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II. THE PETROLOGY OF SIGNY ISLAND

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ABSTRACT

SIGNY ISLAND, the best known of the South Orkney Islands, is composed of a regionally metamorphosed sequence of marbles, *para*-amphibolites and quartz-mica-schists (the Basement Complex of probable Precambrian age), whose stratigraphical succession has been established by earlier workers. These rocks, which have undergone post-kinematic crystallization, belong to the albite-epidote-amphibolite facies, and they probably represent crystallization at a higher grade of metamorphism than the rocks situated to the north on Coronation Island; retrograde metamorphism is purely a local phenomenon. It is believed that these metamorphic rocks were originally sediments of epicontinental facies, i.e. quartzites, mudstones, marls and limestones, and that during metamorphism they underwent a sequence of vein mineralization which was both pre- and post-kinematic. In spite of the widespread veining, there is no conclusive evidence of igneous activity on Signy Island. Only one phase of crystallization is indicated by the rocks examined, although K-Ar age determinations have shown that a much later and more feeble orogeny, which released radiogenic argon, affected these rocks approximately 185 ± 7 m. yr. ago. The metamorphic rocks of the South Orkney Islands are lithologically and petrologically comparable with those of the Elephant and Clarence Islands group, but they differ from the Basement Complex of the Antarctic Peninsula, where *ortho*gneisses are present.

CONTENTS

I. INTRODUCTION

THE South Orkney Islands are situated between lat. 60°15′ and 60°55′S., and long. 44°20′ and 46°45′W. They lie on the southern limb of the Scotia Ridge, the name applied to the submarine ridge enclosing the Scotia Sea (Fig. 1). Signy Island (lat. 60°43′S., long. 45°38′W.), one of the smallest but geologically the most important member of the island group, is situated immediately south of the much larger Coronation Island (Fig. 2).

The history of geological investigations in the South Orkney Islands has been summarized by Adie (1957, 1958) and the petrography of the earlier rock collections has been described by Holtedahl (1929), Tilley (1935), Stewart (1937) and Barth and Holmsen (1939). Geophysical surveys of the Scotia arc and Graham Land began in 1959 (Griffiths, 1963) and they have continued each year since then; the progress of this work has been summarized by Griffiths and Barker (1967). Matthews and Maling (1967) have published the most recent geological information on Signy Island; the present report is a continuation of their work and to a large extent it is based on their rock collections (Table I).

TABLE I

COLLECTIONS OF ROCK SPECIMENS FROM THE SOUTH ORKNEY ISLANDS

Date	*Collector*	*Station numbers*	*Remarks*
1933	Discovery Investigations	1089–1095	Specimens described by Tilley (1935)
1947	R. J. Adie	C.G.1–8 S.F.1–5 S.I.1–11	Laurie Island Coronation Island Signy Island
1947	G. de Q. Robin	H.1–91	Signy Island
1948–49	D. H. Maling	H.97–389	Signy and Coronation Islands
1953	A. G. Tritton	H.501–545 H.546–571	Signy Island Coronation Island
1956	D. H. Matthews	H.1099–1411	Signy and Coronation Islands

Physiography

The overall trend of the South Orkney Islands is in a west–east direction (Fig. 2), although individually the islands have differing structural and physiographic trends. Coronation and Laurie Islands, the two principal members of the group, extend in an approximately west-north-west to east-south-east direction, whilst the smaller Powell and Signy Islands have their longest axes directed north–south.

Each of the South Orkney Islands is characterized by a mountainous interior which is generally covered by ice and snow. The coastlines have steep rocky ridges terminated by bold headlands and sheer cliffs, although where the ice caps descend to the sea the slope is more gentle. Numerous small islands and off-shore rocks occur around all of the islands.

Signy Island, which is between 4 and 5 miles (6·4 and 8·0 km.) long, has a roughly triangular shape. The base of the triangle forms the southern coast of the island and it is slightly more than 3 miles (4·8 km.) long. The highest point is Tioga Hill (907 ft.; 276 m.). The island is separated from Coronation Island by Normanna Strait, a stretch of water which is approximately 1 mile (1·6 km.) wide at its narrowest point; Adie (1964) has inferred that this represents a significant west–east tear fault between the two islands. Much of Signy Island is free of permanent ice owing to its situation in the lee of Coronation Island. In fact, there is only a central permanent ice cap widening southwards into McLeod Glacier. A number of hills, 500 ft. (152 m.) or more in height, occur in the western part of the island and are situated inland from strips of terraced lowland. The largest of the coastal indentations, such as Borge Bay (Plate Ia) and Paal

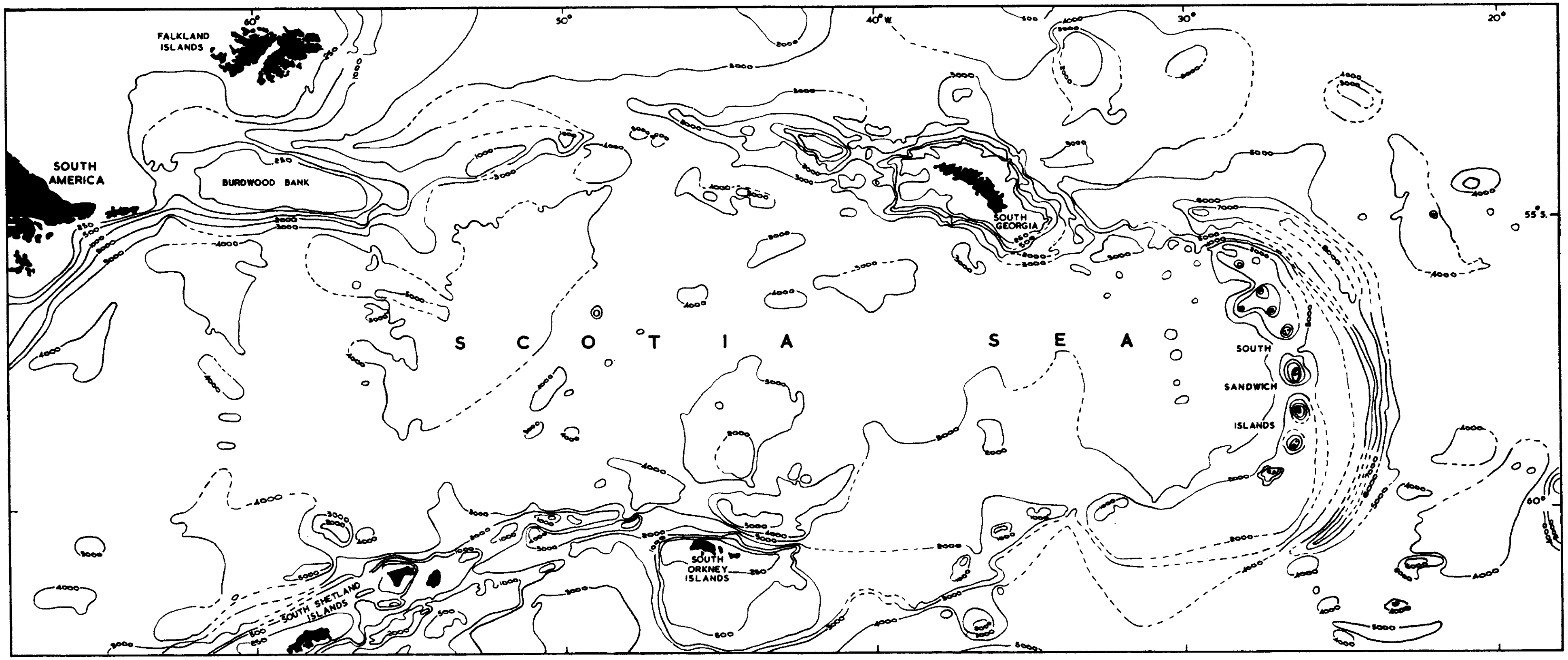

FIGURE 1

Sketch map of the Scotia Ridge and Scotia Sea, showing the position of the South Orkney Islands. The bathymetric contours are at 250, 500 and 1,000 fathoms (457, 914 and 1,830 m.) and at 1,000 fathom (1,830 m.) intervals thereafter (after Herdman, 1948, pl. XXIII).

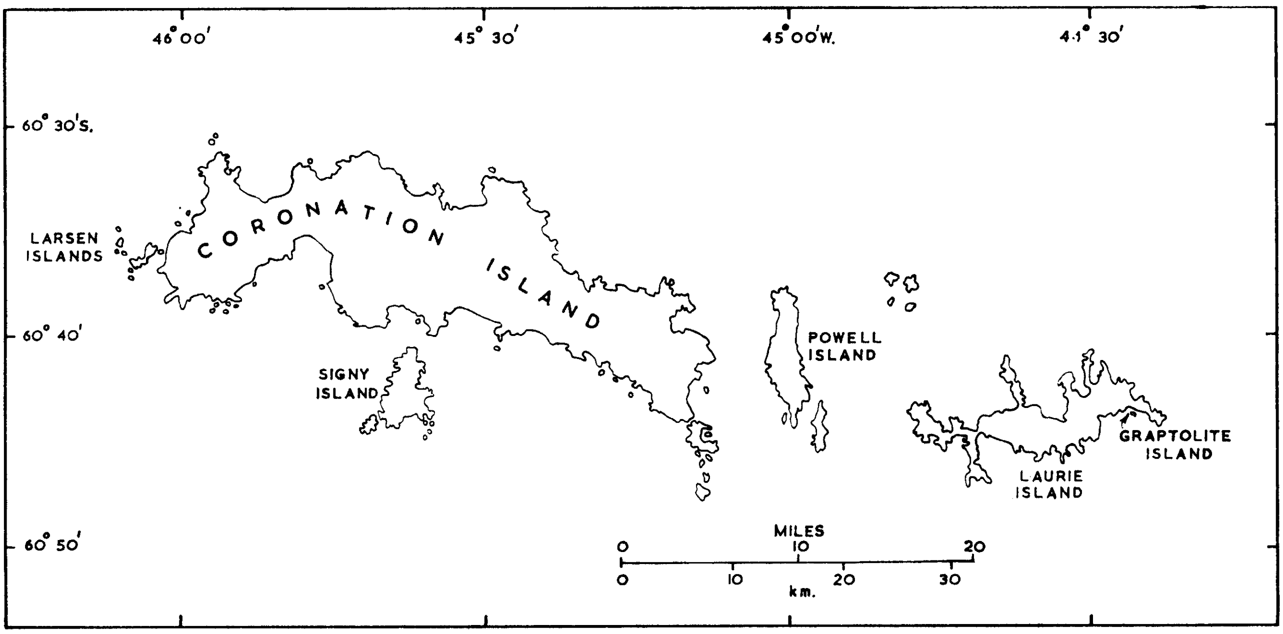

FIGURE 2
Sketch map of the South Orkney Islands.

Harbour, are present on the east coast. Here the lowland areas (Plate Ib) have a mammillated topography (Holdgate and others, 1967), in particular along the north-east coast of the island. Most of the ice-free areas have proved favourable for patterned-ground investigations (Chambers, 1966*a*, *b*, 1967) and soil studies (Holdgate and others, 1967). The ubiquity of the drift deposits indicates that Signy Island formerly had a more extensive ice cover, and it has been suggested by Chambers (1967) that the island now has one of the most geomorphologically active landscapes in the world.

The distribution of lakes on Signy Island and their origin have been studied by Heywood (1967), whilst other aspects of the island's physiography and glaciology have been described by Matthews and Maling (1967).

II. GENERAL GEOLOGY OF THE SOUTH ORKNEY ISLANDS

A. STRATIGRAPHY

The overall stratigraphy of the South Orkney Islands is simple and it is summarized in Table II and Fig. 3. The oldest rocks, a group of quartz-mica-schists, amphibolites and marbles, form the Basement Complex which crops out only on Larsen, Signy and Coronation Islands. Laurie, Powell, Fredriksen, Saddle and Weddell Islands are composed of the much younger unmetamorphosed sediments of the Greywacke-Shale Series and, to a lesser extent, of the (?) Upper Cretaceous conglomerates.

The Basement Complex of Signy Island comprises far more variable rock types than that of Coronation Island. It has a three-fold division (Table II) and is possibly Precambrian in age, although it could be as young as early Cambrian. K-Ar age determinations on quartz-mica-schists from Signy and Moe Islands have yielded an average age of 187 ± 5 m. yr. (Miller, 1960); however, this is merely the age of the latest orogeny to affect the rocks and not their age of formation.

According to Matthews and Maling (1967), the oldest rocks are the Marble Series, a 300 ft. (91·4 m.) thick succession of amphibolites, quartz-mica-schists and marbles. It is followed, possibly unconformably, by the Amphibolite Series—440 ft. (134 m.) of amphibolites and quartz-mica-schists. The succession is capped by the Moe Island Series, at least 1,000 ft. (305 m.) of predominantly quartz-mica-schists but with intercalations of amphibolites and marbles near its base.

TABLE II

STRATIGRAPHY OF THE SOUTH ORKNEY ISLANDS
(after Adie, 1964, p. 127; Matthews and Maling, 1967, table I)

Recent	Raised beaches Wave-cut platforms		
Pleistocene **Pliocene**	*Glaciation*		
? Upper Cretaceous	{ Spence Harbour and Powell Island Conglomerates Shales		
? Upper Jurassic	Dolerite dykes		
Middle Jurassic	Derived Series		
? Carboniferous	Greywacke-Shale Series		
? Precambrian	Basement Complex	Moe Island Series Amphibolite Series Marble Series	(>1,000 ft.; 305 m.) (440 ft.; 134 m.) (⩾300 ft.; 91·5 m.)

Although the metamorphic grade is similar on Coronation Island, there is no evidence for this subdivision of the rocks. Instead, the Basement Complex is composed mainly of quartz-mica-schists, with a group of graphitic schists and phyllites conformably overlying the older rocks on the eastern side of the island.

Laurie Island and the other smaller islands of the group are formed of a highly contorted thick Greywacke-Shale Series, the thickness of which has yet to be determined. Included in these geosynclinal sediments are a number of conglomerates and grit horizons composed of both water-worn and angular fragments, mainly Basement Complex schists and older volcanic rocks. Pirie (1905), who thought they were Ordovician in age, based his assumption on the identification of three fossil specimens collected in 1902–04 from the shales of Graptolite Island off the south-east coast of Laurie Island. One of these specimens was identified as the stipe of *Pleurograptus*, and it was suggested that the other two were phyllocarid crustaceans closely allied to *Discinocaris*. However, it has been pointed out that these are

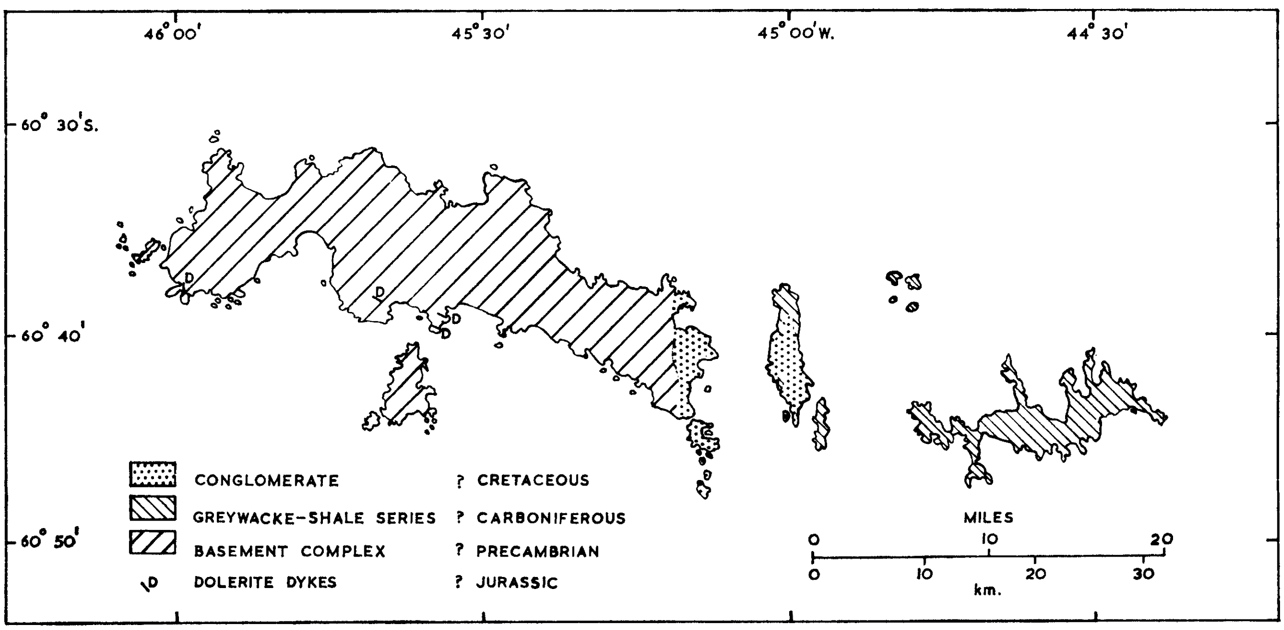

FIGURE 3

Geological sketch map of the South Orkney Islands (after Matthews and Maling, 1967, fig. 1).

not Ordovician fossils (Adie, 1958, 1964). A careful examination has shown that they are probably plant fragments similar to those found at Hope Bay in northern Graham Land. Lithological similarities exist between the Greywacke-Shale Series of the South Orkney Islands, the Trinity Peninsula Series of Graham Land and the Sandebugten Series of South Georgia (Adie, 1958). The Carboniferous age of the Trinity Peninsula Series has recently been confirmed by pollen analyses and it is probable that the Greywacke-Shale Series is also of (?) Carboniferous age.

The Spence Harbour Conglomerate and the Powell Island Conglomerate (? contemporaneous formations) crop out respectively at the eastern end of Coronation Island and on Powell Island. These are coarse-bedded deposits with an almost horizontal disposition and a minimum thickness of 1,700 ft. (518 m.). They were deposited unconformably on the older rocks (mostly brecciated Basement Complex on Coronation Island and the Greywacke-Shale Series on Powell Island), and fragments of these older rocks are contained in the conglomerates. The Spence Harbour Conglomerate is characterized by rounded vein-quartz pebbles and some of the conglomerate boulders contain poor belemnites and fragmented Mollusca. At one locality this conglomerate rests conformably on a thin shale bed, approximately 6 ft. (1·8 m.) thick, which contains a diminutive fauna of lamellibranchs, brachiopods and gastropods. Because of the somewhat fragmentary nature of the fauna from the shale bed, no positive identifications of the fossils have been made, but they are thought to be Mesozoic in age and they may well be Lower Cretaceous (personal communication from Dr. G. M. Bennison). The fauna from the boulders in the quartz-pebble conglomerate is consistent with a Cretaceous age (Adie, 1958, p. 14).

