BRITISH MUSEUM (NATURAL HISTORY)

BRITISH ANTARCTIC ("TERRA NOVA") EXPEDITION, 1910

NATURAL HISTORY REPORT

GEOLOGY. VOL. II. No. 2. Pp. 109—150

THE VOLCANIC ROCKS OF CAPE ADARE SOUTH VICTORIA LAND

BY
W. CAMPBELL SMITH

WITH TWO FIGURES IN THE TEXT AND THREE PLATES

LONDON:
PRINTED BY ORDER OF THE TRUSTEES OF THE BRITISH MUSEUM
Sold by B. QUARITCH, LTD., 11 Grafton Street, New Bond Street, W.1;
WHELDON & WESLEY LTD. Lytton Lodge, Codicote, nr. Hitchin; H.M. STATIONERY OFFICE, York House, Kingsway, W.C.2
AND AT THE
BRITISH MUSEUM (NATURAL HISTORY), Cromwell Road, London, S.W.7
1959

Price Fifteen Shillings

[*Issued April,* 1959.]

THE VOLCANIC ROCKS OF CAPE ADARE, SOUTH VICTORIA LAND

BY

W. CAMPBELL SMITH

WITH TWO FIGURES IN THE TEXT AND THREE PLATES

TABLE OF CONTENTS

Printed in Great Britain under the authority of Her Majesty's Stationery Office by
William Clowes and Sons, Limited, London and Beccles. Wt. P.67280. K.4.

I. INTRODUCTION

The first landing at Cape Adare was made in 1894 by an Australian of Norwegian birth, Carstens Borchgrevink, who had signed on as a member of the crew of the whaler *Antarctic* under Captain Lars Kristensen. A few specimens of the rocks were collected at that time but a more extensive series was obtained in 1898 when Borchgrevink returned to Cape Adare in the *Southern Cross* leading an expedition sponsored by Sir George Newnes. Borchgrevink's expedition was the first to winter on the Antarctic Continent. In the collection of geological specimens he was assisted by Lieutenant Colbeck and by Mr. Louis Bernacchi.

Specimens collected on Borchgrevink's first landing were described by T. W. Edgeworth David, W. F. Smeeth, and J. A. Schofield, and those obtained on the later Southern Cross Expedition were described by G. T. Prior. Most of the specimens were poorly localized but, assisted by the recollections of Colbeck and Bernacchi, Prior was able to give in rough outline a picture of the geology of the region.

Cape Adare itself was shown to consist of volcanic rocks, mostly basalts, while a formation of pale green slates and quartz-grits constituted the main mass of Duke of York Island in Robertson Bay and the same formation occurred also on the neighbouring mainland, Geikie Land, and extended along the coast towards Cape North. There was no very definite observation on the nature of the junction between the volcanic rocks and the slates, but Bernacchi had reported seeing such a junction some two miles south of Duke of York Island and he had formed the impression that the basalt had flowed over the sedimentary formation and hidden its southerly prolongation (Prior, 1902, p. 331). Bernacchi also reported having seen slates at the foot of Mount Melbourne in Newnes Land but this observation has not been confirmed by the later expeditions (see below).

A landing was made on Cape Adare by Sir Ernest Shackleton with H. T. Ferrar and other members of the Discovery Expedition in 1902 and Ferrar, the geologist, gave a brief description of the Cape and details of two sections across the basalts and tuffs in his report (1907, p. 18). Ferrar thought the volcanic formation formed also the high coastal cliff between Cape Adare and Cape Jones, 150 miles to the south, opposite Coulman Island, and basalts appeared to be developed at the base of Mount Melbourne still further to the south*. Prior examined the specimens collected by the Discovery Expedition but did not describe them, as he found them to be quite similar to those already described by him from Cape Adare, Coulman Island, and Franklin Island collected on the earlier expedition.

* Basalt crags near Mount Melbourne are shown in an illustration in *Antarctic Adventure* by R. E. Priestley (1914, p. 206) and the position of Mount Melbourne is shown in map 2 in the same book. It is not certain that these basalts belong to the same volcanic series as those of Cape Adare and Coulman Island.

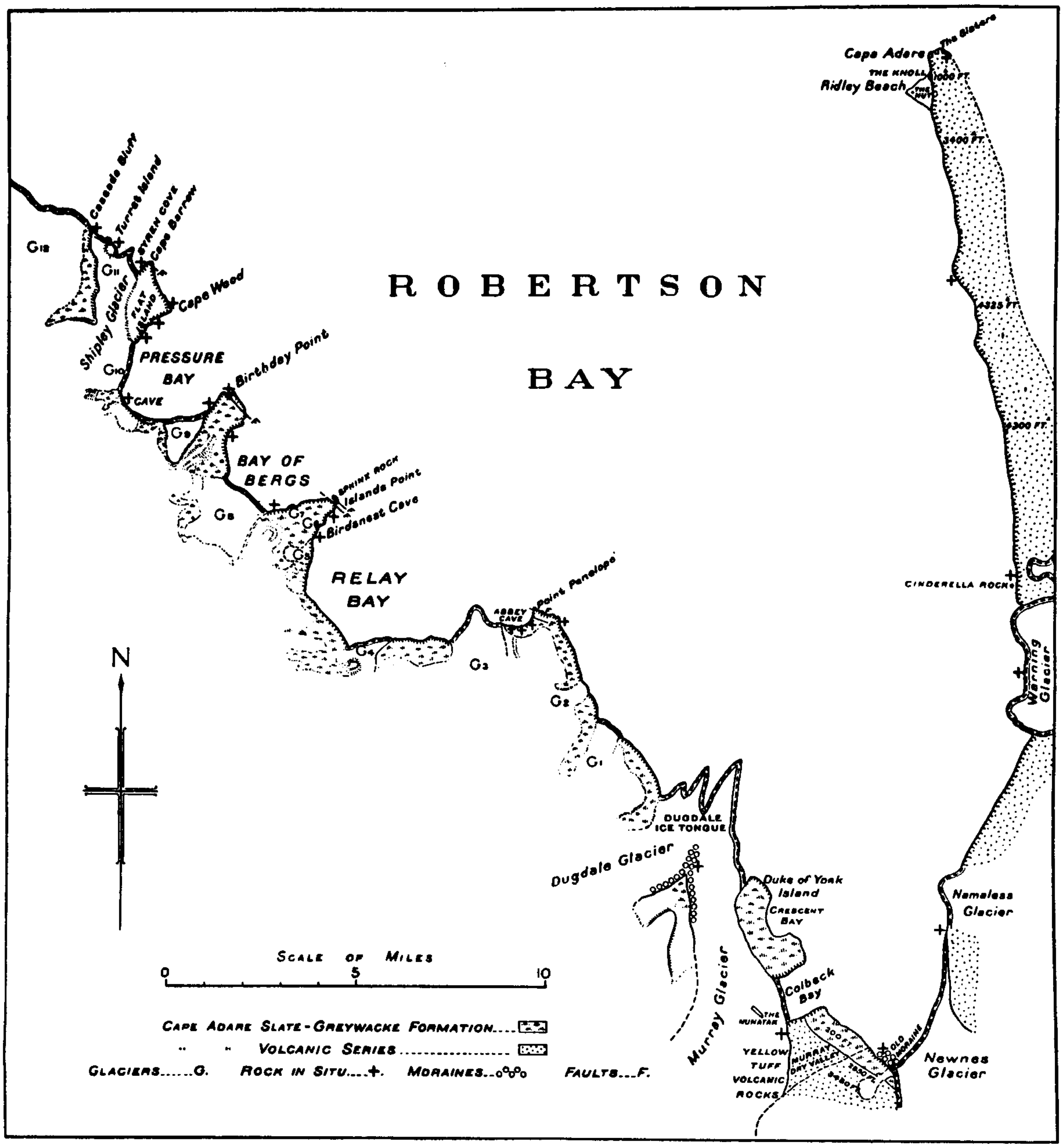

FIG. 1. Map of Robertson Bay Region.

This was the sum total of the knowledge of the geology of Cape Adare and Robertson Bay when the six men of the Northern Party landed from the *Terra Nova* on 18 February 1911. They established themselves on Ridley Beach, a triangular patch of beach, close under the cliffs and about a mile across at its base. Here they built their hut, not far from the old one left by Borchgrevink, and from this base they investigated the physiography and glaciology, kept regular meteorological records, and collected rocks from every accessible outcrop and from the moraines of the glaciers at the end of Robertson

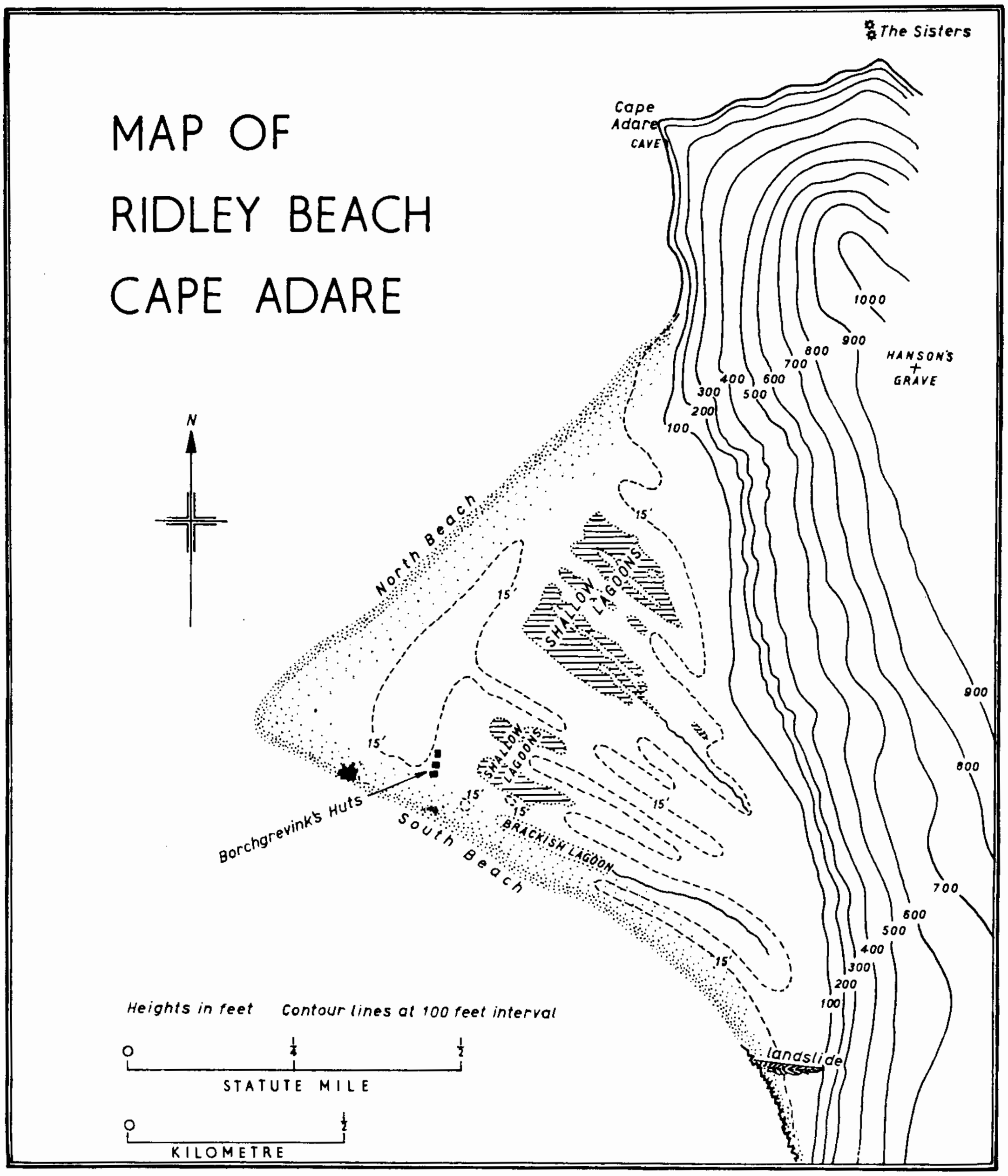

Fig. 2. Map of Ridley Beach.

Reproduced by kind permisson from the inset map II in R. E. Priestley's Memoir on the Physiography of Robertson Bay and based on the plane-table survey by Commander V. L. A. Campbell, D.S.O., R.N. (see Plate 1, fig. 3).

Bay as well as from the beach itself. They remained at Cape Adare until 4 January 1912, having lived there almost a whole year.

The story of the life and the journeys of the Northern Party has been told by Priestley in *Antarctic Adventure* and the results of his work on the physiography and the glaciology have been published in two reports of the scientific results of the Terra Nova

Expedition. *Antarctic Adventure* and the memoirs are all well illustrated by photographs taken by Staff-Surgeon G. Murray Levick, R.N. and Priestley and some of these show very clearly the outcrops and the cliffs where the geology of the rocks *in situ* has been studied.

The sedimentary rocks have been described in a report by R. H. Rastall and R. E. Priestley published in 1921 and the present report contains a description of all the volcanic rocks.

Most attention has naturally been paid to the rocks collected *in situ* but there are also included brief descriptions of the volcanic rocks from the moraines of the Newnes and Murray Glaciers, of erratics from the top of the Cape, and, in so far as they are notably different from others described, of pebbles and cobbles from Ridley Beach. Less attention has been paid to the beach pebbles than to fragments of rock from the moraines, as Priestley has pointed out that at least four sources, in addition to the cliffs of Cape Adare, have contributed to the beach material. These sources are: (1) erratics from the surface of the plateau about 800 feet above sea-level on the Cape itself, left by some former source of land ice; (2) exposures of rock further south along the coast of the mainland; (3) material left by stranded floes and icebergs; and (4) moraine material from a great glacier that may once have filled Robertson Bay to a great depth, possibly over a thousand feet above present sea-level (Priestley, 1923, p. 6).

Priestley's account of the physiography of the region contains information on the distribution of volcanic and sedimentary rocks and the available information is shown on a map accompanying the report on the slate-greywacke formation (1921, fig. 8, p. 122). In *Antarctic Adventure* there are several descriptions of outcrops both of the volcanic rocks on the Cape and of the sedimentary rocks, reached, often with great difficulty, during the spring and summer sledging trips of 1911 (see Fig. 1, p. 112).

Of Cape Adare itself Priestley wrote: 'It is composed in the main of a series of almost horizontal, slightly northward-dipping sheets of basalt lava which are, however, interspersed with much more irregularly-shaped and disposed bodies of agglomerate and tuff, and which are pierced through with numerous dykes and, probably, with less numerous volcanic necks' (1923, p. 8).

Specimens in the collection of scoria, volcanic 'bombs', and masses of ropy lava seem to indicate the former presence of a centre of eruption quite close to Cape Adare.

Volcanic rocks, therefore, are seen to compose the whole of the Cape but west of the Cape they are absent in Robertson Bay.

