REPORTS ON ANTARCTIC FIELDWORK

THE GEOLOGY OF NORTH-WESTERN PALMER LAND

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INTRODUCTION

The work described here was conducted by the authors over two austral summers between 1983 and 1985, working from the British Antarctic Survey's Rothera Station on Adelaide Island.

The study area (Figs. 1 and 2) comprises all the outcrops of north-western Palmer Land between George VI Sound and Dyer Plateau, limited by the Traverse Mountains to the north and the Pegasus Mountains to the south.

Tectonic setting

The Antarctic Peninsula margin of Gondwana was the site of essentially continuous subduction of Pacific and proto-Pacific oceanic crust from early Mesozoic times until the Tertiary (Smellie, 1981; Dalziel, 1982; Storey and Garrett, 1985). This resulted in the formation of an arc–trench system consisting of an accretionary prism, magmatic arc, and fore- and back-arc basins (Suárez, 1976). Subduction ceased as a result of oblique ridge crest-trench collisions along the Antarctic Peninsula progressing from south to north during the Tertiary (Barker, 1982). The study area lies within the magmatic arc.

Previous work

Earlier workers (Rowe, 1973; Skinner, 1973; Smith, 1977) divided the rocks in the area into three broad groups.

(i) Undeformed volcanic rocks believed to be of late Jurassic to Cretaceous age (Adie, 1971), now known as the Antarctic Peninsula Volcanic Group (Thomson, 1982).

(ii) Undeformed plutonic granites and granodiorites believed to be of Mid-Cretaceous age and related to the Andean Intrusive Suite.

(iii) A variety of deformed plutonic rocks, gneisses and migmatites termed the metamorphic complex and generally assumed to be of Palaeozoic age.

The metamorphic rocks have long been referred to as 'basement' and were believed to be unconformably overlain by Jurassic rocks as in South America (Dalziel, 1982). These 'basement' rocks have received various interpretations, often involving an element of Precambrian sialic crust (Smith, 1977), with subsequent metamorphism during the Gondwanian Orogeny, which affected all pre-Mid Jurassic rocks (Dalziel, 1982).

More recent work has emphasized the continuity of subduction and magmatism during the evolution of the peninsula and also the diachronous nature of the various strato-tectonic units (Storey and Garrett, 1985). The importance of late shearing to produce deformed rocks of Mesozoic age, often mistaken for older basement, has also been recognized (Meneilly, 1983).

