VII:13. OUTLINE OF THE GEOLOGY AND PETROLOGY OF THE SØR-RONDANE MOUNTAINS, DRONNING MAUD LAND

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Introduction

"Base Roi Baudouin" (lat. 70°26′ S., long. 24°19′ E.), headquarters of the Expéditions Antarctiques Belges, was constructed by the 1958 expedition (leader G. de Gerlache).

Geological reconnaissance parties of three expeditions explored the Sør-Rondane mountains with dog-hauled sledges.

In 1958 E. Picciotto and J. Giot surveyed the eastern part; in 1959 T. Van Autenboer and K. V. Blaiklock carried out a geological and topographical reconnaissance survey in the western part, and in 1960 T. Van Autenboer and S. Berckmans continued this survey in the central part of the range.

A map (scale – 1 : 250 000) drawn from air photographs taken by the U.S. Navy Antarctic Expedition of 1946–47 (Operation "Highjump") and published by the Norsk Polarinstitutt in 1957 proved to be most valuable during the field work. However, the altitudes had to be changed considerably as a result of triangulation and barometric profiles by BLAIKLOCK [unpublished].

The Sør-Rondane mountains, belonging to the coastal ranges of Dronning Maud Land, form a 250 km long, east–west wedge-shaped range about 200 km south of "Base Roi Baudouin" (fig. 1). The first nunataks break the monotony of the slowly rising inland ice slope some 120 km to the south of the base.

The range, rising up to 3 000 m, is entirely composed of crystalline rocks and belongs to the shield area of eastern Antarctica (FOURMARIER [1951]; DAVIES [1956]; STEWART [1956]; TAYLOR [1960]).

Other papers discuss the age determinations (PICCIOTTO and others [1964]), the gravity measurements (VAN AUTENBOER [1964b]) and the morphology (VAN AUTENBOER [1964a]) of this range.

From the nature, the texture and the structure of the constituent rocks two major entities can be distinguished:

(1) A gneissic one, composed of an important series of gneisses and migmatites, containing marble beds, graphite-schists and quartzites.

(2) An igneous and younger complex composed of homogeneous massifs displaying intrusive characters.

The Gneissic Series

The gneissic series (MICHOT [1963]) is composed mainly of a wide variety of gneisses, ranging from syenitic, granitic, adamellitic and tonalitic to granodioritic; from hololeucocratic to melanocratic; and from homogeneous, streaky, banded, embrechitic, anatexitic (as defined by ROQUES [1961]) to agmatitic and augen-gneisses (fig. 2). Locally, mylonitic gneisses occur.

The series also contains marble beds associated with Ca-silicate-bearing gneisses, graphite-schists and micaceous quartzites. Amphibolites occur as lenses, giant eyes and bands of nodules following the structure of the gneisses, or as fragments in agmatites.

Migmatization of varying intensity (fig. 3) affects the whole series and locally results in the individualization of large masses of granitic metazome.

shallow synclines and recumbent folds in the east. In the west, the structure is east–west with a 45 to 50° dip to the south.)

In detail, however, the structures are very complex, displaying intense small-scale deformation, faults and brecciated or mylonitic zones.

Leucocratic gneisses

The leucocratic gneisses form the greater part of the gneissic series.

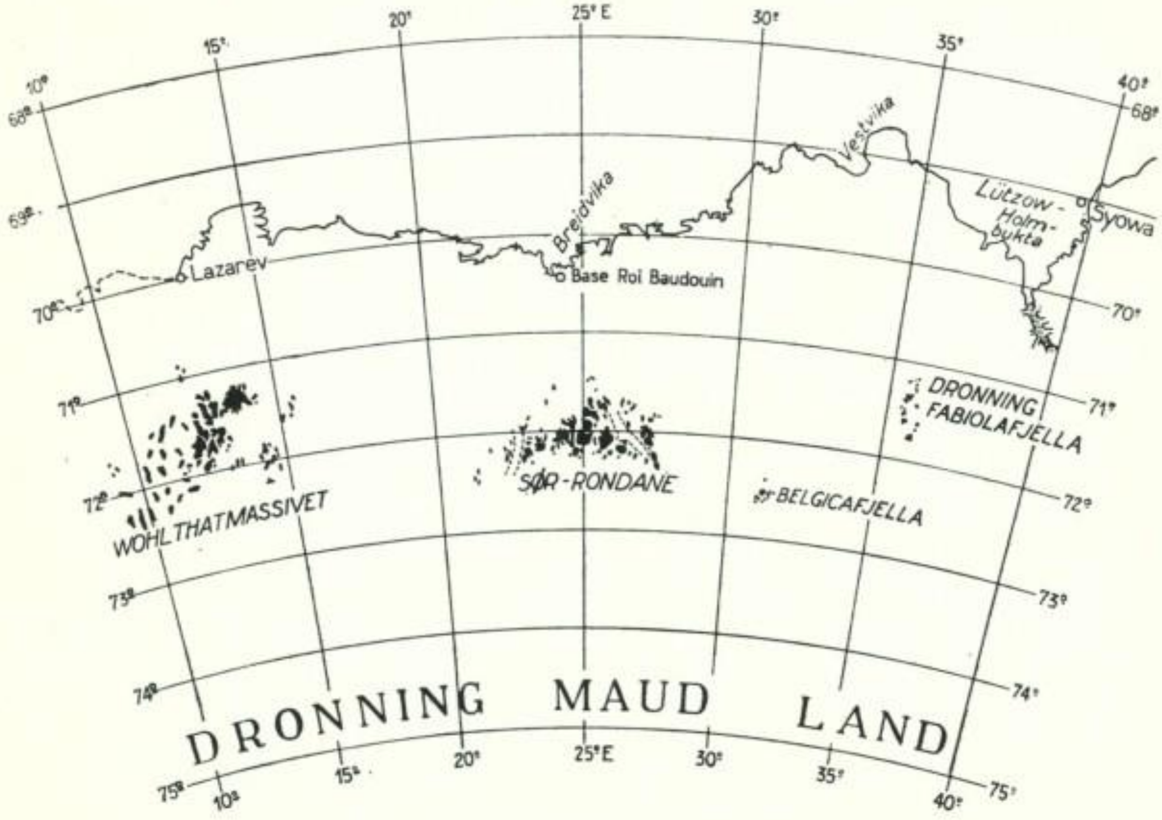

Fig. 1. Eastern Dronning Maud Land.

