THE GEOLOGY OF ISLANDS IN SOUTHERN BRANSFIELD STRAIT, ANTARCTIC PENINSULA

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Abstract. The oldest rocks on the islands in Bransfield Strait are marine turbidites of probable Upper Palaeozoic or Lower Mesozoic age. These rocks of the Trinity Peninsula Group were deformed and subjected to low-grade metamorphism, possibly as part of a subduction complex, during early Mesozoic times. Unconformably overlying the metasediments are abundant volcanic rocks of the Antarctic Peninsula Volcanic Group. These tuffs and lavas range in composition from rhyolite to basalt. Radiometric age determinations indicate that this complex may in part be early Tertiary in age. Intruded into the volcanic rocks are numerous calc-alkaline plutonic bodies of the 'Andean' suite. This suite has a probable Jurassic to Lower Tertiary age range and together with the volcanic rocks of the Antarctic Peninsula Volcanic Group represents the products of a magmatic island arc. The youngest rocks discussed are late Tertiary olivine-basalt. Evidence of extensive mineralization has been recorded on Intercurrence Island.

Introduction

Between the South Shetland Islands and Trinity Peninsula at the northern end of the Antarctic Peninsula is the 65-km-wide Bransfield Strait (Fig. 1). It is an asymmetrical, graben-like structure bounded by normal faults (Ashcroft, 1972). The strait appears to have been formed as a back-arc basin by crustal extension behind the island arc of the South Shetland Islands. The spreading apparently started some 1–2 Ma ago and some form of active spreading is probably taking place at the present day along the northern boundary of the strait (Weaver and others, 1979).

Geological surveys of a number of small islands in the southern Bransfield Strait have been made by members of the British Antarctic Survey over the past 20 years. The results of these surveys have previously been published only in the form of a geological map at a scale of 1:500000 (compiled by Fleming and Thomson, 1979). The present account of the geology of this area is based on the field notes and unpublished reports of P.H.H. Nelson and N. Aitkenhead (1962), L. E. Willey and C. G. Smith (1966), C. M. Bell (1969), P. J. Rowe (1969), A. C. Skinner (1969) and R. D. Hamer and G. Hyden (1979). In addition, all the hand specimens and 120 thin sections of rocks collected during these surveys have been studied.

Most field investigations were carried out from inflatable dinghies working from RRS *John Biscoe*, RRS *Bransfield* and RRS *Shackleton*. In addition, a number of helicopter landings were made from HMS *Protector* and HMS *Endurance*. Rock exposures at sea level are good, but access was hindered in places by the heavy swell and steep cliffs. The smaller islands and isolated rocks have no permanent ice cover but the larger islands are extensively glaciated. An indication of the high relief of the islands is provided by Pavlov Peak on Liège Island, which reaches a height of 852 m within 2 km of the shoreline.

The present investigations included surveys of Liège, Intercurrence, Tower and Astrolabe islands together with numerous smaller islands and rocks extending over an area of about 20 by 250 km. Hoseason, Two Hummock and Trinity islands and

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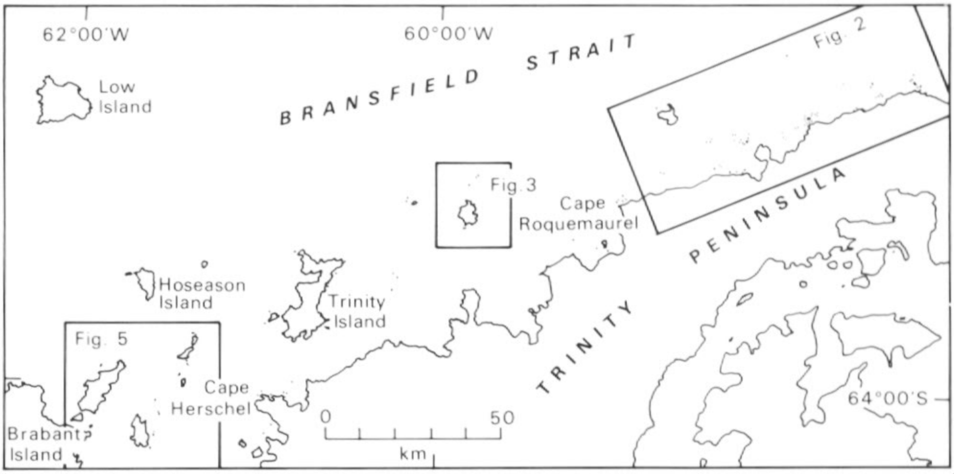

Fig. 1. Location map of islands in the southern Bransfield Strait.

coastal exposures between Cape Roquemaurel and Cape Herschel have yet to be geologically surveyed (Fig. 1).

