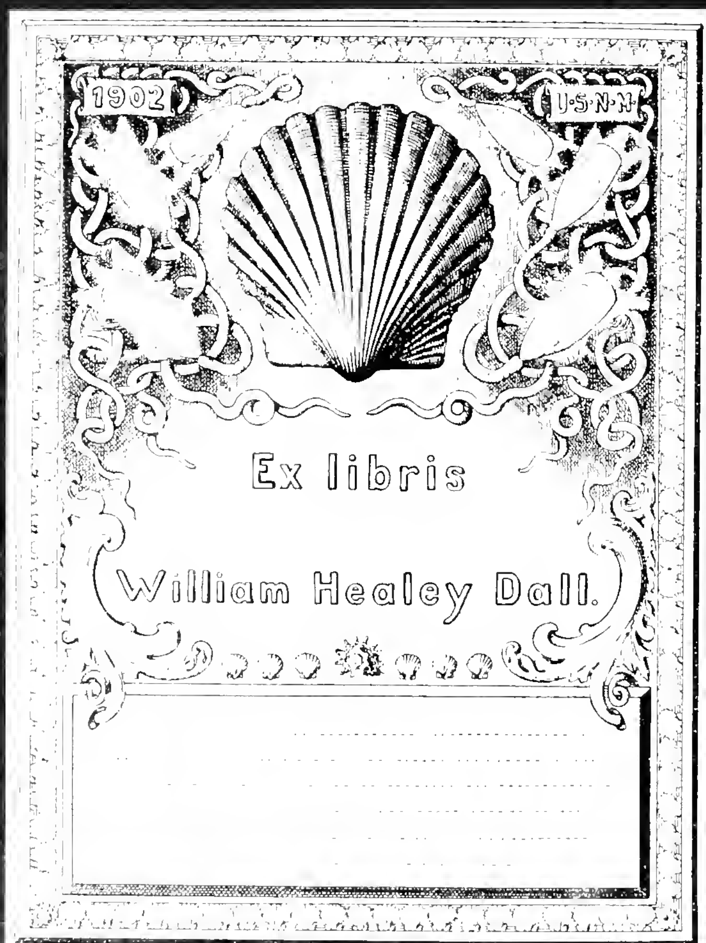
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NATIONAL ANTARCTIC EXPEDITION

1901-1904

NATURAL HISTORY

Vol. I.

GEOLOGY

(FIELD-GEOLOGY: PETROGRAPHY)

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PREFACE.

When, in 1901, the Expedition of the S.S. 'Discovery,' under Captain Scott, R.N., was sent to the Antarctic Regions, the Trustees of the British Museum gave their assistance to this national enterprise by allowing the cases containing the natural history specimens which might be obtained by the Expedition to be sent to the Natural History Museum for unpacking and sorting. They further undertook to publish a detailed report on the collections so obtained, under the superintendence of the Director of the Natural History Departments.

Some of the most important collections have been dealt with by naturalists who were members of the Expedition. Thus, the Mammals and Birds are described by Dr. Edward A. Wilson, the Isopoda and Pycnogonida by Mr. T. V. Hodgson, and the Rocks (in relation to Field Geology) by Mr. H. T. Ferrar. Other groups have been dealt with by members of the staff of the Natural History Departments of the British Museum: Mr. Boulenger describes the Fishes; Mr. E. A. Smith, the Gastropoda, Lamellibranchia, and Brachiopoda; Mr. Jeffrey Bell, the Echinoderma; Dr. Calman, the Crustacea Decapoda, and the Cumacea; Mr. Kirkpatrick, the non-calcareous Sponges; whilst Dr. G. T. Prior has prepared a petrographical description of the Rock-specimens.

It has been necessary to obtain the assistance of other specialists in order to deal with the rest of the collections. So far as the latter group of contributors is concerned, the following is a list of the subject-matters, together with the name of the naturalist who has undertaken the work in each case:—

Embryos of Seals	Dr. Marrett Tims.
Anatomy of Emperor Penguin	Mr. W. P. Pycraft.
Tunicata	Prof. Herdman.
Cephalodiscus	Dr. Ridewood.
Cephalopoda	Dr. Hoyle.
Nudibranchs and Pteropods	Sir Charles Eliot, K.C.M.G.
Polyzoa	Mr. H. W. Burrows.
Eggs and Young of Asterias	Prof. MacBride.
Amphipoda	Mr. A. O. Walker.
Schizopoda	Mr. Holt.
Nebaliæ	Dr. J. Thiele.
Ostracoda	Prof. Brady.
Copepoda	Dr. Wolfenden.

The work of securing the assistance of these specialists and of distributing the collections has been performed by Mr. Jeffrey Bell, of the Zoological Department, who has also acted as sub-editor of the Zoological and Botanical portions of the reports. The Keeper of Minerals, Mr. Fletcher, has superintended the reports in the subjects belonging to his department.

The Director desires to acknowledge the ability and energy which have been brought to bear on the preparation of the Zoological reports by Mr. Jeffrey Bell. Owing to his care, the reports have been got ready by the various contributors and published within a reasonable time after the return of the 'Discovery' from the Antarctic Regions. Neither trouble nor expense has been spared in order to render the illustration and presentation of the Natural History of the Expedition worthy of the generous efforts both of Captain Scott and his fellow-explorers and of those who provided the funds for that enterprise.

E. RAY LANKESTER.

October, 1906.

PREFACE TO VOLUME I.

THE mineral-specimens collected during the 'Discovery' Antarctic Expedition being virtually all of them rock-specimens, their importance depends, not merely on their own characters, but on the mutual relations of the masses which they represent; in these circumstances, a Report descriptive of the specimens themselves can be of little scientific value unless preceded by an account of the rock-masses of which they have formed part.

Mr. H. T. Ferrar, Geologist to the Expedition, had lived in the region and collected nearly all the specimens, and was obviously the one to be invited to prepare a monograph of the Field-geology. Fortunately he was able to accept the invitation, and to submit the manuscript of his Report before leaving England to take up an appointment on the Geological Survey of Egypt.

The scientific description of the specimens was entrusted to Dr. G. T. Prior, Assistant in the Mineral Department, who had already examined and described the mineral-specimens collected during the 'Ross' and the 'Southern Cross' Antarctic Expeditions.

The points regarded by the authors as deserving special attention are conveniently indicated in the respective Summaries (pp. 98, 139).

The elaborate Index to the volume has been made by Dr. Prior.

It has been my duty, as Keeper of the Mineral Department, to supervise the preparation and publication of these Reports, but the scientific part of the work has been done entirely by the respective authors.

L. FLETCHER.

MINERAL DEPARTMENT,
BRITISH MUSEUM (NATURAL HISTORY),
May 1, 1907.

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REPORT ON THE FIELD-GEOLOGY

OF THE REGION EXPLORED DURING THE

'DISCOVERY' ANTARCTIC EXPEDITION, 1901–4.

By H. T. FERRAR, M.A., F.G.S., *Geologist to the Expedition.*

CHAPTER I.

ISLANDS, CHIEFLY OFF THE COAST OF SOUTH VICTORIA LAND.

THE part of South Victoria Land known to us consists of a great range, or series of mountain-ranges, stretching in an almost straight line from latitude 71° S. to lat. 82° S., a distance of about 800 miles. Some of the mountains rise to a height of 13,000 feet, and it is remarkable that there is no extensive area of land lower than 4000 feet. Off this bold coast-line is a shallow sea (Ross Sea), with occasional islands arranged along a line roughly parallel to the coast and close in under it.

The earliest specimens brought back from the Ross Quadrant were those obtained by Captain BALLENY in the year 1839 from the Balleny Islands. Shortly afterwards the 'Erebus' and 'Terror' Expedition under Sir JAMES CLARKE ROSS brought back rock-specimens from other outlying islands, and until the year 1895 no additional specimens of Antarctic rocks were obtained from this area. It was also known that (1) the Balleny Islands are volcanic, one of them possessing an active volcano; (2) South Victoria Land consists of a great range of mountains probably volcanic,* and with at least one volcano still active. The specimens include scoriæ and olivine-basalt from Young Island, one of the Balleny group,† basalts, palagonite-tuffs, and granites from the largest of the Possession Islands, and basalt from Franklin Island, one of the isolated islands off the coast.‡

A French expedition contemporary with that of Ross also obtained granites § from

* Ross, 'Voyage in the Southern and Antarctic Regions, 1839–43,' 1847, vol. ii, p. 415.

† 'The Antarctic Manual' (Roy. Geogr. Soc.), 1901, p. 341.

‡ Prior, Mineralogical Magazine, 1899, vol. xii, p. 91.

§ 'The Antarctic Manual' (Roy. Geogr. Soc.), 1901, p. 449.

low rocky islets lying off the coast of Adélie Land, and these strongly suggested the existence of a continental mass of land.

The fact that blocks of gneiss and granite, probably dropped from icebergs, were dredged up in high southern latitudes during the 'Challenger' expedition was also regarded as evidence of the existence of a continent. Fragments of mica-schists, sandstones, limestones and shales, were also dredged up at the same time.* This fact was sufficient to render it extremely probable that sooner or later fossiliferous sedimentary rocks would be discovered.

In the year 1895 Mr. BORCHGREVINK obtained schistose and granitic rocks from Cape Adare.

The 'Southern Cross' collection described by Dr. PRIOR† includes various plutonic and volcanic rocks as well as siliceous slates, the latter being apparently the first sedimentary rocks found *in situ* in South Victoria Land. The slates are noted as occurring at the head of Robertson Bay. These slates are directly covered by the basalts of Cape Adare on the east, and they have been followed northward along the coast for some five miles.

The islands may be conveniently considered in the order of increasing latitude, commencing with the Balleny group near the Antarctic circle.

BALLENY ISLANDS.

This group consists of five islands lying between longitudes 161° E. and 165° E., and latitudes 66° S. and 68° S., that is to say, about the Antarctic circle. They were discovered by Captain BALLENY in 1839. He brought back specimens from Young Island, and reported the presence of an active volcano on Buckle Island, a report afterwards confirmed by the 'Southern Cross' Expedition.‡

Rowe Island, the most northerly of the group, was very distant from the 'Discovery's' track. Balleny remarks that it is low and offers no remarkable feature.

Young Island, one of the largest, is roughly 10 miles long and 5 miles broad, and, according to BALLENY, is the highest. It rises to an estimated height of 12,000 feet. It is girt by a high cliff and has the form of a terraced cone. The rock-specimens collected here in 1839 were the first obtained from what is now known as the Ross Quadrant. They "prove to be scoriæ and basalt with crystals of olivine." §

Borradaile Island is about 500 feet high and 2 miles long, and, like the others, is bounded by vertical cliffs.

* See also 'Nature,' 1898, vol. lvii, p. 420.
† Prior, Rep. 'Southern Cross' Collections (British Museum), 1902, p. 325.
‡ 'The Antarctic Manual' (Roy. Geogr. Soc.), 1901, pp. 499, 500.
§ 'The Antarctic Manual' (Roy. Geogr. Soc.), 1901, p. 341.

Buckle Island, which bears the active volcano, is probably 15 miles long. The surrounding cliff varies from 100 to 1000 feet in height, while above it the land rises as a dome to a height of about 4000 feet. The volcano is situated on the north end, which is otherwise low and flat.

Sturge Island (Fig. 1) is about 20 miles long and 7 broad, and rises to a height of over 10,000 feet. It is claviform and smooth in outline, and appears as an elongated dome surrounded by a rock-cliff which varies from 1000 to 3000 feet in height. At the north end are seen roughly parallel irregular lines, dipping at an angle of about 15° to the west. Approximately parallel to them are numerous conspicuous lenticular bands of light-yellow colour. The soundings in this area are uniform over great

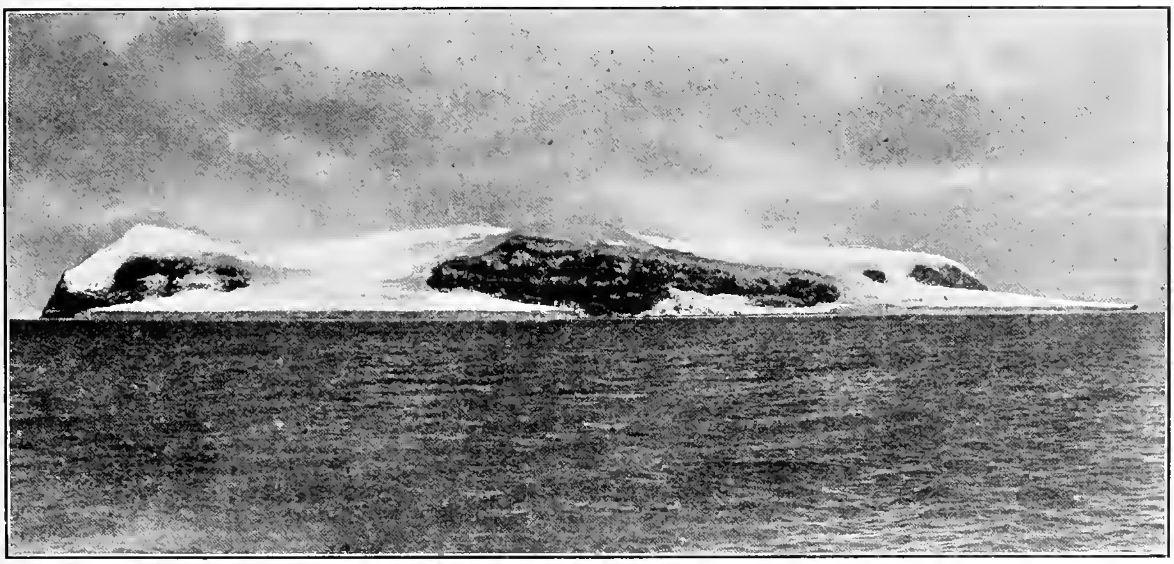

FIG. 1.—STURGE ISLAND, BALLENY ISLANDS, SHOWING TRANSITION FROM "PIEDMONT-AGROUND" TO "PIEDMONT-AFLOAT."

distances, ranging from 260 to 270 fathoms. The sea-bottom is covered with a mixture of rock-flour (902)* and ice-scratched stones (866),* including fragments of dolerite and micaceous schists (see pp. 135 and 139).

SCOTT ISLANDS.

The Scott Islands were discovered by Captain COLBECK in December, 1902,† and are flat-topped rocky islets, which rise 300 feet sheer out of the shallow sea. The smaller is practically an isolated pillar (Haggitt's Pillar), while the larger is about two miles across. Mr. J. D. MORRISON landed on the larger island and collected specimens of a trachytic rock (see p. 114) regarding which he gave the following information:— "No. 1 was taken from the south-east side, lat. 67° 24·5′ S., long. 179° 55·5′ W.,

* The numbers refer to the author's List of Specimens.
† Colbeck, Geog. Journ., 1905, vol. xxv, plate, p. 402.

being broken off the highest accessible point, about 12 feet above water-level. The strata seemed about 2 feet thick, dipping to the south-east side at an angle of 45°, striking S.W. and N.E."

The Possession Islands.

This group consists of two large and five small islands, close under the highest peaks of South Victoria Land and about 5 miles off shore and a little north of the 72nd parallel of latitude (Fig. 2). They were discovered by Sir James Clarke Ross in 1841, when a landing was made and rock-specimens were collected. They include basalts, palagonite-tuff, phonolite, and fragments of granite, but the latter were probably not found *in situ*.* Mr. C. E. Borchgrevink and Captain Jenssen both landed here in

Fig. 2.—Two of the Possession Islands.
The taller one shows the junction of two types of rock.

1895, and collected rock-material. The specimens brought back by the former have been described by Messrs. T. W. E. David, W. F. Smeeth and J. A. Schofield.†

In December, 1902, Mr. Morrison, landing from the relief ship 'Morning,' collected rock-specimens. He obtained only two types of rock *in situ*: one (No. 2) is a palagonite-tuff and the other (No. 3) a grey hornblende-basalt. He gave the following information relative to them :—"No. 2 was taken from the south-west shore of Possession Island, 18 feet above water-level, lat. 71° 56′ S., long. 171° 10′ E. There are no signs of stratification, but there is a very distinct vertical line-of-parting between the rocks forming Nos. 2 and 3. No. 3 was taken from a piece of ice floating close in shore on the S.S.E. side. The cliffs are about 150 feet high and overhanging."

From the view seen from the deck of the 'Discovery,' it would appear that the higher part is composed of palagonite-tuff, and the south side, ending in a bold cliff 300

* Prior, Mineralogical Magazine, 1899, vol. xii, p. 75.
† Journ. Roy. Soc., New South Wales, 1895, vol. xxix, pp. 461–492.

feet high, of basalt. This island, the largest of the group, is 2 miles long in a north-and-south direction. The landing place is at the northern end, which is low, flat and prominently terraced. The next largest island may be a mile across: like the first it has vertical sides. Of the other islands, three are flat-topped, about a quarter of a mile in diameter, and 50 feet high. They appear to be roughly rectangular in shape, and have bare vertical sides. A fourth forms an isolated pillar appearing to be made up of vertical columns, while a fifth is less than a quarter of a mile across and over 100 feet high. This last shows an uneven junction of two rocks at about 50 feet above the sea (Fig. 2). The distribution of snow would seem to show that the rocks are tuff and basalt, the tuff being uppermost. The junction is irregular, but on the whole slopes from west to east, away from the high land.

Fig. 3.—East side of Coulman Island, showing the horizontal structure of the rocks, and the "Piedmont-aground" which surrounds the island.

Coulman Island.

This island is situated in latitude 73½ S., longitude 170° E. It was discovered by Sir James Clarke Ross, but the first rock-specimens were brought back by the 'Southern Cross' expedition; they were determined to be hornblende-basalt and basalt-agglomerate,* but no details were given as to the distribution of the rocks. Here also the land is characterised by bare rock-cliffs more than 1000 feet high, which fall sheer away to the sea. The island has an even outline. Its top is nearly flat at Cape Wadworth, the north end, but at the south end rises to nearly 3000 feet. It is about 20 miles long, and averages 7 miles in breadth. Cape Anne, the south end, terminates in a bare cliff over 2000 feet high. It shows chrome-yellow patches in several places,

* Prior, Rep. 'Southern Cross' Collections (British Museum), 1902, p. 322.

and, by analogy with the yellow lenticular patch of basalt-agglomerate (82) at Cape Wadworth, we may infer that the south end is also partly of the same rock. As the yellow patches lie almost horizontally it is highly probable that the island consists of alternating sheets of basalt and basalt-agglomerate (Fig. 3).

In addition to bedding-planes visible near Cape Wadworth, there are dykes running vertically up the cliffs. Among the specimens collected by the 'Discovery' from this Cape, there are basalt-scoria (80), basalt-agglomerate (82), and a basalt (81) obtained from a dyke standing out on the cliff-face. Such dykes do not reach the top of the cliff but, after extending some way up a steep slope, end off at the base of the agglomerate. Only a quarter of an hour could be allowed on shore, but as the ship steamed into Lady Newnes Bay quite similar structure-lines were seen on the west side of the island and on the mainland (Cape Jones), areas which were possibly at one time continuous. The distribution of snow on the west side of the island points to gentle folding of the rocks about an east-and-west axis, but soundings of over 150 fathoms in the channel show no continuation of this fold towards the west.

Franklin Island.

Franklin Island is situated in latitude 76° 8′ S. and longitude 168° 12′ E., and until the 'Southern Cross' Expedition this was the most southerly land from which rock-specimens had been obtained. The island was discovered by Sir James Clarke Ross, who gave its length as 12 miles and its breadth as 6 miles. He described its north side* as a line of dark precipitous cliffs between 500 and 600 feet high, exposing several longitudinal broad white bands and two or three bands of a red-ochre colour. The specimens he collected are all basalts of one type,† while in the 'Southern Cross' collection there is a specimen of magma-basalt (limburgite) remarkable for the number and large size of the olivine-enstatite nodules.‡

From Mr. J. D. Morrison of the 'Morning' five specimens of similar magma-basalts with olivine-enstatite nodules were received; with them was the following note:—"Nos. 4 and 5 were taken from Franklin Island, from a belt of rock about 30 feet thick running horizontally along one side about 300 feet above sea-level. Height of hill about 700 feet; very difficult to ascend, as the slope is composed of small stones lying at an angle of about 45°. Nos. 6 and 7 were broken from a large boulder lying at the foot of the hill. The beach is about half a mile broad and a mile long, almost flat and about 10 feet above sea-level. Large boulders and heaps of shingle are scattered over the beach, which is on the south-west corner of the island."

* Ross, 'Voyage in the Southern and Antarctic Regions, 1839-43,' 1847, vol. i, p. 215.
† Prior, Mineralogical Magazine, 1899, vol. xii, p. 79.
‡ Prior, Rep. 'Southern Cross' Collections (British Museum), 1902, p. 328.

Beaufort Island.

This island lies in latitude 77° S., longitude 167° E., and about 12 miles off Cape Bird, which is the north extremity of Mount Erebus. Sir James Clarke Ross described it as small and conical;* we saw it from many points of view and estimate its length to be 5 miles, its breadth 2 miles, and height 1000 feet. It has a rugged outline, with a very steep snow-covered slope on the west side and a bare precipitous cliff on the east side. Its summit is a narrow ridge running north-and-south. No specimens have been obtained from this island.

Table of Distances.

A brief table which shows roughly the distances between some of the volcanoes and islands will not be out of place here.

Mount Erebus to Cape Horn	3000 miles
,, ,, to Mount Haddington (Swedish Expedition)	2500 ,,
,, ,, to Mount Gauss (German Expedition)	1600 ,,
,, ,, to Tongariro (an active volcano in New Zealand)	2600 ,,
,, ,, to Buckle Island Volcano	720 ,,
,, ,, to King Edward VII Land	500 ,,
,, ,, to Cape Adare	420 ,,
,, ,, to Mount Longstaff	380 ,,
,, ,, to Possession Islands	375 ,,
,, ,, to Coulman Island	260 ,,
,, ,, to Mount Melbourne	200 ,,
,, ,, to Franklin Island	90 ,,
,, ,, to Mount Discovery	70 ,,
,, ,, to Mount Terror	25 ,,

* Ross, 'Voyage in the Southern and Antarctic Regions, 1839–43,' 1847, vol. i, p. 217.

Chapter II.

THE ROSS ARCHIPELAGO.

This group of islands includes practically all the land within 50 miles of the 'Discovery's' winter quarters, and is the most extensive area not directly joined to the mainland. The group is important because it has long been a centre of volcanic activity, which continues even to the present day.

Ross Island.

Ross Island is practically made up of the volcanic cones, Mounts Erebus and Terror, Cape Bird (Mount Bird, as it may be called), and another convex dome, Mount Terra Nova, lying between Mount Erebus and Mount Terror. This island therefore consists of four distinct volcanoes, and of these the greatest, Mount Erebus, is still active. This mass of ejected material lies between latitudes 77° 9′ and 77° 49′ S., and longitudes 166° 8′ and 169° 10′ E. It forms an island having roughly the shape of an equilateral triangle with a side of 50 miles.

Soundings in the waters around this island are unfortunately incomplete, but the few that we have would seem to show that the depth is greatest close to the shore and decreases gradually outwards. Whether or not this anomalous deepening is due to overweighting of the crust by so many huge volcanic piles close together is not clear, but the occurrence is suggestive.

Mount Erebus (Fig. 4) is 12,922 feet high, and was active when seen by Sir James C. Ross in 1841, "emitting flame and smoke in great profusion." * During our two years' stay in Winter Quarters at its base the snow was always white and continuous to the summit, and only steam was ever seen to be erupted. On three sides the mountain rises directly from sea-level, and has flowing convex curves, which give it a very massive and undenuded aspect. Three stages in its history appear to be recorded in its contours. Of these the first was by far the most violent, and produced a cone with crater about 8 miles in diameter. The walls of this still stand, and encircle it as a girdle about 6000 feet above sea-level. In profile, on the north side this ring appears as a strong outstanding crag, and is separated from the mountain-side by a deep notch, while on the south side there is only a mere shoulder to interrupt the regular convex curve. The second stage is rendered evident by the existence of the lip of a later crater at a height of nearly 11,000 feet. Old lava-streams from it, swept bare of snow, can now be seen. The latest stage is recorded by the present small cone, which has been built up asymetrically within the second, and from this steam now issues. Dr.

* Ross, 'Voyage in the Southern and Antarctic Regions, 1839-43,' 1847, vol. i, p. 216.

WILSON has recorded five or six other steam-jets issuing from the north-east side, but from the ship it was unusual to distinguish more than two. Mount Erebus bears a very striking resemblance to Mount Etna as shown in VON WALTERSHAUSEN'S picture,* and is much more dome-like than is suggested by the published pictures of the better-known active volcanoes.

Owing to the difficulty of access, few rock-specimens could be obtained from Mount Erebus itself. Specimens, however, were got from the following localities: (a) *The Turk's Head*, a bare cliff which rises sharply from the sea to a height of about 300 feet on the south-west side of the mountain. Mr. Hodgson tells me that the tuffs which build up this headland are exposed for a length of about 200 yards along the shore, are bedded, and dip to the north-west at an angle of nearly 40°. (b) *Cape Royds*, a promontory on the west side of Mount Erebus, having an area of about 3 square miles. This area is bare of snow, and consists of dyke-outpourings of basalt with lenticular crystals of felspar (818) (leucite-kenyte, see p. 111). The Cape is rectangular in shape and displays many outstanding dykes which rise to heights of 200 and 300 feet, but are now being rapidly disintegrated. A similar, but vesicular, rock (lava) (820) forms a small knoll, 1500 feet up this side of Mount Erebus, but, as the rest of the surface was covered with snow, no relations between these rocks could be made out. (c) *Cape Barne*, the bare rocks which lie about 3 miles south of Cape Royds and are separated from the latter by a shallow bay. The Cape consists of black vesicular basalt-lava (813) which dips to the west away from Mount Erebus. The extreme end of the Cape is a pinnacle rising 200 feet sheer from the sea, and is separated from the main mass of the Cape by a scree which prevents the junction of the vesicular rock and the basalt-agglomerate (815) of the pinnacle being seen. (d) *The Skuary*, an area of bare land, between Cape Barne and the Turk's Head. This is about 2 square miles in extent, and except along the shore, where rock *in situ* is visible, is covered by moraines. The moraines include fine tuffs (808) and a compact, grey alkaline-basalt or kenyte (812) containing parallel lenticular crystals of felspar. Below them, and extending to the shore, vesicular glassy basalt-rock (811) of the same character is seen *in situ*. This last is over 100 feet thick, and appears to consist of

FIG. 4.—CASTLE ROCK AND MOUNT EREBUS.

* Scrope, 'Volcanos,' 2nd edit., 1862, p. 190, fig. 43.

successive lava-flows laid horizontally one upon another. These rocks are similar in character to the lavas with lenticular felspars of Cape Royds, and are also related to the rocks of the neighbouring Dellbridge Islands, to be considered later.

Mount Bird is a flattened dome over 3000 feet high and, like Mount Terra Nova, which attains a height of about 7000 feet, is an undenuded volcanic cone. No specimens have been obtained from either of these mountains.

Mount Terror (Plate I) is a quiescent volcano 10,750 feet high. It forms the eastern part of Ross Island, and, though not quite so high as Mount Erebus, covers almost as great an area. Its base is circular and has a diameter of perhaps 20 miles; its surface is almost completely snow-covered. On the south side the covering is so thick that no parasitic vents, if present, could be distinguished. On the north side, especially above Cape Crozier, is the largest area of rock-exposure, and here all eminences which have been examined were of the nature of subsidiary surface lava-flows. Some of these are quite conspicuous, and from them many specimens have been collected.

Fig. 5.—Cape Crozier and Mount Terror.

The 'Southern Cross' Expedition* obtained hornblende-basalts from a bare rock-cliff 10 miles or so to the west of Cape Crozier, and from the red and yellow "blazes" that occur in this cliff it would seem that basalt-agglomerate is also present. From the cones on the east side of the mountain above the Great Ice Barrier of Ross, Dr. Wilson collected basalt-scoriæ (824) and limburgite (825) and proved the cones to be due to subsidiary eruptions. From the bare rock-cliffs (Crozier Cliffs), against which the ice-sheet abuts, Dr. Wilson also collected rock *in situ*. His specimens are of two kinds: (1) columnar basalt (830 and 848), which forms the mass of the cliffs and reaches a height of 800 feet above sea-level; and (2) a yellow trachytic rock (831), occurring in irregular lenticles in the mass of the cliff. At one spot a rough stratification was observed, and it is possible that stratified tuffs are there developed.

From a locality he termed the *V-Cliffs Hogsback*, Mr. Hodgson collected specimens of coarse yellow tuff (783), red vesicular basalt (778) and a basaltic bomb (776). This locality is on the south-east side of Mount Terror, 20 miles south of Cape Crozier and 30 from the ship. It is one of two exposures which have been found on

* Prior, Rep. 'Southern Cross' Collections (British Museum), 1902, p. 322.

the south side of the mountain. The other exposure has been termed the *Sultan's Head*, and Mr. Hodgson here obtained some bedded yellow tuffs (785 to 793), also some fragments of vesicular basalt (795).

At *Cape Crozier* (Fig. 5) itself, at sea-level, a stratified palagonite-tuff (228 to 230) was seen bedded parallel to the present slope of Mount Terror and dipping to the west beneath a basaltic lava-flow. This tuff is brown in colour and is very friable, crumbling easily into rounded pellets about an eighth of an inch in diameter. The surface of the rock was whitened by crystallisations of hydrated sodium sulphate (glauber salt). Bombs and a great variety of volcanic rocks, also granites (197), dolerites (210) and sandstones (214), were found lying about at this height, but these were usually ice-scratched (186). A boss about 900 feet high appears to be a pipe or plug of some now defunct volcanic vent; the rock (176) is a limburgite containing red and green olivine-augite nodules. A rounded knoll of trachyte (224), half a mile east of this boss, attains a height of 1400 feet. Black pebbles of glassy basalt (217, 218, 219), quite similar to the majority of the pebbles composing the terraces a short distance lower down the hill, were scattered all over the surface of this trachyte-dome, and appeared to have been included in it, but in the short time allowed on shore no trachyte actually enclosing basaltic pebbles was met with. On the south side, the 900-foot boss of rock mentioned above adjoins a mass of yellow tuff (231) through which a grey green trachytic rock (188, see p. 114) seems to have been forced. From the ship many other parasitic vents were seen on the slopes of Mount Terror, but were not visited.

The Winter Quarters.

Winter Quarters were taken up near the end of a long peninsula which juts out southward from the base of Mount Erebus in latitude 77° 51′ S., longitude 166° 45′ E., and in this district not much information could be obtained relative to the general geological history of South Victoria Land (Plate II). The peninsula is 10 miles long by 2 miles broad, and has an average height of 700 feet. It is entirely composed of recent volcanic rocks, and only about four of its twenty square miles are free from snow.

At *Hutton Cliffs*, a stratified basalt-tuff occurs as a cliff 500 feet high. This tuff-cliff is quite isolated, and is divided into two parts by the snow which falls over the cliff as a small glacier. The northern part (452–457) is composed of rather coarse tuff and is more definitely stratified than the southern (458–462); but for each mass the dip is the same, and is about 60° to the north-north-west. The rock consists mainly of fragments of vesicular basalt-glass and varies from yellowish-green to almost black in colour, but some of the hand-specimens have reddish bands of palagonite, and others have incrustations of calcium carbonate. These cliffs are about 5 miles distant from Castle Rock and 10 miles from the Turk's Head.

The *Sulphur Cones* lie on the north side of the peninsula at the foot of Castle Rock and at a distance of three miles from the ship, and are so called because native sulphur was found scattered over their surfaces. They rise 50 to 100 feet above the ice, and consist of black hornblende-basalt and olivine-basalt (382–386, see p. 103) which have apparently filled up volcanic necks now undergoing rapid denudation. The sulphur (379) is found thickly distributed over the surface of the frost-riven rock and is sometimes in quite perfect crystals.

Castle Rock (Fig. 4), 3 miles distant from Winter Quarters, rises to a height of 1400 feet as a bold crag. It is surrounded by vertical cliffs 400 feet high. On the south the foot of the crag is snow-covered, but on the north the land falls sheer away for 1000 feet. On the east and west sides black basalt can be seen forming the lower part of the crag, which consists above entirely of palagonite-tuff (380). The tuff varies much in texture; sometimes it consists of yellow and black angular fragments of olivine-basalt and basalt-glass half an inch across and very uniform in size; in other places the black masses attain as much as a foot in diameter; sometimes they are almost circular in section, and are often arranged in parallel rows. The summit of the rock is flat and strewn with loose black fragments of olivine-basalt (319), more than two inches in diameter and very uniform in shape and size. About a mile to the northward of this rock occurs another crag consisting of tuff quite like the former and possibly of similar age.

Crater Hill. Along the south-east side of the peninsula there are three scoria-craters. Two of these are rather insignificant, but the third, Crater Hill, rises to a height of over 1000 feet, and the crater-lip at its summit is almost perfect. On the north side the lip rises about 200 feet above the bottom of the crater, but on the south side it has been broken down. The rocks obtained from this hill include black vesicular basalt (341) and red scoriaceous basalt-glass: the latter has obviously flowed over the lip of the crater and now forms the highest point of the hill. Near the south foot of Crater Hill, porphyritic olivine-basalts (656 and 659, see pp. 105–6) rise sheer out of the sea and form a cliff. They appear to extend as horizontal sheets right under both Crater and Observation Hills.

The *Harbour Heights*, or *Arrival Bay Heights*, as they have been sometimes called, include the three prominent eminences between Castle Rock and Hut Point. They rise over 100 feet above the general level of the snow-covered peninsula. Numerous vesicular olivine-basalts (323) and basalt-bombs (367) have recently been ejected from these vents, and an occasional flat space, bare of snow, exhibits massive but vesicular lava-flows of olivine-basalt (366) (Plate II). These volcanoes have a general resemblance to the Pleistocene * volcanoes of Auckland in New Zealand. Between the southernmost crater of the Harbour Heights and Crater Hill there is a basin-shaped depression, the vent of another small volcano. Near this depression occurs a large rock-mass measuring quite 15 feet across and 12 feet high. This rock appears to be the remains of a dyke, and from it the specimens (369–378) were taken. It is a limburgite with abundant foreign inclusions. Of these some are of

* Hutton, Trans. New Zealand Inst. (1899), 1900, vol. xxxii, p. 178.

pure transparent felspar, while others have the mineral composition of gabbro and peridotite (see p. 107). Most of the coloured inclusions are quite angular, but a few are rounded; the largest of them are about three inches long.

On the south-east side of the crater a non-vesicular black olivine-basalt, approaching limburgite in character (326, see p. 105), forms a rugged hillock about 100 feet high. The exposure of rock is quite 50 yards across, but the material is crumbling rapidly away and fresh rock is only obtainable near the summit.

Observation Hill. At the extreme south-west point of Ross Island is Observation Hill, which is separated from its neighbour, Crater Hill, by a narrow *col* called The Gap. Observation Hill has very steep slopes which make an angle of 40° to the horizontal, and, almost meeting in a point, produce a strikingly pyramidal hill (Plate II). The south-west side slopes away more gradually and terminates in Cape Armitage. This prolongation appears to be due to the presence of a sheet of rock which is bedded horizontally. This rock (553) occupies but a small area, about 200 yards long and 50 yards broad. The rock is a porphyritic olivine-basalt, almost black in colour and containing phenocrysts of green olivine up to one-eighth of an inch in diameter. Observation Hill appears to have been built up of successive flows of trachytic lava which have welled up through one single outlet. These flows are now to a great extent denuded; but on the south-east side the remains of a sheet occupy the greater part of the hillside, and rest upon another similar sheet (412). The lower sheet spreads out and forms the flatter south-east side of the hill.

On the north shoulder of the hill the trachytic lavas show a rather greater variety of texture, especially near the 400-feet contour. A dark-grey hornblende-trachyte (273 and 281), with abundant lapilli-like inclusions (see p. 118), up to an inch in diameter, forms the shoulder on which a perched block of black vesicular basalt is prominent. The rock with these inclusions has a conspicuous platy structure, and the upturned edges of the slabs into which it weathers may be traced across the Gap to the base of Crater Hill. This platy rock is considerably contorted and its apparent strike is exceedingly variable, sometimes turning through more than two right angles in 50 yards. It is obviously older than, and unconformably overlain by, the yellow hornblende-trachytes (278, 279, 280) of the higher part of the hill. Higher up the hill occurs a dyke of grey hornblende-trachyte (277, see pp. 117 and 119). The dyke is not more than 10 feet broad, but is traceable 100 feet vertically up the hill. The top of the hill consists of a yellow trachyte; locally it is streaked with grey ribbon-like bands (288) which follow the flow-structure. The weathered surface of the rock is honeycombed, but as here the wind removes the snow immediately after its fall very little frost-action seems to take place. On the southern side of the summit the darker rock begins to preponderate, and at a point some 30 yards away from the top, and 50 feet below it, the yellow rock gives place to a dark-grey hornblende-trachyte (290). Below this rock comes another dark-grey hornblende-trachyte with spheroidal structure (655). The spheres which make up the mass of this exposure sometimes attain a diameter of over 2 feet and are visible over an area of some 200 square feet. The spheres are all planed off to an even surface, and there is no change in the slope of the hill to correspond with the junction of the two rocks.

Turtle Back Island.

Turtle Back Island, low and insignificant in aspect, lies in the bay between the Winter Quarters peninsula and the ice-tongue in Erebus Bay. It is less than a quarter of a mile long and about 100 yards broad, is rectangular in plan, and rises to a height of 50 feet. The loose rock-material on the surface of the island is bedded, and the layers of dark rock form a small anticline, of which the axis is the longer or N.E.-S.W. diameter of the island. Two boulders of kenyte (trachydolerite) with lenticular crystals of felspar (447 and 484) were found on this island. They are similar to the rock-specimens brought from the lower slopes of Mount Erebus, but are more glassy and of a black colour. Black augite-olivine nodules (448 and 451) are common, but the mass of the island consists of fine-grained fragments of olivine-basalt (449).

Black Island.

In point of size Black Island comes next to Ross Island. It lies south of latitude 78°, and is roughly triangular in plan, having a side about 15 miles long (Fig. 32, p. 58). It shows two central peaks, each over 3000 feet high, and appears to be composed entirely of volcanic rock. It is quite surrounded by glacier-ice, and is therefore almost a nunatak. It is probably connected with White Island. situated to the eastward, by an isthmus rising about 200 feet above sea-level. Specimens from rock *in situ* were obtained from a hill, 900 feet high, near the north end of the island. Compact and vesicular basalt-lavas (593, 594, 595) were obtained high up, but no specimens of rock *in situ* could be obtained from the lower slopes, which were completely covered with rock-*débris*. At the south-east end is a yellow trachytic rock (609, 610); it appeared to be a dyke nearly a quarter of a mile wide breaking through the black basaltic rock. The rock forms a bold headland nearly 400 feet high. The major joints, which are vertical, strike north-west and south-east, and notable variations in the appearance of the rock occur on either side of the joints. There are two other apparently similar rock-exposures near this spot, but time did not permit their examination.

White Island.

This island is 20 miles long, but is less than 5 miles broad. Its longer axis is nearly north-and-south; the island lies between the longitudes 167° and 168° E., and is south of latitude 78° S. The land rises very suddenly out of the ice which surrounds it, and attains a height of 2000 feet. The only rock *in situ* obtained from it is a black hornblende-olivine-basalt (311), which occurs as a boss on the summit. One or two crateriform depressions occur on the lower portions of the island, and there seems little doubt that the whole island consists of volcanic rock.

"Brown Island."

This mass of land, about 15 miles long and 5 miles broad, is only apparently an island, for it is connected by a narrow isthmus about 8 miles long to Mount Discovery, a volcanic cone on the edge of the mainland. As the peninsula is so nearly isolated, and bears so great a resemblance to the other islands, it is convenient to include it in this chapter. When the ice was at a maximum "Brown Island" was certainly cut off from the mainland, which lies to the west. If the moraines covering the isthmus could be removed it is probable that even now an island would be produced.

"*Brown Island*" is 2812 feet high and entirely composed of volcanic rocks. The northern end is comparatively low and flat. Since many patches of rock of a bright-red colour occur scattered over it, we may presume that scoria-cones are present. The southern and higher end consists of a single crateriform hill, and around the crater are red vesicular basalt-lavas (605) which have flowed over the sides of the rim. A hornblende-basalt (608, see p. 104) occurs on the east side at a height of about 2000 feet. This rock dips north at an angle of 63°, and from the fact that it ends abruptly as a cliff there is little doubt that much of the original lava-stream has been removed. On the north side of the crater a subsidiary peak of banded yellow rock forms a massive hill 500 feet high. The crater is at least half a mile in diameter, and a small shallow pool about 100 yards long occupies its centre. There is little ice or snow in the crater, the lip of which is about 100 feet above the pond. On the west side a white trachytic rock (606) has forced its way through the covering of basalt-glass, and was found on the crater-lip. On the lower slopes no rock *in situ* was observed, but the whole surface was covered with black smooth loose fragments of basalt (603), like the black pebbles at Cape Crozier described on p. 11.

The Dailey Islands.

A number of conical islands, the Dailey Islands, rise through the floating ice at the head of McMurdo Sound. They are five in number, and all lie almost on the same east-and-west line. Four of these are small and conical, and not more than a quarter of a mile in diameter. The fifth is perhaps a mile long, half a mile wide, and 200 feet high; it is the only one that is at all easily accessible. It is situated on the western margin of the pinnacled ice* (Fig. 44, p. 79). The specimens collected are all of basaltic rocks of limburgite type (510), but plutonic boulders

* Ferrar, Geog. Journ., April 1905, vol. xxv, plate, p. 374.

lie on the surface and in the small crateriform hollow at the centre of the island. There are one or two dykes which project slightly above the loose scoriaceous matter of the general surface.

The Dellbridge Islands.

These four islands lie three or four miles south-west of the base of Mount Erebus and twelve miles north of Winter Quarters; although the nearest together are two miles apart, they are probably all remnants of a once continuous land-mass.

Inaccessible Island, the most northerly of the group, is elongated in an east-and-west direction, and has an almost sheer cliff facing the south. Its north side slopes at about 40°, and is therefore too steep in places to hold the disintegration-products of the rocks which form its higher peaks. The dimensions of the island are, roughly, length two miles, breadth half a mile, and height 500 feet. Mr. Hodgson collected specimens here, and tells me that the rocks are much confused, but generally dip to the north. The specimens include a red vesicular trachytic lava (802), porphyritic basalts (805), yellow trachytes (803), and trachydolerite of intermediate character (804); on the south-east end there are many irregularly bedded chrome-yellow bands. *Tent Island* is nearly rectangular in plan, and has sides about a mile long. Its greatest height is about 400 feet, and the highest point is close above the steep north-west cliff. The upper surface of the island slopes to the south-east and agrees with the dip of the lava-beds. The lowest rock exposed is a basalt-agglomerate (817) which occupies the lowest 100 feet on the north-west cliff. It is covered by sheets of a vesicular glassy kenyte (463–466), with lenticular porphyritic crystals of felspar, like the rock of Cape Royds. These sheets have a dip of about 20°, are parallel, and are each about 20 feet thick. *Razor Back Island* is merely a ridge of rock rising 100 feet above the water. Its sides meet to produce a central ridge of which the angle is not much greater than a right angle. The long axis is perhaps half a mile long, and along the same straight line is the *Little Razor Back Island*. The specimens obtained are vesicular lavas of olivine-basalt (470, 471) and of trachytic rocks (473, 476).

Chapter III.

THE MAINLAND OF SOUTH VICTORIA LAND.

Cape Adare.

It will not be out of place to supply here a few additional notes on the rocks of Cape Adare, latitude 71° S. It may be pointed out that the Cape lies at the foot of the gigantic Admiralty Range, and is formed of horizontal sheets of basalt and basalt-

Fig. 6.—Cape Adare Peninsula, from Ross Sea.

agglomerate, similar to those which occur in Coulman Island and perhaps the other islands off the coast.

