THE GEOLOGY OF THE DUCLOZ HEAD AREA, SOUTH GEORGIA

By B. C. STOREY

ABSTRACT. A sequence of massive silicic, epiclastic and volcaniclastic sediments and basaltic pillow lavas (coastal member) together with thin-bedded andesitic and felsitic tuffs and mudstones (inland member) are termed the Ducloz Head Formation. The volcaniclastic and epiclastic sediments were derived from an active dacitic and rhyolitic volcanic centre and a granitic and low-grade metasedimentary terrain. The coastal member is intruded by massive spilitic rocks. The rocks have suffered extensive ductile and brittle deformation, and are metamorphosed to zeolite and prehnite-pumpellyite facies. It is proposed that the rhyolites and dacites may represent an early acidic stage (Upper Jurassic) of a rift zone that later formed a back-arc basin. The volcaniclastic and epiclastic sediments of the coastal member were derived from these rhyolites and dacites, and from the continental fragment that split off to form the basin; the sediments are the initial fill of this basin. The massive and pillowed spilitic rocks may have been derived from the same basic magma source as that which formed the floor of the basin.

DUCLOZ HEAD (lat. 54°31′S, long. 36°38′W) forms the northern promontory of Undine South Harbour on the south-west coast of South Georgia (Fig. 1). The area was geologically mapped with the aid of air photographs during a brief 6 day visit in the austral field season of 1975–76 as part of the British Antarctic Survey geological programme on South Georgia.

Although Trendall (1959, p. 23) recorded spilitic, pillowed and massive lavas interbanded with "Cumberland Bay type sediments" in this area, the recent field work indicates that the sediments of the Ducloz Head area are different from those of the Cumberland Bay Formation described from north-east South Georgia by Trendall (1953, 1959) and Stone (1982). The sediments, here formally termed the Ducloz Head Formation, are subdivided into a coastal member and an inland member (Fig. 2) separated by a well-marked straight depression devoid of exposure. The coastal member consists of massive epiclastic and volcaniclastic breccias and interbanded sandstones, shales and basaltic pillow lavas. The inland member occupies a 0.5 km wide belt of low relief with highly weathered exposures of thin-bedded tuff and tuffaceous mudstone. A dislocation zone with a vertical fabric separates the inland member from andesitic greywackes of the Cumberland Bay Formation (Fig. 2). Dykes and basic bodies are found only in the coastal member (Fig. 2).

COASTAL MEMBER OF THE DUCLOZ HEAD FORMATION

Epiclastic rocks

Massive grey sub-quartzose sandstones and sandstone breccias, up to 8 m thick, with interbanded thin-bedded sandstone, silt and black shale units form the bulk of the exposure. Many of the coarse sandstone breccias, which form upstanding knolls, appear on fresh surfaces as compact featureless grey crystalline rocks; on weathered surfaces their true clastic nature is seen with angular clasts up to 6 cm occurring in an unsorted gritty matrix. The fine-grained units occur as disorientated sheared blocks between the massive horizons and frequently exhibit graded bedding, ripple marks, fine cross laminations, and load and flame structures. Distorted surfaces suggest some organic activity (bioturbation structures); worm burrows were identified.

Petrology

The sediments consist largely of crystal fragments with subsidiary lithic clasts and variable amounts of matrix. Attempts to make modal estimates of the proportion of matrix, lithic and crystal fragments failed due to recrystallization, which has destroyed the clast boundaries, and due to the similarity between the true matrix and the matrix of the lithic fragments.

