STRUCTURAL GEOLOGY OF PARTS OF ALEXANDER ISLAND

By C. M. BELL

ABSTRACT. Previous structural observations in Alexander Island are discussed and the stratigraphy of parts of the island is summarized. Two major sedimentary formations, the (?) Carboniferous sequence and the Fossil Bluff Formation are separated by a major north–south fault. The older (?) Carboniferous sequence was subjected to at least three phases of folding and extreme cataclasis, probably during an early Mesozoic orogeny. The younger, relatively undeformed Fossil Bluff Formation was subjected to large-scale penecontemporaneous deformation, followed by thrust faulting and two phases of gentle folding. Late Cenozoic block faulting and a southerly regional tilt are controlling factors of the present-day topography of the island.

ALEXANDER ISLAND is the largest of the long chain of islands that extends down the west coast of the Antarctic Peninsula. This peninsula is itself a geographical continuation of the mountain ranges of the southern Andean Cordillera and the islands of the Scotia Ridge. Mountain ranges in Alexander Island are all elongated north–south, parallel to the trend of the Antarctic Peninsula. This linearity is believed to be controlled by major north–south block faults (Bell, 1974). An elongate trough (George VI Sound) separates Alexander Island from Palmer Land; it is over 350 km. long and between 25 and 50 km. wide. Straight coastlines and differences of rock types on either side of this sound could indicate a faulted origin. Remnants of a relatively flat erosional surface on Alexander Island indicate a southerly tilt of the whole island (King, 1964).

This paper summarizes the stratigraphical and structural observations made by the author in Beethoven Peninsula (Bell, 1973*a*), southern Alexander Island (Bell, 1973*b*), northern Alexander Island (Bell, 1974), the Ablation Point area and parts of the south-east coast (Fig. 1). The structural geology of the Fossil Bluff Formation (Taylor and others, 1974) at Ablation Point and south of Neptune Glacier is discussed in detail.

The first structural geological study of any part of Alexander Island was made by Horne (1967), who described the sedimentary rocks of the Fossil Bluff Formation in the area between Uranus and Neptune Glaciers. Grikurov and others (1967) first suggested that there were two major sedimentary sequences in Alexander Island: an older, possibly Upper Palaeozoic succession of tightly folded sedimentary and volcanic rocks (the "Trinity series" or (?) Carboniferous sequence) in western and central parts of the island, and a younger, relatively undisturbed Mesozoic succession (the Fossil Bluff Formation) in the south-eastern part. Horne (1967, p. 9) disagreed with this interpretation and believed that the differences in the pattern and intensity of folding of the two sequences were a reflection of different depositional and tectonic environments within a single sedimentary trough. This controversy has not yet been resolved beyond doubt as no reliable age determination is available for the tightly folded sequence. However, the balance of recent stratigraphical, petrological and structural data favours Grikurov's sub-division of the sediments into two distinct sequences.

STRATIGRAPHY

The stratigraphy of Alexander Island is summarized in Table I and Fig. 2. The rock formations are quite distinct from those of the adjacent areas of Palmer Land.

The oldest known rocks exposed in Alexander Island are those of the (?) Carboniferous sequence. These sedimentary and volcanic rocks were deposited on an unknown basement and are probably equivalent in age to the Trinity Peninsula Series of the north-eastern Antarctic Peninsula. The sedimentary rocks of the (?) Carboniferous sequence consist of thin uniform beds (Fig. 3) of texturally and mineralogically immature sandstones with interbedded mudstones and rare pebble conglomerates. The main detrital constituents of these sandstones were derived from contemporaneous volcanicity (Bell, 1973*b*). Other clasts indicate that quartz-rich sedimentary rocks and some plutonic rocks were also exposed in the source area. Rare current-direction indicators suggest transport of sedimentary material from the north-east. Pyroclastic rocks and basaltic pillow lavas are in places interstratified with the sedimentary rocks. The

TABLE I. THE STRATIGRAPHY OF ALEXANDER ISLAND

Era	Period	Stratigraphy and area of outcrops	Stratigraphical and tectonic events	Reliability of age determinations
CENOZOIC	**Quaternary**	Moraine	Glacial erosion and deposition	Continuing to present day
	Tertiary	Palagonite-tuffs and olivine-basalts (Beethoven Peninsula)	Subaqueous eruption	Late Tertiary or Quaternary. K-Ar dates from comparable volcanic rocks elsewhere in western Antarctica range from Oligocene to Recent (Bell, 1973*a*)
			Block faulting and southerly tilting. Erosional planation	*Age unknown*, probably late Tertiary
		Camptonite dykes (south-east coast)	Intrusion	15 m. yr. K-Ar age (Rex, 1970)
		Dolerite dykes	Intrusion	*Age unknown*, probably Tertiary
			Gentle folding. Possibly some plutonic intrusions	Possibly Eocene if the folding is synchronous with that of the Cumberland Bay type rocks of South Georgia (Grikurov and others, 1967)
MESOZOIC	**Cretaceous** Upper	Tuffaceous sequence of hornblende-porphyry tuffs and agglomerates (Elgar Uplands and Colbert Mountains)	Eruption and intrusion. Some sedimentary deposition	Unconformably overlying the (?) Carboniferous sequence. 70 m. yr. K-Ar age from tuff (Grikurov and others, 1967)
	Cretaceous Lower; **Jurassic** Upper	Fossil Bluff Formation of sedimentary and volcanic rocks (south-east coast)	Sedimentary deposition in a shallow-water marine basin, contemporaneous volcanicity. Large-scale penecontemporaneous deformation	Fossils give ages ranging from Upper Oxfordian–Kimmeridgian (Upper Jurassic) to Albian (Lower Cretaceous) (Taylor and others, 1974)
	Jurassic Middle	Granite and granodiorite batholith (Rouen Mountains). Microgranodiorite dykes (Staccato Peaks)	Plutonic intrusion	*Age very uncertain.* Probably either early Jurassic or late Mesozoic–early Tertiary. Younger than the dioritic intrusions
	Jurassic Lower		Erosional unconformity (Elgar Uplands)	*Age uncertain*
	Triassic	Dioritic intrusive bodies (northern and southern parts of the island)	Intrusion	*Age uncertain.* Pre-Upper Jurassic and post major phase of deformation
			Intense tectonic deformation. Polyphase folding and cataclastic deformation	Pre-Upper Jurassic. Probably late Triassic–early Jurassic (Dalziel and Elliot, 1971; Grikurov, 1971)
PALAEOZOIC	**Permian** **Carboniferous**	(?) Carboniferous sequence of sedimentary and volcanic rocks (large area of northern, central and western Alexander Island)	Deposition and eruption in the distal part of a eugeosynclinal basin	Palynological studies (Grikurov, 1971) indicate a late Palaeozoic age. Probably equivalent to the late Palaeozoic or early Mesozoic Trinity Peninsula Series

Fig. 1. Sketch map of Alexander Island showing the place-names and areas referred to in this paper.

