THE GEOLOGY OF THE MARIAN COVE AREA, KING GEORGE ISLAND, AND A TERTIARY AGE FOR ITS SUPPOSED JURASSIC VOLCANIC ROCKS

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ABSTRACT. Volcanic rocks on Barton Peninsula can be divided into an upper and lower member, and are thought to be penecontemporaneous with a lapillite bed on Weaver Peninsula. Hypabyssal intrusions and a zoned pluton were emplaced into these rocks in the Eocene, the pluton causing alteration in some of the volcanic rocks that can be compared to that of porphyry ore deposits. Volcanism, accompanied and followed by faulting, continued beyond the Eocene. On the basis of field evidence, petrology and radiometric data, it is considered that the volcanic rocks, formerly considered to be Upper Jurassic in age, are Lower Tertiary.

BARTON AND WEAVER PENINSULAS are situated on either side of Marian Cove, on the south-west coast of King George Island, South Shetland Islands (Figs 1 and 2). Landings on both peninsulas were probably made for the first time by sealers and whalers in the early nineteenth century, and some semi-permanent occupation is evident from the remains of a shelter on the summit of Noel Hill, presumably used for whale spotting whilst ships were anchored in Potter Cove (Fig. 3).

The first geological investigations in the Marian Cove area were carried out by Ferguson (1921), from whalers operated by Messrs Salvesen of Leith. Ferguson (1921, p. 42) noted that ". . . sedimentary rocks are seen at its north-west corner [of Potter Cove]. They extend along the north side of the harbour and curve round the coast of Fildes Strait to Marian Cove, ... Marian Cove has been excavated in the black mudstones and their associated grits and andesites. Noel Hill . . . is crowned by black or blue black mudstone, which has been baked and indurated by . . . quartz-diorite."

The rock samples collected by Ferguson were petrologically studied by Tyrrell (1921). Although Ferguson reported a considerable number of exposures of blue-black mudstone, Tyrrell found few sedimentary rocks in his collection, and later workers (Jardine, 1950; Barton, 1965) have failed to identify these rocks in the field. It is the author's opinion that Ferguson misidentified them and that they are in fact fine-grained basaltic and andesitic lavas. Further rock samples were collected during the RRS *Discovery II* expeditions and these were also petrologically studied by Tyrrell (1945). Samples said to be from "Fildes Strait" (Tyrrell, 1945, p. 44) are thought to have been taken from Barton Peninsula, since they contain alteration minerals typical of that area. Tyrrell also reported a soda-rhyolite or quartz-keratophyre from this locality. However, subsequent workers (including the writer) have been unable to find these rocks. It is thought that they have been misnamed and are in fact specimens of quartz–pyrite rock. Tyrrell concluded that the Marian Cove and Admiralty Bay areas are composed of older andesites and pyroclastic rocks interbedded with argillaceous sediments of presumed Mesozoic age and intruded by diorites.

D. J. Jardine, a British geologist working from the FIDS station in Admiralty Bay, visited both peninsulas during his field trip to Maxwell Bay in 1949 and he made detailed field observations of the coastal sections (Jardine, 1950). Using his and other field worker's material, Hawkes (1961) published an account of the petrology of King George Island. He did not mention Weaver Peninsula but described extensively metasomatized pyroxene-andesites from the Noel Hill area (Barton Peninsula), and quartz-diorite and granodiorite from Noel Hill itself. Diaz and Teruggi (1956) made a brief geological examination of Weaver Peninsula and concluded that the rocks belonged to an "older series of effusives". Barton (1965) spent November and December 1960 on Barton Peninsula and prepared the first geological map. He described this area as "the most extensive single outcrop of Jurassic rocks on the island", and in part re-interpreted Jardine's stratigraphical section.

