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THE PETROLOGY OF GRAHAM LAND

I. THE BASEMENT COMPLEX; EARLY PALAEOZOIC PLUTONIC AND VOLCANIC ROCKS

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ABSTRACT

THE Basement Complex, which has been assigned to the Archean, was first discovered by the British Graham Land Expedition, 1934–7, in the Neny Fjord area, south-west Graham Land. Field work carried out by the Falkland Islands Dependencies Survey during 1947 to 1950 has shown that the Basement Complex has a wider northward and southward lateral extent, but so far no outcrops have been discovered in north-east Graham Land or on the east coast. As a result of petrographic investigations it is now possible to subdivide the Basement Complex into eleven types, which, with the aid of field evidence, have been placed in a stratigraphic order. Problems concerning the occurrence of xenoliths in the early Tertiary intrusives and associated assimilation phenomena are discussed in relation to the Basement Complex stratigraphy.

Two granitic plutonic types, which also occur as large xenoliths in the Jurassic andesitic volcanics, have been shown to be earlier than the Jurassic by detailed field observations. In view of their close field relationship they are possibly contemporaneous and have been tentatively placed in the early Palaeozoic. Petrographically identical glacial erratics have been recorded from north-east Graham Land, where they occur as blocks "perched" on top of the James Ross Island Volcanics about 1500 feet above the present level of the ice shelf. So far no outcrops, apart from those described from the Neny Fjord–Black Thumb Mountain area of the Fallières Coast, have been discovered.

On the basis of the occurrence of petrographically identical xenoliths in the early Palaeozoic plutonics of the Black Thumb Mountain area and their more altered and sheared state than the Jurassic andesites, the intermediate volcanic rocks of Alexander I Land and Pourquoi Pas Island are assumed to be pre-Jurassic in age and are accordingly assigned to a pre-plutonics stage of the early Palaeozoic. At Pourquoi Pas Island there is an erosional break between the older volcanics and those belonging to the Jurassic succession.

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CONTENTS

INTRODUCTION

THIS is the first of a series of five reports under the general title of "The Petrology of Graham Land", in which it is hoped to give a comprehensive account of all the accumulated field observations of the Falkland Islands Dependencies Survey in Graham Land since 1946 and laboratory work carried out in the Mineralogy and Petrology Department, University of Cambridge, during 1950–3.

The forthcoming reports will be entitled:

II. The Andean Granite—Gabbro Intrusive Suite.

III. Metamorphic Rocks of the Trinity Peninsula Series.

IV. The Jurassic Volcanics.

V. The James Ross Island Volcanics (with an appendix on zeolites).

In due course, a complete revision of the stratigraphy of Graham Land, embodying both petrological and palaeontological data up to 1952, will appear under the title of "The Geological History of Graham Land".

Up to the present time, J. Gunnar Andersson's (1906) paper "On the Geology of Graham Land" has been the only comprehensive study of the stratigraphy of north-eastern Graham Land, whereas the works by T. F. W. Barth and P. Holmsen (1939), T. F. W. Barth (1940), G. Bodman (1916), E. Gourdon (1905, 1906, 1907, 1908, 1917 and 1919), P. H. Knowles (1945), D. Stewart (1934a and b, 1937, 1945, 1947 and 1951), and G. W. Tyrrell (1945) have been the only significant contributions to the petrology of Graham Land.

Although there has been a great deal of active research in the field of Antarctic petrology in the past, there has been a distinct paucity of material and field observations which has hampered research workers considerably. Nearly all previous petrographic investigation of the Graham Land area has been based on glacial erratics and fragments dredged from the sea-bottom. In the course of extensive field work undertaken by the Falkland Islands Dependencies Survey during the years 1946 to 1952 the greater part of the

Graham Land peninsula has been traversed and geologically examined. Many tons of rock specimens have been systematically collected from widespread localities, and it is upon this collection that the present series of reports is based.

The Basement Complex, originally discovered by the British Graham Land Expedition, 1934–7, in the Neny Fjord area of Marguerite Bay, and the early Palaeozoic plutonics and volcanics are described for the first time in this report.

The numbers given in the text in brackets, e.g. (E.113.1), refer to the official Station Lists of the Falkland Islands Dependencies Survey. The thin sections are housed in the Harker Collection, Mineralogy and Petrology Department, University of Cambridge.

The place names used in this paper will be found listed in the appendix together with the appropriate geographical positions. Those names given between inverted commas are not yet official, but it is expected that they will be accepted. The series of topographical maps on scales of 1/100,000, 1/200,000 and 1/500,000 are described in the Falkland Islands Dependencies Survey Scientific Report No. 1.

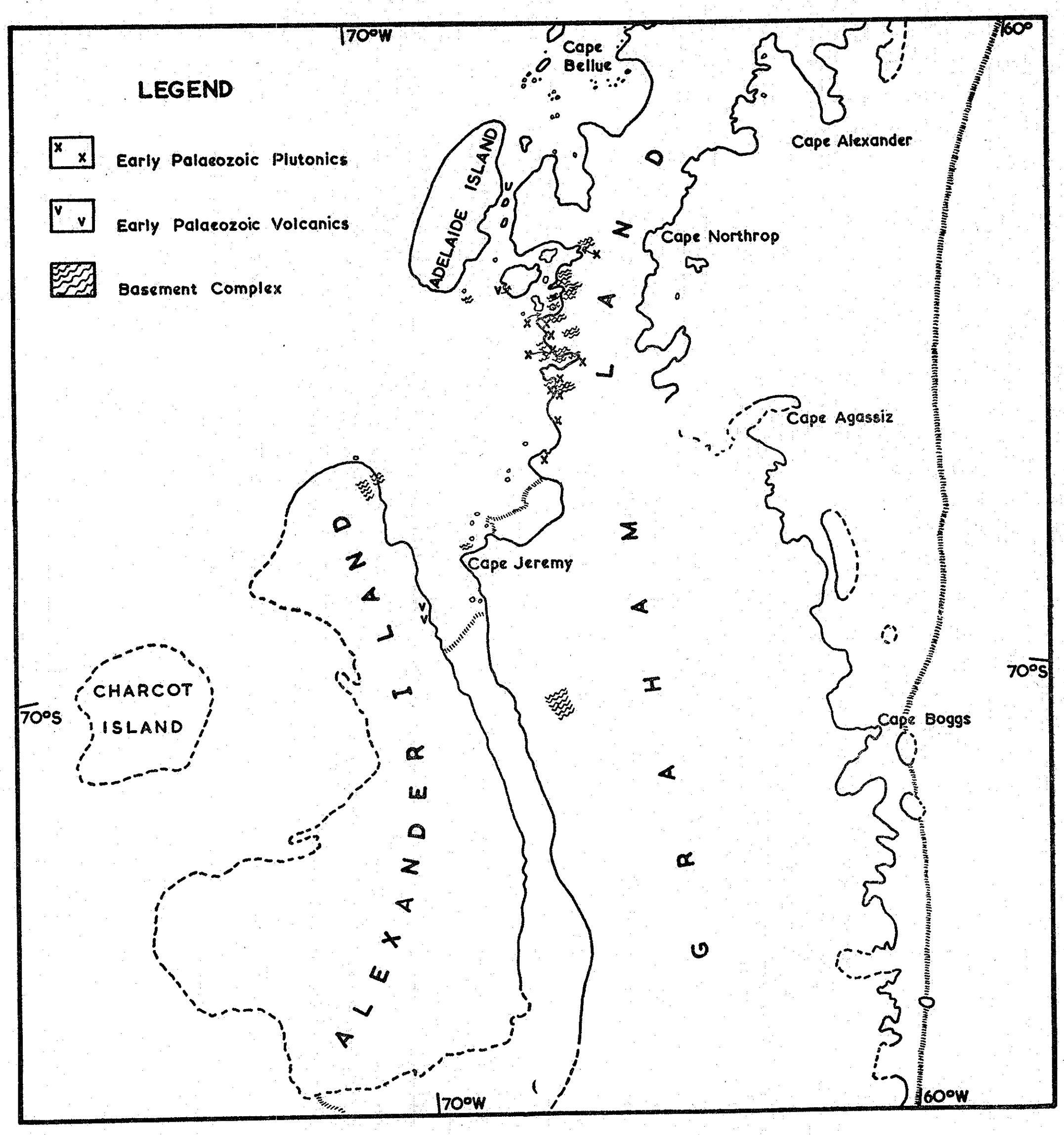

FIGURE 1

Sketch map of south-western Graham Land showing the distribution of the Basement Complex, early Palaeozoic plutonics and volcanics.

A. THE BASEMENT COMPLEX

UP to the present the Basement Complex has been found to be restricted to the Fallières Coast of south-western Graham Land. Outcrops of the Basement Complex have been recorded in the Batterbee Mountains, on the most western of the "Mica Islets" north of Cape Jeremy and in debris derived from the isolated nunataks protruding from the ice-piedmont of north-eastern Alexander I Land. Most is known about the distribution of the Basement Complex in the Bourgeois Fjord–Bigourdan Fjord, Millerand Island–Debenham Islands, Neny Fjord and Black Thumb Mountain areas (Fig. 1). Both the hornblende-schist and basic xenoliths so commonly found in the Andean intrusives of the south-eastern coast of Graham Land and the "Longridge Head" diorite intrusion should not be neglected and are included here.

Since there is relatively little continuity between the outcrops throughout this area, due to the heavily dissected and glaciated nature of the country, it has been difficult to determine an accurate stratigraphic succession in the Basement Complex. In a number of cases it has been necessary to infer age relations from field data such as order of intrusion and xenoliths in the gneisses.

The Basement Complex, which is intensely foliated as a result of one or perhaps two periods of regional metamorphism, comprises various types of gneisses, hornblende- and other schists, and amphibolites. Although the majority of the metamorphics are orthogneisses, some are undoubtedly paragneisses, such as those of "Edisto Rock". The hornblende-schists are probably metamorphosed basic volcanics and associated dykes, whereas the quartz-muscovite-schists of north-eastern Alexander I Land were originally areno-argillaceous sediments.

In this area no more than 3000 feet of the Basement Complex metamorphics are exposed. Without doubt many thousands of feet of the Basement were eroded away in pre-Jurassic times, leaving a sub-mature topography with broad valleys, which have been subsequently filled by Jurassic andesitic lavas and agglomerates. Such infilled valleys have been observed on Millerand and Pourquoi Pas Islands.

Basement Complex inclusions of all the metamorphic types already mentioned have been found widely scattered in the majority of the later volcanics and intrusives. For instance, the Jurassic andesites of the Pourquoi Pas Island and Black Thumb areas contain an abundance of hornblende- and granite-gneiss inclusions, some of which are many cubic feet in size. Hornblende-biotite-gneiss xenoliths have also been observed in the rhyodacites and rhyolites of Mushroom Island and the Batterbee Mountains. The metamorphic xenoliths in the Andean intrusives seem to be confined to amphibolitic and hornblende-schist types, except in the Black Thumb area where large masses of the gneisses have been incorporated by the Red Rock Ridge granite along the contact zone. Complete assimilation of these xenoliths by later intrusives is seldom noticed.