The combination of small scattered islands, limited exposures and complex geology has meant that few definite geological correlations are possible between the island groups. The only firm age constraints are provided by seven radiometric age determinations (Halpern, 1964; Rex, 1976) and one fossil locality (Thomson, 1975*a*). An outline of the geological history is given below:

i. Deposition of marine, turbidite facies sediments of the Legoupil Formation, Trinity Peninsula Group (Halpern, 1965; Hyden and Tanner, 1981) probably during Upper Palaeozoic or Triassic times (Fleming and Thomson, 1979).
ii. These sediments were subjected to multiple folding and regional metamorphism to prehnite-pumpellyite facies (Hyden and Tanner, 1981) during early Mesozoic times.
iii. Unconformably overlying the metasediments is the Antarctic Peninsula Volcanic Group, (Thomson, 1982) a complex of basaltic, andesitic and rhyolitic intrusions, lavas and pyroclastic rocks of possible middle Jurassic to early Cretaceous age (Thomson, 1982). Radiometric age determinations from Two Hummock and Tower islands (Rex, 1976) suggest that at least some of these volcanic rocks are early Tertiary in age.
iv. The volcanic rocks were intruded by the calc-alkaline 'Andean' plutonic suite, which has an extensive age range from Jurassic to Lower Tertiary (Rex, 1976; Pankhurst, 1982).
v. The plutonic and volcanic rocks are unconformably overlain by Late Tertiary basalts.

Islands to the South and South-East of Astrolabe Island

Extending for some 80 km from west to east, to the south and south-east of Astrolabe Island (Fig. 2) is a chain of small islands and rocks adjacent to the coast of Trinity Peninsula. The major island groups include Gourdin Island and Column

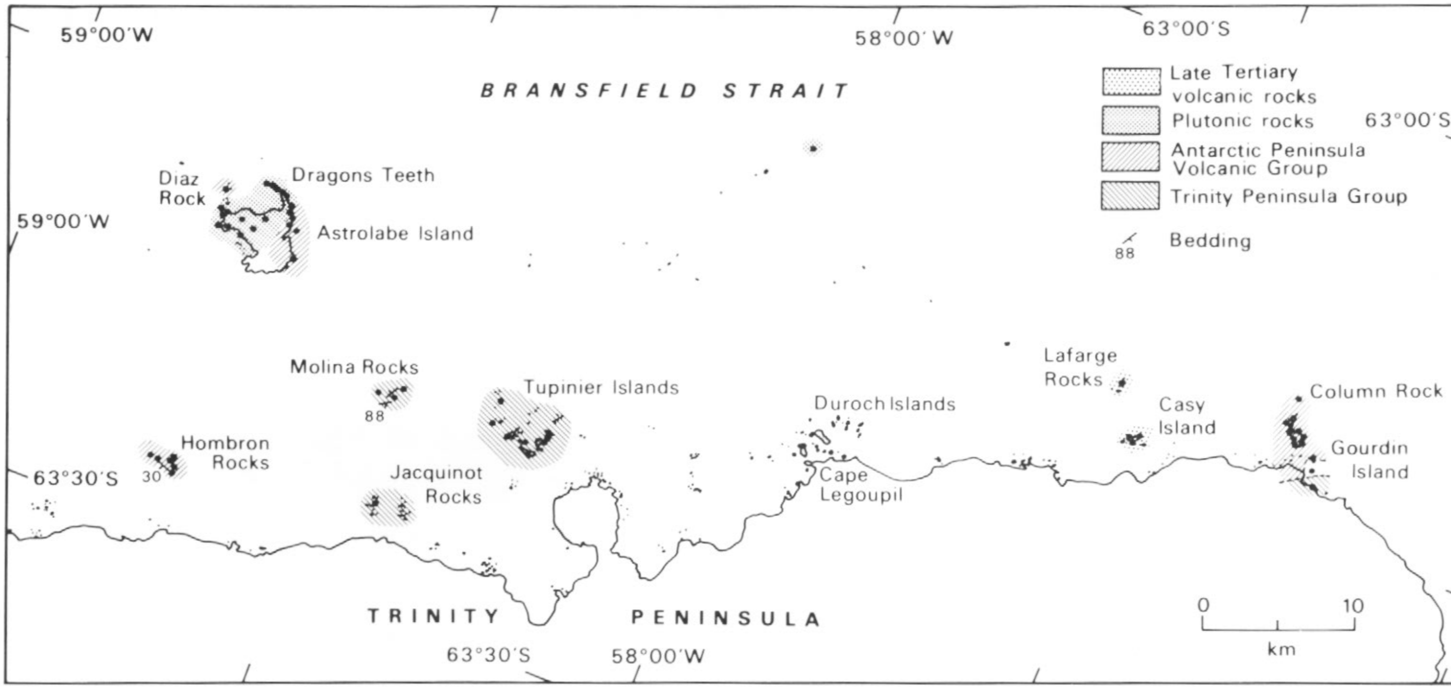

Fig. 2. Map of island groups between Astrolabe and Gourdin islands, showing the geology of localities visited during the present investigations.

Rock, Lafarge Rocks, Casy Island, Montravel Rock, Duroch Islands, Tupinier Islands, Jacquinot Rocks, Molina Rocks and Hombron Rocks.

Gourdin Island

Gourdin Island and its cluster of surrounding rocks form the northernmost point of the Antarctic Peninsula. Rocks on the mainland adjacent to the islands consist of very poorly sorted pebble and granule conglomerates and pebbly mudstones. The well-rounded clasts are predominantly sandstone, mudstone and low-grade metasediment together with rare plutonic, schist and volcanic fragments. The rocks are sheared and veined with calcite, quartz and epidote. The rock types, together with the degree of alteration and deformation, suggest that these sediments form part of the Trinity Peninsula Group (Hyden and Tanner, 1981). Gourdin Island is situated mid-way between the type localities of the Legoupil and Hope Bay Formations (Hyden and Tanner, 1981) but the presence of conglomerates and pebbly mudstones, together with the essentially sedimentary provenance, indicates that these rocks resemble those of the Legoupil rather than the Hope Bay Formation (Halpern 1965; Thomson 1975*a*; Hyden and Tanner, 1981).