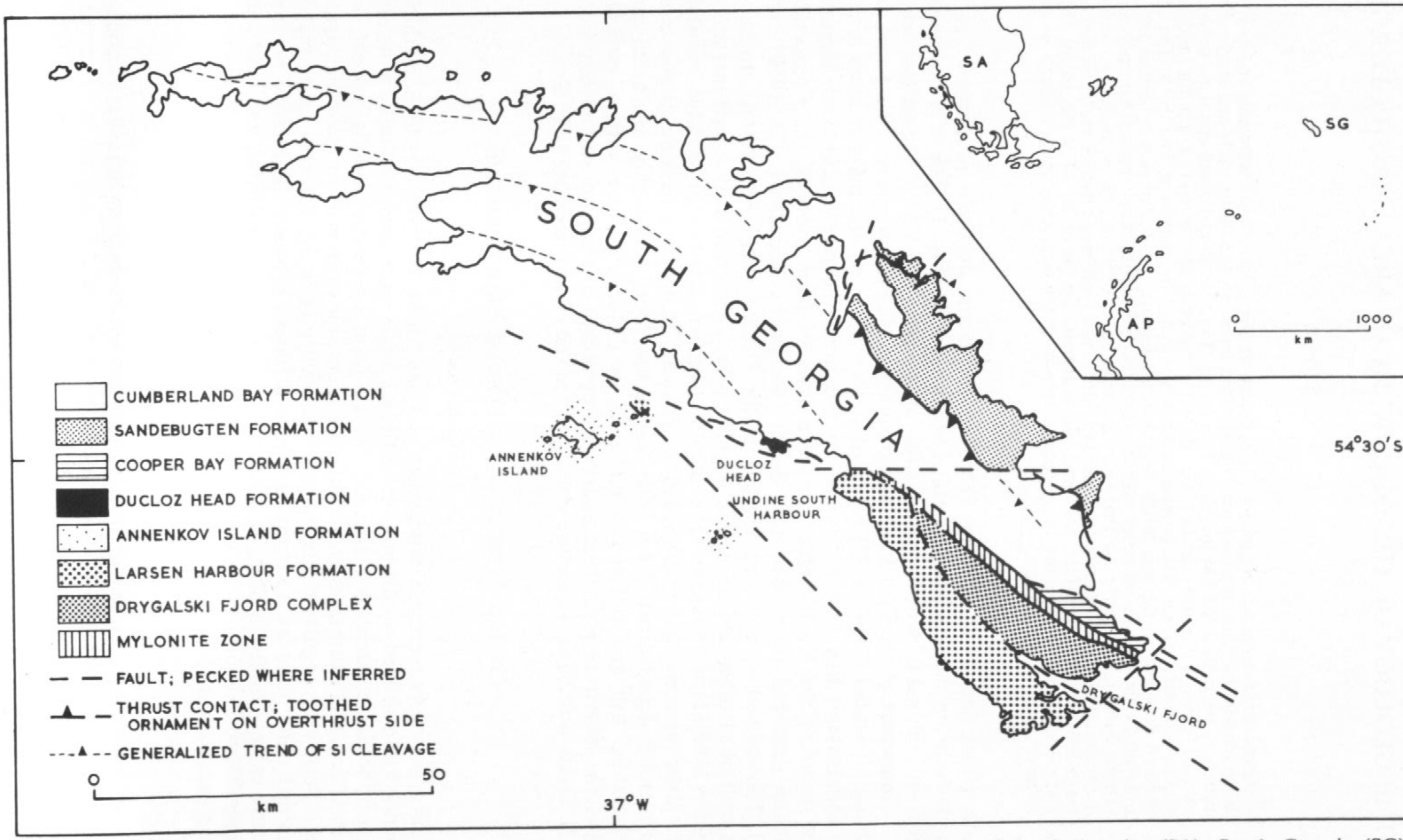


Fig. 1. Simplified geological map of South Georgia. The inset is a location map showing the positions of South America (SA), South Georgia (SG) and the Antarctic Peninsula (AP).

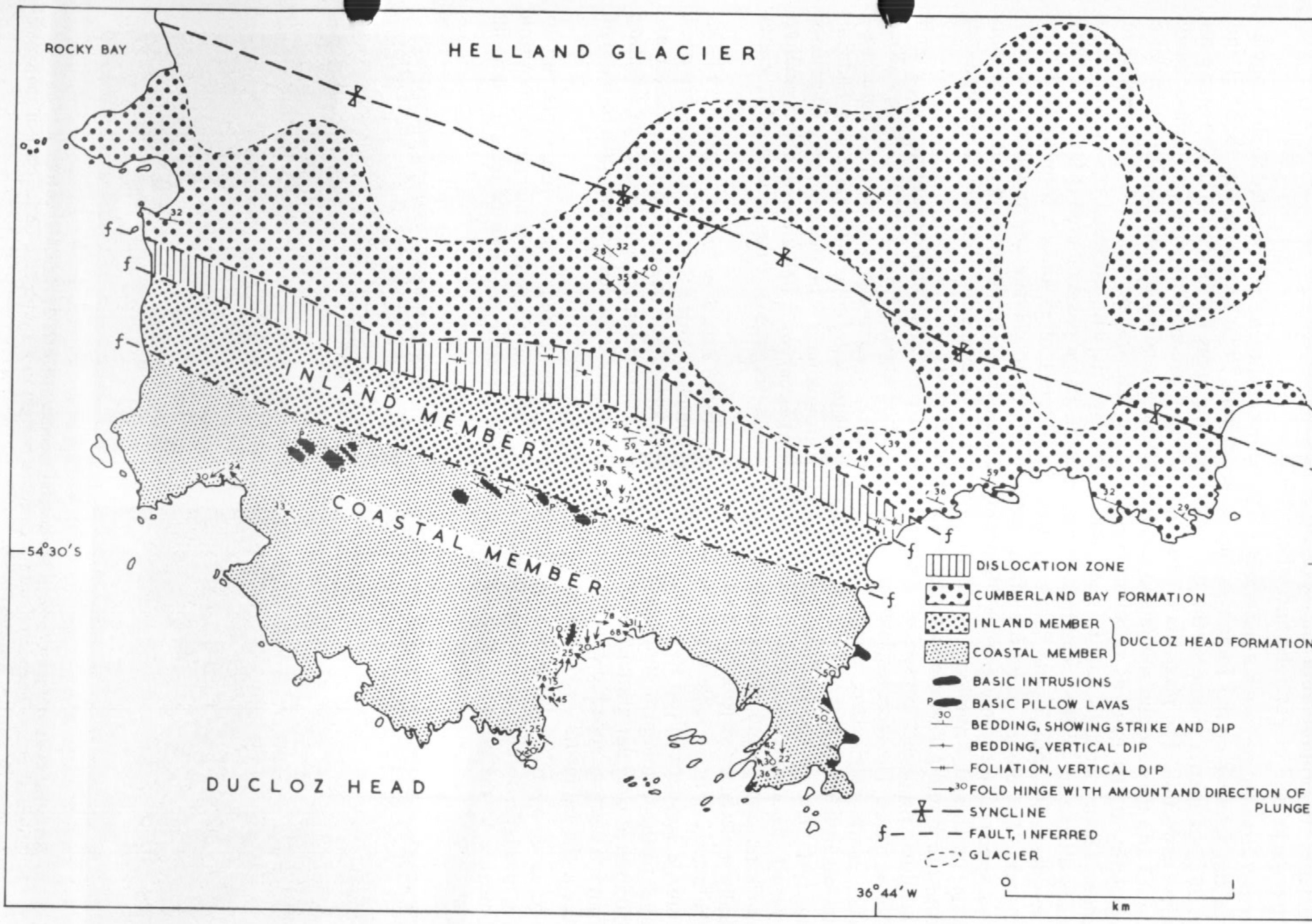


Fig. 2. Geological sketch map of the Ducloz Head area, South Georgia.

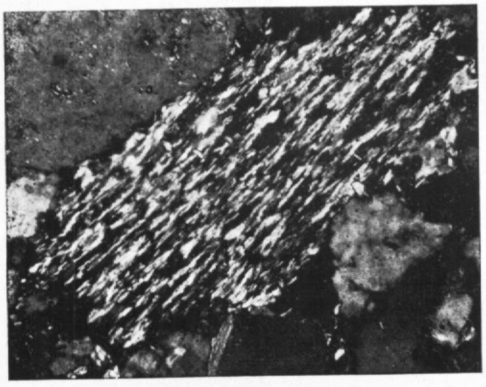
Estimates of the proportion of matrix (5–20%) indicate that the sandstones fall in the arenite and greywacke field of Pettijohn and others (1972).