The peninsula of Cape Adare (Fig. 6) consists mainly of nearly horizontal sheets of basaltic lava laid one above another to form a flat-topped promontory, which gradually increases in height from north-west to south-east. Dykes occasionally cut across these sheets.* The successive sheets are thinner and more numerous at the north-west

* Prior, Rep. 'Southern Cross' Collections (British Museum), 1902, p. 327.

extremity, but they become thicker, and are slightly inclined upwards two miles or so towards the south-east. The following sections may be of interest:—

(A) near the north end of the Cape—

Top.	(6) 100 feet—red basalt-glass (865)
	(5) 300 feet—black hornblende-basalt (859–861)
	(4) 50 feet—tuff (857)
	(3) 100 feet—basalt with vertical joints (856)
	(2) 50 feet—vesicular basalt (854)
Bottom.	(1) 200 feet—talus

(B) about two miles south of the end of the Cape—

Top.	(6) 600 feet—(unexamined)
	(5) 100 feet—tuff
	(4) 50 feet—boulder-breccia (54)
	(3) 60 feet—black olivine-basalt, weathering into vertical columns (49)
	(2) 100 feet—red scoriaceous basalt (51)
Bottom.	(1) 100 feet—scree-slope

This approximately horizontal structure appears to be characteristic of the steep coast line between Cape Adare and Cape Jones, a distance of about 150 miles. This part of the coast is a cliff varying between 1000 and 2000 feet in height. Sometimes anticlinal and synclinal folds, whose axes appear to run east-and-west, are seen. Occasional red bands, possibly like those on Coulman Island and Cape Adare, can be distinguished.

The Volcanic Cones on the Mainland.

The number of volcanic cones on the mainland is less than has been hitherto supposed,* but those seen are interesting from their occurrence on what is probably a great line of fault. These cones all rise from the low foothills that form the coast, and the latter is always parallel to the mountain-ranges. The volcanoes, being isolated cones and having as a background the massive main range, stand out most prominently.

The Summit of Cape Jones (Fig. 7).

The summit of Cape Jones may be taken as a type of these. The hill near the end of the Cape rises to a height of over 3000 feet, and shows admirably the even convex curves of mountains of accumulation. The whole is covered by a deep pall of snow, which either breaks off at the edge of the high sea-cliff, or blends gradually with the ice-sheet of Lady Newnes Bay. This volcano occurs in latitude $73\frac{1}{2}°$ S., longitude 170° E. It lies to the west of Coulman Island, and on the strip of foothills which is here nearly 20 miles broad. From the north these

* J. W. Gregory, 'Nature,' 1901, vol. lxiii, p. 610.

foothills can be seen to be decreasing slightly in height westwards towards the base of the Admiralty Range, and thus appear to mark off a great longitudinal valley running parallel to the coast.

Cape McCormick.

On the end of Cape McCormick, latitude 72° S., there are two bare cones which rise 1000 feet above the sea-cliff. They have crateriform summits which bear a striking resemblance to Crater Hill near the Winter Quarters of the Expedition.

Fig. 7.—A Volcanic Cone on the Mainland; the Summit of Cape Jones. The 'Discovery' in a gulf in the Lady Newnes "Piedmont-afloat."

Mount Brewster.

Mount Brewster, on the north-east side of Lady Newnes Bay, though it does not attain a great altitude, is noteworthy. The mountain is about 3000 feet high, and rises from the flat lowland at the base of the mountain range. The range with its angular spurs towers above the foothills, and Mount Brewster with even outline rises but little above the snow-covered land around it. The summit of this hill is slightly flattened, and some part of the crater may still remain.

Mount Melbourne.

This mountain, 8000 feet in altitude, is situated in latitude 74½° S., longitude 165° E., and on three sides rises directly from the sea; on the fourth side it is joined to a range of higher peaks. The slopes of the mountain are not markedly convex, but appear symmetrical from all points of view. The base is less than 20 miles in diameter, and the mountain, though 8000 feet high, is not nearly so voluminous as Mount Erebus or Mount Terror.

Basalts* appear to be developed at its base, and but few parasitic vents or obvious lava-flows are seen upon its sides. The only specimens brought back by the 'Discovery' Expedition are rounded pumice-fragments (899). These were obtained from the floating ice of Wood Bay, and must have been transported by the wind during the winter months.

Between Cape Washington and Cape Bernacchi, or in other words between Mount Melbourne and Mount Evans, no volcanic cone has been noted. This is important when we remember that here the foothills are absent, and that the coast is straight and uniform for a distance of over 200 miles. South of Cape Bernacchi, foothills composed of gneissic rocks are developed for some 50 miles. These are separated from Mount Morning and Mount Discovery by the valley of the Koettlitz Glacier, which trends north-west and lies parallel to a line joining the two volcanoes.

Mount Morning.

Mount Morning is a low dome 5779 feet high, and is almost circular. At its base it is 10 miles in diameter. On the south side the mountain slopes down to sea-level, and on the south-west it is separated from the main ranges by low foothills. The Koettlitz Glacier, which opens out north-eastward, occupies part of the above-mentioned depression between foothills and mountain-range. Radiating lava-flows are a prominent feature of this mountain, but no specimens could be obtained from them.

Mount Discovery.

Mount Discovery, the last volcanic cone which we shall note, is 9085 feet high, and lies in latitude 78½° S., longitude 165° E. (Fig. 32, p. 58). It adjoins Mount Morning on the west, but is cut off from the nearest mainland by Discovery Gulf, the ice-filled gulf into which the Koettlitz Glacier flows. The mountain is symmetrical in outline and has the form of a bell. The inflected curves of its sides unite at the summit without indicating the presence of a crater, and they spread out to give the mountain a circular base, some 15 miles in diameter at sea-level. This mountain was not visited, but the moraines stranded in the land-locked bay on its north-east side show that basaltic fragments are the commonest ejectamenta.

The Minna Bluff.

The Minna Bluff is a long and narrow promontory which projects south-eastward from the foot of Mount Discovery. It seldom attains a height of more than 2000 feet. It is 35 miles long, but its breadth is rarely greater than 5 miles. Its sides are

* Prior, Rep. 'Southern Cross' Collections (British Museum), 1902, p. 322.

very steep and almost parallel, and their wall-like appearance is unbroken by glacier or ice-cascade. No structural features are very evident, but specimens of basaltic and phonolitic rocks (619 and 622) obtained from two spots near its south-east end prove its volcanic origin. On the north-eastern extremity there are lava-flows quite like those of the east side of Black Island and of the Harbour Heights, Winter Quarters. The outline is unbroken and therefore it is impossible to say whether this peninsula is composed of lava-sheets, or is a series of scoria-cones like those which make up the Harbour Heights.

The Continental Range.

South Victoria Land, as previously mentioned, consists of a great range of mountains stretching in a north-and-south direction for 800 miles at least, and is apparently the eastern edge of a vast plateau, for between latitudes 77° and 78° S. Captain Scott travelled 200 miles westward over a level region having a uniform height of about 7600 feet above the sea.

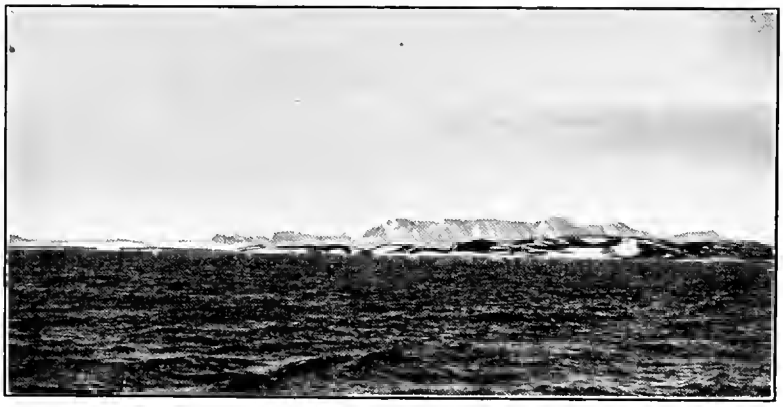

Fig. 8.—Mount Nansen, the tabular mountain south of Cape Washington.

The range maintains a uniform high level. Any peaks, such as Mount Sabine, that rise to heights of over 10,000 feet do so from correspondingly high surroundings, so that there are practically no peaks rising to great altitudes from low levels and towering above the surrounding land. In fact, the land does not show great relief.

Surgeon McCormick, of H.M.S. 'Erebus,' considered the whole range to be volcanic; but this is obviously not the case, for all the higher peaks are pyramidal in outline, and exhibit a house-roof shape which could not have resulted from the eruption of rocks from local centres. The Ross Expedition was less fortunate than the 'Discovery,' for the latter was able to steam in close to the land and see the peaks from nearer points of view. Thus, just south of Cape Washington, a tabular mountain, Mount Nansen (Fig. 8), was observed from the 'Discovery' to have apparently horizontal bedding planes and almost perpendicular scarps showing plateau-structure. The earlier explorers were too far from the land to perceive these characters.

The range, or chain of mountain-ranges, naturally divides itself into sections or links, and these may be conveniently considered separately.

(1) The area between Cape Adare and Cape North, a distance of 100 miles, is

more snow-covered than is the land further to the south, and the coast, which is parallel to the mountains, faces north-east. The mountains here form the main part of the Admiralty Range of Ross. They diminish in altitude as one passes westward to Cape North, and with the decrease in height there is a corresponding increase in the proportion of the snow-covered area. At Cape North itself the covering of snow is almost uninterrupted. Here the peaks which form the horizon are all of the pyramidal type, and they have their easterly shoulders truncated sharply at the shore. There are no deep valleys, but the snow often exhibits prominent series of terraces, one above another and parallel to the coast, and the whole is somewhat suggestive of the existence of some horizontal structure in the rock beneath.

(2) The Range which occupies the 250 miles of coast between Cape Adare and Cape Washington forms the highest, and perhaps the largest, land-mass. This area lies to the south of area (1), the Cape North portion, and is continuous with it. In the south its line of peaks recedes so far from the coast that the connection between this area and the third, or Prince Albert, section is not yet known. Here one sees the possibility of a division into two distinct geological areas, for low foothills are almost continuous along the whole length of the coast from the Cape Adare promontory to Cape Sibbald or even Cape Washington itself. Behind these foothills there appears to be a depression, which takes the form of a series of valleys running north-and-south, and behind the depression is a wall, or possibly a fault-face or escarpment, which rises to heights of 10,000 feet, and has weathered into a series of fine pyramidal peaks.

Many photographs illustrate the form of the range, and some show peaks, such as Mount Minto and Mount Adam, which rise as enormous gables from a plateau already high, and thus do not greatly overshadow the surrounding mountains.

At the head of Robertson Bay the depression at the foot of the mountains resolves itself into a valley, and even the bay itself may be considered a continuation of this. On the south side of Mount Melbourne this depression is again prominent; here it resolves itself into a valley running out to the south-east, and having the volcano (Mount Melbourne) as a part of its left bank, affording evidence that the mountain is situated upon a line of fault.

(3) The Prince Albert Mountains, 200 miles in length and trending due north and south, is the lowest large area of land seen by the Expedition. This range is important, not only because it is practically new, but because of its extreme uniformity of character. It is highest at the north end, where Mount Nansen, mentioned above, rises to 8788 feet, is lowest about the centre, latitude 76° S., where it is only about 3500 feet (Mount George Murray, 3591 feet), and rises again to 8000 feet (Horseshoe Mount, 8228 feet) on the latitude of Mount Erebus. It is remarkable that here the eastern border is always steep and gives one the impression that it is only the outlying edge of some great plateau from which streams of ice come down between

the nunataks. Later, when the former extent of the Beacon Sandstone Formation is considered, it will be seen that this uniformity of landscape is not surprising.

(4) The Royal Society Range has a length of some 50 miles; this length is almost bisected by the 78th parallel of latitude, and is the only part of South Victoria Land which has been examined in detail. In the main all the structures observed in the Admiralty Range are again seen, but are much more strikingly developed (Fig. 9). There are foothills of insignificant height, a north-and-south valley separating the foothills from the main mountain-mass, and a mountain-mass

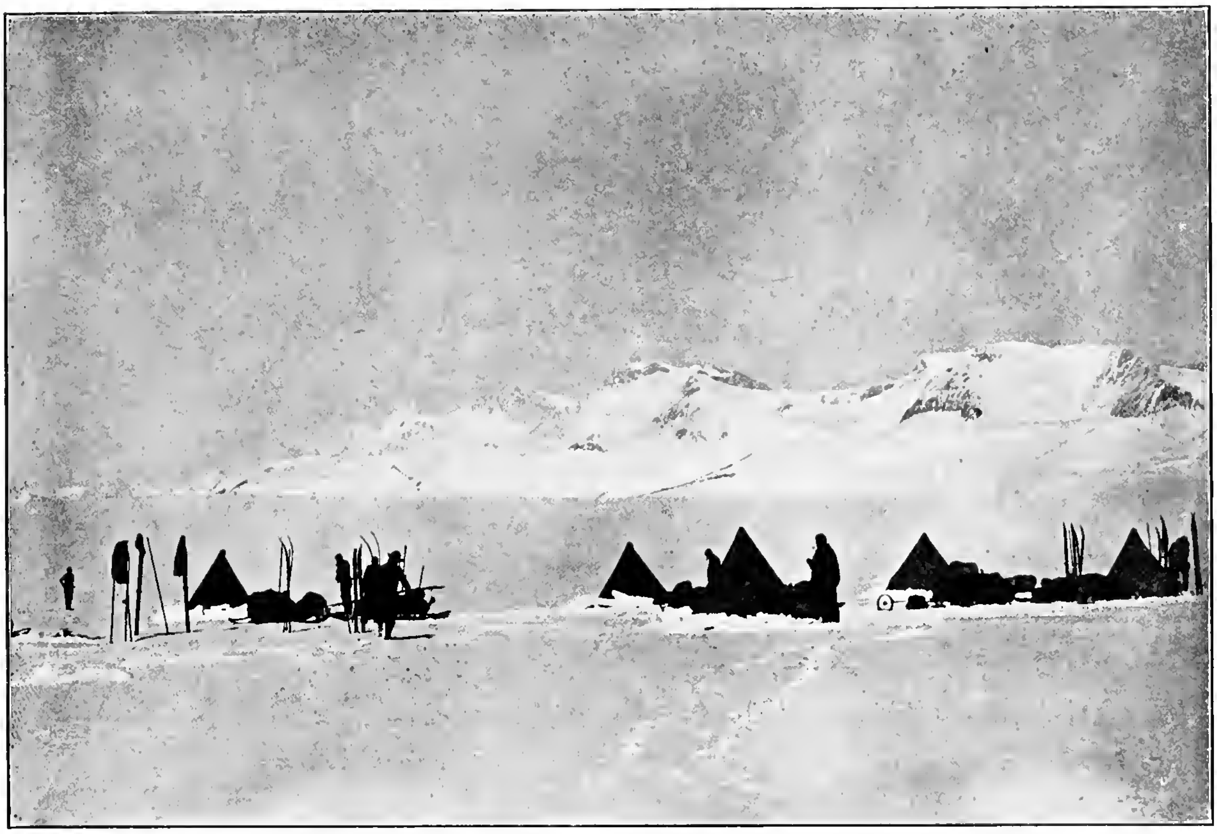

FIG. 9.—MOUNT HUGGINS AND THE ROYAL SOCIETY RANGE.

rising in a uniform cliff behind to a height of 10,000 feet and having occasional peaks over 12,000 feet in altitude.

From our Winter Quarters this range could always be seen, though quite 50 miles away; and so clear was the atmosphere that, even at this great distance, the plateau-form was always evident and was rendered still more striking by the broad band of lighter-coloured rock below. This band must be at least 2000 feet thick; it is apparently bedded horizontally and extends from end to end of the range. The peaks rising above the plateau are of darker-coloured rock and in strong contrast with it.

Thus, the form of the range appears to be determined by the horizontality of the rocks which compose it, a character abundantly proved by the sledge-parties who passed along the deep glacier-filled valleys that cross it eastward to the sea.

(5) The four separate ranges which determine the 300 miles of almost straight coast to the south of latitude 79° S. appear to be exactly similar to those already considered, and may be dismissed with the mention of the plateau-character which is strikingly shown and beautifully illustrated by Dr. WILSON's sketches, made during the great journey to the south, when Captain SCOTT, Lieutenant SHACKLETON, and Dr. WILSON reached latitude 82° 16′ 33″ S. These sketches are all the more valuable in that they were made by an unprejudiced observer.

Each of the four ranges averages 8000 feet in height; they are separated by wide channels far below the level of the plateaux, and such channels, having straight and exceedingly steep sides, appear to be typical features in the geography of all South Victorian mountain ranges.

KING EDWARD VII LAND (Fig. 10).

FIG. 10.—KING EDWARD VII LAND.

This land lies at the eastern end of the Great Ice Barrier of Ross, and is, therefore, connected with the mainland by ice at least. It lies between latitudes 76° and 78° S., and longitudes 148° and 160° W. It rises 2000 to 3000 feet high and is almost wholly snow-covered. The coast trends N.E.-and-S.W., and appears to be banked with low foothills completely covered with snow. It consists of two parts: (1) an isolated headland, some 1500 feet high and 10 miles long, standing well before (2) which, except for the low and isolated peak at the north-east end, is smooth and tabular, but is completely snow-covered. The two areas are separated by a comparatively low snow-covered depression.

The headland is unsymmetrical in shape and has a steep cliff on its north side; at three places, where too steep to hold the snow, there are good rock-exposures. The land was not visited, but specimens obtained from a dredge-haul (256–258) and from two icebergs consist of granites and gneisses and not of volcanic rocks. As the current is south-west along the coast, the rocks dredged up cannot have been carried far; it is also quite improbable that the icebergs can have travelled any great distance.

Chapter IV.

THE GNEISSIC ROCKS AND CRYSTALLINE LIMESTONE.

As the gneissic rocks occur at sea-level at the foot of the highest part of the Royal Society Range, and as they are found in the Range below a sequence of rocks which is 12,000 feet thick, they may be safely regarded as forming the ancient platform on which the central part of South Victoria Land is built. Above the gneisses, come successively, over a very large area, granites, sandstones and dolerites. Little is known of the field-relations of these except the order in which the rocks occur. The important deposit of sandstone provides a convenient stratigraphical datum-line, with reference to which the positions of the other rocks will be considered. The above order seems, however, to be chronological, for, where the junctions between any two rocks were examined, the lower rock usually appeared to be the older. With regard to the gneissic series, the localities at which they have been examined may be considered in three groups:—

(1) The Foothills of the Royal Society Range.
(2) The Kukri Hills.
(3) The Cathedral Rocks.

The Southern Foothills (Fig. 11).

South Side of the Blue Glacier.

On the hill J_1,* 5400 feet high and 15 miles from the sea, occur masses of crystalline limestone which rise at least 1000 feet above the snow. The limestone is almost pure white, and the constituent crystals are often an eighth of an inch across. It becomes so crumbly, on weathering, that it is difficult to get a hand-specimen from the rounded surfaces that are exposed.

The rock (568) has important structural planes which dip at 70° to the east, while the strike is north-and-south. The hill appears to be wholly composed of limestone; its western slope is very straight and steep, and is suggestive of a fault. Parallel to the bedding-planes or, more probably, joint-planes are bands of a dark fine-grained hornblende-biotite-granite (569) from 4 inches to 2 feet in thickness and about 50 yards apart. At this spot there were no obvious metamorphic features near the junction of the two rocks.

* For localities indicated by letters, see the map of the district near the 'Discovery' Winter Quarters, and the sections in Plate VII.

The south end of the Foothills.

Before leaving the discussion of this locality, mention must be made of the specimens brought back by Dr. WILSON from 30 miles further south, close by the Koettlitz Glacier. From the specimens themselves (834–853) and from what he has reported about their occurrence in the field, it would appear that the Foothills are composed of the rocks of the metamorphic series.

Barne Inlet. Latitude 80° *S. Longitude* 161° *E. (about).*

At the entrance to this inlet, Lieutenant M. BARNE collected fragments of granite, gneiss and mica-schist (734) from a scattered moraine. These fragments must

FIG. 11.—THE CRYSTALLINE LIMESTONE ON THE HILL J_1, SOUTH SIDE OF THE BLUE GLACIER.

have been derived from the mass of land lying south of the inlet and quite 170 miles south of the Blue Glacier.

THE NORTHERN FOOTHILLS.

The Northern Foothills occupy an almost rectangular area about 12 miles long and 10 miles broad. The Northern Foothills are separated from the Southern Foothills by the Blue Glacier, which occupies a deep and rather steep-sided valley from 5 to 6 miles across. They appear to be mainly composed of crystalline limestone.

The west side of the foothills, on the north side of the Blue Glacier.

Two miles north of G_1, the limestone is similar to that of J_1, 6 miles distant (Fig. 12). Here, however, the dominant structure-planes strike N.N.E.–S.S.W., and dark veins of a doleritic rock (566) make an angle of about 30° with them. From the floor of the Snow Valley, the snow sloped steeply up to the rock-face at an inclination which was too great for us to get the sledges up. Leaving these at the bottom of the slope for a couple of hours, a very risky proceeding when no landmarks are available, we obtained specimens without mishap. The fault-face on the Northern Foothills is more obvious than on the Southern; it is brought into prominence by the fine, bare and apparently glaciated peak (g), which rises over 4000 feet high.

Half-way down the Blue Glacier.

Working down the Blue Glacier, Dr. KOETTLITZ collected somewhat similar specimens from a hill 5 miles east of G_4; here, as nearer G_4, the bedding-planes dip to the E.S.E., and the dark veins cut across the strike to the E.N.E. On this hill one of the structure-lines is remarkably prominent and suggests a thrust-plane, but no difference in the characters of the rocks on the opposite sides of the line was obvious to the naked eye. The specimens collected by Dr. KOETTLITZ in this neighbourhood include dioritic dyke-rocks (572, 574) and a schist (570).

FIG. 12.—THE CRYSTALLINE LIMESTONE ON THE NORTH SIDE OF THE BLUE GLACIER, AT G_4.

The north-east end of the Blue Glacier.

At G_1, the most south-eastern of the Northern Foothills, the arrangement of the rocks is well seen from a distance. Here, however, the rock is so planed down by ice-action that the rapid alternations of dark dyke-rocks and light-coloured limestone are rendered evident. The dykes crossing the brow of the hill are plainly visible from the glacier. A dyke of kersantite (579, see p. 130), 20 yards wide, cuts the crystalline limestone (575, 576). The hill is 4000 feet high; the snow wraps its base and reaches quite up to the 1000-foot contour. Here again the sledges had to be left more than a mile away from the exposure. On this occasion, owing to the snow-storm that began during our absence, they were difficult to find when we returned.

The right bank of the Ferrar Glacier, between G_2 and G_3 (Plate IV).

The Northern Foothills, as stated above, form a rectangular mass with the north side some 12 miles long, forming the terminal portion of the right bank of the Ferrar

Glacier. The hill G_2 occurs at the north-west corner and sends out a shoulder four miles to the west. This shoulder is cut off from the granite-hills, G_3, by a glacier which flows northward out of the Snow Valley. The shoulder runs out as a narrow promontory along the same line as the north edge of the foothills, and rarely rises much more than about 1000 feet. The tributary glacier flowing north causes an inconvenient belt of hummocks two miles in width, and it is not till a height of 700 feet has been ascended that rock is found *in situ*. The slope of the hill makes an angle of between 30° and 40° to the horizontal, and is covered with loose morainic matter; but at a height of 700 feet a crag of gneiss (729) appears. The rock is dark,

Fig. 13.—The Gneiss at the east end of the Lower Kukri Hills, near the hill H.

fine-grained, and very streaky. The foliation dips to the south-west at an angle of 60°, a fact of some importance, as we shall see when we consider the Kukri Hills.

The Kukri Hills.

This name has been given to the hills lying immediately north of the Ferrar Glacier, as in plan they have the outline of that implement. They separate the North Fork from the East Fork, and are themselves divided, both topographically and geologically, just at that point where the Ferrar Glacier floats off into its deep fiord-like channel. The western and higher part includes all hills denoted by the letter D on the map; while the eastern and lower part is defined by the hills *m* and H, at its western and eastern extremities, respectively.

The Eastern or Lower Kukri Hills hardly rise above 3000 feet, but maintain this height most uniformly over the whole of their length between *m* and H, a distance of 15 miles. These hills form a narrow promontory about two miles in breadth with steep, sometimes almost vertical, sides. They lie six miles or so north of the Northern Foothills.

New Harbour Height (H) (Fig. 13).

At the extreme eastern foot of the hill H, or New Harbour Height, specimens (730, 731) of hornblende-schist and gneiss were obtained. The gneiss belongs to the dark variety, the structure-lines dipping at an angle of 30° to the north-east. About

FIG. 14.—LOOKING UP THE FERRAR GLACIER, NORTHERN FOOTHILLS ON THE LEFT, CATHEDRAL ROCKS NEAR THE CENTRE, AND THE KUKRI HILLS ON THE RIGHT.

a mile west of this point, where a small hanging glacier on the south side of the hill occurs, the dip suddenly changes to one of 20° to the west. The dip is emphasised by the fact that the snow always lies only in sheltered hollows. The hanging glacier lies on what appears to be a fault.

Below the hill D_4.

Below *m* at the western end of the Lower Kukri Hills a white crystalline limestone occurs, and the bedding-planes of this rock dip to the north-east at 70°. The apparent thickness is about 1000 feet, and the strike is N.W.—S.E. Between this white limestone and the dark foliated gneiss at the east end, a long stretch of the valley-side appears to be gneiss with foliation-planes dipping to the west, and therefore to agree with that met with on the south side of the valley near G_2 (Fig. 14). The white limestone (728) abuts upon a grey augen-gneiss (727), but the actual junction could not be examined as a hanging glacier lay upon it. The augen-gneiss appears to be part of the great mass which forms the lower and greater part of the hill and rises to quite 4000 feet.

Below H_2.

At Cape Bernacchi, 20 miles north of the Northern Foothills, the rock composing the hill H_2 has apparently the same structure as that of New Harbour Height, or the hill H, while the elongate hill h_4 is a replica of the portion between H and m, and has structural planes dipping to the west. The rocks were not examined at this spot, but the serrated outline and the trend of the snow-water channels point to the structural lines being exactly parallel to those on the Lower Kukri Hills.

The Cathedral Rocks.

These rocks lie 40 miles from the coast, and rise to heights of over 6000 feet. The glacier-surface at their base is about 1500 feet above sea-level, and the summits of the Royal Society Range, of which the Cathedral Rocks are the northern extremity, rise to altitudes of over 12,000 feet directly behind them. The Cathedral Rocks slope steeply down to the Ferrar Glacier, and form its right bank for a distance of 10 miles. They form three of the shoulders of the range just mentioned, and are separated by tributary glaciers which run out northward along narrow and steep-sided valleys. These shoulders project as *arêtes* from the main plateau of the Royal Society Range. They are composed of gneiss, granite and dolerite, and may be topped by small outliers of sandstone (Plate III and Section II, Plate VII).

There is an exposure of gneiss at the foot of the central shoulder, which is designated E_2 on the map. This exposure rises 500 and 600 feet above the ice (Plate IV). The line dividing it from the granite is very sharp, and can be followed for a distance of some 3 miles along the glacier. On the west it is hidden by a sudden rise of the surface of the ice, and on the east is cut off by a boss of diorite (715), which appears to have burst through from below.

The diorite forms the eastward half of this shoulder as well as the whole lower portion of the eastern shoulder E_1. The gneiss is overlain by a sheet of pink granite, which, once known, is easily recognisable at a distance by the fact that the latter forms screes, whereas the former produces a cliff. The upper surface of the gneiss is a well-marked undulating line, cut off short on the east where it meets the diorite. In certain other places several much smaller dykes transgressing the gneiss were observed. Of these dykes some are grey granite and some are pink granite, and both kinds are more abundant towards the eastern end of the exposure. Here the pink rock displays augen-structure (716), and occasional isolated patches and wisps of the ordinary foliated gneiss were observed in the middle of the masses of augen-rock. The dykes form a rough network over the face of the gneiss, and their thicknesses vary from 6 inches to 12 feet. The most prominent consists of a pink quartz-porphyry (709), cutting through the gneiss perpendicularly to the foliation. The gneiss here is dark in colour, and its alternating laminæ are usually under a quarter of an inch in thickness. These foliations are themselves folded into series of anticlinal or isoclinal folds, with amplitudes of about 8 feet, the various bands remaining parallel.

Other specimens from later veins or dykes traversing the augen-rock may be mentioned, namely :—

(1) A green actinolite-rock (725).
(2) A white pegmatite-vein (723).
(3) A thin seam containing mica-plates up to half-an-inch across.

Chapter V.

THE GRANITES.

Though granitic rocks had not been found *in situ* in the Ross Sea area, the frequency with which fragments had been dredged up by the various ships proved, if not a wide distribution, at any rate a great local development of this kind of rock in the area under consideration. If we neglect the occurrence in moraines such as those found on the basaltic peninsula of Cape Adare or on the slopes of the volcano

Fig. 15.—Dolerite upon Granite on the north side of Granite Harbour.

Mount Terror, there are two localities where granite has actually been found in place. At the first, which has been called Granite Harbour, in latitude 77° S., the granite abounds; though no other rock could be examined in the time available, a dark rock was seen capping the granite (Fig. 15); that this is dolerite is almost certainly proved by the plateau-like form of the hills on the side of the harbour remote from our landing-place, and by the finding of dolerite-fragments on the scree-slopes (see p. 54). The second locality is the Royal Society Range; here the granite has been examined at several spots over a distance of some 20 miles, and appears to occupy an area of quite 200 square miles. This district may conveniently be subdivided into two areas—(1) the Snow Valley west of the Northern Foothills, where the granite occurs in isolated hills, and no other kind of rock has been seen; (2) on the two sides of the Ferrar Glacier, where granite, and its relations to the rocks both above and below, have been examined.

Granite Harbour (Fig. 15).

In this harbour there is a prominent headland some 500 feet high and two miles long; in form it is distinctly like a bursting cabbage. Where a landing was made the rock proved to be entirely granite. The rock-surface is absolutely bare of snow, and is weathering under desert-conditions apparently analogous to those described by Walther as obtaining in Sinai.* The joints tend to be platy and parallel to the surface, but the edges of the joint-blocks are ragged, and the curve is usually convex downwards. In other places the joints are vertical; there the rock breaks up more rapidly, and produces talus-slopes which extend almost the whole height of the cliff-face. Dark circular patches, in rows which are often parallel to the joint-planes, are seen on the surface, and it came as a surprise to find that the rock is coarsely crystalline.

The greater portion of the boss consists of a grey biotite-granite (129), and the larger talus-slopes always follow certain veins or dykes which extend up the whole face of the cliff. The centres of these veins consist of a coarse pink granitic rock (155) with idiomorphic crystals of red orthoclase up to half an inch in diameter, but within a distance of some fifteen feet these phenocrysts become paler in colour, the rock meanwhile becoming less porphyritic, and thirty feet from the centre it has graded into the ordinary grey granite of the main mass of the boss. These pink dykes are about one hundred yards apart; it is noteworthy that in many cases the change from grey to pink is not quite gradual, but takes place in stages at the joint-planes, thus suggesting multiple dykes. These stages of the passage are marked by bands, a foot or so across, which become successively coarser and pinker as one passes from the sides towards the centre.

Thin seams of micaceous schist (96), narrow black basalt-dykes (113), and numerous other varieties of rock, were met with, and specimens of these were collected during our hasty scramble ashore (see p. 126).

The Snow Valley west of the Northern Foothills.

In the area between the Foothills and the Royal Society Range, a district which I have called the Snow Valley, isolated hills just raise their heads above the snow, and expose to view occasional masses of granite-blocks, which at first sight would appear not to be *in situ*. There are five or six of such hillocks, with summits about 3500 feet above sea-level, which form the watershed between the Blue Glacier and the ice-cascade separating the hill G_2 from the hill G_3.

The points η_1, η_2, etc., on the map indicate the positions of these hillocks, but of the four only η_2 was visited; it proves to consist of grey hornblende-biotite-granite (561, 562). The mass exposed is about 100 yards long, and rises 200 feet

* Walther, Abhand. math.-phys. Cl. d. k. sächs. Ges. Wiss., 1891, Bd. xvi, p. 364.

above the snow which surrounds it. When traced from west to east the rock becomes finer grained. In places it encloses many vertical quartz-veins (560).

Near E_4, at a height of 5000 feet, Mr. SKELTON obtained a specimen of grey granite (626), and another from a boss of rock just peeping above the snow. In this exposure the joint-planes dip to the south, and, in places, kersantite-veins (625) cross the mass.

From the "3500 feet Knoll," e_5, Mr. SKELTON brought back a specimen of a somewhat coarse-grained pink granite with phenocrysts of felspar up to a quarter of an inch across (555, 556). The exposure is much weathered, and it is here that the type (A) of hollowed rock* with the white (calcium carbonate) incrustation (554) occurs (Fig. 16). This will be referred to later (see p. 88).

FIG. 16.—HOLLOWED GRANITE-BOULDER IN THE SNOW VALLEY NEAR THE ROYAL SOCIETY RANGE.

At e_6 Dr. KOETTLITZ got a specimen of dark grey hornblende-granite (563) with idiomorphic crystals of pink felspar up to one inch in length. The height at which this exposure occurs is more than 3000 feet, and the rock forms the eastern end of a spur of the Royal Society Range. The joint-surfaces are conspicuously developed, and are arranged as a syncline with east-and-west axis. Other specimens from this locality are a grey biotite-augen-gneiss (564) and a doleritic rock (565).

THE GRANITE HILLS BETWEEN G_2 AND G_3 (PLATE IV).

The hill G_3 rises to a height of 3500 feet above sea-level; it is 1000 feet above the level of the Snow Valley, and nearly 2000 feet above the ice in the valley below. Eastwards the height decreases to 2000 feet, where this patch of bare rock is separated from the gneiss of G_2 by the ice-cascade previously mentioned. As a whole this G_3 block is a series of rounded hills; as viewed from the surface of the Ferrar Glacier (Fig. 43, p. 78), it has no very conspicuous valleys, but presents an almost straight and even valley-wall.

The specimens (557, 558) from near the summit of G_3 are all of hornblende-granite with large pink porphyritic crystals of orthoclase. It is here that type B of hollowed crystalline rock is found, and owing to the rapid weathering the ground

* Ferrar, Geol. Mag., Dec. V, 1905, vol. ii, p. 190.

around is covered with large loose fragments of felspar. At the foot of G_3, 1500 feet above sea-level, the felspars in the rock are even larger than those on the summit, and a dark dyke (714) (see p. 131) with phenocrysts of hornblende up to two inches long is exposed a few feet above the ice. In addition, below this "dark dyke," there is a green band of a fine-grained rock (732) about five feet thick. The dark dyke produces a dark patch on the hillside, which, owing to the contrast, can be seen at least 10 miles away. On the opposite side of the glacier, above d_3, there are three or four similar patches which, though larger, are probably due to a similar occurrence of dykes.

Fig. 17.—Dolerite-cliff standing back from the edge of the Granite of Cathedral Rocks.

The Cathedral Rocks.

These rocks already referred to (see p. 30) form a very imposing triple headland on the south side of the Ferrar Glacier, and are as important as they are picturesque, for here, there seems no doubt, is contained the whole history of the Royal Society Range. At the base, as already stated, is banded gneiss. Above it, and divided sharply from it, is the granite, which must be about 4000 feet thick. Above the granite is a sheet of dolerite, which is rendered conspicuous by its weathering back faster than the granite and leaving a prominent ledge. Upon the dark dolerite-sheet is a yellow cap, presumably of sandstone, which forms the summits of all three headlands (Fig. 17). (See Sections I and II, Plate VII.)

At the foot of E_2, dykes of fine-grained pink (711) and grey (710) granite force their way into the gneiss and blend with the sheet of granite. East of the shoulder E_2, a tongue of granitic rock ends the gneissic exposure, as if here bursting through from below. At the edge this tongue is mainly pink in colour, and occasionally there are large patches of almost pure pink-felspar-rock in it. When traced eastward it passes into a diorite, becoming gradually darker in colour (715) and coarser in texture, while well-formed black crystals of hornblende appear and increase in size up to a quarter of an inch in diameter.

The relation of this rock to the granite making up the hill G_3 cannot be traced owing to the great mass of snow in the Descent Pass, but the sharp dividing line between the granite and the dark-coloured dolerite above it can be followed round all three shoulders and across to the tabular hill E, and thence along the east side of the South Arm for a distance of more than 10 miles, keeping almost exactly the same level all the way. This sheet-like mode of occurrence of the granite appears to be a constant feature in this area and is seen over the whole south side of the Upper Kukri Hills (Fig. 18).

The Kukri Hills.

The Kukri Hills project as a wedge into the depression where the ice from the South Arm meets that flowing east from the inland plateau. From them granite has been actually obtained at three spots, namely, (1) the western extremity below D, (2) near the middle of the south side below D_2, and (3) the eastern end of the upper portion below the peak D_4. (See Section III, Plate VII.)

The hill D, as seen from the south, shows about 2000 feet of dark rock (dolerite) occupying the whole of the cliffs, which fall sheer to the level of the ice, here about 3000 feet above sea-level. In the middle of this great mass of dark rock are three large triangular masses of a light-coloured rock which are plainly visible eight miles away. At the western foot of D is a still larger mass of pale rock which must be 1000 feet thick at least. Viewed from the north and west, this rock, which proved to be a pink granite, could be seen sending tongues into the columnar dolerite, and the junction of the two (699, 700, see p. 128) was seen to be quite irregular; it is quite clear that the granite is here the later intrusion. The joint-planes of the granite dip to the north-east at an angle of nearly 30°; the granite (701), though generally pink in colour, has occasional dark-grey masses (702–703) locally contained in it.

The eastern end of Solitary Rock (D_{5a}) shows four bands of rock with regular horizontal junctions. Two of these bands are dark-brown and two are light-yellow in colour, and the alternation of the colours suggests that the rocks are like those seen on the north side of the North Fork, where yellow and black bands occur in the same order and with similar thickness.

When the Kukri Hills are observed from Knob Head Mountain, or from the summit of Descent Pass, they present an almost sheer wall facing south. This wall is broken at regular intervals by glaciers, which usually occupy hanging valleys. At the mouth of each valley there is a well-marked junction of dark-coloured and light-coloured rock, and in places the colours alternate regularly as before. The hill D contains a straight yellow band near its summit which is formed by a dark rock. The yellow band continues towards the east, and gives to the hill D_1 a tabular outline. On the hill D_2 it is only represented by a small outlier. Below this yellow band on

Fig. 18.—The Horizontal Upper Surface of the Granite on the south side of the Kukri Hills.

the hill D_1 there is a horizontal black band about 1000 feet thick, which appears to be part of the dolerite of D, and this black band extends eastwards beneath the yellow outlier of D_2. Below the black band there is an attenuated wedge of yellow rock, which begins about the middle of the cliff D_1, and, rising slightly, reaches the top of the cliff-face a little to the east of D_2. This yellow wedge shows prominent joint-planes which dip to the east, and appears to weather in quite a different way to the outliers on the summits of D_1 and D_2. It is possible that this is part of the intrusive granite of the promontory D. Below this again is a second dark band, which was subsequently proved to consist of dolerite (704). This, too, is a part of the D mass, and maintains a uniform thickness of about 2000 feet. As it rises to the eastward it forms the highest third of the hill D_3 and caps the hill D_4.

Below D_2 another light-coloured rock, a grey biotite-granite (708), protrudes through the ice, and may be followed for a distance of over 10 miles along the side of the valley. The upper surface of the granite is very well marked and forms an almost horizontal straight line, but near the hill D_3 it becomes somewhat undulating (Fig. 18). This granite forms the greater part of D_4, and finally forms the summit of the hill *m*. It is probably at least 4000 feet thick. Below D_2 the junction of the lower dolerite with the grey granite is 500 feet above the ice, as measured with an aneroid barometer, and about 3000 feet above sea-level, and it would seem that the surface of the granite slopes west at an angle of about 2°. This spot is five miles east of the pink granite at D, eight miles N.N.W. of the granite at Cathedral rocks, and ten miles N.W. of the granite at G_3.

Grey augen-gneiss forms the base of D_4, and was again encountered at the foot of *m* (727). At this last-mentioned spot, as stated in the foregoing chapter, the augen-gneiss adjoins the metamorphic limestone, but a glacier completely covers their junction. From a distance it was seen that the junction must occur just where the higher and western part of the Kukri Hills ends and the lower and more uniform eastern part begins. The augen-rock must be more than 3000 feet below the dolerite-granite junction and at least eight miles east of the hill D_2.

From a consideration of the above it would seem that the grey granite of these hills is older than the dolerite which rests upon its even upper surface, but that the pink granite of D is intrusive and later than the dolerite.

In Moraines.

Fifty miles inland, at a height of 4000 feet above sea-level, small and large boulders of both grey and pink granite (693) were found on the side of Beacon Height West. They were resting upon a surface of the Beacon Sandstone. The spot where these fragments occur is some distance up one of the Dry Valleys. As the land south of the Dry Valleys rises to over 7000 feet in height, it is possible that among these peaks granite occurs at a greater elevation than 4000 feet, and has been brought down to its present place upon the sandstone by the ice which once occupied the valleys.

On the slope of Knob Head Mountain (B_9) there were huge boulders of granite at a height of 4000 feet above the sea, but no granite was found in the upper part of the mountain itself. About one-third of the material of the moraines in the South Arm consists of granite-blocks, and all varieties appear to be there represented.

Chapter VI.

THE BEACON SANDSTONE FORMATION.

The existence of fossiliferous sedimentary rocks in South Victoria Land has been considered probable ever since H.M.S. 'Challenger' dredged up sandstones, limestones and shales* in a high southern latitude, but as it was thought that the coastal belt of the land was composed entirely † of volcanic rocks, there was little to encourage the hope that fossiliferous strata would be met with in the course of the 'Discovery' Expedition.

In dredging off Coulman Island several small fragments of a white granular quartz-grit were brought up, and when just south of the conical Mount Melbourne a tabular mountain, Mount Nansen, was seen, our hopes of finding sandstone were raised to a very high pitch. This mountain showed well-marked horizontal structure, and steep scarp-slopes which vividly recalled Table Mountain at Cape Town in South Africa. Further south, in about latitude 75° 57′, many tabular hills with black caps could be seen fronting the sea, and the possibility of such tabular mountains being composed of plateau-basalt had to be considered. However, when the 'Discovery' anchored on the south extremity of Ross Island, the Western Mountains (the Royal Society Range of our present nomenclature) were seen to be made up of differently coloured horizontal bands which run from end to end of the range. These rock-belts are well brought out in some of the photographs, and at a distance of 50 miles the contrasts of colour were more obvious than in any of the photographs taken close at hand.

Lieut. A. B. Armitage's pioneer-journey through these mountains proved that horizontal structure and plateau-features are extremely constant. The specimens (628, 630, 639–642) he brought back included a sandstone which is somewhat like the Millstone Grit of the top of Ingleborough in Yorkshire, and suggested the probability of the existence of fossiliferous sediments in the district.

Lieut. Armitage reported that the sandstones attained a height of nearly 8000 feet and were accessible at a spot 60 miles inland on the very edge of the Inland-ice. The photographs taken by Lieut. R. W. Skelton on this journey (Fig. 19) showed that the sandstone has a marked effect on the scenery, and the name Beacon Sandstone Formation, which I propose to give to the deposit, is derived from the remarkable mountains B_3 and B_4 to which Lieut. Armitage has given the name Beacon Heights.

Accordingly Captain Scott arranged that I should go with him as far as the edge of the Inland-ice and do as much geological work as was possible on the return

* Murray, Geol. Mag., Dec. IV, 1898, vol. v, p. 270; Prior, Mineralogical Magazine, 1899, vol. xii, p. 81, note.

† Gregory, 'Nature,' 1901, vol. lxiii, p. 609.

journey. A second attempt had to be made, owing to the sledges breaking down on the first, and, even then, bad weather confined the parties to their tents for a period of six and a half days; when the weather had moderated I had but one month in which to examine the 600 square miles of new country.

From what we had seen on the way out, plateau-dolerite would be found overlying the Beacon Sandstone. The latter was not exposed at Depôt Nunatak, but in the moraine at the foot of the rock I found abundant sandstone blocks, and the majority of these were locally blackened by carbonaceous matter (743, 744). None of these blocks contained fossils, other than the small lenticles of carbonaceous material which I thought suggestive of organic origin. These were our first evidences of Antarctic life in the geological past, and as my companions, KENNAR (P. O.) and WELLER (A. B.) spread out our sodden gear in the sun under the lee of the nunatak, hopes indeed ran high, and all looked forward to the joy of further new discoveries.

FIG. 19.—DOLERITE-SILL IN THE BEACON SANDSTONE NEAR FINGER MOUNTAIN.

Next day therefore found the camp near the foot of the hill B_1, where three hundred feet or so of the sandstone could be seen cropping out below the overlying dolerite. Imagine my delight when, arriving with bag and hammer at the rock-face, I found thin, black, irregular bands in a pure white sandstone. Though the bands were two hundred feet below the capping dolerite, their carbonaceous material was much charred; hence, after collecting a few specimens, we left this promising locality, perhaps prematurely, and moved diagonally down the valley to the vast exposures of the Inland Forts. Here I had hoped to find better specimens, but neither here nor elsewhere did we meet with anything nearly so good as at our first locality near the dolerite-junction. The sandstone of these Inland Forts is quite 2000 feet thick, and, though we carefully sought for its base, no indications of that base or of the relations to the underlying rocks could be found.