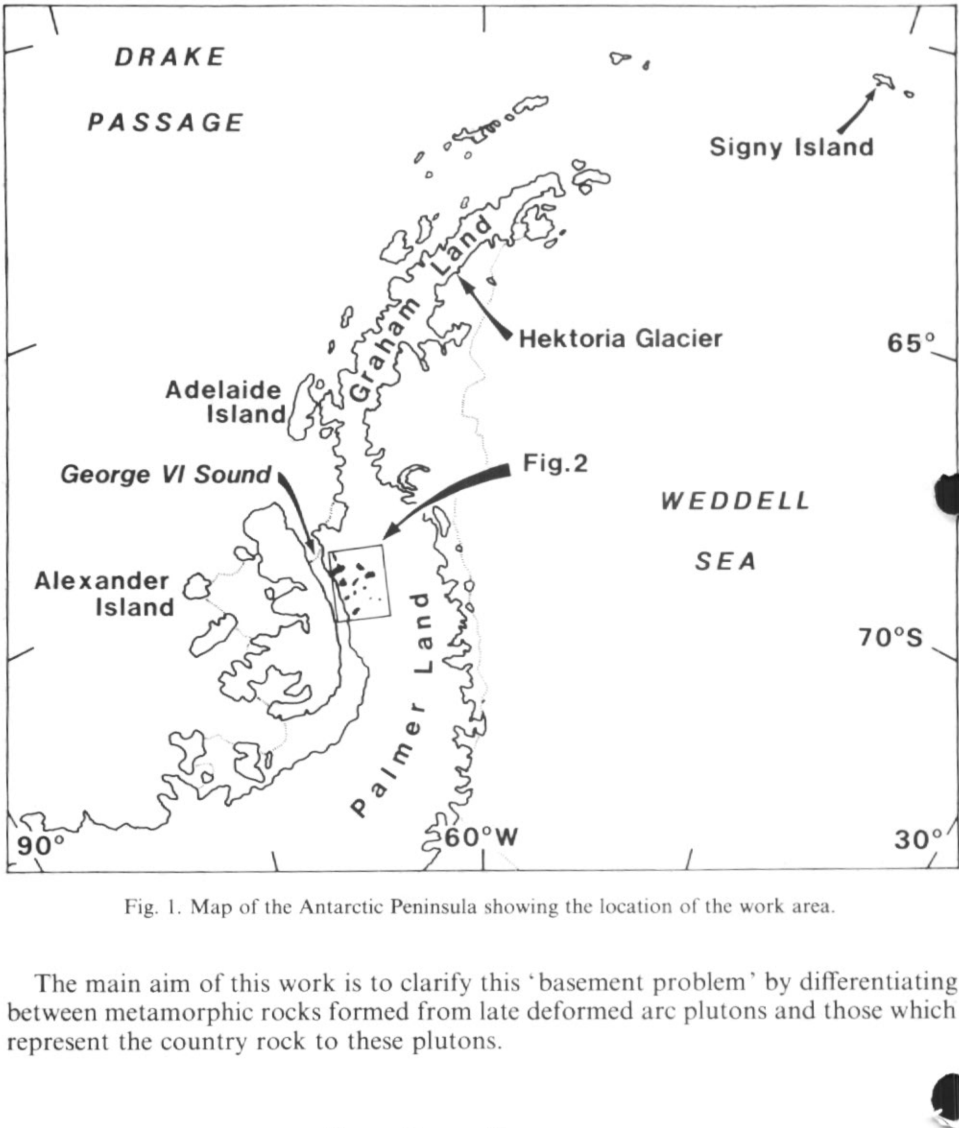

Fig. 1. Map of the Antarctic Peninsula showing the location of the work area.

The main aim of this work is to clarify this 'basement problem' by differentiating between metamorphic rocks formed from late deformed arc plutons and those which represent the country rock to these plutons.

Rock Group Descriptions

A classification of the rocks studied is presented in approximately chronological order in Fig. 3. Each of the major rock groups is described separately and, with the exception of the dykes, their distribution is shown in the geological sketch map (Fig. 2).

Metamorphic complex rocks

The rocks are described in three lithostratigraphic units, these include early, regionally migmatized orthogneiss, paragneiss and metaplutonic rocks (which lack migmatitic and gneissose fabrics) Amphibolite sheets and dykes occur throughout the Metamorphic Complex. The structural trends of these rocks are also briefly discussed.