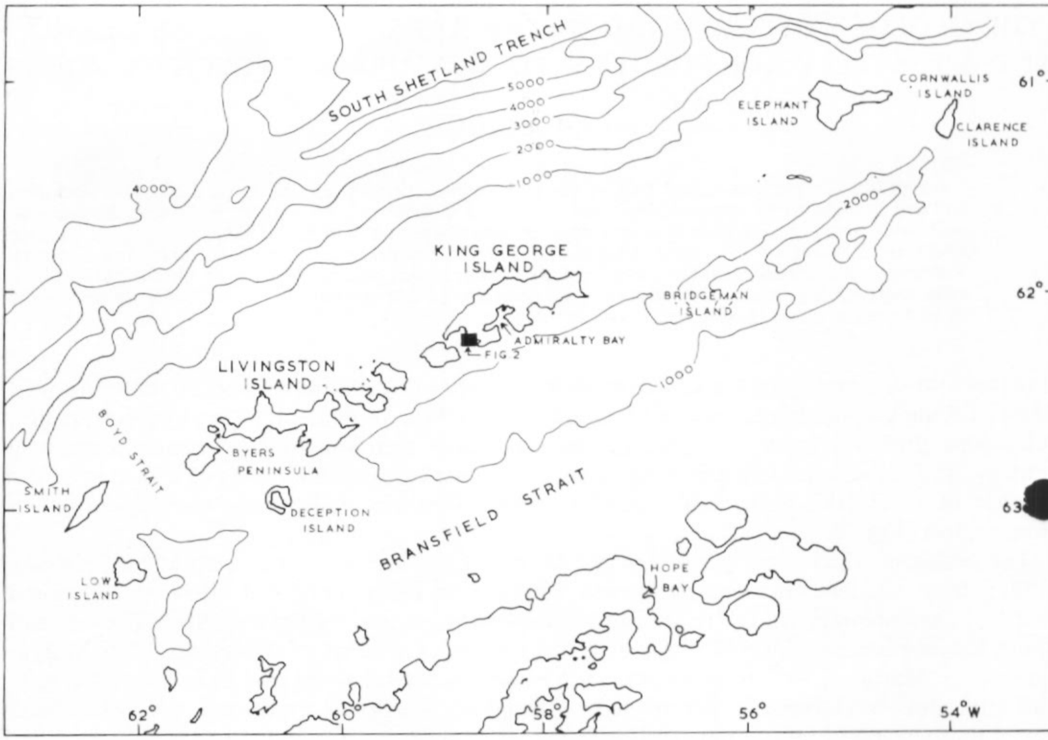


Fig. 1. Sketch map of the South Shetland Islands showing the area described and places mentioned in the text. Bathymetric contours are at 1 000 m intervals.

Grikurov and others (1970) sampled "a small intrusive stock of gabbroids that are differentiated in the marginal areas to granodiorites, in Marian Cove." A sample, presumed to have been collected from Noel Hill, was dated at 55 Ma (whole-rock K-Ar). Watts (in press) has obtained K-Ar ages from King George Island ranging from 46 to 106 Ma. Littlefair (in press) has made a detailed analysis of the mineralogy and chemistry of the quartz–pyrite lodes.

The present paper is based on detailed field work by the author in the Marian Cove area in 1975 and 1976, and this has revealed the stratigraphy shown in Table I. Lower and upper volcanic members, recognized on Barton Peninsula, are correlated with a lapillite bed on Weaver Peninsula. These units are volcanic or volcanogenic and have an andesitic and basaltic andesite petrology. Both areas were intruded in the Eocene by hypabyssal intrusions of dolerite and by plutons of quartz-gabbro and quartz-diorite, the plutons causing extensive alteration of the pre-existing rocks. Subsequently, a breccia flow was deposited on Weaver Peninsula and widespread dyke intrusion and faulting occurred.

Barton Peninsula

Lower volcanic member

The lower volcanic member is a succession of lavas and extrusive volcaniclastic rocks. It is difficult to make a realistic estimate of their thickness because they are disturbed by faulting, their base is nowhere exposed and part of their present dip may be depositional. The dip is variable but it is usually about 20° to the south. No complete stratigraphical column could be prepared for the lower member but lavas dominate the basal section, while volcaniclastic rocks become progressively more important towards the top of the sequence. As can be seen from

