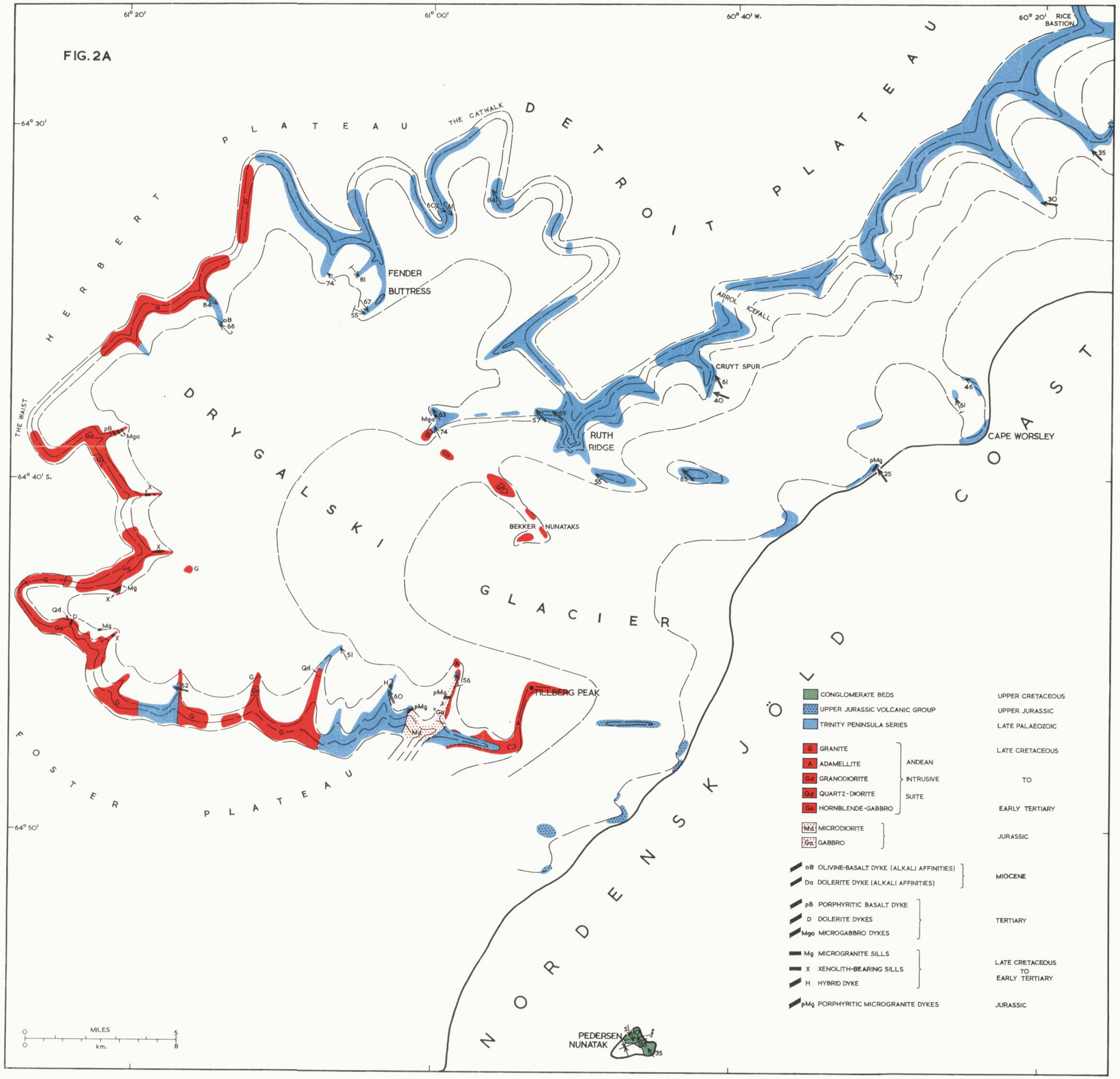

FIG. 2A. Geological sketch map of the area between Drygalski Glacier and Rice Bastion. The form lines are at 500 ft. (152 m.), 1,000 ft. (305 m.) and thereafter at 1,000 ft. (305 m.) intervals.

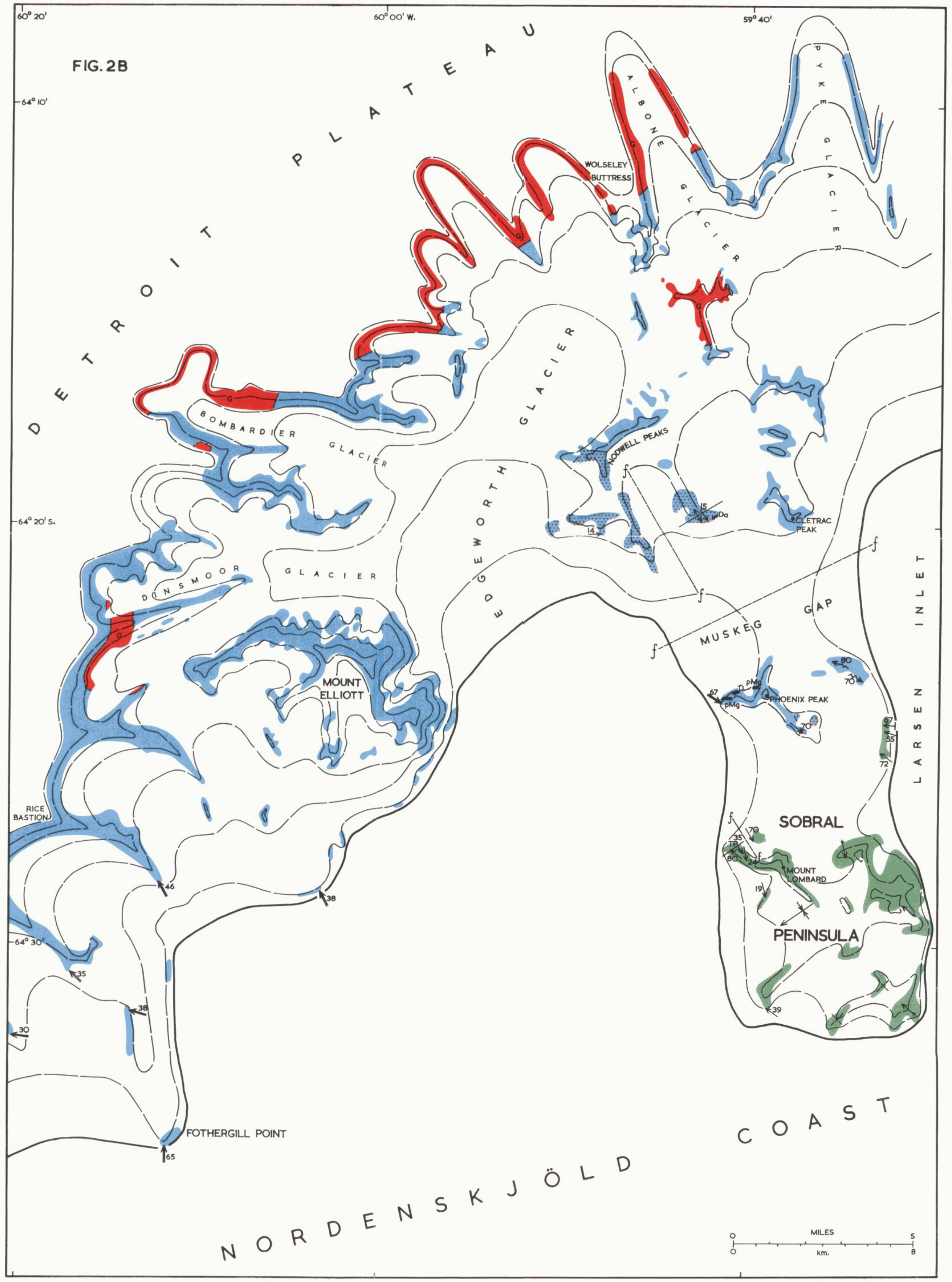

Fig. 2B. Geological sketch map of the area between Rice Bastion and Larsen Inlet. The form lines are at 500 ft. (152 m.), 1,000 ft. (305 m.) and thereafter at 1,000 ft. (305 m.) intervals.