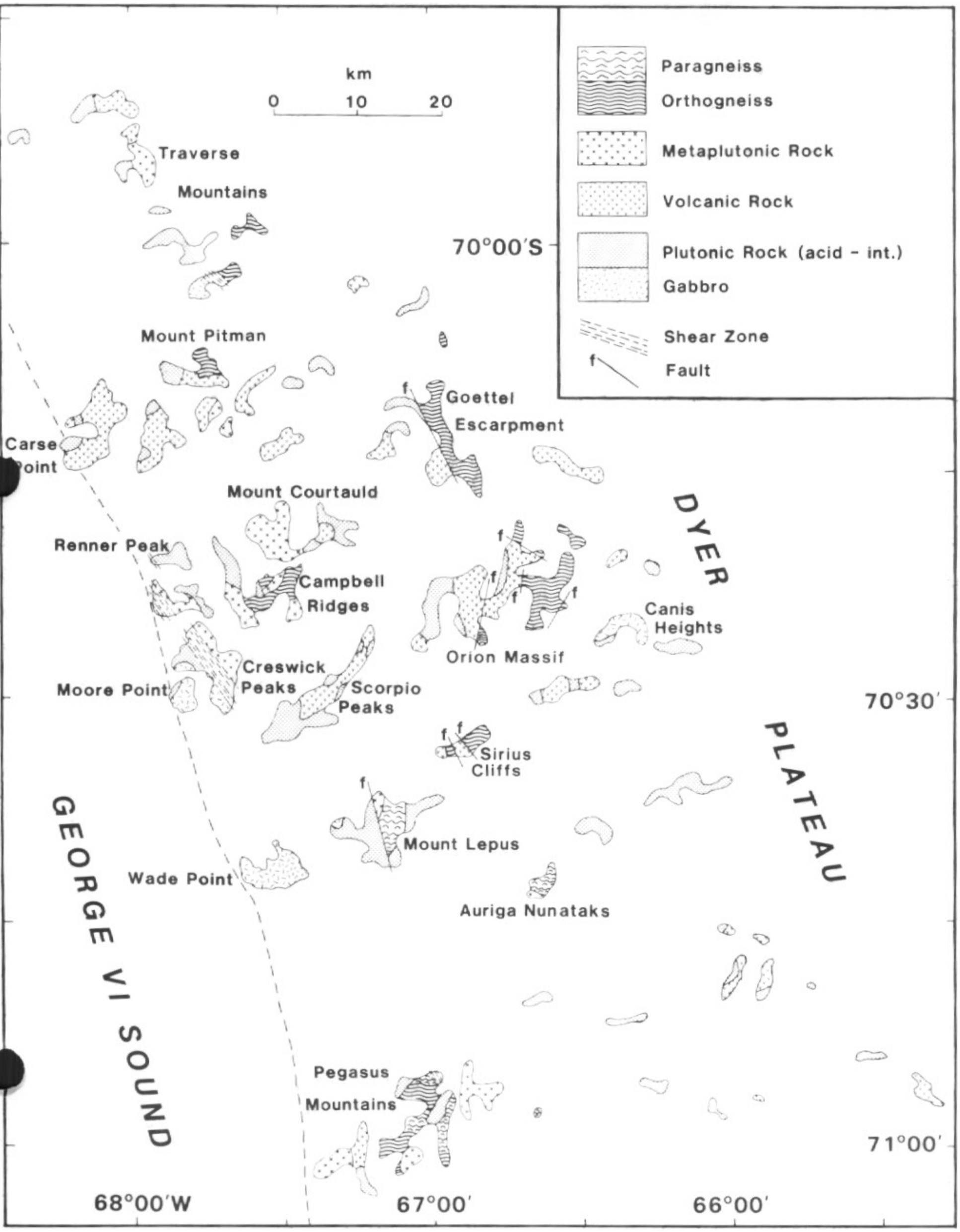

Fig. 2. Geological sketch map of north-western Palmer Land.

Migmatitic orthogneiss and paragneiss. These rocks characteristically have strong metamorphic, wholly recrystallized fabrics, which show considerable variation both mineralogically and texturally.

On the western side of the area along the hinterland of George VI Sound, metamorphic complex rocks are present at Campbell Ridges, Mount Pitman, Pegasus