These complex processes have apparently taken place in different stages and result in the formation of different types of migmatites. Some relations between the type of migmatite and the nature of the palaeozome will be indicated later.

The structure as a whole is rather uniform. (Around east–west, flat-lying with a few degrees dip to south or north but also displaying

They are fine- to medium-grained rocks composed of an alternation of dark amphibole-biotitic and light quartzo-feldspathic layers. Some of the rocks are cut by dykes revealing sharp contacts with the dark beds but grading very regularly into the quartzo-feldspathic ones.

The dark layers are characterized by a granoblastic texture and a well-defined gneissic

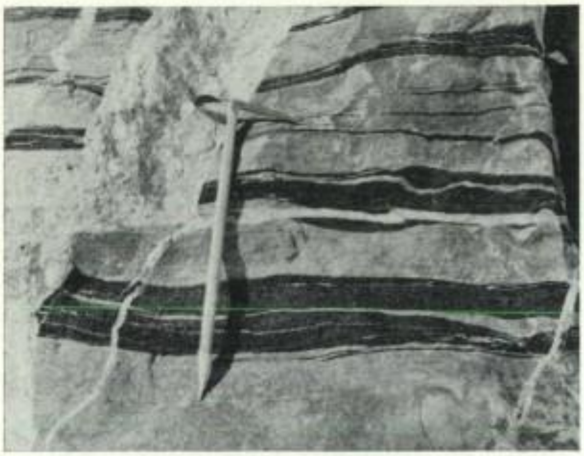

Fig. 2. Banded gneiss cut by a fracture-filling pegmatite; Austkampane.

Fig. 3. Small-scale migmatization and deformation of homogeneous gneiss; Jenningsbreen.

structure, and are composed of plagioclase (oligoclase), sometimes quartz and potash feldspar (0.5 to 1–2 mm in diameter) distributed among parallel aggregates of biotite, amphibole with accessory garnet, opaques, sphene, apatite, epidote, muscovite, chlorite (pennine) and locally allanite.

The lighter layers are composed of plagioclase (oligoclase), quartz and microcline (2–3 mm in diameter) frequently associated with myrmekite and biotite.

As characteristic of the mineral facies can be mentioned: biotite-garnet-gneisses (very common), biotite-hornblende-gneisses, hornblende-clinopyroxene-gneisses, hypersthene-gneisses, sillimanite-muscovite-biotite-gneisses and clinopyroxene-scapolite-gneisses.

Mesocratic and melanocratic gneisses

Several outcrops contain beds of mesocratic to melanocratic rocks of amphibolitic type intercalated in the leucocratic gneisses. The more important amphibolite masses occur as discontinuous lenses, giant eyes or bands of eyes, or lenses following the structure of the gneisses. They also occur as angular to rounded fragments in the agmatites (figs. 5 and 9).

They are homogeneous fine- to medium-grained rocks of a dark green colour. Their gneissic structure is often featured by thin more granular quartzo-feldspathic lenses. Some of these rocks are composed of hololeucocratic, mainly plagioclase-rich, bands (cornéite plagioclasique; Michot [1960]), alternating with melanocratic ferromagnesian ones (cornéite amphibolique).

The thin quartzo-feldspathic lenses have a composition and a texture similar to those which characterize the same associations in the leucocratic gneisses.

The dark beds, with a xenomorphic to hypidiomorphic granoblastic texture, are generally composed of equidimensional plagioclase scattered in an amphibolitic aggregate in which also occur orientated biotite, locally a few grains of pyroxene and accessory opaques, quartz, apatite and epidote.

Dioritic gneisses

Sørhaugen nunatak contrasts clearly among the neighbouring gneisses. It is formed of a dark augen-gneiss of a dioritic or gabbroic type.

It is a homogeneous, medium-grained rock with a slightly orientated structure and a xenomorphic to hypidiomorphic texture.

It is composed of plagioclase, locally forming small aggregates, dispersed in a network of biotite, amphibole, pyroxene, opaques and sphene.

This rock appears as a gneissic, uralitized gabbro or diorite. It has also been observed at

Bautaen where it is composed of clearly zoned plagioclase (An_{40-45} in the centre, An_{30-32} along the border), amphibole and sometimes biotite developing a very typical poeciloblastic texture.

At Menipa, a rock of the same type has been sampled. Its texture and structure show that it has undergone a marked deformation or even a mylonitization. Indeed it appears as an amphibole-biotitic mylonitic augen-gneiss. The plagioclase, which is sometimes concentrated in aggregates with a mosaic texture, is distorted and often broken and saussuritized.

Marble and Ca-silicate-bearing gneisses

Marble beds, mostly associated with Ca-silicate-bearing gneisses and Ca-silicate nodules have been observed within the gneissic complex at a number of localities (nunataks in lat. 72° S., long. 20°15′ E.; Perlebandet; Tanngarden; Vengen; Teltet; Ellisbreen; Jenningsbreen; Lunckeryggen; Brattnipane; Austkampane; Balchenfjella).

The marbles range from pure, white, compact and massive marble (in thin section displaying large granoblastic calcite assemblages as at Teltet and the nunataks in lat. 72° S., long. 24°15′ E.) to granular brittle marble with granoblastic quartzo-feldspathic nodules, and impure marble characterized by the presence of minerals such as forsterite, graphite, diopside, garnet, talc, chrysotile, scapolite, biotite and phlogopite, some of these occurring as idiomorphic crystals.

The thickness of the beds varies from 1 m to probably well over 30 m.

