THE GEOLOGY OF SOUTHERN ALEXANDER ISLAND

By C. M. Bell

Abstract. A sequence of strongly sheared sedimentary and volcanic rocks of (?) Carboniferous age is described. Dioritic intrusions in this formation are themselves intruded by dykes of microgranodiorite and dolerite. This succession is probably separated from the Mesozoic succession to the east by a fault.

Fossiliferous stratified mountains in southern Alexander Island were first described by Ronne (1945) and the rocks collected at lat. 72°08′S. and long. 68°45′W. were described by Knowles (1945, p. 141) as "uniform horizontal strata of compact mudstone, graywacke, arkose and coarse conglomerate. All types appeared to be non-marine sediments, and some of the arkoses contained a small amount of carbonaceous material . . .".

A 244 m. thick conglomerate described by Adie (1964) from Stephenson Nunatak was believed to represent the base of a Cretaceous part of the Mesozoic succession (p. 9).

Horne (1967, p. 9) inferred that a "deep-water axial-turbidite facies zone" of the Mesozoic succession of south-eastern Alexander Island extended south and west into the area described here.

Grikurov and others (1967) suggested that the folded terrigenous strata of the Lully Foothills and the LeMay Range were equivalent to the (?) Carboniferous "Trinity series" [*sic*] of north-eastern Graham Land. Subsequently, palynological data (Grikurov and Dibner, 1968) indicated that this "series" in western Alexander Island was Upper Palaeozoic (Lower to Middle Carboniferous) in age.

Physiography

The area of southern Alexander Island described here is situated between lat. 71°30′ and 72°15′S. and long. 68°30′ and 71°W. (Fig. 1). It is a heavily glaciated plateau punctuated by small groups of steep-sided nunataks.

In the east, a low mountain range parallel to George VI Sound is dissected by four short glaciers (Uranus, Venus, Neptune and Saturn Glaciers) which have cut back westwards through the mountains to drain small areas of the inland plateau. However, most glacial drainage is towards the south and west. Snowfall is lower in these southern areas than farther north where high mountains block the prevailing northerly winds. As a result, the snow cover on the rocks is minimal and glaciers are inactive and relatively crevasse-free.

The highest points of the gently undulating plateau are at about 800 m. on the ridge between Titania and Mimas Peaks. In the west, at Staccato Peaks, the plateau descends steeply to about 250 m., and near Stephenson Nunatak in the south it slopes gently south towards the ice shelf of George VI Sound.

Glacial features similar to the "ice caldera" described by Aitkenhead (1963) occur at Staccato Peaks and at the large nunatak 25 km. west of Stephenson Nunatak. Pits paved with large slabs of ice are approximately 30 m. deep and 200 m. in diameter; they are situated adjacent to and down-stream from high cliffs. These "ice calderas" probably formed from the drainage of summer melt-water lakes which accumulated in ablation hollows (formed by wind erosion and solar radiation). The drainage mechanism was probably similar to that proposed by Aitkenhead (1963), who envisaged melt-water lakes drained by the lifting of adjacent stagnant glaciers under hydrostatic pressure. An alternative theory advanced by Koerner (1964) suggested the slow formation of englacial caverns by melt water followed by sudden collapse during periods of rapid melting.

The contrasting topography of south-eastern and southern Alexander Island is the result of different rock types. In the east, sub-horizontal, relatively easily eroded Mesozoic sedimentary rocks often form flat-topped scree-covered nunataks and ridges, whereas farther west, older more resistant sedimentary and volcanic rocks form jagged steep-sided nunataks.

North-west and north-east-trending joints and faults determine the orientation of the long ridges of Staccato and Mimas Peaks. The 800 m. high scarp of Staccato Peaks (Fig. 2) was probably formed by glacial erosion along joints and cleavage planes.