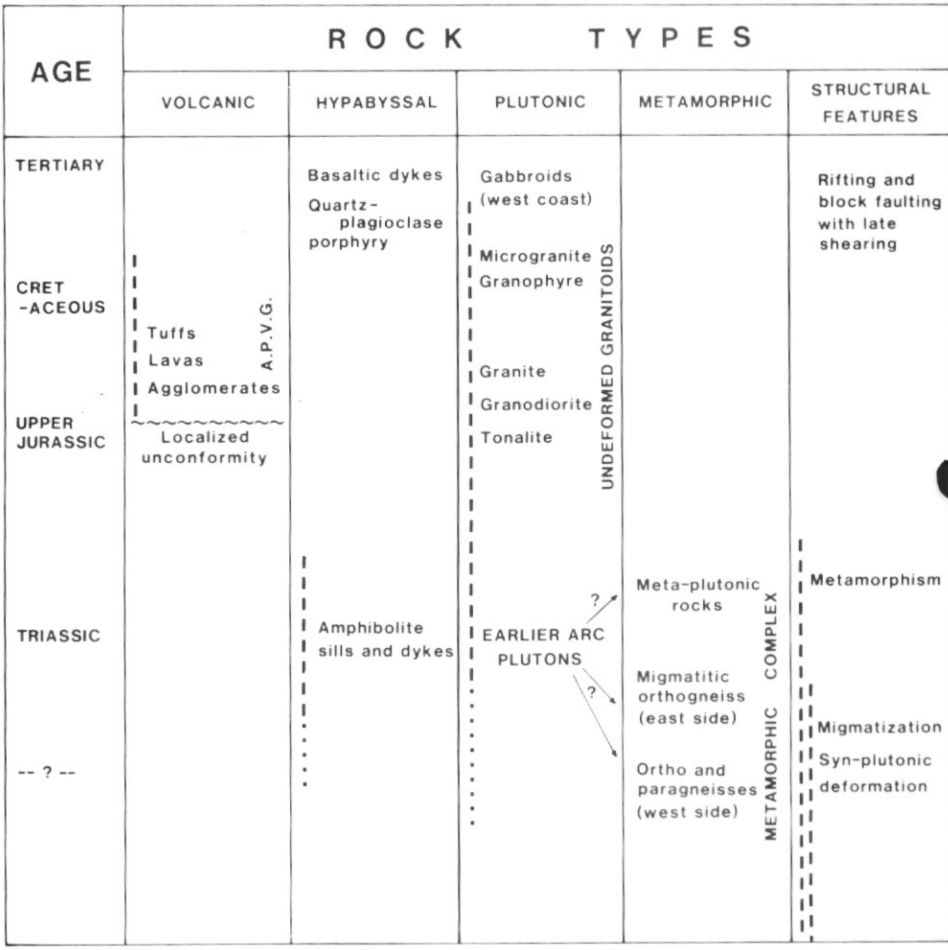

Fig. 3. Summary of the stratigraphy of north-western Palmer Land.

Mountains, Mount Lepus and Auriga Nunataks. In the last two areas, it has been possible to distinguish between orthogneisses and paragneisses. The paragneisses are characterized by continuous banded sequences, varying from granular quartzite and quartzo-feldspathic gneiss to biotite-rich gneiss (Fig. 4), and by the presence of abundant reddish-pink garnet crystals up to 1.5 cm in diameter. A 250 m thick, coarse marble band is intimately associated with the paragneisses at Auriga Nunataks (Fig. 5), thereby reaffirming a sedimentary origin. The orthogneisses are felsic to intermediate in composition and coarse-grained with a strongly developed segregated fabric. These rocks are more massive in outcrop than the paragneisses because of a poorly developed, discontinuous banding defined by amphibolitic schlieren and, in the case of the orthogneiss at Campbell Ridges, the banding is absent altogether. No garnet was found in these rocks.

Elsewhere on the western side it is difficult to distinguish with certainty between orthogneiss and paragneiss. At Mount Pitman, a sequence of finely laminated phyllites and schists is present. These are intermediate to basic in composition and have a strong vertical fabric striking north–south. In the Pegasus Mountains, a more complex

Fig. 4. Paragneisses from Auriga Nunataks showing sedimentary bedding structure.

banded sequence includes massive amphibolite, homogeneous intermediate gneiss with occasional scattered reddish-pink garnet and laminated phyllites and schists. The schists are locally migmatized.

Along the western margin of the Dyer Plateau, migmatitic orthogneisses are best displayed at Goettel Escarpment, eastern Orion Massif, and Sirius Cliffs. They are believed to have been produced by injection of granitic material into a more basic igneous (possibly gabbroic) host. This has produced a great variety of textures and mineralogies ranging from net-veined gabbros and agmatites through various amphibolitic gneisses and banded gneisses to granoblastic granite-gneiss (Fig. 6).

Metaplutonic rocks. The metaplutonic rocks are distinguished from the rest of the metamorphic complex by their much more homogeneous character in both hand specimen and outcrop (Fig. 7). They are clearly igneous in origin with only partial recrystallization, often associated with the alignment of biotite and amphibole. Their compositions range from granitic to gabbroic. Most outcrops occur in the western side of the area, e.g. Campbell Ridges and Mount Lepus, where the more massive metaplutonic rocks cut the foliated and segregated fabric of the orthogneisses.

