Late Archaean metamorphic Rb-Sr isochron ages from basic and ultrabasic rocks in the Bjørnesund – Ravns Storø region, southern West Greenland

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Introduction

The Archaean complex of South-West Greenland (Bridgwater *et al.*, 1976) consists largely of polyphase quartzo-feldspathic gneisses which intrude horizons of amphibolite and anorthosite with genetically and spatially associated ultramafic rocks and minor occurrences of meta-sedimentary material. In the Bjørnesund – Ravns Storø region (fig. 46) 150 km south of Godthåb the amphibolite units are structurally linked together and are considered to represent the same unit (Friend, 1975). The complex was variably metamorphosed to hornblende-granulite or amphibolite-facies conditions. This metamorphism accompanied three main phases of deformation within the region (Kalsbeek & Myers, 1973) and post-dated the formation of the precursors of the amphibolites.

Earlier isotopic work

Black *et al.* (1973) obtained a whole-rock $^{207}Pb/^{206}Pb$ isochron age of 2810±70 m.y. from six anorthosites and a single gneiss sample and suggested that the age was that of the regional granulite-facies metamorphism. Pidgeon *et al.* (1976) found that zircons from the Ilivertalik granite, a relatively young intrusive body about 50 km north of Bjørnesund, were discordant and had an upper intercept age of 2835±10 m.y. The authors interpreted this as the age of crystallisation of zircon during the emplacement of the granite in the waning stages of the granulite-facies event. Kalsbeek (1976) obtained a whole-rock Rb-Sr age of 2770±23 m.y. for both granulite- and amphibolite-facies samples of the Ilivertalik granite.

A Rb-Sr age of 2660±120 m.y. for the amphibolite-facies gneisses, tonalites and some of the constituent minerals has been interpreted as a late epidote-amphibolite facies metamorphism (Pidgeon & Hopgood, 1975).

Consideration of the age and initial ratios of all these rocks suggests that intrusion of their precursors may have been broadly contemporaneous with the polyphase intrusion of the precursors of the Nûk gneisses from the Godthåb – Sermilik area (Moorbath & Pankhurst, 1976).

Work on the supracrustal rocks in the Godthåb region has produced U-Pb ages between 2600 and 2900 m.y. interpreted as that of the metamorphism of the rocks (Baadsgaard, 1976).

K-Ar dating of the amphibolites in the vicinity of Ravns Storø (Larsen, 1966, 1971; Larsen & Møller, 1968) produced dates in the range 2200±160 m.y. to 2690±60 m.y. These are most likely to represent closure ages which post-date the main period of metamorphism.

Field evidence indicates that the amphibolites are the oldest recognisable material in this part of the Archaean craton (Friend, 1975: Bridgwater *et al.*, 1976). The present work was a pilot study to test the feasibility of using Rb-Sr whole-rock studies to establish the chronological history of the mafic and ultramafic rocks of the Fiskenæsset region.

Geological setting and sample description

The sampled amphibolites are a series of relatively unmigmatised, massive to schistose, mafic to ultramafic rocks in which primary structures and relict igneous textures are locally common (Table 9). Included are pillow lavas, agglomerates and gabbroic rocks and mafic dykes. Differing amounts of garnet in GGU 119822 and 119832 is a result of varying bulk-rock chemistry under amphibolite-facies conditions. GGU 129939 is a plutonic, gabbroic phase, while sample GGU 129999 was collected from a grey, garbenschiefer-textured metamorphosed mafic dyke which was intruded after the initial phase of deformation of the amphibolites. GGU 119881 is a representative of a series of leucocratic, anthophyllite-bearing schists, often containing both staurolite and cordierite (Friend, 1975), that outcrops along the south-eastern side of the Ravns Storø Belt. GGU 120386, 149371 and 149706 are from the margins of anorthosite horizons. Primary structures are extremely difficult to recognise but occasional pillow structures may be found at the northern localities (GGU 149371, 149706) where the intrusive relationships of the anorthosite into the amphibolites and ultramafic rocks are preserved. The ultramafic bodies at this locality also preserve exceptional, coarse-grained, unrecrystallised, igneous textures (Friend & Hughes, 1977). These bodies are normally enclosed by the amphibolite and are considered to be a part of the amphibolite unit, most probably tectonically introduced prior to the intrusion of the anorthosite complex. However, where they are in contact with and intruded by veins of anorthosite, mineral assemblages containing sapphirine, kornerupine, corundum, pargasitic amphibole and spinels of various compositions occur (Friend & Hughes, 1977). The analysed olivine, bronzite and phlogopite samples were collected from those areas of the ultramafic bodies which preserve the best igneous textures and mineralogy.