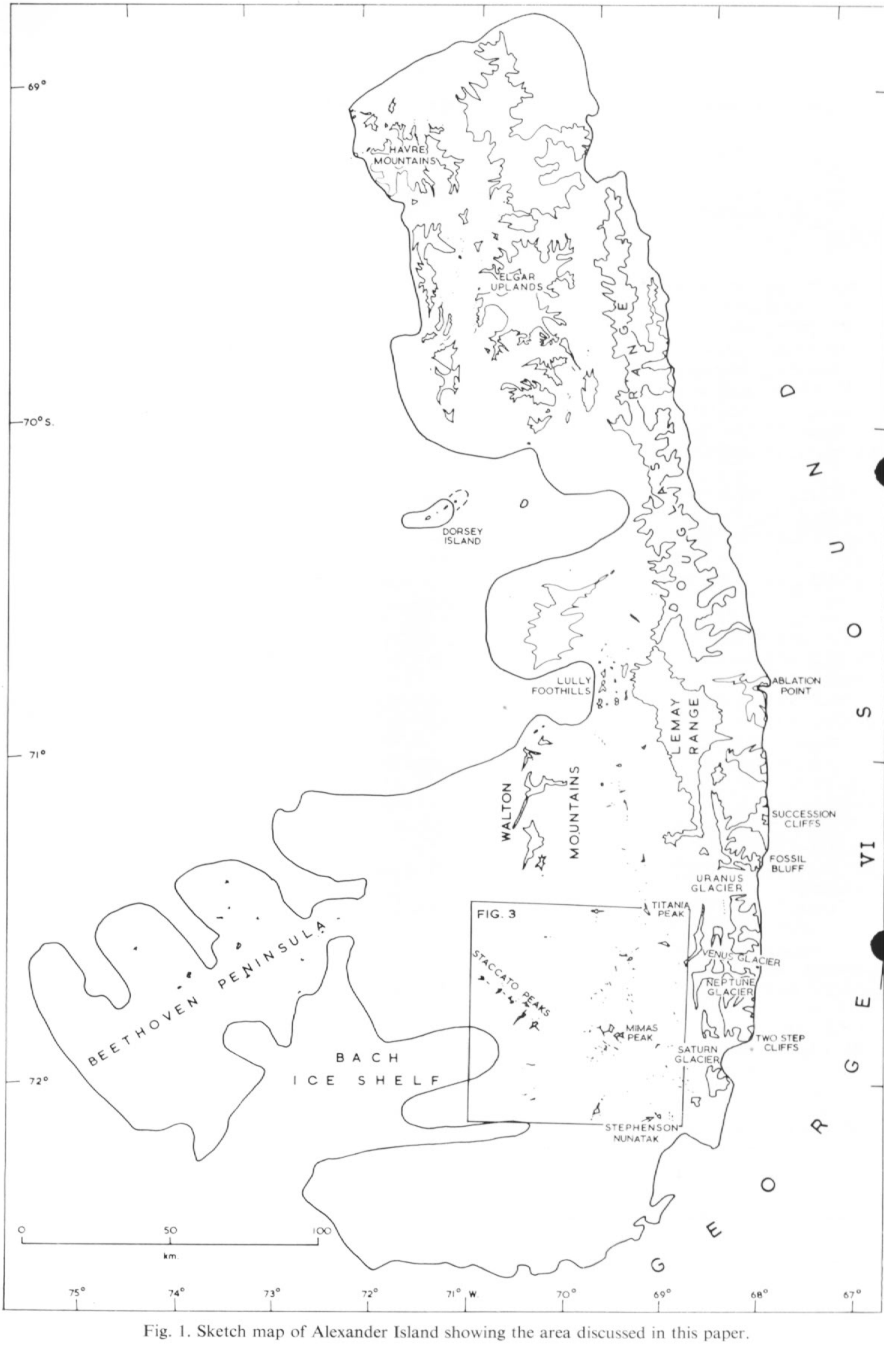

Fig. 1. Sketch map of Alexander Island showing the area discussed in this paper.

Fig. 2. The jagged ridge south-west of The Obelisk, Staccato Peaks.

Five glacier-filled gaps which breach the escarpment of Staccato Peaks together with glacial striae and erratic boulders on the ridges show that the drainage pattern is superimposed.

The large nunatak 15 km. south-east of Titania Peak has a slightly concave 1,000 m. high summit bevel eroded across steeply dipping resistant arkoses. A similar flat erosional surface truncates the northernmost nunataks of Staccato Peaks. These flat-topped nunataks, together with accordant summits between 1,000 and 1,200 m. high, probably represent part of the erosional surface first described by King (1964) from northern Alexander Island.

General Stratigraphy

The stratigraphy of southern Alexander Island is given in Table I.

The oldest rocks are a sedimentary and volcanic sequence which has been previously interpreted as:

i. Part of the (?) Carboniferous "Trinity series" (Grikurov and others, 1967).
ii. A Cretaceous "axial-turbidite facies" of the Mesozoic succession (Horne, 1967).
iii. Part of the Upper Carboniferous to Permian "Trinity Peninsula Series" (Grikurov, 1971). This sequence has also been tentatively dated by spore-pollen analyses (Grikurov and Dibner, 1968) as Carboniferous.

Dioritic intrusions cut by narrow dykes of microgranodiorite and dolerite are intruded into these sedimentary and volcanic rocks.

A fossiliferous Cretaceous marine sedimentary succession is exposed in the east of the area.

(?) Carboniferous Sedimentary and Volcanic Sequence

Folded strata at the southern Douglas Range, Lully Foothills and west of the LeMay Range were first described by Grikurov and others (1967), who suggested that these strata formed part of a sequence older than the Mesozoic succession farther east. Furthermore,

TABLE I. STRATIGRAPHICAL SUCCESSION IN SOUTHERN ALEXANDER ISLAND

Age	
?	Dolerite dyke
	? ~~~~~~~~~~
Cretaceous	Mesozoic sediments
	? ~~~~~~~~~~
?	Microgranodiorite dykes
	~~
?	Dioritic intrusions
	~~
(?) Carboniferous	Sedimentary and volcanic sequence

they subdivided these rocks into lower "horizons" of poorly sorted sandstones and siltstones, and upper "horizons" of better sorted arkoses. They named these strata the "Trinity series" [*sic*], and dated them conjecturally as Upper Palaeozoic from their lithological and structural similarity with the Trinity Peninsula Series (Adie, 1957) of north-eastern Graham Land. They also suggested a Jurassic age for the upper "horizons" based on K-Ar age dates from arkosic sandstones. Subsequently, spore-pollen analyses indicated a Lower to Middle Carboniferous age for the "Trinity series" (Grikurov and Dibner, 1968), but more recently, probable "younger horizons" of the "Trinity Peninsula Series" in Alexander Island have been described as Upper Carboniferous to Permian in age (Grikurov, 1971).

From the air, King (1964) observed folded "Cretaceous strata" in the LeMay Range, most probably the same as those described by Grikurov (1971) as part of the "Trinity Peninsula Series".

Tightly folded arkoses and shales on the northern ridge of Mount Umbriel (comparable to those described from farther north by King (1964)) were believed by Horne (1967, p. 9, 1969*b*, p. 69) to represent a deep-water axial-turbidite facies of the Cretaceous part of the Mesozoic succession. Horne suggested that this axial-turbidite facies was sedimentologically and structurally distinct from his shelf and coastal facies as a result of its relative position in the depositional trough. However, he agreed that these rocks were similar to some of the sedimentary rocks described by Grikurov which may have belonged to an entirely different, probably earlier, cycle of deposition.

Two distinct tectonic patterns (p. 14) suggest that Grikurov was correct in recognizing two sedimentary sequences in Alexander Island and it seems possible that the sediments of the "axial facies" form part of the older sequence. However, Horne's arguments for including his "axial facies" in the Mesozoic succession should not be dismissed until these rocks have been satisfactorily dated.

Regional distribution

Most of the folded and sheared sedimentary and volcanic rocks in northern, central and southern Alexander Island are tentatively grouped in the (?) Carboniferous sequence (Fig. 3). This sequence cannot be satisfactorily subdivided since much of the island has not been mapped geologically.

