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GRANITISATION OF BASIC ROCKS IN THE BJØRNESUND AREA, NEAR FISKENÆSSET, WEST GREENLAND

H. R. Williams

Introduction

The area studied (Fig. 22) is dominantly composed of strongly and poorly banded gneisses with intercalated supracrustal amphibolites, and was finally metamorphosed in upper-amphibolite facies about 2.7×10^9 y ago. Early large-scale isoclinal folds formed during high-grade metamorphism have affected the strongly banded gneisses and amphibolites, but predate the younger, poorly banded gneisses, which were subsequently deformed and metamorphosed along with the banded gneisses and amphibolites. (Williams, 1973).

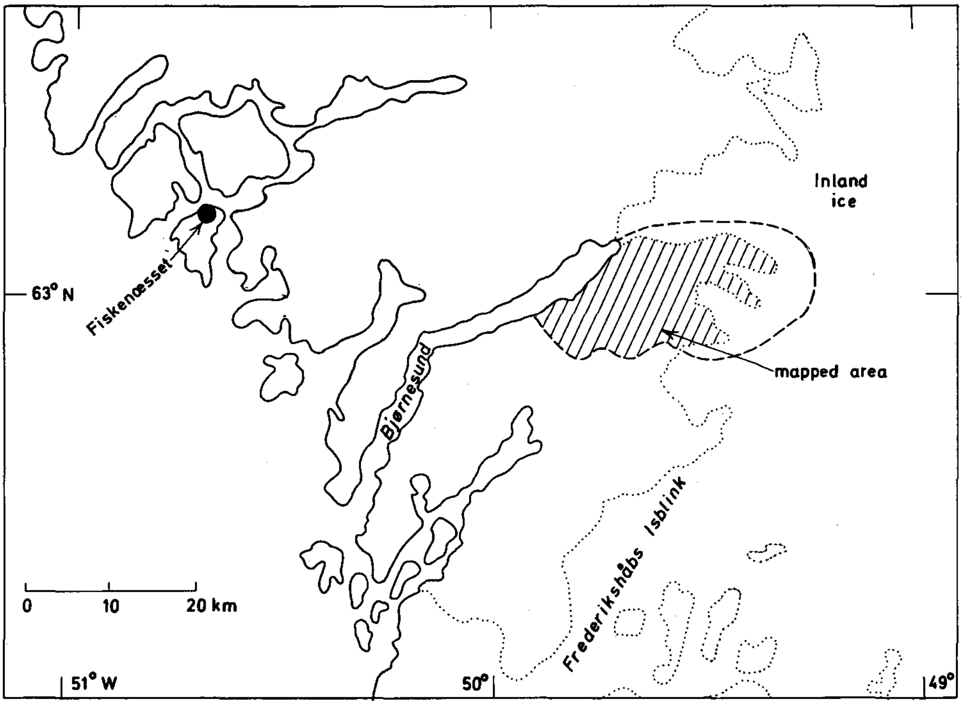


Fig. 22. Location map of part of southern West Greenland showing the position of the area north–east of Bjørnesund.

The amphibolites may locally be traced in the field into poorly banded granodioritic gneisses (fig. 23). The presence of gradational or transitional contacts between rock types, coupled with mineralogical and chemical data, suggests that metasomatic granitisation was responsible for the formation of the poorly banded gneisses from amphibolites, anorthosites and ultramafic rocks.

Field relations

A brief description of the field relations of the granitised rocks is given by Williams (op. cit.).

In Fig. 23 the major geological structure and relationships between lithologies described in this section are outlined. The southern inverted limb of a reclined syncline is partially transformed into granitic *(sensu lato)* material. The underlying, northern limb extends for 15 km as the Qororssuaq anorthosite complex, and is relatively unaffected by granitisation, which seems to have invaded from the anticlinal core to the south.

In the field, banded, medium grained amphibolites may be traced both along and across their strike into poorly banded quartzo-feldspathic gneisses. The passage from parent amphibolite to the product gneiss takes place within a stratigraphic thickness of 200 m.