Although the foliation in the schists and gneisses of the Basement Complex varies widely over the Fallières Coast, there is a regional north-east to south-west strike. The anomalous foliation directions are in almost every case local and due to nearby intrusions of Andean type.

Ptygmatic folding in the gneisses is particularly common in the Millerand Island area, where the granite-gneisses are most abundant. *Lit-par-lit* injection is unusual though it has been observed in the Black Thumb area and at Millerand Island.

From the field data the following succession has been established for the Basement Complex of the Fallières Coast:

Pink granite-gneiss		*Younger* ↑
Garnetiferous granite-gneiss		
Biotite-granite-gneiss		
Biotite-gneiss	Quartz-biotite-gneiss	
Hornblende-biotite-gneiss		
Hornblende-gneiss		
Hornblende-schist	Quartz-muscovite-schist	
Amphibolite	Garnet-mica-schist	*Older*

Hornblende-schists and gneisses which can be matched exactly with those of the Fallières Coast have been found as glacial erratics in north-eastern Graham Land, James Ross Island and the Seal Nunataks.

Though the Basement Complex has not yet been recorded anywhere on the east coast of Graham Land, there is little doubt that it is present in some locality not yet examined. The glacial erratics must have been carried some considerable distance northward at a time when the ice shelf was about 1500 feet higher than at present, because at the Seal Nunataks blocks up to 30 cubic feet in size have been found perched on top of the James Ross Island Volcanics at 1500 feet above the present-day ice shelf level.

The age of the metamorphics assigned to the Basement Complex cannot be stated with certainty. They may belong to the early Palaeozoic but are more probably Archean like the Basement Complexes of South America and South Africa.

1. Garnet-mica-schists

Garnet-mica-schists, interstratified with quartz-muscovite-schists, occur on the most western of the "Mica Islets" about five miles north-east of Cape Jeremy (E.165). These schists are intensely foliated, the schistosity dipping at 65° to the east-south-east. Where shearing has taken place in the schists chloritic zones are developed. Coarse pegmatites with large muscovite segregations accompanied by a little almandine garnet intrude the schists parallel to the foliation strike.

The garnet-mica-schists are medium-grained containing both muscovite and biotite in addition to almandine garnet. The plagioclase is andesine and there is a little interstitial quartz. A large proportion of the biotite has been altered to a bright green chlorite which shows brilliant anomalous purple interference colours.

The quartz-muscovite-schists are petrographically very similar to those found in north-eastern Alexander I Land, being composed of alternating muscovite and quartz bands. They contain no garnet.

These schists are quite distinct from the Trinity Peninsula Series cataclastic metamorphics of the East Russell Glacier area, in that they show no false cleavage or superposed puckering in the muscovite bands.

2. Quartz-muscovite-schists

Although they have not been found *in situ* in north-eastern Alexander I Land, quartz-muscovite-schists have been recovered from the glacial detritus in the ice-cliffs (E.209) and are probably derived from the isolated nunataks on the ice-piedmont to the west.

In thin section these quartz-muscovite-schists are intensely and minutely foliated (Plate IIa), comprising alternating quartzose and muscovite bands. All the quartz grains are elongated in the approximate ratio of three to one and show undulating extinction. In the micaceous bands the muscovites are quite considerably bent and are accompanied by a little epidote and sphene. Idioblastic pale pink almandine garnets are found growing in the muscovite bands and here the muscovite has been bent around them. In the crests of folds secondary calcite frequently occurs in the quartzose bands. There is also a little accessory magnetite. Though rare, plagioclase is present as small lamellar twinned albite crystals in the quartz mosaic. Orthoclase, on the other hand, is fairly common and slightly altered. Chlorite, probably secondary in origin, forms thin wisps throughout the muscovite bands.

Although it is not easy to distinguish between high grade regionally metamorphosed intermediate igneous rocks and impure arenaceous sediments, it is more probable that the quartz-muscovite-schists represented here were originally arenaceous sediments with some degree of argillaceous impurity. In this way they are similar in origin to those of the most western of the "Mica Islets" (E.165).

3. Amphibolites

Non-schistose amphibolites which are almost monomineralic occur only in the Black Thumb–Neny Fjord area of the Fallières Coast. The main localities where the amphibolites have been recorded are the valley north of Black Thumb, "Pyrox Islet" at the head of Neny Fjord and the headland east of it, the north side of Neny Island and "North Star Islet" to the west of Neny Island.

These amphibolites are quite distinct from the hornblende-schists and are readily distinguishable in the field. They are seldom found as xenoliths in the Andean intrusives or the "Coarse Pink Granite", except, of course, where there is a direct field relationship as at Black Thumb and on "Pyrox Islet" at the head of Neny Fjord.

Of the Basement Complex amphibolite occurrences perhaps the best known is that of the Black Thumb area (E.125), where their relationship to other stratigraphic units of the Basement Complex is well known.

In thin section the Black Thumb amphibolites are coarse-grained and have a granoblastic texture. They are composed mainly of a coarse intergrowth of hornblende with a pleochroism scheme: α=straw, β=green-brown, γ=blue-green. The extinction angle, γ:z, is 18° and the 2V=65°. A few remnants of a colourless augite are often found enclosed in the larger hornblendes. Sometimes small interstitial augites are marginally altered to a pale green actinolite, which is quite distinctly secondary. There is a little accessory magnetite and secondary chlorite. Plagioclase is always absent.

At Black Thumb, where the "Coarse Pink Granite" invades the amphibolites there is quite a considerable amount of hybridisation along the contact. The resultant hybrid may be described as a hornblende-biotite-granite, which, apart from the introduction of hornblende, retains all the original characteristic features of the granite, such as coarse granitic texture, perthite and quartz. Along these contacts there are no signs of injection breccias or shearing, though small scale faulting has been observed. Seldom are large amphibolite xenoliths found within the "Coarse Pink Granites".

The contact between the Red Rock Ridge granite and the Basement Complex amphibolites is quite different. On "Pyrox Islet" at the head of Neny Fjord (E.405–7), where the contact may be followed for some distance, it is always in the form of a 10 to 20 ft. shatter band. Large irregularly-shaped blocks have been torn from the amphibolites and are incorporated by the red granite. The contacts between the granite and the amphibolite xenoliths are quite discrete and there are no signs of contamination of the granite by assimilation of the amphibolite. However, along these contacts the Red Rock Ridge granite is finer-grained for a distance of not more than a centimetre. It nevertheless retains its typical myrmekitic texture.

The contact between the biotite-gneisses and the amphibolites at Black Thumb is often difficult to define clearly, because there has been large-scale contamination. Along this contact there is a gradual transition from pure amphibolite to biotite-gneiss with a gradation from coarse- to medium- and fine-grained hybrid phases. From the field relations it seems clear that the biotite-gneisses are later than the amphibolites which they have invaded.

The metamorphics of "North Star Islet" (E.53) may be likened to the hornblendic hybrid granites of the "Coarse Pink Granite"/amphibolite contact at Black Thumb. Biotite, which is common in the Black Thumb contact rocks, is almost entirely altered to a pale chlorite at "North Star Islet".

Unlike the hornblende-schists, which are always much finer-grained and possess quite a large proportion of plagioclase, the amphibolites are undoubtedly of a different origin. They are probably the regionally metamorphosed equivalents of ultra-basic igneous rocks of the pyroxenite type. Though the greater part of the hornblende has formed from pyroxene as a result of regional metamorphism, it is possible that some formed at a late magmatic stage prior to metamorphism. The pale green actinolite replacing pyroxene remnants is undoubtedly a post-metamorphic product.

4a. Hornblende-schist Xenoliths of the East Coast Diorites

(i) *Hornblende-schist Xenoliths*

Widely scattered throughout the intrusive diorite of the Graham Land east coast, especially in the vicinity of its contact with the Trinity Peninsula Series, there are many elongated hornblende-schist xenoliths. Some of these xenoliths appear to be arranged in linear fashion and though partially assimilated in places by the diorites, they extend laterally for some hundreds of yards. Completely isolated xenoliths are also very commonly found.

Under the microscope these rocks, typified by E.29.6, E.29.1 and E.29.10, are true hornblende-schists with definite parallelism of the amphiboles. They are fine- to medium-grained. The hornblende, forming at least 65% of the rock, has a pleochroism α=pale straw, β=bluish-green and γ=emerald green. The extinction angle, γ:z, is 30° and the 2V approximately 80°. Small biotite flakes which frequently have the same cleavage orientation commonly occur as inclusions in the hornblendes.

A pale green non-pleochroic diopsidic augite also appears in aggregates of small equidimensional idioblasts, which are replaced occasionally by a secondary actinolitic amphibole with pleochroism in pale green-blue shades and a small extinction angle. It would therefore appear that the idiomorphic amphibole has been wholly derived from pyroxene, whereas the diopsidic augite has formed due to excess of lime.

Zoned plagioclase felspar with abundant occluded apatite needles and a composition approximating to $Ab_{60}An_{40}$ is interstitial to the hornblende. A good deal of sphene in well-formed idiomorphs is present together with the accessory zircon and iron ores.

These schists could well be called "plagioclase-amphibolites with diopside" and likened to those of the Lizard, Cornwall (Harker, 1939, p. 282). They are probably the metamorphic equivalents of calc-rich basic igneous rocks and *not* the Trinity Peninsula Series sediments.

(ii) *Hornblende-schist* (*marginal phase*)

The marginal phase of the hornblende-schist xenoliths (E.29.1 and E.29.10) is a medium-grained, almost monomineralic rock with a marked decussate texture (Fig. 2). The amphibole here is a common green hornblende with optics similar to those given above.

In some specimens the hornblende is intergrown with an abundance of brown biotite, which is invariably orientated with its elongation parallel to the contact with the diorites. Interstitially, a little intermediate plagioclase felspar and quartz are present together with rare accessory sphene and apatite. This marginal phase extends no further than 2–3 mms. from the contact and passes gradually into the normal hornblende-schist with diopsidic augite and abundant sphene.

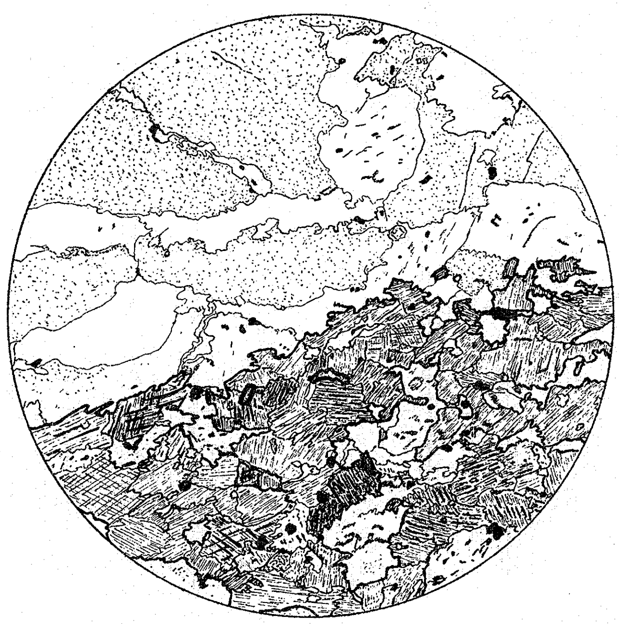

FIGURE 2

Quartz-diorite/hornblende-schist xenolith contact (×30), showing the ferro-magnesian-free margin of the quartz-diorite composed mostly of quartz and plagioclase (E.29.1).