That the volcanics rest on a basis of the slate-greywacke formation is deduced by Priestley from 'the occurrence of scraps of slate and quartzite in the Cape Adare tuffs' (1923, p. 18), and other evidence of this has been yielded by the study of xenoliths in some of the basalts (see p. 120).

Accessible outcrops where sedimentary rocks and basalts or tuffs are in contact are evidently very few. One such junction, as reported above, was seen by Bernacchi south of Duke of York Island, and Priestley records one 'on the most southerly bluff of all' in Robertson Bay 'where the basalt of the Cape Adare series cuts across the sediments in a dead straight line, with features suggesting a fissure eruption on a small scale' (1921, p. 124).

The distribution of basalt and of sedimentary rock in the moraine of the Newnes Glacier and of a tributary has an interesting bearing on the history of the glacier (Priestley, 1923, p. 18) and Priestley was able to make some observations on the relative positions of basalt and sediment on the hills bordering this glacier. Basalt cliffs line the cwm within which the head of the tributary glacier lies (1923, p. 15) and in the course of a painful climb up the hills on the right (west) of the Newnes Glacier Priestley and Dickason found basalt within 700 feet of the top of the hill, there 3,600 feet, and before reaching the basalt they had found green quartzite cropping out above the rubble of the screes and dipping steeply towards the south-west (Priestley, 1914, p. 179).

Such information as there is on the geological structure of the region is discussed in the report on the slate-greywacke formation (1921, p. 123), and Priestley has given reasons for concluding that the main coastal fault-plane, known to be of great importance in the McMurdo Sound region, continues through the Robertson Bay region and on to the north (1923, p. 18).

II. VOLCANIC ROCKS *IN SITU* ON THE CAPE

Olivine-Basalts

Apart from the tuffs and agglomerates referred to in Priestley's description of the Cape the volcanic rocks collected *in situ* are, with the exception of a few specimens from one very restricted locality, all olivine-basalts.

These can be divided on their characters as seen in hand-specimens into three types as follows:

A. Black, glassy, aphanitic olivine-basalt;

B. Dark grey, holocrystalline olivine-basalt; and

C. Porphyritic olivine-basalt with insets of augite and olivine.

The basalts of the second type contain abundant xenoliths of quartzose rocks, and small xenoliths of similar rocks are occasionally seen also in the black glassy basalt. These xenoliths are of particular interest as they afford evidence of the rocks through which the basalts were extruded.

A. Black, glassy Olivine-basalt

This type is best represented by a specimen [432] from an exposure 100 yards north of the northern limit of the snow drift on Cape Adare. Other specimens belonging to the same type, listed in the order in which they are described, are: 426 labelled only Cape Adare; 229 from 300 feet up on the Cape; 246 from the scree; and 247 part of a 'bomb'.

The hand-specimen of 432 is dark neutral grey, compact, aphanitic, and shows only a few small circular vesicles less than 0·5 mm. in diameter. Under a hand-lens on a smooth surface extremely small laths of feldspar can just be distinguished in the dark base. Under the microscope it is seen that the main crystalline constituent is plagioclase feldspar in lath-shaped crystals ranging in size from crystals measuring 1·5 × 0·3 mm. down to microliths in the groundmass 0·007 mm. across. The general impression of the rock, as seen in thin section, is of abundant plagioclase laths and micro-insets of olivine and, less abundant, augite in a brownish glassy groundmass containing slender feldspars, augite prisms, very small olivines, and cubes and 'dendrites' of opaque 'ore' (assumed to be magnetite). The colour of the glass in thin section is deep brownish drab.

The feldspars show Carlsbad and albite twins. Extinction angles measured indicate a composition near An_{67}.

The microliths are a more acid labradorite near An_{52} perhaps ranging up to An_{56}. The olivine of the micro-insets is colourless but stained brown along fissures. The average size for the micro-insets is about 0·25 × 0·17 mm. but crystals of olivine in the groundmass are very small, only about 0·05 mm. across (Plate 2, fig. 1).

The augite is optically positive, 2V moderate, $c{:}\gamma$ near 45°. Micro-insets show faint zoning, the colour in thin section ranging from light vinaceous fawn in the outer shell to pale vinaceous fawn in the core. The groundmass pyroxene is similar in colour to the outer zones of the micro-insets. Though fewer in number than the olivine micro-insets the augites are the larger in size, averaging about 0·75 × 0·2 mm. It is noticeable that the augites sometimes form small radiating groups of twinned prisms.

The other constituent of the groundmass, in addition to the plagioclase, augite, olivine, and glass, is magnetite. This forms small cubes (0·004 to 0·025 mm.). Small combs of dendritic black 'ore' that may be ilmenite are seen under high magnification in the brown glass.

One black glassy basalt of this type [426] shows occasional crystals of brown hornblende, either xenocrysts or insets, similar to the hornblendes in the porphyritic olivine-basalt described below, Type C. (p. 118).

Another example [229] from 300 feet up on Cape Adare is dull, and dark neutral grey in colour and has a dense black glassy base. It lacks the glassy lustre of the other specimens referred to this type. It is somewhat vesicular and some of the vesicles at or near the surface are lined with an opaque white deposit and some contain opaque white crystals. Further reference will be made to these below (p. 122). The surface of the specimen shows ropy structure, indicating that it formed part of a lava flow.

Under the microscope this rock is seen to consist of abundant small, stout laths of labradorite (near An_{66}) with few, small crystals of brown altered olivine and still smaller augites in a dense black glassy base. The proportion of feldspar crystals to glass is about three to five.

A specimen which may represent a holocrystalline equivalent of Type A is 246 from the scree on Cape Adare. The habit of its plagioclase laths and of the very small micro-insets of olivine (here all altered to 'iddingsite') and of augite is similar to the more glassy basalts of this type described above, but the groundmass minerals, plagioclase, augite and magnetite, and acicular inclusions, are in a colourless birefringent base which may be either feldspathic or nepheline. In any case the interstitial base is very small in amount. This specimen is brownish drab in colour. It contains many nearly spherical vesicles, rarely exceeding 1 mm. in diameter, lined with white zeolites, partly isotropic analcime.

A 'bomb' [247] with a black, glassy vesicular outer surface consists of lava of the same type as those here described. Another 'bomb' [253] 'from agglomerate on the road' is very dense and fine-grained and appears to belong to lava of a different kind.

B. Dark grey holocrystalline Basalt

This is represented by a large number of specimens from several localities designated in Priestley's notes as follows:

1. Below the Survey Rock	254, 255, 256, and 258
2. Knoll a little below and a little north of the black Survey Rock	261 to 329
3. Bluff near the end of the upper beach platform .	383 to 425
4. Depot exposure	456 and 460
5. Bluff south of the Depot exposure . . .	468
6. Foot of cliff between Depot exposure and Solitary Rock	477 to 486
7. Exposure one to two hundred yards south of Solitary Rock	522, 527, 530, 543, 544, 545

These dark grey basalts are all vesicular and appear much less fine-grained than the black glassy basalts described above. The colour of most of them is deep neutral grey, sometimes weathering to light purplish grey and deep olive-grey in the vesicles. The vesicles are usually empty, except that some are partly coated with a white powdery substance of the same kind as that found coating patches of the surface of some of the specimens and lining vesicles in the Type A basalt described above.

A rather fine-grained vesicular example of this basalt [485] from the foot of the cliff between Depot exposure and Solitary Rock is seen in thin section to consist of great numbers of slender laths of plagioclase (0·15 × 0·01 mm.) in a dark base with micro-insets of pale buff augite up to 0·4 mm. long and occasional micro-insets of plagioclase. In one specimen [460] augite also appears as insets up to 2 mm. across. Small magnetites (0·1 mm.) occur as micro-insets as well as abundantly in the dark base. The groundmass between the feldspar laths consists of granular augite and magnetite as small cubes (0·01 mm.) and finer dust, and some colourless, birefringent base with refractive index apparently below that of the plagioclase. Some small brown altered olivines are observable and more may be hidden by the magnetite-rich dark base.

The specimens from the bluff near the end of the upper beach platform have a holocrystalline groundmass. They contain small insets of augite, about 1 mm. across, but these are few and inconspicuous. There are occasional idiomorphic insets of colourless olivine, up to 1·5 mm. long with narrow brown edges to the colourless crystals. The groundmass consists of slender laths of plagioclase, augite, brown altered olivine, and magnetite, all lying between the feldspar laths in a base of a colourless mineral of low birefringence containing more small feldspar microliths. The texture thus approaches that usually described as intergranular (Plate 2, fig. 2).

The feldspar laths are very thin, about 0·02 mm. across, and are up to 0·3 mm. long. They show Carlsbad and albite twins in which symmetrical extinction angles give a maximum of 28°, indicating labradorite near An_{52}.

The augite insets, pale vinaceous fawn in thin sections, show 'hour-glass' structure. One inset gave extinction angles $c{:}\gamma = 49°$ in the shell and 53° in the core. Others gave readings ranging from 43° to 50°.

The interstitial colourless mineral in the base is alkali-feldspar. There are in it small dark brown inclusions and minute colourless needles.

C. Porphyritic Olivine-basalts with insets of Augite and Olivine

This type is represented at Cape Adare mainly by specimens from a pseudo-cave, a circular depression in the cliff produced by atmospheric weathering, not far from Borchgrevink's Depot.

Typical hand-specimens of this rock [245, 249] are dense, black, with a glassy lustre and smooth, subconchoidal fracture. One specimen [357] shows many round pale neutral grey spots, the familiar spotty weathering, freckling, or 'Sonnenbrenner', frequent in basalts of this kind in other regions. An extreme porphyritic example of this type [431] contains numerous insets of both augite and olivine up to 8 mm. across. Smaller black augites and brown olivine crystals, 2 to 3 mm. across, are visible in most specimens. The groundmass is aphanitic and neutral grey. Vesicles are usually few. At a rough estimate the insets occupy about 25 per cent by volume of the rock.

Another example [234] contains very abundant fresh, reed-yellow to olive-yellow olivines. This rock has augite insets also but these contain inclusions of opaque groundmass or glass and they then merge so closely with the groundmass that they are hardly distinguishable on the rock surface even with a hand-lens.

Under the microscope it is seen that in addition to the augite and olivine there are in some of these porphyritic basalts insets or xenocrysts of brown hornblende usually in the process of resorption [431, 248]. One specimen [249] contains also a group of tabular labradorite crystals. Apart from this plagioclase has not been observed as insets in any of the specimens from the pseudo-cave.

The hornblende is pleochroic: α' cream-buff, γ' honey-yellow. Absorption $\gamma > \beta > \alpha$. Extinction $c{:}\gamma$ small. The augites are pale vinaceous buff in colour and not appreciably pleochroic: $c{:}\gamma = 52°$. Both olivines and augites range up to 2 to 3 mm. in length.

Magnetite as micro-insets is frequently associated with the augite and olivine. In most specimens the olivines are colourless in thin section but occasionally they show various shades of yellow and frequently have narrow brown altered borders.

The groundmass of a typical specimen of these porphyritic basalts [249] consists of microliths of labradorite, near An_{57}, with small prismatic olivines abundant in a base of fawn-coloured glass with very small augite microliths and magnetite cubes (0·004 mm.). A notable feature is the unusual abundance of small olivine crystals in the groundmass. They are about the same size in cross-section as the feldspars, ranging from 0·02 to 0·007 mm., and generally prismatic in habit. Many of them are hollow at the ends or have cavities filled with groundmass. In some specimens they are all altered to brown iddingsite, and in these cases they do not show the skeletal habit.

Variations in the groundmass are shown by several of the specimens. Some have the groundmass more dense, the magnetite being very abundant, and both feldspar microliths and magnetites are very small, ranging in cross-sections from 0·017 to 0·002 mm. Part of the colourless base of the groundmass in 241 is weakly birefringent and may be alkali-feldspar. In 244 there is a strong tendency to parallel alinement of the feldspar laths, and the groundmass between the feldspars is glass, vinaceous buff to fawn in colour, with abundant granular augite and magnetite. There is less olivine visible in this case. A specimen [676] in which the groundmass is better crystallized and slightly coarser grained than in the specimens from the pseudo-cave was broken off, almost certainly *in situ*, by G. P. Abbott, from 1,000 feet up on the Cape. It shows small brown olivines and black augites, 2 to 4 mm. across, in a dense, dark neutral grey groundmass. (See also p. 138 and Plate 2, fig. 6.)

Other examples of lavas of this type are seen in a basalt-tuff and in a specimen of ropy lava referred to above. In this ropy lava the olivine insets show remarkable black inclusions, presumably of magnetite, almost completely obscuring the original olivine. These are perhaps the result of reheating of the insets in the surface lavas. David, Smeeth, and Schofield described and figured similar olivine insets 'traversed by a dense rectangular network composed of strings of magnetite grains' from an olivine-basalt from Cape Adare collected by Mr. C. E. Borchgrevink in 1894–5 (1896, p. 478 and pl. 13, fig. 4). Something of the same kind has been described by I. D. Muir and C. E. Tilley in picrite-basalts from Kilauea, Hawaii (1957, p. 247).

Another basalt from the agglomerate in the pseudo-cave showing scattered small augites, 1 to 2 mm. across, in an aphanitic, dark neutral grey groundmass shows some differences from the other porphyritic basalts described from this locality. It contains resorbed hornblende insets as well as augites but none of olivine were observed. In their optical properties the hornblendes and most of the augites resemble those of the basalts just described but some augite sections show a pale green (glass-green) core in a narrow shell of the usual prevailing buff colour. Magnetite occurs as small micro-insets and apatite appears occasionally as small hexagonal prisms. The groundmass consists of small laths of plagioclase (0·07 by 0·007 mm. and less), small cubes of magnetite, and granules and small colourless prisms of pyroxene in a faintly buff-coloured weakly birefringent base, which, as shown by an HCl etch test, is, at least partly, feldspathoid.

Porphyritic basalts similar to those described above were recorded by G. T. Prior from the collection made on the Southern Cross Expedition [B.M. 85752, 28, 29 and 30] and one [85752, 23] is figured (1902, pl. 53, fig. 5).

It was not known whether these were *in situ*, but Prior was able to match them with a specimen collected by Lieutenant Colbeck 'from a cliff in Robertson Bay, about four miles south of the camp'. According to Lieutenant Colbeck's description 'they occur in small dykes three feet wide, traversing the cliff from top to bottom at various angles' (1902, p. 327).

A similar basalt is probably the 'olivine basalt (No. 7)' collected by C. E. Borchgrevink in 1894–5 on his landing from the whaler *Antarctic* and described by Edgeworth David, W. F. Smeeth, and J. A. Schofield (1896, p. 477). They give a fairly complete description of the rock with particular reference to the augite and olivine insets, and they also made a chemical analysis, quoted in column 1, table I.

