repeated his objections in a modified form,[||] but, in the writer's opinion, has not succeeded in demonstrating the unsuitability of Lacroix's terms or the superiority of his own. Lacroix's classification is therefore adopted in this paper.

Lacroix has further subdivided his group of homœogenous[¶] inclusions into the following groups:[**]

Allomorphe	homologue. antilogue.
Plésiomorphe	homologue. antilogue.
Polygène	exopolygène. endopolygène.
Pneumatogène.	

The allomorphous inclusions are those torn from masses already consolidated in depth. The plesiomorphous are segregations formed in the magma that have not had a separate existence as geological units. For these Holland's term of autolith seems appropriate. Either of these two types may be homologous, *i.e.* formed by the integral consolidation of the mean type of the enclosing magma, or antilogous, *i.e.* formed by basic differentiation or original heterogeneity. The polygenous types are those which have arisen by the action of the magma on included fragments of other rocks, the endopolygenous resulting from a complete melting of the inclusion and the crystallisation of the endometamorphosed portion of the magma, the exomorphous from the transformation of the inclusion under the influence of emanations coming from the magma. The latter type must therefore grade off into enallogenous inclusions. Finally the pneumatogenous types arise in the way described above for the sanidinites of Somma (*vide ante*).

It is obvious that this classification is ideal and can only be applied in cases where

---

[*] Sollas, W. J., "On the Volcanic District of Carlingford and Slieve Gallion," Part I; "On the Relations of the Granite to the Gabbro at Barnanave, Carlingford"; *Trans. Roy. Irish Acad.*, xxx, 1904, p. 493.

[†] Harker, A., "Igneous Rock Series and Mixed Igneous Rocks," *Journ. of Geol.*, viii, 1900, p. 309.

[‡] Holland, T. H., "The Charnockite Series; a Group of Archæan Hypersthene Rocks in Peninsular India," *Mem. Geol. Surv. India*, xxviii, Part II, 1900, p. 217.

[§] Lacroix, A., "Sur deux nouveaux groupes d'enclaves des roches éruptives," *Bull. Soc. fr. Min.*, xxiv, 1902, pp. 488–9.

[||] *The Natural History of Igneous Rocks*, pp. 346, 347, 1909.

[¶] Dr. Craigie, one of the collaborators on Murray's Oxford Dictionary, in conversation with the writer in 1907 suggested "homœogenous" as the correct English translation of "homœogène."

[**] *La montagne Pelée et ses éruptions*, Paris, 1904. Also *Bull. Soc. fr. Min.*, xxiv, 1901, pp. 488–504.

the origin of the inclusion is beyond doubt. The following application to the present collection* is therefore put forward tentatively:

Homœogenous Inclusions

Allomorphous, homologous	Olivine nodules in limburgites. Gabbroid nodules in basalts. Sanidinites, etc., in trachytes and kenytes.†
antilogous	Olivine and pyroxene nodules in basalts. Hornblendic inclusions in trachytes.
Plesiomorphous, homologous.	
antilogous	Hornblende crystal in basalt.
Polygenous, endopolygenous.	
exopolygenous	? Sanidinites in trachyte of Mt. Cis.
Pneumatogenous.	

Enallogenous Inclusions

Enallogenous inclusions	Sandstones in the trachytes and kenytes. Dolerite inclusions in the trachyte of Mt. Cis.

The microsanidinite in the basic rock from Hut Point may almost be considered an enallogenous inclusion, for although it is distantly related to its host, it may be assumed that it arose from a trachyte differentiate of the primitive magma and not from the primary basic differentiate.

VIII. SUMMARY AND CONCLUSIONS

The following types of inclusions have been described:
Olivine Pyroxene and Gabbroid nodules in the basalts and limburgites of Hut Point.
Olivine Sanidinites and microsanidinites in the phonolitic trachyte of Mount Cis.
Biotite Sanidinites and microtinites in the kenytes. These are new to science.
Hornblendic nodules in the trachytes.
Doleritic inclusions in the trachyte of Mount Cis.
Quartz-pyroxene inclusions in the trachyte of Mount Cis.
Sandstone inclusions in the kenytes.
Miscellaneous erratics, presumed to be inclusions.

Only a limited number of the above types are of sedimentary origin, but those that do occur have an important bearing on the question of the formation of the Ross Sea. Since they are all metamorphosed sandstones, it follows that parts, at least, of Ross Island are underlain by a sandstone formation. This can scarcely be anything else than a down-faulted portion of the Beacon Sandstone. The presence of dolerites as well as sandstones in the trachyte of Mount Cis strengthens this conclusion, since sills of dolerites have been found to be ubiquitous in the Beacon Sandstones of the mainland.

All the other inclusions are of igneous origin and genetically connected with the alkaline rocks of Ross Island. Many of them are types not met with at the surface as separate rocks, viz., peridotites, gabbros, pyroxenites, orthophyric trachytes, sanidinites, microtinites, camptonites, and an orbicular augite syenite. Their study thus gives some idea of the deep-seated rocks whose formation has accompanied the eruption of the lavas. A fuller idea of the possible differentiates of such a magma as the fundamental alkaline magma of Ross Island is thus obtained, and more direct comparisons are possible with areas of deep-seated rocks.

---

* The inclusions of which the host is unknown cannot of course be classed.

† If the slight amount of differentiation be overlooked.

In conclusion the writer desires to express his thanks to Professor David and Mr. Raymond E. Priestley for unfailing kindness and assistance in the preparation of this report, and to Messrs. Priestley and G. Burrows for assistance in the preparations of the illustrations.

EXPLANATION OF THE PLATES

PLATE I

Figure 1.—Olivine nodule, Hut Point. × N.* × 34 diams.
Figure 2.—Anorthoclase in glass at edge of sanidinite, Mount Cis. × N.
Figure 3.—Sanidinite in trachyte, Mount Cis; showing ægirine-augite moulded on felspar. Not × N.
Figure 4.—Ægirine-augite in druse cavity in sanidinite, Mount Cis. Not × N. × 27 diams.
Figure 5.—Microlitic ground-mass of sanidinite in Mount Cis trachyte. × N. × 37 diams.
Figure 6.—Microsanidinite in trachyte, Mount Cis. × N. × 34 diams.

PLATE II

Figure 1.—Sanidinite in Cape Royds kenyte. × N. × 27 diams.
Figure 2.—Sanidinite in Cape Royds kenyte showing rounded character of anorthoclase and titaniferous augite on the margin. Not × N. × 14 diams.
Figure 3.—Zoned plagioclase of microtinite in the kenyte of Tent Island. × N. × 12 diams.
Figure 4.—Sanidinite from Mount Cis suggesting an aggregation of phenocrysts. Hand-specimen.
Figure 5.—An erratic from Cape Royds. Probably a partially remelted sanidinite showing sanidine, leucite, magnetite, and brown glass. Not × N. × 18 diams.
Figure 6.—Camptonitic inclusion in trachyte, Cape Bird, showing analcite and calcite in an amygdule. Not × N. × 37 diams.

PLATE III

Figure 1.—A doleritic inclusion in trachyte, Mount Cis. × N. × 27 diams.
Figure 2.—A doleritic inclusion in trachyte from Mount Cis, showing augite and glass with idiomorphic felspars.
Figure 3.—A quartz pyroxene inclusion in the trachyte of Mount Cis. × N. × 18 diams.
Figure 4.—A quartz xenocryst in the trachyte of Mount Cis, surrounded by a zone of glass with ægirine needles. × N. × 37 diams.
Figure 5.—A sandstone inclusion with slaggy exterior in the trachyte of Mount Cis. Hand-specimen.

FIGURES IN THE TEXT

Figure 1a.—Augite in camptonitic inclusion of Mount Bird trachyte, magmatically resorbed with separation of magnetite and formation of a hornblende rim. Enlarged.
Figure 1b.—Ditto: Hornblende replacing augite on one side only.
Figure 2.—Sketch of polished face of orbicular augite syenite; erratic from near Mount Cis. Enlarged.

---

* × N = Nicol prisms crossed.

PLATE I

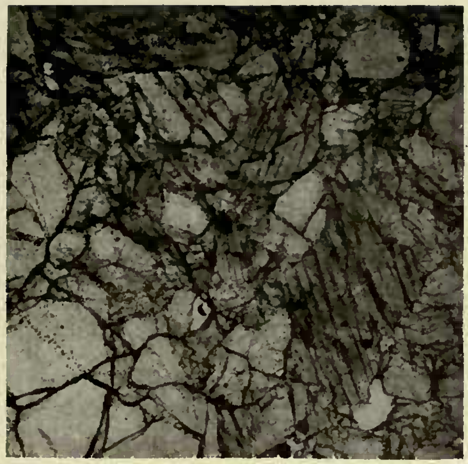


Fig. 1

Fig. 2

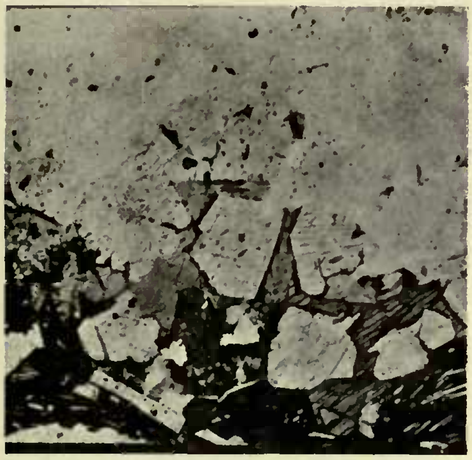


Fig. 3

Fig. 4

Fig. 5

Fig. 6

[*To face p.* 148

APPENDIX TO PART VIII

ÆGIRINE-AUGITE CRYSTALS

FROM A MICROSANIDINITE OUT OF THE TRACHYTE FROM MOUNT CIS, ROSS ISLAND

(*With Four Figures in the Text*)

BY

MISS F. COHEN, B.A., B.Sc.

THE crystals* are all very small, but distinctly prismatic in habit, with a squarish cross-section—average measurements being roughly ½ by ½ by 1 mm. in the direction of the *a*, *b*, and *c* axes respectively.

They are remarkably brittle and readily break into cleavage fragments.

Although good faces were seen embedded in the rock, those crystals that could be isolated were unsatisfactory for purposes of measurement—the faces being nearly all corroded and the extremities of the crystals always more or less broken.

Three crystals were examined, all of which possess the *a* and *b* pinacoids and the *m* (110) prism. In all, *m* is by far the largest face and gives good readings.

The mean angles of the observed forms are tabulated below along with the theoretical values deduced from the calculated elements.

Forms		Measured				Calculated			
		ϕ		ρ		ϕ		ρ	
a	100	0°	0′	90°	0′	0°	0′	90°	0′
b	010	90°	0′	90°	0′	90°	0′	90°	0′
m	110	43°	38′	90°	0′	43°	38′	90°	0′
u	111	54°	19′	45°	50′	54°	50′	46°	11′
s	$\bar{1}11$	24°	38′	33°	25′	26°	00′	33°	44′
o	$\bar{2}21$	35°	08′	55°	55′	35°	46′	55°	57′
e	011	24°	54′	33°	35′	24°	59′	33°	30′
z	021	10°	26′	49°	47′	13°	07′	50°	57′

Of these forms one crystal† possessed *a*, *b*, *m*, *u*, *s*, *o*, and *z* (Figs. 1 and 2), and another only *a*, *b*, *m*, *s*, *e* (Figs. 3 and 4).

---

* *Vide* Dr. Thompson's paper, *ante*.

† The back of the crystal was broken so that other forms may have been present.

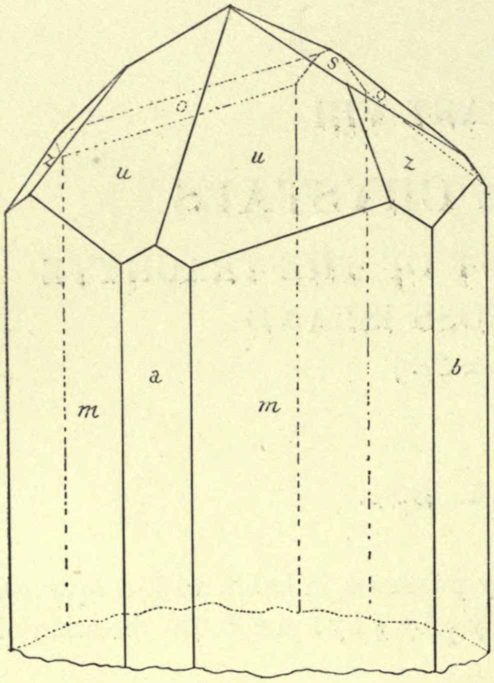


FIG. 1

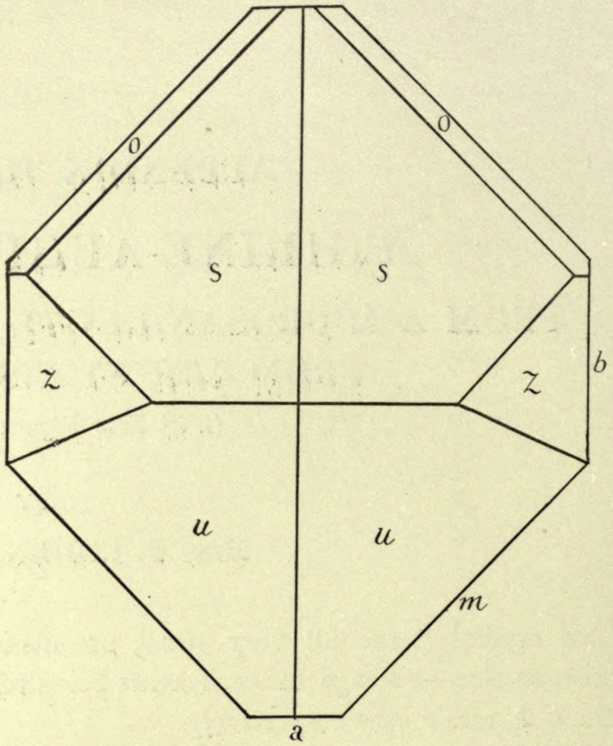


FIG. 2

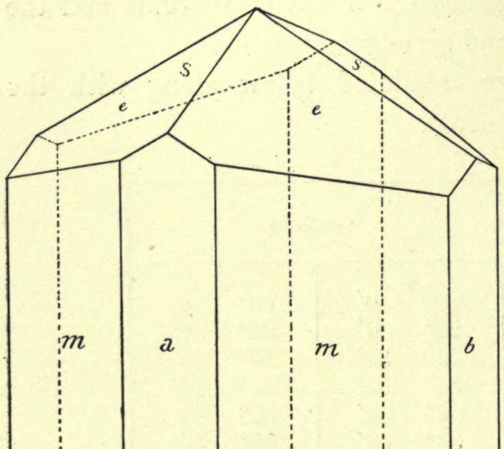


FIG. 3

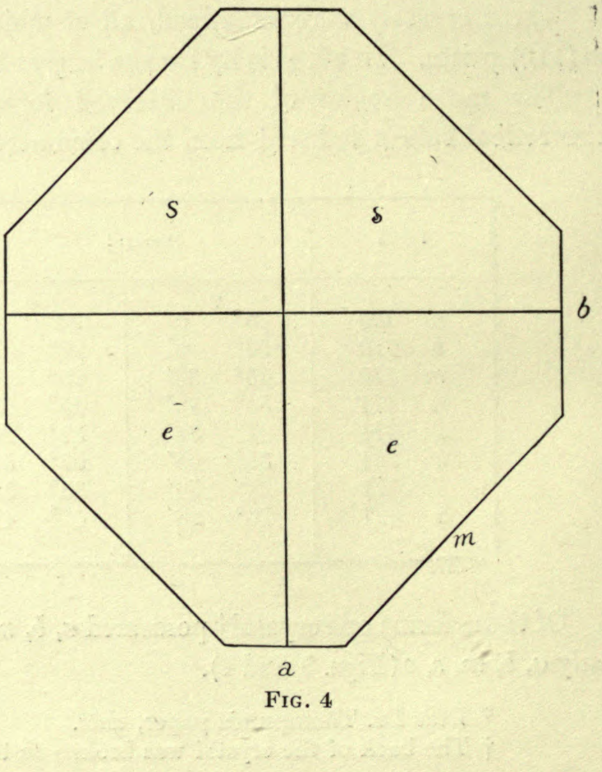


FIG. 4

The presence of the forms *z* and *e* is remarkable, as they apparently have not been observed on ægirine, though they commonly occur on iron-rich diopside.*

The edges between *m* and *u* and *m* and *z* are bevelled—no signal could be obtained from them, so that they are probably due to corrosion.

The elements calculated from the above forms gave the following results:

$a : b : c = 1{\cdot}08909 : 1 : 0{\cdot}600116.$

$\beta = 74^\circ\ 23'$

---

* Zambonini, F., "Die Morphotropischen Beziehungen zwischen Enstatit, Diopsid, Hedenbergit, Ägirin und Spodumen," *Zeits. für Kryst.*, xlvi, 1909, pp. 1–72.

PART IX

REPORT ON THE PETROLOGY OF THE DOLERITES

COLLECTED BY THE BRITISH ANTARCTIC EXPEDITION, 1907–1909

(*With Plate*)

BY

W. N. BENSON, B.Sc.

THE dolerites of South Victoria Land extend over a wide area. They are developed in the Royal Society and Prince Albert Ranges, on the western margin of the Great Ross Barrier and the Ross Sea. They have been proved in the Mount Nansen region and in the Ferrar Glacier valley to extend to more than sixty miles from the coast. An examination of the inclusions in the lavas of Mount Erebus show that they underlie Ross Island, and moraines on the flanks of the mountain itself contain many dolerite erratics, probably brought from far to the south. They also occur in the moraines on the mainland. Pebbles of dolerite similar to these here described have been dredged up off Cape Wadworth, and to the south of the Balleny Islands. The dolerites occur in dykes, necks, and sills in the basement complex, and form huge sills up to two thousand feet in thickness in the overlying Beacon Sandstones. They have been met with to a height of seven thousand feet above sea-level.

The collections of the expedition of 1901–1904 were examined by Dr. G. T. Prior, and the following notes may be considered as supplementing his descriptions.* The material studied by the present writer was collected chiefly from the moraines at Cape Royds, on Ross Island, but a few specimens were submitted from the Stranded Moraines, the Ferrar Glacier valley, and at points visited by the northern party. Several interesting features have been noted that were not mentioned in the previous report. Chief among these is the abundance in the quartz-dolerites of the peculiar pyroxene enstatite-augite, the occurrence of rhombic pyroxene in granular and porphyritic varieties, and in the presence of a passage rock into the essexites.

A convenient subdivision of the rocks studied is into the phaneric and aphanitic groups. The former have a medium grain-size, with an ophitic or gabbroid structure; certain of them are distinctly porphyritic, through the development of phenocrysts of pyroxene or plagioclase. The aphanitic rocks are very finely grained and have a granulitic structure, occasionally becoming slightly ophitic.

The rocks are composed essentially of basic plagioclase and pyroxene, chiefly monoclinic, with a varying amount of a micropegmatitic intergrowth of quartz and felspar occurring interstitially. They thus correspond to the Hunne-diabas of Törnebohm, but,

---

* To be in the forthcoming Geological Memoir of the Expedition, *The National Antarctic Expedition*, 1901–4, vol. i, pt. ii, chap. v.

following the British usage adopted by Dr. Prior, they are here termed quartz-dolerites. In addition there are quartzless and other types of dolerite. Throughout the proportion of the felspar to the pyroxene is fairly constant, the former being slightly, more rarely strongly, in excess.

The plagioclase as a rule is subidiomorphic, occurring in thick platy forms, sometimes with well-developed terminal faces. Its greatest extension is in the 010 plane. The twinning is, as remarked by Dr. Prior, almost always after the Carlsbad law, less commonly on the albite plan. Pericline twinning is infrequent, and is most noticeable on the larger crystals. A single example was noticed of Manebach twinning, the crystal being also twinned on the albite and Carlsbad laws. Zoning is common. When it is well developed, the kernels of the plagioclase crystals, which occupy about half their area, are very basic, approximating in composition to Ab_5An_{95}. Successive zones rapidly decrease in basicity, the change being most rapid near the periphery. The outermost zone has the composition $Ab_{65}An_{35}$, but from it still more acid extensions may pass out into the micropegmatic material. There is never any reversal of the change, an outer zone being invariably more acid than an inner one, showing an uninterrupted change of conditions in the magma during consolidation. It is rarely that there is no sign of zoning; the most nearly homogeneous crystals have the composition of basic labradorite. As a rule the plagioclase is free from apatite and quite fresh. The first alteration product to appear is chlorite, which is brought into the cracks of the felspar by solutions deriving their material from the pyroxene; the purely felspathic decomposition product, sericite, is seen in a few instances only. Occasionally there is a development of very fine cavities filled with liquid, but it is not certain that these are of secondary origin.

The pyroxenes of these rocks present many features of interest. Both the rhombic and monoclinic pyroxenes are present in abundance, and these are developed in several ways. In certain rocks they occur separately as bronzite or enstatite and augite. From these there are passage rocks into those in which the two minerals occur together in regular or irregular micrographic intergrowth. A third manner of joint occurrence is in isomorphous mixture with each other, forming the peculiar enstatite-augite.

In some rocks, in particular that from the moraine on the Knob Head Mountain, in the Ferrar Glacier valley, the enstatite under crossed nicols has a peculiar appearance, recalling that exhibited by anorthoclase. When the vertical axis is placed parallel to the plane of the polariser it is seen that the extinction is slightly undulose, and there appear a number of exceedingly minute needle-like portions that are not in exact extinction; this is possibly due to an almost submicroscopic multiple twinning. The bronzite shows the characteristic pinkish to greenish pleochroism, but in no instance is there any schiller structure. When rhombic and monoclinic pyroxene occur separately the rhombic seems rather the more nearly idiomorphic, though both may be ophitic. When they are intergrown the enstatite or bronzite forms the matrix, and small strips of augite may be scattered about in it quite irregularly, and without any definite orientation or shape. In other cases there is a definite orientation; the augite may form two sets of strips in optical continuity with each other, and elongated parallel respectively to the basal plane and vertical axis of an augite skeleton crystal; and this augite skeleton crystal, composed thus of rods, plates, and hook-like pieces, is oriented in the rhombic crystal so that its vertical axis coincides with that of the latter. When the augite skeleton is twinned, the two sets of stripes parallel to the basal planes form a herring-bone pattern in the rhombic crystal. In some instances there may extend from a twinned augite kernel thin lamellæ of augite, running parallel to its basal plane out into the surrounding rhombic pyroxene (Plate I, Fig. 2). This intergrowth of pyroxenes, "pyroxene-perthite," occurs in a few instances in the phaneric rocks and is best studied there, but it is almost always present in the aphanitic dolerites. Parallel growth of the two pyroxenes without definite intergrowth is also a marked feature of some of the porphyritic rocks (*see* Plate I, Fig. 3).

Enstatite-augite * is the normal pyroxene in the phaneric quartz dolerites. It forms large grains, ophitic to roughly prismatic in habit, and of a pale purple-grey colour. It is frequently twinned on the 100 plane, usually singly only. Besides the prismatic cleavages there is often a marked striation parallel to the basal plane, due partly to the presence of a very fine cleavage in that direction, but also to twinning developed on a very minute scale. It is only in a few favourable instances that these lamellæ are sufficiently thick to be clearly seen. Twinning on the 100 plane gives rise to the herring-bone structure, in which the striations on one side of the twinning plane stand at an obtuse angle to those on the other. The extinction angle c to $\mathfrak{c}$ does not vary greatly, being between 40° and 45°, but the optic axial angle 2E varies very much. In the same slide crystals may occur, the optic axial angles of which vary from 90° to 0°. The most frequent values are those lying between 0° and 30°, and from 65° to 90°.† Values intermediate to these have been noted but are rare. In sections of ordinary thickness there is no sign of pleochroism.

The normal augites in which the optic axial angle is large occur in those rocks in which rhombic pyroxenes are abundant, and in those that are free from micropegmatite. In the latter they are usually very ophitic.

The alteration of rhombic pyroxene commences with the development of pale-green fibres parallel to the vertical axis, and growing in from the periphery, and from the irregular cracks which traverse the crystal. A completely altered enstatite recalls the appearance of serpentinised olivine. The alteration of enstatite-augite, and sometimes of normal augite, commences with development of fibres parallel to the basal striation, greenish-brown in colour, and probably chlorite. With increasing alteration a dense mat of fibres is formed, sometimes with an irregular, though sharply defined, outline. In apparently unstriated grains the alteration may commence in the centre and is accompanied by a decrease in birefringence. Very finely divided carbonate material is sometimes developed with the chlorite fibres. Sometimes brown mica is produced, possibly by interaction with the felspar ; it forms small flakes and rosette-like aggregates. These latter forms of alteration are those that affect the normal augite most. In the pyroxenes there are frequently minute liquid-filled cavities, but it is not certain that these are of secondary origin.

Iron ore occurs in varying amount, either in irregular grains or as plates ; it is nearly all ilmenite. It is nearly always present in the aphanitic dolerites, but occurs less frequently in the phaneric rocks. Biotite is sometimes present in small red-brown flakes. In one instance only is it present in notable amount.

In the intergranular spaces of the rock there is frequently a micropegmatitic intergrowth of quartz and felspar. The coarseness of grain of this is often proportional to that of the rock itself. The felspar may be fresh or clouded, and has a lower refractive index than Canada balsam ; generally it is recognisable as orthoclase. In a few instances, however, it appears as apophyses from the plagioclase crystals, more acid than their outermost zone, and may therefore be albite. A second type of mesostasis is sometimes seen, particularly in certain rocks collected by the Magnetic Pole party. This is very much finer in grain-size. It is composed of cloudy orthoclase, containing thin strips of a clear colourless mineral, more strongly refractive, and disposed in parallel bundles

---

* W. Wahl, "Die Enstatitaugite," Tschermak's *Min. und Petr. Mitt.*, Bd. xxvi, pp. 1–131.

† These figures are rough approximations only.

or in subradiating groups. It is difficult to determine whether these are quartz or not. The intergrowth is identical in character with that forming the mesostasis of the enstatite-augite bearing rock of Launceston in Tasmania, and in this Professor Ossan * considers the clear strips to be andesine on account of their refractive index and birefringence being identical with that of the outer zone of the plagioclase crystals, to which they are sometimes parallel both in extension and optical orientation, Nevertheless a little free quartz in irregular grains is sometimes associated with this intergrowth.

Apatite is present in very small amount only, and occurs almost exclusively with the micropegmatite.

The general type of the phaneric erratics of Cape Royds and that at the pseudo-Cape Irizar is semi-ophitic in texture, and is composed of basic zoned plagioclase, enstatite-augite, and a varying amount of interstitial micropegmatite. In addition there may be a small amount of biotite and ilmenite. In some instances the amount of micropegmatite may be very great (*see* Plate I, Fig. 1). In another variety with a slightly porphyritic habit both monoclinic and rhombic pyroxenes are present; the latter is the more abundant. Its pale pink to green pleochroism prove it to be bronzite. The monoclinic pyroxene is the more ophitic in habit, and its optic axial angle is large. A certain amount of pyroxene perthite is present regularly and irregularly developed. A little biotite, ilmenite, and a fair amount of micropegmatite are also developed. In a somewhat similar rock enstatite-augite occurs with the rhombic pyroxene, sometimes in parallel growth. No. 1545 is strongly porphyritic. The bronzite crystals are up to four millimetres in length; the monoclinic pyroxene, enstatite-augite, is less abundant, ophitic, and with a small optic axial angle ranging from 20° upwards. The plagioclase, labradorite, is slightly zoned, and is present in small tabulæ and a few phenocrysts. The chemical composition of this rock is given on page 157 (No. I).

The rock collected by Priestley from the Knob Head Mountain moraine in the Ferrar Glacier valley is a most beautiful rock, and is quite distinct from that obtained from the mountain itself by Ferrar. It shows in hand-specimen a cloudy white felspar matrix studded with phenocrysts of yellow-brown enstatite. Under the microscope the plagioclase appears to be in very small crystals, though there are some larger grains. It is basic labradorite and is slightly zoned. Here and there are scattered through it patches of isolated grains of colourless augite, in optical continuity. The phenocrysts of enstatite are sometimes four or five millimetres in length, and frequently exhibit the strained anorthoclase-like appearance before described. They are not idiomorphic, but usually are ophitically intergrown with felspar on the periphery, and may contain felspar laths. Sometimes also they are grown with monoclinic pyroxene in parallel position, the latter fraying out ophitically into the felspar (*see* Plate I, Fig. 3).

No. P. 204 is an erratic from Cape Royds in which the ophitic structure is developed to its highest degree. The augite has a large optic axial angle, is pale in colour, and is commencing to alter into chlorite, which in a very few places contains a fibrous, radiating, colourless mineral with some of the optical properties of stilbite. A little ilmenite is present, but no micropegmatite.

No. P. 242 is the alteration product of a rock similar to the above, but differing in the presence of a little biotite and quartz. The felspar laths are changing into sericite, the augite is passing into chlorite carbonates and secondary mica. A little magnetite and a few apatite needles are also present.

With the phaneric dolerites may also be classed No. P. 252, a Cape Royds erratic. It resembles the quartz dolerites in the abundance of the rhombic molecule, and the presence of micropegmatite; it differs in the comparative abundance of potash, as

---

* "Ueber einen Enstatitaugit-führenden Diabase von Tasmanien," *Centralblatt für Mineralogie,* 1907, pp. 705–711.

shown by the presence of notable amounts of biotite and orthoclase. The rock has thus affinities with the essexites. It is seriate porphyroid, but distinctly dopatic. It contains hypersthene, augite, and biotite in a meshwork of felspar laths, with occasionally phenocrysts of plagioclase. Orthoclase and quartz occur interstitially, and a little apatite and ilmenite are present. Basic labradorite is the predominant mineral, hypersthene the more abundant pyroxene, strongly pleochroic and slightly decomposed. Biotite forms irregular flakes, and in one instance appears to be intergrown with hypersthene. A very little brown hornblende occurs on the border of some of the hypersthene crystals; it is possibly secondary. The interstitial orthoclase is sometimes intergrown with quartz. A few octahedra of magnetite are present (*see* Plate I, Fig. 4).

Erratic No. 1100 is the only sample of a hypocrystalline rock submitted. It is strongly ophitic, the pyroxene, the optic axial angle of which is near 90°, being very much divided by the felspar mesh. Irregularly shaped areas occur made up of a dark-brown glass, partly altering to chlorite, and containing idiomorphic or skeleton felspar crystals and a large amount of magnetite, as skeleton crystals or dust. Some plagioclase phenocrysts are developed (*see* Plate I, Fig. 5).

The aphanitic dolerites are all very fine in grain. They are dark greenish-grey in colour, translucent on thin edges, and in general appearance somewhat like hornfels. They are holocrystalline, with an average grain-size of about 0·1 millimetre in diameter. The structure is granulitic; small grains of pyroxene, either irregularly equidimensional or slightly prismatic, lie enclosed in a meshwork of felspar tabulæ of rather smaller size.

The Chemical Composition of Dolerites from South Victoria Land

	I	II	III	IV	V	VI
SiO_2 . . .	54·17	54·16	53·26	52·49	56·74	53·16
Al_2O_3 . . .	14·90	15·08	15·64	16·44	15·46	15·01
Fe_2O_3 . . .	1·09	0·79	0·24	2·60	3·08	1·27
FeO . . .	7·74	8·08	7·44	5·30	7·58	8·29
MgO . . .	10·66	7·14	8·64	6·18	2·54	7·45
CaO . . .	8·79	10·57	12·08	11·71	7·64	10·36
Na_2O . . .	1·27	1·60	1·25	2·06	3·08	2·22
K_2O . . .	0·54	1·11	0·58	1·09	1·59	1·16
H_2O . . .	0·17	0·20	0·35	0·15	1·28	0.56
H_2O + . . .	0·53	0·36	0·41	1·42		
CO_2 . . .	trace	trace	—	—	—	—
TiO_2 . . .	0·64	0·70	0·70	0·62	1·26	0·16
P_2P_5 . . .	trace	trace	0·04	trace	0·15	0·08
MnO . . .	0·15	0·14	0·11	trace	trace	0·15
	100·65	99·93	100·74	100·06	100·40	99·87

I. Erratic No. 1545, Cape Royds; Porphyritic quartz-dolerite with bronzite.
II. Erratic No. P. 366, Cape Royds; Aphanitic quartz-dolerite.
III. Quartz-dolerite from Knob Head Mountain; analysed by Dr. G. T. Prior.
IV. Enstatite-augite bearing diabase from Launceston, Tasmania; analysed by Professor Dittrich.
V. Konga-diabase from North-West Bay, Tasmania; analysed by Dr. Pohl.
VI. Quartz-diabase from the Cuyuni River, British Guiana.

There is no trace of any porphyritic structure or sign of flow in any of the rocks submitted for examination. From the granulitic structure there are gradations into the ophitic, developed to some extent in a few specimens. The plagioclase, basic labradorite, is in short thick tabulæ, mutually interfering, but idiomorphic against the micropegmatite, less commonly against the pyroxene. Both rhombic and monoclinic pyroxenes are usually present. The former, bronzite, is generally rather more nearly idiomorphic. A microperthitic intergrowth of monoclinic pyroxene is very frequent, usually regularly oriented, and often showing single or multiple twinning on the 100 plane, giving a herring-bone or zigzag pattern. The monoclinic pyroxene has a large optic axial angle, and the extinction c to C is about 45°. It is slightly striated and rarely twinned. Varying amounts of ilmenite and biotite are present, the former in small plates, the latter in irregular flakes usually moulded on the ilmenite. A few exceedingly small prisms of apatite are present. A varying amount of a very fine-grained micropegmatite occurs interstitially. All the aphanitic dolerites examined were erratics from Cape Royds, and nearly all were quite fresh. Plate I, Fig. 6, is very typical of these rocks.

