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VOLCANIC ROCKS OF CAPE ADARE
AND ERRATICS FROM
TERRA NOVA BAY REGION, ETC.

BY

W. CAMPBELL SMITH

WITH ONE FIGURE IN THE TEXT AND ONE PLATE

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I. CHEMICAL COMPOSITION OF VOLCANIC ROCKS OF CAPE ADARE

Chemical analyses have been made of seven of the rocks from Cape Adare described in the previous number of these reports. Three are of basalts, three of phonolites, and one of a sandinite from the boulder-bearing agglomerate on the northern face of the cliff at Cape Adare. These analyses have been made by Mr. D. I. Bothwell in the Department of Mineralogy, British Museum (Natural History). They were not available when the petrographical descriptions of the rocks were written, and, in the light of the results of the analyses, some comments on and amendments to those descriptions are now called for. The analyses are tabulated in columns, 33 to 40 of Tables VIII and IX, and X and subsequent tables give the C.I.P.W. norms, the cation per cent composition, and 'basis' of Nigghi and Burri in conformity with the tables in No. 1 of this volume in which the volcanic rocks of the Ross Archipelago are described. The 'Nigghi values' are tabulated in Table XII (p.165).

OLIVINE-BASALTS

On the basis of their characters as seen in hand-specimens and thin sections the Cape Adare basalts were divided into three types: A. Black, glassy, aphanitic olivine-basalt; B. Dark grey, holocrystalline olivine-basalt; and C. Porphyritic olivine-basalt with insets of augite and olivine.

The first point that emerges from a consideration of the analyses of the three olivine-basalts is the close similarity in composition between Types A and C (Nos. 432 and 245). The two types were distinguished mainly on account of the differences in fabric, Type A (p. 115) being compact and aphanitic, with a partly glassy groundmass, and Type C (p. 118) being porphyritic, with insets of augite and olivine, and occasional xenocrysts of brown hornblende, in a dense, black groundmass with glassy lustre. The analyses show that in chemical composition these two types are very similar. The normative composition also is very similar. The percentage of femic minerals is a little higher in Type C. The normative plagioclase in Type A (432) is An_{54} , in Type C (245) An_{56} , or and *ne* are both slightly higher in Type A than in Type C.

Compared with chemical analyses of other South Victoria Land basalts the closest match is presented by a basalt from Sulphur Cones, Hut Point Peninsula, described by Prior as "hornblende-basalt" [B.M. 87171, 385] and re-described in the preceding number of this volume (p. 79). In fact the two rocks are not closely alike in mineral composition, and the closest matches among the Ross Island basalts for the Cape Adare Types A and C seem to be the basalts of Cape Barne,

described in the first place by Jensen from specimens collected on the British Antarctic Expedition, 1907-9, and re-described (p. 86) with an analysis by D. I. Bothwell (p. 99, No. 26a) from material collected by Frank Debenham on the Terra Nova Expedition.

The analysis of the Type B basalt (No. 392) shows slightly lower alkalis than Types A and C but the more striking differences are a high content of H₂O lost above 110°C. and the reversal of the Fe₂O₃:FeO relations, the Fe₂O₃ being in excess of FeO. This and the lower alkali-content induce notable differences in the calculated norms (Table VIIIa), but in the 'Niggli values' the principal differences are the much higher *si*, compared with the *si* for Types A and C.

Plotted on the diagram based on variation of 'Niggli values' with *si* (this volume No. 1, Fig. 5, p. 92) one finds Type B at *si* 110.5 coming very close to a Cape Barne basalt [D24R] while types A and C at *si* 102 and 97 respectively fall on either side of the position of Jensen's basalt from Cape Barne [J4] (except for the *fm* value), and equally close to Prior's 'hornblende-basalt' from Sulphur Cones referred to above. As has been remarked already this 'hornblende-basalt' does not resemble, either in hand-specimen or thin section, the Type A and C basalts, but, contrariwise, there is a fairly good resemblance between the ground-mass of Prior's 'hornblende-basalt' and that of the Type B olivine-basalt. It may be that the siliceous sedimentary xenoliths which the Type B basalt has partially digested has given the rock an abnormally high silica content and perhaps the high H₂O+110° and the oxidation of such a high proportion of the ferrous iron in this basalt may be other effects of the same cause. A similar suggestion was made to account for the unusual composition of the Mount Cis 'trachyte' (this volume, No. 1, p. 93).

