REPORT ON ANTARCTIC FIELDWORK
THE GEOLOGY OF SOUTHERN OSCAR II COAST, GRAHAM LAND

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ABSTRACT. Southern Oscar II Coast is the only area in Graham Land where exposures of Palaeozoic basement rocks are known. Three types of basement rock are present; granitic *ortho*-gneiss, migmatitic banded gneiss and metasedimentary rocks. These are intruded and unconformably overlain respectively by undeformed plutonic and volcanic rocks of the Mesozoic magmatic arc suite. Eastward-dipping normal faulting and quartz-feldspar-porphyry dyke emplacement may also be related to the same magmatic episode.

INTRODUCTION

Prior to the break-up of Gondwanaland, the Antarctic Peninsula formed part of its Pacific margin (Dalziel and Elliot, 1982) and was probably located close to the region now forming the East Antarctic craton. Subduction of proto-Pacific oceanic crust, possibly beneath older crustal material, occurred along this margin during the late Palaeozoic and early Mesozoic, resulting in the formation of fore-arc, magmatic-arc and back-arc terranes. The Antarctic Peninsula block separated from the East Antarctic craton as a result of the break up of Gondwanaland which started in the early Mesozoic. Subduction beneath the Antarctic Peninsula block continued during this event. Upper Palaeozoic–Lower Mesozoic fore-arc and magmatic-arc terranes were thought to be preserved in the Antarctic Peninsula (Smellie, 1981), although they were largely obscured by intrusive and extrusive rocks of a later Mesozoic–Cenozoic magmatic arc. However, much of what had previously been supposed to be pre-Upper Palaeozoic sialic basement in the Antarctic Peninsula (e.g. Adie, 1954, 1972, 1977) has subsequently been shown to be of Mesozoic age (e.g. Rex, 1976; Gledhill and others, 1981; Pankhurst, 1982). Nevertheless, the interpretation of garnet xenocrysts in Mesozoic magmatic-arc rocks of Graham Land as being of lower crustal origin (Hamer and Moyes, 1982), and the presence of rocks with an isotopic indication of crustal history extending back into the early Palaeozoic (Pankhurst, 1983), pointed towards the existence of such a basement at depth. This hypothetical pre-Upper Palaeozoic basement has always figured as a major component in models for the evolution of the Antarctic Peninsula (e.g. Smellie, 1981; Dalziel and Elliot, 1982; Pankhurst, 1982; Dalziel, 1984; Storey and Garrett, 1985).

The purpose of this study was to examine an area on Oscar II Coast (Fig. 1) where Marsh (1968) had described exposures of 'metamorphic complex' rocks. These yielded Triassic K–Ar mineral ages (Rex, 1976) but isotopic work by Pankhurst (1983) suggested that they had a pre-Mesozoic history. First-hand study of any basement rock in the Antarctic Peninsula is important, especially with respect to its influence upon the geochemical evolution of the Mesozoic magmatic arc. The work described here was conducted by the author during two summer field seasons between 1984 and 1986.

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Previous Work

The first geological surveys of central east Graham Land were conducted by R. J. Adie in 1947 and A. J. Standring in 1953 (Adie, 1958. pp. 8–9). However, the existence of metamorphic rocks on the Oscar II Coast was not discovered until the first detailed mapping of this area was undertaken by A. F. Marsh in 1963–65 (Marsh, 1968). He grouped all regionally metamorphosed rocks into a 'metamorphic complex' and described sedimentary rocks which 'probably lie unconformably over metamorphic complex rocks'. Both these rock-types are intruded by plutonic rocks and overlain by volcanic rocks which he considered to range from Triassic to Tertiary in age. K–Ar dating of two metamorphic complex rocks yielded Triassic dates (Rex, 1976) which Marsh considered to be the time when the amphibolite facies regional metamorphism ended. The Oscar II Coast was revisited in 1977–78 by S. K. Longshaw, R. J. Pankhurst and A. D. Saunders as part of wide ranging programs of palaeomagnetic, geochronological and geochemical studies (e.g. Saunders and others, 1980; Pankhurst, 1982; Longshaw and Griffiths, 1983). Poorly constrained geochronological results obtained from metamorphic rocks from this area, showed that some of the rocks preserved an indication of a pre-Mesozoic crustal history (Pankhurst, 1983).