Along the contact with the hornblende-schist xenoliths there is a noticeable absence of ferro-magnesian minerals in the diorites (Fig. 2). Rare biotites with γ=foxy red-brown colour are all orientated parallel to the contact. It would appear that in such a contact there is migration of the ferro-magnesian minerals towards the xenolith itself. The diorite, however, still retains its characteristically zoned plagioclases with a little quartz and orthoclase, accessory apatite and zircon. The orthoclase is usually clouded with degradation products.

Comparison of these schistose xenoliths with the gabbros found further south in this area shows the two rocks are mineralogically very similar, especially in the fact that sphene is so abundant. However, the plagioclase composition is less basic than in the gabbros.

The type of metamorphism observed in these xenoliths is not only thermal but with a relatively high degree of stress, such as may be regarded as being associated with medium to high grade regional metamorphism. In the highest grades of regional metamorphism pyroxene would inevitably replace the amphibole completely. During incorporation by the diorite a certain amount of assimilation would also have occurred, but neither of these facts have been recorded in the material examined.

It is considered that these xenoliths are not derived from the earlier gabbros or hornblendites of the Andean intrusive series but are related in age to the amphibolites of the Black Thumb–Neny Fjord area. The Black Thumb amphibolites are essentially monomineralic and appear to be the metamorphic derivatives of Archean pyroxenites, which are known to have been subjected to at least one phase of regional metamorphism.

The early Tertiary Andean gabbros have never been found in a regionally metamorphosed state, a point which strongly favours the suggestion that the hornblendic xenoliths are considerably older (Archean in age) and have been plucked from the Basement Complex by the much later diorites.

(iii) *Quartz-diorite* (*marginal phase*)

The quartz-diorites are discussed at some length in a later report (The Petrology of Graham Land: II. The Andean Granite–Gabbro Intrusive Suite), but in view of their close field relationship with the hornblende-schist xenoliths, especially on the Graham Land east and west coasts, it is considered necessary that a brief summary be included here.

Although marginally their grain-size is in no way markedly diminished, there is a tendency towards the formation of quartz-plagioclase myrmekitic intergrowths in the quartz-diorites. This becomes especially apparent where ferro-magnesian minerals such as hornblende and biotite are adjacent. Quartz also forms lenticular segregations marginal to the contact, where accessory zircon and sphene occur in small amounts.

TABLE I

MODAL ANALYSES OF QUARTZ-DIORITES NEAR CONTACTS WITH HORNBLENDE-SCHIST XENOLITHS

	E.29.1A	E.29.1B
Quartz	11.7	20.9
Plagioclase	46.8	57.2
Hornblende	21.5	16.0
Biotite	19.1	5.2
Sphene	0.5	0.2
Iron ore	0.1	0.1
Apatite	0.2	0.2
Chlorite	0.1	0.2
	100.0	100.0
Total ferro-magnesians %	41.5	21.9
Plagioclase composition	$Ab_{65}An_{35}$	$Ab_{65}An_{35}$

E.29.1A: More than 2 in. from the quartz-diorite/hornblende-schist contact.
E.29.1B: Within 2 in. of the quartz-diorite/hornblende-schist xenolith contact.

The mineralogy of the quartz-diorite in its contact with the hornblende-schist xenoliths is shown in Table I. From these modal analyses it is clear that the following changes have taken place:

(1) An increase in quartz and plagioclase, particularly as an intergranular myrmekitic intergrowth with plagioclase.

(2) A decrease in hornblende and biotite, especially the latter.

(3) A decrease in sphene.

The accessory and secondary mineral assemblages remain constant throughout the rock, chlorite usually replacing biotite.

Examination of a number of contacts between the quartz-diorite and hornblende-schist xenoliths shows that relatively little hornblende of the latter has been directly assimilated by the diorite.

4b. Hornblende-schist Xenoliths of the West Coast Diorites

At a small island north-west of the Debenham Islands (E.102), at the western end of Cape Calmette and at "Longridge Head" on the east coast of Laubeuf Fjord, hornblende-schist xenoliths similar to those of the Graham Land east coast have been observed in the quartz-diorites. In each case the mineralogy of the xenoliths is the same as that already described for those of the east coast. However, at Station E.102 there are some significant differences which are considered worth recording.

These xenoliths, which are medium-grained and have an intergranular texture (Plate IIb), possess a far higher modal percentage of biotite amounting to about 20%. The biotite, with α=deep straw and $\beta=\gamma=$ nigger-brown, occurs in large flakes and is partially altered to a deep green chlorite. The hornblende, similar to that of the east coast xenoliths, is usually well-twinned and in beautiful idioblasts. Both the andesine and orthoclase are altered and the quartz shows strain shadows. There is a little accessory zircon and magnetite.

The hornblende-schists included in the biotite-gneisses of the north coast of Millerand Island (E.119) are strictly comparable with those of the east coast in that they too are fine- to medium-grained and possess a little biotite altered to chlorite. The hornblende, in well-defined idioblasts, is identical to that of the east coast xenoliths and shows marked parallelism (Plate IIIa). The plagioclase is a basic andesine of a very fresh appearance. Pyrites in well-formed cubes occurs as the accessory iron ore together with magnetite. Though not so common, diopside also makes an appearance as small idioblasts.

5. Hornblende-gneisses

In the Neny Fjord area extensive outcrops of hornblende-gneiss are seldom found. They are confined mainly to the north coast of Millerand Island, "Fitzroy Islet" (to the east of Stonington Island) and the north coast of Neny Island. The only other occurrence outside this area is on the southern coast of Square Bay. Two main types of hornblende-gneiss, characterised by their respective textures and appearance in the hand specimen, can be distinguished in the field. The gneisses of "Fitzroy Islet" and Neny Island are much coarser in texture than the hornblende-gneisses of Millerand Island.

Under the microscope the "Fitzroy Islet" hornblende-gneiss (E.36) is coarse-grained with an equigranular texture, the gneissose structure not being particularly marked. The hornblende, which sometimes exhibits sieve-structure, has a pleochroism scheme α=light brown, β=pale olive-green and γ=deep green. Its extinction angle, γ:z, is 19–26° and the 2V is about 60°. The majority of hornblende cross-sections show good twinning on (100). Chlorite with pleochroism α=straw, β=pale yellow-green and γ=grass-green, and showing brilliant purple anomalous interference colours, replaces most of the biotite, small remnants of which are still present in the chloritic clots. Fine intergrowths of magnetite and ilmenite form rims round the chlorites and are products of chloritisation. There is also a little secondary epidote in association with the hornblende and chlorite.

Orthoclase, dusted with fine sericite, forms a coarse intergrowth with altered oligoclase which possesses in almost every case a narrow rim of clear albite. Orthoclase is always in excess of plagioclase but there is about 20% of interstitial quartz. Apatite, zircon and magnetite are accessory.

These hornblende-gneisses are probably the regionally metamorphosed equivalents of intermediate igneous rocks and are unlike those of Millerand Island in their mode of origin. At Neny Island they are intruded by the biotite-granite-gneisses.

The hornblende-gneisses of northern Millerand Island (E.119) are much finer-grained than those already described from "Fitzroy Islet" and Neny Island, and contain small basic clots of almost completely digested hornblende-schist. They possess a very fine but marked gneissose structure which is almost vertical and strikes east-south-east. The fine-grained pink granite-gneisses which have the same foliation strike intrude them and contain xenoliths of the hornblende-gneisses.

In thin section the Millerand Island hornblende-gneiss is much finer-grained with a distinct intergranular texture. The hornblende, with pleochroism α= pale straw to green, β=yellow-green and γ=grass-green, an extinction angle, γ:z=23° and 2V=60°, forms small but beautifully idioblastic crystals with good lineation. The plagioclase has a composition approximating to $Ab_{56}An_{44}$ and is a little saussuritised. Orthoclase, cloudy with decomposition products, forms a matrix with the andesine and quartz showing strain shadows.

The small amount of biotite in the rock has almost completely been replaced by chlorite, which together with some epidote comprise the secondary minerals. Long, bladed apatites and small zircons are accessory with occasional iron ore. Some minute pyrites cubes have been observed. These are probably secondary.

These hornblende-gneisses are really hybrid rocks which occur as a 40–50 ft. wide contact between the biotite-gneisses and the true hornblende-schists of this area. The presence of partially assimilated hornblende-schist xenoliths within them is testimony to this explanation of their origin.

6. Hornblende-biotite-gneisses

The only localities where non-hybrid hornblende-biotite-gneisses have been mapped are a small island south-west of Cape Calmette and the north-eastern tip of Broken Island, Square Bay. They are identical both in the hand specimen and thin section.

Under the microscope the Cape Calmette gneiss (E.68) is medium- to fine-grained with a granoblastic texture. Hornblende and biotite comprise about 30% of the rock, occurring in approximately equal percentages. Whereas the hornblendes with pleochrosim in green-brown are perfectly idiomorphic, the biotites are generally ragged in outline and mostly altered to chlorite and iron ore. The plagioclase felspar shows signs of zoning and the more basic andesine cores are usually slightly sericitised, whereas the acid andesine rims are fresh. Quartz and orthoclase, the latter also sericitised, sometimes show delicate intergrowths in the matrix between the hornblende-biotite bands. Apatite, zircon and magnetite are the usual accessories. There is a little iron pyrites as minute cubes associated with the ferro-magnesians.

Both at Millerand Island and Black Thumb, hybrid hornblende-biotite-gneisses have been recorded, but they are not to be included here, because of their different mode of origin. The Cape Calmette gneisses are undoubtedly the result of the regional metamorphism of intermediate igneous rocks.

7. Biotite-gneisses

Of all the stratigraphic units of the Basement Complex the biotite-gneisses are by far the commonest both in their abundance and thickness in the Basement Complex succession. At Black Thumb they comprise nearly 2000 feet of the metamorphics. In Neny Fjord, occurrences have been recorded at "Mount Nemesis", the north coast of Neny Island and the north coast of Millerand Island. These gneisses extend northward from Camp Point into the Bourgeois Fjord area where numerous outcrops have been mapped in Dog's Leg Fjord, along the mainland coast east of Broken Island and on the east coast of Centre Island.

The type biotite-gneiss is that of the Black Thumb area (E.125), which is fine- to medium-grained and has a fine gneissic, almost schistose, structure (Plate IIc). It consists of a granoblastic intergrowth of small parallel orientated biotites (with deep straw—nigger-brown pleochroism), quartz, orthoclase and oligoclase. All the felspars are fresh and relatively free from dustiness. Rarely does hornblende occur in these gneisses, except along their contact with the amphibolites where there is often large-scale contamination. The field relations suggest intrusion of the amphibolites by the biotite-gneisses.