Blocks of buff current-bedded sandstone containing poorly preserved plant remains form a small proportion of the fragmental material in the Powell Island Conglomerate. The sandstone is of unknown origin and has been named the Derived Series; attempted identification of the plant fragments suggests that the Derived Series was deposited during the Mesozoic and probably in Middle Jurassic times.

The only igneous rocks recorded in the South Orkney Islands are nearly vertical, altered dolerite dykes of (?) Upper Jurassic age which trend west-north-west to east-south-east. These are intruded into the Basement Complex of Coronation Island but they are not known elsewhere.

B. Tectonic Setting

The South Orkney Islands form part of the Scotia Ridge (Herdman and others, 1956; Matthews, 1959, fig. 2), the name now applied to the great arc of mountainous islands and submarine ridges which seemingly forms a structural connection between South America and the Antarctic Peninsula (Fig. 1). The youngest part of the Scotia Ridge is formed by the South Sandwich Islands. These are supposedly connected to the southern Andes and the Antarctic Peninsula by the sweep of the Scotia arc (Suess, 1909) and they form a regular arc of Recent volcanoes. These islands, which have been described by Holdgate (1963), have been cited by Wilson (1950) as an example of a single island arc.

On the basis of the bathymetry, Herdman (1948) has proposed the existence of two parallel submarine ridges west of the South Orkney Islands. The South Shetland Islands are situated on the northern ridge, whilst the South Orkney Islands and Trinity Peninsula lie on the southern ridge. He believed that the arc was not a regular fold because of this bifurcation. Wilson (1950) has pointed out that the submarine contours between the South Orkney and South Shetland Islands and south of the Burdwood Bank suggest the presence of straight faults in the arc and he has hypothesized that the Scotia arc is a reversed arc (Wilson, 1950, fig. 2) with large strike-slip faults forming the northern and southern boundaries of the Scotia Sea. If such faults are indeed present, the Scotia arc would resemble the structure of the West Indies arc. However, Gutenberg and Richter (1949) have studied the distribution of earthquake epicentres along the northern limb of the Scotia Ridge (between Tierra del Fuego and South Georgia) and they have found that there is little evidence for an active transcurrent fault zone. Occasional shallow shocks have been recorded on the southern limb and there is some geological evidence of such faulting having occurred in the South Orkney Islands (Adie, 1964).

Although Matthews (1959), Hawkes (1962) and Allen (1966) have put forward hypotheses concerning the origin of the Scotia Ridge, corroboration of their theories awaits further geological and geophysical investigations along the Scotia Ridge, particularly since the significance of much of the marine magnetic survey in relation to the present seismic investigations between the South Orkney Islands and South Georgia is not yet clear.

C. General Structure

The overall geographical extension of the South Orkney Islands in a north-north-west to south-south-east direction follows the natural sweep of the Scotia arc in this area (Figs. 1 and 2) and it is particularly emphasized by the trend of Coronation Island. The main structural trend, which is parallel to this direction, is indicated by the strike of the rocks, the fold axes and by the alignment of ridges and peninsulas (Pirie, unpublished).

Minor variations present in the tectonic trend of these islands are the result of at least two periods of tectonism. The Basement Complex of both Signy and Coronation Islands exhibits the same north–south fold system; this is emphasized by the overall elongation of Signy Island parallel to the north–south direction of its fold axes. However, in a number of localities the general pattern of folds has been complicated by subsequent folding on a much smaller scale and by the development of abundant small faults. In spite of the ubiquitous superficial deposits and permanent ice cover which obscure the rock exposures on Signy and Coronation Islands, it can be inferred that their general structure is a series of overfolds cut by faults trending both north–south and west–east; the movement during overfolding was directed from west to east. The prominent fault scarp on the east coast of Signy Island is shown in Plates Ia, b and IIa.

Later folding about a north-north-west to south-south-east axis is indicated in the Greywacke-Shale Series which crops out on Laurie Island. A similar trend was followed by the dolerite dykes intruded into the Basement Complex of Coronation Island, and this suggests that they represent a phase of the same orogeny. Age determinations on quartz-mica-schists from Signy and Moe Islands (Miller, 1960) indicate an Upper Triassic age for the orogeny; this age is based on Kulp's (1961) geological time scale.

A much more recent set of folds has affected the Cretaceous Spence Harbour Conglomerate. This has been gently folded about west–east axes, trending parallel to the west–east tear fault now occupied by Normanna Strait and, according to Pirie (unpublished), the conglomerate dips at 30° to the north-east. Seemingly, these are the latest orogenic movements to affect the South Orkney Islands and because of their feeble character their effects are not particularly prominent. Indeed, they were too weak to release radiogenic Ar from the rocks and age determinations by the K-Ar method only record the earlier, much stronger, Upper Triassic orogeny.

The structural geology of Signy Island has already been described in detail by Matthews and Maling (1967). Unfortunately, there is some disagreement between the authors over their structural conclusions but it may be possible to resolve this difference of opinion by petrofabric analyses of orientated specimens.

III. PETROLOGY OF SIGNY ISLAND

Signy Island is composed entirely of Basement Complex rocks. Garnetiferous quartz-mica-schists and mica-garnet-schists are the predominant rock types and these are intercalated with amphibolites (mostly hornblende-schists) and with subordinate marbles. Quartzites are relatively rare but widespread, and some have been used as field mapping horizons when sufficiently distinctive. Hornblende-garnet rocks and *hornblendegarbenschiefer* are uncommon but they occur in association with marbles, particularly between Jane and Robin Peaks in the north of the island. The general distribution of these rocks and their possible stratigraphical correlation is shown in Fig. 4.

The Basement Complex has already been subdivided into three rock "series" on the basis of field mapping (Matthews and Maling, 1967), and the relative abundance of certain rock types in each stratigraphical "series" has also been described. The sub-divisions used in the following petrographical descriptions are according to rock types *only*, and they have no stratigraphical implications since some of the field mapping of Matthews and Maling may be incorrect.

A. Petrography

There is a natural gradation between quartzite, quartz-mica-schist and mica-garnet-schist and, with the development of hornblende, there is a transition to the amphibolites. Following the paper by Billings (1937), it has been decided that rocks containing more than 80 per cent of quartz should be designated quartzites, those having between 60 and 80 per cent of quartz as quartz-mica-schists, and when less than 60 per cent of quartz is present the rock is a mica-schist. Similar arbitrary limits have been chosen to

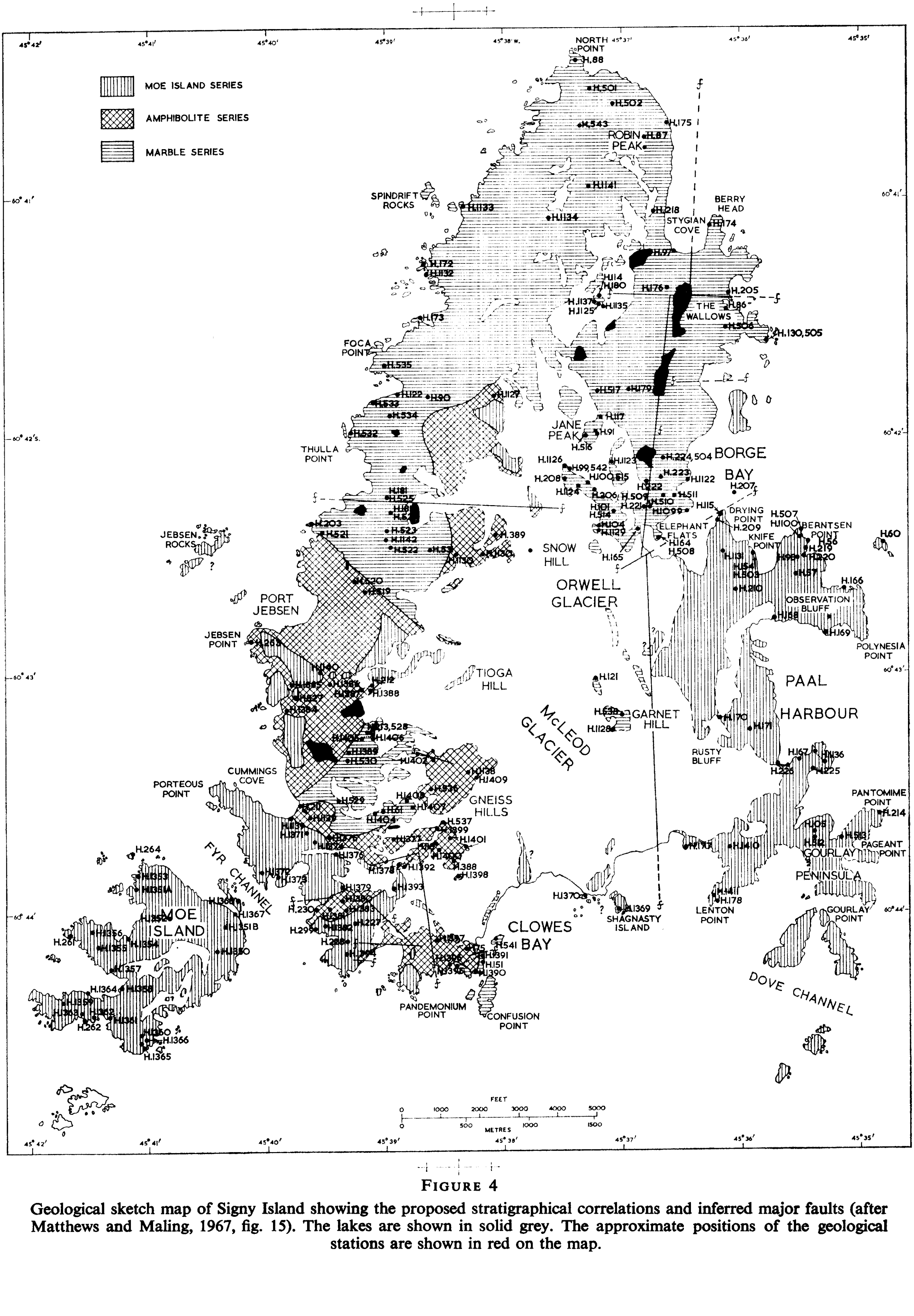

FIGURE 4

Geological sketch map of Signy Island showing the proposed stratigraphical correlations and inferred major faults (after Matthews and Maling, 1967, fig. 15). The lakes are shown in solid grey. The approximate positions of the geological stations are shown in red on the map.

differentiate a true hornblende-schist from a hornblende-mica-schist and also in the division of the epidotic rocks from the amphibolites. These limits are: a hornblende-schist contains more than 40 per cent of hornblende whilst the hornblende-mica-garnet-schists have less than this percentage; rocks with more than 40 per cent of epidote are considered to be epidotic. Modal analyses of typical specimens of these rock types are given in Table III.

TABLE III

MODAL ANALYSES OF THE MAJOR ROCK TYPES FROM SIGNY ISLAND

	H.115.1	H.180.1	H.178.1	H.88.1	H.1396.4	H.1125.1	H.503.3	H.389.1	H.1378.1
Quartz	88·0	79·7	55·0	6·0	1·5	8·9	1·1	1·2	71·0
Plagioclase	—	1·8	32·7	5·5	38·8	47·0	19·8	15·3	—
Hornblende	—	—	—	—	12·0	2·6	50·9	27·2	—
Muscovite	7·6	7·1	4·7	49·1	5·6	—	—	—	—
Biotite	1·9	3·3	4·3	12·5	10·9	5·6	2·2	*	—
Chlorite	*	4·9	3·3	*	1·4	1·6	13·9	8·1	*
Epidote	—	1·0	*	2·4	23·2	5·4	6·7	47·1	—
Garnet	2·5	2·2	*	20·8	3·4	18·4	—	—	29·0
Accessory minerals	*	*	*	3·7†	3·2	10·5†	5·4†	1·1†	*
Plagioclase composition	—	?	An_7	?	An_{12}	An_7	An_6	An_{11}	—

* Present but not in sufficient amount to be recorded.
† Mostly sphene.

H.115.1 Quartzite; Drying Point, Borge Bay.
H.180.1 Quartz-mica-schist; north of Jane Peak.
H.178.1 Albite-mica-schist; Lenton Point.
H.88.1 Muscovite-garnet-schist; North Point.
H.1396.4 Hornblende-mica-garnet-schist; north-west of Confusion Point.
H.1125.1 Garnet-hornblende-"gneiss"; north of Jane Peak.
H.503.3 Hornblende-schist; Knife Point, Borge Bay.
H.389.1 Epidotic schist; Snow Hill.
H.1378.1 Quartz-garnet rock; south-west of Gneiss Hills.

1. *Quartzites, quartz-mica-schists and mica-garnet-schists*

Marked differences in colour and texture of the hand specimens are noticeable between the more siliceous rock types and the micaceous ones. The pure *quartzites* (H.1353.1) are rare and they are usually creamy white and massive. More commonly, the impure quartzites are light buff-grey (H.1131.1) and contain minute silvery flakes of muscovite. It is only when such micaceous laminae are present that the form of folding in the quartzites can be seen (Plate IVa). Specimen H.180.1 represents a rock type transitional to the quartz-mica-schists and it has a somewhat flaggy appearance on weathered surfaces, caused by the differential erosion of narrow micaceous layers from between wider siliceous bands. The pinkish tinge in rocks of this type is due to the concentration of minute garnet crystals along the *s*-planes. In a few rocks (H.1378.1), garnet forms irregular but usually concordant granular masses and it can be sufficiently abundant to define another rock type, the *quartz-garnet rocks*. These are probably the "*pink*" *veins* referred to by Matthews and Maling (1967, p. 12).

A few of the more siliceous rocks have a mineral banding (H.227.1; Plate IVb) due to well-defined alternating micaceous and siliceous bands, with an occasional presence of mica in the quartzo-feldspathic laminae and vice versa. Large quartz segregations and albite porphyroblasts, elongated parallel to the banding (Plate IVc), have also developed in a similar type of rock (H.178.1).

However, the majority of the *quartz-mica-schists* and *mica-garnet-schists* have a typical schistose texture, and many of them exhibit micro-folding (Plate IVd) and irregular puckering of the folia; specimens

H.264.1 and 1402.2 are typical. Small chevron-type folds are more unusual in this rock type (Plate IIIa). These schists are usually dark grey or black in colour and they often contain minute specks of graphitic material. Large garnet porphyroblasts are rarely obvious.

In thin section these rocks are composed of alternating laminae of quartz and quartzo-feldspathic material associated with chlorite, mica, epidote, garnet and variable amounts of accessory minerals. Although the micaceous laminae are usually narrow and well-defined in the siliceous schists, they contain sericitized plagioclase and microcrystalline quartz in the micaceous schists, and generally they are more diffuse. The typical texture of an impure quartzite is shown in Plate VIa.

In the *quartz-mica-schists*, quartz forms well-defined laminae of equant crystal mosaics between the micaceous folia, whereas plagioclase ($Ab_{95-85}An_{5-15}$) invariably occurs as large irregular porphyroblasts confined to the micaceous folia. These are elongated parallel to the alignment of the micas and their margins interdigitate with muscovite and biotite (Fig. 5). Streaks and small flakes of mica are also included within the porphyroblasts, together with small crystals of epidote and quartz. Muscovite, biotite and chlorite are variable in importance and they frequently interdigitate with one another. They usually form well-defined flakes and the biotite is pleochroic from straw to shades of orange-brown (p. 17); the chlorite is only slightly pleochroic from colourless to pale green (p. 17). Small sub-rounded prismatic crystals of epidote (generally a colourless variety of pistacite), elongated parallel to the foliation, are the commonest accessory mineral in the micaceous folia and these are associated with less abundant lozenges of colourless sphene, specks of graphite, minute triangular cross-sections or prisms or tourmaline (ω = olive-green, ϵ = colourless; $\omega > \epsilon$) and small irregular xenoblasts of iron ore.

The *mica-schists* contain much more micaceous material (either biotite or muscovite predominates) and the plagioclase ($Ab_{95-85}An_{5-15}$) forms both medium-grained (0·2–0·5 mm.) allotrioblastic aggregates of crystals (these are associated with quartz in the quartzose laminae) and irregular porphyroblasts interdigitating with the micas in the micaceous folia. Sericitized feldspar is also commoner in this rock type.

The *mica-garnet-schists* comprise both the garnetiferous quartz-mica-schists and the mica-schists. The most siliceous schists contain abundant small polyhedra of garnet in the quartzose laminae (p. 19), whereas the micaceous schists have fewer but larger, more irregular garnet porphyroblasts which are full of helicitic inclusions (p. 20); the latter have developed in the micaceous folia alone.

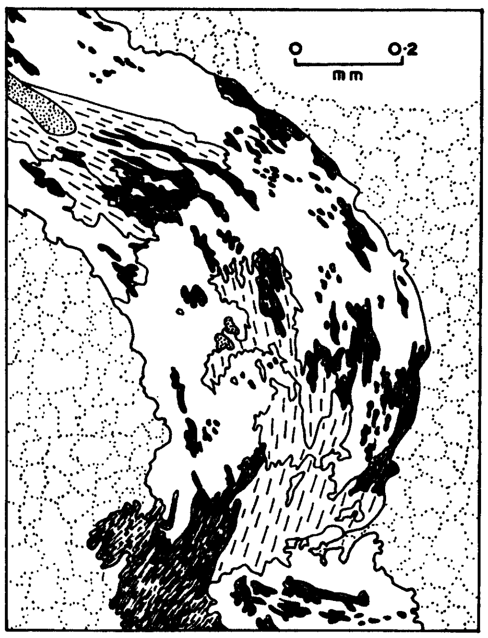

FIGURE 5

An albite porphyroblast (clear) replacing muscovite (coarse shading) in preference to biotite (fine shading); the mosaic represents quartz. Occasional inclusions of epidote (stippled) are also present; mica-garnet-hornblende-schist; south-western Signy Island (H.1375.4c).

Graphitic schists sensu stricto are not present on Signy Island but a few of the mica-schists contain trails of graphite specks which are usually included in the plagioclase porphyroblasts (H.177.1) or in the coarser muscovite flakes.

2. *Amphibolites*

Included with the amphibolites* are the greenschists, epidotic schists, hornblende-garnet rocks, hornblende-schists, biotite-hornblende-garnet- and hornblende-biotite-garnet-schists and the *hornblende-garbenschiefer*.