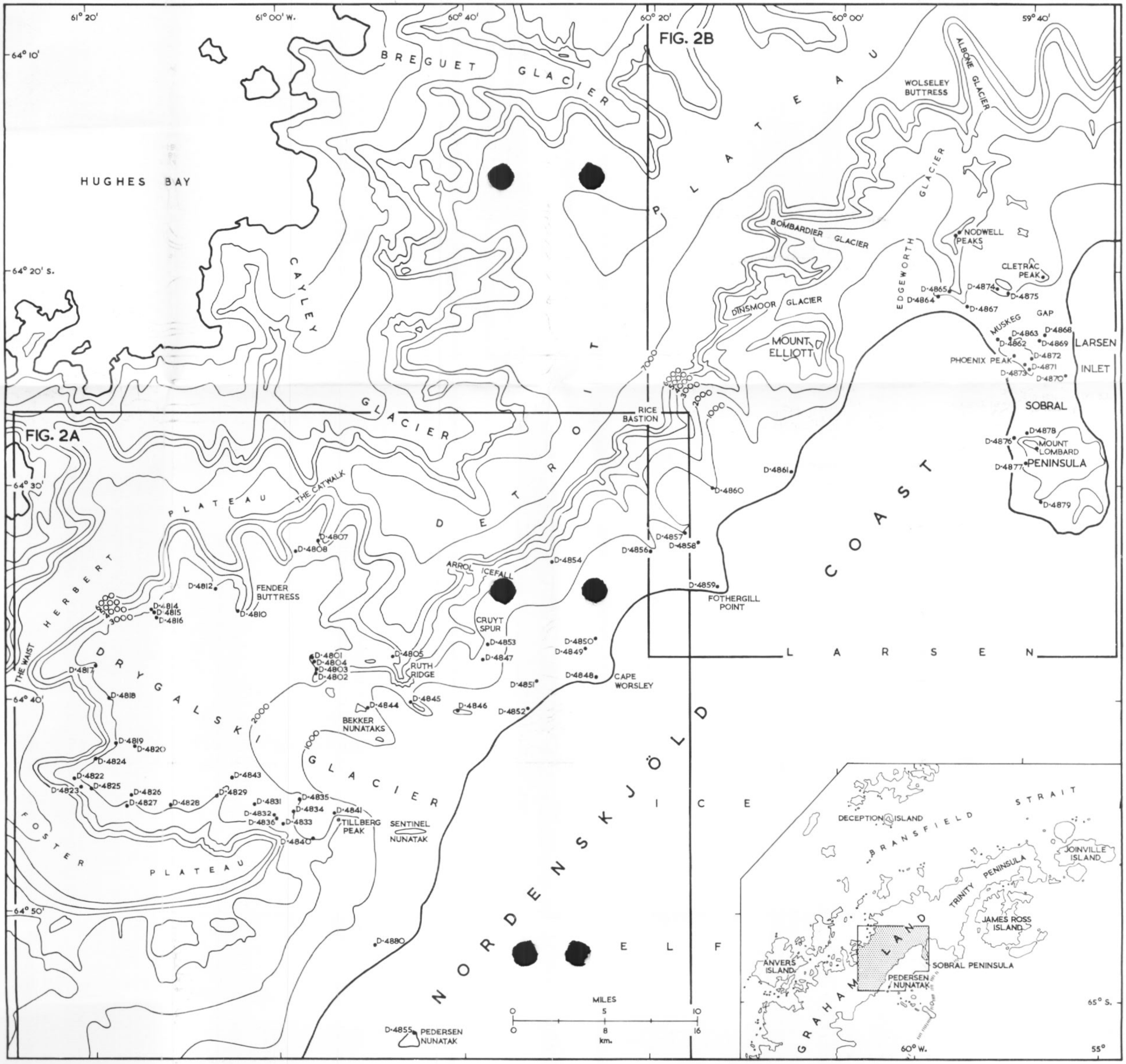

Fig. 1. Sketch map of the Nordenskjöld Coast showing the physiography, place-names and station numbers. The inset shows the position of the area in northern Graham Land. The contours are at 1,000 ft. (305 m.) intervals.

GEOLOGY OF THE NORDENSKJÖLD COAST AND A COMPARISON WITH NORTH-WEST TRINITY PENINSULA, GRAHAM LAND

By D. H. ELLIOT

ABSTRACT. On the Nordenskjöld Coast the Trinity Peninsula Series exhibits an increase in regional metamorphism from north-west to south-east across the axis of the fold belt of Graham Land. In the north-west the sandstones are sheared and a slaty cleavage has been developed in the finer sediments, whereas to the south-east they have been transformed into low-grade schists. The composition of the sandstones gives some indication of their provenance, and the mode of deposition of the sediments is deduced from the repetitive lithology, sedimentary structures and the microscopic texture. An early Mesozoic regional metamorphism has folded these sediments into an anticlinorium with a major axis to the south-east of the area described here. A gabbro intrusion has been tentatively assigned to the post-kinematic stage of this early Mesozoic orogeny. Upper Jurassic tuffites, lavas and pyroclastic rocks overlie the Trinity Peninsula Series near Muskeg Gap and acid tuffs crop out near Tillberg Peak. Intermediate and acid minor intrusions of a similar age also occur in these areas. On Pedersen Nunatak there are Upper Cretaceous conglomerates, sandstones and shales, and similar beds occur on Sobral Peninsula where they form a shallow syncline underlain on the north-west by a low-angle thrust which has caused the steep dips recorded in the adjacent outcrops. The Andean Intrusive Suite forms major intrusive complexes near Drygalski Glacier and Edgeworth Glacier; in the former area an early gabbroic phase is followed by an acid phase of at least three separate intrusions. Near Muskeg Gap and Drygalski Glacier there are a few intermediate and basic dykes of Tertiary age.

The Trinity Peninsula Series, Cretaceous sediments and the Andean Intrusive Suite of the Nordenskjöld Coast are compared with the same formations in north-west Trinity Peninsula, and there is a more general discussion of these rocks, the banded hornfelses and the Upper Jurassic Volcanic Group. The main differences in the Trinity Peninsula Series of these two areas are explained by the early Mesozoic regional metamorphism which has induced folding, shearing and, in most rocks from the Nordenskjöld Coast, complete recrystallization and metamorphism to the greenschist facies. The Cretaceous sediments of the Nordenskjöld Coast are shallow-water and conglomeratic, and they contrast markedly with the geosynclinal sediments of the same age recorded in north-west Trinity Peninsula. The Andean Intrusive Suite has the same general characteristics in both areas but in detail there are certain differences.

THIS paper describes the results of geological investigations on the Nordenskjöld Coast between Sobral Peninsula (lat. 64°30′S., long. 59°35′W.) and Pedersen Nunatak (lat. 64°56′S., long. 60°46′W.) (Fig. 1). The geology north of Muskeg Gap and inland from the coast near Mount Elliott has been inferred from aerial photographs and it has been partly confirmed by J. Mansfield during the course of geophysical work in that area.

The earliest geological work in northern Graham Land was done by the Swedish South Polar Expedition, 1901–03 (Nordenskjöld, 1905; Andersson, 1906), and since 1945 the Falkland Islands Dependencies and British Antarctic Surveys have carried out detailed work in Trinity Peninsula and areas to the south. The oldest rocks are a regionally metamorphosed geosynclinal assemblage called the Trinity Peninsula Series (Adie, 1957), which is believed to be of Carboniferous age. Middle Jurassic sediments and Upper Jurassic volcanic rocks post-date the regional metamorphism of the Trinity Peninsula Series. Apart from Recent moraines, the youngest sediments on the Nordenskjöld Coast are of Upper Cretaceous age. The Andean Intrusive Suite (Adie, 1955) forms large intrusive complexes, mainly within the Trinity Peninsula Series, in northern Graham Land. There are a number of Tertiary minor intrusions of intermediate and basic composition. On the Nordenskjöld Coast the Trinity Peninsula Series and the Andean Intrusive Suite (Fig. 2A and B) form the elevated areas near Drygalski Glacier and Detroit Plateau (Fig. 3) and much of the ice-piedmont area to the south-east (Fig. 4), but they are flanked by Jurassic and Cretaceous rocks in the Sobral Peninsula and Tillberg Peak–Pedersen Nunatak areas.

GENERAL STRATIGRAPHY

The stratigraphy of the Nordenskjöld Coast is given in Table I. The Trinity Peninsula Series crops out extensively north-east and north-west of Ruth Ridge and it forms isolated outcrops

Br. Antarct. Surv. Bull., No. 10, 1966, p. 1-43.

Fig. 3. View looking north-west across Drygalski Glacier from west of Tillberg Peak (near station D.4833). The far left headland is Fender Buttress which is 13 miles (20·9 km.) from the viewpoint; field stations D.4801–4 are on the outcrops at the far right. Apart from granite at station D.4802, all the rocks belong to the Trinity Peninsula Series.

Fig. 4. View from north of Fothergill Point (near station D.4858) looking south-west at the Detroit Plateau scarp and Ruth Ridge (on the left) which is 18 miles (29 km.) distant. The ridge in the foreground (D.4856) is 3 miles (4·8 km.) from the viewpoint.

elsewhere (Fig. 2A and B). Near Fender Buttress these sediments are mainly sandstones and shales, but elsewhere the pre-Jurassic regional metamorphism has transformed them into low-grade schists. The lithology and mineralogy of the sediments near Fender Buttress point to a geosynclinal depositional environment. The gabbro intrusion near Tillberg Peak has been assigned a post-tectonic, probably Lower Jurassic age, and is an additional intrusive phase in northern Graham Land. The Trinity Peninsula Series is succeeded unconformably by inter-

TABLE I. GENERAL STRATIGRAPHICAL SUCCESSION OF THE NORDENSKJÖLD COAST

Age	*Succession*	*Thickness* (ft.)	(m.)
Pleistocene to Recent	Moraines		
Tertiary	Intermediate to basic dykes Andean Intrusive Suite		
Upper Cretaceous	Sediments of Sobral Peninsula	1,400	425
Upper Jurassic	Volcanic group	750	230
(?) Early Mesozoic	Gabbro (near Tillberg Peak)		
(?) Carboniferous	Trinity Peninsula Series	(?) 35,000	10,665

mediate to acid lavas and pyroclastic rocks, and it is cut by intermediate to acid intrusions of the Upper Jurassic Volcanic Group. The Jurassic volcanic rocks crop out mainly near Muskeg Gap and Tillberg Peak. Upper Cretaceous graded conglomerates and some sandstones and shales form shallow synclines at Pedersen Nunatak and on Sobral Peninsula, though the latter area is complicated by thrusting. Near Drygalski Glacier the Andean Intrusive Suite has thermally metamorphosed the Trinity Peninsula Series schists and sediments, and some Jurassic hypabyssal rocks. The compositional range is gabbro to granite but intermediate members are uncommon. The intermediate and basic dykes, which are probably all of Tertiary age, have tholeiitic or calc-alkaline affinities, except for two which are related to the basalts of the James Ross Island Volcanic Group.

Chemical analyses of some Jurassic and Tertiary dyke rocks from the Nordenskjöld Coast, as well as some Trinity Peninsula Series sediments from this area and north-west Trinity Peninsula (Elliot, 1965), are given elsewhere (Elliot, 1967).

TRINITY PENINSULA SERIES

Sediments and metamorphosed sediments of the Trinity Peninsula Series (Adie, 1957) occur round Drygalski Glacier and between Ruth Ridge and Larsen Inlet (Fig. 2A and B). North-west of Drygalski Glacier, the sediments are affected by low-grade regional metamorphism but they still retain their sedimentary features (Fig. 5a); at other outcrops the metamorphism was more intense and transformed the sediments into schists (p. 7) and the associated basic igneous rocks into greenschists (p. 7). Since both groups have suffered regional metamorphism, it is reasonable to correlate them. The thickness of the metamorphosed sediments is estimated at 35,000 ft. (10,665 m.) but, since isoclinal folding is present at two outcrops, the true thickness may be less even though the rocks crop out for 23 miles (37 km.) normal to the strike.