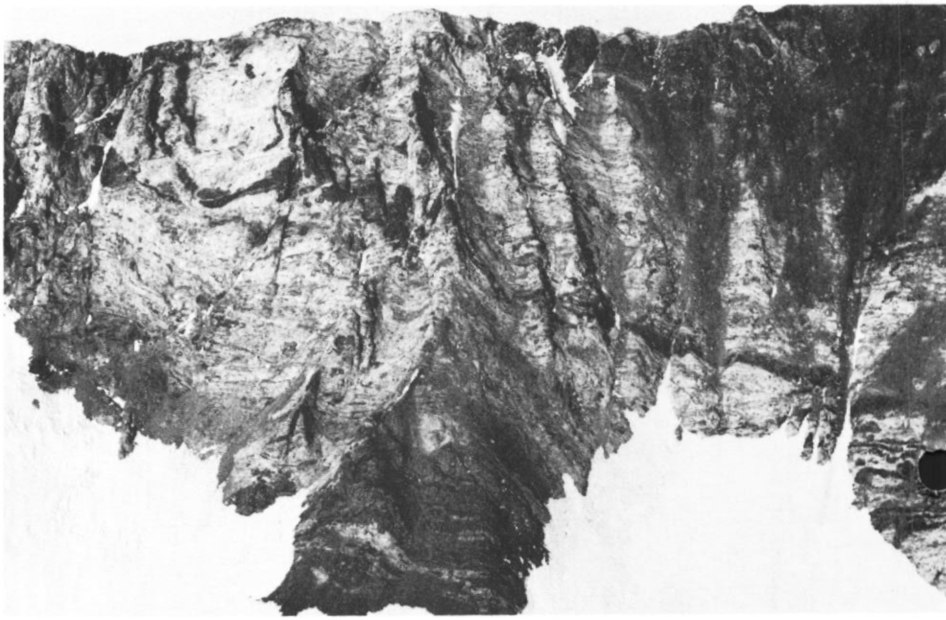

Fig. 5. Aerial view of Auriga Nunataks showing disrupted amphibolite sheets and pods within marble. The face is approximately 500 m high.

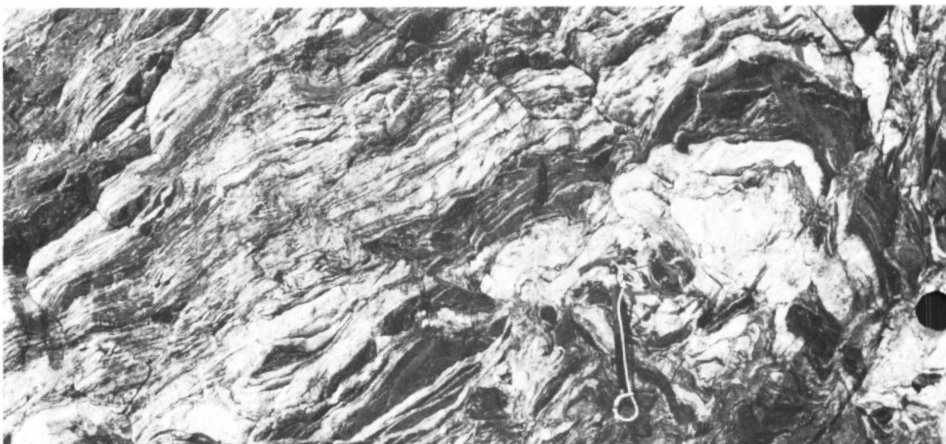

Fig. 6. Contorted and sheared migmatite-gneisses on the eastern side of the Orion Massif.

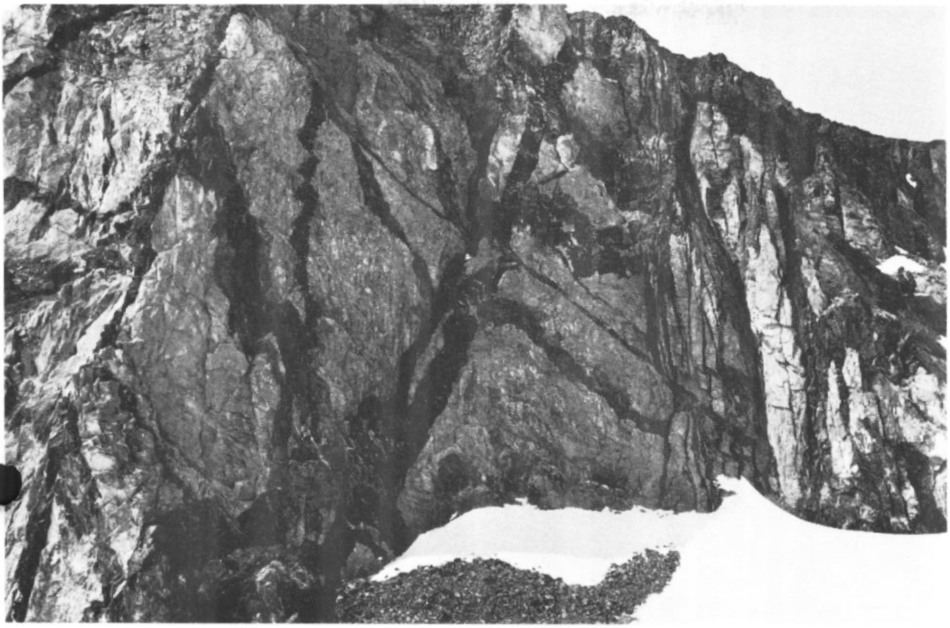

Fig. 7. Metaplutonic rock at Mount Noel cut by amphibolite sheets and dykes. The face is approximately 150 m high.