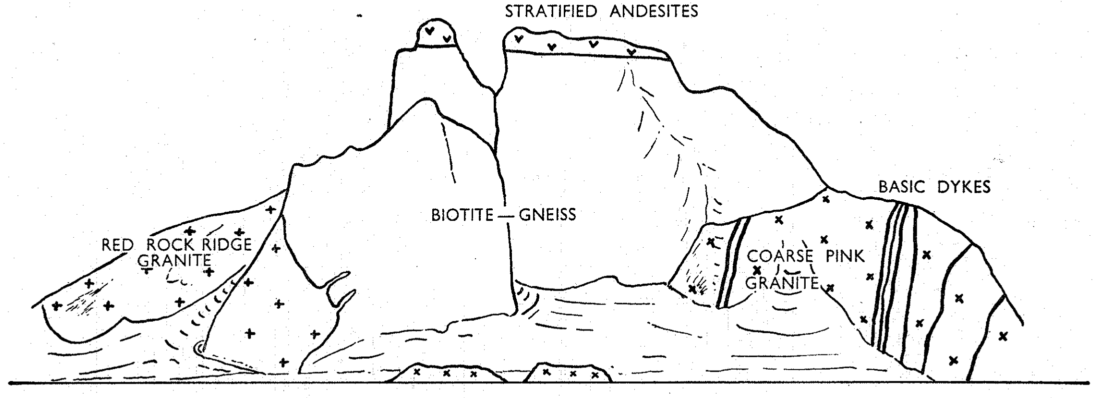

FIGURE 3

The Basement Complex biotite-gneisses of Black Thumb Mountain overlain by stratified andesites. The Red Rock Ridge granite (left) and the "Coarse Pink Granite" (right), the latter traversed by dykes, intrude the gneisses.

Although they closely resemble some of the psammitic types of the Moine Series of Inverness in thin section, the Black Thumb biotite-gneisses are igneous in origin. They appear to have been originally fairly fine-grained acid igneous rocks.

At Black Thumb (E.125, Fig. 3) the "Coarse Pink Granites" invade the biotite-gneisses. Though quite distinct in the field, this contact shows some degree of contamination where the biotite-gneiss has been incorporated by the "Coarse Pink Granite". Also, in the vicinity of the contact numerous clearly defined biotite-gneiss xenoliths occur within the granite.

In thin section the hybrid contact rock appears to be a biotite-granite-gneiss of a coarser texture than the biotite-gneiss itself. Perthitic felspars of the "Coarse Pink Granite" frequently have felted masses of minute biotite crystals moulded round them, and the fine gneissose structure of the original biotite-gneiss is replaced by a coarse granitic-gneiss texture. Quartz and orthoclase appear to be more abundant than in the biotite-gneiss, but accessory zircon and apatite are still present.

The biotite-gneiss of "Mount Nemesis" (E.37) is coarser in texture than that of the Black Thumb area and quite considerably altered, being identical to that of Millerand Island (E.119).

Under the microscope it is medium- to coarse-grained (Plate IId) and contains about 10% of biotite. The biotite is almost entirely altered to a brilliant green chlorite with pleochroism α=straw, β=pale green and γ=bright grass-green. A coarse granitic intergrowth of quartz, oligoclase-andesine and orthoclase comprises the matrix. Both plagioclase and orthoclase are altered and the very dusty quartz has an undulating extinction. Well-terminated zircons and apatites are accessory. Associated with the altered biotite there is a little clustered secondary epidote. Apart from magnetite there is considerable iron pyrites, most of which is altered to hematite and limonite.

The altered biotite-gneisses of the Neny Fjord area may be contemporaneous with those of Black Thumb, but there are several significant differences, the main one being that the former gneisses often possess a myrmekitic intergrowth of quartz and plagioclase. Their origin is possibly the same as the Black Thumb biotite-gneisses.

Similarly altered biotite-gneisses occur at the Debenham Islands where they include hornblende-schist xenoliths. Along the contact there is an intergrowth of biotite altered to chlorite and quartz with a little plagioclase. All these gneisses are sheared, which is probably due to the local intrusion of the "Coarse Pink Granite" into the Basement Complex.

8. Quartz-biotite-gneisses

Granulitic quartz-biotite-gneisses, which are possibly of a sedimentary origin, occur only at "Edisto Rock" (E.59b) to the west of Neny Island. They are fine-grained and exhibit a distinctive banded structure. The red-brown biotite is confined to thin bands separated by wide mosaics of quartz and orthoclase in which a little oligoclase-andesine is present. The orthoclase is mostly dusted with alteration products. Very rounded zircons and a brown tourmaline are accessories. Some narrow veins composed entirely of iron pyrites traverse the rock parallel to the gneissose structure. Occasionally a little of the biotite is altered to bright-green chlorite.

The presence of detrital zircon and tourmaline tends to support the conclusion that these are para-gneisses rather than ortho-gneisses. They were probably originally impure felspathic sandstones inter-bedded with purer quartzose bands which are quite prominent in the hand specimen. Some of the quartzose bands, up to six inches in width, are entirely composed of a fine mosaic of quartz and a little orthoclase dusted with minute magnetite grains. In these bands biotite is notably absent.

The field relations between the quartz-biotite-gneisses and the other members of the Basement Complex are obscure since their occurrence is isolated.

9. Biotite-granite-gneisses

Although they have been observed as inclusions in the Jurassic andesitic agglomerates of Pourquoi Pas Island and elsewhere, biotite-granite-gneisses are not common in the Marguerite Bay area. These gneisses are confined to the true pink granite-gneiss/biotite-gneiss contact zone of north-west and south-west Millerand Island (E.55 and E.119), where their occurrence is very limited. They may be classified as hybrid rocks resulting from the injection of the granite-gneisses. In the hand specimen biotitic schlieren mostly altered to chlorite traverse the rock parallel to the gneissic structure. There is a well-defined and regular transition from biotite-gneiss into granite-gneiss over a distance of about 30–40 feet. Complete migmatisation, in the sense that the rock has been entirely reconstituted, has not taken place, yet there are no signs of *lit-par-lit* injection as in the case of the hornblende-schist/biotite-gneiss contact. Ptygmatic folding of more granitic veins has been observed.

In thin section the biotite-granite-gneisses have a coarse gneissic texture. Highly sericitised orthoclase and altered oligoclase, the latter with pronounced bent albite twin lamellae, together with interstitial quartz (with undulating extinction) comprise the greater part of the rock. There is occasional antiperthite and small quartz blebs in the plagioclase are not unusual. Coarsely intergrown biotites, usually altered to a bright green chlorite and iron ore, comprise narrow schlieren running parallel to the gneissic foliation. Small secondary epidote veins traverse the gneiss and there is a little secondary calcite. Magnetite, zircon and apatite are accessory.

Where porphyritic trachytic andesite dykes intrude these gneisses there is a certain amount of shearing of the gneiss along the contact, though the margin of the dyke is sharply defined and tachylitic.

10. Garnetiferous Granite-gneisses

Granite-gneisses of the Basement Complex which have an appreciable almandine garnet content have been recorded at two localities on the Fallières Coast, namely, the "Garnet Rocks" (E.48), south-east of Red Rock Ridge, and the north-western coast of Dog's Leg Fjord (E.343), east of Ridge Island, Bourgeois Fjord.

The garnetiferous granite-gneisses of Dog's Leg Fjord are white in colour and fairly coarse-grained, comprising mostly orthoclase, plagioclase and quartz with a little accessory biotite, zircon and apatite. Beautiful small idioblastic almandine garnets are liberally scattered throughout the gneiss, which is often intruded by narrow pegmatitic dykes.

In thin section the garnetiferous granite-gneisses of the islets called "Garnet Rocks" are medium-grained and have a granoblastic texture. They are composed of granulitic intergrowths of saussuritised oligoclase and altered orthoclase with interstitial quartz. Delicate quartz mosaics give rise to small augen in the gneiss which is cut by later narrow quartz and pegmatite veins. Muscovite and chloritised biotite form narrow lenses in the felspar/quartz intergrowth and wrap themselves around the quartz augen parallel to the gneissic structure.

Clusters of small euhedral pink almandine garnets, which also form knots within the felspathic masses, are often marginal to the quartz mosaics but never occur in the later quartz veins. It is quite common to find a solitary perfectly euhedral garnet in the centre of a plagioclase crystal. Sometimes the garnets are closely associated with the altered biotite clots, but there is little indication of their derivation from the biotite. Occasional quartz inclusions appear in the almandine, but this is infrequent. Magnetite, zircon and apatite are accessory.

The garnet in these gneisses has probably been derived from biotite as a result of high grade regional metamorphism of the original granites. There is no doubt that these are ortho-gneisses.

An erratic specimen of an almandine-bearing microcline-granite, described by Bodman (1916, p. 3–4) from Seymour Island, is not necessarily related in age to the garnetiferous granite-gneisses described above, since the latter are not microcline-bearing. Bodman describes the microcline-granite as having a "cataclastic appearance and a blasto-granitic structure". He attributes the origin of the garnets to "pneumatolytic and dynamic metamorphism" and compares this granite to that described by Quensel (1912) from Tierra del Fuego. It is, however, interesting to note that in spite of Bodman's suggestion that the microcline-granite had suffered cataclastic metamorphism, neither the Seymour Island nor the Tierra del Fuegean granites show strain structures in the quartz.

11. Pink Granite-gneisses

Of all the Basement Complex metamorphics discussed so far the medium-grained pink granite-gneisses are the most widespread, occurring throughout the length of the Fallières Coast, particularly in the Marguerite Bay and Bourgeois Fjord areas. From its field relations with other units of the stratigraphic succession at a number of localities, this gneiss is the youngest member of the Basement Complex.

In the Neny Fjord area the pink granite-gneiss forms the "Mount Nemesis" – Roman Four Promontory massif and the eastern part of Neny Island. On the islands south-east of the Roman Four Promontory it intrudes some of the earlier amphibolites resulting in a coarse, highly foliated augen-gneiss with a foliation dip of 70° to the east-south-east. The greater part of the metamorphic complex of north-west and south-west Millerand Island comprises the same granite-gneisses though there is considerable contamination by its intrusion into earlier units of the Basement Complex. Outcrops of this gneiss have also been mapped at the Debenham Islands.

In Neny Fjord and at Millerand Island the Red Rock Ridge granite is intrusive into the pink granite-gneisses (Plate Ib). The relationship between the non-gneissic "Coarse Pink Granite" and the gneisses is quite clear, the former intruding the latter. Perhaps the best localities showing the nature of this contact are "Moraine Cove" and the Debenham Islands. Although it is suspected that the same relationship exists between the "Coarse Pink Granite" and the granite-gneisses in the Bourgeois Fjord area, the actual contacts are invariably the sites of glaciers.