The chemical composition of South Victoria Land dolerites will be seen from the table on p. 157.

On calculation the first two analyses give the following " norms " :

	I	II
Quartz	7·26	6·18
Orthoclase	2·78	6·12
Albite	10·48	13·62
Anorthite	33·36	30·86
Diopsite	7·34	17·50
Bronzite	35·82	22·54
Ilmenite	1·22	1·37
Magnetite	1·62	1·16
Water	0·70	0·56
	100·58	99·91

Both of these fall into the division III, 1.4.4.3. of the American classification, being slightly more acid than the rock analysed by Dr. Prior, which is an Auvergnose III, 1.5.4.3.

The study of these rocks may throw some light on the origin of quartz-dolerites. Several hypotheses have been advanced to account for this. One would consider the micropegmatite to have been derived by intrusion of granophyre into the consolidating dolerite, urging in support the frequent association of soda-aplites or granophyres with quartz-gabbros or dolerites. A second considers the rocks to be produced by a mixture in varying proportions of a granophyric with a gabbroid magma. A third would derive the granophyre from the gabbroid or magma by differentiation through fractional crystallisation; the acid residuum either forms the granophyric mesostasis in the rock or is extruded from it to form the dykes of granophyre. Dr. Prior points out that the general variation of the grain-size of the micropegmatite with that of the including rock is the fact used by Dr. Holland in support of his application of the third hypothesis to the explanation of the micropegmatite in the Indian " augite-diorites." * The rarity or absence of veins and dykes of soda-aplite or granophyre in the dolerite masses of South Victoria Land may also be taken to show that their presence is not essential to the formation of quartz-dolerites. But some rocks occur, like certain collected on the Dry Valley by Ferrar, and by the Magnetic Pole party in 1908–9, in which the acid material is very

---

* G. T. Prior, *loc. cit. supra*, p. 136.

fine grained, felsitic, and in patches so distinct from the rest of the rocks as to suggest a mingling of two rock types.

Another point of interest is the widespread distribution of quartz-dolerites, occurring under conditions analogous to those found in the Antarctic. In Tasmania, South Africa, and in parts of South America quartz-dolerites are found forming sills in sandstone and other formations which have intruded during the Mesozoic period.

In particular the similarity between the occurrence of dolerite in Tasmania and South Victoria Land is so striking as to strongly support the view that the two areas form part of a geological unit. Tasmania is chiefly composed of an almost horizontally bedded series of sandstones, coal-measures, mudstones, and limestones of Mesozoic and Permo-carboniferous age, lying on a strongly folded complex of Silurian and older rocks intruded by granite. In Cretaceous times came the intrusions of dolerite,* which formed great sills in the Permo-carboniferous and particularly in the Mesozoic sandstones. After the intrusion the area was broken considerably and differentially elevated with block-faulting. Erosion has now exposed the dolerite which occurs, capping nearly every important elevation in the island. The geology of the Tasmanian and Antarctic dolerite is thus very similar, and the physiography of the two areas is remarkably constant. Microscopically there is also a strong resemblance between the rocks. Dr. Woolnough first drew my attention to the similarity of the Launceston rock to some of the Antarctic dolerites, and the examination of a series of Tasmanian dolerites, kindly sent by Mr. W. H. Twelvetrees, the Government Geologist of Tasmania, fully bears this out. Enstatite-augite has been noted in rocks from several other localities than Launceston, in which it was discovered by Professor Osann, and may be taken to be of fairly general occurrence. The mesostasis is usually of the fine-grained felsitic type, but coarse-grained micropegmatite was noted in a rock from North-West Bay by Dr. F. P. Paul † (*see* Analysis V).

The biotitic variety of dolerite from the Antarctic may have its parallel in the biotitic rock from Dundas described by L. K. Ward.‡

A further point of similarity is in the general absence of olivine from the two areas. The analyses given (Nos. IV and V) are the only ones of Tasmanian dolerites that are available; they would indicate that the percentage of magnesia was less than in those of the Antarctic. According to Mr. W. H. Twelvetrees, in Tasmania also there is an absence of veins of granophyre from the dolerite masses.

In South Africa the dolerites were intruded in Jurassic times into the horizontal or slightly folded beds of the Karoo system, in which they form huge sills up to two thousand feet in thickness. "The constituents are plagioclase, felspar, augite, olivine, and magnetite in the relative order of their abundance; but olivine is not infrequently absent. In addition, biotite may be present and sometimes original hornblende, either independently or in close connection with the augite. In the more acid types quartz and occasionally orthoclase felspar are present, often in the form of micropegmatite." § In certain of these dolerites Wahl has noted the presence of enstatite-augite. The chemical composition of the dolerites is very uniform, but the analyses given by E. Cohen are invariably much higher in ferric oxide and lower alumina than those of Antarctic

---

* It should be remarked that the Tasmanian geologists follow the German usage in terming these rocks "Diabase." For a general description of their mode of occurrence and petrology *see* W. H. Twelvetrees and W. F. Pettard, *Proceedings of the Royal Society of Tasmania*, 1898–99, p. 47, and W. H. Twelvetrees, "The Igneous Rocks of Tasmania" *Report of the Australian Association for the Advancement of Science*, 1902, p. 287.

† "Beitrage zur-petrographischen Kenntniss einiger foyaitischentheralitischen Gesteine aus Tasmanien," Tschermak's *Min. und Petr. Mitt.*, Bd. xxv, p. 267.

‡ *Tasmanian Geological Survey, Bulletin No.* 6, p. 28.

§ A. W. Rogers and A. L. Du Toit, *The Geology of Cape Colony*, chap. ix.

and Tasmanian rocks. As there is nothing in the brief description cited above to suggest any great excess of magnetite, some suspicion is thrown on the correctness of the figures given for these oxides. Otherwise the analyses are not unlike those of Tasmanian rocks.

In British Guiana, overlying the basement complex, there is an extensive series of almost horizontally bedded sandstones, which continue across the borders into Venezuela and Brazil. They are barren of fossils. In the last two countries there is evidence for believing them to be of Cretaceous age, but C. B. Brown considers them to be Triassic on the grounds of their great lithological resemblance to the sandstones of that age in North America. They are intruded by dykes and sills of dolerite (" diabase "), which are of Cretaceous or Tertiary age, and Harrison leans to the latter alternative.* In microscopical features they are very similar to the Antarctic, and the comparison of the analyses quoted (No. VI) of the rock from the Cuyuni River with that made by Dr. Prior (No. III) will show how very similar are the two rocks in chemical composition.

In this connection might also be noted the occurrence of quartz-dolerites in the Mesozoic Newark system near New York, of which the famous Palisades on the Hudson are a part.† Wahl has shown that enstatite-augite occurs in these rocks, and they have other features analogous with those of the rocks here considered.

The author's thanks are due to Professor David and Mr. R. E. Priestley for the opportunity of examining these rocks, and to Mr. Allen Thomson for his assistance.

SYDNEY
December 1910

---

* *See* J. B. Harrison, *The Geology of the Goldfields of British Guiana*, p. 23, *and also* chap. x.

† *See* J. V. Lewis, " Palisade Diabase of New Jersey," *Amer. Jour. of Science*, vol. clxxvi, 1908, p. 155 ; " Structure on Correlation of the Newark Trap Rocks of New Jersey," *Bull. Geol. Soc. of America*, vol. xvii, pp. 195–210 ; " Origin and Relations of the Newark Rocks," *Ann. Rept. State Geologist of N.J. for* 1906, pp. 97–129.

EXPLANATION OF THE PLATE

FIGURE 1.—Plagioclase crystal surrounded by quartz and felspar micropegmatite. Erratic P. 363 from Cape Royds. Polarised light, magnified 1·45 diameters.

FIGURE 2.—Intergrowth of a twinned augite crystal in enstatite. Erratic No. 93 from Cape Royds. Polarised light, magnified 26 diameters.

FIGURE 3.—Parallel growth of ophitic augite and enstatite. The darker central portion of the pyroxene crystal is enstatite, the lighter surrounding portion augite, showing basal striation. Erratic No. P. 82. Knob Head Mountain moraine. Polarised light, magnified 26 diameters.

FIGURE 4.—Essexite dolerite showing hypersthene and biotite, the latter in dark basal sections and lighter vertical sections. Erratic from Cape Royds. Ordinary light, magnified 26 diameters.

FIGURE 5.—Hypocrystalline ophitic dolerite. Erratic No. 1100 from Cape Royds. Ordinary light, magnified 26 diameters.

FIGURE 6.—Aphanitic dolerite. Erratic No. P. 366 from Cape Royds. Ordinary light, magnified 26 diameters.

FIG. 1

FIG. 2

FIG. 3

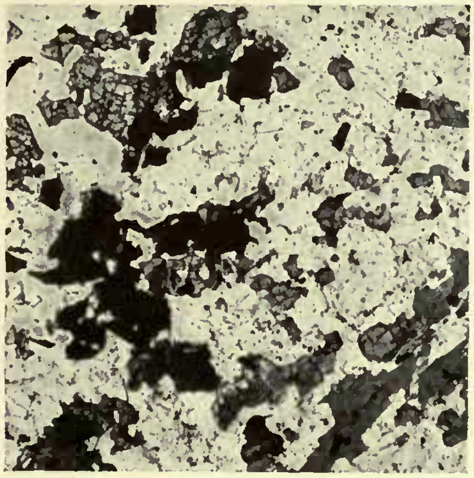


FIG. 4

FIG. 5

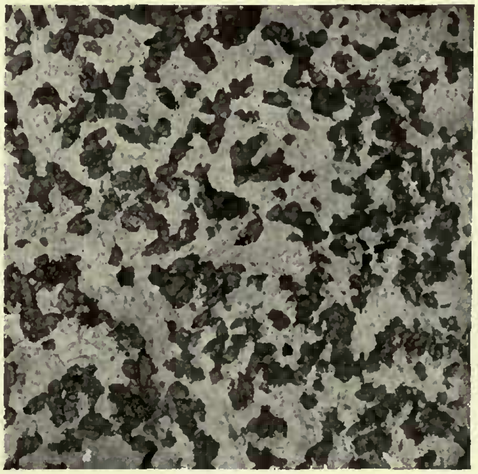


FIG. 6

[*To face p.* 160

PART X

REPORT ON THE PYROXENE GRANULITES

COLLECTED BY THE BRITISH ANTARCTIC EXPEDITION, 1907–1909

(*With Plate*)

BY

A. B. WALKOM, B.Sc.

THE pyroxene granulites described in this paper were all erratics collected at Cape Royds. They are very similar both in hand-specimen and mineral composition to similar rocks which have been described from other parts of the world, viz., Saxony, Canada, Ceylon, Madagascar, etc. Garnet, which is a very common constituent of these rocks in other parts, is quite absent from this series, while sphene, which is not common in other areas, is a very constant constituent here.

These rocks, occurring as they do in the form of erratics, cannot be expected to throw much light on the nature of their origin.

Analyses of two of them have been made by Mr. G. J. Burrows, B.Sc., and myself, with the following results:

	I Erratic No. 96.	II Erratic No. 584.
SiO_2	74·67	71·70
Al_2O_3	8·37	6·90
Fe_2O_3	0·95	0·96
FeO	3·37	3·74
MnO	0·09	0·05
MgO	2·52	2·82
CaO	5·19	11·37
Na_2O	2·09	0·66
K_2O	1·31	0·10
$H_2O +$	0·30	0·22
$H_2O -$	0·26	0·08
TiO_2	1·10	1·11
P_2O_5	0·57	0·09
CO_2	—	trace
ZrO_2	trace	Cl 0·16
	100·79	less ·04 as O for Cl
		99·92

These analyses differ considerably in some respects from those published of other similar rocks. The most noticeable difference is in the case of the relative proportion of CaO to SiO_2. In all similar rocks with a percentage of SiO_2 greater than 70 the CaO rarely goes as high as 2 per cent. and never above 3 per cent., yet in the case of both the present analyses it is considerably above this amount, and in the second of these analyses it has an exceedingly high percentage, viz., 11·37. This high percentage of lime is justified by the fact that all the minerals of the rock (quartz excepted) contain a considerable amount of CaO. The alkalies are fairly normal in analysis No. I, but are almost absent in No. II, their place here being taken by the CaO. The analyses strongly suggest that these rocks belong to Rosenbusch's group of Para-gneisses.

The pyroxene granulites are typically of a greenish colour—some light green and others much darker. They are fine-grained to medium-grained, and the grains are very even in size. They are very hard, much silicified, and have a somewhat greasy lustre. The degree of foliation varies considerably; in some of them there is no foliation present, while in others it is very well marked. The fracture is always smooth and approaches conchoidal. Some of the constituent minerals can generally be identified in hand-specimen—notably quartz and sometimes felspar. The ferro-magnesian mineral, too, is generally recognisable as such, though its more exact determination is difficult. The light- and dark-coloured minerals are distributed fairly evenly throughout the rock, and in a few cases there are coarse veins of quartz running through the hand-specimens.

These rocks may conveniently be divided into three classes, as follows:

(1) Acid pyroxene granulites.
(2) Scapolite-bearing pyroxene granulites.
(3) Basic pyroxene granulites.

The acid pyroxene granulites are those in which quartz is present in large quantity. The presence, in fair amount, of scapolite in a number of the rocks has led to their being classed together as a separate group. The basic pyroxene granulites are those in which quartz is absent or only present in subordinate amount. It is somewhat difficult to place definitely the dividing-line between the acid and basic groups. The amount of quartz present decreases fairly regularly from the most acid down to those where it is quite absent.

The mineralogical composition of these rocks is shown in the table on p. 163.

(1) THE ACID PYROXENE GRANULITES

This class includes those granulites in which quartz is present in abundance. The constituent minerals are quartz, pyroxene (monoclinic), felspar, sphene, zircon, apatite, magnetite, sericite, and carbonate. The quartz, in almost all cases, shows shadowy extinctions and has suffered a certain amount of granulation. The pyroxene is in all cases monoclinic. It is colourless and only exhibits a slight amount of absorption. It is characterised by a fairly uniform high extinction (35° to 40°) and 2V is large. It is, then, almost certainly, diopside. The pyroxene is the same throughout both the acid and basic groups and also in most of the scapolite-bearing group. The felspar is plagioclase, and where suitable sections for its specific determination are present it is found to be labradorite. Sphene and zircon are constant members, and occur in characteristic forms. Apatite, magnetite, and biotite are occasional constituents. Sericite and carbonate, and possibly also some of the biotite, are secondary.

96. Pyroxene Granulite, Erratic (Cape Royds).

In hand-specimen this is a dark-coloured rock, very hard and much silicified. It has a smooth, conchoidal fracture. It is extremely fine-grained and is noticeably banded. Quartz and a light-greenish ferro-magnesian mineral can be recognised and also occasional small flakes of biotite.

Microscopically the rock is seen to have a granulitic fabric; there is a tendency to lepidoblastic structure owing to the biotite occurring in flakes, but the distribution of the flake does not point to any foliation in the rock.

The constituent minerals are: quartz, felspar, biotite, pyroxene, sphene, magnetite, and apatite.

Quartz is easily the most abundant mineral. It is in allotriomorphic grains, and shadowy extinctions are very prominent. It does not appear to be granulated to any extent. The felspar is not very abundant and is mostly untwinned. It is quite fresh but has numerous minute inclusions. Biotite is fairly plentiful in small ragged, elongated flakes, and gives the rock a somewhat lepidoblastic appearance. In some cases it is decomposing, the brown colour being altered to green and the D.R. slightly decreased, thus showing change to chlorite. Pyroxene is present in colourless allotriomorphic bunches. It is diopside. Sphene is present in fair quantity. It is in small characteristic sections, and these have a tendency to cluster together in bunches. Zircon, apatite, and magnetite are sparingly present. For an analysis of this rock *see* p. 161.

MINERALOGICAL COMPOSITION OF ROCKS

	Number of Specimen.	Locality.	Quartz.	Pyroxene.	Felspar.	Sphene.	Scapolite	Zircon.	Apatite.	Magnetite.	Biotite.	Sericite.	Pyrite.	Carbonate.
I Acid Pyroxene Granulites	96	Erratic. Cape Royds	X	X	X	X		X	X	X	X			
	1684	„ „	X	X	X	X		X	X		X		X	
	960	„ „	X	X	X	X		X	X					
	1537	„ „	X	X	X	X		X						X
	P. 376	„ „	X	X	X	X		X				X		X
	1865	„ „	X	X				X		X				
II Scapolite-bearing Pyroxene Granulites	249	„ „	X	X	X	X	X			X				
	584	„ „	X	X	X	X	X		X					
	P 391	„ „	X	X	X	X	X		X					
	P. 355	„ „	X	X	X	X	X				? Diallage			
	459	„ „	X	X	X	X	X						X	
III Basic Pyroxene Granulites	1267	„ „		X	X	X			X					
	1515	„ „		X	X	X								
	e26	„ „	X	X	X	X								
	P. 216	„ „	X	X	X	X				X				

1684. Pyroxene Granulite, Erratic (Cape Royds).

In hand-specimen a dark green, greasy-looking rock; it is much silicified and is slightly foliated. Quartz and a dark ferro-magnesian mineral can be recognised.

Under the microscope the fabric is granulitic; the grainsize is even and medium. A marked degree of foliation is shown by the biotite, pyroxene, and quartz. The biotites have their longer axes in a general parallel direction, as also have the pyroxenes to a lesser degree. The quartz grains are elongated parallel to the same direction.

The minerals present are: quartz, felspar, biotite, pyroxene, apatite, sphene, pyrites, and zircon.

Quartz is most abundant in allotriomorphic grains. It shows shadowy extinction and has undergone a considerable amount of granulation. Felspar is fairly abundant. It is mostly untwinned but occasional grains are twinned after the albite law. It is in subidiomorphic grains, slightly decomposed and with numerous inclusions. Its R.I. is higher than that of quartz. Biotite is present in some quantity in very ragged allotriomorphic grains. It is moulded on both the pyroxene and felspar. In most cases where it is moulded on the pyroxene there is a fairly well-marked line of division between the two minerals; in a few cases, however, the line is not easily distinguished, and it appears in these cases as if the biotite may be the result of an alteration of the pyroxene. The minerals of the rock show considerable granulation, and this is possibly a case of alteration such as described by Parsons.*

Pyroxene is not very abundant in colourless, allotriomorphic grains. Sphene, apatite, pyrites, and zircon are sparingly present.

960. Pyroxene Granulite, Erratic (Cape Royds).

The hand-specimen is a dark-greenish, hard, and somewhat silicified rock. It is very fine-grained and shows very little foliation. Quartz and a dark ferro-magnesian mineral can be recognised. Under the microscope the fabric is granulitic and the grainsize even and medium. Foliation scarcely noticeable. (Plate I, Fig. 1.)

The minerals are: quartz, pyroxene, felspar, sphene, zircon, apatite. Quartz is in irregular allotriomorphic grains, and is easily the most abundant mineral. It is quite clear and free from inclusions, shows shadowy extinctions, and is considerably granulated. Felspar is abundant in subidiomorphic sections twinned mostly after the albite law and occasionally after the Carlsbad. Its R.I. is a good deal higher than that of quartz. Extinctions in sections perpendicular to albite twins go up to about 32°. It is then a basic labradorite. It shows shadowy extinctions; it is only very slightly dusted with decomposition products. Pyroxene is in irregular-shaped grains and columnar sections. It is colourless and without many inclusions. Sphene is plentiful and is mostly included in the quartz and pyroxene. Small zircons and apatites are present.

1537. Pyroxene Granulite, Erratic (Cape Royds).

In hand-specimen a greyish-green holocrystalline rock; medium to fine-grained. No foliation visible. Quartz is recognisable, and the ferro-magnesian mineral is a rather light green in colour.

Under the microscope the fabric is granulitic; grainsize even and fine. Foliation apparent by the direction of elongation of the minerals. (Plate I, Fig. 2.)

The minerals present are: pyroxene, felspar, quartz, sphene, zircon, and carbonate.

Pyroxene is abundant in irregular grains, very light in colour. Felspar is in allotriomorphic grains twinned after the albite, Carlsbad, and pericline laws. The combination of albite and pericline laws gives a cross-hatching appearance very like microcline. It is moulded on quartz and sometimes pyroxene; it is quite fresh. Extinctions in symmetrical sections go up to 33°, and it is therefore a basic labradorite. Quartz

---

* James Parsons, B.Sc., "The Development of brown mica from augite, etc.," *Geol. Mag.*, 1900, p. 316.

is abundant in irregular to rounded grains and generally free from inclusions. Sphene and zircon are present, and also a small amount of carbonate.

P. 376. Pyroxene Granulite, Erratic (Cape Royds).

Hand-specimen missing.

Microscopically the fabric is granulitic and the grainsize even, medium.

The minerals present are: pyroxene, felspar, quartz, sphene, apatite, and sericite.

Pyroxene is most abundant and forms nearly half the rock. It is, as usual, in colourless allotriomorphic grains. Mostly fresh, but occasionally it has undergone a small amount of decomposition. The felspar is plagioclase twinned after albite, pericline, and occasionally Carlsbad laws. It is in subidiomorphic grains with numerous inclusions: decomposed considerably to sericite, with carbonates present as a side-product of the alteration. Quartz is fairly abundant in allotriomorphic, somewhat rounded grains, comparatively free from inclusions. Sphene is abundant and apatite sparingly present.

1865. Pyroxene Granulite, Erratic (Cape Royds).

In hand-specimen a dark-greenish, greasy-looking rock, very much silicified, fine-grained and hard. No foliation visible. Quartz and a ferro-magnesian mineral can be recognised. Under the microscope the fabric is granulitic, and the grainsize even and small.

The minerals present are: quartz, pyroxene, magnetite, and zircon.

Quartz is abundant in small rounded grains. It shows shadowy extinctions; it has very few inclusions. The pyroxene is very light coloured and is in rather rounded grains. Magnetite and sphene are only sparingly present.

(2) THE SCAPOLITE-BEARING GRANULITES

This division is practically a subdivision of the acid group. All the rocks in it would, but for the presence of a fair amount of scapolite, belong to group (1). The amount of scapolite varies considerably in the different members. The mineralogical composition of the various members of the group is very constant, the minerals being almost the same throughout.

249. Scapolite-bearing Pyroxene Granulite, Erratic (Cape Royds). Hand-specimen missing.

Under the microscope the rock is granulitic, consisting of small, even-sized, somewhat rounded grains whose average diameter is about ·15 mm. Occasional larger grains of scapolite are present, and these are usually so full of inclusions as to present a "sieve" structure. There is not a trace of foliation. The minerals are: pyroxene, scapolite, quartz, felspar, sphene, and magnetite.

Pyroxene is the most abundant mineral. It is quite fresh and forms nearly half of the rock. It is Diopside. Scapolite is present in subidiomorphic, colourless grains, some of which show two cleavages at right angles to one another. The D.R. is high (·021 approx.) and negative and the mineral is uniaxial. The larger grains contain very numerous small inclusions of a colourless, strongly doubly refracting mineral, which may be sericite. Quartz is fairly abundant in irregular grains, almost free from inclusions. Most of the quartz shows an entire absence of strain effects and only a very few show shadowy extinction. The felspar is a plagioclase twinned after the albite law. It is in fairly large allotriomorphic grains. Only a few suitable symmetrical sections are present, and their extinctions point to its being labradorite. It is a good deal dusted with decomposition product and in places is slightly sericitised. Sphene and magnetite are sparingly present.

584. Scapolite-bearing Pyroxene Granulite, Erratic (Cape Royds).

The hand-specimen is a dark green mottled rock, very noticeably foliated. Quartz and a clear green pyroxene are easily recognisable. Under the microscope the fabric is granulitic, and the grainsize fairly even and medium. (Plate I, Fig. 3.)

The minerals present are: quartz, pyroxene, scapolite, felspar, sphene, and apatite.

Quartz is the most abundant mineral and occurs in very ragged, elongated grains which show marked shadowy extinctions. The larger grains are very much granulated. Pyroxene is abundant in subidiomorphic grains, light green in colour, with fairly strong absorption but little pleochroism. The D.R. is medium (about ·021) and positive, and the R.I. high. It is most probably augite. Scapolite (Wernerite) is present in irregular grains. Felspar is present in allotriomorphic grains showing albite twins. It is labradorite with composition Ab_1An_1. Sphene is abundant and apatite scarce.

This rock has been analysed and the analysis is given on p. 161.

459. Scapolite-bearing Pyroxene Granulite, Erratic (Cape Royds).

Hand-specimen. A light-greenish, fine-grained rock, fairly hard and heavy. It is very siliceous and has well-marked foliation. Quartz, felspar, and a greenish ferromagnesian mineral can be recognised. Under the microscope the fabric is granulitic and the grainsize even, medium, with the grains having an average diameter of about ·4 mm. Foliation very noticeable both by the pyroxene and sphene.

Minerals present are: scapolite, pyroxene, quartz, felspar, sphene, and pyrites.

Scapolite is perhaps the most abundant mineral. It encloses pyroxene, quartz, and sphene poikilitically. Pyroxene is abundant in subidiomorphic and rounded grains, colourless, nonpleochroic, and with no noticeable absorption. It is Diopside. The sections are mostly longitudinal ones and the cleavages are all in a roughly parallel direction. Quartz is fairly abundant, with very little evidence of strain. Felspar is not abundant. It is in fairly large allotriomorphic grains twinned after the albite law. It is a good deal altered, and the appearance is much the same as when a felspar becomes sericitised, with the difference that the secondary mineral, instead of being sericite, is *scapolite*. The felspar is a labradorite with the composition Ab_1An_1. Sphene is present as numerous small lozenge-shaped crystals. Apatite, zircon, and pyrites are sparingly present.

P. 391. Scapolite-bearing Pyroxene Granulite, Erratic (Cape Royds).

Hand-specimen missing.

Under the microscope the fabric is granulitic and the grainsize uneven.

The minerals are: pyroxene, quartz, felspar, scapolite, sphene, zircon. Pyroxene is easily the most abundant mineral and is present in rounded to columnar grains. The rectangular cleavage is very well marked. It is colourless and quite fresh, and is Diopside. Quartz is in irregular grains, some of which show shadowy extinctions. Felspar is present in subidiomorphic grains twinned after the albite and pericline laws. Its R.I. is less than that of quartz and greater than that of Canada Balsam. It is intermediate in composition between oligoclase and andesine and probably is about the composition Ab_7An_4. In places it is altered to sericite. Scapolite is present and contains numerous small inclusions. Sphene and apatite are also present. There are a few grains of colourless mineral, untwinned and with R.I. less than quartz, and which may be orthoclase.

P. 355. Scapolite-bearing Pyroxene Granulite, Erratic (Cape Royds).

Hand-specimen missing.

Under the microscope the fabric is granulitic and the grainsize uneven, the greater part of the rock having grains of medium size and the remainder coarse. A somewhat gneissic structure is exhibited. (Plate I, Fig. 4.)

The minerals present are: pyroxene, felspar, quartz, scapolite, sphene, and diallage (?).

Pyroxene is very abundant in medium-sized subidiomorphic grains. It is colourless and a small amount of absorption is noticeable. It encloses quartz. The felspar is abundant in fairly large subidiomorphic sections, twinned after the albite law. Symmetrical sections give extinctions up to 26°, and therefore it is a labradorite of composition Ab_1An_1. It is fairly fresh and in places has numerous inclusions. Quartz is abundant in rounded, allotriomorphic grains. It shows shadowy extinction but is not granulated to any extent. Scapolite is fairly abundant in allotriomorphic to subidiomorphic grains, which are sometimes ragged. It is pretty free from inclusions and in one or two places exhibits what seem to be traces of albite twinning. Sphene is fairly abundant and zircon is also present. There are a few grains of a light-coloured mineral which is probably diallage.

(3) THE BASIC PYROXENE GRANULITES

In this class quartz is either absent or only present in comparatively small amount. The most basic ones approach fairly closely to a pyroxenite. They contain pyroxene, felspar, sphene, quartz, apatite, and magnetite. The pyroxene is the same as in the acid class. The felspar is uniformly labradorite, of composition Ab_1An_1 or very slightly more basic. Sphene is present throughout and is occasionally very large.

1267. PYROXENE GRANULITE, ERRATIC (Cape Royds).

The hand-specimen is a mixture of light and dark parts; the light parts are mostly quartz veins and the darker ones are made up of felspar and pyroxene. It is fine to medium grained and shows very little foliation.

Under the microscope the fabric is hypidiomorphic granular, and the grainsize uneven. Felspar and pyroxene, the two most important minerals, have a tendency to cluster in bunches, each mineral separately.

The minerals are: felspar, pyroxene, sphene, and apatite.

The felspar is all plagioclase; it occurs in subidiomorphic grains very variable in size—some of the grains are as large as 1·5 mm. by 1 mm., while in other places there is an aggregate of very small felspar grains, which may be due to granulation of larger felspar grains. It is twinned after the albite and pericline laws, and symmetrical sections indicate that it is a labradorite with a composition Ab_1An_1. There is very little decomposition, only a few grains being slightly dusted with decomposition product. A little sericite is present and may be from the alteration of some of the felspar. The pyroxene is present as large grains, frequently twinned. It is very light coloured and has uniformly high extinction angles in longitudinal sections. It is probably diopside but may possibly be referred to malacolite. Sphene is not abundant but is present in unusually large sections, reaching such dimensions as 1·5 mm. by ·75 mm. Apatite is also present.

1515. PYROXENE GRANULITE, ERRATIC (Cape Royds).

Hand-specimen very similar to 1267.

Under the microscope the fabric is panallotriomorphic granular; poikilitic in places by means of the pyroxene and occasionally by the felspar. A considerable amount of foliation is shown by the arrangement in bands of the felspar and pyroxene. (Plate I, Fig. 5.)

The minerals are: pyroxene, felspar, quartz, and sphene. The pyroxene is very abundant in allotriomorphic grains and forms more than half of the rock. It is colourless and ophitically encloses felspar. Felspar is subordinate in amount to the pyroxene and forms about one-third of the rock. It is twinned after the albite and pericline laws; the striations are very fine and give a general appearance of rather coarse microcline. It poikilitically encloses quartz and more rarely pyroxene. It has the composition about Ab_1An_1, obtained by means of symmetrical sections.

Quartz and sphene are sparingly present.

e26. PYROXENE GRANULITE, ERRATIC (Cape Royds).

In hand-specimen this is a light-greenish rock, very hard and silicified. Quartz and pyroxene can be recognised.

Under the microscope this rock varies a good deal in different parts. The section examined shows quite a contrast between two halves. One-half of the section is a typical pyroxene granulite with granulitic fabric and small, even grainsize ; it contains pyroxene and felspar in about equal amounts. The felspar is in small rounded grains, almost undecomposed and with albite twinning. The larger grains of felspar have, however, undergone a certain amount of sericitisation. The pyroxene is the same as has already been described for these rocks. The other half of the section, on the other hand, approaches very close to a pyroxenite ; it is composed almost completely of rounded, rather small grains of pyroxene. The grains are medium in size and are the same as the pyroxene in the first-mentioned half of the rock.

P. 216. Pyroxene Granulite, Erratic (Cape Royds).

Hand-specimen missing.

Under the microscope the fabric is granulitic and the grainsize uneven and fine to medium.

The minerals are: pyroxene, felspar, quartz, sphene, and magnetite. Pyroxene is in fairly large grains and is, as usual, colourless ; it forms nearly half the rock. Felspar is in large allotriomorphic grains, twinned sometimes after the albite law but often untwinned. It is somewhat decomposed and is a basic labradorite, extinctions in symmetrical sections going as high as 37°. Quartz is not at all abundant and has shadowy extinction. Sphene is in numerous small crystals, and magnetite is present.

In conclusion, the writer desires to express his thanks to Professor David and Mr. R. E. Priestley for the opportunity to do this work and for their kindness and assistance, and also to Mr. G. J. Burrows for his invaluable help with the analyses.

LITERATURE

For full references up to 1896 *see* Judd in *Phil. Trans.*, 1896.

1900. Coomára-Swámy, A. K. "On Ceylon Rocks and Graphite," *Q.J.G.S.*, lvi, p. 592.
Adams, F. D. *Annual Report Geol. Survey*, Canada, viii.
1904. Kastner, Max. "Zur Genesis des sachsischen Granulitgebirges," *Centralbl. Min. Stuttgart*, 1904, pp. 196–206.
1903. Coomára-Swámy, A. K. *Geol. Mag.*, 1903, pp. 348–350.
Prior, G. T. "British East Africa," *Min. Mag.*, 1903, pp. 229–231.
1901–2. Lowe, H. J. "The Sequence of the Lizard Rocks," *Trans. R. Geol. Soc., Cornwall*, 1901 (pp. 438–466) and 1902 (pp. 507–534).
1906. Evans, J. W. "The Rocks of the Cataracts of the Madeira River," *Q.J.G.S.*, 1906 (pp. 88–124).
1907. Credner, H. "Die Genesis des sachsischen Granulitgebirges," *Centralbl. Min.*, 1907 (pp. 513–525).
1907. Peach, B. N. "Horne, J., etc.," *Mem. Geol. Surv. Gt. Brit.*, 1907 (xviii and 668).
1905. Coomára-Swámy, A. K. "The Rocks and Minerals of Ceylon," *Spolia Zeylan*, 3, 1905 (pp. 50–66).
1908. Bergt, W. "Neue Vorkommnisse von Pyroxengranulit und über dessen Allgemeine Verbreitung," Berlin, *Monatsber D. geol. Ges.*, 1909 (pp. 231–234).