Prior was inclined to compare these basalts with those he had examined from Coulman Island [85752, 69–76] and from the foot of Mount Terror, as well as with those from Possession Island collected on the Southern Cross Expedition. He gives a chemical analysis of a hornblende-basalt [B.M. 85752, 93] from the foot of Mount Terror [column 2, table I] but he gave no detailed description of the rock. It contains more xenocrysts of brown hornblende than most of the Cape Adare porphyritic basalts described, and certainly fewer olivine insets. The groundmass has a brown glassy base and is similar to that of the Cape Adare porphyritic basalts, again perhaps with less olivine. Prior's analysis shows very considerable differences from that of the Cape Adare basalt described in David, Smeeth, and Schofield's paper (column 1, table I).

It is worth recording here that a specimen [85752, 101] collected by Mr. Louis Bernacchi on the Southern Cross Expedition, and believed to represent the basalt dike figured in Prior's report on the rock-specimens (1902, p. 327) is a dolerite consisting, as Prior describes it, 'of a medium-grained aggregate of felspar-laths and pale purple augites with only a little magnetite and no interstitial glass'. No rocks resembling this were collected *in situ* at Cape Adare by Priestley.

Xenoliths in the Basalts

Reference has been made above to xenoliths, apparently of sedimentary quartzose rocks, in basalts of Types A and B. In the black glassy basalts, Type A, few xenoliths were seen. They are cream-coloured, compact, and relatively small. From Type B basalts on the other hand large numbers of xenoliths were collected. They are frequently four or five centimetres across and one of the specimens collected by Priestley is 13 cm. in length. These xenoliths show a considerable range of colour from deep greyish olive to brick-red and brown. At exposure 2, near the end of the upper beach platform, the colour ranges from buff to light vinaceous fawn and the edges of the xenoliths adjacent to the basalt are noticeably more pink than in the interior of the xenolith. Penetration of the xenolith by thin stringers of basalt is well shown by some of the specimens.

A good series of thin sections of these xenoliths was examined and some of them were submitted to Dr. S. O. Agrell of the Department of Mineralogy and Petrology at Cambridge and to Dr. A. F. Hallimond for their opinions. Their assistance is here gratefully acknowledged.

TABLE I

	1	2	3	
SiO_2	45·13	47·40	or	16·12
TiO_2		0·63	ab	20·96
Al_2O_3	18·13	20·27	an	20·29
Fe_2O_3	12·94	5·38	ne	15·34
FeO		5·48	di	9·06
MnO		0·17	ol	5·63
MgO	7·33	2·94	mt	7·89
CaO	11·23	7·59	il	1·22
Na_2O	2·14	5·78	ap	2·02
K_2O	0·98	2·73		
$H_2O+110°$	2·18	0·23		
$H_2O-110°$				
P_2O_5		0·85		
Totals	100·06	99·45		

1. 'Olivine Basalt', David, Smeeth, and Schofield, 1895. Cape Adare.
2. 'Hornblende-basalt', Prior, 1902, II.6.(2)3.4. Foot of Mount Terror, Ross Island. G. T. Prior anal. B.M. 85752, 93. (Basalt in Washington, 1917, p. 577).
3. Norm of 2.

All the inclusions examined contain abundant quartz grains and a few turbid grains of plagioclase were also identified. The grains are subangular and they vary in grain-size from about 0·75 mm. down to less than 0·05 mm. The larger quartz grains are cracked. All give sharp extinction and do not show evidence of strain.

The matrix of these grains is in the main glassy. In thin section it is colourless to pale drab or pale buff. Occasionally it shows small-scale perlitic cracks, and nearly always it is crowded with crystallites. Its refractive index is near 1·508. (Pl. 2, figs. 3–5.)

Two kinds of crystallites are very abundant and both are present in every specimen. The most obvious are slender colourless prisms with straight extinction, positive elongation, and refractive index high relative to the glass.

These properties agree with both mullite and with an orthorhombic pyroxene. At Dr. Agrell's suggestion glass containing these crystallites in abundance was finely powdered and allowed to stand overnight in cold HF. The glass and all the crystallites dissolved, thereby proving that the crystallites are not mullite. They are presumed to be the orthorhombic pyroxene, hypersthene. The other abundant crystallites are cordierite. These are colourless prisms with straight extinction, and negative elongation. Some show hexagonal cross-sections and occasionally sector twinning. The birefringence is low and the refractive index is judged to be near that of quartz.

Dr. Agrell identified tridymite in some cavities in the glass, and there are other crystallites that have not been identified. Some of the xenoliths [126, 127, 131, all from locality 2] contain groups of radiating feldspar laths often clustered in rounded patches and filling apparent druses in the glassy matrix.

Several of the xenoliths show in thin-section opaque rod-like bodies. The central part of these 'rods' consists of a weakly pleochroic prismatic mineral, probably hypersthene, associated with much dusty black 'ore'. The glass in the neighbourhood of these 'rods' is crowded to an exceptional degree with cordierite crystallites which are packed along the sides of the 'rods'. Some of these bodies are bent but most of them are straight and Dr. Agrell has suggested that they represent old fractures in the original sediment infilled with material different in composition to the surrounding rock.

G. T. Prior (1907, p. 105) briefly described sandstone xenoliths in olivine-basalt from Castle Rock on Hut Point Peninsula and somewhat similar xenoliths to those described above were among the numerous inclusions in the phonolitic trachyte of Mount Cis on Erebus described by J. Allan Thomson (1916, pp. 144–145). Two xenoliths of the same kind were found in kenyte at Cape Royds and Sentinel Hill, and Priestley and Debenham both collected similar slaggy inclusions at Mount Cis. They differ in detail from the Cape Adare xenoliths but they agree in their abundance of quartz grains and the nearly colourless glassy base (Campbell Smith, 1954, p. 26).

These xenoliths in the Mount Cis 'trachyte' were explained as inclusions of sandstone and David and Priestley (1914, p. 221) had no doubt that they were derived from the Beacon Sandstone Formation and that this sandstone must lie at depth below the volcanic series of Ross Island. This, no doubt, is the correct explanation of the sandstone xenoliths in the trachyte of Mount Cis on Erebus, but a more likely source for the Cape Adare xenoliths is the greywacke of the slate-greywacke formation of Robertson Bay. These rocks have been described by R. H. Rastall and R. E. Priestley (1921, p. 127). They consist mainly of quartz in angular grains with chips and grains of mudstone and slate, and with some feldspar, and mica in a matrix containing quartz, mica, chlorite, and carbonates. There are no chemical analyses available of these greywackes but their general composition would seem to be such as could supply the hypersthene-cordierite assemblage and the glassy matrix and the abundant quartz grains in the xenoliths in basalt described above.

White Incrustation on Basalts

The white coating on some specimens of the basalts, mentioned above (p. 116) may be several millimetres thick and is sometimes stalagmitic in habit.

Qualitative analysis shows the presence of $Mg^{\cdot\cdot}$ and PO_4''', and an X-ray powder photograph identified the material as the mineral newberyite, $MgHPO_4.3H_2O$.

This mineral has been found in caves containing bat guano in Skipton Caves, near Ballarat, Victoria, and in the island of Reunion.* It was identified by G. Richards† on lava collected by R. A. Daly from a cavern in a basalt flow on Ascension Island, and Daly recorded that 'thin deposits of phosphate on the basalt flows occur at many places'.‡ More recently newberyite has been recorded in cracks in fossil mammoths' tusks found buried in clay in Sverdlovsk in the Urals.§

In the occurrences in caves bat guano supplies the phosphate for the newberyite. At Cape Adare it must be derived from wind-blown penguin guano on Ridley Beach. Priestley|| has described how these deposits are carried off each year in the winter gales. The magnesium for the newberyite is presumably supplied by the weathering of the olivine-basalts.

Artificial material with the composition of newberyite is formed by the dehydration of $MgHPO_4.7H_2O$ at ordinary temperatures and this heptahydrate is also known as a mineral, phosphor-rösslerite, but it occurs only in cold wet 'muck' (10° C.) in an abandoned mine working near Schellgaden, Salzburg, Austria.¶ Perhaps phosphor-rösslerite could be formed under Antarctic conditions in winter. If so the newberyite may be its dehydration product.

Phonolites and Trachytoid Phonolite

A phonolite and a phonolitic trachyte, both possibly *in situ*, were collected by Priestley on the Northern Party's first climb to the top of the Cape. These were found at 900 feet above sea-level. The same phonolite was found by G. P. Abbott on a later visit and it is interesting to note that Sir Ernest Shackleton during the Discovery Expedition of 1902 found a specimen of the same phonolite at 'the top of the Cape' [B.M. 87171, 23].

The only other representatives of rocks of these kinds, apart from pebbles on Ridley Beach, are erratics. They come from two sites: (1) a remarkable patch of 'agglomerate' exposed on the northern face of the cliff at Cape Adare; and (2) the plateau between 800 and 1,200 feet above sea-level on the top of the Cape.

The erratics from these two sites will be described below (p. 129 and p. 136).

---

* Dana, E. S., The System of Mineralogy, 7th edition, 1951, vol. 2, p. 710.
† Richards, G., Amer. Min., 1928, vol. 13, pp. 347–401.
‡ Daly, R. A., Proc. Amer. Acad. Arts and Sci., 1925, vol. 60, p. 10.
§ Vertushkov, G. N., Mém. Soc. Russe Min., 1955, ser. 2, vol. 84, pp. 218–220.
|| Priestley, R. E., British (Terra Nova) Antarctic Exp. 1910–1913, Physiography, 1923, p. 3, footnote.
¶ Friedrich, O. M., and Robitsch, J., Zentr. Min., Abt. A, 1939, pp. 142–155.

It is worth noting here that white, powdery coatings similar in appearance to the newberyite, but more easily removed, were found on some loose blocks of kenyte on Mount Erebus [B.M. 1953, 86 (16)] but they proved to be thenardite, Na_2SO_4.

Phonolite

The phonolite found at 900 feet above sea-level [226–228 and 230] is a dull greenish black rock, aphanitic and compact. On its weathered surfaces it develops a mass of small rounded bodies closely packed together and this led to its being first described in the field as a variolitic basalt and under that name it is figured in Priestley's memoir on the Physiography of South Victoria Land (1923, plate 42), (Plate 1, fig. 4). Pebbles of the same phonolite were found on Ridley Beach and also some large fragments of the same rock but without the peculiar weathering. One of these [322] is deep olive-grey in colour and aphanitic, the other [351] deep slate-olive and has many small insets of feldspar in an aphanitic groundmass. The feldspar insets appear to be anorthoclase. Under the microscope it is seen that there are also occasional micro-insets of pinkish vinaceous pyroxene.

The groundmass consists of abundant laths of alkali-feldspar and small, rough-edged prisms of aegirine-augite, magnetite, small amounts of pleochroic green aegirine, and some flakes of deep brown amphibole or, possibly, cossyrite. Feldspar is the dominant light mineral but there are also abundant colourless prisms of nepheline, 0·025 mm. across, and, between the nephelines, colourless isotropic material of very low refractive index that is probably sodalite. The aegirine of the groundmass, where well developed, forms subophitic plates partially enclosing the feldspar laths. It is pleochroic from deep grape-green to deep olive-buff. The pleochroism of the amphibole is from cinnamon-brown to very dark brown, almost opaque.

Nothing has been detected in the microstructure or texture of the groundmass to account for the weathering out of the globular bodies. On broken or naturally exposed surfaces the specimens collected high up on the Cape show small polygons, 3 to 5 cm. across, faintly outlined by narrow, pale grey margins. One of the pebbles from the beach [348] shows circular areas of dull greenish black colour in a very pale olive-grey base. It is this paler weathering material which weathers out, leaving the more resistant parts standing out as rough spheres.

The specimen of this phonolite collected by Abbott at 1,000 feet [674] contains many angular fragments of aphanitic black basalt. Some of them are 3 cm. across but there are also many small subangular black patches no more than a millimetre or two across. These represent basalts through which or into which the phonolite was intruded. The angular fragments are mostly compact, aphanitic, very fine-grained olivine-basalts, and the small subangular patches show enough of their original texture to prove that they also are basalt xenoliths. It is doubtful if any of them can be identified with any of the basalts described above as *in situ* on the Cape and the best that can be said is that a representative specimen with small skeletal olivine micro-insets and abundant laths of labradorite in a dense brownish groundmass resembles the groundmass of the porphyritic olivine-basalts, Type C, from the pseudo-cave (p. 118).

Trachytoid Phonolite

A somewhat vesicular, neutral grey lava [231] was collected with the phonolites at 900 feet up on Cape Adare. The colour of this rock ranges from neutral grey to deep slate-olive. Vesicles are small, numerous, and very irregular in form. The rock is very rough to the touch and rather resembles in texture the well-known Niedermendig millstone lava. Only a few very ill-developed insets of feldspar are visible in the hand-specimen. Under the microscope it is seen that there are small micro-insets of a pale green pyroxene, alkali-feldspar, some magnetite, and some partially resorbed brown hornblende.

Prior described the same rock from a specimen in the Southern Cross collection [B.M. 87171, 31] as 'showing an approach to the hornblende-basalts' (1902, p. 329), presumably on account of its resorbed hornblendes.

The groundmass consists of abundant fibres or very slender prisms of a tea-green pyroxene, a few brown-stained flakes possibly representing amphibole, and many small magnetite cubes in a base of slender microliths of alkali-feldspar. Microchemical tests show that a feldspathoid is concealed in this colourless base but no crystal form to suggest nepheline was seen. The feldspar microliths average 0·03 mm. in length and the pyroxene micro-insets 0·1 mm. Feldspar insets are up to 1 mm. long. The pyroxene is aegirine-augite with pleochroism, α pea-green, β olive-buff, γ tea-green. The brown hornblende shows a long prismatic or bladed habit. The pleochroism is α' warm buff, γ' Dresden brown. The smaller hornblende insets are completely replaced by aggregates of small opaque grains. There are also in this rock some small segregations of brown hornblende with stout laths of plagioclase of much coarser grain than the feldspars in the rest of the rock. They are rather like the hornblendic segregations described by Prior in the trachytoid phonolite of Observation Hill at Hut Point, Ross Island (1907, p. 118 and fig. 66).

III. THE BOULDER-BEARING AGGLOMERATE ON THE NORTHERN FACE OF THE CLIFF

The Agglomerate

Priestley discovered and collected extensively from a patch of a remarkable agglomerate exposed on the northern face of the cliff at Cape Adare. He has described it in his memoir on the Physiography of the region (1923, p. 11) and photographs by Staff-Surgeon G. Murray Levick, reproduced by kind permission in this report (Plate 1, figs. 1 and 2), show its situation on the cliff and the remarkably rounded small boulders and cobbles it contains. Priestley saw, and recorded in his diary, in this agglomerate blocks of greenish greywacke and of other rocks resembling dolerite or norite, granites, schists, etc., and he collected many specimens, several of fair size, with a good deal of tuff matrix adhering to them.