A description by Edgeworth David, Smeeth and Schofield of a pebble of a porphyritic olivine-basalt collected by C. S. Borchgrevink from the beach at Cape Adare in 1895 makes it probable that this specimen, though evidently much weathered, is of a rock similar to the olivine-basalt Type C (see No. 2, p. 120). However, the analyses (op. cit. p. 121, col. 1) of Borchgrevink's specimens shows very much higher MgO and CaO and much lower alkalis than in either the Type C or the Types A and B analyses.

TABLE VIII. CHEMICAL ANALYSES, NORMS, ETC. OF OLIVINE-BASALTS

33. Olivine-basalt, A. "III.6".4.4. 100 yards N. of northern limit of snow drift on Cape Adare. D. I. Bothwell, anal. [432=B.M. 1953, 91, 4]
34. Olivine-basalt, B. II (III).5".3.4. Bluff near the end of upper beach platform, Cape Adare. D.I.Bothwell, anal. [392=B.M. 1953, 91, 40a].
35. Porphyritic Olivine-basalt, C. III.6.2(3).4. Cliff not far from Borchgrevink's Depot, Cape Adare. D. I. Bothwell, anal. [245=B.M. 1953, 91, 151].

In the π -k diagram (No. 1, fig. 7, p. 95) the points corresponding to Types A, C, and B (cols. 33, 35, and 34), fall (in that order) between No. 6, the trachytoid phonolite from Observation Hill, Ross Island, and No. 31 an olivine-basalt [D2F] from 'Black Hill' in the Ferrar Glacier region on the mainland.

The new analyses fill a gap in the series in this diagram and lie smoothly on a curve between the two points at its ends.

PHONOLITE AND TRACHYTOID PHONOLITES

The analysis given in column 36, Table IX, is of the remarkable phonolite with the 'variolitic structure' found at 900 feet above sea-level at Cape Adare [227]. This finds its nearest match among the analyses of volcanic rocks from South Victoria Land in the trachytoid phonolite [188] from Cape Crozier, analysed by G. T. Prior (No. 1, col. 3, Table Ia). Comparison of the two rocks shows, however, that they bear no resemblance to each other in mineral composition. Nothing comparable to this compact phonolite from Cape Adare has been described among the Ross Island volcanics, so for the present it stands alone.

The analysed specimen of the trachytoid phonolite [584] is an erratic from the plateau above Cape Adare. It is a rock of the same kind as one [231] collected at 900 feet above sea-level on the Cape and described in this volume (No. 2, p. 125). Its chemical analysis, given in column 37, Table IX, finds a tolerably close match in an analysis by Prior of a 'phonolitic trachyte' from Scott Island [B.M. 87171, 973] quoted in column 4, Table Ia (No. 1, p. 37).

By comparison the analysis of the Cape Adare trachytoid phonolite shows lower Al_2O_3 and FeO , but higher Fe_2O_3 and more H_2O lost above 110°C . The differences in the 'Niggli values' are in the same sense, that is lower *al* and *fm* for the trachytoid phonolite but also it has higher *alk*, 32.5 as against 30.⁽¹⁾

In thin section the Scott Island rock and the Cape Adare trachytoid phonolite appear to be roughly similar in mineral composition. Comparison suggests that there are more feldspar micro-insets in the Cape Adare rock, while in the Scott Island 'phonolitic trachyte' of Prior there is more brown hornblende and perhaps more magnetite (?), which occurs as occasional micro-insets as well as in the groundmass.

⁽¹⁾ The 'Niggli values', and also the other values, except the analysis and the C.I.P.W. norms given for the Scott Island phonolitic trachyte given in col. 4 of Tables Ic-f are incorrect. The correctly calculated Niggli values are given in Table XII and corrections have also been supplied on a sheet of Errata for No. 1. of this volume.

The Scott Island rock in hand-specimen is compact, fine-grained, deep olive-grey⁽¹⁾ in colour, and it breaks with an undulating platy fracture. The thin section shows frequent micro-insets of simply twinned alkali-feldspar and faintly purplish, green-rimmed pyroxene prisms, as well as a few brown amphiboles and magnetites (as already mentioned). These micro-insets lie in a ground-mass consisting of laths and plates of alkali-feldspar, with granules of a nearly colourless, or faintly yellow pyroxene and also plates of a pale green pyroxene, very small crystals of magnetite (?) and small areas of a colourless birefringent base that may be feldspathoid.

It is difficult to understand why H. S. Washington classified this analysis as 'trachydolerite' (1917, p. 573, No. 40),⁽²⁾ but he had only the analysis to go on as Prior had not published any detailed description of the rock. It is to remedy this position that the above brief description of the rock is included here.