The pink granite-gneisses of "Mount Nemesis" (E.37) and the Roman Four Promontory (E.34) may be considered as being representative of the youngest gneisses. They are finely gneissic, a pale pink in colour and frequently chlorite-speckled. In thin section the rock is medium-grained and composed mostly of felspar and quartz. Of the potash-felspar, microcline, showing typical cross-hatching, is less abundant than orthoclase. The former is unaltered whereas the latter is dusty with sericite and other degradation products. A large amount of the orthoclase is microperthitic. The plagioclase is a finely lamellar twinned oligoclase-albite. Where it impinges on orthoclase grains clear albite rims surround the cloudy altered cores, but in contact with microcline no albite rim is formed. Frequently along the margins of the orthoclases there is a delicate myrmekitic intergrowth with quartz. The interstitial quartz always shows undulating extinction.

The only ferro-magnesian mineral is a little biotite which is usually altered to chlorite and iron ore. Magnetite in small specks, zircon and apatite are the accessories.

Summary

ALTHOUGH at least eleven sub-divisions of the Basement Complex have been described, it must be emphasised that not all these types recognised in the field are true regionally metamorphosed representatives of original rock types. Some of the types described are hybrid and injection products, the result of repeated intrusion over a long period. As far as can be determined, both from the field relations and microscopic study of these gneisses, there are only five true members of the Basement Complex, namely, the garnet- and quartz-mica-schists, amphibolites, hornblende-schists, biotite-gneiss and pink granite-gneiss.

The original Basement Complex was relatively poor in sediments, which are now represented by the quartz-muscovite-schists, garnet-mica-schists and quartz-biotite-gneisses. The amphibolites may be

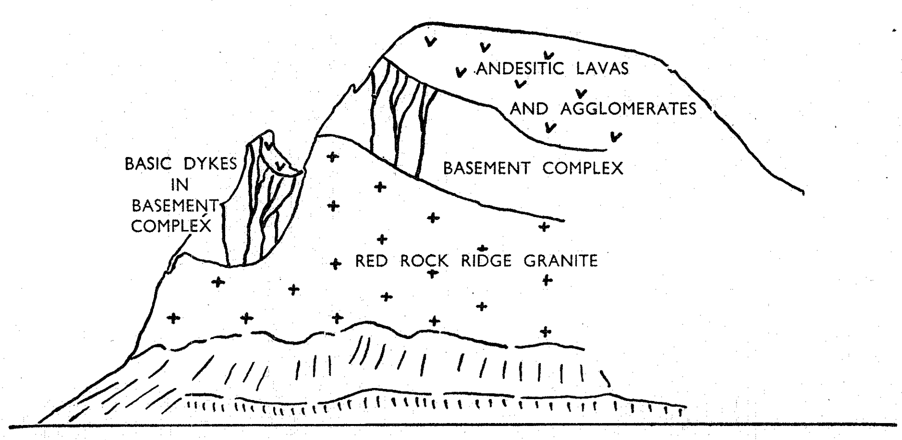

FIGURE 4

Basement Complex gneisses (with dykes) overlain by Jurassic andesites and intruded by the Red Rock Ridge granite at the south-western part of Millerand Island. The nature of the pre-Jurassic erosion surface is indicated.

assigned to a pyroxenitic origin, whereas the diopside-bearing hornblende-schists were, in all probability, basic volcanics rather than plutonics. On the other hand, both the biotite-gneisses and the pink granite-gneisses are ortho-gneisses, being derived from intermediate and acid igneous rocks.

In a complex such as the present one, it is not unusual to expect hybrid and injection gneisses of a wide variety. It is, however, surprising to find there is so little complete migmatisation and reconstitution in this complex. The degree of *lit-par-lit* injection is also very limited, in particular to the areas where the hornblendic schists occur.

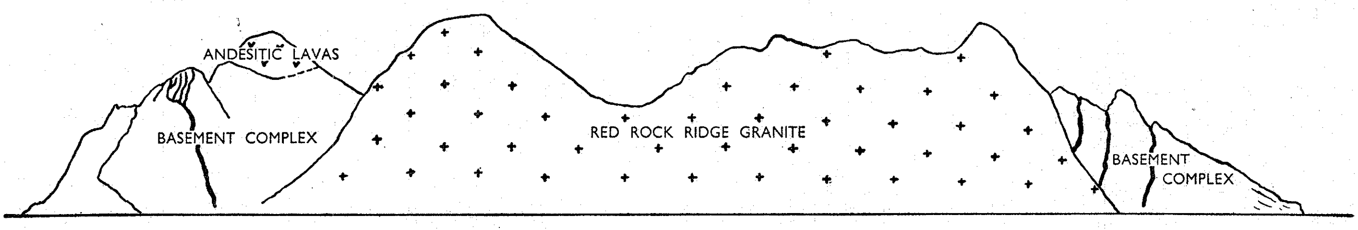

FIGURE 5

The south-western part of Millerand Island showing the Red Rock Ridge granite intruding the dyke-riddled Basement Complex gneisses. Jurassic andesites occupy a valley of the pre-Jurassic erosion surface.

As is to be expected, the Basement Complex throughout this area is completely riddled with acid to basic dykes, associated with the later granites and andesitic volcanics (Figs. 4, 5, 6 and 7). The connection between the dykes and their respective intrusive or extrusive parents can be seen by their field relations. In the field heavy dyke-riddling is a marked characteristic of all the Basement Complex areas.

It is not at all uncommon to find large masses of the Basement Complex, complete with dykes, truncated by the Tertiary Red Rock Ridge granite and overlain by Jurassic andesitic volcanics, as for instance, at Millerand Island (Fig. 4) and Black Thumb (Fig. 3). In each case the intrusive relations of the Red Rock Ridge granite to the Basement Complex are quite definite. All the basic dykes traversing the gneisses are quite clearly feeders to the andesitic lavas. On Millerand Island some agglomeratic extrusive centres cut the Basement Complex (Fig. 6).

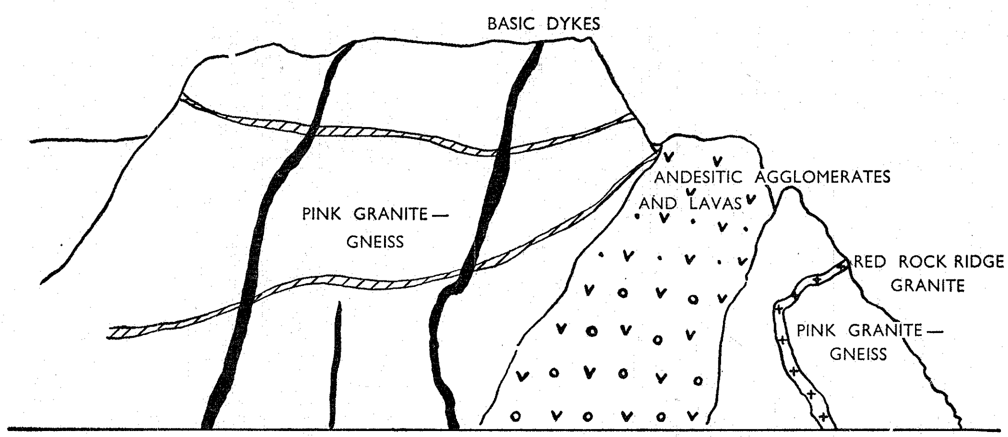

FIGURE 6

Pink granite-gneisses intruded by Jurassic andesitic agglomerates, associated basic dykes and the Red Rock Ridge granite at north-western Millerand Island.

Further more detailed examination of the more southerly parts of the Fallières Coast and the hinterland of the east coast of King George VI Sound* should reveal a considerable amount of additional data which might prove very useful in establishing more clearly the general succession in the Basement Complex.

*The Sound separates Alexander I Land from the mainland.

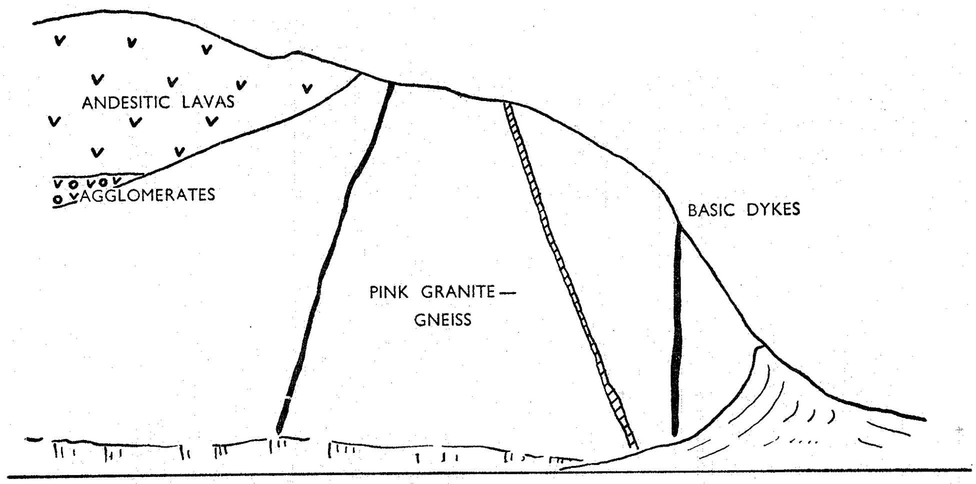

FIGURE 7

Pink granite-gneisses of north-west Millerand Island overlain by Jurassic andesitic lavas and agglomerates, and intruded by basic dykes associated with the lavas.

B. EARLY PALAEOZOIC PLUTONIC AND VOLCANIC ROCKS

COARSE-GRAINED, non-gneissic acid plutonic rocks, which are younger than the Basement Complex yet older than the Jurassic andesitic lavas and agglomerates, have been recorded at a number of localities along the Fallières Coast, both north and south of Neny Fjord. These comprise the "White Granite"* and the "Coarse Pink Granite"*, both of which have been referred tentatively to the early Palaeozoic. The field relations between the two granites are uncertain because they never occur together nor is there any intrusive contact between them. In thin section both granites are very similar and it is possible they are contemporaneous. However, until further detailed field work points to a more definite relationship between them, they are described separately and are not correlated.

For the want of a clearer idea of their age, the highly sheared volcanics of Pourquoi Pas Island and the north-east coast of Alexander I Land are also assigned to the early Palaeozoic. These two sets of volcanics are in no way comparable petrographically, and though they may conceivably represent different geographical facies of the same extrusive phase, they are probably of different ages. On the other hand, the sheared and propylitised lavas of Pourquoi Pas Island may be contemporaneous with the less altered Jurassic andesites also found there.

When a detailed examination of the altered lavas, agglomerates and volcanic breccias collected by the British Graham Land Expedition, 1934–7, from the Danco and Graham Coasts, the Palmer Archipelago and the Biscoe Islands is completed, it may be possible to compare some of them with the present material collected from the Fallières Coast and Alexander I Land.

In spite of a detailed field examination of the east coast of Graham Land north and south of Three Slice Nunatak, neither of the above-mentioned "granites" nor the volcanics have been recorded *in situ*. However, an abundance of similar material occurring as glacial erratics has been observed at the Seal Nunataks, the southern part of the James Ross Island group and the Borchgrevink Nunatak—Gemini Nunatak area. This material has only been examined for the purposes of comparison.