Lithology

The rocks of Oscar II Coast (Fig. 1) are divided into three groups: basement rocks, magmatic-arc rocks and hypabyssal rocks. The term basement rock is used here to include all rocks pre-dating those of the Mesozoic–Cenozoic magmatic arc. It includes both the 'metamorphic complex' and sedimentary rocks of Marsh (1968). Magmatic arc rocks include all undeformed volcanic and plutonic rocks.

Basement rocks

Three types of basement rock are exposed; granitic *ortho*-gneiss, migmatitic banded gneiss and metasedimentary rocks. In places (e.g. 15 km west of Target Hill) a gradation from granitic *ortho*-gneiss to migmatitic banded gneiss is present, but elsewhere the relationship of the migmatitic gneiss is not clear.

Granitic ortho-gneiss. The best exposures of granitic *ortho*-gneiss are at Target Hill, Marsh Spur and Mount Alibi (Fig. 1). Typically these rocks are very weakly foliated but locally the foliation may be strong. Preliminary point counts of a few thin sections indicate a range in composition from tonalite to granite. Recrystallization of quartz and feldspar defines the foliation, which may be accentuated by any phyllosilicates present. Intruding the *ortho*-gneiss are many concordant amphibolite sheets (Fig. 2). The amphibolites characteristically show a good foliation which may exhibit tight angular folds of up to 5 cm wavelength. This folding is not seen in the *ortho*-gneiss but it is thought that this is due to a lack of a fine-scale anisotropy in the *ortho*-gneiss. Preliminary Rb–Sr whole-rock isotopic study of eleven samples of the *ortho*-gneiss collected from northern Target Hill gives two sub-parallel lines indicating an age of approximately 400 Ma (I. L. Millar, pers. comm.) which is the oldest yet obtained from the Antarctic Peninsula. The initial ratio of the lower of the two lines is coincident with that of the mantle at 400 Ma (initial $^{87}Sr/^{86}Sr$ ratio of 0.7030 ± 0.0002) indicating no previous crustal history. If further work verifies this result then Target Hill must represent part of a basement to the Mesozoic magmatic arc of the Antarctic Peninsula which includes Lower Palaeozoic rocks.