Quartzo-feldspathic greywackes and arenites. The main constituents are rounded to sub-angular quartz and feldspar crystal fragments (up to 80%) with lithic fragments (up to 10%) and up to 20% of matrix. Some of the quartz crystal fragments (0.75 mm in length) have an undulose extinction. The plagioclase (An_{28-46}) fragments are clouded with light brown dusty inclusions and they contain zoisite and clinozoisite grains, and sericite flakes with myrmekitic intergrowths at the margins of some crystals; some are fragmented with deformed twin lamellae. Flame perthites and twinned microcline crystals with enclosed opaque granules partially altered to sphene-leucoxene are also present. Large pale-coloured (leached) detrital biotite, muscovite and chlorite flakes (up to 0.5 mm long), often kinked, form up to 3% of these rocks. The biotite plates are often partially altered to chlorite and prehnite, and they contain sphene and epidote granules. Between the lithic fragments, some thin sections contain irregular patches (0.7 mm long) of chlorite with sphene and epidote. Detrital sphene, epidote, apatite, zircon and garnet are scattered in the groundmass.

The lithic fragments consist of igneous, metamorphic and intraformational shale and sandstone clasts. The igneous clasts are medium-grained granitic fragments of polycrystalline quartz, quartz–plagioclase, quartz–plagioclase–biotite, quartz–alkali-feldspar, plagioclase–quartz–alkali-feldspar and occasional porphyritic felsites with euhedral quartz and feldspar phenocrysts in a microcrystalline quartz–feldspar groundmass. The metamorphic fragments are varied; muscovite- and chlorite-schists (Fig. 3a) occur with fine-grained polycrystalline granoblastic quartz and quartz-feldspar-mica gneissic fragments. Fine-grained felsic clasts partially replaced by sericite are also present.

The matrix is of variable grain-size and has undergone extensive recrystallization. Flakes of chlorite and sericite (up to 0.1 mm in length), which in some thin sections are arranged parallel to the lithological banding, occur in a microcrystalline quartz–feldspar groundmass with scattered irregular granules of clinozoisite, pistacite and sphene, and sheaves of radiating prehnite. Accessory euhedral apatite, zircon and opaque minerals also occur; quartz–feldspar veins cut the sediments.

Sandstone breccias. Angular quartzo-feldspathic greywacke and arenite fragments, up to 10 cm in length, occur in an unsorted sandy matrix. The lithic clasts are similar in composition and texture to the greywackes described above, and are believed to be of intraformational origin.



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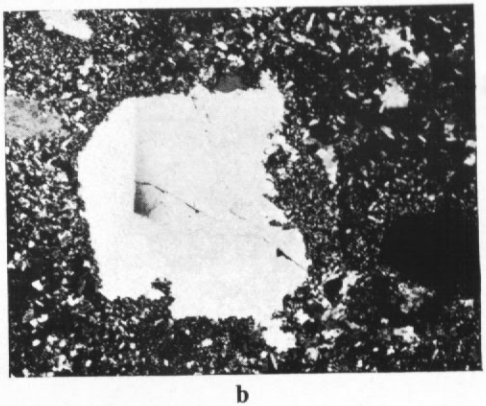

b

Fig. 3. a. Schistose clast in a greywacke of the coastal member (M.4098.2; X-nicols; ×100).
b. Euhedral quartz phenocryst with a corroded margin in a porphyritic dacite clast of the coastal member (M.4103.3; X-nicols; ×15).

Shales. Angular quartz and plagioclase crystal fragments are set in a micro-crystalline matrix. Aligned sericite, muscovite, chlorite and biotite flakes (0.1 mm in length), often bent around the felsic fragments, define a cleavage in the shales; irregular sphene, epidote and opaque granules are found in the microcrystalline quartzo-feldspathic groundmass.

Volcaniclastic rocks

White and buff-coloured massive felsitic volcaniclastic breccias, thin-bedded graded tuffs and interlaminated tuffaceous mudstones occur within the coastal member of the Ducloz Head Formation. The relationship of these rocks to the epiclastic sandstones is not seen but they are believed to be part of a single sedimentary sequence.

Petrology

Felsitic breccias. Angular to sub-rounded white and pink-coloured lithic fragments (2–3 cm long) are the dominant clasts. They are porphyritic rhyolites and dacites in composition. Quartz and plagioclase phenocrysts (0.75 mm long) form up to 10% of the rocks and occur in a microcrystalline quartz–plagioclase–alkali-feldspar felsic groundmass. The quartz phenocrysts are mostly euhedral with angular crystal faces; some have rounded outlines and irregular margins indicating resorption into the groundmass (Fig. 3b). Chlorite-filled vesicles also occur. Twinned oligoclase-andesine crystals are mainly euhedral and many are cloudy with minute dusty inclusions.

The groundmass is mainly felsic, though variable in texture and grain-size; feldspar spherulites and aligned microlitic flow textures indicate a probable extrusive origin for some of the volcanic rocks. A number of coarse-grained quartz–feldspar and coarse polycrystalline quartz fragments with a subophitic texture are probably of a granitic origin. There are some angular unidentifiable fragments (1.0 mm in diameter), with a radiating fibrous texture (spherulites), of a low-relief low-birefringent (? zeolite) mineral. Opaque granules pepper these fragments and the spherulitic clasts mentioned above. Crystal fragments were also recorded but they form a small percentage of the total. Rounded quartz and feldspar grains are the commonest and may represent broken phenocrysts from the porphyritic felsites. Ferromagnesian minerals are almost entirely absent from most of the clasts with the exception of isolated biotite plates up to 1.5 mm long which are often partially chloritized.

Recrystallization has frequently destroyed the clast boundaries. In some cases there is incipient development of a granoblastic quartz–plagioclase texture in the microcrystalline groundmass. Fine-grained sericite flakes are found in the matrix together with fine-grained yellow-green chlorite. Calcite, which may form up to 5% of the matrix, occurs as irregular patches and veins up to 4 cm wide. Irregular patches of prehnite and chlorite, accessory euhedral zircon and disseminated sphene, epidote and opaque minerals also occur in the matrix. A brown stain (oxidized iron) colours much of the matrix of some clasts.