EXPLANATION OF THE PLATE

Figure 1. Pyroxene Granulite, Erratic, No. 960.
Figure 2. Pyroxene Granulite, Erratic, No. 1537.
Figure 3. Pyroxene Granulite, Erratic, No. 584.
Figure 4. Pyroxene Granulite, Erratic, P. 355.
Figure 5. Pyroxene Granulite, Erratic, No. 1515.

PLATE I

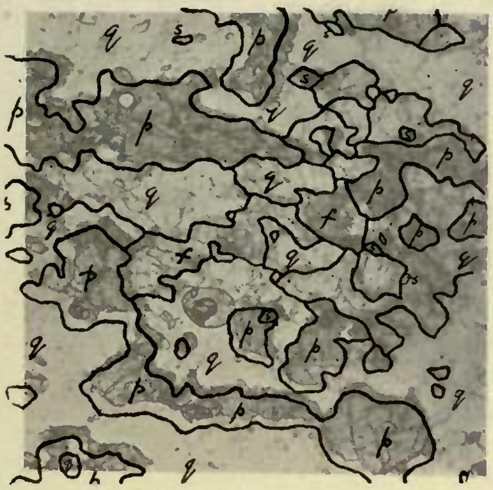


FIG. 1

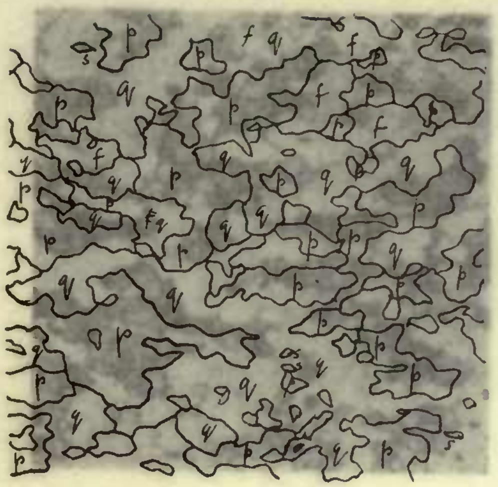


FIG. 2

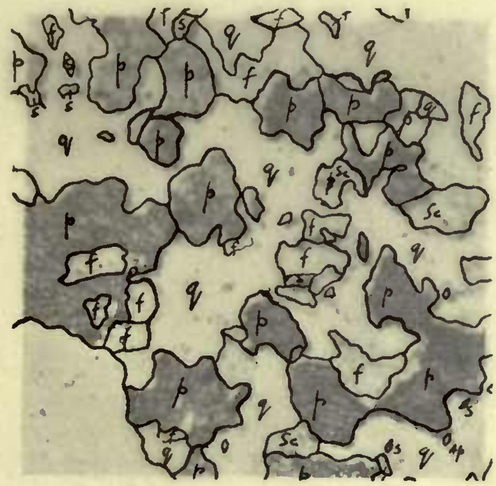


FIG. 3

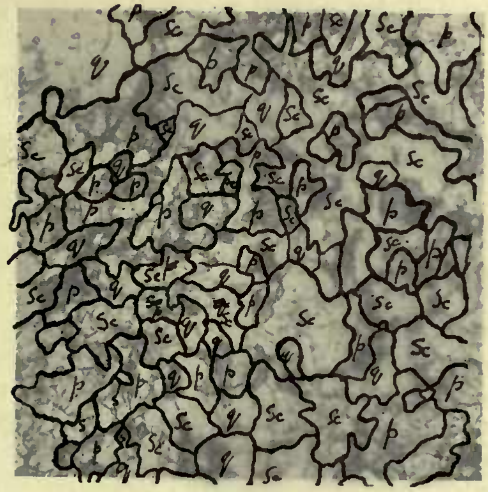


FIG. 4

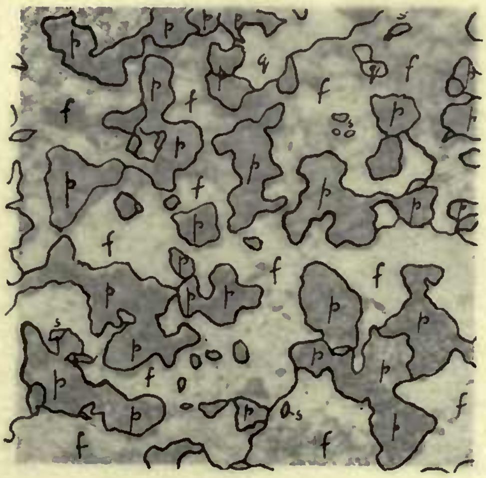
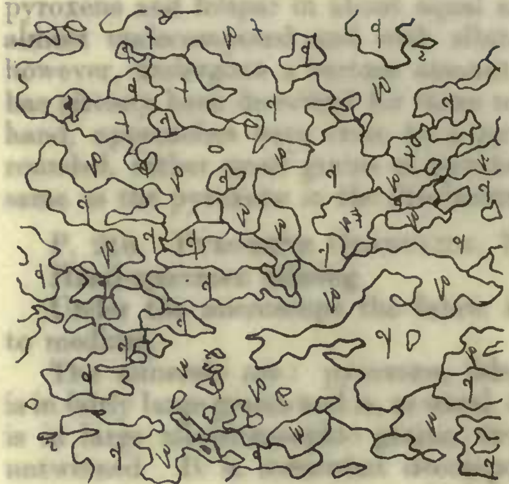
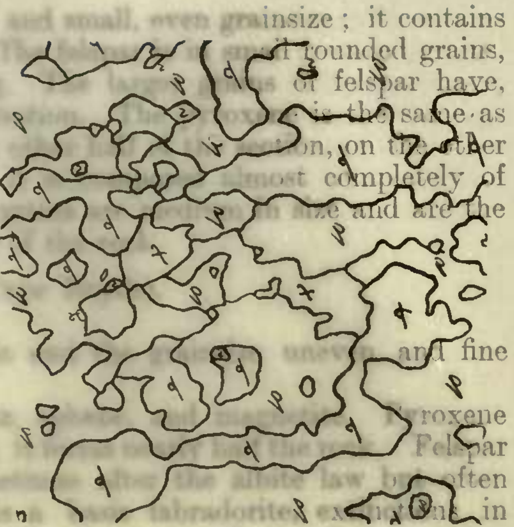


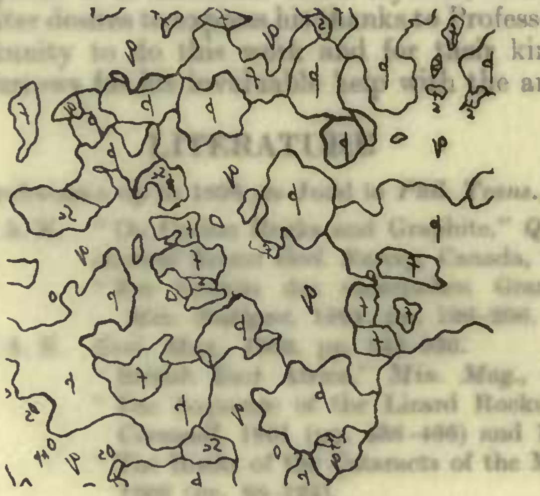
FIG. 5

[To face p. 168

[Tissue of Plate facing p. 168







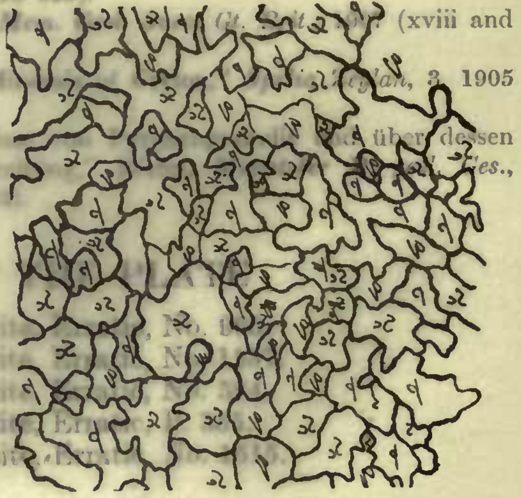


PLATE I

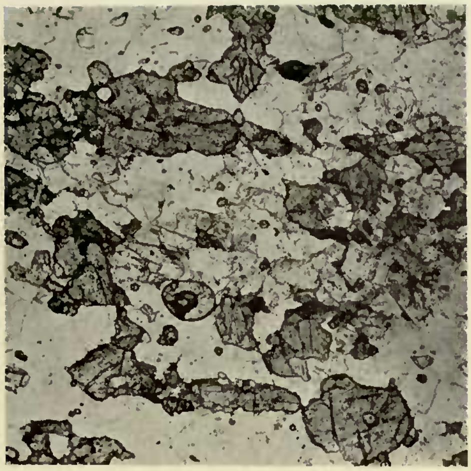


FIG. 1

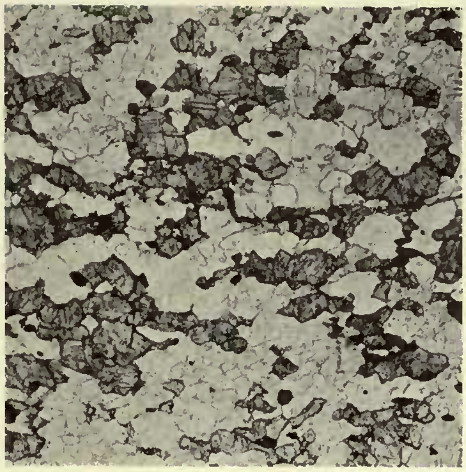


FIG. 2

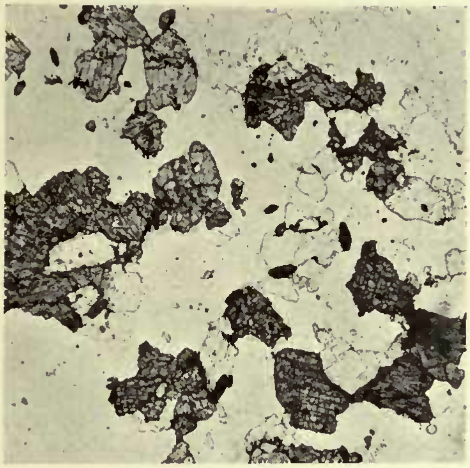


FIG. 3

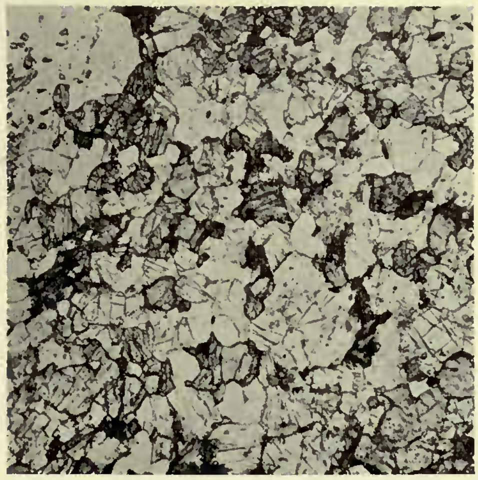


FIG. 4

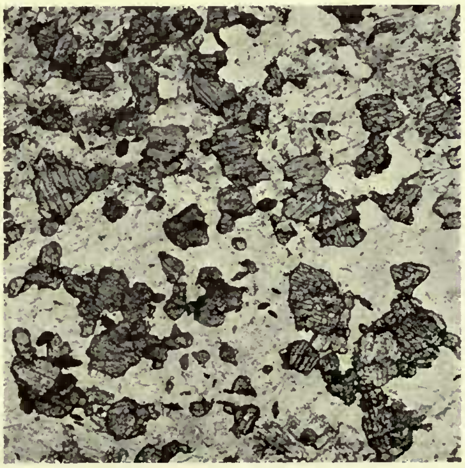


FIG. 5

[To face p. 168

PART XI

PETROLOGICAL NOTES ON SOME OF THE ERRATICS COLLECTED AT CAPE ROYDS

(*With Two Plates and One Figure in the Text*)

BY

DR. W. G. WOOLNOUGH, D.SC., F.G.S.
Professor of Geology, University of West Australia

566. PEGMATITE

Macroscopic Characters.—Light coloured, somewhat mottled, and slightly foliated. Texture varies from rather fine to extremely coarse in different parts of the same specimen, which is evidently part of an aplitic vein in a granite mass. The rock consists essentially of grey quartz and white felspar. The latter mineral occurs in crystals up to 40 mm. in diameter, poikilitically enclosing quartz grains. There is little biotite in flakes up to 5 mm. in diameter.

Microscopic Characters.—The fabric is allotriomorphic granular, the average grainsize being about ·6 mm.

The minerals are orthoclase, microcline, quartz, oligoclase, and garnet, in order of abundance.

Orthoclase shows quite considerable strain effects, where these attain a maximum a decided *moirée* structure is produced. There is a good deal of granophyric intergrowth with quartz round the borders of the larger grains. In addition there is frequently a poikilitic enclosure of quartz grains.

Distinct microcline is present with " Gitter-struktur " well developed, with increasing fineness of the lamellæ a *moirée* structure is produced so that the microcline and orthoclase grade insensibly into one another.

Quartz shows very pronounced evidence of strain. In some of the grains this amounts merely to production of cloudy (undulose) extinction, but many of the grains are completely shattered.

Oligoclase is subidiomorphic in places though it never has definite crystal boundaries. Considerable strain effects are noticeable, including local suppression of albite twinning, and development of that after the pericline law.

All the felspars are slightly kaolinised; the oligoclase less so, and more locally than the potash felspars.

Garnet is fairly abundant in small, faintly pink trapezohedra.

As an accessory mineral a very small amount of greenish mica (bleached biotite) may be noted. This rock may stand as an example of a very common type amongst the erratics.

1874. PEGMATITE

Macroscopic Characters.—A medium to coarse grained rock, consisting of quartz, white felspar, and occasional very large flakes of dark-reddish biotite.

Microscopic Characters.—The rock is hypidiomorphic granular in fabric with a medium grainsize. Felspar makes up about 80 per cent. of the minerals present.

Plagioclase about Ab_5An_3, is present in subidiomorphic sections up to 1 mm. diameter. It shows twinning after the albite Carlsbad and Manebach laws, the striations being very fine and showing pretty examples of bending. The mineral is somewhat decomposed, particularly near the periphery.

Orthoclase is untwinned, slightly decomposed, and exhibits shadowy extinction. It is moulded on plagioclase, and in some cases there is apparently a crystallographic relation between the two, the outgrowths of orthoclase showing optical continuity (Fig. 1).

Quartz is not very allotriomorphic, and shows shadowy extinction due to strain.

Biotite calls for no special description, it is somewhat frayed and contains inclusions of apatite.

There is also a very little light-coloured epidote.

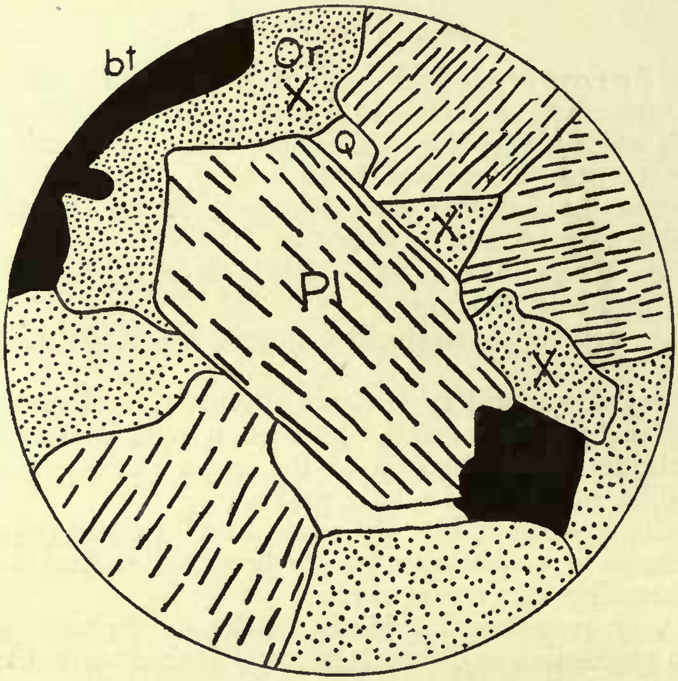


Fig. 1. Sketch showing Relation of Plagioclase and Orthoclase. The grains of orthoclase indicated by X are optically continuous.

439. APLITE

Microscopic Characters.—Allotriomorphic granular rock with an average grainsize of 0·5 mm., consists essentially of quartz and orthoclase with less abundant albite and very little decomposed biotite.

Quartz shows slight evidences of strain; orthoclase is quite ordinary. The plagioclase present is between albite and oligoclase in composition.

Rocks of this type are extremely abundant amongst the erratics; a fact attributable to their resistance to weathering being greater, as a rule, than that of the normal biotite or hornblende granites with which they were in all probability genetically connected.

438. Syenite (Plate I, Fig. 1)

Macroscopic Characters.—Dark grey mottled rock, holocrystalline, medium to coarse. Consists of colourless felspathic material, and still more abundant hornblende. The latter mineral is mostly granular but occasionally is in crystals up to 8 mm. by 1·5 mm.

Microscopic Characters.—The texture is hypidiomorphic granular with fairly even grainsize averaging about 1·5 mm. Hornblende and oligoclase-andesine in about equal proportions make up roughly 80 per cent. of the rock; orthoclase accounts for about 15 per cent., the remainder being biotite, sphene, apatite, and quartz.

Hornblende is light-greenish in colour, the pleochroism being $\mathfrak{a}$ =very light greenish-yellow, $\mathfrak{b}$ =bronze-green, $\mathfrak{c}$ =brownish-green, absorption $\mathfrak{a}<\mathfrak{b}>\mathfrak{c}$. While the bulk of the hornblende is no doubt primary, the nuclei of some of the grains suggest uralite, but no unaltered pyroxene can be observed. Maximum extinction angle measured in the vertical zone 15°.

Oligoclase-andesine occurs in idiomorphic and subidiomorphic sections twinned after the Carlsbad, albite, and pericline laws. It is somewhat clouded by decomposition products, chiefly calcite and sericitic mica. In some instances these products are zonally arranged.

Orthoclase is allotriomorphic and untwinned. It is somewhat kaolinised but is less altered on the whole than the plagioclase.

Biotite in bleached flakes is mostly included in the hornblende.

Sphene is present as greyish grains sometimes moulded on the plagioclase.

Apatite in minute, sharply defined prisms is moderately abundant. There is very little quartz, what there is is graphically intergrown with the orthoclase.

E. 36. Sodalite Syenite with Wöhlerite (Plate I, Figs. 2 and 3)

Microscopic Characters.—This is a most peculiar rock. It is holocrystalline and consists chiefly of felspar, some of the sections of which have diameters of several millimetres. The larger grains are subidiomorphic. The extinction of this felspar is cloudy, reminding one of *moirée* microcline. In some instances excessively fine crossed twin lamellæ can be seen, while in others what looks like perfect microcline "grating" is present. The extinction angles of the lamellæ are 11° to 13°, but the refractive index is decidedly higher than that of cooked Canada balsam, so that the felspar cannot be microcline, and must be a plagioclase near andesine, with quite abnormal development of twin lamellæ. The values for extinction angles given above are not at all satisfactory as the extinction is very cloudy.

The grains of felspar are crowded with markings like those producing "schiller" structure in hypersthene. These are really plates of an isotropic substance perfectly colourless and with a refractive index much below that of Canada balsam, and which I believe to be sodalite. This regular intergrowth of felspar and sodalite forms a veritable sodalite microperthite. In sections cut at right angles to the plane of the plates of sodalite the structure appears laminated. In addition to this intergrowth other felspars without twinning, but with the same relatively high refractive index, show perthitic intergrowth with the microcline-like felspar above described.

Scattered through the rock, and included in the felspars, are fairly abundant stout prisms up to 1·2 mm. by 0·3 mm. of a bright orange-coloured mineral. This has a positive elongation and gives extinctions up to 32° from the length. There is a decided cleavage parallel to the length. The refractive index is considerable and birefringence strong.

It is biaxial, optically positive, with 2V fairly large and shows very decided dispersion, $\rho < v$.

These characteristics are somewhat puzzling. At first sight the mineral suggests a member of the epidote group, but the constant high extinction measured from the length and the character of the dispersion seem to put epidote out of court.

Of all the minerals described in Rosenbusch's *Mikroskopische Physiographe* wöhlerite possesses most features in common with the one under discussion.

It is quite possible that we are dealing with a new mineral; but, unfortunately, only a very small chip of the rock was collected, and there was not sufficient material for analysis or for mineral separation.

Another feature of this remarkable rock is the habit of the magnetite, which is a fairly abundant constituent. In addition to normal octahedra there are still more abundant distorted crystals possessing a prismatic habit.

Magnetite and wöhlerite occur together, forming intergrowths.

Apatite is present in exceptionally large crystals up to 1 mm. by 0·2 mm., together with interstitial sodalite and small grains of magnetite and wöhlerite. Here and there quite large patches of sodalite occur.

535. Sodalite Syenite

Macroscopic Characters.—Light grey rock of even grainsize (0·5 mm.) composed essentially of felspathic and ferromagnesian minerals in about equal proportions. The ferromagnesian minerals include black augite and dark-reddish mica.

Microscopic Characters.—Hypidiomorphic granular rock of medium grain consisting essentially of anorthoclase sodalite, augite, olivine, biotite, micaceous hæmatite, and magnetite; with smaller quantities of hornblende, oligoclase, and apatite.

Anorthoclase is much the most abundant constituent; it is subidiomorphic and tabular parallel to (010). Twinning on a large scale is after the Carlsbad law or is absent, but the individuals are always multiple twinned on an extremely fine scale so that the extinction is quite cloudy. Only occasionally can the actual twin lamellæ be resolved. The refractive index is never higher than that of Canada balsam and is mostly decidedly less.

Sodalite is not very abundant. It is mostly interstitial but in some instances appears to be perthitically intergrown with anorthoclase.

Augite, light bluish-grey, subidiomorphic and mostly untwinned. The crystals are crowded with inclusions chiefly of apatite and magnetite. The mineral is not pleochroic. 2V is large. The grains are moulded on olivine, but are older than hornblende and biotite.

Olivine in idiomorphic crystals up to 0·63 mm. by 0·28 mm. is decidedly yellowish in colour and considerably altered around the outside and along cracks with separation of much magnetite. Two of the cleavages are quite perfect. Double refraction is very strong, while the optic axial angle, though quite large, is nevertheless relatively small for olivine.

Biotite in irregular flakes and occasional subidiomorphic sections, averaging about 0·22 mm. diameter, is very dark in colour, the pleochroism being from brownish-red to opaque. It is crowded with plates of micaceous hæmatite lying parallel with the cleavage.

Micaceous hæmatite is very abundant in flakes averaging 0·16 mm. diameter.

Hornblende is not abundant; it occurs mostly associated with augite, forming a halo round that mineral. The colour is very dark brown, and, when the trace of the vertical axis is parallel to the plane of vibration of the polarizer, it becomes opaque.

A few small but sharply defined crystals of oligoclase are included in the anorthoclase.

A noteworthy feature is the very considerable abundance of sharply prismatic apatite.

This rock is a most peculiar type. In mineral composition it is like laurdalite, except that sodalite is substituted for nepheline. There does not appear to be any alteration product present which would have been formed from nepheline.

443. QUARTZ-DIORITE (Plate I, Fig. 4)

Macroscopic Characters.—A most strikingly handsome rock type. It is fairly coarsely crystalline and is mottled black and white. Sharply idiomorphic prisms of lustrous hornblende up to 10 mm. by 2 mm. are scattered very abundantly through a base of the lighter coloured constituents. Less abundant but quite as conspicuous are very large plates of biotite 18 mm. in diameter, more or less chloritised. Yellowish orthoclase occurs in pseudo-porphyritic grains up to 20 mm. diameter, containing very abundant inclusions of hornblende, biotite, and idiomorphic, colourless plagioclase.

In the light-coloured interstitial material orthoclase, plagioclase, and not very abundant quartz can be recognised.

A very remarkable feature of the rock is the habit and abundance of apatite, which occurs in yellowish and colourless needles up to 8 mm. long by 0·2 mm. thick.

Microscopic Characters.—The texture of the rock is holocrystalline porphyritic with hypidiomorphic granular base of medium grain.

Under the microscope the most conspicuous and abundant minerals are the felspars, of which there is a considerable variety.

Orthoclase composes the largest grains in the rock. In addition, there are smaller grains and patches of the same mineral scattered through the slide. The grains are all completely allotriomorphic, the larger ones poikilitically enclosing crystals of most of the other minerals. Towards quartz the mineral shows occasional traces of crystalline outline, but often the two minerals are intergrown. It is slightly clouded by decomposition, and shows veins due to perthitic intergrowth. All the sections are untwinned.

Plagioclase exists in at least two habits, corresponding to two different varieties: (*a*) strongly idiomorphic thick tabular crystals, twinned after the albite and pericline laws, and often after the Carlsbad law as well; (*b*) in subidiomorphic to allotriomorphic grains with Carlsbad and albite twinning. In the former case there are strongly marked zonal effects which are perfectly continuous from periphery to centre.

Those of the first set are frequently included in individuals of the other type. In the central portions of the former the symmetrical extinctions of the albite lamellæ give a maximum of 32°, with a difference (Δ) of 21° for the extinction in the other half of the Carlsbad twin. The peripheral portions give perfectly straight extinctions. Hence the variation is from Ab_4An_1 on the outside to Ab_9An_{11} at the centre.

The felspars of the second period are less strongly zoned than those of the first, though still quite a noticeable "undulation" in the extinction occurs. The angles measured point to Ab_3An_1 as the composition of the interior while the periphery is more acid.

All these felspars are irregularly clouded by decomposition products (chiefly very fine grains of calcite) and are dusted round their edges with similar material. This makes comparison of refractive indices difficult. In most instances the refractive index of the plagioclase is greater than that of Canada balsam, but an occasional section of the peripheral portion of a crystal of the first period exhibits equality of refractive index with the same standard. The refractive index of the peripheral zones of felspars of the first period is very decidedly less than that of the grains of the second period in which they are imbedded. Quartz is moderately abundant in large grains mostly strained, and many of them showing signs of incipient granulation. Very abundant fluid cavities with spontaneously moving bubbles are present.

Hornblende is abundant in idiomorphic prisms. It is notably complex in character, showing a decided zoning, the central portion being dark brown and the peripheral part dark green. The pleochroism of the brown portion is:

$\mathfrak{a}$ = bright golden yellow;
$\mathfrak{b}$ = very dark brown;
$\mathfrak{c}$ = dark greenish-brown.

$$\mathfrak{a} < \mathfrak{b} > \mathfrak{c}$$

Sections parallel to (010) show twinning, and yield symmetrical extinctions of 17°. The passage from brown nucleus to green rim is very gradual. The central portion frequently shows no cleavage, but is strongly schillerised.

Biotite is fairly abundant in subidiomorphic sections. The pleochroism is golden yellow to dark reddish-brown. The crystals contain inclusions of apatite, plagioclase, and zircon (the latter with pleochroic halos).

Biotite and hornblende frequently show regular intergrowths with definite morphological relationship. Sometimes one is inside, sometimes the other, but mostly the hornblende is the older. Frequently the biotite is completely altered into dark green penninite.

Apatite is extremely abundant in perfect crystals.

448. Granophyric Granite-Porphyry

Macroscopic Characters.—Grey mottled with dark and light spots. The groundmass is fairly fine in grain and consists of felspar and biotite. The lighter coloured phenocrysts consist of pink orthoclase (3 mm.) and grey plagioclase (8 mm. by 3 mm.). The dark patches are finely granular aggregates of greenish-black colour up to 4 mm. by 2 mm.

Microscopic Characters.—The fabric of the base is panidiomorphic granular with the exception of fairly abundant patches which are distinctly granophyric.

The base consists of felspar, quartz, and biotite, with a little accessory zircon and magnetite. The felspars of the base are idiomorphic and subidiomorphic and very even in size. Mostly they are untwinned, have a refractive index less than that of Canada balsam, and give very nearly straight extinctions, so that they are probably orthoclase. A few appear to possess very hazy albite twinning and may possibly be anorthoclase. These felspars are considerably kaolinised so that satisfactory determinations are difficult.

Quartz is not so abundant as felspar; some of it is idiomorphic, some enters into beautiful granophyric intergrowth with the felspar.

The ferromagnesian constituent is not abundant. It occurs in small flakes whose pleochroism is from yellow to dark brown. From this condition it is present in various stages of bleaching, the ultimate product being an aggregate of green fibres. While these aggregates have been described as an alteration of biotite it is possible that they consist of dark uralite with a very small extinction angle. The only conspicuous phenocrysts are felspar much kaolinized and affording no very satisfactory measurements. Some appear to be orthoclase untwinned or twinned after the Carlsbad law. Others are certainly plagioclase with Carlsbad, albite, and pericline twinnings; the measurements indicate very acid oligoclase. In addition there is a good deal of hazy perthitic intergrowth of the felspars and also fringes of granophyre round the felspar grains.

Chemical Composition.—The following is an analysis of this rock by Messrs. Burrows, B.Sc., and A. B. Walkom, B.Sc.:

SiO_2	68·00
TiO_2	0·16
Al_2O_3	17·28
Fe_2O_3	0·07
FeO	3·56
MgO	0·37
CaO	1·67
K_2O	3·59
Na_2O	4·08
H_2O+	0·46
H_2O-	0·23
CO_2	0·27
MnO	0·05
P_2O_5	Trace
	99·79

447. GRANOPHYRE

Macroscopic Characters.—Fine-grained purplish-pink rock, of very even grainsize with a few larger black grains of biotite scattered through it, and occasional phenocrysts of pinkish felspar 2mm. by 1 mm.

Microscopic Characters.—Somewhat porphyritic rock with even-grained, holocrystalline base, the average grainsize being about ·35 mm.

The fabric is micro-graphic. The chief constituents are quartz, felspar, and biotite with minor constituents. There are idiomorphic-phenocrysts of felspar. These are mostly untwinned, but some show Carlsbad twinning, and some lamellæ after albite and pericline laws. No satisfactory extinctions were obtained, but an examination of relative refractive indices indicates that the felspar is oligoclase. All the grains are somewhat decomposed and are surrounded by secondary outgrowths of orthoclase identical in character with the felspar of the groundmass, and, like it, subject to granophyric intergrowth with quartz.

The orthoclase of the groundmass is in quite irregular grain; sometimes these are solid throughout, sometimes solid at the centre with a fringe of granophyric structure round the edges, or granophyric throughout, or, lastly, there may be a quartz nucleus with a granophyric fringe, but this is rarer. The felspar throughout is somewhat clouded by decomposition products.

Quartz is mostly interstitial, though, as above noted, it sometimes forms the nucleus of a granophyric intergrowth.

Biotite occurs in very ragged flakes up to 1 mm. by 0·2 mm. It is all somewhat altered so that the pleochroism is from dark greenish-yellow to opaque. Some flakes are decidedly green, others are clouded and opaque through deposition of limonite. A very little magnetite and apatite are present, and a few small grains of fluorite.

The order of crystallization is somewhat peculiar in this rock: of the essential minerals biotite certainly began to form first, but continued to form for a long time, as it is moulded on all the other minerals, including even quartz. The oligoclase crystals ceased to form comparatively early.

613. FELSPAR PORPHYRY

Microscopic Characters.—The phenocrysts appear to include two species of felspar both occurring in idiomorphic crystals.

Some of these are completely clouded so that measurements are not possible; they appear to be orthoclase. The others are mostly clear, but are decomposed in patches and sometimes zonally. They exhibit well-defined Manebach twinning as well as that after the Carlsbad and albite types. They are mostly slightly more acid than $Ab_1 An_1$, but in some instances there appears to be a definite intergrowth with oligoclase in discontinuous strips parallel to the trace of the vertical crystallographic axis.

The base is finely panidiomorphic granular. It consists chiefly of untwinned columnar felspar, with square cross-sections. The extinction of these laths is never more than 8° from their long axes, so that the felspar is probably soda-orthoclase. In many instances such prisms have a "core" formed by a flake of biotite. Round many of them there is a fringe or halo of very fine granophyric intergrowth with quartz. These felspars are a little decomposed. There is a small amount of free quartz, both interstitial and in subidiomorphic grains, and also a fair amount of biotite in thin, bent flakes with greenish-yellow to dark green pleochroism. Minor constituents are magnetite, sphene, and calcite-epidote aggregates representing the alteration products of a pyroxene or amphibole.

7. MINETTE (Plate I, Fig. 6)

Minette (approaching Camptonite) with a xenolith of altered quartzite.

Microscopic Characters.—The minette is a fine-grained panidiomorphic granular rock without porphyritic structure, composed essentially of prismatic hornblende, plates of biotite, interstitial orthoclase, a little epidote and sphene, and very little ilmenite.

Hornblende is in sharply idiomorphic prisms 0·1 mm. by 0·01 mm.; cross-sections are bounded by (110) with or without (100), but with no trace of (010).