The following is Priestley's own account of the finding of this agglomerate, written in his diary at the time, forty-six years ago:

'3/10/11. I walked out further than I have yet been round Cape Adare and at the farthest place I reached I bore in towards a lenticle of brown rock dipping as all the layers do about 5° towards the west and within a hundred feet of sea-level. A good deal of this had fallen recently on the ice-foot and I collected from there. The rock proved most unusually interesting for it was a basalt agglomerate, rather friable, containing numerous erratic boulders as an essential part of its composition. The most common types of rock were the green quartzite at present common (as an erratic)* on the top of the hill, granite of different types, diorite, and a (rock which reminds me strongly of a)* hypersthene norite or dolerite rich in iron. These were embedded in a loose friable cement and the majority of the pieces I obtained came away from the groundmass, but I managed to secure several bits of the main types of erratics with groundmass attached to them. The erratics were not in one plane but scattered evenly through the blocks and the jointing had taken place through many of them. The largest blocks I saw were a block of quartzite whose exposed face was approximately 12 inches by 14 inches and a block of the dolerite or norite which was well rounded and of the typical triangular shape assumed by so many of the erratics. Its exposed face was about 18 inches in greatest length by 9 inches in greatest width. . . . I also collected two or three specimens of a light yellow tuff that had fallen from some round, exposed sections in the cliff. These masses of tuff in the cliff were generally rounded and very small and might be called "pockets".

'22/10/11. Levick and I walked out beyond Cape Adare and took three photographs of and collected a couple of dozen specimens from the erratic-bearing agglomerate . . . secured several very convincing specimens of fair size of undoubted erratics, including some granite boulders with a good deal of matrix adherent to them.'

This agglomerate presents quite a problem. It apparently contains blocks which Priestley thought must be ice-borne, but its matrix is undoubtedly a volcanic tuff and all the specimens collected are of volcanic rocks but many of these are rocks related to types at present known only as erratics on the plateau at the top of the Cape. Others, as will be shown, have the characters of sanidinites and are thus quite in keeping with the interpretation of this deposit as volcanic.

The matrix adhering to the 'boulders' collected is a fine-grained pale, cinnamon-drab, sandy-textured aggregate containing many angular fragments of rock and great numbers of very small lapilli. The rock fragments are for the most part fine-grained rocks. Some of them are like trachytic and phonolitic rocks, others are fine-grained dark basaltic rocks. Under the microscope it can be seen that the matrix is itself an aggregate of small lapilli of volcanic rocks with here and there a fragment of a clastic, sedimentary rock such as could be derived from the slate-greywacke formation of the district. A considerable variety of rocks is represented among the lapilli but the

* The two phrases in parentheses are additions from the quotation printed on p. 11 of Priestley's memoir on the Physiography referred to above.

majority are alkali-trachytes and trachytoid phonolites. Some are pumiceous glassy types with abundant little crystals of feldspar and brown hornblende, and many are of various kinds of fine-grained basalts, and a very few are of sedimentary rock. The base in which these lapilli are packed is extremely fine-grained and consists of broken glass with crowds of minute crystallites of colourless pyroxene, brown hornblende, and feldspar. These crystallites are extremely small and more definite identifications would be difficult. There are some fragments of larger crystals of feldspar, pyroxene, and hornblende lying among the lapilli.

In addition to this well-consolidated cinnamon-drab tuff in which the fragments and 'boulders' are imbedded, two other kinds of volcanic tuff were collected from this agglomerate exposure.

One of these, represented by half-a-dozen specimens [652, 653, 654, 658, 660, 661], is a trachyte-tuff. It is pale buff in colour, rather friable, and consists of close-packed small buff-coloured pellets 2 to 3 mm. in diameter in a soft matrix. There are also a few small sub-angular fragments of fine-grained basalt but these are rather scarce. The buff-coloured pellets and the soft matrix are pumice, mostly comminuted, but even in the smallest fragments crowded with crystallites of feldspar. There are a few larger fragments of pumice, some of a glassy trachyte with small insets of feldspar, and some fragments of anorthoclase and of pyroxene.

The other specimen [672] is also trachyte-tuff but olive-green in colour. This consists mainly of small lapilli, 3 to 4 mm. across and ranging up to 1 cm. in diameter. Most of the lapilli are of trachyte, though there are also many of dense glassy basalt, and scattered fragments of pyroxene and plagioclase, and fragments of pumice. The very fine-grained base is a colourless glass with microliths of feldspar. It is much richer in microliths than the paler glassy trachyte tuff described above.

It is not known how these trachyte-tuffs are distributed or what their relation is to the more consolidated 'boulder'-bearing agglomerate at this exposure.

Sodalite-trachytes

Many of the 'boulders' collected from the 'agglomerate', some with the matrix still adhering to them, prove to be sodalite-trachytes, grading in some specimens into trachytoid phonolites. Most of them are somewhat coarse-grained for lavas. Weathering has slightly altered many of them and the colours range from greyish olive and slate-olive in the freshest and coarser-grained specimens to drab and hair-brown in the more compact and finer-grained ones.

In thin section these rocks are seen to be porphyritic with abundant small insets and micro-insets of alkali-feldspar in a groundmass of alkali-feldspar with abundant small micro-ophitic patches of green pyroxene and opaque material, probably altered amphibole. All show in the base patches of isotropic sodalite occurring as poecilitic patches enclosing feldspar laths of the groundmass. The sodalite is colourless when fresh but it is usually slightly stained brown in the drab and hair-brown coloured specimens. Most sections of these rocks show occasional micro-insets of nepheline, partly fresh and partly isotropic and brown-stained like the sodalite. These nephelines sometimes have a partial fringe of dark green pyroxene. In some specimens nepheline seems sufficiently abundant to warrant their reference to trachytoid phonolites and one of these is mentioned below.

Another occasional constituent of these rocks is olivine as irregular rounded crystals up to 0·6 mm. across. These are slightly yellow in thin section. In some cases they are surrounded by a border of dark green pyroxene (Plate 3, fig. 5). Opaque ore is present in some sections but most of the opaque material seen is probably altered amphibole.

The feldspar of the insets is anorthoclase. Universal stage measurements showed that the plane of the optic axes is normal to (010), and a determination of the optic axial angle gave $2V = 50°$, negative (values plotted for V ranged between 24° and 30°). The insets are generally rectangular in section and are often in roughly parallel alinement. Many of them are Carlsbad twins. Some indistinct twinning and cross-hatching was observed in certain positions of the sections.

The pyroxene is mostly aegirine-augite. Measurements of extinction angles, $c:\alpha$ range from 35° to 40°. Basal sections are pleochroic, the colours ranging from pale olive-buff to deep olive-buff and chamois for vibrations corresponding to γ'; and for vibrations in the α' and β' directions, shamrock-green and light grape-green to deep greenish glaucous.

Some aegirine is also present among the groundmass pyroxenes. In one specimen [663] prismatic sections gave $c:\alpha = 6°$, and pleochroism α' near grape-green, γ' apricot-yellow.

There are several variations from this average type in addition to the colour variations already noted. One of these [656] has abundant micro-insets of a pale green aegirine-augite. Hand-specimens of this variety are greenish grey (storm-grey) in colour, rather coarse-grained for trachyte, and, like the others described above, they show a sheen from feldspar cleavages on fractured surfaces.

A more fine-grained and more compact example of the same variety is slate-olive in colour [697]. Aegirine-augite micro-insets in this rock are similar to those described above but $c:\alpha = 43·5°$. A frequent accessory constituent in this rock is opaque 'ore', often with hexagonal outlines, probably magnetite. The groundmass consists of abundant laths of alkali-feldspar in partly parallel alinement, with small patches of pale green aegirine and pale brownish-fawn amphibole, both abundant. There are some areas in which the feldspars lie in patches of low refracting material of very low birefringence, probably a zeolite.*

* A specimen [703] otherwise resembling 656 and 697, shows in the hand-specimen rounded areas, 1 to 2 mm. across, slate-olive in colour, in a cream-coloured base. This colour distribution is related to alteration affecting the base of the groundmass of the rock. The thin sections show that the dark rounded areas are slightly turbid and dusty. The groundmass feldspars lie in an apparently isotropic base of low refractive index. In the turbid areas this base has vast numbers of very small (less than 2μ), round, colourless inclusions, apparently of low refractive index. The nature of these bodies is not yet known. Similar round dark 'varioles' are seen in 667 but they do not seem to show up in the thin section in the same way.

Another variation [689] is a paler-coloured 'trachyte', vetiver-green to greyish olive in colour, in which the groundmass laths of feldspar tend to be grouped in radiating sheaves. With the feldspar are associated very abundant grains of pyroxene and altered brown amphibole and many tiny grains of opaque 'ore', and some isotropic and some altered, birefringent base. Occasional small insets of brown hornblende with $c:\alpha = 11°$ show pleochroism α' deep grape-green, γ' cinnamon-buff.

One other variation, a sodalite-trachyte with a remarkably high proportion of dark minerals, is a compact aphanitic rock, deep brownish-drab in colour [705b]. This contains only a few small (2·5 mm.) insets of alkali-feldspar and occasional olivine crystals up to 0·5 mm. across. The main constituent is alkali-feldspar which forms very slender laths, close packed and in parallel alinement. Throughout the feldspar and enclosed by them are vast numbers of minute sodalite crystals, some showing hexagonal shapes and up to 0·014 mm. across but mostly less. The dark minerals are aegirine and altered cossyrite crystals. They form perhaps 20% of the rock, and are partly responsible for the dark colour of this specimen, but in addition a colloidal brown mineral (ochraceous tawny) forms films on feldspars and coats fractures and cleavage surfaces. Other fragments similar in appearance to this rock are frequent in specimens of the enclosing agglomerate.

Trachytoid Phonolite

A variation of these sodalite-trachytes that is probably best described as a trachytoid phonolite [664] is a compact, dark greyish olive rock with many small indistinct insets of alkali-feldspar in an aphanitic crystalline groundmass. The insets are anorthoclase; they are rectangular in section and show Carlsbad twins with occasionally traces of indistinct cross-hatching. There are many micro-insets of the same kind of feldspar, so that the fabric is seriate porphyritic. There are a few small insets also of green aegirine-augite similar to that described above. The pleochroism is α' dark greenish glaucous, β near grape-green and γ' cream-buff. 2V is near 70°, negative. Magnetite(?) with hexagonal sections (cubo-octahedra) is a frequent accessory.

The groundmass is very fine-grained and consists of a greyish green turbid pyroxene(?) and deep brown amphibole or cossyrite in very small micro-ophitic patches or free as small crystals. These lie all through the groundmass of slender laths of alkali-feldspar set in a faintly brown-stained low-index base that is partly isotropic. This base is probably nepheline rather than sodalite and it is on that assumption that the rock is classified as phonolite and described separately from the sodalite-trachytes.

Alkali-trachytes

Some of the boulders in the agglomerate lacking the sodalite that is so constant in the sodalite-trachytes described above are best separately listed under alkali-trachytes.

These [657, 702] are deep olive-grey to dawn-grey in colour and fine-grained and compact with insets of feldspar 2 to 3 mm. long.

Thin sections show the feldspars to be simple Carlsbad twins of anorthoclase with traces of vague twinning. They are abundant and there are also frequent micro-insets of aegirine-augite. The pyroxene is rather similar to those described above with weak pleochroism; deep dull yellow-green, reed-yellow to olive-yellow. Another frequent constituent is olivine as small, pale yellowish, irregular crystals and small magnetites(?) are also common. The groundmass consists mainly of short crystals of alkali-feldspar, slightly elongate but with irregular edges and not showing parallel alinement. With these are small fragments of pale green pyroxene and dark brown amphibole or cossyrite?, both frequent. The pyroxene and amphibole are in micro-ophitic relation to the feldspar. The groundmass feldspars are single crystals or Carlsbad twins, and, in many sections, they give straight extinction parallel to 010.

Sanidinites

The rock fragments in the agglomerate that were referred to above as sanidinites are leucocratic, rather friable rocks with grain-size about 5 mm., but a few are fine-grained, 1 to 2 mm., and speckled, pepper-and-salt rocks quite resembling fine-grained diorites in appearance.

The best example of these rocks [686] is a small boulder, $5 \times 7 \times 10$ cm., pale cream-coloured, and rather friable and granular in texture. It consists mainly of feldspar speckled with black crystals and flakes, among which a black mica is conspicuous and occasionally forms flakes 8 mm. across. The feldspars, which are fresh and have a glassy lustre, are sometimes as much as 10 mm. long by 2 mm. wide, and crystals 4·5 mm. in length are frequent, but the average grain-size is about 2 to 3 mm. In this specimen all the feldspar proves to be anorthoclase. The crystals are allotriomorphic and have one cleavage (001), very well developed in thin sections. Some of the crystals show rather patchy extinction and a few show vague, very thin, twin lamellae.

A pure sample of this feldspar was prepared by Mr. P. M. Game and was analysed by Mr. D. I. Bothwell with the result given in column 1 of the table below. Inspection of the sample under a binocular microscope showed the only impurity to be a few flakes of biotite and the proportion of these present was very small indeed.

The analysis shows that there is a small deficiency in both SiO_2 and Al_2O_3 below the percentages required to satisfy both alkalies and lime for feldspar but the effect of this on the calculated ratio of feldspar molecules is very small. Allotting all the CaO to anorthite and deducting sufficient of the orthoclase molecule to satisfy MgO and FeO (Fe_2O_3) for biotite, the composition may be fairly stated as Or : Ab : An = 36 : 62·6 : 1·4. The specific gravity, determined by Mr. Bothwell, is $2·57 \pm 0·01$.

Measurements on the universal stage gave values for V from 25 to $26\frac{1}{2}°$, negative, and refractive indices for sodium light were determined by the Becke line method as, α' 1·5259, γ' 1·5318, $\pm$ 0·0005.

Comparing these values with those given by O. F. Tuttle (1952, pp. 557 and 559) for 2V and for refractive indices of the alkali-feldspars both 2V and α' and γ' are high for a feldspar of the composition $Or_{36}Ab+An_{64}$. They are, however, sufficiently near to Tuttle's values to show that the feldspar analysed falls in his 'sanidine-anorthoclase cryptoperthite' series. Among the feldspars measured by Tuttle the one nearest in composition to the feldspar now described is anorthoclase from the Azores. Its composition and the values for 2V and refractive indices are given in column 2 of the table.

TABLE II

	1	2
SiO_2	66·8	66·97
TiO_2	nil	0·04
Al_2O_3	19·1	18·75
Fe_2O_3	0·2	0·88
FeO		
MnO	nil	—
MgO	0·2	0·00
CaO	0·3	0·36
Na_2O	7·7	7·88
K_2O	6·4	5·39
P_2O_5	tr.	—
H_2O+	nil	0·01
H_2O-	nil	0·03
Total	100·7	100·31
Or	36	32
Ab	62·6	66
An	1·4	2
2V	(50°)	46°
α'	1·5259	α1·5239
		β1·5299
γ'	1·5318	γ1·5308

1. Anorthoclase from sanidinite, Cape Adare. Anal. D. I. Bothwell.
2. Anorthoclase from 'Grande Caldeira' [Caldeira das Sete Cidades, Saõ Miguel], Azores. Anal. J. H. Scoon. (O. F. Tuttle, Amer. Journ. Sci., 1952, Bowen Volume, p. 555.)