Lithology and petrography

Sediments near Fender Buttress

The sediments are a sequence of unfossiliferous clastic rocks comprising sandstones, siltstones and shales. Sandstones form at least 75 per cent of the sediments at most outcrops. The sandstones occur in beds 1–15 ft. (0·3–4·5 m.) thick and they are interbedded with thin shales and siltstones, which are 1–12 in. (2·5–30·5 cm.) thick at most outcrops but which may reach 15 ft. (4·5 m.) at isolated exposures. Siltstone and shale beds (in 1 in. (2·5 cm.) thick units) also form interbedded sequences. Sedimentary structures are not common; graded- and current-bedding have been observed and there are clastic shale fragments in some sandstones (Fig. 5b).

Medium- to fine-grained sandstones are the dominant rock type. They are immature sandstones comprising sand-sized grains (0·1–1·0 mm.) of quartz, feldspar and rock fragments set in a fine matrix of quartz and micaceous minerals (D.4812.1; Fig. 6a). All the quartz grains

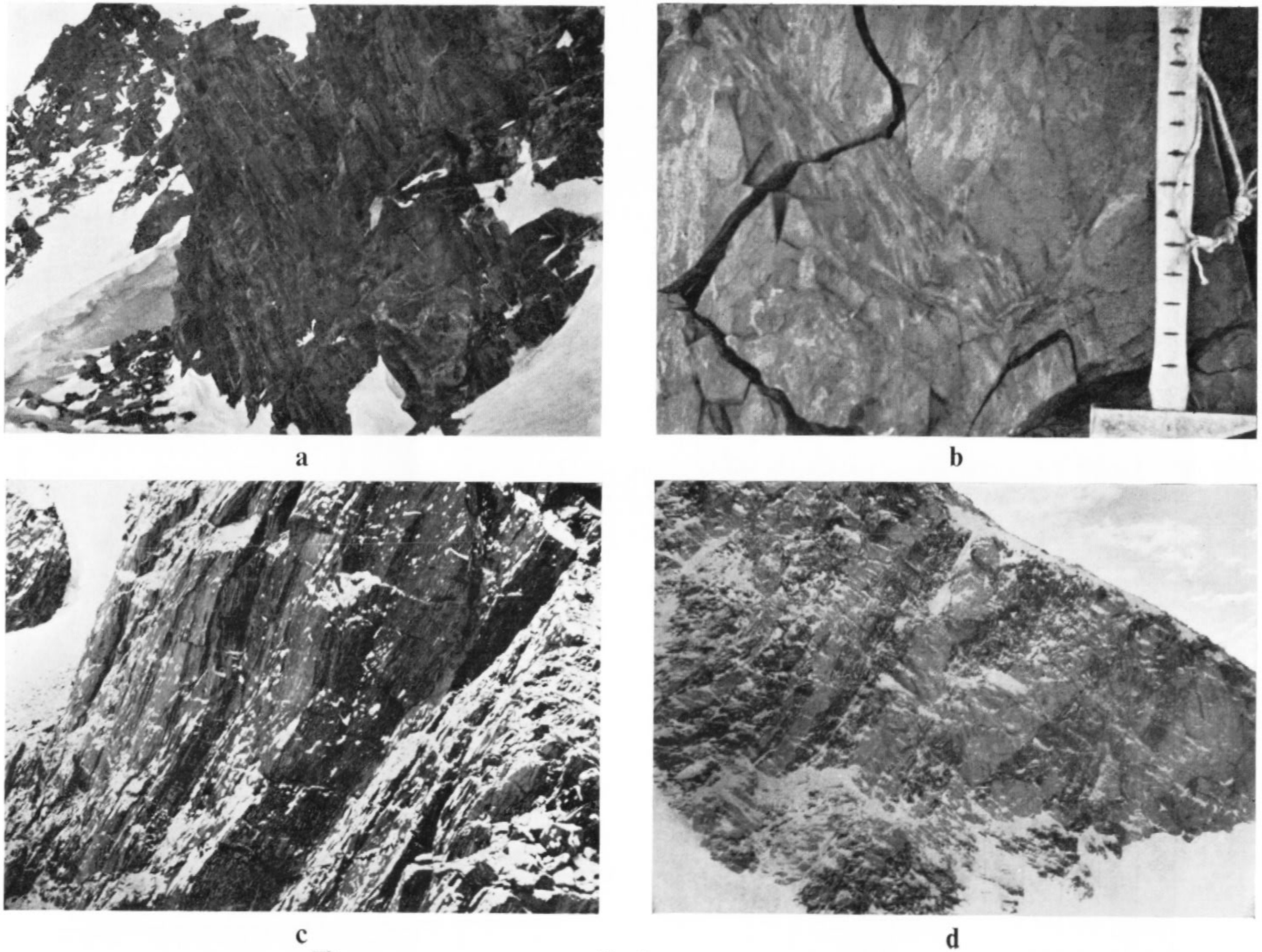

Fig. 5.

show some undulose extinction but composite grains are rare. Stretched metaquartzite fragments have not been found. The division of the plagioclase grains ($Ab_{88}An_{12}$–$Ab_{95}An_{5}$) into simply twinned and altered, and multiple twinned and unaltered types (Elliot, 1965, p. 4) is not clear cut. The rare alkali-feldspar is orthoclase-microperthite. There are few rock fragments except in the basal parts of two sandstones (D.4808.1, 4816.1) which have numerous penecontemporaneous shale clasts. The granitic fragments are quartz-plagioclase aggregates and there is also one of quartz-orthoclase-oligoclase-gneiss. Fine-grained quartzo-feldspathic fragments are the only clasts derived from a volcanic source and metamorphic rocks are represented by a quartz-mica-schist and a metaquartzite. The wide range of heavy minerals includes iron ore partially altered to leucoxene, which is the commonest, a little sphene, zircon and apatite. Allanite, bent muscovite flakes, green hornblende and greenish tourmaline also occur in some of the sandstones. The matrix is composed of fine-grained (0·01–0·03 mm.) quartz, sericite, chlorite, possibly a little feldspar, and low-grade metamorphic minerals (p. 7, 8). Regional metamorphism has caused the recrystallization of the matrix and marginal corrosion of the sand-sized clasts, which invalidates thin-section analysis for the mineral proportions and the sorting and roundness of grains.

Sediments in other areas

Sediments that are not obviously recrystallized are confined to the end of the ridge trending westward from Ruth Ridge (D.4801). They are black shales or silty shales together with a little sandstone which in thin section is seen to be recrystallized except for a few corroded blastophenocrysts of plagioclase.

Other sediments which have not been thermally metamorphosed are completely or almost completely recrystallized to mica-bearing quartzo-feldspathic schists and they occur mainly north-east of Ruth Ridge. These rocks are called schists because the micaceous laminae impart a schistose structure and because the rocks, although they are dominantly quartzo-feldspathic, are in most cases completely recrystallized. Bedding is difficult to prove conclusively except where there is an obvious change of rock type (Fig. 5c). Elsewhere, the regional metamorphism has obliterated both the bedding and the sedimentary structures. Coarse sediments such as conglomerates were not observed in the field and all the schists were derived from feldspathic sandstones and argillaceous beds, except for the few greenschists derived from basic igneous rocks. Variations in composition are reflected in the development of andalusite, cordierite, hornblende and diopside on thermal metamorphism; the first two minerals indicate a high clay content which includes chlorite for the development of cordierite, and the last two minerals indicate a high proportion of lime-bearing minerals in the original sediment. The thickness of beds is between 1 and 15 ft. (0·3 and 4·5 m.) at the few outcrops where accurate measurements were possible.

Metamorphism

Regional metamorphism of the Trinity Peninsula Series was pre-Jurassic (Adie, 1957, p. 5) and it was followed by late Cretaceous to early Tertiary thermal metamorphism by the Andean Intrusive Suite (Adie, 1955, p. 4).

The effects of regional metamorphism are more intense on the Nordenskjöld Coast than at other outcrops in north-east Graham Land, except for a few isolated exposures south-west of Russell West Glacier (Elliot, 1965, p. 12) and a few specimens described from the Graham Coast (Adie, 1957, p. 18). There is a strong contrast between the comparatively unmeta-

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Fig. 5. a. Interbedded Trinity Peninsula Series sandstones and shales which dip steeply to the south-east; the height of the rock face is about 20 ft. (6·1 m.); view looking north-east; Fender Buttress (D.4810).

b. Shale fragments at the base of a sandstone in the Trinity Peninsula Series; the scale on the hammer is in inches; west of Fender Buttress (D.4816).

c. Interbedded schists and greenschists of the Trinity Peninsula Series; the pale greenschist bed in the centre is 10 ft. (3 m.) thick; south-east of Ruth Ridge (D.4845).

d. Rafts of Trinity Peninsula Series sediments in granodiorite; the rafts are up to 30 ft. (9·1 m.) thick and up to at least 100 ft. (30·5 m.) long; view looking north-west; near Bekker Nunataks (D.4844).

