THE GEOLOGY OF PART OF AN ISLAND ARC–MARGINAL BASIN SYSTEM IN SOUTHERN SOUTH GEORGIA

By C. M. Bell, B. F. Mair and B. C. Storey

Abstract. The pre-Cretaceous Larsen Harbour Formation of southern South Georgia is an ophiolite sequence of submarine lavas and sheeted basic dykes emplaced into metasedimentary country rocks in a marginal basin. The ophiolites are probably overlain by the Upper Jurassic–earliest Cretaceous Cumberland Bay Formation, a turbidite succession derived from an andesitic island arc. The roots of the ophiolite sequence are represented by gabbros or basic dykes which crop out to the north-east of Drygalski Fjord. Younger acid plutonic rocks were formed largely by partial melting of the metasedimentary country rocks.

The long chain of mountains and islands of the southern Andes, the Scotia Ridge and the Antarctic Peninsula (Fig. 1) has formed part of an active continental margin at least since the late Jurassic (Katz, 1972; Dalziel and Elliot, 1973; Dalziel and others, 1974, 1975). Detailed mapping of southern South Georgia during the summer of 1974–75 by C. M. Bell, B. F. Mair, B. C. Storey and D. Orchard has clarified some of the stratigraphical problems of this geologically complex area. Of particular importance was the recognition of the upper part of an ophiolite sequence forming a well-exposed and virtually undeformed segment of oceanic crust emplaced into the continental margin.

South Georgia (lat. 54–55°S., long. 36–38°W.) is about 160 km. long and between 5 and 30 km. wide. It forms the central part of a detached block of continental crust on the north Scotia Ridge, separated from its earlier position adjacent to the southern Andes by the probably early Tertiary fragmentation and opening of the continental margin in the Scotia Sea area (Matthews, 1959; Hawkes, 1962; Barker and Griffiths, 1972). The main features of the geology of South Georgia have long been known. Most of the island consists of the Cumberland Bay Formation, a thick sequence of folded volcaniclastic turbidites of late Mesozoic age, thrust over the Sandebugten Formation, a sequence of more quartzose turbidites of unknown age (Trendall, 1953, 1959; Dalziel and others, 1975; Stone, in press). Controversy surrounds the relationship between these two formations. At one time the largely unfossiliferous Sandebugten Formation was believed to be Palaeozoic in age and unconformably overlain by the Mesozoic Cumberland Bay Formation (Trendall, 1953). It has subsequently been suggested that both formations are Mesozoic in age and that they were either deposited synchronously in two parallel basins with different provenances or that their deposition was separated by a palaeogeographical change (Trendall, 1959; Dalziel and others, 1974).

The Cumberland Bay Formation consists essentially of turbidite-facies sediments with some intercalated tuffaceous beds. The turbidites are composed largely of andesitic and dacitic clasts and show a rhythmic alternation of relatively proximal and distal facies (Mortimore, in press) with palaeocurrents directed towards the north-west. An Upper Jurassic–earliest Cretaceous age is indicated by rare belemnite guards (Stone and Willey, 1973). The formation was subjected to polyphase deformation with fold axes of the major episodes of deformation trending roughly north-west and verging to the north-east. A thick and relatively undeformed sequence of andesitic tuffaceous mudstones and structureless volcanic breccias on Annenkov Island off the south-west coast of South Georgia was derived largely from ash falls and mass flows, and was deposited in a shelf environment on the north-eastern flanks of an island arc. These sediments of the Annenkov Island Formation contain Lower Cretaceous fossils and were intruded by consanguineous andesites (Pettigrew and Willey, 1975; Pettigrew, in press). The deposits possibly form a proximal lateral facies variant of the upper parts of the Cumberland Bay Formation.

The turbidites of the Sandebugten Formation are relatively quartz-rich by comparison with those of the Cumberland Bay Formation. They contain rare fragments of carbonized wood and

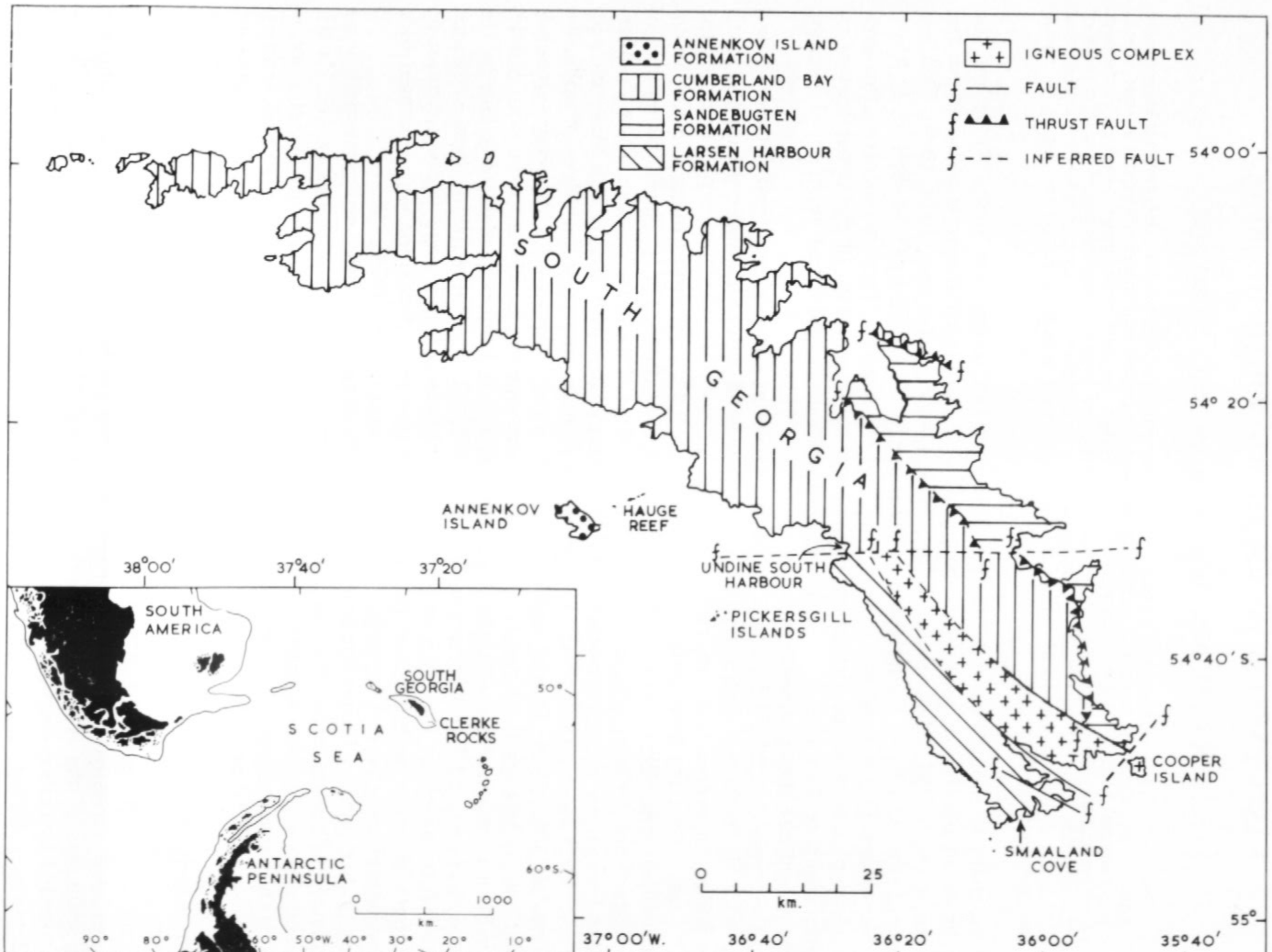

Fig. 1. Geological sketch map of South Georgia to show the relationship between major geotectonic units. The inset is a location map showing the 1,000 m. submarine contour.