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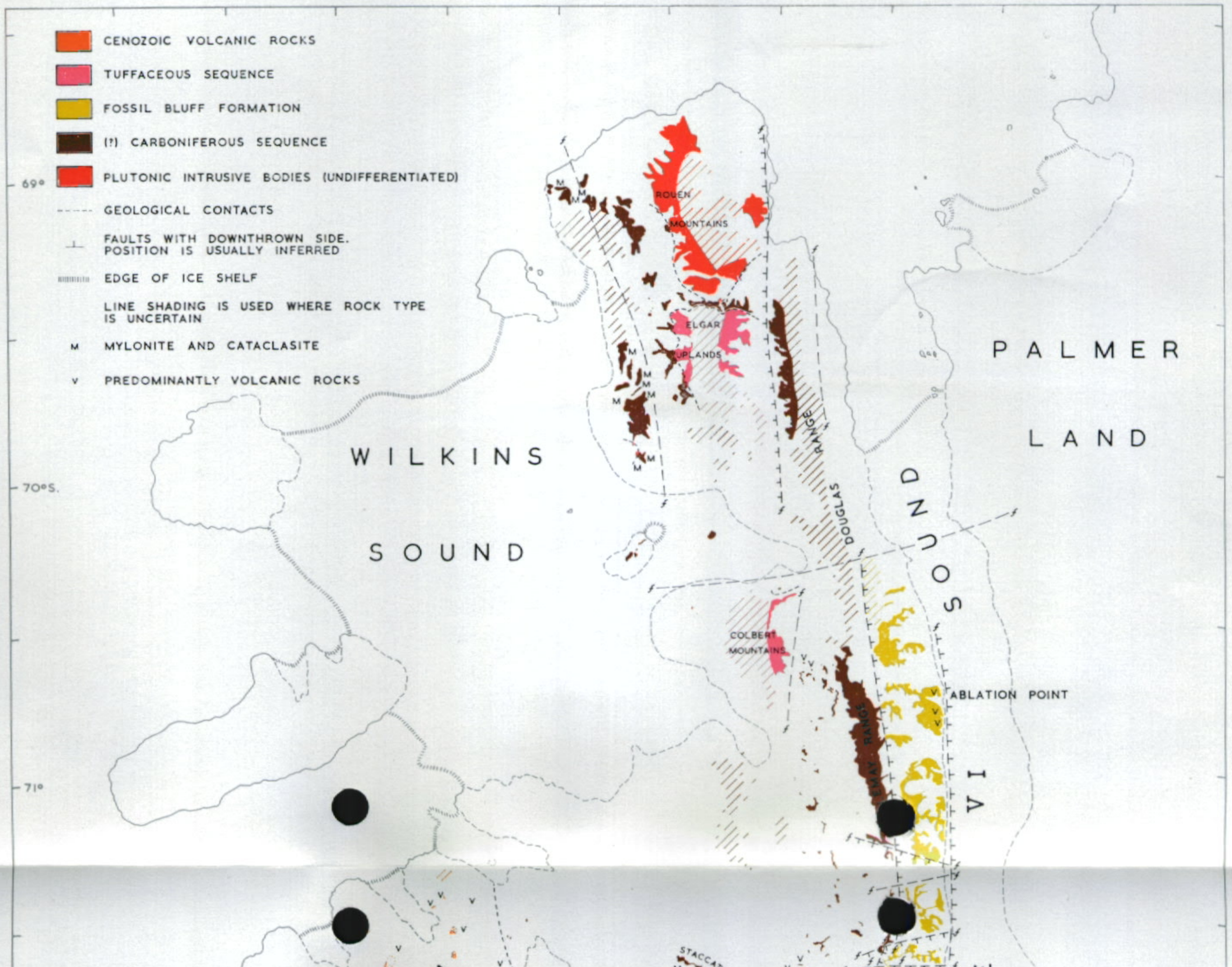

Fig. 2. Geological sketch map of Alexander Island.

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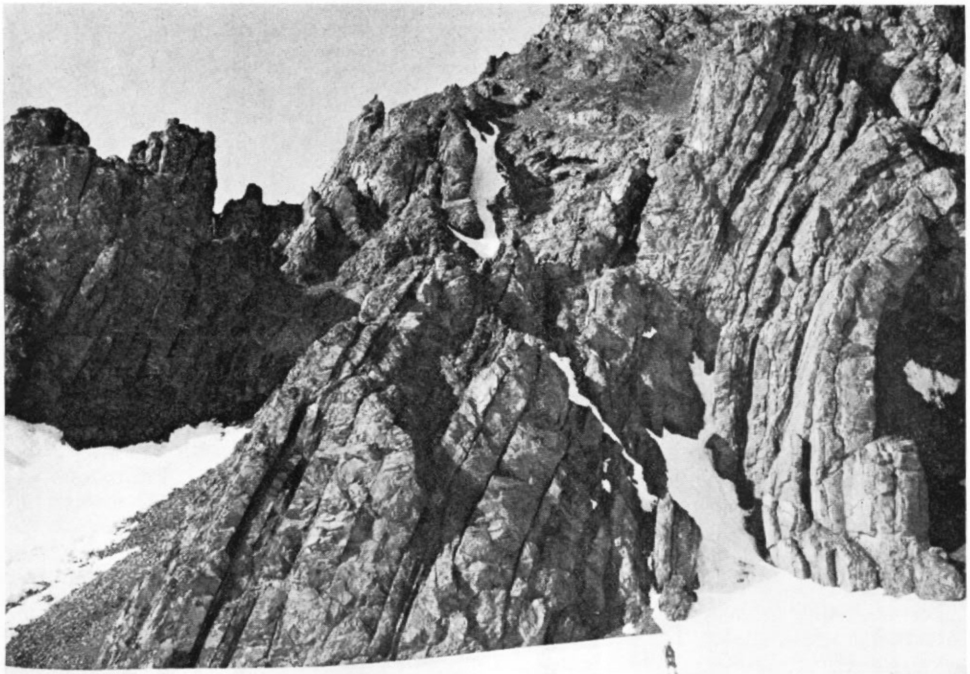


Fig. 3. Steeply dipping arenaceous strata of the (?) Carboniferous sequence, south of Mount Umbriel.

petrology and sedimentary structures of this sequence suggest deposition in a deep-water eugeosynclinal basin.

These (?) Carboniferous rocks were subjected to intense tectonic deformation during an early Mesozoic orogeny and they were later intruded by dioritic intrusive rocks. These intrusive rocks are slightly sheared and extensively hydrothermally altered; they are confined to the western parts of the island and may have been associated with the late stages of the early Mesozoic orogeny. No absolute ages have been determined on these rocks but they are probably pre-Upper Jurassic in age. A granite and granodiorite batholith in the Rouen Mountains and microgranodiorite dykes at Staccato Peaks intrude the dioritic rocks but their absolute ages are not known. They are either early Jurassic or late Mesozoic–early Tertiary in age (Bell, 1973*b*, 1974).

Sedimentary and volcanic rocks of the Fossil Bluff Formation on the south-east coast of Alexander Island are relatively undisturbed and the total stratigraphical thickness is probably in excess of 8,000 m. The basement of the formation has not been observed but these rocks were probably deposited unconformably on an eroded surface of the older (?) Carboniferous sequence. These shallow-water, marine sedimentary rocks contain a varied invertebrate fauna, together with some fish fossils and fossil plant material. These fossils indicate an age range from Upper Oxfordian–Kimmeridgian to Albian (Taylor and others, 1974). Tuffaceous sediments, pyroclastic rocks and andesitic lavas at the base of the Fossil Bluff Formation are probably equivalent to volcanic and sedimentary rocks found elsewhere in the Antarctic Peninsula, and referred to as the Upper Jurassic Volcanic Group. Conformably overlying these volcanic-rich beds is a thick sequence of mudstones, sandstones and conglomerates. The youngest rocks of the formation, exposed in the south-east, are predominantly arenaceous with some conglomerates and mudstones. The petrology of the immature sandstones and the conglomerates indicates a source area of volcanic, plutonic and metamorphic rocks. The proportion of volcanic detritus implies two peaks of volcanic activity: in the Upper Oxfordian–Kimmeridgian and in the Albian. Most current-direction indicators show that the sedimentary material was transported from the north and the east.

A sequence of relatively flat-lying tuffs and agglomerates unconformably overlies the (?) Carboniferous sequence in the Elgar Uplands and Colbert Mountains. These rocks are probably younger than the Fossil Bluff Formation and are possibly late Cretaceous in age (Bell, 1974). Plant fossils in a fine-grained tuff at the north-western Elgar Uplands suggest deposition in a lacustrine environment.