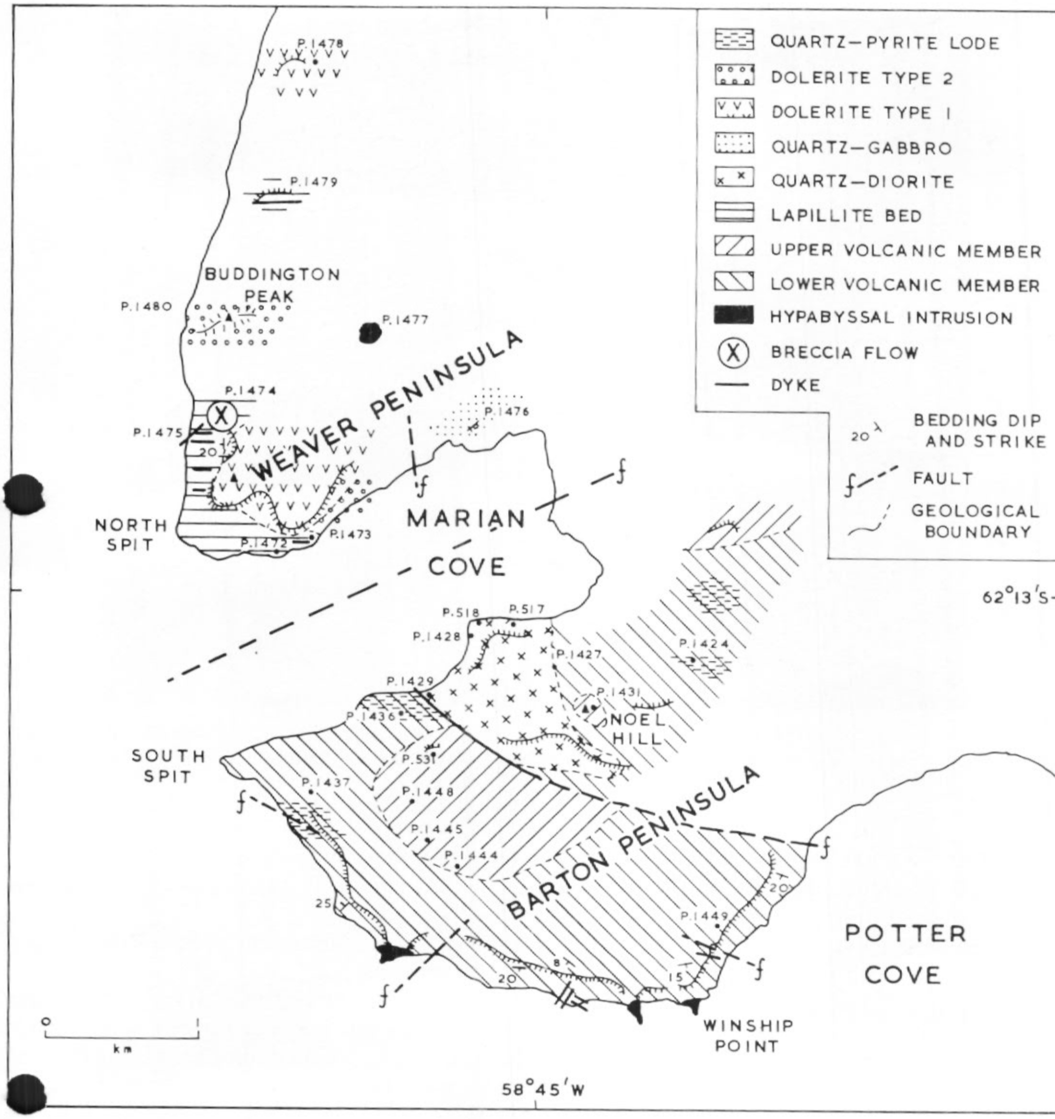


Fig. 2. Geological sketch map of Barton and Weaver Peninsulas compiled from FIDASE air photographs. Principal station numbers referred to in the text are indicated.

the geological sketch map (Fig. 2), the lower member is exposed to the north of Noel Hill (this is the oldest part) and over much of the peninsula apart from the western central area.

Because of intense metasomatism of the lavas by the Noel Hill intrusion, it is difficult to obtain a precise idea of the original petrography of these rocks. It can only be determined that they were originally plagioclase porphyritic and carried subsidiary pyroxene phenocrysts. The lavas vary from a rock consisting of a fine-grained quartzo-feldspathic matrix with accessory biotite (as at the contact with the Noel Hill intrusion; P.1427.1) to a more typical rock such as specimen P.1449.1 (Fig. 4a), which consists of calcite, chlorite and epidote minerals with ghosts of the original feldspar and clinopyroxene phenocrysts. Minor volcanic mudstones

Fig. 3. Air photograph of Maxwell Bay showing Fildes Peninsula (top left), Weaver Peninsula, Barton and Potter Peninsulas (bottom right). (From Hunting Aerosurveys Ltd., by permission of the Government of the Falkland Islands Dependencies.)

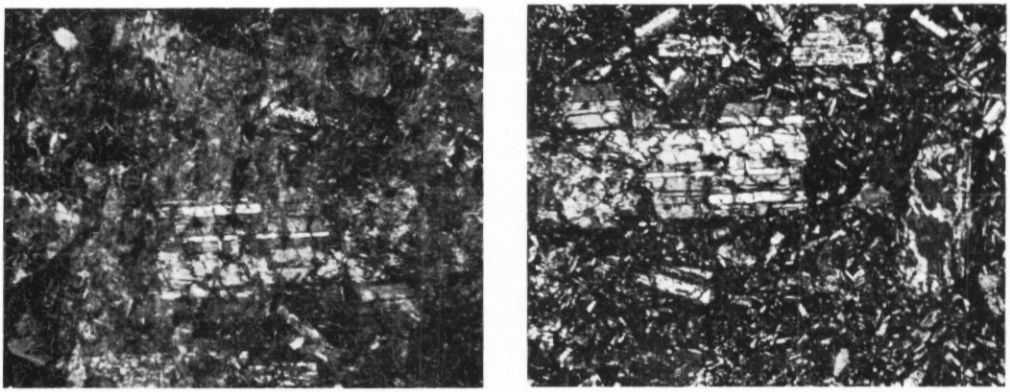
are present but the volcaniclastic rocks are mainly lapillites. Individual beds are generally 0.5–2 m thick and contain angular to rounded clasts of lava and tuff fragments together with a number of acid plutonic clasts.

The so-called quartz–pyrite lodes (Barton, 1965, p. 14; Littlefair, in press; Rowley and Pride, in press) are finely crystalline (0.2 mm) quartz and feldspar rocks with accessory clay minerals and epidote (P.1424.1 and 2, 1436.1 and 1440.3). The pyrite is iron pyrites and occurs as small (0.1 mm) anhedral crystals in three of the samples but it is not present in specimen P.1424.2, which has a uniform cream colour. Where it occurs, pyrite comprises about 10% of the rock and its oxidation produces a bright orange weathered surface making the lodes conspicuous. An accurate mode of formation for these rocks is not known but presumably solutions rich in alkalis and silica emanated from the pluton along joints and faults until a suitable host lithology was encountered and replacement occurred. The host rocks are mainly lavas but specimen P.1440.3 shows a relict lapillite texture with a clast size of 4 mm. Exposures of quartz–pyrite become scarcer south-eastward and are absent in the eastern sector, undoubtedly because of the greater distance from the pluton. From the alteration minerals associated with the plutons of King George Island (sericite, chlorite, epidote, K feldspar, calcite and pyrite), it is reasonable to compare these intrusions to the acid–intermediate stocks found in conjunction with meso- and epithermal mineral deposits, and particularly porphyry ores (Lowell and Guilbert, 1970). These deposits typically have four zones of alteration; a potassic, a phyllic, an argillic and a propylitic zone. For various reasons, not all the zones may be present at a particular site, the most common cause being the level of erosion. On Barton Peninsula, it is thought that the innermost zone seen is the phyllic zone, which is represented by

