PETROGRAPHY OF SOME BASEMENT COMPLEX ROCKS FROM TOTTANFJELLA, DRONNING MAUD LAND

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ABSTRACT. The first collection of schists, gneisses (including porphyroblastic and augen-gneisses) and a metadolerite from Tottanfjella, Dronning Maud Land, is described petrographically. These rocks form part of the Basement Complex of the east Antarctic continental shield, and it is believed that most of them were subjected to regional metamorphism of amphibolite-facies grade.

TOTTANFJELLA (Vardeklettane: lat. 75° 00′ 15″ S., long. 12° 49′ 25″ W.) in Dronning Maud Land are topographically and structurally the south-westerly extension of the north-east trending mountain range, Heimefrontfjella (Worsfold, 1967*a*). Rock samples were first collected from Tottanfjella by D. A. Ardus between 14 and 17 November 1961 and the area was re-visited by R. J. Worsfold during 1963–64. A brief outline of the geology of this area together with some geomorphological observations has already been given by Ardus (1964), but a more detailed geological account of the whole of Tottanfjella and Sivorgfjella has been given by Worsfold (1967*b*). Because Ardus made only a cursory geological survey of the area, his collecting stations are rather widely spaced (Fig. 1) and this has prevented the compilation of a detailed geological map.

All of the rocks have been regionally metamorphosed. Augen-gneisses are by far the most distinctive and widespread of the rocks in this collection but they are nevertheless limited to the central and north-eastern parts of this area. Various other coarse-grained gneisses, gneissic granite and granodiorite, and rare schists crop out in the west and south-west of Tottanfjella and these complete the collection.

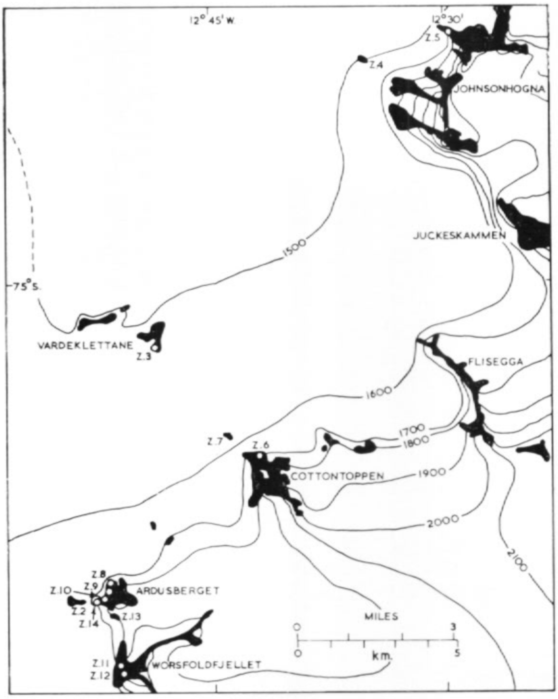

Fig. 1. Sketch map of the south-western part of Tottanfjella showing the physiography, place-names and station numbers.

Schists

Schists are of minor importance in this collection of rocks and they crop out mostly in the west or the south-west of the area. Their localities are shown in Fig. 1, whilst modal analyses of the individual rock specimens are given in Table I.

Table I. Modal analyses of schists from Tottanfjella, Dronning Maud Land

	Z.11.1	Z.3.1	Z.3.5	Z.4.4
Quartz	4·5	55·1	41·3	7·8
Alkali-feldspar	—	9·0	20·5	—
Plagioclase	3·0	5·3	13·3	*
Hornblende	—	—	—	63·4
Muscovite	—	3·1	17·6	—
Biotite	81·6 (Biotite + Chlorite)	25·5	5·4	2·1
Chlorite		1·5	*	*
Epidote	—	*	1·4	21·7
Iron ore	—	*	0·1	0·8
Accessory minerals	10·9	0·5	0·4	4·2
Plagioclase composition	~$Ab_{90}An_{10}$	~$Ab_{68}An_{32}$	$Ab_{70}An_{30}$	—

* Present but not in sufficient amount to be recorded.

Z.11.1 Chlorite-schist; Worsfoldfjellet.
Z.3.1 Quartz-mica-schist; Vardeklettane.
Z.3.5 Quartz-mica-schist; Vardeklettane.
Z.4.4 Hornblende-epidote-schist; station Z.4.

Chlorite-schist

A chlorite-schist (Z.11.1), which is a strongly schistose fine-grained rock with a typical silvery green micaceous sheen, was collected from an intensely folded group of rocks at Worsfoldfjellet. A pronounced lineation of the flaky minerals is present in the hand specimen and a thick irregular replacement vein of smoky quartz is concordant with the schistosity. In thin section the bulk of the rock is composed of well-cleaved, slightly pleochroic chlorite flakes (α = colourless, $\beta = \gamma$ = pale green) crumpled into numerous minor folds. Aggregates of coarser flakes, scattered throughout the rock, exhibit polysynthetic twinning on the penninite law. A mica which interdigitates with chlorite has a more pronounced pleochroism (α = colourless, $\beta = \gamma$ = olive-green or brown) and a stronger birefringence than the chlorite, and it probably represents relict biotite.

Lozenges and granules of sphene, sometimes pleochroic from colourless to pinkish grey, are concentrated in particular along the false cleavage of the schist. Small crystals of sphene are also scattered throughout the schist together with minute crystals of (?) zircon and rare epidote. Small- or medium-sized quartz crystals which are elongated along the limbs of the micro-folds exhibit an undulose extinction. However, the elongate crystals of plagioclase ($Ab_{90}An_{10}$) are not always concordant with the schistosity of the rock (a few have also pushed aside the chlorite flakes as they grew) and the mineral probably crystallized post-kinematically.