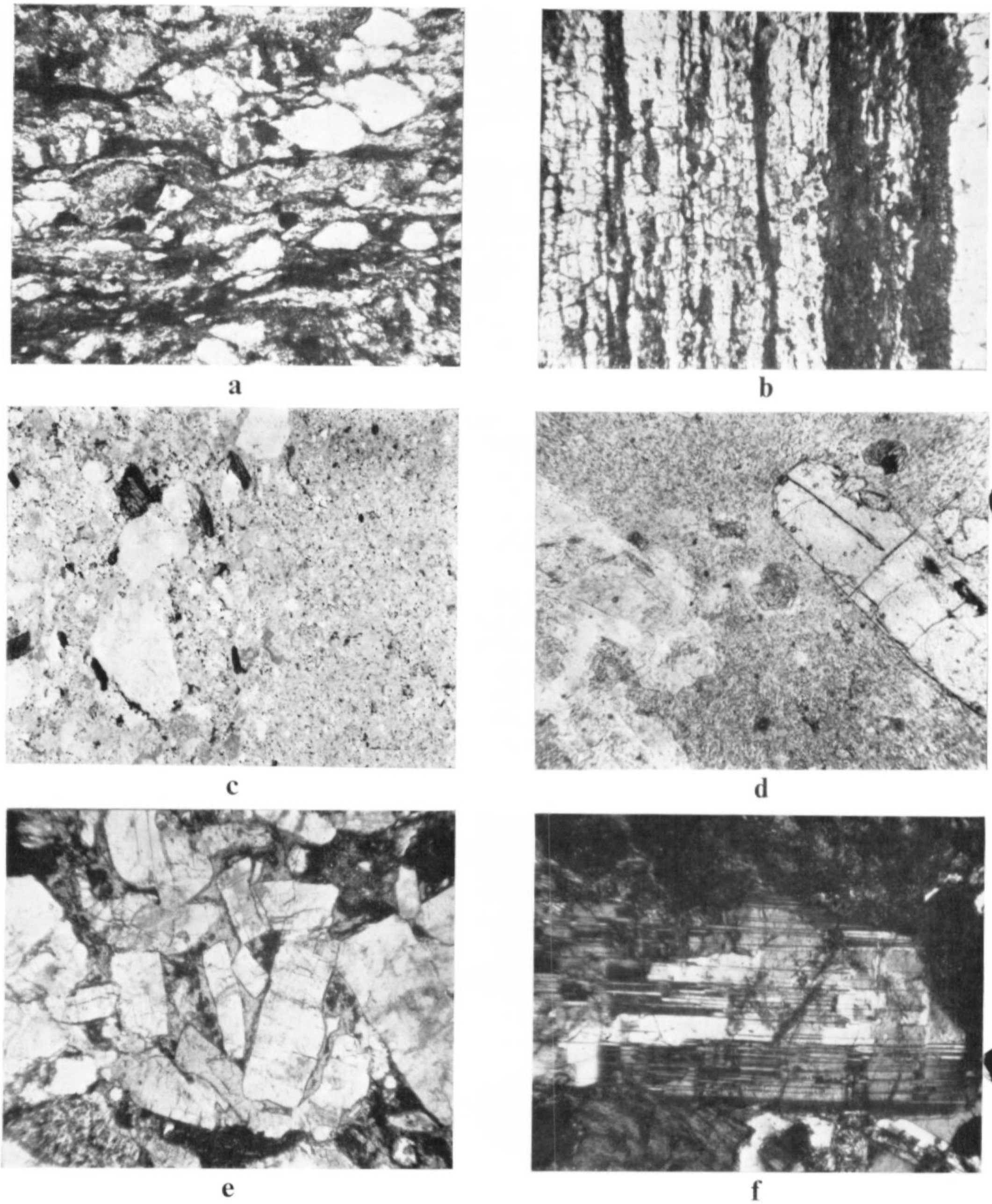


Fig. 6. a. A sandstone with corroded sand-sized grains in a sheared and recrystallized matrix; west of Fender Buttress (D.4812.1; ordinary light; ×35).

b. Metamorphic segregation of quartz and ferromagnesian minerals into parallel laminae; west of Tillberg Peak (D.4843.1; ordinary light; ×35).

c. A tuffite comprising angular fragments and a few rounded quartz crystals (right-hand side) in a fine matrix; south-east of Phoenix Peak (D.4873.2; ordinary light; ×6·7).

d. Pyroxene-andesite with an altered plagioclase phenocryst (left) and a chlorite pseudomorph after orthopyroxene (right); south-east of Phoenix Peak (D.4872.1; ordinary light; ×35).

e. Plagioclase crystals and acid volcanic fragments in a sandstone; the matrix includes altered iron ore (black) and a chloritic mineral (grey); south-east of Phoenix Peak (D.4870.1; ordinary light; ×35).

f. A plagioclase crystal with three composition areas; the most acid is white, the most basic is grey and the intermediate is black; south-west of Drygalski Glacier (D.4817.1; X-nicols; ×60).

morphosed sediments near Fender Buttress and the recrystallized sediments from the Ruth Ridge–Larsen Inlet area.

Thermal metamorphism by the Andean Intrusive Suite has been superimposed on the regional metamorphism. Former sediments at granite and adamellite intrusive contacts belong to the hornblende-hornfels facies. There are no contacts between gabbros and the sediments, though the probable effects of thermal metamorphism by gabbros are present at one outcrop (p. 9). Minor intrusions have also caused thermal metamorphism up to the hornblende-hornfels facies.

Regional metamorphism

Mineralogical changes are subordinate to the dynamic effects of the regional metamorphism in the least metamorphosed sediments. The sandstones near Fender Buttress exhibit a variable amount of intergranular shearing (Fig. 6a), whereas the argillaceous rocks have developed a moderately good slaty cleavage sub-parallel to the bedding. Elsewhere, recrystallization has destroyed any pre-existing shear planes and obliterated most of the bedding, though the regional metamorphism has superimposed cleavage or foliation.

The mineralogical changes in the sandstones are confined to recrystallization of the matrix and marginal corrosion of the sand-sized grains. The lowest grade rocks (D.4807.2, 4808.1) are transitional to the quartz-albite-muscovite-chlorite sub-facies of the greenschist facies (Fyfe, Turner and Verhoogen, 1958, p. 219–23). One of the sandstones (D.4808.1) has a recrystallized matrix of quartz, plagioclase, sericite, a little chlorite, and stilpnomelane laths and aggregates. Apart from the matrix, the stilpnomelane has grown from the margins into the cores of both grains and rock fragments. Other sandstones exhibit superimposed thermal metamorphism (p. 8) which has concealed any low-grade regional effects.

Sediments from other parts of the Nordenskjöld Coast are recrystallized and belong to the quartz-albite-muscovite-chlorite sub-facies of the greenschist facies. Within thermal aureoles there are hornfelses which were probably schists belonging to that grade of regional metamorphism before contact metamorphism; the mineralogy of many of them is similar to that of the schists.

The recrystallized sediments are mica-bearing quartzo-feldspathic schists (D.4848.1, 4853.1) in which the micas form thin laminae in a fine-grained (0·01–0·10 mm.) matrix of quartz and subordinate plagioclase. There are a few blastophenocrysts of plagioclase ($\mathrm{Ab}_{90}\mathrm{An}_{10}$–$\mathrm{Ab}_{96}\mathrm{An}_{4}$) in some specimens (D.4846.1, 4856.1) but most of the feldspar forms matrix grains of composition $\mathrm{Ab}_{88}\mathrm{An}_{12}$–$\mathrm{Ab}_{93}\mathrm{An}_{7}$. The micaceous minerals, muscovite and a little chlorite, impart a poor schistosity to the rocks. There is accessory iron ore, rare zircon, apatite and olive-green tourmaline.

The proportion of micas is variable but it is never high enough for any rock to be called a pelitic schist. Cordierite- and andalusite-bearing hornfelses (D.4835.3, 4840.2) show that former argillaceous beds are present, and that the ubiquitous quartz veins in the quartzo-feldspathic schists probably conceal the former presence of such beds. Many of the quartz veins are sheared and partially destroyed, and some are also strongly folded with the host rock. There are only a few cross-cutting veins (D.4851.2) which were emplaced after the main stage of the deformation.

Greenschists are comparatively rare and crop out at three localities between Ruth Ridge and Mount Elliott. The greenschist beds, which have sharp junctions with the adjacent schists, are 10–20 ft. (3·0–6·1 m.) thick at two localities (D.4845, 4854; Fig. 5c) and about 200 ft. (61 m.) at the third (D.4860). A schistosity is not always well developed and some of the beds are massive. Greenschists have also been recorded by J. Mansfield at an outcrop north-east of Mount Elliott (D.5007).

In thin section one of the greenschists (D.4845.3) is a fine-grained (0·02–0·10 mm.) actinolite-chlorite-schist in which the ferromagnesian minerals form contorted laminae and impart the schistosity. There is a little quartz, plagioclase ($\mathrm{Ab}_{91}\mathrm{An}_{9}$) and unaltered iron ore, and also coarser quartz lenses and calcite aggregates. The lenses and aggregates could be interpreted as former vesicles in a lava, but the evidence is inconclusive. The other sectioned rock (D.4860.2) is an epidote-actinolite-schist of similar grain-size but without a well-developed schistosity. Actinolite and chlorite fibres, and a little granular quartz and plagioclase ($Ab_{88}An_{12}$) are associated with the granular epidote. There is a little muscovite with some of the chlorite and much accessory leucoxene. Calcite is present but it was introduced later. These rocks belong to the quartz-albite-muscovite-chlorite sub-facies of the greenschist facies of regional metamorphism. They were undoubtedly derived from basic igneous rocks which, considering the postulated depositional environment (p. 9), were probably erupted subaqueously.

Thermal metamorphism

Away from intrusive contacts, thermal metamorphism has induced only slight changes in the rocks which have suffered low-grade regional metamorphism. The hornblende-hornfels facies of thermal metamorphism is exhibited by schists and sediments at intrusive contacts but where amphibole and pyroxene are not present distinction between that facies and the albite-epidote-hornfels facies is difficult, because it depends on the plagioclase composition. The width of any thermal aureole does not exceed 1 mile (1·6 km.) at the only outcrop where it can be traced for that distance from the contact, but the presence of biotite in rocks (D.4810.1) 4·5 miles (7·2 km.) from the nearest visible contact indicates the probability of intrusive rocks underlying the sediments. The unorientated biotite of the foliated bioti[illegible] schists suggests that an intrusion is adjacent but not exposed.

Minute unorientated flakes of yellowish brown biotite in the matrix of two sandstones (D.4810.1, 4812.1) from Fender Buttress are the first signs of metamorphism. No other effects can be attributed to thermal metamorphism alone, although it may have caused further recrystallization of the matrix, the growth of a little muscovite and the generation of epidote from the anorthite molecule of plagioclase. These rocks are transitional to the albite-epidote-hornfels facies.

