THE GEOLOGY OF HORSESHOE AND LAGOTELLERIE ISLANDS, MARGUERITE BAY, GRAHAM LAND

By D. W. MATTHEWS

ABSTRACT. The results are presented of geological mapping of Horseshoe and Lagotellerie Islands at a scale of 1 : 25 000. A basal metamorphic complex is represented by both *ortho*- and *para*gneisses. Heterogeneous granites with occasionally a weak foliation are thought to belong to an early suite cut by a volcanic agglomerate. Varied arenaceous sediments may form a base to the main volcanic succession of tuffs, agglomerates and lavas, but volcanic rocks are not very extensive. Intercalated shales on Lagotellerie Island contain Jurassic plant remains. Andean plutonic types are abundant, the southern half of Horseshoe Island being largely Andean granite. The north-western part shows an arcuate arrangement of successive gabbro and granite intrusions, some of which show signs of copper and iron mineralization. A major shear zone of uncertain age is thought to intersect the centre of the island.

HORSESHOE ISLAND (lat. 67°51′S, long. 67°12′W) is one of the larger islands of northern Marguerite Bay and is situated in the entrance of Bourgeois Fjord (Fig. 1). It is surrounded on three sides by land higher than itself, only the western side being open to the sea. Lagotellerie Island is a small mountainous islet 4 km off the south-west corner of Horseshoe Island.

Many geologists have visited Horseshoe Island since 1937 when the British Graham Land Expedition first explored the area. From 1955 to 1960 a station situated on the north-west coast was manned by the Falkland Islands Dependencies Survey and detailed geological and topographical surveys were carried out. There is, however, very little published geological information on the area.

A re-examination of the whole area was carried out by the writer in 1965 and 1966. Geological mapping was based on the 1 : 25 000 topographical sheet available and some of the unpublished notes of earlier workers have been consulted for detailed information on certain localities. Due acknowledgement of these instances is made.

There are very marked topographic differences between the two halves into which Horseshoe Island is naturally divided. The northern part consists mainly of low-lying rocky subdued

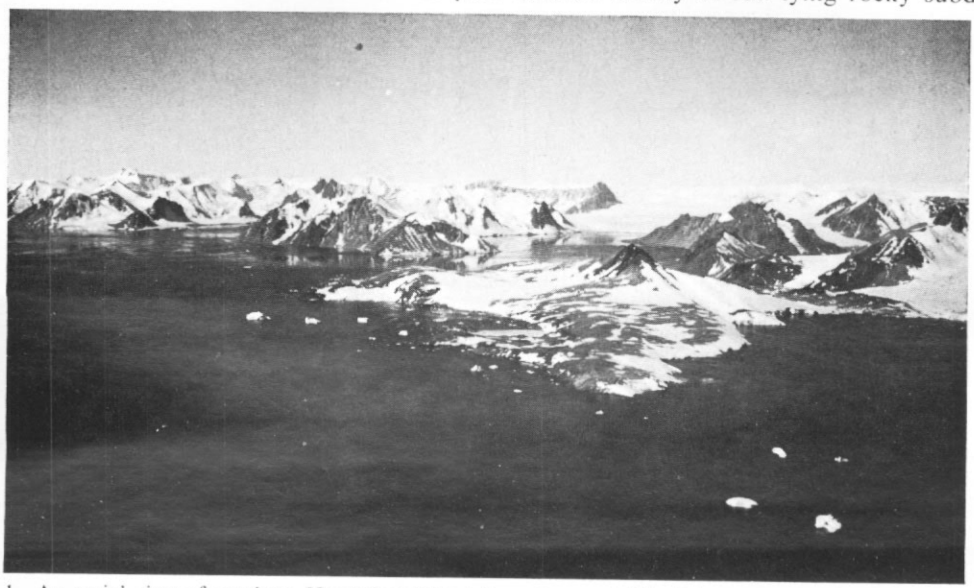

Fig. 1. An aerial view of northern Horseshoe Island from the west. The isthmus area and Mane Skerry are near the right-hand edge.

topography (Fig. 1), relieved only by the isolated nunatak-like peak of Mount Searle rising to 1 761 ft [537 m]. There is an unusually high proportion of exposed rock, especially in the tract of country between Sally Cove and Beacon Head, where fresh-water lakes and pebble terraces are found, the latter at several levels between 5 and 50 m above present mean sea-level. Active glacierization is confined to the southern slopes of Mount Searle.

The south-western part of the island consists of a range of peaks up to 2 881 ft [878 m] at the highest point on Mount Breaker. The south side of this range is extensively glacierized with almost unbroken ice cliffs along the south-western coast line. One short glacier (Shoesmith Glacier) flows north from a low point in the centre of the range and bifurcates into two snouts, one stagnant branch to the east ending in land-locked Gaul Cove and the other more active branch calving into Lystad Bay to the west; the sub-ice topography of this glacier is known (Smith, 1973*a*). East of Shoesmith Glacier, the mountains are more snow-free. Spincloud Heights and Russett Pikes are separated by virtually stagnant valley glaciers and one fresh-water lake with shelving rock and shingle foreshores on the south-east corner of Horseshoe Island adjacent to Reluctant Island.

The two halves of Horseshoe Island are separated by a low-lying isthmus 1.5 km wide between Gaul Cove and Lystad Bay with small rocky knolls and several fresh-water lakes. Smith (1973*a*, *b*) has shown that there is no marine channel beneath the Shoesmith Glacier snout.

Lagotellerie Island is a steep-sided rocky island rising to 947 m and is directly in line with the main mountain range of south-western Horseshoe Island. Its isolation may be due to some intervening geological structure, since there is no evidence of erosion due to north–south glaciation in this area.

Glacial striations are dominantly east–west and the northern half of Horseshoe Island is situated almost directly in line with Forbes Glacier, a major glacier descending straight from the mainland plateau of Graham Land approximately 24 km to the east. It seems probable that in times of heavier glaciation Forbes Glacier may well have flowed right over the northern and central parts of Horseshoe Island with only the top few hundred metres of Mount Searle later exposed as a small nunatak.

TABLE I. THE STRATIGRAPHY OF HORSESHOE AND LAGOTELLERIE ISLANDS

Hypabyssal rocks	Acid, basic and composite dykes	
Andean plutonic suite	"Diorite complex"	
	Gabbro	Northern
	Granite	Horseshoe
	Gabbro	Island
	Granite, granodiorite and diorite	
Hypabyssal rocks	Basic dykes	
Antarctic Peninsula Volcanic Group	Tuffs, agglomerates and andesitic lavas	
	— ? — ? — ? — ? —	
?	Sediments, partly volcanogenic	
"Older" plutonic suite	Granites	
Antarctic Peninsula metamorphic complex	Banded *para*gneisses	
	— ? — ? — ? — ? —	
	Foliated granite-gneiss	

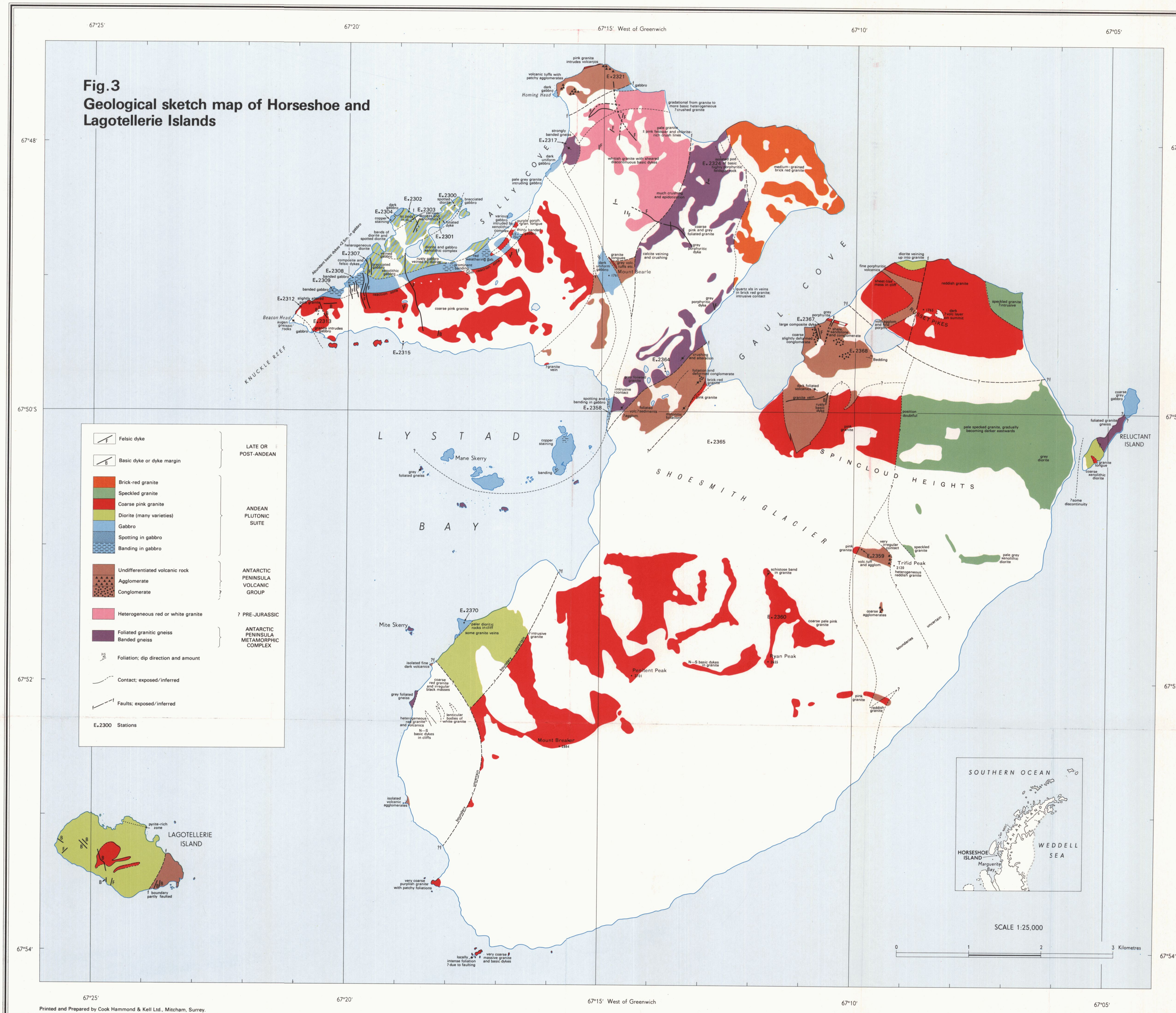

Fig.3
Geological sketch map of Horseshoe and Lagotellerie Islands

Printed and Prepared by Cook Hammond & Kell Ltd., Mitcham, Surrey.
Based upon D.O.S. 310