The contact with the surrounding gneisses is concordant and often characterized by dark diopside-rich beds or lenses. When associated with hololeucocratic zones they form typically banded or streaky gneisses.

These hololeucocratic zones are formed of microcline, quartz and plagioclase, whose granularity reaches 3–4 mm.

The Ca-silicate-bearing rocks are often boudinaged and form bands of nodules with a granoblastic texture and a massive or orientated structure. They are composed of grains of diopside (0.5 to 2 mm in diameter) locally containing a few dots of amphibole; interstitial calcite, amphibole and plagioclase develop.

In the vicinity of the quartzo-feldspathic zones scapolite, phlogopite, epidote and sphene are associated.

The nodules, attaining a length of 60 cm, are separated by coarse calcite (containing some biotite and garnet), and showing strong plastic deformation accompanying the boudinage structure.

The bedding of the marble is marked by the appearance (often in streaks) of the above-mentioned accessory minerals, and remains parallel to the structures of the surrounding gneisses. Locally, however, compressional features are of some importance.

On the northern extremities of the north–south ridges between Gillockbreen and Ellisbreen, and between Ellisbreen and Jenningsbreen, small lenses or pockets filled in a geode-like fashion by yellowish green forsterite crystals occur within the marble (fig. 4).

The lenses are up to 2 m long and 1 m thick, and cut across the bedding of the marble. The forsterite crystals, up to 10 cm long and 2 cm thick, are orientated with their long (c) axes towards the calcite-filled centre of the lens. The crystals are separated by thin zones of chrysotile. When seen in the field this association strongly recalled some organic structures usually associated with corals. In this respect, these structures come perhaps close to the pseudo-organic structures described as eozoon (Harker [1960], p. 85).

Pegmatite dykes occurring within the surrounding gneisses are rarely found within the marbles and they have been seen to stop abruptly at their contact. A lamprophyre dyke was observed within the marbles at the nunataks in lat. 72° S., long. 24°15′ E. Pyroxenite dykes (described elsewhere) were often found in the neighbourhood of the marbles.

Graphite-schists, quartzites

Graphite-schists have been observed at the northern nunatak of Blåklettane and (proving

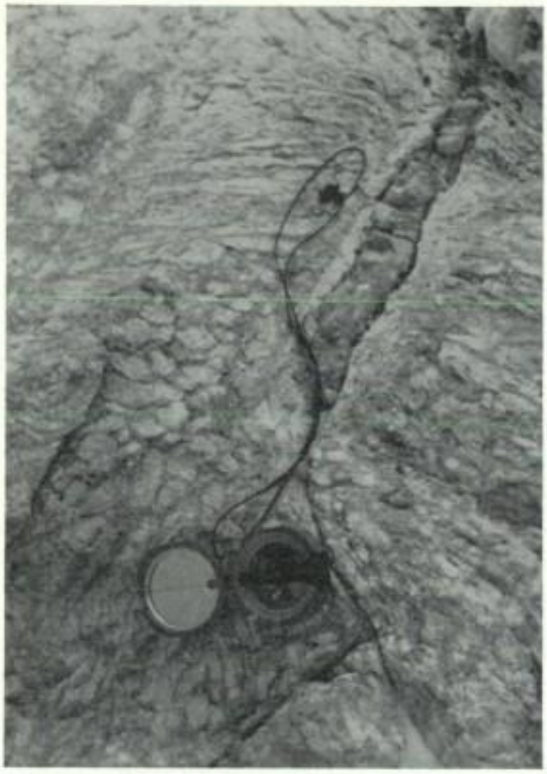

Fig. 4. Forsterite crystals forming pockets in the marble. A central calcite-filled core is visible in the right upper part of the photograph; ridge between Ellisbreen and Jenningsbreen.

their occurrence farther south) in the moraine cover of a nunatak in lat. 72°21′29″ S., long. 20°14′48″ E.

At Blåklettane several 60 cm thick graphite-bearing beds occur in a gneiss and amphibolite complex. They occur at the northern end and farther south near the summit of the nunatak. Both occurrences might well prove to be the same beds repeated by an east–west 45° N. dipping fault zone intruded by granites charging themselves with graphite. The graphite-bearing beds contain up to 50 cm long elongated nodules. One of the smaller nodules which was sampled proved to be a Ca-rich scapolite monocrystal containing orientated inclusions of hematite, pyroxene and some secondary calcite.

The graphite-bearing schists are dark, slightly foliated rocks with irregular lepidoblastic graphite (50 per cent) with quartz (25 per cent), plagioclase (An_{60}) (16 per cent) and hornblende (8 per cent) intergrowth, and accessory hematite and biotite.

Quartzites. Of minor importance also are the micaceous quartzites sampled at Taggen and Bamsefjell. They are leucocratic, fine-grained massive rocks with some biotite streaks marking the foliation which is parallel to the main structures of the gneissic complex. Mostly composed of fine-grained (0.1 mm) granoblastic quartz (from 85 to 90 per cent), they contain some orientated streaks of hypidiomorphic biotite (from 5 to 10 per cent). Accessory minerals are: potash feldspar (also as phenoblasts surrounded by slightly bigger quartz grains), garnet, apatite, opaques and secondary clinozoisite, epidote and muscovite.

MIGMATITES

The migmatization of the gneissic series is apparently a complex phenomenon which has taken place in different stages and results in characteristic field facies of very varying importance.

A distinction is made between homogeneous migmatites, in which palaeozome and metazome cannot be readily distinguished, and heterogeneous migmatites or migmatites *sensu stricto* (epibolites, diadysites, agmatites). This distinction involves the typical large-scale field aspect rather than a genetic relation, different types being often associated with each other.

Homogeneous migmatites

The terms embrechite, anatexite and anatexitic granites as defined by ROQUES [1961] seem most appropriate to characterize both their appearance and formation.

They occur throughout the whole gneissic series, mostly associated with leucocratic gneisses. This type of migmatite often characterizes a narrow contact zone between the pegmatites and the leucocratic gneisses. Here they form a transition zone between the gneiss and the coarse structureless body of the dyke.