TABLE I. STRATIGRAPHICAL TABLE FOR THE MARIAN COVE AREA, KING GEORGE ISLAND

Present interpretation			*Stratigraphy after Barton (1965)*
Epoch	*Age (Ma)*	*Geological event*	*Geological event*
Miocene		Faulting and dyke intrusion	
	22.5		
Oligocene			
	37.5	? Breccia flow of Weaver Peninsula emplaced	Jurassic volcanics
Eocene		? Faulting	
	46–50*	Intrusion of Noel Hill quartz-diorite (Watts, in press)	
	48*	Intrusion of porphyritic dolerite on Weaver Peninsula (personal communication from R. J. Pankhurst)	Andean Intrusive Suite (late Cretaceous to early Tertiary)
	53.5		
	55*	Intrusion of Noel Hill quartz-diorite (Grikurov and others, 1970)	
		Some hypabyssal intrusions	
	59*	Average age of lavas on Fildes Peninsula; ? Upper volcanic member ? Lower volcanic member [Barton Peninsula]; ? Lapillite bed [Weaver Peninsula]	Jurassic volcanics
Palaeocene			
	65		

* K-Ar age (whole rock).



a b

Fig. 4. a. A badly altered lava of the lower volcanic member, Barton Peninsula (P.1449.1; X-nicols; ×25).
b. A lava from the upper volcanic member of Barton Peninsula, showing an andesine phenocryst altering to epidote and sericite, and an augite crystal being pseudomorphed by chlorite (P.532.1; X-nicols; ×25).

the alteration minerals quartz, sericite and pyrite. This is closely associated with the argillic zone of quartz, kaolinite and chlorite. Outside these zones is the propylitic zone containing chlorite, epidote, carbonate and albite. The quartz–pyrite lodes are thought to be facies of the phyllic and possibly the argillic zones, since they only crop out along fractures within 2 km of Noel Hill. Although the characteristic porphyry-deposit alteration minerals are present, there has been no metallization of these rocks.

Upper volcanic member

Lavas and volcaniclastic rocks of the upper member rest unconformably on the rocks of the lower volcanic member and have a sub-horizontal attitude (Fig. 2). Lavas form probably two-thirds of the upper volcanic member, the remaining one-third being lapillites. These lavas are porphyritic and less altered than those of the lower volcanic member (Fig. 4b). They contain basic andesine (An_{35-50}) but some basalt flows with a plagioclase composition of An_{60-70} are present (P.1437.1), and an andesite flow has been sampled (P.1444.1 and 1445.1) with a plagioclase composition of An_{36-48}. Most of the plagioclase is altered to sericite and albite, and occasionally to calcite and epidote. Plagioclase phenocrysts (3–4 mm) and augite crystals of about 2 mm are present in virtually all thin sections. The clinopyroxene is normally fresh though it occasionally has a dusty appearance and commonly shows resorbed margins; it is sometimes replaced by chlorite, epidote, opaque minerals and calcite. Also present are uralite/bastite pseudomorphs which are often tabular and most likely represent original ortho-pyroxene rather than olivine. Plagioclase microlites, 0.2 mm long and often flow-orientated, form the bulk of the groundmass, the remainder consisting of alteration products and devitrified glass.

The lapillite beds (P.531.1 and 1448.1) are dominantly of angular to sub-angular lithic clasts with a modal size of 3–4 mm but ranging from 0.5 to 20 mm; clasts include trachytic, fine-grained and porphyritic lavas, scoriae and mudstone.

Hypabyssal intrusions

Dykes, sills and small stocks crop out in coastal cliffs formed in the lower volcanic member (Fig. 2). They are generally fine-grained and occasionally display traces of flow texture around euhedral augite and plagioclase phenocrysts, which average 2 and 4 mm in diameter, respectively. Alteration is extensive with chlorite after augite, and plagioclase of an original labradorite (An_{50-60}) composition altered to sericite and albite. Although epidote is absent in the minor intrusions to the east, it is present in those to the west, suggesting that the latter have been subjected to the alteration effects of the Noel Hill pluton and are therefore of pre-pluton age.

At station P.1440, a porphyry-dolerite crops out; this is similar in virtually all respects to the porphyry-dolerite of Weaver Peninsula (see below). Specimen P.1440.1 is typical of the lithology and contains large equant euhedral to subhedral plagioclase crystals (An_{60}) up to 1 cm long. Although they are unzoned, they often display complex twinning. The crystals are virtually unaltered with only a small amount of sericitization concentrated in fractures around the edges. Pools of chlorite and epidote (3 mm) represent original mafic minerals with some augite still present. Small plagioclase crystals (0.1 mm) and interstitial epidote comprise the groundmass. Within the intrusion there are enclaves of a petrologically related rock which differs only in the smaller size of its plagioclase phenocrysts (4 mm).