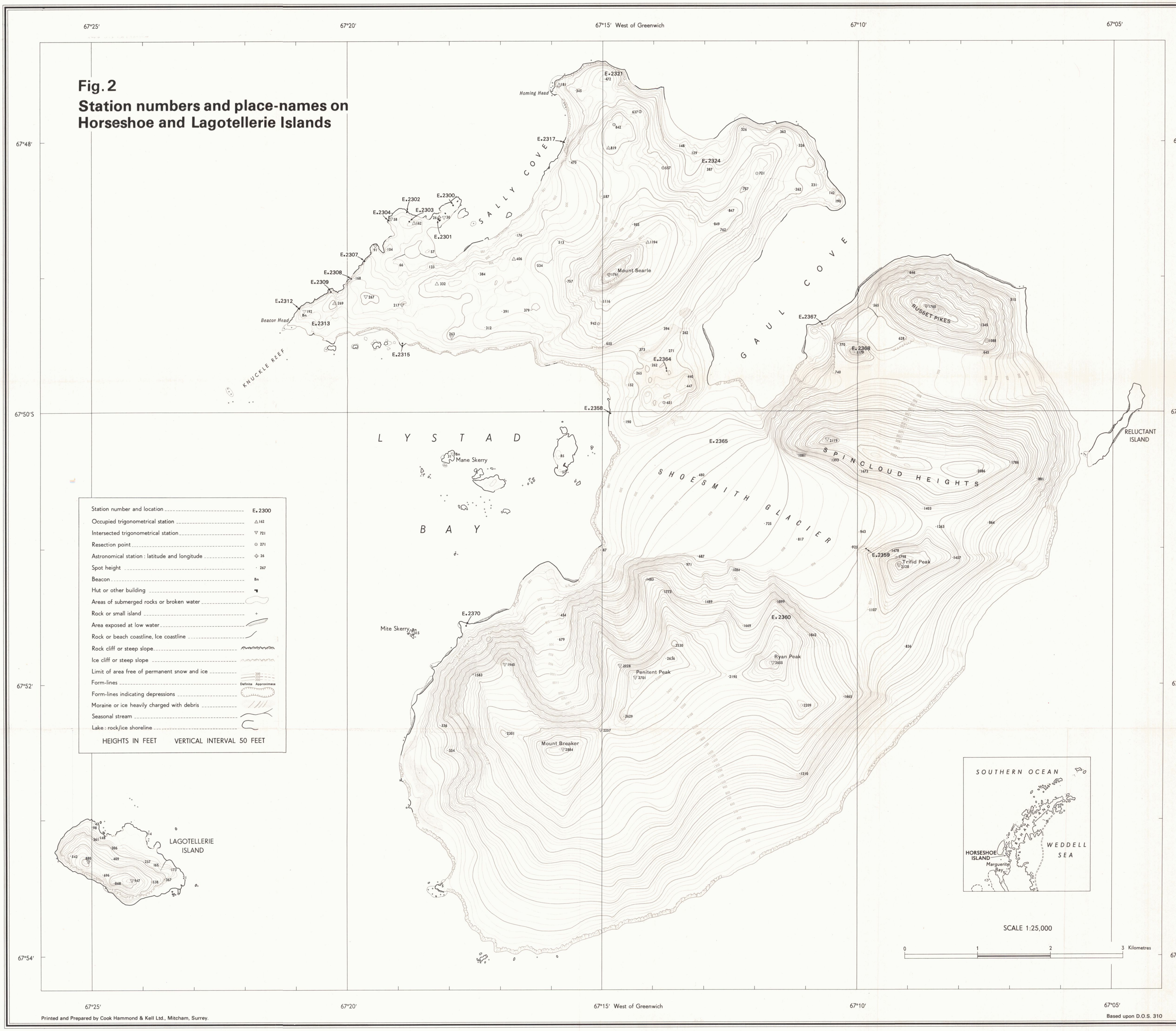

Fig. 2
Station numbers and place-names on Horseshoe and Lagotellerie Islands

Stratigraphy

The geology of Horseshoe Island is complex and varied, and in several places relationships appear ambiguous. It is fortunate that some areas of greater complexity occur in the well-exposed northern half of the island and on Lagotellerie Island. Most of the southern half of Horseshoe Island consists of massive granites. The varying complexity shown on the map (Figs 2 and 3) is, however, partly a reflection of this difference in degree of exposure, especially when concerned with the occurrence of dykes of mappable size.

The main rock groups and their relative ages, where known, are shown in Table I.

No palaeontological evidence has been found on Horseshoe Island for the age of any of the rock groups and the only absolute age determination which has so far been made on any of the igneous rocks is one of an "Andean" dyke by Grikurov and others (1966) which indicated 86 Ma (recalculated to $\lambda_e = 0.584 \times 10^{-10}$ year^{-1} and $\lambda_\beta = 4.72 \times 10^{-10}$ year^{-1}). The age relations of most of the groups are, however, demonstrable in the field and some correlation is possible with published descriptions of other parts of Graham Land and of the Loubet and Fallières Coasts in particular. The use of the term Andean is in accordance with general practice in Graham Land and implies a Cretaceous to early Tertiary age (e.g. Craddock, 1971; Rex, 1976).

Antarctic Peninsula Metamorphic Complex

No clear definition of the "Basement Complex" as a rock group was given by Adie (1954, 1962) but Hoskins (1963, p. 5), in his study of the Neny Fjord area about 55 km south of Horseshoe Island, gave his definition as "the group of high grade metamorphic rocks which are older than the (?) early Palaeozoic intrusive rocks . . .". On Horseshoe Island, there is some evidence to support the age distinction but none to justify the use of the term "high grade" and none yet to throw any light on the absolute age of the rocks.

Gledhill and others (1982) have proposed establishing the status of the metamorphic complex as a gneissic terrain of Gondwanian age with, as yet, no radiometric evidence of any pre-Gondwanian event detected in gneisses from the Marguerite Bay area of Graham Land. In accordance with current usage, the obviously metamorphosed and often gneissic rocks of Horseshoe Island are referred to the metamorphic complex without any positive evidence for their age and without any demonstrable internal age relationships between the differing types.

Gneissose metamorphic rocks are common to the east of Horseshoe Island, in Square Bay and Bourgeois Fjord, and there are two major and several minor isolated occurrences on Horseshoe Island itself.

Sally Cove

The prominent cliffs, approximately 900 m south of Homing Head and overlooking Sally Cove, are conspicuously gneissic (Fig. 4) with alternating white feldspathic and dark green or black bands, from 0.5 cm to 1 or 2 m thick, and containing variably developed augen of white feldspar. The pronounced banding is vertical, striking north-west, but it is dislocated over distances of several metres by many small-scale faults. No contacts are exposed, though the gneiss is veined and intruded by unfoliated granite at the top of the cliffs at station E.2317, and fragments of a very similar banded lithology are seen in the Homing Head volcanic agglomerates close by.

In thin section, quartz and feldspar form the bulk of the gneiss, and chlorite and greenish brown biotite are subordinate, occurring in clots and intergranular streaks which sometimes impart a poor schistosity to the rock. Streaks and lenticles of coarse-grained quartz mosaic lie parallel to the banding with the individual grains in the mosaic only slightly strained and

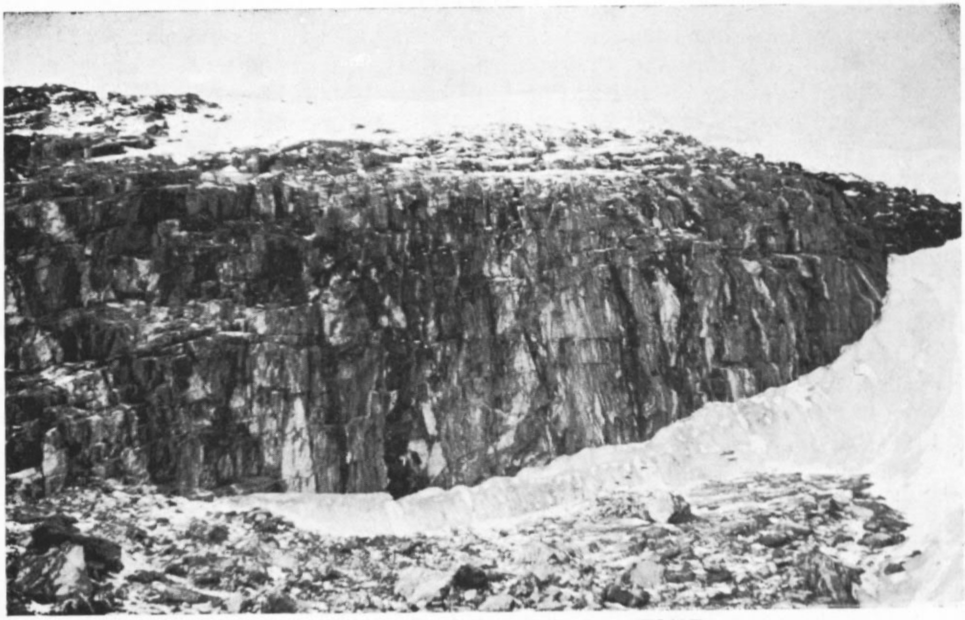

Fig. 4. Banded gneisses at Sally Cove (E2417).

sutured. Plagioclase (An_{20-30}) forms medium to large (up to 5 mm) irregular crystals which enclose granular quartz and some biotite. It is unzoned but moderately or heavily altered and clouded with twin planes occasionally bent and fractured. Potash feldspar also is common as medium and large (up to 10 mm) rounded crystals, some of which show characteristic microcline twinning. It is cloudy with alteration and generally has few inclusions but it encloses some small quartz granules. Planes of finely granular unclouded feldspar in the larger crystals of both feldspars indicate incipient recrystallization.

East side of Mount Searle

Quite different in character, the more extensive of the two occurrences of "Basement Complex" rocks on Horseshoe Island occupies a tract of country extending from north of station E.2324, across the north-east shoulder of Mount Searle to the eastern shore of Lystad Bay, with a probable continuation in the foliated granitic rocks of the southern half of Mane Skerry, in Mite Skerry and in isolated outcrops on the shore below Mount Breaker. These rocks are mainly granitic, pink or grey and coarse-grained in appearance with a vertical foliation striking mainly north-east, which is extremely weak in places but becomes slightly stronger and more pronounced in the Lystad Bay area. An isolated outcrop of similar rocks occurs at the very tip of Beacon Head, where the vertical foliation strikes north-west. The margins of most of this tract are poorly exposed but "gneisses" are intruded by vuggy brick-red granite on the slopes north of Gaul Cove and by dark banded gabbro on the east coast of Lystad Bay. Extensive crushing, brecciation, chloritization and calcite-veining against volcanic rocks on the north-east shoulder of Mount Searle indicate a probable faulted contact against volcanic rocks to the west and against granite to the north-west (see below). A poorly exposed contact on the south side of these foliated rocks, above the west shore of Gaul Cove, is against black schistose sediments of uncertain affinities. This is discussed further below but the isthmus area is one in which major faulting is suspected and the granitic "gneisses" become locally more strongly foliated and heterogeneous than normal.

In this section, the foliated granites show a simple and somewhat monotonous mineralogy. They are essentially quartz-feldspar rocks with plagioclase either absent or subordinate in amount to potash feldspar. Quartz is present in irregular bands and lenticles parallel to the foliation, consisting of a mosaic of virtually unstrained grains or as fine granules adjacent to or enclosed by the large feldspar crystals. All feldspar crystals are heavily clouded with extremely fine-grained alteration products and so are difficult to determine. Most are large, usually untwinned orthoclase, sometimes strained or inhomogeneous, and occasionally showing traces of perthite. A conspicuous feature of these feldspars is the presence of trails of very fine unclouded feldspar granules which cut through and surround the large orthoclase crystals, and which probably represent an early stage of recrystallization of the clouded and strained crystals. There is no evidence that they represent additional metasomatic potash feldspar. There are no primary ferromagnesian minerals other than a little dark bluish green hornblende in grey foliated granite from Mane Skerry but aggregates of chlorite and an opaque mineral, which probably originated as a ferromagnesian phase prior to metamorphism, commonly impart a foliation to the rock. Epidote is a common accessory and large pleochroic crystals of allanite were recorded in the Mane Skerry rocks.

Microscopic examination of these foliated granites has shown that there are no recognizable relics of primary igneous or sedimentary features or of previous high-grade metamorphism. The assemblages indicate that since the last deformation, which presumably gave the rock its weak foliation, recrystallization under quiescent conditions has permitted the quartz to develop an unstrained mosaic that is close to equilibrium and the potash feldspar to recrystallize to a strain-free and unclouded mosaic.

Neither of the rock types described above can be compared closely with "Basement Complex" lithologies described by Hoskins (1963) and others, and assigned in part at least to a Mesozoic age by Dalziel and Elliot (1973). The Sally Cove banded gneisses in particular are unlike other metamorphic complex types seen by the writer in adjacent areas. The gneissic granites, on the other hand, have an undistinguished lithology, comparable with several other occurrences in Marguerite Bay, but they show deformation and metamorphism much less intense than might be expected. There is a possibility, though an unlikely one, that the foliated granites

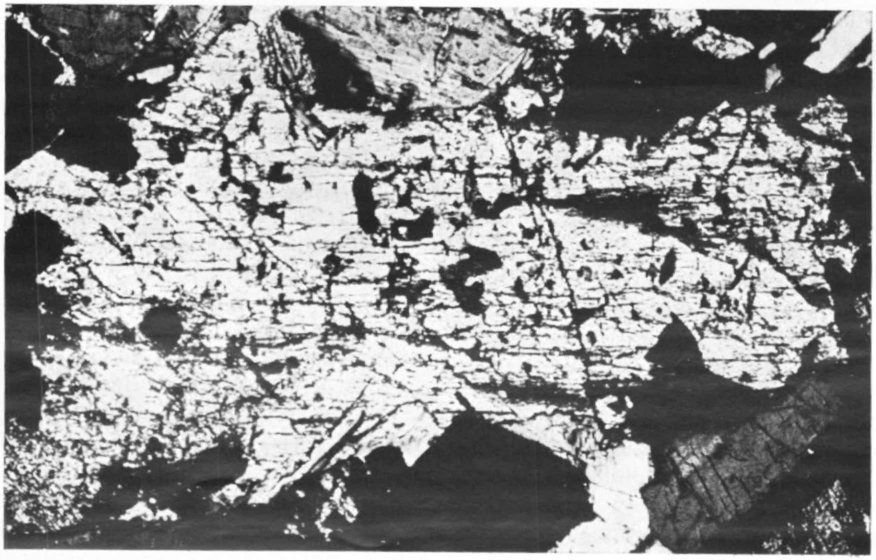

Fig. 5. Photomicrograph of hornblende blebs in clinopyroxene. (Scale 1 cm = 0.1 mm approx.)

are more akin to the "? early Palaeozoic" rocks of the Loubet Coast (Goldring, 1962) and this problem is discussed further below. It is also possible that, of the two very dissimilar rock groups described, the foliated granites are younger and that the banded gneisses of Sally Cove belong to a genuine metamorphic basement of possible pre-Mesozoic age (Dalziel and Elliot, 1973; Gledhill and others (1982).