Early amphibolite sheets and dykes. These mafic bodies are abundant within the metamorphic complex and, on a regional scale, it is likely that there has been more than one phase of intrusion.

Amphibolites within the metaplutonic rocks occur as dykes that are variably deformed and sheared and generally cut the local foliation. Dyke orientations are highly variable but two main orientations are present, one trending north-east and the second approximately normal to this. In contrast, amphibolites within the gneisses are intruded as conformable sheets parallel to the shallow-dipping layering. Deformation is variable but, in the migmatitic rocks along the Dyer Plateau, the sheets are sheared parallel to their margins.

Structural trends of the metamorphic complex. Structures in these rocks consist of compositional banding and mineral alignment. There is considerable variation in the orientation of the banding, even within outcrops, but the main trend is south-easterly with moderate to steep dips to the north-east. No obvious difference in trends has yet been found between the gneisses and the metaplutonic rocks.

In the migmatites along the Dyer Plateau subhorizontal layering and foliation have been produced at an outcrop scale probably by flow shearing adjacent to intruding granite sheets. There is also evidence for larger scale tectonic control of the structure because widely spaced outcrops of migmatite show very similar structural trends.

Volcanic rocks

These rocks are present throughout north-western Palmer Land (Fig. 8). They are horizontally bedded and show little or no sign of alteration or deformation. These rocks include lavas, agglomerates, and tuffs. Amphibolite dykes are absent. On the eastern side of the region at Sirius Cliffs and the Goettel Escarpment volcanic rocks

Fig. 8. Undeformed horizontally bedded volcanic rocks at Sirius Cliffs. The face is approximately 600 m high.

are in fault contact with rocks of the metamorphic complex; at two localities, Sirius Cliffs and Mount Pitman, they lie unconformably upon metamorphic complex rocks. In many areas, the volcanic rocks are intruded by high level plutons, in particular microgranites (see following section).

Undeformed plutonic rocks

These rocks are divided into two groups, granitoids and gabbroids.

Granitoids are common throughout the area and two distinct styles of intrusion can be recognized. Plutons intruding undeformed volcanic rocks are predominantly small bodies of microgranite, often with granophyric textures. Contacts are characteristically sharp and the volcanic rocks are usually hornfelsed adjacent to the granite (Fig. 9). These rocks are inferred to have been emplaced at a shallow crustal level. Elsewhere granitoids of granodioritic and tonalitic compositions form coarser grained isolated intrusions, generally without contact relations. Where contacts are seen they may be sharp, e.g. at Mount Lepus, where granodiorite intrudes metamorphic complex rocks, or more intricate, e.g. Canis Heights, where tonalite intrudes gabbro. Here, country rock xenoliths are included in the margins of the pluton and there is extensive veining of the surrounding units. It is believed that these plutons represent a deeper level of intrusion than the microgranites. However, chemical differences between the plutons, such as volatile content, may account for some of the variations seen; depth of intrusion is not necessarily the most important factor.

The most extensive exposures of gabbroids occur at Wade Point and Moore Point. These are typically heterogeneous, amphibole-rich rocks with both cumulate and non-cumulate textures, varying from ultramafic to anorthositic in composition. Autobrecciation, regular and irregular modal and grain-size layering are present in