Analytical techniques and results

Olivine, orthopyroxene and phlogopite were separated from the ultramafic material by magnetic methods and by hand-picking. Only those grains which were completely free of inclusions and visible alteration were selected for analysis. The mineral samples were warmed several times in quartz-distilled water before further processing.

All samples were spiked with 99.8 % ^{84}Sr and 99.1 % ^{87}Rb spikes before being digested in HF/HNO_3. The amphibolites were processed in a conventional manner. The mineral samples were processed in the manner described by Burwell (1975). Procedural blank contributions to the amphibolite Rb and Sr values were negligible. Corrections for blank have been made to the olivine and orthopyroxene analyses: 7 % and 6 % respectively to both the Sr and $^{87}Sr/^{86}Sr$ values, 4 % and 2 % respectively to the Rb values.

Rb, Sr and $^{87}Sr/^{86}Sr$ analyses were produced by the modified AEI MS 5 at Leeds University. Reproducibility was checked periodically by analysis of the Eimer & Amend standard which gave an overall weighted mean of 0.7081 ± 0.0001 (2σ). All quoted $^{87}Sr/^{86}Sr$ values are normalised to $^{88}Sr/^{86}Sr = 8.3752$ and adjusted to the currently accepted value for Eimer & Amend $^{87}Sr/^{86}Sr$ (0.7080).

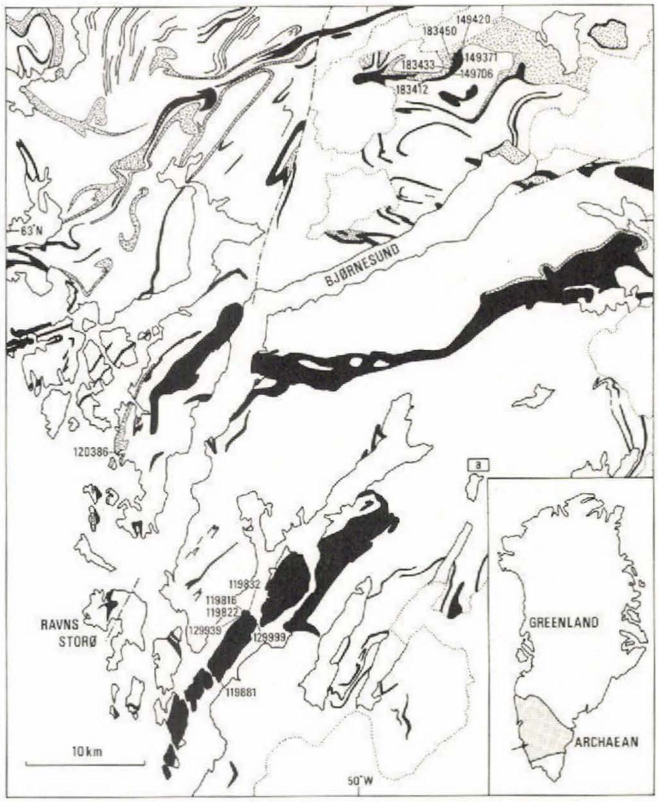

Fig. 46. Sketch map of the geology of the Bjørnesund – Ravns Storø region (after *Rapp. Grønlands geol Unders.* **73**, 1976, Pl. 1). Black: amphibolites and ultramafic rocks; stippled: anorthosites; white: gneiss complex. For descriptions of samples see Tables 9 and 10. The gneisses and tonalites analysed by Pidgeon & Hopgood (1975) were collected from the area marked 'a'.

Results

Rb, Sr and $^{87}Sr/^{86}Sr$ analyses of the amphibolites are presented in Table 9 and plotted on an isochron diagram (fig. 47). In calculating the age (2620±250 m.y.) and initial ratio (0.7014±0.0003) the data from sample GGU 119881 have been excluded. Although the value of the mean square of weighted deviates (MSWD) exceeds unity (1.4) it is not clear whether the scatter of these data exceeds that to be expected from experimental error alone (Brooks *et al.*, 1972) since the experimental error parameters are not sufficiently well defined.

The analyses of Rb, Sr and $^{87}Sr/^{86}Sr$ in the minerals of the ultramafic samples are presented in Table 10 and plotted in fig. 48. The phlogopite data define an isochron (MSWD = 0.05) with an age (2710±180 m.y.) and an initial ratio (0.705±0.065) not significantly different from those given by the amphibolites. Because of uncertainty in the blank corrections to the olivine and orthopyroxene analyses, these have not been included in the calculation of the mineral age.