Quartz-mica-schists

Fig. 2 shows the position of adjacent outcrops of quartz-mica-schist (Z.3.1, 5) and porphyroblastic feldspar-quartz-biotite-gneiss (Z.3.4) in the vicinity of Vardeklettane. Both specimens of quartz-mica-schist are fine-grained and they have a reasonable schistosity and a marked mineral lineation. The micaceous folia are occasionally disrupted by small feldspar augen (0·5–1·0 mm. in length) but the schists contain only a small amount of feldspar (Table I, Z.3.1).

In thin section the larger crystals of quartz (0·5–1·0 mm. in length) have a preferred orientation and they are embedded in a finer-grained mosaic of quartz and occasional small plagioclase crystals (Fig. 3a); undulose extinction is widespread in the quartz. Porphyroblasts of microcline, microperthite and occasionally plagioclase ($Ab_{70}An_{30}$) are often fragmental or eye-shaped and they occur either as isolated crystals or as strings of coalescing augen. The frequency of augen in the rather mylonitic groundmass of these schists naturally causes differences in their textural appearance. Consequently, specimen Z.3.5 has a more gneissose texture than the finer-grained schist (Z.3.1). Alkali-feldspar is always fresh but plagioclase is usually partially sericitized; myrmekite is rare.

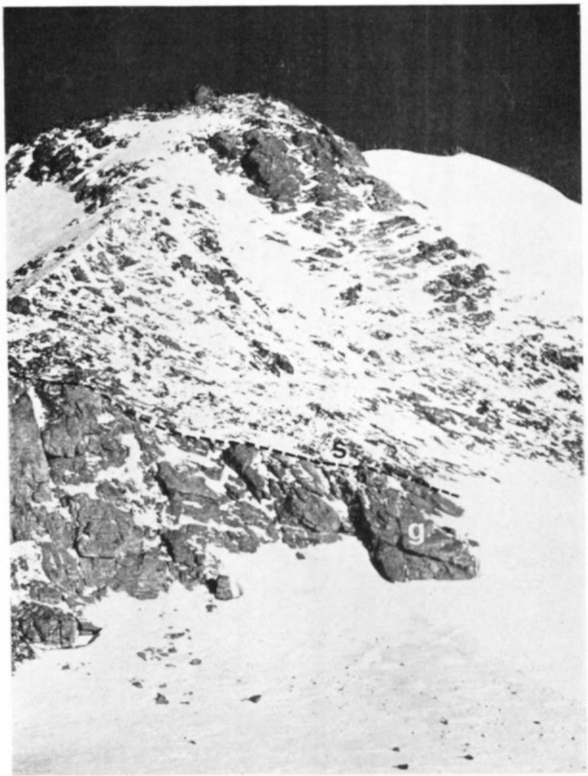

Fig. 2. View of adjacent outcrops of quartz-mica-schist (s) (Z.3.1) and porphyroblastic feldspar-quartz-biotite-gneiss (g) (Z.3.4); Vardeklettane, Tottanfjella. (Photograph by D. A. Ardus.)

The predominant mica of specimen Z.3.1 is biotite but in specimen Z.3.5 muscovite is the most important one. Chlorite is subordinate. Sturdy well-shaped flakes of biotite (α = straw-yellow, $\beta = \gamma$ = dark greenish brown) contrast with the minute flakes of muscovite (occasionally slightly pleochroic from colourless to pale brown) in the micaceous laminae of the schists, although small flakes of both minerals have crystallized in the shear zones around the feldspar augen. Decussate aggregates of muscovite, biotite and chlorite are also common at the interfaces between quartz crystals in the groundmass mosaic.

The accessory minerals are sphene, ilmenite, apatite, zircon and a small amount of epidote. Elongated xenoblasts of sphene in the micaceous laminae often form a secondary rim around large masses and specks of ilmenite. The sphene is white in reflected light and it is probably