Bodman (1916) has described erratics from Seymour Island, Red Island and Cockburn Island under the name of "granitite". From both the macroscopic and microscopic descriptions these erratics are strictly comparable to the material from the Fallières Coast described here.

*These are field names which have been retained for convenience of description.

1. Early Palaeozoic Plutonics

(i) *The "White Granite"*

So far the "White Granite" has been found only at two localities on the Fallières Coast (Fig. 1), namely, the west end of the "Blackwall Mountains" (E.41 and E.42) and the northern side of Cape Calmette (E.98). The field relations at both these places show it to be younger than the Basement Complex but older than either the Red Rock Ridge granite or the Jurassic andesitic lavas, which rest directly upon the granite in the "Blackwall Mountains" area (Fig. 8; Plate Ia).

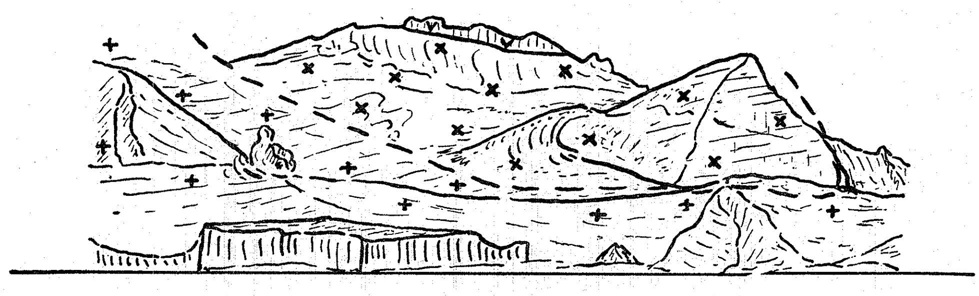

FIGURE 8

The "White Granite"(**X**) east of Red Rock Ridge, Neny Fjord, overlain by Jurassic stratified andesites (**V**) and intruded by the Red Rock Ridge granite (**+**).

In the hand specimen the "White Granite" is very coarse-grained and has an overall milky-white colour. Slightly purplish quartz is quite a marked feature. A little biotite can also be seen but no other ferro-magnesians are obvious.

In thin section the rock exhibits a coarse granitic texture, being composed almost entirely of microperthite, orthoclase, oligoclase and quartz. The potash-felspar is always in excess of the plagioclase felspar. Both the plagioclase and the orthoclase are altered. The former shows slight zoning in the combined Carlsbad/albite twins, the saussuritisation being more pronounced in the calcic zones. Nearly all the plagioclases possess narrow albitic rims which are free from alteration. The plagioclase in the microperthite is also a clear alteration-free albite. The quartz shows no signs of strain but is dusty with inclusions which probably impart the purplish colour to the quartz. It comprises about the same modal percentage of the rock as the oligoclase and about two-thirds the amount of orthoclase and microperthite.

Occasional large biotite flakes, mostly altered to chlorite and marginal iron ore, make their appearance interstitially. Muscovite, zircon, apatite and magnetite are the accessories.

It would be preferable to call this rock an adamellite rather than a biotite-granite, since the plagioclase percentage is somewhat higher than that of a normal granite. However, for convenience the name "White Granite" is still retained.

In contact with the muscovite-schists of the Basement Complex the "White Granite" is considerably altered, sericite and saussurite replacing the greater part of the potash-felspar and plagioclase respectively. Large muscovites even form in some of the orthoclases. The quartz becomes more cloudy with inclusions of iron ore imparting to them a distinct speckled appearance. The proportion of muscovite is certainly higher along the contact than in the main body of the rock, though there is no appearance of large-scale contamination or assimilation of the schists.

(ii) *The "Coarse Pink Granite"*

The distribution of the "Coarse Pink Granite" along the Fallières Coast is far more widespread than that of the "White Granite". Though the main occurrences are in the Neny Fjord–Black Thumb area (Fig. 1), small bosslike intrusions have been mapped in the northern part of Marguerite Bay on the north-eastern side of Bourgeois Fjord, on the small islands south of Horseshoe Island and on the northern coast of Calmette Bay. Similar intrusions have also been recorded on the Debenham Islands (E.103), the northern coast of Millerand Island and at the head of Neny Fjord. The major intrusions south of Red Rock Ridge occur in the Black Thumb area (E.125; Fig 3), the small islands to the west of Black Thumb (E.113), Cape Berteaux (E.205) and "Moraine Cove" on the north side of Windy Valley. Of all the occurrences mentioned above, those of the Debenham Islands and Black Thumb and nearby islands are the most important and are treated here at some length.

Although the general term "Coarse Pink Granite" is used descriptively for all occurrences of this granite on the Fallières Coast, local field names have also been used to identify the same granite, for instance, the "Debenham Granite" and the "Black Thumb Granite".

The field relations contribute very little to establishing the exact age of these plutonics. At the head of Neny Fjord, Black Thumb and the nearby islands, "Moraine Cove" and Millerand Island, the "Coarse Pink Granite" clearly intrudes the amphibolites, biotite-gneisses and the youngest pink granite-gneisses of the Basement Complex. It occurs as large irregular xenoliths in the Jurassic andesites and agglomerates of Black Thumb, the head of Neny Fjord, Millerand Island and north of Camp Point (E.100). It is also present as perfectly rounded and possibly water-worn boulders in the remarkable "Volcanic Conglomerate" of Pourquoi Pas Island, where some of the boulders are up to two feet in diameter.

In the Black Thumb area, at Millerand Island, "Moraine Cove" and the head of Neny Fjord the Red Rock Ridge granite invades the "Coarse Pink Granite" but xenoliths of the latter are seldom found in the Red Rock Ridge granite.

It has not been possible to establish the relationship between this granite and the Trinity Peninsula Series, though it is certain that it is earlier than the sediments. From the above scanty information concerning the field relationships it is only possible to infer an early Palaeozoic age.

In all these localities the "Coarse Pink Granite" exhibits its characteristic rose-pink colour, coarse texture and slightly purplish quartz. Apart from the rose-pink colour, this granite closely resembles the "White Granite" in the hand specimen, but the latter has its distinctive milk-white felspars. As already stated these two granites may be contemporaneous but as yet there is no field evidence to show this.

In thin section the "Coarse Pink Granite" is coarsely crystalline with a granitic texture. Orthoclase, which comprises almost half the rock, is nearly always microperthitic and often altered except where the albitic lamellae occur within it. The plagioclase, also considerably saussuritised, has a composition approximating to $Ab_{85}An_{15}$ and is usually albite/Carlsbad twinned though pericline twinning is not uncommon. Narrow albitic rims, which may be due to exsolution, always surround the plagioclase where it is in direct contact with orthoclase. Quartz in approximately the same modal percentage as the plagioclase is interstitial and usually allotriomorphic. It never exhibits undulating extinction but is frequently dusty with inclusions.

Of the minor constituents, biotite with a pleochroism scheme α=straw and $\beta=\gamma$=dark brown is the commonest, though it may occur in large amounts. It is always partially altered to a deep grass-green chlorite accompanied by iron ore. Beautifully euhedral sphene, magnetite, apatite and zircon are the only accessories. In addition to chlorite a little granular epidote appears as a secondary mineral in association with the biotite.

One of the main differences between the "White Granite" and the "Coarse Pink Granite" lies in the accessory minerals. In the former muscovite is usual but there is never any sphene, whereas the latter always possesses sphene but never muscovite. The degree of alteration of the orthoclase felspars of the two granites is decidedly different, those of the "White Granite" always being more sericitised than those of the pink granite, in spite of the apparent superficial freshness of the specimen.

The "Coarse Pink Granite" of the Fallières Coast may be compared closely with an erratic specimen collected by Bodman (1916) from Red Island in Crown Prince Gustav Channel. In mineralogical composition the type specimen of the "Coarse Pink Granite" (E.113.1, from the small islands west of Black Thumb) is undoubtedly closely allied to Bodman's "granitite" specimen (Table II, No. III). Even in the accessories and degree of alteration there is identity. However, the other erratic specimens described by Bodman (Table II, Nos. II and IV) show zoning in the plagioclases. In this respect they may be compared with the "White Granite". For the purpose of comparison modal analyses of these granites are set out in Table II.

In the hand specimen the older pink granites have a similar appearance to the coarse-grained Tertiary Cape Roquemaurel (D.337) and Mount Reece (D.375) biotite-granites of Trinity Peninsula, which are described in detail in a later report (The Petrology of Graham Land: II. The Andean Granite–Gabbro Intrusive Suite). Though it is not apparent in the hand specimen, detailed examination under the microscope reveals that some hornblende and biotite comprise the ferro-magnesians in the Andengranites.

TABLE II

MODAL ANALYSES OF OLD GRANITES

	E.113.1	II	III	IV
Quartz	21.9	36.8	31.2	34.0
Plagioclase	29.7	40.4	29.6	30.0
Orthoclase } Microperthite }	46.6	16.0	32.8	30.4
Biotite } Chlorite }	1.0	4.8	6.0	0.4
Iron ore	0.8	2.0	0.4	0.4
Sphene	*	*	*	*
Epidote	*	*	*	*
	100.0	100.0	100.0	95.2
Plagioclase composition	$Ab_{85}An_{15}$	$Ab_{95}An_{5}$	$Ab_{85}An_{15}$	$Ab_{72}An_{28}$

*Indicates present but not estimated.

E.113.1 "Coarse Pink Granite" from small islands west of Black Thumb Mountain, Marguerite Bay.

II. "Granitite", erratic from Seymour Island (Bodman, 1916).

III. "Granitite", erratic from Red Island, Crown Prince Gustav Channel (Bodman, 1916).

IV. "Granitite", erratic from Cockburn Island (Bodman, 1916).

Microperthite is less abundant and sometimes completely absent in the Andengranites, which are characterised by a myrmekitic intergrowth of orthoclase and quartz.

Altered porphyritic andesite xenoliths (Plate IIIc), petrographically akin to the early Palaeozoic volcanics described from Alexander I Land and Pourquoi Pas Island in the next section (pages 18 and 19), occur in the "Coarse Pink Granite" on the small islands west of Black Thumb (E.113 and E.124) and at the Debenham Islands. Xenoliths of this type have not yet been observed in the "White Granite".

2. Early Palaeozoic Volcanics

The volcanic rocks which are geographically isolated from those of a definite Jurassic age have been tentatively assigned to the early Palaeozoic. These volcanics include the outcrops on the east coast of Alexander I Land in the vicintiy of latitude 69° 45′ S. and the propylitised, sheared andesitic lavas of the west coast of Pourquoi Pas Island, south of "Dalgliesh Bay" (Fig. 1). Neither of these volcanics contain xenoliths which might have been used for the more accurate determination of their age relations.

(i) *Alexander I Land*

Because of the difficulty of access to the hinterland of north-eastern Alexander I Land on account of the precipitous ice-cliffs extending as far south as the ice shelf in King George VI Sound, only two outcrops at the ice-cliff foot have been examined in detail. These occurrences are two and ten miles respectively north of "Wager Glacier" (E.114 and E.145). They are identical and are composed mainly of light-grey tuffaceous andesites, which are highly sheared and possess a distinct cleavage. Some of the lower volcanics are breccias and agglomerates (Plate IIIb) but others are porphyritic, showing evidence of once having been flow lavas with a semblance of flow structure or stratification.