Most of the Gourdin Island Group consists of ignimbrites with a dacitic to quartz andesite composition. These rocks display distinctive columnar jointing and a streaky flow banding with flattened and wispy shards and lithic fragments up to 60 mm in diameter. Andesine phenocrysts (An_{34}), up to 5 mm in diameter, are corroded and fractured. The groundmass consists of a devitrified felsic mat exhibiting distinctive flow banding. Elongated amygdales are filled with quartz, calcite, chlorite, opaque ore and altered feldspar. Small metasedimentary xenoliths are common. These ignimbrites are part of the Antarctic Peninsula Volcanic Group. The volcanic rocks are cut by a body of diorite, itself intruded by granodiorite, on the small islands in the south-east of the group. The fine-grained porphyritic diorite comprises approximately 50% zoned and altered labradorite phenocrysts up to 2 mm long. Other phenocrysts include augite with a rim of secondary fibrous amphibole. Quartz is a minor constituent of the groundmass.

Abundant dolerite dykes cut both the volcanic and plutonic rocks but they apparently show no preferred orientation. Plagioclase laths (An_{52-62}) in the dolerites commonly exhibit a trachytic texture. Both the diorite and the dolerite are extensively altered with secondary sericite, calcite, chlorite, fibrous amphibole, opaque ore and epidote.

Lafarge Rocks and Casy Island

This small cluster of islands consists entirely of massive, dark-coloured olivine-basalt with vertical columnar jointing. The basalt on Lafarge Rocks comprises a fine-grained mass of relatively unaltered plagioclase laths (An_{52}) together with augite, opaque ore and serpentine pseudomorphs after olivine. The basalt on Casy Island is somewhat more altered but otherwise identical to that on Lafarge Rocks. The age and stratigraphical relationship of these rocks is unknown.

Montravel Rock

The isolated situation of Montravel Rock, some 20 km off the coast of Trinity Peninsula, suggests that it may be geologically related to the chain of offshore islands, which includes Astrolabe Island, to the south-west. Montravel Rock consists of a relatively unaltered dolerite with 75% of fine-grained laths of plagioclase (An_{54}) together with small intergranular augite and hypersthene crystals. Opaque ore forms small intergranular crystals together with irregular rod-shaped crystals within the augite. The well-jointed dolerite is locally intensely sheared. It is cut by dykes of microgranite (aplite) up to 500 mm wide. On the north side of the rock a swarm of these dykes are spaced between 25 and 250 mm apart.

Duroch Islands and Cape Legoupil

These islands consist essentially of turbidite facies sediments of the Legoupil Formation, cut by a number of minor intrusions. The geology of this area has been described in detail in a number of previous publications (Elliot, 1965; Halpern, 1964, 1965; Thomson, 1975*a* and *b*). The most comprehensive account was given by Thomson (1975*a*), who deduced a Triassic age on the basis of a limited bivalve fauna. Radiometric age determinations of 102 Ma for a gabbro (Rex, 1976), 74±2.8 Ma for an andesite dyke cutting the sediments and 86±7 Ma for a porphyritic lava flow, apparently uncomformably overlying the sediments (Halpern, 1964, 1965), have also been determined. Thomson (1975*a*) indicated that the 116±4 Ma given by Halpern (1964, 1965) for a diorite pebble in the Legoupil Formation was anomalous.

Tupinier Islands

Tupinier Islands are a cluster of about 40 small islands and rocks comprising granule conglomerate and feldspathic greywacke of the Legoupil Formation. The sedimentary rocks are cut by a few narrow dykes ranging in composition from microgranite to andesite. On the islands in the north-west of the group are poorly-sorted granule conglomerates with sedimentary clasts (mudstone, siltstone, feldspathic arenite and vein quartz) in a lithic-arenite matrix. The angular to sub-rounded clasts average 1–2 mm in diameter and range up to a maximum of 150 mm. The feldspathic arenite clasts consist of a very poorly-sorted and immature sandstone with a weak metamorphic fabric, indicating a provenance of low-grade metasediments. The conglomerates have undergone extensive alteration but no distinct metamorphic fabric is apparent. In thin section it can be seen that compaction of the rock has caused moulding of mudstone around sandstone clasts.

Islands in the centre and south-east of the group consist of feldspathic arenite and greywacke interbedded with mudstone. A pebbly mudstone at the base of the succession is overlain by a thickly-bedded sequence of sandstones and mudstones. Sandstone beds are thicker at the base of the sequence but the strata become more pelitic and thinly-bedded towards the top. The sandstones vary from medium to fine-grained. They are all extremely poorly-sorted with angular to sub-rounded clasts. The proportion of quartz varies from 20 to 30% and that of feldspar up to 60%. Most feldspar grains are indeterminate due to alteration but grains of plagioclase, microcline and myrmekite are present. Other minor components are biotite, muscovite, zircon, opaque ore and tourmaline, together with secondary quartz, epidote, penninite and sericite. Lithic clasts include mudstone, phyllite, muscovite schist and quartzite. The abundant feldspar, together with the low proportion of quartz, suggests a dioritic or gabbroic source rock. No detailed record of sedimentary structures was made in the field but the lithology suggests a turbidite sequence derived predominantly from a low-grade metasedimentary and dioritic provenance. There is no evidence for volcanic rocks in the source area. The sandstones have a weak metamorphic fabric and have been subjected to low-grade metamorphism. In thin section, the metamorphic fabric is seen to be cut by zones of crushing or shearing. Many minor faults are apparent in the field, frequently shown by slickensides along bedding planes. The sediments are folded with extremely variable dips and strikes.