A few narrow dolerite and camptonite dykes of late Tertiary age intrude the (?) Carboniferous and Mesozoic sequences. In the west of the island, on Beethoven Peninsula, are subaqueously (probably subglacially) erupted palagonite-tuffs and agglomerates overlain by subaerially erupted olivine-basalt lava flows of a late Tertiary or Quaternary age, related to the widespread volcanic activity on the margin on the Pacific Ocean (Bell, 1973*a*).

Structural Geology

The complexly deformed (?) Carboniferous sequence was first described by Grikurov and others (1967) as "folded terrigenous strata" and by Horne (1967) as a deep-water axial facies of the Fossil Bluff Formation which had been subjected to "extreme compressive stress". This sequence has recently been studied in the southern and northern parts of the island (Bell, 1973*b*, 1974), and at least three phases of folding have been recognized, together with intense cataclastic deformation, probably resulting from major strike-slip faulting.

Structures of the relatively flat-lying and little deformed Fossil Bluff Formation were studied by Horne (1967), who described a locally and regionally variable phase of west–east compressive stress, perpendicular to the axial trend of the sedimentary trough. Grikurov (1971) re-interpreted Horne's work and concluded that the late Mesozoic formations in Graham Land and Alexander Island were either horizontal or merely monoclinally tilted, or folded in gentle open folds with a negligible vertical amplitude.

(?) Carboniferous sequence

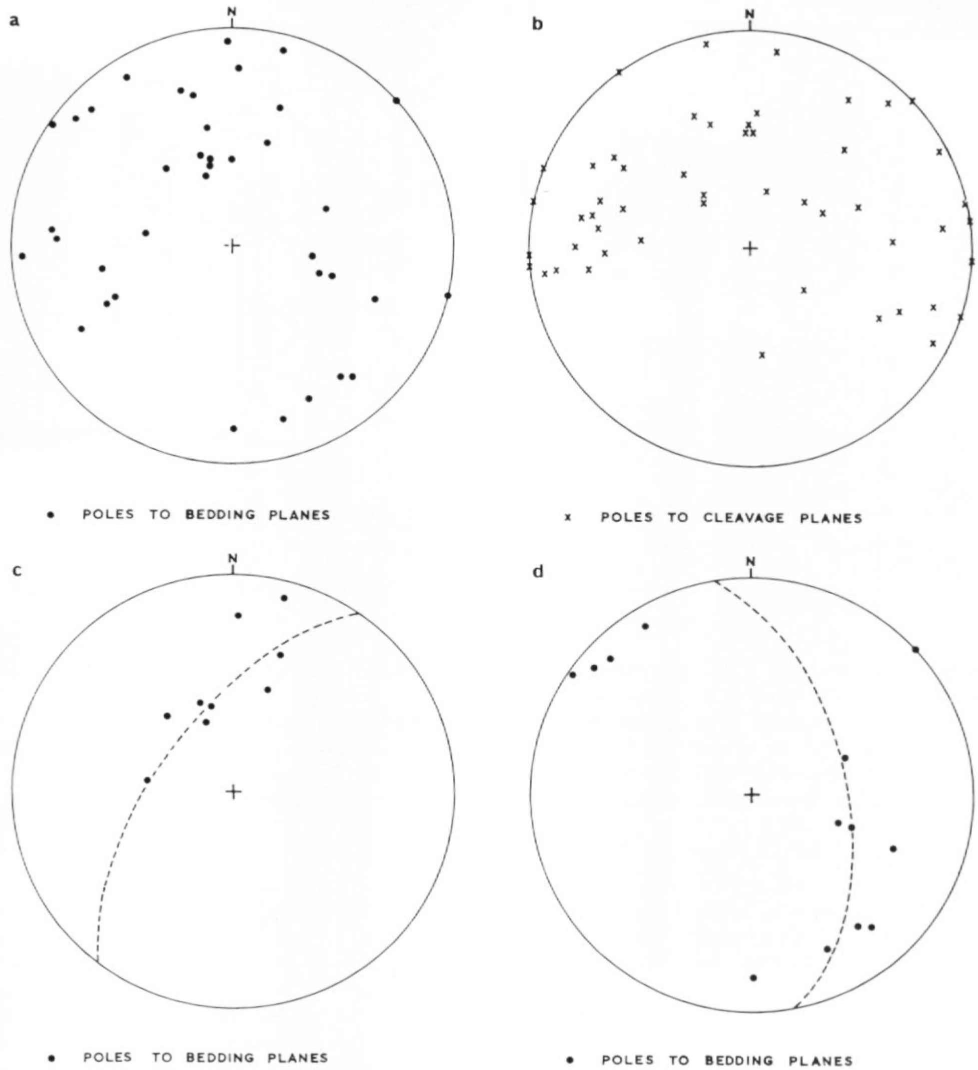
Southern Alexander Island

No dominant overall structural pattern is apparent in the (?) Carboniferous sequence of southern Alexander Island and no evidence of the "distinctly linear system of folds . . . parallel to the axis of the Antarctic Peninsula" reported by Grikurov (1971, p. 163) was found by the author.

The orientation of poles to bedding planes recorded in this area is illustrated in Fig. 4a. The small number of observations is attributable to the extensive cataclastic deformation; clearly recognizable bedding planes such as those shown in Fig. 3 are rare. Some small-scale folds were observed in the field but few orientations of fold axes or axial planes were recorded because of the disruptive effects of re-folding and cataclasis. Both large and small folds are tight with angular hinge zones.

Stereograms of poles to bedding planes from the Mimas Peak area (Fig. 4c) and from the north–south ridge south of Mount Umbriel (Fig. 4d) show concentrations of points on distinct girdles. This suggests that the outcrops in these individual small areas represent the re-folded limbs of major folds. A southerly tilt of beds in the southern Mimas Peak area (Fig. 4c) shows that the strata lie on the south-dipping limb of a large fold. The spread of points in Fig. 4c also indicates re-folding about axes plunging at 25° towards the east-south-east. In the northern Mimas Peak area, the bedding planes have been destroyed by shearing, but the spread of poles to cleavage planes (Fig. 5a) suggests re-folding about axes plunging at 20° towards the south. South of Mount Umbriel (Fig. 4d), the poles to bedding planes are apparently concentrated on a segment of a girdle with an axis plunging westward at about 35°.

Many of the rocks are intensely cleaved and Fig. 4b shows the orientation of the poles to cleavage planes recorded in southern Alexander Island. There is a concentration of points in the northern quadrants of the stereogram but the distribution of poles apparently shows no regular pattern. However, observations from selected small areas indicate a regular system of folds. For example, poles to cleavage planes recorded on the small nunataks south of Titania Peak (Fig. 5b) are spread on a girdle formed by folding about an axis plunging at 40° towards



g. 4. a. Stereogram of poles to bedding planes recorded in the (?) Carboniferous sequence in southern Alexander Island.
b. Stereogram of poles to cleavage planes recorded in the (?) Carboniferous sequence in southern Alexander Island.
c. Stereogram of poles to bedding planes in the (?) Carboniferous sequence in the southern Mimas Peak area.
d. Stereogram of poles to bedding planes in the (?) Carboniferous sequence in the area south of Mount Umbriel.

222°. A parallel minor fold axis recorded in the same area plunges at 36° towards 208°. Folded cleavage planes were observed west of Mount Umbriel.

All of the rocks of the (?) Carboniferous sequence have been subjected to some degree of dynamic metamorphism. As fluxion structures (Higgins, 1971) are generally absent, it has proved impossible to define either the direction of maximum stress or the orientation of the cataclastic zones.