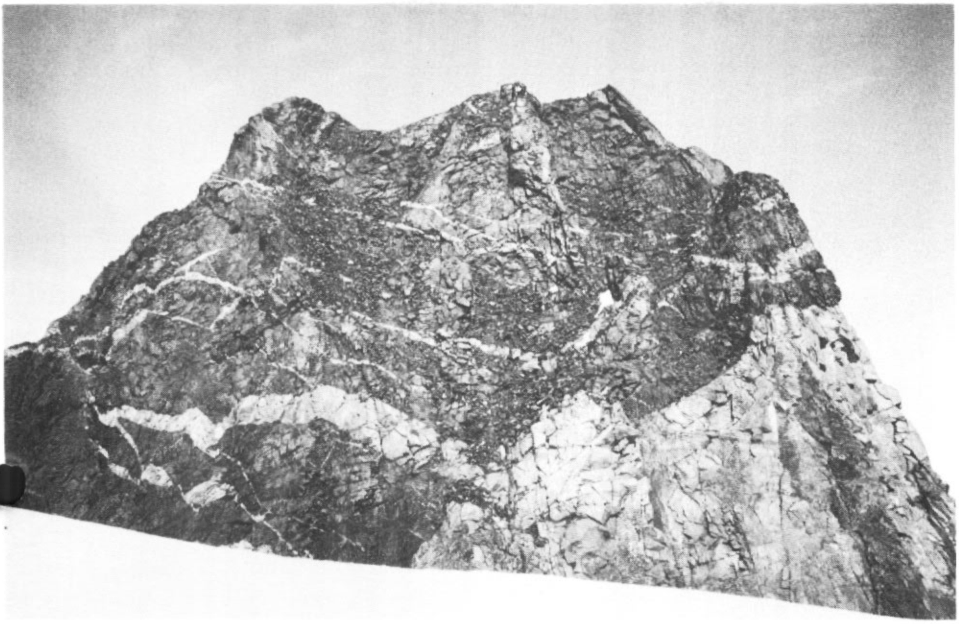

Fig. 9. Microgranite intruding and hornfelsing volcanic rocks at the western end of Sirius Cliffs. The face is approximately 75 m high.

the cumulate rocks. Leucocratic material intrudes these rocks locally either as sharply defined irregular dykes and veins or as net-veins with more gradational margins. At three separate localities, these gabbroic rocks intrude undeformed plutonic rocks considered to be part of the granitoid suite.

Gabbroic plutons do exist elsewhere (e.g. southern Traverse Mountains and Canis Heights) with what appear to be similar mineralogies but their field relationships are enigmatic.

Late shearing, faulting, and hypabyssal intrusions

These features are described together because field relationships suggest that they are closely related in time.

One major shear zone has been identified, which clearly cuts an otherwise undeformed granodiorite, indicating late deformation. This extends from the west side of Renner Peak south-eastward into Creswick Peaks and dips moderately to the north-east. The rocks within this zone are shear-banded gneisses with mylonites locally developed. Mineral lineations are common on planar surfaces and plunge uniformly east indicating dip–slip movement. It is not yet known if this represents normal or reverse movement. Similar sheared rocks occur elsewhere (e.g. Pegasus Mountains and Traverse Mountains) but these zones cannot be correlated on field evidence alone (see later).

Several major faults are exposed on the eastern side of the region and are particularly well-displayed at Sirius Cliffs, juxtaposing metamorphic complex rocks and undeformed volcanic rocks. Similar faulting involving the same rock units is also present at the Goettel Escarpment and Orion Massif. These faults are steeply dipping and are either parallel or orthogonal to George VI Sound, indicating block faulting.

In contrast, a low angle fault at Mount Lepus, trending south-south-east and dipping eastwards, has thrust metamorphic rocks over undeformed acid plutonic rocks.

Late hypabyssal intrusions are common throughout the area. These are steeply dipping mafic dykes, generally 1–2 m wide, with chilled margins. These dykes are always the final intrusive event at any locality. The dykes show the same orientations as the late faults described above and are believed to have been emplaced in response to the same shear regime that caused the block faulting. At Sirius Cliffs quartz-plagioclase porphyry dykes (10–20 m wide) are also associated with this faulting. These dykes predate the mafic dykes described above and may be associated with the microgranite.

Summary and Discussion

The stratigraphy of the area is summarized in Fig. 3. The metamorphic complex is the main concern since little is known regarding the petrogenesis and ages of these rocks.

In the western part of the area, the metamorphic complex consists of orthogneisses and paragneisses intruded by metaplutonic rocks, whereas, farther to the east, it is dominated by orthogneisses. Despite the lack of field relations it is believed that these orthogneisses can be correlated across the area.

The volcanic rocks unconformably overlie metamorphic complex rocks (Sirius Cliffs and Mount Pitman), indicating that metamorphism, uplift and erosion must have occurred prior to the extrusion of the former. At Carse Point, fossiliferous sediments conformably underlying volcanic rocks are Upper Jurassic in age (Thomson, 1975). Therefore, the metamorphic complex rocks must be at least pre-Upper Jurassic in age. This minimum age could possibly be extended, since Thomson and Pankhurst (1983) have shown that volcanism in the Antarctic Peninsula has been essentially continuous from early Jurassic to Tertiary times (*c.* 180–60 Ma).