Molina Rocks

The small islands that comprise Molina Rocks consist of sediments of the Legoupil Formation. The only exception is the small island in the south-west of the group where a fine-grained igneous country rock is intruded by numerous microgranite dykes up to 4 m wide.

The sediments comprise a succession of mudstones, siltstones and fine-grained sandstones. Siltstone from the island in the north-east of the group consists of subrounded to subangular quartz and feldspar together with a few grains of sphene, zircon and opaque ore. The feldspar is mostly untwinned and clouded with alteration products. Secondary minerals include conspicuous poikiloblasts of prehnite and calcite (together up to 60%) together with scattered clinozoisite, pistacite and possible allanite. Narrow sinuous trains of microgranular sphene are common and impart a crude fissility to the rock. The abundant secondary calcite and prehnite strongly suggests a metasomatic origin.

The fine-grained feldspathic greywacke from the island in the south-east is extremely poorly sorted with predominantly angular clasts. Up to 60% consists of sericitized andesine, perthite and potassium feldspar. Accessory minerals include tourmaline, sphene, biotite, opaque ore, zircon and muscovite together with secondary epidote, calcite and penninite. Lithic clasts comprise about 30% of the rock and include mudstone, siltstone, greywacke, mica schist and basic volcanics. The succession exposed on the south-eastern island is a 100-m-thick, upward fining cycle of fine sandstone, siltstone and mudstone. Bedding is regular and continuous for up to 100 m along strike (the full extent of exposures) and beds vary from 50 mm to 1 m in thickness. A pattern of interfering ripples with an amplitude of 15 mm and wavelength of 200 mm was recorded in one sandstone bed. Ripple cross-laminations and graded bedding were observed in a number of sandstone horizons. Convolute laminations are present in many of the 50–200-mm-thick, fine-grained sandstone beds, each convoluted layer is bounded above and below by flat-bedded strata and some layers show apparent erosional truncation. Irregularly contorted lumps and wisps of shale in massive sandstone beds suggest an origin by mass-gravity transport. The only fossil recorded during the present study was a 30-mm-long sinuous trace on a mudstone bedding plane. No current marks were observed but the sedimentary structures and lithology indicate that these rocks are turbidites. Most of the steeply dipping strata are overturned and exhibit a weakly developed cleavage. The strike of both bedding and cleavage trends approximately north-east, parallel to the coast of the Antarctic Peninsula.

Jacquinot Rocks

Like the other islands to the north and north-east, Jacquinot Rocks consist of interbedded sandstones and mudstones. These rocks apparently become less pelitic towards the north-east. Poorly preserved sedimentary structures include convolute laminations and slumped bedding. The strike is variable but predominantly north–south.

Hombron Rocks

Hombron Rocks consist essentially of tuffs and agglomerates with angular to sub-rounded fragments up to 500 mm in diameter. Rounded clasts and poorly-developed bedding are indicative of subaqueous deposition. These pyroclastic rocks are cut by andesitic and doleritic dykes up to 5 m wide. In places the dykes form parallel swarms trending approximately east–west. The two small islands in the north-west of the group consist of a sill of gabbro with columnar jointing. The bedding of the pyroclastic rocks is variable in orientation, suggesting some gentle folding. All the rocks in the island group are intensely faulted and jointed.

Astrolabe Island

Astrolabe Island is approximately 7 km long and reaches a maximum altitude of 562 m. All coastal exposures, apart from those on the south coast, were mapped during the present investigation (Fig. 2). A number of inland sites were also visited by helicopter-borne field workers. The following account is based both on this field work and the study of 29 thin sections.

Astrolabe Island consists of a plutonic complex intruded into volcanic rocks of the Antarctic Peninsula Volcanic Group. The volcanic succession comprises predominantly tuff on the east coast and volcaniclastic sediment and basalt in the north-west of the island. The bedded andesitic and dacitic tuffs have a minimum thickness of 230 m. Angular fragments in the tuffs range up to 10 mm in diameter. Bedding is very regular and parallel with no grading or cross-bedding; the beds, up to 1 m thick are distinguished primarily by colour and grain-size variations. There is no evidence of subaqueous sorting or rounding and deposition was therefore presumably by air-fall into relatively still water. The tuffs comprise trachytic clasts and glass shards in a matrix of devitrified glass. Plagioclase phenocrysts have a composition ranging from An_{40} to An_{47}. The rocks are extensively altered with abundant secondary chlorite, calcite and quartz. At the south-eastern corner of the island, an ignimbrite flow of dacitic tuff and agglomerate has angular clasts and elongated wisps of devitrified glass. On Diaz Rock, at the north-west of the island, a 60-m-thick succession of basalt, basic tuff and volcanic breccia overlies a waterlain sequence of volcaniclastic conglomerates, cross-bedded tuffaceous sandstones and mudstones. The rocks of the volcanic succession are gently folded with fold wavelengths of about 50 m. The bedding dips, predominantly at low angles, towards the north-west.