The structural pattern of the (?) Carboniferous sequence in southern Alexander Island is

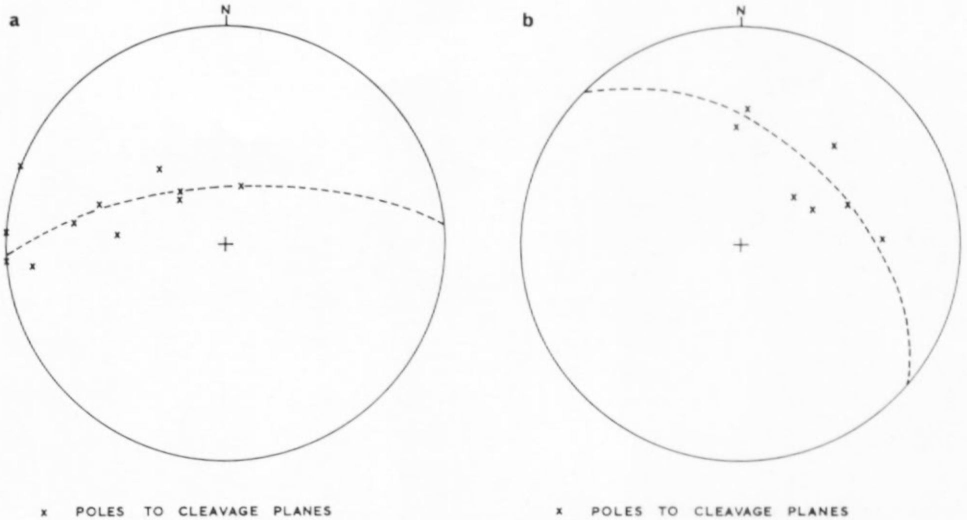


Fig. 5. a. Stereogram of poles to cleavage planes in the (?) Carboniferous sequence in the northern Mimas Peak area.
b. Stereogram of poles to cleavage planes in the (?) Carboniferous sequence in the nunataks south of Titania Peak.

very irregular and the data at present available are inadequate for a complete analysis. There is, however, good evidence for at least three phases of folding:

i. Initial folds with large limbs, possibly overturned towards the north.
ii. A second phase of folding forming tight folds with associated axial-plane cleavage.
iii. A third phase re-folding both bedding and cleavage planes.

The relationship between these phases of folding and the cataclasis is unknown.

Northern Alexander Island

The structural geology of some occurrences of the (?) Carboniferous sequence in northern Alexander Island has been described elsewhere (Bell, 1974). The structural pattern here is similar to that of the southern parts of the island. Three phases of folding have been identified but their orientation was not determined. As in the southern areas, there is no evidence of north–south trending fold axes related to any major phase of folding. A 12 km. wide zone of microbreccia and cataclasite, extending north–south through the western mountain ranges (Fig. 2), was possibly caused by a major strike-slip fault in a deep-seated zone of transcurrent movement.

Fossil Bluff Formation

To some of the early travellers down George VI Sound, the stratified rocks of the Fossil Bluff Formation presented a simple structural picture of an undisturbed sequence with a gentle southerly tilt. Recent investigations, however, have shown that the strata have undergone large-scale penecontemporaneous deformation, thrust faulting and two phases of folding.

Ablation Point area

The first structural observations in the Ablation Point area were made by Adie (1952), who described severe overthrusting from the west, together with folding and transverse faulting. Later, Adie (1964) stated that "severe repeated overthrusting in the vicinity of Ablation Point (and in the hinterland) has been responsible both for the repetition of the stratigraphic succession and the weird fold structures seen in the cliff faces". Horne (1967) also believed that the distorted strata exposed at Ablation Point and elsewhere on the south-east coast of Alexander

Island represented "lubrication zones" resulting from imbricate thrusting from west to east along planes dipping at low angles to the west. Supporting evidence for a theory of imbricate thrusting was provided by Cox (1953) and Howarth (1958), who suggested that both Upper Oxfordian–Lower Kimmeridgian ammonites and Aptian bivalves occurred in a complexly interthrust zone at Ablation Point. However, it has recently been suggested (Taylor and others, 1974) that the Aptian bivalves were misidentified and that all of the complexly deformed strata are Upper Oxfordian–Kimmeridgian in age. It is thus no longer necessary to invoke a mechanism of interthrusting to explain an apparent repetition of the strata.

The "disturbed zone". At the base of the sedimentary succession in the Ablation Point area is a zone of contorted sedimentary and volcanic rocks known as the "disturbed zone" (Fig. 6). This 350 m. thick zone (and others like it in the Fossil Bluff Formation, previously ascribed

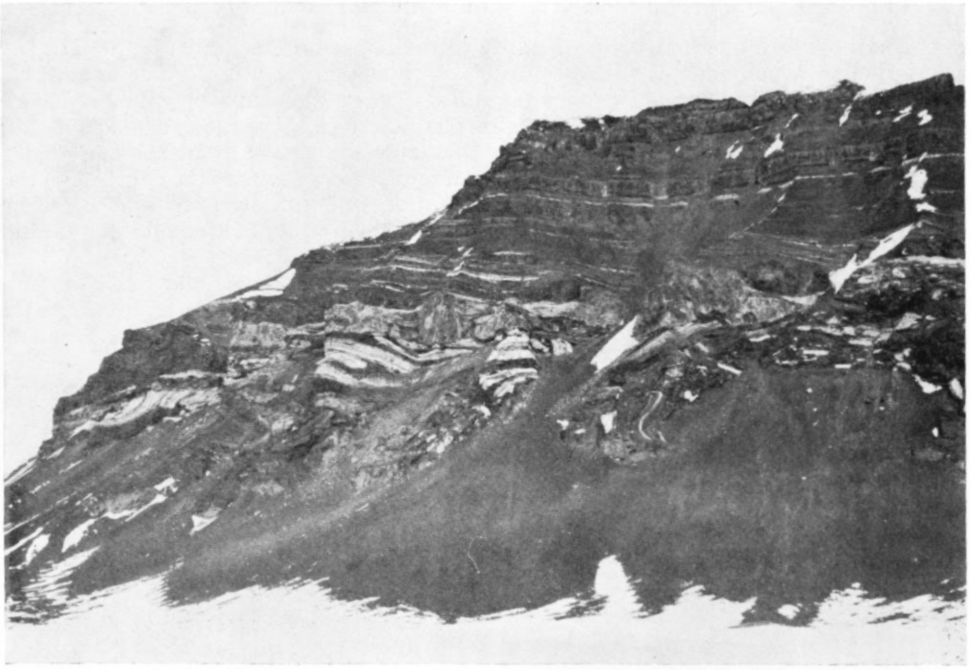


Fig. 6. The "disturbed zone" at Ablation Point.

to thrust faulting), is believed to have formed by penecontemporaneous sedimentary deformation, resulting from slumping or sliding of semi-consolidated strata under the influence of gravity. The total thickness of distorted strata at Ablation Point is not known as the base of the sequence is buried by scree. Exposures of this zone extend westward for about 5 km. and at least 10 km. from north to south.

Although structures resulting from minor surface and near-surface slump movements are common in the Ablation Point area, much of the movement that took place within the "disturbed zone" was probably intraformational, resulting from repeated imbricate sliding of large sheets of strata one over another. It has not proved possible to determine the direction of movement of these slumped sheets because the sparse evidence of down-slope direction provided by folds and imbricate slabs is contradictory.