The amphibolites contain a 350 m thick layer of anorthosites and gabbros with minor peripheral ultramafics. Where these occur on the southern limb, they are involved in the granitisation process. Relics of saussuritised anorthosite and biotised ultramafics occur within otherwise completely granitised material.

Petrology

Amphibolite. The amphibolite parent rocks are commonly saccharoidal medium grained banded and homogeneous rocks containing plagioclase and hornblende. Concordant metre-thick granitic pegmatites occur rarely in these rocks, having sharp contacts. When traced through the granitisation zone towards the poorly banded gneiss, the amphibolites

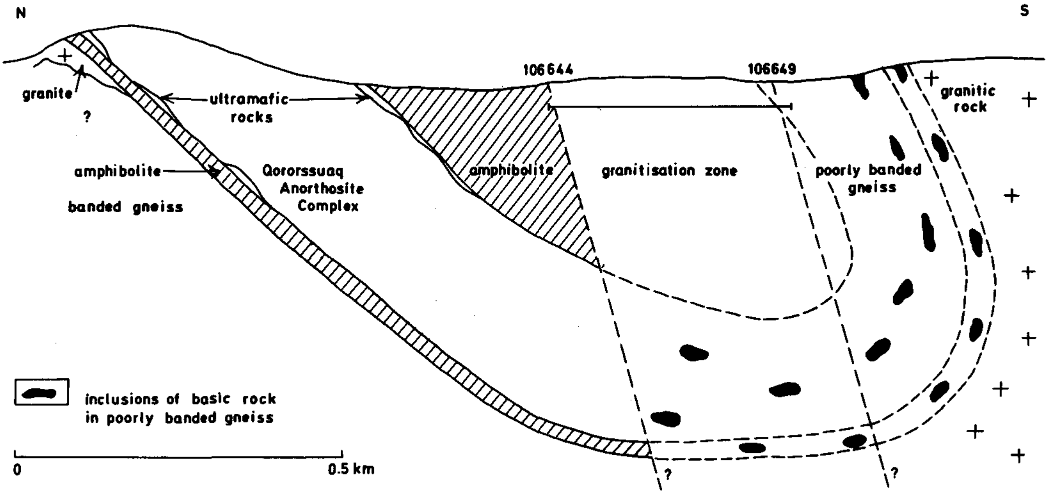


Fig. 23. Diagrammatic cross-section of the reclined syncline in which the granitisation zone is situated. Note that granitic rocks tend to form from banded gneiss material.

become more fissile due to the growth of biotite at the expense of hornblende. The banding on a centimetre scale is due to small changes in the colour index.

Poorly banded gneiss. The product of granitisation is a quartz-feldspar-biotite gneiss. Ill-defined bands of quartzo-feldspathic material give the rock a poor foliation. Portions of the gneiss can be traced into homogeneous partially mobilised granitic rock of igneous appearance and granodioritic composition. Fig. 23.

Garnet-rich rocks. Garnet is strongly enriched in amphibolites and granitic material within amphibolites to the north of the zone of granitisation. The garnet-rich rocks are best developed near to the zone of granitisation, especially where it is narrow, about 50 m, and die out to the north. Similar garnetiferous rocks have been recorded elsewhere, adjacent to sharp contacts between granitic rocks and amphibolites. Normally, garnet-rich rocks are rare away from the granitisation zone.

Partially granitised rocks. The composition, mineralogy and texture of these rocks vary over the range between the amphibolites and the poorly banded gneiss. Amphibolitic rocks containing hornblende, biotite, plagioclase and quartz, when traced towards the gneiss become richer in biotite and quartz, with the development of microcline. Leucocratic veins occur most commonly towards the granitic side of the zone, but never account for more than half the rock.

Diopside, sphene and magnetite have been found in one transition zone sample in anomalously high quantities.

Detailed description of the granitisation zone

The zone can be traced for 10 km along the strike of the amphibolites, and has a maximum thickness of 200 m. The northern boundary consists of normal amphibolitic rocks, the southern, of poorly banded gneiss.