The third analysis (No. 670, col. 38) is of one of the boulders of sodalite-trachyte from the 'agglomerate' on the northern face of Cape Adare, described in the preceding number of this volume (pp. 127-8). The analysed specimen is representative of the rocks there described, except that olivine, recorded as an occasional constituent in these rocks (p. 128), is very rare in the thin sections of the analysed specimen. Also it is evident from the low Cl' that sodalite forms only a small percentage of the mineral composition.

None of the analysed phonolitic trachytes from South Victoria Land are at all near this sodalite-trachyte in composition. In the variation diagram based on the 'Niggl' values⁽¹⁾ it falls, owing to its *si* value, near the two analysed Mt. Cis 'trachytes', but its other values do not fit in at all well with these. Comparing thin sections of the two rocks one notes that the Mount Cis trachyte contains fewer insets, its green pyroxene is relatively poorly developed, and the feldspar laths of the groundmass are much more slender and more closely packed. However, I have recorded probable sodalite, both as small colourless cubes (p. 24) and as interstitial material between the feldspars (p. 23) in the Mount Cis 'trachyte' which is another point of resemblance with the sodalite-trachytes. As remarked above (p. 25 and p. 93) the Mount Cis 'trachyte' analyses may have unusual composition owing to partial assimilation of so many inclusions of Beacon Sandstone in the 'trachyte', so that the *si* values may be relatively high. It is of interest to note a rather remarkably close similarity between the chemical analysis of the sodalite-trachyte [670] and that of the hedrumite from between Sundet and Delingsdal on Lake Åstum, east of Lougenthal, Hedrum,

(1) Names used for colours are based on 'Color standards and color nomenclature'. By R. Ridgway. Washington, 1912.
 (2) References given by date and page in parentheses refer to the list on p. 149 of No. 2 of this volume.

in the Oslo region, described by W. C. Brøgger⁽¹⁾. The modal mineral composition of the two rocks is also very similar but they differ notably in texture, the hedrumite, a dyke, being a medium- to coarse-grained rock with trachytic structure, whereas the sodalite-trachyte is fine-grained and porphyritic. This contains more nepheline than some hedrumites described by Brøgger. The mode calculated by Brøgger shows 7.3 per cent nepheline, and according to Johanssen 'the pyroxene is predominantly aegirite with subordinate aegirite-augite';⁽²⁾ also the brown mica, lepidomelane, the predominant coloured mineral in the Skirstad and Ostö hedrumites is very subordinate (3%) to the pyroxene.

TABLE IX. CHEMICAL ANALYSES, NORMS, ETC. OF PHONOLITES

36. Phonolite. 'II.6.1.4.
900 feet above sea-level, Cape Adare.
D. I. Bothwell, anal. [227=B.M. 1953, 91, 316].
37. Trachytoid phonolite. "II."6.1.4.
Erratic from plateau on the top of Cape Adare.
D. I. Bothwell, anal. [584=B.M. 1953, 90, 57].
38. Sodalite-trachyte. II'.(5)6.1'.4.
Boulder from the 'agglomerate' on northern face of cliff, Cape Adare.
D. I. Bothwell, anal. [670=B.M. 1953, 90, 82].

TABLE IX

<i>a</i>				<i>b</i>			
CHEMICAL ANALYSES				C.I.P.W. NORMS			
	36	37	38		36	37	38
SiO ₂	56.2	55.5	59.2	Q	—	—	—
TiO ₂	0.2	0.6	0.2	or	31.14	22.80	33.36
Al ₂ O ₃	18.7	18.2	17.5	ab	26.86	40.87	37.20
Fe ₂ O ₃	3.0	3.9	3.9	an	—	1.67	—
FeO	1.8	3.0	2.1	ne	21.51	15.05	11.64
MnO	0.2	0.2	0.2	hl	—	—	0.47
MgO	0.3	0.9	0.4	ac	8.78	—	7.39
CaO	1.6	3.6	1.6	ns	0.73	—	—
Na ₂ O	9.4	8.1	8.2	di	6.5	7.98	6.18
K ₂ O	5.3	3.9	5.6	wo	—	2.78	—
H ₂ O+	2.7	1.2	0.6	ol	0.51	—	0.35
H ₂ O—	0.3	0.3	0.1	mt	—	5.57	1.86
P ₂ O ₅	0.1	0.2	0.1	il	0.46	1.22	0.46
Cl'	—	—	0.3	ap	0.23	0.50	0.34
TOTALS	99.8	99.6	100.0				

⁽¹⁾ Brøgger (W. C.). Die Eruptivgesteine des Kristianiagebietes. III. Das Gangfolge des Laurdalits. 1898, pp. 185-6, and p. 192.