The metaplutonic rocks may be related to the Mesozoic magmatic arc (Storey and Garrett, 1985) and are possibly of early Jurassic age. The orthogneisses may also be related to this arc, representing an earlier magmatic phase. However, they could also be pre-Mesozoic continental crust or perhaps a remelt of such material.

The paragneisses, on the other hand, must have been deposited as sediments prior to the metamorphism and migmatization and are therefore likely to be of pre-Mesozoic age. Possibly, they represent metamorphosed accretionary prism sediments similar to the Scotia metamorphic complex on Signy Island (Storey and Meneilly, 1985), which has been assigned a Permian age for sedimentation (Pankhurst, 1982). This complex contains numerous marble layers which, though mostly on a centimetre scale, may be similar in origin to the large marble band exposed at Auriga Nunataks. The only other significant exposure of metamorphosed limestone described from the Antarctic Peninsula is a small outcrop (200 m high and 100 m wide) on the western side of Hectoria Glacier (Fig. 1) (Fleet, 1965). This has been speculatively assigned to the Trinity Peninsula Group for which age estimates range from Carboniferous to Triassic (Smellie, in press). Limestones and metamorphosed equivalents elsewhere have been recorded from the Ellsworth Mountains (79° S, 80° W) and along the Transantarctic Mountains and Shackleton Range, a long linear mountain chain on the western margin of Greater Antarctica. All these rocks are largely Cambrian in age (Laird, 1981).

The undeformed granitoid intrusions (with associated late shear zones) are likely to be mostly of Mid-Cretaceous age, as indicated by the ages previously obtained from some of these plutons in Palmer Land (Rex, 1976), and also from similar plutons throughout Graham Land (Pankhurst, 1982).

The gabbroid intrusions at Moore Point and Wade Point are unlikely to be related to the arc granitoids for two reasons. Firstly, intrusive margins suggest they are younger than the granitoids. Secondly, these basic rocks coincide with a steep linear magnetic and gravity anomaly, occurring on the eastern edge of, and lying parallel to, George VI Sound (Renner and others, 1985). This is part of a continuous belt of anomalies present along the length of the west coast of the Antarctic Peninsula (Renner and others, 1982), which has been related to crustal thinning and basic magmatism associated with Tertiary, intra-arc extension during cessation of subduction (Garrett and Storey, in press). The eastern margin of these anomalies coincides with the shear zones described above from the Traverse Mountains, Renner Peak area, and Pegasus Mountains, suggesting that these shear zones may be linked and related to gabbroid intrusion along George VI Sound. The remaining gabbroids, especially those farthest from George VI Sound (e.g. Canis Heights), are more likely to be the basic relatives of the more differentiated granitoids. Gabbroic relicts similar to the Canis Heights gabbro occur as pods in the banded migmatitic orthogneisses at the eastern side of the Orion Massif. Such field relationships suggest that basic rocks were involved in the formation of these gneisses. It is not yet known whether these relicts are related to the undeformed gabbros such as at Canis Heights, but it is possible that this undeformed material represents unmigmatized country rock older than, or contemporary with, the migmatitic orthogneisses.

The classification of the rock units in this paper is based on localities where the field relationships are well-exposed. Classifying isolated outcrops without field relationships is often speculative, especially where sheared rocks are concerned. Late shearing has been identified but such deformation has also taken place at other times in the region's history. This is particularly apparent in the metamorphic rocks and therefore an isolated outcrop of shear-banded gneiss could represent a late sheared granitoid or a sheared paragneiss with a complex metamorphic history.

Structural considerations are important in explaining the pattern of outcrop within the area. Tertiary rifting to form George VI Sound (see above), and block faulting throughout the area (Crabtree and others, 1985), have juxtaposed different structural levels on a local scale, for instance, the fault contacts between volcanic rocks and the banded migmatites. A more important feature is the contrasting lithologies in the metamorphic complex between the east and west sides of the study area. This may be explained by the presence of a major fault, parallel to George VI Sound, which follows a break in outcrop to the east of Mount Courtauld, Scorpio Peaks, and Mount Lepus. This region contains several glacially overdeepened troughs, probably produced by preferential erosion along a fault zone (Crabtree, 1981). Movement on this fault (either normal or strike–slip) may well account for the differences in outcrop geology. From the field evidence, the rocks along the western side of George VI Sound appear to represent a deeper structural level than those farther east. This may explain the local importance of the paragneisses, which are not seen in the migmatitic orthogneiss along the eastern side of the region.

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