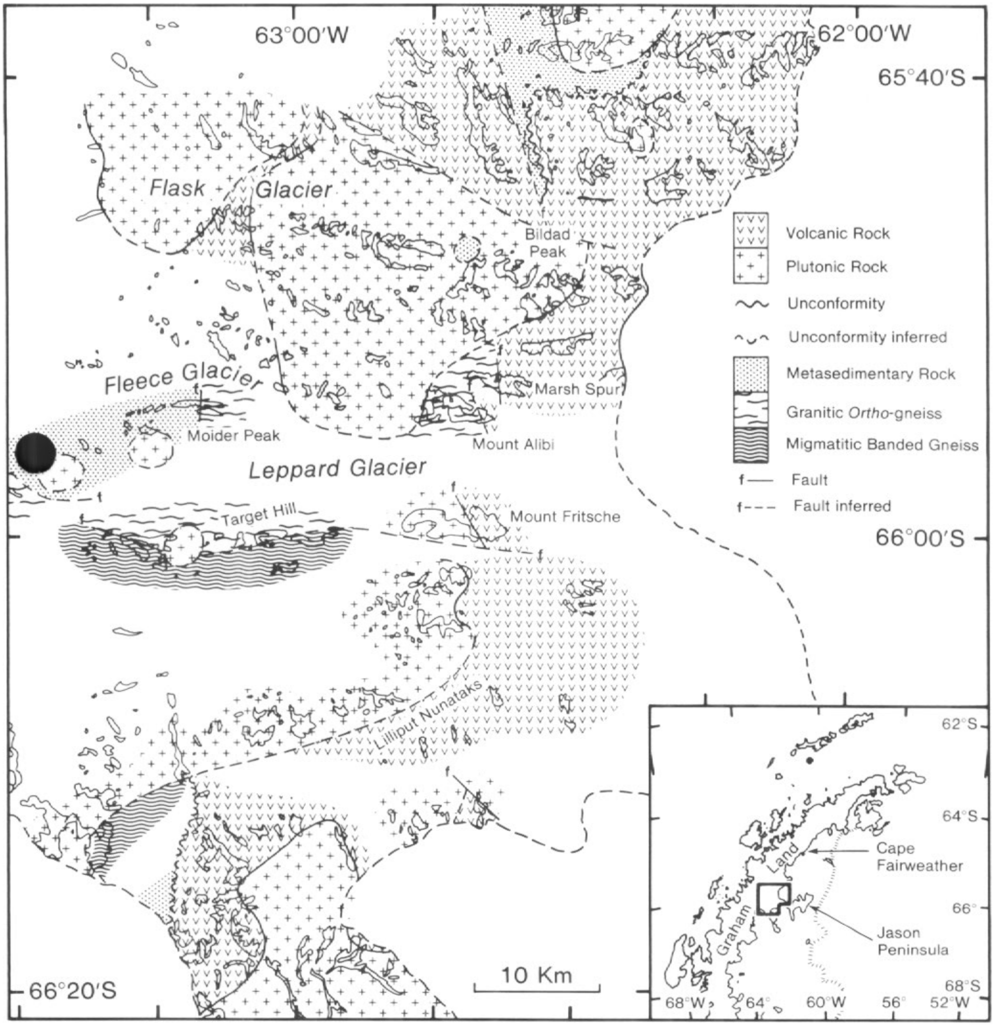

Fig. 1. Geological sketch map of southern Oscar II Coast.

Migmatitic banded gneiss is often present near granitic *ortho*-gneiss (Fig. 3). Banding is on the scale of 1 cm–1 m with the individual bands showing a wide range of composition. Leucocratic bands consist mainly of quartz and feldspar and may include significant proportions of biotite, muscovite or garnet. Melanocratic bands are generally biotite amphibolites. Two phases of folding are present in the banded migmatite. The first phase is of isoclinal folds with axial–planar cleavage; fold closures are rarely visible. Small (10 cm wavelength), upright, open folds are common. These were seen to deform an isoclinal fold at one outcrop and represent a second phase.

Metasedimentary rocks occur north of Flask Glacier and at Moider and Bildad peaks. They are unconformably overlain by Mesozoic volcanic rocks (Fig. 4) and the unconformity is cut by quartz-feldspar-porphyry dykes and by a north-east–south-west striking fault. They are also intruded by Mesozoic plutonic rocks. The metasedimentary rocks are unfossiliferous, mature, quartz-rich mudstones, siltstones