It seems certain that the feldspar in the sanidinite [686] is all of one kind and that it is correctly assigned to anorthoclase. (Plate 3, fig. 3.)

In some of the other specimens of the sanidinites from this deposit there appear to be two kinds of feldspar in that some of the feldspar crystals show fine albite-twinning more definite than the rather patchy and obscure lamellar twinning shown by some anorthoclase. Also in these rocks determinations of refractive indices by the immersion method indicate that the feldspar showing fine twin-lamellae has a higher refractive index than the untwinned feldspars in the same rock.

Values obtained for the refractive indices for sodium light were:

Untwinned feldspar: α' 1·523₅; γ' 1·529–1·530.

Twinned feldspar: α' 1·528–1·534; γ' 1·536–1·538.

The extinction angle measured from the trace of the twin lamellae is 5°.

The values obtained for the twinned feldspar are still within the range for anorthoclase, though they could also fit for a plagioclase with An up to, say, 8 per cent.

The dark minerals are brown amphibole, green pyroxene, biotite, and some opaque 'ore'.

The amphibole has intense absorption parallel to β and in basal sections pleochroism is tawny olive to black. The absorption for vibrations along the length of longitudinal sections is also very strong, and it was not possible to determine certainly the angle of extinction or the sign of elongation. One section gave an extinction angle of 33°. These characters, so far as they go, agree with those of aenigmatite or cossyrite.

The pyroxene, in 686, is aegirine-augite, similar to that in the sodalite-trachytes described above. Pleochroism is: α' deep bluish glaucous, β' deep olive-buff, γ' tea-green. $c{:}\alpha = 31°$. Some of the pyroxenes have darker outer shells, and there are some crystals all aegirine with $c{:}\alpha = 12°$, and in one specimen [653] $c{:}\alpha = 9°$, and pleochroism is α' very dark green, γ' deep colonial buff.

The biotite is intensely pleochroic from ochraceous buff and Dresden brown to black.

The three dark minerals are closely associated and they may form a reaction series. Some sections show amphibole surrounding pyroxene and in places both partially surround the biotite, but the reverse relation can also be seen.

In some cases the ferromagnesian minerals have undergone resorption. Thus, in 659, relics of brown amphibole lie in a dense swarm of rods and tiny cubes of magnetite (?), a few flakes of biotite, and prisms of aegirine.

Accessory minerals identified are apatite and, in some specimens, sphene. The latter is abundant in a dark variant of the sanidinites described below. Calcite occurs filling interstices in one specimen [686] and the same specimen contains colourless interstitial patches that may represent altered cancrinite (see below, footnote p. 133).

The texture of these sanidinites varies somewhat. In some [686] it is allotriomorphic as described above, but in others [653, 659] it is hypidiomorphic with the feldspars tending to form laths and thin plates 4 or 5 mm. long. In some specimens between the larger feldspars there are areas where the feldspar is fine-grained and granular, and others where it is fine-grained but occurring as laths and divergent radial. In such areas dark minerals are more frequent and the biotite is pale brown and shows much less intense absorption than in the coarser-grained, more normal, parts of the sanidinites. Thus its pleochroism in 659 is ochraceous orange to light buff or pale ochraceous buff. One sees in some of these fine-grained areas an approach to the mineral composition of some of the alkali-trachytes and the resemblance is enhanced by the presence of some interstitial patches of a colourless, weakly birefringent mineral, perhaps a zeolite.

A darker variety [671b], rather finer grained than the more leucocratic examples, owes its darker colour to very evenly distributed ferromagnesian minerals which are present in considerable abundance. There are a few larger feldspars, 5 to 8 mm. across, but apart from these the rock is very even-grained, 1 to 2 mm. The texture is allotriomorphic granular, though the feldspars tend towards a tabular habit. The feldspars are Carlsbad twins and some show vague albite-twinning. They are almost certainly anorthoclase.

The ferromagnesian minerals are a brown amphibole, a pyroxene, and biotite.

For the amphibole $c{:}\gamma = 11^\circ$, and the pleochroism is α' cinnamon-buff, β' olive, and γ' buffy olive.

The pyroxene is aegirine-augite. $c{:}\alpha = 30^\circ$. Pleochroism: α' deep malachite-green, β' malachite-green, and γ' pale olive-yellow to reed-yellow.

The biotite is intensely pleochroic from ochraceous buff to clove-brown, almost opaque.

All these ferromagnesian minerals are well crystallized and they tend to be closely associated and clustered together. Sphene is also present in these groups as well as some apatite which, in this specimen, is also present as an accessory mineral throughout.

Cancrinite-bearing Sanidinite

One of the sanidinites differs from all the others in containing cancrinite. It is a small fragment only about 3 cm. across and is the only one of its kind found in the collection. This is unfortunate, as the feldspars present an interesting problem.

The specimen consists mainly of feldspar, rectangular and tabular in habit, up to 8 mm. long and 2 mm. across. The dark mineral is biotite forming glistening black flakes and under the microscope showing intense pleochroism, buckthorn-brown to opaque. Neither amphibole nor pyroxene was observed. Sphene is quite frequent and there is some interstitial calcite. The cancrinite, colourless in thin section, occupies roughly triangular interstitial areas between the feldspars. For the most part it is fresh and shows its characteristic high birefringence, low refractive index, and negative elongation.*

The feldspar in this rock is of considerable interest. Many of the feldspars show an approach to rectangular forms. Many broad plates show no twinning, others more rectangular in outline show albite lamellae; all the sections show mottling due to the association of the two kinds. The twinned feldspar is mottled by intergrown untwinned feldspar of lower index. In the platy sections that show no twinning the birefringence as well as the refractive index is higher in the host.

---

* In the typical sanidinite described above [686] there are some interstitial areas filled with a granular aggregate of colourless minerals that may possibly represent altered cancrinite. The minerals have not been identified. They comprise: rounded grains of an isotropic mineral of low refractive index; groups of radiating blades and fibres of another apparently isotropic mineral with refractive index less than balsam; and a third, rather turbid and highly birefringent, that may be calcite. In the same specimen calcite is seen occasionally filling interstices.

Measurements on the Universal stage show that the untwinned feldspar that forms patches and cores in the clearer, more highly refractive feldspar has the optical orientation of sanidine and is almost uniaxial. Measurements by Mr. P. M. Game on some half-dozen selected crystals gave the following data: $\alpha \| 010$; $\alpha \wedge$ the a-axis $[100]=9°$; $001 \wedge 010=89°$; $[001] \wedge \perp(001)=26°$; $2V=$ approximately $0°$.

The approximation to zero of 2V was checked many times on crystals of differing orientation.

The refractive indices for the untwinned feldspar in this rock for sodium light are: α' 1·5199, β' 1·5239 ± 0·0005. These are not far from values given by E. Spencer for sanidine from the Eifel, for which, however, $2V=24°$ (Spencer, 1937, p. 458 and pl. 18) or 17° (Tuttle, 1952, p. 555). The composition of the Eifel sanidine is $Or_{78}Ab_{21}An_1$.

The twinned feldspar in the section has proved very difficult to identify. All the sections approximately perpendicular to (010) show fine twin-lamellae parallel to that plane, but in the great majority of sections the lamellae are too fine to permit of measurements. However, fairly good readings were obtained on four more coarsely twinned crystals. The mean value for the orientation given by these four are: $\alpha \wedge [100]=15°$, $\gamma \wedge \perp(010)=15°$, and $2V_\alpha=85·6°$ (on one direct measurement). Refractive index measurements gave for twinned cleavages: α' 1·5296, γ' 1·5363 for sodium light. These values and the optical data (except the negative sign of the optic axial angle) agree tolerably well with albite near An_4 referred to the optical orientation based on universal stage measurements and with albite near An_8 judged by the refractive indices.

As there is so little material available one cannot proceed with more detailed investigation of these interesting feldspars. The data obtained seem to indicate that the mixed feldspar is an antiperthite consisting of near uniaxial sanidine in an albite host.

In this connection it is interesting to note that P. Quensel (1914, p. 166), describing the alkaline rocks of Almunge in Sweden, records two kinds of feldspar associated with the cancrinite, nepheline and albite in the canadites. These are soda-orthoclase (in the sense of Brögger, i.e. showing no twinning), and microcline-microperthite (antiperthite) in which patches of microcline are distributed in large albite crystals. This microcline-microperthite (antiperthite) is however scarce in typical canadites.

In another well-known cancrinite-bearing nepheline-syenite, litchfieldite, antiperthite with patches of microcline in large albite crystals is described by W. S. Bayley in his description of this rock (1892, p. 237).

If the original feldspar in this cancrinite-bearing sanidinite was originally a patchy antiperthite the present nearly uniaxial sanidine may be the result of subsequent heating of the 'bomb' in the deep-seated part of the Cape Adare volcano.

Published records of uniaxial natural sanidines are very rare. A. Mulheims (1888, p. 235) reported sanidine from Wehr in the Eifel as uniaxial but this was on the basis only of refractive index measurements for which he found β and γ to be equal. He is quoted by O. Mügge (1925, p. 666) as authority for $2E=0°$ for this sanidine. Mügge also quotes Des Cloiseaux (1862) as having found $2E=17°$ for red light for 'orthose' (sanidine), also from Wehr. More recently O. F. Tuttle (1952, p. 5) quotes F. Tucan for $2V = 15\text{–}18°$ for a feldspar in dacite from Yugoslavia with composition $Or_{52}Ab_{43}An_5$.

The identification of these medium-grained feldspathic rocks in the agglomerate as sanidinite is well supported by their close similarity to described sanidinite bombs from other volcanic areas. In this connection the sanidinites of Saõ Miguel in the Azores have already been mentioned. These were described in some detail by A. Osann (1888, p. 117) and more recently by P. Esenwein (1929, p. 125), who gave a new analysis, and determined 2V for the feldspar as 60°, negative, and extinction $a{:}\alpha = 13°$ (op. cit. p. 111).

In the Laacher See district in Germany the name sanidinite has been used in a wide sense to include a great variety of ejected blocks in the tuff, but there are also great numbers of sanidinites consisting mainly of feldspar, and it is interesting to note that cancrinite has been described from some of these by R. Brauns and J. Uhlig (1913). It had been described earlier as scapolite. The canrinite-bearing bombs are regarded as original syenitic material (1913, p. 210).

The sanidinites have no known near analogues among South Victoria Land rocks at present described. They do not closely resemble the sanidinites in the Mount Cis 'trachyte' described by J. Allan Thomson (1916, p. 131), which are rich in pyroxene and in olivine and carry neither amphibole nor biotite.

An erratic from Cape Royds described by W. G. Woolnough (1916, p. 172) as sodalite-syenite (1916, p. 172, No. 535) has a similar mineral assemblage to the sodalite-trachytes of Cape Adare but no occurrence of such a rock *in situ* in the Ross Archipelago or on the mainland is known.

IV. THE ERRATICS FROM THE PLATEAU ON THE TOP OF CAPE ADARE

Priestley has given some account of the plateau and of the strew of erratics on its surface in his memoir on the Physiography (1923, p. 10), and a note on the erratics of plutonic rocks on the plateau and some remarks on their possible sources was published in a report on the plutonic and hypabyssal rocks of South Victoria Land in 1924 (W. Campbell Smith, 1924, p. 214).

Compared with the plutonic and sedimentary erratics the volcanic rocks collected are few. Two of the specimens [579 and 584] are the same as the trachytoid phonolite from 900 feet above sea-level described above. Five of them are basalts of which two may not be far from their outcrops. The remainder, 8 in number, are trachytoid phonolites and alkali-trachytes not known to be *in situ* on the Cape but related to some of the types described from the 'agglomerate' on the northern face of the cliff. Briefly described, these are as follows:

Trachytoid Phonolites and Alkali-trachytes

585. A small boulder, smoothed on three faces. Aphanitic, slate-olive in colour, compact. In thin section it is seen to contain small insets of thin, tabular feldspars and a few micro-insets of a tea-green pyroxene and occasional micro-insets of magnetite. The groundmass consists of closely packed laths of alkali-feldspar with abundant small 'mossy' patches of dark green aegirine and a brown amphibole or cossyrite. Between the feldspars are abundant small interstitial patches and hexagonal sections probably of sodalite. All the feldspars, both insets and groundmass, are affected by some alteration which renders them slightly turbid. The feldspar insets show no cross-hatching and give very low extinction angles measured from the trace of 010. They are simple Carlsbad twins.

575, 582, 588, 602. A group of four specimens all of the same kind and all broken from larger specimens seen as erratics.

These are characterized by very abundant large insets of anorthoclase showing the characteristic cross-hatching and some having lozenge-shaped sections common for this feldspar. There are occasional micro-insets of a pale purple drab, green-shelled aegirine-augite, and frequent pseudomorphs of hornblende now represented by dense aggregates of magnetite and a green pyroxene. The groundmass, not very fine-grained, consists of a mass of platy and lath-shaped alkali-feldspars with pale green aegirine-augite, some altered brown hornblende and magnetite and a little sodalite. The sodalite in these rocks is not interstitial as in the sodalite-trachytes described above but occurs as thin scales actually in the feldspars. In addition to the micro-insets mentioned above there are occasional small insets of pale yellow olivine, usually rimmed by clusters of green pyroxene crystals (Compare 370 from Ridley Beach, Plate 3, fig. 2).

Examples of these porphyritic types were collected also from the beach as pebbles and a pebble of the same kind [B.M. 87171, 25] was collected by H. T. Ferrar on the Discovery Expedition and briefly described by Prior (1907, p. 116). It was one of two specimens from Cape Adare that Prior suggested bore close relations with the kenytes, but he was then using 'kenyte' in a very wide sense, and actually the relationship of these rocks to the kenyte of Mount Erebus is not a close one.

Their nearest match among described volcanic rocks from South Victoria Land is to be found in some porphyritic rocks [B.M. 87171, 622] collected by H. T. Ferrar on the Discovery Expedition from debris heaps on Minna Bluff, south of Ross Island. A somewhat similar rock was recorded by Jensen from Cape Bird (1916, p. 119) [P341].

Ferrar's specimen 622 was described by G. T. Prior (1907, p. 119) and it has been further described in the earlier part of this report on the volcanic rocks of the Ross Archipelago (1954, p. 35). In thin section it is seen to differ in some respects from the rocks described above. Hornblende insets are absent, and the feldspar insets are uniformly rectangular in habit in the Minna Bluff rock.