Crystal lithic tuffs and tuffaceous mudstones. The fine-grained laminated units are similar in composition to the breccias. Euhedral andesine (An_{30-38}) and quartz phenocrysts, and isolated biotite plates, occur in a microcrystalline quartz–plagioclase–alkali-feldspar groundmass; fine margins of secondary quartz surround some of the euhedral quartz crystals. Aligned micaceous and pale green chlorite micro-flakes, disseminated opaque red-brown limonite and sphene granules, and occasional zircons, are found in the matrix. Very fine chlorite-filled veins occur parallel to the lamination. Brown circular and ellipsoidal spores (up to 0.1 mm) which often have a reticulate surface pattern, and disseminated brown organic material, are scattered throughout and are often concentrated in bands in some of the tuffaceous units.

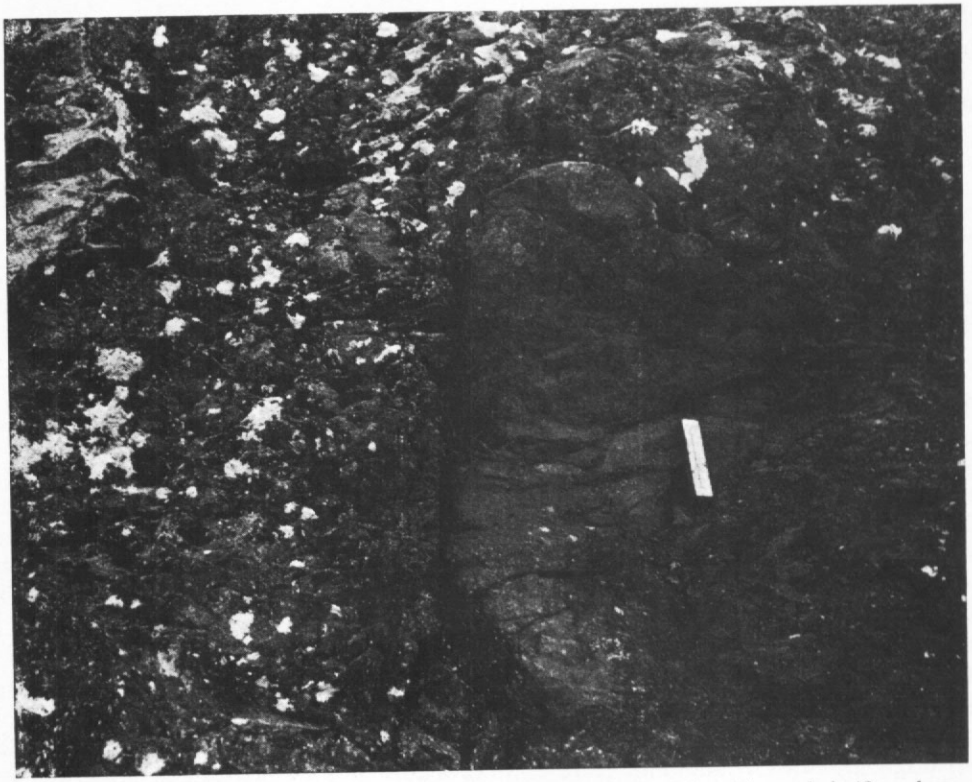

Fig. 4. Pillowed lava interbanded with sandstones of the coastal member. The scale is 10 cm long.

Pillow lavas

Extrusive pillowed basalts are part of the coastal member of the Ducloz Head Formation (Fig. 2). Contacts are mainly tectonic but pillow lava units up to 30 m thick are interbanded with the massive sediments (Fig. 4). The pillows are elongated in vertical section with shapes indicating steeply inclined planes of deposition.

The pillowed lavas show a high degree of alteration. Phenocrysts of augite and feldspar, up to 1 mm in diameter, form up to 10% of the rock and occur in calcite–prehnite–chlorite–feldspar groundmass. Amygdales are filled with calcite and radiating flakes of chlorite with anomalous blue (penninite) and brown-grey birefringence. The phenocrysts are mainly augite with some cloudy albite. Feldspars in the groundmass show some alteration: the sharp boundaries of the multiple twins are less well developed and the feldspars are cloudy, probably as a result of albitization. Radiating chlorite flakes and irregular patches of epidote minerals, pistacite and clinozoisite, with isolated tremolite-actinolite needles, radiating sheaves of prehnite and scattered dusty opaque minerals also occur.

Inland Member of the Ducloz Head Formation

Thinly laminated, highly folded, poorly preserved tuffs and mudstones comprise this well-defined member. The tuffs occur as yellow to dark brown laterally persistent graded units 3–12 cm in thickness. Cross lamination was recorded in some thin-bedded laminated horizons. Thin-bedded, cherty looking, radiolarian-rich black mudstone horizons, up to 5 cm thick, with occasional carbonized plant remains are interbanded with the tuffaceous horizons.

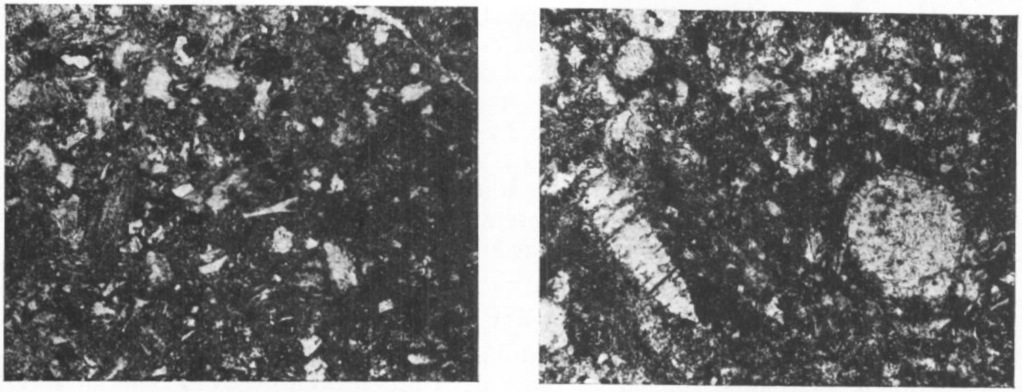

Fig. 5. a. Volcanic shards in a vitric tuff of the inland member (M.4087.3; X-nicols; ×100).
b. Calcite-filled conical and spherical radiolarian tests in a tuffaceous mudstone of the inland member (M.4087.4; X-nicols; ×100).