As a field unit they are of some importance in the west of the range where they form a large massif, including the whole of Vikinghøgda, the

Fig. 5. Agmatite. Rounded, elongated and apparently displaced amphibolitic fragments in a granitic matrix; occurrence with the homogeneous migmatites of Vikinghøgda.

Fig. 6. Concretion pegmatite; Otto Borchgrevinkfjellet.

northern side of Otto Borchgrevinkfjellet and the southern side of Tanngarden.

In the north the gneissic series grades into augen-gneisses, embrechites (still displaying planar structures) and anatexites (in which the planar structures become vague and irregular) associated with granitic zones. The foliation when visible remains parallel to the general structures of the gneissic series. The outlines of the different units are difficult to map, each unit grading imperceptibly into the other. In the granitic parts, nebulitic structures often remain and amphibolitic rocks occurring within the Vikinghøgda migmatites are less assimilated and were observed forming the rounded or elongated fragments of agmatites (fig. 5). Some concretion pegmatites occur (fig. 6). The transition of the Vikinghøgda massif to the agmatite facies characterizing the south of the range has not been observed.

On the eastern side of Vikinghøgda the homogeneous migmatites are in turn cut by a stockwork of pegmatite dykes, indicating at least two stages of migmatization. In thin section, these rocks appear as hypidiomorphic granular aggregates of large, often slightly perthitic, microcline crystals, quartz, plagioclase (sericitized, saussuritized) and more or less orientated streaks of biotite (partly chloritized). As accessory minerals are sphene, allanite, zircon, chlorite, epidote, zoisite and clinozoisite. The mortar texture and the saussuritization of the plagioclase indicate the proximity of the cataclastic mylonitic zone of the south.

Heterogeneous migmatites or migmatites sensu stricto

The gneissic series is cut by aplitic to pegmatitic dykes of varying composition (leucogranitic, granitic, leuco-adamellitic, leucogranodioritic, leucotonalitic) with biotite, garnet, sphene, apatite and zircon as accessories and with local concentrations of magnetite, hematite and ilmenite (fig. 2).

The dykes, of varying dimensions, are often zoned with a fine-grained outer zone and a central pegmatitic core; they contain gneissic relics or display nebulitic structures often parallel to the foliation of the surrounding gneisses. Occasionally their occurrence can be traced to tectonic accidents of varying importance (Balchenfjella, Bulken, Blåklettane). The contact with the gneisses is usually clean-edged but gradual textural transitions were noted where the dykes occur within the granitic gneisses (see homogeneous migmatites). Locally, lateral apophyses penetrate the surrounding gneisses.

Epibolites. Many exposures show the intercalation of numerous layers or lenses concordant with the structures of the gneisses. They are mostly of granitic to pegmatitic character (fig. 7). Locally (Birger Bergersenfjellet), the granitic lenses can be traced to more important granite masses displaying the same macroscopic and microscopic characters (see fine-grained microcline-granite).

Diadysite. A very special and often sensational facies characterizes a large area in the east (Birger Bergersenfjellet, Fidjelandfjellet, Nordhaugen, Tårnet, Salen, Komsa,) and some nunataks in the west (eastern side of Vikinghøgda, nunataks in lat. 72° S., long. 20°15′ E.) (fig. 8).

The gneissic series is cut by a very complex and irregular network of granitic to pegmatitic dykes. The thicknesses of the dykes vary from a few centimetres to several metres. The form of the dykes is very irregular and they often display pinch and swell structures. Their intersections demonstrate an origin in different stages. This type of migmatite seems mostly associated with a more basic palaeozome. Geographically, they are well localized; at Tårnet the frequency of the dykes progressively diminishes southwards.

Fig. 7. Epibolite. Slightly folded banded gneiss showing pinch and swell structures of concordant pegmatite dykes; Lågkollane.

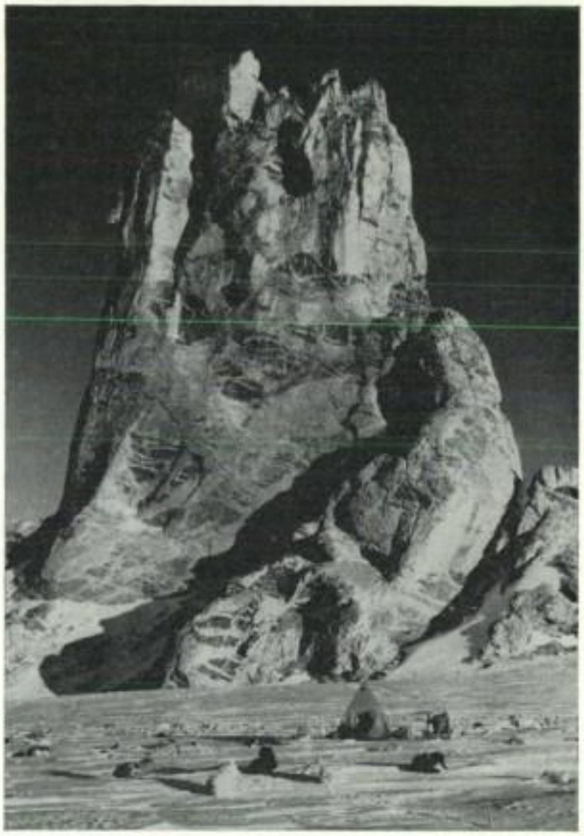

Fig. 8. Diadysite. Complex stockwork of aplitic and pegmatitic dykes cutting palaeozome. The exposed cliff has an estimated height of 800 to 1 000 m; Tårnet.

Fine-grained microcline-granites. Similar to and often associated with the metazome of the heterogenous migmatites are more important masses of fine-grained microcline-granite.

In contrast with the coarse-grained granite associated with the embrechites and anatexites, this granite forms massifs with sharp-cut borders containing displaced xenoliths. The structure of these masses is homogeneous in detail but on a larger scale shows nebulitic structures.