A slightly higher grade of metamorphism is shown by the biotite-schists which occur only near Bekker Nunataks. These foliated quartz-feldspar-biotite-schists comprise alternating quartz-rich and mica-rich laminae (0·05–3·0 mm. wide), and the growth of biotite at high angles to the foliation (D.4805.1) is probably a thermal metamorphic effect caused by adjacent but concealed parts of the intrusions near Bekker Nunataks. The quartz-rich laminae enclose plagioclase, muscovite and biotite crystals. The mica-rich laminae are composed of sub-parallel or unorientated biotite with some muscovite, chlorite, fine granoblastic quartz and plagioclase crystals of composition $Ab_{90}An_{10}$–$Ab_{93}An_{7}$. Accessory minerals include iron ore, apatite, zircon and rare olive-green tourmaline. The foliation is a metamorphic segregation rather than an original compositional difference, because in one rock (D.4804.2) there are relict plagioclase grains (up to 1·2 mm.) with multiple albite and pericline twinning; unmetamorphosed sediments with plagioclase of that grain-size and type are impure sandstones rather than beds composed of alternating thin laminae of quartzo-feldspathic and argillaceous sediment. The biotite is attributed to thermal metamorphism, because of the unorientated flakes (D.4805.1) and the presence of plagioclase blastophenocrysts and quartz veins in rocks that should be at the same or a lower metamorphic grade than the underlying quartzo-fe[illegible]spathic schists. These rocks also belong to the albite-epidote-hornfels facies. The biotite-schists are cut by numerous quartz veins (D.4805.2) which may explain the highly siliceous composition of the recrystallized quartzo-feldspathic schists, because the identity of original quartz veins could have been destroyed.

Nearly all rocks of higher metamorphic grades are completely recrystallized hornfelses close to intrusions but the palimpsest foliation in some of them indicates their derivation from schists. One of these rocks (D.4815.1) is fine-grained (0·01–0·30 mm.) and has a granoblastic texture comprising quartz and plagioclase ($Ab_{67}An_{33}$–$Ab_{77}An_{23}$) together with unorientated flakes of biotite. There is accessory iron ore, zircon and apatite. Two hornfelses (D.4835.3, 4842.1) also have cordierite porphyroblasts up to 2·0 mm. across, whereas another (D.4801.3) has, in addition to biotite, diopside and hornblende, and it also carries relict clastic plagioclase grains. The co-existence of biotite- and pyroxene-bearing laminae shows that diffusion was restricted to the hornblende-bearing lamina between them. The compositional differences between the biotite- and pyroxene-bearing bands were probably original and not due to metamorphic segregation.

Hornfelses at contacts have a restricted composition and all but one are quartz-oligoclase-biotite-hornfelses of the hornblende-hornfels facies. The one exception (D.4840.2), from near Tillberg Peak, is a quartz-muscovite-biotite-andalusite-hornfels in which the andalusite porphyroblasts are up to 4·5 mm. long. The plagioclase is albite ($Ab_{90}An_{10}$), but in comparison with other contact specimens the plagioclase should be in the oligoclase-andesine range; it is likely that this rock is deficient in lime and more basic plagioclase could not be generated. The alkali-feldspar in two metamorphosed schists (D.4835.2, 3) is a metasomatic introduction from the adjacent intrusion.

Extreme metamorphic segregation is shown by one hornfels (D.4843.1) which cannot be less than 50 ft. (15·2 m.) from an intrusive contact. This hornfels is a foliated rock comprising coarse quartz laminae (0·05 to 0·40 mm. wide) separated by laminae of pyroxene, pyroxene and amphibole, or amphibole and biotite, all of which may also contain small quartz and untwinned oligoclase crystals as well as accessory iron ore, apatite and zircon. Regional metamorphism induced the extreme parallelism in the coarser quartz laminae (Fig. 6b) but there has been later thermal metamorphism, because the cross-cutting stringers of pyroxene and amphibole could not have survived the metamorphic segregation imposed on the rock. The distance from any contact, at least 50 ft. (15·2 m.), suggests metamorphism by a basic intrusion. The original rock, which is believed to have been a sediment, must have included a high proportion of lime-bearing minerals.

The rafts in the granodiorite near Bekker Nunataks (Fig. 5d) are schists derived from the Trinity Peninsula Series and thermally metamorphosed to quartz-mica-hornfelses (D.4844.2). Most of the foliation in the schists has been preserved but there has been growth of andalusite and of biotite and muscovite flakes which are at high angles to the foliation and are coarser (up to 1·0 mm.) than in other schists and hornfelses. Plagioclase crystals ($Ab_{67}An_{33}$) occur in both the quartz and micaceous laminae. The accessory minerals are iron ore, apatite and greenish brown tourmaline. These rocks are in the hornblende-hornfels facies of thermal metamorphism.

Correlation

The most important factor in the correlation of the comparatively unmetamorphosed sediments of Fender Buttress with the schists elsewhere is that both have undergone regional metamorphism, of which there is only one period after the deposition of the Trinity Peninsula Series. The less metamorphosed sediments are comparable in mineralogy with the Trinity Peninsula Series of north-west Trinity Peninsula (Elliot, 1965, p. 4), and the schists are comparable with the metamorphosed sediments from south-west of Russell West Glacier (Elliot, 1965, p. 12). Also, the schists occur south-east of the less metamorphosed sediments and towards a major anticlinal axis (p. 33), the direction in which the metamorphic grade is likely to increase. The absence of stages intermediate between the sandstones and the schists with a few relict plagioclase grains makes the correlation inconclusive, though the frequency of plagioclase relics and the heavy mineral assemblage, particularly the tourmaline, suggest a source area common to both groups of rocks.

Depositional environment and provenance

Recrystallization of the matrix and corrosion of the clasts has modified the microscopic properties of the sandstones, but they are believed to have been bimodal, to have had a medium- to coarse-grained sand-sized fraction (because the clasts do not exceed 1·0 mm.) and to have been composed of angular to sub-rounded grains. The sorting of the grains cannot be estimated. These sandstones are comparable to those of north-west Trinity Peninsula and, by comparison, they were probably deposited by turbidity currents. The great thickness of sediment, comprising sandstones, siltstones and shales, and the probable deposition of the sandstones by turbidity currents, points to a geosynclinal environment of deposition.

Sheared granitic rocks with some acid volcanic and metamorphic rocks formed the source of these sediments. Granitic rocks are postulated from the strained quartz, the less altered feldspar and the granitic and granite-gneiss fragments. The volcanic rocks are indicated by the quartzo-feldspathic fragments. The rare schist fragments and detrital amphibole were derived from metamorphic rocks. The provenance is comparable with that postulated for the Trinity Peninsula Series of north-west Trinity Peninsula (Elliot, 1965, p. 14).

EARLY MESOZOIC INTRUSIONS

Near Tillberg Peak a gabbro is intruded by a porphyritic microgranite and both are cut by an adamellite. An exact age cannot be determined for any of the intrusions but some relationships can be inferred. The adamellite is clearly the youngest intrusion and it almost certainly belongs to the Andean Intrusive Suite. The microgranite dyke is possibly part of the Upper Jurassic Volcanic Group, because rocks of a similar mineralogy are known only from that group, although it could belong to the Andean Intrusive Suite and have been intruded between the basic and acid phases (p. 37). However, the gabbro is believed to be either an early basic member of the Upper Jurassic Volcanic Group, or a post-orogenic intrusion following the regional deformation of the Trinity Peninsula Series.

Basalts are rare in the Upper Jurassic Volcanic Group; Curtis (1966) has recorded basaltic andesites from the Graham Coast and Scott (1965) andesitic basalts from the Gerlache Strait area. Pyroxene-andesites crop out near Muskeg Gap but they have not been found either near Tillberg Peak or to the south where volcanic rocks form extensive outcrops. Basic intrusions corresponding to these rocks and pyroxene-andesites might be expected but th[illegible] have not yet been recorded. An alternative age, that of the regional deformation of the Trinity Peninsula Series which has been inferred as Upper Triassic–Lower Jurassic (199–176 m. yr.) (Miller, 1960), is favoured even though intrusions of that age have not yet been proved in Graham Land.

The gabbro (D.4834.3) is a medium-grained mesocratic rock composed of feldspar and amphibole. The subhedral feldspar (0·5–4·0 mm.) is a slightly sericitized labradorite ($Ab_{40}An_{60}$), some of which has a patchy replacement of the core and rims by more acid plagioclase ($Ab_{70}An_{30}$). Much of the amphibole, which is a brownish green hornblende, is replaced by actinolite aggregates. The actinolite ranges from an almost colourless variety to one which is pleochroic from straw to green. Red-brown biotite and iron ore occur with many of the actinolite aggregates. There is a little interstitial quartz and accessory apatite. The replacement of the hornblende by actinolite aggregates was probably caused by hydrothermal activity associated with the emplacement of the adamellite.

UPPER JURASSIC VOLCANIC GROUP

Extrusive and intrusive rocks of Upper Jurassic age crop out near Muskeg Gap and Tillberg Peak. At Hope Bay in north-east Graham Land there are Middle Jurassic sediments beneath the volcanic rocks, but in the area described here there are no sediments definitely of that age. Although the rocks on the Nordenskjöld Coast are placed in the Upper Jurassic, the only evidence of the age and time span of the vulcanicity is that it post-dates the regional metamorphism of the Trinity Peninsula Series and is older than the Upper Cretaceous.

Extrusive rocks

Lithology

Lavas, pyroclastic rocks and tuffites crop out near Phoenix Peak and north of Muskeg Gap. Individual outcrops have a variable composition; south of Nodwell Peaks the rocks are andesite lavas, frequently autobrecciated (Fig. 7), which overlie acid crystal tuffs; dacite crystal tuffs and agglomerates crop out south-east of Nodwell Peaks and near Phoenix Peak there are tuffites, andesite flows and massive agglomerates.