small clusters of radiating burrows but are otherwise apparently unfossiliferous. The intensity of polyphase deformation and grade of metamorphism (lower greenschist facies) of the Sandebugten Formation increase towards the south-west. The intensely deformed and metamorphosed sediments in the Cooper Bay area of southern South Georgia are not geographically contiguous with exposures of the Sandebugten Formation but they have been tentatively correlated on structural and petrological grounds (Stone, in press).

Geotectonic Sub-divisions of South-eastern South Georgia

South-eastern South Georgia (Fig. 2) consists of three distinct geotectonic units separated by major faults (Fig. 3). From west to east these units are:

i. The Larsen Harbour Formation, forming the upper part of an ophiolite sequence.
ii. The south-eastern igneous complex (Trendall, 1959) and its sedimentary and metasedimentary country rocks.
iii. Metasediments of the Cooper Bay area, possibly forming part of the Sandebugten Formation.

Larsen Harbour Formation

A thick sequence of submarine volcanic rocks and sheeted dykes in south-eastern South Georgia is here designated the Larsen Harbour Formation. Volcanic rocks of this formation were first observed by Trendall (1953, 1959) and described as spilitic and basaltic lavas.

Type locality

Larsen Harbour, lat. 54°50′S., long. 36°00′W. (Fig. 4). The Larsen Harbour Formation crops out over an area of approximately 10 km. by 48 km. It is bounded to the north-east by a fault along Drygalski Fjord and extends at least as far north as Undine South Harbour, where

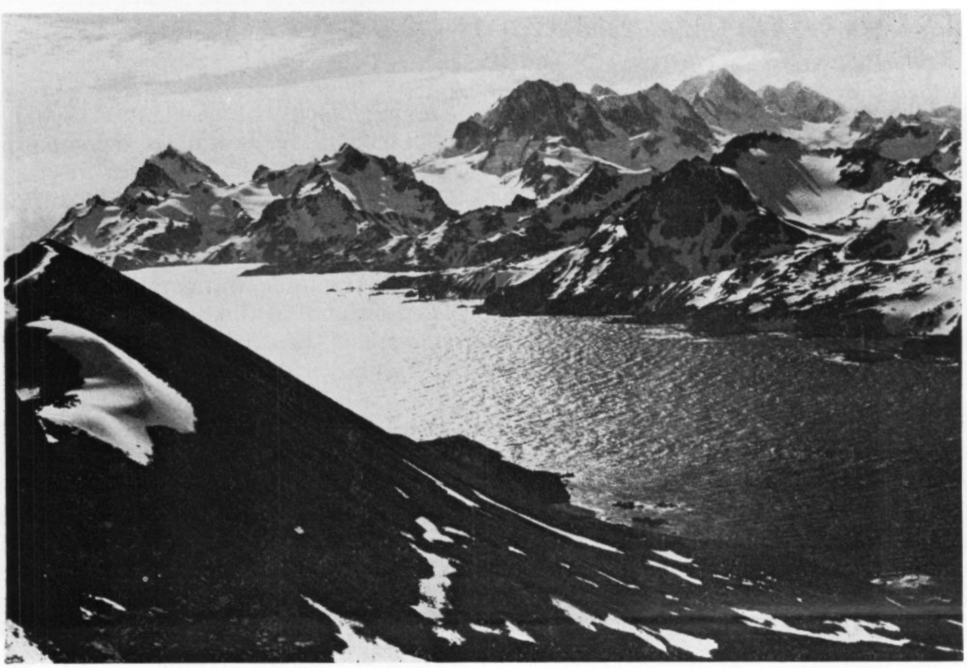

Fig. 2. The mountains of southern South Georgia; a view westward from Cooper Island.

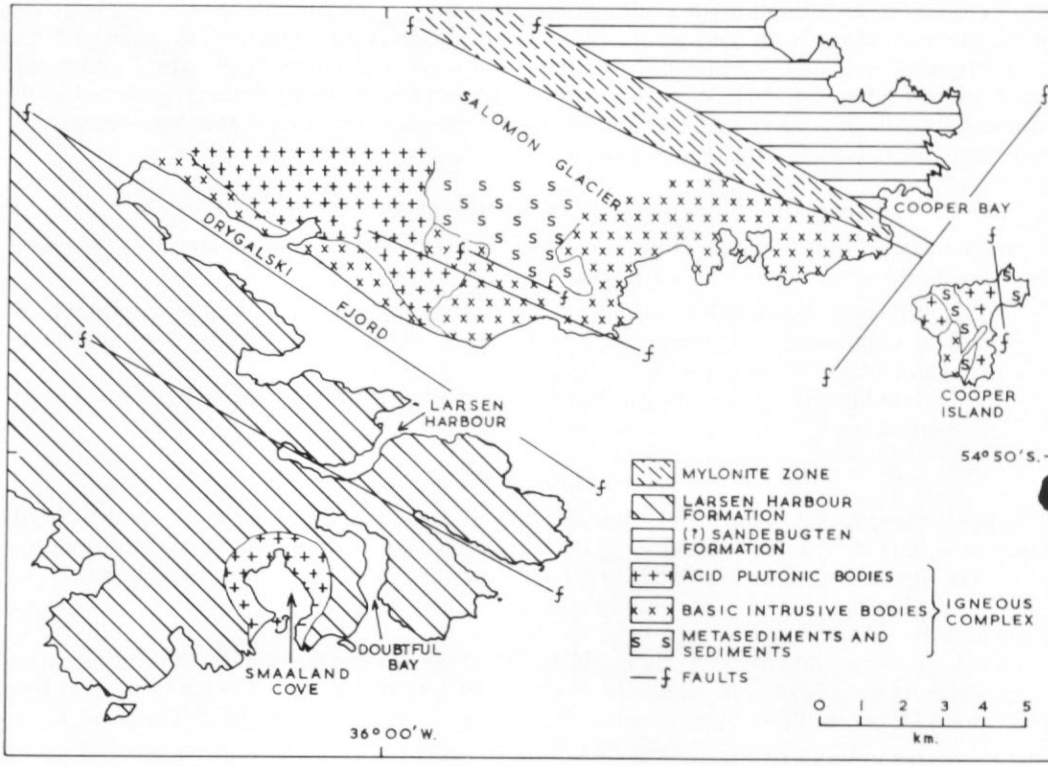

Fig. 3. Simplified geological sketch map of southern South Georgia.

it is probably terminated by a fault occupied by Brögger Glacier. This formation comprises a thick pile of basaltic pillow lavas and breccias with a few massive lava flows and subordinate amounts of rhyolite and tuffaceous sediment. The extrusive rocks were fed by fissure eruptions from swarms of multiple and composite dykes. Stratification in the lava sequence is irregular and indistinct, and consequently it is difficult to measure except in the interstratified sediments and breccias. The formation is not folded, exhibits no penetrative fabric and has an average dip of about 25° towards the west-south-west. The total stratigraphical thickness is unknown but an estimate based on a dip of 25° over a distance of 10 km. suggests a thickness in excess of 5 km. However, this figure probably represents the composite thickness of overlapping lava sheets or lenses (cf. Gibson and Piper, 1972) rather than the true vertical thickness of the formation.