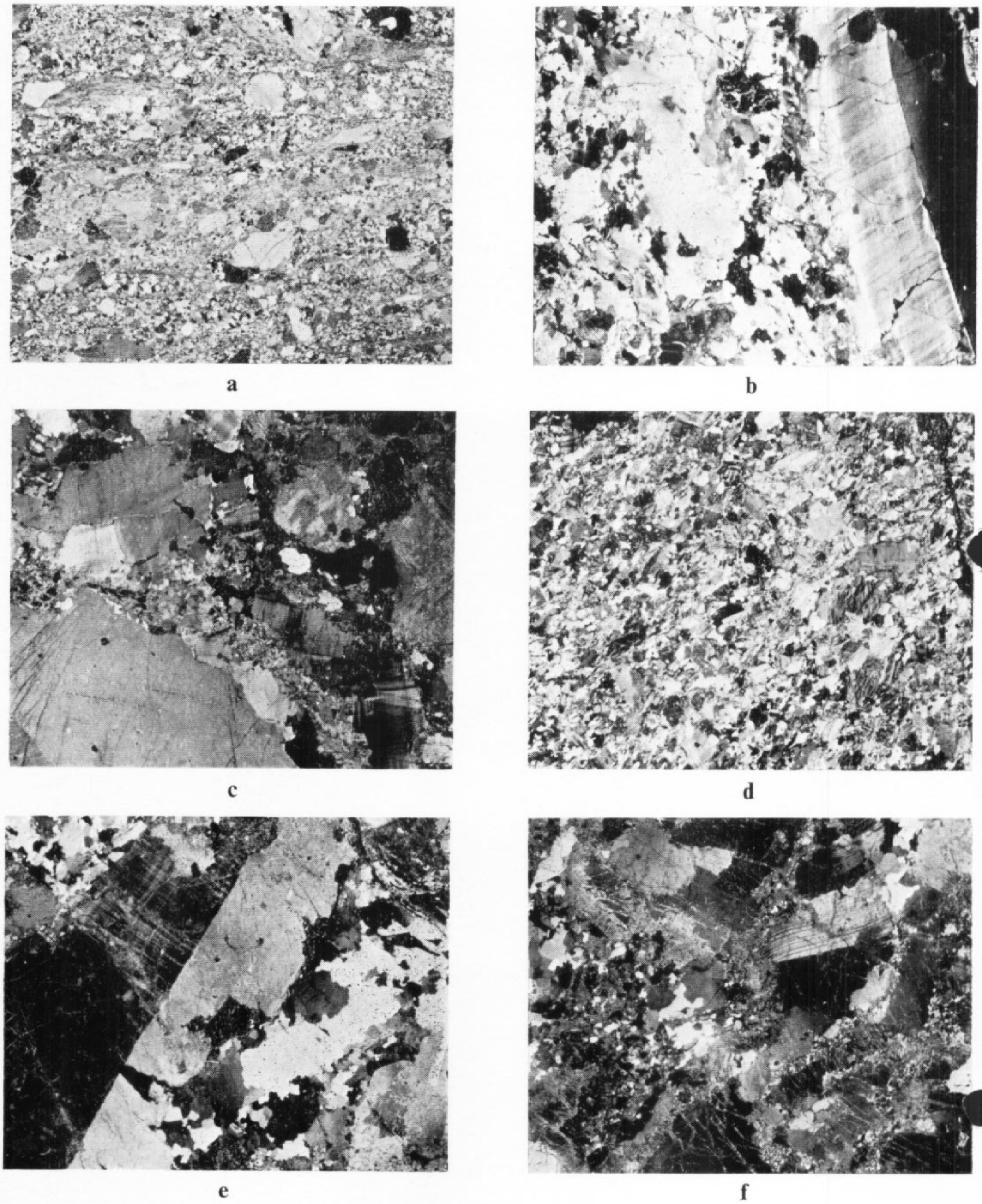

Fig. 3. a. The general mylonitic texture of a quartz-mica-schist. Fresh porphyroblasts of alkali-feldspar and more altered ones of plagioclase are embedded in a groundmass of quartz and plagioclase; Vardeklettane, Tottanfjella (Z.3.5; X-nicols; ×6·8).

b. An extremely large alkali-feldspar porphyroblast in a porphyroblastic feldspar-quartz-biotite-gneiss; Vardeklettane, Tottanfjella (Z.3.4; X-nicols; ×6·8).

c. Two sets of glide twins in a sericitized plagioclase crystal (extreme right) and a twin-plane shear zone in a microperthite crystal (bottom left). The fine-grained material surrounding the large microperthite crystal is mostly myrmekite; porphyroblastic feldspar-quartz-biotite-gneiss; Vardeklettane, Tottanfjella (Z.3.2; X-nicols; ×6·8).

d. Xenoblasts of microcline and microperthite embedded in a quartz-plagioclase groundmass; quartzo-feldspathic gneiss; south of Ardusberget, Tottanfjella (Z.13.1; X-nicols; ×6·8).

e. Unusual twin pattern caused by gliding in a plagioclase porphyroblast. Numerous small "inclusions" of alkali-feldspar are widespread in this and other plagioclase porphyroblasts in the rock; pegmatitic gneiss; Worsfoldfjellet, Tottanfjella (Z.12.1; X-nicols; ×6·8).

f. The general texture of a "granodiorite". Distortion of the twin lamellae in plagioclase porphyroblasts is uncommon; Ardusberget, Tottanfjella (Z.10.1; X-nicols; ×6·8).

leucoxene, described by Tyler and Marsden (1938) as an amorphous variety of TiO_2 formed by deuteric or hydrothermal alteration of titanium-bearing minerals. More recently it has been referred to as an aggregate of haematite, pseudobrookite and rutile (Karkhanavala and Momin, 1959), a solid hydrogel of TiO_2 (Dyadchenko and Khatuntseva, 1961) or "meta-ilmenite", an aggregate of haematite, rutile and anatase (Buddington and Lindsley, 1964). This mineral is therefore referred to here as "leucoxenic sphene" to distinguish it from syngenetic sphene. Apatite is not common although it forms large xenoblasts. Small crystals of epidote are a pale yellowish green colour and minute zircons are surrounded by metamict haloes in biotite.

Hornblende-epidote-schist

Although no specimens of hornblende-epidote-schist were collected *in situ* in the gneissic terrain at station Z.4, specimen Z.4.4 was collected from boulders found in this vicinity. These boulders were probably derived from bands and lenses of amphibolite within the gneisses, similar to the other amphibolites of Tottanfjella described by Worsfold (1967*b*, p. 47) and to those of Fimbulheimen (Gjelsvik, 1962, p. 100).

Specimen Z.4.4 is a medium-grained, dark greyish green rock which has only a poorly defined schistosity and no marked mineral lineation. In thin section the elongate xenoblasts of hornblende (2·5 mm. in length) are strongly pleochroic (α = pale greenish or yellowish brown, β = apple-green, γ = deep blue-green; $\gamma : c = 17°$) and they form branching discontinuous folia separated by segregations of quartz, epidote and occasionally plagioclase. Patchy colour distribution in the eye-shaped scaly aggregates of hornblende is enhanced by alteration of the amphibole to a turbid mixture of chlorite, biotite and epidote.

The greater part of the light-coloured bands between those of hornblende is occupied by a virtually colourless and usually granular epidote. However, the yellowish green colour and perceptible pleochroism observed under high magnification indicates that the mineral is pistacite and not clinozoisite. Although small crystals of hornblende, flakes of biotite and a few quartz crystals (slightly flattened and exhibiting undulose extinction) are embedded in the compact masses formed by the epidote granules, epidote itself is apparently included in the xenoblasts of sphene. Biotite is an occasional but widespread mineral. It generally occurs as small flakes (pleochroic in shades of orange-brown) in the epidotic segregations but in addition it is often intimately associated with hornblende. "Leucoxenic sphene" is widespread and it occurs as irregular elongate masses up to 4 mm. in length; small granular aggregates or larger masses of ilmenite form relicts in the cores of these masses, and inclusions of other minerals are also present in several of the sphene xenoblasts. Plagioclase is a rare mineral and it is invariably xenoblastic.