The tuffites, which are water-laid beds composed of volcanic and sedimentary material, overlie the Trinity Peninsula Series but the contact is obscured by frost-shattered debris and the true relationship is unknown, although it is probably unconformable (p. 35). In this area there was a period of subsidence during which the tuffites and overlying agglomerates were deposited before their burial beneath subaerial volcanic products. The tuffite beds have a variable grain-size and some of them show graded-bedding (Fig. 8). The outcrop is covered with frost-shattered debris derived from the friable tuffites and only the more resistant beds form solid outcrops. The total thickness of the tuffites, assuming that they fill the gaps

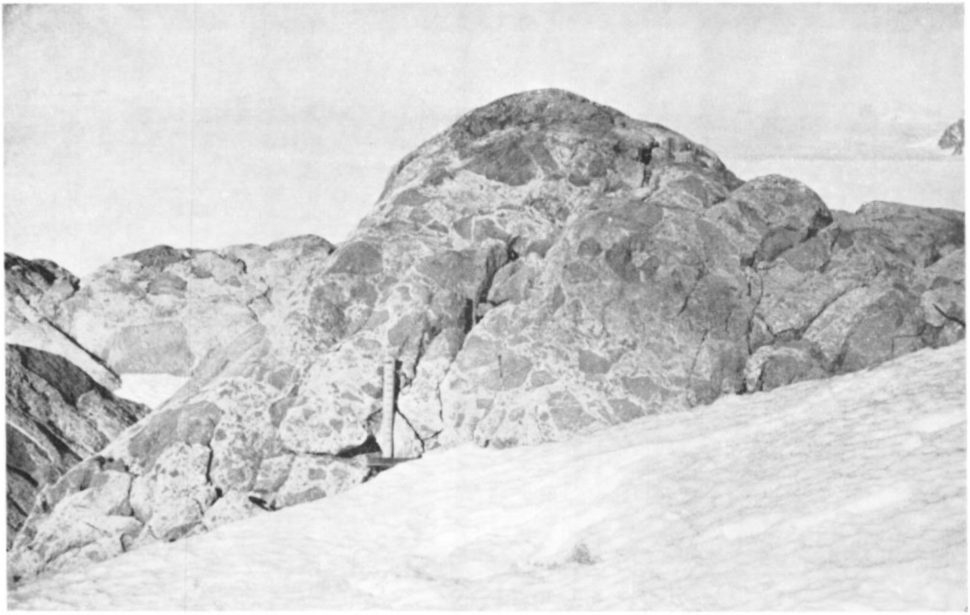


Fig. 7. Autobrecciated andesites of Upper Jurassic age; the scale on the hammer is in inches; view looking south-west; south of Nodwell Peaks (D.4864).

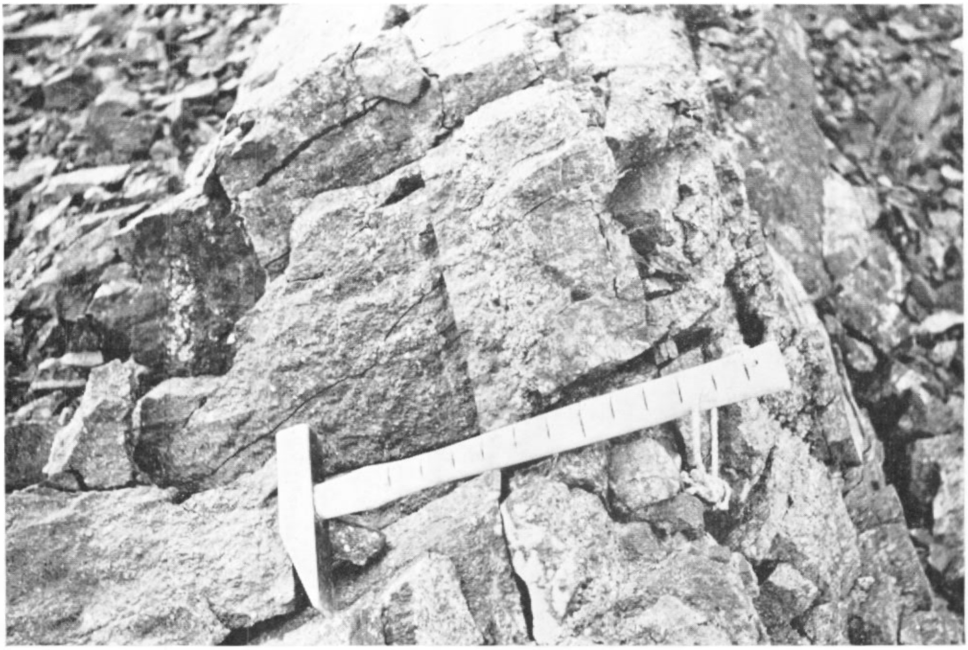


Fig. 8. Resistant graded tuffite beds which dip steeply to the south-east; the scale on the hammer is in inches; view looking north-east; south-east of Phoenix Peak (D.4873).

between the resistant beds, is about 200 ft. (61 m.) and they are followed by about 150 ft. (46 m.) of massive agglomerates (Fig. 9a). The agglomerates do not possess any stratification but there is a slight orientation of the fragments sub-parallel to the tuffite bedding. The agglomerate fragments, which are sub-angular to sub-rounded and no more than 9 in. (23 cm.) long, are of andesites and acid tuffs similar to those occurring south of Nodwell Peaks, and they are set in a fine friable volcanic matrix. The variable composition and the rounding of som[illegible] fragments show that they were probably re-deposited. The adjacent outcrops are composed of tuffs and andesite lavas. The tuffs include rocks which may be tuffites and in some there are coarse fragments of schist similar to the Trinity Peninsula Series schists.

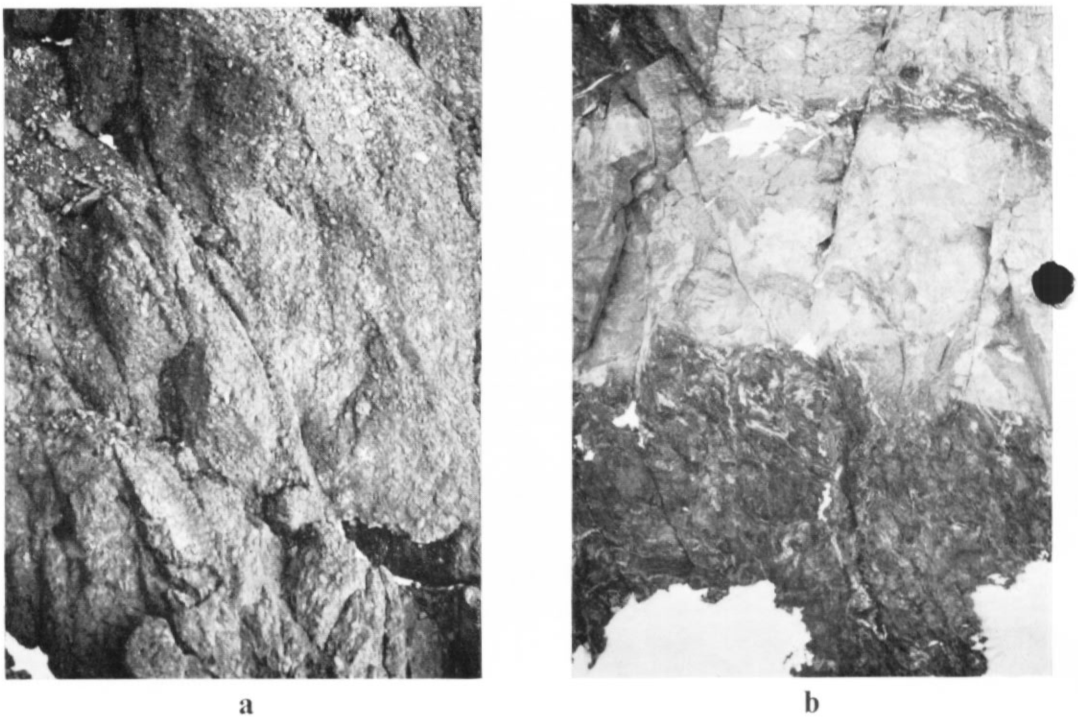


Fig. 9. a. Massive agglomerates; the height of the rock face is about 30 ft. (9·1 m.); south-east of Phoenix Peak (D.4871).
b. Trinity Peninsula Series schists separating Jurassic minor intrusions of which the lowest is 5 ft. (1·5 m.) thick; view looking south-west; west of Tillberg Peak (D.4836).

There is no evidence of the relationship of the other outcrops to those described above. At the nunatak south-east of Nodwell Peaks the minimum thickness of the volcanic succession is 750 ft. (230 m.), but the total thickness is likely to be greater than this because of the lack of correlation. This nunatak is composed of acid crystal tuffs and agglomerates. The outcrops south of Nodwell Peaks comprise andesite flows of variable thickness, which at one exposure (D.4867) succeed acid crystal tuffs. Flows show complete autobrecciation (Fig. 7), brecciated tops and bottoms only, or no brecciation at all. The only reliable criteria for the thicknesses of flows are the abrupt changes from brecciated to unbrecciated rocks and the occasional purple weathered surface caused by oxidation of iron ores to haematite. The thickness of flows is between 1 ft. (0·3 m.) and at least 15 ft. (4·5 m.).

Quartz-plagioclase crystal tuffs occur at the only outcrop examined east of Tillberg Peak (D.4880), but the other nunataks in that area are probably also composed of volcanic rocks.

Petrography

Tuffites. The water-laid beds composed of sedimentary and volcanic detritus occur only near Phoenix Peak and they are well-bedded stratified rocks. The tuffites (Fig. 6c) comprise angular and rounded crystal and rock fragments set in a fine greenish matrix. The crystal fragments (0·1–2·0 mm.) are of quartz and plagioclase ($Ab_{65}An_{35}$), and the rock fragments (0·1–4·0 mm.) are of sediments, schists, tuffs and lavas (D.4873.2). The sediments and schists are similar to those of the Trinity Peninsula Series, and the volcanic rocks are similar to the acid crystal tuffs and andesites at other outcrops. The matrix is mainly quartz, yellowish green chlorite and some sericite, together with a little plagioclase, iron ore, and accessory zircon and tourmaline. The matrix also includes penninite pseudomorphs derived, after deposition, from pre-existing minerals which were probably pyroxenes but could have been other minerals or rock fragments. Some of the crystals and rock fragments are rounded and a few of the quartz grains are well-rounded; the grading displayed by the tuffites is not well developed but, together with the roundness of some of the grains, the evidence favours a subaqueous depositional environment in which the angular fragments were transported only a very short distance. The rock fragments indicate that the tuffites are not the lowest members of the Upper Jurassic Volcanic Group even though they apparently rest on the Trinity Peninsula Series.