One additional minor group of rocks must be mentioned in this section, though its affinities are by no means certain. It occurs in isolated outcrops within the foliated granite at station E.2324 and has no exposed relationships to other rock types. The rocks are unfoliated, mainly dark grey and of igneous aspect, varying from medium to coarse grain, and with sheet-like bodies of an extremely coarse-grained highly porphyritic lithology. There are no other comparable occurrences on Horseshoe Island but superficially similar rocks have been found on Pourquoi Pas Island in a very different setting and with clearer "Andean" affinities. In thin section, their texture is more igneous than metamorphic and they consist essentially of plagioclase and green-brown hornblende, plagioclase being the coarsely porphyritic phase. These are almost certainly Andean magmatic rocks but their position as small masses within foliated granites is unexplained.

"Older" Plutonic Suite

A variety of plutonic rocks is grouped under this proposed heading. There is little direct evidence on Horseshoe Island for their age but they have certain similarities among themselves and with rocks described from elsewhere in Graham Land (Adie, 1954; Goldring, 1962; Rowe, 1973). In general, they are unfoliated and are therefore assumed to be younger than the metamorphic complex rocks described above but they have an altered and heterogeneous appearance, and are more affected by major and minor faulting and disruption than are the normal Andean intrusive rocks. They are visibly intruded by Andean granite and probably intrude the Sally Cove gneisses described above. These plutonic rocks appear to be older than the volcanic rocks (which by analogy are believed to be Upper Jurassic on Horseshoe Island), although the evidence for this is not entirely unambiguous.

An "early Palaeozoic" age was inferred by Adie (1954) for his rock types "white granite" and "coarse pink granite" from the Fallières Coast, based on the limited evidence that they are (a) younger than "Basement Complex" and (b) older than "Jurassic volcanics", as well as on petrographic differences between them and normal Andean granites. Subsequent workers (Goldring, 1962; Curtis, 1966) have not always agreed with the possibility of a petrographic distinction and the field evidence has remained largely unsubstantiated but Goldring (1962), in particular, has described a whole suite of plutonic rocks from the Orford Cliff area of the Loubet Coast which field evidence shows to be earlier than "Jurassic" volcanic rocks and which Adie (1964) has correlated with his Marguerite Bay types. Although some similarity exists between rocks of the Orford Cliff suite and the Marguerite Bay "early Palaeozoic" types, the former have undergone intensive deformation with recrystallization of many minerals, so that some are termed gneissose and foliated granites. It is not clear to what extent this cataclastic deformation of the Orford Cliff suite can be considered a local phenomenon but, since Goldring suggested their possible emplacement at a late stage of a folding and metamorphism such as the Trinity Peninsula Formation must have undergone, he must presumably have considered the cataclasis of the Orford Cliff suite to be of regional significance. In terms of modern geochronology, the Orford Cliff suite might therefore be late Gondwanian (Dalziel and Elliot, 1973), involved in the final stages of a dying orogeny. In this case, the Horseshoe Island rocks would, by comparison, be younger and post-orogenic. Attempts so far to date Marguerite Bay examples have proved inconclusive, although a Cretaceous age is indicated for the type coarse pink granite (Adie, 1964) from the Debenham Islands (Gledhill and others, 1982). Grikurov and others (1966), for example, suggested that the status of these rocks is still uncertain. Since the problem of "mixed" ages for

metamorphic complex rocks is an accepted fact of Antarctic Peninsula geochronology, the same partial re-setting of K-Ar ages by Andean plutonism would also affect rocks of any pre-Andean suite. The problem therefore remains unresolved but there is no doubt that some of the earlier evidence offered in favour of the existence of this suite is very ambiguous, particularly that of purely petrographic and visual similarities (West, 1974).

On Horseshoe Island there are three areas in which the suspected "older" plutonic rocks occur.

Mount Searle to Homing Head

Considering first the large tract of granite covering the northern slopes of Mount Searle towards Homing Head, this is mainly a medium-grained white, pale grey or pink rock often speckled with pink feldspar and cut by numerous small discontinuous basic "dykes" and thin yellow and black crush lines and stringers. The dominant trend of these features is north to north-west. The spotting by pink feldspar appears to increase in amount towards the south-east where foliated granites occur, though there is no clear reason for this.

To the north, no contact is exposed against the volcanic rocks of the Homing Head area but a major topographic depression follows the line of the contact with abundant evidence of crushing and alteration of the granite, and some induration and quartz veining of the volcanic rocks. It seems probable that this is a major fault. Towards this fault, the granite becomes darker and greenish in colour due to alteration, giving the false appearance of becoming a more basic rock type.

To the north-west, the granite appears intrusive against the banded gneisses overlooking Sally Cove but its margins are not exposed to the west against gabbro or Beacon Head granite (see below) due to the large icefield covering much of the northern slopes of Mount Searle. To the south-east, there is another long topographic depression following a major fault against foliated granite of the metamorphic complex with extensive crushing, chloritization and epidotization on both sides. Against the volcanic rocks of Mount Searle, the contact is less certain, being mainly obscured by scree, but again it is thought to be faulted.

In thin section, this granite is a very variable heterogeneous rock. It is essentially a two-feldspar granodiorite, both of the feldspars being heavily clouded and obscured by alteration products. Sodic plagioclase is dominant over orthoclase and quartz is present in only minor quantities. The main ferromagnesian mineral is chlorite, usually containing granules of iron oxide. A pale green hornblende is present in some thin sections but it shows little or no sign of altering to chlorite; in preference, it is recrystallized marginally to small patches of fine-grained acicular colourless amphibole. Granular epidote is common throughout the rock and is, presumably, an alteration product; it is occasionally concentrated in individual large plagioclase crystals and may obscure as much as 50% of the host crystal. Although some epidote may be derived from the break-down of the anorthite molecule in the plagioclase, it seems unlikely that the original plagioclase of the granodiorite was sufficiently calcic to have formed all its enclosed epidote. Much must therefore have been derived from the break-down of ferromagnesian minerals in the rock. Throughout the granodiorite, feldspar grains are cracked and distorted, and in crush lines irregular fragments of quartz and feldspar are enclosed in streaks of very fine-grained mylonitized (?) volcanic material. The discontinuous basic "dykes" mentioned above have been much involved in the crushing and have perhaps been dislocated by the same forces; where discernible, the basic material seems to have chilled against the granodiorite. In the vicinity of the small gabbro wedge near station E.2321, there is recrystallization of the granodiorite with the development of a most spectacular intergrowth of potash feldspar and quartz; there are also a number of small dark xenoliths but the origin of these is unknown.

Mount Breaker

The second major area of suspected "older" plutonic rocks covers the western side of Mount Breaker, much of which is accessible only with difficulty. The rock here is a reddish heterogeneous granite, very friable and heavily weathered, which in places shows a faint and irregular foliation. It also shows a large number of irregular, often dyke-like masses of dark fine-grained volcanic rock with a dominantly north–south trend. High up on the west face of Mount Breaker are several conspicuous lenticular masses, several hundred metres long, of a coarse white granite; these lenticles also have a north–south trend. This white granite is even more heavily weathered than the country rock and no exposed contact was found in accessible parts of the cliff; its origin, therefore, remains uncertain. This rock type appears to be unique in this occurrence, nothing comparable having been seen elsewhere in northern Marguerite Bay. The country-rock granite is greatly affected by faulting and the lenticles of white granite could have been faulted in; equally, they could be magmatic inclusions stoped off the roof of some original granite intrusion. Neither explanation accounts for the apparent absence of similar rocks in surrounding areas.

In thin section, these granites show a high degree of alteration, with some recrystallization. The country-rock granite is reddish and consists of a strain-free mosaic of quartz with large heavily clouded and altered feldspar, at least some of which is recognizable as microperthitic potash feldspar. Graphic intergrowth of quartz and feldspar is well developed in places. In contrast to this, the white granite consists of coarse highly strained and sutured quartz with a fine-grained strain-free mosaic only just beginning to form; the feldspar is presumed to be potash feldspar but is completely obscured by a felt of sericitic mica. Neither granite contains any ferromagnesian mineral. A basic dyke, which cuts the white granite, also shows considerable alteration with no primary ferromagnesian mineral remaining either as phenocrysts or in the groundmass and with plagioclase phenocrysts heavily altered especially in their rims. The state of the quartz shows that the white granite has subsequently been subjected to stress with no later opportunity for the quartz to recrystallize under strain-free conditions. This indicates that the white granite lenses could be tectonic rather than magmatic fragments of an older granite mass.

Trifid Peak

The summit and eastern half of Trifid Peak are composed of a similar reddish heterogeneous granite intruded on the north-east side by a coarse speckled Andean granodiorite but showing a very irregular and confused contact against volcanic rocks on the west ridge of Trifid Peak. Critical evidence that this granite is earlier than the volcanic rocks is provided by this contact. It is interpreted as an explosive vent margin with coarse agglomerate containing abundant granite fragments grading further away from the contact down the west ridge into finer agglomerate and tuff with a greater variety of fragments.

In thin section, this granite is seen to consist of individual crystals of heavily clouded and altered feldspar, and aggregates of quartz. These constitute less than half the volume of the rock, the remainder being a uniform fine-grained mosaic of quartz, feldspar and iron ore grains. The latter are interpreted as the result of incomplete annealing of a previously coarse-grained granitic rock. Such a texture is consistent with the granite being older than the volcanic rocks and suggests that it may have been subjected to a degree of heating during volcanic eruption. None of the granite fragments in the agglomerate can conclusively be identified with the adjacent granite but the similarities in the hand specimen and thin section are sufficient to justify a tentative correlation.

In conclusion, three granite masses on Horseshoe Island have in common a more altered, heterogeneous and disrupted appearance than the normal Andean granites; they often show a weak and variable foliation, and they show signs of volcanic disruption and hypabyssal

intrusion that are not found in Andean rocks. In the Trifid Peak occurrence, there is a contact with volcanic rocks which suggests that this granite at least may be earlier. Comparison with the deformed rocks of the Orford Cliff suite shows that the Horseshoe Island rocks have not undergone the same degree of cataclastic deformation but are broadly similar lithologies.

Antarctic Peninsula Volcanic Group

There is little direct evidence for the age of the volcanic and associated sedimentary rocks occurring on Horseshoe and Lagotellerie Islands other than that they are older than some Andean intrusions. By analogy with volcanism and sedimentation elsewhere in Marguerite Bay, and from limited evidence on Lagotellerie Island (Hoskins, 1960), where traces of plant fossils have been found, the rocks are provisionally classified as Upper Jurassic in age (Thomson, 1969; Dewar, 1970).

The sedimentary rocks on Horseshoe Island, which have volcanic associations but which are characterized by a moderate degree of shearing and deformation, represent an additional problem. It is possible that the effects are due to major shearing and faulting locally, in the area around Gaul Cove, but that volcanic rocks elsewhere were not affected. It is also possible that the deformation is of more regional significance, in which case the whole question arises of an earlier age for the sediments with the possible existence of sediments of the Trinity Peninsula Formation in Marguerite Bay.

These deformed sediments are not seen in sequence with the main volcanic succession. They occupy the southern half of the isthmus separating Lystad Bay from Gaul Cove and part of the south side of Gaul Cove. They range from fine siltstones to coarse conglomerates and show varying degrees of deformation, mainly cataclastic.

Isthmus

At this locality, strongly foliated and often highly contorted black schists occupy the tract of low-lying country across the isthmus with prominent hillocks due to irregular outcrops of a massive dark lithology. Foliation in these rocks is variable but mainly vertical with a strike north to north-east. The lithology is also variable and is apparently unbedded. There is a mass of coarse deformed conglomerate at one point overlooking Gaul Cove and there is a small patch of more heterogeneous agglomeratic rock at the western extremity of outcrops overlooking Lystad Bay. The northern margin against foliated metamorphic complex granite is interpreted as a fault and the foliation increases in intensity on both sides of this boundary. To the south, near station E.2365, there is a major fault with a notable change in the character of the black schists; they become strongly and more regularly foliated and dark green in colour with regular small angular folds carrying an axial lineation plunging steeply to the north. In the extreme south-east corner of the tract of exposed rock, against the eastern snout of Shoesmith Glacier, two small outcrops of different granites were found, the earlier of which is in very irregular contact with the black foliated rocks. Altered and elongated fragments of the earlier of the granites are enclosed in black schist, while the younger of the granites veins and intrudes both rocks. In thin section, the earlier granite shows large heavily clouded feldspar in a medium-grained mosaic of fresh unstrained quartz, this recrystallization most probably being due to the intrusion of the younger granite and obscuring the nature of the contact between earlier granite and schist. There are, therefore, three main possibilities:

i. That the first granite is older than the schists and the inclusions of granite in the black schist represent some sort of boulder bed at the base of the sedimentary succession.
ii. That the first granite is younger and intruded into the black schist, later metamorphism giving the schist its foliation and forming boudin-like granite fragments.
iii. That the contact is tectonic.

