AGE AND PETROLOGY OF THE CORNWALLIS ISLAND GRANODIORITE

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ABSTRACT. A K-Ar age of 9·5 m. yr. obtained on a granodiorite from Cornwallis Island, Elephant and Clarence Islands group, makes it the youngest plutonic rock so far dated from the Scotia arc and Antarctic Peninsula region. The rock has a low potash/soda ratio in comparison with other granitic rocks of the Andean Intrusive Suite. K-Ar determinations on mica from a schist from nearby Elephant Island give an apparent age of 100 m. yr. This is likely to be an updated figure influenced by a thermal event with which the granodiorite may have been associated.

ELEPHANT ISLAND lies at the north-eastern end of the South Shetland Islands and is the largest of a group of islands which includes Clarence Island, Cornwallis Island and the smaller Gibbs Island group (Fig. 1).

The first geological observations were made by Wordie (1921) as a member of Shackleton's Antarctic expedition which took refuge on Elephant Island in 1916. The *Quest* expedition made rock collections on Elephant Island in 1922 (Douglas, 1923; Tilley, 1930) and there have been occasional landings in more recent years. Dalziel (1972) reported K-Ar whole-rock ages on four schists from Elephant Island. On the basis of these observations, the Elephant and Clarence Islands group was considered to be composed exclusively of metamorphic rocks, mostly schists and phyllites, with the exception of the dunite-serpentinite of Gibbs Island (Tyrrell, 1945, p. 84–86).

During the Joint Services Expedition to Elephant Island 1970–71, a "white biotite-granite" (granodiorite) was discovered on Cornwallis Island (Roxburgh and Burkitt, 1971, p. B2). The samples collected by the expedition form the subject of this account.

K-Ar AGE DETERMINATIONS

Results of K-Ar determinations made on the Cornwallis Island granodiorite and on mica separated from an Elephant Island schist are given in Table I. Potassium was determined by flame photometry, the quoted result being the average of three determinations. The argon was extracted by fusion *in vacuo* and measured by isotope dilution on a modified AEI MS10 mass spectrometer operated under static conditions and fitted with digital output (Rex and Dodson, 1970). The errors quoted are at the 95 per cent confidence limit and are determined from replicate analyses.

TABLE I. K-Ar DATA

Specimen	*Mineral analysed*	K (per cent)	*Radiogenic* ^{40}Ar (s.c.c./g. $\times 10^{-4}$)	*Radiogenic* ^{40}Ar (per cent)	*Age* (m. yr.)
Granodiorite (JSE2/106/6)	Biotite	7·91	0·0302 0·0298	51·4 60·8	9·6 9·4 } 9·5±0·4
Schist (JSE2/36/7)	Mica	7·05	0·2930 0·2842	66·6 87·6	101 98 } 100±4

$\lambda_\beta = 4{\cdot}72 \times 10^{-10}$ yr.$^{-1}$; $\lambda_e = 0{\cdot}584 \times 10^{-10}$ yr.$^{-1}$.
^{40}K $= 1{\cdot}19 \times 10^{-4}$ mole/mole K.

The K-Ar age of the granodiorite from Cornwallis Island of 9·5 m. yr. extends the range of ages on the Andean Intrusive Suite in the Antarctic Peninsula region. The youngest previously reported age (Rex, in press) was 49 m. yr. on the quartz-diorite from Port Lockroy. This can be compared with the new data from southern Chile (Halpern and Carlin, 1971), where the