Gneisses

Gneisses are widespread in Tottanfjella and they crop out at all of the peaks named in Fig. 1. Augen-gneisses, together with porphyroblastic gneisses, are the most distinctive of this rock type in the hand specimen but they only crop out in the central and north-eastern parts of this area. Porphyroblastic gneisses are in contact with schists on Vardeklettane, whilst a specimen of a normal gneiss was collected from a peak near the granite pod of Ardusberget (p. 69). Modal analyses of these gneisses are given in Table II.

Feldspar-quartz-biotite-gneiss

Specimen Z.2.1 is a typical dark medium-grained gneiss with abundant bronze-coloured biotite and semi-flattened streaks of alkali-feldspar. A coarse pegmatitic replacement-type vein of greenish alkali-feldspar and smoky quartz cuts the gneiss in the hand specimen and included within it are flames and blebs of the host rock. In thin section, the overall texture of the gneiss is xenoblastic. The crystal boundaries are usually poorly defined due to extensive sericitization of the plagioclase ($Ab_{70}An_{30}$) and the development of either an (?) albitic rim around both plagioclase and alkali-feldspar (microcline) crystals, or globular myrmekite wherever the two feldspars are in mutual contact. The feldspar porphyroblasts are embedded in a groundmass of altered plagioclase and quartz crystals (0·5 mm. in diameter) and they

TABLE II. MODAL ANALYSES OF GNEISSES AND GRANITIC ROCKS FROM TOTTANFJELLA, DRONNING MAUD LAND

	1	2	3	4	5	6	7	8	9	10	11
Quartz	23·6	30·5	32·4	19·7	30·6	36·6	44·9	23·4	32·6	36·2	*
Alkali-feldspar	43·0	40·8	20·1	46·9	39·1	17·0	34·5	21·6	28·5	19·3	*
Plagioclase	21·5	20·7	33·6	20·6	16·1	37·0	16·1	40·8	23·0	29·7	*
Amphibole	—	0·2	0·4	—	—	—	—	*	2·1	*	49·2
Muscovite	—	0·2	0·1	—	0·9	—	*	—	—	—	—
Biotite	11·4	4·8	11·8	*	9·6	6·4	1·8	10·3	7·1	13·4	†
Chlorite	*	0·6	*	11·5		*			3·8		*
Epidote	—	0·1	—	0·1	2·9	1·1	—	*	0·1	*	48·2
Accessory minerals	0·5	2·1	1·6	1·2	0·8	1·9	2·7	3·9	2·8	1·4	2·6
Plagioclase composition	An_{30}	An_{29}	?	An_{29}	An_{24-32}	An_{26}	$\sim An_{26}$	An_{27}	$\sim An_{26}$	An_{30}	—

* Present but not in sufficient amount to be recorded.
† Included with amphibole.

1. Z.2.1 Feldspar-quartz-biotite-gneiss; nunatak west of Ardusberget.
2. Mean of two porphyroblastic gneisses; Vardeklettane (Z.3.2,4).
3. Z.3.3 Xenolith in specimen Z.3.2; Vardeklettane.
4. Z.13.1 Quartzo-feldspathic gneiss; Ardusberget.
5. Mean of six augen-gneisses (Z.4.1,2,3, 5.1, 6.1, 7.1).
6. Z.12.1 Pegmatitic gneiss; Worsfoldfjellet.
7. Z.9.1 Granite; Ardusberget.
8. Z.10.1 "Granodiorite"; Ardusberget.
9. Mean of two gneisses; Ardusberget (Z.8.1, 14.1).
10. Z.8.2 Fine-grained gneiss; Ardusberget.
11. Z.8.3 Metadolerite; Ardusberget.

resemble those of the augen-gneisses (p. 67). The quartz of the gneiss contains minute scattered dust inclusions (sometimes aligned in Boehm lamellae) and it has undulose extinction, whereas the quartz in the pegmatitic vein is unstrained.

Biotite is reasonably abundant and it usually has a well-defined lepidoblastic texture. Large idioblastic flakes (0·5–1·0 mm. in length; α = colourless, $\beta = \gamma$ = deep red-brown) have an unusual lamellar appearance because they partially replace an earlier, slightly pleochroic orange-brown biotite. The two interdigitating biotites are easily distinguished by their differences in pleochroism and birefringence; the colour of the earlier biotite masks its interference colours, whereas the later foxy-red biotite displays typically bright interference colours. The primary orange-brown biotite is considerably finer-grained than the foxy-red one and it generally lacks any crystalline form, merely occurring as irregular aggregates of minute scales. The foxy-red biotite is also "sagenitic" as it includes a mass of needles orientated parallel to three directions at approximately 60° to each other. Niggli (1965) has described similar "sagenitic biotites" from the Alps and he concluded that the inclusions in the biotite are either rods of rutile or sphene. Because the rods included in the Tottanfjella biotites have a rather variable extinction, dependent on their position in the biotite crystal, they are probably sphene and not rutile.

Accessory minerals associated with the biotite are large elongate, oval or broken crystals of apatite, irregularly shaped yellow grains of allanite (0·3 mm.) surrounded by metamict haloes in the biotite, and unusually coarse crystals of zircon. Small masses of ilmenite are rather uncommon.

Porphyroblastic feldspar-quartz-biotite-gneiss

These gneisses (Z.3.2,4) are very distinctive in the hand specimen (Fig. 4). Large milk-white plagioclase and clear white alkali-feldspar porphyroblasts (at least 3 cm. long) are usually idioblastic and it is the widespread presence of crystal form which distinguishes these gneisses from the augen-gneisses (p. 66). Bronze-coloured biotite is the main dark mineral but it is less abundant than in the finer-grained gneisses of this area; garnet is not obvious in the hand specimen.