Since the presence of a major fault is also inferred on other field evidence, a faulted contact is regarded as most likely. The earlier granite, although its character has been altered by thermal metamorphism, is petrographically similar both to the foliated "Basement Complex" granites on the north side of Gaul Cove and to the batholithic granite of southern Horseshoe Island (see below).

Many of the fine-grained black schists are very friable; others are a heterogeneous rock, dominantly a quartz-mica-schist, often with a considerable amount of carbonaceous dust and containing abundant crystals of quartz and feldspar as well as rock fragments. Fragment lithologies are mainly volcanic or granitic but include one rich in epidote (possibly derived from the break-down of plagioclase) and one rich in carbon and showing curious spheroidal structures which could be sedimentary or organic in origin but more probably consisting of palagonite of volcanic origin. It is difficult to decide to what extent these fragments have been altered during the deformation that imparted the schistosity to the rock but considerable recrystallization has obviously taken place and no original sedimentary texture remains. It is supposed, however, that the rocks were primarily volcanogenic with fragments of a variable nature and haphazard distribution, and with a high proportion of fine-grained erosional and tuffaceous material. The more massive flinty black lithologies, forming areas of higher topographic relief, are composed of an extremely fine-grained quartzitic mosaic, possibly with some feldspar and chlorite though this has not been definitely determined, and a very fine-grained tremolitic amphibole. These rocks show no foliation and are of uniform grain-size, though they have clearly been able to recrystallize at some stage. They presumably represent a more competent arenaceous original sediment with a proportion of ferromagnesian, possibly volcanic, detritus.

The more strongly foliated and lineated rocks adjacent to Shoesmith Glacier prove, in thin section, to be no more strongly deformed than the black schists but they have clearly been subjected to more extensive alteration and recrystallization which could have obscured a greater degree of earlier cataclastic deformation. The groundmass of quartz and feldspar has recrystallized to a coarser grain-size than normal with streaks of carbonate, chlorite and epidote parallel to the foliation, while the clasts (originally agglomeratic), consisting mainly of plagioclase with some quartz and potash feldspar, are much clouded and altered with incipient recrystallization to a clear mosaic. The strong deformation noticed in the hand specimen has thus been obscured by purely thermal metamorphism due to intrusion of the brick-red granite.

Some very coarse agglomerate was recorded at the western extremity of the isthmus overlooking Lystad Bay; in contrast to this, an outcrop of what appears to be very coarse conglomerate occurs in the cliffs facing the west end of Gaul Cove (E.2365). It is assumed to represent a local boulder deposit, possibly water-lain.

Gaul Cove

Sediments crop out more extensively on the south side of Gaul Cove, where the lithologies are less deformed and in a more intelligible pattern. Foliation is usually weak or absent but when present it is parallel to the compositional banding and original sedimentary bedding which is occasionally visible. The foliation dips steeply south-west or is vertical with a south-easterly strike.

The structure of these rocks is simple. No significant deformation of the foliation has been seen, though a number of small faults cut both matrix and fragments alike and displace the foliation. A lineation plunging 20–40° to the west-north-west is seen in the most slaty lithologies.

A traverse across the strike, at station E.2367, reveals a sequence of shales, tuffaceous silts and conglomerates. The last are coarse (Fig. 6) and similar to the conglomerate described from station E.2365 with mainly granitic pebbles and boulders up to 50 cm across, which

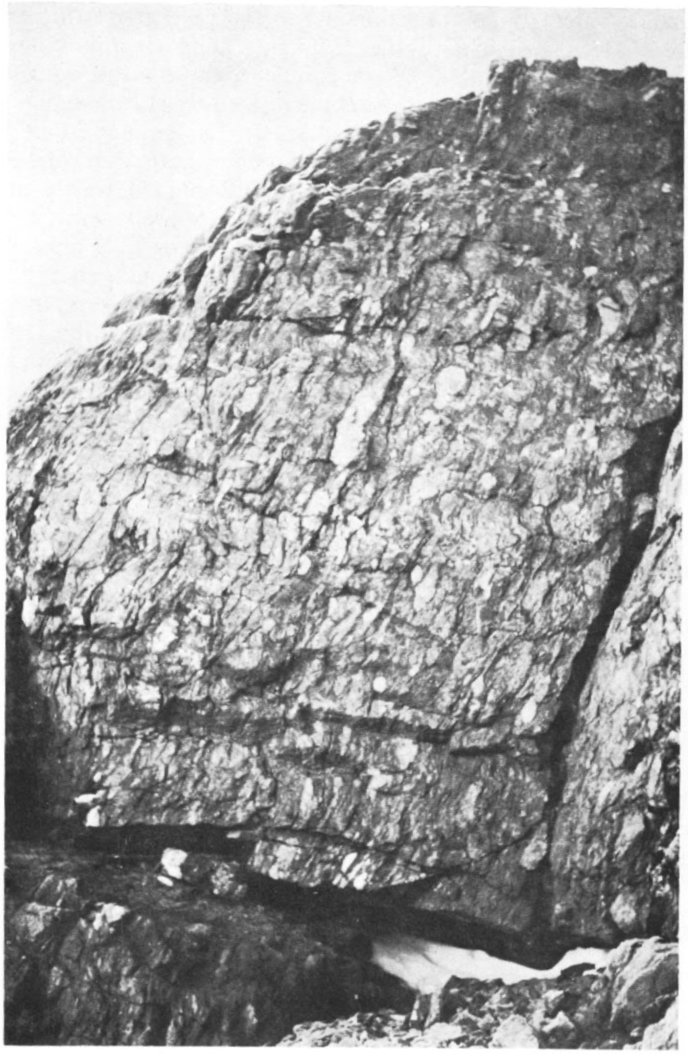

Fig. 6. Conglomerate, slightly deformed, in sediments of the isthmus (E.2367).

are elongated parallel to the locally pronounced foliation. These conglomerates disappear rapidly along the strike, being either lenticular or faulted in outcrop. To the north of these outcrops, a major fault truncates the sedimentary rocks along the valley containing the fresh-water lake between Spincloud Heights and Russett Pikes, while to the west, in cliffs overlooking Gaul Cove just east of station E.2367, there is an intrusive contact between brick-red granite and sediments. This latter contact is itself cut by a large "dyke" of highly porphyritic rock emanating from a larger mass to the north which is assumed to be terminated by the same major fault. To the south, a major contact between sedimentary rocks and the pink granite of Spincloud Heights is prominent in the cliffs overlooking the corner of Gaul Cove and Shoesmith Glacier. The plane of this contact dips moderately to the north and is apparently intersected by the north slope of Spincloud Heights. There is no good evidence for the nature of the contact but one large acid sheet cuts the sediments and there is slight

veining in the small isolated tongue of sediments to the east, suggesting that it is intrusive rather than faulted. Metamorphism of the sediments supports this conclusion but there is an acute re-entrant angle in the plane of the contact high up in the west face of Spincloud Heights, which faces up-dip and may indicate some downthrow of the sediments to the north.

In thin section, these rocks range from extremely fine-grained shales to very coarse conglomerates. The majority are approximately siltstone in grain-size with poor to moderate sorting, a mainly small proportion of matrix and sub-rounded clastic material in which quartz is greatly predominant in the feldspar. The siltstones are usually well bedded in thin units a few centimetres thick, as at station E.2368 (the bedding here dips north at 70°), and show some small-scale sedimentary structures such as current bedding. The shales are extremely fine-grained quartz-feldspar-sericite rocks, while the coarser conglomerates contain a great variety of sizes of crystal and lithic fragments, mainly granitic. The conglomerates are common but with no apparent relationship between outcrops; they show a higher degree of deformation than the finer-grained rocks, giving rise to a flaser-like structure.

At both these sediment localities, original sedimentary structures and textures have been masked by later thermal and/or deformational events. These have led first to the usual break-down of feldspar but many rocks show a more advanced stage where quartz and feldspar are partially or completely recrystallized and muscovite is present as coarse flakes which are unlikely to be detrital in origin. The origin of the sedimentary material is partly tuffaceous but the preponderance of quartz and the lack of lithic fragments in the siltstones suggest sub-aqueous deposition of both erosional and volcanogenic material. The lack of regular bedding and the common occurrence of sub-angular fragments, conglomerates, etc. may indicate rapid and irregular deposition on or adjacent to steep slopes.

The petrographic evidence thus throws little light on the age of these sedimentary rocks. There is not even much similarity between the two areas of exposure described above, although they are only a few kilometres apart. There are undoubtedly some similarities with sediments and intercalated volcanic rocks found on the east coast of Graham Land but the closest similarities are with water-lain sediments of the "Upper Jurassic" volcanic formation on southern and eastern Adelaide Island (Thomson, 1969; Dewar, 1970). It is with the lower part of this formation that these rocks are tentatively correlated, possibly representing the earliest stages of volcanism and instability as subduction and the building up of a volcanic arc commenced in Marguerite Bay.

Volcanic rocks with lesser amounts of intercalated sediment occur at four main localities on Horseshoe Island, while the best exposed and least disturbed quence is on Lagotellerie Island. They are distinct from the predominantly sedimentary strata described in the foregoing sections in that they are normally unfoliated and undeformed, and include only minor non-volcanogenic sedimentary horizons.

Lagotellerie Island

The sequence here is fault-bounded to the west against later intrusives and is thermally metamorphosed in places but only mildly warped and faulted, the strata generally dipping 20–45° westward (Fig. 7). The sequence consists of agglomerates, lavas and tuffs to a thickness of about 100 m as shown in Fig. 8. Plant remains in shaly bands interbedded with the tuffs indicate a Jurassic age (Hoskins, 1960). Individual agglomerate horizons are up to 10 m thick and commonly contain fragments (up to 0.5 cm) of foliated granites and volcanic lithologies. Interbedded lavas are andesites, the highest flow seen on Lagotellerie Island being a pyroxene-andesite lying with pronounced unconformity on agglomerates and tuffs.

In thin section, the groundmass of the lavas is andesine, interstitial actinolite and magnetite with corroded phenocrysts of colourless augite in the top flow. Slight retrograde metamorphism and alteration to actinolite, carbonate and chlorite is common. Numerous dykes cut the sequence but no feeders have been proved.

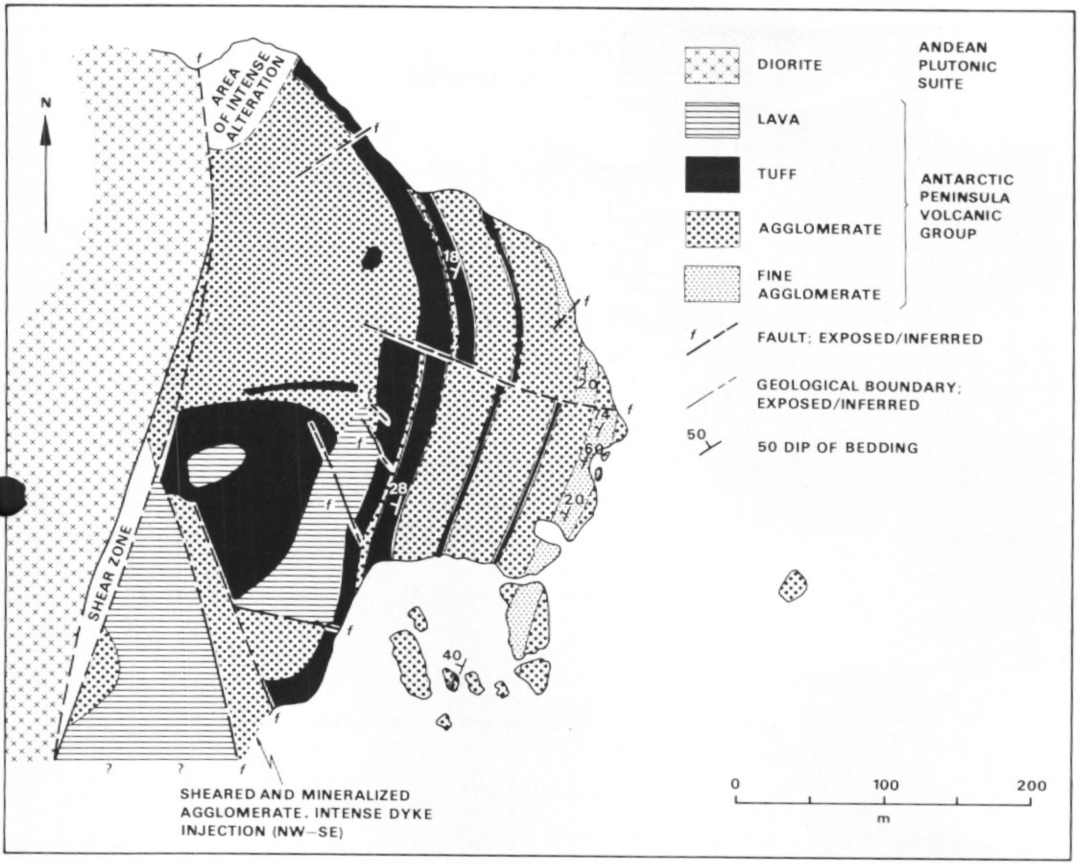

Fig. 7. Geological sketch map of eastern Lagotellerie Island (after A. K. Hoskins).