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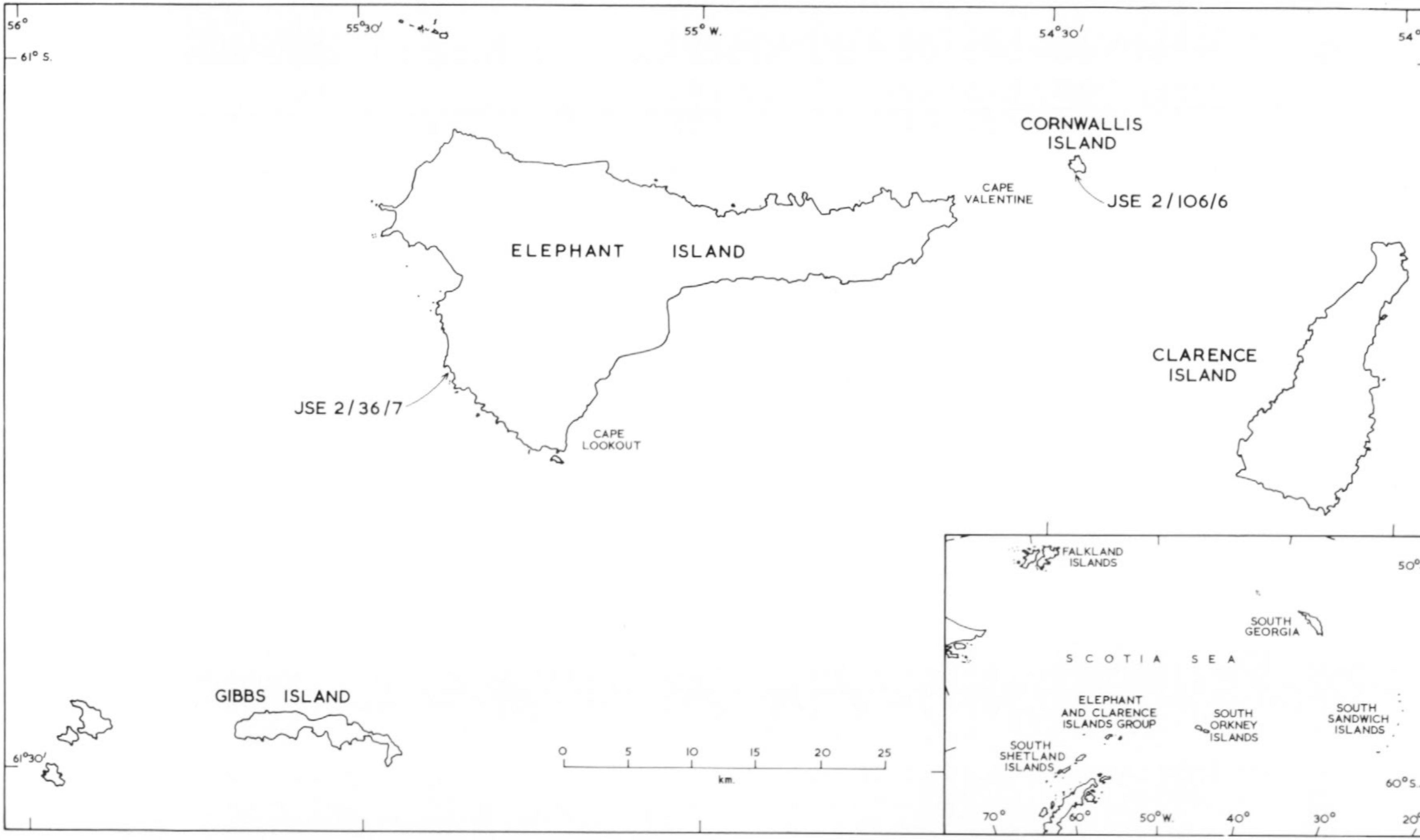

Fig. 1. Sketch map showing the location of Cornwallis Island, Elephant and Clarence Islands group, and the positions of collecting stations.

Cerro Payne quartz-diorite gives a Rb-Sr mineral age of 12 m. yr. From this and other evidence (Rex, in press; paper in preparation by M. Halpern), it seems that there has been virtually continuous plutonic igneous activity in the South American–Antarctic Peninsula region from the Jurassic until the late Tertiary.

The 100 m. yr. age obtained on the mica separated from a sample of schist from Elephant Island is in general agreement with the ages reported by Grikurov and others (1970) and Dalziel (1972). The metamorphic rocks of the South Shetland Islands have been compared with the South Orkney Islands schists and gniesses (Tyrrell, 1945; Dalziel, 1972). A Rb-Sr whole-rock isochron age of 300±50 m. yr. has been obtained by Rex on the schists of Signy Island which yield K-Ar mineral ages of 180–200 m. yr. (Miller, 1960; Rex, in press). Dalziel concluded that the Elephant Island schists had been updated by thermal events associated with the Andean orogeny. The true age of these and lithologically related schists in the Scotia arc will not be known for certain until more Rb-Sr whole-rock isochrons have been completed.