Fig. 4. Characteristic porphyroblasts of alkali-feldspar and plagioclase in a porphyroblastic feldspar-quartz-biotite-gneiss. Note the irregular xenoliths of more homogeneous rock; Vardeklettane, Tottanfjella. (Photograph by D. A. Ardus.)

The porphyroblasts of microperthite, microcline and subordinate plagioclase ($Ab_{71}An_{29}$) are extremely large in thin section, especially the alkali-feldspars (7·9 × 6·6 mm.) (Fig. 3b). Much of the plagioclase is altered to a felted mass of sericite and chlorite but a number of secondary polysynthetic albite glide twins (Vance, 1961) cut across earlier twins and are orientated at right-angles to them (Fig. 3c). Myrmekite is well developed in specimen Z.3.2. Although these rocks have been somewhat deformed and undulose extinction is ubiquitous in the interlocking variably sized quartz crystals of the groundmass, flaser structure is not widespread. Well-defined shear zones in the feldspar porphyroblasts are a further product of cataclasis, and movement of up to 0·7 mm. along a shear zone was observed in one microperthite crystal (Fig. 3c), accompanied by crushing of the feldspar along the shear.

Lepidoblastic biotite (α = straw-yellow, $\beta = \gamma$ = orange-brown) contains inclusions of acicular sphene; it is quite widespread and scaly aggregates of an earlier pale mica are less common. There are no interdigitations of the two biotites but a few crystals of the secondary one are "symplektitically" intergrown with quartz close to garnet crystals. Garnet, the most important of the accessory minerals, forms highly irregular porphyroblasts which vary in size up to 1·6 mm. in diameter. The crystals are often fragmentary but the larger complete porphyroblasts are riddled with small vermicular inclusions of quartz. In places the garnet is pseudomorphed by chloritized, pale brownish green biotite, and bleb-like xenoblasts of ilmenite; occasionally a narrow rim of "leucoxenic sphene" surrounds the ilmenite. Coarse xenoblasts of apatite (0·5 mm. in length), flakes of muscovite and zircon crystals are rare.

Xenoliths (Z.3.3; Fig. 4) occur in the porphyroblastic gneisses and, although they are now mineralogically similar to the host rock, they differ from them in their essentially non-porphyroblastic texture.

Quartzo-feldspathic gneiss

Specimen Z.13.1 is a light grey fine-grained gneiss with a rather massive equigranular, "salt-and-pepper" texture. Microcline and microperthite xenoblasts are the most important crystals (Fig. 3d) and they are embedded in a groundmass of equant and irregular quartz and plagioclase xenoblasts. The alkali-feldspar is generally fresh and it contains occasional inclusions of plagioclase in addition to numerous rounded inclusions of quartz. Altered crystals of plagioclase ($Ab_{71}An_{29}$) have distorted glide-twin lamellae or exhibit a coarse, poorly defined type of albite twinning; myrmekite is absent.

The mafic minerals are confined to narrow, impersistent and undulating layers. Coarse flakes of penninite are associated with smaller ones of brown biotite (or more commonly with a deep olive-green or brown chloritized biotite), large semi-prismatic crystals of epidote (often turbid) and small granules of sphene. Small euhedral flakes of muscovite are widespread but relatively uncommon, and zircon and apatite (large oval xenoblasts) are rare and garnet is absent.

Augen-gneisses

The augen-gneisses (Z.4.1–3, 5.1, 6.1, 7.1; Fig. 5) are distinguished from the porphyroblastic gneisses by the generally irregular shape of their feldspar porphyroblasts (Figs. 6 and 7). The porphyroblasts (2·0–5·5 cm. in length) are pale pink or greenish white in colour and they are embedded in a groundmass of flattened quartz crystals, flakes of chlorite and subordinate biotite. Small xenoblastic red garnets (Z.4.1–2, 7.1) are rare and usually fragmented. Wisps and small blebs of the groundmass are included in the feldspar augen and the degree of

Fig. 5. Large feldspar porphyroblasts in an augen-gneiss; station Z.4, Tottanfjella. (Photograph by D. A. Ardus.)

flattening and shearing to which the porphyroblasts have been subjected varies from one rock to another. In many cases the eye-shape of the porphyroblast is not obvious in the hand specimen but in others the augen texture is well developed (Fig. 6) and the shear zones around the feldspar porphyroblasts can also be observed (Fig. 7).

In thin section, microcline and microperthite have average dimensions of approximately 1·0 × 1·3 cm. Microcline displays typical grid-iron twinning, whilst microperthite often has a patchy appearance under crossed nicols. A number of large rounded inclusions (0·1–0·7 mm. in diameter) of plagioclase and quartz in the microcline and microperthite crystals are indicative of alkali-feldspar porphyroblastesis. The augen texture is not always apparent in thin section

Fig. 6. Typical pinch-and-swell structure in an augen-gneiss; Cottontoppen, Tottanfjella (Z.6.1; × 1·75).

but in specimen Z.6.1 the rim of muscovite, biotite and epidote developed along the bounding shears of the augen is well defined. In some specimens the augen are not complete porphyroblasts but an aggregate of fragments; this is particularly obvious where plagioclase crystals are involved because twin lamellae can often be matched in contiguous fragments. In several of the augen-gneisses the alkali-feldspar has tended to develop after deformation ceased and the microcline or microperthite has grown over the cataclastic contacts of the original porphyroblasts.