The criteria for distinguishing penecontemporaneous sedimentary deformation from the deformation resulting from tectonic disturbances have been listed by various authors, including Rettger (1935), Potter and Pettijohn (1963), Grant-Mackie and Lowry (1964) and Gregory

(1969). These criteria agree remarkably well with the observed features of the "disturbed zone" at Ablation Point:

i. Zones of contorted strata are generally conformable with the bedding; flat-lying, undisturbed beds are frequently interbedded with intensely contorted strata (Fig. 6).
ii. Some of the crumpled beds are laterally truncated (Fig. 7), whereas others are continuous for several kilometres.
iii. Fold axes and axial planes of folds are invariably re-folded, resulting in migmatite-like flowage structures (Fig. 8) with associated micro-faulting. Most fold axes and axial planes are near horizontal.
iv. "Packets" of undisturbed or gently folded strata, incorporated in an original slurry of water-saturated mudstone and sandstone, form sedimentary breccias of disorientated blocks set in a crumpled muddy matrix.
v. There is no rock cleavage related to the folding. Cleavage planes, slickensides, mylonites, crush breccias and mineral-filled veins all post-date the slumping.

Folding. The most prominent structural feature of the Ablation Point area is the large asymmetrical anticline which extends from Grotto Glacier in the north to Jupiter Glacier in the south (Fig. 9). Relatively flat-lying strata adjacent to George VI Sound form the broad eastern limb of the fold. Bedding planes on this limb are characterized by gentle irregular undulations and dips of less than 15°. A stereographic plot of the poles to bedding planes recorded from this fold (Fig. 10a) defines a fold axis plunging at a few degrees towards the south. The precise orientation of the eastward-dipping axial plane is impossible to determine due to the broad open nature of the folding. Most of the fold axes in the Ablation Point area plunge at a shallow angle towards the south and south-east (Fig. 10b).

Cleavage planes recorded in the Ablation Point area are near vertical and strike in a north–south direction (Fig. 10c), parallel to the major fold axes. Cleavage planes transect the folded structures of the "disturbed zone" and provide indisputable evidence that the movements of

Fig. 7. A laterally truncated band of crumpled strata in the "disturbed zone" at Ablation Point.

Fig. 8. Crumpled bedding with migmatite-like flowage structures in the "disturbed zone" west of Ablation Point.

the "disturbed zone" occurred prior to the north–south folding. A strong system of joints parallels the cleavage but no systematic measurements of joint orientations have been made. Ammonites on the ridge south of Ablation Valley are slightly distorted by the cleavage.

Calcite-filled tension gashes post-date the cleavage and provide evidence of a later phase of tectonic activity.

Faulting. Many minor thrust faults with a displacement of several metres or less have been observed in the Ablation Point area. They dip both westward and eastward, and form a conjugate system of shearing possibly related to the main phase of west–east compression.

A major thrust fault with a vertical displacement of several hundred metres was observed on the cliffs south of Grotto Glacier, 10 km. west of Ablation Point. The thrust plane dips at about 45° towards the south-west and minor associated thrust faults and drag folds (Fig. 11) indicate that the overthrusting was towards the north-east. A broad zone of contorted mudstones above the thrust plane possibly formed a lubrication zone for much of the movement. Structures in the sandstones and conglomerates beneath the fault plane suggest that movement was taken up both by plastic flow and by brittle shear fracture (Fig. 12). These structures are very similar in appearance to those attributed to penecontemporaneous deformation at Ablation Point. There is apparently no geometrical relationship between the orientation of the thrust plane and the tectonic fold axes in the adjacent strata, thus suggesting that the thrust faulting is unrelated to the folding.

South-eastern Alexander Island

Most of the sedimentary rocks in south-eastern Alexander Island, south of Venus Glacier, show no evidence of intensive deformation, and the structural pattern lacks any dominant strain direction. The bedding planes of the coastal areas adjacent to George VI Sound have a gentle southerly tilt and give no indication of the relatively complex structural history of the area.

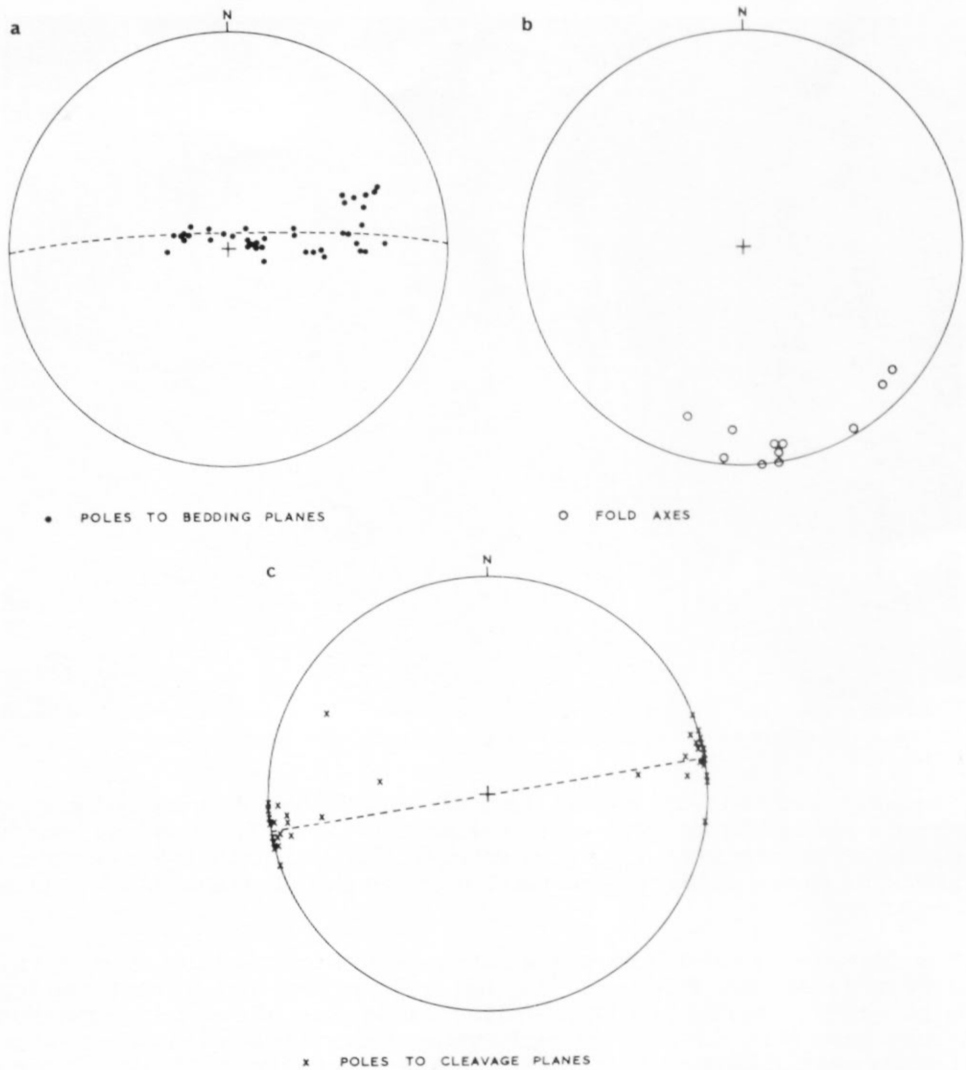


Fig. 10. a. Stereogram of poles to bedding planes of the asymmetrical anticline, south of Ablation Point.
b. Stereogram of fold axes in the Ablation Point area, calculated from π diagrams of bedding-plane orientation.
c. Stereogram of poles to cleavage planes in the Ablation Point area.

There is a simple relationship between the fold pattern and lithology in this area. In the east is a relatively flat-lying and little deformed arenaceous sequence, whereas the argillaceous rocks in the west have been more tightly and irregularly folded. Bedding planes in the arenaceous sequence generally dip at less than 10° but farther west the argillaceous rocks frequently have dips exceeding 70°. It has proved very difficult to delineate individual folds, particularly in the areas of scattered nunataks, due to the complexity of the fold pattern and the lack of exposure. Structural contours drawn by extrapolation between bedding-plane orientation symbols on the structural map (Fig. 13) define some of the larger folds.