⁽²⁾ Johanssen (A.). A descriptive petrography of the igneous rocks. Vol. 4 (1938), p. 26.

TABLE IX (continued)

c				d			
CATION PER CENT				'BASIS'			
	36	37	38		36	37	38
SiO ₂	51.2	51	53.7	Cp	0.17	0.4	0.3
TiO ₂	0.16	0.44	0.2	Ru	0.16	0.4	0.2
Al ₂ O ₃	20	19.6	18.7	Kp	18.4	13.5	19.6
Fe ₂ O ₃	2.1	2.7	2.6	Ne	41.8	43.3	36.5
FeO	—	—	—	Ns	4.1	—	3.3
MnO	1.5	2.5	1.74	Cal	—	1	—
MgO	0.4	1.25	0.05	Cs	2.25	4.5	2.15
CaO	1.6	3.6	1.6	Fo	0.6	1.8	0.8
Na ₂ O	16.7	14.4	14.35	Fa	2.3	3.7	2.6
K ₂ O	6.1	4.5	6.5	Fs	3.1	4.0	3.9
H ₂ O+	—	—	—	Q	27.0	27.4	30.4
H ₂ O—	—	—	—	Q	27.1	27.6	30.6
∑P ₂ O ₅	0.08	0.16	0.1	L	60.5	58.5	56.5
TOTALS	99.8	100.15	99.5	M	12.4	14.1	12.85
	36	37	38	π	0	0.02	0
				γ	0.27	0.32	0.22

Two further analyses enable one to extend the variation diagram (this vol., No. 1, fig. 5) beyond the *si* values of the 'sodalite-trachyte' and the Mount Cis phonolitic trachyte. These are analyses of one of the sanidine blocks from the agglomerate on the north face of the cliff at Cape Adare described in the previous number of this volume (pp. 130-132), and a 'trachyte' collected at Cape Adare [from the beach?] by C. E. Borchgrevink in 1895 and described and analysed by Edgeworth David, Smeeth and Schofield (1896, pp. 473-4). The analyses of these two rocks are given in Table X and their calculated 'Niggli values' at the top of Table XII.

The description by Edgeworth David, Smeeth, and Schofield of the 'trachyte' is as follows:—

Trachyte (Nos. 1 and 2)

'Compact, greenish-grey in colour, somewhat fissile. Sp. gr. 2.49. Under the microscope the rock is seen to be composed principally of sanidine microites. There is a small proportion of lath-shaped triclinic microites and of crypto-crystalline interstitial material. The sanidines are apparently all tabular in form, some slices showing nothing but tabular sections while others yield only lath-shaped ones.

The ferromagnesian constituent is represented by an aegirine which is present in considerable quantity (probably nearly 25% of the whole bulk). It exhibits brownish-green to bluish-green pleochroism with a small extinction angle. It is uniformly distributed in minute angular patches moulded on the feldspars with here and there a tendency to an elongated prismatic habit. In places it shows ophitic structure on a small scale. The only porphyritic constituents are a few rounded grains of this same aegirine and a few large grains of magnetite.

As accessory constituents there are a number of minute flakes of a brown biotite, some needles of apatite included in the feldspars, a few zircons and a little magnetite."

Among the many pebbles collected from Ridley Beach (this volume, No. 2, p. 138) are two of phonolitic trachytes [355, 369] whose mineral composition and structure agrees fairly well with the above description of Borchgrevink's specimen, probably also a pebble picked up on the shore (op. cit. 1896, p. 468), but the high SiO_2 in the chemical analysis implies that in this case the rock is 'saturated' and nepheline is absent from the norm.

TABLE X. CHEMICAL ANALYSES, NORMS, ETC. OF SANIDINITE AND TRACHYTE
39. Sanidinite. (I)II.5.1.(3)4.

Boulder from the 'agglomerate' on northern face of cliff, Cape Adare.
D. I. Bothwell, anal. [686=B.M. 1953, 90(95)].

40. Trachyte, Edgeworth David, Smeeth and Schofield, 1896. Washington, 1917, p. 430.

Pebble collected by C. E. Borchgrevink, 1895, from the beach at Cape Adare. J. A. Schofield, anal.