In the hand specimen, the *greenschists* are either soft and flaky (chlorite-epidote-biotite-schists), hard and flaky (actinolite-albite-chlorite-schists) or hard and more massive (albite-epidote-schists). The flaky greenschists are composed of a felted mass of light green, fine-grained amphibole, probably an actinolitic hornblende which has a pleochroism from colourless to pale bluish green and $\gamma{:}c = 14°$. These rocks are invariably schistose and provide good examples of small irregular chevron folds (H.543.1, 1140.1; Plate Va). The presence of chlorite and a little brown or brownish green biotite flakes enhances the schistosity. A variable amount of epidote ($\alpha{:}c = 28°$; pleochroic from colourless to a pale greenish yellow) and plagioclase, in the albite-oligoclase range ($Ab_{95-87}An_{5-13}$), are seen in thin section together with accessory minerals such as sphene, ilmenite and apatite. Garnet ($n = 1{\cdot}795 \pm 0{\cdot}002$) is rare.

The *epidotic schists* are a sub-division of the greenschists and they include the epidote-chlorite-biotite- and epidote-hornblende-chlorite-schists. The highly epidotic rocks are rather massive (H.389.1); epidote (α = colourless, β = greenish yellow, γ = pale yellowish green; $\alpha{:}c = 23°$) is either disseminated evenly throughout the rock (H.388.1) in granular patches (Plate VIe) or it is segregated into wide irregular layers (H.1130.2b). Tourmaline (ω = olive-green, ϵ = pale brown), confined to an irregular band, was observed in only one specimen (H.537.1; Plate Vb). Its size (0·5 mm. long) and form (well-defined prismatic poikiloblasts) (Plate VIf) differ from the tourmaline crystals present in the quartz-mica-schists, and its occurrence could possibly be an indication of igneous activity on Signy Island.

The *hornblende-schists* are dark green in colour and they are relatively free from chlorite. They generally appear to be more massive than the greenschists, and streaks of quartzo-feldspathic material either form layers in the schistose rocks or they occur as randomly scattered patches in the more massive ones. These schists have a variable grain-size. The finer-grained specimens consist of well-defined laminae of lepidoblastic hornblende ($2V\alpha \simeq 80°$; $\gamma{:}c = 14$–$22°$; α = colourless, β = green, γ = blue-green) separated by glomeroblastic aggregates of poikiloblastic plagioclase ($Ab_{93-89}An_{7-11}$). The coarse-grained schists have large hornblende crystals (1–2 mm. in length) associated with equally large plagioclase poikiloblasts and their banding is less apparent. The plagioclase is usually untwinned but simple albite twins are sometimes present. The poikiloblasts include small rounded inclusions of epidote, sphene and occasionally acicular crystals of hornblende.

Although some of the hornblende-schists contain epidotic bands, this mineral is not particularly abundant and it is only obvious in some of the coarser-grained, more "gneissose" amphibolites. Crystals of pistacite are much commoner than those of clinozoisite ($2V\gamma \simeq 60°$; $\alpha{:}c = 5°$).

Garnet is uncommon in the hornblende-schists but it is present particularly in the *hornblende-garnet rocks* collected in the vicinity of Borge Bay (H.176.1, 210.2). These garnets ($n = 1{\cdot}795$–$1{\cdot}800 \pm 0{\cdot}002$) are brick-red in colour, their grain-size varies from 2 to 5 mm. in diameter and their generally hypidioblastic or xenoblastic crystals tend to be concentrated in well-defined layers, usually associated with quartzo-feldspathic material. In the greenschists the garnets form knots between the hornblendic folia (H.176.1, 181.4). Iron pyrites is rare and it was observed only in the greenschists.

The accessory minerals are sphene, apatite and ilmenite. The sphene is mostly a colourless, slightly pleochroic variety but some yellow-brown crystals associated with ilmenite have been observed. Ilmenite is only abundant in the chloritic hornblende-schists, in which it occurs as tabular or skeletal crystals.

The *biotite-hornblende-garnet-* and *hornblende-biotite-garnet-schists* differ from the mica-garnet-schists only in the presence and abundance of hornblende. The coarser rocks are typically "gneissose" (H.99.3). Large flakes of muscovite (1 mm. in length) and coarse blades (2–4 cm. long) of dark green hornblende

* Matthews and Maling (1967) have ambiguously applied the term "amphibolite" to all those rocks from Signy Island which are either green or hornblendic, however small the amphibole content of the rock. The author would prefer to confine this term to those rocks containing essential hornblende (more than 50 per cent) and lacking any schistose structure (Layton, 1963, p. 270–71). In order to retain continuity between the report by Matthews and Maling (1967) and the present one, "amphibolite" has been used here in the same sense implied by Matthews and Maling.

(α = colourless or light green, β = green, γ = blue-green; γ:c = 14–25°) are often quite spectacular. Large red garnet (n = 1·810±0·002) porphyroblasts (2–4 mm. in diameter) are common. Some of these rocks are so coarse-grained that they could be more aptly described as "pegmatitic gneisses".

The *hornblendegarbenschiefer* (H.542.1, 1125.1; Plates Vc, VIId) are included among these rocks and in the hand specimen they are the most spectacular of the rocks from Signy Island. They are composed of large knots of garnet, ranging in size from 0·7 to 1·2 cm. in diameter, set in a granoblastic quartzo-feldspathic matrix and associated with large bladed porphyroblasts of hornblende and flakes of muscovite and biotite. In thin section the groundmass is composed of small quartz crystals associated with a mosaic of medium-sized clear, untwinned plagioclase crystals ($Ab_{93}An_7$) including minute rounded quartzes. Narrow undulating laminae of small, colourless sub-prismatic crystals of pistacite, lozenges of sphene and xenoblasts of ilmenite are interspersed between the quartzo-feldspathic mosaic and the wider laminae of long, bladed and sometimes poikiloblastic hornblende crystals (α = pale green, β = green, γ = blue-green; γ:c = 18°) associated with flakes of brown biotite and muscovite. Large irregular garnet porphyroblasts are scattered throughout the rock and these are usually crowded with helicitic inclusions of sphene and epidote; the periphery of some crystals is sieve-like (Fig. 6) due to the inclusion of larger quartz crystals. Apatite is a rare accessory mineral and it tends to occur in clusters of small crystals; ilmenite occurs mainly as relicts in the cores of the larger sphene crystals.

A few of the "*pegmatitic gneisses*" are virtually monomineralic (H.1137.6), being composed of hornblende crystals larger than 5 cm. in length.

The hornblende-schists differ from the greenschists in the replacement of green biotite by a brown variety, and in the importance of hornblende relative to any other mineral. The texture of the plagioclase is typically poikiloblastic but aggregates of allotrioblastic crystals are also common. A greater abundance of mica, quartzo-feldspathic material and garnet provides a transition into the hornblende-biotite-garnet- and biotite-hornblende-garnet-schists, and hence to the rock types mentioned on p. 10.

3. *Marbles*

There are numerous outcrops of marble on the coastal lowlands west of Borge Bay (Plate IIIb). Most of these marbles are medium- to coarse-grained, massive, white crystalline rocks but some are bluish grey in colour and contain minute graphite particles. Thin laminae of muscovite and/or biotite and graphite

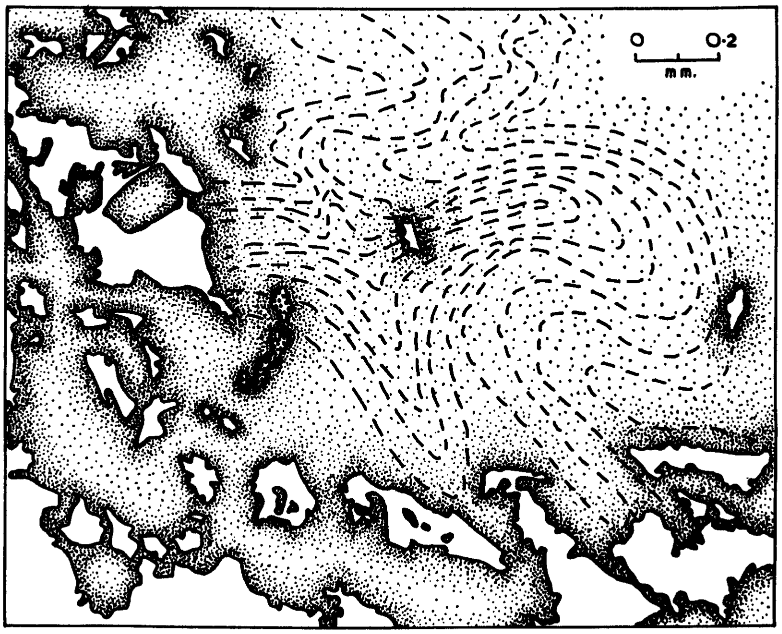

FIGURE 6

Garnet porphyroblast from a garnet-rich layer in a hornblende-schist. The broken lines represent the form of the fine-grained helicitic inclusions found only in the core of the crystal. Note the rim of sieve-like garnet including quartz (clear) and epidote (coarse stipple); Borge Bay, Signy Island (H.210.2).

probably represent original bedding planes (H.214.1) but they are somewhat impersistent and irregular. Thick, well-defined alternating bands of marble and dark quartz-mica-schist were observed in specimen H.100.3 (Plate Vd), providing a gradation into the hornblende-mica-quartz-schists; a similar rock has been described by Tilley (1935, p. 388). An example of marbles interbedded with amphibolites is shown in Plate IIIc. An horizon of small quartz pebbles, ranging in size from 0·2 to 1·0 cm., was noted in a marble from an island in Clowes Bay (H.541.1). A few of the marbles are fine-grained and they possibly represent recrystallized calcilutite.

In thin section the majority of the marbles are composed of a mosaic of sutured calcite crystals with ubiquitous glide twin lamellae (Plate VIIa) and it is only in the more deformed marbles (H.213.1) that granulation of calcite crystals and deformation of their twin lamellae has occurred. The mineral impurities are confined to bands and they are formed by muscovite flakes (0·2–0·5 mm. long), poorly defined grains of epidote and specks of graphitic material. Isolated crystals or ovoid segregations are uncommon. Plagioclase usually occurs as discrete xenoblasts but a granoblastic mass of clearly zoned crystals was observed in one specimen (H.224.1).

Actinolite is present in a few of the marbles (H.164.1, 214.1) and in a bedded marble (H.100.3). Sphene is a rare accessory mineral in the marbles but it occurs particularly in Discovery Investigations station No. 1092, slide No. 36041.

An impersistent band of coarse xenoblastic clinozoisite (Plate VIIb, c) was recorded in specimen H.206.1 from an outcrop south of Jane Peak and similar crystals have been observed in other specimens (H.100.2, 101.1); (?) talc occurs in specimen H.504.1 from Waterpipe Beach, Borge Bay. No calc-silicate minerals have been identified in these marbles, probably because the metamorphic environment was not appropriate for their development.

4. *Quartz-tremolite-garnet rock*

The quartz-tremolite-garnet rock (H.1393.1) collected from the vicinity of Pandemonium Point is unique in the Signy Island rock collection. This rock is essentially a thinly bedded quartzite but certain impersistent bands in it are peppered with small pinkish red garnet crystals ($n > 1{\cdot}79$), and *s*-planes are defined by large sheaf-like aggregates of tremolite.

In thin section a mosaic of quartz crystals forms a groundmass for small garnet crystals ranging in diameter from minute to 0·2 mm. Although they are generally discrete and hypidioblastic, the garnet crystals occasionally form aggregates. Tremolite ($\gamma{:}c = 11°$) forms large prismatic crystals 2–3 mm. long which poikiloblastically include ovoid, elongate or irregular crystals of quartz and, rarely, garnet. It is polysynthetically twinned and all of the crystals have been stained by iron-rich hydrothermal solutions percolating along fractures.

B. Mineralogy

1. *Quartz*

This mineral is virtually ubiquitous in the Signy Island rocks. It is dominant in the quartzites and quartz-mica-schists but variable amounts are present in the amphibolites and it is not unknown as inclusions in the marbles. Its occurrence in the amphibolites often denotes a late phase of mineralization, since it forms veins and irregular segregations within them, either elongated parallel to or transverse to the main tectonic lineation.

Quartz invariably forms a sutured crystal mosaic but the grain-size is often variable and a flaser texture has been noted in a few of the quartzites. However, there is little preferred optical orientation of quartz in any of the siliceous rocks examined. The lack of triple junctions with straight quartz–quartz boundaries indicates that "strain-induced boundary migration" (Rast, 1965, p. 88) occurred during crystallization. Undulose extinction is usual, even in the late-phase segregations, and this is a further indication that a shearing stress was still operative when the quartz was mobile, and that it has crystallized under strain. However, the stress must have been waning since no Boehm lamellae (Hietanen, 1938, p. 32) were observed. Mortar structure occurs in a few severely deformed rocks (H.1407.1).

2. *Plagioclase*

Plagioclase is decidedly porphyroblastic in the rocks ranging from quartzite to quartz-mica-hornblende-schist. Large irregular crystals elongated parallel to the schistosity have developed in the micaceous bands and they have apparently grown by the absorption of muscovite (Jones, 1961, p. 51); X-ray studies have indicated that the white mica in these rocks is a mixture either of two minerals (muscovite and paragonite) or of two species of muscovite, but it is undecided which mixture is present in the rocks of Signy Island.

Preferential absorption of muscovite is clear, since small isolated flakes and scales of biotite (probably originally interdigitating with muscovite) remain as inclusions in the porphyroblasts (Fig. 5), whereas muscovite is absent. Orville (1962, p. 299) has stated that during alkali metasomatism a number of cation-exchange reactions involving alkali silicates may be important in nature, although such reactions have not yet been verified due to the lack of available data. Jones (1961) suggested that insufficient soda could be released from muscovite to form albite in the rocks from the Ben More-Am-Binnein area of western Perthshire, and that soda must have been introduced from an extraneous source during large-scale metasomatism. The apparent absence of igneous activity on Signy Island makes such an hypothesis untenable for the rocks discussed here, and it is more likely that the excess soda was derived *in situ* from authigenic albite in the original sediments from which these rocks are believed to have been formed (Deer and others, 1963, p. 148).

Plagioclase tends to form in glomeroblastic aggregates and lenses within the hornblende-schists and epidotic schists. Each individual grain is xenoblastic and it is separated from the contiguous grains by a narrow border of sericitic material. Poikiloblastic crystals containing small rounded inclusions of quartz and epidote (Plate VIb) are commoner in these rocks than in the siliceous ones. Such helicitic inclusions are conformable with the *Se* of the schist and they indicate that plagioclase porphyroblastesis occurred during a static phase of crystallization, subsequent to the growth of the micas and epidote but prior to the development of hornblende and garnet (since plagioclase is included in the latter two minerals).

It has been difficult to determine the exact composition of the water-clear plagioclase present in the schists and "gneisses" of Signy Island because of the lack of twinned crystals. Refractive index measurements have been used (where possible they have been compared with Canada balsam, $n = 1 \cdot 537$) and these indicate an acid plagioclase in the range albite-oligoclase. Random measurements of extinction angles from crystals twinned on the albite law indicate compositions of an albite ($Ab_{95-93}An_{5-7}$) and an oligoclase ($Ab_{90-85}An_{10-15}$). These values should only be taken as a rough guide to the anorthite content of the plagioclase molecule because of the infrequency of appropriately twinned crystals.

Compositional zoning of the crystals is quite common but it is particularly patchy and ill-defined when plagioclase is associated with microcrystalline quartz (Fig. 7); such crystals probably represent recrystallized authigenic feldspar incorporating parts of the quartz groundmass as it developed. The outer rim of all the zoned crystals is of variable width and it is invariably formed by an oligoclase-rich plagioclase, i.e. reversed zoning is present (Deer and others, 1963, p. 149); oscillatory zoning is unusual and it has only been observed in a "pegmatitic gneiss" (H.1137.3). Zoning is enhanced by preferential sericitization of oligoclase in a number of crystals.

Some plagioclase crystals contain evenly disseminated minute particles of sericite and others contain

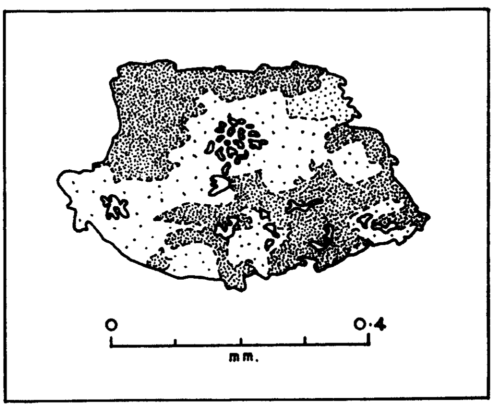

FIGURE 7

A patchy plagioclase porphyroblast including globules of quartz (clear); mica-garnet-schist; north-eastern Moe Island (H.1351B.1).

undulating included trails of dust conformable to the *Se* of the rock. These show that some altered feldspathic material was present when the new plagioclase began crystallizing and that not all of the sericite formed during a late hydrothermal phase.

The paucity of twinning in plagioclase crystals from Signy Island corroborates the observations of Turner (1951). Most of the relatively rare twins observed are seemingly simple twins but it is believed that they are A-twins (Gorai, 1951, p. 588) twinned on the albite law and not C-twins according to the Carlsbad law. However, it is impossible to confirm this without Universal Stage work because of the difficulty in distinguishing between Carlsbad and non-lamellar albite twins (Tobi, 1962, p. 266). Abrupt terminations of twin lamellae (Fig. 8) and sudden variations in their width are indicative of primary twinning (Vance, 1961, p. 1103) and only rare instances of glide twinning were observed.

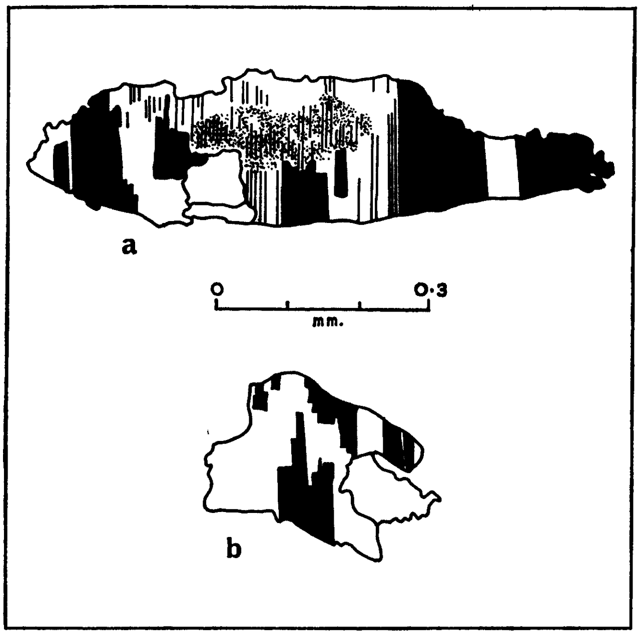

FIGURE 8

Two of the rare albite-twinned plagioclase crystals in a mica-garnet-schist. The core of the large flattened crystal (a) is riddled with specks of (?) iron ore or graphitic material. The impurities have probably induced fine lamellar twinning in the core and this contrasts with the coarse albite twinning in the main part of the crystal. The smaller crystal (b) shows typical irregular terminations of the albite twin lamellae; Moe Island (H.1356.1).