Highly weathered pale green felsic tuffs were also recorded. Calcareous nodules, which have previously been described from South Georgia (Trendall, 1953), are widespread within these sediments.

Petrology

Tuffs. Crystal vitric lithic tuffs with angular plagioclase and subsidiary quartz crystal fragments, vitric shards and microlitic feldspathic clasts are disseminated throughout and concentrated in thin lenses in a devitrified glassy matrix. The crystal fragments (up to 0.6 mm) are mainly oligoclase-andesine with up to 10% quartz fragments. The vitric fragments, pumice and tricuspate shards (Fig. 5a) are in many cases replaced by a clear isotropic low-relief zeolite mineral (analcite) which is occasionally rimmed by fine opaque minerals or contains opaque and chlorite-filled vesicles; microlites are found in the devitrified glassy matrix. Flow-aligned and disorientated microlitic feldspar fragments and subsidiary dusty brown felsic fragments form a high proportion of the clasts in some tuffaceous bands. A zeolite with a spherulitic hour-glass structure was also recorded.

The matrix is mainly analcite (? devitrified glass) with disseminated dusty opaque minerals, chlorite lamellae and fine sericite flakes. Patches of recrystallized quartz and feldspar also occur. Opaque minerals, which are disseminated throughout and concentrated in irregular lamellae and lenses, are an important constituent; limonite, haematite and pyrite occur with a red-brown staining disseminated throughout the more altered thin sections. Calcite, opaque, yellow-green chlorite and analcite veins transgress the tuffs. Brown isotropic patches (0.1 mm in diameter), which may be spores, also occur in some thin sections.

Thin-bedded crystal-tuff units contain quartz (up to 10%) and feldspar crystal fragments (up to 1.0 mm) in a chloritic (devitrified glass) matrix. The feldspar fragments (andesine) are partially replaced by a low-relief low-birefringent mineral; the chloritic matrix contains fine opaque granules.

The pale green felsic tuffs are largely granoblastic and have a microlitic feldspar and quartzo-feldpathic groundmass with occasional angular feldspar crystal fragments. Patches of yellow-green, slightly pleochroic chlorite lamellae occur with a high proportion of fine-grained sphene and epidote granules and occasional euhedral apatite crystals.

Mudstones. The calcic mudstones are characterized by rounded and ovoid calcite-filled Radiolaria (0.1 mm in diameter). A reticulate pattern is occasionally preserved; segmented rims surround some of the infillings; segmented conical-shaped Radiolaria (Fig. 5b) also occur. The matrix, which is almost devoid of crystal and lithic fragments, is cloudy with calcite; brown and black opaque minerals are scattered in the groundmass. Some mudstones contain sub-rounded pellets of dusty brown tuffaceous material (? lapilli-tuff); the pellets contain some fine-grained crystal and lithic fragments and circular chlorite infillings. A brown mineral (? collophane), often showing a shape typical of molluscan fragments with a laminated structure, is scattered throughout some thin sections. They may represent fossil bone or replaced calcareous organisms. Occasional feldspar crystals and microlitic feldspar and pumice clasts are recorded. Veins of calcite are common in the mudstones.

Cumberland Bay Formation

Massive, moderately inclined, north-east-dipping volcaniclastic greywackes of the Cumberland Bay Formation, similar to those described previously from South Georgia (Trendall, 1953, 1959; Stone, 1980), crop out to the north-east of the inland member (Fig. 2). The massive greywacke units, which form part of a turbidite sequence, are composed of sub-angular to rounded lithic fragments with minor amounts of crystal fragments. The lithic fragments are mainly volcanic porphyritic andesites and quartz-andesites with euhedral andesine and augite phenocrysts in a microlitic feldspar groundmass. The microlites are often aligned, probably representing a flow lamination. A small percentage of felsitic clasts with quartz and plagioclase phenocrysts occur in a microcrystalline quartz–feldspar groundmass; angular feldspar and occasional quartz and augite crystals form the bulk of the crystal fragments. Prehnite, replacing plagioclase, is an important alteration mineral. Black shales and laminated black and white fine-grained vitric tuffs are interbanded with the massive greywackes.

The tuffs are largely composed of prehnitized pumice fragments and undeformed glass shards which are randomly distributed in a microcrystalline chloritized groundmass with disseminated sericite flakes and epidote granules, and occasional felspar fragments. The devitrified shards and pumice fragments show well-preserved infilled vesicles and tricuspate shapes.

Basic Intrusions

Fine- to medium-grained green igneous rocks occur as sheared blocks, up to 30 m wide, within the deformed sediments of the coastal member of the Ducloz Head Formation (Fig. 2). A single cross-cutting basic dyke (1.2 m wide) was noted.

The rocks have a similar petrography to the pillow lavas described previously. They are mainly spilites with most of the primary mineralogy destroyed; primary clinopyroxene exists in a chlorite–albite–epidote–prehnite–calcite groundmass. Ophitic plates of augite (1.5 mm) may form up to 50% of these rocks. A medium-grained intrusion is formed of 80% andesine laths 1–5 mm long, which are often cloudy with calcite-filled cracks and chlorite flakes aligned along the cleavage and show replacement by epidote and prehnite. Amygdales filled with radial spherulites of chlorite with well-formed hour-glass structure and radiating sheaves of prehnite are common in some massive bands. Opaque minerals, altered to sphene, are an important constituent of these rocks; skeletal ilmenite, 2 mm in size, occurs in some thin sections. Sphene and epidote are disseminated throughout the groundmass. The epidote minerals are colourless clinozoisite and pale yellow, slightly pleochroic pistacite; closely associated with the pistacite are high-relief, pale coloured, blue-green pleochroic to colourless laths with anomalous blue birefringence and an undulose extinction. The close association with epidote suggests that they may be an epidote mineral but the biaxal positive sign and absorption colours are more characteristic of pumpellyite. (?) Pumpellyite also occurs in pillow lava, co-existing with chlorite and calcite. Associated with the (?) pumpellyite are cloudy areas of moderate relief and an undulose extinction. The cloudiness masks the true characteristics of the mineral which is believed to be prehnite.