The Beacon Sandstone is also present at the foot of Knob Head Mountain, which is over 30 miles to the east of Depôt Nunatak and about 3000 feet lower. The localities at which the Beacon Sandstone was examined will therefore be considered in turn, in the order in which we came to them.

Below the Hill B_1.

From a position on the side of the hill B_1, we could see some miles away striking alternations of dark and light bands just peeping up from below the brown rock of a_{15}. The dark bands are conspicuously paler than the overlying rock (dolerite) and are presumably carbonaceous sandstone. If we take this into consideration and the fact that carbonaceous sandstone is found in the Depôt Nunatak moraine, and bands of it occur below B_1, it would seem that only the upper portions of the Beacon Sandstone are fossiliferous.

The Beacon Sandstone at B_1 is locally disrupted by the dolerite, but the horizontal bedding is not materially disturbed, except at one place where huge masses of the sandstone have been bodily upraised. One of these dislocated masses is 100 feet thick and a quarter of a mile long. It contains many small black iron-stained nodules (663), which are set in a matrix of very coarse quartz-grains. Of the 300 feet exposed near the camp, the major part is a pure, even-grained, coarse sandstone.

False bedding or current-bedding is displayed, and locally there are discontinuous bands of quartz-pebbles (673, 674). The pebble-bands appear and disappear quite suddenly in the ordinary sandstone, and they are never more than four inches thick; the pebbles themselves vary from the size of a sparrow's egg to that of a hen's egg, and quite 99 per cent. consist of vein-quartz or quartzite (672). Sometimes the pebbles are very sparsely scattered, and a bed 12 feet thick may contain only a single pebble. The quartzite (quartz-schist) pebble (675) was found under such circumstances and measures 8 × 5 × 4 inches. The sandstone-blocks of Depôt Nunatak display abundant lenticular pieces of yellow mudstone up to two inches in length, but these lenticles were not observed elsewhere.

The carbonaceous matter (743–762) only occurs in the lowest hundred of the 300 feet exposed; the carbonaceous bands, like the pebble-bands, are there discontinuous, and often follow the intricacies of the current-bedding. The black bands commonly range from an eighth to a quarter of an inch in thickness; some of them were found to extend horizontally for quite 100 yards, others disappear completely within a very few feet.

Near this spot the sandstone is partially calcareous, and a blue limestone-band formed a conspicuous shelf projecting from the cliff-face. Just below this was a well-marked band of pebbles set in incoherent sand, or in sand only slightly cemented by carbonaceous matter. The following sequence, in order of superposition, will give some idea of the nature of the Beacon Sandstone at this spot.

Top.	(7)	200 feet—almost pure sandstone with occasional pebbles (665)
	(6)	2 feet—band containing carbonaceous substance (745–762)
	(5)	12 feet—sandstone with brown bands
	(4)	12 feet—hard white sandstone with a three-inch strip of fibrous mineral (wollastonite) (676)
	(3)	12 feet—black shale and shaly sandstone (754)
	(2)	6 inches—limestone-band (671)
Bottom.	(1)	6 feet—black shale (754)

The carbonaceous band (6) had been slickensided and baked to such an extent that it has proved impossible to determine the fossils which it contains (see report by Mr. E. A. Newell Arber, on p. 48).

The Inland Forts (Fig. 20).

Five miles west of the Inland Forts, at the spot marked γ_2 on the map, the cliff forming the north side of the glacier is composed of two rocks, a yellow one below and a dark one above. The junction as usual is regular and almost horizontal. On examination the yellow rock proved to be sandstone. The only accessible part was the base of the cliff where the rock is a sandstone barren of fossils. It is subdivisible into a series of alternate yellow and white beds, and a few pebble-patches were noted. The following section from the level of the ice upwards, shows the order of succession :—

Fig. 20.—The Inland Forts. Sandstone capped by Dolerite.

Top.	(4)	100 feet—brown columnar rock (dolerite)
	(3)	100 feet—yellow sandstone
	(2)	100 feet—uniformly light-coloured sandstone
Bottom.	(1)	100 feet—a yellow and much banded sandstone.

At the Inland Forts, where the hills are at about the same level as those below γ_2, 2000 feet of the Beacon Sandstone are exposed, and of this nearly 1500 feet have been examined. The Forts are four conspicuous hills mainly composed of sandstone, but they are capped by dolerite (Fig. 20). They are separated by well-marked *cols* through which the ice once forced its way northwards into the adjoining drainage-system. The exposure is well illustrated by the photographs of this side of the valley. The sandstone is part of a great deposit which is buried westwards beneath the Inland-ice and determines the distinctive features of the mountains on each side of the main valley of the Ferrar Glacier.

Extending southwards from C_6 and C_8 are two ridges of similar sandstone. These ridges have rounded outlines and resemble groins built against a sea-wall to break the force of the waves. Though now above the level of the ice, they formerly acted like groins and thus collected rock-material on their westward side. These ridges, which I have termed the West and the East

Groin respectively, are low and attenuated spurs of the horizontally bedded sandstone, which is here cut into *cirques*. The groins afford the most easily accessible exposures of sandstone in the whole region. The slope was seldom too steep to be climbed, and, as the horizontal structure is well etched out by denudation, any particular bed may be traced along the whole length of the ridge. Here, too, the rock was a white or yellowish sandstone with not so much as a sign of a shale or a limestone-band. So far as could be ascertained, only one of its horizons contained organic remains, and these of a most doubtful nature. These were found on West Groin, where the surface of a sandstone-bed was covered by what appeared to be cylindrical casts of some organism (763–767). Possibly these cylinders may be entirely a result of weathering, but, as they are all of much the same diameter and cross and intercross in all directions, I thought at the time that they are probably more than this, and I still think that they may be of organic origin. There is no sign of actual structure in the boundaries of the cylinders, but there is usually a slight depression parallel to, and close along, their sides. The length of the cylinders varies from six inches to three feet, and the diameter is usually about half an inch; they project nearly half an inch above the smooth surface of the surrounding sandstone.

At another spot on West Groin, 800 feet above the level of the ice, there occurred an impression (763, 764) on the surface of the sandstone. This appeared as a shallow hollow, somewhat like the imprint of a flat crooked stick with a blunt rounded end (Fig. 21). The impression was an eighth of an inch deep, two inches wide, and one and a half feet long. Along the central line there are two markings parallel to the outer boundary and about a quarter of an inch apart. These run nearly the whole length of the impression, and on either side of them are rows of rather deeper pits about a quarter of an inch apart, which alternate on the two sides of the central lines (see note by Mr. E. A. Newell Arber, on p. 48).

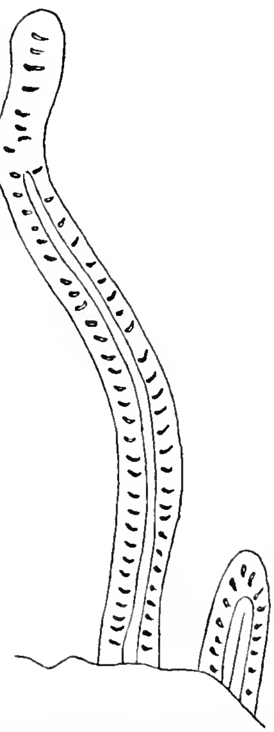

Fig. 21.—Impression in Sandstone at West Groin. Copy of Sketch made in the Field.

Sundry other, but smaller, rod-like markings (765–769) occur on other specimens, and with the same alternate pits, and I am inclined to think that these impressions are, at least remotely, derived from bodies with organic structure. One of the smaller impressions, which are 6 inches to 1 foot long and about half an inch across, still retains fragmentary remains of dark carbonaceous matter. The following table of the succession, from the bottom of West Groin to the top of its corresponding hill, shows how uniform is the Beacon Sandstone Formation.

Top.	(14)	100 feet—dolerite, which caps the sandstone
	(13)	200 feet—yellow sandstone
	(12)	100 feet—sandstone with occasional yellow bands
	(11)	100 feet—sandstone with ferruginous concretions (677)
	(10)	200 feet—yellow sandstone
	(9)	100 feet—sandstone with cylindrical casts (764–767)
	(8)	200 feet—yellow sandstone with ferruginous concretions
	(7)	50 feet—white sandstone
	(6)	200 feet—yellowish sandstone
	(5)	100 feet—marble-like sandstone (679)
	(4)	50 feet—nearly white sandstone
	(3)	10 feet—stalagmitic sandstone (678)
	(2)	60 feet—almost white sandstone
Bottom.	(1)	30 feet—variegated brown and yellow sandstone (hard).

The variegated brown sandstone (1) at the base appeared to be altered to a slight extent; it is harder than most of the higher beds, and the ferruginous concretions in it are sometimes two feet across. They are flattened horizontally, and are sometimes joined together.

The stalagmitic sandstone (3) is so called because stalagmites stand out between successive beds on the rock-face, and it would appear that the rock had been locally hardened by infiltration. It is made up of alternate hard and soft layers which are each about a foot thick.

The marble-like sandstone (5) (679) was harder than that above and below, and locally its surface has a superficial glaze. The ferruginous concretions (11) (677) in the upper band often weather out as balls up to a foot in diameter; sometimes, however, the concretions have disintegrated faster than the rocks in which they were imbedded and have left spherical hollows.

Finger Mountain (B) (Fig. 22).

Before we entered the district of the Dry Valleys, the Beacon Sandstone was examined near the foot of Finger Mountain; though 10 miles south of the preceding area, it retains the same characters and appears to be barren of fossils throughout. Near the contacts with the dolerite, variegated bands (635) have been produced. At this spot the sandstone, like that at B_1, has been dislocated; but again its general horizontality has not been disturbed, notwithstanding that intrusive sheets of dolerite, up to 500 feet thick, have forced their way along joints and bedding-planes.

Finger Mountain (B) contains a wedge of sandstone which separates two sheets of dolerite (Fig. 22). One of these sheets caps the hill; the other separates the wedge from the major portion of the sandstone which only just appears above the ice. The whole sequence occupies a cliff of about 500 feet high; the wedge of sandstone is about 100 feet thick at its eastward extremity, whence it thins westwards and disappears in a distance of about two miles. One bed of sandstone after another is cut out by the dolerite as it transgresses them upwards to join the mass which caps the hills to the south of Finger Mountain. Immediately to the south of Finger Mountain the wedge is considerably thinner. It is exposed in the valley, which, cutting back, produces the sharp spur marked b_1, b_2.

Again, on the north side of the glacier in Round Mountain (C_1) is a wedge of yellow rock, which is probably a similar sandstone, and is also caught up by the dolerite in exactly the same way. This mountain, however, differs from Finger Mountain in having a small sandstone-outlier which caps and protects the dolerite at the summit.

Along the right bank of the Ferrar Glacier from B_1 to B the sandstone may be seen above the level of the ice, but local disturbances prevent the upper surface from appearing as a continuous line along this side.

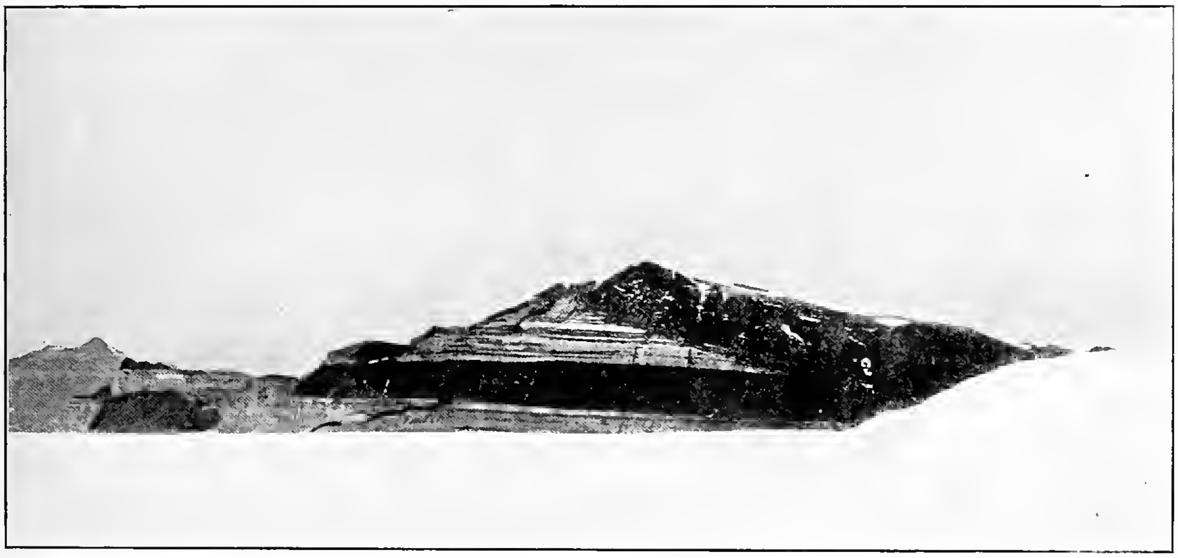

Fig. 22.—Finger Mountain. Wedge of Sandstone in the Dolerite.

The Dry Valleys (Plate V).

These two valleys lie on the south side of the Ferrar Glacier and on the west side of the Beacon Heights (B_4, B_3). Both have vertical sides 500 feet high, which suddenly give place above to less steep slopes as the surrounding mountains are approached. Both are tributaries of the main valley. The smaller lies immediately south of Finger Mountain, and, narrowing the while, trends due west for a distance of two miles; at this point the valley suddenly turns southwards, the ice which occupies it suddenly ends, and displays a bare, flat, stony bed. The confining walls continually approach each other, and one mile above the ice-cliff they suddenly come together in a veritable *cul-de-sac.*

The larger valley is about four miles long and also ends in a cliff. Its sides are steep and parallel, and maintain the same height all the way round. The valley-bed here also is flat and free from ice; it is strewn with boulders of all sizes, and is therefore exceedingly rough. The breadth is less than two miles, but near the mouth, where it is joined by the smaller valley, it widens, and together they open out into the main depression of the Ferrar Glacier.

The Beacon Sandstone on the north side of the smaller valley is most accessible at a spot west of b_2, where the usual sandstone is capped by dolerite. About 300 feet are exposed, and the beds can be traced horizontally all round the left side until cut off by the dolerite of the hill x. The main mass of x is dolerite, but a small exposure of sandstone is visible at its western foot. In the middle of the mass there are two other narrow strips of sandstone, each about 20 feet thick and half a mile long, which seem to have been caught up by the intrusion. At the west foot of this hill the Beacon Sandstone shows a new feature, for on the under side of a large block there was a six-inch bed composed of angular quartz-fragments (681). These pieces of quartz are fairly regular, almost cubic, and about an inch long. They are set in a matrix of the usual sandstone, and it is worthy of note that no rounded pebbles were here observed.

There are four very prominent buttresses south of x, which form the sides of the larger valley, and in each of the buttresses two bands of yellow rock and two of brown rock were seen alternating regularly. These alternations possibly represent parts of once continuous intrusions of dolerite which follow the same bedding-planes across the whole area. A similar arrangement also holds in the buttresses of the eastern valley wall.

The Beacon Heights (B_4, B_3) (Plate V, and Section I, Plate VII).

On the western side of Beacon Height West (B_4) there is a small outcrop of the Beacon Sandstone. This, as before, has horizontal bedding-planes. The bulk of the rock is coarse, even-grained in texture, and almost white in colour. The greater part of the mountain appears to consist of sandstone, for the lower 2000 feet shows a yellow rock, with horizontal joints or bedding-planes, where the even covering of dark talus-products is wanting. The summit is a small cap of brown rock, which is separated from a larger mass of the same brown rock by a band of yellow about 500 feet thick, also bedded horizontally. The larger mass of brown rock is continued in the summit of B_3, and even extends to the summit of Knob Head Mountain further to the east.

The sandstone crops out as a small cliff on the side of this mountain (B_4); there the cylindrical rugosities (see p. 43) are again developed and appeared to be quite similar to those observed on West Groin. This outcrop was traced for a distance of a quarter of a mile along the hillside, and the cliff is on an average 50 feet high.

The Terra Cotta Mountains (Fig. 23).

The Terra Cotta Mountains (B_6, B_7, B_8) appear to be composed mainly of sandstone. They are abundantly riddled by dykes of dolerite which appear to have had considerable effect on the sandstone. The sandstone has a pale-pink tinge, and in the distance the hills have a dull-red colour, which contrasts strikingly with the dazzling snow and the yellow sandstone elsewhere. Some of the specimens from the moraine show that the sandstone has been altered to quartzite (697). The dykes will be mentioned in the next chapter when the dolerite-rocks are considered.

Knob Head Mountain (B_9) (Plate V).

The last spot where the Sandstone Formation was examined is on the east side of Knob Head, 30 miles from the South-west Arm or the hill B_1, and about 30 miles from the sea. Here a small outcrop, similar to that on the west of Beacon Height, is found at an elevation of about 3500 feet. At a distance the whole lower portion of Knob Head Mountain appears to consist of the sandstone. The mountain, like the Beacon Heights, has a small cap of dark-coloured rock (dolerite), which is separated from a larger sheet below by a narrow and horizontal yellow band. This similarity in the summits of the three mountains makes it probable that all are parts of the same two sheets of dolerite.

Fig. 23.—Terra Cotta Mountains, showing Dykes of Dolerite.

The sandstone-outcrop on Knob Head is less than a quarter of a mile long and about 100 feet high. Here again one bed was observed to have, all over its surface, cylindrical prominences like those described on page 43. At this spot, also, some beds contain alternate dark-coloured and light-coloured laminations, but nowhere did the rock show bands at all like the black bands found near the foot of B_1, nor was there found any structure in these dark laminæ which would suggest organic life.

APPENDIX TO CHAPTER VI.

REPORT ON THE PLANT-REMAINS FROM THE BEACON SANDSTONE.

By E. A. Newell Arber, M.A., F.L.S., F.G.S., University Demonstrator in Palæobotany, Cambridge.

The remains collected by the 'Discovery' Antarctic Expedition, and regarded as probably of the nature of fossil plants, are unfortunately of little value botanically.

The material was derived from two localities, viz., the hill B_1 in the South-west Arm of the Ferrar Glacier, and the Inland Forts. The specimens of Beacon Sandstone, containing much carbonaceous material, from the hill B_1 were collected by Mr. Ferrar on the 12th and 13th of November, 1903, at a height of 50 feet above the level of the ice (see p. 41). Several of these show fair-sized, carbonaceous impressions or markings, which, in all probability, are of vegetable origin. One example somewhat resembles in appearance a piece of petrified wood, but a microscopic section made from this material has failed to show any trace of organic structure.

The specimens from the Inland Forts are pieces of a pale yellow sandstone, obtained by Mr. Ferrar on November 16, 1903, at a spot some 800 feet up the West Groin (see p. 43). Some of these show one or more series of irregular puckerings, consisting of slight pits or depressions, sometimes lined by a small amount of carbonaceous material. It appears, however, to be impossible to form any opinion as to whether these features are due to vegetable agency or otherwise.

The imperfect evidence presented by these specimens will neither permit of any opinion as to the botanical nature or affinities of the fossils themselves, nor of the geological age of the beds in which they occur. Their discovery may, however, be regarded as affording indications that, at some period or other in geological time, vegetation flourished so far south as latitude $77\frac{1}{2}°$. Such a conclusion is of great geological interest, and is in harmony with the fact, now ascertained beyond doubt by the discovery * of abundant evidence of varied vegetations belonging to several different geological epochs, that the climate of the Antarctic, as of the Arctic regions, has been much more genial at more than one period in the past than at the present day.

* Nathorst, A. G., Sur la flore fossile des régions antarctiques, Compt. Rend. Acad. Sci., 1904, cxxxviii, p. 1447.

Chapter VII.

THE DOLERITES.

The doleritic type of rock has been found in practically the same localities as the Beacon Sandstone, and it will, therefore, be convenient to consider the localities in the same order as before. The dolerite of Depôt Nunatak is the highest point from which rock of any kind has been collected in South Victoria Land. Dolerites occur here at an elevation of 7000 feet, and, at the foot of Knob Head Mountain, about 30 miles nearer the coast, they have also been seen only 3500 feet above sea-level. There is no evidence of the presence of surface-outpourings, and as no vesicular or scoriaceous rocks were observed, even in the moraines, it would appear that these rocks are wholly intrusive.

Fig. 24.—Depôt Nunatak, from the East.

Depôt Nunatak (A.) (Figs. 24 & 25).

Lieutenant A. B. Armitage on the first journey through the Royal Society Range obtained weathered dolerite-fragments (632, 633) at Depôt Nunatak, and at the same time Engineer-Lieutenant R. W. Skelton photographed the parent rock which rises as a mass of great columns through the snow. The rock (662) is an outlier, and protrudes through the snow at an elevation of about 6000 feet. The nunatak rises to a height of nearly 500 feet above the snow and is exceedingly columnar throughout. Some of the columns are 12 feet in diameter and, though broken, give the impression that they extend the whole height of the cliff. Depôt Nunatak is 60 miles from the coast and is entirely cut off from the dolerite capping the sandstone eight miles to the east.

The Hill B_1.

Here the dolerite caps the sandstone and produces a cliff which rises vertically for more than 500 feet. This cliff forms the east side of the South-west Arm for a length of ten miles. As before, the columns which go to make up the sheet are about 12 feet in diameter, and weather to a bright-chocolate colour. At its junction (668) with the sandstone it becomes finer in texture, and it has obviously altered the sandstone for a distance of two feet, at least, from the contact. At one spot a mass of sandstone has been caught up in the sheet, and, near by, a pipe of dolerite 50 yards in diameter cuts vertically across the bedding-planes of the sandstone. The sheet extends along the side of the valley towards Finger Mountain and is interrupted by occasional small faults, the throw of which is always less than 100 feet.

The Inland Forts (Fig. 20).

On the north side of the Ferrar Glacier the hills are very uniform in height and are capped by a dark rock for a distance of 20 miles. At the point γ_1 a pipe or dyke of the dolerite cuts through the sandstone and joins the mass above, and at γ_3 there are two sheets of dolerite separated by sandstone. Further east again, at C_7, the cap of dolerite has been removed by denudation, and the lower sheet, which is reduced to under 100 feet in thickness, caps these isolated hills. Near the Inland Forts three dykes of the dolerite were examined, and a series of specimens (682–688) of dolerite and sandstone was collected along a line transverse to one of these dykes. These dykes are about 12 feet across and rise vertically through the sandstone to join the dolerite-sheets above. Where the dolerite meets the sandstone weathering has been accelerated, and the dykes lie in chimneys* which are sometimes 20 feet deep. One of these pipes is on the south end of West Groin, the other on the north end of East Groin and close to West Fort (C_9).

Fig. 25.—Columnar Dolerite of Depôt Nunatak.

Finger Mountain (B) (Fig. 22).

This mountain is 7084 feet high, and is composed of alternate layers of sandstone and dolerite. The lowest rock visible at the base is Beacon

* A. Geikie. 'Ancient Volcanoes of Great Britain,' 1897, vol. ii, p. 120.

Sandstone, of which not more than 100 feet appears. Above this there is a sheet of columnar dolerite 200 feet thick, which on the west side of the hill unites with another sheet of dolerite. These two sheets are separated by the wedge of sandstone already referred to in Chapter VI. The bedding-planes of this wedge are horizontal, and are made conspicuous by the intrusion of numerous thin sills of dolerite along them. The wedge tapers to the west, and at this end the columns of dolerite do not appear continuous throughout the cliff, but break and bend over to the west at a line which follows the inclination of the upper surface of the now absent wedge. Finger Mountain narrows eastward to a sharp spur (b_1–b_2). The upper sheet of dolerite ends at a scarp at the summit of B, while the lower continues some distance and is cut off by a structure-line, parallel to the line of transgression followed by the sill above the sandstone-wedge. This spur is capped by an outlier of the dolerite, which is separated by sandstone from a lower sill of transgressive dolerite 200 feet thiek.

Specimens were colleeted both from the last sheet (692) and from a dyke (691) eutting across the bedding-planes between this and the one above. Dykes and sills are numerous at this rather disturbed locality. A sill of dolerite 30 feet thick extends for a hundred yards along a bedding-plane, then terminates suddenly with a vertical end. Another sill 10 feet thick runs along a bedding-plane for 50 yards, breaks steeply downwards for 50 feet, and then, forcing its way along a bedding-plane for 100 yards, finally thins out and disappears. A third sill, 2 feet thick, extends 50 yards along a horizontal bedding-plane, but gradually deereases in thickness and ends as a wedge.

The specimens (695, 696; see p. 138) were collected from the base of *x*, from a sheet of dolerite below 200 feet of sandstone. Here also the dolerite occurs in sheets which alternate with the layers of sandstone, and dykes and thin sills are numerous.

Knob Head Mountain (B_9) (Fig. 26).

At a height of 3000 feet above the sea, and 30 miles inland, close under the foot of Knob Head Mountain, which is over 8000 feet in altitude, there is a cliff, 100 yards in length and 200 feet high, composed of columnar dolerite. Above the cliff the hillside slopes up more gently, and is covered with drift-blocks of granite and dolerite; the covering is broken only by this exposure of rock near its base. The outcrop shows columns 12 feet in diameter, and from 20 to 200 feet in height. There are oecasional horizontal cross-joints, but cup-and-ball structure is not developed. The Beacon Sandstone appeared to rest upon this dolerite-mass (661); it forms the main mass of the mountain, but the junction of the two could not be found. The hill B_6, three or four miles to the west, consists mainly of sandstone, but is riddled by dykes which form a network on its surface. On its west side there is a pipe of dolerite about 100 feet in diameter, which rises vertically through the sandstone, but cannot be traced to a junction with any of the overlying sheets of dolerite.

THE KUKRI HILLS (Fig. 27).

The bluff D forms the western extremity of the Kukri Hills and, as already stated, consists mainly of dolerite. If reference be made to the section along the Kukri Hills (Section III, Plate VII) it will be seen that two parallel sheets of dolerite, each

FIG. 26.—COLUMNAR DOLERITE AT THE FOOT OF KNOB HEAD. THE LARGE BOULDER ON THE SKY-LINE IS OF GRANITE.

about 2000 feet thick, run together at D. These sheets dip to the westward, and a specimen (704) obtained shows that the dolerite becomes finer in texture at its junction with the granite. The specimen was got from just above the lower junction and below D_2. The junction here is most striking and extends in an absolutely straight line for a distance of 10 miles along the side of the East Fork.

From the regular alternations of yellow and dark-coloured rock, I was at first inclined to suppose that there are two sandstone-deposits, but further work proved that the intrusive sheets cannot be continuous over the whole area. It would, however, be interesting to know what structural weaknesses have induced the dolerites to maintain uniform horizons for so great a distance, and to remain always separated by the same thickness of sandstone. The sandstone between the sills is always about 500 feet thick.

The Former Extension.

On consideration of the facts stated above, it will be seen that wherever a dark rock was encountered it proved to be dolerite; further, all the abundant dark fragments in the moraines belonged to that kind of rock. Dolerite has been shown to cap the highest sandstone seen, and to be intrusive into it on each side of the upper Ferrar Glacier. Some mountains are entirely composed of dolerite, and others, such as the Beacon Heights or Knob Head Mountain, have mere caps of that rock, which may be remains of a once continuous sheet. At the Cathedral Rocks dolerite must rest upon granite, and apparently at one time have been continuous with the sheet which caps the granite in the Kukri Hills. Further, the Royal Society Range, which is a faulted crust-block * and is higher than any of the surrounding country, has strongly developed plateau-features (Fig. 9, p. 23); the rock which forms the highest peaks is dark and therefore probably dolerite. If this be so, we may be sure that both dolerite and the Beacon Sandstone Formation extend quite 50 miles in an east-and-west direction.

Cathedral Rocks Kukri Hills

Fig. 27.—The dark band in the Kukri Hills on the right shows the Dolerite-sheet resting upon the even surface of the Granite.

Next, dolerite caps the Beacon Sandstone at the Inland Forts, and the hills for at least 10 miles north are capped by rock which cannot be other than dolerite. The contrast in colour between cap and sandstone is always so strong that this inference could be made even without regard to the evidence of abrupt changes in the hill-outlines at the junctions. For similar reasons there can be no doubt that the dolerite still caps the sandstone-hills, which extend 10 miles to the south of the main Ferrar Glacier (Fig. 28). These facts render it extremely probable that the

* Gregory, 'The Great Rift Valley,' 1896, p. 220.

Fig. 28.—The South Arm, with tabular features exhibited on the left, and Knob Head on the right.

sandstone-dolerite area is at least 50 miles long in a north-and-south direction, and has an extent of 2500 square miles at least.

A few of the hills in this neighbourhood, and especially the hill we called Obelisk (C_3), 10 miles east of Inland Forts, are pointed (Fig. 39, p. 72) and resemble the hills in the Torridon Sandstone districts of north-west Scotland; we may surmise that in these cases the cap of dolerite is lacking.

In Granite Harbour a dark rock which weathers like columnar dolerite may be seen above the granite (see p. 32), and further up the coast to the north the higher peaks of many of the hills were formed of a dark rock and stood out in striking relief over the Inland-ice against the cloudless sky. The black tabular formation is most striking about latitude 77° 0′ S., longitude 164° 49′ E., and again in latitude 75° 57′ S., longitude 163° 56′ E.

The area occupied by the Sandstone Formation is a question still to be solved. At the outskirts of the area indicated above there seems to be no doubt the sandstone has an enormous thickness, roughly 2000 feet. Lieutenant M. Barne records horizontal structures in latitude 80° S., and Lieutenant E. H. Shackleton has taken a photograph still further south which shows the plateau-features to be still prominent there. Towards the north we need only mention Mount Nansen in latitude 75° 30′ S., and the pyramidal forms of the peaks of the Admiralty Range discussed above.

Chapter VIII.

THE SEA-ICE AND THE SHORE-ICE.

The Sea-ice.

During the winter months the surface of the sea in high latitudes often freezes in a uniform sheet which does not vary greatly in thickness. This covering has had many names given to it, but on the whole Sea-ice is perhaps the most suitable, as suggesting that the ice is derived directly from the sea.

Sea-ice requires to be distinguished from other floating ice (ice at sea) of different origin, and this can readily be done by the close examination of even a small fragment. *The Structure* of sea-ice has been dealt with by Dr. Axel Hamberg,* Dr. von Drygalski,† and others. Dr. von Drygalski describes sea-ice as being composed of bundles of fibres packed together perpendicularly to the surface of cooling. A point not mentioned by him is, that, when the sea first freezes, the upper two inches consists of plates, a quarter of an inch across and a sixteenth of an inch thick, which lie horizontally, and only gradually do these give place to the sheaves of vertical fibres which make up the greater mass of the ice. Between the plates and the fibres is a layer of ice, about half an inch thick, of which the structure is very confused. Fig. 29 shows a mass of ice-crystals which have grown upon a fishing line. Mr. Hodgson records these crystals as occupying a length of 17 fathoms of his line, and gradually diminishing in quantity from the surface downwards.

Fig. 29.—Crystals of Ice which have grown upon a Fishing Line several fathoms below the lower (or freezing) surface of the sea-ice.

The Salinity * † seems to depend more upon the rate of freezing than upon the depth or distance from the surface. Both the authors quoted above have made

* Axel Hamberg, Bihang, K. Svenska. Vet.-Akad. Handl., 1895, Bd. xxi, Afd. 2, No. 2.

† Drygalski, 'Grönland-Expedition,' 1897, Bd. i, p. 424.

observations in this connection, and have proved a great amount of variation. Our observations show that the variation is even greater than they have recorded. We may mention here that the average amount of salt in dry sea-ice is about 4·3 grams a litre, whereas 32·8 grams a litre is the average salinity of the sea.

Ice met with at sea is more variable, and the amount of salt contained in it depends upon the previous history of the ice.

Near the shore, where floe-ice has buckled below the level of the sea-surface, shallow ponds form, and a gradual concentration of the dissolved salts takes place. Solutions containing as much as 266·6 grams of salt a litre have been found in such pools.

When the open sea first freezes, part of the concentrated solution left yields well-crystallized rosettes (ice-flowers) on the upper surface of the ice. The rosettes are usually two to three inches across and about an inch high and are scattered thickly over the surface; they are always extremely saline. If the sea-ice becomes depressed by a great accumulation of snow, the original upper surface is still always capable of identification through this local first salt-concentrate.

Fig. 30.—The Pack-ice, seen from the Crow's Nest of the Ship.

The Snow on the sea-ice in McMurdo Sound does not often accumulate to a thickness greater than two feet. Where any object interrupts the uniform level of the ice, snow-drifts form. The amount of the drift depends upon the magnitude of the object; such an object as our vessel produced a drift some 30 feet thick. The accumulation of local drifts has little ultimate effect upon the depth of the lower surface of the ice, for the snow, as it accumulates, pushes down the underlying layers into a region where the temperature of the water approaches that corresponding to greatest density; the lower ice then melts and is transported by the currents of the water (Fig. 49, p. 85). The equivalent of more than 18 feet of snow has been observed to be removed by this means during two consecutive years. From this observation it would seem impossible that a very thick sheet of ice could be entirely built up through continued deposition of snow on sea-ice or oceanic ice.

At a hole near the ship the upper surface of the snow was three feet above water-level, and the original freezing surface of the ice had been depressed to four feet below water-level. The total thickness of snow accumulated at this spot during the two years was more than 20 feet; as the thickness here when the ice broke up was only 15 feet, the whole of the original ice and the earliest deposits of snow must have been entirely removed by the melting action of the sea-water previous to the final break-up. By this means, water-vapour from low latitudes is condensed in high latitudes and transported again to low latitudes, without taking part in the glaciation of the polar land-masses.

Size of floes. Names * such as Pancake-ice, Bay-ice, Field-ice, Pack-ice, Stream-ice, are given to sea-ice at certain periods of its short life. Thus Pancake-ice is the first product of the frozen sea. It is an aggregation into roughly circular masses of the ice-plates which first crystallize. The flat cakes thus formed are about an inch thick and one to two feet across, and have notably turned-up edges. In a sheltered bay where these cohere to form a thin sheet, the result is called Bay-ice. Later, this thickening extends to large areas and the ice is then called Field- or Fast-ice. During the summer Field- or Floe-ice breaks up into *floes*, which float out northwards from McMurdo Sound and join the belt of Pack-ice (Drift-ice, *Treib-eis*) encircling the Antarctic regions (Figs. 30, 31). As the floes drift north they break up and dissolve away, and they are met with at sea in elongate and scattered patches which are termed Stream-ice. The size of the floes varies greatly; one may be 100 yards across, another may be two miles or more, but the thickness in the Ross Sea is never more than six feet. The floes are necessarily larger † on the south side of the belt of pack, as there they are protected from the swell by the stream-ice. Outside, the swell is most destructive and rapidly breaks up any large ice-field.

FIG. 31.—THE 'DISCOVERY' BROUGHT TO A STANDSTILL BY PACK-ICE.

Hummocks are rather exceptional in the sea-ice of South Victoria Land, and all that occurred in McMurdo Sound were less than three feet high. These seemed to be caused by the ice in the outer part of the bay breaking for a time

* Markham, 'The Antarctic Manual' (Roy. Geogr. Soc.), 1901, p. xiv; H. Rink, 'Danish Greenland,' 1877, p. 73.

† Colbeck, Geog. Journ., 1905, vol. xxv, p. 403.

Fig. 32.—Water-holes in Sea-ice at Cape Armitage and Hut Point in January, 1904.

from the inner ice which is fixed, and then impinging on it again and again. In the belt of pack-ice, hummocks are rare and usually less than 10 feet in height.

The Ross Ice-sheet presses against the sea-ice on the south-east side of the Winter Quarters peninsula, and produces a series of hummocks some two miles long. Some of the hummocks rise as bucklings of the sea-ice, here 8 feet thick; in others the sea-ice breaks into pieces about 20 feet long and these are forced up on end. Four parallel rows stretched out south-west from Pram Point and grew very gradually before the movement of the ice-sheet, only becoming conspicuous at the end of the first winter.

The Thickness.—The sea-surface freezes during the winter, but its ice rarely exceeds a thickness of 8 feet. Our observations on the thickness of sea-ice are rather exceptional for McMurdo Sound as a whole; for in one case the ice-gauge was placed where a strong current was known to exist, and in the other case the ice-gauge was placed in a sheltered bay, in ice which was always wind-swept and free from snow. At the former spot on March 1st, 1903, a water-hole was open: on the 24th of April the ice in it was 3 feet thick; and by about mid-winter (June 27th) it had grown to 5 feet. On August 23rd the thickness was 6 feet 6 inches, and water continued to freeze until December 5th, by which time it attained its maximum (8 feet 5¾ inches). After this date the ice began to disappear from below, and by January 28th was all gone. A water-hole off Cape Armitage (Fig. 32) was observed to open each year, which shows this melting action of the sea on sea-ice to be important. In 1904 the ice which surrounded the 'Discovery' broke up naturally and rapidly floated away, and the rate at which the break-up took place seemed to be independent of the thickness (Figs. 33, 34).

Fig. 33.—Sea-ice breaking away from the Winter Quarters in 1902.

Transport.—During the winter-months cracks in sea-ice, radiating from both Hut Point and from Cape Armitage, were formed. These cracks are produced by the ice in the middle of the strait being pushed forward faster than the ice at the sides. The pressure is always in one direction, and is caused partly by the movement of the Ross Ice-sheet and partly by accumulations of snow along the shore. The cracks freeze up soon after they are formed, and no movement in the reverse direction can therefore take place. Cracks made in this way seldom open much more than two inches at any time, but during the year have indicated a movement of more than 20 yards. Sea-ice therefore is removed in three ways: (1) through corrosion by sea-water, (2) breaking up and floating away piecemeal, (3) creeping bodily away from the land.

The "creep" of sea-ice is very small compared with the movement which takes place when an ice-field breaks up at the end of the winter; but it is important, as it prepares the field-ice for the action of the ocean-swell which breaks it up during the

Fig. 34.—The Relief-ships forcing their way through the barrier of Floe-ice in 1904.

summer. As the field-ice breaks up, the floes that are formed drift northwards to augment the pack-ice.

Thawing.—Virtually no surface-thawing of the sea-ice takes place, for the air-temperature in the open is always far below the freezing point, and the snow reflects most of the radiant heat. Locally dust and other extraneous particles sink into the ice or snow, but the holes thus formed are filled by the silting action of the snow. Mention has already been made of the action of the sea in reducing the thickness of the floe-ice, and it is noteworthy that during sunny days the sea-temperature itself is slightly raised and then the water melts more quickly the ice at its seaward edge. This greater capacity for melting the ice has been observed for at least two miles within the margin of the fast-ice of McMurdo Sound.

The Shore-ice.

The shore of South Victoria Land is always fringed with ice, which ends sharply seawards in a perpendicular wall (Plate 11). The wall varies in height from 3 to 300 feet, and two types of fringe may be distinguished.

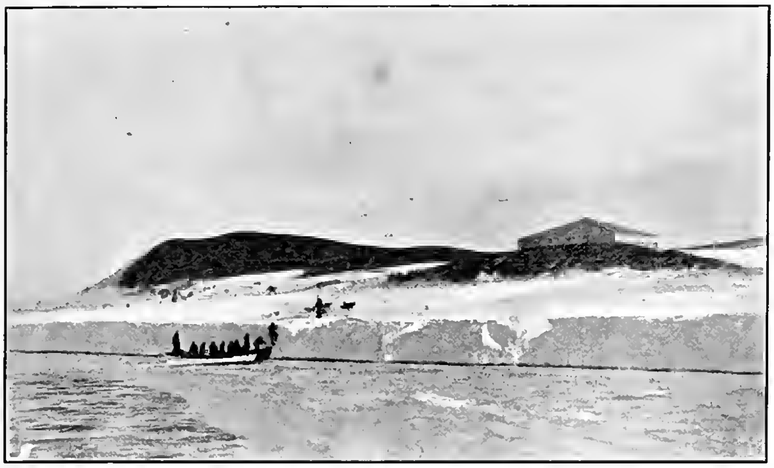

Fig. 35.—The Ice-foot at Hut Point.

(1) *Fringe due wholly to the frozen spray.* Such fringing ice never attains a height of more than six feet. The fringe of ice around the land in Granite Harbour is perhaps most characteristic, and forms a typical ice-foot.* It remained firmly frozen to the land all the year round. It is not materially added to by snow-precipitation, and dissolves rather than increases during the few summer-days when the sea washes against it. As the maximum rise and fall of the tide is less than three feet, a low ice-foot, as contrasted with the high ice-foots of Arctic regions, is to be expected. The breadth of the fringe varies from 6 to perhaps 60 feet, and the surface, which is usually fairly flat, often contains pools of water during summer. The chief action of the fringe is conservative.† It protects the land from the action of eroding breakers and floating ice, and more especially protects the rock-cliff by cementing together its talus.

Fig. 36.—Shore-ice wrapping the Land near the foot of Castle Rock.

(2) *Fringe of glacier-ice adherent to the land* (Figs. 35, 36). The ice is free from salt, shows the well-known blue bands, and has a well-marked granular structure. Such fringes vary much in

* Drygalski, 'Grönland-Expedition,' 1897, Bd. i, p. 285.
† Bonney, Quart. Journ. Geol. Soc., 1902, vol. lviii, p. 699.

their dimensions. The height varies from 6 feet to 300 feet, and the breadth from 10 yards to a mile. The surface usually dips at about 20° towards the ice-cliff.

As in the case of the first type, the action is wholly protective, but is even more effective owing to the greater size of the fringe.

A fringe of glacier-ice wraps the west side of Winter Quarters peninsula from the base of Mount Erebus to Crater Hill; near Castle Rock, where the ice-cliff reaches 300 feet, the fringe is perhaps at its highest.

Around Winter Harbour the cliff varies from 10 to 40 feet in height, and has a breadth which is sometimes as much as 100 yards; there, and in several other places, this type of fringe forms a sort of ill-marked terrace about 100 feet above sea-level, and slopes gently out towards its seaward face.

As in the case of glacier-terminations, it would seem that a lofty ice-cliff has always correspondingly deep water immediately adjoining it.

Chapter IX.

THE LAND-ICE.

The following classification of the land-ice of South Victoria Land has been found convenient. The headings are largely taken from Dr. E. von Drygalski's 'Grönland Expedition,' and from Dr. Albert Heim's 'Handbuch der Gletscherkunde,' but have been to some extent modified to meet local requirements.

(1) *Ice-sheet,** or *Inland-ice,** is the name applied to a mass of ice which covers a continental area of land. In South Victoria Land the sheets are of unknown extent, and enwrap and obliterate the inequalities of the interior land-surface, leaving coastal land-fringes comparatively free from ice.

(2) *Local Ice-caps,*† *Hochlandeis,*† the ice covering partially or wholly a limited land-mass. This ice may extend as an unbroken mass right down to the sea, or may escape as ice-streams. Such a cap may be defined as an ice-sheet on a small scale. These terms are necessarily relative, for we frequently speak of a polar *ice-cap* with reference to the earth as a whole, or again of a "*local ice-cap*," such as that upon Hayes Peninsula, quite a small area.

(3) *Piedmont-glaciers* ‡ are formed by ice crowding on to a coastal plain at the foot of a mountain-range. In South Victoria Land three types are distinguished: (a) normal piedmonts-on-land; (b) piedmonts-aground; (c) piedmonts-afloat.

(4) *Glaciers of Greenland type, or Ice-streams,*§ drain an ice-sheet and end in the sea.

(5) *Glaciers of Norwegian type* ‖ consist of streams of ice flowing down well-defined valleys (fiords) from a large firnfield.

(6) *Glaciers of Alpine type,*¶ *Valley-glaciers,* drain small intermontane basins (firnmulden): seldom advancing far from their mountain-sources, they never reach the sea.

* H. Rink, 'Danish Greenland' (1877), p. 39; Drygalski, 'Grönland-Expedition,' 1897, Bd. i, Chapter IV; Heim, 'Handbuch der Gletscherkunde,' 1885, p. 51; Garwood and Gregory, Quart. Journ. Geol. Soc., 1899, vol. lv, p. 682; Nansen, 'First Crossing of Greenland,' Chapters XV to XVIII.

† H. Rink, 'Danish Greenland' (1877), p. 366; Drygalski, 'Grönland-Expedition,' 1897, Bd. i, p. 118; Chamberlin, Journal of Geology, 1895, vol. iii, p. 66.

‡ I. C. Russell, 'Glaciers of North America,' 1897, p. 2.

§ H. Rink, 'Danish Greenland' (1877), p. 369; Heim, 'Handbuch der Gletscherkunde,' 1885, p. 51, ff.; Drygalski, 'Grönland-Expedition,' 1897, Bd. i, Chapter IV (Die Karajak-Eisströme und ihr Nahrgebiet).