Pleochroism is slight, $\mathfrak{a}$ colourless, $\mathfrak{b}$ and $\mathfrak{c}$ faint green, extinction angle 15°.

Biotite is in thick hexagonal plates, ·06 mm. in diameter; strongly idiomorphic. These are pleochroic from light brown to dark brown.

Away from the contact there is no augite.

The felspar, whose refractive index is less than that of Canada balsam, forms a not very abundant paste.

On the other side of the contact the rock consists essentially of quartz and augite (with, possibly, some epidote). The quartz amounts to about 40 per cent of the rock. It is in fair-sized grains, showing considerable undulose extinction. The augite is finely granular and colourless.

The contact zone, which is about 2 mm. in width, is rather finer in grain than the rock on either side. On the minette side there is an admixture of augite in fine grains, and a very well-marked development of "Schlieren." On the quartzite side there is a noticeable development of biotite and a little hornblende.

The altered rock is probably derived from an argillaceous sandstone rather than from an eruptive rock, as no felspar is present in it.

534. MINETTE

Macroscopic Characters.—Dark grey granular rock with occasional irregular light-coloured patches. The apparent grainsize is about 0·25 mm. The most abundant constituent is a greenish-black micaceous mineral. Interstitial felspar is not abundant. The larger white patches are of quartz and calcite up to 3 mm. in diameter.

Microscopic Characters.—Grainsize even, fabric panidiomorphic granular.

The most abundant constituent is orthoclase in idiomorphic crystals, untwinned or twinned after the Carlsbad law. Occasionally a multiple-twinned plagioclase crystal can be seen whose extinction angles and refractive index point to a composition of Ab_9An_1 about.

All these felspars are very much clouded by decomposition, and are crowded with flakes and tufts of light-yellowish chlorite or mica. Many such clouded crystals have outgrowths of clear orthoclase in crystal continuity. In both nucleus and outgrowth the extinction angles, measured from the long axis, are very small; but a difference of 1° or 2° between inner and outer portions can be detected. Many of the cloudy crystals are enclosed in extensive optically continuous areas of somewhat cloudy orthoclase.

Some of the felspars are more or less replaced by quartz in a manner so irregular as to point to metasomatic action.

There is much biotite with very light yellow to reddish-brown pleochroism, and showing bright polarisation tints. This mineral is considerably altered to green penninite with separation of the titanium content in the form of "sagenite" webs and granular leucoxene. Much ilmenite is present, slightly decomposed to leucoxene.

Apatite in relatively large needles is very plentiful, but is almost confined to the quartz, and does not enter much into the felspar or biotite.

There is not much calcite, but what there is is in large patches mixed with quartz in such a way as to suggest progressive replacement by the latter mineral.

There is quite abundant clear quartz, mostly interstitial in character, and probably secondary. The graphic intergrowth with what appears to be secondary orthoclase has been noted above, as has also the fact that the quartz contains inclusions of apatite. The appearance is strongly suggestive of secondary action having introduced quartz, orthoclase, and apatite. Such a process, if it happened, is somewhat remarkable.

1066. VOGESITE

Macroscopic Characters.—Dark-greenish rock of very fine grain. The only noticeable feature is the development of abundant irregular flecks of dark-coloured material up to 2 mm. diameter.

Microscopic Characters.—The rock, which is much decomposed, shows a holocrystalline porphyritic structure with a panidiomorphic granular base. It is composed essentially of felspar, hornblende, uralitised augite, and chlorite (apparently after biotite), in about equal proportions. The felspars average about 0·25 mm. by 0·1 mm. in size, and are very cloudy from secondary material. All are apparently orthoclase.

Hornblende is in idiomorphic prisms with an extinction angle of 17° on (010):

$\mathfrak{a}$ = yellow; $\mathfrak{b}$ = dark brown; $\mathfrak{c}$ = dark brown.

$$\mathfrak{a} << \mathfrak{b} > \mathfrak{c}$$

The sections are somewhat chloritised. The mineral occurs in one generation only.

Chlorite occurs in small flakes and also in large patches (penninite). These large patches are all apparently in secondary spaces, and are associated with other secondary minerals. The smaller flakes suggest original biotite, but none of the latter mineral has survived.

Augite occurs in two generations. The individuals belonging to the second are about equal in size to those of felspar and hornblende. They occur in quite colourless prisms with extinction angles up to 45°. Sometimes the ends of the prisms are frayed out and uralitised; the central portions are fresh. In many instances they have been converted into green reedy hornblende, quite distinct from the primary mineral. The augites of the first generation are in grains up to 0·5 mm. by 0·3 mm., colourless and with 2V very large. There is much epidote (pistacite) in relatively coarse-grained aggregates up to 1 mm. in diameter, associated with calcite, uralite (in fibres), penninite and a biaxial zeolite, apparently stilbite. No fresh iron ores are present, but there is much leucoxene.

372 (P. 112). Porphyrite (Plate I, Fig. 5)

Macroscopic Characters.—Mottled rock with dark grey lithoidal base. The phenocrysts are white plagioclase up to 10 mm. by 4 mm. (but mostly much smaller), sharply defined hornblende prisms up to 4 mm. by 1 mm., and biotite up to 2 mm. by 1 mm.

Microscopic Characters.—The rock is porphyritic with a panidiomorphic granular base, whose average grainage is about 0·04 mm. The base consists chiefly of acid felspar (probably anorthoclase), with small quantities of quartz, and flakes of green and brownish minerals, including apparently both hornblende and biotite.

The most abundant phenocrysts are plagioclase in thick tabular crystals, giving sections up to 3 mm. by 1 mm. These are zoned, and measurements indicate a composition of Ab_5An_3 for the outer zones, while the bulk of each crystal is slightly more basic than Ab_1An_1. These felspars are very slightly decomposed and contain liquid inclusions with moving bubbles.

Hornblende is present with prismatic habit, sharply idiomorphic and characterised by a strong development of the orthopinacoid (100). The highest extinction in sections from the prism zone is 15° measured from the trace of the vertical axis. The pleochroism is:

$\mathfrak{a}$ = light yellowish-green;
$\mathfrak{b}$ = dark clove-brown for the inner portions;
$\mathfrak{b}$ = very dark brownish-green for the outer zone;
$\mathfrak{c}$ = very dark green, almost opaque.

Absorption = $\mathfrak{a} < \mathfrak{b} < \mathfrak{c}$.

This zoning is not prominent in vertical sections, but is well marked in those which are cut transversely. The characters of this hornblende suggest a relationship between this rock and numbers 441 (p. 180) and 452 (p. 179). The present rock may represent a hypabyssal facies of which the other two are the plutonic and volcanic types respectively.

Biotite is idiomorphic to subidiomorphic in sections up to 1·2 mm. by 0·5 mm. It shows pleochroism from golden yellow to very dark brown, some basal sections being practically opaque.

Apatite and zircon occur as inclusions in both hornblende and biotite.

There appears to be considerable overlap in the crystallisation periods of the porphyritic constituents. Hornblende is for the most part the earliest, but very occasionally is moulded on felspar and hornblende; but also occurs included in the large felspars.

284 (610). Sericitised Diabase-Porphyry

Microscopic Characters.—The base of the rock is rather coarsely pilotaxitic in fabric. It consists mostly of oligoclase-andesine in idiomorphic crystals, 0·3 mm. by 0·2 mm., which are fairly fresh and undecomposed. There is a good deal of strongly prismatic uralite in crystals, 1 mm. by 0·1 mm., a little dark brown biotite in flakes or confused aggregates, and still smaller quantities of magnetite. Throughout the base abundant leucoxene is scattered.

The phenocrysts are large idiomorphic plagioclases up to 1·5 mm. by 0·5 mm., almost completely sericitised. In the majority of instances the phenocrysts are converted into pseudomorphs of interlacing fibres, the whole aggregate possessing strong double refraction; but there is always an outer zone of clear felspar, showing strongly zonal extinction, but with low angles like those of the felspars of the second generation. In a few instances patches of the original material are sufficiently unaltered to get symmetrical extinctions up to about 32° (Ab_9An_{11}). Under high powers the alteration products of the felspar can be resolved into fine interlacing laths of sericitic mica extending inwards from the sides of the original crystals. While there may be considerable divergence of individual laths yet there is a very marked regularity in their general arrangement. They are distributed along certain definite crystal planes whose positions have not been identified. In any particular haphazard section the angles between the different solution planes (if such they be) depends upon the orientation of the section. In one instance, where two well-defined axes of arrangement made an angle of 58° with one another, the traces of the (001) and (010) cleavages of the felspar appeared symmetrically placed with respect to the said axes. This rather suggests that a pair of brachydome faces may lie parallel to the solution planes, but of this I cannot feel at all certain.

There is a good deal of secondary material throughout the rock. Leucoxene has been mentioned already. In addition there is much quartz, calcite, and some chlorite. The quartz and calcite often enclose or partly enclose the main constituents of the rock, suggesting an original miarolitic texture.

452. Sölvsbergite (Plate II, Figs. 3 and 4)

Macroscopic Characters.—Dark grey porphyritic rock with stony groundmass. There are abundant phenocrysts of colourless felspar, up to 2 mm. in diameter occasionally. Hornblende is very abundant and conspicuous in sharply defined prisms which occasionally reach 5 mm. by 0·5 mm., but are mostly much smaller. Occasional grains of pyrites are visible.

Microscopic Characters.—The rock is porphyritic, with very fine textured pilotaxitic base consisting of lath-shaped felspars apparently hornblende and quartz granules.

The most abundant phenocrysts are plagioclase, twinned after both Carlsbad and albite laws. There seem to be two sets of phenocrysts of plagioclase, the larger ones are andesine Ab_5An_3 on the outside and approach anorthite in the kernel and are very strongly zoned. These have dimensions about 1·5 mm. by 0·75 mm., parallel to (010), but are very thin, only about 0·15 mm. in the direction of the *b* axis.

The other plagioclase phenocrysts are smaller and stouter than these, and are more acid in character.

The most striking mineral present is the amphibole, which is markedly composite. The greater part of each crystal is brown in colour, but the outer zones, and particularly the ends of sections from the prismatic zone, are dark green. In a section parallel to (010) $c : \mathfrak{c} = 14°$. The pleochroism is:

$\mathfrak{a}$ = brownish-yellow;
$\mathfrak{b}$ = reddish-brown;
$\mathfrak{c}$ = dark clove-brown;

and absorption $\mathfrak{a} < \mathfrak{b} = \mathfrak{c}$.

These properties indicate that the mineral is barkevicite.

The optical properties of the green portion are somewhat anomalous, and perfect extinction between crossed nicols does not occur. The extinction angle appears to be about 5° greater for the green than for the brown. Many of the crystals are twinned after the common law, and, in addition, some curious interpenetration twins occur also.

Quartz is not abundant, the grains average about 0·25 mm. in diameter, and are granophyrically intergrown with orthoclase round the borders. In addition to the orthoclase just mentioned there are a few independent crystals, twinned after the Carlsbad law, and perfectly clear and undecomposed.

A few apatite needles are scattered through the rock.

Flakes of green penninite occur, indicating that biotite was an original constituent of the rock in all probability.

441. Sölvsbergite

Microscopic Characters.—Somewhat similar to No. 452 but less trachytic in structure. The base consists of a confused aggregate of rather decomposed, untwinned orthoclase, abundant greenish chloritic material (probably derived from amphibole) and very little quartz.

The phenocrysts are kaolinised felspars with zonal decomposition near periphery. The refractive index of these is less than that of quartz but equal to or greater than that of Canada balsam. Some of them show multiple twinning but no good sections for determination were encountered.

A few grains of quartz which are present seem to be foreign inclusions. One fragment included in the slide consists of quartz, complicated saussuritised felspar, a very large apatite crystal and green hornblende quite distinct from that of the rock itself.

Hornblende is abundant in perfectly idiomorphic crystals very similar to that in No. 452, but without the well-marked green borders there described.

430. Sapphire-bearing Trachyte

Microscopic Characters.—The rock is markedly trachytic in character, with a few porphyritic crystals.

The base consists mostly of lath-shaped felspars up to 1·2 mm. by 0·04 mm. Almost all are sharply twinned on the Carlsbad law, and one or two of the largest show hazy patches of what may be very fine multiple twinning, but this is doubtful. One of the larger twinned microlites shows symmetrical estimations of 8° and the smaller ones give extinctions from 0° up to 8°, so that they consist of soda-sanidine. Many of them are forked and bent. The larger crystals are crowded with apatite and magnetite inclusions, the latter being zonally arranged.

There is a good deal of interstitial augite of a green colour often ophitically enclosing the felspar laths. In some cases the augite grains are covered with a network of black needles strongly suggesting skeleton crystals of magnetite.

The infrequent phenocrysts consist of tabular felspar with undulose extinction, augite with an extinction angle of 41°, and large corroded grains of brown sphene.

One small grain of light blue sapphire occurs in the slide.

387 (E. 11). Corundum-bearing Trachyte (Plate II, Figs. 1 and 2)

Microscopic Characters.—Porphyritic, with trachytic base.

The base is composed of sanidine needles, augite needles, magnetite, and a little glass. There is a very strong fluidal arrangement of the constituents. Sanidine in crystals 5 mm. long and very narrow shows Carlsbad twinning only. The extinction nowhere measures more than 3° from the length of the needles.

Augite is light green, much corroded, and of the same order of size as the sanidine.

Magnetite. Idiomorphic sections very minute but pretty numerous.

Phenocrysts are numerous.

Plagioclase in sections up to 4·5 mm. by 0·9 mm. with symmetrical extinction of the albite lamellæ of 8°, and a refractive index decidedly higher than that of Canada balsam. The plagioclase contains very remarkable inclusions. There are small apatite crystals and grains of greenish augite and of almost opaque dark hornblende; these are not abundant. There are, however, large irregular patches and inclusions in the form of negative crystals of colourless glass. From the edges of some of the larger cavities partial spherulites composed of slightly greenish fibres extend inwards.

There are a few large phenocrysts of anorthoclase up to 2 mm. by 0·8 mm. of sanidine-like habit. These show Carlsbad twinning, and very occasional small patches of gridiron twinning. The extinction angles are almost straight and the refractive index is about equal to that of Canada balsam. The optical sign is negative and the optic axial angle small. The mineral is perfectly fresh and is probably anorthoclase. The most conspicuous constituents of the rock are numerous, almost completely altered crystals of dark hornblende up to 1 mm. by 0·5 mm. The resorption has completely darkened the sections in most instances, but here and there small elliptical patches of the original mineral are preserved. The colour is brown and there is strong pleochroism, brownish-yellow when the vibrations are transverse, brownish-orange when they are longitudinal in prismatic sections. In every grain examined the extinction angle was very small, not more than 2°. Some of the sections are distinctly twinned, the extinction being just sufficiently oblique to make the phenomenon apparent. The perfection of cleavage, the colour, the double refraction, and the very small extinction angle all suggest biotite; but the optic axial angle is very considerable, hence I have called the mineral hornblende. It is possible that both minerals may be represented. Each, very much altered, crystal is surrounded by a halo of small augite needles and grains in the base.

There is a little bright red micaceous hæmatite.

Augite in purplish phenocrysts, stout prisms 0·25 mm. long, is easily confused with the corundum on casual inspection.

$\mathfrak{a}$ = brownish-grey; $\mathfrak{b}$ = grey-violet;
$\mathfrak{c}$ = purple; 2V is large.

Corundum in the form of sapphire is quite a notable constituent. It occurs in tabular crystals, 0·1 mm. by 0·02 mm., very much corroded by the magma. It is not noticeably pleochroic. It is included in all the other minerals except apatite, of which there is a little.

There are irregular glassy veins about 0·05 mm. in width running through the rock. Sanidine crystals project from the sides, suggesting a miarolitic fabric. Here and there are tufts of fibrous radial mineral like that described in the inclusions in the felspar. The interstices are filled with colourless glass (or possibly opal).

444. SPHERULITIC TRACHYTE

Macroscopic Characters.—Very fine-grained rock of brownish-grey colour, with rather scanty phenocrysts of felspar up to 3 mm. by 1 mm., and still less abundant thin flakes of biotite up to 5 mm. by 1 mm.

Microscopic Characters.—Contains phenocrysts of felspar, biotite, and magnetite in a finely spherulitic base.

The base consists mostly of microlites of felspar and biotite with a little interstitial quartz, and felspar of a character different from that of the microlites. This interstitial felspar is certainly orthoclase.

The microlites have rather a rosette grouping than a spherulitic arrangement. Many of the microlites are distinctly cored.

The main part of the crystal extinguishes at 5½° from the length, while the core extinguishes at 22°. The highest extinctions measured in such microlites is 12°, and the elongation is negative.

Quartz and biotite are not abundant; the former shows very fine granophyric structure in places.

The phenocrysts of felspar are most remarkable in exhibiting a veritable "bearded" structure. The main crystals are strongly idiomorphic and apparently consist of anorthoclase and plagioclase. Rather unsatisfactory measurements indicate a normal andesine for the latter, which show complicated twinning after pericline, albite, Carlsbad, and Manebach laws.

While any of the porphyritic felspars may show the remarkable outgrowths above mentioned they are much more frequent and striking on the anorthoclase.

Along the direction of the brachy-diagonal the microlites are closely set and parallel to the crystal axis, but on other faces and on fracture they tend to arrange themselves in rosettes. In character they are similar to the microlites of the base except that none were noticed showing the forked structure described above. The extinction angle is 14° from the length of the fibres.

Biotite phenocrysts are not very abundant and are mostly associated with phenocrysts of felspar or included in masses of the latter. This rather suggests that some of the larger felspar crystals, together with these aggregates, may be included fragments of older rocks. The biotite shows light yellow to very dark reddish-brown pleochroic colours, and is crowded with apatite crystals and contains also a few minute zircons with pleochroic halos. Side by side with perfectly fresh crystals of biotite occur others of similar size and habit completely converted into bright green penninite.

433. DENSE PORPHYRITIC BASALT

Microscopic Characters.—The base is a very dense aggregate of minute brown needles of augite and tiny octahedra of magnetite with somewhat larger microlites of plagioclase whose composition is about Ab_3An_4.

The phenocrysts are chiefly purplish titaniferous augite whose size is about 0·56 mm. by 0·34 mm. These are slightly pleochroic, have an extinction angle on (010) of 41° from the cleavage, birefringence notably weak for an augite, and a wide optic axial angle.

Phenocrysts of labradorite up to 7·0 mm. by 2·5 mm. also occur. These have a composition about the same as those of the base and exhibit Carlsbad and albite twinning. One very noticeable feature is the great abundance in them of corrosion hollows or inclusions of brownish glass, a characteristic which appears to be common in rock types intermediate in mineral composition and texture between basalt and andesite.

Large crystals of olivine (1·7 mm. by 0·8 mm.) occur. The cleavage is very good for olivine, and the optic axial is almost 90°.

1278. Actinolite Gneiss (Plate II, Fig. 6)

Macroscopic Characters.—Medium-grained, strongly foliated rock, the colour bands of which are about 25 mm. wide. The lighter coloured bands consist of quartz and white felspar, the darker ones of these minerals together with an equal amount of light green actinolite in roughly prismatic grains.

Microscopic Characters.—The rock is porphyroblastic with a granoblastic ground fabric. Quartz is the most abundant constituent. In the large, complex grains and in the ground fabric also it shows considerable evidence of strain. The large grains are almost certainly secondary growths. There is a good deal of another colourless mineral whose refractive index is greater than that of the quartz; this is most likely untwinned plagioclase. An occasional grain shows exceedingly fine lamellar twinning through part of it. Still more colourless material has a refractive index less than that of quartz, and is probably orthoclase. There are occasional phenocrysts of andesine up to 2 mm. by 1 mm. Actinolite is in irregular patches up to 1 mm. by 0·5 mm. showing sieve-structure. On rotation it changes from faint green to colourless.

There is a little sagenite.

A good deal of colourless epidote is present in prisms and aggregates, generally associated with the actinolite.

440. Tremolite Gneiss (Plate II, Fig. 5)

Macroscopic Characters.—Grey schistose rock, medium grained, somewhat foliated. On fresh fractures the lustre is almost silky owing to the flashing cleavage faces of the very fine tremolite prisms in parallel orientation.

Microscopic Characters.—Granoblastic, with a decided tendency to lepidoblastic texture in places. Average grainsize 15 mm.

Untwinned and multiple-twinned felspar and tremolite are the most abundant constituents, though the amount of quartz is notable.

Felspars showing albite twinning give symmetrical extinctions up to 23°, indicating labradorite of the composition $Ab_{11}An_9$. These felspars are very slightly sericitised.

There is also a very little untwinned orthoclase. Tremolite is in well-defined rods which are almost colourless, and show, at most, a very faint brownish-grey tint when the vibrations are parallel to the axis of greatest absorption, namely, $\mathfrak{c}$.

Quartz is in irregular grains with well-marked undulose extinction due to strain. Small irregular grains of sphene and crystals of apatite and pyrites are rare.

1863. Actinolite Schist

Macroscopic Characters.—Very dense grey rock with decided tendency to cleavage. Transverse to the direction of parting a perfect conchoidal fracture is developed. An obscure banding can be noticed. No individual constituents can be recognised.

Microscopic Characters.—The banding noted in the hand-specimen is very distinct under the microscope. The more coarsely crystalline bands are extremely fine, and the finer ones are crypto-crystalline. The coarser bands have strongly parallel arrangement of the prismatic constituents. Most abundant and conspicuous are prisms of actinolite up to 0·2 mm. long and extremely slender. These, together with flakes of light brown mica and longish splinters of quartz, are embedded in a base of quartz and twinned and untwinned felspar, too fine for optical determination.

In the finer bands actinolite prisms of much larger size (0·8 mm. to 0·2 mm.) are sparsely distributed. In cross-sections of these prisms the trace of the (100) face is predominant and (010) is absent. Sometimes these larger prisms project from the finer into the coarser bands. In the latter the centres of crystallization of the amphibole are much more numerous, and there is a tendency for the formation of feathery aggregates.

It is possible that this rock is a somewhat altered lightish coloured lamprophyre of very fine grain. The *arrangement* of the larger actinolite crystals is a little suggestive of this; but, on the other hand, the *habit* of this mineral, the character of the mica, and the mode of occurrence of the quartz all point to a metamorphic origin. The rock is very similar to quite a number of others whose metamorphic origin is undoubted.

1869. Actinolite Schist

Macroscopic Characters.—Very dense and heavy dark-greenish rock, distinctly banded. Splits parallel with the plane of the bands, but in other directions has a conchoidal fracture. No individual constituents visible.

Microscopic Characters.—Generally similar to No. 1863, but not so distinctly foliated. It consists essentially of actinolite, quartz, and brownish mica, but contains less quartz than the rock just described. The lepidoblastic ground fabric consists almost entirely of actinolite prisms with a little interstitial quartz.

There are a few small porphyroblasts of a colourless prismatic mineral with its long axes lying across the schistosity. This may be cyanite; it gives extinction angles up to about 30° from its length, and in optical character, optical sign, optic axial angle, and double refraction, answers to that mineral. The refractive index appears to be somewhat low.

1855. Actinolite Schist

Macroscopic Characters.—An extremely fine-grained black rock, finely banded, some of the bands being strongly pyritic.

Microscopic Characters.—The rock is distinctly banded, the alterations in colour being due to differences in the character of the actinolite in the different bands. The fabric is distinctly lepidoblastic on the whole, the essential constituents being actinolite and colourless base with minor amounts of magnetite, calcite, and greenish mica. In the dark bands the actinolite is very abundant, quite dark green and strongly pleochroic:

$\mathfrak{a}$ colourless; $\mathfrak{b}$ and $\mathfrak{c}$ dark green.

In the lighter bands the actinolite appears at first sight to be granular, but between crossed nicols it is shown to be optically continuous over areas of several square millimetres, so that the structure is poikiloblastic, approaching diablastic.

The colourless interstitial material is certainly complex; the greater part appears to be quartz, but quite a considerable amount of it has a refractive index decidedly greater than that of quartz and is probably untwinned basic felspar.

There are occasional flakes of colourless material answering to brucite.

265. FINE TREMOLITE-SCHIST

Microscopic Characters.—A very fine-grained and distinctly banded lepidoblastic rock.

It consists essentially of quartz, scaly muscovite, and prismatic tremolite, with slightly larger flakes of greenish clinochlor. Some of the bands are nematoblastic on account of the aggregation of the tremolite prisms.

There are also present minute ovoid grains of a mineral, greenish to colourless with a very high refractive index and strong double refraction, which, however, does not seem to be epidote.

P. 239. SPOTTED SCHIST

Microscopic Characters.—In section the spots are quite distinct: they appear to contain the same colourless constituents as the remainder of the rock without any of the biotite which occurs in the granulitic ground fabric.

The grainsize of the rock is very fine, which makes it very difficult to distinguish the constituents.

The colourless mineral appears to be almost all quartz. The spotted appearance is strikingly suggestive of development of incipient andalusite crystals, but no distinct evidence of this mineral could be observed. There is a little magnetite present mostly in the ground fabric, but occasionally in the spots as well.

602. PHYLLITE

Macroscopic Characters.—Chocolate-coloured rock, with well-developed slaty cleavage. On the cleavage surfaces the lustre is satiny.

Microscopic Characters.—The rock consists of angular quartz fragments, many of them showing strain effects, cemented by a fine sericitic mortar, which is stained with limonite.

464 (P. 89). QUARTZ SCHIST

Macroscopic Characters.—A cherty-looking rock, of light yellowish-grey colour and very close texture. The lustre is sub-resinous and fracture sub-conchoidal. The rock is distinctly banded and its general appearance is extremely suggestive of a limestone metasomatically replaced by silica.

Microscopic Characters.—The rock is lepidoblastic, with a fine-grained ground fabric (average grainsize about 0·1 mm.) containing "auge" of quartz up to 2 mm. by 1 mm. The ground fabric consists of finely granular quartz and flaky sericite with a very little epidote. The constituents show a slight tendency to segregate into folia. There is a very peculiar arrangement of the ground fabric with two axes of schistosity, making an angle of 40° with one another, so that, between crossed nicols, when both sets of mica plates are illuminated, there is a decided meshwork. Here and there the sericite is segregated into moderately large patches.

There are sporadic areas where epidote is fairly abundant in minute crystals with rather dark colour.

The "auge" consist mostly of quartz without strain structure and probably recrystallised. The long axes of these "auge" lie parallel to one of the axes of schistosity above mentioned.

Amongst the quartz there occur large grains and crystals of pyrites *in lamellar intergrowth with magnetite.* Also large flakes of phlogopite generally associated with these composite grains.

There are a few rather conspicuous aggregates of secondary sphene and some larger flakes of calcite.

450. MICACEOUS SANDSTONE

Microscopical Characters.—Consists of angular and subangular grains and flakes of quartz, and also of cherty material with a micaceous cement. There is a well-marked stratification of the constituents. In addition to its presence as a fine-textured scaly cement there are large flakes of mica, both muscovite and biotite. A little ilmenite occurs also. Some of the quartz grains show signs of strain.

PLATES

EXPLANATION OF THE PLATES

PLATE I

Figure 1.—Microphotograph of rock 438 × 11 diameters (about).

Figure 2.—Microphotograph of rock E. 36 × 19 diameters. The colourless holocrystalline base consists of acid felspar intergrown with sodalite. The small, sharply defined, dark prisms are wöhlerite, bright orange in colour.

Figure 3.—The same × 55 diameters. Owing to the non-actinic colour of the larger wöhlerite crystals they have photographed black. The difference in refractive index between the felspar and sodalite is indicated by the " Becke's effect."

Figure 4.—Microphotograph of rock 443 × 11 diameters. The photograph contains more than the normal proportion of biotite.

Figure 5.—Microphotograph of rock 372 × 18 diameters. The dark prisms are hornblende.

Figure 6.—Microphotograph of rock 7 × 55 diameters, showing the fine-grained panidiomorphic mixture of hornblende, biotite, and felspar.

PLATE II

Figure 1.—Microphotograph of rock E. 11 × 19 diameters, showing the general aspect of the rock with strongly corroded hornblende and corundum grains.

Figure 2.—The same × 55 diameters, showing sharply idiomorphic phenocrysts of anorthoclase.

Figure 3.—Microphotograph of rock 452 × 11 diameters.

Figure 4.—The same × 62 diameters, showing the character of the composite hornblende crystals.

Figure 5.—Microphotograph of rock 440 × 31 diameters, showing well-defined tremolite.

Figure 6.—Microphotograph of rock 1278 × 55 diameters.

PLATE I

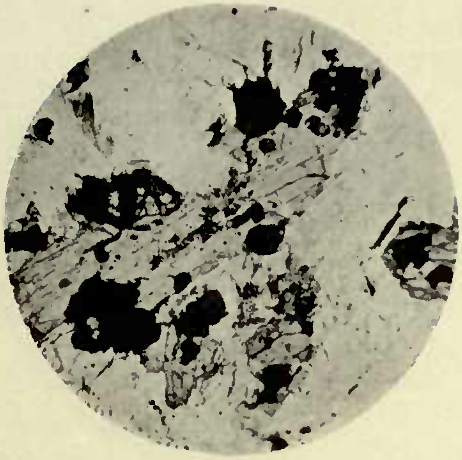


Fig. 1

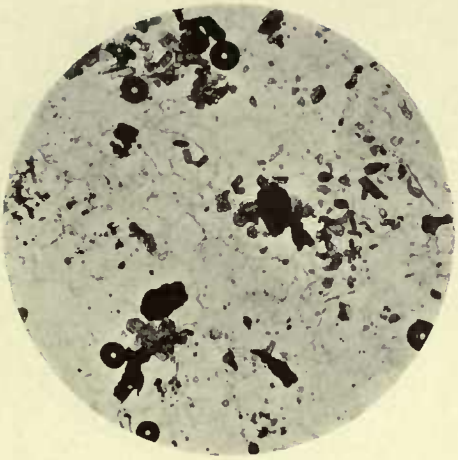


Fig. 2

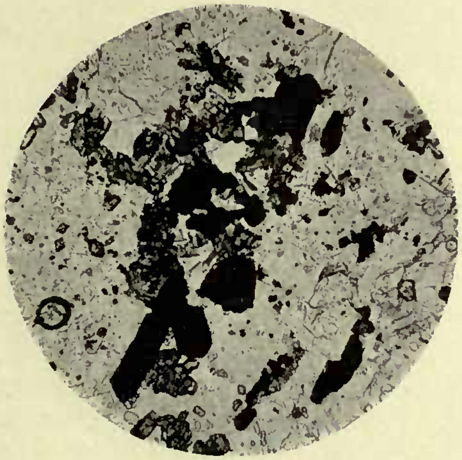


Fig. 3

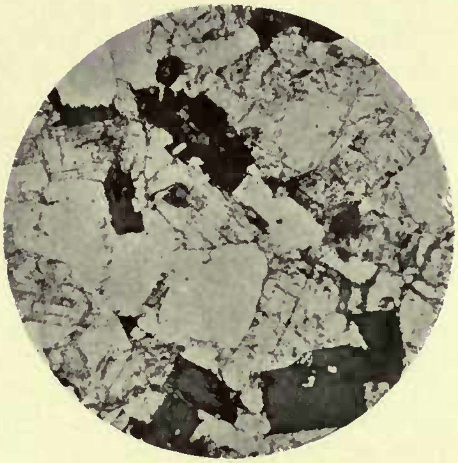


Fig. 4

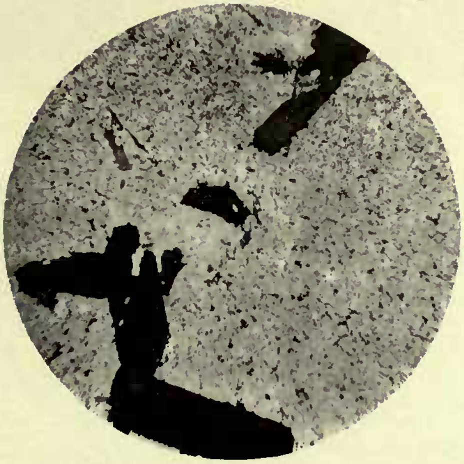


Fig. 5

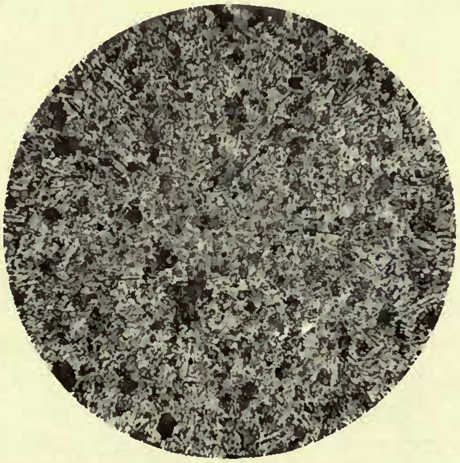


Fig. 6

[*To face p.* 188

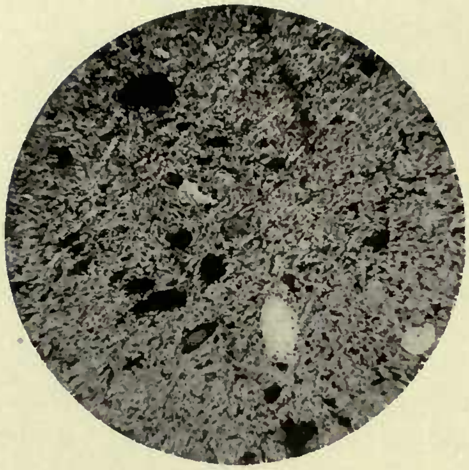


FIG. 1

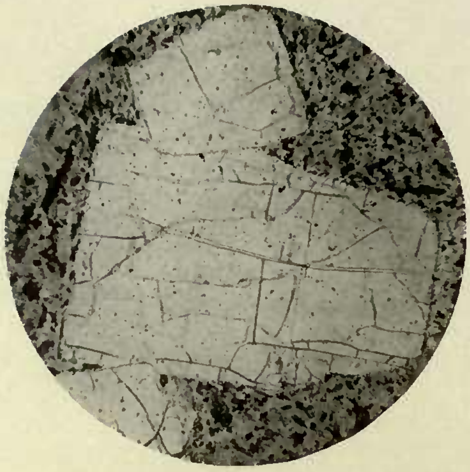


FIG. 2

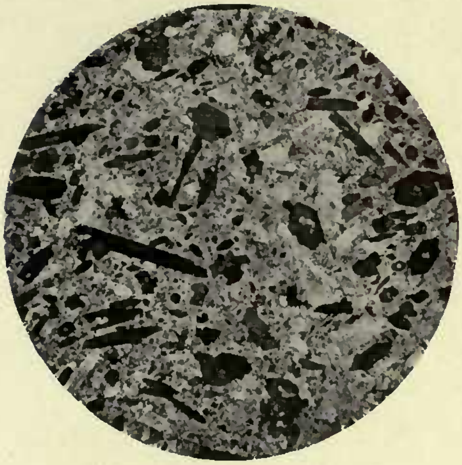


FIG. 3

FIG. 4

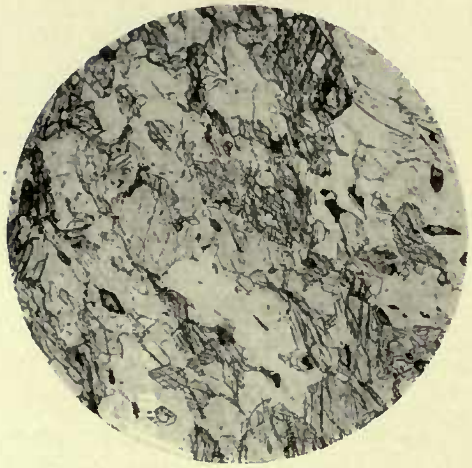


FIG. 5

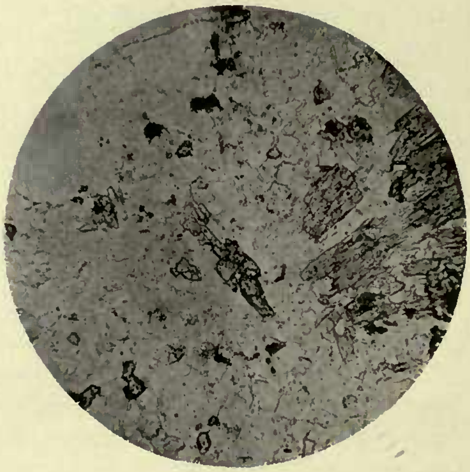


FIG. 6

PART XII

REPORT ON THE PETROLOGY OF SOME LIMESTONES FROM THE ANTARCTIC

(*With Two Plates*)

BY

ERNEST W. SKEATS, D.Sc., A.R.C.S., F.G.S.