The basic dyke, mentioned above, contains xenoliths and is doleritic in composition. Long (0.75 mm) prismatic pleochroic (α = light brown, β = brown, γ = green-brown) hornblende and subhedral augite phenocrysts occur in a matrix of feldspar laths, acicular tremolite-actinolite, calcite, sericite, muscovite, penninite and scattered opaque minerals. Some phenocrysts are cracked and partially replaced by chlorite and surrounded by a rim of fine-grained opaque granules. Patches of calcite with a slight brown staining also occur and they probably represent former feldspar phenocrysts. The feldspar in the groundmass has mainly low relief, is untwinned with an undulose extinction and is probably secondary albite.

The enclaves are porphyritic quartz microdiorites with quartz and plagioclase phenocrysts in a microcrystalline quartzo-feldspathic matrix with micas (muscovite and biotite), chlorite, calcite and apatite. In some cases the phenocrysts are replaced by calcite, chlorite and epidote.

Deformation and Alteration

The rocks of Ducloz Head have suffered extensive ductile and brittle deformation. Within the coastal member, sheared blocks of folded sediments, sandstone and shale units occur within disorientated massive sandstone and breccia units. Ductile deformation has also occurred, with large- and small-scale folded and boudinaged sediments found within the sheared blocks. The large-scale folds, which are mainly close with angular hinge zones, are disrupted by shearing. Fold hinges are variable in trend and plunge (Fig. 6a), which may be due to polyphase folding or have resulted from dislocation and disorientation of the folded blocks. Angular kink bands are found within the laminated sediments. Small-scale folds are well developed with contemporaneous corrugation lineations developed on some bedding planes. The folds are impersistent and die out along their length. A fabric is not well developed in these rocks. In the fine-grained lithologies, a slaty fabric is defined by aligned chlorite, muscovite and occasionally biotite plates.

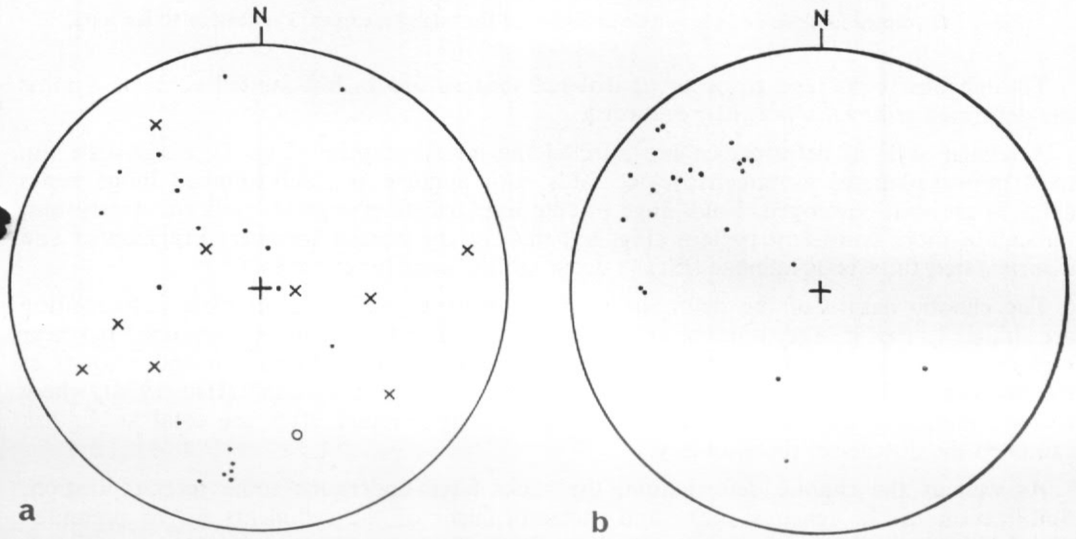

Fig. 6. a. Stereogram of fold hinges (●), kink fold hinges (×) and corrugation lineations (○) of the coastal member.
b. Stereogram of fold hinges of the inland member.

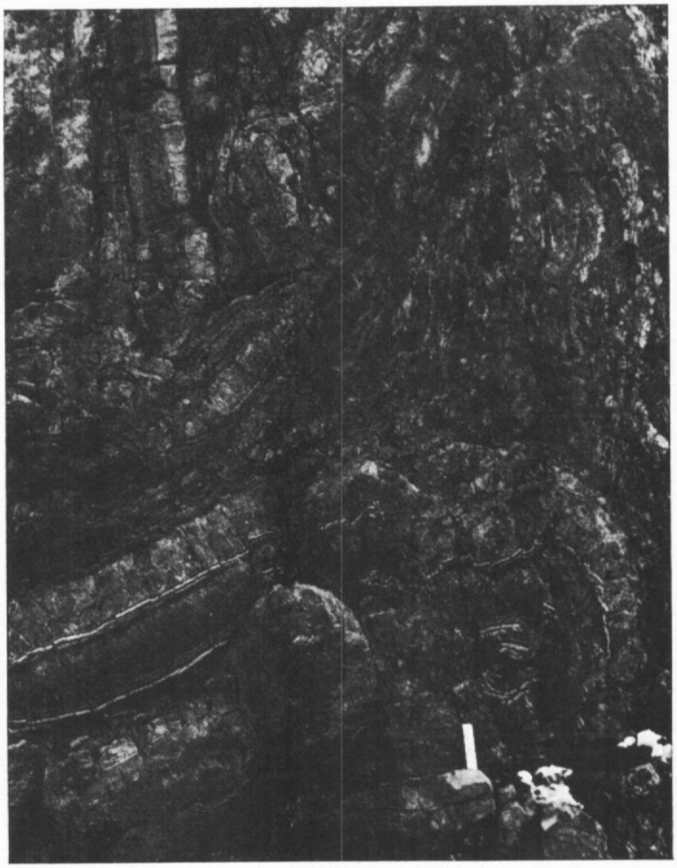

Fig. 7. Disrupted laminae and chaotic deformation of the inland member. The scale is 10 cm long.