The Noel Hill quartz-diorite

The pluton exposed on the flanks of Noel Hill has been mentioned by many workers (Ferguson, 1921; Tyrrell, 1921; Jardine, 1950; Hawkes, 1961; Barton, 1965; Grikurov and others, 1970), who have given it a variety of names. Since it has now been more fully investigated, it is proposed to formally name it the "Noel Hill quartz-diorite". It has a roughly triangular outcrop, approximately 1 km long in a north-west to south-east direction and 0.6 km across at its widest part, on the south-eastern shore of Marian Cove (Fig. 2). From sea-level, the quartz-diorite is exposed up to an altitude of approximately 250 m. Although no contacts are exposed, field relationships suggest that the southern boundary is faulted, and that the more sinuous north-eastern boundary is an intrusive contact.

Although the name quartz-diorite has been given to the pluton, there is a systematic variation in composition across the body (Table II; Fig. 5); it is most acidic on its north-eastern contact where it has the composition of a granodiorite (P.517.1 and 1427.2). The bulk of the intrusion can be correctly called quartz-diorite but there is a trend of increasing basicity towards the south-west until, on the south-western border, little or no alkali-feldspar is present and the rock there may be termed a tonalite (P.1429.1). Two basic enclaves were sampled (P.517.3 and 1428.1) from sites in the centre of the coastal section; these presumably represent incorporated early formed marginal facies of the intrusion. The mineralogy of the intrusion is conventional (Table II) with 50% plagioclase, which ranges from andesine (An_{30}) to labradorite (An_{60}) but it is most frequently andesine (An_{40-50}). Quartz and alkali-feldspar (invariably altered) are generally present in sub-equal amounts. Amphibole is the dominant mafic mineral, both as primary hornblende and as uralite secondary after augite. The combined content of pyroxene and amphibole is usually about 10% but this rises to about 30% in the tonalite facies. Biotite is usually present but it never comprises more than 4% of the rock. Opaque minerals (magnetite/ilmenite and pyrite) normally constitute only 1% but this may increase to as much as 6% where there has been significant uralitization of pyroxene with consequent exsolution of iron. Chlorite and epidote only account for 1% or 2% and accessory apatite is also present.

The range of rock type across the pluton indicates that it is not completely exposed but forms part of a larger pluton that may crop out under much of the ice cap of King George Island. Outcrops of related intrusions at Crépin Point, Rose Peak and Weaver Peninsula may be surface expressions of the same pluton. Quartz-gabbros at Crépin Point and Weaver Peninsula can reasonably be expected to have formed a marginal facies of the pluton, while the granodiorites of Noel Hill and Rose Peak may have formed the core of the body. Post-Eocene faulting is believed to be mainly responsible for the present fragmented nature of the pluton.

TABLE II. MODAL ANALYSES OF THE NOEL HILL QUARTZ-DIORITE

	P.517.1	P.517.2	P.517.3*	P.518.1	P.518.2	P.535.1	P.535.2	P.535.3	P.1427.2	P.1428.1*	P.1429.1	P.1429.2	P.1434.1	P.1434.2
Quartz	20	12	14	13	17	7	7	17	19	1	1	17	14	10
Plagioclase	46	53	52	55	53	57	51	50	46	61	68	53	55	61
Orthoclase	24	21	23	19	16	24	21	15	22	3	—	18	14	5
Biotite	—	1	tr	3	3	tr	1	1	4	1	1	4	2	2
Amphibole	6	8	8	2	7	10	11	13	6	18	17	4	9	18
Augite	1	—	tr	4	2	—	2	—	—	12	8	1	2	1
Opaques	2	2	1	4	1	1	5	3	1	4	6	1	3	3
Accessories	1	3	1	tr	2	tr	1	tr	1	—	—	1	tr	tr

* Enclaves.
tr Trace.
500 counts per thin section.