Professor of Geology in the University of Melbourne

INTRODUCTION

About forty sections and eight hand-specimens of limestones were submitted to me for examination by Mr. R. E. Priestley and Professor David. They represent marine shallow-water limestones, some, possibly all, of Cambrian age, and contain *Archæocyathinæ*, sponge spicules of colloid silica, etc. Many of the limestones have been subjected to earth movements and veined with calcite and they present interesting examples of metasomatic change, showing all stages of dolomitisation and silicification. Staining with Lemberg's solution and the attack with hydrofluoric acid were found useful in investigating these two changes respectively.

Examples of regional dolomitisation were noticed, indicating a shallow-water origin for the limestone. This was confirmed by the presence of detrital fragments of quartz, olivine, etc., in some of the rocks, and by the fact that some of the limestones were oolitic. The oolitic grains show good concentric structures, possibly due to organic tubules; many are dolomitised and silicified, and these show radial structures in addition to the concentric. Some of these superficially resemble radiolaria but are believed to be of inorganic origin. A comparison with dolomitised oolites from the Transvaal has been made. Two limestones, *in situ*, from Farthest South were examined. They contain *Archæocyathinæ*, and one of them a greenish material. A chemical analysis of this rock has been made, and an estimate of the composition of the green material, which may be a submarine tuff of an intermediate alkali rock, or may be, since it contains a colourless micaceous mineral, detrital material.

DETAILED DESCRIPTIONS OF THE LIMESTONES

No. 8. *Limestone Breccia.* Cloudmaker, October 12, 1908. (P. 79.) (*Erratic*)

The rock is a limestone breccia. Large fragments of a fairly dense limestone, containing no dolomite and traversed in places by secondary calcite veins, form the bulk of the rock. The rest consists of an iron-stained brecciated area, in which angular pieces of quartz and elongated fragments of muscovite are set in a groundmass of calcite. In some fragments micro-crystalline chalcedonic silica partly replaces calcite. Some calcite veins appear to fill cracks opened since the breccia was formed, since they pass through not only the matrix of the rock but also across the angular quartz fragments.

No. 12. *Dolomitic Limestone.* Cloudmaker. (*Erratic*)

Two sections of this rock have been stained with Lemberg's solution. The rock is fine-grained, with minute fragments of limestone in a calcareous matrix. Scattered through the rock are unstained areas of dolomite, mostly irregularly distributed, but in places following lines of fracture. A few calcite veins also traverse the rock. The rock therefore is a minutely fragmental dolomitic limestone.

No. 3. *Limestone Breccia.* Lower Glacier Depot, Beardmore Glacier, October 12, 1908. (*Erratic*)

About twenty rock sections have been examined, mostly slices from one specimen. The general characters are seen in the figure (Plate I, Fig. 1). The rock is strictly a dolomitic breccia, and is interesting from its fossil content, structure, metasomatic change, and origin.

Structure.—The rock is mainly composed of angular to rounded fragments of a limestone which was completely dolomitised before being broken up. In some sections, however, pieces of a calcareous and micaceous sandstone are seen (206, 207, 212), detrital fragments of chert (206, 207), dark cherty shale (212), or silicified oolite limestone (209). Angular fragments of quartz resembling vein quartz are sometimes abundant in the breccia; while sometimes elastic fragments of dolomite contain water-worn fragments of quartz (212), or even other calcareous fragments (206). Cracks in the original dolomitised and silicified limestone have been filled with calcite before the rock was broken up and water-worn. Subsequently the fragments have been cemented with calcite, the cemented breccia again cracked, and the cracks once again filled with calcite.

Fossil content.—Several of the sections show traces of organisms. *Archæocyathinæ* have been recognised, I believe, in some; but those which I have examined have been so metasomatised that only the dark rims or "ghosts" of the organisms now persist.

Metasomatism.—The water-worn pebbles of limestone in the breccia show that their earlier history includes two types of metasomatic change involving the formation of dolomite and of a silicified rock.

Dolomitisation.—Several of the rock sections have been stained with Lemberg's solution so that the dolomite and calcite could be precisely determined. The staining has shown that the matrix of the breccia and the vein fillings, both those formed before the pebbles and those of subsequent date, consist entirely of calcite. The calcareous pebbles, with one doubtful exception, consist entirely of dolomite. The dolomite is frequently cloudy, with central dark areas, and consists of interlocking allotriomorphic crystals. Lining what were cavities in the rock are well-shaped rhombohedra, some of which are zoned with altered chalybite, and occasionally with calcite (3). From the fact that all the calcareous pebbles consist entirely of dolomite, one may draw the conclusion that they have been derived from a limestone which had not been merely locally dolomitised along cracks by later infiltrations of magnesian waters, but had suffered complete regional submarine dolomitisation during the formation of the limestone.

This observation is of special interest, as it indicates that the limestone was formed in shallow water, a conclusion we are entitled to draw owing to the evidence of the mode of occurrence of dolomite among ancient and modern coral limestones, as recorded by Dr. Cullis and by the author, among others.* The shallow-water origin

---

* Cullis, *Funafuti Report*, 1904. Skeats, *Bull. Mus. Comp. Zool. Harvard*, vol. xiii, 1903, p. 125. *Q.J.G.S.*, vol. lxi, 1905, pp. 133–137.

of the rock is also confirmed by the presence of detrital quartz fragments in some of the dolomite pebbles (212), and by the fact that some of the pebbles show well-defined oolitic structure (209), which, whether of organic or inorganic origin, is confined to limestones of shallow-water origin.

Silicification.—Some of the dolomite pebbles and fragments have also been silicified. The introduction of silica followed and did not precede dolomitisation. This is clear from a study of the mode of occurrence of the silicified areas. These are frequently irregular patches, appearing sometimes to fill up cavities in the rock which had been lined by perfectly shaped rhombs of dolomite. In one section of the dolomite breccia a fragment of a silicified and dolomitised oolitic limestone (209) occurs. Replacement of the dolomitised oolitic grains and of the matrix by chalcedonic silica is almost complete. A few rhombs of dolomite remain; the outlines of the oolitic grains are ill defined, and later cracks through the pebble, formed since it reached its present position, have been filled with calcite.

History.—A study of this dolomite breccia and its components suggests the existence in the area whence the fragments were derived of a pre-Cambrian series of igneous rocks, acid, and probably also basic and also of micaceous and calcareous sandstones. The Cambrian sea received fragments of these rocks along the shore-line while the shallow-water *Archæocyathinæ* limestones were being laid down. Dolomitisation and silicification of the limestones occurred, and at a later stage they were elevated, disintegrated, seamed with veins of calcite and subsequently denuded. They then provided the materials for a dolomitic breccia which, after consolidation by a calcite matrix, was traversed by differential movements, forming cracks which were again filled with calcite.

THE OOLITIC LIMESTONES

The presence of silicified oolite pebbles has already been noted in the description of the dolomite breccia. Further evidence is obtained from erratics at two localities at Cloudmaker, on the Beardmore Glacier, and also from among the erratics of Cape Royds.

No. 20. *Oolitic Limestone.* Cloudmaker, Beardmore Glacier. (*Erratic*)

Three sections of this rock were examined, of which two were stained with Lemberg's solution. Its appearance is shown in Plate I, Fig. 2. The rock shows the very well-preserved oolitic or pisolitic structure, the grains being of large size, ranging up to 4 mm., or about $\frac{1}{6}$th inch in diameter. The majority of them are spherical in shape, but some are elongated, and others have been fractured. One or two examples of double oolitic grains were seen. The central part of the grain appears usually to have been recrystallised, and consists now of large interlocking crystals, mostly of calcite. No radial structure is noticeable, but the concentric layers are well preserved. The layers appear to consist of minute tubes which are occasionally not arranged concentrically, and this would appear to support the view that these large oolitic or pisolitic grains are of organic origin. The matrix of the rock, like the centre of the grains, has been recrystallised to a calcite mosaic. The rock also shows partial dolomitisation. Much of the dolomite appears to be sporadic in occurrence, but some crystals are definitely placed along cracks in the rock.

Except along cracks, the general matrix of the rock has not been dolomitised. The oolitic grains, particularly their central parts, are noticeably dolomitised, the salient angles of the rhombs in places advancing into the marginal part, which shows the concentric structure. All stages in the replacement of the oolitic grains can be seen. In a few cases the whole of the grain, periphery as well as nucleus, has been completely converted into dolomite.

These areas show up well by their freedom from stain after treatment of the rock with Lemberg's solution. In places, however, these large crystals of dolomite include minute areas of unaltered calcite, as is shown by the slight difference in refractive index and by the staining of such areas.

Silicified Oolitic Limestone. Cape Royds. (*Erratic*)

Nine sections labelled as above have been examined; seven of these have been sliced from the same specimen, and two, numbered P. 86, have different characters.

P. 86.—The two sections examined consist entirely of chalcedonic silica and dolomite rhombs. The dolomite rhombs are arranged as minute irregular rings, the long ones ranging from about $\frac{1}{15}$ to $\frac{1}{5}$ mm. The central parts of the rings and the matrix between them consist of chalcedonic silica. There can be no doubt that the rock was originally calcareous, and afterwards at any rate partially dolomitised. Possibly parts which remained as calcite were then dissolved away, and secondary chalcedonic silica filled the spaces so left. A few calcareous centres to the rings of dolomite are to be seen, but the remainder of the ring-centres in ordinary light show a colourless and structureless infilling of silica. The origin of these ring-shaped areas is doubtful. They may represent remains of oolite grains distorted in shape after the removal by solution of the central areas, but they are of much smaller dimensions than the undoubted oolites, and no positive opinion can be expressed.

The remaining seven sections (Nos. 222, 233, 240, 244, 245, and two unnumbered ones) all show fairly uniform characters, which are seen in Plate I, Figs. 3 and 4.

General characters.—They are all dolomitised and silicified oolitic limestones. The average diameter of the grains is about $\frac{1}{2}$ mm., while that of the grains from Cloudmaker is, as previously noted, about 4 mm.

A few irregular, structureless pellets occur, some of which consist of dolomite, others are partially or wholly silicified. A few composite oolitic grains occur, but the large majority are simple, and nearly spherical in shape. In these silicified rocks a few of the oolite grains show the concentric structure only, the great majority having a central nucleus, an outer margin showing concentric structure, and a middle layer with a well-pronounced radial structure.

Comparison with radiolaria.—So closely do these latter oolitic grains resemble radiolaria on first inspection that I have paid particular attention to them and instituted careful comparisons with recent and fossil radiolaria. I have been led to abandon the idea that they might be radiolaria for the following reasons:

(1) *Size.*—The average diameter is about 5 mm., while the diameters of most of the recent and fossil radiolaria I have measured ranged between ·08 and ·3 mm.

(2) *Structure.*—(*a*) There is no trace of the reticulated or mesh structure as seen in the skeletons of radiolaria.

(*b*) Instead of a uniform series of concentric layers at fairly wide intervals, as is usual in many radiolaria, these grains show commonly several closely adherent layers round the outer margin of the grains—a feature characterising undoubted oolitic grains.

(*c*) The radial appearance seen is probably due to crystallisation and not to organic structure, for in the case of the composite grains not only is it seen in the individual grains but it occurs also in the outer part of the composite grain.

(3) *Composition.*—There can be little doubt that the original composition of the

rock, both matrix and grains, was calcareous, and that subsequently dolomitisation and afterwards silicification occurred. In accordance with this, it is found that in places the matrix remains as dolomite, some of the indifferentiated pellets persist as dolomite, some of the oolitic grains are also entirely preserved in dolomite, and where the grains have been silicified the concentric and radial structures are usually defined by minute rhombohedra of dolomite. On the view that the radial structures were the skeletons of radiolaria, one would have to assume that the siliceous network was first replaced by dolomite, and that later extensive silicification of the rock replaced most of the matrix and filled the spaces between the radial and concentric structures. There is no warrant for this view, and all the evidence points to the original composition being calcareous.

Staining and acid attack.—Two of the sections were stained with Lemberg's solution with negative results, demonstrating that the minute rhombohedra are dolomite and not calcite. In the case of one section, where the rock had been silicified to a varying extent in different parts, it was found that the structure of the oolitic grains was only faintly visible in some cases, as all the dolomite rhombs had been replaced by chalcedonic cryptocrystalline silica. One half of this section was then attacked by hydrofluoric acid, with the result that the radial and concentric structures of the silicified grains were rendered more clearly visible owing to a differential attack of the acid. The chalcedonic silica of the matrix was also unequally attacked, bringing out a banded agate structure, which was previously not noticed (*see* Plate II, Fig. 1). Possibly the calcareous matrix surrounding the grains had been dissolved out, and later the silica was deposited in concentric layers round the grains.

Structure and metasomatism in the oolitic grains.—From the above it will be clear that in the oolitic rocks which have remained calcareous only the concentric structure was seen, while both concentric and radial structures occur in each section of the silicified rocks. The following statement defines the types of structure and the probable order of metasomatic change in the oolitic limestones. The types are separated for clearness of statement, but many of them occur together in the same section, showing that in the same rock metasomatic changes affected separate grains in different degree.

PURELY CALCAREOUS TYPES

(1) Oolitic limestones composed entirely of calcite, the oolitic grains showing concentric structure only. The matrix consists of coarse interlocking crystals of calcite. Example: Cloudmaker, Beardmore Glacier, No. 20.

(2) *Dolomitised oolite.*

(*a*) *Partially dolomitised.* Generally the nucleus is alone dolomitised. Concentric structure shown. (No. 20.)

(*b*) *Completely dolomitised.* All structure destroyed. (No. 20.)

SILICIFIED TYPES

In these rocks both matrix and grains have been silicified in varying degree.

The matrix.—The matrix occasionally retains some dolomite, but for the most part it is siliceous, and ranges from cryptocrystalline chalcedonic silica to a definite quartz mosaic. Attack with hydrofluoric acid, as noted above, develops a banded agate structure in the matrix. It is noted that when both matrix and oolitic grains are silicified the silica of the grains is usually cryptocrystalline and finer in texture than that of the surrounding matrix.

(3) *The oolitic grains.*

Completely dolomitised oolite, but showing both radial and concentric structures.

(4) *Dolomitised and silicified oolitic grains.*
  (*a*) With both concentric and radial structures.
  (*b*) With only concentric structure.
  (*c*) With central structureless silicified part and outer ring of dolomite.

(5) *Silicified oolitic grains in which all dolomite has been replaced by silica.*
  (*a*) With concentric and radial structure.
  (*b*) With concentric structure alone.
  (*c*) Spherical in shape, but structureless.

A rather interesting resemblance is noticeable between these silicified oolitic limestones and certain siliceous and dolomitic oolites occurring among the probably pre-Cambrian dolomites of the Transvaal. Two sections from Krugersdorp, in my possession, show oolitic grains with concentric and radial structures preserved in dolomite more or less completely replaced by chalcedonic silica. The matrix of the rocks is also partly siliceous, partly calcareous.

P. 282. Stranded Moraine, East Fork, Ferrar Glacier. (*Erratic*)

A very fine-grained dense limestone, whether dolomite or calcite cannot be determined, as opportunity for staining was wanting. The interest of this rock depends upon the presence of volcanic fragments and minerals and of fossils (Plate II, Fig. 2). The volcanic material consists of angular, brown, iron-stained fragments and of crystals of biotite. A little quartz is also present as minute fragments. This material may be of detrital origin, but it is suggestive of the intermixture of particles of a submarine tuff in a marine limestone. The fossils noticed are several broken pieces of sponge-spicules. The fragments are each in length about two or three times the diameter of the spicule. In each case the central canal is clearly preserved, and the silica remains in its original colloidal form. A comparison with some sponge-spicules of Tertiary age shows a similar freshness, comparable dimensions, and in each case a refractive index lower than that of Canada balsam. These fragments do not present characters definite enough for identification, and so yield no direct information as to the age of the limestone. As remains of *Archæocyathinæ* are believed to occur in some of the Antarctic limestones, the question arises whether these spicules may be of Cambrian age. In general form, dimensions, and the relation of diameter of the canal to that of the whole spicule they are similar to some sponge-spicules I found in cherty rocks of the Heathcotian series in Victoria (L. Ordovician or U. Cambrian ?). Dr. Hinde kindly examined these for me and confirmed their identification as sponge-spicules, but could not name them. These Heathcotian spicules are recrystallised to chalcedonic silica. While, then, the preservation of the colloidal character of the spicules in the Antarctic rock suggests that the rock has no great geological antiquity, there is nothing in their form and structure to negative the idea of a Cambrian age for the rock if that is indicated by other evidence.

No. 15. Cloudmaker, Beardmore Glacier, December 10, 1908. (*Erratic*)

A limestone which has been extensively shattered and recrystallised. In consequence the rock now consists mainly of large interlocking, frequently twinned, and cloudy crystals of calcite. Staining with Lemberg's solution shows that along the structural cracks in the rock magnesian solutions have entered, with the production of crystals of dolomite more or less confined to the fractured areas. Still later cracks have been healed by the deposition of clear twinned crystals of calcite.

P. 301. *Marble.* Stranded Moraine. (*Erratic*)

The rock is a recrystallised limestone. It consists now mainly of large, interlocking, twinned crystals of calcite, one or two pieces of quartz, some opaque fragments of graphite and of pyrite altering to limonite, and a number of small colourless crystals of talc. The talc is recognised by having a fairly low refractive index, high polarisation colours in prismatic sections, by giving a pseudo-uniaxial and negative interference figure, and by its micaceous habit. The talc may have been developed in the rock during recrystallisation, and may be the product of dedolomitisation of a slightly siliceous and magnesian limestone. The quartz and opaque material, however, appear to be detrital, and the talc may have a similar mode of origin.

P. 305. Dry Valley, Antarctic. (*Erratic*)

A carbonate forms the bulk of this rock. The section was mounted unstained, so it remains uncertain whether the mineral is calcite or dolomite; probably it is the former. Several detrital grains of olivine, more or less altered to serpentine, are scattered through the rock. Minute crystals of pyrite are also present. Reddish-yellow ferric hydroxide occurs in irregular areas or surrounding opaque masses of some iron mineral. Irregular patches of graphite are noticeable in places. In addition there are scattered through the rock a number of irregular-shaped sections of a colourless mineral with a refractive index a little higher than that of Canada balsam. The majority of the sections show no cleavage and low polarisation colours; while the sections showing cleavage exhibit bright colours. In convergent light pseudo-uniaxial or slightly biaxial figures are seen. The sign is negative. The mineral is therefore almost certainly talc. The olivine in the rock is certainly of detrital origin, and its presence indicates that the limestone formed near a shore-line consisting in part of basic igneous rocks. The talc may be detrital, but from its irregular boundaries with the limestone may have developed in the rock by the alteration of a magnesian mineral. The rock is a limestone of shallow-water origin.

K1. Dunlop Island; between Cape Bernacchi and Granite Harbour. (*Erratic*)

This is a very fine-grained rock, consisting of minute allotriomorphic granules of a single material, which is probably dolomite.

P. 268. Dunlop Island. (*Erratic*)

This section is exactly similar to K1 described above.

No. 4. *Detrital Rock.* Cloudmaker, December 10, 1908. (*Erratic*)

This rock is not a limestone, but an altered detrital rock. The hand-specimen is very hard and compact. Under the microscope irregular minute yellow-brown specks of hydrated oxide of iron are distributed through the rock, and a few irregular grains with fairly high refractive index and bright polarisation colours consist probably of a pyroxene.

The bulk of the rock is a colourless groundmass which in polarised light consists of a cryptocrystalline to microcrystalline arrangement of crystals polarising in neutral tints. Some are rectangular in outline, and may be felspar; the majority are irregular in shape, and consist probably of chalcedonic silica. The rock presents considerable resemblance to a fine-grained spilosite, but may be a dense ferruginous chert.

LIMESTONES IN SITU FROM FARTHEST SOUTH

Two specimens brought back from Farthest South owe their importance to their geographical position, to the fact that they were taken from rocks *in situ*, and to the fact that the discovery in them of *Archæocyathinæ* fixes their age as Lower Cambrian.

No. 106. Farthest South.* December 20, 1908. (*In situ*)

Six sections of this rock have been examined, five mounted in the ordinary way, the sixth after staining with Lemberg's solution. The hand-specimen is a grey, dense limestone, with a few lighter calcite veins and specks of pyrite scattered through it.

Under the microscope staining shows that the rock consists chiefly of calcite, with a subordinate development of dolomite. For the most part the dolomite is developed in sporadic crystals throughout the rock. In places, however, it occurs along cracks, and at one point a large number of well-developed rhombohedra are grouped together with a calcite background. The rhombohedra of dolomite have cloudy centres and clear margins. This cloudy material is for the most part dolomite, since it is unstained; but in two cases the kernel of the crystal consists of calcite and the margin of clear dolomite in optical continuity with the calcite. The rock is slightly mineralised, as cubes of pyrite are sparsely scattered through it. There are faint indications of the former presence of organisms, and structurally the rock has been subjected to considerable earth movements. Some of the cracks lined with dark material or with dolomite crystals show a very tortuous passage through the rock, indicating later squeezing. The latest movements induced straighter cracks, now filled with clearer, larger crystals of calcite than in the matrix, which consists of somewhat cloudy allotriomorphic calcite crystals.

No. 107. Farthest South, December 20, 1908. (*In situ*)

The hand-specimen is a dense, fine-grained rock with irregular streaks of a green material distributed through it.

Two sections have been examined, of which one was stained with Lemberg's solution (Plate II, Figs. 3 and 4). No dolomite can be recognised, the whole of the background of the rock consisting of minute greyish granules of calcite, except for a few micaceous particles. Obscure traces of fossils, including *Archæocyathinæ*, can be seen. A point of considerable interest is the nature and origin of the material, which has a greenish appearance in the hand-specimen. Under the microscope it is very fine-grained, and is barely resolved under a $\frac{1}{6}$-inch objective.

Chemical composition.—With the idea that a chemical analysis would help in the elucidation of this question, I asked Mr. F. L. Stillwell, B.Sc., Kernot Research Scholar in Geology in the University of Melbourne, to undertake this for me. I am much indebted to Mr. Stillwell for the care and time he has given to this work. He

---

* This refers to the "farthest south" outcrop of rock in this vicinity; not the farthest south point reached by the party.

took several grammes of the rock, ground it very fine, and took one gramme from this powder for a bulk analysis. The result is as follows:

SiO_2	= 22·19
Al_2O_3	= 6·05
Fe_2O_3	= 1·30
FeO	= 1·55
TiO_2	= 0·55
CaO	= 34·44
MgO	= 1·98
K_2O	= 2·51
Na_2O	= 1·96
CO_2	= 26·55
H_2O − (below 110°)	= ·46
H_2O +	= ·92
	100·46

An attempt was made to determine the composition of the green material by dissolving the carbonates in dilute hydrochloric acid (1 in 6) and analysing the insoluble residue. It was found, however, that the acid had attacked a part of the green material, since 2 per cent. of SiO_2 and 3 per cent. of Al_2O_3 occurred in the soluble portion, and this attempt was abandoned. The composition of the green material was eventually arrived at by alloting all the CO_2 to the lime and magnesia in the analysis and expressing the result as carbonates of lime and magnesia. For this purpose the assumption was made that the carbonates are present in the rock in the same proportions as the oxides in the analysis. In this way the carbonates were determined as follows:

$CaCO_3$	56·82
$MgCO_3$	2·98
	59·80

After satisfying the carbon dioxide with lime and magnesia an excess of 2·62 per cent. of the former and ·56 of the latter remained, which was allotted to the remainder of the rock. This has the composition shown in Column I. Calculated to 100 per cent. it is shown in Column II.

	I	II
SiO_2	22·19	54·55
Al_2O_3	6·05	14·85
Fe_2O_3	1·30	3·20
FeO	1·55	3·81
TiO_2	·55	1·35
CaO	2·62	6·44
MgO	·56	1·38
K_2O	2·51	6·17
Na_2O	1·96	4·82
H_2O −	·46	1·13
H_2O +	·92	2·26
	40·67	99·96

Microscopic characters of the green material.—Examination under a one-inch objective showed the green material to be composite in character, and to be distributed in streaks which passed through the rock in an irregular way. A thick band tails out in a short distance to a thin filament or branches into a number of threads traversing the limestone. It is difficult to decide whether this is an original arrangement due to irregularity in deposition or whether the irregularity has been subsequently induced by pressure. Under a $\frac{1}{6}$-inch objective the most prominent mineral is a colourless to pale greenish micaceous mineral, showing sometimes fairly bright polarisation colours. A good deal of the greenish area, however, shows low polarisation colours in the first order, and in places minute felspar crystals appear to be present. In addition minute brownish specks represent oxide of iron, possibly an alteration product of a ferro-magnesian mineral, and some rather highly refracting fragments appear to be isotropic.

Nature and origin of the green material.—Two alternatives present themselves as to the nature of this material. It may be very fine-grained detrital material washed out from a shore-line and deposited with mica among the calcareous matter of the limestone. On this view its irregular distribution through the rock would be accounted for by the subsequent irregular squeezing of the limestone during earth movements.

On the other hand, it may be a submarine tuff. On this view its peculiarities of distribution might be to some extent original and connected with explosive discharge and irregular settling from a neighbouring vent.

If the material consists of tuff fragments its chemical composition should help to place it.

In the American classification the norm calculated from its chemical composition is as follows:

Orthoclase	36·70
Albite	24·63
Anorthite	·83
Nephelite	8·80
Diopside	11·53
Wollastonite	7·08
Magnetite	4·64
Ilmenite	2·58

Its position in the classification is:

Class II., Dosalane.
Order V., Germanare.
Rang I., Peralkalic-Umptekase.
Subrang III., Sodi-potassic Ilmenose.

This is a subrang including a few rocks such as representatives of the porphyrites, kersantites, and rather basic alkali trachytes. The analysis of a porphyrite from Thuringia comes closest to it.

In determining the probable nature of the green material we have, then, the choice between a tuff from a rather alkali intermediate rock such as a porphyrite or somewhat basic trachyte on the one hand and fine-grained micaceous detrital material on the other. The available evidence is not sufficient to enable a positive choice to be made, but the presence of a considerable amount of the colourless micaceous mineral suggests that the detrital view of its origin may be the correct one.

EXPLANATION OF THE PLATES

PLATE I

Figure 1.—No. 3. × 5. *Dolomitic breccia* with *Archæocyathinæ*, Beardmore Glacier.

Rounded and angular fragments of dolomitised limestone with angular and crushed quartz fragments are set in a matrix of calcite. Later veins of calcite traverse the larger fragments and the matrix.

Figure 2.—No. 20. × 12. *Dolomitic oolitic limestone.*

Several grains show good concentric structure, one grain in the centre of the field is largely replaced by dolomite and three defined rhombohedra of dolomite have invaded the concentric layers of a grain near the upper part of the field. The matrix is chiefly clear calcite.

Figure 3.—No. 245. × 12. *Silicified oolite* from erratic at Cape Royds.

The grains show both concentric and radial structures. One composite grain is seen near the lower part of the field. The substance of the grains is chiefly dolomite with partial replacement by metasomatic silica. The groundmass is partly dolomite but sporadic clear areas of chalcedonic silica indicate partial metasomatic replacement.

Figure 4.—No. 240. × 28. *Silicified oolite* from erratic at Cape Royds.

A good example of a dolomitised grain showing radial structure, another concentric and a third composite are seen. An irregular pellet, dolomitised and silicified, has its boundary defined by a dark layer. The matrix is now mainly chalcedonic silica.

PLATE II

Figure 1.—No. X. × 28. *Silicified oolite* from erratic at Cape Royds.

Several stages in the silicification of dolomitised oolitic grains are seen. The original matrix has been mainly replaced by chalcedonic silica. Attack by hydrofluoric acid has affected the silica unequally and has developed an agate structure between the individual grains.

Figure 2.—P. 282. × 277. *Limestone* from Stranded Moraine, East Fork, Ferrar Glacier.

A fine-grained limestone with two or three fragments of sponge spicules. One spicular fragment showing the central canal is seen above the centre of the field.

FIGURE 3.—No. 107. × 29. *Limestone,* Farthest South, December 20, 1908. (*In situ.*)

A non-dolomitised limestone with irregular bands of insoluble material including a pale greenish micaceous mineral. These bands may be detrital in origin or may be pyroclastic.

FIGURE 4.—No. 107. × 83. *Limestone,* Farthest South, December 20, 1908. (*In situ.*)

The same as Figure 3, but more highly magnified and showing better the nature and arrangement of the band of greenish insoluble material.

All the negatives were taken by Mr. H. J. Grayson, and in ordinary light.

No. 3. × 5 diams.

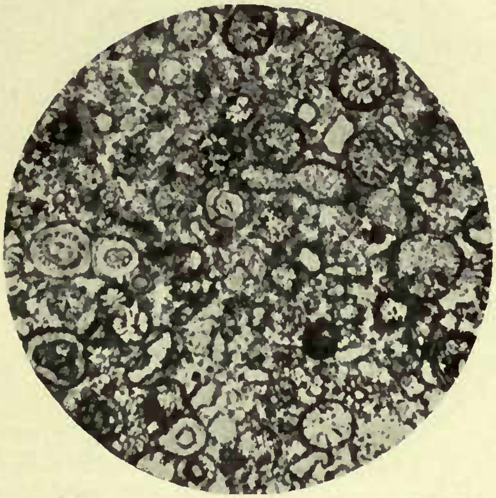
FIG. 1

Limestone breccia, Cloudmaker, with fragments of Archæocyathinæ dolomitised limestone, quartz fragments and later calcite veins.

No. 20. × 12 diams.

FIG. 2

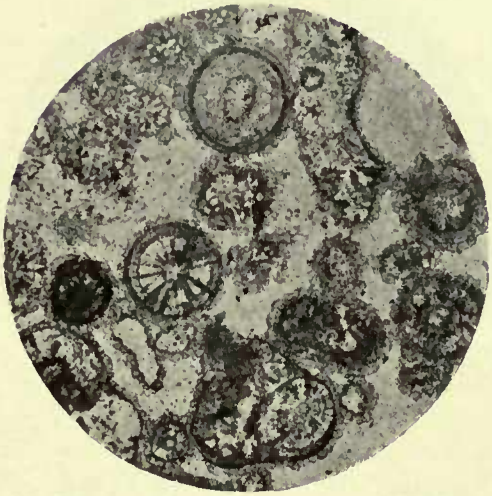
Cloudmaker, Beardmore Glacier. Partially dolomitised oolitic limestone.