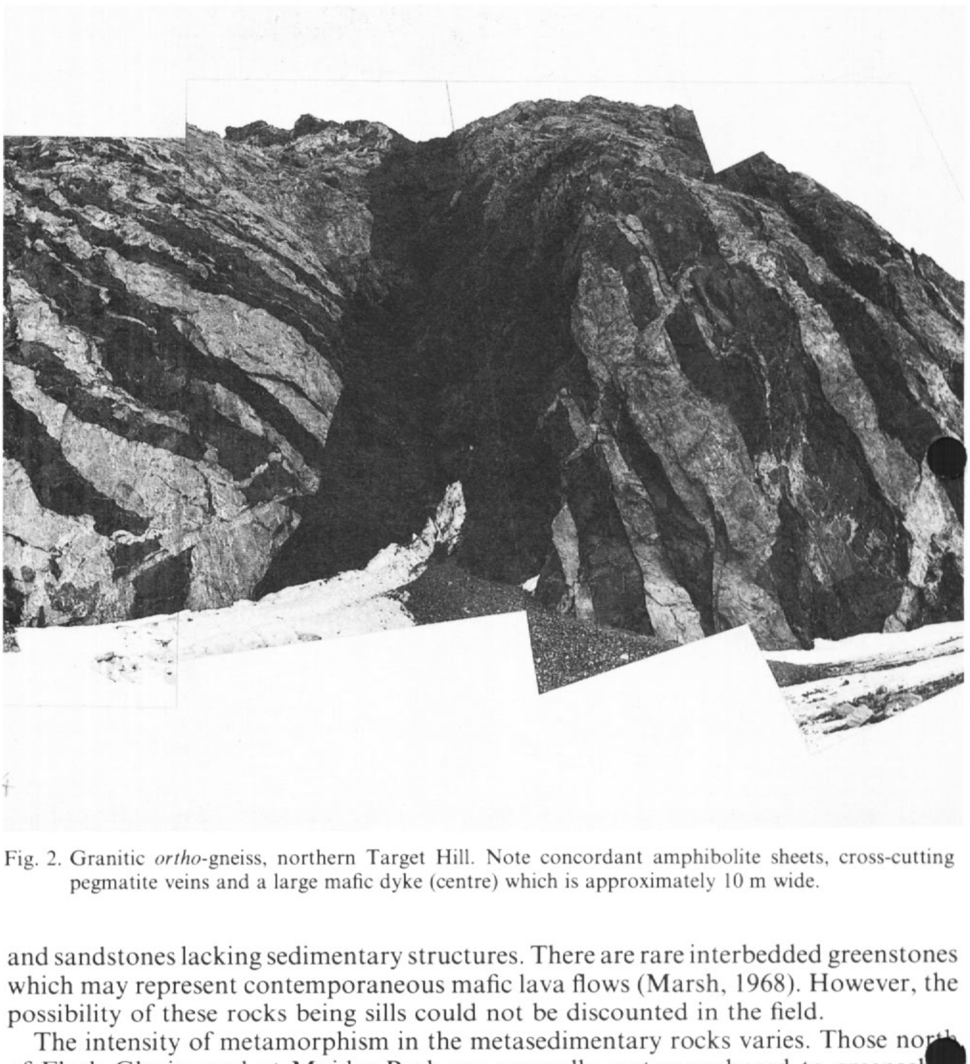

Fig. 2. Granitic *ortho*-gneiss, northern Target Hill. Note concordant amphibolite sheets, cross-cutting pegmatite veins and a large mafic dyke (centre) which is approximately 10 m wide.

and sandstones lacking sedimentary structures. There are rare interbedded greenstones which may represent contemporaneous mafic lava flows (Marsh, 1968). However, the possibility of these rocks being sills could not be discounted in the field.

The intensity of metamorphism in the metasedimentary rocks varies. Those north of Flask Glacier and at Moider Peak are generally metamorphosed to greenschist facies whereas those at Bildad Peak have reached amphibolite facies. In addition, intrusion of Jurassic plutons has contact-metamorphosed many occurrences of the metasedimentary rocks, which locally contain small porphyroblasts of garnet, andalusite and cordierite close to the intrusion (Fleet, 1968). Examples of a cordierite-andalusite-spinel hornfels were found as xenoliths in the intruding tonalite at Bildad Peak, although such a hornfels is not present as larger exposures.

The sedimentary rocks north of Flask Glacier are probably equivalent to Fleet's 'Jurassic sedimentary rocks' of the area around Stubb and Starbuck Glaciers but, whereas he suggested a conformable contact with the overlying Upper Jurassic Volcanic Group and no regional metamorphism, the field relations here indicate an unconformity. As Fig. 4 shows there is a discordant relationship between the bedding of the underlying metasedimentary rocks and the bedding of the volcanic conglomerates and tuffs.