Microscopically, this granite shows the same features as the quartzo-feldspathic lenses distributed in the gneiss. Its texture is xenomorphic and its structure locally is slightly orientated (biotite). It is composed of plagioclase (An_{15}), quartz and potash feldspar (microcline) associated with some flakes of biotite.

The plagioclase, when in contact with the potash feldspar, shows a thin albitic rim and in some places an irregular myrmekitic border; quartz locally shows a poecilitic-interstitial texture; potash feldspar develops as very irregular individual crystals with, in some places, a poeciloblastic texture.

Accessory minerals are chlorite (pennine), calcite, muscovite (sericitized), zircon, apatite and allanite.

Chemical analyses are given in table 1.

Agmatites

The agmatites associated with the amphibolitic layers within the gneiss series have already been mentioned. In contrast to these minor features associated with the migmatization of the gneiss series, agmatites characterize the field facies of the south-west part of the range (Nils Larsenfjellet, Widerøefjellet, the southern side of Otto Borchgrevinkfjellet, Walnumfjellet).

TABLE 1

Chemical compositions and Niggli parameters of 13 selected samples

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	75.20	73.20	74.85	74.15	63.92	50.63	67.95	73.31	71.04	71.46	57.05	61.70	60.55
TiO_2	0.21	0.22	0.20	0.18	1.03	3.25	0.40	0.22	0.28	0.23	1.06	0.51	0.42
Al_2O_3	11.05	12.00	12.65	12.10	16.41	17.52	15.42	12.61	14.70	14.60	15.50	16.80	0.42
Fe_2O_3	0.65	0.56	0.60	0.37	1.00	1.38	1.41	0.52	0.77	0.70	1.72	2.23	14.65
FeO	2.65	3.00	1.17	1.67	5.08	7.08	1.68	2.22	1.75	1.75	2.40	1.32	2.21
MnO	0.04	0.05	0.03	0.02	0.05	0.07	0.02	tr	tr	0.03	0.06	0.02	6.46
MgO	0.08	0.08	0.12	0.08	1.34	2.97	0.70	0.20	0.55	0.78	3.20	0.48	0.14
CaO	1.60	1.70	1.31	1.42	3.51	8.34	1.69	1.42	1.50	1.23	3.97	1.70	3.50
Na_2O	3.20	2.70	3.85	3.70	3.60	3.23	3.57	2.69	3.11	3.20	1.65	3.05	7.57
K_2O	5.00	6.10	4.90	5.50	4.04	2.15	5.28	5.04	5.19	5.26	11.50	11.45	2.05
H_2O^+	0.10	0.22	0.15	0.54	0.64	0.84	0.74	0.60	0.68	0.73	0.15	0.43	0.21
H_2O^-	0.02	0.39	0.02	0.07	0.14	0.10	0.15	0.14	0.10	0.11	0.03	0.07	2.05
P_2O_5	0.08	0.07	0.05	0.06	0.24	2.70	0.15	0.02	0.08	0.06	0.86	0.08	0.30
	99.88	100.29	99.90	99.86	101.00	100.26	99.16	98.99	99.75	100.14	99.15	99.84	100.53
Niggli parameters													
si	432	395	432	420	241	144	321	424	365	366	185	243	193
ti	1.70	1.04	1.04	0.88	2.9	7	1.4	1	0.9	0.9	2.65	1.46	0.99
al	37.5	38.0	43.0	40.5	36.5	29.3	42.8	43.0	44.5	44.0	29.5	39.0	27.5
fm	16.5	17.0	9.5	10.5	26.3	32.5	16.7	14.6	14.8	16.0	26.5	14.0	39.5
c	10.0	10.0	8.0	8.5	14.3	25.4	8.5	8.7	8.3	6.8	15.0	7.0	26.0
alk	36.0	35.0	39.5	40.5	22.9	12.8	32.0	33.7	32.4	33.2	29.0	40.0	7.0
k	0.50	0.59	0.45	0.49	0.42	0.31	0.49	0.56	0.52	0.52	0.80	0.71	0.08
mg	0.04	0.04	0.11	0.06	0.28	0.39	0.29	0.12	0.29	0.36	0.59	0.2	0.42
o	0.17	0.14	0.29	0.17	0.10	0.09	0.30	0.24	0.21	0.15	0.16	0.48	0.13
Section	IV	IV	V	V	IV	V	IV	IV	IV	III–IV	IV	IV	IV

1. Grey porphyroid biotite-hornblende-granite; Utsteinen (Anal: Van den Berghe).
2. Grey porphyroid biotite-hornblende-granite; Menipa (Anal: Van den Berghe).
3. Pink medium-grained biotite-granite; Dufekjfellet (Anal: Van den Berghe).
4. Grey fine-grained biotite-granite; Perlebandet (Anal: Van den Berghe).
5. Red porphyroid biotite-hornblende-granite; Romnaesfjellet (Anal: J. Barbette; mean of 4 analyses).
6. (Quartziferous) biotite-diorite; Småhausane (Anal: J. Barbette, J. Klerkx; mean of 2 analyses).
7. Fine-grained microcline-granite with slight gneissic structures; Austkampane (Anal: J. Barbette, J. Klerkx; mean of 4 analyses).
8. Granite; Austkampane (Anal: J. Barbette, J. Klerkx; mean of 4 analyses).
9. Fine-grained microcline-granite; Bautaen (Anal: J. Barbette; mean of 2 analyses).
10. Fine-grained microcline-granite; Strandrudfjellet (Anal: J. Barbette; mean of 2 analyses).
11. Syenite; Lunckeryggen (Anal: Van den Berghe).
12. Granitic matrix of igneous breccia; Lunckeryggen (Anal: Van den Berghe).
13. Tonalitic matrix of agmatite; Hargreavesbreen (Anal: Van den Berghe).

In the west this facies reaches perhaps as far as Bamsefjell, where a tonalitic rock similar to the tonalitic matrix of the agmatite was sampled.