At the contact between the volcanic and the plutonic rocks at the south end of Dragons Teeth Peninsula, the hornfelsed volcanic rocks are cut by a network of irregular and randomly orientated thin veins of microgranite, microtonalite and microgabbro. The plutonic complex that forms the central mass of Astrolabe Island comprises a succession of intrusive rock types. The oldest are gabbro and diorite containing xenoliths of the volcanic country rock, these are cut by abundant granodiorite and tonalite which is in turn intruded by microgranite. In thin section the medium-grained gabbro from the Dragons Teeth consists of interlocking labradorite laths (An_{62}) together with intergranular augite and minor proportions of biotite and opaque ore. Schillerization is apparent in the augite, which in places has altered to a secondary fibrous amphibole. Quartz-gabbro from the west coast of the island has euhedral olivine crystals partly altered to opaque ore and bowlingite and rimmed with hypersthene. Augite and a minor proportion of quartz is found between the labradorite laths. Most of the gabbros are remarkably unaltered. Diorite from the Dragons Teeth has a medium-grained granitic texture and comprises approximately 60% andesine (An_{44}), 5% quartz and 10% augite. Abundant secondary fibrous amphibole and chlorite has replaced biotite. Accessory minerals include opaque ore, rutile and apatite.

Intruded into these basic plutonic rocks are abundant tonalites and granodiorites. The typical granodiorite is porphyritic and medium to fine-grained with abundant basic xenoliths. The main constituents are 50–60% zoned andesine (An_{43-49}), 20% potassium feldspar and 15–20% quartz. The ferromagnesian minerals are fibrous amphibole (secondary after pyroxene) biotite and opaque ore. The xenoliths are finer-grained with a higher proportion of ferromagnesian minerals and more calcic plagioclase (An_{54}). The perthitic and altered potassium feldspar is extremely difficult to distinguish from untwinned plagioclase.

Abundant dykes, intruded into both the volcanic and plutonic rocks, include microtonalite, quartz-dolerite and dolerite. The microtonalite consists of zoned labradorite phenocrysts in a groundmass of quartz, plagioclase, pyroxene, biotite, opaque ore and fibrous amphibole. The youngest intrusive rocks are dykes of porphyritic olivine basalt with a trachytic texture.

Dumoulin and Kendall Rocks

These rocks form a 5-km-long archipelago off the north-east coast of Tower Island. They consist of basaltic tuffs and basalts. Clasts in the tuffs have an average diameter of 10 mm but range up to 50 mm. A 70-m-thick succession of bedded tuffs on Dumoulin Rocks dips at 44° towards the north-west. The rocks are extensively altered and the only minerals recognizable in thin section are sericitized plagioclase laths. Intruded into the volcanic rocks on Dumoulin Rocks are numerous dolerite and microgranite dykes.

Tower Island

Tower Island is about 8 km long and most of the accessible coastal exposures were visited during the present investigation (Fig. 3). The geology of the island closely resembles that of Astrolabe Island, with an essentially pyroclastic volcanic succession intruded by a plutonic complex of granodiorite, tonalite and diorite (Fig. 4), itself cut by dolerite and microgranite dykes.

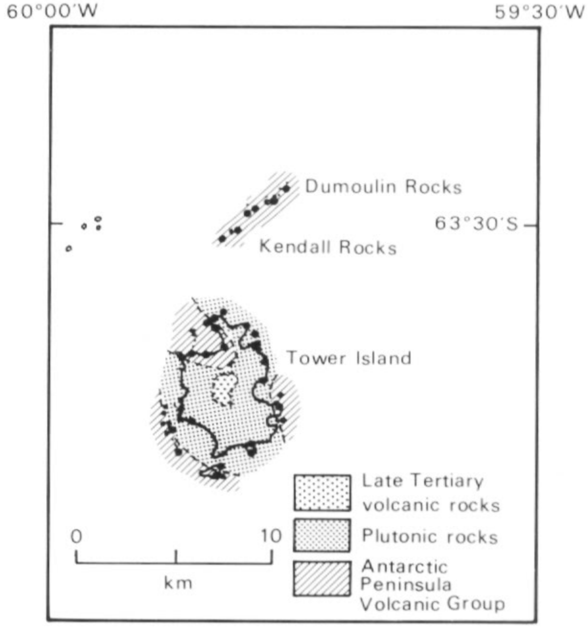

Fig. 3. Tower Island showing the geology of locations visited during the present investigations.

Fig. 4. Typical exposures of plutonic rocks of the 'Andean' suite on the east coast of Tower Island.

At the base of the volcanic succession is a 15-m-thick series of coarse tuffs and agglomerates overlain by up to 150 m of fine-grained banded tuffs. The tuffs range in composition from andesitic to basaltic. The basaltic tuff at the north of the island comprises plagioclase phenocrysts (An_{68}) together with lithic fragments of trachytic basalt. A few grains of strained quartz and metasediment give an indication of the nature of the country rock. Andesitic tuffs from the north of the island contain rounded and sorted lithic clasts, which suggest an origin by explosive volcanic activity followed by subaqueous deposition. Amygdaloidal basalts were observed at the south-east of the island. The volcanic rocks are cut by narrow shear zones associated with abundant quartz veins. Basalts in the north of the island were radiometrically dated by Rex (1971). K/Ar whole rock determinations gave ages of 54 ± 2 and 58 ± 2 Ma. Overlying these early Tertiary volcanic rocks, near the summit of Tower Island, are probable exposures of basalt (only observed from a distance) of possible late Tertiary age.