Homing Head

This locality covers the whole of a hummocky tract of ground fringed on three sides by considerable sea cliffs; it consists of tuffs, agglomerates and lavas, apparently broken up by faulting, and cut by numerous basic dykes which are well displayed in the cliffs of Homing Head itself. Agglomerate, often coarse with slightly rounded blocks up to 0.5 m in size, is patchily distributed but it is well developed, for example at station E.2321, where fragments of banded gneiss similar to that found at station E.2317 are conspicuous. Granitic fragments are unusually scarce.

The south-eastern boundary of these volcanic rocks follows a long topographic depression representing a major fault. At the extreme western tip of Homing Head, facing across Sally Cove, a sea stack is composed of dark gabbro intruding fine-grained volcanic rocks. One other contact is exposed on the northernmost strip of coast approximately 0.5 km east of Homing Head. Here, a coarse pale pink granite intrudes and veins volcanic rocks and cuts across a number of basic dykes.

In thin section, the lavas are variable, mainly andesitic, with a plagioclase composition of approximately An_{40} and small amounts of interstitial quartz; chlorite and an opaque mineral are abundant. The grain-size of the groundmass varies considerably. Some lavas are porphyritic, phenocrysts of plagioclase being present in one specimen, while in another a pale blue-green hornblende is abundantly present both in the groundmass, which is notably coarse, and has acicular phenocrysts which have occasional cores of colourless pyroxene heavily clouded by an opaque mineral, presumably derived from the alteration of pyroxene to hornblende. The agglomerates are completely unsorted but some of the fragments show

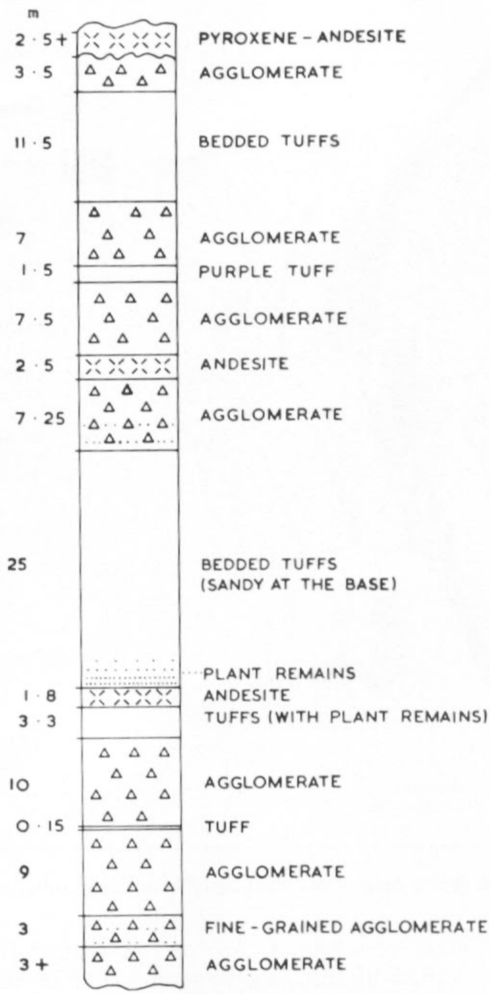

Fig. 8. Sequence of Jurassic volcanic rocks on Lagotellerie Island (after A. K. Hoskins).

a degree of rounding. A fine-grained matrix forms up to 25% of the rock. Fragments are composed of many lithologies, including foliated rock types and volcanic debris, with also many individual crystals of quartz and feldspar.

Mount Searle

The Mount Searle area consists largely of a vertical gabbro sheet (forming the summit) intruding grey and black volcanic rocks, which form the north-east and south-west ridges of the mountain. On the north-east ridge, a major fault which, farther north, brings "older" granite into contact with foliated metamorphic complex granite, almost certainly continues over the shoulder of the mountain towards Lystad Bay, bringing volcanic rocks into contact with the same metamorphic complex granite. To the west, the volcanic rocks are intruded by Beacon Head granite. Although this contact is largely obscured by scree, a prominent vein of granite intrudes volcanic rocks in the north-westerly facing cliffs. Similar large veins and tongues of granite are found invading the volcanic rocks on the eastern side of the gabbro

sheet, extending right up to the summit ridge of Mount Searle and branching off into several inclined sheets of contaminated granite, cutting both gabbro and volcanic rocks, and containing large dyke-like masses of volcanic rock. The nearest exposures at the base of the screes below these tongues are, however, definitely of the "older" granite extending down towards Homing Head (most of this area is covered by an icefield). Though this critical area is unexposed, it is suggested that the contact between "older" granite and volcanic rocks is faulted.

In thin section, the volcanic rocks of Mount Searle are intermediate to acid tuffs, possibly with some lavas, which appear to have been metamorphosed and recrystallized to the extent that fragments and matrix are beginning to merge and homogenize. Recrystallization is particularly marked in the acid tuffs, which consist only of quartz and feldspar. This metamorphism is attributed to intrusion by the gabbro and, later, the Beacon Head granite, and it effectively masks any details of the contact between volcanic rocks and "older" granite.

Trifid Peak

In the southern half of Horseshoe Island, there are only two occurrences of comparable volcanic rocks. Trifid Peak shows a complicated succession of tuffs and agglomerates in its northern cliffs. In general, the agglomerate appears coarsest on its eastern side, close to a vertical contact against "older" granite. This may be the explosive margin of an ancient vent. At station E.2361, on the south ridge of Trifid Peak, there are further, though isolated, outcrops of porphyritic acid lava with particularly coarse agglomerate containing many granite fragments up to 0.5 m in diameter. However, no granite is exposed here and the relations of this agglomerate to the *in situ* granite mass are therefore only assumed to be the same as on Trifid Peak itself.

In thin section, the tuffs and agglomerates are extremely variable. The finest-grained rocks are crystal tuffs in which the crystals are less than 1 mm across and form less than 50% of the rock, the remainder being a variety of fine-grained matrix. The agglomerates, often very coarse, contain an assortment of fragments; most common are several types of granite, none definitely identifiable in thin section, although some are very similar to the postulated "older" granite and some resemble the poorly foliated granites of the metamorphic complex. Also recognizable, are fragments of quartz-biotite-feldspar rocks presumably from the metamorphic complex and fragments of lava and agglomerate from within the volcanic succession itself.

Russett Pikes

What appears to be a large inclined sheet tapering down-dip to the west is seen in the largely inaccessible north-west cliffs of Russett Pikes. On its north side, this sheet is composed of both pale and dark grey, fine-grained flinty porphyritic lavas, while on the south side, overlooking the large fresh-water lake, there is in addition some agglomerate.

In thin section, the porphyritic lavas have a fine-grained groundmass of quartz and feldspar with patches of more coarsely recrystallized quartz mosaic in which heavily clouded, often multiple, subhedral plagioclase phenocrysts are common. Quartz spherulites occur in one specimen. These rocks have undoubtedly undergone recrystallization and were primarily acid, intermediate and basic lavas, some of which may have been glassy.

The nature of this sheet is problematical. It appears to have been baked and metamorphosed by the granite, though it is not visibly veined or intruded. High up in the cliff there are conspicuous irregularities in the sheet, which looks as though it is truncated on its east side by a major fault forming a wide gully just to the west of the main summit. A possible explanation is that it forms a raft in the later reddish granite intrusion, such as a large roof pendant. Features within the granite (see below) also indicate proximity to the roof of the intrusion.

Andean Plutonic Suite

Andean plutonic rocks crop out extensively on Horseshoe Island in considerable variety, doubtless representing a considerable span of time since at least three phases of intrusion are demonstrably present. No absolute ages have yet been obtained from these rocks but they are massive, mainly undeformed and, in many cases, are demonstrably younger than the volcanic succession.

In the northern half of the island, Andean plutons dominate the large well-exposed area of low relief between Mount Searle and Beacon Head, as well as the islands of Mane Skerry, and the large peninsula on the north side of the entrance to Gaul Cove. In the southern half, a much more mountainous area stretching from Mount Breaker to Ryan Peak is composed of a single supposedly Andean granite stock, while to the east, Spincloud Heights and Russett Pikes are formed mainly of granite and diorite. Lagotellerie Island consists largely of Andean diorite faulted against volcanic rocks.

Gabbro

There are six distinct occurrences of gabbro, two of which are of major extent and importance, and a third possibly of moderate importance.

Sally Cove to Beacon Head

This is the best exposed intrusion for which the name Sally Cove gabbro is proposed. It shows a conspicuous contact running along the slopes above the south side of Sally Cove to station E.2312, 0.5 km north-east of Beacon Head. Geophysical evidence (Smith, 1973*a*) suggests that the gabbro forms an elliptical mass centred approximately 1 km south of the station hut and its northern margin does not appear on Horseshoe Island. It is a massive dark coarse-grained rock with malachite and limonite staining frequently visible on joint surfaces. The long and well-exposed southern contact is marked by a 20 m wide reaction zone. All previous workers (Exley, 1958*a*, *b*; Grimley, unpublished field notes) have considered this gabbro to be earlier, even "Palaeozoic", but the reaction seen between gabbro and granite would be unlikely to take place at the lower temperature of intrusion of granite. Towards the gabbro contact, for instance at Beacon Head, the granite becomes a purplish colour in the hand specimen and develops a pseudo-porphyritic appearance. The gabbro, on the other side, contains blebs and patches of acid material within 25–50 m of the contact. The contact zone itself is formed of a coarse quartzo-feldspathic rock with prominent large prismatic hornblende crystals, some containing a white core of feldspar. No gabbroic xenoliths were identified in the granite and xenoliths of any lithology are rare near the contact. Towards the eastern end of its outcrop the gabbro encloses a large tongue, parallel to the main granite contact, of pale purplish pseudo-porphyritic granite, virtually identical with the main contact facies. This could be a roof pendant or marginal raft of granite almost fully detached from the country rock.

In thin section, the normal gabbro is decidedly variable and often moderately altered, particularly its pyroxene and plagioclase. In general, it is rather sodic with a plagioclase composition in the range An_{40-50} and with relatively little modal orthopyroxene or olivine; free quartz is absent. The main ferromagnesian phases are clinopyroxene and hornblende. The former is invariably a colourless diopsidic variety, while the latter is common brown hornblende occurring either as large fresh poikilitic crystals or as mantles to clinopyroxene and as blebby alteration within pyroxene crystals. Pale green acicular actinolitic amphibole sometimes forms as an alteration product of brown hornblende and sometimes forms within chlorite aggregates, which themselves are thought to be pseudomorphous after primary ferromagnesian minerals. Plagioclase is coarse-grained and commonly cracked and altered to a moderate extent; it also shows patchy extinction and zoning but its normal range of composition is andesine to labradorite. An opaque mineral is an abundant accessory,

particularly in pyroxene which is partly altered to hornblende, and as grains scattered throughout the rock. Red-brown biotite is common in accessory amounts. Olivine occurs as corroded relics and chlorite pseudomorphs, and it is apparently commonest in the banded gabbros when it may form 10–20% of the mode.

Within about 25 m of the granite–gabbro contact, quartz appears interstitially and the plagioclase becomes increasingly heavily altered until it contains recognizable pleochroic epidote. In the reaction zone at the contact, reddish brown to green pleochroic hornblende forms large fresh crystals up to 1 cm long (some with irregular cores of plagioclase). Plagioclase, forming the bulk of the rock, is very patchy and zoned, and also is often very coarse-grained. Potash feldspar and quartz are present in graphic intergrowth. Within approximately 200 m of the contact, on the granite side, potash feldspar becomes heavily clouded and very coarse and perthitic; closer to the contact it has recrystallized to a finer-grained mosaic with some exceptionally well-developed graphic intergrowth. A pro-grade sequence of alteration and metamorphism from biotite to chlorite and then to acicular amphibole can be observed towards the contact.

A thinly repetitive pale to dark banding up to 1 m thick is often well developed in the gabbro (Fig. 9) with parallel mineral lamination sometimes visible. The dip of this foliation is variable and changes from 70° to near horizontal in as little as 100 m (e.g. near station E.2309). The strike is, however, relatively constant and is usually parallel to the granite–gabbro contact. This banding is most commonly developed within 100–300 m of the contact where it has a steep dip, while farther away from the outcrop of the contact banding is less common and its dip is usually shallow. In thin section, the paler bands consist almost entirely of plagioclase with a composition approximately An_{60}, though with some normal zoning at the rim; no primary ferromagnesian minerals are present in these paler bands but only a small number of clots of chlorite with small feathery crystals of actinolitic amphibole. The darker bands are normal olivine-bearing gabbro.