On Beethoven Peninsula, arkoses possibly belonging to the same formation were intruded by Cenozoic olivine-basalts (Bell, 1973), whereas in the north of the island similar sedimentary rocks are intruded by granites, granodiorites, diorites, dolerites and hornblende-porphyry. In the Elgar Uplands, the (?) Carboniferous formation is unconformably overlain by a sequence of relatively flat-lying tuffs and lavas. The (?) Carboniferous formation is widely distributed

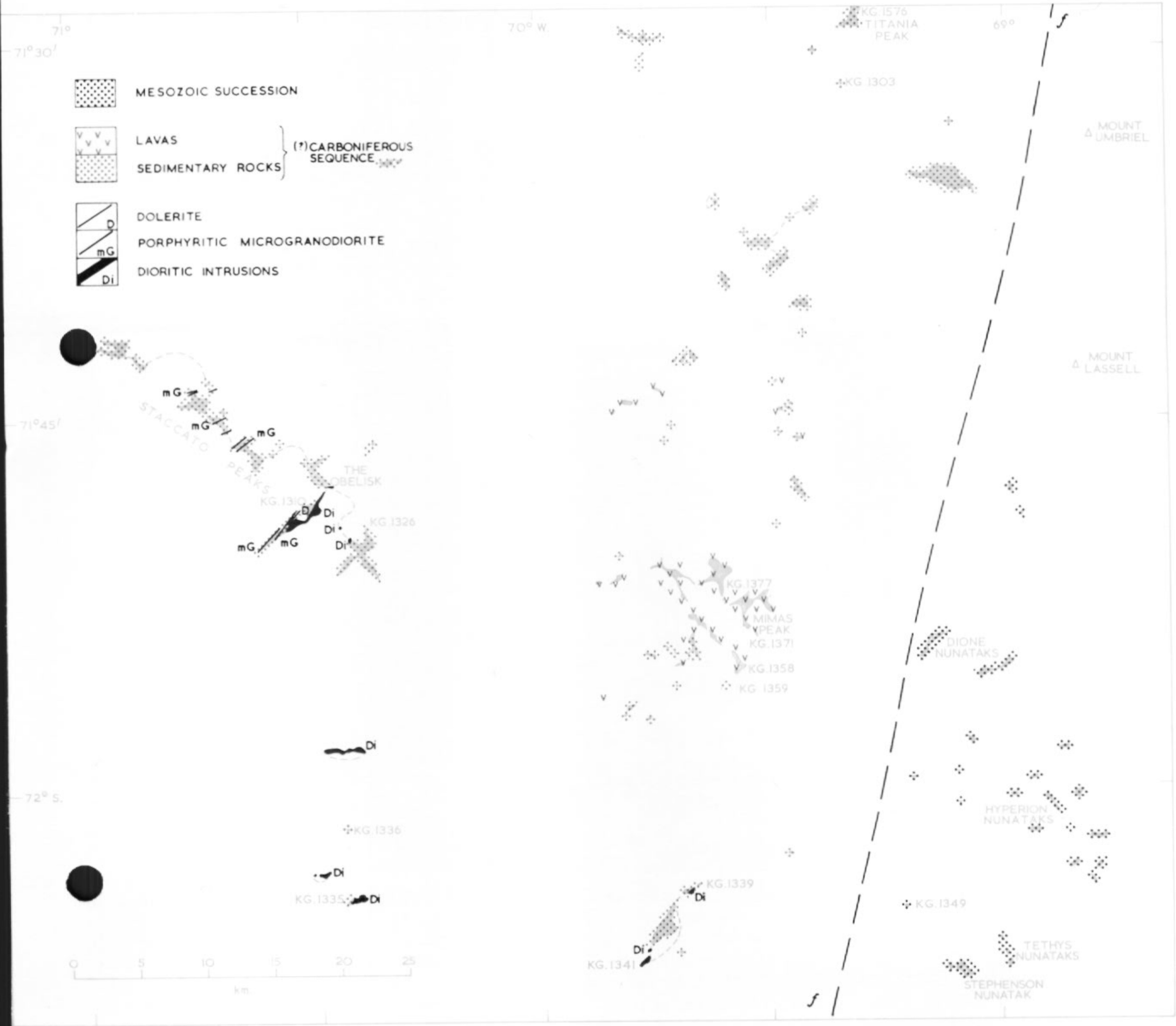

Fig. 3. Geological sketch map of southern Alexander Island.

in northern and central Alexander Island, notably in the northern Douglas Range, Havre Mountains, Lully Foothills and the western LeMay Range where tightly folded and sheared arkoses and siltstones occur. Pillow lavas in the Lully Foothills probably also form part of this formation.

No comparable sedimentary sequence has been reported from equivalent latitudes on the west coast of Palmer Land.

Sedimentary rocks

In southern Alexander Island the (?) Carboniferous formation consists primarily of texturally and mineralogically immature sedimentary rocks. No estimate of the thickness of the succession has been possible due to complications produced by folding and shearing. However, Grikurov and others (1967) estimated a thickness of 2,000–3,000 m. for the folded strata farther north.