There are two other porphyritic rocks among the erratics which are closely related to those just described. These are:

236. This has a few small insets of plagioclase as well as the abundant anorthoclase some of which are 5 mm. in length. Also frequent are small insets of a zoned pale purple-drab and pale green pyroxene and many insets of a dark pleochroic yellowish olive amphibole, partly resorbed. The groundmass is very fine-grained and consists of abundant pale green pleochroic pyroxene and some laths of feldspar with much colourless apparently isotropic interstitial material and small patches of highly birefringent fibres, like sericite, that may represent altered nepheline.

567. The last of these porphyritic erratics to be mentioned is of rather particular interest, as it is similar to a specimen collected on the Southern Cross Expedition [B.M. 85752, 24] described and figured by Prior and claimed by him to approach 'closely to the rocks from Mount Kenya to which Professor Gregory has given the name "kenyte" ' (1902, p. 329 and plate 53, fig. 4).

It is a clove-brown to dark olive porphyritic rock with an aphanitic groundmass containing many insets of anorthoclase up to 5 mm. in length, small insets of aegirine-augite and of serpentinized olivine, and small magnetite crystals in a fine-grained groundmass of alkali-feldspar laths, grains of nearly colourless pyroxene and of magnetite, with small amounts of colourless weakly birefringent base. It does not show any insets of nepheline, as the kenytes of Mount Kenya do, and its feldspars, both in size and habit, are quite unlike those in the Mount Erebus kenytes.

An analysis of this rock was published in the report on the collection of the Southern Cross Expedition by Prior (1902, p. 329) and this has been republished in H. S. Washington's tables of analyses of igneous rocks (1917, p. 339, no. 36) and named 'phonolite'. However, its norm shows 11·64 of normative quartz. A microchemical test for feldspathoids on the groundmass was negative, so it seems probable that this rock is wrongly classified as a phonolite. If it were found *in situ* it could be further investigated.

1246. This differs considerably from the trachytoid phonolites and porphyritic types just described but is doubtless related to them. It is an alkali-trachyte with small tabular insets of alkali-feldspar, probably anorthoclase, in a groundmass of feldspar laths with much colourless, birefringent, and turbid low-index interstitial material and scattered small crystals of opaque 'ore'. Brown-stained patches may result from altered pyroxenes or amphiboles but the rock is too much altered to make further study worth while. In addition to the feldspar insets there are rare micro-insets of a pale green pyroxene. This is not represented by other specimens from the plateau but many pebbles of this trachyte were collected on Ridley Beach (see below).

Basalts

There are only five basalts among the erratics collected on the plateau at the top of the Cape and they fall into two kinds.

One [592] resembles the black aphanitic basalt common among the pebbles on the beach. It carries neither insets nor micro-insets and consists of abundant long plagioclase laths arranged in parallel alinement in a dense and apparently partly glassy base.

This base consists of tiny microliths of feldspar, granules of augite, some translucent orange-brown pseudomorphs of olivine(?), 'dusty' magnetite and some isotropic material, nearly colourless but slightly turbid with minute inclusions.

The other basalt, represented by **591**, is a porphyritic olivine-basalt that must be closely related to the porphyritic olivine-basalt, Type C, of the rocks *in situ*, but the erratic has a holocrystalline and relatively lighter-coloured groundmass. A basalt of this kind [232] with a dark, partly glassy base was actually collected at 900 feet up on the Cape at the same time as the 'variolitic' phonolite (p. 124). It has been assumed that these specimens were *in situ*. If so the erratic [592] may not be far from its outcrop.

The insets in this basalt are olivine, colourless in thin section, and more abundant insets, and micro-insets, of augite sometimes enclosing small crystals of magnetite. In the groundmass there are abundant small crystals and granules of augite and many small crystals of magnetite, laths of plagioclase, and a colourless, apparently isotropic base (Plate 2, fig. 6).

A fine example of this kind of basalt, similar to 232, is **1231**, but it is not certain whether this was from the plateau or the beach. Another, **1243**, about which there is the same uncertainty of provenance, is also porphyritic with olivine insets but there are fewer insets than in the other specimens of this type and the texture of the groundmass is nearer that of a trachybasalt, of which there are examples among the pebbles described below.

V. PEBBLES FROM RIDLEY BEACH

Among the pebbles collected from Ridley Beach as representing types not seen *in situ* on the Cape are several kinds of phonolitic trachytes or trachytoid phonolites and of basaltic rock. Those of trachytoid phonolites and trachytes are similar or very closely related to some of the erratics collected on the plateau and these call for no further description. Among the basalts, however, are some that show differences from any of the erratics or *in situ* rocks and it seems worth while to record these briefly.

Black, aphanitic basalts, usually with many very small vesicles, are a common type [331, 343, 430, and 452]. Pebbles of this kind are found to be feldspar-rich and poor in olivine, and they all carry xenocrysts of partly or wholly resorbed brown hornblende. Under the microscope they show very abundant small slender laths of plagioclase with a tendency to parallel alinement in a dense base of dark brown glass with minute pyroxene grains and abundant 'dusty' magnetite. There are a few small insets and frequent micro-insets of augite, plagioclase, and colourless olivine, and micro-insets of magnetite and scattered xenocrysts of the resorbed brown hornblende. Apatite as stout prisms is a rather frequent accessory.

In one pebble that belongs to this type the groundmass is not glassy but consists of very abundant laths of plagioclase with some parallel alinement, granular pyroxene, and magnetite. Small patches of calcite presumably represent an altered groundmass constituent and a few small vesicles carry zeolites(?). The plagioclase of the microliths is labradorite.

Basalts similar to these, characterized by xenocrysts of brown hornblende, were described as 'basaltic andesite' by Edgeworth David and others (1896, p. 475 and plate 14, fig. 3) and by Prior from Cape Adare [B.M. 85752, 23] and Prior also described a similar basalt from the foot of Mount Terror. From the earlier collections specimens of similar basalts are also described from Possession Islands and from Coulman Island.

Fragments of the same kind of basalt are the main constituent in a pebble of agglomerate from the beach, so it is likely that they represent an early phase of the vulcanicity rather than very recent flows as Prior seems to suggest in the Southern Cross report.

There are other variants of these aphanitic hornblende-bearing basalts and some of these may be briefly mentioned, for example:

432. A basalt with frequent small insets of plagioclase and a few of augite and xenocrysts of hornblende in a fine-grained groundmass in which brown-stained grains probably represent olivine.

368. A basalt slightly coarser-grained than the others with fresh brown hornblende insets and much augite in the groundmass, which also contains small altered olivines, magnetite, and laths of plagioclase in a colourless base that may be alkali-feldspar or nepheline. Large apatite prisms are frequent. Amygdale-like bodies in these rocks are partly filled with calcite and partly with zeolite material.

372. Another aphanitic black basalt with rare glassy insets of augite is perhaps near to the trachybasalts. This carries many small insets of a plagioclase with refractive index only slightly above Canada balsam, occasional insets of augite, and some micro-insets of augite, iddingsite after olivine, and magnetite, and occasional relics of resorbed hornblende. The groundmass consists of abundant slender laths of plagioclase with tiny magnetite cubes, granular augite, brown altered olivine(?), and small amounts of a colourless birefringent base. Purplish inclusion-rich apatite is a notable accessory. This, like several others of the basalt pebbles, is traversed by pale buff-coloured veins which contain some phosphatic material. Borchgrevink collected a similar specimen [B.M. 85752, 29].

Two other pebbles are either trachybasalts or tephrites. One of these [433] with a few tabular insets of plagioclase and some of hornblende in a rather light-coloured, slate-grey groundmass is a very good example of the veining mentioned above. The central part of these veins in this rock is colourless and partly of quite low birefringence but the yellower parts of the vein and the margin of basalt permeated by the vein material show crystals that appear to be epidote. The feldspar in the groundmass of this rock has generally rather low extinction angles and the feldspar of the insets appears to be andesine.

Two others [333 and 360] which microchemical tests show have feldspathoids in their groundmass are fine-grained neutral grey rocks with small insets of augite and micro-insets of magnetite. One of them carries also small brown hornblendes and rather large apatite prisms are frequent in both. The plagioclase has low extinction angles in both these rocks.

VI. FRAGMENTS FROM THE MORAINES OF THE NEWNES AND MURRAY GLACIERS

The Newnes Glacier

On several occasions Priestley collected from the moraines of the Sir George Newnes Glacier at the end of Robertson Bay. Many of the specimens collected are of basalts and some are tuffs.

The basalts are all variants of olivine-basalts. They are probably closely related in composition to the basalts of Cape Adare but those examined do not match any of the types of olivine-basalt found *in situ* on the Cape, nor any of the basalts described from pebbles on Ridley Beach.

The basalts collected on the moraine can be grouped under slightly different headings according to their macroscopic appearance and their mineral composition but they probably do not differ much in composition and the whole collection may have come from rocks outcropping over a very limited area.

(*a*) The coarsest-grained and most easily recognizable variety among these moraine specimens is one that should perhaps be described as a dolerite on account of the grain-size of its groundmass constituents. Specimens of this group are characterized by very abundant small dark insets in a pale olive-grey groundmass. The insets look like fragments rather than definite crystals and the rock in consequence looks more like a tuff than a lava. The dark insets, 2 to 4 mm. across, consist of black to very dark green augite and smaller olivines. The augites occasionally show rectangular outlines but most of them are irregular in outline and the small olivines are rounded. In addition there are frequent insets of glassy feldspar up to 6 mm. across.

Thin sections show the abundant insets of olivine, augite, and labradorite. Extinction angles indicate a range in different specimens from An_{60} to An_{68}. Some of the augite insets and the olivines contain many inclusions of groundmass and none of the insets are very sharply bounded. This may indicate that aggregation of insets and crystallization of groundmass overlapped considerably. Needles of apatite are frequent in the feldspars. Magnetite occurs both as small crystals in the groundmass and as micro-insets and micro-ophitic plates. The groundmass itself consists of laths of labradorite, An_{55-62}, with magnetite, small nearly colourless augites, small olivines, and small amounts of alkali-feldspar interstitial to the feldspar laths. Biotite, as small flakes, is an accessory groundmass mineral. Pyroxene in the groundmass gave $c{:}\gamma = 46°$.

(*b*) Probably closely similar to the porphyritic, doleritic type just described are specimens characterized by few insets of glassy feldspar and abundant small dark greenish brown and yellowish green olivines and fewer, darker augites in a holocrystalline light olive-grey groundmass. Some vary a little in general colour to deep olive-grey and mouse-grey and a somewhat altered specimen [GN 1026] is brownish drab.

In thin section an outstanding character of these rocks is their amazing freshness and cleanness. The insets are colourless olivine, and olive-buff augite, and plagioclase. All three are rather abundant. The feldspars are labradorite, An_{60-65}, and the augites give extinction angle $c{:}\gamma$ up to 42°.

The groundmass consists of clear laths of labradorite, An_{57-65}, and many grains of pale yellow-bordered olivine with small olivines, augites, and magnetites between the feldspar laths. A few small flakes of biotite occasionally appear in the groundmass [GN 976]. Some sections show interstitial plates of simply twinned feldspar (oligoclase?).

An altered, brownish drab specimen [GN 1026] shows black-rimmed olivines and a general darkening (reddening) of the ferromagnesian minerals and of the magnetite in the groundmass.

Specimens of a slightly coarser-grained, aphyric, and slightly drusy rock [GN 945, 977] are doleritic variants of this type. They consist of pale yellowish olivine and stout laths of labradorite, augite, and magnetite, and biotite is a conspicuous constituent. In the drusy cavities are many tiny crystals of augite or olivine, magnetite, and feldspar.

(*c*) The third group of porphyritic basalts from the moraine are all very dark, olivaceous black to dark olive-grey, and carry a few insets of glassy feldspar and some, less noticeable, of olivine and augite. The feldspars are labradorite near An_{65}, and are short tabular in habit. The groundmass is very fine-grained aphanitic. Several of the specimens are vesicular. Some slightly altered specimens are brownish drab in colour.

The dense groundmass of these specimens is difficult to resolve. In a representative specimen [GN 1049] it is seen to contain abundant small laths of labradorite (An_{60-65}), yellow 'stained' olivine, minute prisms of colourless augite, and grains and cubes of magnetite. There is a small amount of interstitial base which, in one case [GN 1035], is colourless feldspathoid, but in other specimens [e.g. 1021] it is dark brown glass with inclusions of thin blades of opaque 'ore' and some acicular crystallites.

The altered brownish drab coloured examples of this group show in thin section an increasing opacity in the ferromagnesian constituents of the groundmass and the olivine insets have strong black borders and are completely filled with minute black inclusions which lie in a colourless birefringent base. In hand-specimen the olivines are quite black and opaque. This sort of alteration has been observed also in basalts from Cape Adare itself and was earlier described by Edgeworth David and others (see p. 119).

One specimen of this group contains a xenolith of a medium-grained sandstone recalling the xenoliths so frequent in the Cape Adare basalts.

In addition to the porphyritic basalts there are several variations of aphyric fine-grained olivine-basalts.

(*d*) Most widely represented is a basalt with few visible small olivine insets in an aphanitic neutral grey to dark neutral grey groundmass. Several of these basalts have very irregular flattened vesicles coloured on weathered surfaces citrine-drab and carrying numerous lustrous black semi-globules or botryoids of pitchy-black mineral (limonite) and some minute white crystals (perhaps feldspars weathering out) and glistening tiny crystals of magnetite, and some hematite. Several other rocks in this group are slightly porous in structure and these also show the bright metallic crystals in the cavities, while over the whole rock feldspar cleavages are clearly visible, indicating a holocrystalline and medium-grained texture. Several specimens of this group are slightly reddened and are brownish-drab in colour and these, in common with others altered in this way, show in thin section olivine micro-insets black rimmed and nearly opaque with inclusions of 'ore'.

A great many of the specimens of this type show the slight reddening in colour and in all these the olivines are altered and almost filled with the minute black inclusions and the ferromagnesian minerals are opaque. A fresher example of the group [GN 938] shows micro-insets of pale yellowish olivine and very abundant plagioclase present both as micro-insets and as small laths as well as in the groundmass. Extinction angles in the micro-insets indicate basic labradorite near to bytownite, but the groundmass microliths are less basic labradorite, in one specimen [GN 932] near An_{50}. The very fine-grained groundmass consists of the plagioclase microliths with much granular augite, probably olivine, and much magnetite as very small grains. Some sections [GN 932] show small amounts of interstitial alkali-feldspar.

One specimen of this kind [GN 934] is much altered, the augite appearing yellow like epidote and the olivine red-brown in the thin section. It may have been a xenolith from a later lava.

(*e*) Represented by only two specimens [GN 943, 1002] is a dense, aphanitic olivaceous black to iron-grey olivine-basalt that carries small amounts of accessory biotite. It has small insets and micro-insets of nearly colourless olivines with brown borders, and many flakes of brown biotite and abundant small micro-insets of plagioclase in a very fine-grained groundmass. The plagioclase of the micro-insets is basic labradorite, An_{65-70}.