Plagioclase shows a considerable variation within the composition range $Ab_{76}An_{24}$–$Ab_{68}An_{32}$ and it generally occurs in either small porphyroblasts 3·5 mm. in length or as aggregated crystals 0·7 mm. in diameter. Glide twinning on the albite law or occasionally on the combined pericline and albite laws is a common feature in fresh crystals; however, alteration to a fine-grained flaky mass of chlorite and granular epidote overgrown by coarse flakes of sericite is

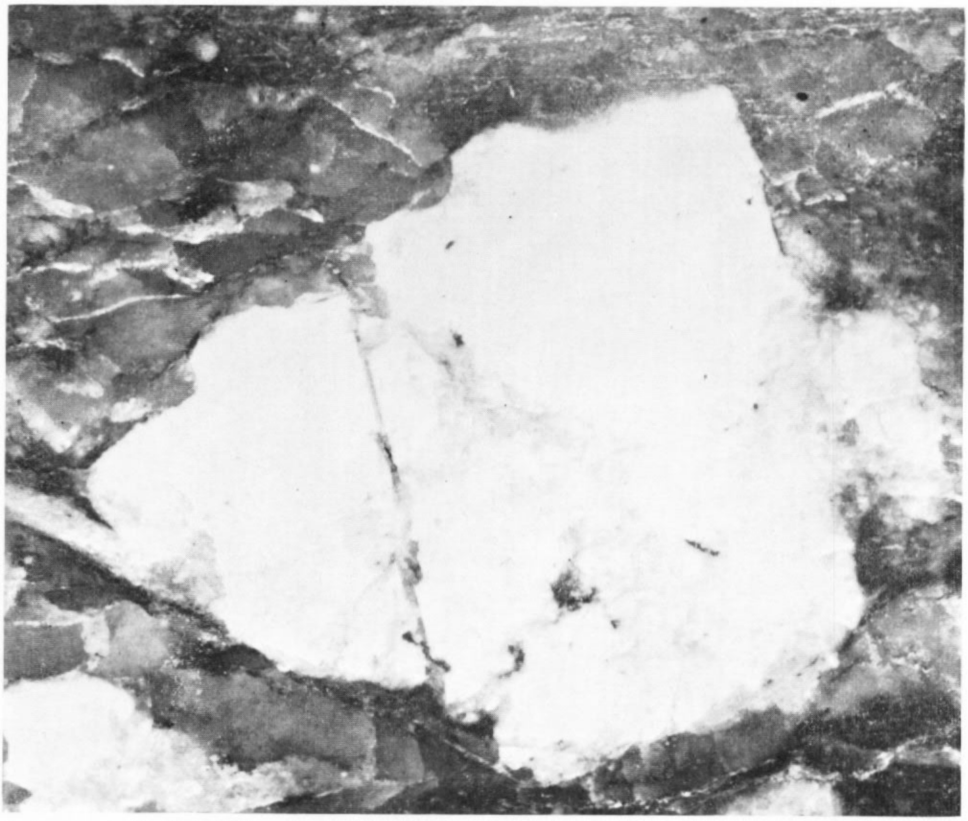

Fig. 7. An augen of alkali-feldspar bounded by mica-filled shear zones; augen-gneiss; station Z.4, Tottanfjella (Z.4.1; × 2·6).

frequent and it obscures much of the twinning. The twin lamellae are usually undistorted and they have very fine chisel-shaped terminations. Distortion, when present, is in the form of gentle flexures.

Small xenoblasts of oligoclase are ubiquitous around the periphery of the alkali-feldspar porphyroblasts, whilst myrmekite is common wherever porphyroblasts of the two feldspars are in contact. Much of the myrmekite occurs in fan-shaped patches protruding into crystals of alkali-feldspar but the rest forms irregular areas of variable shape and size separating the different feldspars from each other. The globules of quartz included in the myrmekite also vary considerably in size. Some of the myrmekitic structure is obscured by saussuritization of the host plagioclase in the more altered of the augen-gneisses but in other specimens there is a simple replacement of plagioclase by alkali-feldspar. In the latter case, polysynthetic twins are partially obliterated by irregular patches of fresh alkali-feldspar developed during a late phase of metasomatism.

The greater part of the quartz in the groundmass occurs as a relatively fine-grained granular mosaic of equant or irregular crystals (0·1–1·0 mm. in diameter). Undulose extinction is widespread although rare quartz crystals exhibit a flaser structure (Z.5.1), and grain elongation is usually slight. Quartz porphyroblasts (1·5 mm. in diameter) form irregular lenses containing patchy inclusions of saussuritized feldspar and flakes of mica; the absence of alkali-feldspar inclusions indicates that quartz porphyroblastesis was probably the forerunner of potash metasomatism and the formation of microcline and microperthite porphyroblasts. A small amount of quartz filling small fractures in the feldspar augen occurs either alone or is associated with muscovite and chlorite.

The groundmass is composed of alternating laminae or lenses of quartz with plagioclase, and mica accompanied by accessory minerals. Biotite is the principal mica and it occurs in all of the specimens. Muscovite is not always present but in a few of the rocks its modal percentage may exceed that of biotite and chlorite. The micas form discontinuous undulating layers or they occur along the shear zones surrounding feldspar augen. In particular, coarse muscovite flakes have developed in the minimum pressure zones of the augen. Biotite (0·4–0·6 mm. in length) does not normally contain "sagenitic" inclusions of sphene, apart from the biotite in specimen Z.4.3, and it is often chloritized. Its colour varies from a clear green (possibly indicative of high FeO, and low TiO_2 and MgO (Hall, 1941, p. 32)) through greenish brown to an olive-brown (α = straw-yellow, $\beta = \gamma$ = brown or green), and its birefringence is frequently masked by the mineral colour or it shows low interference colours typical of incipient chlorite. In specimen Z.6.1 there are two varieties: an unusual clear blue-green one with a perfect crystalline shape and a brown one with a marked pleochroism. The flakes of mica in the other augen-gneisses are generally less perfectly shaped. Relict slivers of an orange- or red-brown biotite are common in the penninitic chlorite (α = straw-yellow, β = yellowish green, γ = blue-green), whilst a few small flakes of biotite are intersected by fine needles of muscovite.