‖ Heim, 'Handbuch der Gletscherkunde,' 1885, p. 50; Drygalski, 'Grönland-Expedition,' 1897, Bd. i, p. 298, ff.

¶ Heim, 'Handbuch der Gletscherkunde,' 1885, p. 55; Drygalski, 'Grönland-Expedition,' 1897, Bd. i, p. 298, ff.; A. Geikie, 'Textbook of Geology,' 4th edit., 1903, vol. i, p. 535, ff.

(7) *Cliff-glaciers,** *Re-cemented glaciers*, *Glaciers remaniés* are broken glaciers of the above types, which having a *Thalweg*, too steep in places to hold the ice, have areas of bare land separating the firnfields and the final tongues of ice which they produce.

(8) *Hanging glaciers,*† *Corrie-glaciers*, *Hängegletscher*, are masses of snow and ice lying in *cirques*, corries or hanging valleys. The ice in these disappears by melting, or by ablation, or by both processes, before the glacier can reach the main ice-stream.

(9) *Ice-slabs* are apparently peculiar to South Victoria Land, and are glaciers which, from the cessation of ice-supply, have slipped away from their former firnfield.

(10) *Icebergs* ‡ are common to both the polar regions, and may be appended to this list as products of the breaking-up of all glaciers which reach the sea.

1. The Inland-ice.

We have seen that the mountain-belt of South Victoria Land, quite 60 miles in breadth, buttresses a firnfield of vast but unknown extent. This ice-sheet has a horizontal upper surface, which on the west of the Royal Society Range has an elevation of 7650 feet. It flows eastward through the range in a deep-sided valley which bifurcates downwards in a most peculiar way. In the Prince Albert Range the flow passes between nunataks, which are sometimes 20 miles long, in arms ten miles across. The nunataks are usually broadside on to the present flow. The passes are shorter than they are broad, and have a striking similarity to those on the west coast of Greenland.§

In the ranges lying south of the Royal Society Range are deep and narrow channels termed "inlets" by Captain Scott. These channels are ice-filled, but lie much below the level of the adjacent mountain-ranges and have very steep sides. A theodolite showed only a very slight rise in the horizon along these, so that if the *Hinterland* rises at all high it must lie many miles west of the coast. The Inland-ice flows through these channels to feed the Ross Piedmont or Ice-sheet.

The surface of the Inland-ice, where observed, consists entirely of soft snow-powder and shows no gradual passage through granular snow to compact ice. The soft snow-powder, being readily taken up by wind and whirled about, is removed in bulk and transported bodily into the Ross Sea.

* Heim, 'Handbuch der Gletscherkunde,' 1885, p. 58.
† Heim, 'Handbuch der Gletscherkunde,' 1885, p. 45.
‡ Heim, 'Handbuch der Gletscherkunde,' 1885, p. 273; Drygalski, 'Grönland-Expedition,' 1897, Bd. i, Chapter XIV.
§ Drygalski, 'Grönland-Expedition,' 1897, Bd. i, Chap. IV. and maps at end of vol. i.

2. Local Ice-caps.

The icy covering of Mount Erebus provides, perhaps, the best example of an Antarctic local ice-cap, and its features are exactly those of the Greenland ice-caps on a small scale. Snow covers the greater part of the area, ice-streams flow down between bare nunataks,* *e.g.* The Turk's Head and The Skuary, and there is the bare coastal fringe between Cape Royds and Cape Barne.

The streams of ice which radiate from the mountain are too ill-defined to be called true glaciers. They have no snow-sheds, neither have they any well-defined banks. Still, all the mountains of Ross Island are completely covered with snow, and at definite points give off icebergs, which float away to the open ocean. The upper parts of Mount Erebus are covered by snow so thin that the outlines of lava-streams near the summit can be recognised at a very great distance. The middle slopes have occasional patches of bare rock protruding through the snow, and rising up or dipping so steeply that snow cannot long remain upon them. The lower slopes are even more broken by bare lava, and the ice must always average less than 700 feet in thickness, for the ice sea-cliff is never more than 100 feet high.

Fig. 37.—Ice-foot and Pack-ice in Wood Bay at foot of Mount Melbourne.

The surface of Mount Erebus shows numerous ice-falls in which the crevassed ice-surface stands out above the level of the more even normal ice-covering. Mount Terror, Sturge Island of the Balleny Group, Coulman Island and Mount Melbourne, all form centres of local ice-shedding (see Plate I and Fig. 1 (p. 3), Fig. 3 (p. 5), Fig. 37).

3. Piedmonts.

Masses of ice, which have a breadth greater than the length measured along the direction of flow, and lie at the foot of all large areas of high land, are conveniently referred to as *piedmonts*. These masses in South Victoria Land differ from such a

* I. C. Russell, 'Glaciers of North America,' 1897, Tacoma, p. 62, Fig. B.

typical piedmont as the Malaspina Glacier * in that they are supplied by driftings and snow-cascades from the adjoining land-mass, whereas the Malaspina Glacier lies below the snow-line and is only fed by distinct valley-glaciers.

Three types of piedmont are distinguishable.

(*a*.) *Normal piedmonts, piedmonts-on-land.*

On the west side of McMurdo Sound, between the moraines and the Northern Foothills, there is a continuous ice-belt without apparent source of supply and lying wholly upon low land. This ice-belt occupies an area 10 miles long and 5 miles broad, and appears to be fed by the snow drifting over the lower passes of the foothills. On the west it covers the hills to a height of quite 1000 feet, but on the east it ends as an insignificant marginal sea-cliff less than 50 feet high. On the north it slopes sharply down towards the depression of the Ferrar Glacier, but on the south it merges into the Blue Glacier. On the whole the surface is convex, and slopes more steeply around the outer edge. The whole of the ice rests on land, and seems, by entirely burying the shore, to protect it from denudation.

Occasionally, along the base of the Prince Albert Range, the convex ice-slopes, such as the one discussed, connect definite ice-streams, which, strangely enough, are always at a lower level. From Cape Bernacchi to Granite Harbour, and from there to Cape Gauss, there are two notable unbroken stretches of ice-covered land. These areas may be regarded as series of land-piedmonts. Occasionally, conspicuous sea-washed rock-cliffs protrude through them, and the ice-cliff facing the sea is obviously the edge of a broken ice-lenticle. The length of the mass varies from 10 to 50 miles, but the breadth cannot be more than about 10 miles. The evidence would seem to suggest that piedmonts are rather relics of a former greater ice-supply than products of the present conditions; their action would appear to be now entirely protective.

(*b*.) *Piedmonts-aground.*

Piedmonts-aground are well represented along the sides of Coulman Island, which has bare cliff-sides and a flat snow-covered top (Fig. 3, p. 5). It is surrounded by a comparatively low ice-wall produced by a talus of snow, which drifts off the top of the cliff and accumulates along the cliff-sides to form a continuous belt. Sometimes the talus is a mixture of rock and ice, but as a rule rock-matter was conspicuously rare. Small cascades of ice fall over the rock-cliff along the dykes and joint-cracks, which are seldom large enough to be called valleys.

This fringe has in section a convex upper surface. Near the rock-cliff it becomes steeper. At the seaward edge the convexity increases, and the termination is a cliff 100 feet high. Sections parallel to the shore would show a series of undulations, the crests being opposite to the main points of supply. Such fringes

* I. C. Russell, 'Glaciers of North America,' 1897, p. 109.

as that of Coulman Island are sometimes as much as 15 miles long, but are rarely more than 2 miles broad. The snow encircles the rock-cliff up to heights of 200 to 400 feet above sea-level, and the seaward edge is not often more than 70 feet above water. The distinction between "piedmont-on-land," and "piedmont-aground" is to some extent hypothetical, for it is difficult to make sure that ice at any particular point does not extend below sea-level (Fig. 56, p. 93).

On Sturge Island of the Balleny Group, a transition from "piedmonts-aground" to "piedmonts-afloat" is also evident, for sometimes the undulating fringes flatten out along definite lines parallel to the shore and extend at least 5 miles out to sea, and so are probably partly afloat (Fig. 1, p. 3).

(c.) *Piedmonts-afloat.*

Piedmonts-afloat are represented by four important examples, (1) the sheet of ice which fills up Lady Newnes Bay, (2) the sheet at the foot of Mount Neumayer, Drygalski Piedmont, (3) the sheet which extends from Cape Gauss eastwards for 20 miles at least, Nordenskiöld Piedmont, and (4) the Ross Ice-sheet, or Great Ice Barrier of Ross. All these are characterised by great extent with flat or slightly undulating surface, and by a cliff-edge between 50 and 200 feet high, which has enough water immediately in front of it to completely float the ice. The best known of these floating piedmonts is the ice-mass which Ross in 1841 called the Great Ice Barrier, but as this name entirely fails to convey the idea of vast extent, we conclude not to adopt it as a general type, but prefer rather to class the Ice Barrier of Ross and similar ice-masses as a subdivision of Russell's term 'Piedmont.'*

The Ross Piedmont has a seaward edge some 500 miles long, and its terminal edge rises to an average height of 150 feet (Fig. 38). The depth of water close to this ice-face is usually between 300 and 400 fathoms, and the sea-floor is covered with fine rock-flour. If reference be made to the chart at the end of the volume, details of heights and depths along it may readily be seen. If it be assumed that aerated glacier-ice floats with at most six-sevenths of its volume immersed in sea-water,† we may take it that the height in feet of the sea-cliff above is equivalent to the depths in fathoms below, and hence that this ice-cliff must be afloat. Further evidence that it floats is afforded by the tide-crack around Mount Terror, White Island, and in many other places. The uniform horizontality of the upper surface was proved by Captain SCOTT in his sledge-journey to the south, and by Lieutenant ROYDS and Mr. BERNACCHI in their trip for 155 miles to the south-east.

The intimate structure of Piedmont-ice shows that as far as water-level it consists of normal glacier-ice. On the surface away from the land only fine snow was met

* I. C. Russell, 'Glaciers of North America,' 1897, pp. 2 and 3.

† Heim, 'Handbuch der Gletscherkunde,' 1885, p. 278, and H. Rink, 'Danish Greenland,' 1877, p. 358.

with, but close to the shore crevasses and pressure-ridges show massive and vesicular ice. The vesicular ice contains air * amounting on the average to about 8·5 per cent. of its own volume, and the ice-grains are usually less than a quarter of an inch across. Near White Island the grains are at least half an inch across and of a very uniform size. This occurrence, however, is exceptional, for though no running water was seen, the patches of bare ice are quite saturated with water, and it has already been proved by Herr EMDEN † that growth of glacier-grains takes place most rapidly at or near the freezing point. All observations made seem to show

FIG. 38.—THE ROSS PIEDMONT FROM THE SIDE OF MOUNT TERROR, SHOWING THE CLIFF-EDGE AND FLAT UPPER SURFACE.

that the Ross piedmont is produced by ice-streams, not able to melt upon land, being pushed out to unite in a shallow bay, after which the ice-mass floats off towards the deep sea. It is remarkable that along the whole cliff-face from Cape Crozier to Cape Colbeck no trace of foreign matter in the ice could be observed. At the eastward end the land is completely buried in snow, but along the west side the land is comparatively bare. Rock-*débris* was never met with more than a very few miles from land. The chasm ‡ that skirts the west side is in itself sufficient to

* Heim, 'Handbuch der Gletscherkunde,' 1885, p. 113.
† Emden, Neue Denkschr. schweiz. nat. Ges. 1893, Bd. xxxiii, Abth. 1.
‡ Scott, Geog. Journ., April 1905, vol. xxv, p. 366, plate.

prevent boulders rolling on to the surface, but well-developed moraines on it are seen where, on Minna Bluff and Black Island, the ice hugs the shore. These moraines, however, will be discussed later; they are mentioned here as evidence that the ice-sheet does transport matter upon its surface. The movement of this piedmont seems to be comparatively rapid. Where measured by Lieutenant BARNE at Minna Bluff, it was proved that a point moved through 608 yards* in thirteen and a half months.

4. GLACIERS OF GREENLAND TYPE. (Plate III.)

Under this head will be included such ice-streams as flow from the Inland-ice. In the Antarctic region this type of glacier is magnificently developed, and every gradation, from streams 5 to 60 miles long, and 5 to 10 miles wide, is to be seen.

The Prince Albert Mountains exhibit features so similar to those of the west coast of Greenland that one description would suffice for both. Attention may, however, be drawn to the fact that the Greenland ice-streams end in fiords and come down between nunataks free from snow, whereas the ice-streams of the Prince Albert Range, though they may, perhaps, lie in fiords, project as if towards the edge of some coastal platform parallel to the mountains and well above the snow-line. The nunataks are wholly encircled by snow-slopes which are rather higher than the ice between them. The Ferrar Glacier is the only one that has been entirely traversed. Situated as it is on one of the highest ranges of South Victoria Land, it can hardly be considered quite typical, though steep inlets, which break directly from the coast and back into the high mountains, are peculiar to the whole region. The Ferrar Glacier has its source in the Inland-ice which lies at an altitude of 7600 feet above sea-level to the west of the Royal Society Range. The head of the glacier is an amphitheatre some 10 miles across, and is marked off by a few small nunataks. The sudden rise to the Inland-ice is almost semicircular and stretches round from Depôt Nunatak to the North-west Nunataks, with a curve concave to the east. This concave curve is marked by two parallel ice-falls, each about 500 feet high. From the foot of this fall the ice moulds itself to the valley, and between straight, parallel, and almost vertical, rock-walls flows off eastwards. Near Finger Mountain the valley widens somewhat, the north wall continues its straight course, but the south wall recedes irregularly to the base of Knob Head, and in this way leaves the depression at the Solitary Rocks (D_5) through which the ice from Windy Gully and South Arm enters. The ice from South Arm splits on a submerged water-shed and part flows first westwards and then northwards into the North Fork, while the rest, considerably supplemented by the discharge from the west of the Royal Society Range, fills up the East Fork, and eventually floats in the narrow fiord between the Lower Kukri Hills and the Northern Foothills.

* Scott, Geog. Journ., April 1905, vol. xxv, p. 363.

At the same time, of the ice from the upper portion of the Ferrar Glacier, part flows round the south side of Solitary Rocks and unites with that from Windy Gully and South Arm; part ends short of the *col* between the Solitary Rocks (D_5 and D_{5a}) in a gradually attenuated tongue; and the rest, which hugs the north side, probably extends past D_{5a} to be joined by that from the two tributaries from the south. Captain SCOTT travelled down the North Fork, and tells me that the ice there ends in an insignificant cliff some 12 feet high, leaving the lower portion of the valley strewn with moraines and in part occupied by small frozen lakes.

At γ_1 the height of the north wall is not more than 1000 feet above the ice, but by about 10 miles farther eastward the valley-bed has fallen 1000 feet while the adjoining mountains remain at about the same altitude. The valley deepens continually; near the Kukri Hills it has fallen nearly 5000 feet below the mountains and is bare of ice. The south wall, west of Finger Mountain, averages 500 feet above the ice, though the mountains are very much higher and culminate in the tabular mass T.

Windy Gully and South Arm also probably come down from the Inland-ice, which, about 20 miles further south, lies at an altitude of 7600 feet. The cañon-like form of the valley, therefore, is not so pronounced here as in the North Fork. Where Cathedral Rocks face the Kukri Hill, the East Fork is 6 miles wide, and, having sides 4000 feet high, is remarkably cañon-like. It is about 20 miles long; further eastwards it passes into the long fiord (nearly 15 miles long) which lies between the Lower Kukri Hills and the Northern Foothills.

The surface of the ice is locally crevassed, and it is noticeable that the crevassed areas, as on Mount Erebus, stand up above the general ice-surface. Crevassed areas are found: (1) in the middle of the glacier, six miles north-east of Depôt Nunatak; (2) close to the foot of Finger Mountain, where the valley-wall begins to retreat southwards; (3) close to b_2, where the ice is forced sharply round into the Dry Valleys; (4) on the south side of Solitary Rocks, where the ice enters North Fork; and (5) in the middle of East Fork, opposite Cathedral Rocks and three miles from them. Marginal ice-cliffs are a constant feature of the glacier, and moraines are rarely entirely absent.

5. GLACIERS OF NORWEGIAN TYPE.

The Norwegian type of glacier is well represented by the Blue Glacier referred to in connection with the gneissic series of rocks. The Snow Valley, which lies parallel to the base of Royal Society Range, has at one time fed five or six valley-glaciers which flowed out eastward into Discovery Gulf. All except the Blue Glacier have been broken across by diminution of ice-supply; and the Blue Glacier, draining a very extensive firnfield, is so nearly stagnant that, where measured, it had not moved more than about three feet in the year.* Its length, measured from the

* Ferrar, Geog. Journ., April 1905, vol. xxv, p. 381.

point where definite banks begin to be evident, is some twelve miles; but, if measured from the foot of the mountain-range, is about double that amount.

The surface of the glacier is snow-covered, and on the north side the snowdrifts of the foothills quite blend with those of the glacier-ice. No definite *Bergschrund* could be made out. For the last four or five miles the north side of this glacier adjoins the land-piedmont described above; but here again no evidence of movement was seen. The south side of the glacier is bare ice, and below the hill J_1 crevassed areas, as in the ice of the Ferrar Glacier, stand in relief. Again, on the south side of the glacier-snout, the ice stands off from the land and leaves the conspicuous channel noted so frequently. The ice-wall adjoining this channel shows sections of enclosed dirt-bands and moraine, and these are specially abundant in the lower part. As the cliff forming the snout is very clean and free from rock-*débris*, such matter as is now being carried must be close down upon the sole of the ice. The Koettlitz Glacier may belong to this class, but little is known of its upper reaches, and it apparently ends to the south of the Southern Foothills. At this point an ice-tongue from the Koettlitz Glacier breaks into the lower part of one of the minor valleys of the foothills, stagnates, and is no longer joined by the local glacier of the valley. The latter still exists as an ice-slab higher up. The main glacier advances a little further along its main valley and feeds the floating ice of Discovery Gulf (see Plate VI).

Two glaciers flow into Granite Harbour and join at the sea-edge, but as their sources are unknown they also cannot be classified with certainty. They are peculiar in that they too lie in narrow valleys which have very steep and straight sides, and from a distance are very like the Ferrar Glacier. All these valleys lie approximately at right angles to the main trend of coast and mountain-range, and seem to be a characteristic structural feature of the region. Glaciers of similar type are quite numerous among the snow-covered foothills of the Admiralty Range; some of them come down from valleys in the main range, while others arise in the snowfields of the foothills themselves. Into Robertson Bay flow some ten or twelve great glaciers which appear to drain the Inland-ice to the west of the mountains.* The Cape North portion of the mountains is traversed by at least two of the trough-like valleys carrying glaciers, but as the whole region is completely covered with snow and ice it is not easy to distinguish the types of the glaciers.

6. Glaciers of Alpine Type: Valley-glaciers.

The most picturesque glacier of Alpine type is that of the deep and narrow valley between the hills E_2 and E_3 of Cathedral Rocks. This glacier is partly supplied with snow from the plateau south of Cathedral Rocks. It is about five miles in length and one in breadth. It is crevassed from end to end. It joins the Ferrar Glacier about 2500 feet above sea-level, and causes at least three transverse bucklings on the surface of the latter.

* Bernacchi, 'The Antarctic Manual' (Roy. Geogr. Soc.), 1901, p. 503.

On the north wall of the North Fork, three glaciers drain out of one firnfield and end about 1000 feet above the ice of the main valley (Fig. 39). Two of these are cliff-glaciers, for the ice breaks off at the edge of a cliff and falls in avalanches which are lost in the main glacier at the foot of the cliff. The third has lately been a cliff-glacier, but its present loss by ablation exceeds the supply, and it now ends some distance from the edge of the cliff and therefore is of Alpine type. The south side of the Upper Kukri Hills has a numerous series of hanging valleys distributed at regular intervals between D and D_4. There are at least eight in a

A Dolerite Sheet.

The Obelisk C_3

FIG. 39.—THREE ICE-TONGUES FALLING INTO NORTH FORK.

distance of 10 miles. Of the eight between D and D_4, five have glaciers of Alpine type which, keeping their continuity, fall as cascades into the main valley below, and give rise to little or no disturbance in the latter.

7. CLIFF-GLACIERS.

The three other glaciers between D and D_4 are true Cliff-glaciers and, ending some 700 or 800 feet above the main glacier, discharge only as avalanches down the face of the cliff. The width of these glaciers is usually less than a quarter of a mile. They extend most of the way down the cliff, which is here about 4000 feet high. The hanging valleys all hang about 300 feet above the ice of the main valley, and therefore at about 2000 feet above sea-level. In some of them the hanging lip is very evident, while in others the *Thalweg* is very nearly uniform all the way.

8. Hanging Glaciers; Corrie-glaciers (Fig. 20, p. 42).

Four Corrie-glaciers are worthy of mention. These lie on the south side of the Inland Forts and occupy the *cirques* below the *cols* which link up the Forts. Three of these glaciers are quite isolated, but the fourth is joined by a tributary from the west side of Round Mountain (C_1). All flow southwards, but fail to reach the ice of the main valley, and are now building up crescentic moraines at their terminations. The interest of these glaciers lies in the fact that, though they now flow southward, they were formerly forced northward by the Ferrar Glacier into another drainage-system. Their supply is local from the Inland Forts, and the *cols* at their heads are completely bare.

9. Ice-slabs (Plate VI).

Ice-slabs are found in all valleys on the east side of the Southern Foothills of the Royal Society Range. These slabs are masses of ice, four to six square miles in extent and about 50 feet thick. They are the relics of glaciers which once drained the Snow Valley; but, owing to diminution of ice-supply, this has now become an inland basin, and its overflows have slipped away from it, leaving a subsidiary watershed bare. The surface of the ice-slabs is quite clean, and free from mud or stones. It is convex and slopes gently outwards from a centre. The ice-cliffs which bound ice-slabs show abundant dirt-bands and scattered morainic matter in their lower parts. In each valley in the Southern Foothills there is a glacier of this type, and it would seem that their development is due to the peculiar forms of the hills and their surroundings.

10. Icebergs (Fig. 40).

Icebergs have been defined by Heim as masses of glacier-ice floating in the sea. They are common to both polar regions. The icebergs of South Victoria Land are usually tabular in form, and the vast majority seem to be derived from some common source. Shore-ice is not prolific in the formation of bergs, as such ice remains firmly fixed to the land throughout the year. Blue Glacier was under observation for over sixteen months, and during that time no berg broke away from it, the snout remaining firmly frozen on to the sea-ice from the year 1902 to the year 1904. Within a mile of Blue Glacier, however, five bergs were aground, and could only have been derived from it.

If no ice-stream moved faster than does the Ferrar Glacier the number of bergs would be almost negligible. Doubtless the numerous ice-streams crossing the Prince Albert Mountains must give rise to a certain number of bergs, but even then the number is probably small. The piedmonts-on-land, lying on a flat shore and receiving only a small supply of snow, can seldom provide enough ice to form icebergs. Cliffs that encircle shore-ice hold snowdrifts which are sometimes as much as 60 feet thick. These always float out to sea during the summer, and produce small bergs which may easily be mistaken for the broken-up masses of

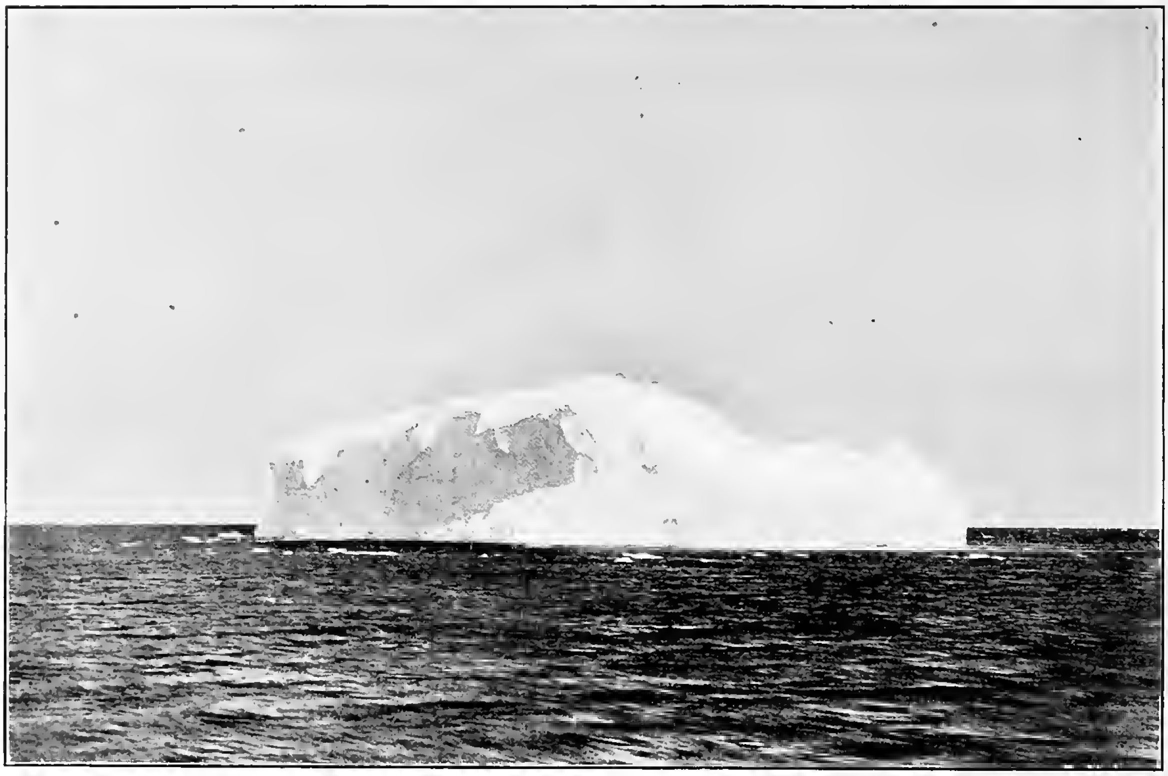

Fig. 40.—An Iceberg, over 150 feet high, tilted through nearly 90°.

tabular bergs. Piedmonts-aground do appear to produce icebergs which have irregular shapes and are produced in the manner of text-book icebergs.

On the Balleny Isles, where the snowfall is much greater, the piedmonts creep further out to sea and therefore supply larger bergs. It is, however, to floating piedmonts that we must ascribe the great majority of Antarctic bergs, and when we remember that the edge of the Ross Piedmont, whose ice is advancing northward faster than any other ice in South Victoria Land, has lost a belt averaging 15 miles in width during the last sixty-five years, we see that it must have given rise to innumerable bergs.

Piedmonts-afloat, from their configuration, can only supply tabular bergs, and the sizes of these vary enormously. Although the Ross Piedmont rises over 200 feet above sea-level, bergs over 150 feet high were seldom seen. Most bergs are less than a quarter of a mile long and about 70 feet high. The largest bergs seen were near King Edward VII Land, where there were many over 150 feet high; they had grounded in places where soundings showed 100 fathoms of water. Local ice-caps supply few bergs. Mount Melbourne, for example, has its ice-cliffs cavernous and overhanging, and we may conclude that years have elapsed since bergs separated from them (Fig. 37, p. 65).

Distribution.—Icebergs float northward along the coast of South Victoria Land bearing with them their burden of mud and stones, and soundings seem to show that most of this is dropped within the Antarctic Circle. In latitude 67° S. the sea-floor proved to consist of mud and ice-scratched stones, whereas only diatom-ooze had been obtained in the deeper water of latitude 60° S. The distribution of bergs in latitudes which are being constantly navigated is represented on the Admiralty Ice-chart, No. 1241, and a short paper by Mr. H. C. Russell * gives some measurements as to the sizes of the bergs. For our purpose, however, the northerly migration along the coast is the point of interest; the long string of bergs grounded near Cape Adare seemed to have formed a banner-shoal; melting there, they must deposit the moraine brought by them from higher latitudes.

Icebergs are destroyed by two agents, the sea and the sun. Some bergs float north into the warmer waters of more temperate latitudes and are there quickly melted. As the berg is undermined by the warm sea-water it becomes top-heavy and sometimes turns over, large pieces being broken off in the process. Some bergs ground in high latitudes and are only slowly dissolved. At certain stages these may float off the shoal and go to swell the mass of drifting ice.

Bergs containing mud, sand or gravel absorb radiant heat, and some ice is melted. The water produced distributes the mud over the surface and the rate of destruction is increased; on December 7th, 1903, a hot day, a berg was seen to have rivulets over all the sides turned towards the sun. A berg becoming inverted may carry mud and stones from the sea-floor above water, and these the sun immediately utilizes for the disintegration of the berg. In latitude 77° S., thawing of ice is of little importance except in December and January. Melting begins in the middle of November, becomes comparatively rapid by the middle of December, continues through January, and virtually ceases about the middle of February.

* H. C. Russell, Journ. Roy. Soc., New South Wales, 1898 (1897), vol. xxxi, p. 221.

Chapter X.

THE LAND-ICE—*continued.*

Englacial rock-débris may usually be seen near the terminal ends of glaciers. It occurs in well-defined bands interlaminated with bands of almost pure ice. The ice-walls which form the edge of a glacier also show rock-matter, and, as near the

Fig. 41.—Uplift of Morainic Material in the Ice at the foot of Knob Head.

snout, the rock-matter is more abundant in the lower layers. In the upper reaches of the Ferrar Glacier, the ice-cliffs though 100 feet high show only occasional small stones, but in the middle reaches, *e.g.*, at the base of Knob Head Mountain, boulders up to four feet across were observed low down in the ice-cliff. These boulders are ice-scratched and sub-angular: they are mixed with numerous small stones and some sand. At this spot also two streams of ice meet, and at their junction the englacial matter is forced up 70 feet and appears as a normal medial moraine (Figs. 41, 42).

Below the hill D_4 the chasm between ice and rock is only about 50 feet deep and some 30 feet wide. The lower 20 feet of the ice-cliff is heavily charged with rock-*débris* of all shapes and sizes. Rounded and apparently water-worn boulders up to 12 feet across are exuded from the ice, together with fine sand and mud.

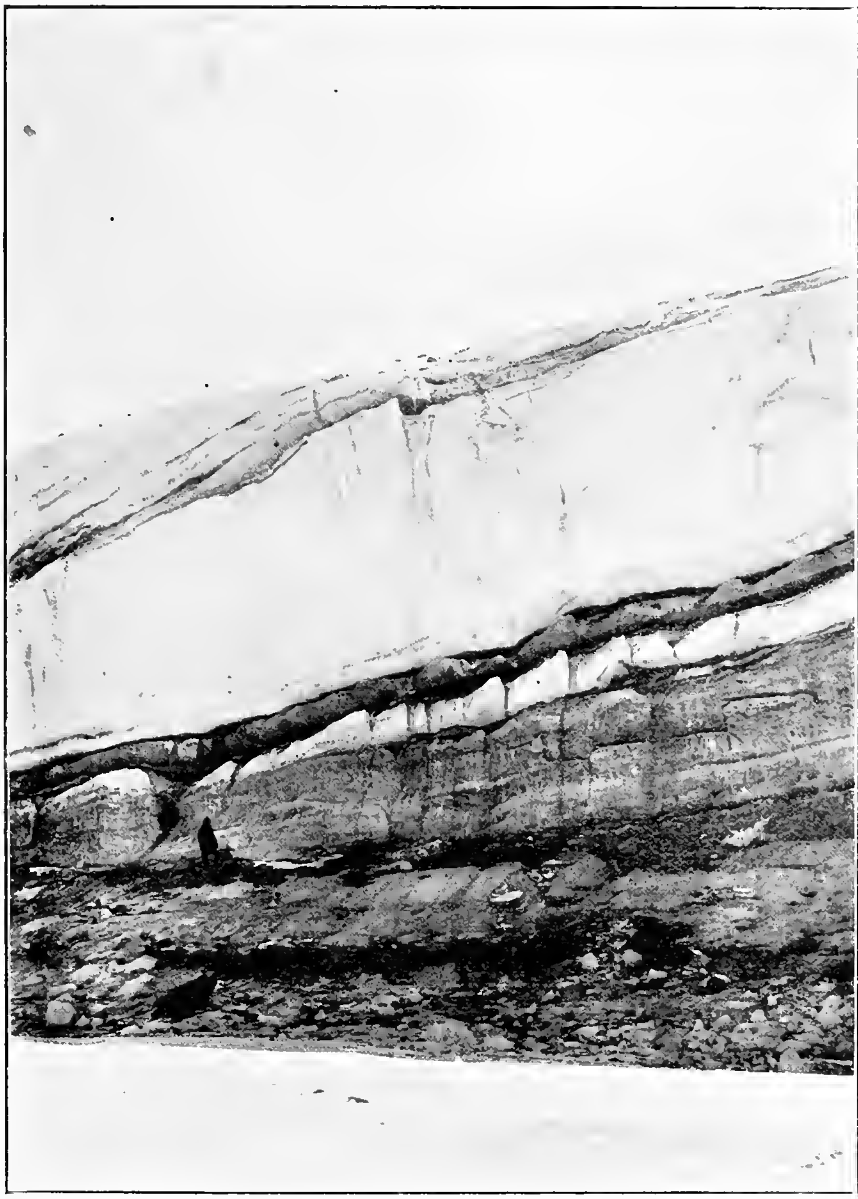

FIG. 42.—THE DARK BAND OF ICE-WITHOUT-GRAIN, BELOW NORMAL GLACIER-ICE, AT THE FOOT OF KNOB HEAD.

The sun is wasting the cliff away so rapidly that a lateral moraine is appearing below the general level of the glacier, and a small stream flowing along it is carrying away the finer material which is being dropped into it by the rapidly thawing ice.

On the south side of the snout of the Blue Glacier and 50 feet below the upper surface, there occur a channel and ice-cliff, like those of the Karajak ice-stream figured by Dr. DRYGALSKI;* along the channel, bands of mud and stones are visible in the ice-cliff. In one of the ice-slabs of the Southern Foothills sandy englacial matter occurs in much the same way as in the Ivory Glacier of Spitzbergen.†

Supraglacial matter is remarkably scarce. In this respect the glaciers of the Antarctic region stand in contrast with those of Switzerland or New Zealand. The latter are so much covered with angular rock-*débris* that no ice can be seen within three miles of the actual snout. The lateral and medial moraines on the Ferrar Glacier are not often as regular in distribution as moraines of other regions. Sometimes they begin suddenly about five miles from the nearest rock-exposure, and, after extending some way down the valley, end as suddenly as they began. Again, though bare rocks, such as Depôt Nunatak, shower talus upon the ice, the moraine produced can only be followed some two or three miles down the valley. In the Dry Valleys, the moraines appear to be melting off and to be falling back into the channels between ice and rock. A few isolated moraines are also scattered at random over the surface of the invading Ferrar Glacier.

FIG. 43.—MORAINE ON THE FERRAR GLACIER.
KUKRI HILLS ON THE LEFT, GRANITE-HILLS (G_2, G_3) ON THE RIGHT.

The moraines which are brought down by South Arm are perhaps the most striking in the region. Five of them are very prominent. One in the middle of this tributary extends north past the base of Knob Head, then turns for a time north-west, and finally curves round to the north-east, and on entering the North Fork is lost. Two pairs of moraines, rather nearer the east side of the glacier, bend round into East Fork and following the ins and outs of the valley, eventually find their way on to the floating ice at its mouth (Plate III). This double pair, as seen from Descent Pass, looks like the single pair of wheel-tracks of a waggon, but, as a matter of experience, at least half a mile of bare ice separates one pair from the other.

* Drygalski, 'Grönland-Expedition,' 1897, Bd. i, plate 14, p. 64.
† Garwood, Quart. Journ. Geol. Soc., 1898, vol. liv, plate 16.

The moraines consist of three-foot boulders of dolerite, granite and sandstone, which are accompanied by very little fine material (Fig. 43). The moraines are 30 feet wide, and the boulders are scattered thickly over the whole width. At the base of Cathedral Rocks another moraine commences and accompanies the other four. They produce parallel furrows in the surface of the ice which increase in depth as the boulders disappear. About 10 miles east of Cathedral Rocks these moraines are still represented by the parallel depressions, but the boulders are few and isolated, and numerous patches of coarse-grained ice mark the positions of those which have sunk through. Out on the floating portion of the Ferrar Glacier the boulders are even more scattered, and solitary survivors, about 100 yards apart, are all that represent the moraines of the upper reaches.

It was among these moraines, at heights between 3000 and 4000 feet, that we found numerous mummified carcases of the crab-eating seal (*Lobodon carcinophagus*). These are interesting in that the movements of seals ashore are always slow and laboured; how they could have travelled 40 miles uphill over rough ice and soft snow is an unsolved mystery. A pecten shell was also met with in gravel 10 miles up the Ferrar Glacier and 20 feet above the sea. The gravel had formed a glacier-table (Fig. 44), and the ice around was all glacier-ice, but is not above the reach of some exceptional tidal wave.

FIG. 44.—GLACIER-TABLE FORMED BY A LAYER OF GRAVEL.

On floating ice at the head of McMurdo Sound there are great quantities of moraine (Figs. 45, 47); the latter completely covers the ice and makes it difficult to make sure that this great mass is really afloat. There is, however, the tide-crack, which, following the land-boundary, marks off this *débris*-strewn area as a stagnant but floating mass. Our observations seem to show that the ice is really an overflow from the Ross Piedmont. In Discovery Gulf, also, the surface of the floating ice carries much rock and some organic (512, 513) *débris*, and extends for a distance of more than 20 miles from land. Between Black Island and Brown Island the morainic matter is unworn, its stones being usually angular. The moraines occur in long trains of cones which often rise 50 feet above the general level of the ice. Sometimes the cones blend with one another, and produce a series of ridges whose direction follows the former direction of movement.

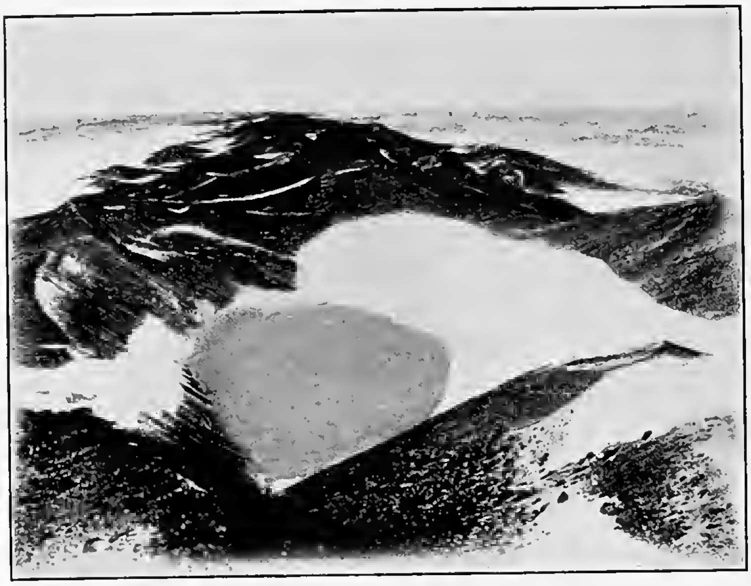

Fig. 45.—Moraines on Floating Ice at the Head of McMurdo Sound.

On rounding the north end of Black Island, the lines of cones curve westward, and are further continued northward to the "pinnacled ice" or old ice-edge. Occasionally large boulders up to four feet in diameter are found, but these disappear and are replaced by great quantities of coarse sand (261), which is often blown about by wind. It is this sand which, by inducing melting, produces the rivulets. These give rise to the fantastic "pinnacled ice" which presents so insuperable a difficulty to the sledge-traveller.

Re-sorted moraines were observed at Cape Adare; the "beach," from which so varied an assortment of pebbles has been taken, is one mass of such moraines. The average height of the beach is about 20 feet above the sea, but only 30 yards of the northern fringe has recently undergone modification by water. In detail the beach consists of parallel series of ridge-and-furrow with amplitude of about four feet. The ridges curve with the rock-wall. Sometimes the fine material appears stratified, but the covering of pebbles usually hides all evidence of structure. The ridges, which are occupied by penguins, flatten northward; and the depressions which contain stagnant water sometimes join up and form large digitating ponds. At an elevation of more than 800 feet on Cape Adare are other moraines. These cross the peninsula to the

Fig. 46.—Moraine-cone of Ice-scratched Stones, on which the Balanus Shells were found, on the floating Glacier-ice in the bay between White Island and Black Island.

north-east; they consist of small stones, some ice-scratched boulders, and a few blocks of rock up to 12 feet across. The beaches of Possession Island, Wood Bay and Franklin Island, appear to be similar to the Cape Adare beach.

Stranded moraines also occur above Cape Crozier on the slopes of Mount Terror at heights of 300 to 500 feet. Others on the south-east side are very striking. They lie 800 feet above sea-level and are 200 or 300 feet above the level of the Ross Piedmont. Other moraines occur on that shoulder of Mount Erebus which terminates in Cape Royds. They occur up to a height of 1000 feet, and are very well seen near the 800-foot contour. They cover some three square miles of area. Granites, and rocks like the dolerites of the Royal Society Range, are the most conspicuous components.

Fig. 47.—Moraines supported by Ice, on the west side of McMurdo Sound.

The moraines on the west side of McMurdo Sound are developed on a larger scale than any other moraines in South Victoria Land. An area there, 5 miles by 3, is one mass of *débris*-cones, some of them being as much as 100 feet high (Fig. 47). These cones rest in some cases upon land, in other cases upon fixed ice, and occur on a flat which is not more than 4 feet above the sea. The cones are more or less in lines, and the lines appear to radiate irregularly from two points, one set of them converging near the snout of Blue Glacier. Though the cones rise considerably above the edge of the land-piedmont described on p. 66, they follow its eastward border. On the south side of Blue Glacier these cones are replaced by a continuous line of moraine, and this hugs the edge of the Southern Foothills for a distance of some 30 miles.

Before leaving the subject we must briefly mention the ice which supports the cones and occasionally protrudes through the covering of *débris*. In particular cases it is often impossible to say what part of the material is ice and what part is rock-*débris*, and hence no attempt has here been made to distinguish between moraines still being carried by ice and moraines now resting upon the land. Even on Cape Royds water oozing from some of the ridges showed that the latter contained ice. During summer the fine material is continually being separated from the coarse by the water from melted ice (Fig. 52, p. 89). In some cases, however, the cloak of *débris* is too thick to allow the heat of the summer sun to get through, and the ice beneath it may then be preserved almost indefinitely.

The characteristic sheer ice-walls bounding the glaciers of South Victoria Land show that under present conditions the sides are receding from the land. The intervening channels often contain frozen ponds, which in some cases, though only 50 yards broad, are more than a mile in length. The large pond at the base of Knob Head may be contrasted with the Marjelen See, in that it follows the straight side of the main valley instead of merely occupying the dammed-up end of a tributary valley (Fig. 41, p. 76).

The structure of the ice between the bands of intra-glacial material at the base of Knob Head shows remarkable variations. The uppermost 40 feet appears to be quite normal vesicular glacier-ice and is free from rock-*débris* (Fig. 42, p. 77). Below this are several notable dirt-bands, and among them other bands from 2 to 10 feet thick, perfectly clean, and clear as rock-crystal. On melting small fragments from these bands no granular structure could be seen, and it is suggested that they are, in part at least, due to intrusive thaw-water. Other bands showed air-vesicles elongated at right angles to the banding. The ice which contains the majority of boulders has a structure comparable to that of ordinary rock-fault breccias, and it would appear that the ice here glides forward as a series of rigid sheets along parallel thrust-planes.

Up-thrust of morainic material similar to the up-thrust in Spitzbergen described by Professor GARWOOD,* was also observed at Depôt Nunatak, where Beacon Sandstone boulders are brought up to the surface. Up-thrust was again in evidence behind the Solitary Rocks on the Ferrar Glacier. Up-thrust produced by impact of two streams of ice is further seen at the foot of Knob Head, where the dirt-bands with large boulders bend up and appear on the surface 70 feet above their usual position (Fig. 41, p. 76).