The biotite has pleochroism, ochraceous orange to colourless, and resembles in colour the biotite in some nepheline-basalts. The groundmass consists of microliths of labradorite (near An_{63}) with granular augite and magnetite between the feldspars. One section showed small amounts of a colourless interstitial base.

(*f*) Another variety is an aphanitic, olivaceous black, very fine-grained basalt consisting of small micro-insets of olivine and plagioclase in a very dense groundmass of slender laths and crystallites of feldspar, augite, and much dusty magnetite [927, 977]. One rock of this kind contains a large xenocryst 15 mm. across, of glassy feldspar

[GN 926]. There are several specimens of this kind varying a little in the size of olivines and feldspars and in the grain-size of the groundmass [GN 1034, 1066].

(*g*) A vesicular aphanitic olivine-basalt with small insets and micro-insets of very pale yellow, nearly colourless, olivines and occasional small insets of pale buff augite has a dark groundmass consisting mainly of closely packed stoutish laths of labradorite (An_{55-60}). Between the feldspar is fine-grained granular augite, perhaps a little olivine, and much opaque 'ore' [GN 991]. The colour is deep neutral grey and the well-rounded vesicles are quite empty. Another specimen of the same type shows the reddening and characteristic alteration of olivine noted in so many of the specimens from this moraine [GN 1028].

(*h*) Several specimens of these reddened lavas are fine-grained, aphanitic, 'sandy' rocks with the characteristic brownish-drab colour. Under the microscope they show rare small insets of the altered, opaque olivine in a groundmass of tiny laths of labradorite (near An_{55}), with much opaque deep brown augite, doubtful olivine, and magnetite.

(*i*) Among all the specimens of volcanic rocks from this moraine there is only one representative of an olivine-free basalt and that occurs as subangular fragments, 1 cm. or more across, in a tuff [GN 955]. The thin section shows small insets and micro-insets of pale purple-drab, zoned augite in a very dense groundmass. The groundmass consists of microliths of plagioclase in a pale brown to fawn-coloured glass crowded with minute augites (perhaps some very small olivines) and magnetites. There is some occult feldspathoid in the glass base. Magnetite as small micro-insets is a notable accessory.

Several specimens were collected by Priestley to illustrate xenoliths in these lavas. They generally prove to be xenoliths of quartzose sedimentary rocks of the same kind as some rocks in the slate-greywacke formation of Robertson Bay [GN 944].

For the Newnes Glacier it only remains to record that there are two specimens of a friable orange-coloured palagonitic tuff. This is rather similar to the tuffs of the Murray Glacier moraines which are described below (p. 145).

THE MURRAY GLACIER

Specimens of volcanic rocks were collected from two different parts of the Murray Glacier. The greater number come from the southern lateral moraine but a dozen specimens of volcanic rocks are from morainic material in the so-called 'Dry Valley', a low plateau over a mile broad left by the glacier at a time when part of its ice poured out south of Duke of York Island. The main stream now goes out on to the Dugdale Ice Tongue on the other side of the island (see Priestley, 1923, pp. 15–16 and plates 14 and 15).

Of the specimens from this 'Dry Valley' moraine nine are of basalt-tuffs and one is an aphanitic black basalt. Volcanic rocks collected from the southern lateral moraine comprise fourteen specimens of the basalt-tuffs and ten of a porphyritic olivine-basalt with very fresh green olivine a conspicuous constituent. These basalts will now be described.

Olivine-basalts

The most common basalt from the lateral moraine is a grey chrysophyric basalt characterized by abundant insets of fresh olivine and augite. The general colour of these rocks varies from light greyish olive to mouse-grey, and in a few specimens deep brownish drab. The olivine insets are light yellowish olive to olive-yellow and, in some specimens, dark greenish black and iridescent. The olivines range up to 1 cm. in length and the augites are only a little less, 6 mm. The augites are dark greenish black. In thin section the olivines are almost colourless and the augites very pale olive-buff. The extinction angle in the augites, $c{:}\gamma$, is up to 47°.

In the specimens with the coarsest-grained, holocrystalline groundmass there are no crystals ranking as micro-insets and the groundmass consists of plagioclase laths and small olivine crystals, with smaller augites and crystal grains of opaque 'ore'. The texture is intergranular [1160]. From this type there are gradual variations of the groundmass texture and grain-size. For example in 1178 in addition to the abundant insets of olivine and augite there are a few micro-insets of plagioclase. The groundmass consists of plagioclase laths, small olivines and augites, and fairly abundant crystals and blades of opaque 'ore'. The fabric of this groundmass is seriate in the sense that while it contains abundant plagioclase laths, olivine, and augite of about 0·05 mm. average diameter, there is interstitial to this larger feldspar mesh a base of much smaller crystals of olivine and augite and plagioclase and crystals and blades of opaque 'ore'. The opaque crystals referred to as blades are probably ilmenite. In some sections dark patches mark concentrations of these bladed crystals in the groundmass [1159], and the blades are more abundant than the more quadrate crystal grains of magnetite(?).

Increase in the proportion of opaque 'ore', the bladed crystals generally predominating, leads to darker holocrystalline groundmass, and, in specimens with very fine-grained groundmass, the constituent minerals are hardly resolvable. Examples of actual glassy groundmass were not found nor was actual or occult feldspathoid detected.

Another variation is that specimens with very fine-grained dark base carry micro-insets of plagioclase and small crystals of olivine and augite as well as the very abundant larger insets of these minerals [1168, 1125]. The feldspar in these basalts is labradorite near An_{65}.

The only other basalts collected from the southern lateral moraine appear to be fragments from the basalt-tuffs. One of these [1131], a dark neutral grey aphanitic olivine-basalt, occurs as fragments in a smoke-grey fine-grained matrix of volcanic tuff.

Another basalt from the same moraine [1157], unfortunately only now represented by two thin sections, contains abundant short laths of plagioclase in a dense black glassy base. Half-hidden in the glass are small micro-insets of olivine and augite, both rather rare. It seems possible that this might resemble the black glassy basalt (Type A) *in situ* at Cape Adare. The sections of this rock are interesting as they show sections of small oval bodies that appear to be xenoliths, consisting now largely of sillimanite with a little dark green spinel, as small octahedra, and some feldspar at the margin of the xenolith.

A black aphanitic olivine-basalt [1066] from the moraine in the 'Dry Valley' is rather like one of the basalts, lettered (*f*), from the Newnes Glacier. This contains a white granular patch 2 cm. across with scattered white crystals around it.* The thin section of the basalt shows many micro-insets of colourless olivine and a few of augite in a very fine-grained groundmass of abundant plagioclase laths and small, brown-stained olivines in a fine-grained dark base. The base is rather variable in density and is roughly banded, some parts being lighter coloured than others. In the lighter parts it can be seen that the groundmass consists of very small microliths of feldspar among abundant small magnetite crystals and augite granules, with a few small olivines, recognizable as apart from the augite by the yellow colouration.

Palagonite-tuffs

The rocks referred to above as basalt-tuffs, of which some two dozen specimens were collected on the moraines of the Murray Glacier, all prove to be fairly typical palagonite-tuffs comparable with those from Sicily and from the Lahntal in Nassau.

Some of the tuffs are fairly even-grained and, in hand-specimens, appear as if bedded. Most of them contain abundant dark lapilli of various sizes ranging up to 2·5 cm. in length, but few actually measure as much as 0·5 cm. across and most of them are only 1 or 2 mm. in diameter. Most of the larger lapilli examined are of basalt but a few are of dark very compact sedimentary rocks.

Thin sections show that the sedimentary fragments, usually subangular in form, comprise fine-grained greywacke and micaceous siltstone. Occasionally the greywacke type contains wisps of chlorite, indicating a low grade of metamorphism. Such sediments might be derived from the Robertson Bay slate-greywacke formation.

As for the basalt lapilli, some are black glassy basalts with very small, altered olivines, augite and abundant plagioclase laths [1075]; others are glassy limburgitic basalts with many crystals of olivine and augite and relatively few of feldspar [1158]. These latter show very many small spherical vesicles and similar 'bubbles' are still more abundant in the small lapilli of pale yellow basalt-glass that actually constitute the greater part of all these tuffs. These glassy lapilli contain many feldspar microliths and abundant fragments of olivine and some of augite. The colour of the glass is pale yellow.

The great abundance of tiny 'bubbles' in the yellow glass is very remarkable. Their frequency is comparable with that of the bubbles in some of the silica-glasses of meteoritic origin, where they are taken to indicate very high fluidity and very rapid

* Fragments from this patch are plagioclase feldspar near oligoclase, but the inclusion was not fully investigated. The refractive indices are near 1·53.

cooling of a frothy glass. Some of these little vesicles in the lapilli are empty but some are filled with clear colourless carbonate and very many are either lined or filled with a slightly turbid, isotropic material a little darker in colour than the surrounding glass. This material often shows concentric arrangement and there are traces of radial fibrous structure in the outer lining.

The matrix of most of these tuffs consists of comminuted glass and fragments of augite and of olivine crystals. Sometimes the glass of the matrix seems to merge with that of the lapilli themselves. In one specimen [1060] the matrix is clear, partly granular calcite and the lapilli, all very small, are almost all of the pale yellow glass. Only a few are of black glassy basalt, and sedimentary fragments seem to be rare.*

One rounded basalt fragment [1134] is an amygdaloidal very fine-grained olivine-basalt in which all the abundant vesicles are filled with carbonate. In many vesicles the carbonate has a radial structure and sometimes prismatic habit suggesting aragonite. Also parts of the vesicles are occupied by pinkish cinnamon isotropic material perhaps similar to that in the vesicles in the lapilli. It seems likely that this basalt is only one of the larger lapilli from the tuffs.

If found *in situ* much more time could be profitably spent in the study of these interesting palagonite-tuffs; indeed there is ample material for more work on the samples Priestley collected, but an end must here be made to this account of them.

VII. COMPARISON WITH VOLCANIC ROCKS FROM SOUTH VICTORIA LAND

Some of the basalts and some of the trachytoid phonolites found at Cape Adare show fairly close resemblances with rocks from other areas in South Victoria Land and from the off-shore islands.

Rocks from Possession Islands, which lie about 60 miles to the south of Cape Adare, were collected on the first voyage southward of Sir James Clarke Ross's Antarctic Expedition of 1839–43 and these were described by G. T. Prior (1899, p. 75). Others collected by C. E. Borchgrevink and Captain Jenssen in 1895 were described by Edgeworth David and others (1896, p. 484), and Prior (1902, p. 326) described the specimens collected on the Southern Cross Expedition in 1898. Some of the basalts *in situ* are similar to the porphyritic olivine-basalts with insets of augite and occasional brown hornblendes such as those described from the pseudo-cave on Cape Adare (p. 118).

A few specimens have been collected from Coulman Island, about 150 miles south

* Similar tuffs with very vesicular pale yellow basalt-glass lapilli in a calcareous cement are known from the volcano of Low Layton, west of Port Antonio, St. George's, Jamaica. According to Dr. C. T. Trechmann (A New Explanation of Mountain Uplift, 1955, p. 33), the Low Layton lava 'flowed out into a bed of one-time wet and sludgy Globigerina marls of late Miocene age'. It would be interesting to find under what conditions the calcareous palagonite-tuff was formed in the Cape Adare district.

from Cape Adare, and many pebbles were brought up in dredges off its shore. Little has been published about these specimens. Those collected by H. T. Ferrar, on 15 January 1902, 40 or 50 feet above their landing place at Cape Wadworth at the north end of the island are dense, aphanitic, black glassy basalts, or basanites. They are not of the same kind as any of the described basalts from Cape Adare. They are extremely fine-grained and contain abundant microliths of plagioclase and many small brown pseudomorphs after olivine, and small magnetites in a pale glassy base with minute blades and grains of opaque 'ore'. The HCl-etch solution test shows that feldspathoid is occult in the colourless base. These rocks [B.M. 87171, 75, 76, and 81] may be glassy equivalents of a basalt like the black basalts of Type A on Cape Adare.

Some of the dredged pebbles are very fine-grained aphanitic basaltic rocks and these also may resemble some Cape Adare basalts. Several other pebbles from dredges at depths between 8 and 15 fathoms off Cape Adare and about a mile west of Coulman Island are phonolitic trachytes or trachytoid phonolites bearing a general family likeness to the phonolitic rocks found as pebbles on Cape Adare beach, and some may compare with the trachytoid phonolite *in situ* there.

Admittedly there is ample room for more detailed work when more material is available but such comparisons as have been made are sufficient to confirm Priestley's description of Cape Adare (1923, p. 8) as 'the northward extension of the great volcanic series of rocks which appears to form the coast from Cape Phillips northwards along the mainland of South Victoria Land, and of which Coulman Island and Possession Islands form a part'.*

Looking further afield for comparisons, on Ross Island and the neighbouring smaller islands one finds that the trachytoid phonolite of Cape Adare [231], compares tolerably well with some variations of the trachytoid phonolite (Mount Terror type). Examples of such comparable types are specimens from the neighbourhood of Mount Terror and Cape Crozier [B.M. 87171, 243, and 251]† and other comparisons can be found among the trachytoid phonolites from Tent Island [D52E] and the Razorback Islands in the Dellbridge Group [B.M. 87171, 573 and D28E]. However, these lavas from the Dellbridge Group contain only a few micro-insets of pyroxene, hornblende insets are not much in evidence, and the proportion of dark minerals to light is high compared with the Cape Adare trachytoid phonolite.

The debris heap on Minna Bluff, about 50 miles to the south of Ross Island, provides another trachytoid phonolite [613] comparable with the one represented by many pebbles on Cape Adare beach (p. 138), and, as mentioned above (p. 136), another of the boulders from Minna Bluff [622] is somewhat similar to the porphyritic phonolite pebbles

* Cape Phillips is a little north of Coulman Island.

† It is interesting to note, *à propos* of the remarks above on Coulman Island, that Prior had noticed a close comparison between one of the Mount Terror phonolitic trachytes and one of the pebbles dredged off Cape Wadworth. He also compared basalts from Coulman Island with a 'hornblende-basalt' from Mount Terror (1907, p. 115, and plate 8, fig. 4).

from Cape Adare. Another comparison made above with a Cape Adare pebble is one of the rocks recorded by Jensen as 'trachyphonolite' from Cape Bird (1916, p. 119), and other comparisons might be found among Ferrar's specimens from Brown Island.

Again among the basalts some comparisons can be made between some of the hornblende-bearing basalts of Cape Crozier and from Cape Bird at the south end of Ross Island on the one hand, and some of the porphyritic olivine-basalts with hornblende from Cape Adare on the other.