The agmatites characterizing this facies comprise elongated, angular to sub-rounded amphibolitic fragments enclosed in a tonalitic to granodioritic matrix displaying some vague strucnotures (fig. 9).

Fig. 9. Agmatite facies of the south-western part of the Sør-Rondane. Angular elongated fragments held in tonalitic matrix; Widerøefjellet.

The orientation of the elongated fragments is parallel to the structures of the matrix and roughly concordant with the general orientation of the gneissic series.

The agmatites are further cut by mylonitic zones characterized by phyllonites and calc-chlorite-schists, and are locally associated with more homogeneous amphibolitic bodies of (uralitized) dolerite (Gunnestadbreen).

The amphibolitic fragments are composed of poeciloblastic hornblende, plagioclase (mainly replaced by saussuritization) and chlorite. They show flaser structures and are invaded by apophyses from the matrix.

The matrix (table 1) itself is composed of quartz in orientated streaks showing undulating extinction, or in small irregular-grained cataclastic zones, flasers formed by saussuritized plagioclase and chlorite. Accessory minerals are secondary epidote, zoisite and calcite.

The strong cataclastic to mylonitic textures and accompanying saussuritization, uralitization and transformation of biotite into chlorite occurred after the formation of the agmatite. As indicated by the large field extension and the association with dolerites, it seems likely that the amphibolitic rocks represent igneous gabbroic rocks, brecciated and cemented by the tonalite. The tonalite is at least older than the intrusive granites, as tonalitic inclusions were found in the granites (Lunckeryggen).

Pyroxenites

Pyroxenites, apart from those connected with the marble beds as lenses and nodules, also occur as small bodies (up to 3 m in diameter) and appear as intrusive bodies (Vengen, Perlebandet).

The irregular bodies formed by these ultrabasic rocks cut through the structures of the gneiss, of which they contain relics.

At Perlebandet the pyroxenite itself is cut by a pegmatite dyke. They were mostly observed in the vicinity of the marbles, and therefore a genetic relation with these beds must not be excluded.

In hand specimen these rocks are green, massive and coarse-grained with pegmatitic zones of calcite and phlogopite (Vengen).

The sample from Vengen is a hypidiomorphic granular aggregate of diopside (53 per cent), phlogopite (27 per cent), calcite (10 per cent); hornblende (10 per cent), often contains a pyroxene core and seems to have been formed by uralitization.

Accessories are zircon and secondary epidote. The clinopyroxene also occurs as inclusions in the calcite and biotite.

At Perlebandet scapolite-bearing pyroxenites occur.

The Intrusive Series

The second and younger complex is formed by igneous rocks displaying characters which classically could be described as intrusive. They form homogeneous bodies of massive, apparently structureless, coarse-grained rock and contain displaced xenoliths.

Their contacts with the surrounding rocks, where occasionally typical contact metamorphic mineral associations were noted, are sharp.

This complex is mainly represented by granites, syenites and gabbroic rocks.

The homogeneous texture and lack of structure in the intrusive rock increases their resistance to the main forms of weathering under desert conditions. This causes these rocks to form many of the steep nunataks to the north and the west of the range, which in another paper (PICCIOTTO and others [1960]) allowed a distinction between the "Zone des nunataks" and the "Zone de la chaîne".

GRANITES

Granites, apart from the anatexitic types already mentioned, are widespread in the Sør-Rondane (Romnaesfjellet, Perlebandet, Bamsefjell, Tertene, Blåklettane, the Pingvinane group of nunataks, Utsteinen, Vengen, Lunckeryggen, Dufekfjellet, Menipa, Austkampane).

These granites form small, homogeneous and structureless bodies. Structural control of the intrusion was noted at Blåklettane where the granite follows an east–west orientated, 45° N. dipping, fault zone.

The granites usually contain xenoliths apparently originating from the gneiss series (gneisses, amphibolites, Ca-silicate rocks). The random orientation of the structures in the xenoliths indicates displacement. Their degree of assimilation by the granite varies and occasionally only skialiths or schlieren indicate their presence. Laterally, these skialiths have been noted to pass into less assimilated inclusions.

Another type of inclusion is typical in some of the granites. These occur as perfectly rounded, dark, fine-grained zones occasionally displaying potash feldspar porphyroblasts. They are composed of fine-grained mesocratic aggregates of granitic composition but showing a considerable increase in biotite. Some pegmatitic zones occur within the granite at Pingvinane. Where the contact with the surrounding gneissic series was seen it displays knife-sharp boundaries. Pegmatite dykes occurring as apophyses from the granite are rare.

At Pingvinane a diopside-wollastonite-colourless garnet-marble and a diopside-scapolite-marble probably represent a contact-metamorphic mineral facies.

The granites range from red, pink or grey, porphyroid biotite-hornblende-granites to pink or grey, medium- and fine-grained biotite-granites. They form homogeneous massive rocks often with large, red to slightly green feldspars twinned after the Carlsbad law. Their texture is hypidiomorphic to xenomorphic granular. The potash feldspar (mostly microcline) is strongly perthitic (ranging from the string to the replacement type), and is seen replacing the plagioclase of which it often contain relics.

The plagioclase, ranging in composition from An_{17} to An_{40}, is often zoned with an increase in An percentage towards the centre.

Myrmekites occur commonly, while quartz-biotite-symplectites are only occasionally noted.

This mineralogical composition, which is characteristic of most of the granites of the Sør-Rondane, indicates a parallel geological history. The modal compositions, however, show some variation, indicating different related magma types, which is corroborated by the chemical analyses and Niggli parameters for 5 of the granites (table 1).

The interpretation of MICHOT [1962] for the granite of Romnaesfjellet remains valid at this stage of the study for the other granitic massifs.

Here the first elements to crystallize were a basic oligoclase and a pyroxene (locally retromorphosed), followed by the simultaneous crystallization of the other minerals. A late magmatic phase with potassium enrichment is indicated by the replacement of the plagioclase by the potash feldspar and the local porphyroblastic appearance of this mineral. This potassium enrichment and consequent biotitization seems to be connected to an autometamorphic process related to the myrmekites and symplectitic biotites.