Leucocratic veins become more abundant in the granitisation zone towards its southern boundary, and are deformed into thin gneissose layers having a variable degree of foliation. These form the main body of the poorly banded gneiss which contains about 5% melanocratic material as inclusions at the southern boundary of the granitisation zone. The colour contrast between the leucocratic veins and the amphibolitic host decreases as the proportion of ferromagnesian minerals falls during granitisation.

Mineralogy

Ferromagnesian minerals and plagioclase are replaced by biotite, quartz and alkali feldspar in the granitisation zone. Alkali feldspar forms a greater proportion of the rock than the original plagioclase, and is formed by the decomposition of biotite and plagioclase, together with the metasomatic influx of sodium and silica. The plagioclases in the partially granitised zone show strong normal zoning and a decrease in anorthite content southwards across the zone. The saccharoidal texture of the amphibolitic rocks is altered to a faintly foliated, somewhat granitic texture.

Mineralogical data for rocks collected from the granitisation zone is shown in Table 5. The samples represent a trend showing a decrease in colour index, hornblende/biotite ratio and plagioclase anorthite content, and an increase in modal quartz and feldspar.

Table 5. Modal and mineralogical composition data from the transition zone

GGU No.	106644	106643	106642	106645	106646	106647	106648	106649
Hbld/Bi ratio	8	3	?	0.3	2	25	0.2	0
Modal Plagioclase	46	47	57	56	50	40	51	55
An% content	42	36	48-32	42	46-38	46	32	25
Modal quartz	11	16	14	20	13	5	33	35
Modal C.I.	43	37	22	24	36	55	14	10

C.I. refers to colour index

Sample 106647 represents a basic inclusion on the gneiss side of the partially granitised rocks, while sample 106642 occurs on the amphibolite side of the zone, and is enriched in diopside, sphene and magnetite.

Chemistry of the granitisation zone

Mineralogical and petrological observations have been confirmed by major-element analyses of the rocks collected from the granitisation zone. Sodium, potassium, titanium and manganese concentrations demonstrate the transitional nature of the rocks outcropping between the amphibolites and poorly banded gneisses (Table 6).

The transitional rocks of the granitisation zone are amphibolitic in appearance but show relatively high contents of sodium and potassium, while the manganese and titanium contents are lower than average for basic rocks in the area.

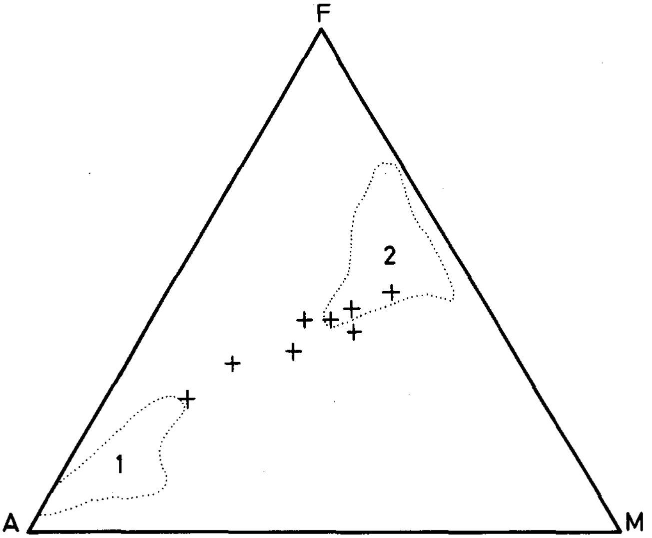
Initially, potassium, sodium, and water were added to amphibolitic rocks forming biotite, with a corresponding decrease in titanium and manganese concentrations. A concentration of titanium is seen in the sphene-rich rock 106642. Iron and magnesium are concentrated in the amphibolites north of the granitisation zone, resulting in the formation of garnet in large quantities.