The general characters of these basalts from Cape Crozier and Cape Bird were described briefly in the report on the volcanic rocks of the Ross Archipelago (1954, p. 81). It should be noted that many of the 'hornblende-basalts' from Cape Bird described by H. I. Jensen (1916, p. 121) have insets of labradorite as well as of augite, and moreover they show few or none of olivine.

Among the basalts from Hut Point Peninsula on Ross Island several of the olivine-basalts with small insets of augite and olivine (Campbell Smith, 1954, p. 76) are closely allied to the porphyritic olivine-basalts of Cape Adare, and also some of the Hut Point basalts of the type described by Prior (1907, p. 102) as 'hornblende-basalts' are similar to some of the Cape Adare hornblende-bearing types. The general impression one gets by comparing the olivine-basalts of the two areas is that the Hut Point basalts all contain more abundant olivine insets than any of those from Cape Adare.

Such comparisons as have been made above would have more force were they backed by chemical analyses and by more detailed descriptions of the individual specimens described. However, perhaps sufficient resemblances have been established to suggest a relationship between the Cape Adare lavas and some of the volcanic rocks from the outlying parts of the Ross Island coast, though not with known volcanics from the main central mass around Mount Erebus.

VIII. LIST OF REFERENCES

BAYLEY, W. S. 1892. Eleolite-syenite of Litchfield, Maine. Bull. Geol. Soc. Amer., vol. 3, pp. 231–252.

BORCHGREVINK, Carstens. 1901. First on the Antarctic Continent. London, 8vo.

BRAUNS, R., and UHLIG, J. 1913. Cancrinit- und nephelinführende Auswürflinge aus dem Laacher Seegebiet. Neues Jahrb. f. Min., Beil.-Band 35, pp. 119–220.

DAVID, T. W. Edgeworth, SMEETH, W. F., and SCHOFIELD, J. A. 1896. Notes on Antarctic rocks collected by Mr. C. E. Borchgrevink. Journ. & Proc. Roy. Soc. N.S.W. (for 1895), vol. 29, pp. 461–492.

DES CLOISEAUX, A. 1862. Manuel de Minèralogie, vol. 1, p. 330.

ESENWEIN, P. 1929. Zur Petrographie der Azoren. Zeits. f. Vulkanol., vol. 12, pp. 108–227.

FERRAR, H. T. 1907. Report on the field-geology of the region explored during the 'Discovery' Antarctic Expedition 1901–1904. National Antarctic Expedition 1901–1904. Natural History, vol. 1: Geology (Field-geology: Petrography), pp. 1–100.

JENSEN, H. I. 1916. Report on the petrology of the alkaline rocks of Mount Erebus, Antarctica. British Antarctic Expedition 1907–9. Reports of the Scientific Investigations. Geology, vol. 2: Contributions to the Palæontology and Petrology of South Victoria Land, pp. 93–128.

MOUNTAIN, E. D. 1925. Potash-oligoclase from Mt. Erebus, Antarctica, and anorthoclase from Mt. Kenya, East Africa. Min. Mag., vol. 20, pp. 331–345.

MUIR, I. D., and TILLEY, C. E. 1957. Contributions to the petrology of Hawaiian basalts. I. The picrite-basalts of Kilauea. Amer. Journ. Sci., vol. 255, pp. 241–253.

MULHEIMS, A. 1888. Ueber eine neue Art der Axenwinkelmessung und über die Bestimmung von Brechungsexponenten nach der Methode der Totalreflexion. Zeits. Kryst., 1888, vol. 14, pp. 202–236.

MÜGGE, O. 1925. Mikroskopische Physiographie ... (von H. Rosenbusch), vol. 1, 2nd half, p. 666.

OSANN, A. 1888. Ueber Sanidinite von Sao Miguel. Neues Jahrb. f. Min., pp. 117–130.

PRIESTLEY, R. E. 1914. Antarctic Adventure. London, 8vo.

—— 1923. Physiography (Robertson Bay and Terra Nova Bay Regions). British (Terra Nova) Antarctic Expedition 1910–13.

PRIOR, G. T. 1899. Petrographical notes on the rock-specimens collected in Antarctic Regions during the voyage of H.M.S. *Erebus* and *Terror* under Sir James Clark Ross, in 1839–43. Min. Mag., vol. 12, pp. 69–91.

—— 1902. Report on the rock-specimens collected by the '*Southern Cross*' Antarctic Expedition. *In* Report on the collections of Natural History made in the Antarctic Regions during the voyage of the "*Southern Cross*", pp. 321–332.

—— 1907. Report on the rock-specimens collected on the 'Discovery' Antarctic Expedition 1901–4. National Antarctic Expedition 1901–4. Natural History, vol. 1: Geology (Field-geology: Petrography), pp. 101–140.

QUENSEL, P. 1914. The alkaline rocks of Almunge. Bull. Geol. Inst. Univ. Upsala, vol. 12, pp. 129–200.

RASTALL, R. H., and PRIESTLEY, R. E. 1921. The slate-greywacke formation of Robertson Bay. *In* The Sedimentary Rocks of South Victoria Land. British Antarctic (Terra Nova) Expedition 1910. Natural History Report. Geology, vol. 1, pp. 121–129.

SPENCER, E. 1937. The potash-soda felspars. I. Thermal stability. Min. Mag., vol. 24, pp. 453–494.

SMITH, W. Campbell. 1924. The plutonic and hypabyssal rocks of South Victoria Land. Brit. Ant. (Terra Nova) Exp. 1910. Nat. Hist. Rep. Geology, vol. 1, pp. 167–227.

—— 1954. The volcanic rocks of the Ross Archipelago. Brit. Ant. (Terra Nova) Exp. 1910. Nat. Hist. Rep. Geology, vol. 2, pp. 1–107.

THOMSON, J. Allan. 1916. Report on the inclusions of the volcanic rocks of the Ross Archipelago. Brit. Ant. Exp. 1907–9. Reports on the Scientific Investigations. Geology, vol. 2, pp. 131–148.

TUTTLE, O. F. 1952. Optical studies on alkali feldspars. Amer. Journ. Sci., Bowen Volume, pp. 553–567.

WASHINGTON, H. S. 1917. Chemical analyses of igneous rocks. U.S. Geol. Surv., Prof. Paper 99, 1201 pp.

WOOLNOUGH, W. G. 1916. Petrological notes on some of the erratics collected at Cape Royds. Brit. Ant. Exp. 1907–9. Reports on the Scientific Investigations. Geology, vol. 2, pp. 169–186.

EXPLANATIONS OF PLATES

PLATE I

FIG. 1. Cliff at the northern end of Cape Adare. The boulder-bearing agglomerate is in the centre (p. 125).

FIG. 2. The boulder-bearing agglomerate at Cape Adare (p. 125).

FIG. 3. The beach platform under Cape Adare. Part of Ridley Beach is seen beyond the end of the terrace.

FIG. 4. Weathered 'variolitic' phonolite, Cape Adare (p. 124). Photographs by Staff-Surgeon G. Murray Levick.

PLATE II

FIG. 1. Black glassy olivine-basalt with abundant plagioclase laths. From exposure 100 yards N. of the northern limit of snowdrift, Cape Adare. [432] ×20 (p. 116)

FIG. 2. Dark grey holocrystalline basalt (Type B). From bluff near end of upper beach platform, Cape Adare. [391] ×20 (p. 118)

FIG. 3. Contact of basalt (Type B) and xenolith of sedimentary rock. From bluff near end of upper beach platform. Abundant quartz grains in the xenolith and at the edge. The white space in the basalt at the lower end of the figure is a hole in the slide. [398] ×20 (p. 121)

FIG. 4. Xenolith in basalt (Type B) showing feldspar laths near the margin (left edge of the figure), small-scale perlitic cracks in clear glass with crystallites, passing into more turbid glass towards the interior of the xenolith. From the same exposure. [398] ×20 (p. 121)

FIG. 5. Part of the same xenolith in basalt showing the rod-like bodies rich in hypersthene and with fringes of crystals of cordierite. Many vesicles in the glass. ×20 (p. 122)

FIG. 6. Porphyritic olivine-basalt (Type C). From 900 feet above sea-level on Cape Adare. [232] ×20 (pp. 119 and 138)

PLATE III

FIG. 1. Alkali-trachyte with interstitial sodalite. Pebble from Ridley Beach, Cape Adare. [370] ×20 (p. 136)

FIG. 2. Olivine insets rimmed by green pyroxene in the alkali-trachyte of fig. 1. [370] ×20 (p. 136)

FIG. 3. Sanidinite. A small boulder in the agglomerate on the northern face of the cliff at Cape Adare. Aegirine, dark with a good cleavage. The amphibole and magnetite are both appearing opaque, black, in the figure. The feldspar is anorthoclase. [686] Crossed polaroids. ×20 (p. 131)

FIG. 4. Sodalite-trachyte. A boulder in the agglomerate on the northern face of the cliff, Cape Adare. [670] Crossed polaroids. ×20 (p. 127)

FIG. 5. Sodalite-trachyte. A boulder from the agglomerate on the northern face of the cliff, Cape Adare. [700]. Insets of anorthoclase and olivine crystals with a rim of dark green pyroxene. Crossed polaroids. ×20 (p. 128)

Fig. 1. Cliff at the northern end of Cape Adare. The boulder-bearing agglomerate is in the centre.

Fig. 2. The boulder-bearing agglomerate at Cape Adare.

Fig. 3. The beach platform under Cape Adare. Part of Ridley Beach is seen beyond the end of the terrace.

Fig. 4. Weathered 'varioloitic' phonolite, Cape Adare.

Photographs by Staff-Surgeon G. Murray Levick.

Fig. 1

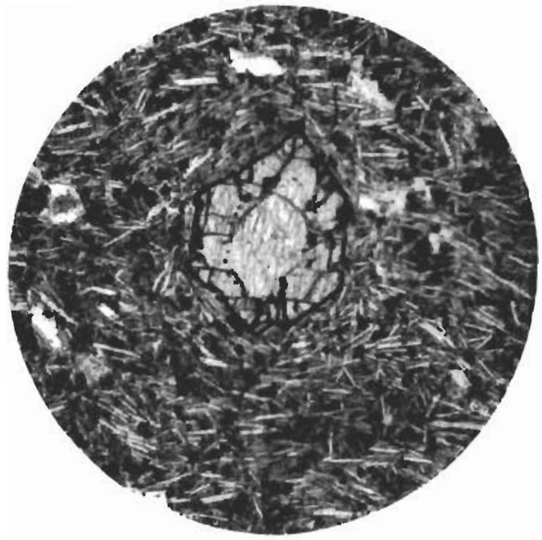

Fig. 2

Fig. 3

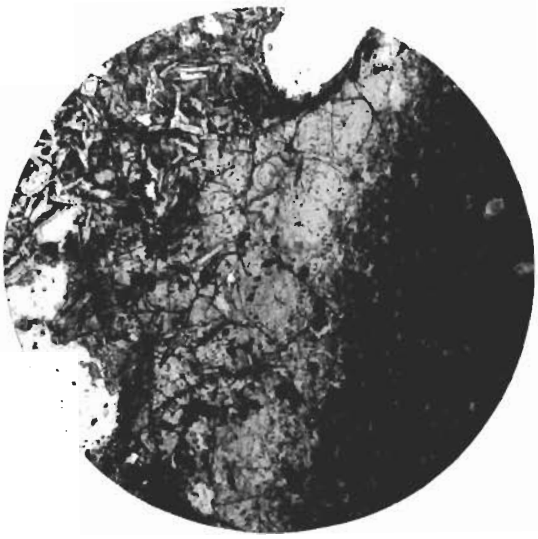

Fig. 4

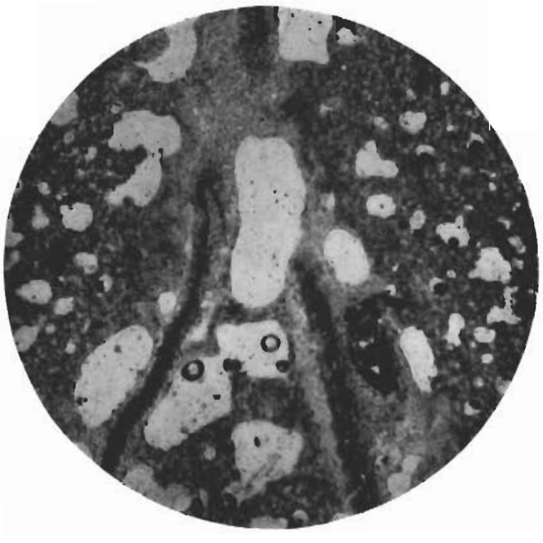

Fig. 5

Fig. 6

B. M. (Nat. Hist.), photo.

OLIVINE-BASALTS AND INCLUDED XENOLITHS
FROM CAPE ADARE

Fig. 1

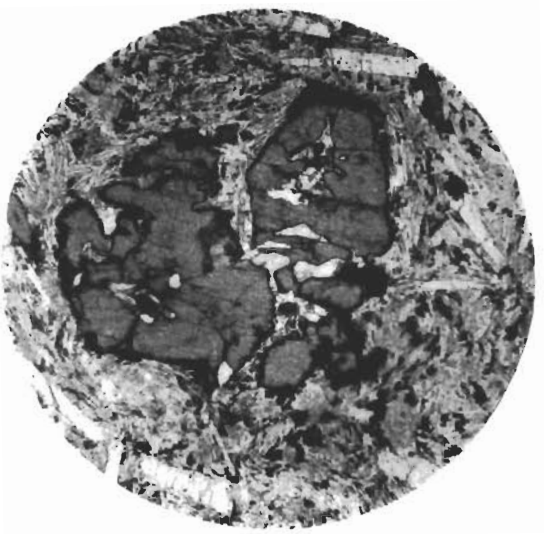

Fig. 2

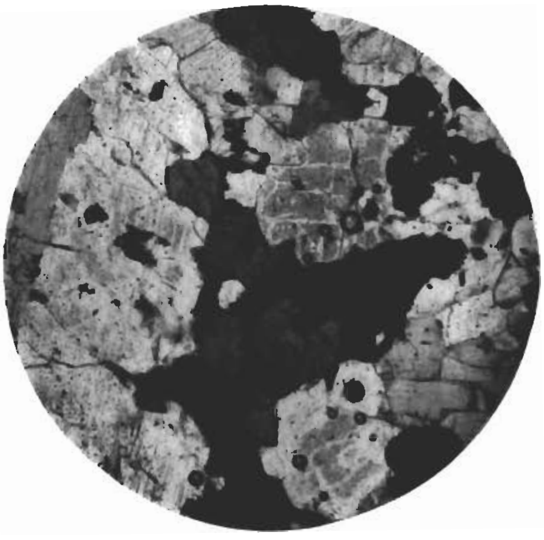

Fig. 3

Fig. 4

Fig. 5

B. M. (Nat. Hist.), photo.

ALKALI-TRACHYTES, SODALITE-TRACHYTES, AND SANIDINITE FROM CAPE ADARE