Folding. The irregular fold pattern in this area is dominated by large, gently folded, asymmetrical folds with gently to moderately plunging fold axes. Most of the principal folds have

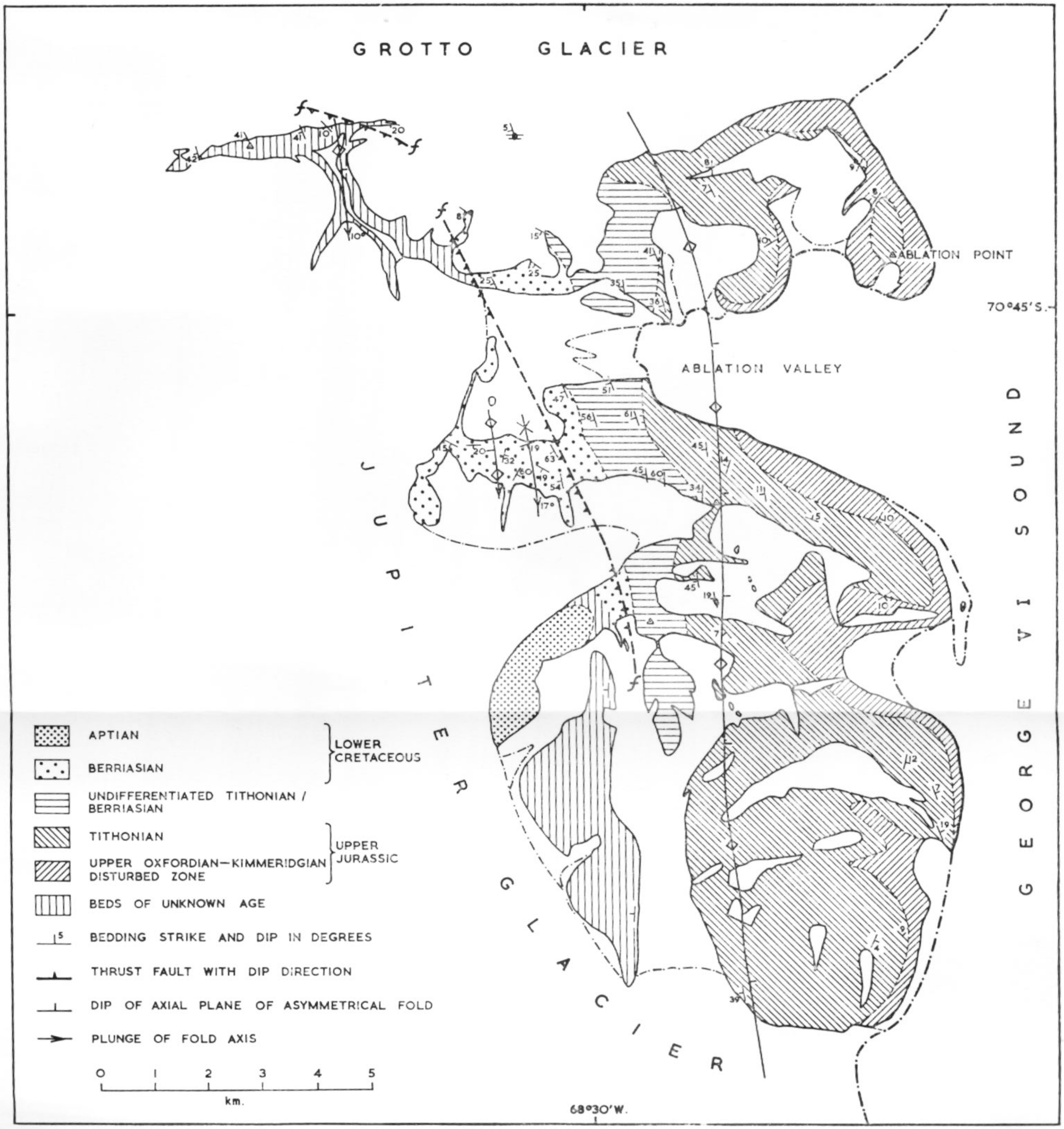


Fig. 9. Geological sketch map of the Ablation Point area.

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Fig. 11. Major thrust-fault plane with associated minor thrust faults and drag folds, south of Grotto Glacier.

easterly or south-easterly plunging fold axes, with a maximum recorded plunge of 40° (Fig. 14a). The folds vary in size, with wave-lengths between about 1 and 20 km. There are no mesoscopic folds with readily measurable fold axes or axial surfaces and consequently it was only during statistical analysis that the complexity of the fold pattern first became apparent. The orientation of most of the fold axes and axial planes is extremely difficult to define due to the effects of re-folding. Furthermore, there is usually no point of maximum curvature in the broad open folds which may be defined as a hinge.

The largest and most obvious fold is the asymmetrical syncline north of Saturn Glacier (Fig. 13). In the west, the fold axis of this syncline plunges towards the east-south-east at about 6° with symmetrical limbs dipping at between 15° and 20° towards the axis. Farther east the plunge of the fold axis steepens and the dip of the limbs becomes markedly asymmetrical. The southern limb steepens to dip at about 40° towards the axis, and the strike of the northern limb swings round into a north-east–south-west direction, perpendicular to the fold axis.

A double asymmetrical syncline (or box fold) at eastern Dione Nunataks has north–south trending fold axes cut by younger north-west–south-east cleavage planes.

Despite the absence of any distinctive penetrative fabric, weakly developed cleavage planes were observed in some mudstone beds. The orientation of these planes is so indistinct as to be unmeasurable, but weathering and erosion have formed linear mudstone "pencils" bounded by the intersecting cleavage and bedding planes. A rose diagram of the orientation of these

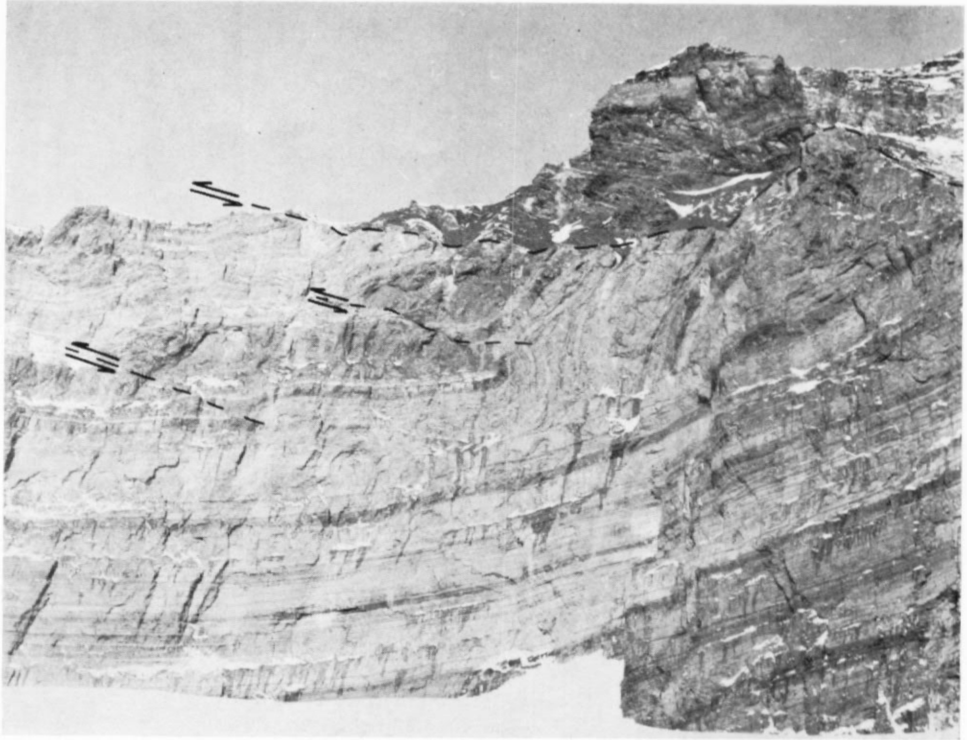


Fig. 12. Major thrust fault south of Grotto Glacier, showing overthrust and contorted strata beneath the fault plane.