Ice-movement.—Owing to the great distance which separated Winter Quarters from any glacier, our observations on the rate of ice-movement have been few in number. The rate at which the ice from South Arm forces its way into East Fork of the Ferrar Glacier is probably less than six feet per month. Other observations made at its snout indicate that the rate is extremely small. The Blue Glacier moves less than four feet a year, while the Ross Piedmont, as measured by Lieutenant BARNE from the depôt off Minna Bluff, moved no less than 608 yards in 13½ months. The movement of Ferrar Glacier or Blue Glacier causes little disturbance of the sea-ice; slight movements are transmitted to the latter and become lost in its more ordinary movement. Where the Ross Piedmont abuts against Mount Terror, three parallel and well-defined ridges appear. These are at least 50 miles long and usually some 50 feet high. They have been traced by Lieutenant ROYDS towards the north end of White Island, but gradually flatten out and fan. At Pram Point four lines of parallel hummocks, each about 15 feet high,

* Garwood and Gregory, Quart. Journ. Geol. Soc., 1898, vol. liv, p. 219.

are caused by an overflow of Ross Piedmont. Captain SCOTT found that the ice of such channels as Mulock Inlet pushes the piedmont-ice away from the land and leaves a chasm,* some 100 feet deep, in the intervals between them. At such outstanding points as Minna Bluff, cracks and crevasses radiate outwards, particularly towards the east and north-east; but a sledge-party, by giving the land a wide berth, was able to avoid most of these. Near the north end of White Island also, series of radiating cracks are found. It would therefore seem probable that the Ross Piedmont is moving northwards bodily.

The ice-falls of Ferrar Glacier indicate movement, but, as the crevasses always remain drifted up with snow, the rate must be exceedingly slow. In the channel at the foot of Knob Head, where the evidence of up-thrust is recorded above, the banks of the frozen ponds have several small ridges alongside and parallel to the glacier-side. These ridges, which are occasionally broken along their length, indicate a certain amount of movement; as this is the only spot where rupture caused by shearing movement is obvious, the fact is noteworthy.

Near the sea, where the ice-tongue floats in its valley, the tide-crack follows the side of the glacier for a distance of at least 10 miles. Near the foot of the hill G_2 the crack trends towards the centre, and, gradually disappearing, is replaced by other cracks which trend inwards up the valley. It would seem that the point of replacement indicates the floating of the ice, and that the oblique cracks show a slightly more rapid forward movement of the mass of ice behind.

In the amphitheatre or depression of the Ferrar Glacier, two miles from the foot of Knob Head, the ice shows a network of ribbon-like cracks or fracture-lines (*Risse* †). These are often less than two inches apart, and, without opening more than a hair's breadth, extend for great distances. Parties camped on this ice have observed on several occasions that very rapid splitting or bursting asunder takes place with loud report, as soon as the hills cast their shadows on the ice. The reports which accompany the splitting are loud and frequent, and often resemble the noise of independent rifle-firing. The noises frequently continue for an hour and a half at a time. Rupturing has also been observed at several other spots, and seems to be caused by strain set up by changes of temperature in the ice. That the ice is in a state of strain is proved by the fact that a blow from an iron-shod ski-stick has produced cracks which have extended 50 yards across the surface of a mass of ice not less than 100 feet thick.

Snow.—The usual accumulation of snow took place during violent blizzards when the air became thick with fine snow-dust (Fig. 48). On a few occasions in the summer, however, large flakes fell gently from a cloudy sky. Sometimes soft hail in rounded pellets and soft woolly hexagonal snow-crystals descended from an overcast sky. Occasionally also, during summer, hexagonal ice-crystals up to half an inch across fell

* Scott, Geog. Journ. April 1905, vol. xxv, p. 366, plate.

† Drygalski, 'Grönland-Expedition,' 1897, Bd. i, p. 80; Heim, 'Handbuch der Gletscherkunde,' 1885, p. 202.

from a clear sky; on the surface of the Ross Piedmont, they supplied much of the superficial ice of the area. In the course of a day or two the crystal-plates break up into grains, which drift hither and thither with the wind. After a blizzard, soft snow usually becomes tightly packed, and the snow-dunes which have been formed show a smooth and hard surface. Later this dune-snow granulates, notwithstanding that the temperature remains constantly below 0° F. If a wind springs up, the grains are carried away and the dunes disappear. Graduated pegs were set up in the snow to determine the changes which take place in its surface, and the observations show that during two years much snow drifted past them. Wind carries the snow bodily away; the importance of this factor in reducing the height of the inland-ice of South Victoria Land will be appreciated if we recall the six and a half days during which the sledge-parties were weather-bound on the edge of the inland-ice. During that week, the air, which passed at an average rate of 50 miles an hour, was so charged with fine snow that objects 10 yards away were indistinguishable. That this is not unusual may be inferred from the fact that at Winter Quarters the days on which no silting, or surface-drift, of the snow took place were few.

Fig. 48.—Undulating surface of hard "Marbled" Snow.

The winds by carrying snow on to the surface of sea-ice help to drain the land; and the sea-ice, as it breaks up and floats north, takes away much superfluous water-substance which has had no opportunity of glaciating the land (Fig. 49).

The snow-dunes usually took the form of crescents and symmetrical elongated domes, never more than three feet high. The longer axes of the domes were parallel to the direction of the prevailing winds, those of the crescents transverse. As soon as their substance becomes granular, the winds remove and obliterate all trace of them.

During the process of destruction, snow-surfaces resemble a wind-worn surface of false-bedded and slightly indurated sand. The less granulated layers are the more indurated, and stand out beyond the coarser and less resisting bands, thus giving the appearance of stratification. The forms assumed by the disintegrating dunes are very variable,* and some become very fantastic. The silting snow helps

* Vaughan Cornish, Geog. Journ., August 1902, vol. xx, p. 137.

the wind and behaves like a sand-blast, cutting away both the soft and the hard layers.

No transformation from snow to glacier-ice could be observed. Present climatic conditions are such that thawing, even partial thawing, only takes place very locally, and all the surfaces encountered were either granular white snow or compact ice. Even at the head of the Ferrar Glacier the change from snow to ice is absolutely sudden, and along the base of the great cascades the ice presents its characteristic rippled surface. Local accumulations of snow do occur in the larger depressions, but the line separating granular snow from glacier-ice is always sharp. A few snow-dunes were also seen, consisting of opaque white snow, too hard to be cut even with an iron spade.

In 1902 Lieut. ARMITAGE travelled up Ferrar Glacier over soft snow, and at one of his camp-sites left pieces of spun yarn, a tin and a piece of wood; they were found by our party a year later and lay loose upon hard transparent ice; the tracks of his men and sledges could have been followed all the way up the glacier. The sledge-tracks appear as two parallel ridges, standing in relief nearly an inch above the general ice-level. The footprints of the men also stood in relief, but the dark objects left lying about were not so raised. From these facts it would seem that in this locality loss by ablation exceeds gain by precipitation.

FIG. 49.—THE TWO LOWER MEN ARE STANDING UPON THE UPPER SURFACE OF SEA-ICE DEPRESSED BY SNOW BELOW WATER-LEVEL.

A surface of white snow absorbs little incident radiant heat. Owing to the low temperature of the air, the growth of the grain can therefore only take place slowly. In sheltered spots or near bare rock, snow and ice melt rapidly during summer, and even in the open long furrows filled with water * appear. The best example of this was seen among the hummocks near Black Island, where long furrows filled with fresh water separate rows of hummocks (*Hügel* †) from one another.

Temperatures at fixed depths in the ice were determined during 1903, and the observations show that the variations from day to day are surprisingly small. It will suffice here to note that the highest temperature recorded at a depth of six feet was $-9°$ C. and the lowest $-24 \cdot 4°$ C. The change was gradual throughout the year.

* Drygalski, 'Grönland-Expedition,' 1897, Bd. i, p. 78, plate.

† Drygalski, 'Grönland-Expedition,' 1897, Bd. i, p. 86, plate.

The minimum reading was taken after mid-winter and the maximum occurred in January, and hence a considerable lag in temperature is produced by the six feet of ice. Temperatures at greater depths in the crevasses* show that there the lag in temperature is even greater, and also that the maximum temperature reached by the ice is far below the melting point. The following observation from a crevasse near the junction of the ice of South-west Arm with that from inland is of interest :—

November 3rd, 1903, 7 P.M. Depth of crevasse 30 feet.
Temperature of the air +20° F. (−6·7° C.).
Temperature of the ice −21° F. (−29·4° C.).

* Drygalski, 'Gronland-Expedition,' 1897, Bd. i, p. 450; Heim, 'Handbuch der Gletscherkunde,' 1885, p. 288; Nansen, Meteorological Report, 1894, 1895, 1896.

Chapter XI.

DENUDATION.

Wind-action.—The winds in South Victoria Land prove to be as strong and as constant as any oceanic trade-wind. Around Winter Quarters the bare land-surfaces are usually covered to a depth of six inches by a loose cloak of rock-*débris*. Below this the earth is permanently frozen throughout the year, and here rock-surfaces due to fracture often seem to remain quite unweathered. The layer of rock-*débris* consists of a mixture of occasional boulders, abundant small stones and rock-chips, embedded in a matrix of impalpable flour, and all would seem to be rapidly disintegrating. Many of the boulders seem to have no very definite outer boundary, and the protected surface may be seen to pass gradually through a state of crumbling (547) into impalpable powder (446). This cloak is usually damp for a week or two in summer, but becomes dry and loose when frozen during winter. Here decomposition and disintegration proceed simultaneously, and any particles loosened by frost from the upper surfaces are at once blown away by the wind; the fine material which remains is always an inch or so below the loose layer of stones at the top of the deposit.

Fig. 50.—Hollowed Granite-boulder with Incrustation of Calcium Carbonate, near Descent Pass.

The loose stones are often smoothed and pitted (325) in the manner peculiar to the wind-worn stones of desert regions,* and some of the harder ones have a superficial glaze. Some of the boulders are too granular to receive polish; gradually crumbling away, they for a time leave patches of small angular fragments, still too large to be transported by the wind, to mark the spots they once occupied.

The wind has carried away the smaller rock-fragments from the summits of Observation Hill and Castle Rock. Those which remain are upwards of two inches in diameter. The summit of the former, which is composed of trachytic lava, is

* Walther, Abhand. math.-phys. Cl. d. k. sächs. Ges. Wiss., 1891, Bd. xvi, p. 447. (Dreikanter.)

honeycombed to a remarkable extent. The boss of trachyte above Cape Crozier, the kenyte of Cape Royds and basalts of other areas, show similar wind-effects.

The Beacon Sandstone of the Royal Society Range, likewise, was almost free from the fine disintegration-products, particular beds being often bare for lengths of a mile or more. The loose quartz-grains derived from these seem only to remain in crevices or below projecting rock-shelves. Dolerite-columns, too, are quite smooth, and are coated with a bright chocolate-coloured crust (670) rarely more than one-eighth of an inch thick.

Hollowed granite-boulders (Fig. 16, p. 34; Fig. 50) were observed at the foot of Royal Society Range near Descent Pass, and two types may be distinguished.

(A) In fairly normal granite. The rock (555, 556) is a grey to pink granite with felspars usually about a quarter of an inch long; it appears to be quite fresh even on the surface, and has a marked superficial glaze on both convex and concave surfaces. The most striking cavity is on the south and weather-side of a large block and therefore faces away from the sun; it is about eighteen inches across at the opening, and the diameter increases inwards to at least two feet. The depth of the cavity is a little more than a foot, and the back wall is partially covered with a hard mamillated or botryoidal crust (554), consisting mainly of calcium carbonate, the surface being white, and harsh to the touch. The crust was lamellar, scarcely more than one-eighth of an inch thick, but the projecting botryoids, which are sometimes partially hollow, may be more; it was firmly fixed to the granite-face, so that it was impossible to decide whether the surface beneath was or was not glazed.

Fig. 51.—Saline Pond in Moraines on west side of McMurdo Sound.

(B) In a very coarse granite containing abundant large crystals of orthoclase. The hollowed blocks (557, 558) are rounded, but the surface, owing to the rapid disintegration, is roughened rather than glazed. The largest cavity is in a block 6 feet by 4 feet by 4 feet, which is hollowed almost to a shell. The cavity is four feet long, three feet deep, and two feet high, and has four apertures varying from a foot to eighteen inches in diameter, one on each side of the block. The lip of the apertures is exceedingly sharp, the angle being certainly not greater than 30°. No incrustation was seen on the walls of this cavity, but on the floor is a sprinkling of the finer disintegration-products of the granite which abundantly litter the surrounding area.

These cavities in crystalline rocks apparently resemble the cavities in granite observed by Mr. F. F. TUCKETT * and Professor T. G. BONNEY † in Corsica and by the Rev. R. BARON ‡ in Madagascar, but the incrustation of calcium carbonate shows that wind is not the only factor involved in their formation. As in Corsica, many saucer-like depressions and a few potholes were observed, and seem to mark stages in the development of the completed cavities. Internal incrustations do not seem to be recorded, but Mr. BARON mentions a "white powder alkaline to the taste" as occurring in the hollowed blocks of Madagascar.

Water-action.—Water, as an agent of denudation in South Victoria Land, is at present a factor of limited importance (Figs. 51, 52, 53). On glaciers it merely washes away the finer material already thawed out of the ice. On bare rock it seldom appears, but along the south side of the Kukri Hills and in other places a marked water-channel occupies the marginal ice-area, and in summer water flows along the junction of ice with rock. Water, therefore, may undercut rock-cliffs and tend to widen and terrace the sides of valleys. Any ice thawed away by water is at once replaced by the advance of fresh ice, a process which tends to render permanent the course of the water-channel. Actual undercutting of rock-cliff was only seen occasionally, but at the foot of the hill D, along the Cathedral Rocks and along the foot of the granite hills G_3, was most evident.

FIG. 52.—WATER SEPARATING MUD FROM GRAVEL IN THE MORAINES ON MINNA BLUFF.

During the summer, water everywhere distributes mud and sand over the ice. Much of this mud is derived from the moraines which protect ridges of ice, and the running thaw-water sorts sand from gravel and fine mud from sand. In this way stratified and false-bedded sands and gravels may be derived and appear among morainic accumulations (Fig. 52). Channels cut in the floating glacier-ice are common at the head of McMurdo Sound, and during summer

* Tuckett, Geol. Mag., Dec. V, 1904, vol. i, p. 12.
† Bonney, Geol. Mag., Dec. V, 1904, vol. i, p. 389.
‡ Baron, Geol. Mag., Dec. V, 1905, vol. ii, p. 17.

the water flowing through them often spreads sand and mud over the surface of the sea-ice.

The most notable effects of water-action in the area were seen on the north-east side of Brown Island, an island which retains practically no snow on its surface. In January, 1902, a very warm clear day followed a summer snow-storm, and caused a rapid melting of the snow just deposited. Rivulets becoming confluent produced comparatively large streams, which coursed in straight and narrow trenches down the hillside. The slope here is very steep, and trenches sometimes 20 feet deep had been eroded. The coarser material washed off the hillside spreads out as a delta on land, but much of the finer material is carried further by the muddy stream, in and out among the lines of moraines, and distributed over the surface of the floating glacier-ice. We observed a stream increase in depth from one foot to three feet in the space of a few hours. The swollen stream cuts into the protected moraines and, overflowing the more level areas, there deposits its silt. Finally, the stream coursing northwards into McMurdo Sound passes off the pinnacled or floating glacier-ice * on to the sea-ice which its finest sediment then sullies (Figs. 53, 54).

A similar flood must have occurred early in

FIG. 53.—WATER-CHANNEL ON FLOATING ICE IN MCMURDO SOUND.

J_1 Blue Glacier G

FIG. 54.—SEAWARD EDGE OF THE GLACIER-ICE FLOATING IN MCMURDO SOUND.

* Ferrar, Geog. Journ., April 1905, vol. xxv, plate, p. 374.

December, 1903, for an area of sea-ice, six square miles in extent, was found with an average of eighteen inches of muddy water upon it. Some of this water may possibly have been produced in place, for this inundated area lay along the north edge of the floating glacier-ice, and during the winter-gales must receive foreign matter.

Chemical action.—Chemical decomposition of rocks is more obvious in the dry climate of South Victoria Land than in other areas, for rain can usually remove soluble salts as fast as they form. On Hut Point all rock-fragments have thin incrustations of sodium sulphate (398). The incrustation is sometimes so abundant that the rocks look as if they have been dusted over with lime or flour; if the loose surface-matter be scraped away, thin discontinuous beds of the pure salt may be seen dipping gently into the hill. The surfaces of many boulders in The Gap are covered by a lace-like network of white lines (262, 263) consisting of calcium carbonate.

Near the north end of White Island a great quantity of perfect crystals of sodium sulphate (298) was obtained on a mound of the floating glacier-ice (Fig. 55). The percentage of water in this salt, as determined by Dr. Prior, was 55·86, which is virtually identical with that characteristic of pure Mirabilite or Glauber Salt.

Fig. 55.—Fractured Dome in the Floating Glacier-ice, near the spot where Sodium Sulphate Crystals were found, two miles from the north end of White Island.

Near the isolated moraines in the bay between White Island and Black Island, on floating glacier-ice, there are five or six mounds, two feet high and up to five feet across, of the same white salt (623). The mounds are entirely composed of the salt, which is in well-formed crystals, though the outer ones have effloresced to some small extent. The moraines near these mounds contain *balanus* shells (612) together with ice-scratched granite and other boulders (Fig. 46, p. 80). In one of the moraine-cones on the west side of McMurdo Sound, a bed of this salt (741), about eighteen inches thick, is traceable horizontally for about ten yards. This bed is at least 50 feet above a pond of brackish water which occurs at the foot of the moraine. Dr. E. A. Wilson also found this salt (740) near the head of Discovery Gulf, and Mr. T. V. Hodgson (742) on Inaccessible Island. As many of the ponds among the moraines are much too saline for drinking, it is possible that this peculiar and abundant concentration of soluble salt may be due to a former crystallization from similar ponds.

Frost-action.—Owing to the very low temperatures prevalent in high southern latitudes, the denuding action of frost is not strikingly conspicuous. As a rule, the wind removes all snow from bare rocks, and a marked line always divides the local snow-fields from the areas free from snow. Thawing and freezing only occur near the edge of snow-fields, and, therefore, owing to the general absence of water, frost-action is once more rendered impotent. Castle Rock was perhaps the best example of a frost-riven mass near Winter Quarters. It rises sheer above the snow-covered peninsula; but the side facing the sun (the north side) slopes steeply down to shore-ice nearly 1000 feet below. Snow is drifted by the prevailing easterly wind on to the north side, and in summer large riven blocks fall down and litter the area below. The north side of Cathedral Rocks is similarly shattered; from its pinnacled outline it would appear to be more subject to frost-action than the isolated peaks further to the west.

The dolerite, though forming no prominent talus-slopes, appears more prone to split than other less-jointed rocks and a conspicuous ledge is always left at its contact-junctions. Where dolerite occurs above sandstone, a terrace of the sandstone stands out in front of the steep dolerite-cliff. Fans of dolerite-talus are very conspicuous in the smaller of the Dry Valleys, also below the hill D, and along the south side of the Kukri Hills.

No screes encroach upon the upper parts of the Ferrar Glacier, and the dolerite usually rises perpendicularly from the ice. Along the ice-streams talus-fans are rarely abundant enough to become continuous even at their base. The sandstone undergoes little frost-action. Often its surfaces still retain the rounded outlines which have been produced by ice-action. All transport of rock-material is now accomplished by wind, which carries off the sand-grains as fast as they are loosened.

An important agent in wearing down the sandstone, and one which can hardly be classed with any of the ordinary agents of denudation, may be included here. The columns of dolerite, in falling down the cliffs, break away the softer sandstone-beds and produce a sort of "chimney talus-shoot," which conveys the *débris* to the fan at the bottom. Other fragments follow this line of descent, and thus the deepening of the gully is accelerated. On the hill x several such gullies may be seen. At a height of about 500 feet above the ice, the edges of the sandstone-beds which have been caught up by the dolerite (see p. 46) are serrate, and at one spot a groove or gully, 20 feet wide, of U-shaped section, has been produced. This groove has perpendicular sides, and the uppermost bed of sandstone has been cut back 20 feet from the edge of the cliff.

The granites of Antarctica, as of other regions, seem prone to form screes. In the metamorphic limestone area, the hills are usually so rounded that there is seldom an opportunity for a loosened block to change its position, and no transport takes place until the rock is so finely disintegrated that it can be carried off by the wind.

Ice-action.—Adopting the same plan as before, we shall briefly review the general action, as a geological agent, of each specified form of ice. The sea-ice, as already pointed out, seldom runs aground, and is therefore negligible as an agent for striating or abrading rocks or for contorting beach-deposits. Sea-ice forced up on to the land has been observed at only one spot. This was the very exposed north-east corner of the stranded moraines on the west side of McMurdo Sound, where sorting and rearrangement of the moraines is so constantly happening that no permanent effects of sea-ice could be traced. As a transporting agent, sea-ice is not very effective. Sometimes a boulder may roll across the fringe of shore-ice on to it and be taken out to sea. The original boulder may be angular or it may be ice-scratched; its condition when on the ocean-floor can hardly be said to indicate its method of transport. Dust and fine sand are often blown on to sea-ice and may then be further transported. In Wood Bay great numbers of pumice-pebbles (899) had been blown on to sea-ice, which would be drifted far to the North by the prevalent ocean-currents before it melted.

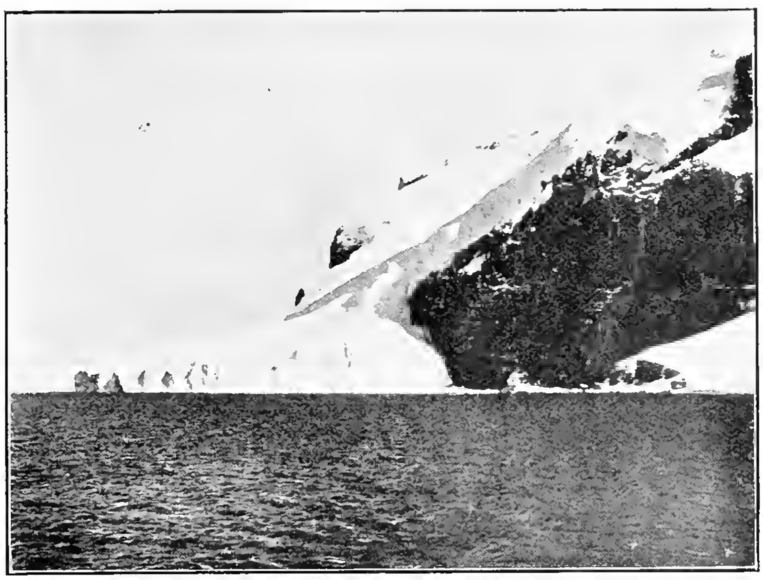

Fig. 56.—A Glacier descending from the top of Coulman Island into the Sea.

The shore-ice has a conservative * effect upon the land. It binds together the talus of the hills, and so protects talus and rock from the eroding action of drifting ice-floes or waves. When a piece of an ice-foot floats out to sea it usually carries a great load of *débris*. Stones roll on to the surface, and, through the melting of the ice around, work downwards. Pockets of dust (*Kryokonit*) † are exceedingly numerous; probably also much rock-material is held within the sole. All these must be transported. As ice which has left the shores of South Victoria Land seldom grounds, the abrading or striating action of shore-ice there must be small.

The glaciers taken as a whole are not now modifying the form of the land to any great extent. The corrie-glaciers and ice-slabs appear to be aggrading rather than excavating the valleys in which they lie (Fig. 56). The corrie-glaciers at the Inland Forts have a *Bergschrund*, but, judging from the small amount of terminal

* Bonney, Quart. Journ. Geol. Soc., 1902, vol. lviii, p. 699; Bonney, Geog. Journ., 1893, vol. i, pp. 481–499.

† Drygalski, 'Grönland-Expedition,' 1897, Bd. i, p. 94, ff.

moraine encircling them, no serious "plucking" of large rock-masses* can now be taking place. This plucking does seem to be illustrated in the ice-free *cirque* to the north of the Forts. There several blocks of Beacon Sandstone, as much as 20 feet in diameter, have been extracted and transported about 50 yards; the sockets from which the boulders are derived are still very evident, and contain frozen water-ponds.

The ice is everywhere retreating; some few valleys are now quite bare and are moraine-covered. No obvious ploughing effects of ice were seen, and *roches moutonnées* are not by any means conspicuous. In Granite Harbour a few perched blocks and a few ice-planed rock-surfaces were observed. This harbour is fiord-like, and has depths of over 100 fathoms within a quarter of a mile of the shore. At G_1 of the Northern Foothills, close to the Blue Glacier, the metamorphic limestones are beautifully rounded more than 1000 feet above the present ice-level and perched blocks are everywhere abundant. Observations at the snouts of several glaciers seem to show that no regular shedding of bergs is going on. Bergs from the Blue Glacier would contain a great quantity of rock-matter, and in former times must have transported an enormous quantity of *débris*.

Of the many icebergs met with, few showed rock-*débris* on their surfaces, and, as piedmonts supply the vast majority of bergs, this freedom from rock-material is not surprising. A few bergs showed angular rock-fragments on their upper surfaces, and one or two had coloured dirt-bands interstratified with the snow-layers. Icebergs aground often capsize and bring up material from the local sea-floor; this may be further transported, for through the melting of the berg its draught diminishes. At the same time the rock-flour, which is a very wide-spread deposit in the Ross Sea, is likely to be contorted by the moving berg. On the whole, then, we may conclude that owing to the form of the coast of South Victoria Land, rock-surfaces abraded or scratched by floating ice must there be exceptional.

It would also seem probable that as the sea-ice diminishes during the summer, so are the floating piedmonts now diminishing. The numerous soundings taken by the 'Discovery' along the edge of the Ross Piedmont, at places which at the time of the voyage of Ross (1841) were beneath the ice, show that the sea-floor is covered with a stiff yellow clay (soundings 10–41), which contain tests of foraminifera, many diatom-frustules and a few sponge-spicules. A somewhat similar clay (soundings 176, 177, 178) was found 10° further north near Balleny Island, also from 368 fathoms, (sounding 13) off the Nordenskiöld Piedmont. In water shallower than 100 fathoms oceanic currents apparently remove the fine material and, as in other regions, deposit it beyond the littoral zone. The whole of the floor of the Ross Sea seems to consist of rock-flour milled by the great glaciers of South Victoria Land.

* Willard D. Johnson, Journal of Geology, 1904, vol. xii, p. 573.

APPENDIX TO THE REPORT ON THE FIELD-GEOLOGY.

NOTES RELATIVE TO MACQUARIE AND AUCKLAND ISLANDS, OUTSIDE THE ANTARCTIC CIRCLE.

Macquarie Island (Fig. 57).

Macquarie Island is situated in the South Indian Ocean in latitude 54° 30′ S., longitude 158° 30′ E., and it has been suggested that it is part of the "zone of

Fig. 57.—The Strand and the Steep Coast-line of the east side of Macquarie Island.

fire"* which connects New Zealand with Mount Erebus and Mount Terror. It is about 23 miles long and five miles broad. It has an average height of 500 feet, but one of its peaks rises to quite 2000 feet. The longer axis is in a north-east and south-west direction and the south-east side is a precipitous cliff almost 200 feet high. The foreshore is narrow and the cliffs are remarkably straight; they

* Judd, 'Volcanoes,' 3rd edit., 1885, p. 230; Scrope, 'Volcanos,' 2nd edit., 1862, p. 471; Bonney, 'Volcanoes,' 1899; map of distribution of Volcanoes at end of the volume.

extend for about 10 miles on either side of Lusitania Anchorage, where the 'Discovery' remained for about four hours.

The cliffs do not rise directly from the foreshore but from a slightly raised platform or strand about 100 yards wide, and, in many places, more or less covered with talus. In places the cliff is broken by steep gully-like water-courses coming down from the plateau behind. The exposures in these gullies show that the rocks all dip at about 10° to the north-west.

Small peat-bogs occur behind the harder rock-outcrops which hold back the streams; in the bogs round pebbles and sandy gravel occur. On the seaward side of the hard outcrops a terrace at the level of the peat-bogs behind, at least 20 feet above the level of the stream, extends some way towards the sea. The terrace, sometimes 100 yards or more in breadth, consists of stratified clays, sands and gravels. In plan it has the form of a delta which has been cut into by the present stream and it may possibly be a raised beach. The rock-specimens obtained are dolerites and basalts (see p. 109) which show little relationship to those from South Victoria Land.

All the specimens are volcanic, many of them are slickensided, and others, such as (9), have obviously been considerably crushed. The specimens (1) to (6) inclusive were collected successively on our way up the gully. The specimen (11) came from a height of about 1000 feet, from a bold crag overlooking the peat-bogs.

A few dykes are seen crossing the strand. One of these (13) is 20 feet across, and, with another (12), runs out to sea as a dangerous reef.

Auckland Islands (Fig. 58).

This group of islands was visited by Sir James Clarke Ross, and the specimens collected have been described by Dr. Prior.*

The hills surrounding Ross Harbour rise over 1200 feet; they appear to be built up of series of basaltic sheets,† but owing to the extreme density of the vegetation few exposures could be found. These occur as "scars" or small cliffs, over which streams sometimes plunge as waterfalls, but the scars are seldom high enough to rise above the brushwood. The lowest rocks exposed along the shore are all basalts, and are much more porphyritic than those (879 and 880) from the summit of Mount Eden. All the basalts at sea-level are prominently columnar; the columns are about two feet in diameter and are sometimes, *e.g.* Deas Head, 300 feet high.

The eastern coast of the main island is a maze of fiords into which flow the streams coming down from the western peaks. All the higher peaks lie

* Prior, Mineralogical Magazine, 1899, vol. xii, p. 71.

† Hector, Trans. New Zealand Inst., 1870 (1869), vol. ii, pp. 179–183.

close to the western shore, where the land rises sheer from the sea as an enormous cliff. This cliff would seem to be undergoing rapid denudation by reason of the prevailing westerly winds. The basalt-sheets dip slightly to the eastward, and at sea-level occasional dykes (877, 892, 893) may be seen.

Another point of interest is the delta at the head of Laurie Harbour, the inner land-locked part of Ross Harbour. This consists mainly of sand and shingle, but has occasional shell-layers which in some cases are several feet above the high-tide mark. The main stream of the Laurie Harbour valley now cuts into this and it would therefore appear, that here, as in Macquarie Island, we have some evidence of very recent elevation. Again, near Erebus Cove, a low spit of rock is covered by about 3 feet of clay (874) and boulders. All the boulders are rounded and

Fig. 58.—The south side of Ross Harbour, Auckland Islands, showing Submerged Valleys.

water-worn; they vary from two inches to a foot in diameter. The smaller boulders occur in layers as if stratified, and the whole is overlain by a bed of peat. Basalt-outpourings were found in Enderby Island, and in addition curious deposits of clay and sand also occur. The clay seems to cap the basalts of the interior and is easily distinguished by its covering of tussock-grass. The sand appears in Sandy Bay as a bare hill edged with trees.

SUMMARY.

Although the geological work of the 'Discovery' Expedition was confined to a limited area, the collections of rocks and photographs which have been obtained provide materials for forming some definite conclusions as to the geological history of the region. The other expeditions, which lately entered the South Polar Regions, worked in localities much more than 1000 miles distant from the 'Discovery' area and from each other, and information obtained in one area may not hold for all.

Chapter I deals with most of the islands which occur at intervals along the straight north-and-south coast of South Victoria Land, and also with various islands lying between New Zealand and Cape Adare and within the Antarctic Circle. They are bounded by inaccessible cliffs, and the surrounding sea is comparatively shallow. Apparently they all consist of recent volcanic rocks.

Chapter II deals with the islands in the vicinity of Mount Erebus and our Winter Quarters. This group I have spoken of as the Ross Archipelago, and of the greatest of the group as Ross Island. This island has been built up by the volcanoes Erebus and Terror, of which the former is still active; only steam, never any lava or solid matter, was seen to be emitted from the vent at its summit, 12,000 feet above the sea.

In Chapter III the relations of the conical volcanoes on the mainland are considered. The conical volcanoes lie at the foot of a great wall-like range of mountains, which in latitude 78° S. (the Royal Society Range) has a simple tabular structure. This range is at least 800 miles long, trends due north-and-south, and occasionally rises to peaks 13,000 feet high. On the east it ends abruptly in the open Ross Sea, and on the west, for a distance of 200 miles at least, it forms a great plateau some 7000 feet above sea-level.

In Chapters IV, V, VI and VII, the rocks which build up this great range are considered in the order in which they occur in the field.

The gneisses have been found at sea-level and at the base of a series of rocks quite 12,000 feet thick, and may safely be regarded as forming the ancient platform on which the central part of South Victoria Land is built.

The granites belong to two periods, one older and one younger than a certain sheet of dolerite. The older granite lies upon the gneissic rocks at the foot of the Cathedral Rocks, and dykes from the former ramify into the latter. A peculiarity of this mass of granite is that it has a nearly horizontal upper surface which can be traced for many miles along the sides of the Ferrar Glacier.

The Beacon Sandstone Formation is a deposit about 2000 feet thick and remarkably uniform in texture. It proved to be quite barren of organic remains except near the top, where, at a height of nearly 7000 feet above sea-level, fossil plant-remains were found. Unfortunately, owing to decay of the plants and to changes produced by a neighbouring sheet of dolerite, their characters are almost indeterminate. This intrusive dolerite, though it gives no evidence of surface-flows, forms the highest peaks of the Royal Society Range. The plateau-features are still obvious, but the original plateaux seem to have been dissected prior to the earth-movements which dislocated the sandstone.

Chapters VIII, IX and X, describe the ice as met with in the Ross Sea area. The thickness, salinity and behaviour of the sea-ice, the shore-ice (ice-foot), and the glaciers are described. The inland-ice, local ice-caps and piedmont-glaciers are contrasted with those that have been observed in the Arctic regions. Temperatures in the ice at various fixed depths were determined; they show that at these depths the ice remains permanently some degrees below its melting point. Ice-slabs, or glaciers which have slipped away at their heads owing to decrease in the supply of water-substance, occur among the foothills of the Royal Society Range, and appear to be of a type not yet observed elsewhere.

There is one fact on which most of the observers, in both the Arctic and Antarctic regions, seem to agree, viz., the recession of the ice. TYNDALL * foretold that the ice would be tending towards a minimum when the condensation on both poles was about equal; whereas J. D. WHITNEY † maintains that only general glaciation can occur when there are bi-polar ice-caps, and that we are now entering upon a glacial epoch. The ice in the 'Discovery' area was found to be developed on a comparatively small scale, the steep-sided valleys providing almost ideal rock-exposures.

In Chapter XI the agents of denudation are discussed. The wind plays a comparatively important part in this dry area, while the effects of water-action are conspicuous by their absence. Chemical action is very pronounced in some localities, while frost-action, owing to the small amount of precipitation, is almost quite absent. The geological action of the ice is only briefly touched on.

In an Appendix are given some brief notes relative to Macquarie and Auckland Islands, at which brief stays were made during the voyage.

It is my pleasant duty to express my thanks to the many kind friends who have assisted me in my work. To Captain R. F. SCOTT, R.N., C.V.O., D.Sc., and the officers of the 'Discovery,' my thanks are due for the interest taken in my work

* Tyndall, 'Heat: a Mode of Motion,' 1898, 11th edit., p. 231, and 'The Forms of Water,' 1892, 11th edit., p. 154.

† Whitney, 'The Climatic Changes of later Geological Times,' Mem. Mus. Harvard Coll., 1882, vol. vii, p. 321.

and the ever ready help they accorded me; all assisted me in collecting, and the photographs taken by Engineer-Lieutenant R. W. Skelton, R.N., are invaluable; the arrangements made for me by Captain Scott were all that I could have wished.

I am indebted to Dr. G. T. Prior for the names of the rocks and minerals mentioned in the text.

Lastly, I am very grateful to Mr. W. G. Fearnsides, M.A., F.G.S., Fellow of Sidney Sussex College, for kindly reading the whole of the manuscript and suggesting many improvements in the text.

REPORT ON THE ROCK-SPECIMENS

COLLECTED DURING THE

'DISCOVERY' ANTARCTIC EXPEDITION, 1901-4.

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Introductory.

The rock-specimens brought back from the Antarctic regions by the 'Discovery' Expedition are listed under about 1,000 numbers. Amongst them is much transported material obtained from moraines, scree-slopes and soundings, but most of the specimens were collected *in situ* by Mr. Ferrar, the geologist to the Expedition.

The specimens obtained from Cape Adare, Coulman Island, and Franklin Island consist of hornblende-basalts and limburgites, similar to those which were brought back by the 'Southern Cross' Expedition and were described in the Report relating thereto.*

The following notes, therefore, refer mainly to the specimens from the Ross Archipelago, and from the opposite mainland which was the scene of most of Mr. Ferrar's work in the field.

For purposes of description they will be taken in the following order, which corresponds fairly closely with that adopted by Mr. Ferrar for the Report on the Field-geology :—

Chapter I.—Volcanic rocks.

These include the eruptive rocks of the Ross Archipelago, Scott Islands, Auckland Islands, and Macquarie Island.

Chapter II.—The crystalline-limestones, gneisses and granites, which form the basement-rocks of South Victoria Land.

Chapter III.—The lamprophyric and other dyke-rocks, intrusive in the basement-rocks.

Chapter IV.—The Beacon sandstone and other sedimentary rocks.

Chapter V.—The dolerites intrusive in the Beacon sandstone.

* Prior, Rep. 'Southern Cross' Collections (British Museum), 1902, pp. 321–332.

Chapter I.

VOLCANIC ROCKS.

Basalt appears to be the prevailing lava which has been erupted by the volcanoes of this Antarctic region. The 'Southern Cross' collection showed that Cape Adare and, in all probability, also the islands off the north coast of South Victoria Land, are mainly composed of this rock; but the presence, in that collection, of one or two specimens of a phonolitic character was sufficient to suggest that in this Antarctic region there is a similar association of basalts with more-acid rocks rich in alkalies to that which prevails in East Africa and along the Atlantic volcanic chain generally.*

This suggestion is amply confirmed by the specimens brought back by the 'Discovery' from the Ross Archipelago. Basalts of a basic type are the prevailing lavas, but accompanying them are phonolitic trachytes and kenytes (trachydolerites of Rosenbusch) very rich in alkalies. To this latter type belong perhaps the most remarkable specimens in the collection, viz., the rocks from the slopes of Mount Erebus, showing conspicuous lenticular crystals of anorthoclase and exhibiting characters almost precisely identical with those of the rhomb-porphyries of Norway and the more recent kenytes of Mounts Kenya and Kilimandjaro in East Africa.

Basalts of the Ross Archipelago.

The basalts of the Ross Archipelago are very similar to those of Cape Adare. They present the same two types, viz., hornblende-basalts with few and small phenocrysts, and olivine-basalts with plentiful and fairly large porphyritic crystals of olivine and augite.†

Hornblende-basalts.

The hornblende-basalts are dark gray, slightly vesicular rocks, showing only sparingly small black porphyritic crystals of hornblende and augite. They are rather more coarse-grained than the very compact rocks of Cape Adare.

Under the microscope small phenocrysts of pale purplish-brown augite and deep reddish-brown basaltic hornblende (or more often magnetite-pseudomorphs after hornblende) are seen in a ground-mass of felspar-laths, magnetite-grains, purplish augite in grains and needles, and small olivines.

The felspar-laths are mostly of labradorite, giving symmetrical extinctions in twin lamellæ of about 22°. Apatite is plentiful in the ground-mass and as inclusions in the hornblende-pseudomorphs (see Fig. 59); it has often a pinkish tinge and is cloudy with black inclusions arranged in lines parallel to the sides of hexagonal sections.

In most of these basalts the hornblende is only represented by pseudomorphs, but

* Prior, Rep. 'Southern Cross' Collections (British Museum), 1902, p. 328, and Mineralogical Magazine, 1903, vol. xiii, p. 261.

† Prior, Rep. 'Southern Cross' Collections (British Museum), 1902, p. 326.

in a specimen (218)* from the top of the 1300-ft. knoll of Mount Terror it is for the most part unaltered. Most of the phenocrysts in this rock, however, show two stages of growth, in which variations of chemical composition are indicated by differences of optical characters; a rounded and corroded nucleus of cossyrite-like hornblende, having pleochroism from brown (for vibrations across the length) to black (for vibrations along the length) is surrounded by the more usual barkevikite-like hornblende with less absorption, from bright yellow to deep reddish-brown. The augites in this rock also show similar variations in composition, and have generally a pale-green nucleus surrounded by a pale-purple zone; but in this case the change has been continuous, and there is no evidence of corrosion of the first-formed green nucleus.

The hornblende-pseudomorphs in these rocks are similar to those which have been often described.† They consist mainly of grains and rods of magnetite, sometimes in radiating groups, but generally arranged in lines roughly parallel to the length of the crystal, with purplish augite and a little felspar crystallised about them. With the magnetite is usually associated a cossyrite-like hornblende, showing pleochroism from deep brownish-red for vibrations across the length of fibres to nearly opaque for vibrations along the length. The pseudomorphs are generally surrounded by a narrow, sharply defined border of purplish augite like that of the ground-mass.

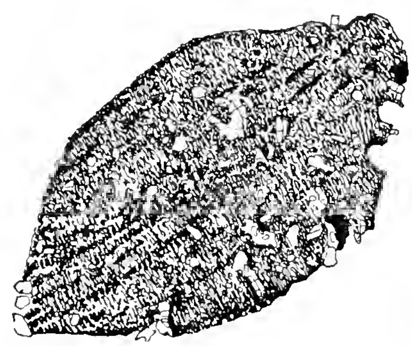

Fig. 59.—Pseudomorph after Hornblende in Basalt (691) from Castle Rock, showing inclusions of Apatite. (Magnification, 10 diam.)

According to Becke's theory ‡ the alteration and partial absorption of the hornblende probably took place during phases in the eruption in which the pressure diminished much more rapidly than the temperature.

A quantitative chemical analysis of a hornblende-basalt from the Sulphur Cones (385) gave the following result § :—

		mol. ratios.
SiO_2	= 43·92	·727
TiO_2	= 4·19	·052
Al_2O_3	= 17·42	·170
Fe_2O_3	= 4·09	·026
FeO	= 8·83	·123
MnO	= 0·09	
CaO	= 9·53	·170
MgO	= 4·89	·121
Na_2O	= 4·60	·074
K_2O	= 2·17	·023
P_2O_5	= 0·67	·005
H_2O at 110°	= 0·06	
H_2O above 110°	= 0·11	
	100·57	

* The numbers refer to Mr. Ferrar's List of Specimens.

† For bibliography see Hyland, Tschermak's Min. Petr. Mitth., 1889, Bd. x, p. 238; also Washington, The Volcanoes of the Kula Basin in Lydia, New York, 1894.

‡ Becke, Tschermak's Min. Petr. Mitth., 1896–7, Bd. xvi, p. 335.

§ For discussion of the results of analyses see p. 119.

Hornblende-basalts were found on the 1300-ft. knoll on Mount Terror (218), at the Sulphur Cones near Winter Quarters (382, 385, 391), and also on Brown Island (608). The latter specimen is almost precisely identical in microscopic characters with the rocks from the Sulphur Cones.

Olivine-basalts.

To the basalts with porphyritic crystals of augite and olivine belong, apparently, most of the more basic lavas of the Ross Archipelago. They are dark-gray to black rocks, showing to the naked eye numerous crystals of these minerals. By increase of glass and decrease of felspar in the base they pass into limburgite-like rocks, in some of which the clear yellowish-green olivine-phenocrysts reach a considerable size (up to 1 in. in length).

Under the microscope (Plate VIII, Fig. 1) the olivines are seen to be mostly of very irregular outline and to be often deeply indented and corroded: they are clear, colourless and fresh, showing generally only a few inclusions of magnetite. A marked exception to this rule, however, is presented by the phenocrysts of a basalt from Harbour Heights (366), which resemble closely the pseudomorphs after hornblende described above (Fig. 59), since they are rendered almost opaque with magnetite arranged in parallel lines. They may possibly mark a stage in the conversion of hornblende into olivine.* In some of the more limburgite-like rocks (*e.g.*, 176 from Cape Crozier) the olivine shows small brown octahedral inclusions of picotite, and also numerous vermiform inclusions similar to those in the augite and olivine of the nodules described in the following section (see Fig. 60, p. 108).

The augite-phenocrysts are of the pale purplish-brown titaniferous variety common to basaltic rocks. As in the hornblende-basalts, variations of composition are indicated by changes in tint and by zonal structure exhibited between crossed nicols.

In the ground-mass occur olivines and augites of the same character as the phenocrysts, together with magnetite and ilmenite in grains or rod-like skeletal crystals, sharply defined felspar-laths, and, in many cases, brown glass.

The structure varies from pilotaxitic to hyalopilitic; in some of the rocks fluidal structure round the larger phenocrysts of olivine is well marked.

The felspar-laths are of labradorite, giving symmetrical extinctions of about 25°. Only rarely is a much-corroded small phenocryst of felspar seen in these rocks. In some fine-grained basalts (*e.g.*, 180, from the top of the 900-foot knoll at Cape Crozier, and 311, from White Island) the phenocrysts are very sparingly distributed. In these rocks olivine occurs very plentifully in the ground-mass, either as small rhombic sections or (in specimen 180) as long prismatic crystals, not easily to be distinguished in ordinary light from the lath-shaped felspars. In some specimens (222) augite-phenocrysts are seen to have been formed round magnetite-pseudomorphs after hornblende. In others (335) unaltered hornblende occurs as phenocrysts in addition to the augite and olivine.