The stratification of the volcanics is most erratic, dipping at 27° to the south-south-east at Station E.144 and at 25° northward at Station E.145. There are many local variations in the general stratification dip which are due to small-scale puckering and the development of an apparent false cleavage.

Coarse volcanic breccias composed of dark-coloured angular andesitic fragments incorporated in a silicified mylonitic matrix are found near the base of the section exposed at Station E.145. Along shear-planes in the volcanic tuffs of the higher part of the succession mylonites are also developed. Silicification along these planes is very common in addition to transverse quartz veins.

In thin section the tuffs are composed of trachytic andesitic lapilli in a matrix of welded andesitic glass shards. Orientated microlitic plagioclases in the lapilli are oligoclase-andesine, set in a fine-grained matrix. Occasional zoned plagioclase phenocrysts with cores of basic andesine are highly altered and composed almost entirely of coarse sericitic flakes. Secondary calcite, epidote and chlorite are scattered throughout the rock. Late quartz veins traverse it and there is general silicification between lapilli. Micro-shear-planes are all silicified. The majority of the glass shards are devitrified and are now replaced by small felted masses of crystallites.

(ii) *Pourquoi Pas Island*

Unlike the Jurassic andesites which comprise the greater part of the Pourquoi Pas Island hinterland, supposedly older propylitised porphyritic volcanics are confined to the coastal areas of "Dalgliesh Bay" and the offshore islands to the west (E.71). An apparent stratigraphic or erosional break separates the lower from the upper volcanics. Chloritic crush zones ramify through these volcanics, whereas the Jurassic andesites of the area are relatively free from brecciation and hydrothermal alteration.

Microscopic examination of the older volcanics reveals them to be very fine-grained with a pilotaxitic texture. A felted aggregate of lath-like acid andesine crystals and rare isolated altered augites forms the matrix enclosing scattered albite-twinned phenocrysts of more basic andesine. The majority of these phenocrysts are almost completely replaced by calcite and granular epidote, whereas the small pale green chloritic pseudomorphs are the result of replacement of augite micro-phenocrysts. The matrix is also riddled with chlorite. Irregular patches of magnetite and ilmenite are the main accessories, but there is, in addition, a little zircon and apatite. Small cubes of iron pyrites are probably of hydrothermal origin rather than being primary and are associated with propylitisation.

In contrast to the older andesites, those of the Jurassic are invariably fresh, stratified trachytic andesites, micro-porphyritic augite-andesites or andesitic agglomerates.

(iii) *Xenoliths in the "Coarse Pink Granite"*

The most frequent among the inclusions found in both the "Coarse Pink Granite" of the small islands west of Black Thumb (E.113 and E.124) and the "Debenham Granite" are altered porphyritic andesites, which are petrographically similar to the older volcanics of Alexander I Land and Pourquoi Pas Island.

In thin section the andesitic xenoliths (Plate IIIc) exhibit a micro-porphyritic texture with frequently saussuritised oligoclase-andesine micro-phenocrysts set in an almost cryptocrystalline matrix in which felted aggregates of oligoclase-andesine ($Ab_{75}An_{25}$) microlites also occur. Any pyroxene which may have been present originally has been entirely replaced by a pale green chlorite or epidote. A little granular iron ore is disseminated throughout the matrix, in which there is an abundance of secondary chlorite.

The discovery of these andesitic inclusions in the assumed early Palaeozoic plutonics is of considerable significance. Their presence indicates that the older volcanics of Alexander I Land and Pourquoi Pas Island are earlier than the plutonics. It is therefore quite legitimate to assign them tentatively to an older stage of the early Palaeozoic.

SUMMARY

IN spite of the paucity of observed field occurrences of the older granites in Graham Land, both the widespread distribution of xenoliths in the Jurassic volcanics and glacial erratics in the north point to a wider and, as yet, unexplored lateral extent. These older granites may have played a far more significant rôle in the early building of the Graham Land peninsula than is to be inferred from their present limited distribution.

Both the Alexander I Land and Pourquoi Pas Island volcanics show considerably greater alteration than the Jurassic andesites of the Neny Fjord–Black Thumb type area. Furthermore, although the rhyolite–andesite succession of Mushroom Island shows a certain degree of hydrothermal alteration due to its close proximity to an extrusive centre, there are no signs of such extensive shearing and chloritisation. In order to obtain a more accurate estimate of the age of these volcanics than that inferred from the xenoliths in the "Coarse Pink Granite", further detailed field work is necessary.

An extensive study of the older igneous rocks of the Graham and Danco Coasts, the Palmer Archipelago and the Biscoe Islands may add greatly to the knowledge of the early Palaeozoic succession of the Fallières Coast.

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APPENDIX

A LIST OF PLACE NAMES, THEIR CO-ORDINATES AND THE APPROPRIATE MAP SHEETS*

NOTE: Only the mid latitude and longitude of each feature is given.
Names which are not yet officially accepted are printed in inverted commas.

Alexander I Land	72°S., 70°W.	1/500,000 Sheets F, G & K.
Batterbee Mountains	71°23′S., 66°55′W.	1/200,000 Sheet 71 66
Berteaux, Cape	68°51′S., 67°29′W.	1/200,000 Sheet 68 66
Bigourdan Fjord	67°33′S., 67°20′W.	1/200,000 Sheet 67 66
Biscoe Islands	65°45′S., 66°15′W.	1/500,000 Sheet C.
Black Thumb Mountain	68°25′S., 66°53′W.	1/200,000 Sheet 68 66
"Blackwall Mountains"	68°24′S., 66°48′W.	1/200,000 Sheet 68 66
Borchgrevink Nunatak	66°03′S., 62°30′W.	1/200,000 Sheet 66 62
Bourgeois Fjord	67°40′S., 67°05′W.	1/200,000 Sheet 67 66
Broken Island	67°49′S., 66°57′W.	1/200,000 Sheet 67 66
Calmette Bay	68°03′S., 67°10′W.	1/200,000 Sheet 68 66
Calmette, Cape	68°04′S., 67°14′W.	1/200,000 Sheet 68 66
Camp Point	67°58′S., 67°19′W.	1/200,000 Sheet 67 66
Centre Island	67°52′S., 66°58′W.	1/200,000 Sheet 67 66
Cockburn Island	64°12′S., 56°50′W.	1/100,000 Sheet 64 56 NW.
Crown Prince Gustav Channel	63°55′S., 58°20′W.	1/200,000 Sheet 64 58
"Dalgliesh Bay"	67°45′S., 67°36′W.	1/500,000 Sheet C.
Danco Coast	64°45′S., 62°00′W.	1/500,000 Sheet A.
Debenham Islands	68°08′S., 67°07′W.	1/200,000 Sheet 68 66
Dog's Leg Fjord	67°43′S., 66°50′W.	1/200,000 Sheet 67 66
"Edisto Rock"	68°13′S., 67°07′W.	1/200,000 Sheet 68 66
East Russell Glacier	63°44′S., 58°17′W.	1/100,000 Sheet 63 58 SE.
Fallières Coast	67°55′S., 66°45′W.	1/500,000 Sheet C.
"Fitzroy Islet"	68°12′S., 66°59′W.	1/200,000 Sheet 68 66
"Garnet Rocks"	68°21′S., 67°03′W.	1/200,000 Sheet 68 66
Graham Coast	66°05′S., 65°20′W.	1/500,000 Sheet C.
Gemini Nunatak	66°08′S., 62°30′W.	1/200,000 Sheet 66 62
Horseshoe Island	67°51′S., 67°12′W.	1/200,000 Sheet 67 66
James Ross Island	64°05′S., 57°45′W.	1/500,000 Sheet B.
Jeremy, Cape	69°24′S., 68°51′W.	1/200,000 Sheet 69 68
Laubeuf Fjord	67°30′S., 67°50′W.	1/500,000 Sheet C.
"Longridge Head"	67°24′S., 67°33′W.	1/200,000 Sheet 67 66
Marguerite Bay	68°30′S., 69°00′W.	1/500,000 Sheet G.
"Mica Islets"	69°21′S., 68°42′W.	1/200,000 Sheet 69 68
Millerand Island	68°09′S., 67°13′W.	1/200,000 Sheet 68 66
"Moraine Cove"	68°35′S., 67°07′W.	1/200,000 Sheet 68 66
Mushroom Island	68°53′S., 67°53′W.	1/200,000 Sheet 68 66
"Nemesis, Mount"	68°12′S., 66°53′W.	1/200,000 Sheet 68 66
Neny Fjord	68°16′S., 66°50′W.	1/200,000 Sheet 68 66
Neny Island	68°12′S., 67°02′W.	1/200,000 Sheet 68 66
"North Star Islet"	68°12′S., 67°07′W.	1/200,000 Sheet 68 66
Palmer Archipelago	64°20′S., 63°00′W.	1/500,000 Sheet A.
Pourquoi Pas Island	67°41′S., 67°30′W.	1/200,000 Sheet 67 66
"Pyrox Islet"	68°12′S., 66°40′W.	1/200,000 Sheet 68 66
Red Island	63°44′S., 57°52′W.	1/100,000 Sheet 63 56 SW.
Red Rock Ridge	68°18′S., 67°05′W.	1/100,000 Sheet 68 66 NW.
Reece, Mount	63°50′S., 58°32′W.	1/500,000 Sheet B.

* The map series referred to are described in the F.I.D.S. Scientific Report No. 1.