Pillow lavas are the most abundant rock type in the Larsen Harbour Formation. They were deposited as ill-sorted and unstratified masses of amygdaloidal and vesicular basalt often more than 100 m. thick, with pillows up to 1 m. in diameter and surrounded by small amounts of apparently chloritic matrix (Fig. 5). Breccias composed of ellipsoidal and irregularly rounded to angular fragments of amygdaloidal basalt set in an abundant chloritic matrix (Figs. 6 and 7) commonly form thick deposits interstratified with the pillow lavas. In most places the breccias are structureless but in some the outlines of pre-existing pillows can be identified. This suggests an origin by the partial alteration of the pillow lavas subsequent to their emplacement. However, lithologically comparable breccias with a poorly developed stratification (Fig. 8) and detached pillows (Fig. 7) were probably formed by the disintegration of lavas prior to

Fig. 4. Larsen Harbour in the foreground with Drygalski Fjord and the mountains of southern South Georgia.

Fig. 5. Basaltic pillow lava. The hammer shaft is 30 cm. long.

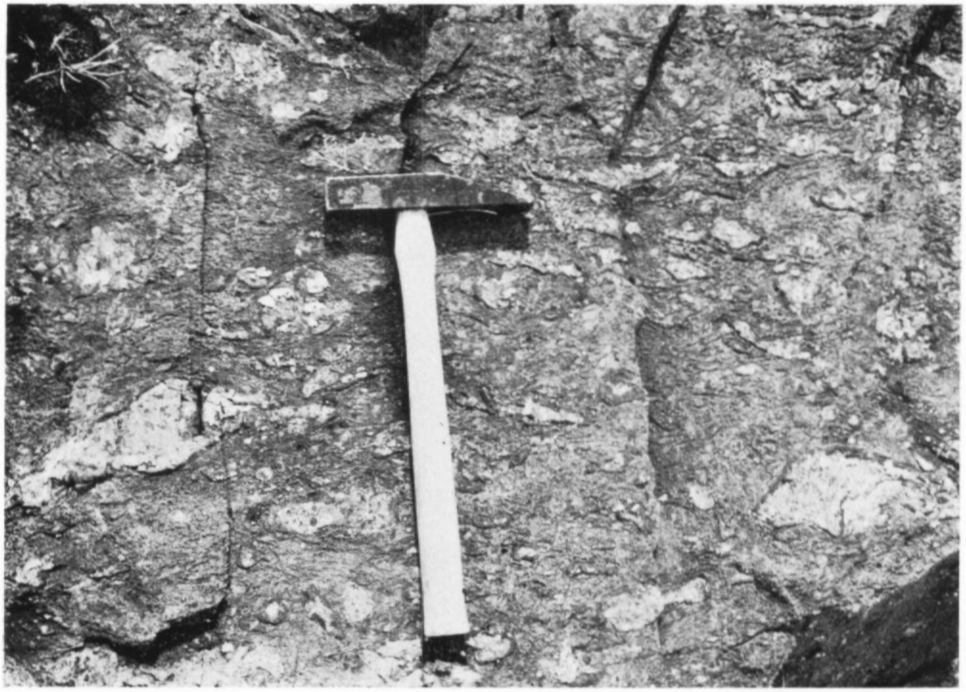

Fig. 6. Weathered surface of a basalt breccia. The hammer shaft is 30 cm. long.

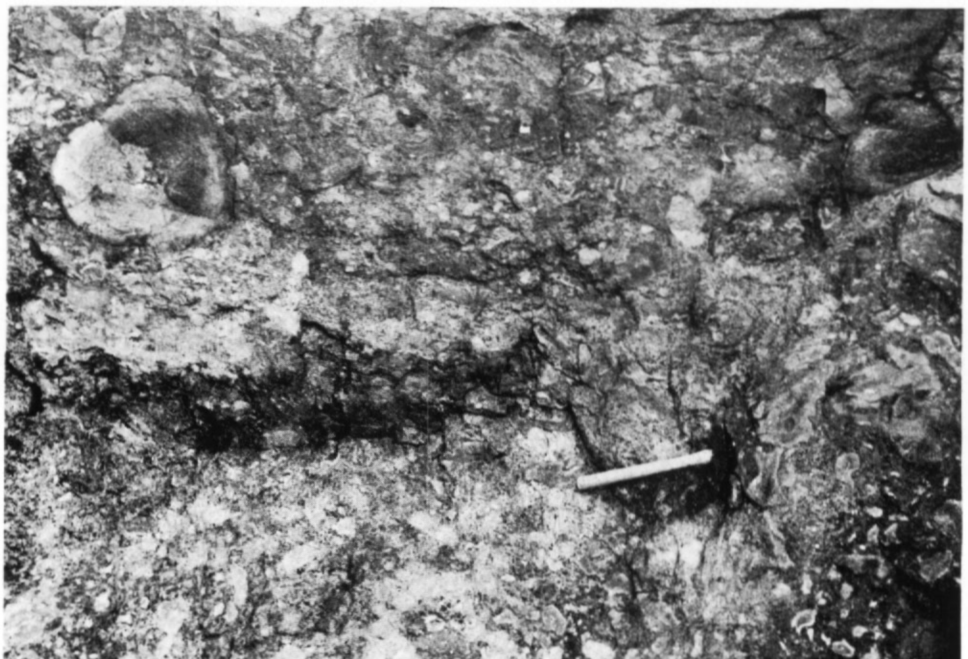

Fig. 7. Structureless breccia of amygdaloidal basalt containing a well-formed and detached pillow. The hammer shaft is 30 cm. long.

Fig. 8. Stratified volcanic breccia with more typical massive unstratified deposits on the right.

deposition. Massive lava flows are very rare and difficult to distinguish from intrusive sills. Intrusive and extrusive lensoid bodies of rhyolite up to 50 m. thick, with syn-genetically folded and brecciated flow banding, occur sporadically within the basic lava sequence. Rare volcaniclastic sediments and radiolarian cherts are also interbedded with the lavas; these sedimentary sequences reach a maximum thickness of 10 m. but they are generally much thinner and impersistent along the strike. The bedding is usually horizontal with no sedimentary structures apart from rare repetitive graded sequences.