Table 6. Means and standard deviations of oxides from amphibolites, poorly banded gneisses, granitic rocks and transition zone samples

	TiO_2	MnO	K_2O	Na_2O
Amphibolites	1.09 (0.36)	0.20 (0.01)	0.38 (0.08)	2.37 (0.95)
Poorly banded gneisses	0.25 (0.12)	0.04 (0.01)	1.95 (1.53)	4.97 (0.84)
Granitic rocks	0.23 (0.13)	0.04 (0.01)	3.27 (1.40)	4.59 (1.12)
8 samples from transition zone	0.58 (0.12)	0.10 (0.03)	1.02 (0.59)	3.80 (0.74)

Weight per cent

Fig. 24. AFM diagram showing the fields of poorly banded gneisses (1), amphibolites (2), and the eight samples from the transition zone.



On an AFM diagram, Fig. 24, the transitional rocks show a marked linear trend exhibiting alkali enrichment. They occupy a field between poorly banded gneisses and amphibolites, partially overlapping the latter. Their composition is limited by increase in alkalies and loss of ferromagnesian components.

Fig. 25 shows the gradual increase in alkalies in the partially granitised rocks in relation to average values for amphibolites and poorly banded gneisses in the Bjørnesund area, with two exceptions, 106642 and 106647.

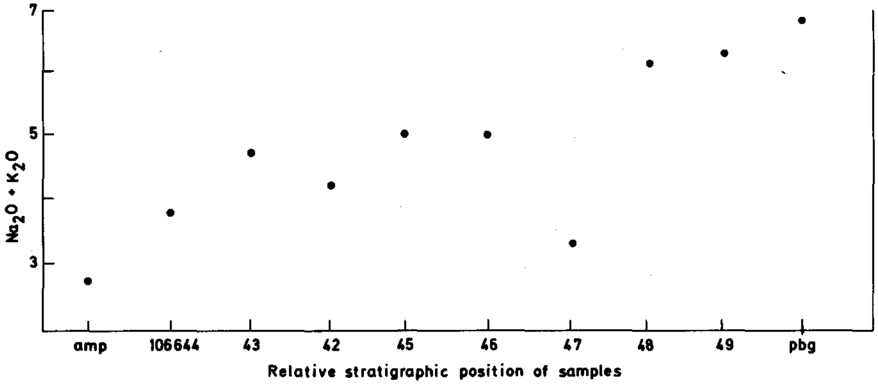


Fig. 25. Plot of total alkalies against relative stratigraphic position for rocks from the transition zone. The mean total alkali contents of amphibolites and poorly banded gneisses are also plotted for comparison. The anomalous status of samples 106642 and 106647 is clearly shown.

Discussion

The Qororssuaq granitisation zone

The rocks from the granitisation zone described in the previous sections illustrate a trend in colour, mineralogy, texture and chemistry between the amphibolites and poorly banded gneisses. Exceptions may be due to one or both of two mechanisms. The first is that proposed by Reynolds (1946), who introduced the concept of geochemical culminations, described as basic fronts. The anomalous rock 106642, rich in sphene, magnetite and diopside, indicating a concentration of titanium, iron and calcium may represent part of such a front. Secondly, the process may have acted preferentially within certain rock-types, or in certain areas, leaving recrystallised relic basic rocks such as 106647. The granitisation zone shows a time and space sequence of events. The spatial relationship is clear, but the time sequence can only be inferred from the spatial one between amphibolites and gneisses by assuming that rocks most transformed represent the final stage of granitisation.

The initial formation of biotite from and around hornblende requires an influx of water, potassium and sodium from the gneiss side of the granitisation zone. The sodic rim to the zoned plagioclases seen in the transitional rocks suggests that they were in disequilibrium due to the migration of alkalies along grain boundaries during metasomatic influx. These two facts justify the interpretation given here of the less objective evidence, in that the process is one of granitisation of amphibolites, and not basification of granitoid rocks.

As the ratio of dark to light minerals decreases, iron, titanium, magnesium appear to leave the transitional rocks, but the transport mechanism is not clear. This results in only minor quantities of biotite and magnetite occurring in the poorly banded gneisses. A corresponding fall in the anorthite content of the plagioclase, from An 42 to An 25, together with the decrease in modal hornblende as granitisation proceeds, indicates a general expulsion of calcium from the transitional rocks. Misch (1968) describes a similar situation in which there is an increase in leucocratic minerals during metasomatic granitisation.