The igneous rocks tend to occur as isolated sheared blocks but faulted contacts against the deformed sediments were also recorded.

A similar style of deformation has affected the inland member (Fig. 7). Large-scale (up to 4 m wave-length) asymmetric close folds with angular and sub-rounded hinge zones (Fig. 8) are well developed. Fold-hinge orientations, which plunge towards the north-west, indicate a more consistent pattern (Fig. 6b) than in the coastal member. Fragmented and disorientated tuffaceous laminae (Fig. 7) occur within some hinge zones.

The chaotic nature of the deformation and the variety of rocks in close juxtaposition are similar to that in a tectonic mélange where different tectonic units are bounded by shear surfaces. As no exotic blocks were recorded, the scale of the deformation and amount of the dislocation may better be described by the term "broken formation" (Hsu, 1974), where rocks undergoing ductile deformation may eventually fracture after the total strain has exceeded the ductile-brittle boundary.

As well as the chaotic deformation, the rocks have undergone some recrystallization. Spilitization of the igneous rocks and metamorphism of the sediments up to prehnite–pumpellyite facies have taken place. In the spilites, clinopyroxene is metastable, co-existing with epidote, prehnite, pumpellyite, calcite, chlorite, albite, sphene and actinolite. Coombs (1974) has suggested that spilites belong to prehnite–pumpellyite low-grade mineral facies

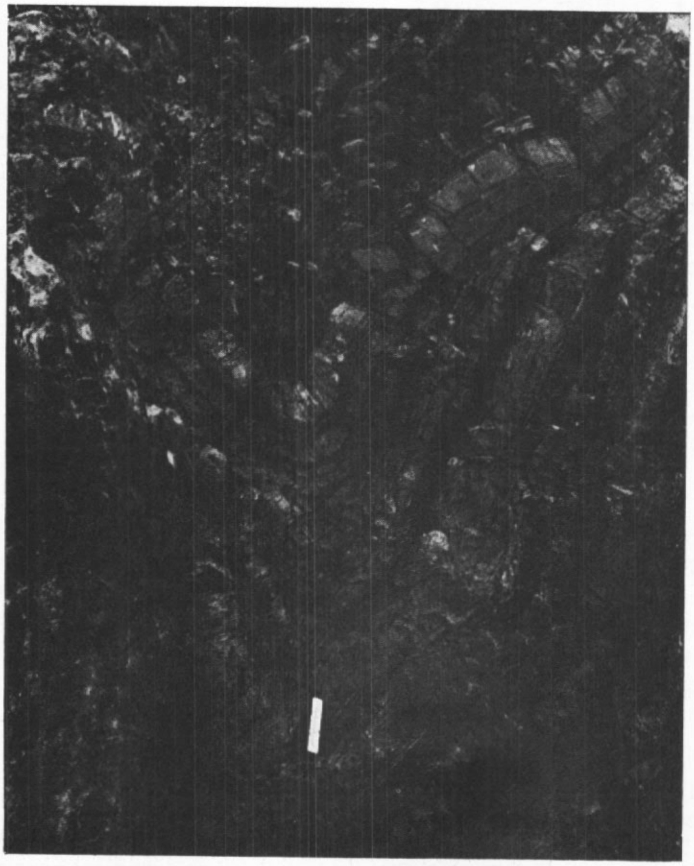

Fig. 8. Fold of the inland member of the Ducloz Head Formation. The scale is 10 cm long.

and may develop by burial, regional or hydrothermal low-grade metamorphism long after the consolidation and complete cooling of a parent basaltic magma. In the Ducloz Head area, this hypothesis is supported by the fact that the associated sediments have also undergone low-grade metamorphism.

The degree of metamorphism of the sediments in the Ducloz Head Formation is variable. The inland member is characterized by a zeolite-facies assemblage with the occurrence of analcite and quartz. The epiclastic and volcaniclastic sediments of the coastal member contain secondary epidote, chlorite, sericite, albite and prehnite and are probably also part of a prehnite–pumpellyite facies. The Cumberland Bay Formation is of prehnite–pumpellyite facies with a mineral assemblage chlorite–epidote–prehnite–muscovite. Pumpellyite has been recorded from the Cumberland Bay Formation about 20 km north-west of Ducloz Head (Tanner, 1982).

There is thus some variation in the mineral assemblage of the Ducloz Head area: zeolite facies of the inland member and prehnite–pumpellyite facies of the coastal member, basic rocks and the Cumberland Bay Formation. The occurrence of these rocks in close juxtaposition indicates extensive vertical movement after the metamorphism of the rocks.

Provenance of Sediments

Coastal member

The interbanded, texturally immature epiclastic and volcaniclastic sandstones and shales of the coastal member, with angular to sub-rounded grains which are chemically unstable, suggest that some of the sediments were deposited by turbidity currents. The massive breccia units (up to 8 m) are not a characteristic of true turbidites but may be related to submarine landslides or fluxoturbitites deposited by a highly charged density current in a rapidly subsiding basin, perhaps fault bounded and close to a volcanic source. The periodic inclusion of volcaniclastic breccias and tuffs supports a nearby volcanic source.

The clastic grains of the coastal member of the Ducloz Head Formation were derived from a volcanic and plutonic granitic and metamorphic terrain. Variations in the proportions of the felsitic and volcanic fragments are interpreted as an indication of periodic volcanic activity in the source region. During intermittent uplift and reduced levels of igneous activity, increased amounts of quartz and feldspar crystal debris and non-volcanic lithic fragments, mainly plutonic and metamorphic rocks, formed the epiclastic sediments.