Gorai (1950, 1951) has made statistical analyses of the number of twinned and untwinned plagioclase crystals in metamorphic rocks. His UAC diagram (Gorai, 1950, p. 152) for schists and gneisses indicates that C-twins are rarely, if ever, present in these rock types. A similar brief statistical survey of comparable rocks from Signy Island confirmed his findings, but, although most of the plagioclase crystals studied had the same grain-size, it is not known whether this was the case with Gorai's analyses. Consequently, no conclusions can be reached about the relationship of twinning to grain-size in these rocks. However, many of the isolated plagioclase porphyroblasts in the rocks ranging from quartzite to hornblende-mica-quartz-schist are larger than the average grain-size of the glomeroblastic crystals. They are invariably untwinned but this may be due to the irregularity of their grain growth inhibiting twin development (Vance, 1961, p. 1105) and it is not necessarily dependent on their grain-size.

The relationship between twinning and zoning has been discussed by Emmons and Mann (1953) and Vance (1961). Their observations are based mostly on plagioclases from igneous rocks, and Emmons and Mann (1953) held the extreme view that all polysynthetic twinning in plagioclase is secondary and that it replaces, and is consequent upon, zoning. They suggested that twinning develops concurrently with the elimination of zoning and that zoning is a prerequisite for twinning. Although this has not been confirmed in a study of the plagioclases from Signy Island, clearly zoned crystals are not usually twinned.

In conclusion, the plagioclase crystals from Signy Island are typically untwinned. The relatively rare twinned crystals are apparently simple but it is believed that they are in fact twinned according to the albite law. All of the twins are primary and grain growth has probably been an important factor in inhibiting twin development in some crystals. The presence of reversed zoning implies that the outer zone, being oligoclase-rich, crystallized at a higher temperature than the albitic core and consequently the metamorphism affecting these rocks was progressive and not, at any time, retrograde.

3. *Hornblende*

The typical amphibole of the greenschists is a pale green actinolitic hornblende, whereas a deeper green hornblende is characteristic of the hornblende-schists and the other amphibolites. However, there is no sharp distinction between the optical properties of the two amphiboles (γ:*c* = 14–18°, although larger extinction angles have been recorded (γ:*c* = 25°); 2Vα = 80–90°; α = colourless or light green, β = green, γ = blue-green) and, although the colour is deeper and the pleochroism more marked in common hornblende, there is seemingly a natural gradation from an actinolitic hornblende in the greenschists to a common hornblende in the hornblende-mica-garnet-schists and "pegmatitic gneisses".

The six-sided cross-sections of the hornblende crystals, even in the greenschists, are more typical of hornblende than of actinolite. The mineral usually occurs as hypidioblastic crystals 2–3 mm. long but much smaller crystals are present in the greenschists and abnormally large ones occur in the "pegmatitic gneisses". A lepidoblastic texture is common in the greenschists and finer-grained hornblende-schists. The coarser crystals, in particular, are markedly poikiloblastic; rounded, helictic inclusions of epidote, sphene, quartz, iron ore and (apatite) are arranged with *Si* conformable to *Se*. In addition, small blades of hornblende have crystallized mimetically around the crests of micro-folds (H.1381.1; Plate VIc). Both features indicate post-kinematic crystallization. The mineral parageneses of hornblende and plagioclase are not always clear. In a number of cases, hornblende includes large irregular and sometimes rounded albite crystals, or it is interstitial to plagioclase, but in some rocks the reverse has been noted. Possibly the end of plagioclase crystallization was contemporaneous with incipient hornblende crystallization.

The majority of the crystals are fresh but in specimen H.1407.3 (an amphibolite from the Gneiss Hills area) the amphibole has been pseudomorphed by a mixture of chlorite, calcite and quartzo-feldspathic material. Similar pseudomorphs have been noted in the Basement Complex rocks of Graham Land (Hoskins, 1963, p. 34). This chlorite is distinct from the coarse tabular crystals of chlorite in the groundmass of the schist (its interference colours are brownish purple) and because the latter crystals are considerably deformed it is probable that this rock was involved in late shearing movements, which caused local retrograde metamorphism. The crystallization of calcite as a replacement product confirms that the amphiboles in these rocks are calciferous (Phillips and Layton, 1964) and the type of chlorite (p. 17) suggests that they are rich in ferrous iron (Agar and Emendorfer, 1937).

4. *Chlorite, muscovite and biotite*

Chlorite is common in most rocks but it predominates in the greenschists. It is usually pale green and only slightly pleochroic but in the epidotic schists, where it is associated with green biotite, it is markedly pleochroic: α = straw, β = γ = apple-green and γ:*c* = 0–5°. The large porphyroblastic crystals (0·5–1·0 mm. long) generally have a plumose or tabular habit and they sometimes exhibit polysynthetic twinning on the penninite law. A few of the larger crystals in the epidotic schists contain inclusions of dusty particles; these are probably sphene. Interference colours are characteristically grey-green or brownish purple and it is probably a penninitic chlorite.

Muscovite and biotite both interdigitate with chlorite in the quartz-mica- and mica-garnet-schists; because there are no definite replacement textures of one mineral by another, they probably crystallized simultaneously. *Muscovite* forms fairly small (0·1–0·3 mm. long) well-defined flakes in the quartzites but in the schists it is coarsely porphyroblastic (1–2 mm. long) with a preferred orientation parallel to the schistosity. It is usually colourless but it does occasionally have a faint pleochroism from colourless to very pale straw.

Biotite shows a variation in pleochroism which seems to be dependent on its host rock type. In the quartzites it is fairly pale and its pleochroism is not marked: α = straw, β = γ = light brown (H.154.3). The colour deepens slightly in the quartz-mica-schists and the pleochroism becomes α = straw, β = γ =

greenish brown (H.180.1) or orange-brown (H.207.1). In the mica-garnet-schists quite a deep orange-brown or reddish brown biotite has been observed (H.1374.1, Discovery Investigations station No. 1092, slide No. 36044), and similar pleochroism schemes are also present in biotites from the amphibolites.

The epidotic schists are characterized by green biotite (α = straw, $\beta = \gamma$ = olive-green). The relation between the colours of biotites and their chemical compositions has been studied by Hall (1941). She suggested that the red-brown colour of biotite was due to a high titanium content but that in some cases magnesium probably masks this colour effect. Because many of the Signy Island schists contain appreciable quantities of sphene in association with the deeper-coloured biotites, it is quite probable that the biotite is fairly rich in titanium. The paler biotites in the quartzites and the relatively sphene-free quartz-mica-schists are probably magnesium-rich with a low titanium content. On the other hand, the green biotite of the epidotic schists (which are also rich in sphene) is probably low in iron and it contains appreciable amounts of titanium, whose effect is masked by a high magnesium content.

Green biotite is replaced by incipient crystals of hornblende in the epidotic schists and neither muscovite nor biotite are common in the hornblende-schists, in which they occur as small (0·1 mm. long) scattered flakes interstitial to hornblende crystals. They are more important in the hornblende-mica-garnet- and mica-hornblende-garnet-schists, in which they tend to be porphyroblastic. This indicates that they become unstable under the slightly higher temperatures and pressures necessary for hornblende crystallization.

Small metamict haloes around minute inclusions of clinozoisite are infrequently present in both biotite and chlorite in the quartz-mica- and mica-garnet-schists. It has already been noted (p. 14) that "muscovite" and biotite have been replaced by, and included within, plagioclase porphyroblasts. Since the mica also exhibits mimetic crystallization around the crests of micro-folds (H.1382.1; Plate VId) and the crystals are undeformed, it must have crystallized post-kinematically.

5. *Epidote*

Epidote is only an accessory mineral in the rock types discussed on p. 10-12 but it becomes increasingly important in the hornblende-schists and it is widespread in the epidotic schists.

Pistacite is the commonest variety present. Although it is not always pleochroic and the small crystals are usually colourless, larger crystals are either completely pleochroic or contain pleochroic cores (α = colourless, β = greenish yellow, γ = pale yellow-green; $\alpha{:}c = 28°$). The pleochroism of the pistacite is most marked in the epidotic schists but it is often absent from epidote in the siliceous rocks. Zoned crystals are not widespread but polysynthetically twinned ones are quite common in a few of the schists.

Clinozoistite ($\alpha{:}c = 0$–$5°$; $2V\gamma = 40°$) has a limited distribution and only some of the schists are clinozoisite-rich (H.130.3, 206.2). It generally forms large isolated, bladed crystals elongated parallel to the *b* crystallographic axis, and these contrast with the granular masses and well-defined closely packed layers of prisms typical of pistacite (Plate VIe). Only occasional crystals of clinozoisite are associated with pistacite in these schists, and clinozoisite has been recorded in only a few of the marbles (H.100.2, 101.1, 206.1) in this collection of rocks.

Allanite is rare but a few strongly pleochroic crystals (α = light brown, β = yellow-brown, γ = very dark red-brown) were observed in the mica-garnet-schist, Discovery Investigations station No. 1092, slide No. 36044.

The epidotes discussed here belong to the Al-Fe series described by Strens (1965, 1966). They apparently formed fairly early in the crystallization history of these rocks, since they form inclusions in plagioclase, hornblende and garnet, and a few crystals are included in biotite and chlorite flakes.

6. *Garnet*

The garnets are usually deep red in the hand specimen but in thin section they are either colourless or a very pale pink. The majority of them are perfectly isotropic and only a few of them are slightly birefringent. Refractive index measurements have indicated that there is only a slight variation in the chemical composition of garnets from different rock types. All of the garnets belong to the pyralspitic series with $n = 1{\cdot}79$–$1{\cdot}81$ and $a = 11{\cdot}63$Å; these values are indicative of either a spessartine or almandine garnet (Deer and others, 1962, tables 14, 18) but the approximate value of 4·0 for the specific gravity is more typical of almandine.

A crystal-size distribution study of garnets from Signy Island was made because of the apparent decrease in the ability of garnet to form perfect crystals, with a concomitant increase in crystal-size as the host rock varies from quartzite to amphibolite. Similar studies have previously been made by Jones and Galwey (1964), Galwey and Jones (1966) and Kretz (1966*a*). Thin-section studies of quartzites, quartz-mica- and mica-garnet-schists provided sufficient data for a statistical analysis of the crystal diameters (only circular sections of crystals were used where possible) but garnets occurring in the amphibolites were too large and hand-specimen measurements were used in preference. The results of the thin-section analyses were plotted as histograms (Fig. 9); measurements on hand specimens show that the average crystal diameter is 2–4 mm. in amphibolites and 0·7–1·2 cm. in the "pegmatitic gneisses" and *hornblendegarbenschiefer*.

Each histogram is unimodal with a positive skew but the peak of each histogram occurs at a different crystal diameter. Therefore, it can be inferred that there is a preferred crystal radius in each specimen studied and that this preferred radius remains constant for all samples of that rock type. The unimodal form of the histogram also shows that the nucleation rate for garnets increased with time initially and then declined (Kretz, 1966*a*).

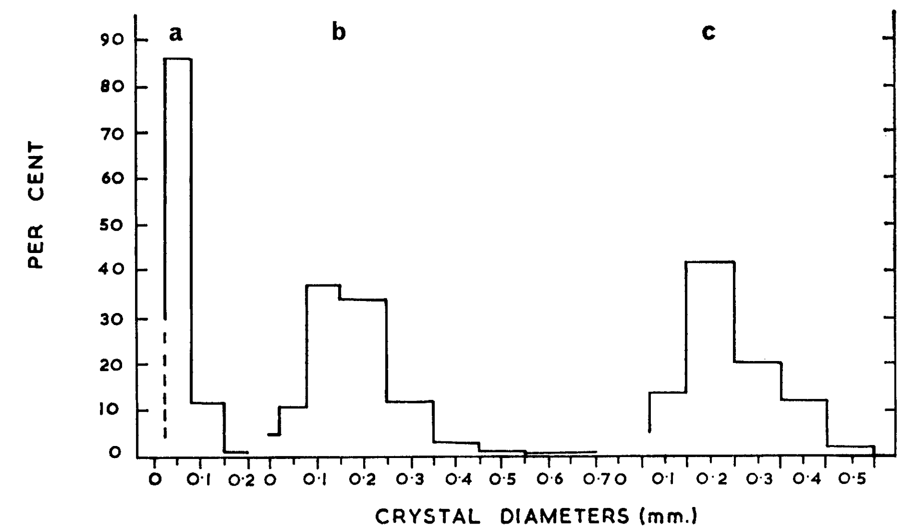

FIGURE 9

Histograms showing the crystal-size distribution of garnets in different rocks from Signy Island. a. Quartzite; b. Quartz-mica-schist; c. Mica-garnet-schist.

Kretz (1966*a*, p. 162) considered that all crystals grow at the same rate but they do not nucleate at the same time; this provides a reason for garnets of differing size in one single rock specimen (Fig. 10). Consequently, the size of crystals in metamorphic rocks is determined by the rate of nucleation relative to the rate of crystal growth. However, it has been impossible to ascertain what factors controlled the nucleation rate of garnets in these rocks but it is probable that the chemical composition of the host rock bears some relationship to the nucleation factor. This is suggested because most garnet crystals are concentrated in well-defined layers parallel to the original stratification of the rock and the largest crystals occur in those rocks which are rich in ferromagnesian minerals, indicating the possible availability of the required elements. Harker (1950, p. 198) considered that under conditions of regional metamorphism an increase in grain-size indicated a rise in metamorphic grade, whilst Rast (1958, p. 418) has suggested that the size of garnet crystals in rocks adjacent to the Boundary Slide (in the Schichallion Complex) is influenced by their proximity to the tectonic movements concentrated along that slide.

However, measurements of the number of crystals per unit volume of rock (Jones and Galwey, 1964; Galwey and Jones, 1966) are necessary before any conclusive arguments can be put forward concerning the factors which control garnet nucleation.

Apparently, the velocity of crystal growth is not always as uniform as has been suggested by Kretz (1966*a*). Spry (1963) has shown that the rate of growth will be controlled by the availability of material, viscosity, temperature, etc., and, since these may vary during the formation of a crystal, it is impossible to see how velocity growth can be uniform. Rast (1958) has shown that the zonal distribution of inclusions in some garnet crystals may be the result of fluctuations in the crystal growth rate; zones which are inclusion-free probably crystallized at a sufficiently slow rate to enable the chemical removal of included material, whereas a rapid growth rate tends to preserve inclusions. Only a few of the medium-sized garnet crystals from Signy Island (H.230.1) exhibit this type of zoning. Usually, the small crystals are inclusion-free (apart from occasional specks and clusters of graphitic material concentrated in the cores of some crystals) and the large crystals of the amphibolites (2–4 mm. in diameter) are riddled throughout with inclusions. In the zoned crystals of specimen H.207.1 the inner zone is imperfectly shaped and it has a cluster of inclusions (mainly of iron ore and unidentified opaque dust) at its margin but the outer zone is clear and forms a perfect crystal shape. This corroborates Rast's (1958) conclusions that a rapid velocity of growth inhibits the crystallographic form.

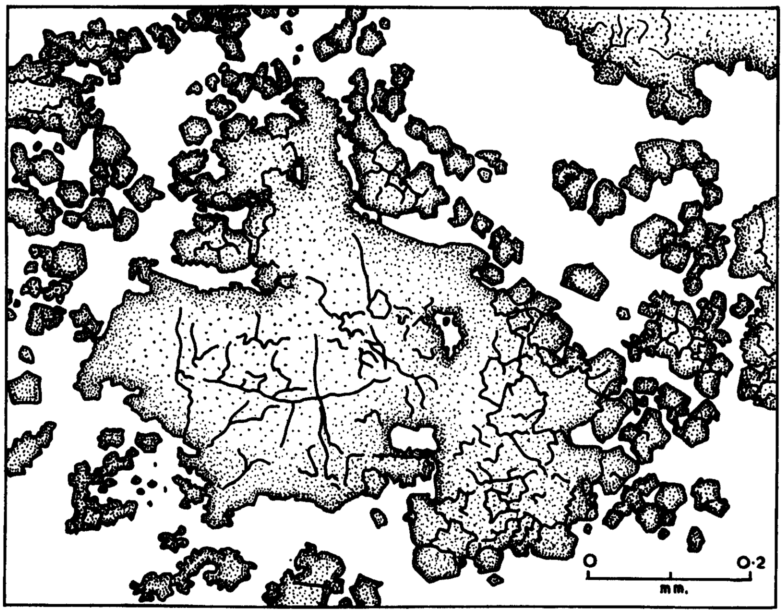

FIGURE 10
Polygonal crystals and granular aggregates of garnet (high relief) in a quartz-garnet vein; Jane Peak, Signy Island (H.1126.2).

Helicitic inclusions and sieve-like textures (Fig. 6; Plate VIId) are usual in the coarse crystals. The former are composed predominantly of sphene and epidote, whilst the latter are generally formed by quartz and plagioclase, probably by diffusion along feldspar/quartz boundaries (Gresens, 1966). The helicitic inclusions are usually much finer-grained than the texture of the host schist and it is suggested that the increase in grain-size of the inclusions, in passing outwards from the core of both garnet (H.210.2) and hornblende (H.525.2) porphyroblasts, is due to these two minerals crystallizing initially in the micaceous laminae of the rocks when the grain-size of the host rock was still small. As the porphyroblasts grew larger the groundmass became coarser. Garnet and hornblende were the two latest minerals to cease crystallization and towards the end of their crystallization history their crystal boundaries had probably overlapped on to the quartzose laminae. Thus the now coarse crystals of quartz and plagioclase became available for inclusion in the growing porphyroblasts.

The textural relationship of garnets has been discussed in terms of crystal growth by Rast and Sturt (1957) and Galwey and Jones (1962). Their use in elucidating the structural/metamorphic history of the host rocks has been described by Rast (1958), Howkins (1961), Rast and others (1962) and Spry (1963), and the relationship of the included material to the host crystal structure has been discussed by Powell (1966).

The garnets from Signy Island show little evidence of rotation during crystallization and the irregular form of *Si* is purely a reflection of the pre-existing irregular schistosity forming *Se*; *Si* is usually conformable with *Se*. A few crystals have possibly been rotated after crystallization ceased since *Si* is seemingly oblique to *Se*, but the evidence is inconclusive and it appears that the majority of garnets crystallized during a post-kinematic phase. This mineral was one of the last to crystallize, since it includes nearly all of the minerals (except hornblende) present in the host rock, and it is only in some of the mica-schists and amphibolites that it has suffered local retrograde metamorphism to biotite and chlorite (H.220.1). Specks of iron ore and crystals of epidote (relict inclusions from the garnet) commonly occur in these pseudomorphs. Although flakes of biotite often form a rim around garnet, they are not deflected by the later mineral and they are cut across in a typical porphyroblastic relationship (Plate VIIe). However, in a few fine-grained hornblende-schists the garnet pushes aside the hornblende folia (Plate VIIf). This indicates that the force of crystallization (Ramberg, 1947; 1952, p. 14–15) is not particularly significant during static post-kinematic growth of crystals.