The rocks of the plutonic core of the island form an intrusion breccia at their contact with the volcanic country rock. Xenoliths are abundant in all the plutonic rocks and some of the variations in composition are probably the result of assimilation of the more basic country rock. The medium-grained tonalite from Zigzag Island has a granitic texture with approximately 70% altered and zoned oligoclase and 15% intergranular quartz. Ferromagnesian minerals include about 10% opaque ore together with indeterminate fibrous amphibole and secondary chlorite.

INTERCURRENCE ISLAND

Intercurrence Island forms an elongated ridge about 9 km long and up to 2 km wide. A total of 16 localities on the north and east coasts were visited during the present investigations (Fig. 5).

Intercurrence Island consists of a sequence of basic to andesitic tuffs intruded by a dioritic pluton, itself cut by numerous microgranite, quartz-andesite and dolerite dykes. The country rock is a massive, uniform and extremely shattered and altered basic to feldspathic volcanic rock. In thin section the very fine-grained andesitic lavas from the north of the island contain phenocrysts of plagioclase (possibly andesine) up to 2 mm in diameter. The bulk of the rock is a mass of secondary fibrous amphibole, chlorite, sericite, epidote and calcite with a small proportion of opaque ore. In some specimens, small euhedral porphyroblasts of secondary amphibole and biotite have developed, possibly as a result of contact metamorphism. Quartz-filled amygdales and a trachytic texture seen in a few thin sections suggests an origin as lava flows.

Most of the west coast and the interior of the island apparently consist of a dioritic pluton and, in the north of the island, the basic volcanic country rock is cut by a

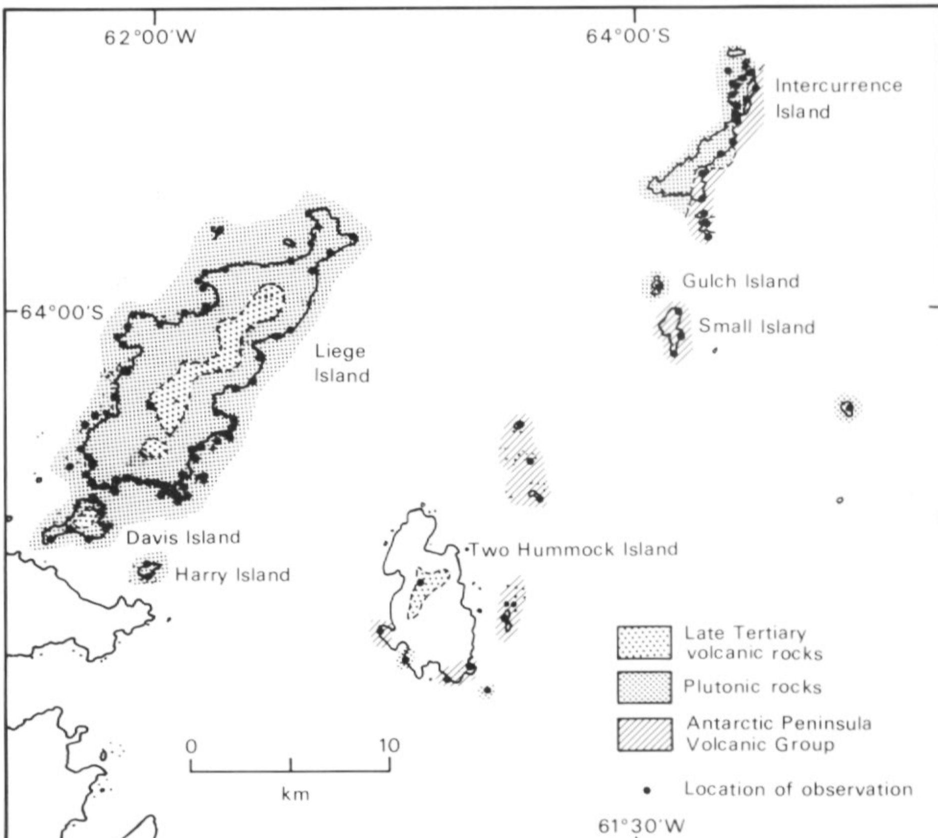

Fig. 4. Liège and Intercurrence Islands showing the geology of localities visited during the present investigations.

complex of pale-coloured diorite veins. At the contacts, the diorite forms a net-vein complex between partially assimilated basic xenoliths. The plutonic rocks are diorite and quartz-diorite with medium-grained granitic to porphyritic textures. The proportion of plagioclase (An_{34-54}) ranges from 50 to 70%, the crystals clouded with abundant alteration products. The quartz content ranges from 2 to 10% and, in places, the quartz forms myrmekitic intergrowths with plagioclase. The main ferromagnesian mineral is a secondary fibrous amphibole (replacing clinopyroxene). Other secondary minerals include chlorite, penninite and epidote. Accessory apatite and opaque ore (up to 2%) are also present.

Sub-horizontal microgranite dykes intrude the diorite at a number of localities. These dykes are themselves intruded by quartz andesites (up to 30 m wide) and younger near-vertical dolerite dykes (up to 1 m wide).