* See Mügge, Petrog. Untersuch. an Gest. v. d. Azoren. Neues Jahrb. 1883 (ii), p. 224.

A basalt (431) from the foot of Castle Rock contains curious opaque white inclusions up to 2 inches in diameter. They appear to be fragments of sandstone caught up in the lava; but if so they have suffered extreme metamorphism. The basalt has permeated them in thin black vesicular glassy veins. The inclusions consist of a hard, minutely vesicular, glass which is colourless except at the actual contact with the basalt, where it becomes brown and nearly opaque. The glass incloses a few small scattered irregular grains of quartz and felspar, and is crowded with minute needle-like microlites, and, nearer to the basalt, with larger needles of colourless augite, such as have been described in the case of sandstone metamorphosed by basalt.*

The results of chemical analyses of the olivine-basalt (656) from near the Gap, and of a limburgite-like rock (326) from Ridge Road, near Winter Quarters, are as follows under I and II respectively †:—

		I. (656)	Ia. mol. ratios.	II. (326)	III. (Gräveneck)	IV. (Härtlingen.)
SiO_2	=	42·14	·698	42·10	41·17	44·14
TiO_2	=	4·90	·061	4·93	3·08	1·34
Al_2O_3	=	14·95	·146	14·87	13·24	13·87
Fe_2O_3	=	2·90	·018	3·26	3·56	11·73
FeO	=	9·71	·135	9·76	12·50	4·78
MnO	=	0·12		0·07		
CaO	=	10·32	·184	10·63	10·24	10·86
MgO	=	9·47	·235	8·88	8·21	7·23
Na_2O	=	3·27	·053	3·20	2·57	3·25
K_2O	=	1·80	·019	1·80	1·60	1·54
P_2O_5	=	0·40	·003	0·58	0·53	0·80
H_2O at 110°	=	0·12		0·11		
H_2O above 100°	=	0·16		0·12	3·21	1·87
S	=				0·09	
CO_2	=				0·64	
		100·26		100·31	100·64	101·41

The two results are almost identical, showing that probably most of the limburgite-like rocks only differ from the other olivine-basalts by their much more glassy base, in which little felspar has been developed.

For comparison with these results are given under III an analysis by Senfter of a "hornblende-diabase" of Devonian age from Gräveneck, Nassau, which was described by Streng;‡ and under IV an analysis by Sommerlad of a Tertiary hornblende-basalt from Härtlingen, Westerwald.§ The close similarity between I and III extends even to the very high percentage of titanic acid.

Olivine-basalts were found on Mount Terror, at Cape Crozier (830, 222, 218); and near Winter Quarters, at the Sulphur Cones (383) accompanying the hornblende-

* Dannenberg, Tschermak's Min. Petr. Mitth., 1895, Bd. xiv, p. 53.

† For discussion of the analyses see p. 119.

‡ Streng, Ber. oberhess. Ges. f. Nat. u. Heilkunde, 22, 1883, p. 248.

§ Sommerlad Neues Jahrb., 1883, Beil.-bd. ii, p. 165.

basalts, Castle Rock (431, 319), Crater Hill (341), Harbour Heights (323, 325, 366), and between the Gap and Horseshoe Bay (656).

Specimens of the more glassy limburgite-type were obtained from the same localities, and also from Turtle Back Island (449) and Dailey Islands (510).

The basalt (553) from Cape Armitage has microscopic characters precisely similar to those of the basalt (656) from between the Gap and Horseshoe Bay, and is probably the prolongation of that rock mentioned on p. 12 of the Report on the Field-geology.

The bombs found on Harbour Heights (367, etc.) consist of olivine-basalt like that of the lavas.

The results of the analyses both of the hornblende-basalt and of the olivine-basalts indicate that nepheline is present in these rocks, either in the interstices of the felspar-laths or potentially in the glassy base. Generally it could not be recognised with certainty under the microscope, but in a basalt (718) from the scree-slope below Cathedral Rocks could be distinguished in the ground-mass small colourless patches of isotropic analcite (?), and of doubly-refractive nepheline of which the refraction was about the same as that of Canada balsam. This rock, which showed under the microscope small phenocrysts of pale-purple augite and rounded olivines in a ground-mass of felspar-laths, augite and magnetite, has a much closer relationship to the recent basalts of the Ross Archipelago than to the dolerites of the Ferrar Glacier.

Analcite is probably present in some of the other basalts which show small amounts of colourless isotropic material in the base, *e.g.*, specimens from Cape Adare (49), from Little Razor Back Island (471), and from the top of Castle Rock (319).

As a connecting link between the olivine-basalts with no porphyritic felspars and the alkaline rocks (kenytes) with porphyritic anorthoclases, to be described in a later Section (p. 110), are a few specimens of basalt showing conspicuous phenocrysts of felspar.

These come from Black Island (593), the *débris*-heap off Minna Bluff (619), Inaccessible Island (805), Turtle Back Island (484, a boulder), and Cape Barne (814). They show numerous phenocrysts of clear glassy felspar in a ground-mass of felspar-laths, magnetite in grains and rods, pale-purplish augite and a little olivine. The rocks resemble the kenytes, but the felspar-phenocrysts have not the characteristic shape of the anorthoclases; instead, they consist of an acid labradorite or andesine, having a specific gravity of 2·68, and showing an extinction on *b* (010) of about 16°. In the case of the boulder (484) from Turtle Back Island, these phenocrysts are so flattened that the rock appears to be composed of alternating white and black layers.

Coarse-grained Felspathic and other Nodules in the Basalts.

A striking feature in the basalts of the Ross Archipelago, especially in those of limburgite-type, is the number of included coarse-grained nodules. These were found plentifully, not only enclosed in basalts but also in loose lumps, in the neighbourhood of Winter Quarters.

Some of them are of the usual type common to many basalts, and consist mainly of olivine and enstatite, with brilliant green chrome-diopside, like the nodules in the limburgite of Franklin Island.*

Others, however, differ from most of those previously described in consisting to a large extent of plagioclastic felspar, and thus have the character of gabbros rather than of peridotites.†

Such gabbro-like nodules were found in the hornblende-basalt (385) from the Sulphur Cones, and in the limburgites from the neighbourhood of Winter Quarters (408, 316, 335, 415), as well as in the basalt (375) from Harbour Heights to which reference has been made in the Report on the Field-geology (p. 13).

In the latter rock many of the inclusions, as stated by Mr. Ferrar, are quite angular. In fact, some of them appear to be only loosely held in the basalt, like fragments caught up in the molten mass. In most of the other specimens, however, the nodules present the more usual rounded appearance, and are completely enclosed by the basalt. In some cases (385) the junction is perfectly sharp, and the rock shows under the microscope no variations in structure or composition in the neighbourhood of the nodule. In other cases (335) the basalt has obviously permeated the nodule in thin veins. This nodule (335) is composed mainly of pale-green augite, enstatite and olivine, but contains also a little basaltic hornblende and biotite, and some plagioclastic felspar in broad plates. Where the basalt has permeated the nodule, the augite-plates have been converted into aggregates of small grains which bear some resemblance to the bronzite-chondrules in meteorites. The hornblende in the nodule may possibly have been derived from the basalt, which contains phenocrysts of similar hornblende; the biotite also may have resulted from the interaction of basalt and nodule; but the felspar can hardly be conceived to owe its origin to the basalt, since the latter is of distinctly limburgite-type, showing under the microscope little or no felspar. Moreover, the most felspathic nodules of those examined, viz., 385 and 316, show no signs of having been attacked by the enclosing basalt.

These two felspathic nodules consist of granular aggregates of plates of labradorite, giving symmetrical extinctions of 20°–30°, and irregular crystals and corroded patches of nearly colourless augite having a roughly parallel arrangement; a little olivine is also present in specimen 385. Under the microscope the pale yellowish-brown augite has a rough, dirty appearance due to numerous inclusions. These consist for the most part of gas-bubbles, glass and opacite, but some fantastically-shaped ones are probably liquid inclusions. One crystal showed long black needles arranged in parallel lines, like those observed by Dannenberg in augite-nodules in the basalts of the Rhine.‡ The felspars in these nodules also enclose numerous gas-bubbles.

* Prior, Rep. 'Southern Cross' Collections (British Museum), 1902, p. 328.

† Felspathic nodules in the basalts of the Siebengebirge have been described, see Dannenberg, Tschermak's Min. Petr. Mitth., 1895, Bd. xiv, p. 35; Laspeyres. Verh. naturh. Ver. pr. Rheinl., 1900, Jahrg. lvii, p. 194; and Zirkel, Abhand. math.-phys. Cl. d. königl. sächs. Ges. d. Wiss., 1903, Bd. xxviii, p. 165.

‡ Dannenberg, l.c. p. 40.

A nodule (342) found near the ship, and consisting of pale-green diopside, grains of clear olivine and plates of labradorite, showed a few dull-green isotropic grains of picotite. In another somewhat similar nodule (478), from below Castle Rock, occurs a little hypersthene, showing straight extinction and pleochroism from pale-pink to pale-green.

The nodule (415), which is represented in section in Plate VIII, Fig. 2, was enclosed in a hornblende-limburgite from between the Gap and the ship. It consists of a granular aggregate of labradorite and pale-green diopside, with smaller grains of altered olivine and a little basaltic hornblende. The labradorite shows symmetrical extinctions of 23°–26°, and encloses numerous gas-bubbles. The olivine grains are red with oxide of iron, which is often arranged in bundles of wavy threads crossing each other at right angles; probably these threads were originally of magnetite, like the inclusions in the olivine-nodules described below.

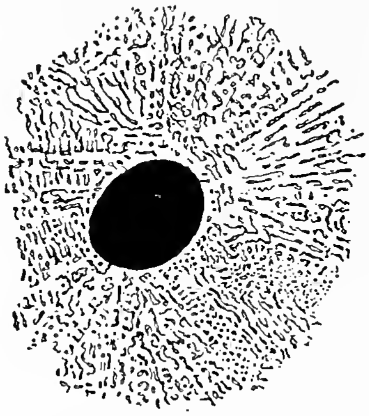

Fig. 60.—Inclusions in Augite of Nodule from Turtle Back Island. (Magnification, 100 diam.)

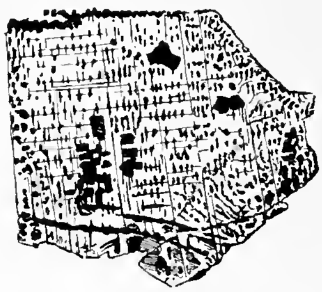

Fig. 61.—Olivine with Magnetite-inclusions, from Castle Rock. (Magnification, 60 diam.)

Of the non-felspathic nodules, one (180, from the 900-ft. knoll on Mount Terror) consists of olivine, enstatite, and purple titaniferous augite; another (438, from Harbour Heights) almost entirely of clear, colourless olivine and enstatite; while others are composed wholly of olivine impregnated with magnetite. A nodule (or possibly a bomb) from the south slope of Turtle Back Island consists mainly of smoky-black augite, and shows only a little yellow olivine in bands. Under the microscope the augite shows some pleochroism from pale smoky-purple to brownish yellow, and has numerous gas and vermiform liquid (?) inclusions arranged in lines; in one crystal a halo of fantastically-shaped inclusions surrounds an included dark rounded grain (see Fig. 60).

Some of the nodules in the basalt near Winter Quarters (375 and 437) are of dark ironstone-like appearance. They were found to consist wholly of olivine-grains densely impregnated with magnetite, and thus resemble the olivine-phenocrysts in the basalt (366) from Harbour Heights (see p. 104). Under the microscope one of these grains showed an obtuse negative bisectrix, being cut parallel to 010. In this case the magnetite is seen to be arranged in lines parallel to the (100) cleavage, and also in more wavy lines approximately at right angles to the first; along the latter lines the magnetite occurs in blobs, which are flattened out at right angles along the more definite cleavage (see Fig. 61). This olivine with included magnetite is very similar to that figured by Tschermak in the Sierra de Chaco meteorite.*

The origin of the so-called "olivine-nodules" in basalts has been the subject of much discussion.† The presence in these Antarctic rocks of felspathic gabbro-like nodules as well as those having the composition of peridotites is of interest, since the general absence of felspar in "olivine-nodules" has been used as an argument against the theory that they are intratelluric separations from the magma.

Basalts and Dolerites from Auckland Islands and Macquarie Island.

The specimens brought back from Auckland Islands are olivine-basalts similar to those collected by the Ross Expedition and described by the present writer in Mineralogical Mag. 1899, vol. xii., pp. 70–73. Those with conspicuous phenocrysts of olivine and augite resemble the olivine-basalts of Cape Adare and the Ross Archipelago.

The dyke-rock (893) from Williamson Point shows under the microscope large and much-corroded crystals of colourless olivine and pleochroic (purple to yellow) titaniferous augite in a base of felspar-laths, purple augite, and magnetite in grains and skeleton-crystals.

The basalts from Macquarie Island are of a somewhat different type. They are much more altered than the rocks of the Auckland Islands, and appear to be of greater age.

The more coarse-grained rocks (1, 5, 6) are diabasic in character, and consist of a medium-grained aggregate of felspar-laths, colourless augite (sub-ophitic), large magnetite-grains, sparingly distributed, and interstitial green chloritic and hornblendic alteration-products. The rock (4) from "100 yards up the stream" (see p. 96) shows large phenocrysts of labradorite and a few chloritic pseudomorphs after olivine. The crushed rock (9) is a much-altered andesitic basalt showing large phenocrysts of labradorite in a very fine-grained altered base.

Basalt-tuffs.

Fragmental basaltic rocks were found in most of the localities on Ross Island where bare rocks are exposed, viz., Cape Crozier, V-Cliffs Hogsback, Sultan's Head, Castle Rock, The Turk's Head and Hutton Cliffs.

The pale-yellow tuff from Sultan's Head contains numerous black fragments of vesicular basalt which show under the microscope a few sharply defined felspar-laths and grains of olivine in a glassy base dense with magnetite. The tuff, however,

* Tschermak, Mikr. Beschaff. Meteoriten, 1885, Lief. III, Pl. XXIII, Fig. 4.

† See Zirkel, Lehrbuch d. Petrographie, 1894, Bd. ii, p. 931; and Abhand. math.-phys. Cl. d. kgl. sächs. Ges. d. Wiss. 1903, Bd. xxviii, p. 103.

consists mainly of fragments of vesicular basalt-glass imbedded in a base of angular grains of orange-yellow palagonite with a little magnetite and small felspars; in parts this fragmental material is cemented with calcite. In the fragments of basalt-glass, all of which have been converted into palagonite, magnetite has separated in fairly distinct crystals, and the felspar-laths and olivine-grains which the glass contains are fresh and unaltered.

The tuff from Castle Rock is of similar character; in the fragments of basalt-glass, however, much purplish augite, besides olivine and felspar, has been developed; the felspar also occurs in thin, broad plates as well as in laths. In the basalt-glass of the tuff from Cape Crozier, on the other hand, no felspar has been developed, but it shows sharply defined crystals of olivine and purplish augite.

The tuffs from the "Bare Rocks" at Hutton Cliffs in Erebus Bay differ remarkably from the others in appearance and general character. They are of a dull-green colour,

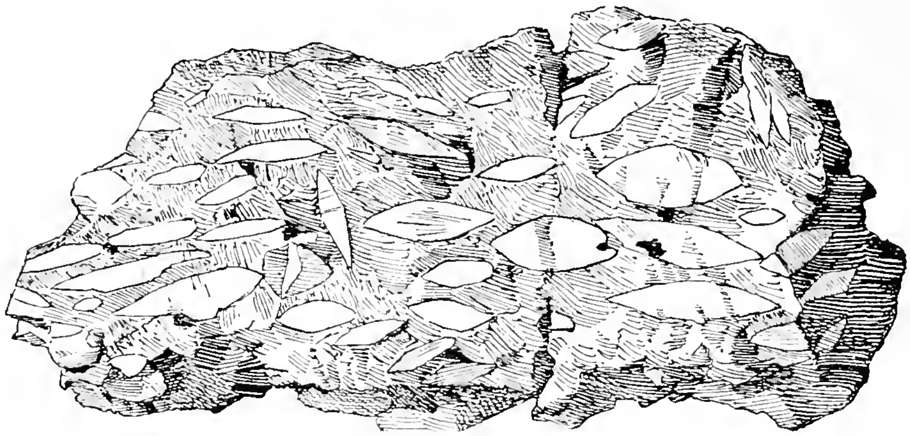

Fig. 62.—Kenyte with Porphyritic Anorthoclase, boulder from Turtle Back Island. (Natural Size.)

and are much more compact, so much so that it is not easy with the unaided eye to recognise their fragmental nature. They have the appearance of greater age than the other tuffs, and show under the microscope that they have been much altered. They consist mainly, like the other tuffs, of a very vesicular basalt-glass, but in this case the glass has been converted into a dull-green chloritic or serpentinous alteration-product instead of into yellow palagonite, and most of the crystals and microlites of augite and olivine have been obliterated; only rarely is seen a fragment of vesicular basalt-glass in which small prismatic purplish augites can be recognised. The tuff contains larger fragments of a less glassy non-vesicular basalt, showing under the microscope lath-shaped felspars and magnetite in skeleton-crystals, with green altered ferromagnesian minerals.

Kenytes (Trachydolerites, Alkaline-basalts, Rhomb-porphyries).

From the slopes of Mount Erebus and the islands in Erebus Bay come the remarkable rocks mentioned on p. 102. These are distinguished from the basaltic rocks of Mount Terror and Winter Quarters by their numerous and large (2–3 cm. in length) porphyritic lozenge-shaped crystals of anorthoclase, resembling those of the well-known rhomb-porphyries of Norway (see Fig. 62). They are almost precisely identical in characters and chemical composition with the kenytes of Mount Kenya,* and the description recently published by Dr. Finckh of the rhomb-porphyries (kenytes) of Kilimandjaro † could be followed almost word for word in an account of these Antarctic rocks. They are alkaline basalts or trachydolerites (Rosenbusch), intermediate in type between ordinary basalts and phonolites.

In colour they vary from dark-gray, to nearly black in the more glassy varieties. Under the microscope they show, besides the large phenocrysts of anorthoclase, small rounded olivines and pale-gray or brown to pale-purple augites sparingly distributed.

In different specimens the ground-mass varies in texture, and to some extent also in mineral composition. In some (812 from the Skuary) it is quite holocrystalline, and consists of a trachytic mesh of interlacing felspar-laths (mainly anorthoclase) with interstitial shreds and small prismatic crystals of a pale-green augite and grains of magnetite; in others (464 from Tent Island) it is a brown glass, dense with magnetite in grains or rod-like skeleton-crystals, but showing in clearer pale-brown streaks minute microlites of felspar and augite. In the boulder 447 from Turtle Back Island, the glassy base is confusedly spherulitic with minute magnetite-grains arranged in radiating wavy lines. In Fig. 63 is represented a spherule with the black cross as seen between crossed nicols. The glass in the base of specimen 541 from the slope of Mount Erebus is almost colourless, but in parts is rendered nearly opaque with fine dusty magnetite; in the clear brown glass, however, which is included in the anorthoclase-phenocrysts of the same rock there has been no separation of magnetite except round the edges, from which project long, colourless, needle-like microlites of augite.

FIG. 63.—SPHERULE WITH MAGNETITE, IN GLASSY KENYTE, FROM TURTLE BACK ISLAND. (Magnification, 200 diam.)

The rocks from Cape Royds (818, 820) present a distinct variety characterised by the presence of leucite. They show large phenocrysts of anorthoclase and, very sparingly, small rounded olivines, like those in the other kenytes, but contain in the ground-mass fairly numerous, small, rounded, isotropic crystals of leucite having characteristic central and marginal inclusions of the magnetite and augite of the base (see Plate VIII, Fig. 3). These rocks are therefore similar to the leucite-rhomb-porphyries

* Gregory, Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 205.

† Finckh, Festschr. z. siebzigsten Geburtstage von Harry Rosenbusch, 1906, pp. 373-397.

of Kilimandjaro described by Finckh.* The leucites show a refraction markedly less than that of Canada balsam. In most of the small crystals the central inclusion of base occupies the greater part; in many also the outer edge is invaded by the minute felspar-laths which generally form a fringe round the crystal. That the leucitic material in these rocks is only in small amount is indicated by the result of the bulk-analysis (see p. 113), and more especially by the partial analysis of the part soluble in nitric acid, the result of which is as follows, under I:—

	I.		II. (Nepheline.)
SiO_2	= 43·12	...	43·74
Al_2O_3, Fe_2O_3	= 33·32	...	34·48
CaO	= 2·63	...	—
Na_2O	= 14·96	...	16·62
K_2O	= 3·73	...	4·55
Cl	= 0·70	...	—
H_2O etc. (diff.)	= (1·54)	...	0·86
	100·00		100·25

The rock-powder gelatinised readily with acids, and as much as 25% was decomposed by half an hour's digestion with dilute (1 : 5) nitric acid. Under II is given, for comparison, the result of an analysis by Clarke of a nepheline from Litchfield, Maine.

The result of the above analysis suggests, therefore, that the soluble portion of the rock consists mainly of nepheline.

An attempt was made to separate the leucites in the rock-powder by means of heavy liquids, but the grains which floated in a liquid in which moonstone sank and leucite floated were in very small amount, and of these only a few remained dark between crossed nicols.

The anorthoclase-phenocrysts in all these rocks have the characteristic lozenge-shape determined by the development of the faces M $(1\bar{1}0)$, m (110), and y $(\bar{2}01)$. They almost invariably show minute twin-striations, occasionally in two rectangular directions according to the albite- and pericline-laws. Like the similar phenocrysts in the kenytes of Mount Kenya, they contain numerous inclusions of glassy base, and also occasionally inclusions of olivine, augite, apatite, and magnetite or ilmenite. On this account no chemical analysis was attempted. In physical characters they agree perfectly with the anorthoclases of Pantelleria and Kilimandjaro. The specific gravity is 2·62. Cleavage-flakes parallel to *b* (010) show a positive bisectrix, slightly inclined, and give an extinction-angle with the trace of *c* (001) of about 6°, while cleavage-flakes parallel to *c* (001) have extinctions of about 1°. The refraction was about the same as that of clove-oil (1·538). Wolff (quoted by Finckh) found the value of γ_{na} for the anorthoclase of Kilimandjaro to be 1·5376.

Nepheline was not found as phenocrysts in these rocks, neither could it be with certainty detected in the base, but that it is present is indicated by the results of the bulk-analysis.

* Finckh, l.c., p. 382.

The olivine-phenocrysts occur very sparingly, and are generally less than 1 mm. in diameter; they are clear and colourless, and often contain inclusions of apatite and magnetite. They are generally of irregular and sometimes of perfectly round outline: only occasionally is one seen with distinct crystalline shape. Intergrowths of augite and olivine occur, and in one case augite was seen to be enclosed in olivine.

Augite-phenocrysts occur even more sparingly than the olivines. They are generally without distinct crystalline outline, and consist of a pale-gray or brown augite having angles of extinction of over 40°. In a specimen (837) of glassy kenyte from a moraine at the "mouth of 2nd Alpine Valley," in Discovery Gulf, the augite-phenocrysts are in larger amount, and attain a length of 2 to 3 mm.: usually they are less than 1 mm. in length. The augite of the ground-mass occurs generally in small prisms of a pale-gray to green colour, but in some specimens this is replaced to some extent by grass-green ægirine-augite.

Apatite is fairly plentiful in these rocks; often it is of a pink colour, and dense with dark inclusions arranged in lines parallel to the length of the needles.

A chemical analysis of the leucite-kenyte (818) from Cape Royds gave the following result under I*, as compared with that of a kenyte from Mount Kenya under II†, a leucite-kenyte ("leucite-rhomb-porphyry") from Kibo (Kilimandjaro) under III‡, and a nepheline rhomb-porphyry from Vasvik, Norway, under IV:—

		I. (Cape Royds.)	Ia. Mol. ratios.	II. (Mt. Kenya.)	III. (Kibo.)	IV. (Vasvik.)
SiO_2	=	56·09	·929	53·98	53·44	56·04
TiO_2	=	1·23	·015	0·57	0·69	0·65
Al_2O_3	=	20·79	·203	19·43	20·39	21·50
Fe_2O_3	=	1·54	·010	4·39	4·22	1·06
FeO	=	3·84	·054	2·05	1·76	3·28
MnO	=	0·05		0·26	trace	
CaO	=	3·18	·057	2·04	2·13	2·42
MgO	=	1·26	·031	1·07	1·12	1·12
Na_2O	=	7·33	·118	8·81	8·76	8·39
K_2O	=	3·91	·041	5·27	5·75	5·03
P_2O_5	=	0·38	·003	0·30	0·49	
Cl	=	0·17				
H_2O at 110°	=	0·19		0·13 }	0·97	0·67
H_2O above 110°	=	0·39		1·66 }		
SO_3					0·22	
ZrO_2					0·27	
		100·35		99·96	100·21	100·16

Phonolitic Trachytes (Trachydolerites) and Phonolites.

Most of the rocks which are here included under the name of trachyte are of a somewhat basic type, and so closely related in chemical composition to the preceding alkaline basalts or kenytes that some hesitation is felt in separating them; with the kenytes they might all be classed under the trachydolerite group of Rosenbusch.

These trachytes are pale ash-gray compact rocks; but weathered specimens (in

* For discussion of analyses, see p. 119.

† Prior, Mineralogical Magazine, 1903, vol. xiii, p. 247.

‡ Finckh, l.c., p. 392.

which the augite of the ground-mass, together, apparently, with some of the magnetite, has been altered, with development of orange-yellow epidote) are of a pale-yellow or pink colour. They differ from the kenytes in showing either no phenocrysts of anorthoclase or only few and small ones.

Those which approximate most closely to the kenytes show under the microscope an occasional small rounded phenocryst of olivine and augite in a ground-mass consisting of a mesh of felspar-laths, with interstitial irregular grains and shreds of dull-green augite, needles of pleochroic (yellow to dull-green) ægirine-augite, and only a few magnetite grains. The felspar-laths are not sharply defined, and are often associated with more platy felspars; they have a refraction not greater than clove oil (1·538), and consist mainly of anorthoclase. That nepheline is present in these rocks is probable, although it cannot with certainty be recognised under the microscope.

To this type belong specimens 804, from Inaccessible Island, and 473, from Little Razor Back Island.

The specimens collected by the 'Morning' from Scott Island and a trachyte (188) from the top of the 900-ft. knoll at Cape Crozier are of similar character, but show no porphyritic olivines and augites in the thin slices examined. The rock from Cape Crozier is of a lighter-gray colour and of more salic character than the specimens from Scott Island; it shows the peculiar surface-shimmer, due to the parallel arrangement of the platy felspars, which is so characteristic a feature of many of the alkaline rocks of Norway (solvsbergites) described by Brögger.*

A coarse-grained inclusion in this trachyte (188) consists of an aggregate of stout felspar-prisms, with some pleochroic (yellow to grass-green) ægirine-augite and a little cossyrite-like hornblende showing pleochroism from reddish-brown for vibrations across the length to black for those along the length; the felspars are partly oligoclase with symmetrical extinctions of about 8°, and partly anorthoclase.

The results of chemical analyses of the rock from Scott Island, and of the trachyte from Cape Crozier (188) are given under I and II respectively.† They show the close chemical relationship between these rocks and the leucite-kenyte, the analysis of which is given on p. 113.

		I. (Scott Island.)	IA. Mol. ratios.	II. (Cape Crozier.)	IIA. Mol. ratios.
SiO_2	=	55·93	·926	57·95	·959
TiO_2	=	0·64	·008	0·40	·005
Al_2O_3	=	19·61	·192	20·43	·200
Fe_2O_3	=	1·75	·011	3·43	·022
FeO	=	6·32	·090	1·35	·020
MnO	=	0·13		0·07	
CaO	=	3·53	·063	1·90	·034
MgO	=	0·50	·013	0·26	·006
Na_2O	=	7·75	·125	8·32	·134
K_2O	=	3·67	·039	5·96	·063
P_2O_5	=	0·12	·001	0·07	·001
H_2O at 110°	=	0·10		0·23	
H_2O above 110°	=	0·19		0·39	
		100·24		100·76	

* Brögger, Eruptivgesteine des Kristianiagebietes, 1894, I, p. 76.

† For discussion of the analyses see p. 119.

Closely related to the preceding, but of a more definite trachytic type, are other ash-gray rocks, which show under the microscope small, sharply defined rectangular phenocrysts of anorthoclase in a ground-mass consisting of a trachytic mesh of felspar-laths, with interstitial dull-green ægirine-augite and a little magnetite (*see* Plate VIII, Fig. 4). The felspar-phenocrysts show the minute twin-striations characteristic of anorthoclase, and similar striations can also be detected in some of the larger felspar-laths of the base. The ægirine-augite is in small, prismatic crystals, and shows pleochroism from brownish yellow to dull-green.

To this type belong most of the ash-gray or yellow (when weathered) trachytic rocks from Cape Crozier (248, 224, 251, 243, etc.), as well as specimens from Inaccessible Island (802, 303, 807), Brown Island (598, 600), and Black Island (610).

Of almost precisely similar character to the rock (248) from Mount Terror (Plate VIII, Fig. 4) are trachytic rocks (55) obtained from the dredge off Cape Wadworth, Coulman Island.

Of extremely salic character is the phonolitic trachyte (607) from the middle of the crater of Brown Island. It is a white, friable rock, resembling a domite. It consists of a fine-grained aggregate of small felspars (mostly short rectangular, but some lath-shaped) without flow-structure, in the interstices of which are distributed a few magnetite-grains and, very sparingly, needles of dull-green ægirine-augite ; a few grains of ægirine and small crystals of sphene are also present. The felspars have a refraction near that of Canada balsam, and are doubtless mainly anorthoclase. With a high power, under the microscope, are seen numerous minute and very thin hexagonal and square sections of an undetermined mineral, which is isotropic or only very feebly doubly-refracting, and has a refraction markedly less than that of Canada balsam. That nepheline is present in the base, although it cannot be definitely distinguished, is indicated by the chemical analysis of the rock, the result of which is as follows under I* :—

	I. (Brown Island.)	Ia. Mol. ratio.	II. (Mont Miaune.)
SiO_2	= 58·64	·977	58·51
TiO_2	= 0·28	·003	trace
Al_2O_3	= 22·55	·221	19·66
Fe_2O_3	= 0·97	·006	3·13
FeO	= 0·99	·014	—
MnO	= trace	—	trace
CaO	= 1·43	·023	1·53
MgO	= 0·16	·004	0·31
Na_2O	= 9·87	·159	10·04
K_2O	= 4·98	·053	4·71
P_2O_5	= trace	—	—
H_2O at 110°	= 0·08 }	—	1·00
H_2O above 110°	= 0·35 }		
			SO_3 = 0·27
	100·30		99·46

* For discussion of the analyses, *see* p. 119.

Under II., for comparison, is appended the analysis of a phonolite from Mont Miaune, Velay, France.*

More closely approaching phonolites are rocks from the *débris*-heaps at Minna Bluff (613) and from Black Island (530).

Specimen 613 from the Minna Bluff is a dark greenish-brown compact rock showing no phenocrysts. Under the microscope are seen feathery flakes of pale-green ægirine-augite, and ragged tufts of cossyrite and of a brown altered mineral (probably another soda-hornblende or pyroxene). These are thickly and uniformly distributed in a rather unindividualised base, showing indistinct felspar-laths and a few magnetite-grains; nepheline is probably present in the base, but could not be definitely identified. The ægirine-augite shows extinctions up to 37°, and pleochroism from pale grass-green for vibrations along the length to pale pinkish-yellow for those across the length. The cossyrite has pleochroism from nearly colourless to deep purplish-brown or opaque; the shreds were too irregular to admit of a more precise determination of the optical characters.

The rock (530) from Black Island is nearly colourless. Under the microscope it shows (*see* Plate VIII, Fig. 5) a fine-grained trachytic felt of felspar-laths, with much deep-blue riebeckite-like hornblende scattered in minute shreds through the section, and accumulated in patches round small altered crystals of what was once probably nepheline. The riebeckite shows pleochroism from pale-brown to colourless across the length of fibres to indigo-blue along the length. These two rocks are similar to some of the phonolitic rocks of the Rift Valley, East Africa.†

Of phonolitic rocks closely related to the kenytes two specimens deserve mention, viz., a rolled pebble (25) from the beach at Cape Adare, and a dark-green compact rock (622) from Minna Bluff (*débris*-heap).

The pebble from Cape Adare is a dark-green compact phonolite showing numerous porphyritic felspars having the characteristic lozenge-shape of anorthoclase. Under the microscope, besides the large (up to 1 cm. in length) phenocrysts of anorthoclase showing minute twin-striations, are seen a few small phenocrysts of deep reddish-brown hornblende, and more numerous pseudomorphs, after hornblende, consisting of grains of magnetite and deep-green ægirine-augite. The ground-mass consists of numerous shreds and small prismatic crystals of ægirine-augite, like that in the hornblende-pseudomorphs, evenly distributed in a base of felspar-laths (not sharply defined) and interstitial nepheline. Magnetite-grains occur very sparingly in the base. A few small crystals of sphene are also present.

Of somewhat similar composition is the dark-green phonolitic rock (622) from the Minna Bluff. It shows under the microscope numerous long prismatic phenocrysts of orthoclase and anorthoclase in a very fine-grained base consisting of a mesh of minute felspar-needles with globulites and microlites of green ægirine-augite. Small crystals

* Emmons, On some Phonolites from Velay and the Westerwald. Dissertation, Leipzig, 1874.

† Prior, Mineralogical Magazine, 1903, vol. xiii, p. 237.

of this mineral are also included in the porphyritic felspars, and occur sparingly as phenocrysts. The anorthoclase-phenocrysts show no twin-striations, but have mottled extinctions; the refraction is not appreciably higher than that of Canada balsam.

The trachytic rocks of Observation Hill present a special type which approaches very closely to the "tephritic trachyte" of Forodada, Columbretes, described by Becke * and placed by Rosenbusch in the group of trachydolerites.

The mineral which especially characterizes them is a reddish-brown basaltic hornblende similar to that which is present in so many of the basalts. This mineral occurs in small prismatic crystals, only occasionally large enough to be detected by the naked eye.

These trachytic rocks practically compose the whole of Observation Hill, near Winter Quarters. All the rocks described on p. 13 of the Report on the Field-geology, both the slabby rocks (281, 291), the spheroidal rock (655), the dyke-rock (277), and the yellow rocks (279, etc.), are very similar in microscopic characters, and only differ in the more or less glassy nature of the base or in the size and number of the hornblende-needles. The yellow rocks from the top of the hill appear to be only weathered gray rocks. In specimens showing alternating bands of gray and yellow (see p. 13) these bands show under the microscope a precisely similar and continuous mesh of felspar-laths, and only differ in the yellow bands containing plentiful yellow grains of epidote in place of the minute magnetite-grains and small dull-green augites of the gray bands. These trachytes show no phenocrysts of felspar, augite or olivine. Under the microscope are seen small prismatic crystals of basaltic hornblende (or of black magnetite-pseudomorphs after it) in a trachytic mesh of minute felspar-laths, showing generally well-marked flow-structure, with thickly disseminated grains of magnetite and small needles of pale dull-green augite.

In the dyke-rock (277) and in the dark rock (290) on the S. side of the hill the hornblende is less altered and in larger amount than in most of the other specimens, and the flow-structure of the lath-shaped felspars is less pronounced (see Plate VIII, Fig. 6).

A black streaky rock with greasy lustre (264), half-way up the hill, is a glassy variety presenting some interesting features. Under the microscope it shows a few small prismatic hornblendes in a base consisting of a nearly colourless glass enclosing felspars, partly in sharply defined laths, but mainly in very thin hexagonal or nearly rectangular plates: small prismatic crystals, both of pale dull-green augite and of basaltic hornblende, and minute needle-like microlites of augite with a very little magnetite, are also present. In parts of the slide occur groups of minute colourless circular or roughly six-sided and eight-sided isotropic crystals (Fig. 64). Though they appear to have a high relief, the Becke-effect shows that their refraction is less than that of Canada balsam, and they are here referred to leucite. Minute icositetrahedra

* Becke, Tschermak's Min. Petr. Mitth., 1896–7, Bd. xvi, p. 174.

of leucite were found by Becke in the glassy base of the trachyte from Forodada.* The platy felspars in this rock have a refraction a little lower, and the lath-shaped felspars a refraction a little higher, than that of Canada balsam. Most of the felspar is probably anorthoclase.

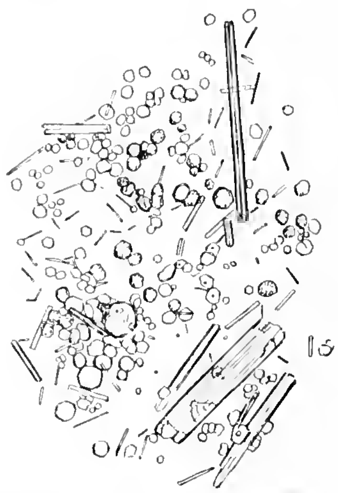

Fig. 64.—Leucite-crystals in Base of Glassy Hornblende-trachyte (264), from Observation Hill. The prismatic crystals are mostly augite: the long one at the top is hornblende. (Magnification, 150 diam.)

Fig. 65.—Dendritic Magnetite in Glassy Base of Trachyte from Observation Hill. (Magnification, 200 diam.)

Another very similar glassy variety (442) from between the ship and Observation Hill shows under the microscope, throughout the slide, small dendritic patches (see Fig. 65) of magnetite (possibly altered riebeckite or other soda-hornblende).

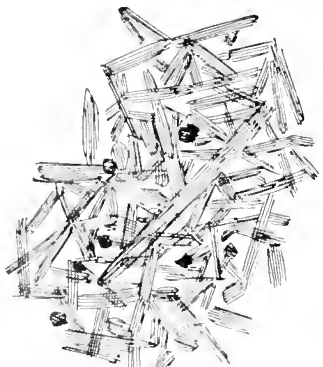

Fig. 66.—Hornblende-inclusions in the Trachyte of Observation Hill. (Magnification, 150 diam.)

A noteworthy feature of these trachytes of Observation Hill is the presence in many of them of dark "lapilli-like" enclosures. In the yellow rocks on the top of the hill these dark rounded enclosures, about the size of a hazel-nut, stand out on the weathered surface like fragments of black basalt caught up in the trachyte. Under the microscope, however, they are seen not to have the character of basalt, but to 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 (see Fig. 66). These enclosures are therefore somewhat similar to those described by Becke † in the case of the similar tephritic trachyte of Ferrera, Columbretes. The hornblende in these enclosures and in the trachytes has the characters of barkevikite and shows pleochroism, $\alpha =$ yellow, β and $\gamma =$ deep reddish-brown; the long prisms have straight extinction and compensate across their length with a quartz-wedge cut parallel to the optic axis.

* Becke, l. c. p. 176.

† Becke, l. c., p. 16, 8 and Taf. III, fig. 4.

A chemical analysis of the hornblende-trachyte (277) from Observation Hill gave the result under I.* With this is compared the analysis of the tephritic trachyte from Forodada under II,† and that of a trachydolerite (haüyne-phonolite) from Campanario, Palma, under III.‡

		I. (Observation Hill.)	IA. Mol. ratios.	II. (Forodada.)	III. (Campanario.)
SiO_2	=	55·47	·918	56·19	55·40
TiO_2	=	1·32	·017	0·57	0·43
Al_2O_3	=	20·67	·202	20·25	21·03
Fe_2O_3	=	2·83	·018	2·76	1·64
FeO	=	1·86	·026	2·32	3·04
MnO	=	0·02			trace
CaO	=	3·43	·061	4·30	3·57
SrO	=	0·01			
MgO	=	1·43	·035	1·12	0·91
Na_2O	=	8·33	·134	6·33	7·64
K_2O	=	4·86	·051	4·19	4·12
P_2O_5	=	0·03		0·54	0·23
H_2O at 110°	=	0·08		0·65	0·95
H_2O above 110°	=	0·12			
			Cl, SO_3, etc.	0·25	0·57
		100·46		99·47	99·83

As in the case of the kenytes and the other trachytes, the analysis indicates the presence of nepheline which, however, could not be detected with certainty in the base of the rock.

A determination was made of the silica-percentage of the altered yellow trachyte (278) from the top of Observation Hill and gave the result 56·96.

Chemical Relations of the Preceding Volcanic Rocks.

For convenience of comparison the results of the analyses of seven of the rocks described in the preceding pages are brought together in the following table.§

		(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)
SiO_2	=	42·14	43·92	55·47	55·93	56·09	57·95	58·64
TiO_2	=	4·90	4·19	1·32	0·64	1·23	0·40	0·28
Al_2O_3	=	14·95	17·42	20·67	19·61	20·79	20·43	22·55
Fe_2O_3	=	2·90	4·09	2·83	1·75	1·54	3·43	0·97
FeO	=	9·71	8·83	1·86	6·32	3·84	1·35	0·99
MnO	=	0·12	0·09	0·02	0·13	0·05	0·07	trace.
CaO	=	10·32	9·53	3·43	3·53	3·18	1·90	1·43
SrO	=			0·01				
MgO	=	9·47	4·89	1·43	0·50	1·26	0·26	0·16
Na_2O	=	3·27	4·60	8·33	7·75	7·33	8·32	9·87
K_2O	=	1·80	2·17	4·86	3·67	3·91	5·96	4·98
P_2O_5	=	0·40	0·67	0·03	0·12	0·38	0·07	trace.
Cl	=					0·17		
H_2O at 110°	=	0·12	0·66	0·08	0·10	0·19	0·23	0·08
H_2O above 110°	=	0·16	0·11	0·12	0·19	0·39	0·39	0·35
		100·26	100·57	100·46	100·24	100·45	100·76	100·30

* For discussion of analyses see below.

† Becke, l.c., p. 177.

‡ Sauer, Untersuch. ü. phonolit. Gesteine der Canarischen Inseln, Inaug. Diss., Halle, 1876, p. 60.

§ The analysis of the glassy limburgite 326 is here omitted, since the result is almost identical with that of the holocrystalline olivine-basalt 656.

(1). Olivine-basalt, cliff between the Gap and Horseshoe Bay (656).
(2). Hornblende-basalt, cone below Castle Hill (385).
(3). Hornblende-trachyte (trachydolerite), 500ft. up Observation Hill (277).
(4). Phonolitic trachyte (trachydolerite), Scott Island.
(5). Leucite-kenyte, "Keep" of Cape Royds, slope of Mount Erebus (818).
(6). Phonolitic trachyte, top of 900-ft. Knoll, Mount Terror (188).
(7). Phonolitic trachyte, crater of Brown Island (607).

As an experiment in the use of the American quantitative system of classification* the "norms" (percentage mineral composition by weight) of the seven rocks were calculated, and are given in the following table:—

		(1)	(2)	(3)	(4)	(5)	(6)	(7)
$KAlSi_3O_8$	=	10·55	12·79	28·95	21·76	22·92	35·60	29·47
$NaAlSi_3O_8$	=	4·19	12·05	29·30	35·24	41·47	34·82	39·30
$CaAl_2Si_2O_8$	=	20·57	20·29	4·69	7·81	12·23	0·77	2·50
$NaAlSiO_4$	=	12·78	14·48	21·56	16·53	11·07	18·72	23·66
$NaFeSi_2O_6$	=			1·88			1·58	
$CaSiO_3$	=	11·71	9·51	5·23	3·71	0·46	3·64	1·62
$FeSiO_3$	=	2·51	2·90		9·37	0·39		0·79
$MgSiO_3$	=	8·20	6·00	3·60	1·30	0·30	0·66	0·40
Fe_2SiO_4	=	3·67	2·34			3·67		
Mg_2SiO_4	=	10·78	4·27			1·96		
$FeO \cdot Fe_2O_3$	=	4·17	6·03	2·25	2·55	2·32	3·41	1·39
$FeO \cdot TiO_2$	=	9·27	7·90	2·54	1·22	2·28	0·77	0·46
Ca_32PO_4	=	0·93	1·55	0·20	0·31	0·93		

The names which the rocks would receive in this new classification are as follows:—

(1) Limburgose.
(2) Limburgose.
(3) Laurdalose.
(4) Essexose.
(5) Laurvikose.
(6) Miaskose.
(7) Miaskose.

The result shows that the classification supplies a variety of names to rocks not differing very widely in chemical composition.