"pencils" (Fig. 14b) shows a north-west–south-east concentration, distinct from the more prominent north–south axial-plane cleavage of the Ablation Point area. At eastern Dione Nunataks the cleavage is obviously unrelated to the fold axes, but elsewhere (e.g. at southern Hyperion Nunataks) the fold axes and cleavage are parallel to each other. The north-west–south-east striking cleavage in south-eastern Alexander Island is clearly related to the parallel south-east plunging fold axes. These structures are undeformed and are therefore younger than the north–south trending folds.

There is thus clear evidence of two phases of folding in the strata of the Fossil Bluff Formation:

i. Fold axes are frequently bent and are usually gently to moderately plunging.
ii. Poles to bedding planes (recorded in Fig. 14c) have a very broad spread indicative of re-folding.
iii. In the Ablation Point area north–south cleavage planes parallel the major fold axes but farther south the cleavage/bedding intersection lineations transect the older north–south fold axes.

An initial west to east compressive phase (Horne, 1967) was orientated perpendicular to the present-day linearity of the Antarctic Peninsula. A second phase of folding, resulting from north-east—south-west compression re-folded the earlier structures. The intensity of both phases of folding was approximately the same but the second phase had most effect on the southern part of the sedimentary basin. The two phases of folding probably occurred during a late Mesozoic–early Tertiary orogeny (Dalziel and Elliot, 1971).

Faulting. Faults are difficult to detect in the sedimentary rocks of the Fossil Bluff Formation in south-eastern Alexander Island. In most cases the zones of weakness along the fault lines have been exploited by weathering and erosion to form glacier-filled valleys. With the exception

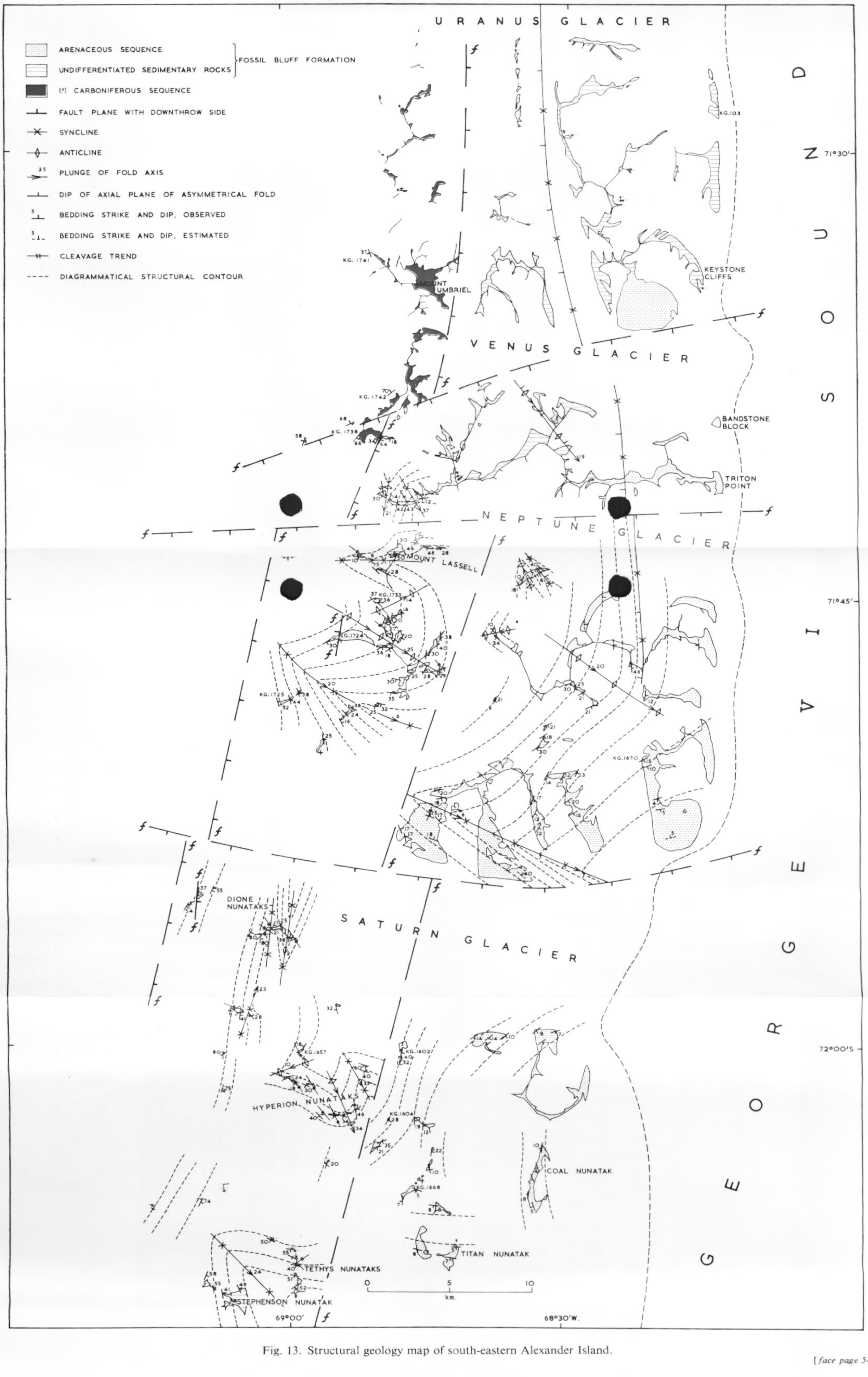
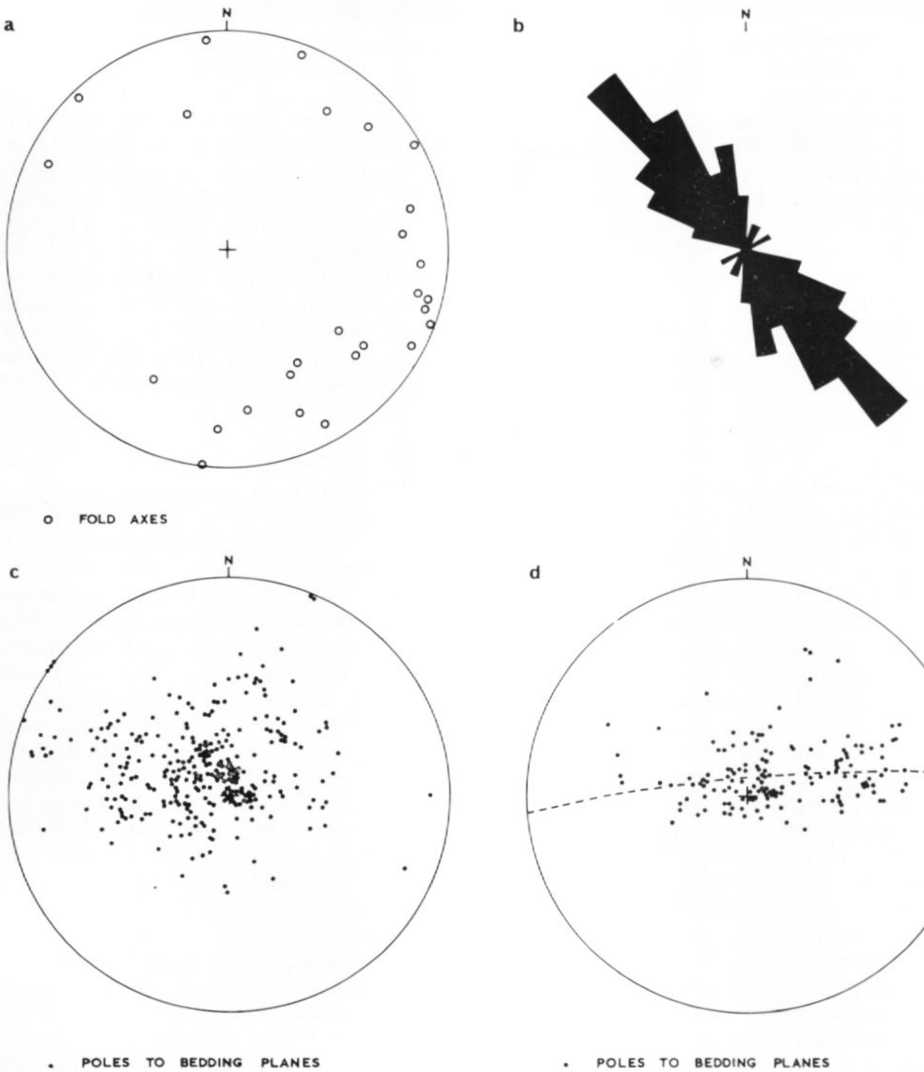