7. *Accessory minerals*

Sphene is the commonest and most widespread of these minerals. It is particularly abundant in the amphibolites (Table III, specimens H.88.1, 389.1, 503.3, 1125.1) and two forms are present in the calciferous amphibolites.

In the micaceous schists it is commonly associated with epidote, occurring as small hypidioblastic lozenges or larger xenoblasts arranged in discontinuous layers; it forms coarse crystals in the amphibolites, in addition to closely packed aggregates of lozenge-shaped crystals. It is usually colourless or weakly pleochroic to pinkish grey (pleochroism is slightly stronger in the amphibolites and some crystals are brownish grey) and a few large crystals exhibit multiple twinning. The sphene is primarily syngenetic (Serdyuchenko and Moleva, 1961) and it is only in the calciferous amphibolites that there is any indication of a secondary origin. In these rocks the light-coloured crystals occasionally include granular crystals of a dark yellowish brown material. Since this is commonly intermingled with iron ore (ilmenite), it is believed to be a variety of leucoxene rich in anatase (Tyler and Marsden, 1938; Buddington and Lindsley, 1964, p. 326) rather than a variety of rutile (Bloomfield, 1958). A similar form of sphene occurs in the Basement Complex rocks of Graham Land (Hoskins, 1963; Fraser, 1965).

Iron ore is never very abundant but it is particularly apparent in a few of the quartzites as late-stage iron pyrites and haematite, and the former also occurs in the greenschists. Hexagonal crystals of ilmenite were observed in one hornblende-schist (Discovery Investigations station No. 1092, slide No. 36039) and deformed tabular crystals in another specimen (Discovery Investigations station No. 1092, slide No. 36042).

Graphite is much commoner and it is especially abundant in some of the mica-schists as aggregates of dusty particles included in biotite.

Apatite is widespread but not very abundant. It forms discrete rounded or ovoid porphyroblasts which are sometimes poikiloblastic and it seems to have crystallized at a fairly late stage. Vein-like segregations were recorded only in the calciferous amphibolites (H.388.1, 1380.2b).

Tourmaline is virtually confined to the siliceous schists but one epidotic schist (H.537.1) contains a band or vein of coarse tourmaline crystals. It occurs typically in the siliceous rocks as minute semi-triangular or prismatic idioblastic crystals scattered sporadically throughout the micaceous folia of the schists. The pleochroism is usually weak with ω = olive-green, ϵ = colourless, which is indicative of schorlite. Cross-sections often display zonal colouring with a yellow-green core surrounded by a blue-green rim. Concentrations of graphite particles are also present in the cores of some crystals. A few brownish crystals were observed in specimen H.166.1. In specimen H.537.1 tourmaline forms large (0·5 mm. long) idioblastic and hypidioblastic crystals, some of which are notably poikiloblastic with inclusions of epidote and iron ore. The mineral is pleochroic from pale brown to olive-green (absorption for $\omega > \epsilon$); zoning is rare (Plate VIf) and marked by a bluish green core.

Calcite is rare in the siliceous and micaceous schists but it is more widespread and abundant in the amphibolites. In all rocks it occurs in veins, sometimes rather narrow and impersistent and filling zones of weakness, or in irregular interstitial patches, particularly associated with sericitized feldspar. The crystals are coarse and twinned, and they occasionally contain perfectly shaped inclusions of quartz (H.1398.5), an example of differing relative isotropy and anisotropy between the host and included mineral (Kretz, 1966*b*, p. 80).

C. Petrogenesis

Regional metamorphism was induced by considerable tectonic movements and these resulted in the formation of sharp irregular small-scale folds and micro-folds in the micaceous schists. A study of the mineral parageneses has shown that the greater part of metamorphic recrystallization took place post-kinematically and that metamorphism was progressive; only a few instances of local retrograde metamorphism have been recorded.

Thin-section studies of a representative sample of the available rock collections have confirmed Tilley's (1935, p. 389) conclusion that "the metamorphic series [from the South Orkney Islands] represents a group of altered sediments ranging in composition from a pure carbonate through types representing marls to a dominant argillaceous facies". No relict igneous textures have been observed in thin section, although Matthews and Maling (1967) discovered apparent "*ortho*gneisses" (H.1407, 1408) cropping out in the amphitheatre east of Cummings Cove (Plates Ic, IIb) and in a small cove immediately west of Confusion Point (H.1396). After a cursory examination of these rocks, they concluded that they were normal members of the Marble and Amphibolite Series, respectively, which had been involved in extreme folding and faulting.

"The hornblendic types are characteristic derivatives of marly sediments" (Tilley, 1935, p. 389) and their intimate interbanding with marble (H.100.3) is indicative of an original sedimentary sequence. The mineral stratification observed in the quartz-mica-schist (H.227.1; Plate IIIb) is probably a mineral segregation resulting from compositional heterogeneity in the original sediment (alternating argillaceous and gritty layers (Harker, 1950, p. 19)) and it is not a pseudo-stratification caused by metamorphic differentiation (Turner, 1941).

D. Veins and Mineralization

The mineral veins observed in the hand specimens from Signy Island are similar to those described from their field work by Matthews and Maling (1967, p. 12).

Veins of quartz are the most widespread type and these occur in both the quartz-mica-schists and the amphibolites. They are either concordant pre-kinematic segregations which have undergone later folding, or they form discordant or sub-parallel post-kinematic veins.

"Pink" veins (H.1378.1) are common but less widespread than the quartz veins. On Coronation Island their typical development is at the contact between amphibolites and quartz-mica-schists (personal communication from Dr. D. W. Matthews). Since marbles are very rare on Coronation Island, the development of these veins on Signy Island is probably less restricted than envisaged by Matthews and Maling (1967, p. 12). The veins and segregations are composed of quartz arranged in impersistent sub-parallel bands which alternate with segregations of small polyhedra or granular masses of pale orange-red garnet (Fig. 10).

Discordant veins of prochlorite-albite and quartz-albite are not particularly common on Signy Island, unlike their development on Coronation Island, and only one (?) vein of tourmaline (H.537.1) has been recorded. The albite has a typical adularia habit (Marfunin, 1962, p. 150) and when it is associated with prochlorite the latter usually occurs in vermicular crystals. Most of the tourmaline occurs as small crystals in the micaceous folia of the quartz-mica-schists. This is indicative of boron trapped during the deposition of the original pelitic sediments (Hutton, 1939; Ojakangas, 1965; Levinson and Ludwick, 1966) and small black graphite particles included in a few of the tourmaline crystals indicate that the rock was originally a dark or black shale (Krynine, 1946, p. 69). However, the (?) vein of tourmaline in specimen H.537.1 is of doubtful origin and it may well be an indication of igneous activity on the island.

IV. PETROLOGY OF THE BASEMENT COMPLEX OF THE WESTERN ANTARCTIC

A. South Orkney Islands and Elephant and Clarence Islands

The Basement Complex rocks of Coronation Island, situated immediately north of Signy Island, represent a metasedimentary sequence similar to that of Signy Island. However, there are several petrological differences between the rocks of the two islands, the most significant of which is the variation in abundance of certain rock types on each island:

i. Marbles and amphibolites are widespread and abundant at the base of the stratigraphical succession on Signy Island, whereas there are few recorded outcrops of similar rocks on Coronation Island, except along its southern coast.
ii. The succession on Signy Island is capped by quartz-mica-schists of the Moe Island Series. These crop out only on Moe Island (Plate IIId), part of south-west Signy Island and in Gourlay Peninsula (Plate Ia), and their more limited distribution is in contrast to the widespread quartz-mica-schists of Coronation Island. Such rocks are the characteristic type on Coronation Island and it has been noticed that they are also generally finer-grained than the schists forming the Moe Island Series of Signy Island.
iii. Mica-garnet-schists are well-developed on Signy Island but they are relatively rare on Coronation Island.
iv. Graphitic schists *sensu stricto* and phyllites are unknown on Signy Island but they crop out in eastern Coronation Island, where they apparently conformably overlie the older rocks.

It is believed that these differences are due mainly to variations in the depositional environment of the original sediments. The Marble Series and the Amphibolite Series of Signy Island probably represent the metamorphosed equivalents of sediments belonging to the epicontinental facies, e.g. quartzites, marls, mudstones and limestones. Subsequent shallowing of the seas was concomitant with the deposition of sandy sediments; these are now represented by the Moe Island Series of Signy Island and the widespread quartz-mica-schists of Coronation Island. Possibly, the phyllites and graphitic schists, which occur at the eastern end of Coronation Island, represent muds and organo-argillaceous accumulations.

During a thin-section study of rocks from both Signy and Coronation Islands, it was noticed that garnet is widespread and abundant on Signy Island whereas it is rare in most parts of Coronation Island, apart from sections along the southern coast. It is suggested that this is because of differences in the grade of metamorphism between the two islands, and that during metamorphism much of Coronation Island probably crystallized under the metamorphic conditions of the biotite zone instead of the garnet zone.

Because marbles and amphibolites are rare on Coronation Island, there is the possibility that a plunging structure is present in the South Orkney Islands (personal communication from Dr. R. J. Adie) and that the exposures on Coronation Island are at a higher structural and stratigraphical level than those on Signy Island.

It has already been noted (p. 22) that veins are more widespread and varied on Coronation Island. All of the veins are of the replacement type and their greater abundance on Coronation Island suggests that the latter is probably located nearer to a deep-seated magmatic source than Signy Island. This is also indicated by the restricted intrusion of dolerite dykes in (?) Upper Jurassic times. Although there has been no previous indication of igneous activity on Signy Island (Matthews and Maling, 1967, p. 10, 12), the tourmaline vein (p. 21) is probably more likely to have been due to igneous activity than to be sedimentary in origin, i.e. it does not represent recrystallized detrital tourmaline in the original sediment (Hutton, 1940, p. 64-65).

The Inaccessible Islands, situated approximately 20 miles (32 km.) north-west of the South Orkney Islands, are composed of similar *para*schists (personal communication from Miss S. M. West). Tuffs were probably intercalated with the sediments, and Tilley (1935, p. 389) described one specimen from these islands which he considered represented "a dynamically metamorphosed basic igneous rock of original doleritic character".

*Para*schists have also been recorded in the Elephant and Clarence Islands group of the South Shetland Islands (Tilley, 1930; Tyrrell, 1945). The northern part of Elephant Island, at "Minstrel Bay" and Cape Valentine, is composed of leaden-grey phyllites probably similar to those occurring on Coronation Island. These were believed to be normal sediments by Tilley (1930) but Tyrrell (1945, p. 77) considered that some may have been volcanic sediments. The south of the island, at Cape Lookout, is composed of a series of marbles and *para*-amphibolites similar in most respects to those occurring on Signy Island, although they differ from them in their graphitic nature. They have been subdivided into three petrographical groups (Tilley, 1930, p. 58):

i. Garnet-hornblende-albite-schists.
ii. Amphibole-bearing marbles.
iii. *Para*-amphibolites.

These rock types are comparable with those occurring at the base of the succession on Signy Island and they indicate that there is "a close lithological and metamorphic relationship" (Tilley, 1935, p. 390) between Elephant Island and the South Orkney Islands. Specimens of glaucophane-schists and quartz-albite-tremolite-epidote-schists obtained from dredgings south of Clarence Island probably represent original basic igneous rocks or tuffs, or rocks from the spilitic suite, respectively (Tyrrell, 1945, p. 82–83). Gibbs Island, situated 20 miles (32 km.) south-south-west of Elephant Island, is composed of fine-grained chlorite-sericite-albite-schists or phyllites associated with a mass of dunite-serpentinite (Tyrrell, 1945, p. 84). A (?) serpentinitic sheet, which has been recorded on Fredriksen Island (personal communication from Dr. D. W. Matthews), provides an additional similarity between the lithology and petrology of the Basement Complex of Elephant and Clarence Islands and the South Orkney Islands. Such similarities confirm Andersson's (1906) suggestion that there may be a geological link between these two groups of islands and they also indicate that the two groups were probably originally much closer together, prior to the formation of the Scotia arc.

B. Antarctic Peninsula

Basement Complex rocks crop out along the Fallières Coast of the south-western Antarctic Peninsula, south of lat. 67°S. (Adie, 1954, p. 4) and they also occur as infrequent xenoliths in tonalites and granodiorites on the Loubet Coast (Goldring, 1962, p. 6); there are no known outcrops of the Basement Complex along the east coast of the peninsula.

Adie (1954) described various types of gneisses, hornblende-schists, garnet- and quartz-muscovite-schists from the Fallières Coast and offshore islets, including schists recovered from moraines in north-eastern Alexander Island. He concluded that the original Basement Complex was relatively poor in sediments (these are represented by the quartz-muscovite- and garnet-mica-schists and the quartz-biotite-gneisses) and that most of the gneisses were derived from intermediate and acid igneous rocks. The hornblende-schists are diopside-bearing and they were probably basic volcanic rocks, whereas the amphibolites were originally pyroxenites.

Hoskins (1963) and Fraser (1965) have described in detail Basement Complex rocks from areas in Marguerite Bay (Neny Fjord, and Stonington and Trepassey Islands). Both areas are composed of *ortho*-gneisses associated with amphibolites and hornblende-schists but no garnet- or quartz-mica-schists are present. All of these rocks are believed to be igneous in origin and they are therefore notably different from the succession of *para*schists and *para*-amphibolites occurring in the South Orkney Islands and the Elephant and Clarence Islands group.

Neither of the two areas in Marguerite Bay provides any conclusive evidence for the age of the Basement Complex. However, the Basement Complex rocks of the Antarctic Peninsula could be early Palaeozoic (Cambrian) in age and therefore they would be younger than the Basement Complex rocks of the South Orkney Islands.

V. METAMORPHISM

Various aspects of the metamorphism affecting the rocks of the South Orkney Islands have already been discussed in earlier parts of this report. This section summarizes the earlier data and discusses in particular the application of metamorphic rock classifications to the rocks of Signy (and Coronation) Islands.

A. Classification

The most recent re-appraisal of the metamorphic facies concept (Fyfe and Turner, 1966) has simplified the application of facies in metamorphic rock classification by the removal of sub-facies. Consequently, the albite-epidote-amphibolite assemblage of rocks, into which category the Signy Island rocks have been placed, has been upgraded from a sub-facies (Turner and Verhoogen, 1960, p. 539) to the status of a facies. Only a few of the Coronation Island rocks have a mineral assemblage which is typical of the greenschist facies.

It has already been noted (p. 23) that garnet is abundant at Signy Island. Since this is one of the critical minerals in a metamorphic mineral assemblage, it is probable that these rocks belong to the Barrovian-type garnet zone of the albite-epidote-amphibolite facies. At first, the lack of garnets over most of Coronation Island was considered a reflection of the chemical composition of the rocks, which was not appropriate for garnet formation. However, biotite is quite widespread in these rocks and they are generally finer-grained than the quartz-mica-schists of Signy Island. Consequently, they may belong to the lower-grade biotite zone of the albite-epidote-amphibolite facies. Unfortunately, detailed field mapping of Coronation Island has not yet been completed and the outcrops on the island are not clearly defined, but it would be interesting to know whether a garnet isograd could be mapped in the field. Future chemical analyses of the rocks will also show whether garnet formation was hindered by chemical as well as by physical conditions.

If a garnet isograd is indeed present, and if the phyllites which crop out in eastern Coronation Island are an indication of the greenschist facies, there is evidence of a progressive grading of mineral changes in the Basement Complex rocks similar to those described by Barrow (1893), Tilley (1925) and Phillips (1930) in the Dalradian rocks of Scotland. The petrography of the rocks has already been discussed (p. 8–14) and the evidence of deformation and post-kinematic recrystallization indicates that these rocks have undergone regional dynamothermal metamorphism (i.e. regional metamorphism *sensu stricto* (Winkler, 1965, p. 2)) and not just regional burial metamorphism. Although there is only evidence of one phase of crystallization, K-Ar age determinations on quartz-mica-schists from Signy and Moe Islands (Miller, 1960; Rex, 1967) have shown that a later orogeny (185 ± 7 m. yr.) affected both the Basement Complex rocks and the Greywacke-Shale Series. However, there is no petrographical evidence of this later orogeny and the Basement Complex rocks are considered to be essentially monometamorphic (Hsu, 1955). Widespread retrograde metamorphism and phyllonitization (Knopf, 1931) are unknown but there are local instances of it on both islands; this is usually shown by the alteration of garnet to biotite and chlorite. In fact, such features are indicative of small-scale disequilibrium. Fyfe and Turner (1966, p. 356) have noted that the mineral assemblages in metamorphic rocks form equilibrium systems, although "the facies concept does not necessarily imply that metamorphic mineral assemblages are systems in equilibrium". They have also maintained that disequilibrium is characteristic of polymetamorphic or incompletely metamorphosed rocks, whilst Turner (1948, p. 14) has pointed out that the simple mineralogy of metamorphic rocks is indicative of chemical equilibrium.

Palm (1960) has made a study of wet and dry regional metamorphism, in which he defined two petrographically distinct series of regionally metamorphosed rocks. These are the "schist-granite" and "schist-granulite" series, the former being characterized by extreme mobility of elements and the latter by virtually negligible mobility. The close petrographic resemblance between the schists and gneisses of the two series shows that the physico-chemical conditions operating during their formation were very similar for low grades of metamorphism. However, porphyroblastic albite-schists are unknown in the "schist-granulite" series and therefore the South Orkney Islands rocks probably belong to the "schist-granite" series. Palm believed that the latter was the result of the progressive metamorphism of sediments saturated with sea-water. (He also believed that sea-water is the source of soda for the albite porphyroblasts.) He presumed that concordant quartz lenses and veins in the mica-schists are syn-kinematic and that silica was mobile under the physical conditions governing the lower grades of metamorphism. This corroborates an earlier suggestion (p. 14) that the undulose extinction invariably present in quartz indicates that the quartz was still mobile during its crystallization under stress.