Acid crystal tuffs. The tuffs are structureless grey-green rocks with quartz and feldspar fragments in an aphanitic matrix. Specimen D.4875.3, a dacitic tuff, has angular plagioclase ($Ab_{67}An_{33}$) and corroded quartz crystals (0·05–1·50 mm.) in a very fine (0·002–0·030 mm.) quartzo-feldspathic matrix in which there are sericitic shreds and leucoxene grains. The only abundant xenoliths are very fine-grained quartzo-feldspathic fragments derived from acid volcanic rocks. Compositional variations are shown in a rhyodacitic tuff (D.4872.5) by a yellowish green chloritic matrix and plagioclase mantling alkali-feldspar crystals, which indicates two crystallization environments. Another tuff (D.4874.1) has pseudomorphs after biotite, fine granular epidote and coarser epidote and prehnite crystals replacing the matrix, and allanite crystals. The acid crystal tuffs (D.4880.1) near Tillberg Peak consist of large heavily corroded phenocrysts (up to 2·5 mm.) of quartz, alkali-feldspar (which is rarely perthitic), twinned oligoclase ($Ab_{88}An_{12}$) and chlorite pseudomorphs after biotite, all set in a very fine-grained quartzo-feldspathic matrix which includes sericite, chlorite, leucoxene, zircon and secondary calcite.

Andesite lavas. The greenish autobrecciated lavas are mainly very severely altered pyroxene-andesites. A comparatively unaltered andesite (D.4872.1) south-east of Phoenix Peak has phenocrysts (0·2–3·0 mm.) of sericitized plagioclase ($Ab_{57}An_{43}$) and penninite pseudomorphs after pyroxene (Fig. 6d). The penninite pseudomorphs occasionally form octagonal cross-sections but they tend to be euhedral prisms crossed by transverse cracks; this suggests derivation from orthopyroxene. The matrix is a very fine-grained aggregate of quartz (0·01 mm.), orientated plagioclase laths ($Ab_{70}An_{30}$; 0·04 mm.), leucoxene, chlorite and sericite. The lavas north of Muskeg Gap are extensively altered but some include clinopyroxene phenocrysts almost completely replaced by colourless chlorite, prehnite and leucoxene (D.4865.5). The purple colour of some of the lavas is caused by oxidation of iron ores to haematite (D.4865.5). Generally there is extensive replacement of both the phenocrysts and matrix by secondary minerals such as chlorite, epidote, prehnite, leucoxene, calcite and haematite.

Intrusive rocks

The Jurassic intrusions are porphyritic acid dykes and microdiorites. The intrusions are most numerous near Tillberg Peak and only acid dykes occur elsewhere, near Cape Worsley and Phoenix Peak.

Microdiorites

West of Tillberg Peak there is a microdiorite intrusion which is associated with some porphyritic acid dykes or sills. The microdiorite crops out south of the gabbro, which is probably early Mesozoic in age (p. 10), but the actual contact is concealed by snow. Traced westwards, the microdiorite passes into a series of several accessible and numerous inaccessible minor intrusions which include porphyritic acid types (Fig. 9b). These dykes or sills, which are separated by schists, dip steeply but there is no evidence of their attitude at the time of intrusion. The intrusions are 5–30 ft. (1·5–9·1 m.) thick and have chilled margins against the schists which are similar to those of the Trinity Peninsula Series. Most of the intense deformation of the schists is pre-Jurassic, but there has been some post-Jurassic movement, probably caused by the emplacement of the Andean Intrusive Suite, because several of the acid hypabyssal rocks are sheared.

The microdiorites are greenish grey, medium-grained rocks comprising, in specimen D.4836.1, highly altered euhedral plagioclase ($Ab_{66}An_{34}$; 0·5–2·0 mm.) and ferromagnesian mineral pseudomorphs, together with interstitial granophyric quartz and feldspar. Penninite, epidote, calcite and some leucoxene, form the pseudomorphs which were probably derived either from amphibole or, where zircon or haloes are present, from biotite. The interstices are filled mainly by a granophyric intergrowth of quartz and alkali-feldspar which may also replace the plagioclase, and by secondary minerals such as leucoxene, penninite, epidote and calcite. The intense alteration is believed to have been caused by the adjacent adamellite of the Andean Intrusive Suite.

Porphyritic acid intrusions

West of Tillberg Peak microgranite intrusions occur in the series of parallel dykes or sills described with the microdiorites and as a single 15 ft. (4·5 m.) wide dyke cutting the gabbro which has been tentatively assigned an early Mesozoic age (p. 10). The Trinity Peninsula Series on the north side of Phoenix Peak is intruded by a number of acid intrusions up to 30 ft. (9·1 m.) thick and also at Cape Worsley by several 2 ft. (0·6 m.) wide acid dykes. The dyke (D.4834.1) cutting the gabbro and one of the acid dykes near Phoenix Peak (D.4862.3) have been analysed and their geochemistry is discussed elsewhere (Elliot, 1967).

One of the dykes near Phoenix Peak (D.4862.3) is a leucocratic porphyritic microgranite with quartz, feldspar and ferromagnesian mineral phenocrysts in an aphanitic matrix. The quartz phenocrysts (up to 2·0 mm.) are strongly corroded and the subhedral plagioclase ($Ab_{86}An_{14}$) is very heavily sericitized and also marginally corroded. Biotite is pseudomorphed by penninite and leucoxene. The matrix is a fine-grained (0·02–0·10 mm.) intergrowth of quartz, alkali-feldspar, a few plagioclase crystals ($Ab_{89}An_{11}$) and a little chlorite and sericite.

The porphyritic microgranite intrusions near Tillberg Peak differ slightly. They show the effects of thermal and dynamic metamorphism, both probably caused by the emplacement of the Andean Intrusive Suite. The microgranite dyke (D.4834.1) cutting the early Mesozoic gabbro has granoblastic quartz aggregates pseudomorphing former quartz phenocrysts, partially recrystallized plagioclase phenocrysts, biotite aggregates and a finer-grained matrix enclosing much muscovite. Those in the series of parallel minor intrusions have been dynamically metamorphosed. Quartz phenocrysts either exhibit a marked undulose extinction (D.4832.1) or they are broken up (D.4832.5). The biotite pseudomorphs and plagioclase phenocrysts are sheared into fragments (D.4832.1) and the matrix in some rocks is crossed by numerous shear planes which are picked out as muscovite-sericite-rich trails (D.4832.2, 5).

CRETACEOUS SEDIMENTS

On the east coast of Graham Land, Cretaceous sediments crop out extensively on James Ross Island and adjacent islands but they form only large isolated outcrops elsewhere. An account of these sediments has been given by Bibby (1966) but he has referred only to James Ross Island where sedimentation starts in the Lower to Middle Campanian with coarse conglomeratic rocks and passes upwards into ferruginous sandstones and shales. Bibby (1966) has estimated a total thickness of 17,000 ft. (5,180 m.) of sediment including 1,000 ft. (305 m.) of conglomerates at Stoneley Point and 500 ft. (152 m.) of possibly basal conglomerates at Lagrelius Point. At Cape Longing there are 1,000 ft. (305 m.) of sandstone and shale (Adie, 1953, p. 31). On Sobral Peninsula there are at least 1,400 ft. (425 m.) of coarse sediments which are dominantly conglomeratic, and at Pedersen Nunatak there are more than 300 ft. (91·4 m.) of conglomerates and sandstones.

Sobral Peninsula

Field examination of the sediments was confined to the Mount Lombard area (Fig. 10), and one outcrop to the south and one to the north-east of it. The sediments comprise pebble to cobble (Wentworth, 1922, p. 381) conglomerates with a small proportion of finer sediment. Sandstones occur at the tops of graded conglomerate beds, in a sequence of interbedded sandstones and pebbly sandstones on Mount Lombard and in two isolated outcrops comprising shales and sandstones.

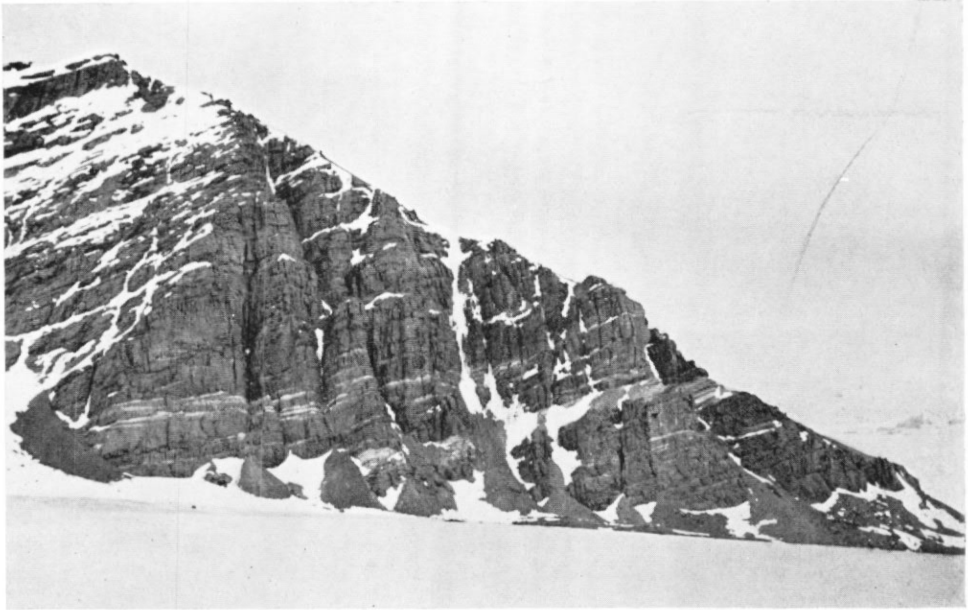


Fig. 10. View looking south-west towards Mount Lombard which is composed of conglomeratic sediments (dark grey) and a little interbedded finer sediment (pale grey); Fig. 11b illustrates the intersection of the latter with the ridge; Mount Lombard, Sobral Peninsula (D.4876).