Fig. 13. Structural geology map of south-eastern Alexander Island.



g. 14. a. Stereogram of fold axes in south-eastern Alexander Island, calculated from π diagrams of bedding-plane orientation.
b. Rose diagram of the orientation of linear mudstone "pencils" formed by intersecting cleavage and bedding planes in south-eastern Alexander Island.
c. Stereogram of poles to bedding planes in south-eastern Alexander Island.
d. Stereogram of poles to bedding planes in the Ablation Point area.

of a small section of a fault zone south of Mount Umbriel, the positions of the major faults shown in Fig. 13 are conjectural and their existence has been inferred from geological and physiographical evidence. Bell (1973*b*) believed that the two sedimentary successions of southern Alexander Island are separated by a major north–south fault. A small section of this fault was observed cutting a ridge approximately 7 km. south of Mount Umbriel. The rocks are down-thrown on the east and the fault is marked by a zone of crushed and slickensided sandstone more than 10 m. wide. The exact orientation of the fault plane is difficult to define due to the cataclasis of the adjacent rocks, but it appears to be near vertical and to strike at 020°. West of this fault are tightly folded sandstones of the (?) Carboniferous sequence and to the east are the relatively flat-lying sandstones and mudstones of the Fossil Bluff Formation (containing belemnites of Upper Jurassic–Lower Cretaceous age). The dip of the strata of the Fossil Bluff Formation increases towards the fault as a result of drag on the fault zone. Near the fault the strata strike 027° and dip at 54° towards the east, but farther south they strike 091° and dip at 18° to the south. Sediments near the fault zone are cut by numerous minor faults marked by thin breccias and slickensides. Observations from the air and a study of the U.S. Navy trimetrogon photographs indicate that this fault extends northward from the vicinity of Mount Umbriel, along the Milky Way east of the LeMay Range and across the western side of Nonplus Crag to reach the coast about 30 km. north of Tilt Rock (Fig. 2).

Adie (1958, 1964) first suggested that glaciers separating the sedimentary mountain blocks of eastern Alexander Island occupied fault lines transverse to the main north–south faulting. By contrast, King (1964) ascribed Hampton, Grotto and Uranus Glaciers to trough faulting, possibly as rifts subsidiary to the main rift of George VI Sound. Horne (1967) suggested that the linear sides of Saturn, Uranus, Grotto and Hampton Glaciers are controlled by oblique-slip faults, developed synchronously with the thrusting and folding of the sediments.

The formation of George VI Sound

The straight-sided, parallel coastlines of George VI Sound have long been ascribed to a faulted origin (Joerg, 1937; Fleming, 1938; Stephenson, 1940; Fuchs, 1951; King, 1964). Nichols (1953) first suggested that, although George VI Sound had been assumed to be a tectonic valley, it could just as well be a structurally controlled erosional valley. Adie (1964) believed that the main north–south part of the sound was a rift valley, whereas the southern west–east section had probably resulted from glacial erosion. Horne (1967) suggested that the straight western coast of George VI Sound had resulted essentially from the formation of a high, north–south, linear mountain escarpment by overthrusting of the sediments of eastern Alexander Island. He envisaged that the "uplift of a thick sequence of superimposed thrust sheets . . . would result in the development of an eastward-facing mountain front or escarpment. . . . This high escarpment would overlook the trough of George VI Sound, whose elevation would be reduced both by the underthrusting movement and by isostatic depression by loading of the superimposed thrust sheets" (Horne, 1967, p. 21). Thus the linear escarpment of eastern Alexander Island was believed to have formed contemporaneously with the folding and thrusting. Horne (1967, p. 6) also suggested that some of the rocks were still only weakly lithified during this deformation. It is difficult to envisage the development of an upstanding linear scarp in weakly lithified sediments and, moreover, if such a scarp was formed it seems extremely unlikely that it could have resisted erosion to the present day.

King (1964) and Bell (1974) suggested that much of the striking north–south linearity of the mountain ranges of Alexander Island resulted from block faulting. Adie (1971) also suggested that block faulting controlled the linear coastlines of many islands off the western coast of the Antarctic Peninsula. The mountains of northern Alexander Island have a very high relief, together with planed summit plateaux at various levels (Bell, 1974). This is indicative of recent earth movements and suggests that the block faulting is probably of late Cenozoic age. Thus it seems reasonable to assume that the straight eastern coast of the island (and hence the coast of George VI Sound) also resulted from late Cenozoic block faulting.

Southerly regional tilt

The mountains of eastern Alexander Island decrease steadily in height from about 3,000 m. in the Douglas Range to a few hundred metres south of Uranus Glacier. King (1964) suggested that this was a direct result of a southerly tilt of the whole island during Plio-Pleistocene uplift, possibly related to the earlier, more significant southerly dip of the sedimentary rocks.

Horne (1967) described a regional south-south-westerly dip of between 5° and 30° in the sedimentary rocks of south-eastern Alexander Island. Poles to bedding planes recorded in the Ablation Point area (Fig. 14d) indicate an overall southerly tilt of 6° and poles to bedding planes in the Fossil Bluff Formation south of Venus Glacier (Fig. 14c) indicate an overall southerly dip of between 5° and 10°.

Summary

The oldest strata in Alexander Island are the sedimentary and volcanic rocks of the (?) Carboniferous sequence. These rocks were subjected to at least three phases of folding and in places they underwent extreme cataclasis, possibly as a result of strike-slip faulting related to large-scale crustal movements. Batholiths, dykes and other irregular plutonic bodies were intruded after the folding and cataclasis but prior to any further deposition.

The relatively undeformed strata of the Fossil Bluff Formation, probably deposited unconformably on the older (?) Carboniferous sequence, were subjected to two phases of gentle folding. The first phase formed asymmetrical folds with a vertical north–south axial-plane cleavage; the strata were later gently re-folded about north-west–south-east axes. Some steeply dipping thrust faults indicate overthrusting from west to east and south-west to north-east but some zones of disturbed bedding, previously identified as thrust-fault planes, are now believed to be zones of penecontemporaneous sedimentary deformation.

The sequence of tuffs and agglomerates of the Elgar Uplands and Colbert Mountains was deposited unconformably on the (?) Carboniferous sequence and is probably younger than the Fossil Bluff Formation.

A gently undulating erosional land surface was formed in late Cenozoic times. A southerly tilt of this surface, together with north–south block faults and transverse west–east faults are the main controlling factors of the topography of Alexander Island and George VI Sound. Subglacially erupted basalts of Beethoven Peninsula indicate late Cenozoic volcanic activity.

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