Table 9. Rb-Sr isotopic analyses of amphibolites, Bjørnesund – Ravns Storø region

G G U sample no.	Sample details and location	*Rb(ppm)	*Sr(ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Abs. std. error (2σ)
119816	Homogeneous foliated amphibolite Hb, Pl, Qz, Sph, Ap, Ore, (Chl, Ep, Cc). N. end of Ikatup nunâ, Ravns Storø.	1.4	125	0.0320	0.7024	0.0003
119822	Homogeneous foliated garnet amphibolite. Hb, Pl, Ga, Qz, Sph, Ore, (Ep). N. Ikatup nunâ, Ravns Storø.	4.9	144	0.0981	0.7053	0.0002
119832	Homogeneous garnet amphibolite. Hb, Pl, Ga, Qz, Ore, (Ap). N. Ikatup nunâ, Ravns Storø.	0.66	7.1	0.2719	0.7114	0.0002
119881	Foliated leucocratic amphibolite. Ant, Bi, Pl, Chl, Rt, (Qz, Ap). S.E. Ikatup nunâ, Ravns Storø.	5.7 6.2	155 159	0.1075 0.1124	0.7078 0.7075	0.0002 0.0001
120386	Homogeneous amphibolite. Hb, Pl, Ep, (Chl). Qeqertarssuaq, Ravns Storø.	3.3	49	0.1920	0.7079	0.0004
129939	Homogeneous gabbroic amphibolite with relict plagioclase phenocrysts. Hb, Pl, Sph, (Ep, Ore). N.E. Ikatup nunâ, Ravns Storø.	2.2	106	0.0601	0.7033	0.0004
129999	Homogeneous amphibolite dyke. Hb, Pl, Ore, (Ap). N.E. Ikatup nunâ, Ravns Storø.	4.3	340	0.0362	0.7030	0.0003
149371	Homogeneous foliated amphibolite. Hb, Pl, Bi. N. of Bjørnesund.	1.8	38	0.1405	0.7070	0.0006
149706	Hornblendite. Hb, Bi, Pl. N. of Bjørnesund.	7.6	26	0.8443	0.7329	0.0002

Hb = hornblende, Pl = plagioclase, Qz = quartz, Bi = biotite, Sph = sphene, Ap = apatite, Chl = chlorite, Ore = opaque iron oxides, Cc = calcite, Ga = garnet, Ep = epidote, Ant = anthophyllite, Rt = rutile, Br = bronzite, Sp = spinel, Phl = phlogopite, Ol = olivine, () = minor component

*Determined by isotope dilution. $^{87}Sr/^{86}Sr$ values normalised to $^{88}Sr/^{86}Sr = 8.375$ and to Eimer and Amend $^{87}Sr/^{86}Sr = 0.7080$

Discussion

The age derived for the amphibolites (2620±250 m.y.) does not relate closely to the time of formation of the amphibolite precursors. From field evidence it appears that the formation of the amphibolite precursors pre-dated the emplacement of the gneiss precursors (2900–3000 m.y., Pidgeon & Hopgood, 1975), the regional granulite-facies metamorphism (2810±70 m.y., Black *et al.*, 1973) and the subsequent emplacement of the Ilivertalik granite (2835±10 m.y., Pidgeon *et al.*, 1976). The 'young' age derived for the amphibolites therefore implies that there has been considerable migration of Rb and/or Sr subsequent to the precursor formational event due to thermal/metamorphic effects.

The supposition of migration of Sr and Rb on a large scale during amphibolite-facies metamorphism is at variance with the findings of Krogh & Davis (1971, 1973) and Hickman & Wakefield (1975) who found that migration of Sr and Rb had been restricted to the scale of centimetres during amphibolite-facies metamorphism of gneisses. However, large-scale migration of Sr and Rb in the amphibolites is perhaps not unexpected in view of the fact that they were intruded by granites (*sensu lato*) (at *c.* 2900±3000 m.y.) with markedly different chemistry, particularly with respect to Rb. The amphibolite age of 2620±250 m.y. may therefore be regarded as an 'errorchron' age which marks the time of cessation of significant thermal perturbation of the area. This age accords well with the late epidote-amphibolite facies age of 2660±120 m.y derived for the gneisses north of Frederikshåbs Isblink (Pidgeon & Hopgood, 1975).

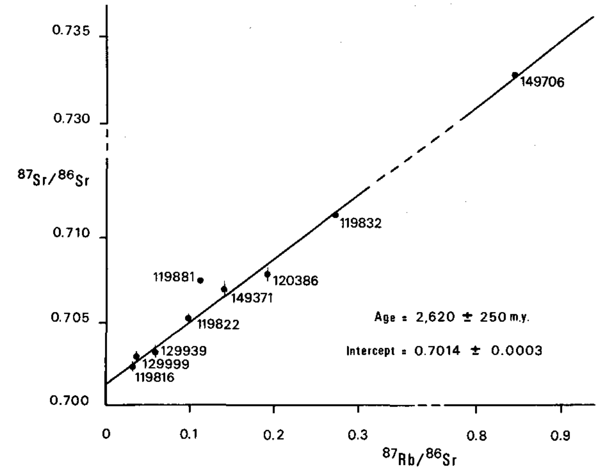

Fig. 47. Rb-Sr isochron plot for amphibolites, Bjørnesund – Ravns Storø region. Errors at 2σ level, decay constant used = 1.39 × 10^{-11} y^{-1}).