No. 245. × 12 diams.

FIG. 3

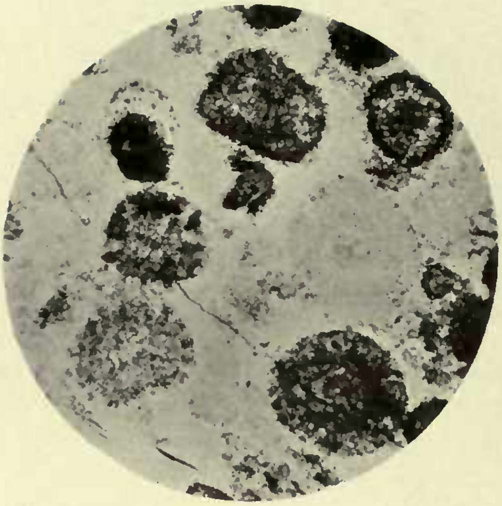
Erratic, Cape Royds. Dolomitised and partially silicified oolitic limestone.



No. 240. × 28 diams.

FIG. 4

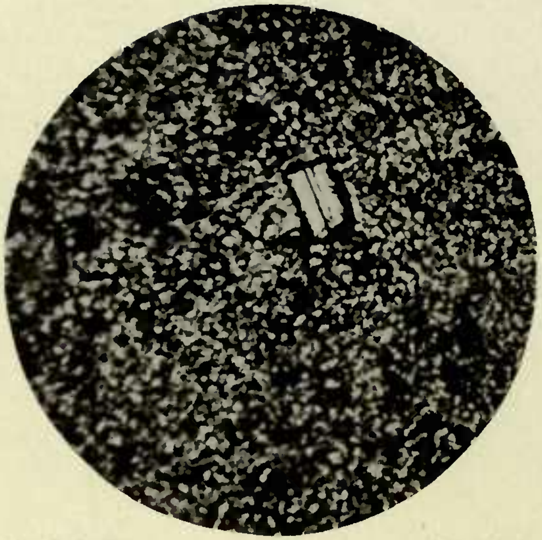
Erratic, Cape Royds. Dolomitised and partially silicified oolitic limestone.



No. X. × 28 diams.

Fig. 1

Erratic, Cape Royds. Etched with Hydrofluoric acid. Dolomitised and silicified oolitic limestone with banded agate structure in matrix.



No. P. 282. × 300 diams.

Fig. 2

Stranded Moraine, East Fork, Ferrar Glacier. Dense limestone with volcanic fragments, quartz, and fresh sponge spicule.

No. 107. × 28 diams.

Fig. 3

Farthest South, December 20, 1908. *In situ* Stained with Lemberg's solution. Archæocyathinæ limestone with greenish veins of detrital or tuffaceous material.

No. 107. × 90 diams.

Fig. 4

Farthest South, December 20, 1908. *In situ*, Stained with Lemberg's solution. Archæocyathinæ limestone with greenish veins of detrital or tuffaceous material.

PART XIII

PETROLOGY OF ROCK COLLECTIONS

FROM THE MAINLAND OF SOUTH VICTORIA LAND

BY

D. MAWSON, D.Sc,, B.E.

University of Adelaide

CONTENTS

PETROLOGY OF ROCK COLLECTIONS
FROM THE MAINLAND OF SOUTH VICTORIA LAND

BY

D. MAWSON, D.Sc., B.E.
University of Adelaide

THE material described is included in three collections made respectively by the Southern Party from the vicinity of the Beardmore Glacier 83° 50′ to 85° 10′ S. lat.; the Western Party from the Ferrar Glacier region, 78° S. lat., and the Magnetic Pole Party* from the coast-line between 78° and 75° S. lat. The geological conditions over this region appear to be very similar. For this and other reasons it is found advisable to tabulate under one scheme the specimens from all three sources. In most cases the specimens were collected as erratics; when otherwise the fact is expressly stated.

THE SEDIMENTARY ROCKS

Typical conglomerates, sandstones, slates, limestones, and even carbonaceous shales and sandstones, as well as true coal, are exemplified. These argue water conditions and a milder climate than now prevails in those latitudes. There are, nevertheless, often present certain characters which indicate a severe and almost glacial climate. The diagnosis of deposition under semi-glacial conditions lies in the intimate character of the rocks as revealed by microscopic study and analysis. The thick arkose and greywacke formations I regard as corresponding to such semi-glacial conditions. I have arrived at this conclusion after a detailed study of the glacial and interglacial sediments in Australia corresponding with the Cambrian and Permo-Carboniferous ice ages. Similar arkoses and greywackes, as well as unleached muddy silts, invariably accompany these tillite horizons, often repeated many times in waning sequence above and below the latter. This recurrence indicates the continuance of strophic periods.

Examples of true tillite are almost absent amongst the collection: these are limited to several pieces of a recent character from the coastal moraines of McMurdo Sound, and a scrap of an older-looking type from a moraine at sea-level near Mount Larsen.

In the valleys inundated with summer waters in the Ferrar Glacier region there is evidence that deposition of travertine is now taking place. Travertine is found coating the pebbles and even cementing gravel to form a hard rock.

The existing arid conditions, united with the fact that complete ablation of snow and ice masses usually takes place before a melting temperature is reached, result in the concentration of any contained dissolved salts. Thus residues of sodium, magnesium, and lime sulphates and chlorides are of frequent occurrence.

---

* The MS. of this paper was received by the General Editor in September 1911. Subsequently Scott's Northern Party, in 1912, recovered the collection of rocks cached and unretrieved by us at Depot Island. In my absence in Antarctica the Depot Island collection has been described by Mr. L. Cotton and forms a further section of this volume.—D. M., *January* 1916.

PSEPHITES

The conglomerates are almost all referable to the Beacon Sandstone formation, and usually represent pebbly bands interlaminated with the fine-grained sandstone. It is safe to assume that the base of the series is a definite conglomerate horizon, as coarse examples, likely to have come from such a situation, are met with in the recent moraines. A specimen of such a conglomerate from the Knob Head Mountain Scree,* west (Ferrar Glacier), is at hand. In it there is a general absence of anything but quartz, of which the pebbles range up to 3 cm. in diameter, and are very firmly cemented together.

A conglomerate of a much later age appears amongst the material from the Stranded Moraines, McMurdo Sound, and from Dry Valley, New Harbour. It is suggestive of a recent age, and, as it contains fragments of the mainland dolerite, it is almost certainly Tertiary or Post-Tertiary. Its constituents have accumulated under water and the pebbles are not obviously glaciated. The constituents comprise biotite, muscovite, felspar, crystal quartz, jasper, chert, and composite rocks ; amongst the latter are dolerite and a pre-existing grit consisting chiefly of white and crystal quartz. Cementing these there is an abundance of a light yellow mud consisting mainly of carbonates of lime and magnesia. This rock appears to tally with that mentioned by Dr. Prior † as occurring on the western promontory of Black Island. Its characteristics suggest an aqueo-glacial origin and its distribution infers deposition in recent times in connection with the affluent streams and ponded waters at the termini of the large mainland glaciers.

PSAMMITES

These are chiefly sandstones and arkoses, which are represented in varying degree of metamorphism. By a study of the moraine-derived specimens it is not possible to say how far the quartzites represent the Beacon Sandstone, or to what extent they proceed from older formations. Amongst the metamorphic rocks are sandstones and greywackes intruded by granite ; this infers a certain antiquity for the intruded sediments.

In the collection from the East Fork of the Ferrar Glacier is a very white fine-grained quartzite ; between this quartzite and an almost pure marble, graduated steps are represented by other specimens. These marbles are thought to be of Palæozoic age, and the inference is that quartzites, also of this age, exist.

The facies of the Beacon Sandstone formation is so distinctive that one has no hesitation in referring almost all the psammites to this formation. A collective description will be found most convenient.

The Beacon Sandstone

A wide geographical range is indicated by its appearance in all the mainland collections. Amongst the collection made by Priestley in the Ferrar Glacier region it is most typical and abundant. The Southern Party met abundance of the more felspathic varieties between 83° 50′ S. lat. and 85° 10′ S. lat. A few fragments only were met with by the Magnetic Pole Party, though the topographical features of the coast ranges in that direction infer its continuance northward on a grand scale.

The constitution of this rock varies through wide limits, from a nearly pure quartzose

---

* For maps refer to vol. i of these Reports.

† *British Museum Reports on National Antarctic Expedition,* 1901–4, vol. i, Geology, p. 139.

sandstone to a highly felspathic arkose. The former is the typical Beacon Sandstone described in Dr. Prior's reports.* In point of general description nothing remains to be recorded more than is therein detailed. Exceptional features are, however, abundant and worth notice.

The usual characters are a medium-grained sandstone composed of angular or somewhat rounded grains of quartz usually but loosely cemented together; accessory ingredients such as felspar, garnet, and rutile are quite common. The cementing material, usually siliceous, is frequently calcareous. The typical sandstone passes over on the one side to conglomerate or arkose and on the other to much fine-grained saccharoidal varieties (Fig. 1, Plate I).

A sample of this latter variety, from Dry Valley, grades from a very white saccharoidal sandstone above into a band below, studded with partially abraded quartz pebbles as much as 18 mm. long. The sand grains are sub-angular, frequently exhibiting shining crystal faces, and are but loosely adhering. Quite fresh felspar grains are not uncommon. The grain size averages 0·75 mm. A crystal of gypsum was noted adhering to the wall of a cavity in this specimen.

In a specimen from the Lower Medial Moraine, Ferrar Glacier, fragments of grey-blue shale appear. These exactly resemble similar inclusions in the psammites of the older glacial horizons of Australia. Some specimens collected opposite the Cathedral Rocks, Ferrar Glacier, are highly felspathic; some are strongly and others loosely cemented.

In some specimens the grains are much more rounded, as in the case of a very white rock from Knob Head Mountain Scree, Ferrar Glacier, in which the quartz grains are embedded in a kaolin base.

This latter type is usually closely associated with carbonaceous varieties. A specimen of such a rock from the moraine below Cathedral Rocks contains quartz, some felspar, and occasional faintly pink garnet in fairly well rounded grains. The carbonaceous matter follows along certain planes of deposition associated with accumulations of silt. Muscovite plates are conspicuous along these planes.

An exceptional tinted variety is one from the Medial Moraine, Ferrar Glacier, where the interstices are filled with a chloritic substance contributing a greenish colour.

Quartzites of essentially the same characters but almost flinty in fracture, met with amongst the moraines of the Ferrar Glacier, are regarded as Beacon Sandstone metamorphosed, probably by local igneous action.

Ferrar and Prior † have referred to stalagmitic and marbled forms of the Beacon Sandstone. This is due to unequal cementation in the sandy beds, perhaps resulting from local infiltration of alkaline solutions. Weathering processes often result in stalagmitic relief; at other times concretionary forms are developed. Numerous examples of the latter occur in Priestley's collections from the Knob Head Mountain Scree, and from the Medial Moraine opposite Cathedral Rocks, Ferrar Glacier. These concretionary nodules are spherical (Fig. 2, Plate I) and saucer-shaped (Fig. 3, Plate I). The former, though cemented firmly in the peripheral zone, often contain within much calcareous and clayey matter. The central portions are thus but loosely cemented. When, in nature, fracture of the hard shell takes place, due to accidental circumstances, the softer central portions are quickly removed by wind erosion and the concretions are hollowed out (Fig. 2, Plate I). *In situ*, these concretions appear either as spherical balls in relief or, where hollowed out, as wells sunk in the weathered surface. On slicing a completely spherical specimen 7 cm. diameter it was found to consist of an

---

* *British Museum Reports on National Antarctic Expedition*, 1901–4, vol. i, Geology.

† *Ibid.*, p. 139.

outer shell 1·2 cm. diameter in which the quartz particles are cemented by growth-enlargment of the grains themselves, and of an interior filling 4·6 cm. diameter of quartz grains cemented by calcite in optical continuity. Obviously the localisation of alkaline substances or calcite has determined the formation of these concretions.

One fragment of the Beacon Sandstone formation from the Moraine, East Fork of the Ferrar Glacier, is loaded with calcite in optical continuity. A similar Fontainbleau Sandstone occurs directly above the Permo-Carboniferous tillite at Hallett's Cove, South Australia.* It appears to be commonly the case that mechanical sediments of glacial periods become loaded with calcite or other chemical precipitate.

Certain specimens from the East Fork of the Ferrar Glacier, obviously belonging to the Beacon Sandstone horizon, are highly felspathic. They contain quartz, orthoclase, acid plagioclase, muscovite, biotite, pink garnet, rutile, and iron ores. This is a transition towards the typical psammite of the Beardmore Glacier area, which is an arkose quite remarkable in character and deserving a special description. There seems to be no reason to doubt its identity as an example of the Beacon Sandstone formation. Its peculiar characters are just such as would be expected from rapid disintegration under semi-glacial conditions. Carbonaceous material appears along the bedding planes of some of the specimens, just as is the case in the specimens from the Ferrar Glacier.

The following description refers to the more massive varieties free from organic matter.

Arkose from the Upper Glacier Depot, Beardmore Glacier

The *hand-specimen* is an even-grained sand-rock of an ash-grey colour. A large proportion of felspathic material, partly kaolinised, is present. Particles of mica are not infrequent, most abundantly distributed along the bedding planes ; this endows the rock with a ready fissility. With the aid of a pocket-lens particles of pink garnet are rendered obvious.

A *microscopic examination* showed it to be composed of particles averaging in the prepared slide 0·12 mm. diameter.† (Figs. 1 and 2, Plate III). The grains have angular and sub-angular boundaries with splintered edges.

Quartz is the chief constituent. Under crossed nicols most of the particles exhibit strain shadows or are seen to have suffered crushing by granulation. Frequently a rejuvenation is evidenced by clearer border zones. Abundant inclusions, chiefly rutile needles, are present. The *felspars* are predominantly orthoclase, microcline, and anorthoclase, though a minor proportion show albite lamellæ and agree in optical properties with albite and oligoclase. They have a dusty appearance in transmitted light due to partial kaolinisation, and certain grains show chloritic changes. Under crossed nicols the effects of strain are again noted. *Mica*, both muscovite and biotite, is present sparingly, in small particles, usually partly converted to chlorite and often much bent. *Apatite* in occasional inconspicuous grains. Particles, originally *ilmenite*, now altered to *leucoxene*, are frequent. Pink *garnet* in small quantity, often embedded in the felspar individuals, is scattered throughout the section. *Rutile* is present as microscopic hair-like inclusions in the quartz and rarely as isolated grains. *Sphene* grains are amongst the rarest of the accessory constituents.

A Rosiwal determination of the approximate mineral composition by volume gave :

---

* "Mineralogical Notes," *Trans. Roy. Soc. S. Aust.*, vol. xxxi, 1907, p. 119.

† Note that in a granular rock the average absolute diameter of the grains is about twice that obtained by averaging the diameters observed in the microscope slide.

	Per cent.
Quartz	54·0
Felspar	42·0
Mica	2·5
Garnet	0·5
Apatite	0·5
Sphene, Leucoxene	0·5
	100·0

A *chemical analysis* made by A. B. Walkom, B.Sc., and G. J. Burrows, B.Sc., resulted as follows :

SiO_2	76·01
TiO_2	0·31
Al_2O_3	13·29
Fe_2O_3	0·52
FeO	1·75
MnO	0·01
MgO	0·60
CaO	0·72
Na_2O	3·33
K_2O	2·63
H_2O+	0·25
H_2O-	0·27
P_2O_5	0·37
CO_2	0·06
Total	100·12

A comparison of the *norm* and *mode* is of interest. The latter is the percentage weight composition calculated from the volume composition already noted.

THE NORM (Percentage weight)	
Quartz	44·46
Orthoclase	15·56
Albite	28·30
Anorthite	0·28
Corundum	4·90
Hypersthene	3·74
Ilmenite	0·61
Magnetite	0·70
Apatite	0·93
Water	0·52
	100·0

THE MODE (Percentage weight)	
Quartz	54·2
Felspar	41·0
Mica	2·8
Garnet	0·7
Apatite	0·6
Leucoxene, Sphene, etc.	0·7
	100·0

These figures correspond with those of the chemical composition of an extremely acid granite.

Chemico-mineralogical Classification: Class 1, Order 3, Rang 2, Subrang (Alsbachose.)

This is distinctly more acid than the massive granite outcrops of South Victoria Land. Concentration of the quartz grains and the elimination of soluble alkali and iron would be expected to attend any sedimentation process to a more or less marked extent.

The abundance of microcline felspar, the strain features, and the presence of garnet indicate an origin from acid igneous rocks metamorphosed prior to the period of sedimentation represented by the arkose. The character of the garnet and its association with the felspar is clear evidence that the garnet was developed secondarily in the original gneiss at the expense of anorthite molecules of the felspars. The most important contributor to the newer sediment, it appears, was an acid garnetiferous gneiss. The unsorted character of the mineral constituents—the angular nature of the grains—and the freedom from chemical decomposition are, I believe, evidence that disintegration and deposition took place under semiglacial conditions. In small hand-specimens, rocks of this character are difficult to distinguish from some dynamometamorphosed granites, but I feel satisfied that there is no confusion in this case. Thick deposits of a similar nature are regularly met with amongst the beds associated with glacial horizons in South Australia.

Other specimens from the Upper Glacial Depot, Beadmore Glacier, not otherwise differing from this arkose type, carry abundant carbonaceous material along certain of the bedding planes. Thus, finally, carbonaceous shale and grits are arrived at and indeed coal* itself is amongst the specimens associated therewith.

Though this arkose appears to be the prevailing psammite of the Beadmore Glacier area there are, also, specimens more nearly approaching normal quartzites. One of these from the Cloudmaker is a buff-coloured felspathic quartzite. Distinct and regular bedding lines are marked out by iron-ore zones alternating with bands free from iron ores. In it, current bedding is well shown.

PELITES

Examples of this class are rare amongst the collections. On the magnetic pole journey only a few specimens of limestone and a few chips of slate were met with; amongst the former is an interesting erratic from Dunlop Island, the latter are mostly from amongst the moraines in the vicinity of Mounts Larsen and Nansen. From the Ferrar Glacier area Priestley collected fragments of a dense calcareous slate from the upper moraines. This material in character recalls the non-fossiliferous Cambrian slates of South Australia, with which I am familiar.

In the Beardmore Glacier collection are a number of examples of slates and phyllites. It is quite likely that all are of one age, as indicated by a specimen which clearly shows that its phyllitic characters have been induced by the infiltration of mineral-bearing waters along a fissure now occupied by vein quartz. Specimens from the vicinity of the Cloudmaker range from a faintly purple-coloured slate to light grey or greenish coloured phyllites in which abundant sericite has been developed; minute particles of pyrite are also frequent. In one case the phyllite is spotted and contains a pyrite crystal 1 cm. square. The evidence of the quartz vein and the general metamorphism of the slates argues a date of deposition antecedent to an igneous intrusive period in the local geological history. It is unlikely that these sediments are newer than the Palæozoic. Associated with these slates and phyllites are calcareous types and even pure limestones.†

---

* The coal strata are described elsewhere in these volumes.

† The limestones are elsewhere specially described by Professor E. W. Skeats.

THE IGNEOUS ROCKS

Ferrar and Prior have described a large series of igneous rocks from South Victoria Land. Most prominent amongst these are granites, mostly very ancient, dolerites of intermediate age, and a recent alkali series of intermediate and basic rocks. None of the latter occur *in situ* on the mainland in the region within the scope of these collections. Erratic blocks are, however, frequent. Ferrar distinguishes an older and a younger granite. The older granites are grey and intrude an ancient metamorphic series of gneisses and schists. The younger granites are pink in colour, and according to Ferrar intrude the dolerite sills which are themselves younger than the Beacon Sandstone. More information on the subject of the relative ages of the pink granite and the dolerite is desirable, for our observations have shown that there do exist grey granites of the same age as some pink granites.

Ferrar also met with diorites, syenites, gabbros, and lamprophyric, aplitic, and pegmatitic rocks.

For convenience I have recognised the following groups:

The Granites and their associated Dyke Rocks. The latter include porphyrites, aplites, pegmatites, and lamprophyres. Granites of several ages are recognised.

The Diorites. These doubtless correspond in age with some of the granites.

The Gabbros. Most of those classified under this heading are believed to be older than the "dolerites"; others may be special phases of the latter.

The Dolerites. Included herein are a variety of closely similar types all of the same period, intrusive in the Beacon Sandstone formation, and therefore comparatively young. They appear to belong to the one great intrusive act illustrated by the dolerites of Tasmania. They range over an enormous area of Antarctica.*

The Recent Volcanic Series. Rocks of this series are of tertiary and recent age and are exemplified in the extravasations of Mount Erebus. It is doubtful whether any outpourings of this class have taken place on the mainland proper within the area embraced by these collections.†

THE GRANITES AND ASSOCIATED DYKE ROCKS

Granites and their dynamometamorphic equivalents form a large part of the exposed areas, and consequently the collections are rich therein.

The majority of the specimens collected are coarse-grained and porphyritic with large pink orthoclase crystals. Very large outcrops of this granite are known to occur between 75° 50′ S. lat. to 78° S. lat. It is probable, however, that the areas occupied by grey granites predominate. Petrological comparisons and certain field evidence indicates a relationship between the pink granites and certain of the grey granites. This relationship is closer than is likely to be the case if they belong to two widely separated periods. This, however, appears to be the case with others of the grey granites as indicated by Ferrar's field evidence.‡

In any case it is certain that granites older than the pink felspar granites exist, for some of the granite-gneisses are plainly of such antiquity. It is significant that of the arkoses, so frequent amongst the sedimentary rocks, none have yet been met containing pink felspars.

---

* These are described in detail elsewhere in this volume by W. N. Benson, B.Sc.

† Examples of such rocks have been brought to light by the recent Scott Expedition.—D. M., 1916.

‡ *Loc. cit.*, p. 36.

Accompanying these granites are frequent dyke rocks, including granite porphyrites, aplites, pegmatites, and lamprophyres.

In regard to the metamorphic action of the granites upon the intruded rocks, little exact information is available. It is more than likely, however, that the majority of the schists and gneisses, so abundantly represented in our collections, originated in connection with the intrusion of the granites.

It seems sufficiently clear at least that the great marble and calc-silicate belt owes its present condition to the influence of these intrusions upon original limestones.

THE PINK GRANITES

Chiefest and best known is the coarse-grained pink granite typically developed at Cape Irizar. The outcrop there protrudes from the ice over a length of half a mile or more.

Other examples were met with in the Ferrar Glacier locality and at intervals along the coast. Dr. Prior has described this and allied granites occuring *in situ* at the Ferrar Glacier,* and at Cape Adare.† Professor David, Mr. Smeeth, and Mr. Schofield have described granite erratics collected by Mr. Borchgrevick at Cape Adare.‡

The textures vary somewhat in the different outcrops. At Cape Irizar the Shap Fell type is general, whilst certain of the specimens from the Ferrar Glacier are textured like the Rapakiwi granite. Very similar granites are met with intruding the Cambrian sediments of South Australia ; *e.g.* at Murray Bridge and Granite Island.

The pink coloration is due to the prevailing tint of the abundant orthoclase felspars. The depth of colour is affected somewhat by exposure, for the outcrops are generally pinker than freshly broken faces. The tinting is by no means evenly distributed, but even in small exposures varies from a deep red to practically white. At Cape Irizar a fracture zone in the granite, up which a lamprophyric magma ascended, has assumed a deep red colour, due, obviously, to secondary causes. In general the deeper coloured the rock the greater is the content of accessory minerals.

All the pink granites are hornblendic ; with the hornblende is usually some biotite also. In this way they differ from the grey granites, which contain but little or no hornblende.

HORNBLENDE-BIOTITE GRANITE ; CAPE IRIZAR. (Plate I, Fig. 4)

Most conspicuous in the *hand-specimen* are abundant porphyritic rectangular pink orthoclase crystals twinned after the Carlsbad law : these are embedded in an even granular base containing a little orthoclase, much plagioclase, abundance of quartz blebs, conspicuous hornblendes, and a varying quantity of biotite. The chief variants are the hornblende and biotite. In particular parts of the outcrop the one may increase in quantity almost to the exclusion of the other.

Microscopic Characters. (Figs. 4 and 5, Plate III.) The texture is porphyritic granular. Large idiomorphic orthoclases distributed through a hypidiomorphic granular base consisting of plagioclase, orthoclase, quartz, hornblende, mica, and accessory minerals.

Quartz in subangular grains often showing strain effects. The usual inclusions are present. It is a later crystallisation than the plagioclase, and appears to have accompanied the latest phase of orthoclase separation. *Orthoclase.* Present in two forms. The porphyritic individuals measure up to 2·5 cm. diameter and are twinned after the Carlsbad law. Idiomorphic plagioclases are often included in them. The small orthoclases in the ground-mass and certain additions to the porphyritic individuals

---

* *Loc. cit.* p. 125.

† "'Southern Cross' Collections," Brit. Mus. Nat. Hist. publication, 1902, p. 322.

‡ *Proc. Roy. Soc. N.S.W.*, vol. xxix, p. 481 (1895).

represent the latest separations of orthoclastic material. There has probably been no lapse of time between these successive modes of separation, the variation being merely consequent upon the changing physical-chemical conditions existing in the magma.

Microperthitic intergrowths are common. Some part of the orthoclase showing mottled markings under crossed nicols appears to be soda orthoclase. Generally speaking the mineral is very fresh. Dusty change-products become prominent in the redder felspars of certain outcrops where metamorphosing external agencies, referred to later, exerted an influence. *Plagioclase*, chiefly oligoclase but occasionally as basic as andesine. Twinning is usually after the albite law only, though occasionally noted compounded with the Carlsbad type. It is always more dusty than the orthoclase. Amongst the secondary minerals white micaceous flakes are recognisable. The plagioclase has crystallised earlier than the quartz and orthoclase. The *mica* is a biotite, pleochroic (yellows and browns). The laminæ are often slightly bent. The *hornblende* occurs in irregular prisms. At a hasty glance it is not easily distinguished from the biotite. It is pleochroic from light yellow to dark green. Chloritic decomposition products are sometimes observed. *Magnetite* in irregular grains only rarely seen. *Sphene* is still rarer and observed almost always adhering to magnetite grains. *Apatite* is very rare: it appears always in the tiniest crystals adhering to magnetite or embedded in the biotite. *Zircon* appears to be more frequent in some specimens than others. It is seen as minute grey crystals almost always embedded in the biotite mica and surrounded by pleochroic haloes. *Allanite* is by far the commonest of the accessory minerals appearing in nearly all the granites in our collections. In slides from this particular rock grains ·5 mm. diameter were met with. It is generally associated with biotite and is always idiomorphic. It is of a brown colour, slightly pleochroic and distinctly zoned. It is weakly doubly refracting and has high refractive indices.

An approximate Rosiwal *mineral analysis* gave:

	MODE
Quartz	29·5
Orthoclase, including soda orthoclase	32·0
Microcline	7·2
Plagioclase, chiefly oligoclase	25·0
Biotite	4·0
Hornblende	2·0
Accessories	0·3

The following is a *chemical analysis* of a fresh sample made by A. B. Walkom, B.Sc.:

SiO_2	71·87
TiO_2	0·25
Al_2O_3	15·16
Fe_2O_3	0·62
FeO	2·10
MnO	0·04
MgO	0·29
CaO	0·84
Na_2O	3·88
K_2O	4·72
H_2O+	0·35
H_2O-	0·15
P_2O_5	trace
CO_2	0·09
	100·36

COMPOSITION OF THE NORM

Quartz	27·60
Orthoclase	27·80
Albite	33·01
Anorthite	4·17
Corundum	2·14
Hypersthene	3·74
Ilmenite	0·46
Magnetite	0·93
	99·85

Chemico-mineralogical Classification: Class 1, Order 4, Rang 1, Subrang 3 (*Liparose*).

The dyke-rock "following" includes granite porphyries, aplitic pegmatite, and kersantite. These are fully described in a later section. Metamorphism affecting this rock is also referred to under the general subject of metamorphism.

Similar granites are to be met with at intervals between McMurdo Sound and Mount Nansen. A red granite is observed extensively exposed on the mountain scarps to the north-west of Granite Harbour. A whale-backed promontory (practically an island) between Gregory Point and Ross Cape is composed entirely of this rock and its dyke following. At other points erratic specimens were met. Certain outcrops of a grey granite are texturally similar to the pink type, and it appears that they are but variations of it. The grey granites in the neighbourhood of Mount Larsen are to be mentioned in this connection.

Dr. Prior has already dealt with the pink granitic rocks of the Ferrar Glacier region. Priestley's collection contains abundant specimens also, one from a moraine in the East Fork of the Ferrar Glacier proves to be identical with that already described; the others are more in the nature of granite porphyries and descriptions will appear later.

THE GREY GRANITES

In the present state of our lack of knowledge concerning the field relations of these rocks, the only other obvious subdivision into which we can split the granites is the group of grey granites.

Sufficient has already been said to make it clear that these do not all belong to one period of igneous activity; furthermore, it seems clear that some of the grey granites are closely connected with the pink granite already described. Such is the grey granite, to be referred to immediately, occurring *in situ* to the south-east of Mount Larsen. A comparison of the analyses shows the kindred characters of these rocks. The difference lies mainly in increased proportion of plagioclase in the Mount Larsen rock. A quartz porphyry dyke which crosses the grey granite has a chemical composition almost that of the pink granite, being richer in potash felspar than the parent grey granite.

Evidence culled from observations relating to field occurrence, and especially chemical composition in the differentiation sequence, suggests that much of the original granitic magma has solidified as a more highly biotitic and plagioclastic grey granite, followed by the separation of an orthoclastic hornblendic magma solidifying as a pink granite occupying subsidiary bosses and dykes.

In this connection the Mount Larsen grey granite is specially worthy of study.

BIOTITE GRANITE FROM NEAR MOUNT LARSEN. (Fig. 6, Plate I)

Granite *in situ* at the foot of the Backstairs Passage Glacier, the sharp ascent to the Larsen Glacier. A ridge composed of broken masses of this granite extends for a distance of several hundred yards. In the *hand-specimen* it appears as an even fine-grained light grey granite. Quartz, plagioclase, and biotite are the obvious constituents. This rock is quite different in appearance to the Cape Irizar granite; most noticeable is the want of orthoclase.

Microscopic Characters. The grain size in the slide averages 1·5 mm. diameter. The texture is hypidiomorphic granular.

Quartz in regular allotriomorphic grains. It is one of the last products of crystallisation. Strain shadows are universal. *Orthoclase* is present only in very small quantities as compared with the plagioclase. It usually shows the faint striæ of anorthoclase. *Plagioclase* is very abundant, and is distinguished by the fine lamellæ of the albite twin; Carlsbad twins are also rather frequent. The plagioclase crystals are hypidiomorphic and occasionally idiomorphic. Both orthoclase and plagioclase are comparatively fresh. *Biotite* is abundant; pleochroism light yellow to deep yellowish-green. *Allanite* occurs in stout prisms embedded in the biotite. It is of a yellowish-brown colour and well zoned. *Apatite* in colourless stout prisms is also frequently observed enclosed in the biotites.

The *chemical analysis* determined by A. B. Walkom, B.Sc., is as follows:

SiO_2	69·85
TiO_2	0·36
Al_2O_3	15·35
Fe_2O_3	0·40
FeO	3·88
MgO	0·52
CaO	2·94
K_2O	2·87
Na_2O	3·13
H_2O+	0·24
H_2O-	0·03
CO_2	0·01
MnO	0·06
P_2O_5	0·50
	100·14

COMPOSITION OF THE NORM

Quartz	31·86
Orthoclase	17·24
Albite	26·20
Anorthite	10·84
Corundum	3·06
Hypersthene	7·50
Magnetite	0·70
Ilmenite	0·61
Apatite	1·34
	99·35

Chemico-mineralogical Classification: Class 1, Sub-class 1, Order 4, Rang 3, Subrang 3 (*Amiatose*).

An even-grained grey granite collected as an erratic specimen from Dry Valley, New Harbour, is very similar to that from Mount Larsen.

Fine-Grained Granite ; Beardmore Glacier. (Fig. 7, Plate I)

A fine even-grained light grey granite composed of quartz, white felspar, and fine fragments of biotite from the Lower Glacier Depot, Beardmore Glacier.

Microscopic Characters (Fig. 3, Plate III). Allotriomorphic granular texture. The minerals are chiefly quartz, orthoclase (microline and anorthoclase), plagioclase (oligoclase chiefly), biotite, apatite, and magnetite.

The *quartz* is present as clear grains of irregular or rounded boundaries; these seldom exceed 1 mm. diameter. Rounded blebs of quartz (quartz de corrosion) are frequently embedded in the microcline. The *orthoclase* is chiefly microcline and anorthoclase though clear simple-twinned orthoclase is present. Gitter structure is beautifully shown in the microcline, which is always fresh. *Plagioclase* is generally dusty with change products which include flakes of secondary white mica. Measurements of the optical constants show the range to be between acid andesine and acid oligoclase. *Biotite*, pleochroic in green and yellow, is present in very small amount only; a change to chlorite is observable. *Muscovite* in small quantity is present also. Scattered grains of *magnetite* and tiny rods of *apatite* complete the list of constituents.