B. Growth of Metamorphic Minerals

The nucleation and growth of metamorphic minerals (Rast, 1965) has already been discussed with particular reference to garnets (p. 19). However, the shape of metamorphic minerals (Kretz, 1966*b*) is of some interest and it will be discussed at greater length here. The shape of crystals in metamorphic rocks is governed to some extent by the interfacial energy* (Buerger, 1947; DeVore, 1956, 1959), and the mosaic texture (Harker, 1950) present in such rocks as quartzites, marbles and hornfelses has been attributed to interfacial tension (Griggs and others, 1960; Kretz, 1966*b*). When the interfacial tensions of the boundaries of three contiguous crystals are in equilibrium, the angle at the junction is commonly 120° (Harker and Parker, 1945), although in practice there is a deviation from this value of about 7·5° (Kretz, 1966*b*, p. 74). The equilibrium shape of a mineral does not necessarily develop during crystal growth and it may only attain its shape during subsequent diffusion of matter. Consequently, if crystallization is only operative over a short period of time, only the small crystals will achieve their equilibrium shape. It appears that the crystal-boundary angles at the junction of three similar minerals, e.g. quartz and feldspar, are not affected

* Specific interfacial free energy is the specific Helmholtz free energy associated with the surface area of the interface (Kretz, 1966*b*, p. 69).

by the crystal orientation and it is probable that the interfacial tensions are independent of crystal orientation. However, Kretz (1966*b*, p. 78) has shown that the orientation effect becomes more noticeable at the junction of grains of hornblende, biotite or any other mineral which has a relatively large crystallographic anistropy.

The shape of inclusions of one mineral in crystals of another was originally thought to be a function of Becke's crystalloblastic series of minerals. This was considered an arrangement of the common metamorphic minerals into a series, such that a mineral high in the series (e.g. sphene, garnet and tourmaline) is capable of imposing its form against all minerals below it in the series, e.g. hornblende, biotite, quartz and plagioclase. However, there are exceptions to this rule, and Kretz (1966*b*) has suggested that Becke's classification could be refined by replacing the minerals by particular interfaces, e.g. garnet (110)–quartz, and arranging them in order of increasing specific interfacial free energy. (This assumes that these interfaces are practically independent of the orientation of quartz.) Since the greater part of the included material in the minerals of the metamorphic rocks of the South Orkney Islands is either spherical or polyhedral, it is assumed that either the crystallization period was very brief or that equilibrium of the interfacial energies could not be attained.

The overall shape of the minerals is never particularly well defined but when it does occur it complies with the general crystalloblastic series of Becke. The mosaic texture present in the quartzites, quartz veins and the marbles of the South Orkney Islands is often highly irregular in configuration. The crystal-boundary angles show a considerable departure from 120° and this is indicative of a high interfacial energy. The presence of inclusions in a crystal also represents a state of relatively high interfacial energy (Kretz, 1966*b*, p. 92).

TABLE IV

POTASSIUM-ARGON AGE DETERMINATIONS ON QUARTZ-MICA-SCHISTS FROM THE SOUTH ORKNEY ISLANDS

Specimen number	*Locality*	*Mineral separated*	*Age* (m. yr.)
H.60.3*	Signy Island	Biotite	176±5
H.86.1*	Signy Island	Biotite	199±5
H.154.8*	Signy Island	Biotite	183±5
H.164.2*	Signy Island	Biotite	184±5
H.205.2*	Signy Island	Biotite	195±5
H.220.1†	Signy Island	Biotite	177±7
H.246.1†	Coronation Island	Muscovite	187±7
H.507.3*	Signy Island	Biotite	195±5
H.507.3*	Signy Island	Muscovite	176±5
H.1351B.1†	Moe Island	Muscovite Biotite	186±7 178±7
H.1365.1* H.1384.1*	Moe Island Signy Island	Biotite	193±5
H.1369.1*	Shagnasty Island	Biotite	189±5
H.1374.1†	Signy Island	Muscovite	189±7

* Miller (1960).
† Rex (1967).

VI. POTASSIUM-ARGON AGE DETERMINATIONS ON ROCKS FROM THE SOUTH ORKNEY ISLANDS

A SMALL number of quartz-mica-schists from the South Orkney Islands have been dated by the K-Ar method (Miller, 1960; Rex, 1967) and the results of these determinations are given in Table IV. Miller (1960) has applied this method to micas (mostly biotite) separated from the schists of Signy and Moe Islands, and his results have yielded a mean age of 187 ± 5 m. yr. Rex (1967) has carried out similar determinations on quartz-mica-schists from Coronation, Signy and Moe Islands and his results (a mean age of 183 ± 7 m. yr.) corroborate those of Miller.

This age does not represent the time of the regional metamorphism which caused the recrystallization of the Basement Complex rocks, but it is probably the age of the well-known Andean orogeny which folded the overlying Greywacke-Shale Series of the South Orkney Islands. Although this later orogeny was sufficiently intense to release radiogenic argon from the micas, it was not so intense that it induced recrystallization of the existing metamorphic minerals. Since there was apparently little, if any, concomitant increase in temperature, it is believed that the metamorphism induced by this later orogeny was essentially dynamic.

VII. CONCLUSIONS

THE study of small-scale structures has shown that the Basement Complex rocks of the South Orkney Islands were subjected to considerable deformation. The resultant large-scale recumbent folds trending north–south have been mapped in the field and they are associated with abundant small-scale folds and micro-folds. The period of waning tectonism was characterized by faulting which formed two sets of faults trending both west–east and north–south.

The associated regional metamorphism produced post-kinematic crystallization of the minerals and, because mica and hornblende have crystallized mimetically around the crests of micro-folds, the Basement Complex rocks have been tentatively classified as mimetic tectonites. K-Ar age determinations on the quartz-mica-schists have indicated that a later orogeny (185 ± 7 m. yr.) affected the South Orkney Islands but, although this was so strong that it released radiogenic argon from the micas, it was incapable of inducing another phase of recrystallization in the metamorphic rocks. Since there is no textural or mineralogical evidence of this later orogeny, the rocks are considered to be essentially monometamorphic.

The Basement Complex rocks belong to the albite-epidote-amphibolite facies of regional metamorphism. There is some evidence that the metamorphism was progressive (p. 17) and it is believed that the lack of garnet on Coronation Island was probably caused by the crystallization of the rocks within the biotite zone of this facies. Garnet is abundant on Signy Island but the presence of a garnet isograd somewhere along the south coast of Coronation Island is purely a tentative suggestion, because no garnet-free nor garnet-rich zones have been recorded in the field work of Matthews and Maling (1967). Retrograde metamorphism is only a local phenomenon.

The metamorphic rocks of Signy and Coronation Islands represent a metasedimentary sequence. The relative abundance of marbles and amphibolites on Signy Island, and their paucity on Coronation Island, is probably due to varying conditions within the depositional environment of the original sediments. It is believed that this environment was appropriate for the deposition of sediments belonging to the epicontinental facies, i.e. limestones, marls and quartzites. The supposedly younger quartz-mica-schists of the Moe Island Series on Signy Island and the widespread quartz-mica-schists of Coronation Island probably represent more clastic sediments (sandstones and arkoses) deposited in shallower water close to a rising landmass. It is also possible that Coronation Island is at a higher structural and stratigraphical level than Signy Island (p. 23) and this could cause the variations in the abundance of rock types between the two islands.

The age of the Basement Complex is uncertain but it is probably Precambrian. Similar *para*-metamorphic rocks have been recorded in the Elephant and Clarence Islands group but the Basement Complex of the Antarctic Peninsula consists mainly of *ortho*gneisses associated with relatively uncommon *para*-schists and *para*gneisses.

The altered dolerite dykes which intrude the Basement Complex of Coronation Island are the only conclusive evidence of igneous activity in the South Orkney Islands. The discordant veins (composed mainly of quartz, albite and chlorite) which cut the schists are commoner on Coronation Island than on Signy Island and they could have been derived from a distant magmatic source which was situated closer to Coronation Island than Signy Island.

VIII. ACKNOWLEDGEMENTS

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IX. REFERENCES

ADIE, R. J. 1954. The petrology of Graham Land: I. The Basement Complex; early Palaeozoic plutonic and volcanic rocks. *Falkland Islands Dependencies Survey Scientific Reports*, No. 11, 22 pp.

————. 1957. Geological investigations in the Falkland Islands Dependencies before 1940. *Polar Rec.*, **8**, No. 57, 502–13.

————. 1958. Geological investigations in the Falkland Islands Dependencies since 1940. *Polar Rec.*, **9**, No. 58, 3–17.

————. 1964. Geological history. (*In* PRIESTLEY, R. E., ADIE, R. J. *and* G. DE Q. ROBIN, *ed. Antarctic research.* London, Butterworth and Co. (Publishers) Ltd., 118–62.)

AGAR, W. M. *and* E. H. EMENDORFER. 1937. Manganiferous prochlorite from Hawleyville, Conn. *Am. J. Sci.*, Ser. 5, **34**, No. 199, 77–80.

ALLEN, A. 1966. Seismic refraction investigations in the Scotia Sea. *British Antarctic Survey Scientific Reports*, No. 55, 44 pp.

ANDERSSON, J. G. 1906. On the geology of Graham Land. *Bull. geol. Instn Univ. Upsala*, **7**, 19–71.

BARROW, G. 1893. On an intrusion of muscovite-biotite gneiss in the south-eastern Highlands of Scotland, and its accompanying metamorphism. *Q. Jl geol. Soc. Lond.*, **49**, No. 195, 330–56.

BARTH, T. F. W. *and* P. HOLMSEN. 1939. Rocks from the Antarctandes and the Southern Antilles. Being a description of rock samples collected by Olaf Holtedahl 1927–1928, and a discussion of their mode of origin. *Scient. Results Norw. Antarct. Exped.*, No. 18, 64 pp.

BILLINGS, M. P. 1937. Regional metamorphism of the Littleton-Moosilauke area, New Hampshire. *Bull. geol. Soc. Am.*, **48**, No. 4, 463–565.

BLOOMFIELD, K. 1958. The Chimwadzulu Hill ultrabasic body, southern Nyasaland. *Trans. geol. Soc. S. Afr.*, **61**, 263–82.

BUDDINGTON, A. F. *and* D. H. LINDSLEY. 1964. Iron-titanium oxide minerals and synthetic equivalents. *J. Petrology*, **5**, Pt. 2, 310–57.

BUERGER, M. J. 1947. The relative importance of the several faces of a crystal. *Am. Miner.*, **32**, Nos. 11 and 12, 593–606.

CHAMBERS, M. J. G. 1966*a*. Investigations of patterned ground at Signy Island, South Orkney Islands: I. Interpretation of mechanical analyses. *British Antarctic Survey Bulletin*, No. 9, 21–40.

————. 1966*b*. Investigations of patterned ground at Signy Island, South Orkney Islands: II. Temperature regimes in the active layer. *British Antarctic Survey Bulletin*, No. 10, 71–83.

————. 1967. Investigations of patterned ground at Signy Island, South Orkney Islands: III. Miniature patterns, frost heaving and general conclusions. *British Antarctic Survey Bulletin*, No. 12, 1–22.

DEER, W. A., HOWIE, R. A. *and* J. ZUSSMAN. 1962. *Rock-forming minerals. Vol. 1. Ortho- and ring silicates.* London, Longmans, Green and Co. Ltd.

————., ————. *and* ————. 1963. *Rock-forming minerals. Vol. 4. Framework silicates.* London, Longmans, Green and Co. Ltd.

DEVORE, G. W. 1956. Surface chemistry as a chemical control on mineral association. *J. Geol.*, **64**, No. 1, 31–55.

————. 1959. Role of minimum interfacial free energy in determining the macroscopic features of mineral assemblages. I. The model. *J. Geol.*, **67**, No. 2, 211–27.

EMMONS, R. C. *and* V. MANN. 1953. A twin-zone relationship in plagioclase feldspar. (*In* EMMONS, R. C., *ed.* Selected petrogenic relationships of plagioclase. *Mem. geol. Soc. Am.*, No. 52, 41–54.)

FRASER, A. G. 1965. The petrology of Stonington and Trepassey Islands, Marguerite Bay. *British Antarctic Survey Scientific Reports*, No. 52, 51 pp.

FYFE, W. S. *and* F. J. TURNER. 1966. Reappraisal of the metamorphic facies concept. *Contr. Miner. Petrol. (Beitr. Miner. Petrogr.)*, **12**, No. 4, 354–64.

GALWEY, A. K. *and* K. A. JONES. 1962. Inclusions in garnets. *Nature, Lond.*, **193**, No. 4814, 471–72.
———. *and* ———. 1966. Crystal size frequency distribution of garnets in some analysed metamorphic rocks from Mallaig, Inverness, Scotland. *Geol. Mag.*, **103**, No. 2, 143–52.
GOLDRING, D. C. 1962. The geology of the Loubet Coast, Graham Land. *British Antarctic Survey Scientific Reports*, No. 36, 50 pp.
GORAI, M. 1950. Proposal of twin method for the study of the "granite problem". *J. geol. Soc. Japan*, **56**, No. 655, 149–56.
———. 1951. Petrological studies on plagioclase twins. *Am. Miner.*, **36**, Nos. 11 and 12, 884–901.
GRESENS, R. L. 1966. Dimensional and compositional control of garnet growth by mineralogical environment. *Am. Miner.*, **51**, Nos. 3 and 4, 524–28.
GRIFFITHS, D. H. 1963. Geophysical investigations in the Scotia arc and Graham Land. *British Antarctic Survey Bulletin*, No. 1, 27–32.
———. *and* P. F. BARKER. 1967. Marine geophysics of the Scotia Ridge and Scotia Sea. *British Antarctic Survey Bulletin*, No. 12, 93–99.
GRIGGS, D. T., PATERSON, M. S., HEARD, H. C. *and* F. J. TURNER. 1960. Annealing recrystallization in calcite crystals and aggregates. (*In* GRIGGS, D. [T.] *and* J. HANDIN, *ed.* Rock deformation (a symposium). *Mem. geol. Soc. Am.*, No. 79, 21–37.)
GUTENBERG, B. *and* C. F. RICHTER. 1949. *Seismicity of the Earth and associated phenomena.* Princeton, Princeton University Press.
HALL, A. J. 1941. The relation between colour and chemical composition in the biotites. *Am. Miner.*, **26**, No. 1, 29–33.
HARKER, A. 1950. *Metamorphism: a study of the transformations of rock-masses.* 3rd edition. London, Methuen and Co. Ltd.
HARKER, D. *and* E. R. PARKER. 1945. Grain shape and grain growth. *Trans. Am. Soc. Metals*, **34**, 156–201.
HAWKES, D. D. 1962. The structure of the Scotia arc. *Geol. Mag.*, **99**, No. 1, 85–91.
HERDMAN, H. F. P. 1948. Soundings taken during the Discovery Investigations, 1932–39. '*Discovery*' *Rep.*, **25**, 39–106.
———., WISEMAN, J. D. H. *and* C. D. OVEY. 1956. Proposed names of features on the deep-sea floor. 3. Southern or Antarctic Ocean. *Deep Sea Res.*, **3**, No. 4, 253–61.
HEYWOOD, R. B. 1967. Ecology of the fresh-water lakes of Signy Island, South Orkney Islands: I. Catchment areas, drainage systems and lake morphology. *British Antarctic Survey Bulletin*, No. 14, 25–43.
HIETANEN, A. 1938. On the petrology of Finnish quartzites. *Bull. Commn géol. Finl.*, **21**, No. 122, 118 pp.
HOLDGATE, M. W. 1963. Observations in the South Sandwich Islands, 1962. *Polar Rec.*, **11**, No. 73, 394–405.
———., ALLEN, S. E. *and* M. J. G. CHAMBERS. 1967. A preliminary investigation of the soils of Signy Island, South Orkney Islands. *British Antarctic Survey Bulletin*, No. 12, 53–71.
HOLTEDAHL, O. 1929. On the geology and physiography of some Antarctic and sub-Antarctic islands. *Scient. Results Norw. Antarct. Exped.*, No. 3, 172 pp.
HOSKINS, A. K. 1963. The Basement Complex of Neny Fjord, Graham Land. *British Antarctic Survey Scientific Reports*, No. 43, 49 pp.
HOWKINS, J. B. 1961. Helicitic textures in garnets from the Moine rocks of Moidart. *Trans. Edinb. geol. Soc.*, **18**, Pt. 3, 315–24.
HSU, K. J. 1955. Monometamorphism, polymetamorphism and retrograde metamorphism. *Am. J. Sci.*, **253**, No. 4, 237–39.
HUTTON, C. O. 1939. The significance of tourmaline in the Otago schists. *Trans. R. Soc. N.Z.*, **68**, Pt. 4, 599–602.
———. 1940. Metamorphism in the Lake Wakatipu region, western Otago, New Zealand. *Geol. Mem. N.Z.*, No. 5, 84 pp.
JONES, K. A. 1961. Origin of albite porphyroblasts in rocks of the Ben More–Am-Binnein area, western Perthshire, Scotland. *Geol. Mag.*, **98**, No. 1, 41–55.
———. *and* A. K. GALWEY. 1964. A study of possible factors concerning garnet formation in rocks from Ardara, Co. Donegal, Ireland. *Geol. Mag.*, **101**, No. 1, 76–93.
KNOPF, E. B. 1931. Retrogressive metamorphism and phyllonitization. *Am. J. Sci.*, Ser. 5, **21**, No. 121, 1–27.
KRETZ, R. 1966*a*. Grain-size distribution for certain metamorphic minerals in relation to nucleation and growth. *J. Geol.*, **74**, No. 2, 147–73.
———. 1966*b*. Interpretation of the shape of mineral grains in metamorphic rocks. *J. Petrology*, **7**, Pt. 1, 68–94.
KRYNINE, P. D. 1946. The tourmaline group in sediments. *J. Geol.*, **54**, No. 2, 65–87.
KULP, J. L. 1961. Geologic time scale. *Science, N.Y.*, **133**, No. 3459, 1105–14.
LAYTON, W. 1963. Amphibole paragenesis in the Birrimian Series of the Winneba District of Ghana. *J. geol. Soc. Aust.*, **10**, Pt. 2, 261–71.
LEVINSON, A. A. *and* J. C. LUDWICK. 1966. Speculation on the incorporation of boron into argillaceous sediments. *Geochim. cosmochim. Acta*, **30**, No. 9, 855–61.
MARFUNIN, A. M. 1962. Polevye shpaty–fazovye vzaimootnosheniya, opticheskie svoistva, geologicheskoe raspredelenie [The feldspars–phase relations, optical properties, and geological distribution]. *Trudy̆ Inst. Geol. rudn. Mestorozh.*, Issue 78. [English translation by J. Kolodny. Jerusalem, Israel Program for Scientific Translations, 1966, 317 pp.]
MATTHEWS, D. H. 1959. Aspects of the geology of the Scotia arc. *Geol. Mag.*, **96**, No. 6, 425–41.
———. *and* D. H. MALING. 1967. The geology of the South Orkney Islands: I. Signy Island. *Falkland Islands Dependencies Survey Scientific Reports*, No. 25, 32 pp.
MILLER, J. A. 1960. Potassium-argon ages of some rocks from the South Atlantic. *Nature, Lond.*, **187**, No. 4742, 1019–20.
OJAKANGAS, R. W. 1965. Petrography and sedimentation of the Precambrian Jatulian quartzites of Finland. *Bull. Commn géol. Finl.*, **33**, No. 214, 74 pp.
ORVILLE, P. M. 1962. Alkali metasomatism and feldspars. *Norsk geol. Tidsskr.*, **42**, Pt. 2, 283–316.