PETROGRAPHY

Granodiorite

The report by Roxburgh and Burkitt (1971) referred to a large outcrop of "white biotite-granite" on Cornwallis Island. It is a coarse-grained leucocratic rock with quartz, white feldspars and clusters of dark biotite readily identifiable in the hand specimen. A modal analysis of specimen JSE2/106/6 is given in Table II. The proportion of alkali feldspar was

TABLE II. MODAL ANALYSES

1		2	
Oligoclase	50·2	Albite	37·1
Quartz	33·0	Quartz	30·2
Biotite	11·1	Muscovite	25·3
Alkali feldspar	4·0	Chlorite	5·0
Muscovite	1·7	Garnet	1·3
Sphene	<1	Calcite	1·0
		Epidote	<1
		Graphite	<1

1. Granodiorite, Cornwallis Island (JSE2/106/6).
2. Quartz-albite-muscovite-schist, Elephant Island (JSE2/36/7).

determined after staining with sodium cobaltinitrite. The rock is classified as a granodiorite on the basis of the high ratio of plagioclase to alkali feldspar, associated with a high percentage of quartz. However, from the almost complete suppression of alkali feldspar together with the high SiO_2 and modal quartz, the name trondhjemite is also applicable.

The specimen has a hypidiomorphic texture dominated by subhedral plagioclases zoned largely within the range An_{32-20}. The cores of many of the oligoclase crystals show advanced saussuritization. The alkali feldspar (orthoclase) has crystallized at a late stage, tending to develop in poikilitic relationship to the earlier oligoclase (Fig. 2). Traces of alkali feldspar also occur as interstitial grains, as a marginal phase to some of the oligoclase crystals or as exsolved perthitic lamellae in the plagioclase. The biotite is partially altered to chlorite, and sphene is the only significant accessory mineral.

Quartz-albite-muscovite-schist

The granodiorite was probably intruded into phyllites and schists like those exposed on nearby Elephant Island. A modal analysis of the schist on which the K-Ar age was determined

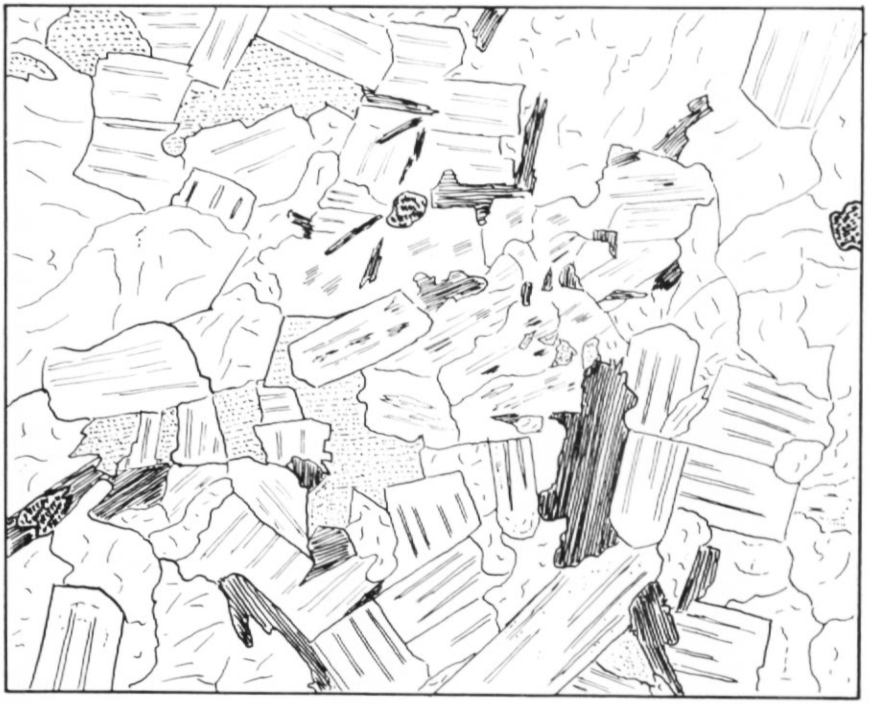

Fig. 2. Micrograph of the analysed granodiorite (JSE2/106/6) from Cornwallis Island (×8·5). Dominant plagioclase (oligoclase) shows twinning and partial alteration to sericite. Abundant quartz shows cracks. Alkali feldspar (light stipple) has a poikilitic habit. Biotite (lined) is the only dark mineral and sphene (heavy stipple) is the only accessory.

is given in Table II. It consists of porphyroblastic albite developed in bands of sutured quartz crystals flanked by trains of muscovite and chlorite. Minor constituents include garnet, calcite, epidote and graphite.