The approximate composition of the *mode* as determined by the Rosiwal method is as follows:

	Per cent.
Quartz	26
Orthoclase	12
Microcline and anorthoclase	39
Plagioclase	19
Mica	4
	100

Stress is indicated by the optical characters of the constituents. It closely resembles certain Pre-Cambrian granites of South Australia and is likely to prove of considerable antiquity. The arkose already described from this locality contains an abundance of microcline likely to have been derived from this and similar rocks.

From this locality was got a specimen of a like granite stained yellowish due to weathering.

PORPHYRITIC BIOTITE GRANITE; BEARDMORE GLACIER. (Fig. 5, Plate I)

A grey granite from the Lower Glacier Depot. It contains porphyritic white orthoclase crystals 2·5 cm. diameter twinned after the Carlsbad law. The texture of this rock resembles that of some of the porphyritic pink felspar granites of the Cape Irizar type.

The *orthoclase*, largely anorthoclase and microcline, is almost exclusively comprised in the porphyritic crystals. The *plagioclase* is an acid *andesine* and *oligoclase* and constitutes a large part of the finer material of the rock. *Biotite* is present, pleochroic from light yellow to deep brown. Associated with the biotite is a little *sphene* and abundant tiny prisms of *apatite*.

There is no evidence opposed to a possible relationship of this granite with those described from more northerly areas.

From the same locality comes a still coarser porphyritic granite similar in other respects. This bears distinctly pegmatitic characters. One of the large orthoclases contains scattered quartz fragments in a semi-graphic arrangement. Coarse black biotite flakes reach 5 cm. diameter. Embedded in the biotite in one place is a red brown crystal of sphene 3 mm. diameter.

A grey porphyritic granite very similar to the local pink variety is met with in the form of erratics at Cape Irizar and at the rocky cape a few miles to the south. These all contain sphene. In a more even-grained variety allanite is prominent, pleochroic (light yellow to red-brown) and twinned.

Grey granites are described by Prior and Ferrar as occupying large areas in the Ferrar Glacier region, at Granite Harbour, and at Cape Adare. Frequent erratics of more or less metamorphosed grey granites were noted by us along the coast-line. We came upon extensive outcrops of such at Cape Roberts, Cape Ross, Depot Island, and in the Mount Larsen neighbourhood. Lamprophyric dykes and inclusions are frequent amongst them.

THE GRANITE PORPHYRIES

A notable example of this class is that occurring *in situ* at the western end of the Kukri Hills, Ferrar Glacier. There is little doubt but that this is a dyke rock of the Cape Irizar granite magma. It is an intermediate stage between the granites already described and the quartz and felspar porphyries to follow. As porphyritic ingredients it contains large pink orthoclase crystals 2·5 cm. long, less noticeable smaller white oligoclases, small idiomorphic quartz crystals, and abundance of hornblende prisms. These coarse crystallisations are scattered through a uniform even fine-grained pink base composed of granular quartz, orthoclase, and plagioclase, with some biotite and subordinate hornblende.

Other specimens nearly related thereto, representing variations in the solidification of the magma, occurring under conditions ranging from those which lead to the development of typical granite, and those characterising the solidification stages of porphyritic aplites, are represented.

One of these from the Knob Head Moraine carries a phenocryst of orthoclase 7 cm. in length. This crystal and even the smaller individuals of ground-mass show indications of dynamic force by fracture. Occupying a fissure in the orthoclase is a vein of hornblende.

Another example from the Stranded Moraines, East Fork, Ferrar Glacier, shows hornblende prisms 1 cm. long, and these enclose flakes of biotite.

In another specimen from this latter locality the hornblendes contain poikilitically included felspar.

THE FELSPAR AND QUARTZ PORPHYRIES *

Quartz Porphyry from near Mount Larsen

Quartz Porphyry occurring *in situ* as an injection in the even granular granite already described outcropping to the south-east of Mount Larsen (Fig. 3, Plate II).

The *hand-specimen* shows idiomorphic crystals of quartz and faintly pink orthoclase distributed through a dense grey base. The orthoclase crystals reach a length of 7 mm. and the quartz individuals a diameter of 4 mm. Occasional planes of fracture traversing the massive rock are filled with pistacio-green epidote. These veins are never more than 2 mm. across.

The *microscopic examination* shows the presence of some plagioclase, biotite, magnetite, and sphene, in addition to the above. *Quartz* phenocrysts of idiomorphic form are prominent. The hexagonal bipyramids, which are perfect in form, reach a diameter of 4 mm. The *orthoclase* is very fresh. Carlsbad twins are combined with delicate cross twin-striæ indicating the felspar to be a soda variety of the anorthoclase type. In one case a Baveno twin makes its appearance. *Plagioclase* crystals are present though much less frequent and smaller than the orthoclase. Extinction determinations indicate them to have the composition of oligoclase. They are yellowish to greenish-yellow in colour, due to secondary alteration, which is much more evident than in the case of the orthoclase. An idiomorphic oligoclase individual was noted embedded in an anorthoclase. *Biotite* as irregular fragments showing strong absorption, pleochroic in yellows and greens. *Magnetite :* a few idiomorphic grains. *Sphene* of grey colour in scattered irregular aggregates, sometimes encased in the mica. *Apatite* as minute prisms noted only very rarely. *Allanite.* Rare scattered prisms are met with floating

---

* Rocks of this class from Cape Adare are described by Dr. Prior, *loc. cit.*, p. 324.

freely in the base. The *base* presents a very even appearance under the microscope. It is composed of uniform grains ·025 mm. diameter. This fine granular material is observed to consist of clear quartz and slightly dusty felspar, the latter apparently orthoclase as its refractive index is below that of Canada balsam. This is not the usual devitrified base typical of the quartz porphyries, but approaches the character of granite aplite. The analysis further corroborates this observation. It is clear that this porphyry is a separation from the granite in which it is found.

The *chemical composition* as determined by A. B. Walkom, B.Sc., is as follows :

SiO_2	73·55
TiO_2	0·21
Al_2O_3	13·70
Fe_2O_3	0·24
FeO	2·36
CaO	0·92
MgO	0·26
Na_2O	3·59
K_2O	4·46
H_2O+	0·36
H_2O-	0·08
CO_2	0·04
MnO	0·05
P_2O_5	Not det.
	99·82

THE NORM

Quartz	31·74
Orthoclase	26·13
Albite	30·39
Anorthite	4·45
Corundum	1·33
Hypersthene	4·43
Ilmenite	0·46
Magnetite	0·23
	99·16

Chemico-mineralogical Classification : Class 1, Sub-class 1, Order 4, Rang 2, Sub-Rang 3 (*Toscanose*).

Felspar Porphyry. Black porphyry from a rocky cape about 8 miles south of Cape Irizar. In one specimen the porphyry is conjoined with a grey biotite granite which it has evidently intruded (Fig. 4, Plate II).

This granite is identical in character to that described as occurring *in situ* south-east of Mount Larsen. The porphyry, though strikingly different in outward appearance, is, therefore, closely related to that just described. In the hand-specimen small white and pinkish felspars appear distributed through a black cryptocrystalline base.

Under the microscope the felspar is noted to be *orthoclase* twinned after the Carlsbad law, and rarely acid plagioclase. A few grains of faintly coloured *epidote* are present in close connection with the felspars, obviously an alteration product. *Biotite* is present as occasional flakes, yellowish to greenish-yellow in colour. More rarely grains of *ilmenite* are met with. The *base* is a devitrified glass, partly doubly refracting but unidentifiable.

Orthoclase Porphyry. A rock (Fig. 1, Plate II) from the Stranded Moraines, East Fork, Ferrar Glacier, is best catalogued here. It differs considerably from other specimens, but the character of the orthoclase phenocrysts suggests that it, also, belongs to the granite following. It consists of large white orthoclase crystals, about 1·5 cm. diameter, twinned after the Carlsbad law; these are scattered through a fine dark-coloured base. The base contains acid plagioclase, quartz, a little hornblende and unresolvable devitrified greyish interstitial matter.

Red Felspar Porphyry. An erratic specimen from Cape Irizar. Studded through the jasperoid base are occasional white felspars.

Pink and Grey Porphyries from the Stranded Moraines, East Fork of the Ferrar Glacier. The porphyritic constituents are white or pinkish felspar, quartz, and frequently mica. There is a marked orientation of the felspars and flow is further indicated by parallel dark streaks. These rocks are very dense and of the hälleflinta type, and may possibly be of much older age than those described earlier. They very closely resemble certain Pre-Cambrian porphyries of Southern Australia. In the case of other porphyries from the East Fork of the Ferrar Glacier, the bases are microscopically crystalline and in other respects they resemble the aplitic porphyries of the Cape Irizar granite following.

Another interesting *orthoclase porphyry* (Fig. 2, Plate II) is a grey hornblendic variety occurring *in situ* at the Kukri Hills, Ferrar Glacier. This is rather more basic than usual as it contains much plagioclase. It is rendered remarkable on account of the white orthoclase crystals 12 mm. in length, studded throughout the hand-specimens. The ultimate base consists of quartz and orthoclase, which frequently exhibit a micropegmatitic structure.

THE APLITIC GRANITE PORPHYRIES

There are now to be considered a large number of specimens illustrating granite porphyries in which an aplitic base is the most conspicuous part. They always form part of the granite masses but are usually of small size and very irregular in shape. In the more regular dyke-like occurrences, the porphyritic constituents diminish in bulk and typical aplites are arrived at. The aplitic condition is perfect when the rock is an even-grained panidiomorphic mixture of quartz and orthoclase with inconspicuous amounts of accessory minerals. The base is either grey or pink in colour ; as a rule the more aplitic types are the pinker in colour.

Aplitic Granite Porphyry ; Cape Irizar

A typical example of this aplitic granite porphyry occurs at Cape Irizar, about a quarter of a mile west of the extreme point. There, there are two parallel outcrops emerging from amongst the granite ; the junctions are unfortunately obscured. In the hand-specimen it appears grey, with rather large pieces of porphyritic orthoclase as much as 9 mm. in diameter.

Hornblende prisms up to 6 mm. diameter are not infrequent. Aggregates of varying size consisting of porphyritic *quartz, felspar, mica,* and even hornblende are scattered through the finer base.

In the *microscopic section* (Figs. 6 and 8, Plate III) porphyritic *orthoclase, anorthoclase, oligoclase, hornblende,* and *quartz* are distinguished. The hornblende and some of the felspars are in sharply defined crystals, whilst other minerals are corroded. *Hornblende* is plentiful, pleochroic in light yellow, yellowish-green, and blue-green. Viewed in ordinary light it is of a blue tint. Some are true *reibeckite* whilst others appear to be intermediate between the latter and common hornblende. The *base* is a fine granular mixture of quartz and orthoclase and some oligoclase. The grain size averages 0·15 mm. The felspar is hypidiomorphic or idiomorphic in form. Graphic intergrowths of the quartz and felspar are often present in this class of rock, but are not marked in this particular outcrop. *Allanite :* several pieces noted. There are a few grains of *ilmenite, leucoxene,* and of *pyrites.*

The granite, near the junction of this aplitic porphyry, contains a larger proportion of hornblende, entirely replacing the biotite. Zoning is noticeable in some of the plagioclase crystals.

The *chemical composition* as determined by A. B. Walkom, B.Sc., is as follows :

SiO_2	73·64
TiO_2	0·33
Al_2O_3	13·93
Fe_2O_3	0·90
FeO	1·40
MnO	trace
MgO	0·30
CaO	0·96
K_2O	2·73
Na_2O	5·17
H_2O+	0·47
H_2O-	0·16
P_2O_5	not det.
	99·99

COMPOSITION OF THE NORM

Quartz	30·24
Orthoclase	16·12
Albite	43·49
Anorthite	4·73
Corundum	0·82
Hypersthene	1·99
Magnetite	1·39
Ilmenite	0·61
Water	0·63
	100·02

Chemico-mineralogical Classification: Class 1, Order 4, Rang 2, Sub-rang 4 (*Lassenose*).

Several nearly spherical masses, only a few inches in diameter, of this type of rock were observed embedded in the coarse crystallised granite of the main outcrop at Cape Irizar. In this again the hornblende is abundant and some of distinctly alkaline type. Allanite and pyrites are also frequent.

In another specimen from Cape Irizar the hornblendes are sometimes surrounded by an outer zone of an irregular greenish-blue colour. In this case the porphyritic crystals are all plagioclase.

A further specimen of the grey rock occurring as an erratic at Cape Irizar yields additional information. In this the hornblende needles are more distinct. Porphyritic idiomorphic plagioclase crystals are also a feature of the rock.

Under the microscope (Fig. 7, Plate III) the plagioclase phenocrysts are noted to be well zoned, ranging from an acid labradorite within to a basic oligoclase without. They are much changed to dusty doubly refracting aggregates, so that it is difficult to distinguish exactly the relative proportions of plagioclase and orthoclase. *Quartz* is abundant but present only as small particles amongst the orthoclase felspars of the base. The *hornblendes* are idiomorphic and zoned. The usual pleochroism is red-brown, greenish-yellow, light yellow. The extinction angle is nearly straight. The periphery of the hornblendes appear to be undergoing a chloritic change. There are grains of *magnetite* frequently with a little leucoxene attached. The *base* is composed of a fine-grained mass of even-sized idiomorphic felspars with some quartz. Several cracks traversing the specimen are occupied by yellowish *epidote.*

There are a number of specimens collected as erratics similar to these, but of a general pink tint. A typical example is the following from Cape Irizar. The *hand-specimen* is of a pink colour and shows abundant porphyritic felspars and some finer hornblende. *In the section* it is apparent that the porphyritic felspars are almost all *plagioclase* which are changing with the production of faintly coloured *epidote.* There are some *orthoclase* crystals twinned after the Carlsbad law. The *hornblende* is pleochroic from light yellow to bluish-green to red-brown. In the case of one crystal a bluish-green border was observed on a red-brown basal section. Grains of magnetite and sphene are obvious. The base is principally quartz and orthoclase in eutectic, largely graphic, arrangement ; there is here also a little acid plagioclase.

Another specimen from the same locality contains a cavity occupied by calcite. The walls of the cavity are quartz and felspar in drusy relief. The felspar is much altered, so much so that, in the case of some squarish sections occupied by secondary minerals, it is not certain that they may not have been nephelines. In all these rocks no stainable products were discovered, and therefore this suggestion of nepheline cannot bear much weight.

Aplitic granite porphyries, both pink and grey, are met with in the Ferrar Glacier collection. These are notably from the moraines of the East Fork of the Ferrar Glacier and elsewhere in the neighbourhood of the Kukri Hills.

THE APLITES

As already stated the aplitic granite porphyries are a transition stage between the hypidiomorphic-granular granite and the panidiomorphic fine-granular aplite. Between the aplitic granite prophyries and the true aplites are porphyritic aplites of the alsbachite type. In the typical aplites the chief components are orthoclase and quartz, and the texture expresses eutectic composition. Numerous specimens were found as erratics in the vicinity of the granite outcrops. Of these the following two from Cape Irizar are worthy of description. One of these is of an almost white colour relieved by black specks of biotite. Small porphyritic crystals of anorthoclase are studded sparingly through the finer grained base. *Under the microscope* the base is seen to be granular and poikilitic patches are frequent. The *quartz* grains are surrounded by *orthoclase* arranged with great regularity. The *biotite* shows light yellowish and greenish tints.

The other example is of a light pink colour. The texture is very fine and even. *Under the microscope* (Fig. 9, Plate III) small porphyritic *oligoclase* crystals appear at intervals and are invariably surrounded by radial-graphic *quartz* and *orthoclase.* The remainder of the section consists of granular *quartz* and *orthoclase* with occasional but rare porphyritic orthoclases of a late period of crystallisation. Ferromagnesian minerals are almost absent. Grains of *ilmenite,* and rarely small yellowish grains appearing to be *epidote* are present.

In this rock, obviously, a sprinkling of small plagioclase crystals was the first act in crystallisation.

THE PEGMATITES

Pegmatite veins in connection with the pink granite appear to be of rare occurrence for none were met with *in situ.* Examples of coarse pegmatites occur amongst our collections of erratics.

Ferrar mentions quartzose, felspathic, and micaceous veins in the grey granites of the McMurdo Sound region. Priestley's collection also contains coarse pegmatitic granite and vein quartz. In some cases these are to be seen traversing a grey granite.

The outcrops of the gneiss and schist series are never free from pegmatite veins, and undoubtedly the majority of the erratic specimens are derived therefrom. Such a one is a coarse quartz-microcline rock from the Stranded Moraines ; this also carries some muscovite and frequent pink garnets, the latter up to 3 mm. diameter.

The gneiss at Cape Roberts is rich in coarse-crystallised veins, usually quartz and felspar, at other times quartz, felspar, and biotite. Amongst these, felspars 23 cm. in length and much graphic quartz and orthoclase were noted.

At Cape Bernacchi, and at Marble Point several miles to the north of the latter, an ancient sedimentary series, conspicuous amongst the members of which is a thick marble formation, is crossed by pegmatitic formations. Amongst these is a quartz-felspar-mica rock, sometimes containing much black tourmaline ; quartz veins carrying pyrites ; also more basic formations containing abundant biotite and hypersthene.

From the Beardmore Glacier are specimens of reef quartz and coarse quartz-microcline-biotite rock.

THE LAMPROPHYRES

Kersantites (Camptonitic)

Associated with the granites are frequent narrow basic dykes (Fig. 4, Plate IV). That described at length herewith is a kersantite, but others appear to tend towards camptonites and tinguaites. The dykes are usually irregular in length and narrow in width. When as narrow veins they are very close textured, in part devitrified glasses. In almost all cases a marginal zone, a few centimetres wide, appears to have solidified as glass. Where the dykes are some feet in width, the central portions are occupied by material in which the crystallisation is evident to the unaided eye. It is not unusual to find a sprinkling of small porphyritic plagioclase crystals. At all times fragments of the enclosing granite or of the minerals therefrom may be expected, partially corroded, suspended in the dyke rock.

The lamprophyres are always very dark in colour, practically black. The weathered surfaces often exhibit dark bluish and greenish tints. As it is more readily weathered than the enclosing granite, it is usual to find the dykes occupying depressions in the surface. On this account, also, lichens are more frequently noted adhering to its surface than to the granite.

The effect of these intrusions upon the neighbouring granite is marked to the naked-eye inspection by an increased depth of colour in the pink granite. The large orthoclase crystals are converted to a bright red colour. Examined under the microscope the changes are seen to lie chiefly in notable sericitisation of the felspar and chloritisation of the hornblende and biotite. In addition the quartzes often appear smoky, and there is generally present a larger content of accessory minerals. Slides of the granite cut in close proximity to the contact show numerous planes of fracture approximately parallel with the main line of fissure. These average not more than 0·75 mm. in width and are occupied by the crushed and recemented constituents of the granite.

Specimens from different locations are found to vary very much in the freshness of the constituents. In some uralisation, chloritisation, and serpentisation are far advanced and the original characters of the more readily affected minerals entirely obliterated.

Kersantite from Cape Irizar

This is one of the denser types. In it minute *plagioclase* laths can be distinguished, also frequent grains of strongly pleochroic (yellow to dark brown) *hornblende.* Grains of *ilmenite* and *pyrites* are present. The *base* is very dense and may have partly solidified as a glass. It is now pervaded with a chloritic alteration. The hornblendes are also attacked by chloritisation.

Specimens from other portions of the same dyke throw more light upon the mineral composition of this rock. There is a dominance of *plagioclase* (acid labradorite to andesine) which is present both as small laths and larger porphyritic zoned crystals. Carlsbad, albite, and pericline twins are present. *Hornblende* (usually basaltic) is present in idiomorphic rods. Light-coloured *pyroxene* partly uralitised is present in this dyke but seldom in others. Rarely flakes of *biotite* appear. *Ilmenite,* usually leucoxenised, is always abundant, so also is *apatite.* The finer material of the base of holocrystalline samples appears to contain some fine granular *orthoclase.* In these cases particles of *quartz* are evenly distributed through the section.

In a specimen from one portion of the dyke where the base appears to be a devitrified glass, there appear numerous polygonal, nearly spherical, clear patches of aggregates of a highly refracting colourless mineral suggesting change products of leucite. These are as much as 0·25 mm. diameter.

An *analysis* made by A. B. Walkom, B.Sc., of the dense variety of this rock first mentioned is as follows :

SiO_2	54·27
TiO_2	1·33
Al_2O_3	19·23
Fe_2O_3	0·73
FeO	8·29
MgO	3·74
CaO	6·41
Na_2O	3·05
K_2O	2·49
H_2O+	0·77
H_2O-	0·18
CO_2	0·05
MnO	not det.
P_2O_5	not det.
	100·54

COMPOSITION OF THE NORM

Quartz	1·92
Orthoclase	15·01
Albite	25·68
Anorthite	31·69
Hypersthene	21·84
Magnetite	0·93
Ilmenite	2·43
H_2O	0·95
CO_2	0·05
	100·50

Chemico-mineralogical Classification: Class 2, Order 5, Rang 3, Sub-rang 4 (*Andose*).

A comparison of this analysis with that of the granite shows a marked increase in the basic constituents, lime and magnesia, and a concentration of soda as opposed to potash. In the mineral components the fundamental difference lies in the elimination of orthoclase with substitution of plagioclase. It is obviously a lamprophyric separation from the granitic magma.

The character of some of the occurrences are suggestive of tinguaites, but in no case have staining methods revealed the presence of any felspathoid. Furthermore, the alkali content of the above analysis is too low to suspect the presence of felspathoids.

These lamprophyres frequently resemble camptonites and it is probable that the camptonites mentioned by Dr. Prior [*] are closely related to these intrusions. The analysis of the rock type here described is, however, unlike that of the camptonites, for it lies with the more acid lamprophyres.

As hornblende is the dominant coloured constituent in all the outcrops, the choice lies with kersanite and spessartite. The low magnesium and iron content and the high proportion of plagioclase felspar clearly indicate the rock analysed to be a kersantite. As hornblende is present in quantity in all the outcrops, sometimes to the exclusion of the biotite, they are more correctly described as hornblende kersantites.

Dr. Prior [†] has described a kersantite from a dyke intersecting the ancient crystalline limestone formation in the Ferrar Glacier region. This is an augite-biotite-kersantite and differs somewhat in appearance from the dyke rocks commonly met with by us. There is, nevertheless, no doubt but that it is genetically related to that just described. The analysis is strikingly similar.

---

[*] *Loc. cit.*, p. 129.

[†] *Loc. cit.*, p. 130.

Analysis of Augite-Biotite-Kersantite by Dr. G. T. Prior

SiO_2	50·71
TiO_2	2·71
Al_2O_3	17·08
Fe_2O_3	1·38
FeO	8·71
MnO	0·09
CaO	5·75
MgO	3·63
Na_2O	3·82
K_2O	3·63
P_2O_5	0·57
H_2O+	1·75
H_2O-	0·16
CO_2	trace
	99·99

Dr. Prior describes, from various occurrences in the Ferrar Glacier region, lamprophyric rocks related to banakite. These contain basaltic hornblende both porphyritic and amongst the finer material of the base, but are specially distinguished as containing porphyritic orthoclases. The field occurrences and the consanguinity, as indicated by the analysis, suggest that these banakites are also a further variation of the one series.

Analysis (by Dr. Prior) of Lamprophyric Dyke related to Banakite from the Ferrar Glacier Area

SiO_2	48·22
TiO_2	2·09
Al_2O_3	18·47
Fe_2O_3	5·28
FeO	3·90
MnO	0·10
CaO	6·02
MgO	2·07
Na_2O	4·94
K_2O	3·47
P_2O_5	0·88
H_2O+	2·89
H_2O-	0·44
CO_2 and loss	1·23
	100·00

A lamprophyric dyke met with at Cape Ross was observed to be shot through with abundance of idiomorphic hornblende needles. Unfortunately the specimens of this rock were left at the Depot Island cache.*

Amongst Priestley's collection from the Dry Valley moraines is a nice example of a vein of this lamprophyre intersecting a pinkish granite-porphyry. Both of these rock types correspond with those at Cape Irizar. The lamprophyre contains phenocrysts of porphyritic andesine, often zoned, and abundance of idiomorphic twinned basaltic hornblende rods. Kaolinisation has attacked the interior of the felspars but there generally remains a clear border zone. The fine material of the base consists of tiny particles of plagioclase, orthoclase, quartz, and iron ores.

---

* *See* description by L. A. Cotton in appended Notes.

BASIC (LAMPROPHYRIC ?) INCLUSIONS

The granites ot South Victoria Land offer plentiful examples of basic inclusions.

The inclusions fall into two classes. The one is biotitic, the other hornblendic. The former, though of common occurrence, is unimportant and can be quickly despatched. These are dark-coloured patches appearing at intervals in the face of the granite. They are generally of but a few inches in diameter. The constituents are the same as those of the granite, but the more basic minerals predominate.

A slide of one of these patches from the Cape Irizar granite exhibits the following characters : Even fine-grained, lacking the porphyritic orthoclases of the parent granite. Its relations to the enclosing granite indicate it to be endogenous, and an early crystallisation product. It is allotriomorphic granular; grain size averages 1 mm. *Orthoclase* is present in small amount. *Oligoclase* and *andesine* predominate. *Quartz* is plentiful. *Biotite* is abundant. *Apatite* and *zircon* are both much more concentrated than in the granite. A few grains of *sphene* are also noted. This inclusion is, therefore, syenitic in character.

Much more important are the hornblendic (dioritic) masses distributed through the grey gneissic granite of Depot Island. These are sub-angular to rounded and vary from a few inches to several feet in diameter. They weather out in relief on the cliff faces and have undoubtedly solidified prior to their inclusion in the granite. Their chemical composition indicates that they are related to the granite magma itself, and it appears as if they are earlier lamprophyric separations, subsequently burst through by the mother magma.

These boulders are fairly uniform in texture, though frequently intersected by coarser veins of the same constituents. The arrangement of these veins is pegmatitic and the distribution of the minerals in the veins is uneven. Many of the veins pass out of the inclusions into the gneiss, and show their period of formation to have followed upon the solidification of the enclosing gneiss. The constituent * minerals are biotite, hornblende, plagioclase, quartz, and accessories. The latter include abundance of a reddish-brown sphene.

Unfortunately our specimens were unrecovered† from the depot and microscopic and chemical analysis cannot be effected. There seems to be no doubt, however, but that this is one of a dioritic class well represented in our collections. Examples of the latter occur as erratics weighing as much as one hundredweight on Ross Island; they are also found in the Ferrar Glacier collections, as erratics at Cape Irizar, and in the vicinity of Mount Larsen.

Ferrar describes‡ masses of hornblendic rock occurring in the pink granite of the Kukri Hills as metamorphosed inclusions of the intruded dolerites. If this is so it seems likely that there exists no relation between these inclusions and those of Depot Island, for the analysis of the supposedly similar hornblendic rocks to be described later in no way corresponds with that of a dolerite.

Further, Ferrar has noted the pink granite of the Cathedral Rocks || gradually passing over to a coarse-grained diorite similar in most respects to the Depot Island inclusions.

This evidence favours the origin of the basic boulders in the Depot Island gneiss as earlier solidified differentiation products from the granite magma itself.

---

* From field notes.

† Since writing this the specimens have been recovered by the Scott Expedition of 1912. For description *see* Paper following by L. A. Cotton.—D.M., 1916.

‡ *Loc. cit.*, pp. 36 and 128.

|| *Loc. cit.*, 36.

A comparison of the analyses of the granites and lamprophyre is worthy of note; these are tabulated below:

	Red granite—Cape Irizar	Grey Granite—Mt. Larsen	Porphyry Dyke connected with grey granite—Mt. Larsen	Kersantite Dyke crossing red granite —Cape Irizar
SiO_2	71·87	69·85	73·55	54·27
TiO_2	0·25	0·36	0·21	1·33
Al_2O_3	15·16	15·35	13·70	19·23
Fe_2O_3	0·62	0·40	0·24	0·73
FeO	2·10	3·88	2·36	8·29
MnO	0·04	0·06	0·05	—
MgO	0·29	0·52	0·26	3·74
CaO	0·84	2·94	0·92	6·41
Na_2O	3·88	3·13	3·59	3·05
K_2O	4·72	2·87	4·46	2·49
H_2O+	0·35	0·24	0·36	0·77
H_2O-	0·15	0·03	0·08	0·18
CO_2	0·09	0·01	0·04	0·05
P_2O_5	trace	0·50	—	—
Total	100·36	100·14	99·82	100·54

THE DIORITES

As suggested under the last section, there is reason to believe some of these at least to be genetically closely connected with the earlier granites—probably lamprophyric differentiation products. As nothing is yet known of the occurrences, *in situ*, of the specimens hereunder described this point cannot now be cleared up. The rocks are of such special interest that detailed descriptions are warranted.

Sphene-Biotite-Hornblende Diorite; near Mount Larsen

This was found as an erratic boulder from a moraine on the ice-fringe about 20 miles south-east of Mount Larsen (Fig. 5, Plate IV). In the *hand-specimen* this rock is even-grained and speckled-grey in colour. The obvious minerals are plagioclase, hornblende, mica, and beeswax-yellow sphene.

Microscopic Characters. Hypidiomorphic-granular with grain size, in the section, averaging 0·7 mm. (Fig. 1, Plate IV). A considerable amount of granular *quartz* is present, often exhibiting shadowy extinction; it is certainly one of the latest crystallised products. It is doubtful if any orthoclase is present, none could be recognised in the two slides.

Plagioclase is present in abundance, ranging from acid labradorite to basic oligoclase. The more basic individuals are early idiomorphic crystallisations. Zoning is almost universal. *Biotite* is abundant; pleochroism—light yellow, bronze, to deep yellowish-brown. *Hornblende* is plentiful; extinction angle about 13 degrees; pleochroism, light yellow, yellowish-green, to dark green. The hornblende encloses biotite. *Sphene,* light yellow by transmitted light, dull grey by reflected light; grains often 2 mm. in length; in some sections two sets of cleavage are clearly shown; crystallisation of the sphene appears to have taken place after much of the felspar. *Magnetite,* apparently titaniferous, appears in small not abundant grains usually embedded in the biotite. *Pyrites* in scattered grains is more frequent than the magnetite. *Apatite* in very small laths is rather abundant, usually embedded in the felspars. Occasional small grey rods of *zircon* highly refracting and with straight extinction.

An *analysis* made by A. B. Walkom, B.Sc., gave the following :

SiO_2	51·91
TiO_2	2·34
Al_2O_3	20·75
Fe_2O_3	1·08
FeO	7·32
MgO	3·05
CaO	7·07
Na_2O	3·04
K_2O	2·44
H_2O+	0·58
H_2O-	0·04
CO_2	0·11
P_2O_5	0·52
	100·25

COMPOSITION OF THE NORM	
Quartz	2·88
Orthoclase	14·46
Albite	25·68
Anorthite	31·41
Corundum	1·63
Hypersthene	16·18
Ilmenite	4·41
Magnetite	1·62
Apatite	1·34
	99·61

Chemico-mineralogical Classification: Class 2, Order 5. Rang 4, Sub-rang 3 (*Hessose*).

Specimens of a rock similar in all respects but containing less sphene were found in the same moraine.

Biotite-Hornblende Diorite ; near Mount Larsen

A very similar rock to the preceding, though deficient in sphene. It was collected from the lateral moraine near Camp Lake at the foot of the Larsen Glacier. This is a fine granular grey rock exhibiting, to the naked eye, plagioclase, hornblende, and biotite.

Microscopic Characters. Hypidiomorphic granular ; average grain size in the section 0·75 mm. The constituent minerals are quartz, plagioclase (andesine and oligoclase), hornblende, biotite, apatite, magnetite, and sphene.

Quartz is present as irregular grains in small quantity only ; it is the last crystallisation product; strain shadows are frequent. The *plagioclase* is zoned and ranges between andesine and oligoclase; saussuritisation is advanced. The *hornblende* is fresh and in idiomorphic or panidiomorphic forms ; twinning is frequent ; pleochroism is strong (light yellow, deep greenish-yellow, and bluish-green. *Biotite* is distributed unequally, but always subordinate to hornblende ; the flakes are frequently bent ; pleochroic (light yellow to deep yellowish-brown). *Apatite* is abundant as idiomorphic prisms. *Sphene* is comparatively rare, occurring in minute grey grains.

An *analysis* of this rock made by A. B. Walkom, B.Sc., gave the following figures :

SiO_2	51·35
TiO_2	0·79
Al_2O_3	18·90
Fe_2O_3	2·03
FeO	7·87
MgO	3·30
CaO	8·81
Na_2O	3·73
K_2O	1·48
H_2O+	0·97
H_2O-	0·09
CO_2	8·01
P_2O_5	0·57
	107·90

COMPOSITION OF THE NORM	
Orthoclase	8·90
Albite	31·44
Anorthite	30·30
Diopside	8·39
Hypersthene	9·31
Olivine	4·47
Magnetite	3·02
Ilmenite	1·52
Apatite	1·34
	98·69

Chemico-mineralogical Classification : Class 2, Order 5, Rang 4, Sub-rang 3 (*Hessose*).

BIOTITE-HORNBLENDE DIORITE ; CAPE IRIZAR

An erratic specimen from Cape Irizar is similar to the first of the diorites described above. In this, however, the grain size is somewhat larger and the constituents show a greater tendency to panidiomorphism.