Epidote is the main accessory mineral. It is prominent where coarse "sagenitic" biotite has been replaced by chlorite and it forms needles, elongate narrow masses or coarse prisms which are slightly pleochroic in shades of pale yellow. Iron ore forms large irregular aggregates or small scattered specks associated with biotite and chlorite; most of it is secondary ilmenite or magnetite probably released during retrograde metamorphism, but primary ilmenite is also present in these gneisses and it is partially or completely altered to "leucoxenic sphene". The rare garnet is usually xenoblastic and fragmentary. Sieve-texture is present in the vein-like garnets, many of which have been partially pseudomorphed by a mass of biotite associated with bright green chlorite. Muscovite, epidote and quartz are also associated with these garnets. Zircon is included in biotite and coarse oval xenoblasts of apatite are common but allanite is rare (Z.6.1).

Pegmatitic gneiss

The macroscopic differences between the pegmatitic gneisses and the augen-gneisses are only slight (in one of the pegmatitic gneisses (Z.12.1) the feldspar porphyroblasts are up to 5 cm. in length, irregular and rarely augen-shaped) but microscopically the pegmatitic gneisses are quite distinct. Numerous small patches of microperthite and a little microcline are apparently included in large fresh porphyroblasts of plagioclase ($Ab_{74}An_{26}$) and it is this phenomenon which distinguishes the two rock types. Because the alkali-feldspar porphyroblasts in the same rock are similar to those of all the other gneisses of the area, i.e. they are unaltered and contain rounded inclusions of plagioclase and quartz, it is believed that the microcline/microperthite inclusions in the plagioclase crystals are in fact centres of replacement for alkali-feldspar; in one complex example the plagioclase included in microcline itself contains "inclusions" of microcline/microperthite. In contrast with the other gneisses, the plagioclase porphyroblasts are as fresh as those of alkali-feldspar and thin hair-like glide-twin lamellae (Vance, 1961) (Fig. 3e) are clearly visible. Although it is widespread, myrmekite is not well developed. Biotite, garnet, ilmenite, epidote and allanite are relatively unimportant minerals in this gneiss.

Granitic Rocks

A small pod of pink granite, which crops out on the western side of Ardusberget adjacent to a granodioritic rock of unusual appearance, is probably closely associated with a sequence of gneisses which are present both on the north-west point of Ardusberget and south-west of the granite pod. Modal analyses of these rocks are given in Table II.

Granite

Specimen Z.9.1 is a coarse-grained, deep pink, gneissic granite which is rich in alkali-feldspar and smoky quartz. Pale green plagioclase crystals are less common, and xenoblastic garnets and mafic minerals are relatively rare. Microscopically, this granite is very similar to the porphyroblastic gneisses and the augen-gneisses. Large irregular porphyroblasts of microperthite and microcline contain patchy inclusions of plagioclase and quartz but the plagioclase porphyroblasts ($Ab_{74}An_{26}$) are so completely sericitized that relict twinning is rarely observed and myrmekitic intergrowths are obscured. Large porphyroblasts of quartz exhibit undulose extinction. Vein-like xenoblasts of pale pink garnet are partially replaced by aggregates of chlorite (α = straw-yellow, $\beta = \gamma$ = olive-green) and a brownish green biotite associated with rare small needles of muscovite and a few granules of epidote.

"Granodiorite"

A dark grey-green, medium- to coarse-grained rock (Z.10.1) which crops out adjacent to the gneissic granite is rich in felsic material in spite of its dark colour in the hand specimen and it is believed to be a granodiorite. Crystals of smoky quartz and greenish feldspar (0·5–1·2 cm. in length) are the main constituents of the rock and mafic minerals are uncommon. In thin section the "granodiorite" resembles the pegmatitic gneisses (p. 69), because the plagioclase porphyroblasts ($Ab_{73}An_{27}$) are usually fresh, polysynthetic glide twinning on the albite law is widespread (Fig. 3f) and they contain small irregular "inclusions" of microcline. Microperthite and microcline porphyroblasts including patches of altered plagioclase are less common but there are many excellent examples of myrmekite bordering the feldspar crystals. Quartz forms an interstitial mosaic of medium-grained crystals in addition to large porphyroblasts, and undulose extinction is usual. Vein-like poikiloblastic garnets include vermicular quartz and they are accompanied by blebs of ilmenite surrounded by brown biotite (α = straw-yellow, $\beta = \gamma$ = red-brown) and scaly aggregates of pale green chlorite. Oval crystals of apatite included in ilmenite are rare and "sagenitic" biotite (α = straw-yellow, $\beta = \gamma$ = golden brown) is uncommon (this biotite is "symplektitically" intergrown with quartz and epidote in some parts of the rock). Large rounded crystals of zircon, prisms of pistacite and acicular epidote associated with allanite are of minor importance.

Associated gneisses

Most of the gneisses from Ardusberget are fairly coarse-grained dark grey rocks in the hand specimen (Z.8.1, 14.1) and macroscopically they resemble normal gneisses. However, in thin section the mafic minerals are more varied and they form clusters or patchy aggregates of crystals in this essentially quartzo-feldspathic rock type. Porphyroblasts of microcline and microperthite (4 mm. in diameter) are embedded in an equigranular mosaic of strained quartz crystals and they contain abundant quartz but relatively few plagioclase inclusions. Plagioclase porphyroblasts ($Ab_{74}An_{26}$) are usually small, fresh and polysynthetically twinned, and myrmekite is widespread.