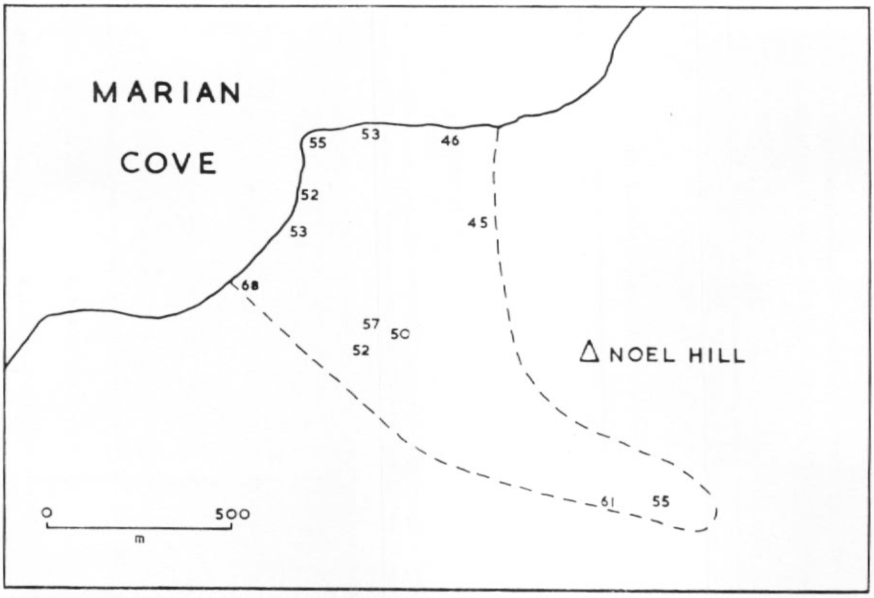


Fig. 5. Sketch map of the Noel Hill quartz-diorite showing the progressive variation in composition. Numbers refer to the percentage of plagioclase present as determined by modal analysis.

WEAVER PENINSULA

Lapillite bed

All the exposures of volcaniclastic rocks are thought to belong to a single "lapillite" bed. Although it is not a true lapillite throughout, this is the commonest lithology. The two extremes of the bed are: an agglomerate at station P.1472 with clasts up to 40 cm, and a fine volcanic siltstone at station P.1475. Lava fragments, some showing flow textures, and pumice form most of the clasts. They have all been badly altered, mostly showing calcification. Dips are variable, probably due to depositional features and faulting, but a moderate (10–20°) westerly dip is valid for the majority of the exposures.

Intrusions

These form all the elevated areas and it is possible to subdivide them genetically into three types. The commonest of the three is a porphyritic dolerite (type 1) represented by specimens P.1472.7, 1473.5 and 1478.1. A similar intrusion occurs on Barton Peninsula (P.1440.1) and it is included in this type for description. It is characterized in thin section by large unzoned euhedral plagioclase crystals (2–10 mm, typically 8 mm long) with a narrow labradoritic compositional range of An_{54-68}. These phenocrysts comprise approximately 50–70% of the rock. Specimen P.1473.5 is unusually fresh; in fact, it is the least altered rock on the peninsula but the other members of the group show characteristic fracturing of plagioclase and alteration to albite, sericite and calcite. Clinopyroxene (1–5 mm) is or has been present in all specimens. Where it is unaltered, it can be identified as augite, and interstitial pigeonite is present in specimen P.1473.5. The ophitic and subophitic textures demonstrate the affinity of this rock type to the dolerite family. Small interstitial (0.4 mm) patches of uralite in specimen P.1475.3 may represent original hypersthene. Where determinable, microlite composition is basic andesine to acid labradorite An_{40-55}. A notable macroscopic feature of this group is the presence of enclaves of a texturally different porphyritic dolerite (Fig. 6). The enclaves comprise about 30% of the rock at station P.1472. They are generally sub-angular in shape and

Fig. 6. The porphyritic dolerite of Weaver Peninsula at station P.1472 showing the enclaves. The pencil is 8 cm long.

7–8 cm in diameter but range from 2 to 15 cm. Partial resorption of the enclaves has resulted in ill-defined boundaries. Although they are similar to the host rock, the enclaves contain larger and more densely packed plagioclase crystals.

The second group is also represented by a porphyritic dolerite (type 2) but it is distinguished from the first by smaller (3 mm) zoned plagioclase crystals. Specimens P.1473.2, 4 and 1480.2 represent this type which has altered to calcite, sericite and albite. However, in many cases the plagioclase alteration is confined to the more calcic cores, leaving a clear unaltered rim. It is not possible to determine accurately by optical means the composition at which alteration begins but at Buddington Peak (P.1480.2) it is about An_{60}. Clinopyroxene is, or was, present as small phenocrysts 1–5 mm in diameter and as interstitial grains. All three specimens display 1 mm tabular uralite/serpentine pseudomorphs thought to be after orthopyroxene. The groundmass plagioclase composition could only be determined in specimen P.1480.2, in which it is sodic labradorite (An_{50-60}).

Field relationships indicate that the porphyritic dolerite containing the unzoned plagioclase phenocrysts (type 1) is slightly later than the other dolerite (type 2). At station P.1473, the type 1 dolerite forms a core to the surrounding type 2 dolerite, whereas at station P.1472 a mutually intrusive contact is exposed (Fig. 6), indicating that the intruded rock had not completely crystallized at that time. The presence of zoned plagioclase is indicative of a long magmatic history with frequent changes in the composition of the liquids directly adjacent to the phenocrysts, either through transport of the crystals to different regions of the magma chamber or by physico-chemical changes in the magma. Conversely, unzoned plagioclase crystals grow in stable magmatic environments, so that the two dolerites probably formed in separate magmatic environments. It is most likely that the type 2 dolerite was a magma reservoir for an active vent, each eruption probably causing zoned growth of the plagioclase phenocrysts. When eruption ceased, the reservoir slowly crystallized more or less *in situ*.