Besides the banding, copper and iron staining are common features; the former occurs in

Fig. 9. Thin banding in Beacon Head gabbro (near station E.2310).

several areas near Sally Cove and the latter particularly in the area of station E.2304 and around the old British station hut. No relationship between igneous banding and metalliferous showings has been seen. Another variation within the gabbro is the development of randomly distributed dark spots of poikilitic hornblende up to 0.5 cm across. In thin section, the spots consist of single crystals of normal fresh brown hornblende enclosing fresh plagioclase, which is usually slightly finer-grained than in the bulk of the rock. They are therefore assumed to be a late-stage magmatic feature.

Lystad Bay

A second large outcrop of gabbro, similar to but not connected with the first, occupies most of the islands of Mane Skerry, a coastal strip at station E.2358 and a small outcrop, probably related, at station E.2313 near Beacon Head. Its contact is exposed in only two places: at station E.2313, where the gabbro is veined and sharply intruded by Beacon Head granite, and at station E.2358, where there are extensive coastal exposures of the gabbro intruding acid gneissic rocks with alteration and contamination of the gabbro for several metres on the west side of the contact. Within approximately 100 m of this latter contact, the gabbro shows abundant banding of paler and darker components and in thin section it shows small amounts of quartz and potash feldspar with only a little hornblende. The banding is mainly vertical, often highly irregular, but it is otherwise similar in appearance to the banding of the Sally Cove–Beacon Head gabbro and also the Anagram Islands gabbro (Fraser, 1964). Spotting by large poikilitic hornblendes is also prominent, particularly at the north-west extremity of the outcrop approximately 150 m from the contact.

In the islands of Mane Skerry, the same gabbro is coarse, massive and uniform apart from patchy development of copper and iron staining on weathered surfaces and thin regular banding of paler material with a moderate northerly dip. Mite Skerry and the southern islets of Mane Skerry are composed of "Basement Complex" rocks and the gabbro contact is not exposed anywhere between station E.2358 and Beacon Head. However, the line of the contact is assumed to extend across Lystad Bay towards Beacon Head, where it is cut by the later granite. These interpretations give a notably arcuate pattern to the two gabbro intrusions, which are separated in space and time by the Beacon Head granite.

Mount Searle

The summit of Mount Searle is formed of a thick vertical sheet of coarse dark gabbro, showing sharp intrusive contacts against volcanic rocks and cut by veins of granite. Towards the centre of the sheet, which is approximately 300 m thick, the gabbro becomes slightly paler and more acid with a scaly metalliferous coating on joint surfaces. In thin section, it consists mainly of intermediate plagioclase (An_{40-50}) with colourless clinopyroxene extensively altered to pale green acicular hornblende; the plagioclase is also cracked and obscured by alteration products. Epidote, apatite and opaque minerals are common accessories and a little biotite, partly altered to chlorite, is also present. In the more acid core of the sheet, clinopyroxene is entirely replaced by pale green actinolitic amphibole but the plagioclase is too altered to detect any significant change in composition. Biotite and epidote are more common and small amounts of interstitial quartz are present.

The north-westerly continuation of this sheet is possibly represented by outcrops on the shore of Sally Cove (near station E.2317) and at Homing Head, though petrographic similarities are not particularly marked. At the former locality, a dark uniform gabbro is exposed on the shore; it has a sharp contact showing Beacon Head granite veining and intruding the gabbro on its west side but there is no contact exposed on its east side where banded gneisses crop out. At Homing Head, the westernmost stack is composed of a similar gabbro with a possible intrusive contact against volcanic rocks, though this is not very clear in the field. The thin section of a specimen from near station E.2317 (see Table II) shows a

TABLE II. APPROXIMATE MODAL ANALYSES OF SOME ANDEAN PLUTONIC ROCKS

	Acid rocks				
	E.2312.2	E.2315.1	E.2359.7	E.2359.1	E.2360.1
Quartz	15	20	26	36	44
Potash feldspar	49	42	27	43	26
Plagioclase	33	31	39	19	24
Hornblende	1	5	5		
Biotite			1		
Accessories	1	2	2	2	6

E.2312.2 Whitish granite; Beacon Head.
E.2315.1 Porphyritic pink granite; Beacon Head.
E.2359.7 "Speckled granodiorite"; Trifid Peak.
E.2359.1 Pink granite; Trifid Peak.
E.2360.1 Coarse pink granite; Ryan Peak.

	Basic rocks				
	E.2300.1	E.2300.2A	E.2304.1	E.2313.1	E.2317.2
Plagioclase	86	54	44	70	74
Clinopyroxene	2	21	32	15	5
Altered clinopyroxene		8	3	1	12
Hornblende	5	5	8	1	4
Biotite	1	1	1		
Quartz	4*			7	1
Accessories	2	11	12	6	4

* Includes potash feldspar.

E.2300.1 "Diorite"; north side of Sally Cove.
E.2300.2A Gabbro; north side of Sally Cove.
E.2304.1 Gabbro; coast north-east of Beacon Head.
E.2313.1 Gabbro; coast south-east of Beacon Head.
E.2317.2 Gabbro; shore of Sally Cove near Homing Head.

coarse rock consisting of relatively fresh and unaltered labradoritic plagioclase enclosed by large (up to 3 mm) poikilitic crystals of colourless clinopyroxene, which is altering to aggregates of colourless acicular amphibole and blebs of brown hornblende. Brown hornblende also occurs as large fresh poikilitic crystals often in continuity with clinopyroxene crystals and is probably magmatic in origin.

The south-easterly continuation of the Mount Searle gabbro is not at all clear but it is considered probable that the Mount Searle sheet is an offshoot of the Mane Skerry gabbro. Lithological similarities are not marked but their fundamental characteristics are comparable.

Mount Breaker

A small outcrop on the foreshore promontory north-west of the summit of Mount Breaker is composed of dark uniform gabbro backed by cliffs of a paler appearance intruded by veins of granite from the main granite mass to the south and east. Most of this area proved inaccessible but a prominent notch in the cliffs above the promontory may indicate the position of a contact between gabbro and more acid rocks. In thin section, it can be seen that this is not a true gabbro but some sort of basic hybrid. Plagioclase (andesinic) is dominant and is more than usually zoned, patchy and irregular. Quartz and orthoclase are present in minor interstitial amounts and deep red-brown biotite is common. Hornblende is virtually absent but two pyroxenes are present; a fresh slightly pleochroic hypersthene and a colourless mainly fresh clinopyroxene showing slight blebby alteration to hornblende.

Reluctant Island

At the northern end of this island there is an isolated exposure of feldspar-rich gabbro with no exposed contacts.

Homing Head

A small wedge of gabbro occurs adjacent to "older" granite at the eastern end of the fault separating "older" granite from volcanic rocks. In thin section, this is a mafic gabbro and the plagioclase is again strongly zoned with patchy extinction, suggesting some degree of hybridization or contamination. Clinopyroxene, the only other important primary mineral, is extensively altered and mainly replaced by pale acicular amphibole and an opaque mineral. The status and field relations of this gabbro are uncertain.

Diorite

The name diorite has been used rather loosely here for a large group of rocks, broadly dioritic in character. On Horseshoe Island there are four major occurrences.

Sally Cove

A large central part of the Sally Cove–Beacon Head gabbro is intruded in a very complex manner by paler more acid rocks, many of which approximate to diorite in composition. Although previously referred to (in unpublished reports) as Palaeozoic in age, these rocks are interpreted here as the youngest plutonic rocks on the northern half of Horseshoe Island and are referred to the Andean. The contact between the dioritic rocks and the surrounding gabbro is often well exposed and it is very irregular and variable. In places, as near station E.2307, the gabbro is spectacularly veined and brecciated by more acid rocks (Fig. 10), while elsewhere, although veining and brecciation are still the commonest form of intrusion, the contact is often vague and confused. A typical example of this type of contact occurs directly in front of the old British hut at station E.2301, where an aplite vein follows an irregular diorite–gabbro contact for some distance (Figs 11 and 12).

The diorite itself is extremely variable and heterogeneous but it is typically a coarse-grained grey rock. In thin section, the diorite seems frequently more altered than the gabbro with clouding and heavy alteration of the feldspars. Andesine is the dominant mineral, brown hornblende the main ferromagnesian constituent and colourless clinopyroxene, altering to hornblende, is common. Quartz and orthoclase are present in minor interstitial amounts. The sheet-like intrusion in front of the old British station hut is much finer-grained and at its lower margin has a porphyritic texture (with plagioclase phenocrysts); the upper margin shows no chilling and contains more abundant quartz and potash feldspar. The aplitic and other more acid sheets and veins are not obviously related to the diorites and granodiorites,

Fig. 10. Gabbro brecciated and veined by diorite near Beacon Head (E.2307).

Fig. 11. Aplite vein intruded along the contact between spotted gabbro and xenolithic finer-grained diorite (E.2301).

Fig. 12. The same aplite vein as in Fig. 11, becoming transgressive.

and they consist mainly of a heavily clouded plagioclase–orthoclase assemblage, commonly with quartz.

The commonest variant is "spotted" diorite, owing its appearance to large poikilitic hornblende crystals which, in thin section, are seen to enclose plagioclase laths that are generally smaller than those in the normal rock matrix. The enclosed plagioclase is fresher and may be systematically more sodic in composition than the normal matrix plagioclase. The occurrence of spotting is unpredictable but, for instance near station E.2305, it has been seen in vertical bands up to 100 m wide alternating with unspotted but otherwise similar diorite; the bands have sharp margins but there is no evidence for chilling of either rock. "Spotted" diorite has also been seen as xenolith-like inclusions in unspotted diorite.

The second major variety of diorite is a complex heterogeneous rock so full of xenoliths of dioritic, gabbroic and other material that the dioritic host is sometimes difficult to distinguish. This is well developed at station E.2302 and at the west end of Sally Cove near the fresh-water lakes. These xenoliths may be mostly cognate but accidental xenoliths are undoubtedly abundant on the hill at station E.2303, where metamorphosed sedimentary, sometimes carbonate-bearing, rocks are uniquely represented. The source of these sedimentary xenoliths is not known; they are completely recrystallized into granular mosaics of quartz with varying amounts of feldspar, carbonate, etc. and with larger feldspar crystals surviving in patches. One pale grey xenolith shows a crude zonal arrangement of minerals; lobate crystals of monticellite (up to 0.5 cm across) form its margin and the core is a pure plagioclase rock. Approximately 3 cm into the xenolith, the plagioclase coarsens in grain-size, changes gradually from intermediate to bytownite in composition and is associated with small fresh acicular crystals of (?) scapolite. Outwards from the margin, the (?) monticellite is increasingly altered to very pale green chlorite and quartz is present; there is also an orthorhombic amphibole within 1–2 cm of the margin of the xenolith in place of the pyroxene or monoclinic amphibole of the normal diorite.

A finer-grained paler grey lithology is common, occurring as relatively well-defined sheets and veins which are best developed when cutting gabbro (as at station E.2308) rather than normal diorite. In thin section, this finer-grained type is more acid and nearer to granodiorite in composition with significant proportions of quartz and orthoclase, and with abundant greenish brown hornblende showing occasional relics of pyroxene.

The overall impression is that this area from Sally Cove to Beacon Head represents an intrusive magmatic complex where some differentiation of a contaminated approximately dioritic magma has started to take place but where emplacement has occurred in a rapid and disorderly manner within a still hot though solid gabbro country rock. There is no chemical evidence yet for a common magmatic origin for both the "diorites" and the gabbro but the magmatic history is clearly one of complicated intrusive events leading to great heterogeneity of the rock types, due probably to a rapid sequence of intrusive events before cooling and solidification of each phase was properly complete. The Sally Cove gabbro may itself have been emplaced while the Beacon Head granite was still hot, followed closely by dioritic and more acid fractions, which could have extended the cooling history of the whole complex and thus increased the possibilities for the postulated gabbro–granite reaction at the main contact and the development of the other unusual features.

Russett Pikes–Spincloud Heights

The rocks of this area include one large mass of diorite and granodiorite, very different in character and field relations from the Sally Cove diorite. The eastern ridge of Trifid Peak, the eastern half of Spincloud Heights and the adjacent part of Reluctant Island are composed of diorite and granodiorite. This rock becomes gradually more acid in character near its western margin so that there appears to be a gradation from diorite to a "speckled granodiorite" with pink grains of potash feldspar. It is markedly xenolithic on Reluctant Island and south of Trifid Peak. In thin section, the diorite contains significant amounts of quartz and orthoclase, and is often near to granodiorite in mineralogy. Dark brown biotite and pale green hornblende are the main ferromagnesian components, accompanied in some cases by relict colourless clinopyroxene which is altering to hornblende. Plagioclase is marginally the dominant feldspar and is moderately altered and often heavily zoned within the oligoclase-andesine range. Orthoclase is heavily clouded.