All the rocks on Intercurrence Island have been subjected to a remarkable degree of alteration, mineralization and shearing. Fault trends of 017°, 056° and 140° were recorded. Extensive mineralization was observed on the north-west coast, where abundant veins up to several mm in width cut the dioritic country rock. Vein minerals include quartz, epidote, chalcopyrite, bornite, malachite, azurite and magnetite. The association of mineralization with an area of extensive faulting is worth further investigation.

Islands south and south-west of Intercurrence Island

Immediately south of Intercurrence Island is Gulch Island, where massive well-jointed granodiorite has been recorded. To the south of this is Small Island with sub-horizontal basalt sills and lava flows in a sequence at least 100 m thick. These basalts are cut by dolerite dykes and veined with epidote. The rocks between Small and Two Hummock islands consist of basalts and andesites. Two Hummock Island has yet to be surveyed in detail but a number of localities on the south coast indicate the presence of basalt, andesite, agglomerate, diorite and gabbro. The top of the island is a stratified sequence of fine-grained basic volcanic rocks. Specimens collected from a height of 700 m in the south-west of the island have been radiometrically dated at 35±2 Ma (Rex, 1971).

Liège Island

The accessible exposures on Liège Island (Fig. 5) are found along the indented coastline and most of the interior of the island is covered by a thick ice sheet. The island extends some 20 km from south-west to north-east and reaches a maximum altitude of 852 m. The island group of Liège, Harry and Davis islands comprises part of a large plutonic complex ranging in composition from gabbro to quartz-monzodiorite and diorite and enclosing abundant basic xenoliths. Intruded into the plutonic rocks are dykes of felsic microgranite and dolerite. The plutonic rocks are unconformably overlain by a stratified sequence of fresh basalts and palagonite tuffs, which dip gently towards the north.

The plutonic rocks on Davis Island comprise a breccia of gabbro intruded by quartz-monzonite. The gabbro is fine to medium-grained with a granitic texture. Anhedral zoned crystals of labradorite comprise some 50% of the rock. Pyroxene crystals are rimmed and mottled with secondary fibrous tremolite and hornblende. About 10% of the rock is opaque ore. Secondary minerals include muscovite, chlorite and epidote. Xenoliths consist of clusters of ferromagnesian minerals, including hornblende, biotite and opaque ore, together with about 30% andesine. The quartz monzodiorite is also fine-grained with a granitic texture. Zoned crystals of plagioclase with a composition An_{38-50} constitute 50–60% of the rock. Potassium feldspar consists of 5–10% of untwinned intergranular crystals. Strained quartz is 10–20% of the rock. Other minerals present include up to 10% biotite, partly altered to chlorite, and up to 15% anhedral to euhedral hornblende. The irregular shape of many of the hornblende crystals, together with their mottled appearance suggests that they are secondary after pyroxene. Accessory minerals include zircon, sphene, apatite and opaque ore together with secondary epidote. Intruded into the monzodiorite are very pale-coloured dykes of felsic microgranite with less than 5% of ferromagnesian minerals and indeterminate proportions of oligoclase and microperthitic potassium feldspar. The microgranite is itself cut by dolerite dykes up to 10 m wide. In places, all these rock-types are cut by veins of pyrite, chalcopyrite and magnetite (up to 2 mm wide).

Harry Island consists of a xenolithic diorite and the small island immediately to the south is a remarkably fresh trachytic olivine-basalt. The basalt is very fine-grained with phenocrysts of olivine and orientated labradorite in a groundmass of plagioclase, pyroxene and opaque ore.

The volcanic rocks that unconformably overlie the igneous complex on Harry Island consist of porphyritic basalt and palagonite tuff. The palagonite tuff comprises basaltic clasts with microlites and euhedral phenocrysts of labradorite (An_{62}), clinopyroxene and olivine in a glassy matrix. The glass is rimmed with palagonite suggesting subaqueous, possibly subglacial, eruption.

The north and north-west coasts of Liège Island are a plutonic complex of gabbro, diorite, granodiorite and tonalite. These rocks are characterized by a high percentage of plagioclase, lack of potassium feldspar, and secondary hornblende replacing pyroxene. Scattered rounded xenoliths of microtonalite (up to 100 mm in diameter) are locally concentrated in zones up to 1 m wide. The south and south-west coast of the island consists of a complex of pale-coloured tonalite and diorite enclosing porphyritic basic xenoliths. These xenoliths become very abundant in the south-east and in places they form a breccia with up to 90% of large basic xenoliths (up to 1 m in diameter) veined by a network of medium-grained diorite.

The gabbros are fine to medium-grained with 60–75% plagioclase (An_{54-56}). Crystals are up to 5 mm in length and most specimens exhibit slight deformation of the twin lamellae. Augite and hornblende together constitute up to 30% of the gabbro. The pyroxene encloses and is surrounded by the secondary hornblende and, in some specimens, the pyroxene has been completely replaced by amphibole. Accessory minerals include opaque ores (up to 10%), sphene and zircon. The diorites and quartz diorites have a medium-grained granitic texture with up to 70% plagioclase (An_{32-42}). Some specimens contain both hypersthene (with schiller structure) and augite but in most cases the clinopyroxene has been completely replaced by large poikilitic crystals of hornblende. Up to 10% of quartz is present as small intergranular crystals. Accessory minerals are opaque ore, zircon, sphene, apatite and biotite.