Syenites

Lunckeryggen 2380 is composed of an homogeneous massif of syenite cut by a few, thin, lighter-coloured granitic dykes.

The dark brown, massive, coarse-grained rock displays some irregular and locally more or less parallel structures as schlieren.

They are formed by the concentration of ferromagnesian minerals (often associated with visible apatite and sphene) and finer-grained biotite-rich zones. Locally, the large feldspars show some linear parallelism. Parallel with this lineation there are some darker bands.

Towards the north the massif is progressively brecciated to form near Lunckeryggen 1750 a real igneous breccia (fig. 10).

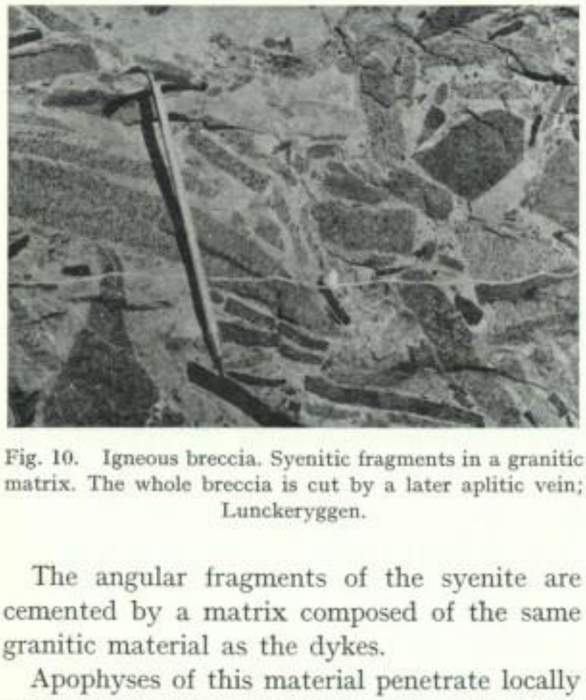

Fig. 10. Igneous breccia. Syenitic fragments in a granitic matrix. The whole breccia is cut by a later aplitic vein; Lunckeryggen.

The angular fragments of the syenite are cemented by a matrix composed of the same granitic material as the dykes.

Apophyses of this material penetrate locally into the fragments, and on a minor scale some assimilation of the syenite has taken place. Some minor pegmatitic dykes cutting the whole breccia formation are clearly younger. Small slickensided surfaces indicate ulterior displacements.

In thin section the homogeneous syenite is composed of a hypidiomorphic-granular leucocratic aggregate of microcline (80 per cent), augite (7 per cent), amphibole (7 per cent) and biotite (4 per cent), sphene (1 per cent), apatite (1 per cent).

The large microcline crystals are not perthitic and display linear arrangements of rods or hexagonal flakes of a dark brown to reddish mineral (hematite).

The colour of the rock is due to these Schiller inclusions.

The augite forms euhedral and often zoned crystals with augite cores and a soda-augite border. The euhedral amphiboles are of an intermediate composition (richterite) and are clearly primary *.

The schlieren-like zones show a considerable enrichment in ferromagnesian minerals, sphene and apatite.

The fine-grained zones, characterized by the same minerals, show zoned microcline (a core with Schiller inclusions and an outer zone without).

The syenite in the brecciated zone and in contact with the granitic matrix displays cataclastic textures with strongly perthitic (plagioclase An_{11}) microcline (Schiller inclusions). The pyroxene is nearly completely replaced by xenomorphic poeciloblastic amphibole occasionally containing an augite core. The amphibole is slightly darker than the primary amphibole which is still present. The secondary minerals remain the same.

The granitic matrix of the breccia is a fine-grained hololeucocratic, hypidiomorphic-granular aggregate composed mainly of strongly perthitic (plagioclase An_{10}) microcline lacking the Schiller structure, quartz, biotite and opaques.

* Determination by H. Jans.

Augite: Border zone, Na-augite (10 to 15 per cent aegirine).

Strongly coloured, moderately pleochroic with N_a = green; N_b = brown; N_c = green; absorption: $N_a > N_b > N_c$ $N_a/C = 39°$; elongation negative; $2V_z = 69-70°$.

Amphiboles: Intermediate composition (richterite).

Strongly pleochroic with N_a = colourless; N_b = smoky blue; N_c = blue-green; absorption: $N_c \geqslant N_b \gg N_a$.

Birefringence 0.015; $N_a = 1.638$; $N_b = 1.653$; $N_c/C = 23°$; elongation positive.

Distinct inclined dispersion with resulting strong dispersion of the optical axis near the C direction $V > \rho$; $2V_a = 64°$.

The chemical analyses of the syenite and the granitic matrix of the breccia are given in table 1. The petrographic study points to an early crystallization of augite and microcline with Schiller structure, followed by a late magmatic phase with sodium enrichment leading to the formation of soda-augite and amphibole.

This phase is possibly related to the brecciation with cataclastic deformation and to the intrusion of the granite with further introduction of sodium (perthite) and water (uralitization).

GABBROS

Gabbroic rocks are represented at Isrosene, Nordtoppen and Småhausane in the east and at Taggen in the west part of the range. They form homogeneous massifs but may locally show a very slight foliation. At Nordtoppen and Småhausane, the massifs are cut by some minor granitic dykes. The rocks are massive, homogeneous and medium-grained with a uniform distribution of the ferromagnesian minerals.

In thin section these rocks are biotite-(quartz-)diorites, monzodiorites, diopside-biotite-leuconorites, biotite-hypersthene-norites and, as a result of uralitization, amphibole-gabbros. Their texture is hypidiomorphic to xenomorphic granular, characterized by the following minerals: plagioclase (An_{35-43} in the centre, An_{28-36} at the border), biotite, small rounded augites (diallage) with uralitic border zones, hypersthene in large poikiloblastic grains, and hornblende as a result of the uralitization.

Accessories are opaques, apatite, microperthite, sphene, zircon and quartz.