On the coast below the north slopes of Russett Pikes, a grey dioritic rock is exposed in the lower part of the cliff. It lies below granite and has a rather irregular contact with pronounced veins running up into the granite. In thin section, this rock also proves to be nearer to granodiorite in composition with no pyroxene and only a little pale green subhedral amphibole. Chlorite is common, especially as an alteration product of biotite. Both plagioclase and orthoclase are relatively fresh, the plagioclase being strongly zoned and mainly oligoclase. Quartz is present as a coarse-grained interstitial phase.

The veins on Russett Pikes are the only evidence of an intrusive origin for this rock. Its speckled appearance is characteristic and it is interpreted as a small discrete stock of a xenolithic diorite–granodioritic magma which had probably differentiated before emplacement, and which was probably contaminated before or during differentiation.

Mount Breaker

One further mass of diorite occurs on the north face of Mount Breaker but this was almost entirely inaccessible and therefore is not yet known in detail. A contact against granite can be seen high in the north ridge of Mount Breaker and granite veins are prominent cutting assumed diorite in the face of the cliff. As mentioned above, the contact against gabbro at station E.2370 is thought to be intrusive, occupying the prominent notch approximately 30 m above sea-level. A fault is assumed to separate this diorite from the older granite on the west face of Mount Breaker.

In thin section, colourless clinopyroxene is common and is partially altered to a ragged growth of pale amphibole with red-brown biotite which is extensively altered to chlorite. Andesinic plagioclase is the dominant mineral and is cracked and altered. Small amounts of quartz and potash feldspar are present interstitially. The diorite is thus quite distinct from the Trifid Peak rock and is older than it.

Lagotellerie Island

The bulk of Lagotellerie Island is formed of a mass of almost xenolith-free quartz-diorite, intruding and metamorphosing some volcanic rocks. It contains patches of pegmatitic diorite and some patchy gradation to granodiorite, suggesting a certain amount of *in situ* differentiation and a rather high-level emplacement. It is intruded by a darker finer-grained diorite showing no sign of chilling and by a later granodiorite forming two irregular masses in the central saddle of the island. The contact in the latter case is sharp with some contamination and reaction visible in both granodiorite and diorite up to 3 m from the contact. These events may, therefore, all have taken place prior to complete cooling.

In thin section, this diorite contains brown-green hornblende, biotite and a slightly titaniferous augite, with plagioclase (An_{45} zoned to An_{30}) and heavily altered minor orthoclase. Quartz is accessory only. The granodiorite is extremely altered but it contains a substantially higher proportion of orthoclase and the plagioclase is oligoclase. Chlorite has replaced biotite and is the only ferromagnesian mineral present. These are small but distinct differences from the Horseshoe Island lithologies.

Granite

In spite of the fact that two of the granites of Horseshoe Island have been tentatively classified as pre-Jurassic, a considerable area is still occupied by granites assumed to be Andean in age. No absolute age data are yet available for these granites and their relative ages are uncertain.

Southern Horseshoe Island

The largest single mass of granite on the island forms the mountain chain running from Mount Breaker to Ryan Peak. In the Ryan Peak area, the granite is mainly coarse-grained, pink and relatively homogeneous but scree specimens from the western end and the northern slopes of Penitent Peak suggest that the granite here becomes quite heterogeneous. The colour becomes variable to pale greyish pink and the grain-size is not uniform, giving rise, on occasion, to a very faint and irregular foliation but more often simply to a blotchy and heterogeneous appearance. Quite distinct from this patchy variation are very definite shear zones which cut the granite, the best example being found at the lower end of the north ridge of Ryan Peak where the granite develops locally a strong schistosity dipping steeply north-west. In the islets just off the shore south-west of Mount Breaker, the granite also shows a strong though variable foliation, believed in this case to be due to faulting. The presence of this sporadic foliation poses problems since, on the whole, known Andean rocks are unfoliated and post-date any major crustal event that can be invoked as a cause. There is therefore a possibility that the southern Horseshoe Island granite could equate to the "older" plutonic group outlined above or to an as yet undefined interim event. The most probable cause, however, is held to be faulting of Andean or younger age, which has led to the development of distinct shear zones trending north-east to south-west.

This granite, in thin section, shows little variation. All the specimens examined show at least a moderate degree of alteration, primary ferromagnesian minerals being entirely replaced by chlorite and plagioclase being heavily clouded with fine-grained epidote and other alteration

products. Potash feldspar is commonly microperthitic, often well developed, and may also show microcline twinning. Plagioclase is the subordinate feldspar in amount and is often enclosed by potash feldspar. Quartz is abundant in all specimens and in most is coarse-grained with strongly developed straining and suturing. There is thus considerable evidence of post-crystallizational deformation and alteration but not to the extent that is found in the "older" granites or metamorphic complex rocks.

The granite of Spincloud Heights and the lower end of the north ridge of Trifid Peak is similar in the hand specimen and thin section to that of Ryan Peak, being coarse-grained, pink and relatively homogeneous. At the summit of Spincloud Heights, it becomes finer-grained and redder in colour, though the only obvious difference in thin section appears to be a significant amount of carbonate in cracks and interstices in the redder variety. The granite of Russett Pikes also is similarly reddish, though slightly heterogeneous and is probably related. No contact was found on Spincloud Heights to suggest that the redder granite might be a separate intrusion and it is suggested that the redder variety is a high-level facies of the normal pink granite, indicating proximity to the roof of the main intrusion. The disposition of adjacent volcanic rocks supports this and suggests that they form part of an irregular "roof" to the pluton.

Exposed contacts with other rocks are scarce and most have been described above. Granite veins are seen cutting diorite in the north face of Mount Breaker. The granite also apparently intrudes volcanic rocks on the north ridge of Trifid Peak and sediments on the north face of Spincloud Heights.

North side of Gaul Cove

The major promontory forming the northern side of the entrance to Gaul Cove consists of a brick-red granite, quite distinct from any other type found on Horseshoe Island. It is a homogeneous rock and occupies an area of moderate relief but subdued outcrop. Its contact against the metamorphic complex is exposed near the north shore of Gaul Cove, where the granite is intrusive with a vuggy character near the contact. Only quartz was found in the vugs which were often completely empty. Another contact is exposed by the corner of Shoesmith Glacier in Gaul Cove, where the brick-red granite intrudes both the foliated sediments described above and the pink granite of southern Horseshoe Island. It is very similar in all respects to the Red Rock Ridge granite (Hoskins, 1960).

In thin section, this rock has a coarse though very irregular texture. Biotite is the only primary ferromagnesian mineral, present as dark brown flakes with green chlorite. Both feldspars are heavily but irregularly clouded; orthoclase is dominant over plagioclase and is microperthitic. Quartz is abundant as large anhedral unstrained crystals.

Beacon Head granite

This intrusive rock has been recognized as a distinct type by previous workers in the area. Characteristically, it is a coarse-grained homogeneous granite varying in colour from pale purplish pink to almost white. It occupies a tract of rocky ground from the western slopes of Mount Searle extending all the way to Beacon Head and the offshore skerries. Some of its contacts with other rocks have already been described. It veins the volcanic rocks and gabbro of Mount Searle (which may form part of its roof) but it is intruded and extensively altered by the gabbro west of Sally Cove. It is also cut by many acid, basic and composite dykes, which also cut the gabbro.

In thin section, there is only a small amount of pale blue-green hornblende with some chlorite as the ferromagnesian component. The feldspars are very coarse-grained (up to 5 mm) and heavily though patchily altered and clouded. Potash feldspar is dominant and shows some microcline twinning and some microperthite. Plagioclase twinning is also patchily developed. Quartz is coarse-grained (2–5 mm) and unstrained.

Towards the gabbro contact north-east of Beacon Head, the granite becomes porphyritic in appearance and in thin section some metamorphism is evident. Some large feldspar crystals remain, clouded and altered almost beyond recognition, while the rest of the rock is recrystallized to a mosaic texture or, as is particularly well developed in one specimen approximately 1 m from the contact zone, a coarse graphic intergrowth of quartz and potash feldspar. The contact itself is diffuse as already described with a broad reaction zone. Colourless amphibole is developed on the granitic side of this zone. The grade of metamorphism is not high but no particularly suitable indicator minerals are present. The width of the reaction zone and the degree of intermingling of the two rock types, for example at Beacon Head, are indicative of a prolonged period of metamorphism which must have to some extent re-mobilized materials in the granite.

Homing Head

There is a small isolated occurrence of granite on the extreme northern shore of Horseshoe Island. This is a pale pink coarse-grained granite similar in appearance to the Beacon Head granite. It forms several rocky exposures on the shore at the foot of high cliffs composed of dark volcanic rocks, in which granite veins cut both the volcanic rocks and their associated basic dykes.

Hypabyssal rocks

Pre-Andean

There is relatively little evidence for dykes of this antiquity on Horseshoe Island and none on Lagotellerie Island. The gneissic rocks of the metamorphic complex contain no foliated dykes. The earliest hypabyssal intrusive rocks are suspected but not yet proven in age. They are a suite of felsic, often porphyritic, dykes seen cutting the "older" granite between Mount Searle and Homing Head, which have not been found cutting the adjacent volcanic rocks at Homing Head. Probable Jurassic hypabyssal intrusive rocks are the very irregular, usually thin basaltic dykes cutting so-called "older" plutonic rocks. Positive evidence for the age of these is also missing. In other areas of Marguerite Bay (Hoskins, 1960; Fraser, 1962), definite feeders to the Jurassic volcanic rocks have been recorded. Basic dykes actually cutting the volcanic rocks at Homing Head and on Lagotellerie Island, and cutting sediments in Gaul Cove, are probably Jurassic in age and could possibly be feeders to higher lavas not preserved in this area. They are not seen cutting any of the Andean plutons and they are definitely earlier than the small exposure of Beacon Head type granite at Homing Head.

Andean and younger

A considerable variety of acid, basic and composite dykes cuts both the Andean and the earlier plutonic rocks of Horseshoe Island. They are particularly well displayed in the well-exposed area east of Beacon Head, where a number of dykes can be traced across the gabbro–granite junction. The dominant dyke trend is north-west but there are many deviations from this and many dykes are sinuous or even apparently distorted during their emplacement. Several examples of this are well displayed in the Beacon Head area. As many as five distinct phases of dyke injection may be represented in the Sally Cove–Beacon Head area but mutual age relations and any systematic differences in trend or composition are as yet indeterminate. The granites of southern Horseshoe Island are only occasionally dyke intruded and clearly lay outside the main foci of activity.

Structure

Folding and foliation

The gneissic rocks of the metamorphic complex show no recognizable folding but an elongation lineation is visible in places and the trend of the foliation varies from area to area, as shown on Fig. 3.

Most of the Jurassic volcanic rocks are tilted into varying attitudes but again no recognizable folds have been seen and no schistosity is developed. The fine-grained sediments on Horseshoe Island are, however, strongly deformed in the central isthmus area, their foliation being a strong irregular schistosity. This foliation shows a general tendency to strike north to north-east and be vertical. Small, apparently random contortions abound but a more regular crenulation in more mylonitic schist adjacent to Shoesmith Glacier is formed by small angular folds with an axial elongation lineation plunging steeply northward.

Foliation in the granites of Horseshoe Island presents a particular problem. Those which are held to be pre-Jurassic, as proposed in this paper, show a weak and variable foliation largely due to cataclasis of quartz and feldspar but no recognizable folding. On the other hand, the large granite pluton of southern Horseshoe Island, which is thought, on field evidence, to be more probably Andean in age, also shows locally a strong foliation restricted to certain zones. Instances are seen on Ryan and Penitent Peaks where several broad zones up to 50 m wide show a strong near-vertical foliation striking north-east. In one instance, the rock becomes almost mylonitic with an elongation lineation plunging down dip but it is still recognizably the same granite.

Faults

Small faults are common within all rock groups but larger normal faults are postulated only at Homing Head, at station E.2324 and on the north and south sides of Gaul Cove to account for the juxtaposition of differing rock types. They are substantial and do not show any preferred trend. The Homing Head fault and the large fault running south-west from station E.2324 may both be pre-Andean, since they both pre-date the Mane Skerry–Homing Head gabbro, if its boundaries are correctly inferred.

Major faulting of unknown age may be represented by the foliated zones in the central isthmus and in the southern granite on Horseshoe Island. The two are not necessarily the same but in both cases a strong north-easterly foliation has resulted. Indications are that the isthmus shear zone is older than the brick-red granite and the Mane Skerry gabbro, whereas the Ryan and Penitent Peaks shear zones are less extensive and are presumably Andean or later. The crustal significance of these zones is not yet understood but, on the northern side of the isthmus, gneissic foliation is modified by the shearing and the rock is reduced in grain-size; the effects are therefore spread over a width of at least 1 km. Such shear zones have been described from the southern South American Cordillera and equated, at least in part, with stress systems operating during batholith emplacement (Dalziel, 1974) but no such relationship is evident on Horseshoe Island. The topographic feature shows up faintly in the bathymetry west of Horseshoe Island but again there is no clear relation yet known with crustal fracture systems in oceanic crust farther west (Herron and Tucholke, 1976).