Multiple basic dykes, trending north-west parallel to the strike of the lavas, formed feeders for the extrusive rocks and locally they are concentrated in distinct closely packed swarms. The near-vertical dykes have an average width of about 1 m. and are frequently amygdaloidal with slightly sinuous margins and a distinct compositional banding. Rare rhyolite dykes and composite dykes with basic margins and rhyolitic cores indicate an intimate connection between the acid and basic lava types (cf. Walker, 1964). North-west of Doubtful Bay the host rock of pillow lava and rhyolite is broken into thin screens between a dense swarm of dykes. 29 basic dykes, varying between 5 cm. and 10 m. in width, comprise 55 per cent of a 117 m. measured section. The measured orientation of 775 basic dykes intruded into the Larsen Harbour Formation indicates that the common north-west-trending feeder dykes of the formation are cut by a substantial number of younger dykes trending approximately north–south.

The proportion of dykes to lavas should increase with depth in an ophiolite suite but no such increase in the occurrence of dykes or dyke swarms has been observed in progressively older lavas in South Georgia. This suggests that the lava pile is composed of lenticular lava units overlapping towards the south-west rather than a single conformable sequence, and it also explains the anomaly of lavas with a regional south-westerly dip cut by near-vertical feeder dykes. The source of magma supply and the overlying spreading centres and eruptive centres probably migrated towards the south-west during the emplacement of the Larsen Harbour Formation (cf. Walker, 1964; Cann, 1974). The pattern of geographically distinct dyke swarms indicates multiple centres of eruption, possibly related to the upwelling of north-westerly elongated diapirs of basic magma (Karig, 1971). The sparsity of sedimentary material in the lava sequence indicates either relatively rapid extrusion or a paucity of detrital material.

A large composite pluton containing rocks ranging in composition from granitic to gabbroic is intruded into the Larsen Harbour Formation at Smaaland Cove. This pluton generally has sharp contacts with the overlying extrusive rocks (Fig. 9) but in places the contact exhibits

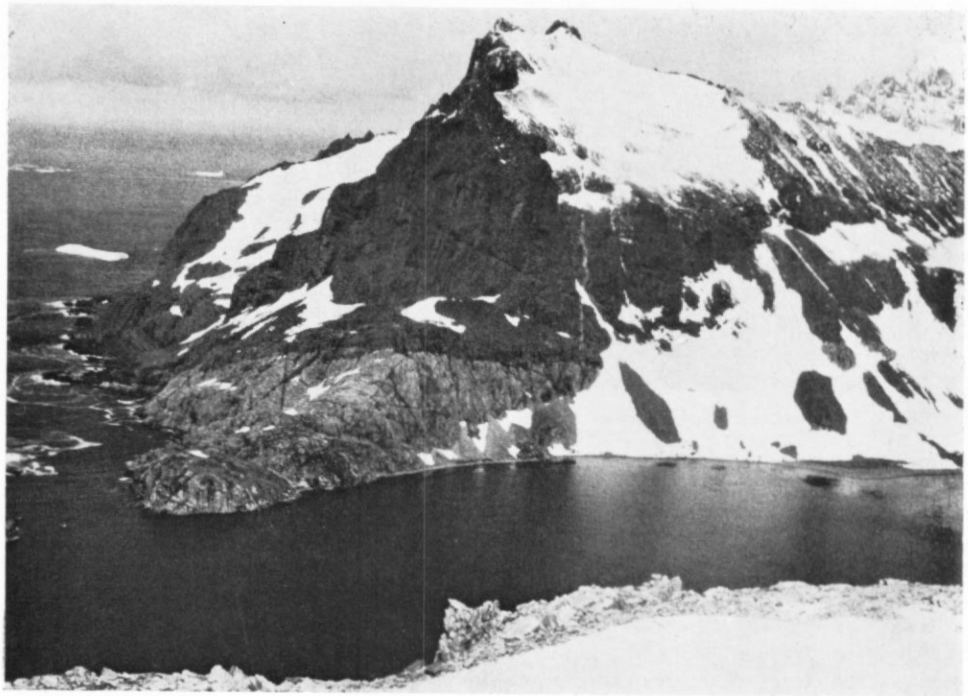

Fig. 9. Acid pluton intruded into basic lavas at west Smaaland Cove. Younger basic dykes cross-cut the pluton.

stoping and brecciation of the lavas. The pluton crops out over an area of at least 2 $km.^2$ and is cut by several intersecting sets of younger basic dykes.

The age relationship between the Larsen Harbour Formation and the sedimentary sequences of South Georgia is uncertain. A comparison with the stratigraphy of the southern Andes suggests that the Larsen Harbour Formation was emplaced into metasedimentary country rocks and that it is conformably overlain by turbidites of the Cumberland Bay Formation. The age relationship between the Larsen Harbour Formation and the intrusive rocks of the igneous complex which crop out to the north-east is also unknown. Banded gabbros of the igneous complex may represent the root zone of the Larsen Harbour Formation but it is possible that the ophiolites are related to a younger basic dyke swarm.

The Larsen Harbour Formation is cut by fault planes dipping at about 35° to the south-west. These faults do not cut the Smaaland Cove pluton and thus they were formed at an early stage in the tectonic history of the ophiolites. They may represent low-angle normal faults associated with the emplacement of the ophiolites or thrust faults caused by subsequent compression.

South-eastern igneous complex

The south-eastern igneous complex of South Georgia comprises acid to basic plutonic bodies and basic dykes cropping out between Drygalski Fjord and Cooper Bay in the south and possibly extending as far north as Spenceley Glacier. Gabbroic and granitic plutonic rocks cut by basic dykes at Clerke Rocks (Fig. 1) indicate a probable extension of the igneous complex for about 64 km. to the south-east. Quartz-diorites on Hauge Reef and the Pickersgill Islands off the south-western coast of South Georgia have recently been interpreted as remnants of the roots of a volcanic arc which supplied the detritus for the Annenkov Island and Cumberland Bay Formations.

The country rocks of the igneous complex are metasediments, sediments and felsites, which were subjected to varying degrees of regional and contact metamorphism and polyphase deformation.

Metasedimentary country rocks of the igneous complex

Metasediments comprise the country rocks of the igneous complex in the central parts of south-eastern South Georgia. They were first described by Trendall (1959) as a large quartz-granulite xenolith enclosed by granite. The metasediments crop out over large areas south-west of Salomon Glacier and also form abundant xenoliths in the acid plutonic rocks north-east of Drygalski Fjord. They comprise quartzose gneisses, schists and granulites with some poorly preserved relicts of bedding laminations, ripple cross laminations, finely graded bedding and syn-depositional folding. The metasediments consist essentially of mosaic quartz with scattered grains of plagioclase and interbanded flakes of biotite.