Biotite and chlorite are the commonest of the dark minerals but a considerable amount of amphibole is present and garnet is more abundant. The biotite, which has a patchy colour distribution (α = straw-yellow, β = pale yellow-brown, γ = yellow, yellow-brown or orange-brown), is slightly chloritized in places; this is often merely a greenish tinge at the periphery of the biotite flakes (Z.14.1) and it forms aggregates of thin scales centred around large irregular masses of ilmenite. Chlorite (α = pale yellow-green, $\beta = \gamma$ = green) is also fine-grained and scaly but incipient crystals of hornblende (α = colourless or very pale green, β = green, γ = blue-green; $\gamma : c = 24°$) are semi-prismatic when they have developed at the cores of chloritic patches or xenoblastic when contiguous with masses of actinolite (weakly pleochroic from colourless to very pale green; $\gamma : c = 14°$) (Z.8.1). The actinolite occurs as interstitial masses of long and short flakes interspersed with biotite, chlorite, ilmenite, allanite and scattered crystals of hornblende. Although the two amphiboles are often contiguous, there is never any apparent gradation from the one mineral into the other since crystal boundaries are always sharp. Similar relationships have been described by Miyashiro (1958, p. 234) and Shidô (1958, p. 172), both of whom have suggested that a miscibility gap must exist between actinolite and hornblende, under the appropriate metamorphic conditions, to explain the equilibrium co-existence of these two amphiboles.

Large vein-like poikiloblasts of pale pink garnet contain abundant inclusions of long quartz vermicules; replacement of garnet by biotite and chlorite is incomplete and rare. Large rounded xenoblasts of apatite are common and a narrow partial rim of yellow allanite sometimes surrounds the masses of ilmenite occurring at the cores of biotite-chlorite-actinolite aggregates. Irregular masses of yellow allanite included in actinolite are enclosed by a wide metamict halo; small crystals of zircon and acicular epidote are uncommon.

Specimen Z.8.2 is much finer-grained than the other gneisses from Ardusberget and it is texturally quite different from them. Porphyroblasts are notably absent but light greenish grey areas of feldspar and quartz are interspsersed with irregular dark patches of garnet and mafic minerals. Biotite, chlorite, actinolite and hornblende bear similar relationships to one another as in specimen Z.8.1, but in this specimen heterogeneous scaly aggregates are commoner than the well-defined corona-type aggregates of specimen Z.8.2. The core consists of minute actinolite blades associated with acicular epidote, some biotite and a considerable amount of quartzo-feldspathic material, and it is surrounded by a narrow rim of granular dark blue-green hornblende. Abundant dark brown biotite, chloritized biotite and chlorite occur near these zoned aggregates and they are accompanied by poikiloblastic garnets, blebs of ilmenite, a small amount of apatite, allanite with concomitant metamict haloes, and crystals of zircon.

Metadolerite

No *in situ* metadolerites were observed at the north-west point of Ardusberget but specimen Z.8.3 was collected from a boulder at this locality. This specimen is an altered, aphanitic, dark grey-green rock, which in thin section is composed of irregular sub-prisms of actinolite (pleochroic from colourless to pale green) and anhedral patches of blue-green hornblende, small prisms or needles of epidote and scattered imperfect flakes of biotite (α = straw-yellow, $\beta = \gamma$ = orange-brown). Pseudomorphs of either olivine or pyroxene are represented by large aggregates of biotite occasionally enveloped by a rim of poorly crystalline actinolite and associated with abundant specks of iron ore. Dusty patches of (?) sphene are ubiquitous in this rock but small crystals of quartz and/or feldspar are rare.

Modal Analyses

The results of the modal analyses of these rocks are given in Tables I and II. Analyses 5–9 of Table II are included for comparison with the other gneisses but, because of the abnormally coarse texture of these rocks, it is doubtful whether the modes obtained are truly representative. The augen-gneisses and pegmatitic gneisses (Table II, 5 and 6) have large feldspar crystals and since one of these can occupy half the area of a thin section, sampling errors (Bayly, 1960; Solomon, 1963) become a major problem during the analyses. More accurate modes of similar rocks obtained by a macroscopic method of analysis have been given by Worsfold (1967*b*, tables I, II and III).

Discussion

The general geology of western Dronning Maud Land has previously been described by Roots (1953) and that of east Antarctica by Klimov and others (1964). Gjelsvik (1962) noted coarse-grained crystalline rocks similar to those of Tottanfjella in an area east of Heimefrontfjella (lat. 72° S., long. 2° 30′–7° 00′ E.) and similar granitic and granodioritic gneisses (although they contain additional hornblende and diopside) are present in "zone 2" of the Sør-Rondane mountains (Naert, 1968). Worsfold (1967*b*) has included the detailed petrology of identical rocks from Tottanfjella in his description of the geology of southern Heimefrontfjella.

Since the present paper is based on a laboratory study of only those rocks collected by Ardus, their paragenesis will not be considered here, but the origin of similar rocks from Tottanfjella has already been discussed by Worsfold (1967*b*, p. 26–33, 54–56). However, it is suggested that these rocks have been regionally metamorphosed under the conditions of the amphibolite-facies (Fyfe and Turner, 1966) grade of metamorphism and that the rocks of Ardusberget, adjacent to the granite pod, were probably subjected to local thermal effects during the intrusion of the granitic rocks. A phase of potash metasomatism during regional metamorphism caused the development of alkali-feldspar porphyroblasts and the widespread replacement of plagioclase in all of these rocks. Local orogenic movements subsequent to this metasomatic phase caused flattening and shearing of the feldspar porphyroblasts, although in some specimens metasomatism and cataclasis were probably contemporaneous phenomena since a few of the alkali-feldspar porphyroblasts continued to grow over the cataclastic contacts of their original crystals; one centre of deformation was probably located at Cottontoppen where specimen Z.6.1 (Fig. 6) was collected. The similarity between the mineralogy of the granite (Z.9.1) and the gneisses of Tottanfjella is indicative of their common synorogenic formation.

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