The sedimentary rocks are ill-sorted, extensively altered and dynamically metamorphosed (Fig. 4). Subgreywackes (with a high proportion of volcanogenic clasts) and arkoses are

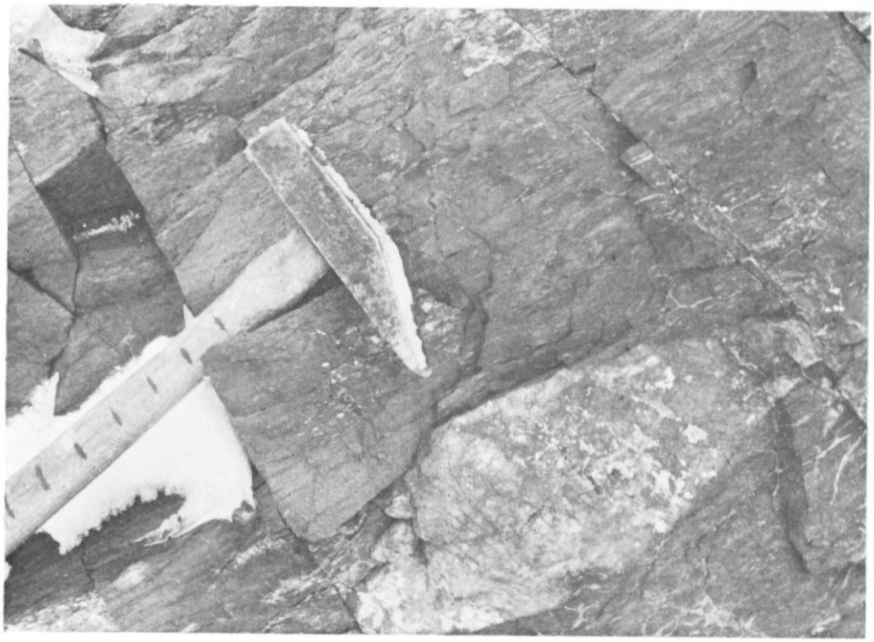

Fig. 4. Strongly sheared volcanic subgreywacke, south of Mimas Peak. The hammer head is 15 cm. long.

interbedded with subsidiary amounts of mudstone, agglomerate and conglomerate. These sediments are classified according to Pettijohn (1957).

Volcanic eruptions which accompanied sedimentation resulted in interbedded lavas and abundant volcanogenic clasts. Such an intimate association of ill-sorted sediments with submarine lavas is characteristic of a eugeosynclinal cycle of sedimentation.

Most of the depositional features of the dark grey sedimentary rocks are masked by cleavage, joint planes and mineral veins, and the microscopic determination of rock types is hindered by alteration and metamorphism.

The apparent absence of macro-fossils is due both to unfavourable depositional conditions and subsequent metamorphism and cataclasis. However, diagnostic micro-fossils of an Upper Palaeozoic age were collected by Grikurov and Dibner (1968) from similar sediments farther north.

The provenance of the sedimentary rocks is incompletely known but three distinct sources are indicated by the conglomerate clasts:

i. Quartzite, quartz-mica-schist and rare plutonic fragments from a metamorphic and plutonic terrain.
ii. Probably penecontemporaneous clasts of sandstone and mudstone.
iii. Contemporaneous volcanic fragments.

Depositional features. Thin persistent beds indicate stable subaqueous deposition. Sedimentary structures are infrequently preserved and no cross-laminations, rhythmic or graded bedding were observed. Elongated, asymmetrical flute casts in mudstone (15 km. south-east of Titania Peak) suggest a current direction from the north.

A concentration of volcanogenic material in the sandstones near the volcanic centre of Mimas Peak indicates that there was a common eruptive source for the volcanic material of both the sedimentary and volcanic rocks.

Petrology. The composition of the sedimentary rocks is masked by hydrothermal alteration and cataclasis which invalidates a detailed classification.

Thin beds of conglomerate consisting of well-rounded pebbles enclosed in arkose and subgreywacke are occasionally observed. 5 km. north-east of Mimas Peak a subgreywacke encloses penecontemporaneous slabs and irregular fragments of mudstone (up to 20 cm. long) orientated parallel to the bedding. Contemporaneous volcanogenic clasts are the commonest lithic fragments in the conglomerates but pebbles of quartzite, quartz-mica-schist, diorite and granite also occur. Coarse agglomerate is interbedded with a volcanic subgreywacke south of Mimas Peak.

Detailed petrological studies of the sandstones indicate that they are texturally and mineralogically immature. They contain 5–30 per cent of quartz with some myrmekitic and graphic intergrowths. Plagioclase and alkali-feldspar (extensively altered to sericite and kaolinite) are the commonest constituents of these rocks. Subordinate minerals include magnetite, ilmenite, muscovite, biotite, hornblende, pyroxene, zircon, sphene and garnet. Secondary alteration products (up to 80–90 per cent of the whole rock) consist of sericite, chlorite, calcite, epidote, prehnite, biotite, quartz and kaolinite.

As much of the micro- and cryptocrystalline "matrix" of the sandstones is the result of alteration and recrystallization, it is difficult to determine whether there are any true greywackes in the sequence. Similarly, many rocks previously described as greywackes may in fact have originated from post-depositional alteration (Cummins, 1962).

Contemporaneous clasts of feldspar-porphyry, amygdaloidal lava, tuff and altered glass form more than 70 per cent of some subgreywackes. At Titania Peak, a subgreywacke (KG.1576.2) with poorly sorted angular to well-rounded clasts and about 5 per cent matrix consists of about 65 per cent of volcanic material, 20 per cent of sericitized plagioclase and 5 per cent of quartz together with magnetite, pyroxene and fragments of sandstone, mudstone and quartzite.

At station KG.1339 a typical sheared arkose consists of 25 per cent of angular to sub-rounded quartz, 30 per cent of plagioclase and a few crystals of microperthite. A few bent and orientated flakes of biotite and muscovite occur together with magnetite, hornblende, sphene, apatite, zircon and garnet. Clasts of mudstone, sandstone and quartz-mica-schist, and about 5–10 per cent of matrix, comprise the remainder of this rock.

Volcanic rocks

The oldest igneous rocks of southern Alexander Island are basalts, pillow lavas, tuffaceous sandstones and dolerites of the (?) Carboniferous sequence. Similar rocks from the Lully Foothills in central Alexander Island have been described by Grikurov (1971) as: "Intensely folded and cataclastically deformed metavolcanic rocks of a basic composition intercalated with quartzites and greywacke sediments . . . in close association with the Trinity Peninsula Series."

There are thus two known centres of volcanic activity in western Alexander Island:

i. Lully Foothills (Grikurov, 1971).
ii. Mimas Peak and surrounding nunataks.