General discussion

Examples of transitions between amphibolitic and granitic rocks involving metasomatism are common. Misch (1968) and Jacobsen (1961) have described similar transitions in detail. Kornerup (1879), Escher (1966), Windley *et al.* (1966), Dawes (1969), Bonnard (1971), Henriksen (1969) and Rivalenti (1973) and others in West Greenland have demonstrated that some quartzo-feldspathic material in contact with amphibolites can be derived from granitised basic rocks. The contact between the siliceous and basic material has been called a "migmatite front", and can either be sharply defined or a gradational discontinuity.

Jacobsen contributed chemical evidence for one example of the complete granitisation process in West Greenland, while Escher (op. cit.), Brown (1967) and Misch (op. cit.) have published analyses of the starting materials and the products, but do not include information on the intermediate stages. Rivalenti demonstrated that alkali/silica metasomatism might cause basic rocks to change composition towards that of granodioritic gneisses.

The occurrence of zircon in the 'transformed' gneiss in unusually high quantities for amphibolite parent material led Kalsbeek (1970) to suppose that no transformation had taken place, and that the composition of the gneisses had always been granitic. Zircon contents of the amphibolites in the Qororssuaq complex are similar to those in the transformed rocks, generally low. Both Hietanen (1947) and Edelman (1972) found zircons in rocks known to be granitised basic material.

Part of the gneissose material adjacent to amphibolites in certain areas is therefore derived from the latter by alkali metasomatism, the source of which is in the underlying gneisses. Misch describes a metasedimentary sequence that is migmatised, so that only relics are recognisable in a host of quartz-dioritic gneisses. Similar relics have been found in the Qororssuaq occurrence where they have been used to determine the original structure before granitisation (Fig. 23). The variation in width of the zone indicates that a metasedimentary origin for the gradational zone is unlikely.

Although Kalsbeek has suggested that the transitional contact may be due to the difference in ductility and melting behaviour of siliceous and basic rocks during upper-amphibolite facies metamorphism, it is unlikely that a ductility contrast or metamorphic differentiation would generate the gradual chemical and mineralogical gradients discussed in this paper, unless metasomatism was also involved. The Qororssuaq granitisation zone shows no sign of partial melting or of large-scale granitic sheeting during granitisation.

Unless a large volume or density increase takes place, expulsion of unwanted material such as magnesium and iron is necessitated. The formation of garnet in amphibolites and granitic pegmatites adjacent to the transition zone, sphene, diopside and magnetite-rich rocks within the zone support the concept of expulsion of cafemic ions from the amphibolites undergoing granitisation. Dunn (*in* Reynolds, 1946) describes garnet-rich rocks, diabrochites, probably formed by a similar process. Garnet occurs in the Bjørnesund rocks, not only where the contact between basic and siliceous rocks is gradational, but also where it is knife-sharp. It seems clear that the elements not needed during granitisation are expelled into the surrounding rocks. A similar situation is described by Anderson (1937) and Newhouse (1947).

The significance of large-scale metasomatic granitisation

Nearly 100 m of amphibolite has been completely changed in composition to poorly banded granodioritic gneiss, while a further 200 m was frozen during processing, so that the intermediate stages are visible. The metasomatic granitising material appears to be derived from the gneisses underlying the amphibolites, although these are not necessarily the ultimate source of the material.

Concentrations of calcium, iron, titanium and magnesium are possible analogues to Reynolds' geochemical culminations where they occur in both partially transformed rocks and amphibolite parental rocks.

Granitisation is a minor process, both spatially and quantitatively, but it forms an integral part of Archaean greenstone-belt models propounded by Anhaeusser *et al.* (1968), and others. Metasomatic activity is concentrated along supracrustal-basement contacts. Alkalies, silica and water may flow upwards through the granitic Archaean crust during the deformation and metamorphism of greenstone-belt type sequences due to the expulsion of these ions from crustal material undergoing extreme grades of metamorphism and dehydration. Basic supracrustal sequences deficient in these components are most likely to absorb the upward flow, and at the same time undergo granitisation.

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