Geochemistry

Chemical analyses of the granodiorite and the schist are given in Table III. In each case, SiO_2 was determined gravimetrically, FeO by the dichromate method, Na_2O and K_2O by flame photometry, H_2O by the Penfield tube method and the remaining constituents by X-ray fluorescence. The analyses were made by D. Richardson and A. Gray.

Previous analyses of granitic rocks of the Andean Intrusive Suite (Adie, 1955, p. 24, table VIIa; Fleet, 1968, p. 33, table IV) show K_2O in excess of Na_2O. The Cornwallis Island granodiorite is conspicuously different from these in having a low K_2O/Na_2O ratio; the value is 0·46 as compared with an average of 1·16 in the analyses of Andean granites. Normative ratios of the Cornwallis Island granodiorite together with those of the Elephant Island schists are projected from the granodiorite system on to the plane Qz–Or–Ab for comparison with granitic rocks from the Antarctic Peninsula (Fig. 3).

The anomalous composition of the Cornwallis Island granodiorite in comparison with acid rocks of the Andean Intrusive Suite may reflect a change in tectonic environment or may simply mean that it evolved from a different source material. The quartz-albite-schists widely exposed in the Elephant and Clarence Islands group (Tyrrell, 1945, p. 87–88; Dalziel, 1972) might be considered as possible source material of an appropriate composition. The schists project in the same part of the Qz–Or–Ab–H_2O system as the granodiorite (Fig. 3). However, rocks of the composition of the schists could only have yielded melts of granodiorite composition with relatively high degrees of partial melting. Lower degrees of fusion in these rocks,

TABLE III. CHEMICAL ANALYSES

	1	2	3	4	5
SiO_2	72·15	73·44	73·83	66·31	71·80
TiO_2	0·21	0·22	0·15	0·69	tr
Al_2O_3	14·67	14·33	14·87	14·78	11·87
Fe_2O_3	0·47	0·52	0·95	0·76	2·21
FeO	1·60	1·18	0·95	4·16	2·30
MnO	0·07	0·02	0·05	0·11	0·45
MgO	0·63	0·21	0·29	1·51	1·94
CaO	3·00	2·13	0·59	3·06	3·02
Na_2O	3·91	3·09	3·91	3·27	3·27
K_2O	1·79	3·87	4·07	2·19	1·02
H_2O+	0·61	0·52	0·42	1·87	1·29
H_2O-	0·04	0·11	0·05	0·05	0·48
P_2O_5	0·06	0·29	0·03	0·15	0·16
CO_2	—	—	0·01	0·93	0·00
TOTAL	99·21	99·93	100·17	99·84	99·81
			C.I.P.W. NORMS		
Q	32·5	36·0	33·6	26·2	36·9
or	11·0	22·8	24·1	13·5	6·5
ab	36·0	26·2	33·0	31·0	30·5
an	14·5	8·6	2·7	16·0	15·0
cor	1·2	1·8	3·0	1·6	0·2
hy	3·8	1·9	1·5	9·8	8·4
mt	0·4	0·7	1·4	0·9	2·4
il	0·4	0·5	0·3	1·0	0·0
ap	0·2	0·7	0·1	0·2	0·2

tr Trace.

1. Granodiorite, Cornwallis Island (JSE2/106/6). (Anal. D. Richardson and A. Gray.)
2. Biotite-granite, Cape Roquemaurel, Trinity Peninsula (D.337.1). (From Adie, 1955, p. 24, table VIIa, No. 12.)
3. Adamellite, near Hektoria Glacier, Oscar II Coast (D.4630.1). (From Fleet, 1968, p. 33, table IV, No. 11.)
4. Quartz-albite-muscovite-schist, Elephant Island (JSE2/36/7). (Anal. D. Richardson and A. Gray.)
5. Garnet-albite-schist, Lookout Harbour, Elephant Island. (Anal. F. Herdsman; from Tyrrell, 1945, p. 87, table 6, No. 4.)

which have a significant content of normative anorthite, would have yielded aplitic melts (von Platen, 1965, p. 210). On the other hand, there is no reason to suppose that these schists, now exposed at the surface, necessarily existed at depth where the granodiorite magma was generated. There is also the question of an adequate heat source, a point on which there is no evidence. Though plausible on compositional grounds, there is therefore little else to support the idea that the Cornwallis Island rock represents an anatectic granodiorite derived by melting within the schists.