Sedimentary and felsitic country rocks on Cooper Island

Quartzose sediments with associated felsites intruded by basic and acid rocks of the igneous complex crop out on Cooper Island. These sedimentary and volcanic rocks may be the non-metamorphosed equivalents of the metasediments found elsewhere in the igneous complex. The sediments are best preserved in the north-east of Cooper Island where they form a 50 m. thick sequence cut by several vertical zones of crushing and brecciation but exhibiting no other penetrative deformation. Sedimentary structures indicate that the whole sequence is inverted, probably as a result of nappe-type overfolding. The sediments are turbidites with poorly developed graded bedding forming repetitive sequences between 1 cm. and several metres thick. The quartzitic sandstone horizons are generally massive but some display small-scale ripple cross laminations. Bottom structures include small lobate, rill-and-groove casts and some load casts. Sedimentary dykes and syn-sedimentary folding and faulting also occur. Rare plant stem impressions and vermicular trace fossils in the mudstone horizons were the only fossils observed. Small occurrences of fine-grained laminated felsites enclosed in the intrusive rocks are possibly interstratified with the sediments but their exact relationship was not observed.

Gabbroic bodies

Gabbroic plutons are probably the oldest and most abundant intrusive rocks of the igneous complex. They are irregular in shape and frequently exhibit cumulate layering which in places is brecciated and folded by syn-magmatic disturbances. The gabbros range in composition from extremely feldspathic to very basic and enclose small ultrabasic bodies of probably syngenetic origin. Intrusive contacts between the gabbros and the previously metamorphosed metasediments show no significant metamorphic effects.

Basic dykes

Basic dykes are abundant in the igneous complex. The number of dykes increases towards the west but a preliminary statistical study of recorded trends shows no distinct pattern of preferred orientation. However, field observations suggested that the commonest trend was towards the north-west. Basic dykes were intruded at several stages during the development of the igneous complex; the oldest cut the gabbros but they are themselves cut by acid plutonic bodies. The acid plutonic rocks were subsequently intruded by several cross-cutting sets of younger dykes.

Acid plutonic rocks and migmatites

The widely distributed acid plutonic rocks of the igneous complex include granitic, granodioritic and dioritic bodies and frequently enclose abundant xenoliths. Some of the acid plutonic rocks are intrusive but others originated *in situ* by partial fusion (anatexis) of the metasediments. The anatectic acid plutonic rocks are distinguished by migmatitic textures, relict fabrics (Fig. 10) and screens of orientated metasedimentary xenoliths. As the process

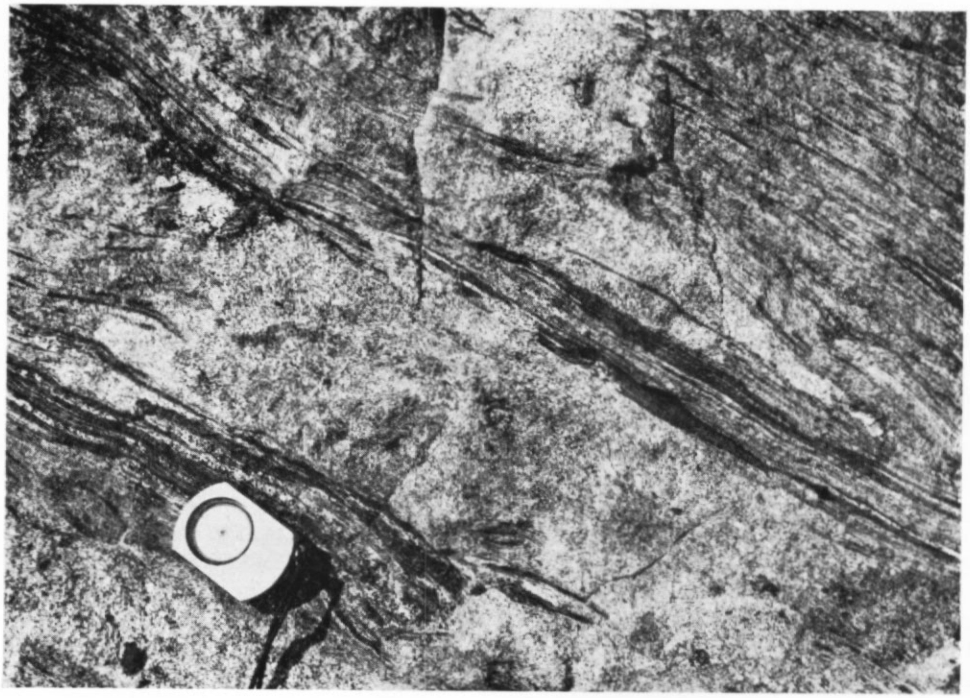

Fig. 10. Medium-grained granite with a relict metasedimentary fabric. The compass dial has a diameter of 4·25 cm.

of anatexis proceeded, the proportion of metasedimentary relics decreased and the rocks assumed the appearance of uniformly crystallized magma. The distinction between magmatic and anatectic granites is thus not clear and the extent to which anatexis contributed to the origin of the acid intrusive rocks is uncertain.

Relict dykes and anatexis

Aligned chains of basic xenoliths are a common feature of acid plutonic bodies in active magmatic belts and they have been variously ascribed to:

i. The intrusion of basic dykes into unconsolidated or semi-consolidated acid magmas (syn-plutonic dykes).
ii. The formation of acid magmas by partial melting (anatexis) subsequent to the intrusion of the basic dykes (relict dykes).
iii. Re-melting of acid plutonic rocks after the intrusion of the basic dykes.

Angular or rounded and partly assimilated basic xenoliths are locally abundant in the acid plutonic rocks of the igneous complex of South Georgia, and in places they form aligned chains of fragments derived from the brecciation of basic dykes (Fig. 11). The intrusive veins of acid material are generally paler and more feldspathic (Fig. 12) than the main plutonic bodies and in places they form net veins (Fig. 13) surrounding irregular pillow-like fragments of basic rock. The acid veins were formed at a late stage in the history of the igneous complex,