The gabbroic rocks are marked by the same succession of events as described for the granites; an early crystallization of basic plagioclase and pyroxene followed by a final autometamorphic phase with the fixation of minor potassium and silica, the appearance of myrmekites and biotite-quartz-symplectites, and a marked biotitization.

Discussion

The most important parts of the observations and samples are still being studied. However, some major facts characterizing the geology of the Sør-Rondane mountains are clear.

The gneissic series represents an important metasedimentary formation comprising originally quartzo-pelitic sediments containing organic debris, arkosic rocks, argillaceous, magnesian and more or less pure limestone.

Gabbroic rocks associated with these sediments probably represent both an initial geosynclinal basic magmatism, and a deep-seated synorogenic magmatism. Basic intercalations showing ophitic structures have been mentioned to the west of the Sør-Rondane, which favours this hypothesis (RAVICH [1959b]).

The mineral facies characterizing the series indicate folding and metamorphism in the upper catazone with a slight retrometamorphism into the mesozone. Locally, this retrometamorphism seems to be related to dynamometamorphic causes.

The gneissic series has further been subjected to migmatization of varying intensity, resulting in field facies of widely different aspects. Locally, this leads to the formation of vague anatexitic granitic masses, or to the individualization of mobilized granitic material in the form of small granitic units related to the heterogeneous migmatites.

The different types of migmatite are often associated and locally grade into each other. However, some relation of the type of migmatite and the nature of the palaeozome is indicated. The migmatization has further proved to have been a complex phenomenon which took place in different stages.

Geological information available from other areas enables the Sør-Rondane complex to be placed more clearly in the crystalline series of eastern Antarctica.

(1) The mineral facies of the area studied occupies an intermediate position in a metamorphic range increasing from west to east.

Indeed, the western part of Dronning Maud Land, studied by the Norwegian-British-Swedish Antarctic Expedition, 1949–52 (ROOTS [1953]), shows a predominant mesozonal facies associated with some epizonal horizons. To the east of the Sør-Rondane, Edward VII Gulf, Enderby and Kemp Lands are characterized by charnockitic to mangaritic facies typical of the deeper catazone.

In the nearer vicinity, Ongul Island, Lützow-Holmbukta in the east and the area between long. 9°25′ E. and 18°37′ E. (TATSUMI and KIKUCHI [1959]; RAVICH [1959c]) the mineral facies is rather similar.

In the latter area, however, the migmatization phenomena are less pronounced. This indicates, as pointed out by RAVICH [1959a], that the area is situated at the border of the zone of regional migmatization. This author also referred to the above-mentioned distribution of mineral facies.

(2) Effects of retrograde metamorphism are known in the area from long. 2° E. to 60° E., which indicates the importance of this process (see also RAVICH and others [1962]).

(3) The anatexitic phenomena of varying importance seem equally widespread. Together with those described here, they indicate the importance of granitic palingenesis in the east Antarctic metamorphic complex.

(4) The rather uniform large-scale structure contrasting with the intense small-scale deformations has often been noted by geologists in Antarctica. Contrary to the views of Roots, this is held to indicate intense orogenic deformation with the formation of recumbent folds.

This first phase, contemporaneous with the main metamorphism, seems to have been followed by another less accentuated phase.

(5) No Permo-Triassic sediments were encountered in the Sør-Rondane. The dolerite dykes represent only minor features, and no volcanic activity was recorded.

The intrusive series and its characteristics can be best explained by a magmatic origin. The different granitic and gabbroic rocks can be related to different magma types, but at the present time no indication of a common origin, or more exactly of differentiation from the same parent magma, has been found.

The intrusives are clearly younger than the gneiss series, but only partial evidence for the chronology of the intrusion was found.

The autometamorphism characterizing the final stage of the evolution of these series seems to have taken place during the same geological phase and under the same physical conditions.

These conditions, as shown by the stability of the biotite in the late magmatic products and by the absence of saussuritization of the plagioclase, seem to have occurred in the deeper mesozone (MICHOT [1939]).

It must be emphasized that the autometamorphic processes are caused by the residual liquids which result from the consolidation of the igneous rocks. Hence, these solutions must be distributed throughout the igneous bodies when the temperature of the reactions are reached.

Such igneous bodies are, therefore, generally characterized by the lack of pegmatitic dykes. This character seems to apply to the igneous masses of the Sør-Rondane. Only a few granitic dykes and pegmatitic veins cut across these masses and represent the last igneous events in the area studied.

Geological age. Hitherto no fossils have been found either in the Sør-Rondane or in the east Antarctic Basement Complex.

Isotopic age determinations remain the only way to establish the geological ages of the various units of the Sør-Rondane. This information is given in another paper by PICCIOTTO and others [1964].

These authors reach the conclusion that the intrusives are about 520 m.yr. old, which corresponds to a Middle or Lower Cambrian age.

As yet there is no evidence for a significantly greater age for the gneissic complex. It is tentatively assumed that the metamorphism and the intrusions belong to the same orogenic cycle. These two phenomena seem to be separated by a time interval of less than 30 m.yr., which is the quoted uncertainty of the ages given.

These conclusions are not in contradiction to the petrographic study, indicating a similar bathymetric evolution for both complexes. This adds evidence for a large part of the east Antarctic basement to be younger than Precambrian, as it was previously assumed.

Acknowledgements

Two of the authors (E. P. and T. V. A.) wish to thank the members of the Expéditions Antarctiques Belges, and especially J. Giot, K. V. Blaiklock and S. Berckmans for their helpful co-operation during the field work.

T. Van Autenboer is indebted to Professor de Béthune, Director of the Laboratoire de Pétrographie, Université de Louvain, and to W. Loy, K. Naert and H. Jans for their support and assistance in the laboratory investigations.

Financial support from the Centre National de Recherches Polaires de Belgique is acknowedged.

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Discussion

E. S. W. SIMPSON: The authors' attention should perhaps be drawn to the published work of Dietrich, Barth, and others on very similar rocks in southern Norway.