CONCLUSION

The granodiorite from Cornwallis Island is younger than any of the Andean intrusive rocks so far dated. It is chemically and mineralogically different from the older granitic rocks, the most significant features being a low K_2O/Na_2O ratio expressed modally in the low content of alkali feldspar.

The Elephant Island schists, supposedly equivalent to those of the South Orkney Islands, nevertheless have a younger apparent age (100 m. yr.).

The data are open to several interpretations but one possibility is that the granodiorite was formed as an anatectic magma by melting of relatively soda-rich greywacke or quartz-albite-schist source rocks. The emplacement of this magma or the thermal event it represented caused partial loss of argon from the country-rock schists and a reduction in their apparent age.

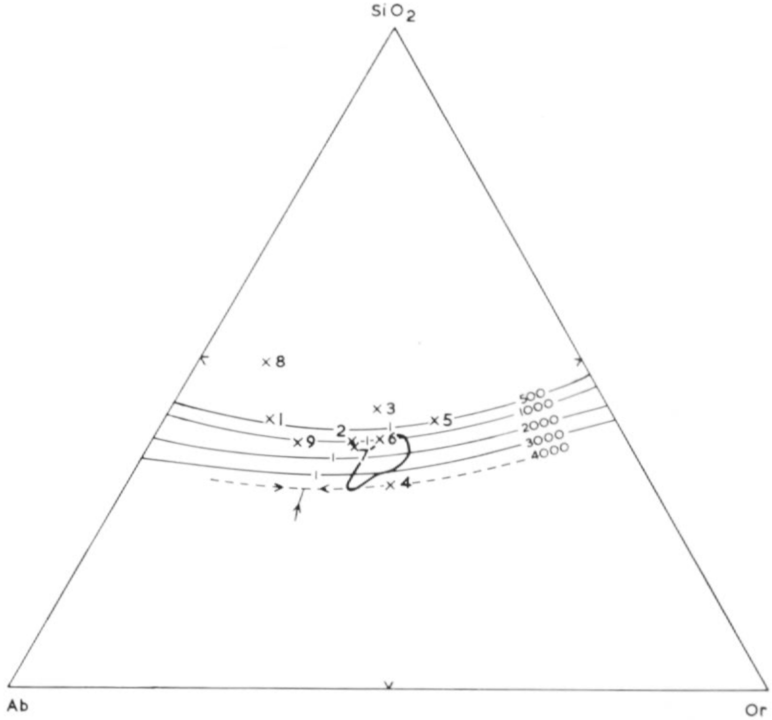

Fig. 3. Plot of the normative quartz–orthoclase–albite ratios of the Cornwallis Island granodiorite, granitic rocks of the Andean Intrusive Suite and two Elephant Island schists in the system $NaAlSi_3O_8$–$KAlSi_3O_8$–SiO_2–H_2O. Details of the system are from Tuttle and Bowen (1958, p. 75, fig. 38) and show positions of the quartz–feldspar boundary at 500–4,000 kg./cm.^{2} water-vapour pressure, together with isobaric minima for these pressures. The outline of the field of maximum concentration of granites is also shown. 1. Cornwallis Island granodiorite (JSE2/106/6); 2. and 3. Biotite-granites, Trinity Peninsula (D.375.2 and D.337.1) (Adie, 1955, p. 26); 4–7. Acid intrusives from the Oscar II Coast (D.4614.1, TL.34.1, D.4622.1 and D.4630.1) (Fleet, 1968, p. 33, table IV); 8. Garnet-albite-schist, Elephant Island (Tyrrell, 1945, p. 87, table 6); 9. Quartz-albite-muscovite-schist, Elephant Island (JSE2/36/7).
Note that the granodiorite and schist compositions represent projections on to this plane from within the granodiorite system (Qz–Ab–Or–An).

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