Ridge Island	67°42′S., 67°06′W.	1/200,000 Sheet 67 66
Roman Four Promontory	68°13′S., 66°58′W.	1/200,000 Sheet 68 66
Roquemaurel, Cape	63°33′S., 58°56′W.	1/100,000 Sheet 63 58 SE.
Seal Nunataks	65°03′S., 60°18′W.	1/500,000 Sheet D.
Seymour Island	64°17′S., 56°45′W.	1/500,000 Sheet B.
Square Bay	67°51′S., 67°00′W.	1/200,000 Sheet 67 66
Stonington Island	68°11′S., 67°00′W.	1/200,000 Sheet 68 66
Three Slice Nunatak	68°02′S., 64°58′W.	1/200,000 Sheet 68 64
Trinity Peninsula	63°30′S., 58°00′W.	1/500,000 Sheet B.
"Wager Glacier"	69°48′S., 69°22′W.	1/200,000 Sheet 69 68
Windy Valley	68°37′S., 66°50′W.	1/200,000 Sheet 68 66

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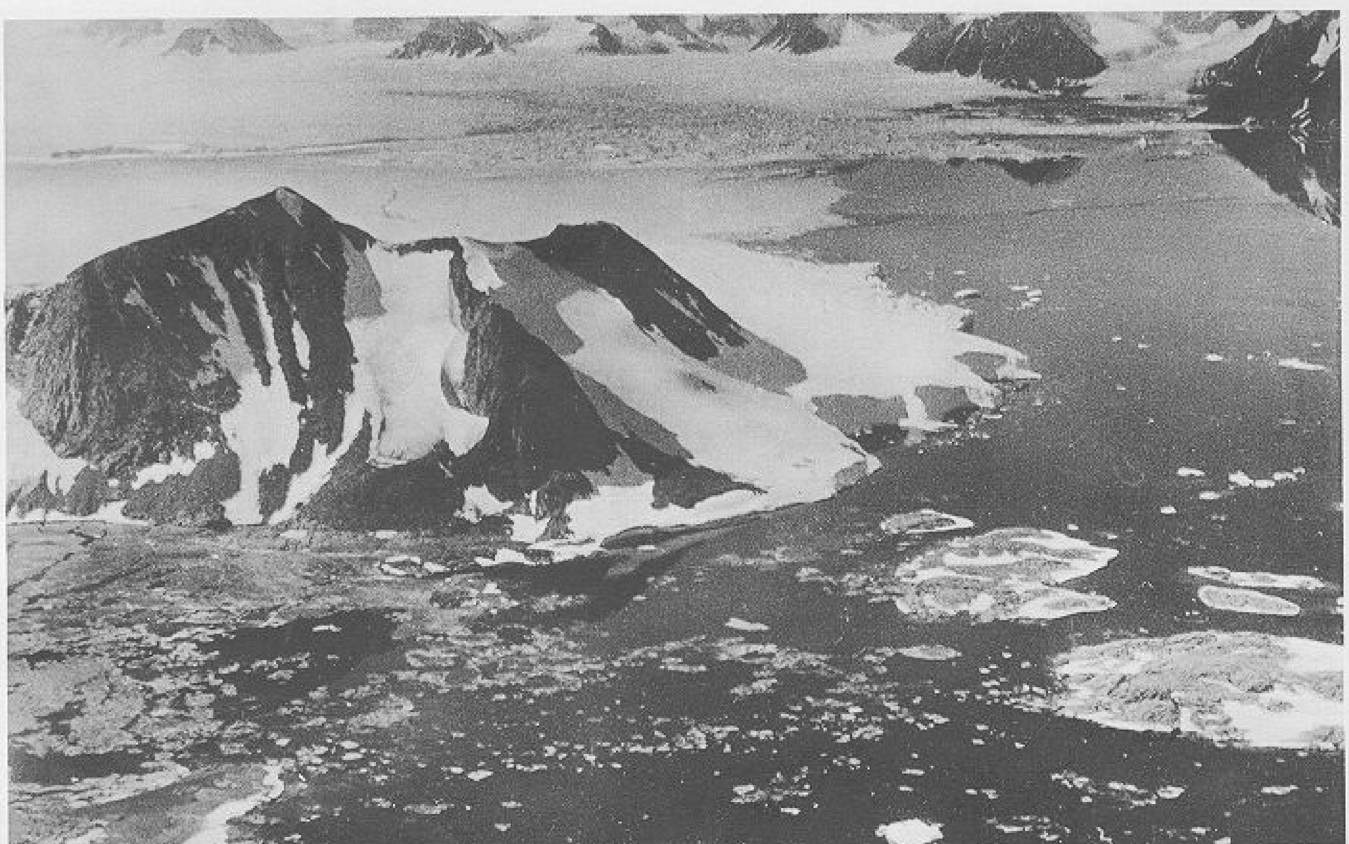
PLATE I

a. Jurassic andesites lying on top of the "White Granite", southern side of Neny Fjord, east of Red Rock Ridge, Marguerite Bay. The Red Rock Ridge granite on the left of the photograph intrudes both the "White Granite" and the andesites.

b. Aerial view of the southern end of Millerand Island, Marguerite Bay, showing the Red Rock Ridge granite boss which intrudes the dyke-riddled pink granite-gneisses of the Basement Complex. Stonington Island is in the background beneath the two rocky mountains

R.J.A.

a



R.J.A.

b

PLATE II

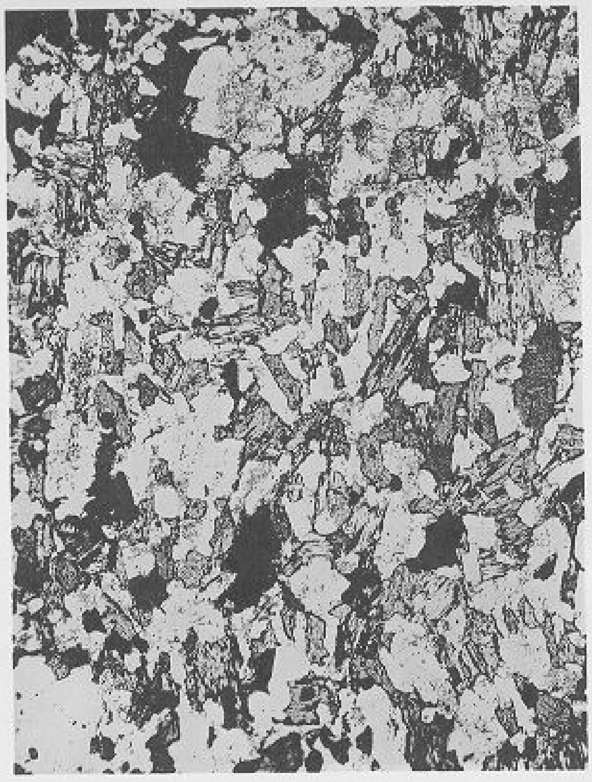
a. Quartz-muscovite-schist showing contortion of schistosity; foot of ice-cliffs east of nunataks, north-east Alexander I Land (E.209.1A; X-nicols; ×19).

b. Hornblende-biotite-schist xenolith in quartz-diorites; Islets north-west of the Debenham Islands, Marguerite Bay (E.102.2; ordinary light; ×19).

c. Banded biotite-gneiss; valley beneath the north face of Black Thumb Mountain, Marguerite Bay (E.125.11; X-nicols; ×19).

d. Biotite-gneiss; one mile west of the north-east point, northern coast of Millerand Island, Marguerite Bay (E.119.6A; ordinary light; ×19).

a



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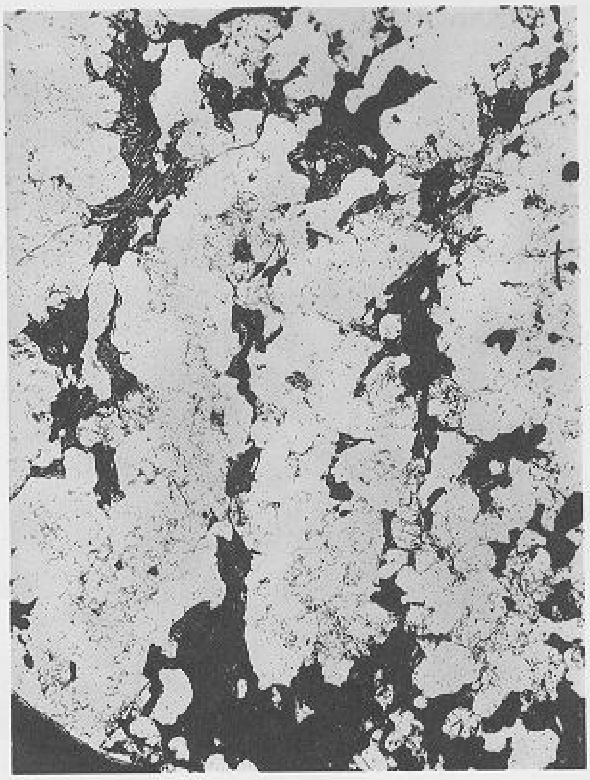

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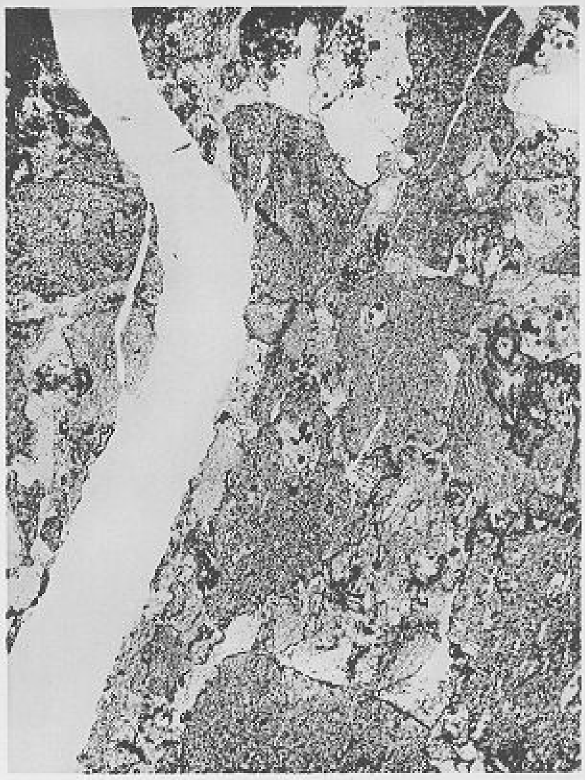
PLATE III

a. Contact between biotite-gneiss and hornblende-schist xenolith showing slight contamination of the gneiss; one mile west of the north-east point, northern coast of Millerand Island, Marguerite Bay (E.119.6B; ordinary light; × 19).

b. Sheared and altered andesitic agglomerate; ten miles north of "Wager Glacier", Alexander I Land (E.145.1A; ordinary light; × 19).

c. Altered porphyritic andesite inclusion in the "Coarse Pink Granite"; island about two miles west of Black Thumb Mountain, Marguerite Bay (E.124.4; ordinary light; × 19).

a



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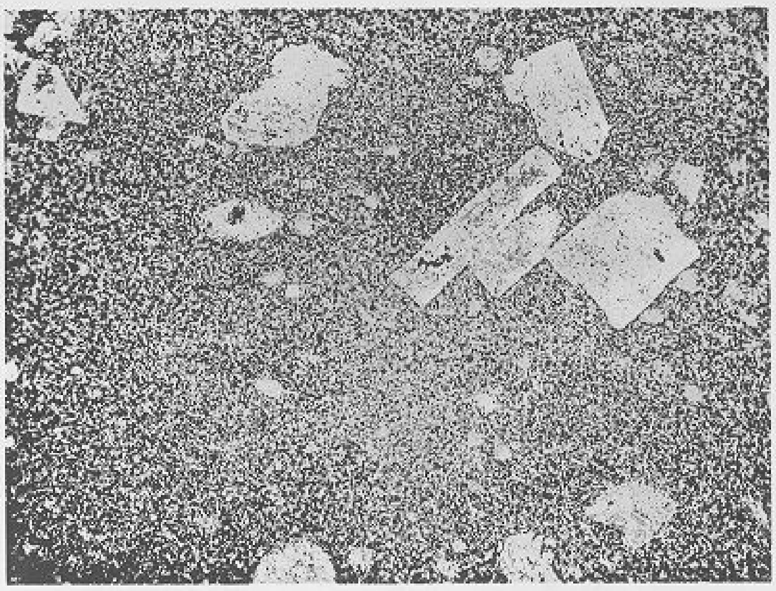

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