Another system for the chemical classification of igneous rocks, which has been recently brought forward, is that of Osann.†

This classification is based on the molecular percentages as calculated from the results of analysis. For the seven analyses the molecular percentages are as follows:—

		(1)	(2)	(3)	(4)	(5)	(6)	(7)
SiO_2	=	45·06	48·92	62·78	63·17	63·66	66·49	66·92
TiO_2	=	3·96	3·52	1·13	0·54	1·05	0·35	0·20
Al_2O_3	=	9·11	11·46	13·81	13·11	13·96	13·85	15·14
Fe_2O_3	=	1·17	1·72	1·21	0·75	0·66	1·49	0·41
FeO	=	8·73	8·27	1·79	6·12	3·71	1·37	0·96
CaO	=	11·87	11·12	4·18	4·29	3·89	2·34	1·58
MgO	=	15·15	8·15	2·42	0·81	2·14	0·45	0·27
Na_2O	=	3·40	1·99	9·17	8·52	8·09	9·28	10·89
K_2O	=	1·22	1·55	3·51	2·66	2·84	4·38	3·63

* Quantitative Classification of Igneous Rocks, Cross, Iddings, Pirsson and Washington, Chicago, 1903.
† Osann, Tschermak's Min. Petr. Mitth., 1900, Bd. xix, p. 351, and 1901, Bd. xx, p. 399.

In the Osann formulæ, which represent the chemical composition of the rocks, the number of molecules of SiO_2 (including TiO_2) are denoted by s; the alkalies are united to Al_2O_3 (as in the felspars and felspathoids) in a group $(NaK)_2Al_2O_4$, which is denoted by A; the remainder of the Al_2O_3 is united with CaO (as in anorthite) in a group $CaAl_2O_4$, which is denoted by C; and the rest of the CaO with the other metallic oxides (FeO, MgO) are united in a group RO represented by F. The number of molecules of Na_2O is calculated on the assumption that $Na_2O + K_2O = 10$ and is denoted by n. Moreover, as the absolute magnitudes A, C, F are not necessary, since $2A + 2C + F = 100 - s$, their ratios a, c, f, where $a + c + f = 20$, are used. The ratios a, c, f give an approximate idea of the relative amounts in which the alkali-felspars, anorthite and dark constituents, enter into the composition of the rocks.

For the seven rocks the Osann formulæ are as follows under (1)–(7):—

(1)	$s_{48 \cdot 91}\ a_2\ c_2\ f_{16}\ n_{7 \cdot 35}$	I.	$s_{50 \cdot 77}\ a_2\ c_2\ f_{16}\ n_{7 \cdot 8}$
(2)	$s_{52 \cdot 14}\ a_{3\frac{1}{2}}\ c_{2\frac{1}{2}}\ f_{11}\ n_{7 \cdot 63}$	II.	$s_{50 \cdot 78}\ a_3\ c_2\ f_{15}\ n_{7 \cdot 2}$
(3)	$s_{63 \cdot 91}\ a_{11}\ c_1\ f_8\ n_{7 \cdot 23}$	III.	$s_{63 \cdot 34}\ a_{10}\ c_1\ f_9\ n_{7 \cdot 4}$
(4)	$s_{63 \cdot 72}\ a_{10}\ c_{1\frac{1}{2}}\ f_{8\frac{1}{2}}\ n_{7 \cdot 62}$	IV.	$s_{63 \cdot 78}\ a_{11}\ c_{\frac{1}{2}}\ f_{8\frac{1}{2}}\ n_7$
(5)	$s_{64 \cdot 71}\ a_{10}\ c_{2\frac{1}{2}}\ f_{7\frac{1}{2}}\ n_{7 \cdot 10}$	V.	$s_{63 \cdot 79}\ a_{10\frac{1}{2}}\ c_{2\frac{1}{2}}\ f_7\ n_{7 \cdot 2}$
(6)	$s_{66 \cdot 81}\ a_{13\frac{1}{2}}\ c_0\ f_{6\frac{1}{2}}\ n_{6 \cdot 79}$	VI.	$s_{68 \cdot 29}\ a_{14}\ c_0\ f_6\ n_7$
(7)	$s_{67 \cdot 12}\ a_{16}\ c_1\ f_3\ n_{7 \cdot 50}$	VII.	$s_{67 \cdot 14}\ a_{16}\ c_0\ f_4\ n_{7 \cdot 6}$

For comparison, opposite the formula of each Antarctic rock, is appended the formula (I–VII) of the following:—

I. Nepheline-basanite from Hundskopf, Salzungen.
II. Limburgite from Heldburg, near Coburg.
III. Phonolite from Mädstein, Bohemia.
IV. "Rhomb-porphyry" (kenyte) from Kibo, Kilimandjaro.
V. "Haüyne-tephrite" from Campanario, Palma.
VI. Phonolite from Bull Cliff, Colorado.
VII. Phonolite from Mont Miaune, Velay.

The analytical results show that these Antarctic volcanic rocks do not form anything in the nature of a rock-series, but that they may be divided fairly sharply into two groups, a basic one consisting of hornblende- and olivine-basalts of limburgite-type (1 and 2), and one of medium basicity consisting of kenytes and phonolitic trachytes (3–7) very rich in alkalies.

These two groups appear to represent the two main products into which the magma has been differentiated in this Antarctic region.

A graphical representation (according to Brogger's method)* of these two differentiation-products, as illustrated by rocks (1) and (5), is shown in Figs. 67 and 68 respectively.

In an Osann triangle,† the rocks of the first group fall into Division III, and those of the second group into the upper part of II, in a similar position to that assigned by Becke‡ to the tephritic and phonolitic rocks of the Bohemian Mittelgebirge.

* Brögger, Eruptivgesteine des Kristianiagebietes, 1898, III, p. 255.
† Osann, Tschermak's Min. Petr. Mitth. 1900, Bd. xix, p. 363, and Pl. IV.
‡ Becke, Tschermak's Min. Petr. Mitth. 1903, Bd. xxii, p. 214, and Pl. II.

In both the basaltic and alkaline groups, the ratio of soda to potash is nearly the same, with Na > K. A similar basaltic hornblende occurs in certain rocks of each group, and not in others in which its place is taken by olivine. The presence or absence of hornblende in both groups probably depended to a large extent upon the conditions of eruption; in the dyke-rocks, which cooled while still under a high pressure, the mineral was more likely to survive than in the lavas.

Altogether, this Antarctic region, from Scott Island in the north to the Minna Bluff in the south, has good claim to be regarded as a definite petrographical province

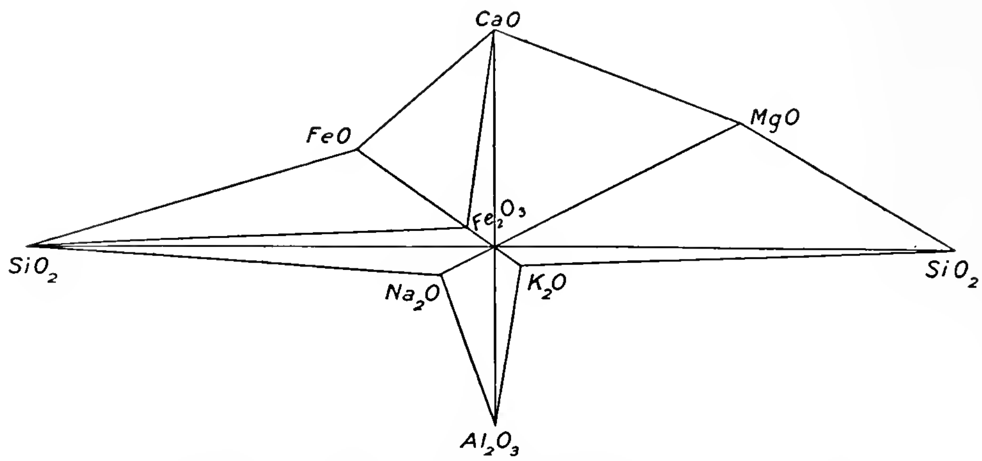

FIG. 67.—GRAPHICAL REPRESENTATION OF THE CHEMICAL COMPOSITION OF THE OLIVINE-BASALT (656) FROM NEAR THE GAP.

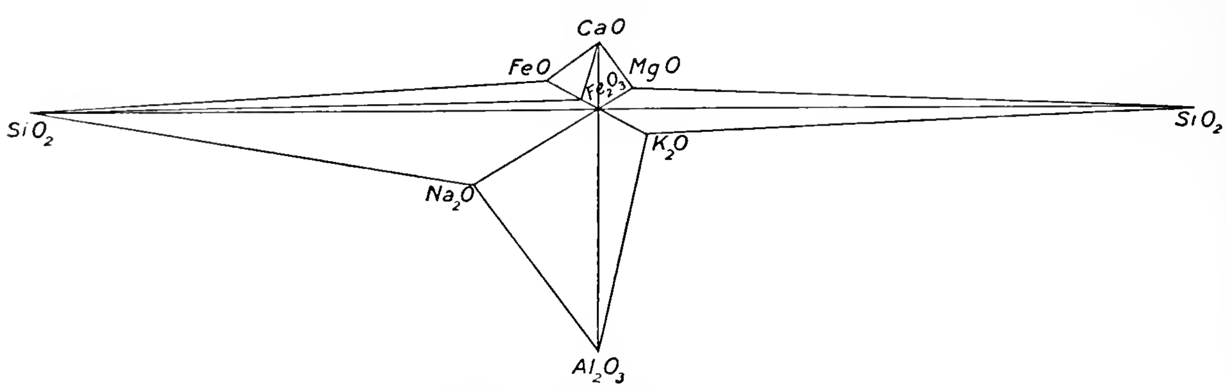

FIG. 68.—GRAPHICAL REPRESENTATION OF THE CHEMICAL COMPOSITION OF THE LEUCITE-KENYTE (818) FROM CAPE ROYDS.

characterised by the association of basalts of limburgite-type with alkali-rich rocks of medium basicity in which anorthoclase is the prevailing felspar.

In a wider sense, these Antarctic rocks belong undoubtedly to the great Atlantic as opposed to the Pacific type of eruption. The marked contrast between the younger volcanic rocks of the Atlantic volcanic chain and its lateral branches, and those of the volcanoes encircling the Pacific Ocean, was pointed out by the author amongst the conclusions drawn from a study of the igneous rocks of the Great Rift Valley of East

Africa.* In the same year similar ideas were brought forward with greater elaboration by Becke in a striking contrast which he drew between the volcanic rocks of the Bohemian Mittelgebirge and those of the Andes.† He suggested that these two Pacific and Atlantic types were intimately connected with the two tectonic processes of Suess which have mainly affected the earth's crust, viz., faulting by tangential pressure, and fracture by radial contraction; where young volcanic rocks occur along a faulted mountain-chain like the Andes, they belong to the Pacific group; where, on the other hand, they occur on block-fractures ("Schollenbrüche"), they belong to the Atlantic type.

In the case of these Antarctic eruptions, we have volcanic rocks of undoubtedly Atlantic type developed along a coast which has been described as typically Pacific.‡ They form, therefore, apparently an exception to Becke's rule; but it may be pointed out that the volcanoes of South Victoria Land, from which specimens of lava have been obtained, are not generally ranged parallel to the coast, but appear to occur along lines of weakness directed nearly at right angles to it.§

As regards the relative ages of the basalts and alkali-rich rocks of the Ross Archipelago, the observations in the field lead to no very conclusive result. From the intrusive appearance of the trachyte on the south-east end of Black Island (*see* p. 14), Mr. Ferrar was inclined to regard the trachytes as younger than the basalts, but he was unable to examine closely the actual junction of the two rocks at this spot. In the case of the kenytes of Mount Erebus and the islands in Erebus Bay, Mr. Ferrar is of opinion that they are older than the basalt-flows of Winter Quarters, since on Razor Back Island they are bent into a sharp anticline which has not affected the other rocks. It seems probable, therefore, that the trachytic rocks having a chemical composition so similar to that of the kenytes are also older than the basalts. This idea is also supported by the fact that the bombs scattered over trachytic rocks are of the same character as the basalts. Mr. Ferrar also describes the trachyte-bosses (*e.g.*, that exposed in the Gap) as occurring like "islands," without off-shoots into the basalt. Thus Observation Hill is probably not intrusive in the basalts, but stands out from them as an older rock, just as the phonolite-peak of Fernando Noronha projects above the younger basalts.

On the whole, therefore, it seems probable that in these Antarctic volcanic rocks the sequence of eruption has been from rocks of medium basicity to basic, and that the trachytes and kenytes preceded the basalts.

* Prior, Contributions to the Petrolog. of British East Africa, etc., Mineralogical Magazine, 1903, vol. xiii, p. 260.

† Becke, Tschermak's Min. Petr. Mitth. 1903, Bd. xxii, p. 248.

‡ Gregory, Nature, 1906, vol. lxxiii, p. 300.

§ See, however, footnote on p. 140.

CHAPTER II.

THE BASEMENT-ROCKS OF SOUTH VICTORIA LAND.

CRYSTALLINE LIMESTONE.

THE crystalline limestones, which appear to constitute the prevailing rock of the Northern and Southern Foothills, are coarse-grained aggregates of calcite-crystals loosely held together. For the most part they are very pure, and show, in addition to the calcite, only a few small flakes of graphite and of a nearly-colourless phlogopite. Amongst the specimens, however, which were found by Dr. Wilson along Discovery Gulf, are fragments of crystalline limestone containing numerous rounded yellow crystals, which analysis has shown to be of chondrodite. The rock (see Fig. 69) is very similar in appearance to the chondrodite-limestones of Burma and Finland.

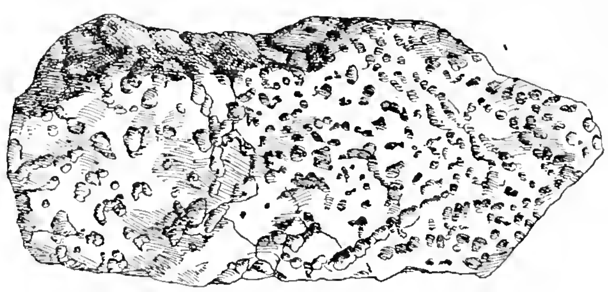

FIG. 69.—CRYSTALLINE LIMESTONE WITH CHONDRODITE, FROM SOUTHERN FOOTHILLS. (Natural Size.)

Amongst the boulders found on the East of Mount Terror, just above the Barrier, is one of a schistose crystalline limestone, or calc-schist, containing quartz in fine grains in alternating bands with the calcite.

GNEISS.

Of gneisses there are not many specimens in the collection. They are gray and red foliated medium-grained rocks, some of which show conspicuous augen-structure. Like the Arctic gneisses of Greenland* these Antarctic rocks have the characters of metamorphosed granites and diorites (orthogneiss). They consist of orthoclase, oligoclase, quartz, biotite, and almost invariably hornblende. Microcline was not detected in any of the gneisses examined, but it occurs in large plates in a felspathic grit on Finger Mountain, which had obviously been derived from the decomposition of gneissic and granitic rocks.

In the augen-gneiss, orthoclase generally forms the "eyes" which enclose biotite, idiomorphic oligoclase, and occasionally rounded blebs of quartz.† The "eyes" are mostly altered and red with oxide of iron. They are enclosed in a mosaic consisting of

* Belowsky, Beit. z. Petrog. west. Nord-Grönlands, Zeit. d. deut. geol. Ges., 1905, Bd. lvii, pp. 15–90.

† Evans, Quart. Journ. Geol. Soc., 1906, vol. lxii, p. 96.

interlocking grains of clear quartz and slightly altered oligoclase and orthoclase, with biotite and hornblende in strings marking the foliation. Both quartz and orthoclase in the mosaic occur in very irregular interpenetrating patches, which in ordinary light appear to belong to individual crystals, but break up between crossed nicols into a number of differently orientated grains. Cataclastic structure of this kind is well marked in the augen-gneiss 727 (see Plate IX, Fig. 1) from D_4 in the Kukri Hills (pp. 30 and 38). In this rock the interspaces between the large "eyes" of orthoclase are occupied partly by a quartz-mosaic showing marked undulose extinctions, and partly by shattered felspars crowded with small blebs of quartz ("*quartz de corrosion*," as described by Lacroix in the case of the charnockites of India*), or forming with quartz a micropegmatitic intergrowth (see Fig. 70).

The red augen-gneiss (716) from Cathedral Rocks has somewhat similar characters, but the quartz-felspar-mosaic between the large "eyes" of pink orthoclase shows less pronounced cataclastic structure, and the quartz and felspar are in more distinct grains; effects of pressure, however, are evident in the bent twin-lamellæ of the oligoclase, and quartz of corrosion is also present. This red granite-gneiss appears to be intrusive in the gray, just as in Greenland the fine-grained red gneisses are intrusive in the gray mica- and hornblende-gneisses.

Fig. 70.—Micropegmatite surrounding Felspar in Augen-gneiss (727) from the Kukri Hills. (Magnification, 25 diam.)

From Cathedral Rocks comes a hornblende- or diorite-gneiss (724) consisting of a granular aggregate of quartz and plagioclastic felspar with much pleochroic (green to brownish-yellow) hornblende. The quartz is not in large amount, and the felspar is more basic than the oligoclase of the other gneisses, since it shows symmetrical extinctions of 18°–21°.

Associated with the gneisses are hornblende-schists (730, 704) which help to give the dark streaky appearance to the rocks referred to on p. 28.

Granites and Diorites.

The granites of South Victoria Land are for the most part typical hornblende-biotite-granites similar to those from Cape Adare brought back by the 'Southern Cross' Expedition.

Of these rocks the more noteworthy will be considered under the particular localities from which they come, and as far as possible in the order in which they are mentioned in the Report on the Field-geology.

Granite Harbour.—The gray biotite-granite (129) which forms the greater part of the boss at Granite Harbour (see p. 33) is somewhat gneissic in character, and shows signs of parallel structure in the arrangement of the shreds of biotite. It consists of

* Lacroix, Rec. Geol. Surv. Ind., 1891, vol. xxiv, p. 168.

large plates of orthoclase and oligoclase, with interstitial quartz-mosaic (cataclastic structure) and flakes of biotite. The oligoclase is mostly idiomorphic, and shows both albite- and pericline-twinning. A little sphene and small rounded zircons are present as accessory minerals. The rock shows evidence of pressure in the strain-shadows in the quartz, as well as in slight bending of the twin lamellæ and fracture of the crystals of oligoclase. The dyke-rock (155), except for the large porphyritic red felspars, is similar to 129, and also shows parallel structure in the arrangement of the biotite-flakes, but the quartz-mosaic is of coarser grain. The large porphyritic orthoclases enclose rounded crystals of oligoclase.

Other veins in the gray granite are of quartz-porphyry, and are doubtless apophyses of the granite (155), since they show similar large red porphyritic crystals of orthoclase and oligoclase. In specimen 168 these phenocrysts occur with large rounded quartz-crystals and small pleochroic (grass-green to yellow) hornblendes in a cryptocrystalline felsitic base.

The rock-specimens collected from the scree-slopes in Granite Harbour include :—augen-gneiss; epidosite; granites with large red porphyritic felspars; pegmatite; very beautiful quartz-porphyries, showing large pink porphyritic felspars and rounded quartz in a fine-grained felsitic base; diorites with large porphyritic hornblendes, somewhat similar to the dyke-rock (715) from Cathedral Rocks described below; sandstones and dolerites (see p. 138), precisely similar to those of the Ferrar Glacier; and also gabbros, showing under the microscope large ophitic plates of colourless augite and green uralitic hornblende in a coarse-grained aggregate of plagioclastic felspars with much pleochroic (colourless to rose-red) sphene.

The Southern Foothills.—The gray rock (569) from the Southern Foothills, which occurs in bands parallel to the joint-planes of the crystalline limestone (see p. 25), consists of a medium-grained allotriomorphic aggregate of oligoclase, orthoclase and quartz, with shreds of green to brown hornblende and biotite showing well-marked parallel structure. Grains of honey-yellow sphene are very abundant.

The Snow Valley.—Of the granites from the Snow Valley between Cathedral Rocks and the Northern Foothills (p. 33), the porphyritic rock (563) from e_6 is the most noteworthy. It shows large porphyritic pink crystals of orthoclase, around which lines of small hornblende-crystals appear to flow. Under the microscope the groundmass is seen to consist of allotriomorphic oligoclase and orthoclase and pleochroic (yellowish-brown to black) hornblende, with quartz in quite subordinate amount. The coarse-grained porphyritic granite (555) from the knoll e_5 shows fairly idiomorphic oligoclase and less sharply defined orthoclase embayed by quartz, which has been obviously the last mineral to consolidate; hornblende and biotite are not in large amount: some sphene is present. A dark patch in this granite has the composition of a basic diorite or essexite somewhat like the rock of the "tongue" (715) described on the next page. It consists of a coarse-grained aggregate of plates of altered plagioclase, large ophitic reddish-brown hornblende and colourless diopside.

Cathedral Rocks.—Of the specimens from Cathedral Rocks, the rock 715 of the 'tongue' or 'pipe' east of the shoulder E_2 presents noteworthy features and has the characters of a basic diorite or hornblende-gabbro. It consists (Plate IX, Fig. 2) of fairly idiomorphic crystals of labradorite, showing symmetrical extinctions of about 22°, and large ophitic plates of hornblende, with interstitial quartz in quite subordinate amount. The hornblende has pleochroism from brownish-yellow to deep reddish-brown like that of barkevikite, but the extinction in some crystals is as high as 15° ; it encloses small altered felspars and much apatite. The section shows also two plates of hypersthene, one enclosed in hornblende and the other altering to fibrous actinolité ; it gives straight extinction and is faintly pleochroic, from pale-green for vibrations along the length to pale-pink for those across. Other specimens (712 and 721) from the same 'tongue' show similar ophitic plates of hornblende, but contain also some biotite and orthoclase and much more quartz. They approach, therefore, more closely to hornblende-granites. The hornblende, too, in these specimens is of somewhat different composition, showing pleochroism from dark-green to brown. Prisms of allanite occur in these rocks and apatite is very plentiful.

A chemical analysis of specimen 715 gave the following result under I :—

		I. (Cathedral Rocks.)	IA. Mol. ratios.	II. (Hurricane Ridge.)	III. (Sweet Grass Creek.)
SiO_2	=	53·06	·884	53·71	53·48
TiO_2	=	1·60	·020	0·74	1·07
Al_2O_3	=	18·65	·183	18·00	19·35
Fe_2O_3	=	1·44	·009	3·99	2·37
FeO	=	7·58	·105	4·05	4·90
MnO	=	0·05	·001	0·24	0·06
CaO	=	8·22	·147	6·88	7·55
MgO	=	3·78	·094	5·19	3·67
Na_2O	=	3·20	·051	3·50	4·07
K_2O	=	1·55	·016	3·10	1·41
P_2O_5	=	0·38	·003	0·38	0·62
H_2O at 110°	=	0·16		0·55	0·16
H_2O above 110°	=	0·94			0·80
					SrO etc 0·38
		100·61		100·33	99·89

The Osann formula of this rock is :—

$$s_{59\cdot75}\ a_3\ c_{5\frac{1}{2}}\ f_{11\frac{1}{2}}\ n_{7\cdot61}$$

which is between that of Osann's Hurricane Ridge type :—

$$s_{58\cdot91}\ a_4\ c_4\ f_{12}\ n_{6\cdot3}$$

and his Sweet Grass type :—

$$s_{60\cdot05}\ a_4\ c_{5\frac{1}{2}}\ f_{10\frac{1}{2}}\ n_{8\cdot1}.$$

The analysis of the mica-gabbro from Hurricane Ridge, Yellowstone National Park, is given under II,* and that of the quartz-diorite from Sweet Grass Creek, Crazy Mountains, under III.†

* Iddings, Monogr. U.S. Geol. Surv., 1899, No. 32, Part II, p. 340.

† Clarke, Bull. U.S. Geol. Surv., 1897, No. 148, p. 143.

Calculation of the "norm" gave the following result :—

$KAlSi_3O_8$	=	8·90
$NaAlSi_3O_8$	=	26·72
$CaAl_2Si_2O_8$	=	32·25
SiO_2	=	3·48
$CaSiO_3$	=	2·55
$FeSiO_3$	=	10·03
$MgSiO_3$	=	9·40
$FeO.\ Fe_2O_3$	=	2·09
$FeO.\ TiO_2$	=	3·04
Ca_32PO_4	=	0·93

In the American quantitative system the rock would be classed as Hessose.

Blue Glacier.—Of somewhat similar character to the rock of the "tongue" are the dyke-rocks (572–574) collected by Dr. Koettlitz half-way down the Blue Glacier. One of these, in which the hornblende occurs in large ophitic plates, is almost identical with the rock of the "tongue," but the others are less coarse-grained, and show more numerous and better crystallised phenocrysts of hornblende. In this respect they resemble camptonitic rocks from Montreal, but are of coarser grain and approach to essexites. Under the microscope (Plate IX, Fig. 3), they show long, prismatic crystals of hornblende in large amount, with interstitial plates of altered felspar; hexagonal sections of apatite are very plentiful, while grains of magnetite and ilmenite occur very sparingly. The hornblende is similar to that in the "tongue" with pleochroism : α = brownish-yellow, β and γ = deep reddish-brown, and extinction as high as 15° ; most of the sections show a dark-green margin.

Kukri Hills.—The specimens (699, 700) from the Kukri Hills, illustrating the intrusion of granite into dolerite (*see* p. 36), show pink granite in contact with and almost surrounding fragments of a dark-gray rock. Under the microscope the latter is seen to consist of felspar, in interlocking grains and indistinct prisms, with shreds and irregular patches of green hornblende and a little quartz. Accessory constituents are one or two small crystals of sphene and a few shreds of chlorite enclosing magnetite. The hornblende shows pleochroism : α = pale yellowish-brown, β = dark greenish-brown, γ = dull green. If this rock, therefore, represents a dolerite like those described in a later section (p. 136), it has suffered as extreme a metamorphism as some of the old dolerites of Cornwall.

Amongst the pebbles from the dredge off King Edward VII Land are hornblende-biotite-granites and gneisses, and diorites with large ophitic plates of hornblende. One pebble of coarse-grained biotite-granite differs from the others in containing large crystals of microcline.

A boulder of hornblende-biotite-granite from the 500-ft. slope on Mount Terror deserves mention owing to the peculiar character of the biotite, which occurs in small thick crystals standing out conspicuously from the white ground-mass.

Chapter III.

DYKE-ROCKS (LAMPROPHYRES, etc.).

The dyke-rocks in the crystalline limestones and granites form an interesting series ranging from kersantites to rocks allied to the banakites of Wyoming. Some of the dykes show numerous phenocrysts of basaltic hornblende and approach to camptonites such as occur generally in association with nepheline-syenites. No specimens, however, of the latter rocks appear to have been met with in this Antarctic region.

Camptonites.

A typical camptonite is the dark-gray rock (839) found *in situ* by Dr. Wilson at the south end of the Southern Foothills, near the Koettlitz Glacier. To the naked eye this rock shows only a few small phenocrysts of hornblende. Under the microscope (see Plate IX, Fig. 5) the rock is seen to consist of small prismatic crystals of reddish-brown hornblende thickly distributed in a base of lath-shaped felspars with a little quartz. The hornblende has the same optical characters as that in the diorite described above (p. 127). The felspar-laths are of labradorite with refraction markedly greater than that of Canada balsam, and symmetrical extinctions as high as 19°. Magnetite and ilmenite are virtually absent. The section shows one or two foreign enclosures of quartz containing liquid-inclusions with bubbles.

To the camptonites must also be referred a specimen (629) brought by Lieut. Armitage from the foot of Cathedral Rocks. It is a dark greenish-gray rock showing to the naked eye no porphyritic crystals. Under the microscope small green uralitic hornblendes are seen in a base of felspar-laths and thickly-distributed ragged prisms and minute needle-like microlites of basaltic hornblende with a little biotite. The felspar-laths appear to be of oligoclase: one rhombic section cut nearly parallel to *b* (010) gave a positive extinction of about 10°. The hornblende-prisms show well-marked flow-structure.

A specimen (498) from a moraine at New Harbour Height (S. foot) shows the junction of a gray hornblende-biotite-granite and a black fine-grained camptonitic rock. The latter consists of numerous small sharply-defined prismatic crystals of basaltic hornblende, in a base showing a few felspar-laths and a little quartz but rendered dense with long hornblende-microlites. Besides the hornblendes a few prismatic crystals of colourless augite are also present. None of the small phenocrysts exceed 0·3 mm. in length. Near the junction the base becomes more dense and glassy and shows no well-defined hornblende-microlites.

Kersantites.

The twenty-yards-wide dyke (579) cutting the crystalline limestone at G_1 in the Northern Foothills (*see* p. 27) is an augite-biotite-kersantite. It is a speckled gray rock showing to the naked eye numerous flakes of biotite. Under the microscope irregular pale-green to pale-purple augites and much biotite in shreds and straggling ophitic patches are seen in a medium-grained mesh of plagioclase-laths with a little interstitial quartz (see Plate IX, Fig. 4). A little reddish-brown hornblende of the same character as in the preceding rocks is also present. The felspars are altered and kaolinised; some with refraction less than that of Canada balsam are doubtless orthoclase, but most have higher refraction and are probably oligoclase.

A chemical analysis of this rock gave the following result under I. For comparison is appended, under II, an analysis of a kersantite from Stengerts, Spessart,* and under III that of a shoshonite from Beaverdam Creek, Yellowstone Park.†

	I. (Northern Foothills.)	IA. Mol. ratios.	II. (Stengerts.)	III. (Beaverdam Creek.)
SiO_2 =	50·71	·840	51·80	53·49
TiO_2 =	2·71	·034		0·71
Al_2O_3 =	17·08	·167	16·65	17·19
Fe_2O_3 =	1·38	·009	4·93	4·73
FeO =	8·71	·122	2·14	3·25
MnO =	0·09		0·29	0·14
CaO =	5·75	·102	7·35	6·34
MgO =	3·63	·090	6·90	4·42
Na_2O =	3·82	·061	3·68	3·23
K_2O =	3·63	·037	4·05	3·86
P_2O_5 =	0·57	·004		0·43
H_2O at 110° =	0·16		}	
H_2O above 110° =	1·75		} 1·32	2·17
CO_2 =	trace		0·50	BaO = 0·06
	99·99		99·61	100·02

The Osann formula of this rock is:—

$$s_{59\cdot66}\ a_5\ c_3\ f_{12}\ n_{6.15}$$

which is near that of the shoshonite from Beaverdam Creek:—

$$s_{60\cdot21}\ a_{4\frac{1}{2}}\ c_{3\frac{1}{2}}\ f_{12}\ n_{5\cdot6}$$

Calculation of the "norm" gave the following result:—

$KAlSi_3O_8$	=	20·57
$NaAlSi_3O_8$	=	31·96
$CaAl_2Si_2O_8$	=	18·63
$CaSiO_3$	=	2·67
$FeSiO_3$	=	1·45
$MgSiO_3$	=	1·20

* Goller, Die Lamprophyrgänge des südlichen Vorspessart. Neues. Jahrb., 1889, Beil.-bd. vi, p. 566.

† Iddings, Geol. of the Yellowstone National Park. Monogr. U. S. Geol. Surv., 1899, No. 32, Part ii, p. 340. Analysis by Eakins.

Fe_2SiO_4	=	6·94
Mg_2SiO_4	=	5·32
$FeO.\ TiO_2$	=	5·17
$FeO.\ Fe_2O_3$	=	2·09
Ca_32PO_4	=	1·24

In the case of this micaceous rock the "norm" diverges from the "mode," since much of the potash occurs in biotite and not in orthoclase.

In the American quantitative system the rock would be classed as Shoshonose. Thus both chemical systems refer the rock to the same type, from which, however, it differs somewhat in mineral composition. As a shoshonite it is chemically closely related to the banakite-like rocks described in the next section.

Another kersantite appears to be the dark-gray dyke (625) intrusive in the gray granite at E_4 at a height of about 5000 feet. Under the microscope it shows long shreds of biotite and much-altered green hornblende (mostly uralitic after augite, of which a little still remains) in a ground-mass of altered prismatic plagioclastic felspars.

Dykes Chemically Related to Banakite.

Under this heading are here included certain dyke-rocks which bear some relation to the camptonites in containing basaltic hornblende as phenocrysts and also occasionally in the ground-mass, while they differ from them by the presence of numerous phenocrysts of felspar, some of which are of orthoclase.

To this group belongs the brown dyke (714) in the granite at G_3 in the Northern Foothills. Besides the large porphyritic crystals of basaltic hornblende referred to on p. 35 it shows also numerous phenocrysts of felspar and a few of augite. The felspar-phenocrysts are mainly of labradorite, with symmetrical extinctions in albite-lamellæ of 26°. Others, however, with low refraction and showing no twin-striations are of orthoclase, while some with mottled extinctions and refraction about the same as that of Canada balsam are probably of anorthoclase. A few rounded phenocrysts of analcite are also present (see Plate IX, Fig. 6).

The ground-mass consists of a holocrystalline medium-grained aggregate of plagioclastic felspars (mainly in rectangular sections, but also in laths), prismatic crystals of pale-purple augite, and magnetite. Some of the rectangular felspars in the ground-mass are of labradorite giving symmetrical extinctions as high as 25°. Apatite-needles are plentiful, and shreds of brown altered hornblendic material are scattered through the slide.

A coarse-grained inclusion consists of an aggregate of felspar with refraction near that of Canada balsam, pale-green to purple augite, basaltic hornblende, and analcite, with large needles of apatite and much magnetite.

A somewhat similar dyke-rock (720) comes from Cathedral Rocks at E_2. It shows porphyritic crystals of labradorite (symmetrical extinctions of about 28°) and green uralitic pseudomorphs, in a ground-mass of rectangular felspars and long needles of brown hornblende. Some of the felspar-phenocrysts are much decomposed, but show a narrow margin of quite unaltered material.

A chemical analysis of specimen 714 from G_3 gave the following result under I:—

		I. (714.)	IA mol. ratios.	II. (Banakite.)	III. mean of—(1) and (5), (p. 119)
SiO_2	=	48·22	·804	51·46	49·11
TiO_2	=	2·09	·026	0·83	3·06
Al_2O_3	=	18·47	·181	18·32	19·10
Fe_2O_3	=	5·28	·033	4·61	2·22
FeO	=	3·90	·051	2·71	6·78
MnO	=	0·10	·001	0·17	0·08
CaO	=	6·02	·108	6·03	6·75
MgO	=	2·07	·052	2·91	5·36
Na_2O	=	4·94	·080	4·11	5·30
K_2O	=	3·47	·037	4.48	2·85
P_2O_5	=	0·88	·006	0·86	0·39
H_2O at 110°	=	0·44	}	3·89	
H_2O above 110°	=	2·89	}		
CO_2 and loss	=	(1·23)			
		100·00		100·38	

The Osann formula of this rock is:—

$$s_{60 \cdot 44}\ a_{6\frac{1}{2}}\ c_{2\frac{1}{2}}\ f_{11}\ n_{6 \cdot 83}.$$

The formula for a banakite-dyke from Ishawooa Canyon, Wyoming,* the analysis of which is given under II, is:—

$$s_{60 \cdot 64}\ a_{5\frac{1}{2}}\ c_{3\frac{1}{2}}\ f_{11}\ n_{5 \cdot 8}.$$

Calculation of the "norm" gave the following result:—

$KAlSi_3O_8$	=	20·57
$NaAlSi_3O_8$	=	25·15
$NaAlSiO_4$	=	8·90
$CaAl_2Si_2O_8$	=	17·79
$CaSiO_3$	=	3·12
$FeSiO_3$	=	3·30
$MgSiO_3$	=	5·20
Fe_2O_3	=	5·28
$FeO.TiO_2$	=	3·95
Ca_32PO_4	=	1·86

In the American quantitative system, the rock would be classed as Akerose, but a very slight difference in the ratio $\frac{K_2O + Na_2O}{CaO}$ would refer it to Shoshonose, like the kersantite described above (p. 130).

Under III is appended the result of taking the mean of analyses (1) and (5) (see p. 119) of the olivine-basalt (656) and the leucite-kenyte (818) of the Ross Archipelago. Although it may have no real significance, it seems worthy of note that the chemical composition of this ancient dyke-rock (714) should be so near the mean of the two

* Iddings, Monogr. U.S. Geol. Surv., 1899, No. 32, Part II, p. 347. Analysis by Eakins.

principal products into which the magma appears to have been differentiated in the recent lava-flows. If the FeO and Fe_2O_3 are taken together, then no item in the two results, except that of the MgO, differs by more than 1 per cent. In these banakite-like dykes, too, occurs the basaltic hornblende which is so ubiquitous a mineral in the recent lavas. The ratio of $Na_2O : K_2O$ is also nearly the same as in the younger rocks.

Doubtfully to be referred to under the heading of banakite is the dyke-rock (566) intrusive in the crystalline limestone of the Northern Foothills at G_4. It is a dark-greenish-gray speckled rock, showing to the naked eye no phenocrysts. Under the microscope it is seen to be microporphyritic, with numerous small, sharply-defined phenocrysts of purplish augite, green chloritic and serpentinous pseudomorphs (possibly after hornblende) and a few altered felspars. The ground-mass consists of altered felspar prisms with shreds of biotite and hornblende and sparingly scattered magnetite-grains.

Of very similar character is the dyke (565) in the granite at e_6 above the head of Blue Glacier.

The specimen (646) found by Lieut. Skelton in a moraine, ten miles beyond Cathedral Rocks, deserves mention here. It is a brownish-grey compact rock, conspicuously porphyritic, and showing to the naked eye small prismatic felspars and a few crystals of augite and hornblende. Under the microscope are seen phenocrysts of oligoclase (symmetrical extinctions of 10°) and sharply-defined, nearly-colourless, augites in a base of felspar-laths ; phenocrysts of basaltic hornblende are also sparingly distributed. The rock is altered, with development of much epidote in the phenocrysts of felspar and augite.

Chapter IV.

THE BEACON SANDSTONE AND OTHER SEDIMENTARY ROCKS.

The Beacon Sandstones are medium-grained rocks, for the most part remarkably free from ferruginous or other coloured impurities. The quartz-grains which compose them have doubtless been derived from the granitic and gneissic rocks, as they show liquid inclusions with bubbles, and occasionally numerous hair-like inclusions (rutile ?) such as are often found in the quartz of granites. In some of the grains these needles occur in lines perfectly straight and parallel to the directions of extinction. Accessory constituents are rare in these sandstones, but in some specimens opaque and kaolinised white and pink felspars are plentiful. In a fine-grained quartz-grit (641) at the base of Finger Mountain are small irregular grains of pink garnet and rounded crystals of zircon and rutile, and in coarse-grained felspathic grits (640, 642) from the same locality occur large angular fragments of microcline. In these grits the quartz-grains are quite angular, but most of those in the ordinary sandstones are fairly well rounded.

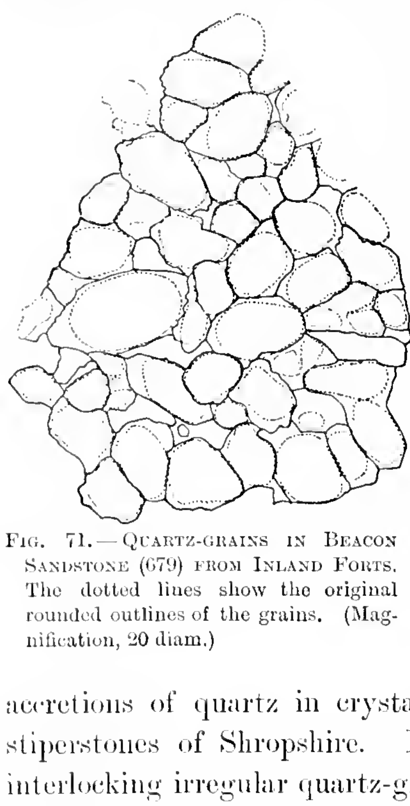

Fig. 71.—Quartz-grains in Beacon Sandstone (679) from Inland Forts. The dotted lines show the original rounded outlines of the grains. (Magnification, 20 diam.)

The cementing material is siliceous and usually is not in large amount, so that the grains are loosely cohering, but in the "stalagmitic" and "marbled" sandstones, mentioned on p. 44, narrow seams of the rock have been converted into compact quartzite, owing probably to local infiltrations of siliceous material. Under the microscope such parts of the sandstone (679) show rounded grains of quartz cemented by accretions of quartz in crystalline continuity with the grains, as in the case of the stiperstones of Shropshire. Between crossed nicols the slide has the appearance of interlocking irregular quartz-grains, but in ordinary light the perfectly rounded oval outlines of the original grains are clearly seen (see Fig. 71, in which the dotted lines show the outlines of the original rounded grains).

Of the larger pebbles in the Beacon Sandstones, most consist of granitic quartz with liquid inclusions and moving bubbles, but one specimen (638) from below Finger Mountain appears to have been derived from an earlier sandstone, as it consists of rounded and sub-angular quartz-grains cemented by quartz. Another pebble (675) from the sandstone under B_1 consists of a quartz-schist showing, under the microscope, irregular interlocking grains of quartz, with strings of carbonaceous material marking the foliation. Pebbles of fine-grained quartz-grits, obviously derived from granitic material, were obtained in the dredge off King Edward VII Land.

From various localities come specimens of dark micaceous schists, which under the microscope have much the appearance of contact-metamorphosed sediments.

One of these specimens (96) comes from Granite Harbour. It consists of sub-angular grains of quartz and some plagioclastic felspar, with strings of strongly pleochroic (from nearly colourless to deep reddish-brown) mica; grains of sphene are also plentiful. A very similar rock (578), but of finer grain, was found near the contact of the kersantite (579) with the crystalline limestone (576) at the north-east end of the Blue Glacier. Somewhat similar rocks, but of still finer grain and more slaty in appearance, were found amongst the rock-fragments from the dredge, both off Balleny Islands (866) and off King Edward VII Land.

Black shaly to slaty rocks (836, 496) were obtained from moraines on the Blue Glacier and at the south-east end of Black Island (525), and also from the dredge off Balleny Islands (866).

Chapter V.

THE DOLERITES.

The dolerites, intrusive in the Beacon sandstone and the granite, are remarkably uniform in appearance and in microscopic characters, from Depôt Nunatak at the head of the Ferrar Glacier to the Kukri Hills near its mouth.

The rock (662) from Depôt Nunatak is fairly typical of all the specimens (see Plate X, Fig. 1). It is a mottled gray-brown medium-grained dolerite, showing no porphyritic crystals. Under the microscope it is seen to be made up mainly of colourless augite, partly in long prismatic crystals, and partly in irregular sub-ophitic plates, and plagioclastic felspar (labradorite chiefly) in stout prisms and lath-shaped crystals. Grains of magnetite and ilmenite are very sparingly distributed.

Fig. 72.—Micropegmatite in Dolerite (662) from Depôt Nunatak. (Magnification, 100 diam.)

A characteristic feature of most of these dolerites is the presence, in patches and in the interstices of the augite and felspar, of more acid material, showing quartz in radiating (spherulitic) and micropegmatitic intergrowth with felspar. In the section of specimen (662) quartz is seen to have crystallised round prisms of felspar, from the end of which springs a micropegmatitic intergrowth (see Fig. 72).

In this respect, as well as in their general characters, these dolerites bear a striking resemblance to the so-called "augite-diorites with micropegmatite," which are intrusive in the gneisses and pyroxene-granulites of Southern India (Madras Presidency), and have been described by Dr. T. H. Holland.* In both cases the coarseness of grain of the micropegmatite varies directly with the texture of the rock, and thus one of the principal arguments used by Dr. Holland in favour of the primary origin of the micropegmatite is applicable also to these Antarctic rocks. In some specimens, however, (*e.g.*, 692 from Dry Valleys) this more acid and (in the case of this specimen) finer-grained felsitic material occurs in such distinct patches (up to 2–3 mm. in diameter), with interspaces nearly free from it and consisting simply of the felspar-augite aggregate, as to suggest an intermingling of two rocks (granophyre and gabbro), such as occurs so commonly in Skye.† It is remarkable that in this rock the magnetite (in rod-like skeleton-crystals) is mainly confined to the more acid patches. Some of the specimens of dolerite found (but not *in situ*) at Depôt Nunatak are gabbro-like in coarseness of grain, and in these the micropegmatite is also coarse-grained, and constitutes practically the ground-mass of the rock. One of these gabbro-like rocks (632) contains olivine intergrown with the augite, which in this case is of the purplish titaniferous variety.

* Holland, Quart. Journ. Geol. Soc., 1897, vol. liii, p. 405.

† Harker, The Tertiary Igneous Rocks of Skye. Mem. Geol. Surv. of the United Kingdom, 1904, p. 169.

In certain specimens (698 from Dry Valleys and 661 from Knob Head) the micropegmatitic patches are not so prominent, but quartz is still present in the ground-mass. These rocks are of somewhat finer grain, and consist of a base, of small stout felspar-prisms with a little quartz, from which the colourless augites stand out conspicuously in large irregular ophitic plates.