TABLE X

<i>a</i> CHEMICAL ANALYSES			<i>b</i> C.I.P.W. NORMS		
	39	40		39	40
SiO_2	60.6	61.01	Q	—	0.84
TiO_2	0.5	—	or	31.9	31.14
Al_2O_3	17.3	16.62	ab	46.56	49.78
Fe_2O_3	1.9	3.55	an	1.12	3.34
FeO	4.3	2.81	ne	5.57	—
MnO	0.2	0.55	di	9.20*	6.63
MgO	0.4	0.06	wo	—	2.20
CaO	2.5	3.27	hy	—	—
Na_2O	6.7	5.92	en	—	—
K_2O	5.4	5.22	ol	1.74*	—
$\text{H}_2\text{O} + 110$	0.3	1.13	mt	2.76	5.10
H_2O —	0.2	—	il	0.9	—
P_2O_5	0.1	tr.	hm	—	—
Cl	0.03	tr.	ap	0.27	—
less O for Cl					
TOTAL	100.1	100.14			

The *di* has CaSiO_3 4.43 and MgSiO_3 1.0:
*the *ol* is fayalite, Fe_2SiO_4 .

TABLE X (continued)

c			d		
CATION PER CENT			'BASIS'		
SiO ₂	55.3	56.5	—	—	—
TiO ₂	0.33	n.d.	—	—	—
$\frac{1}{2}$ Al ₂ O ₃	18.58	18.15	32	19.8	—
$\frac{1}{2}$ Fe ₂ O ₃	1.35	2.45	—	—	—
FeO	3.24	2.17	—	—	—
MnO	0.15	0.44	2	—	—
MgO	0.54	0.11	3.9	3.9	—
CaO	2.45	3.23	0.02	3.3	—
$\frac{1}{2}$ Na ₂ O	11.85	10.6	3.3	3.3	—
$\frac{1}{2}$ K ₂ O	6.28	6.25	3.7	3.7	—
H ₂ O ⁺	—	—	36.2	36.2	—
H ₂ O ⁻	—	—	—	—	—
$\frac{1}{2}$ P ₂ O ₅	0.07	n.d.	—	—	—
TOTAL	100.14	99.90	100.02	100.02	—
SiO ₂	39	40	39	40	—
Cp	0.2	0.2	0.2	0.2	—
Ru	0.3	0.3	0.3	0.3	—
Kp	18.9	18.9	18.9	18.9	—
Ne	35.5	35.5	35.5	35.5	—
HI	0.1	0.1	0.1	0.1	—
CaI	0.7	0.7	0.7	0.7	—
Cs	3.3	3.3	3.3	3.3	—
Fe	0.8	0.8	0.8	0.8	—
Fa	4.9	4.9	4.9	4.9	—
Fs	2.0	2.0	2.0	2.0	—
Q	33.4	33.4	33.4	33.4	—
TOTAL	100.1	100.1	100.1	100.1	—
Q	33.4	33.4	33.4	33.4	—
L	55.1	55.1	55.1	55.1	—
M	11.5	11.5	11.5	11.5	—
π	0.013	0.013	0.013	0.013	—
γ	0.3	0.3	0.3	0.3	—

The sanidine [686], as remarked above, was described in the previous number of this volume, a chemical analysis of its feldspar was given (p. 131) and its composition and optical properties were there discussed. The accompanying minerals recorded were: "brown amphibole, green pyroxene, biotite, and some opaque 'ore'; and unidentified minerals perhaps representing altered canerinite appearing in some small interstitial area (footnote, p. 133). Since the publication of that description of the minerals further determinations of optical properties of the biotite and of the brown amphibole have been attempted with the following results. The biotite is biaxial with 2V at least 20°. The refractive index, γ is near 1.67. Comparable high values for γ are recorded for siderophyllite and also for several biotites with high FeO and low MgO. Larsen and Berman⁽¹⁾ quote one with FeO+Fe₂O₃ 38.4% having $\gamma=1.677$, while G. Schaubberger⁽²⁾ quotes an analysis for a mica, said to be from Brevik, as having γ 1.697, the FeO being 24.36% and Fe₂O₃ 16.48 with MgO 1.08.

(1) Larsen (Esper S.) and Berman (Harry). 1934. The microscopic determination of the non-opaque minerals. U.S. Geol. Surv. Bulletin 848, 1934, p. 238.
 (2) Schaubberger (G.). 1927. Biotit in tertiären Erupitivgesteinen Böhmens. Centr. f. Min., Abt. A., 1927, p. 103.