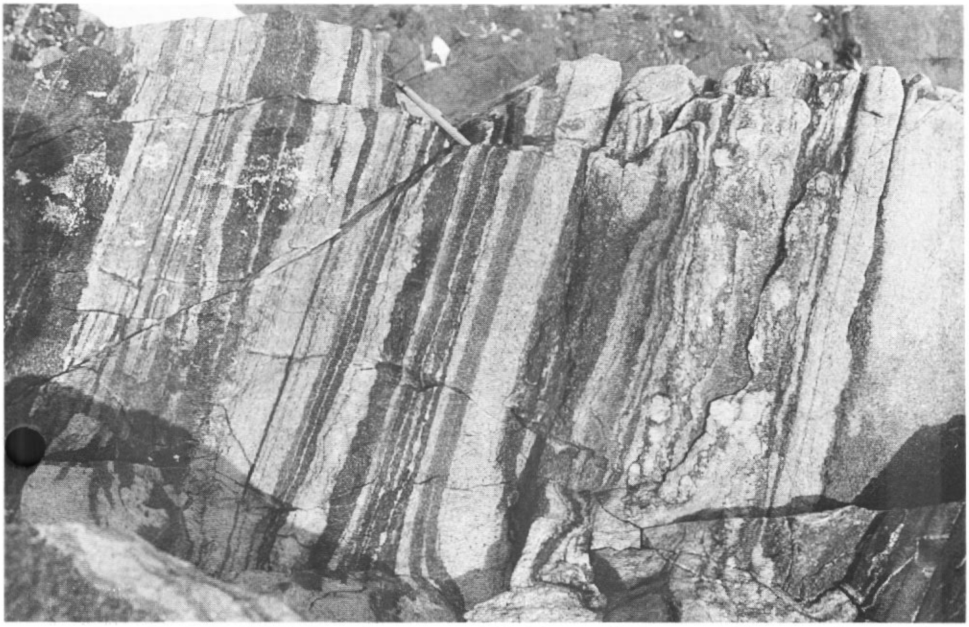

Fig. 3. Migmatitic banded gneiss, southern Target Hill. The pencil, (top centre) is approximately 10 cm long.

Mesozoic magmatic arc rocks

The most common rock-types on Oscar II Coast are acidic and intermediate plutonic and volcanic rocks. The plutonic rocks tend to be exposed inland and the volcanic rocks on the coast, perhaps because of the existence of eastward-dipping normal-faults (below) resulting in a deeper structural level being found towards the plateau.

Rb–Sr and K–Ar geochronology of magmatic arc rocks from Oscar II Coast suggests that the majority of the plutonic and volcanic rocks from this area were emplaced over a period of 25 Ma in the Jurassic but some Upper Cretaceous plutons are present also, mainly in the north (e.g. at Cape Fairweather, Pankhurst, 1982). The Jurassic plutonic rocks range in composition from tonalite to granite and the Cretaceous plutonic rocks are predominantly diorites and granites. The volcanic rocks are mainly sub-aerial pyroclastic rocks of dacitic-rhyolitic composition but subordinate lava flows and agglomerates also occur. Some fragments of poorly preserved fossil wood were found in the tuffs at Lilliput Nunataks.

Hypabyssal rocks

Two main types of dyke occur on southern Oscar II Coast: quartz-feldspar-porphyry dykes and basaltic dykes. Fleet (1968) suggested that the porphyry dykes are closely related to the Jurassic magmatic arc rocks, possibly feeding extrusive rocks from a granitic magma chamber. There is a tendency for these dykes to be emplaced along faulted contacts (e.g. at Marsh Spur), however, they show no consistent preferred orientation.