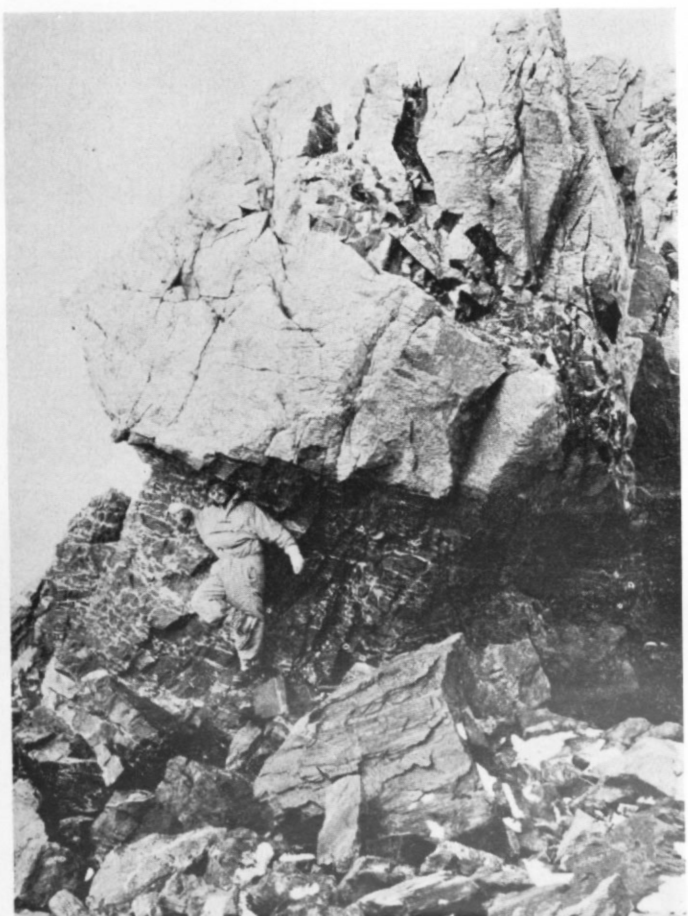

Fig. 11. Cross-cutting basic dykes brecciated and net-veined by coarse-grained granite derived by anatexis of pre-existing metasediments.

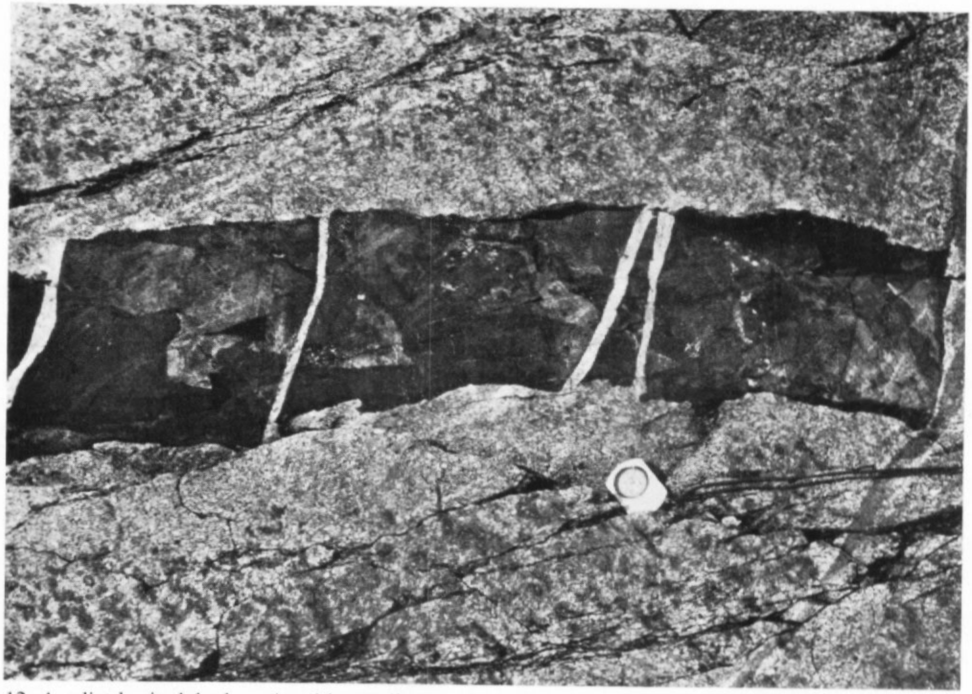

Fig. 12. A relict basic dyke brecciated by medium-grained granite. The compass dial has a diameter of 4·25 cm.

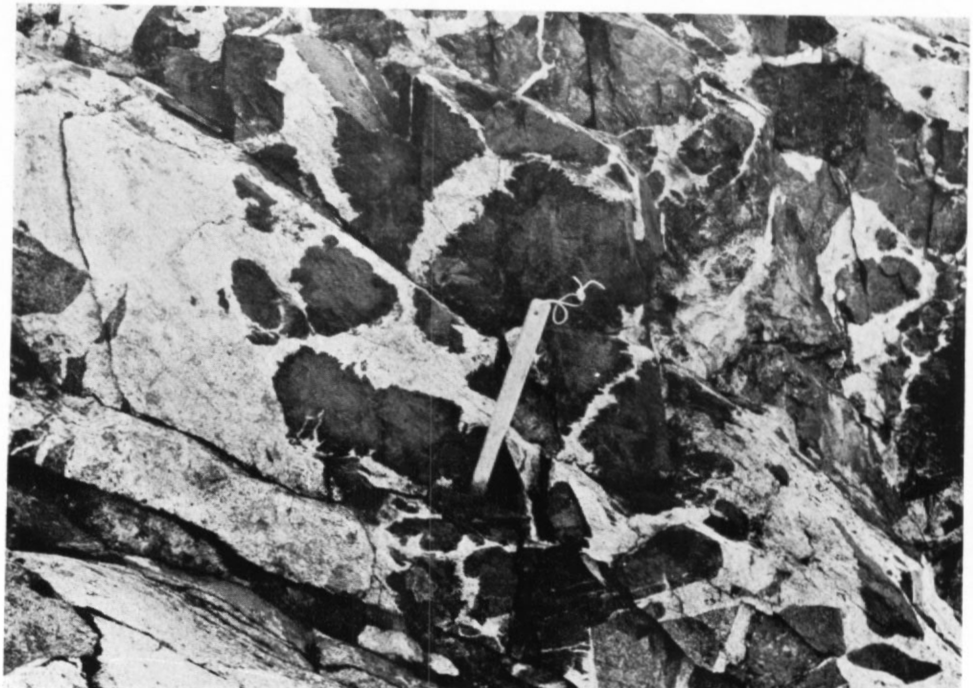

Fig. 13. Net veins formed by the brecciation and partial assimilation of gabbro and a basic dyke by granite. The hammer shaft is 30 cm. long.

after the intrusion of cross-cutting basic dyke swarms into the metasedimentary country rocks and older gabbroic bodies. In places, the acid veins intruded and brecciated both the basic dykes and the gabbros, but generally they intruded along the basic dykes in preference to the gabbros. Most of the acid brecciation occurred *in situ* and the acid magmas were derived from local melting of the metasediments. Little movement of the rocks occurred subsequent to the acid intrusion and many xenoliths are still in their original positions relative to the country rocks. The brecciated basic dykes are generally straight sided and usually exhibit distinct chilled margins (Fig. 12). Anatexis of the metasedimentary rocks resulted in local melting and the formation of acid magmas which were then intruded as veins and net veins into the older basic rocks. Thus the brecciated basic dykes are true relict dykes rather than syn-plutonic intrusions. As anatexis progressed, the degree of brecciation increased, resulting eventually in a xenolithic granite. Some basic rocks were also brecciated by irregularly flow-folded metasediments (Fig. 14) without the formation of acid plutonic rocks, indicating that the metasediments became plastic during the process of anatexis.

Various hybrid rocks resulted from the complete or partial assimilation of basic material by the acid magmas. Basic xenoliths are commonly surrounded by partially assimilated haloes of hybrid material and in some places darker-coloured patches of hybrid material are the only indication of pre-existing basic xenoliths in the granites and granodiorites.