No major post-Andean block faults intersect Horseshoe Island and it is clear that the erosion level in the area is only moderately deep. No great thickness of volcanic strata is preserved and only relatively minor amounts of metamorphic gneiss are exposed. The erosion level on Horseshoe Island is therefore not deep and there is some evidence that it might be a little higher on Lagotellerie Island, suggesting a north–south fault between the two.

Jointing in the plutonic rocks of northern and western Horseshoe Island, particularly the gabbros, is well developed with a prominent north-north-west trend, and the complementary east-north-east set is less well seen but is present.

Mineralization

Prominent malachite and limonite staining have been recorded on Horseshoe Island since the earliest visits. It is particularly pronounced in the Sally Cove gabbro near the old British

station hut and less well known but equally extensive in the Mane Skerry gabbro. Very similar staining has been reported in the banded gabbro of the Anagram Islands (Fraser, 1964) due to late oxidation of sulphides introduced by late pneumatolytic action and to iron oxide of primary magmatic origin. Such features are common in gabbros in many parts of the world and are not usually of any commercial significance.

Elsewhere on Horseshoe Island, minor occurrences of sphalerite have been recorded in joint fissures and small veins. These are emplaced in volcanic rocks on Russett Pikes, adjacent to reddish granite, with a gangue of quartz and epidote. They are almost certainly derived from the granite and, if the supposition presented in this paper is correct (that exposure level is very near the roof of the granite in Russett Pikes and Spincloud Heights), other mineralization of late magmatic origin may well be found there.

Joint- or fault-controlled mineralization has not been seen, though the prominent jointing in Andean rocks of northern Horseshoe Island certainly shows signs of controlling late-stage pneumatolytic alteration. Some unaltered oxide (probably haematite) occurs on joint surfaces in the gabbro of Mount Searle, which it is suggested in this paper may be just above the roof level of an Andean granite (Beacon Head granite).

The overall situation of Marguerite Bay in relation to subduction-controlled mineralization cannot yet be discussed in detail due to lack of regional evidence. However, it can be compared with that of Palmer Land (Suárez, 1976) and it seems probable that Horseshoe Island is located towards the westerly edge of the overriding plate margin, eroded to a fairly deep level into plutons of relatively early Andean age. It might therefore lie in a more westerly longitudinal zone in the sense of Sillitoe (1976) but nothing is known yet of the disposition of Graham Land in relation to mineralized latitudinal segments. The apparent spread of relative ages of plutonic masses on northern Horseshoe Island and the abundance of gabbro are probably not typical of the region.

Discussion

Evidence of a long and varied geological history is preserved on Horseshoe and Lagotellerie Islands. Until geochronological determinations are made, the ages of some igneous events remain in doubt but field petrographic and fossil evidence suggests the following general geological history.

The earliest rocks are gneissic and foliated, both *ortho-* and *para*gneissic types being represented. They are of unknown ages and may belong to a true metamorphic crystalline basement or to a later orogenic event. They show no deformational fold structures and show no evidence of high-grade metamorphism. Furthermore, they do not resemble particularly closely any of the already established metamorphic complex types elsewhere in northern Marguerite Bay, apart from the general absence of polyphase ductile deformation.

A group of "older" plutonic rocks in faulted and possibly intrusive contact with this metamorphic complex is postulated on the basis of two pieces of evidence:

i. The sporadic appearance of a weak foliation with a possibly cataclastic character.
ii. The interpretation of one contact on Trifid Peak as an explosive vent margin against younger Jurassic volcanic rocks.

There is also the fact that many volcanic agglomerates of the Antarctic Peninsula Volcanic Group contain fragments of non-gneissic granitic rocks, although numerous attempts to correlate these petrographically with exposed plutons in the Marguerite Bay area remain at best unconvincing. The geochronology of postulated "older" granites from elsewhere in Marguerite Bay is still ambiguous (Rex, 1976).

Correlation of these proposed "older" plutonic rocks with the Orford Cliff suite (Goldring, 1962) 100 km farther north is an obvious possibility and the similarities are pronounced. Low-grade cataclastic deformation on the Loubet Coast is much more intense and the rock

types included in the suite are more varied but the evidence in Marguerite Bay of a pre-volcanic plutonic suite is comparable. Both could therefore be late Gondwanian in age.

A mixed group of silts and volcanogenic sediments, moderately deformed, occurs on Horseshoe Island separately from the main area of volcanic agglomerates and lavas. They are provisionally assigned to the same formation, probably near its base, which is assumed to be Upper Jurassic in age. A mixed volcanic sequence, which includes sediments, occurs on Lagotellerie Island and contains carbonized plant remains of Jurassic affinity. There is no evidence on Horseshoe Island for the existence of an earlier suite of volcanic rocks. The volcanic strata on Horseshoe and Lagotellerie Islands are only moderately warped and tilted. Deformation of the volcanic formation elsewhere in the Antarctic Peninsula is variable in intensity and supposedly Andean in age. The evidence in Marguerite Bay on this point is ambiguous but the fact that some volcanic rocks are considerably disturbed (Goldring, 1962; Hoskins, 1960), compared with for example flat-lying and relatively undisturbed volcanic strata on Adelaide Island and farther north on the Loubet Coast, suggests that local events of various ages may have been responsible. It is probable that these events were related to emplacement of Andean plutons and to post-volcanic faulting.

Andean igneous activity in northern Horseshoe Island is interpreted as an intrusive sequence gabbro–granite–gabbro–"gabbro/diorite complex" with a roughly concentric arcuate arrangement of intrusions. The rock types are typically fresh and undeformed, and the later part of the sequence shows an extremely complex, probably closely spaced record of magmatic events. A late brick-red miarolitic granite north of Gaul Cove is the only example of a high-level pluton, closely comparable with the Red Rock Ridge granite farther south.

The diorite–granodiorite association is represented on southern Horseshoe Island and on Lagotellerie Island but without any clear relation to the northern Horseshoe Island diorite.

Larger batholithic granite occurs on southern Horseshoe Island, earlier than the brick-red granite but otherwise of doubtful status in the sequence. It is cut by several zones of shearing and foliation so that, although apparently later than the volcanic rocks, it may represent an earlier phase of Andean emplacement subject to localized later disruption.

A number of episodes of dyke intrusion have occurred. A doubtful suite of pre-volcanic dykes is the earliest recorded but an extensive suite of basic dykes is closely associated with the volcanic formation. Andean and later dyke intrusion was varied and extensive, particularly in northern Horseshoe Island and to a lesser extent on Lagotellerie Island.

Minor faulting of Andean age is common. Major normal faults at Homing Head, Russett Pikes and elsewhere show no systematic trend and the first at least could be pre-Andean. Major strike-slip faulting may be represented by the extensive shear zones of the central isthmus and of the Ryan Peak–Penitent Peak granite. No major late crustal block faults intersect Horseshoe Island but a north–south fault may separate Lagotellerie Island from Horseshoe Island.

Acknowledgements

Thanks are due to Drs C. W. M. Swithinbank, P. D. Clarkson, P. W. G. Tanner and Mrs J. W. Thomson for advice and help in the preparation of this work, and to the latter two for critical reading of the manuscript. Numerous colleagues helped in various ways with the field work and manuscript preparation. Unpublished material which has been consulted is that of Dr A. K. Hoskins, particularly in relation to Lagotellerie Island, and also Drs A. G. Fraser, P. H. Grimley and N. A. A. Procter, J. A. Exley and P. J. Rowe.

MS received 10 July 1978

REFERENCES

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

———. 1962. The geology of Antarctica. (*In* WEXLER, H., RUBIN, M. J. *and* J. E. CASKEY, *ed. Antarctic research: the Matthew Fontaine Maury Memorial Symposium.* Washington, D.C., American Geophysical Union, 26–39.) [Geophysical monograph No. 7.]

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

CRADDOCK, C. 1971. Antarctic tectonics. (*In* ADIE, R. J., *ed. Antarctic geology and geophysics.* Oslo, Universitetsforlaget, 449–55.)

CURTIS, R. 1966. The petrology of the Graham Coast, Graham Land. *British Antarctic Survey Scientific Reports*, No. 50, 51 pp.

DALZIEL, I. W. D. 1974. Evolution of the margins of the Scotia Sea. (*In* BURK, C. A. *and* C. L. DRAKE, *ed. Geology of continential margins.* Berlin, Springer-Verlag, 567–79.)

———. *and* D. H. ELLIOT. 1973. The Scotia arc and Antarctic margin. (*In* STEHLI, F. G. *and* A. E. M. NAIRN, *ed. The ocean basins and their margins. I. The South Atlantic.* New York, Plenum Publishing Corporation, 171–246.)

DEWAR, G. J. 1970. The geology of Adelaide Island. *British Antarctic Survey Scientific Reports*, No. 57, 66 pp.

EXLEY, J. A. 1958*a*. Progress report on the geology of Horseshoe Island (F.I.D. Sci. Bureau No. 170/58), 9 pp. [Unpublished.]

———. 1958*b*. Progress report on the geology of Horseshoe Island (F.I.D. Sci. Bureau No. 176/58), 6 pp. [Unpublished.]

FRASER, A. G. 1962. The Upper Jurassic volcanic rocks of Millerand Island, Graham Land. *British Antarctic Survey Preliminary Geological Report*, No. 22, 15 pp. [Unpublished.]

———. 1964. Banded gabbros of the Anagram Islands, Graham Land. *British Antarctic Survey Bulletin*, No. 4, 23–38.

GLEDHILL, A., REX, D. C. *and* P. W. G. TANNER. 1982. Rb-Sr and K-Ar geochronology of rocks from the Antarctic Peninsula between Anvers Island and Marguerite Bay. (*In* CRADDOCK, C., *ed. Antarctic geoscience.* Madison, Wisconsin, The University of Wisconsin Press, 315–23.)

GOLDRING, D. C. 1962. The geology of the Loubet Coast, Graham Land. *British Antarctic Survey Scientific Reports*, No. 36, 50 pp.

GRIKUROV, G. E., KRYLOV, A. YA. *and* YU. I. SILIN. 1966. Absolyutnyy vozrast nekotorykh porod iz rayona zaliva Margerit, Antarkticheskiy poluostrov [Absolute age of certain rocks in the Marguerite Bay region of the Antarctic Peninsula]. *Dokl. Akad. Nauk SSSR*, Geology, **171**, No. 6, 1399–401. [English translation: *Dokl. (Proc.) Acad. Sci. U.S.S.R.*, Geological sciences sect., **171**, 127–30.]

HERRON, E. M. *and* B. E. TUCHOLKE. 1976. Sea Floor magnetic patterns and basement structure in the south-eastern Pacific. (*In* HOLLISTER, C. D. *and* C. CRADDOCK, *ed. Initial reports of the Deep Sea Drilling Project.* Washington, D.C., U.S. Government Printing Office, **35**, 263–78.)

HOSKINS, A. K. 1960. The geology of parts of the Loubet and Fallières Coasts, Graham Land. *Falkland Islands Dependencies Survey Preliminary Geological Report*, No. 6, 38 pp. [Unpublished.]

———. 1963. The Basement Complex of Neny Fjord, Graham Land. *British Antarctic Survey Scientific Reports*, No. 43, 49 pp.

REX, D. C. 1976. Geochronology in relation to the stratigraphy of the Antarctic Peninsula. *British Antarctic Survey Bulletin*, No. 43, 49–58.

ROWE, P. J. 1973. The geology of the area between Riley and Bertram Glaciers, Palmer Land. *British Antarctic Survey Bulletin*, No. 35, 51–72.

SILLITOE, R. H. 1976. Andean mineralization: a model for the metallogeny of convergent plate margins. (*In* STRONG, D. F., *ed.* Metallogeny and plate tectonics. *Spec. Pap. geol. Ass. Can.*, No. 14, 59–100.)

SMITH, I. F. 1973*a*. Gravity survey on Shoesmith Glacier, Horseshoe Island, Graham Land. *British Antarctic Survey Bulletin*, Nos. 33 and 34, 77–82.

———. 1973*b*. Gravity survey in northern Marguerite Bay, Graham Land. *British Antarctic Survey Bulletin*, No. 36, 115–21.

SUÁREZ, M. 1976. Plate-tectonic model for southern Antarctic Peninsula and its relation to southern Andes. *Geology*, **4**, No. 4, 211–14.

THOMSON, M. R. A. 1969. The marine origin of water-lain volcanic sediments of south-west Adelaide Island. *British Antarctic Survey Bulletin*, No. 19, 83–88.

WEST, S. M. 1974. The geology of the Danco Coast, Graham Land. *British Antarctic Survey Scientific Reports*, No. 84, 58 pp.