Inland member

The thin-bedded vitric tuffs of the inland member are basic in composition with a dominance of microlitic volcanic fragments and plagioclase crystal fragments. Together with the Radiolaria-rich calcareous mudstones of the inland member, they are characteristic of a continental shelf environment. The mudstones represent normal hemi-pelagic subaqueous sedimentation with the graded tuff units formed from periodic introductions of pyroclastic material from an intermittent volcanic source.

Relationship to Other Sedimentary Formations on South Georgia

A number of sedimentary formations having similarities to the Ducloz Head Formation have been described from other parts of South Georgia. They are the Cumberland Bay, Sandebugten, Cooper Bay and Annenkov Island Formations (Fig. 1). They may have been deposited in an Upper Jurassic–Lower Cretaceous island-arc–marginal basin system (Dalziel and others, 1975; Suárez and Pettigrew, 1976).

The Cumberland Bay Formation (Trendall, 1953, 1959) is a thick sequence of island-arc derived andesitic volcaniclastic greywackes.

Rocks of the Sandebugten Formation (Trendall, 1953, 1959; Stone, 1980), which were derived from the continental margin (Dalziel and others, 1975), contain up to 25% felsic volcanic material, mainly dacitic with some trachytes, trachyandesites and andesites, and up to 50% detrital quartz in polycrystalline and monocrystalline fragments. Granitic, feldspar crystal fragments, shale and slate clasts are also present together with detrital biotite, amphibole, sphene, zircon and rutile.

The petrography of the Cooper Bay Formation, which occurs at the south end of the island (Fig. 1), is similar to that of the Sandebugten Formation (Stone, 1981) with clastic grains of quartz, plagioclase, perthitic and graphic orthoclase, and fragments of trachytic lava and felsite.

On Annenkov Island, west of Ducloz Head, a sequence of thin-bedded tuffs, tuffaceous mudstones and volcaniclastic breccias is termed the Annenkov Island Formation (Pettigrew, 1981). The tuffaceous mudstones consist of angular pyroclastic materials (pumice, andesite, dacite and crystal fragments) set in a recrystallized matrix of calcite and zeolites. The breccias are composed of andesitic clasts and an andesitic and dacitic sandy matrix.

The andesitic tuffs and mudstones of the inland member of the Ducloz Head Formation are similar to the Annenkov Island Formation and probably represent part of the island-arc assemblage.

The coastal member is more similar to the Sandebugten Formation and Cooper Bay Formation sediments than to the Cumberland Bay Formation with a predominance of quartz and metamorphic and felsitic rock fragments. It probably represents part of a sedimentary sequence derived from a continental margin and continental margin felsitic volcanic rocks (cf. Sandebugten Formation). As the coastal member contains large clasts of volcanic rock and thick breccia units, it is a more proximal facies than the Sandebugten Formation. As these proximal sediments (coastal member) are now situated on the island-arc side of the back-arc basin, they may have been derived from the segment of continental crust and associated volcanic rocks that split off from the continental landmass to form the back-arc basin or from a fragment of rifted-off continental crust (Drygalski Fjord Complex; Storey and others, 1977) within the basin; the sediments may represent the initial fill of this basin. The Sandebugten Formation may be more distal sediments derived from this segment of continental crust or, as suggested by Dalziel and others (1975), have been derived from the opposite side of the basin.

To the south of Ducloz Head, the Larsen Harbour Formation (Fig. 2), which is part of an ophiolite sequence (Mair, 1983) of submarine pillows, vesicular lavas and sheeted dykes, may form the floor of the back-arc basin. The spilitic lavas in the Ducloz Head area are similar to the lavas of the Larsen Harbour Formation and were probably also derived from the basic magma which may have formed the floor of the basin. Felsites similar to the Ducloz Head area are also emplaced within the Larsen Harbour Formation.

Comparison with the Southern Andes

The geology of South Georgia has previously been correlated with South America (Dalziel and Elliot, 1971; Dalziel and others, 1975; Suárez and Pettigrew, 1976; Bell and others, 1977; Storey and others, 1977), both being part of a probable island-arc–back-arc basin system. In South America the boundary of the marginal basin on the continental side is marked by a 5–12 km belt of Middle–Upper Jurassic acid volcaniclastic rocks of the Tobífera Formation (Suárez and Pettigrew, 1976). These sediments, although very similar to the Ducloz Head Formation, have suffered more extensive deformation. A silicic unit of Upper Jurassic–Lower Cretaceous volcaniclastic rocks of the Hardy Formation, which is believed to be part of the island-arc assemblage, also crops out in South America (Suárez and Pettigrew, 1976).

Various modes of origin are possible for the Ducloz Head felsites, some of which (i–iii below) were outlined by Suárez and Pettigrew (1976) for the Tobífera Formation:

i. They may be related to subduction of the Pacific oceanic plate along the continental margin prior to or during the early phase of the opening of the marginal basin.
ii. They may represent an acid stage of a rift zone which may have preceded the basic magmatism related to the opening of the marginal basin (Karig and Jensky, 1972).
iii. They may have formed by crustal melting as a result of the rise of mantle material related to the opening of the South Atlantic.
iv. They may be part of the back-arc basin volcanism and may have formed by differentiation of the basic magma.
v. They may be part of the island-arc volcanism which developed after the formation of the marginal basin and from which the andesitic volcaniclastic greywackes of the Cumberland Bay Formation were derived.

It is not certain which of these hypotheses applies to the Ducloz Head felsites as the available evidence from a small area of fault-bounded exposure is not conclusive. However, the proximal nature of the Ducloz Head sediments and the fact that they are interbanded with spilitic pillow lavas similar to those of the Larsen Harbour Formation, contain continental fragments and are situated on the margin of the basin, support the hypothesis that they are derived from an acid stage of an initial rift (ii above). The felsites probably formed by crustal melting of quartz-rich metasediments as a result of high heat flow associated with the opening of the marginal basin. Alternatively, the spatial association with the island-arc-derived inland member and with the Cumberland Bay Formation suggests that the spilitic pillows and felsites could be part of the Lower Cretaceous island-arc volcanism. The author favours hypothesis (ii) and considers that the felsites are equivalent to the Middle–Upper Jurassic Tobífera Formation of South America.

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