The augite in these dolerites gives extinctions of over 40°; the sections are for the most part without definite crystalline outline; most of them show the usual twinning on 100, and many of them also exhibit the "herring-bone" structure due to fine striations parallel to 001 in the two halves of a twin.*

The felspar-prisms in these rocks generally show Carlsbad-twinning. Albite-twinning is not so common, but in some sections showing twin lamellæ symmetrical extinctions of 26° were observed.

The result of a chemical analysis of specimen 661 from Knob Head is as follows under I. Under II is given, for comparison, the analysis of the "augite-diorite" from Madras referred to above.

	I. (Knob Head).	Ia. Mol. ratios.	II. (Madras).
SiO_2	= 53·26	·882	51·15
TiO_2	= 0·70	·009	0·44
Al_2O_3	= 15·64	·153	15·92
Fe_2O_3	= 0·24	·001	9·34
FeO	= 7·44	·105	2·87
MnO	= 0·11	—	0·09
CaO	= 12·08	·215	10·40
MgO	= 8·64	·214	6·48
Na_2O	= 1·25	·020	1·19
K_2O	= 0·58	·006	1·61
P_2O_5	= 0·04	—	0·06
H_2O at 110°	= 0·35	—	0·11
H_2O above 110°	= 0·41	—	
	100·74		99·66

The Osann formula for this rock is :—

$$s_{55\cdot46}\ a_1\ c_{4\frac{1}{2}}\ f_{14\frac{1}{2}}\ n_{7\cdot62}$$

which is near the formula for a basalt from Etna belonging to Osann's "Royat" type, viz. :—

$$s_{54\cdot21}\ a_1\ c_5\ f_{14}\ n_8$$

Calculation of the "norm" gave the following result:—

$KAlSi_3O_8$	=	3·34
$NaAlSi_3O_8$	=	10·48
SiO_2	=	3·36
$CaAl_2Si_2O_8$	=	38·09
$CaSiO_3$	=	9·05
$FeSiO_3$	=	13·72
$MgSiO_3$	=	21·40
FeO. TiO_2	=	1·37
FeO. Fe_2O_3	=	0·35

* Schaub, Neues Jahrb., 1905 (i), p. 100, and Plate VI, Fig. 5.

In the American quantitative system the rock would be classed as Auvergnose.

The contact-effects produced in the dolerites intrusive in the sandstone and granite respectively are of interest. In each case the effects are similar, and due mainly to the sudden cooling. In place of a coarse-grained dolerite, the rock a few feet from the contact has the characters of a basalt, which becomes finer-grained and more glassy the closer it approaches the sandstone or granite; at the same time the felspar and augite become long prismatic, with the former often enclosed in the latter (see Plate X, Fig. 3). At one or two inches from the contact the dolerite changes from black to a pale-green colour. That the production of this compact green aphanitic material is not due to any absorption of silica from the sandstone is shown by a determination of the silica in it, which gave a result 51·96, actually lower than that obtained in the above analysis of the dolerite from Knob Head.

In Plate X, Figs. 2–5 represent, as seen under the microscope, thin slices of specimens of dolerite collected at different distances from the contact with sandstone.

Specimen 696 (Plate X, Fig. 2), from Dry Valleys, at 2ft. from the sandstone, still shows some augite in ophitic patches enclosing felspar-laths, but most of the pyroxene is in long prisms scattered through a base of felspar-laths, with interstitial felsitic material crowded with magnetite in rod-like skeleton-crystals.

Specimen 687 (Plate X, Fig. 3), from Inland Forts, at 6in. from the sandstone, shows long interlacing felspar-laths and colourless augite dispersed about them and sometimes enclosing them, with interstitial patches of brown glass, dense with magnetite in rods and grains.

Specimen 695 (Plate X, Fig. 4), from Dry Valleys, at 2in. from the sandstone, shows a further stage in the passage to a glass. The rock is variolitic, and much finer-grained than the preceding; it shows a few porphyritic felspars, but consists mainly of radiating sheaves of felspar-needles, with interstitial glass dense with magnetite.

Finally, at the actual junction with the sandstone, the rock (specimen 669, from B_1) is a pale-brown glass with dark-brown clouded patches arranged in wavy lines roughly parallel to the line of contact (Plate X, Fig. 5). Close to the junction the magnetite is in feathery tuffs surrounded by clearer halos, but at a few millimetres distance it occurs in more distinct grains; here also are seen one or two small porphyritic felspars and altered augites in a base which is confusedly crystalline, with radiating sheaves of minute felspar-needles, as in the preceding specimen but on a finer scale.

Specimens from the contact of dolerite and granite at D_2 in the Kukri Hills show similar characters, except that in this case the chilling process has not proceeded so far. Thus specimen 705 shows, at the actual junction, no glass, but exhibits characters intermediate between those of specimens 687 (Plate X, Fig. 3) and 695 (Plate X, Fig. 4).

The dolerite (119) from Granite Harbour has the same characters as those of the dolerites of the Ferrar Glacier, and shows similar patches of acid material. Specimen 154 from this locality is a peculiar hybrid rock. It is a dark dolerite with numerous small (from 2 to 3 mm. in diameter) rounded red patches of granitic material fairly uniformly distributed through it. Under the microscope (Plate X, Fig. 6) the main mass of the rock is seen to consist of small purple sub-ophitic augites, felspar-laths, magnetite-rods, and green pseudomorphous hornblende. The red patches are composed of stout red and kaolinised felspar-prisms, with a little interstitial quartz and a few shreds of biotite.

Of interest in connection with the wide extension of the dolerite-sandstone formation (*see* p. 53) is the fact that amongst the pebbles dredged up off Cape Wadworth, and also to the south of the Balleny Islands, are some of dolerite like that of the Ferrar Glacier, and showing similar spherulitic and micropegmatitic patches. Further, a pebble (866) from the dredge south of the Balleny Islands shows characters almost precisely similar to the "chilled" dolerite (687) from Inland Forts at the junction of dolerite and sandstone.

The dolerite fragments found in moraines on Mount Terror are similar to the dolerites of the mainland; some are very coarse-grained and gabbro-like, with coarse-grained micropegmatite, as in the specimens from Depôt Nunatak described above.

In a moraine off White Island was found a fragment (307) of typical olivine-gabbro. Under the microscope it shows broad plates of labradorite with glomero-porphyritic groups of pale yellowish-brown diallage in large irregular plates and small olivines intergrown with the diallage.

In connection with the dolerites, a peculiar conglomerate found on the west promontory of Black Island deserves mention. It consists mainly of rounded grains of quartz and a little felspar (including microcline), cemented by calcite; but it also contains numerous fragments of dolerite, similar to that of the mainland.

SUMMARY.

The basement-rocks of South Victoria Land consist of crystalline limestones, gneisses and granites.

The crystalline limestones are remarkably free from accessory constituents, but some contain chondrodite.

The gneisses are metamorphosed granites (orthogneiss) and are often characterised by prominent augen-structure and by cataclastic effects.

Above the gneisses occur masses of red and gray granites which pass occasionally into more basic diorites or hornblende-gabbros.

Intrusive in these basement-rocks are dykes, chiefly of lamprophyric rocks including camptonites and kersantites, but comprising also quartz-porphyries and rocks chemically allied to banakite.

Upon the granite has been deposited an extensive sandstone-formation in which some obscure charred plant-remains have been found.

Through the sandstones have been intruded very widespread sills and dykes of dolerite. This dolerite is very uniform in mineral-composition throughout wide areas, and is characterised generally by the presence in the ground-mass of patches of a micropegmatitic or spherulitic intergrowth of quartz and felspar. In this and other characters it strikingly resembles the so-called "augite-diorite," dykes of which break through the pyroxene-granulites and gneisses of Southern India.

The sandstone-dolerite formation of South Victoria Land appears to be very extensive, for fragments of the characteristic dolerite were met with in most of the localities within the Antarctic Circle visited by the 'Discovery,' and were found in the dredgings even as far north as near the Balleny Islands.

Finally, the islands off South Victoria Land, from the Scott Islands in the north to the Ross Archipelago in the south, as well as Cape Adare on the mainland, and in all probability many of the mountains, such as Mount Melbourne, which fringe the coast below the main plateau, consist of volcanic rocks of comparatively recent date.

These volcanic rocks may be regarded as belonging to one petrographical province characterised by the association of hornblende- and olivine-basalts approaching the limburgite-type, with very alkali-rich rocks of medium basicity comprising phonolitic trachytes and phonolites, and also alkaline-basalts or kenytes almost identical in mineral and chemical composition with the ancient rhomb-porphyries of Norway and the very similar recent lavas of Mount Kenya and Mount Kilimandjaro in East Africa.

A striking feature in the basalts of limburgite-type is the high percentage of titanic acid and the number of included coarse-grained nodules, many of which are felspathic and gabbro-like in character.

These volcanic rocks of South Victoria Land belong undoubtedly to the Atlantic group, although they occur along a coast which has been described as distinctly of the Pacific type.*

* While these pages were in the press, Band II, Theil I of the Deutsche Südpolar Expedition (1901–1903) was published: in No. 2, 'Geologische Beschreibung des Gaussberges,' by E. Philippi, the author brings forward arguments in favour of the view that the coast of South Victoria Land is really of Atlantic type.

INDEX.

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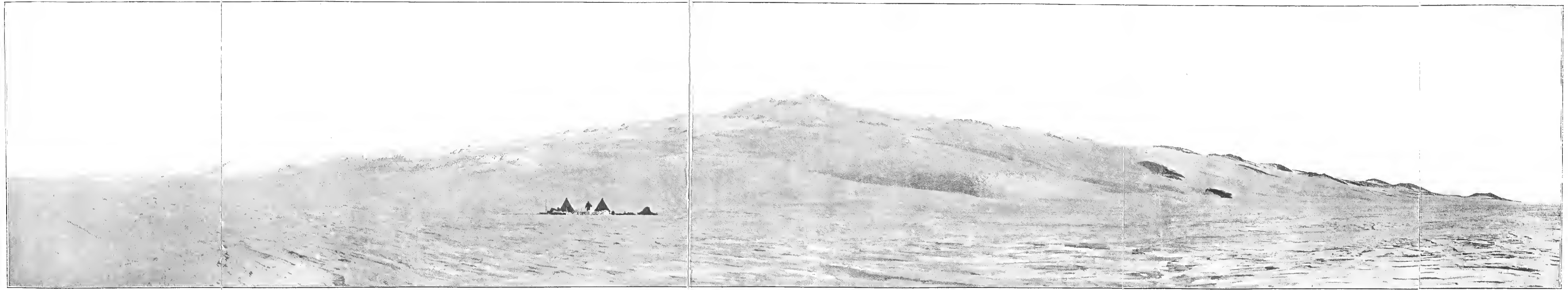
National Antarctic Expedition, 1901-1904. British Museum



A PANORAMA OF MOUNT TERROR FROM THE SOUTH-EAST.

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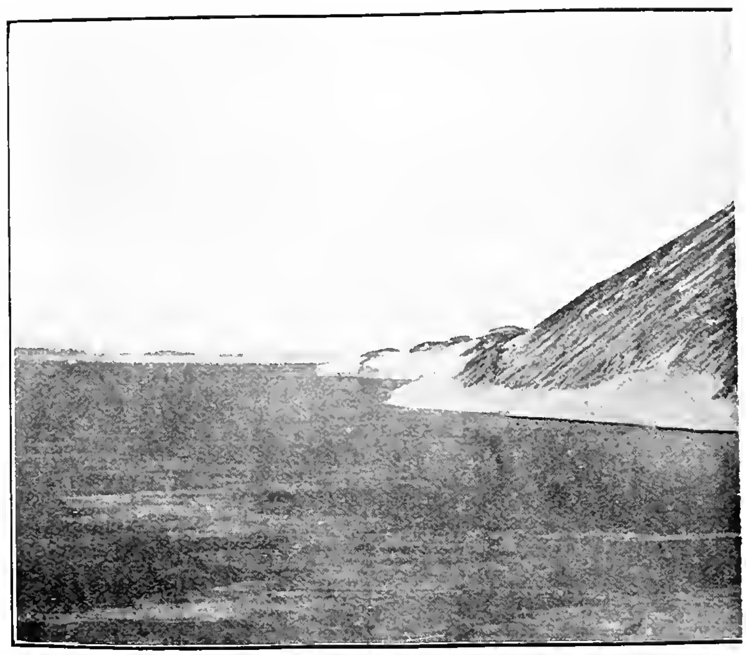

Arrival Bay.

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National Antarctic Expedition, 1901–1904. British Museum Report. Field-geology.

A PANORAMA OF WINTER QUARTERS, SHOWING HARBOUR HEIGHTS, CRATER HILL AND OBSERVATION HILL.

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Plate III.

THE ROYAL S
Looking up Ferr

THE NORTH END OF THE ROYAL SOCIETY RANGE AND THE SOUTH SIDE OF THE KUKRI HILLS.

Looking up Ferrar Glacier from Descent Pass. See pp. 30, 69, 78.

PLATE IV.

Gneiss shoulder.

E_1
Cathedral Rocks.

27, 30, 34.

VIEW DOWN THE EAST FORK OF THE FERRAR GLACIER.

Showing the low granite-hills between G_2 and G_3 and the gneiss-exposure at the foot of Cathedral Rocks. See pp. 27, 30, 34.

Plate V.

γ_1

Upper Reach of the Glacier.

PANORAMA OF THE SOUTH SIDE OF THE FERRAR GLACIER AS SEEN FROM A POINT ABOVE THE SOLITARY ROCKS. See pp. 45–47, 69–70.

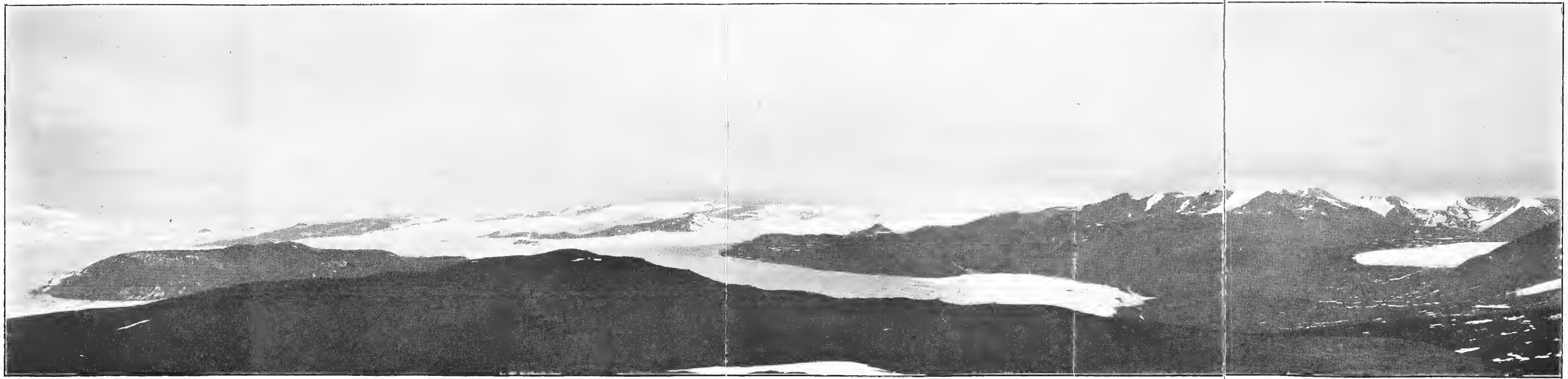
National Antarctic Expedition, 1901–1904. British Museum Report. Field-geology.

PLATE VI.

the background).

The Ends of Ice-slabs.

TO A TRIBUTARY VALLEY CON



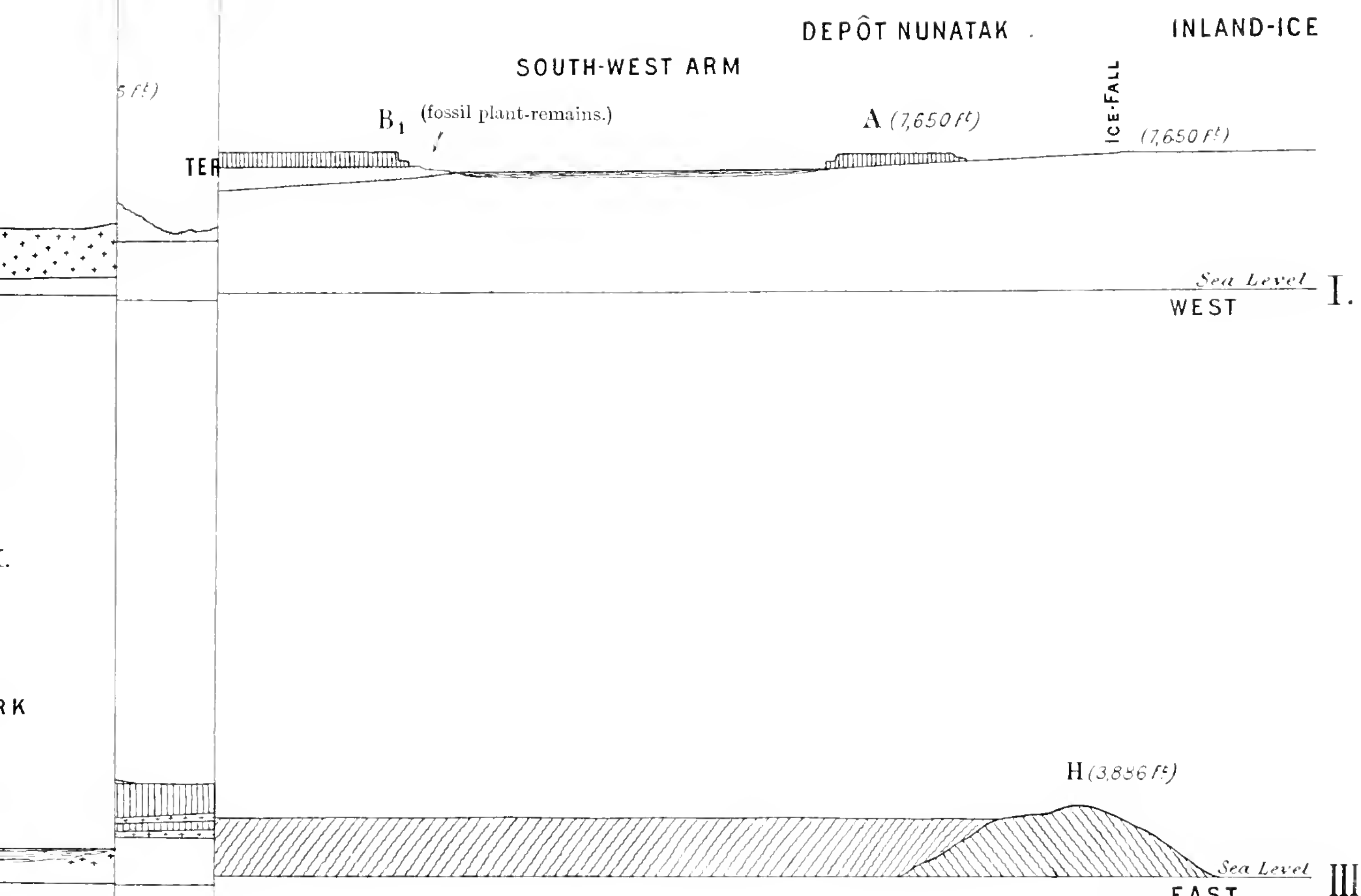
Mount Morning (in the background).

The Ends of Ice-slabs.

THE OVERFLOW OF THE KOETTLITZ GLACIER INTO A TRIBUTARY VALLEY CONTAINING AN ICE-SLAB. See pp. 71, 73.

National Antarctic Expedition, 1901–1904. British Museum Report. Field-geology.

PLATE VII.



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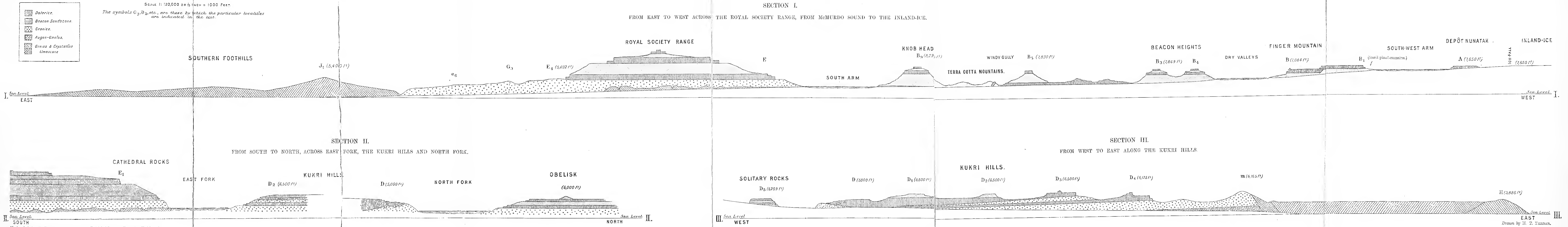

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Drawn by H. T. Ferrar.

EXPLANATION OF PLATE VIII.

FIG. 1.—Olivine-basalt (656) from cliff between Gap and Horseshoe Bay (p. 104).

All the clear olivines, except the three crystals at the top, belong to one individual: the more shaded crystals are augite.

Magnification, 30 diam., 1 inch objective.

FIG. 2.—Gabbro-like nodule (415) in limburgite, from Winter Quarters (p. 108).

The dark grains are altered olivine, the shaded grains are pale-green diopside, a rather more deeply-shaded grain on the left below is hornblende, the clear crystals showing twin-striations are felspar.

Magnification, 30 diam., 1 inch objective.

FIG. 3.—Leucite-kenyte (818) from Cape Royds (p. 111).

The large phenocryst of anorthoclase shows crossed twin-striations as seen between crossed nicols; numerous small leucites with central inclusions are seen in the base; on the left towards the bottom is a small phenocryst of olivine.

Magnification, 20 diam., $1\frac{1}{2}$ inch objective.

FIG. 4.—Phonolitic trachyte (248) from Mount Terror (p. 115).

A rectangular phenocryst of anorthoclase is seen in a trachytic mesh of felspar-laths with dark grains of ægirine-augite.

Magnification, 30 diam., 1 inch objective.

FIG. 5.—Phonolite (530) from Black Island (p. 116).

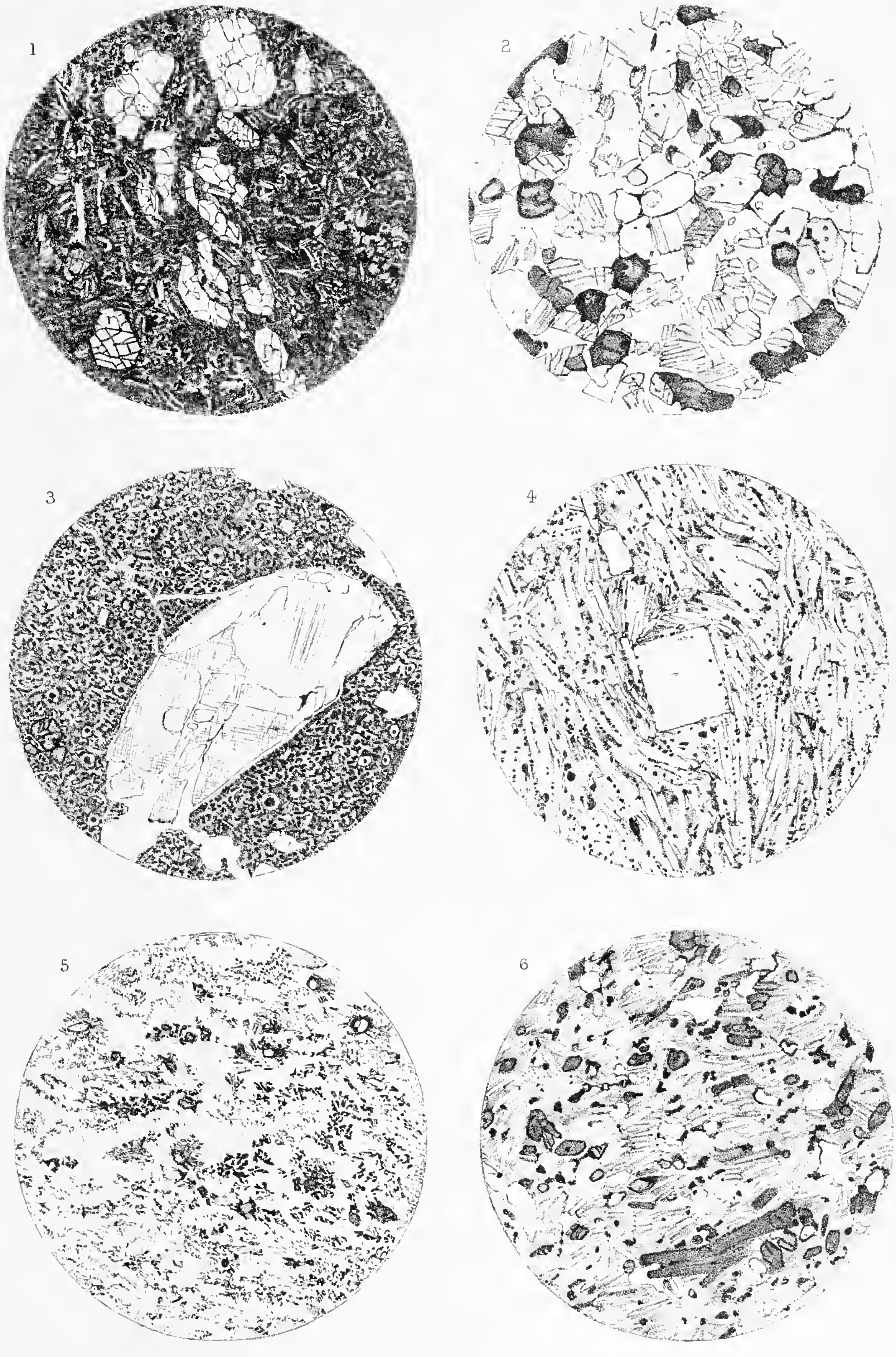
Hornblende near to riebeckite, in moss-like patches, in fine-grained trachytic felt of felspar-laths.

Magnification, 30 diam., 1 inch objective.

FIG. 6.—Phonolitic hornblende-trachyte (277) from Observation Hill (p. 117).

Prismatic crystals of basaltic hornblende in trachytic mesh of felspar-laths.

Magnification, 30 diam., 1 inch objective.



ROCK-SPECIMENS.

E. Drake del. et lith.

EXPLANATION OF PLATE IX.

FIG. 1.—Augen-gneiss below D_4, Kukri Hills (p. 125).
Cataclastic structure as seen between crossed nicols.
Magnification, 20 diam., 1½ inch objective.

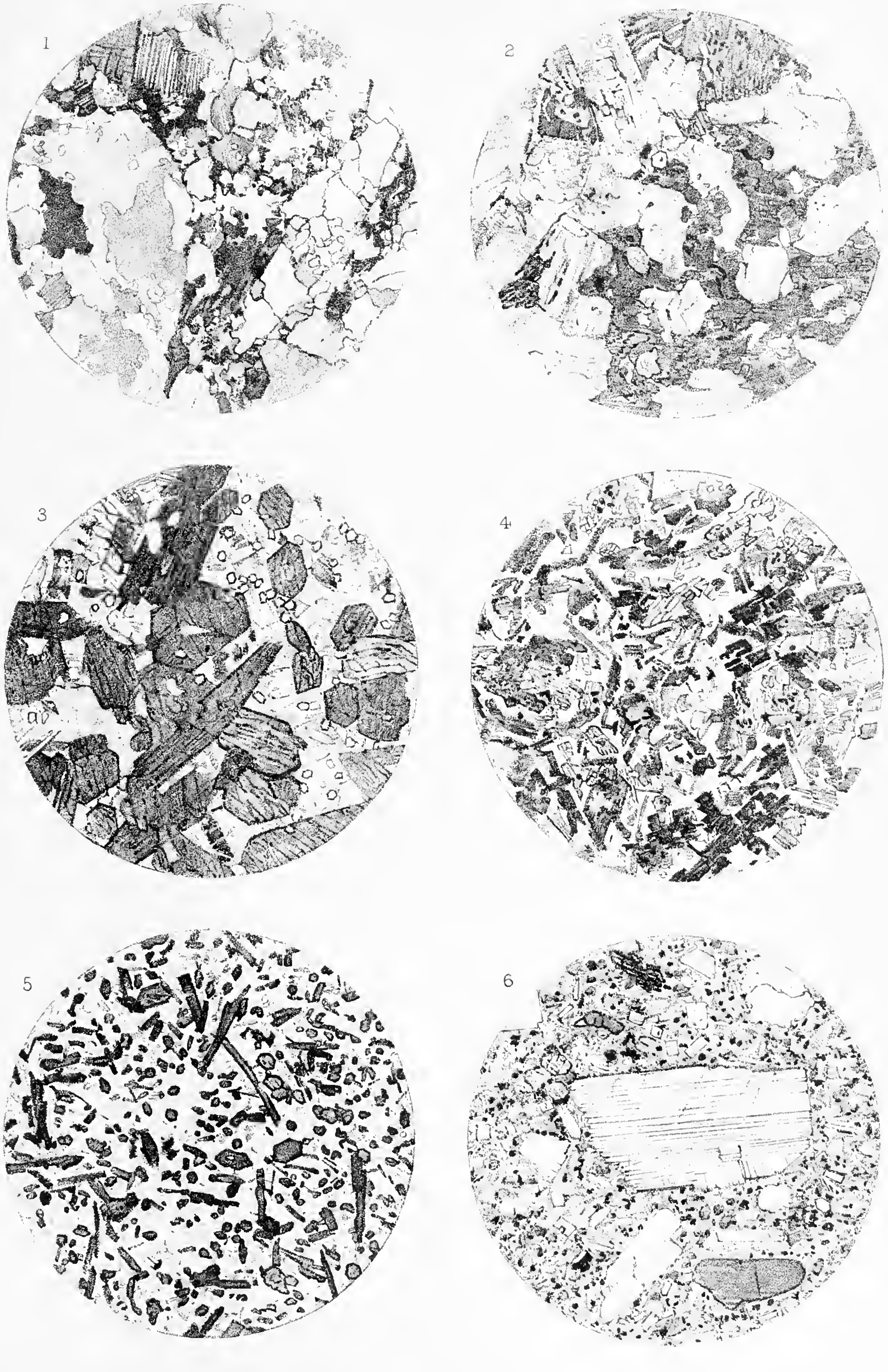
FIG. 2.—Diorite (715) from Cathedral Rocks (p. 127).
Large ophitic plates of brown hornblende, and labradorite.
Magnification, 20 diam., 1½ inch objective.

FIG. 3.—Diorite to essexite (572) from the Blue Glacier (p. 128).
Large sharply-defined crystals of brown hornblende with altered felspars, and much apatite in small hexagonal sections.
Magnification, 20 diam., 1½ inch objective.

FIG. 4.—Kersantite (579) from Northern Foothills (p. 130).
Biotite (dark, straggling crystals) and nearly colourless diopside (irregular, shaded plates) in a base of kaolinised felspar-laths.
Magnification, 20 diam., 1½-inch objective.

FIG. 5.—Camptonite (839) from Southern Foothills (p. 129).
Small, sharply-defined, crystals of reddish-brown hornblende in a base of felspar-laths.
Magnification, 20 diam., 1½-inch objective.

FIG. 6.—Dyke-rock (714) related to banakite, from the Northern Foothills (p. 131).
Phenocrysts of labradorite (in centre), orthoclase (below, to the left), brown hornblende (below, to right), analcite (round section, below the labradorite to the right), and purplish augite (above the labradorite to the left), in a base of rectangular and lath-shaped felspars.
Magnification, 20 diam., 1½-inch objective.



ROCK-SPECIMENS.

E. Drake del. et lith.

EXPLANATION OF PLATE X.

FIG. 1.—Dolerite (662) from Depôt Nunatak (p. 136).

The shaded crystals are of augite; some of the darker ones are altered and coloured brown with oxide of iron. The clear sections are of labradorite. On the left and in the interstices of the felspars and augites are seen patches of spherulitic material.

Magnification, 20 diam., 1½-inch objective.

FIG. 2.—Dolerite (696), 2 ft. from junction with sandstone, Dry Valleys (p. 138).

The augite is mainly in long prismatic crystals, the felspars in small laths: interstitial felsitic material is crowded with magnetite.

Magnification, 30 diam.. 1-inch objective.

FIG. 3.—Dolerite (687), 6 in. from junction with sandstone, Inland Forts (p. 138).

Long prismatic felspars and augites, and interstitial glass black with magnetite.

Magnification, 30 diam., 1-inch objective.

FIG. 4.—Dolerite (695), 2 in. from junction with sandstone, Dry Valleys (p. 138).

Radiating sheaves of felspar-laths, and interstitial glass dense with magnetite; a few porphyritic felspars.

Magnification, 30 diam., 1-inch objective.

FIG. 5.—Junction of dolerite and sandstone (669) at B_1 (p. 138).

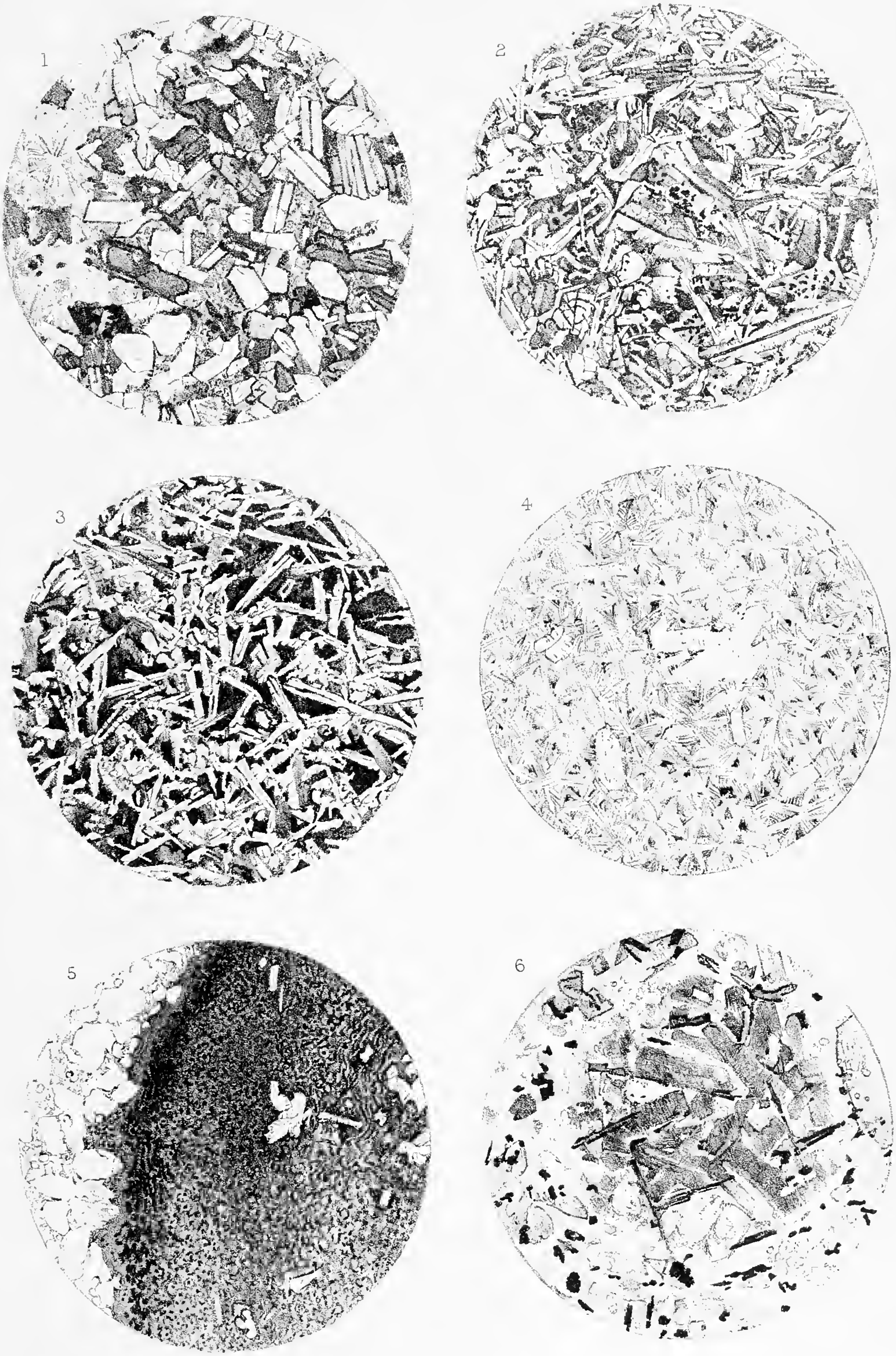
Brown glass, with dark, cloudy patches; a few porphyritic felspars.

Magnification, 20 diam., 1½-inch objective.

FIG. 6.—Dolerite (154) with granitic patches. Granite Harbour (p. 139).

Dolerite of purplish augites, felspar-laths and magnetite, with coarse-grained patch of altered felspars and quartz.

Magnification, 30 diam., 1-inch objective.



ROCK-SPECIMENS.

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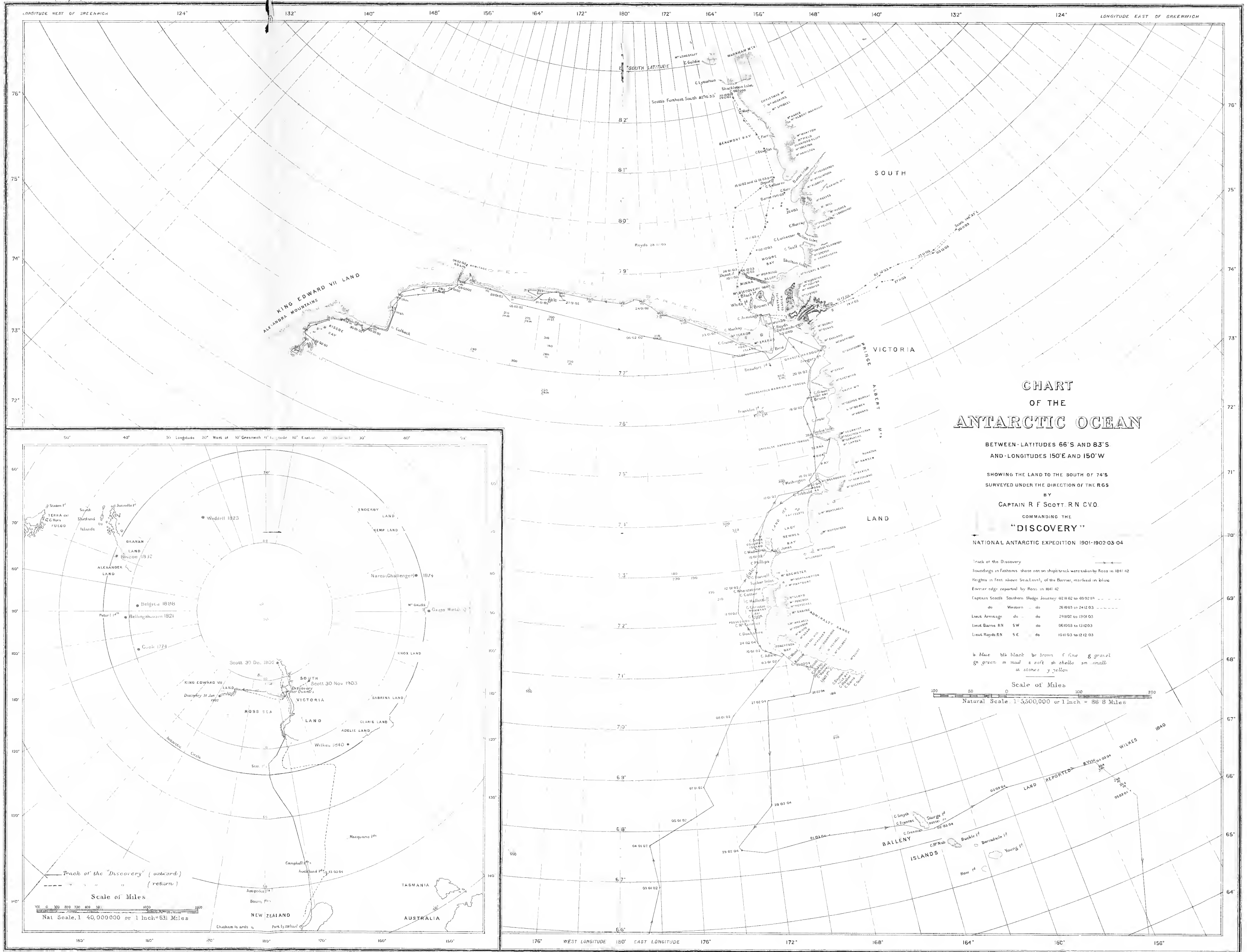

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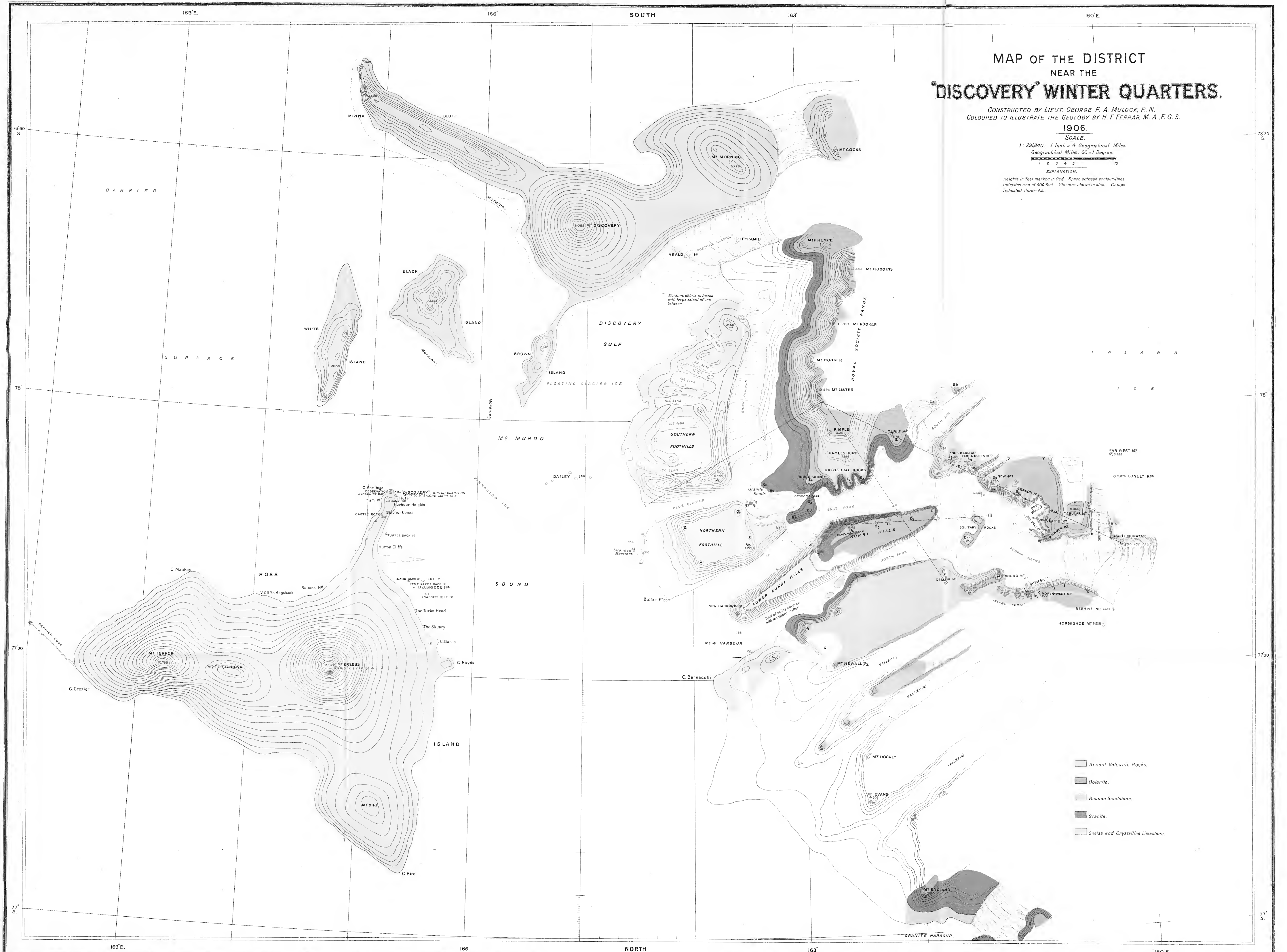

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