The formation of the acid plutonic rocks of the igneous complex is envisaged as a high-temperature process of transformation of quartzose metasediments into medium- to coarse-grained granites, granodiorites and diorites. Most of the acid rocks formed *in situ* but in places they became sufficiently liquid to be intruded as magmas. The anatexis was accompanied by extensive recrystallization of the older gabbros and basic dykes.

Cooper Bay metasedimentary rocks

The intensely deformed metasedimentary rocks of Cooper Bay have been described as cataclasites, schists, phyllites and slates, produced by low-grade regional metamorphism to the biotite zone of the greenschist facies with the local development of mylonites (Stone, in press). These metasediments may be the metamorphosed equivalents of a facies variant of the Sandebugten Formation (exposed elsewhere on the north-east coast of South Georgia). The metasedimentary rocks of Cooper Bay are separated from those of the igneous complex by a fault zone marked by a broad belt of cataclastic rocks. They exhibit a lower grade of regional metamorphism than the schistose metasedimentary country rocks of the igneous complex but both occurrences have a similar tectonic history; both underwent polyphase deformation and exhibit a schistose fabric and boudinaged quartz veins cut by a later mylonitic fabric. It is possible, therefore, that the sediments of the Sandebugten Formation, the metasediments at Cooper Bay, the sediments and felsites of Cooper Island and the metasedimentary country rocks of the igneous complex all form part of the same succession. These rocks are probably equivalent to the Palaeozoic metasediments of the southern Andes.

DEFORMATION

The rocks of southern South Georgia have been subjected to repeated tectonic deformation. The degree and number of episodes of deformation depend both on the relative competence of the various rock types and on their location. A tentative outline of the tectonic history of southern South Georgia and its relationship to the episodes of sedimentation and igneous activity is given in Table I.

Possibly the oldest episode of deformation was the overturning of the turbidites of Cooper Island, probably as a result of nappe formation (D1). No fold axes have been preserved and consequently the direction of overturning is unknown. The relatively undeformed Cooper Island sediments are tectonically anomalous in an area of intensely deformed metasediments

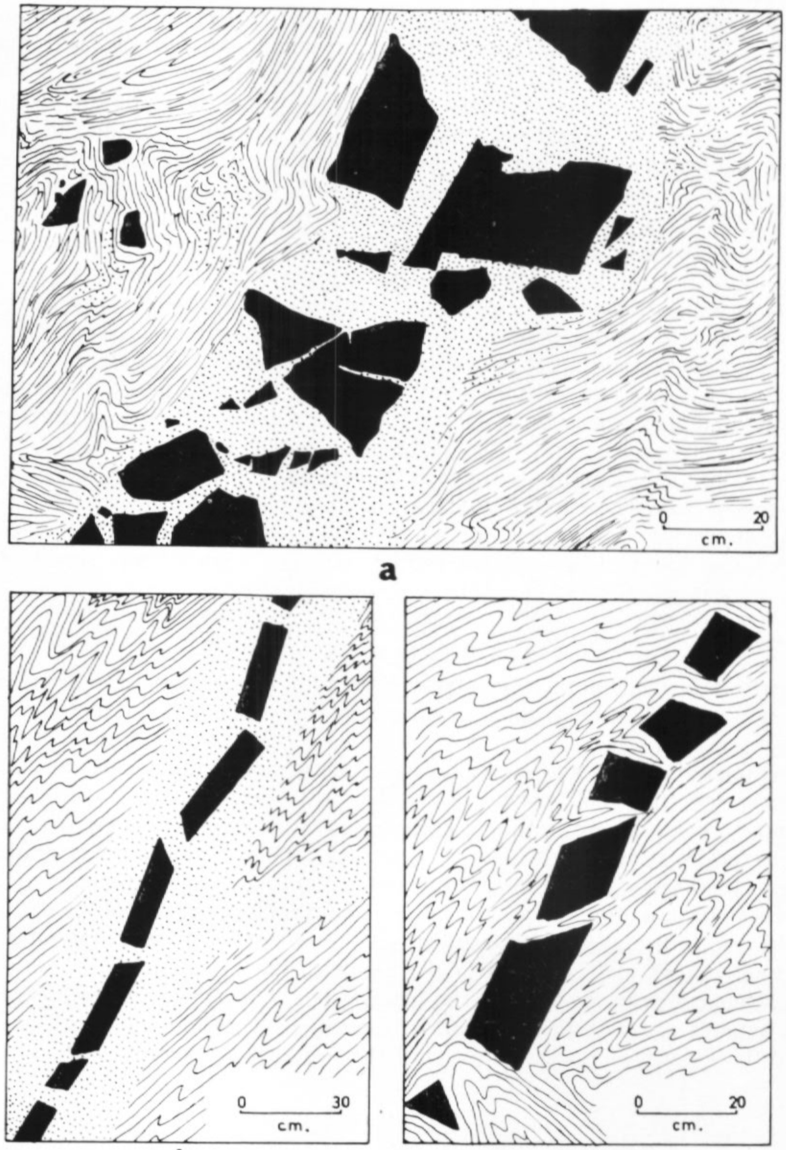

Fig. 14. a. A relict basic dyke brecciated both by granite and by plastic deformation of metasediments. (Sketch from a photograph. Black represents the basic dyke, stipple the granite and hatching the metasediments.)
b. A relict basic dyke brecciated by granite intruded into metasediments. (Field sketch.)
c. A relict dyke brecciated by plastic deformation of metasediments. (Field sketch.)

TABLE I. AN OUTLINE OF GEOLOGICAL EVENTS IN SOUTHERN SOUTH GEORGIA

Age	*Geological event*	*Tectonic event*	*Deformational episode*
		Polyphase folding (F6–F8) of S5 foliation	D6–D8
		Formation of mylonite zone and S5 mylonitic foliation	D5
Lower Cretaceous	Deposition of the Annenkov Island Formation	Island-arc volcanism	
Late Jurassic to early Cretaceous	Deposition of the Cumberland Bay Formation		
	Intrusion of basic dykes		
Late Jurassic to early Cretaceous	Partial melting of metasediments, forming acid plutonic rocks and migmatites	Anatexis, possibly associated with the emplacement of a batholith to the south-west	
		Folding F4	D4
(?) Late Jurassic	Emplacement of the Larsen Harbour Formation	Marginal basin development	
	Intrusion of gabbros and basic dykes		
		Compression forming S3 schistosity	D3
(?) Early Mesozoic orogeny	Regional metamorphism; formation of metasediments	Folding F2	D2
		(?) Nappe formation F1	D1
(?)	Deposition of quartz-rich turbidites and felsites		

and it is possible that they were preserved at a higher structural level and subsequently down-faulted to their present position.

Deformation of the metasediments in the igneous complex

Early episodes of deformation (D2–D4), which occurred prior to the formation of the D5 mylonitic fabric, are best preserved in the metasediments of the igneous complex, but later post-mylonite episodes (D6–D8) can be identified with certainty only in the mylonite zone and in the metasediments of Cooper Bay.