Dark grey and black pillow lavas and basalts interbedded with tuffaceous sandstones crop out over an area of approximately 500 km.^{2} around Mimas Peak. Clasts and pyroclastic fragments from these volcanic rocks also form an important component of the sedimentary rocks of the (?) Carboniferous sequence.

The pillow lavas near Mimas Peak and on scattered nunataks up to 15 km. to the north are indicative of submarine eruption. Folding and shearing have complicated the stratigraphy of these lavas but they total at least 1,000 m. in thickness. Individual beds up to 10 m. thick are composed of pillows with an average size of 30 cm. in diameter by 10 cm. thick and a maximum size of 100 cm. in diameter by 20 cm. thick. The pillows are flattened parallel to the bedding and irregularly distorted by folding. Radial cooling cracks and calcite-filled amygdales are concentrated near their rims. A sheared cryptocrystalline matrix of calcite and chlorite occupies the interstices between the pillows.

Strongly developed cleavage planes and narrow bands of greenschist cut these rocks. South-east of Mimas Peak (KG.1371) the greenschist consists of fine-grained bands of orientated chlorite, sericite and magnetite crystals veined with quartz and calcite. Perpendicular to the cleavage planes are calcite-filled sigmoidal tension gashes (Fig. 5).

In a fine-grained amygdaloidal pillow lava (KG.1358.1) south of Mimas Peak, the elongated amygdales are calcite-filled and rimmed with pale green chlorite. Tabular minerals are flow-orientated but extensive alteration has masked the mineralogy. Fibrous radiating crystals of

Fig. 5. Calcite-filled tension gashes in sheared lava, south of Mimas Peak. The hammer head is 15 cm. long.

green actinolite are interwoven with laths of plumose (?) pyrophyllite. Pale green chlorite, together with calcite and numerous flecks of iron ore fill the interstices.

Basalt flows, interbedded with the pillow lavas, have been similarly altered. Pyroxene has been replaced by pale green hornblende and needles of tremolite, and other minerals have been altered to chlorite, calcite, epidote and sericite. Irregular narrow veins are filled with calcite, quartz, epidote, penninite, prehnite, pyrite and garnet. The thickness of individual flows was not determined due to cataclastic deformation.

West of Mimas Peak, a porphyritic amygdaloidal basalt (KG.1377.1) has sericitized plagioclase phenocrysts in a fine-grained groundmass of chlorite, sericite, calcite and epidote. Cross-cutting veins are filled with quartz, epidote and calcite.

A dolerite, which is possibly related to the extrusive rocks of this formation, crops out on a nunatak 25 km. north of The Obelisk. This sheared rock consists of angular fragments of altered dolerite (oligoclase, pigeonite and ilmenite) separated by crushed zones of epidote, chlorite and other unidentified material.

Contact metamorphism of the (?) Carboniferous sequence

The sedimentary rocks of this formation have been contact metamorphosed to the albite-epidote-hornfels facies (Turner and Verhoogen, 1960), up to 0·5 km. from the dioritic intrusions.

Quartz is common both as composite grains and single crystals in these hornfelses. Feldspars (usually clouded with sericite) include orthoclase, albite and oligoclase. Minute equigranular flakes of secondary biotite are usually associated with sericite, magnetite, epidote, calcite and chlorite, and more rarely with schorlite, cordierite, zircon and actinolite. Ferromagnesian minerals are gathered in dark clusters, and acicular rutile crystals are enclosed in quartz and biotite in specimen KG.1326.2.

Prior to the dioritic intrusions, the sedimentary rocks had been sheared and hydrothermally metamorphosed. Subsequent contact metamorphism caused recrystallization and the formation of new minerals which are less altered than those of the sheared rocks. Thus, quartz grains in the sheared sediments always show undulose extinction, whereas unstrained quartz occurs in the metamorphosed rocks.

High-temperature veins of penninite, quartz, albite, radiating prismatic aggregates of zoned schorlite and cassiterite were observed in specimen KG.1310.2, 4 km. south-west of The Obelisk. Younger cross-cutting veins are filled with quartz, epidote, calcite and penninite.

Mesozoic Succession

The sedimentary rocks of Stephenson, Tethys, Hyperion and Dione Nunataks form part of the Mesozoic succession of south-eastern Alexander Island, and are thus lithologically and structurally distinct from the (?) Carboniferous sequence of the western nunataks. A north–south fault probably separates the two formations. The general structural geology of both the (?) Carboniferous and the Mesozoic successions is discussed elsewhere (p. 14).

As only 17 exposures of the Mesozoic succession were visited in this area, the geology is incompletely known. However, the sedimentary rocks are similar to those exposed along the south-eastern coast of the island, i.e. shallow-water marine mudstones, sandstones and conglomerates with a diverse fauna and flora.

A 244 m. thick conglomerate at Stephenson Nunatak was believed to mark the base of the Cretaceous beds, a fact seemingly confirmed by the "presence of Aptian molluscan fossils in the beds immediately above the conglomerate" (Adie, 1964). The only fossil described from Stephenson Nunatak prior to 1964 was a fragment of (?) *Trigonia* (Cox, 1953, p. 3). This fragment has been re-examined by M. R. A. Thomson, who has suggested that its ornament is more closely comparable with that of *Grammatodon*, a genus which occurs at many horizons throughout the Upper Jurassic–Lower Cretaceous succession of Alexander Island.

Moreover, it is now known that the conglomerate at Stephenson Nunatak *overlies* beds of mudstone and sandstone containing *Antarcticoceras*, an ammonite of probable early Albian age (Thomson, 1973). Associated with this ammonite are *Aucellina*, belemnites, plant fragments and trace fossils of the type referred to by Taylor (1967) as vermicular structures.

The conglomerate which crops out at Stephenson and Tethys Nunataks is unlike others in the Mesozoic succession (Horne, 1969*a*) in having a high proportion of well-rounded white quartzite and sandstone clasts. Volcanic and plutonic clasts which are common elsewhere in the succession are virtually absent.