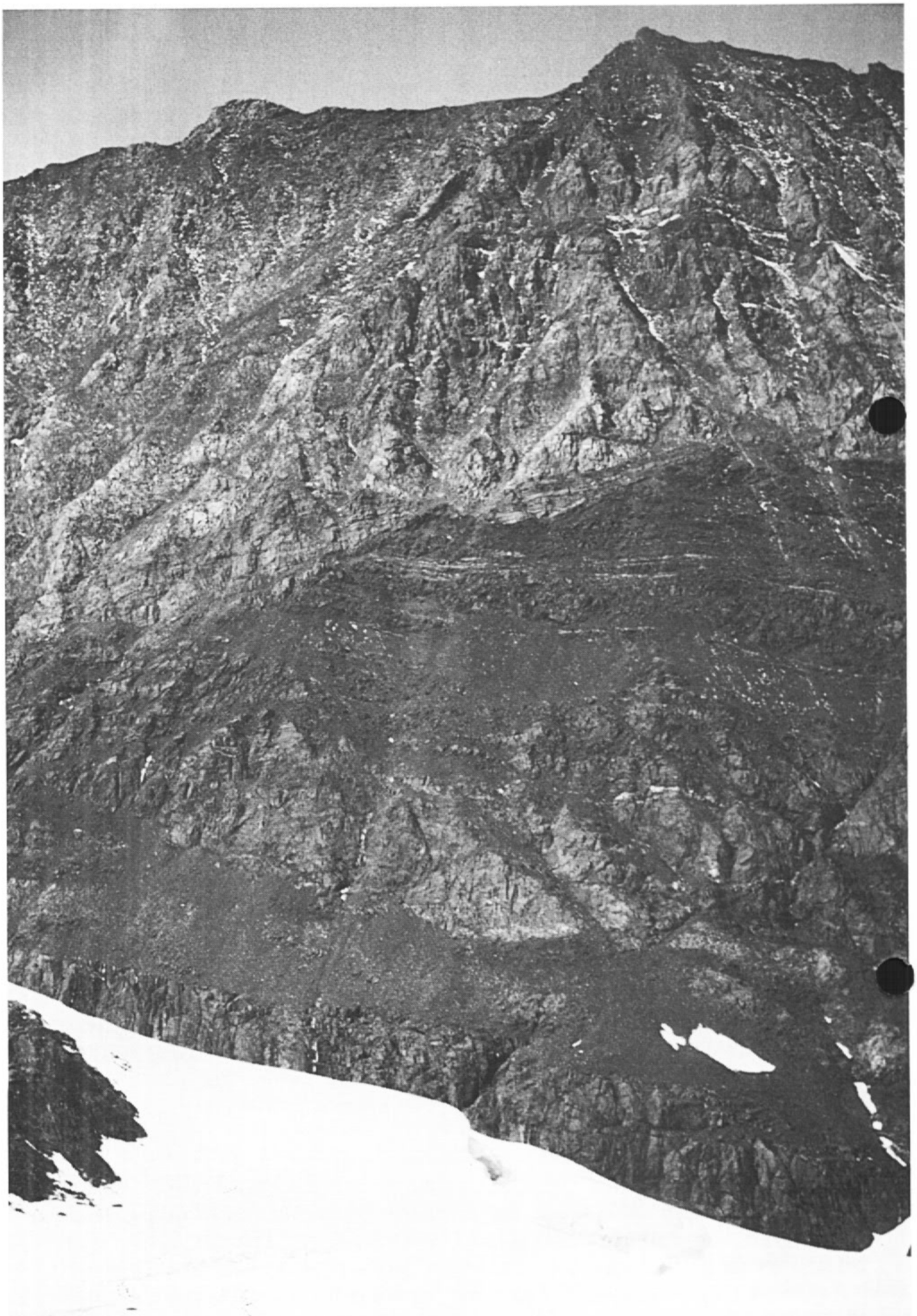

Fig. 4. Mesozoic volcanic rocks (pale-coloured) unconformably overlying dark-coloured metasedimentary rocks north of Flask Glacier.

The basaltic dykes are ubiquitous and cut all the lithologies on Oscar II Coast. They tend to be thin (< 2 m), close to vertical and have a dominant north-east–south-west strike (Fig. 5).

Other hypabyssal rocks include a gabbroic dyke at Mount Alibi and a coarse amphibole-rich mafic sill east of Fleece Glacier. Pegmatite veins up to 1 m wide which may be of Jurassic age cut the *ortho*-gneiss and amphibolite sheets in the basement rocks (Fig. 2).

Structure

In the basement rocks there is a significant amount of deformation. The migmatitic banded gneiss exhibits two phases of folding; early isoclinal folds and later upright open folds. The orientation of the later folding shows local consistency but does not display a simple structure over the whole area. The *ortho*-gneiss and amphibolite sheets show less obvious deformation but may well have been subjected to the same stresses. It is possible that the migmatitic banded gneiss and the granitic *ortho*-gneiss are genetically related and that the migmatites are just a deeper structural counterpart of the granitic gneisses. There is only a minor amount of deformation in the magmatic-arc rocks; gentle folding of large wavelength (> 500 m) is seen in the volcanic rocks of the coastal nunataks and microshears occur mainly in the plutonic rocks. It is thought that both the shearing and folding are due to emplacement of the plutonic rocks. The emplacement of a large volume of magma in a position corresponding to the present-day eastern edge of the plateau may also be responsible for eastward-dipping normal faulting. Exposure of these faults is very poor but two major north-west–south-east trending faults are present at Marsh Spur and Mount Fritsche.