Two exposures at the eastern end of the peninsula are the only expression of the third magma type to which the name quartz-gabbro has been given. This unusual lithology was also reported from Crépin Point in Admiralty Bay (Fig. 1) by Tyrrell (1921), who described two specimens. Specimen P.1476.1 is similar to the altered specimen described by Tyrrell, i.e. it is dominated by euhedral to subhedral sodic labradorite (An_{50-60}; 2–3 mm), showing slight alteration to sericite and albite. Plagioclase forms about 70% of the rock and most of the remainder consists of xenomorphic, ophitic and subophitic augite (1–3 mm). A distinctive feature is the symplektitic intergrowth of magnetite, ilmenite and uralite; these are about 2 mm long and usually tabular in form. They are probably due to exsolution of iron and magnesium during the alteration of orthopyroxene. Alkali-feldspar predominates over quartz in the interstices, and chlorite and epidote are also present, some of the later being primary. Apatite is an accessory mineral.

Breccia flow

A volcaniclastic deposit crops out 0.5 km south of Buddington Peak (Figs 2 and 7), and consists of rock fragments surrounded by a green matrix. The matrix (P.1474.9) is a vesicular, dirty-green fine-grained tuff whose colour has probably resulted from chlorite growth during devitrification. Calcified plagioclase phenocrysts about 6 mm long comprise about 15% of the matrix and they are scattered throughout. The rock fragments are mostly small; about half of them are less than 5 cm and only about 5% are between 1.5 and 2 m in diameter. The larger clasts predominate at the western end of the exposure. A wide variety of lithologies comprises the rock fragments and the following is a field estimation of their abundances: heavily altered lavas 40%, fine-grained lavas 20%, feldspar-porphyritic lavas 15%, lapilli-tuffs 15%, quartz–pyrite 10%; a small amount of pumice is also present.

Specimen P.1474.7 is representative of the heavily altered lavas, and contains calcite and albite pseudomorphs of plagioclase crystals (2–3 mm) set in a fine-grained altered groundmass.

The fine-grained lavas are typified by specimen P.1474.5, which shows calcite, chlorite and epidote alteration but still contains relict augite. The plagioclase crystals are completely altered. Specimens P.1474.8 and 10 represent the porphyritic lavas. Densely packed labradorite (An_{50-65}) crystals constitute about 75% of the rocks. The mafic minerals are all altered except for some partially resorbed augite in specimen P.1474.10.

Although quartz–pyrite fragments form one of the smaller clast groups, they are the most distinctive due to their bright orange-red oxidation stains (Fig. 7). Specimen P.1474.2 from this lithology has been interpreted as originally being a lapilli-tuff that has subsequently been entirely recrystallized to a microcrystalline intergrowth of silica and feldspar with some chlorite and abundant minute (less than 0.1 mm) pyrites.

This heterolithologic, unsorted and non-stratified deposit is interpreted as being originally an underground breccia flow (Parsons, 1969), which flowed down-slope on reaching the surface, probably with the aid of water. The lack of recognizable chill zones, grading and sorting structures indicates that the amount of water involved was small. From the lithologies present as clasts, it is evident that the breccia flow sampled a sequence of rocks similar to those now exposed on Barton and Weaver Peninsulas. It is also clear that the flow incorporated the fragments after they had suffered the alteration seen in their parent rocks.

Dykes and hypabyssal intrusions

These are the youngest rocks that crop out on Weaver Peninsula and they cut every rock type except the quartz-gabbro, which has a limited exposure. They virtually all trend east–west and all but three have a similar mineralogy. The majority of the dykes are plagioclase-phyric (1–4 mm) with a fine-grained groundmass of alteration products. Alteration is intense in all specimens but it becomes more severe towards the centre, an indication that they acted as channelways for metasomatizing fluids. Plagioclase composition, where it could be determined,

Fig. 7. The breccia flow on Weaver Peninsula at station P.1474, showing the quartz-pyrite clasts. The hammer shaft is 50 cm long.

varies from sodic andesine to calcic labradorite (An_{45-65}). No microlite compositions could be obtained. Alteration minerals in approximate order of abundance include: calcite, sericite, albite, chlorite and occasionally epidote. Some plagioclase crystals show evidence of having been originally zoned and a number of specimens display glomeroporphyritic textures. All specimens contain clinopyroxene, or pseudomorphs after it, and orthopyroxene pseudomorphs are thought to be present in some. At one locality (P.1475), five dykes have been intruded in a very small area, so that they all intersect, or lie within previous dykes. This high density of dykes is assumed to be an indication of the close proximity of the volcanic centre.

An altered, prehnite-bearing andesite dyke (P.1473.3) intrudes part of the type 2 dolerite but it is not seen to intrude the adjacent type 1 dolerite. Although it is possible that the dyke pinches out in the latter body, it seems more likely, in view of the different alteration states of the two dolerites, that the type 1 dolerite is a slightly later intrusion.

An unusual clastic dyke at station P.1478 consists of lapilli and fine-grained and porphyritic lava fragments which probably represent surface ash deposits. The dyke is thought to have formed either by infilling of a fissure opened by earth tremors or by forceful subterranean injection.

Discussion

The stratigraphy of the Marian Cove area, as understood at the present time, is summarized in Table I. It can be seen by comparison with the stratigraphy established by Barton (1965) that there are some gross differences. In order to explain these, it is helpful to understand the evolution of the stratigraphical table as used by Barton and other workers in the South Shetland Islands.