At southern Hyperion Nunataks there are coarse sandstones with large-scale cross-laminations in beds up to 3 m. thick. These cross-laminations, together with wash-out channels filled with sand and plant fragments, indicate deposition in a shallow-water deltaic environment. Several thin beds of poor-quality coal are also interbedded with mudstones. By contrast, delicate plant fronds in mudstones indicate a quiet depositional environment. Thick sandstone beds with abundant plant fossils have also been reported from farther east at Coal Nunatak and Corner Cliffs (Horne, 1969*b*).

Thin beds of vertically dipping mudstones 6 km. north-west of Stephenson Nunatak have numerous vermicular structures. One slab of grey mudstone (KG.1349.1) also contains two ammonite fragments. These have been described by M. R. A. Thomson as follows:

> "The larger ammonite fragment is the internal mould of part of a body chamber. Its exposed flank is flattened but the ventro-lateral shoulder is well rounded and the venter is arched. Ornamentation is rather feeble and is restricted to widely but irregularly spaced, thin weakly flexuous ribs which are most pronounced on the dorsal half of the flank. Some ribs are scarcely visible as they cross the venter in a gently projected curve. Faint growth lines can be detected under oblique lighting. Without better preserved material, it would be ill advised to attempt a precise identification of this specimen or to attach any definite age significance to it. Similar whorl forms and ornament patterns occur both among members of the Desmoceratidae (Valanginian–Maastrichtian) and Pachydiscidae (Upper Albian–Maastrichtian) but, since this ammonite has been recognized nowhere else in Alexander Island, the inference is that it possibly indicates the presence of marine strata younger in age than the (?) Lower Albian *Antarcticoceras* beds of Succession Cliffs and Stephenson Nunatak. The second fragment is an internal mould from the septate part of an ammonite conch. It is smaller than the first specimen and may therefore represent either the inner whorls of that specimen, or a completely different species. The suture is not readily decipherable but it is complicated and the folioles of the saddles appear to be phylloid, as in the Phylloceratidae."

In the central part of the Hyperion Nunataks, mottled sandstones with coarse cross-laminations contain cannon-ball concretions (Horne and Taylor, 1969) up to 1 m. in diameter. In the northern part, mudstones and sandstones with some slump-shear folds (Horne, 1968) are flexed about north–south fold axes. The presence of *Aucellina* in these rocks suggests a Cretaceous age. Other fossils include numerous fragments of large *Inoceramus*-like bivalves, belemnites and plant stems.

The western Dione Nunataks are formed by a 20 m. high scarp of conglomerate with well-rounded clasts (up to 2 m. in diameter) of granite, diorite, basic lava, schist and sandstone. Underlying sandstones contain numerous carbonized plant fragments. By contrast, the eastern Dione Nunataks are part of a tightly folded syncline of mudstone and sandstone, with numerous slump-shear folds and a pebbly mudstone horizon (Horne, 1968). 18 km. north of the Dione Nunataks, a mottled sandstone with rounded quartzite pebbles, cannon-ball concretions and slumped bedding, contains numerous plant fragments. A small nunatak 6 km. west of Mount Lassell consists of sheared mudstone and pebbly mudstone containing belemnite and bivalve fragments.

Palaeogeography

The fossiliferous Mesozoic sedimentary succession exposed between Stephenson Nunatak and the Dione Nunataks was deposited in a shallow-water marine environment. Cross-laminated sandstones with wash-out channels (at southern Hyperion Nunataks) and polymict conglomerates (at Stephenson, Tethys and Dione Nunataks), together with numerous plant fragments and some coal beds, suggest near-shore deltaic deposition.

Three synchronous "facies zones" deposited parallel to the length of the Mesozoic depositional trough and described as structurally distinct were recognized farther north-east between Uranus and Neptune Glaciers (Horne, 1967). Equivalent structural zones were thought to "extend from the southern limit of outcrops near Stephenson Nunatak northwards to the latitude of Transition Glacier" (Horne, 1967), thus by implication the "facies zones" also extended south to Stephenson Nunatak. Subsequently, Horne (1969*b*) described a continuous east–west facies zonation varying from shallow-water deltaic to deep-water axial facies. In the

Mount Umbriel area, the deep-water axial-turbidite facies was believed to extend an undetermined distance westwards and to be bounded by a chain of volcanic islands.

Thus, according to Horne's zonation scheme, the sedimentary rocks between Stephenson Nunatak and the Dione Nunataks should form part of his "axial facies", whereas they are (at least in part) shallow-water and deltaic deposits. There is no evidence for a volcanic island arc or landmass west of Mount Umbriel.

Intrusive Rocks

Irregular bodies of xenolithic diorite, tonalite and porphyritic microdiorite were intruded into the folded and sheared rocks of the (?) Carboniferous sequence, resulting in their local contact metamorphism. No comparable plutonic intrusions have been observed in the Mesozoic succession.

A swarm of narrow vertical dykes of porphyritic microgranodiorite, intruding both the older sedimentary rocks and the plutonic rocks, are undisturbed by cleavage or faulting. The youngest intrusive rock is a dolerite dyke which has partly assimilated an earlier microgranodiorite near The Obelisk.

Plutonic intrusions

Probable synchronous intrusions of diorite, tonalite and porphyritic microdiorite crop out on isolated nunataks in the south-west. Mylonitized sedimentary rocks on the ridge south-west of The Obelisk are intruded by a large body of tonalite, whereas other intrusive rocks are limited to the south of Staccato Peaks and the ridge 25 km. west of Stephenson Nunatak.

These dioritic rocks, which have many well-rounded xenoliths of sedimentary and volcanic rocks, are surrounded by narrow zones of contact metamorphism and associated high-temperature mineral veins. The emplacement of these diorites has resulted in coarse "intrusion breccias" which consist of large angular blocks of country rock surrounded by diorite dykes (Fig. 6).

There are two petrologically distinct rock types with an unobserved intrusive relationship:

i. Porphyritic microdiorite on the ridge south-west of The Obelisk.
ii. Diorite and tonalite widely distributed in the south-west of this area.