Examination of the ultramafic material suggests that the age of 2710±180 m.y. derived for the phlogopites is unlikely to relate to a primary formation event. Although the phlogopite forms part of an apparently primary igneous texture (Friend & Hughes, 1977), the presence of anthophyllite in two of the samples (GGU 183412 and 183450) and the partial break-down of phlogopite to chlorite are evidence of the action of a percolating, hydrous phase (presumably a metamorphic effect). Thus, it is probable that the primary distribution of Rb and Sr amongst the phases of the ultramafic material was modified during metamorphism.

In conclusion it appears unlikely that further Rb-Sr work will produce a primary formation age for the amphibolite precursors. However, analysis of closely-spaced samples may allow more precise estimates of the age of the metamorphism to be made.

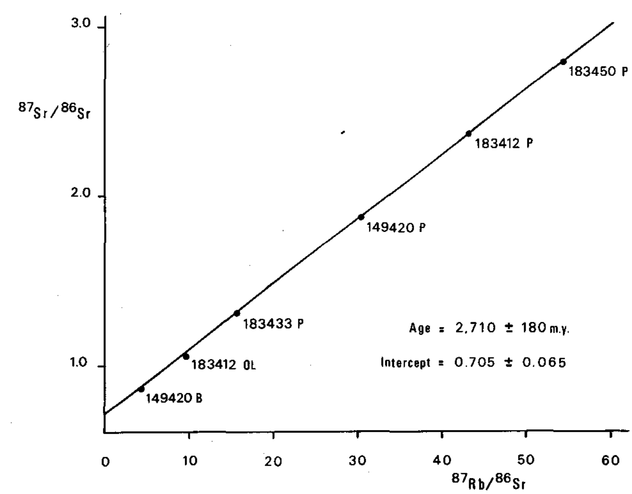

Fig. 48. Rb-Sr isochron plot for minerals separated from ultramafic samples, Bjørnesund – Ravns Storø region. The age and initial ratio have been calculated from the phlogopite data alone. P: phlogopite; OL: olivine; B: bronzite.

Table 10. Rb-Sr isotopic analyses of minerals separated from ultramafic material, Bjørnesund – Ravns Storø region

GGU sample no.	Sample details and location	*Mineral	*Rb(ppm)	*Sr(ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Abs. std. error (2σ)
149420	Coarse-grained ultrabasic. Br, Sp, Phl, Chl. N. of Bjørnesund	Phl.	427	45.4	30.39	1.8696	0.0007
		Br.	0.12	0.08	4.33	0.865	0.001
183412	Bladed olivine-spinel ultrabasic. Ol, Sp, Phl, (Ant). N. of Bjørnesund.	Phl.	603	47.0	43.24	2.3663	0.0004
		Ol.	0.25	0.08	9.63	1.058	0.004
183433	Very coarse-grained bladed olivine-spinel ultrabasic. Ol, Phl, Sp. N. of Bjørnesund.	Phl.	425	83.0	15.70	1.3081	0.0007
183450	Coarse-grained bladed olivine-spinel ultrabasic. Ol, Phl, Sp, Ant. N. of Bjørnesund.	Phl.	214	13.7	54.25	2.789	0.003

*See key to Table 9

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Potassium-argon ages from Phanerozoic basic dykes in South-East Greenland

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Introduction

Nine basaltic dykes were sampled by coring during geological reconnaissance of the south-east coast of Greenland (Bridgwater *et al.*, 1977) between Angmagssalik (65°40′) and Nordfjord (fig. 49). The samples were initially collected for palaeomagnetic investigations (Beckmann, 1977). In the field it was assumed that all the fresh basic dykes in the region were Tertiary in age and represented a southern continuation of the coastal dyke swarm described by Wager & Deer (1938). The timing of dyke injection is very important as a possible indication of the initial break-up of the original North Atlantic mass. Furthermore, it was assumed that the major coast-parallel dyke swarm (for example site 26 & 28, see fig. 49) was the continuation of the more intense Tertiary dyke swarm reported by Wager & Deer (1938) further north, while the more sporadic dykes with other trends were presumed also to belong to the same general period of injection. The preliminary palaeomagnetic studies by Beckmann (1977) showed no consistent differences between dykes grouped according to their trends.