The first published account of the stratigraphy for the South Shetland Islands was by Ferguson (1921), who recognized three periods of volcanic activity. The oldest was the "mudstone andesite series" (dated as probably late Jurassic) followed by basalts and olivine-andesites of "mid Kainozoic" age. The third group included the basalts and palagonite-tuffs of Deception, Bridgeman and Penguin Islands, and is of no further concern here. In ascribing an age to the pluton at Noel Hill, Tyrrell (1921, p. 76) said: "If the great plutonic masses of Graham Land . . . be regarded as the products of one episode . . . they must be placed . . . towards the end of the Mesozoic era, or at the beginning of the Kainozoic." These deductions were made by correlation with the Hope Bay area (Andersson, 1906) and were based on the argument that, because there were no plutonic clasts in the Middle Jurassic plant-bearing shales, the plutons had to be emplaced after the Middle Jurassic. Furthermore, the late Jurassic age for the volcanic rocks of King George Island were inferred by correlating them with tuffs overlying the plant-bearing shales at Hope Bay and the fact that they are intruded by a "Cretaceous" pluton on Barton Peninsula.

These suppositions formed the basis of stratigraphical correlation in the South Shetland Islands until the advent of radiometric dating. Both Hawkes (1961) and Barton (1965) used these suppositions to put broad age limits on the rocks. The first dissentions to these ideas were voiced by Grikurov and Polyakov (1968), who said of the Marian Cove area "The age of both rock varieties is young, in our opinion, most likely Miocene." This opinion was based on lithological similarities of rocks of the Marian Cove area with the Tertiary rocks of Fildes Peninsula. Subsequently, Grikurov and others (1970) published a number of K-Ar age determinations for the South Shetland Islands, including one of 55 Ma (latest Palaeocene) for the Noel Hill quartz-diorite. The authors believed this result re-affirmed the opinions of Grikurov and Polyakov (1968).

The discovery reported here, of quartz–pyrite clasts in the breccia flow at Weaver Peninsula (Fig. 7), was the first reliable field evidence that the existing stratigraphy of the area needed revision, as the rocks of this peninsula had previously been regarded as Upper Jurassic in age. The quartz–pyrite lodes of King George Island almost certainly formed as a result of alteration from the emplacement of plutons now believed to be no older than Upper Palaeocene. Thus the quartz–pyrite lodes probably formed in late Upper Palaeocene or Lower Eocene times and any deposits containing clasts of quartz–pyrite are post-Lower Eocene. It is of interest to note here that Jardine (1950, p. 5) reported quartz–pyrite fragments from an agglomerate at Ullmann Spur, a site long regarded as virtually a type locality for "Jurassic Volcanics" in King George Island. Jardine (1950) also stated that he considered that the geological history of King George Island was largely confined to the Cenozoic.

A radiometric age (whole-rock K-Ar) of 47.8 ± 1.8 Ma (personal communication from R. J. Pankhurst) has been obtained from the type 1 dolerite of Weaver Peninsula. Clasts similar to this intrusion are included in the breccia flow and this would suggest that the flow is no older than Middle Eocene. The age of the rocks into which the Noel Hill quartz-diorite is intruded cannot be accurately dated due to alteration but they are obviously the oldest rocks in the Marian Cove area and are probably among the oldest on King George Island. However, since their petrology (andesites and basaltic andesites) indicates that they formed from a magma similar to that of the Noel Hill quartz-diorite, it is believed that they represent the surface volcanic activity which accompanied the intrusion of the plutons. The Noel Hill quartz-diorite then subsequently intruded these volcanic rocks. It is hoped to test this suggested relationship by forthcoming geochemical studies.

Lavas from Fildes Peninsula have an average age of 59 Ma (personal communication from R. J. Pankhurst) and their petrology is essentially that of the rocks of the Marian Cove area but they are less altered (Hawkes, 1961). It is believed that both these areas were part of the same Palaeocene volcanic field and that pre-Tertiary volcanic rocks are absent.

This new interpretation of rocks from parts of King George Island has important stratigraphical implications for the Antarctic Peninsula. Ever since Andersson (1906) and Halle (1913) provided evidence that volcanic rocks at Hope Bay were Upper Jurassic in age, the term Upper Jurassic volcanics has been loosely applied by a number of authors to many petrologically similar rocks in the Antarctic Peninsula area. However, the term was formalized by Adie (1962, table 4) as "Upper Jurassic Volcanic Group" in reference to Hawkes's (1961) "Jurassic Volcanics" of Admiralty Bay. The term "Upper Jurassic Volcanic Group" has since been used extensively in the Antarctic Peninsula area (Goldring, 1962; Elliot, 1964; Curtis, 1966; Fleet, 1968; Dewar, 1970) for altered dominantly andesitic volcanic rocks that could not be accurately dated. Although recent work (Adie, 1971; Thomson, 1972; Rex, 1976) has confirmed a Jurassic age for some of these rocks, the data presented here indicate that the "Jurassic Volcanics" on King George Island are probably Cenozoic in age and therefore caution must be exercised when correlating volcanic rocks in the Antarctic Peninsula on the basis of petrology alone.

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