These two rock types are genetically related, as porphyritic microdiorite (with quartz and biotite) is chemically very similar to tonalite (Hatch and others, 1961, p. 287). The microdiorite is distinguished petrologically from diorite and tonalite by a porphyritic texture and abundant amphibole instead of pyroxene.

Porphyritic microdiorite. The microdiorite is medium- to fine-grained with euhedral phenocrysts and a porphyritic or granitic texture. Extensive alteration has produced:

i. Concentrated zones of sericite flakes within the plagioclase.
ii. Chlorite and calcite derived from biotite.
iii. Chlorite, magnetite, epidote and calcite formed from hornblende.

Large euhedral phenocrysts of andesine, hornblende and biotite together with intergranular quartz are enclosed in a fine-grained groundmass. The accessory minerals are magnetite, zircon, apatite, tourmaline and pyrite.

Phenocrysts and anhedral masses of plagioclase comprise 45–75 per cent of the rock. Zoned phenocrysts have cores with a composition of approximately An_{60} surrounded by more sodic rims. Twinned plagioclase crystals are fractured by the growth of alteration minerals, and twinned euhedral phenocrysts of hornblende enclose laths of andesine.

Diorite. The diorites consist of about 50 per cent of sericitized plagioclase (An_{60}–An_{65}) together with extensively altered pyroxene replaced by hornblende, penninite and tremolite. Biotite, zircon, magnetite, ilmenite and pyrite are the accessory minerals and veins are filled with calcite and chlorite.

Tonalite. Extensively altered tonalite with a medium- to fine-grained granitic texture is the commonest plutonic rock (Fig. 7). It is composed of 45–75 per cent of plagioclase and up to

Fig. 6. Intrusion of tonalite into mylonitized sedimentary rocks south-west of The Obelisk, Staccato Peaks.

Fig. 7. Vertically jointed tonalite, south of The Obelisk, Staccato Peaks. The ice-axe shaft is 55 cm. long.

20 per cent of quartz together with orthoclase, pyroxene and biotite. The accessory minerals are zircon, magnetite, apatite and schorlite.

Quartz is present as intergranular masses and as myrmekitic and rare graphic intergrowths. Large anhedral and subhedral plagioclase crystals (An_{50}–An_{60}) have both normal and oscillatory zoned extinction. Zones and irregular cracks in the plagioclase are filled with sericite and calcite.

The ferromagnesian minerals are replaced by tremolite-actinolite, chlorite (usually penninite), calcite, magnetite, sericite, hornblende and epidote. Small areas of relict augite within the alteration minerals exhibit characteristic twinning.

Porphyritic microgranodiorite

Irregular dykes of porphyritic microgranodiorite 10–25 m. wide intrude sedimentary and plutonic rocks at Staccato Peaks (Fig. 8). They were emplaced parallel to a vertical north-east-trending cleavage and are less deformed than the country rocks (Fig. 9).

In specimen KG.1310.4, corroded quartz phenocrysts with altered inclusions are surrounded by radiating microperthite intergrowths. Euhedral oligoclase phenocrysts are slightly corroded and sericitized, and pseudomorphs of clinochlore and penninite entirely replace the ferromagnesian minerals. Other alteration products are calcite, magnetite and epidote.

Dolerite

South-west of The Obelisk, a narrow dolerite dyke has partly assimilated a parallel porphyritic microgranodiorite dyke. Zoned augite phenocrysts (and other indeterminate minerals) are extensively replaced by chlorite and sericite in specimen KG.1310.5. The groundmass is a fine-grained mat of plagioclase and augite enclosing a few large pyrite crystals rimmed with haematite.

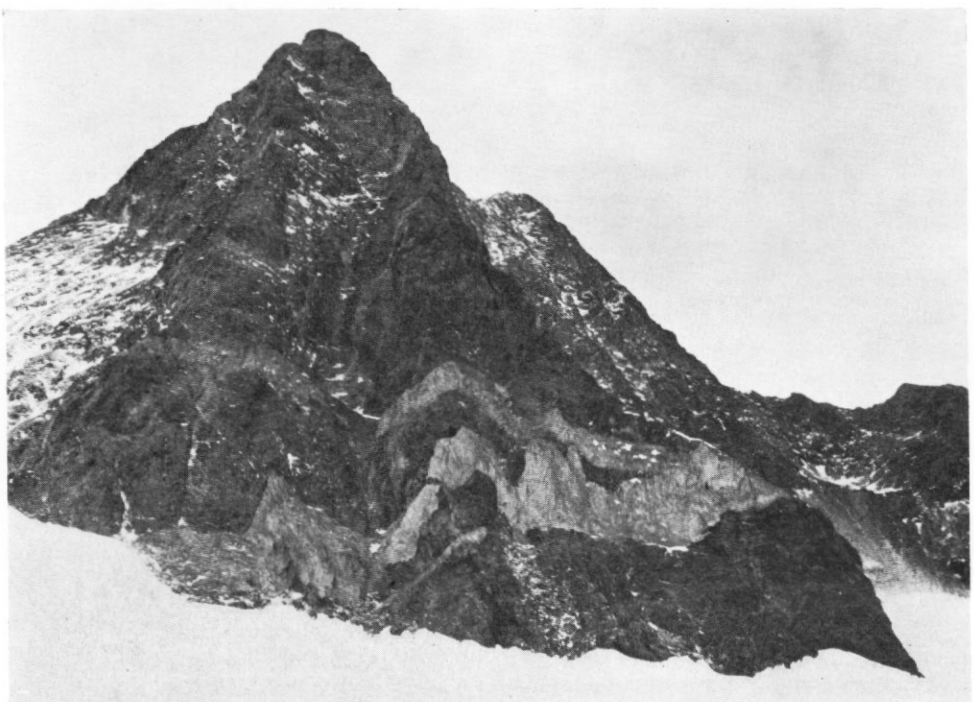

Fig. 8. Porphyritic microgranodiorite dykes at northern Staccato Peaks. The total relief is about 250 m.