PALM, Q. A. 1960. Wet and dry regional metamorphism. *Geologie Mijnb.*, N.S., **22**, Nr. 6, 244–52.

PHILLIPS, F. C. 1930. Some mineralogical and chemical changes induced by progressive metamorphism in the Green Bed group of the Scottish Dalradian. *Mineralog. Mag.*, **22**, No. 129, 239–56.

PHILLIPS, R. *and* W. LAYTON. 1964. The calciferous and alkali amphiboles. *Mineralog. Mag.*, **33**, No. 267, 1097–109.

PIRIE, J. H. H. 1905. On the graptolite-bearing rocks of the South Orkneys. *Proc. R. Soc. Edinb.*, **25**, Pt. 6, 463–70.

————. Unpublished. Geology of the South Orkneys. *Scottish National Antarctic Expedition Reports*, 1–10.

POWELL, D. 1966. On the preferred crystallographic orientation of garnet in some metamorphic rocks. *Mineralog. Mag.*, **35**, No. 276, 1094–109.

RAMBERG, H. 1947. The force of crystallization as a well definable property of crystals. *Geol. För. Stockh. Förh.*, **69**, Pt. 2, 189–94.

————. 1952. *The origin of metamorphic and metasomatic rocks: a treatise on recrystallization and replacement in the Earth's crust.* Chicago, The University of Chicago Press.

RAST, N. 1958. Metamorphic history of the Schichallion complex (Perthshire). *Trans. R. Soc. Edinb.*, **63**, Pt. 2, No. 19, 413–31.

————. 1965. Nucleation and growth of metamorphic minerals. (*In* PITCHER, W. S. *and* G. W. FLINN, *ed. Controls of metamorphism. A symposium held under the auspices of The Liverpool Geological Society.* Edinburgh and London, Oliver & Boyd, 73–102.) [*Geological Journal*, Special issue No. 1.]

————. *and* B. A. STURT. 1957. Crystallographic and geological factors in the growth of garnets from central Perthshire. *Nature, Lond.*, **179**, No. 4552, 215.

————., ————. *and* A. L. HARRIS. 1962. Inclusions in garnets. *Nature, Lond.*, **195**, No. 4838, 274–75.

REX, D. C. 1967. *Isotopic age determinations of rocks from the Antarctic Peninsula.* M.Sc. thesis, University of Leicester, 120 pp. [Unpublished.]

SERDYUCHENKO, D. P. *and* V. A. MOLEVA. 1961. Sphenes from Archean rocks of southern Yakut. *Dokl. (Proc.) Acad. Sci. U.S.S.R.*, Earth sciences sections, **132**, Nos. 1–6, 590–92. [Translation of: Titanity iz Arkeyskikh porod yuzhnoy Yakutii. *Dokl. Akad. Nauk SSSR*, **132**, No. 1, 1960, 181–84.]

SPRY, A. 1963. The origin and significance of snowball structure in garnet. *J. Petrology*, **4**, Pt. 2, 211–22.

STEWART, D. 1937. Petrography of some rocks from the South Orkney Islands and the Antarctic archipelago. *Am. Miner.*, **22**, No. 3, 178–94.

STRENS, R. G. J. 1965. Stability and relations of the Al-Fe epidotes. *Mineralog. Mag.*, **35**, No. 271, 464–75.

————. 1966. Properties of the Al-Fe-Mn epidotes. *Mineralog. Mag.*, **35**, No. 275, 928–44.

SUESS, E. 1909. *The face of the Earth (Das Antlitz der Erde). Vol. 4.* Oxford, Clarendon Press. [Translated by H. B. C. Sollas under the direction of W. J. Sollas.]

TILLEY, C. E. 1925. A preliminary survey of metamorphic zones in the southern Highlands of Scotland. *Q. Jl geol. Soc. Lond.*, **81**, Pt. 1, No. 321, 100–10.

————. 1930. Petrographical notes on rocks from Elephant Island, South Shetlands. (*In Report on the geological collections made during the voyage of the "Quest" on the Shackleton-Rowett Expedition to the South Atlantic and Weddell Sea in 1921–1922.* London, Trustees of the British Museum, 55–62.)

————. 1935. Report on rocks from the South Orkney Islands. *'Discovery' Rep.*, **10**, 383–90.

TOBI, A. C. 1962. Characteristic patterns of plagioclase twinning. *Norsk geol. Tidsskr.*, **42**, Pt. 2, 264–71.

TURNER, F. J. 1941. The development of pseudo-stratification by metamorphic differentiation in the schists of Otago, New Zealand. *Am. J. Sci.*, **239**, No. 1, 1–16.

————. 1948. Mineralogical and structural evolution of the metamorphic rocks. *Mem. geol. Soc. Am.*, No. 30, 342 pp.

————. 1951. Observations on twinning of plagioclase in metamorphic rocks. *Am. Miner.*, **36**, Nos. 7 and 8, 581–89.

————. *and* J. VERHOOGEN. 1960. *Igneous and metamorphic petrology.* 2nd edition. New York, Toronto and London, McGraw-Hill Book Company, Inc.

TYLER, S. A. *and* R. W. MARSDEN. 1938. The nature of leucoxene. *J. sedim. Petrol.*, **8**, No. 2, 55–58.

TYRRELL, G. W. 1945. Report on rocks from west Antarctica and the Scotia arc. *'Discovery' Rep.*, **23**, 37–102.

VANCE, J. A. 1961. Polysynthetic twinning in plagioclase. *Am. Miner.*, **46**, Nos. 9 and 10, 1097–119.

WILSON, J. T. 1950. An analysis of the pattern and possible cause of young mountain ranges and island arcs. *Proc. geol. Ass. Can.*, **3**, 141–66.

WINKLER, H. G. F. 1965. *Petrogenesis of metamorphic rocks.* Berlin, Heidelberg and New York, Springer-Verlag.

PLATE I

a. Air photograph of the south-east and east coasts of Signy Island viewed from the south-east. Clowes Bay and Gourlay Peninsula are in the foreground and Paal Harbour and Borge Bay are the major indentations on the east coast. A fault scarp extends beyond them to the north of the island. Part of Coronation Island can be seen in the background. (Photograph by courtesy of the M.O.D. (Navy).)

b. Air photograph of Stygian Cove and The Wallows, Signy Island, viewed from the north-east; Berry Head is in the foreground and Robin Peak is at the extreme right of the photograph. Note the coastal lowland to the left of Berry Head and the pronounced fault scarp forming the sheer cliffs beneath Robin Peak. (Photograph by courtesy of the M.O.D. (Navy).)

c. Air photograph of the Gneiss Hills, Signy Island, viewed from the south-west. Porteous Point with the long narrow bay of Cummings Cove behind it is in the foreground. (Photograph by courtesy of the M.O.D. (Navy).)

a

b

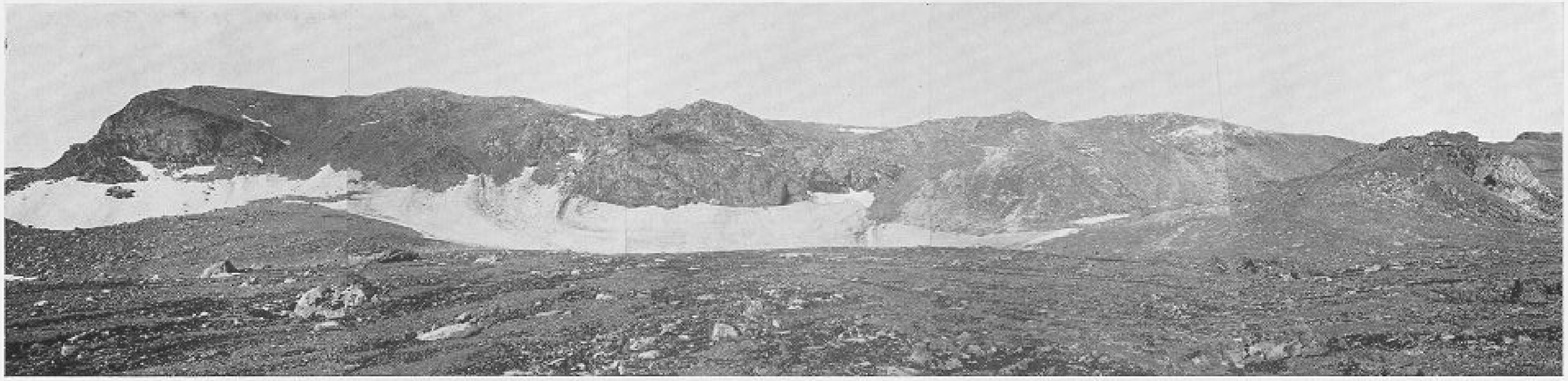
c

PLATE II

a. Part of north-eastern Signy Island viewed from the vicinity of the original Falkland Islands Dependencies Survey station hut. Amphibolites are the commonest rock type at the summit of Jane Peak (left), whereas quartz-mica-schists form the cliffs (a fault scarp) beneath Robin Peak (right). Borge Bay is in the foreground.

b. Panorama of the south and east walls of the amphitheatre east of Cummings Cove. The geological interpretation of this area has been given by Matthews and Maling (1967, pl. IIIb).

a



b

PLATE II

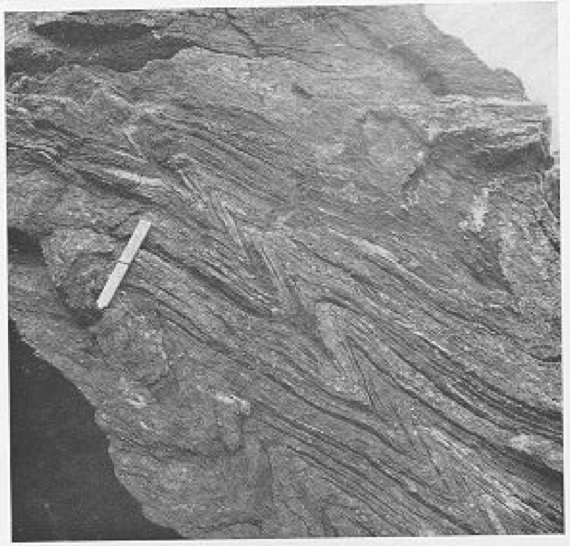
PLATE III

a. Small chevron-type folds in garnetiferous quartz-mica-schist at Berntsen Point, viewed normal to the fold axes.

b. Elongated ridges of marble on the coastal lowland west of Borge Bay, viewed from the ice cap south-east of Jane Peak. Berntsen Point is on the right behind the boulder-strewn entrance to Elephant Flats, and part of Coronation Island is in the background.

c. Minor folds in marbles interbedded with amphibolites. The outcrop is at the head of the valley between Snow Hill and Jane Peak.

d. Moe Island and Porteous Point viewed from the hill south of Port Jebsen.



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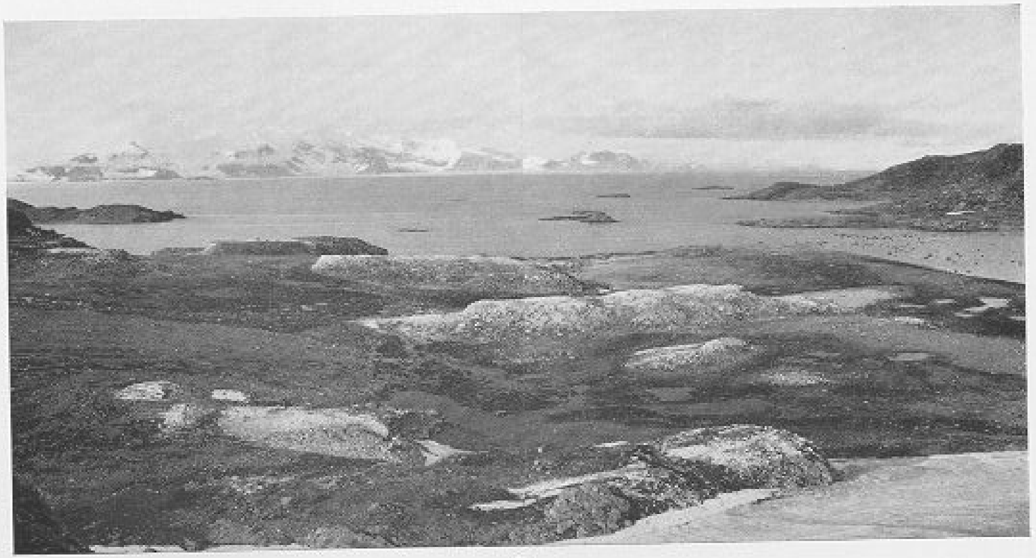

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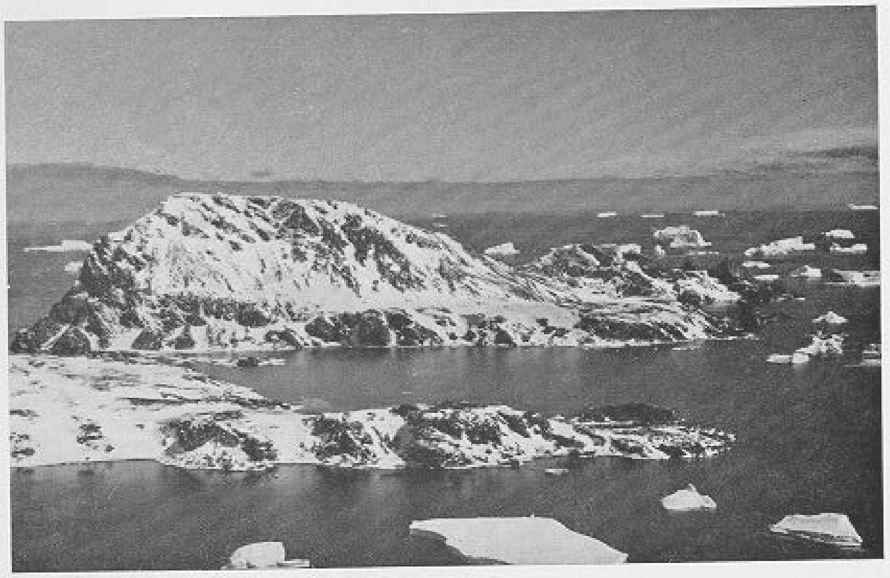

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PLATE III

PLATE IV

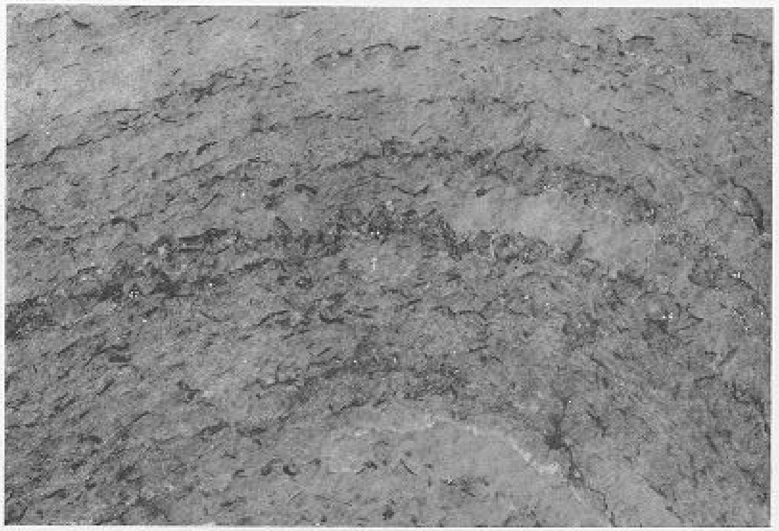
a. A gentle flexure in a micaceous quartzite. The folding is emphasized by the micaceous laminae; south-western Signy Island (H.230.1; ×2·2).

b. A quartz-mica-schist showing marked mineral banding in the hand specimen; south-west Signy Island (H.227.1; ×5).

c. Albite porphyroblasts and quartz segregations flattened parallel to the mineral banding of a mica-garnet-schist; Lenton Point, Signy Island (H.178.1; ×4).

d. Small-scale irregular folds in a quartz-mica-schist. Note the change in style of the fold throughout the length of the axial plane; south-western Signy Island (H.230.2; ×1·2).

PLATE IV



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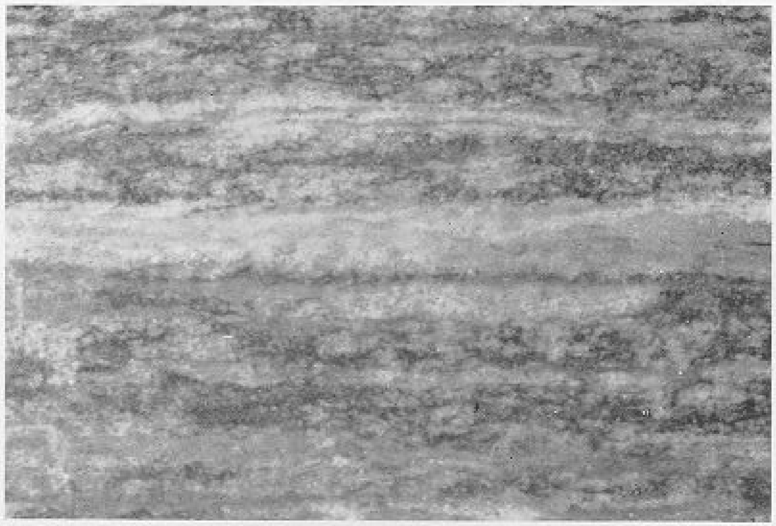

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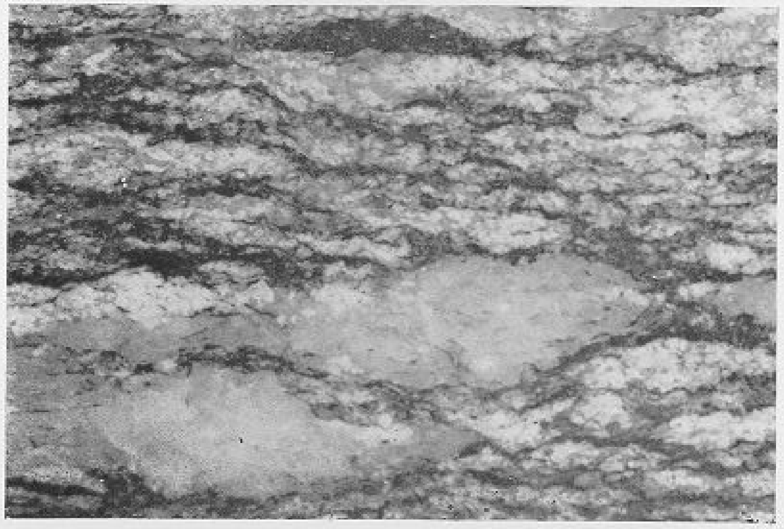

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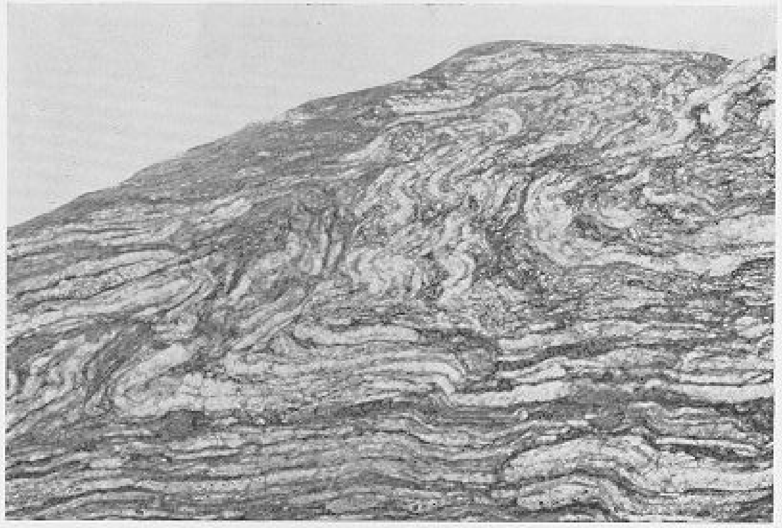


d

PLATE VI

a. A micaceous quartzite; Drying Point, Signy Island (H.115.1; X-nicols; ×16·7).

b. Poikiloblastic plagioclase exhibiting albite twinning and including rounded and polyhedral grains of epidote, iron ore and quartz; epidote-chlorite-biotite-schist; Gneiss Hills, Signy Island (H.1401.1; X-nicols; ×20).