The metasediments in the igneous complex are characterized by a well-developed schistosity (S3) (Fig. 15), which is marked by prominent L3 lineations formed by the intersection of the planes of schistosity and earlier planar elements. The depositional and structural history of the metasediments prior to the formation of the S3 schistosity is largely unknown, due to the masking effects of deformation and regional metamorphism. Abundant small-scale F2 folds are the only indication of folding prior to the formation of the S3 schistosity. Well-developed boudins (Fig. 15) and ptygmatic veins are indicative of the intense deformation that

Fig. 15. Metasediments with a strong schistosity (S3) and boudinaged quartz veins subjected to gentle re-folding (F4). The hammer shaft is 30 cm. long.

resulted in the S3 schistosity. In most areas south-west of Salomon Glacier the schistosity is near horizontal. The metasediments were later subjected to a further phase of folding (F4) of variable intensity and in places forming asymmetrical folds (Fig. 15) indicative of near-horizontal compression from the north-west.

A gently folded basic dyke and a fabric of orientated poikiloblastic crystals in the older basic dykes and some of the gabbros indicate deformation (? F4) after the initial phase of basic intrusion but prior to or during the emplacement of the acid plutonic bodies.

Formation of the mylonite zone and subsequent episodes of deformation

A broad (0·75–2 km. wide) north-west-trending zone of cataclastic rocks forms the boundary between the igneous complex and the Cooper Bay metasediments. A parallel mylonitic foliation (S5) in the Cooper Bay metasediments was probably formed at the same time, after the youngest intrusions of the igneous complex. Consequently, the S5 mylonitic fabric forms an important structural marker, superimposed on and in places obliterating the older fabric of the metasediments. The intensity of D5 deformation decreases away from the mylonite zone and it is probably represented only by shear zones and a locally developed schistosity of the acid plutonic rocks in the igneous complex. At least three phases of folding (F6–F8) post-date the formation of the S5 mylonitic fabric but these have only been identified in the mylonite zone and in the metasediments at Cooper Bay; they did not affect the metasediments enclosed in the relatively competent block of the igneous complex.

The rocks of the mylonite zone are locally completely crushed ultramylonites but elsewhere the crushing was less intense and was concentrated in distinct bands between less deformed rocks. Gabbros and basic dyke rocks tended to resist cataclastic deformation and they frequently form uncrushed boudins surrounded by mylonite and ultramylonite. The cataclastic foliation is locally intensely deformed (F6–F8) but in general it is undeformed and dips steeply towards the south-west beneath the igneous complex, suggesting that the mylonites formed by lateral compression from the south-west.

The first two phases of deformation identified by Stone (in press) in the metasediments of Cooper Bay are comparable with the F2 and F4 deformational phases of the metasediments in the igneous complex (Table I). Stone's third and fourth phases are equivalent to the post-mylonite (F6–F8) folding.

Late Mesozoic Geotectonic Development of the Southern Andes and South Georgia

The Upper Jurassic–Lower Cretaceous Yahgan Formation of the southern Andes is closely comparable to the Cumberland Bay Formation of South Georgia; the two formations were deposited in the same sedimentary basin prior to the break-up of the continental margin. Similarly, the mainly pyroclastic Hardy Formation (a facies variant to the south of the Yahgan Formation) is equivalent to the Annenkov Island Formation of South Georgia (Suárez and Pettigrew, 1976). Pyroclastic rocks of the Hardy and Annenkov Island Formations have been interpreted as being detritus deposited on the north-eastern flank of an island-arc volcanic chain. The turbidites of the Yahgan and Cumberland Bay Formations were probably derived from the same source but they were deposited in a basin farther from the island arc.

West of the Yahgan Formation is the Patagonian Batholith, a complex body of numerous small granitic plutons intruded into and enclosing large enclaves of Palaeozoic metasediments, mid to late Jurassic silicic volcanic rocks and late Jurassic to early Cretaceous basic volcanic rocks. The batholith has been interpreted as forming the roots of the andesitic island arc which supplied detritus to the Yahgan Formation (Dalziel and others, 1974). Development of the batholith was probably initiated during the mid Jurassic, possibly as a result of subduction of the Pacific plate beneath the continental margin. This subduction may also have caused the earlier deformation and metamorphism of the Palaeozoic metasediments. Initially, the Patagonian Batholith was overlain by a volcanic chain comparable with the present-day central Andes, but during the late Jurassic the continental margin behind the volcanic chain was split by the emplacement of ophiolites. As a result of this, the volcanic chain moved oceanwards as an island arc and the ophiolites spread to form a marginal basin between the island arc and the continent (Dalziel and others, 1974). Subsequent eruptions along the volcanic island arc provided the detritus deposited on its flanks (Hardy Formation) and in the marginal basin (Yahgan Formation).

In places the Yahgan Formation is floored by Palaeozoic metamorphic rocks and mid to late Jurassic silicic volcanic rocks, and elsewhere by the ophiolites of the marginal basin (Dalziel and others, 1974). The floor of the Cumberland Bay Formation has yet to be identified but a stratigraphical comparison suggests that it is underlain partly by metasediments and partly by ophiolites of the Larsen Harbour Formation.

Acid plutonic rocks of the south-eastern igneous complex on South Georgia have radiometric ages comparable with those of the Patagonian Batholith and have a similarly complex relationship with large bodies of metasediment. The metasedimentary country rocks of the igneous complex and their possible equivalents at Cooper Bay and Cooper Island were probably derived from a continental source and deposited near the continental margin. They were subjected to deep burial with associated metamorphism and polyphase deformation, possibly during an early Mesozoic orogeny. There is no evidence on South Georgia of late Jurassic sedimentary or pyroclastic rocks associated with a volcanic chain or island arc which may have been active before or during the emplacement of the Larsen Harbour Formation. The sedimentary rocks of the Cumberland Bay Formation were probably deposited on top of the Larsen Harbour Formation and their island-arc source was apparently active only after the emplacement of the ophiolites. The lensoid shape of the ophiolite exposures in the southern Andes and the folding of the overlying sediments has been ascribed to compression and closing of a previously more extensive marginal basin (Dalziel and others, 1974). By contrast, the Larsen Harbour Formation is little deformed and it seems likely that the elongated shape of the exposures is a primary feature rather than the result of basin closure. Folding of the overlying sediments may have resulted from gravitational deformation following uplift in the south-west.

The working model proposed for South Georgia is that of a thick turbidite sequence (Cumberland Bay Formation) derived from an andesitic island arc to the south-west and deposited in a marginal basin on a composite floor consisting of the Larsen Harbour Formation (an elongated strip of oceanic crust) emplaced into metasedimentary continental crust. The basic intrusive rocks of the igneous complex may represent the roots of the Larsen Harbour Formation but younger acid plutonic rocks were formed after the emplacement of the oceanic crust by partial melting of the metasedimentary country rocks, possibly in association with the emplacement of a batholith to the south-west.

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