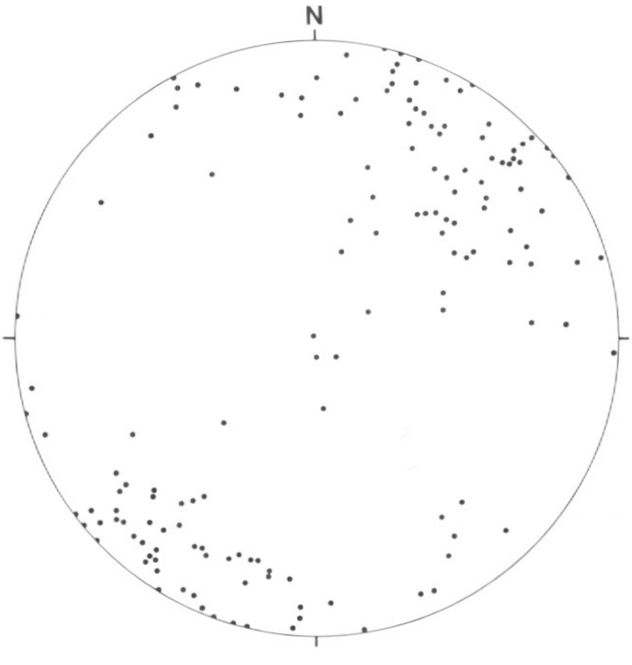

Fig. 5. Poles to 140 basaltic dykes plotted on the lower hemisphere of an equal-area projection.

At Marsh Spur where there is a faulted contact between *ortho*-gneiss to the west and volcanic rocks to the east, there is deformation of the *ortho*-gneiss associated with the fault. This fault, which downthrows to the east, has produced westward-verging folds in the *ortho*-gneiss and the deformation in the *ortho*-gneiss is at its most intense adjacent to the fault, becoming weaker to the west. Here there is a quartz-feldspar-porphyry dyke emplaced along the faulted contact. It is thought that the faulting and porphyry dyke intrusion were synchronous with the emplacement of the plutonic and volcanic rocks during the Jurassic. A similar style of deformation occurs at Moider Peak where a vertical faulted contact between the metasedimentary rocks and *ortho*-gneiss is exposed. In the vicinity of the fault both lithologies are intensely sheared and there is a 50-cm wide zone of folded gneiss at the contact. The sense of displacement of this fault is not known. As Fig. 5 shows there is a general north-east–south-west trend for the orientation of the basaltic dykes. With the exception of late Cenozoic olivine basalts on Jason Peninsula (Saunders, 1982), these dykes are the youngest rocks in the area. There are many throughout Oscar II Coast and they indicate a period of significant crustal extension but at present these dykes have not been dated so it is not yet possible to tell when this extension took place.

Discussion

The area studied has a geological history extending back into the mid-Palaeozoic. At that time the precursor to the Antarctic Peninsula was attached to Gondwanaland probably close to the 'Pacific' margin of East Antarctica. The tectonic setting of the granitic *ortho*-gneiss and banded migmatitic gneiss is not known but it is expected that planned geochemical analyses of the collected samples will shed some light on this. The gneisses may represent magmatic arc granitic rocks emplaced beneath a subduction-related arc. Assimilation of material by some of the parent magma at the time of emplacement could explain the different initial ratios of the two parallel lines which indicate an age of 400 Ma. The age of the metasedimentary rocks is unconstrained but must be greater than Middle Jurassic. Their provenance is unknown but there are indications of contemporaneous volcanicity. As mentioned above, these may be equivalent to Fleet's so-called Jurassic sedimentary rocks but they are certainly pre-Middle Jurassic in age and could be considerably older. The Upper Palaeozoic–Triassic Trinity Peninsula Group, which crops out extensively north of lat. 65° 30′ S, is a possible correlative but the maturity of the Oscar II Coast metasedimentary rocks compared with the Trinity Peninsula Group suggests that they are unrelated. When the Antarctic Peninsula began to separate from Gondwanaland in the latest Palaeozoic, the magmatic activity increased significantly and the emplacement of a large volume of magma beneath the peninsula could have been an important element in the uplift and related normal faulting.

During the early Mesozoic, intense volcanic and plutonic activity formed the majority of the rocks exposed on Oscar II Coast. The intensity of the magmatism in this area declined towards the end of the Mesozoic. The basaltic dykes were emplaced after the main magmatic episode, possibly in the Tertiary.

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