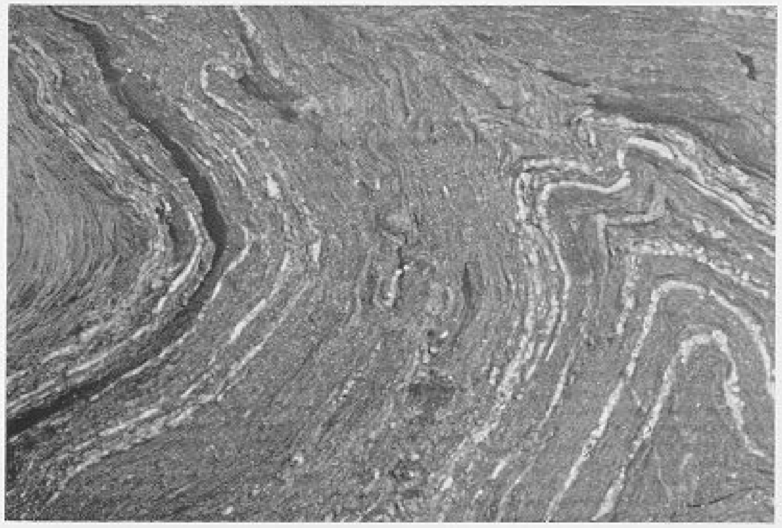
c. Mimetic crystallization of hornblende around the crest of a micro-fold in a hornblende-schist; south-western Signy Island (H.1381.1; X-nicols; ×30).

d. Mimetic crystallization of mica around the crests of micro-folds in a mica-garnet-schist; south-western Signy Island (H.1382.1; X-nicols; ×16·7).

e. Crystals of epidote forming a granular segregation in an epidotic schist; south of the Gneiss Hills, Signy Island (H.388.1; ordinary light; ×30).

f. A zoned tourmaline crystal from the vein-like band in an epidote-schist (Plate Vb); Gneiss Hills, Signy Island (H.537.1; ordinary light; ×45).

PLATE V



a

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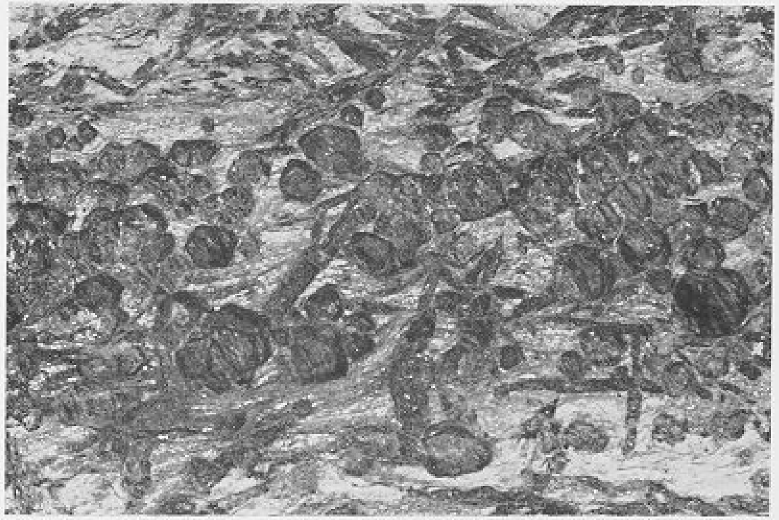

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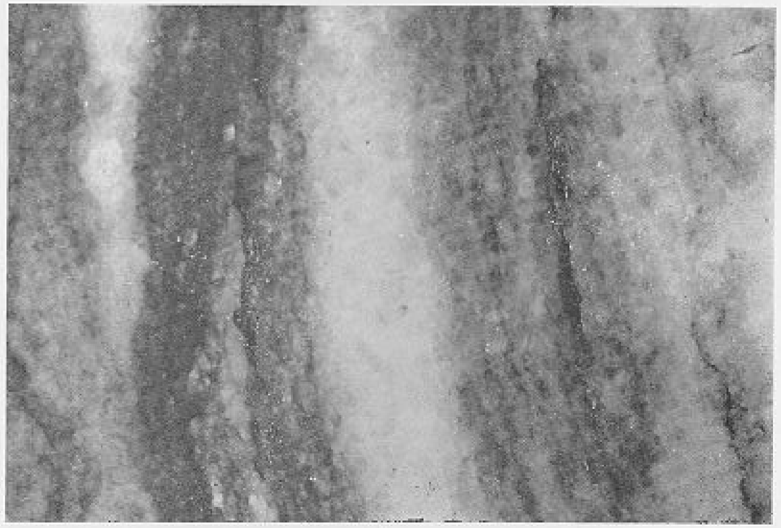

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PLATE V

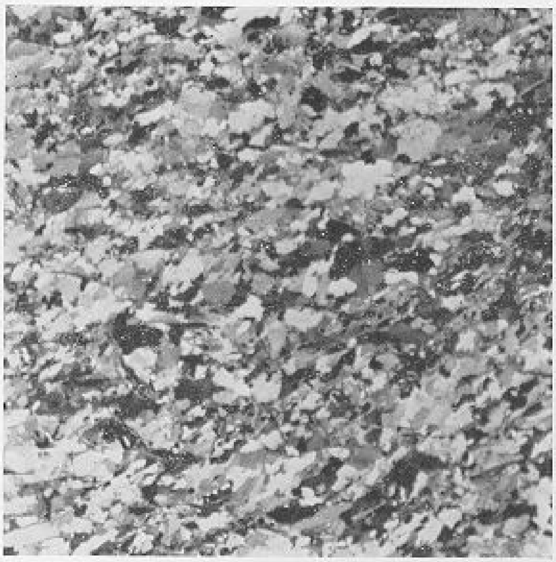
a. Irregular small-scale chevron folds in a greenschist; Jebsen Point, Signy Island (H.1140.1; ×1·2).

b. Prominent epidotic segregations (grey) in an epidote-schist. Tourmaline (black) occurs either as a discontinuous band or as small scattered crystals (bottom left). The dark grey streaks are chlorite associated with hornblende; Gneiss Hills, Signy Island (H.537.1; ×2).

c. *Hornblendegarbenschiefer*; Signy Island (H.542.1; ×1).

d. A banded marble; valley between Jane Peak and Snow Hill, Signy Island (H.100.3; ×2·9).

PLATE VI



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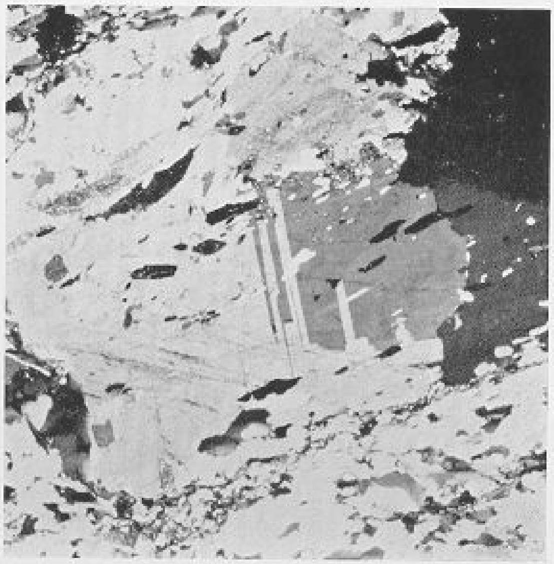

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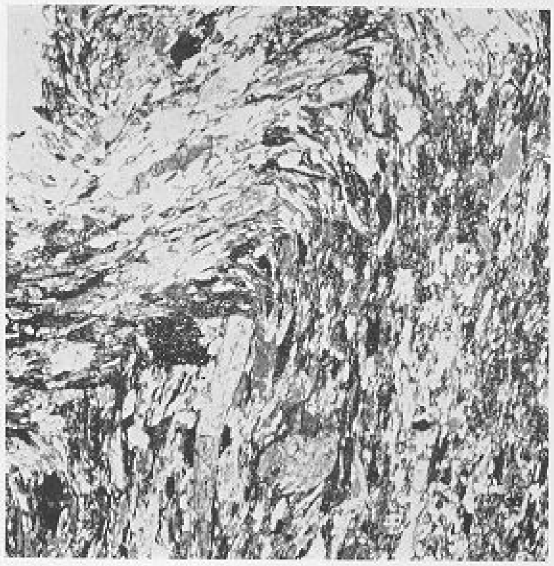

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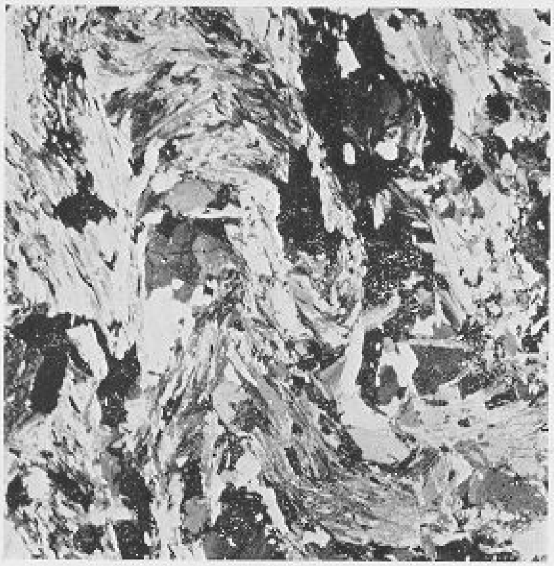

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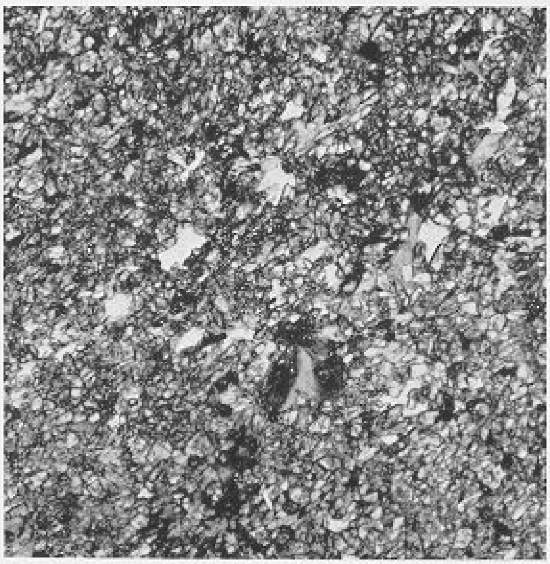


e

f

PLATE VII

a. Calcite crystals in a banded marble showing well-defined twin lamellae; valley between Jane Peak and Snow Hill, Signy Island (H.100.3; X-nicols; ×10·7).

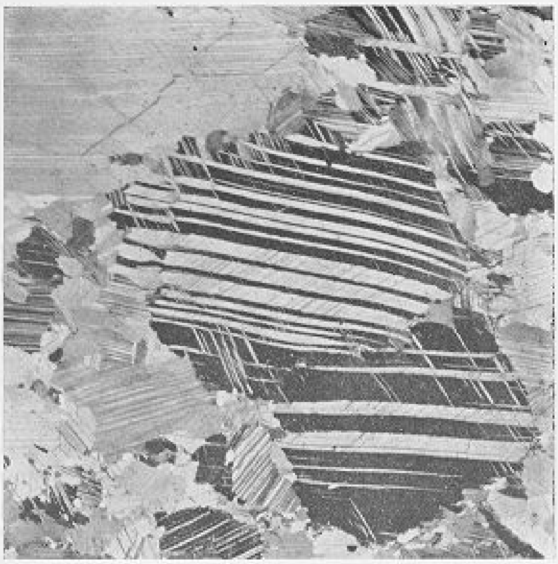
b. A discontinuous band of clinozoisite in an impure marble; valley between Jane Peak and Snow Hill, Signy Island (H.206.1; X-nicols; ×20).

c. Enlargement of part of the clinozoisite band shown in Plate VIIb (H.206.1; X-nicols; ×47).

d. A typical garnet porphyroblast in a *hornblendegarbenschiefer*. Note its irregular shape and the helicitic form of the included material; col between Robin Peak and Jane Peak, Signy Island (H.1125.1; X-nicols; ×8).

e. Muscovite flakes in a mica-garnet-schist which have been relatively undisturbed by the growth of garnet porphyroblasts; north-eastern Moe Island (H.1351B.1; X-nicols; ×25).

f. Lepidoblastic hornblende in a fine-grained hornblende-schist which has been pushed aside by the growth of a large garnet porphyroblast; south-east of Thulla Point, Signy Island (H.181.4; X-nicols; ×6·7).



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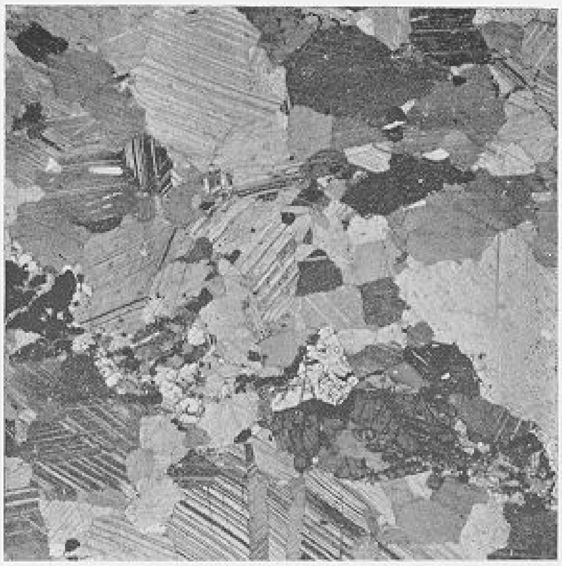

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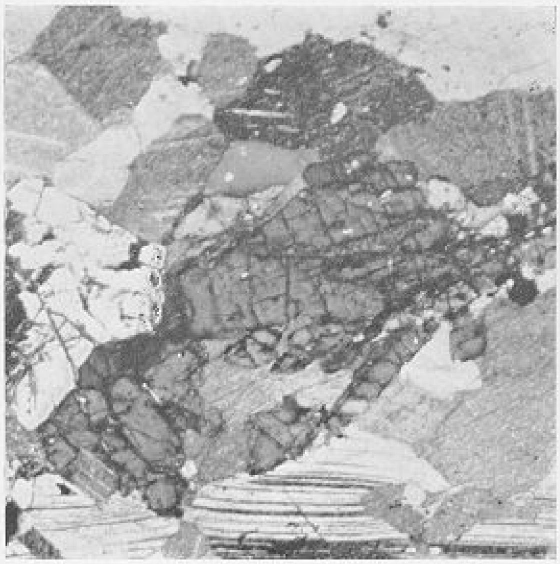

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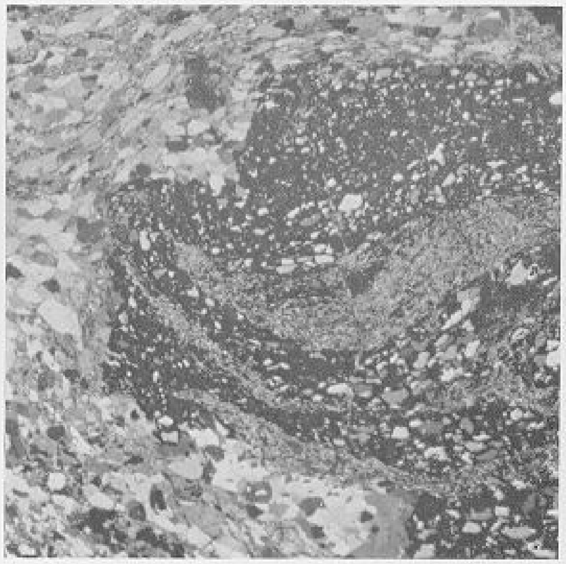

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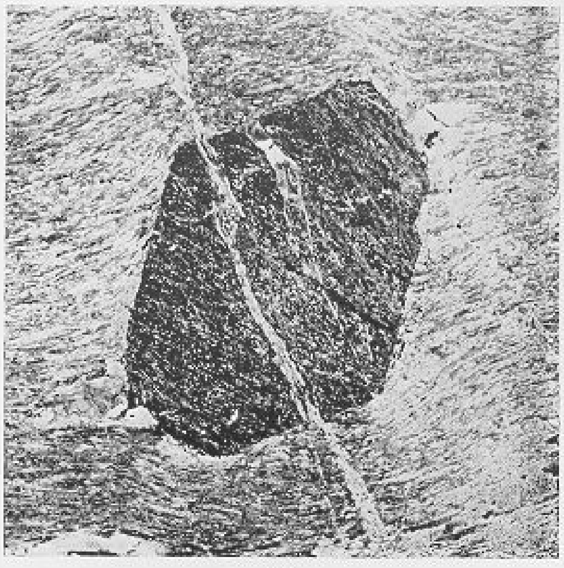

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