The granodiorite and tonalite also has a fine- to medium-grained granitic texture with up to 80% plagioclase (An_{32-54}) as distinctly zoned anhedral crystals. Up to 20% consists of quartz, with large, strained crystals and, in places, a myrmekitic intergrowth with the feldspar. A small percentage of perthitic potassium feldspar is present in some specimens. Pyroxene is rare and mostly replaced by large poikilitic hornblende crystals. Biotite is partly altered to chlorite. In common with all the plutonic rocks on Liège Island, the granodiorites are little altered with only minor amounts of sericite, epidote and calcite.

In the south-east of the island, the dioritic and gabbroic country rock is cut by

Table 1. The stratigraphy of islands in southern Bransfield Strait.

	Liège Island Davis Island	*Intercurrence Island*	*Tower and Kendall Rocks Dumoulin Rocks*	*Astrolabe Island*	*Hombron Rocks*	*Molina Rocks Jacquinot Rocks*	*Montraval Rock*	*Tupinier Islands*	*Duroch Islands Cape Legoupil*	*Lafarge Rocks Casy Island*	*Column Rock Gourdin Island*
Late Tertiary volcanic rocks	Olivine basalt Palagonite tuff		Basalt	Olivine basalt dykes						Olivine basalt	
Dykes and sills	Dolerite Microgranite	Dolerite Quartz andesite Microgranite	Microgranite Dolerite	Microgranite Dolerite Microtonalite	Dolerite Andesite	Microgranite	Microgranite Dolerite	Microgranite Andesite	Andesite		Dolerite
Plutonic rocks of the 'Andean' suite. Jurassic to Lower Tertiary	Granodiorite Tonalite Quartz monzonite Monzodiorite Gabbro Diorite	Quartz diorite Diorite	Diorite Tonalite Granodiorite	Granodiorite Tonalite Gabbro Diorite					Gabbro		Granodiorite Diorite
Antarctic Peninsula Volcanic Group. Mid-Jurassic to Lower Cretaceous		Basaltic to andesitic lava and tuff	Andesitic to basaltic tuff and agglomerate Basalt	Andesitic and dacitic tuff Volcaniclastic conglomerate and sandstone Basalt	Tuff and agglomerate				Porphyritic lava		Andesitic to dacitic ignimbrite
Trinity Peninsula Group. Triassic						Fine-grained sandstone, siltstone mudstone		Granule conglomerate, sandstone, mudstone	Sandstone mudstone Triassic fossils		Pebble conglomerate pebbly mudstone

numerous veins containing quartz and chalcopyrite. The mass of the rock also contains up to 2% of scattered chalcopyrite.

Summary and Interpretation

Despite the lack of firm evidence for the ages of the rocks in the southern Bransfield Strait, a relative sequence of events common to most of the islands can be determined with some degree of certainty (Table I). The oldest rocks are the turbidite sediments of the Trinity Peninsula Group, probably deposited during Triassic times, possibly in a fore-arc environment (Smellie, 1981; Hyden and Tanner, 1981). The deformation and metamorphism of these rocks was probably the result of subduction of an oceanic plate beneath the sedimentary sequence in late Triassic or early Jurassic times.

Overlying the sediments with a marked angular unconformity are the volcanic rocks of the Antarctic Peninsula Volcanic Group. These rocks are predominantly pyroclastic and range in composition from basaltic to dacitic. They presumably formed part of the middle Jurassic to early Cretaceous island arc complex that produced extensive volcanic deposits over the whole of the Antarctic Peninsula area (Thomson, 1982). The only direct evidence of the age of the volcanic rocks in this area is the radiometric ages determined by Rex (1976) and Halpern (1964, 1965). These latest Cretaceous to Eocene ages conflict with the age range for the Antarctic Peninsula Volcanic Group indicated by Thomson (1982) and Fleming and Thomson (1979). This suggests either that some of the volcanic rocks in this area form part of a younger volcanic sequence or that the age of the Antarctic Peninsula Volcanic Group extends into the Tertiary. This latter interpretation is supported by Pankhurst (1982) who indicates essentially continuous igneous activity from late Triassic to early Tertiary times in the northern Antarctic Peninsula. Widespread intrusion of calc-alkaline plutonic rocks of the 'Andean' suite of probable Jurassic to mid-Tertiary age (Pankhurst, 1982) also reflects the situation of these rocks on an island arc (Saunders and Tarney, 1982). After mid-Tertiary times, the volcanic and plutonic activity ceased as the subduction of the Pacific oceanic plate stopped (Weaver and others, 1979). The plutonic rocks are all fine- to medium-grained and they range in composition from diorite and gabbro to tonalite and granodiorite. No granites were identified during the present investigation. The plutons form relatively small bodies, up to about 30 km in diameter, (as illustrated on the map produced by Fleming and Thomson (1979)). It is probable that the four larger islands, Liège, Intercurrence, Tower and Astrolabe islands, owe their resistance to erosion to a core of plutonic rock.

In most localities, the plutonic rocks are cut by thin microgranite dykes of unknown age, themselves cut by younger dolerite dykes. These younger dolerites and the basaltic lavas that cap Liège and adjacent islands in the south-west of the group are relatively fresh and may possibly be related to the late-Tertiary opening of Bransfield Strait by back-arc extension (Weaver and others, 1979).

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