Fig. 9. 10 m. wide dyke of porphyritic microgranodiorite intruded into mylonitized sedimentary rocks south-west of The Obelisk, Staccato Peaks.

At the contact between the dolerite and the microgranodiorite is a zone of altered quartz-augite-porphyry produced by partial assimilation of the microgranodiorite by the dolerite. Phenocrysts of embayed quartz, augite and plagioclase are surrounded by a groundmass of calcite, chlorite and sericite. Other phenocrysts are entirely replaced by calcite, chlorite, epidote and sericite.

STRUCTURAL HISTORY

In southern Alexander Island, the two tectonically distinct sedimentary sequences are probably separated by a major north–south fault. In the west, the (?) Carboniferous sedimentary and volcanic rocks have been metamorphosed by folding, cleavage and intrusion. By contrast, the younger Mesozoic succession is gently folded and is affected only by low-grade load metamorphism (Taylor, 1967, p. 2). The later phase of folding had little noticeable effect on the older (?) Carboniferous sequence.

Structural geology of the (?) Carboniferous sequence

Dynamic metamorphism has distorted and in most places destroyed the original sedimentary structures of these rocks, and any structural interpretation is complicated by shearing, faulting and mylonitization. An initial compressive phase resulted in steeply dipping bedding planes (Fig. 10a). The spread of poles to bedding planes in the north-east quadrant indicates re-folding

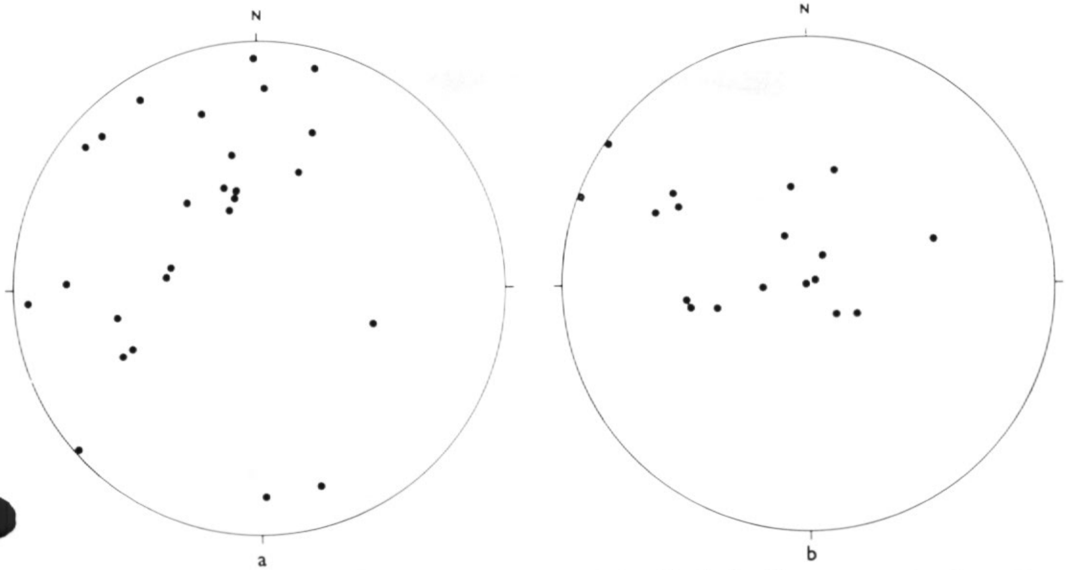

Fig. 10. a. Poles to bedding planes in sedimentary rocks of the (?) Carboniferous succession in southern Alexander Island.
b. Poles to bedding planes in sedimentary rocks of the Mesozoic succession between Stephenson and Dione Nunataks.

of earlier folds about steep south-east-dipping fold axes. This re-folding, which also caused tightly folded cleavage and fault planes, is unrelated to the folding of the Mesozoic succession of the east coast.

Mudstone and sandstone pebbles in a conglomerate at station KG.1359 have been flattened parallel to the cleavage, whereas hard quartzite pebbles in the same conglomerate have resisted this deformation. Similarly, pillows in pillow lavas near Mimas Peak have been elongated parallel to the cleavage.

The compaction of the sandstones has caused an undulose extinction in the quartz crystals and bent plagioclase twin lamellae; similarly, mica flakes are bent between harder grains. Impacted crystals are frequently shattered by irregular radiating cracks. Extreme crushing of the sedimentary rocks, particularly at Staccato Peaks, has formed a pale grey mylonite consisting of angular mineral fragments in an amorphous groundmass. Mylonite is not restricted to fault planes and is an important rock type, indicating the great extent and degree of dynamic metamorphism suffered by the rocks of the (?) Carboniferous sequence.

Calcite-filled sigmoidal tension gashes are developed perpendicular to cleavage planes both in the lavas and the sandstones. Numerous other irregular veins are filled with calcite or quartz, or more rarely with siderite, penninite, sericite, epidote, prehnite or pyrite.

Structural geology of the Mesozoic succession

The Mesozoic succession of south-eastern Alexander Island is structurally distinct from the rocks farther west. Despite some folding and faulting, the fossiliferous succession is relatively undisturbed.

A regional south-south-westerly dip of 5–30° was observed south of Uranus Glacier (Horne, 1967) but there is no such significant southerly dip either south-west of this area or to the south between Coal Nunatak and Two Step Cliffs.

A stereographic projection of the poles of bedding planes for the folded strata between Stephenson Nunatak and the Dione Nunataks shows a broad girdle resulting from irregular west–east compression (Fig. 10b). Yet farther east, between Coal Nunatak and Two Step Cliffs, the bedding is flat-lying. A similar variation in intensity of folding west–east was recorded by Horne (1967) south of Uranus Glacier.

A north–south decrease in intensity of folding throughout the island suggested by Horne (1967, p. 3) is not supported by recent investigations, since areas as far apart as Ablation Point and Stephenson Nunatak have a similar pattern and intensity of folding.

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