Microscopic Characters. The *plagioclases* show albite, carlsbad, and pericline twins and are very strongly zoned ; the zoning, which is from andesine to oligoclase, is often repeated a second time. *Hornblende* is more abundant than biotite and the prisms reach 6 mm. in length. The *biotite* is often enclosed within the hornblende. *Quartz* is more prominent than usual and often surrounding many crystals in poikilitic fashion. *Sphene* appears in scattered grey grains ; in the hand-specimen these are yellowish-brown. *Apatite* prisms are abundant. *Zircon*, occasional rods ; one of these is surrounded by a halo.

A rock of this class occurs amongst our collection from Dunlop Island, on the coast-line farther to the south.

Amongst the collection from the Ferrar Glacier Moraines are two very striking specimens of sphene-bearing amphibolites allied in composition to the preceding.

Sphene-bearing Amphibolite, Ferrar Glacier Moraines. This is a coarse-granular speckled rock composed of dark amphibole, white plagioclase, quartz, flakes of biotite. and grains of clove-brown sphene.

Microscopic Characters. Hypidiomorphic-granular texture. *Quartz* occurs in large and small pieces. The *plagioclase* have the composition of andesine. *Amphibole* is the most abundant constituent ; it is uralitic. *Sphene* and *apatite* are unusually abundant. *Magnetite* grains are rarer.

Another specimen of this class, though finer grained, comes from Dry Valley (Fig. 2, Plate IV).

Under the subject of the lamprophyres of the granite following reference has been made to the occurrence of a large outcrop of diorite in connection with the pink granite at Cathedral Rocks, Ferrar Glacier, as described by Ferrar. The diorites described in these pages are similar in composition, though differing somewhat in mineral contents. The characters of these rocks are not typical of normal diorites but are suggestive of lamprophyric separations. It is significant that their composition is very similar to the kersantite dykes met with intersecting the granites ; this is illustrated in the following tabulated analyses :

I. Diorite from Camp Lake at the foot of the Larsen Glacier.
  Analyst : A. B. Walkom, B.Sc.
II. Diorite from moraine about 20 miles south-east of Mount Larsen.
  Analyst : A. B. Walkom, B.Sc.
III. Diorite from Cathedral Rocks, Ferrar Glacier.
  Analyst : Dr. Prior.
IV. Kersantite crossing pink granite, Cape Irizar.
  Analyst : A. B. Walkom, B.Sc.

	I	II	III	IV
SiO_2	51·35	51·91	53·06	54·27
TiO_2	0·79	2·34	1·60	1·33
Al_2O_3	18·90	20·75	18·65	19·23
Fe_2O_3	2·03	1·08	1·44	0·73
FeO	7·87	7·32	7·58	8·29
MnO	—	—	—	—
MgO	3·30	3·05	3·78	3·74
CaO	8·81	7·07	8·25	8·41
Na_2O	3·73	3·04	3·20	3·05
K_2O	1·48	2·44	1·55	2·49
H_2O+	0·97	0·58	0·94	0·77
H_2O-	0·09	0·04	0·16	0·18
CO_2	0·01	0·11	—	0·05
P_2O_5	0·57	0·52	0·38	—
Total	99·90	100·25	100·59	102·54

THE GABBROS

No occurrences were met with *in situ*. Erratic specimens, however, are not rare in the McMurdo Sound region. These are often sphene-bearing, and in other ways approach the sphene diorites so closely as to suggest a mutual relationship. A specimen of this kind from the East Fork of the Ferrar Glacier, Upper Kukri Hills, is an allotriomorphic-granular rock with average grain size about 3 mm. Plagioclase, biotite, and uralite can be distinguished with the naked eye. The *felspars*, which are basic-labradorites, are partly saussuritised; they are twinned in broad lamellæ after the albite law, with occasional carlsbad combinations and frequent pericline twins. Colourless idiomorphic *diallage* is present, but largely converted to uralite. The *uralite* is colourless to greenish-yellow to bluish-green. Rarely small *hypersthenes* are met. Occasional idiomorphic crystals of *hornblende*, dark greenish-yellow to light yellow. Abundant *biotite*, light yellow to red-brown. Accessories are *apatite*, *magnetite*, and grey *sphene*.

Very similar to this, but more highly altered, is a sphene-bearing amphibolite from the Dry Valley Moraines.

Hypersthene Gabbro. An erratic from Dry Valley. The constituents are: *Basic labradorite* showing carlsbad, albite, and pericline twins; some individuals are zoned; *uralite* after *diallage*, remnants of which only remain; *hypersthene* changing to *bastite*; *biotite* in scattered flakes; *magnetite* in large original grains, and also as secondary dust; *apatite* in medium-sized rods; *chlorite* in connection with some of the biotite.

Another specimen almost identical with this comes from the same locality.

Uralite Porphyry. A third specimen is more porphyritic and the plagioclases are largely of a coarse lath-shaped variety. The hand-specimen is of a general dark grey colour with scattered porphyritic black uralites. In many cases kernels of diallage and hypersthene yet remain. Occasional flakes of biotite are present.

Bronzite Gabbro. This is a striking rock found in the lower moraines, McMurdo Sound. Idiomorphic honey-yellow crystals of bronzite up to 6 mm. diameter are studded through a white labradorite base.

In the slide the bulk of the constituents is found to be composed of coarse lath-shaped interlacing plagioclases ; the maximum symmetrical extinction angle on the albite twins is about 35 degrees, it is therefore a *labradorite*. The *bronzite* is fresh. There is present a very little *apatite*.

THE DOLERITES

The occurrence of extensive dolerite pipes and sheets intrusive in the Beacon Sandstone formation over a large area in the Ferrar Glacier region has been ably described by H. T. Ferrar.* The latter, arguing from physiographic forms, further suggested the extension of the area affected by these intrusions far to the northward and southward. Our collections show the truth of this surmise even to a still wider extent. Fortunately, as shown by Dr. Prior,† certain characters of this rock are quite distinctive, and serve as reliable criteria in allocating erratic specimens to that particular intrusion. A typical specimen of this dolerite is described by Dr. Prior as being of a mottled grey-brown colour, medium-grained and showing no porphyritic crystals. Under the microscope it is seen to be composed mainly of colourless augite—partly in long prismatic crystals, and partly in irregular sub-ophitic plates—and plagioclase felspar (labradorite chiefly) in stout prisms and lath-shaped crystals. Grains of magnetite and ilmenite are very sparingly distributed.

The characteristic feature which serves as a criterion for distinction is the presence, in the interstices of the rock, of more acid material showing quartz in micropegmatite intergrowth with felspar.

This micropegmatite is sometimes abundant, in other cases it is almost absent.

The texture of these rocks varies in different outcrops, and is sometimes gabbroic. In the same way slight alterations in the mineral constituents are to be noted, for instance, in the amount of the residual micropegmatite ; at other times olivine makes its appearance and the augite may be of the purplish titaniferous variety.

An *analysis* made and quoted by Dr. Prior of the dolerite from Knob Head, Ferrar Glacier, is as follows :

SiO_2	53·26
TiO_2	0·70
Al_2O_3	15·64
Fe_2O_3	0·24
FeO	7·44
MnO	0·11
CaO	12·08
Na_2O	1·25
K_2O	0·58
P_2O_5	0·04
H_2O –	0·35
H_2O +	0·41
Total	92·10

Chemico-mineralogical Classification: Class 3, Order 5, Rang 4, Sub-rang 3 (*Auvergnose*).

Dolerite erratics of this class occur throughout the whole range of our collections.

Three specimens are represented in the Beardmore Glacier material. These are of the normal type with the typical micropegmatite patches. The ferromagnesian mineral is augite, which is undergoing uralitisation, in some cases more advanced than in others.

---

* *Loc. cit.*, p. 49.

† *Loc. cit.*, p. 136.

There are two specimens of the normal dolerite from one of the Ferrar Glacier Moraines. From this locality, also, is a variation of the usual type which, however, has already been noted by Dr. Prior: this is an olivine-bearing variety with violet titaniferous pyroxene. Both the pyroxene and olivine are ophitic. Magnetite is abundant and apatite unusually so. The structure is typical of the diabases but no micropegmatite appears in the slide.

A dense variolite from the Stranded Moraines, McMurdo Sound, appear to belong to the dolerite series, and may represent the quickly chilled marginal zone as described by Dr. Prior.

At Dunlop Island, Cape Roberts, Cape Irizar, and the Moraines 20 miles south-east of Mount Larsen other examples of the usual type met with as erratics.

At Cape Irizar, dolerite erratics are frequent and some diverge from the usual class by containing a residual devitrified or variolitic glass and in some cases by uralitisation of the pyroxene. One of these erratics from Cape Irizar, judged to be an example of the dolerite formation which has suffered chemical metamorphism, is worthy of special mention. The structure is coarse doleritic. It consists of well-zoned labradorite felspars, a little interstitial quartz, deep-coloured biotite, and much uralitic hornblende, observed, in some cases, to be after almost colourless pyroxene; accessory minerals are frequent apatite rods, and occasional grains of pyrites and magnetite. No micropegmatite is observable.

DOLERITE; CAPE BERNACCHI

A hybrid rock, an *erratic from Cape Bernacchi,* proves to be a variety of the dolerite of unusual character. This is a dark grey fine-crystalline dolerite studded with somewhat oval patches up to a half-inch in diameter of a pink-coloured coarser crystallisation. These pink patches are arranged with their longer axes roughly parallel, and are suggestive of the amygdules common in lavas.

Microscopic Characters. Most of the *pyroxene* of the grey dolerite has changed to *uralite* and *chlorite.* The *plagioclase* is much clouded. *Iron ores* are abundant in grains, partly leucoxenised.

The pink areas are more coarsely crystalline and differ in constitution from the main body of the rock as follows: The felspars are *orthoclase* much kaolinised and stained with hæmatite. Yellow *biotite* in small flakes is plentiful. Occasional small idiomorphic *hornblendes* appear of yellowish and greenish tints. *Ilmenite* partly leucoxenised in grains. Frequent patches of *calcite* occupying irregular spaces between the orthoclases. The calcite is generally concentrated towards the centres of the patches, and is always so arranged as to indicate its being the latest constituent.

The pink patches are regularly distributed. The plagioclases of the surrounding dolerite are arranged with their long axes parallel to the boundaries of the patches. The crystal arrangements in the patches sometimes show a marked radial development. Occasionally the peripheral zone of the patches is rich in biotite. These facts indicate that the pink patches are later solidifications than the main bulk of the rock and are really of the nature of pegmatites occupying what apparently were residual spaces.

The association of this orthoclastic separation with the dolerite recalls the relation of the residual micropegmatite to the normal dolerite.

A like case is that cited by Dr. Prior * of a dolerite erratic from Granite Harbour.

These facts lead to the suggestion of magma-splitting on a larger scale, whereby a magma of the type producing the pink granite might be expected to result from the splitting of the parent, more basic magma, in which the dolerites were concerned.

---

* *Loc. cit.* 139

RECENT VOLCANIC SERIES

Rocks of this class are all erratics and were collected from moraines at or near the present sea-level. They have obviously been transported by floating ice from the volcanoes of McMurdo Sound.

As all the types have been met with *in situ*, and described either by Dr. Prior or Dr. Jensen, a descriptive list is all that is required here.

Cape Roberts : Kenyte : Olivine basalt.

Dunlop Island : Kenyte : Basalts : Phonolite.

Cape Bernacchi : Kenyte : Olivine basalt.

*Dry Valley.** Kenyte tuffs : Scoriaceous and tuffaceous lavas of the kenyte family : Vesicular basalt : Tinguaite.

Stranded Moraines, McMurdo Sound : Kenyte with glassy base : Kenyte pitchstone : Olivine-bearing kenyte : Glassy basalt with phenocrysts of olivine and augite : Vesicular basalt : Vesicular basalt with porphyritic augites : Basalt containing much hypersthene : Vesicular basalt containing porphyritic augite and olivine ; the vesicules are largely filled with radial-fibrous calcite : Fine-grained tuff.

THE METAMORPHIC ROCKS

Metamorphic processes are evidenced on a grand scale in the basement complex of South Victoria Land : amongst the types represented, obvious meta-sediments are prominent ; these are marbles, mica-schists and injection-gneisses. Meta-igneous rocks are represented by gneisses and amphibolites. In the case of the newer formations, local metamorphism near contacts is all that is evidenced. The vastness of the subject does not allow of any adequate discussion based on the meagre collection at hand ; but short reference to more interesting rocks only is warranted.

METAMORPHISM OF THE GRANITES

The majority of the gneiss exposures have all the appearance of having originated by the dynamo-metamorphism of granite. Many of the granites have been noted to show cataclastic structure and some of the outcrops may be seen passing into gneissic varieties. Coarse granite-gneiss of this kind forms the promontory of Cape Roberts whilst the granite mass of Granite Harbour, close by, shows clearly the first stages of dynamometamorphism : this gneiss contains frequent basic schliers and both these and the gneiss itself closely resemble those of the South Neptune Islands, off the South Australian Coast.

An erratic block of granite at Cape Irizar, weighing several tons, shows well the early stages of gneissification. This granite is of the Shap Fell type, carrying large rectangular white anorthoclases. Both the mica and the large felspar exhibit a general parallelism. The quartzes have been reduced to a mosaic : the felspars usually show crush only round the edges. It contains, besides the usual constituents, a little grey sphene, pleochroic yellow-brown allanite, and small apatite prisms.

A Gneissic Granite from a rocky point about eight miles South of Cape Irizar represents a more advanced stage. It is crossed by a narrow epidote vein. The quartzes and felspars are completely crushed to form nests of granules strung out in a linear direction. Accessory minerals are abundant, amongst them are several grains of faintly coloured fluor spar.

* T. G. Taylor, of the recent Scott Expedition, discovered a local volcanic centre at Dry Valley from which some of these may have originated.

Epidotised Granite from the same locality. This has suffered crushing and shows bundant greenish-grey epidote along the crush-lines. The ferromagnesian constituents are partly chloritised.

Another example of a crushed granite is an even-grained light-coloured gneiss from the moraine twenty miles south-east of Mount Larsen.

This is a schistose granular rock consisting of quartz, orthoclase, plagioclase, a little light-coloured yellow and green biotite, and grains of ilmenite. Granulation is far advanced.

Another specimen from the same moraine resembles this in every respect but that it appears to represent a more advanced condition of dynamometamorphism. Granulation is complete. Accessory minerals are abundant, including poikiloblastic pink garnet, light yellow zircon, and rare apatite and titaniferous magnetite.

An Erratic Specimen from Marble Point, five miles North of Cape Bernacchi, is a granite metamorphised by solutions which have passed along a vein now occupied by reef quartz. The ferromagnesian minerals have been leached out in proximity to the vein and the felspars completely saussuritised. Grains of leucoxene are abundant. The quartz shows shadowy extinction. Away from the vein biotite appears, this is pleochroic, colourless to orange-brown. The vein contains quartz with some pyrites.

Several gneissic specimens from the Beardmore Glacier are either meta-granites or meta-arkoses of the composition of granite. Obviously it is impossible to distinguish between these in the case of loose specimens.

METAMORPHISM OF THE BASIC IGNEOUS ROCKS

No cases of this kind were met with *in situ*, unless the case of the basic inclusions in the granite of Depot Island is regarded as such. Ferrar refers to a metamorphism of the dolerites by intrusion of the pink granites. It may be that some of the amphibolite erratics referred to elsewhere in the text have originated in this manner. Among these amphibolites there is a general development of uralite and saussuritisation of the felspars.

Other metamorphic rocks of igneous origin are : A banded gneiss and a mica schist with large poikiloblastic felspars, both from Dry Valley ; also a sphene-bearing actinolite gneiss from the upper glacial moraine, Ferrar Glacier.

METAMORPHOSED SEDIMENTS

Ferrar has described an extensive calcareous sedimentary belt outcropping in a nearly north and south direction along the foothills of the Admiralty Range and towards Cape Bernacchi. This we found to continue almost to Dunlop Island. At Cape Bernacchi is a thick series of contorted and brecciated sedimentary rocks, prominent amongst which is a saccharoidal marble. Zones of pseudo pebbles are evidence of dynamic forces having been involved. Mineral solutions have risen in fissures intersecting the outcrops in all directions, and have effected powerful changes in the adjacent strata.

Amongst these are quartz veins with occasional pyrites and quartz-felspar-muscovite veins with abundant black tourmaline. The coarse saccharoidal marble is the rock of chief interest. It contains a small percentage of graphite particles and crystals of iron pyrites. Several crystals of copper pyrites were also noted. Where slight impurities occur, bands containing much epidote are met. A reddish biotite is also frequently developed. Other patches contain red garnet.

At Marble Point, five miles to the north of Cape Bernacchi, a similar outcrop of marble occurs. Associated with this is a fine mica-granulite, also pyrite- and epidote-bearing quartz veins and irregular patches a few feet in diameter of coarse biotite-bronzite rock.

Several fragments of the marble formation appear amongst the rocks collected from the stranded moraines (Fig. 3, Plate IV). These are coarse-grained and granular; average grain size in the slide 0·8 mm. The rock consists almost wholly of calcite except in dark bands, where graphite makes its appearance. Besides graphite there are minute quantities of quartz, apatite, iron pyrites, and copper pyrites.

The red-brown biotite met with in the marble series is also a notable constituent of several schists and gneisses from the Dry Valley Moraines. These have the appearance of originating from calcareous slates and sandstones. The red-brown mica of one of these specimens, apparently an altered sandstone, was found to contain a notable percentage of manganese, to which, apparently, is due its colour. In another of these rocks is a band rich in poikiloblastic garnets.

Other fine-grained mica schists originating from sediments are numerous. These are similar to those frequently met with in the metamorphic zone bordering upon granitic intrusive masses. In one case, from Dry Valley, the specimen shows an actual contact of granite and mica schist, the latter representing an original sandstone.

In this case the granite is an even-grained grey variety. The schist is chiefly composed of quartz showing undulose extinction. Strongly pleochroic yellow biotite is abundant. There is present a very small amount of orthoclase showing Carlsbad twins. Minute colourless garnets are frequent.

One of the specimens from the Stranded Moraines, McMurdo Sound, is apparently an altered greywacke. It is of a general dark grey colour and composed of very regular laminæ about 1·5 mm. apart. It consists of mineral grains, chiefly quartz and felspar in the lighter bands and admixtures of ferromagnesian minerals elsewhere. Small particles of pyrites are distributed through the section.

From the Beardmore Glacier come several specimens of highly crushed granitic rocks which, as already mentioned, there is reason to believe may be metamorphosed arkoses. One of these from the Cloudmaker is of a light yellowish-grey colour showing quartz, kaolinised felspar, and glistening scales of muscovite. Cataclastic structure is evidenced under the microscope, and colourless garnets are frequent.

A very close-grained dark grey rock from the Upper Glacial Depot is very similar to this in section. In this case granulation is complete. The quartz grains appear as a mosaic under crossed nicols. The base is chiefly composed of alteration products of the felspar, namely, epidote and sericite. Occasional grains of felspar still show albite lamellæ with extinction angles corresponding to acid oligoclase. Accessory minerals are ilmenite, magnetite, apatite, and less frequent particles of sphene.

From the vicinity of the Cloudmaker comes a fine even-grained grey mica schist. The chief constituents are quartz and biotite. It is intersected by irregular veins of quartz and felspar.

In connection with the Beacon Sandstone reference has already been made to quartzites developed therefrom by the intrusions of dolerite.

EXPLANATION OF THE PLATES

(*Photographs by the Author*)

PLATE I

Figure 1.—A hand-specimen of Beacon Sandstone; $\times \frac{3}{8}$ diameter. Note the water-worn quartzose pebble in the lower part of the photograph.

Figure 2.—A concretionary nodule weathered out of the Beacon Sandstone, Ferrar Glacier; $\times \frac{3}{8}$ diameter. This has been fractured and hollowed out as described in the text.

Figure 3.—A saucer-shaped concretionary nodule weathered out of the Beacon Sandstone, Ferrar Glacier; $\times \frac{3}{8}$ diameter.

Figure 4.—The pink granite, *in situ*, at Cape Irizar; $\times \frac{3}{4}$ diameter. The large crystals are pink orthoclase; the finer material is a mixture of quartz, oligoclase, hornblende, and orthoclase. A hornblende-biotite granite.

Figure 5.—The porphyritic grey granite from the Beardmore Glacier; $\times \frac{2}{3}$ diameter. The large individuals are chiefly anorthoclase; the finer crystallisations include quartz, orthoclase, microcline, biotite, and oligoclase. A biotite granite.

Figure 6.—The grey granite, *in situ*, at the foot of the steep ascent to the Larsen Glacier; $\times \frac{5}{8}$ diameter. This is an even-grained grey biotite granite.

Figure 7.—The even-grained grey granite from the Beardmore Glacier; $\times \frac{3}{4}$ diameter. The principal minerals are quartz, microcline, anorthoclase, oligoclase, biotite, and muscovite.

PLATE II

Figure 1.—Orthoclase porphyry from the Stranded Moraines, East Fork, Ferrar Glacier; $\times \frac{3}{4}$ diameter. The porphyritic crystals are orthoclase: the base contains acid plagioclase, quartz, a little hornblende, and unresolvable devitrified interstitial matter.

Figure 2.—Grey hornblendic orthoclase porphyry, *in situ*, at the Kukri Hills, Ferrar Glacier; $\times \frac{9}{16}$ diameter.

Figure 3.—Quartz porphyry, *in situ*, as a dyke-like mass cutting the grey granite twenty miles south-east of Mount Larsen; $\times \frac{3}{4}$ diameter. Idiomorphic crystals of quartz and orthoclase are seen distributed through a grey felsitic base.

Figure 4.—Black felspar porphyry occurring as an erratic at a rocky cape about eight miles south of Cape Irizar; $\times \frac{5}{8}$ diameter. The lower light-coloured portion of the photograph is a grey biotite granite which the porphyry has evidently intruded.

PLATE III

Figure 1.—A microphotograph (× 17 diameters) of arkose from the Upper Glacial Depot, Beardmore Glacier. The photograph shows dusty felspars and clear quartzes; less frequent are darker patches of mica.

Figure 2.—The same under crossed nicols (× 17 diameters). The albite lamellæ in some of the felspar grains are rendered apparent.

Figure 3.—A microphotograph, under crossed nicols (× 16 diameters) of the even-grained light-grey granite from the Lower Glacial Depot, Beardmore Glacier. The principal minerals present are quartz, anorthoclase, microcline, oligoclase, biotite, and muscovite. Clear blebs of quartz are seen included in the felspar.

Figure 4.—A microphotograph (× 16 diameters) of the pink granite from Cape Irizar. The minerals present in the photograph are clear quartz, dusty anorthoclase, a small amount of plagioclase, biotite, and hornblende. Biotite-hornblende granite.

Figure 5.—The same under crossed nicols (× 16 diameters). The anorthoclase and plagioclase can now be distinguished by the twin lamellæ.

Figure 6.—A microphotograph (× 16 diameters) of the grey aplitic granite porphyry from Cape Irizar. This particular slide illustrates the aplitic base which predominates over the porphyritic material. In the photograph, the dusty felspar is readily distinguished from the clear quartz. The dark minerals are biotite and hornblende.

Figure 7.—A microphotograph (× 17 diameters) of a hornblendic aplitic granite porphyry occurring as an erratic at Cape Irizar. The porphyritic light-coloured individuals are zoned plagioclases. Idiomorphic hornblendes are abundant.

Figure 8.—A microphotograph (× 16 diameters) of a pink aplitic granite porphyry occurring, *in situ*, amongst the granites at Cape Irizar. This comes from another portion of the same outcrop as Fig. 6. The porphyritic individuals are plagioclase.

Figure 9.—A microphotograph, under crossed nicols (× 17 diameters) of a pink-coloured graphic aplite occurring as an erratic at Cape Irizar. Note the graphic quartz and orthoclase surrounding small porphyritic oligoclases.

PLATE IV

Figure 1.—A microphotograph (× 18 diameters) of sphene diorite from the moraine twenty miles south-east of Mount Larsen. The minerals present visible in the photograph are quartz, plagioclase, biotite, hornblende, sphene, and apatite. A sphene-biotite-hornblende diorite.

Figure 2.—A microphotograph (× 16 diameters) of a sphene-bearing amphibolite collected as an erratic from the Dry Valley Moraines, McMurdo Sound. This rock is an altered gabbro or basic diorite, and is notable for the amount of clove-brown sphene which it contains. The larger dark areas in the photograph are uralite ; smaller fragments of biotite are numerous. The felspar is of the composition of andesine and oligoclase. Grains of quartz are not infrequent. Sphene and apatite are comparatively abundant.

Figure 3.—A microphotograph under crossed nicols (× 18 diameters) of a saccharoidal marble found as an erratic at the Stranded Moraines, McMurdo Sound. Black spots of graphite appear amongst the granular calcite.

Figure 4.—A photograph of a hand-specimen of the pink granite from Cape Irizar showing on the left-hand side of the photograph a junction with a black kersantite vein ; × $\frac{1}{1}\frac{1}{2}$ diameter.

Figure 5.—A photograph of a hand-specimen of the sphene diorite found as an erratic at a moraine on the ice-fringe twenty miles south-east of Mount Larsen ; × $\frac{1}{1}$ diameter. This rock is notable for the amount of beeswax-yellow sphene which it contains. Fig. 1 is a microphotograph of the same rock.

FIG. 1

FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6

FIG. 7

[To face p. 234

PLATE II

FIG. 1

FIG. 2

FIG. 3

FIG. 4

PLATE III

Fig. 1

Fig. 2

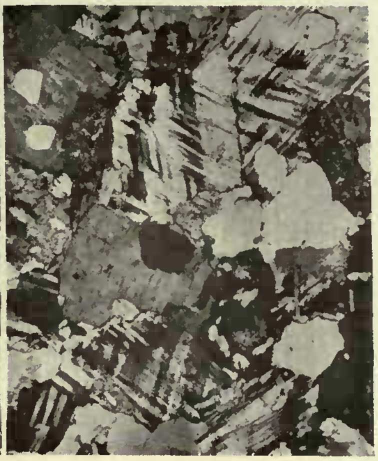


Fig. 3

Fig. 4

Fig. 5

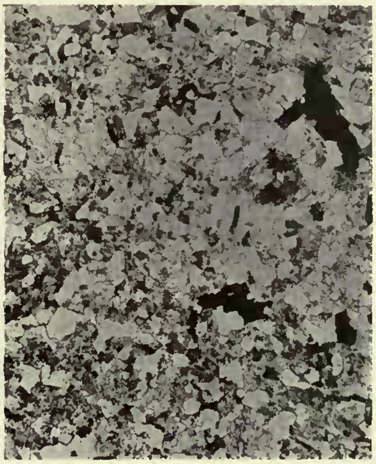


Fig. 6

Fig. 7

Fig. 8

Fig. 9

PLATE IV

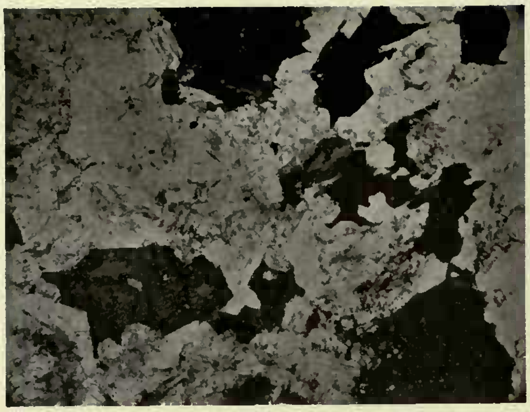


Fig. 1

Fig. 4

Fig. 2

Fig. 5

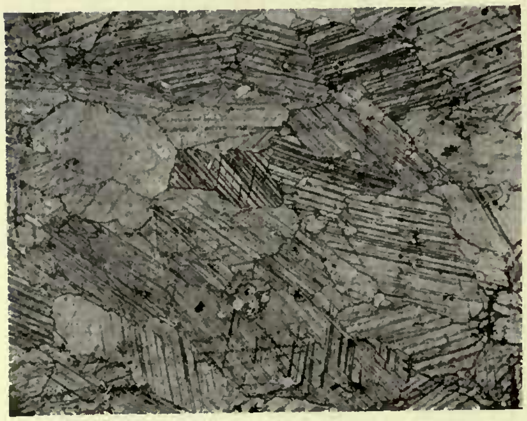


Fig. 3

APPENDIX TO PART XIII

PETROGRAPHICAL NOTES ON SOME ROCKS RETRIEVED FROM THE CACHE AT DEPOT ISLAND, ANTARCTICA

BY

LEO A. COTTON, B.A., B.Sc.

DYKE ROCK FROM CAPE ROSS, SOUTH OF DEPOT ISLAND

CRYSTALLINITY : holocrystalline.
Grain size : relative—porphyritic ; absolute—porphyritic crystals, 1 mm. ; ground-mass, ·1 mm.
Minerals present in decreasing order of abundance : hornblende, plagioclase, quartz, magnetite.
Secondary mineral : kaolin.

The hornblende is the basic variety, deep brown in colour and strongly pleochroic. The crystals are idiomorphic, excellent prismatic and basal sections being present. In a number of basal sections a colourless kernel similar in shape and similarly situated to the outline of the basal section was observed. This kernel has a refractive index and double refraction like that of felspar, but could not be with certainty determined.

There is a marked parallelism of the prismatic hornblende crystals.

The felspar is a plagioclase with very little decomposition. There is a tendency to trachytic structure, but the parallelism of these crystals is not nearly so well marked as in the case of the hornblende.

A few crystals of quartz were observed. These were rounded and possessed an outer concentric shell. They are probably foreign to the magma and the shell represents the result of chemical interaction. The shell consists of an undeterminable colourless base resembling felspar, studded with minute crystals of basic hornblende radially arranged.

The ground-mass of the rock consists of fine crystals of plagioclase and basic hornblende, with a few scattered crystals of magnetite. This rock may be termed a Camptonite.

DYKE ROCK FROM CAPE ROSS, SOUTH OF DEPOT ISLAND

Crystallinity : holocrystalline.
Grain size : relative—porphyritic ; absolute—phenocrysts, about 1 mm. (constituting less than 5 per cent. of the rock) ; ground-mass, ·05 mm.
Minerals present in their order of abundance : plagioclase, diopside, allanite (?), quartz, magnetite.
Secondary mineral : chlorite.

The plagioclase is mostly contained in and makes up about half the ground-mass. The crystals form an interlacing network between the meshes of which are contained the diopside and allanite (?) grains. The average size of the felspar laths is about ·2 mm. by ·02 mm.

Diopside is very abundant in the ground-mass and most of the phenocrysts are of this mineral. In the base the crystals take either a granular or tabular habit.

Allanite (?). This mineral is very abundant, and is quite comparable in quantity with diopside. It is strongly pleochroic from light to dark brown. Prismatic sections show a good cleavage parallel to the length. The refractive index and double refraction are both high. The crystal grains are very small and uniform in size and average only ·02 mm. in diameter. On this account the sign could not be determined. The mineral resembles, and probably is, allanite, but the small size of the grains makes the determination difficult.

Quartz is present only as a few inclusions. One large piece 2 mm. in diameter was found quite rounded. A well-marked zone about ·4 mm. in width surrounded the grain and was evidently the result of the interaction of the magma and quartz. The zone consists of small diopside crystals arranged with their lengths perpendicular to the outlines of the grain.

Magnetite occurs as a few scattered grains in the ground-mass.

Chlorite occurs in feather-like aggregates but does not appear to be due to the alteration of any of the primary minerals.

No flow structure is present. This rock may be termed an augite porphyrite.

GRANITE, SLIGHTLY FOLIATED, FROM DEPOT ISLAND

Crystallinity : holocrystalline.
Grain size : relative—even to coarse ; absolute—1 to 5 mm.
Fabric : granitoid, with very small patches showing micrographic intergrowth.
Minerals present in order of their abundance : orthoclase, quartz, albite, microcline, biotite, labradorite, apatite.
Secondary minerals : chlorite and kaolin.

The orthoclase is fairly fresh, rather more than 50 per cent. being clear and undecomposed. It has a cloudy extinction and possesses a great number of small wavy fracture lines. These indicate strain after consolidation.

The quartz for the most part has crystallised after the felspar, but small rounded or oval patches occur as inclusions in the orthoclase. This with the small amount of micrographic structure shows that some of the quartz crystallised before some of the felspar. In this respect it resembles the Skiddaw granite.* On the whole the bulk of the orthoclase crystallised before the bulk of the quartz.

These two minerals, quartz and orthoclase, constitute more than 85 per cent. of the rock. The remaining minerals occur rather sparingly. Only one crystal of labradorite was observed. This was about 2 mm. in diameter and gave a symmetrical extinction of 28° on the albite twin lamellæ.

Very little apatite was found.

The rock is a granite having affinities with the pegmatite group.

* *Q.J.G.S.* (1895), vol. li. p. 145.

Basic Enclosure in Granite of Depot Island

Crystallinity : holocrystalline.
Grain size : relative—fine to medium : absolute—·5 to 1·5 mm.
Fabric : granitoid.
Minerals present in decreasing order of abundance ; labradorite, biotite, apatite, sphene.

The labradorite is rather basic, having an extinction angle of 25° on the symmetrical albite twins. This corresponds to a composition Ab_7An_{13}.

The biotite is a deep brown variety, intensely pleochroic. There is a suggestion of parallelism in the arrangement of the prismatic flakes.

A few small crystals of apatite are present.

No sphene was observed in either of the two slides examined, but some large porphyritic crystals, 6 mm. × 4 mm. were observed in the hand-specimen.

The rock is an uncommon type, being a pure mica diorite with sphene.

INDEX

PRINTED AT THE COMPLETE PRESS
WEST NORWOOD
LONDON