The conglomerates form massive beds from 3 to 50 ft. (0·9 to 15·2 m.) thick and they consist of densely packed pebbles and cobbles with a coarse sand- to granule-sized matrix of rock fragments and mineral grains (Fig. 11a). In many beds the pebbles and cobbles diminish in number until they form less than half the rock, and at the same time the size diminishes to the smaller end of the pebble range. Finally, the pebbles disappear and the rock becomes a coarse sandstone which varies from a light buff to a dark greyish green colour. The grading in some conglomerate beds stops at a less coarse conglomerate with less densely packed pebbles, rather than a sandstone. The water-worn fragments of the conglomerates vary between pebble- and boulder-size, reaching 2 ft. (0·6 m.) in rare instances, but most are in the pebble range. The commonest pebbles and cobbles are pyroxene-andesites and crystal tuffs similar to those of the Upper Jurassic Volcanic Group occurring to the north. Others are Trinity Peninsula Series fragments and there are also some quartz pebbles.

The sequence of interbedded light buff sandstones and pebbly sandstones represents a period of quieter deposition. These beds vary in thickness from 1 in. (2·5 cm.) to 7·5 ft. (2·3 m.) and few beds are lithologically the same. Shallow-water structures such as current-bedding were not recorded in the field. Some of these sandstones are very poorly cemented and they are more easily weathered than other beds (Fig. 11b).

Most of the sediments on Mount Lombard (Fig. 10) dip gently south-eastwards but, near the end of the ridge trending north-westwards from the summit, the conglomerates are underlain by similar beds which dip steeply to the north-west. The relationships of the steeply dipping

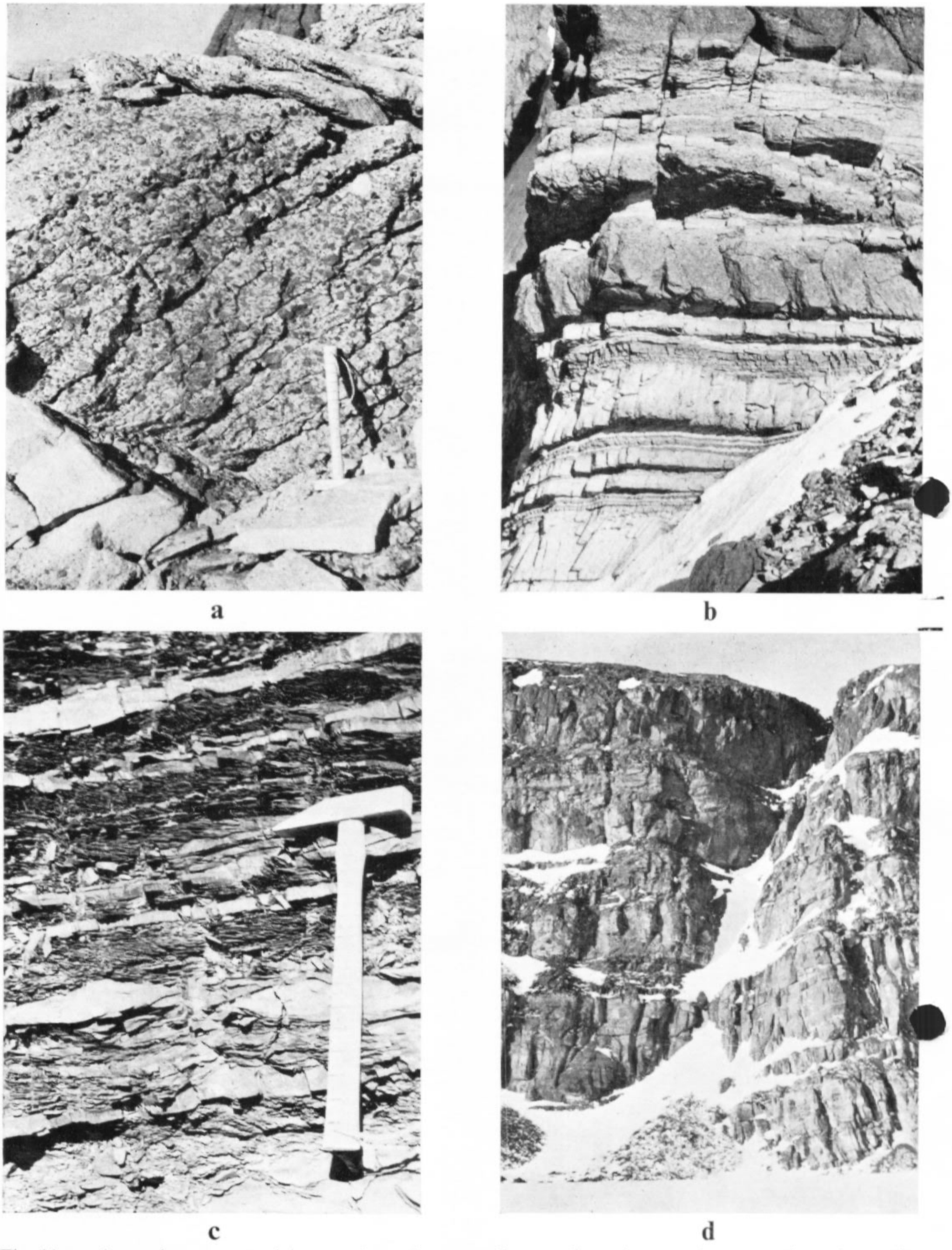


Fig. 11. a. A conglomerate overlying a pale sandstone at the top of another conglomerate; the scale on the hammer is in inches; Mount Lombard, Sobral Peninsula (D.4876).

b. Interbedded sandstones and pebbly sandstones together with a few intercalated finer beds and overlain by conglomerates; the more resistant beds form ledges; the height of the rock face is 60 ft. (18·3 m.); Mount Lombard, Sobral Peninsula (D.4876).

c. Interbedded sandstones and shales; the scale on the hammer is in inches; view looking south-east; south-east of Phoenix Peak (D.4870).

d. A 300 ft. (91 m.) succession of five graded conglomerate-sandstone beds; view looking south-east; north-west side of Pedersen Nunatak (D.4855).

conglomerate beds, the overlying beds and the isolated outcrops of finer sediment, which are described below, are discussed on p. 35.

One of the isolated outcrops, south-east of Phoenix Peak (D.4870), is a series of thin interbedded shales and dark grey sandstones, and the other is a series of folded shales and fine sandstones with rare coarse sandstones near Mount Lombard (D.4878). The thickness of unrepeated sediment does not exceed 100 ft. (30·5 m.) at either outcrop. At one of them (D.4870; Fig. 11c) the thickness of individual shale beds is 1–10 in. (2·5–25·4 cm.), and of the few sandstones is 1 in. to 2 ft. (2·5 to 61 cm.). At the other outcrop the shale rarely occurs as solid outcrops and it mostly forms the frost-shattered debris between the thin ribs of more resistant fine-grained sandstone. The preservation of some plant remains in these shales favours lacustrine or estuarine rather than a marine depositional environment.

Pedersen Nunatak

The best exposed rocks, which crop out on the north-west side of Pedersen Nunatak, form a 300 ft. (91·4 m.) succession of five graded conglomerate-sandstone beds (Fig. 11d). Elsewhere there is a more varied lithology consisting of conglomerates, sandstones and shales. The fragments in the conglomerates are pebble- to boulder-sized with the majority in the pebble range. They are either densely packed or sparsely distributed and many of the beds grade into sandstones or shales. The thickness of the beds varies from 1 ft. (30 cm.) for the sandstones up to 60 ft. (18·3 m.) for the graded conglomerates. Pebbles of quartz and porphyritic acid intrusives, which are similar to some Jurassic dykes near Tillberg Peak and to other Jurassic rocks farther south (personal communication from M. Fleet), are the commonest but the more angular boulders and some of the pebbles are composed of shale or siltstone. Bibby (1966) has noted that the Stoneley Point conglomerates contain rounded rhyolitic fragments similar to those of the Upper Jurassic Volcanic Group, and angular sandstone fragments which indicate the possibility of eroded Lower Cretaceous sediments.

Petrography of the sandstones

The sandstones of Sobral Peninsula are coarse sediments with a grain-size up to 2·0 mm.; three of them have been examined in thin section and they are feldspathic sandstones. Twinned and slightly zoned plagioclase grains ($Ab_{48}An_{52}$–$Ab_{59}An_{41}$) are the commonest; they are fragmented euhedral crystals with only slight rounding of the original faces in one sandstone (D.4870.1; Fig. 6e) but rather more in the others (D.4878.1, 4879.1). Angular and corroded volcanic quartz is uncommon but fine-grained acid volcanic fragments are numerous. There is every gradation from partially recrystallized glassy fragments to very fine-grained quartzo-feldspathic rocks, and many of them enclose small quartz, feldspar and iron ore crystals. The few andesite fragments have a trachytic texture and are composed of plagioclase laths with a little iron ore. Iron ore, silt-sized quartz and clay minerals are present in the matrix but calcite and a green chloritic mineral form a high proportion of the cement. A few small areas of a fibrous zeolite (probably thomsonite) and of spherulitic chalcedony were observed and one sandstone (D.4879.1) contains pyrite which is partially altered to haematite. The colour of the sandstones is partly influenced by the cementing minerals.

One coarse dark grey sandstone (D.4855.3) from Pedersen Nunatak, which carries a few carbonaceous stems, was examined microscopically. There are angular quartz, feldspar and lithic fragments (0·1–1·0 mm.), and a little interstitial clay but it is cemented mainly by calcite. Most of the feldspar is unaltered albite ($Ab_{92}An_{8}$) and there is a little alkali-feldspar with characteristic brown dusting. A few small areas of a zeolite (probably thomsonite) and one of chalcedony also occur. The volcanic clasts are similar to those in the sediments on Sobral Peninsula but fragments of schists similar to those of the Trinity Peninsula Series are more numerous. There are also a few penecontemporaneous shale fragments.

Correlation

A few unidentifiable carbonaceous stems were found at one outcrop on Sobral Peninsula (D.4870), but another locality (D.4878) yielded three comparatively well-preserved plant remains: two are pinnae which resemble *Zamites* and the third is a poorly preserved coniferous shoot. The palaeobotanical evidence, because of the Middle Jurassic plant-bearing Mount Flora beds at Hope Bay, would favour a Jurassic age but the mineralogy of the interbedded sandstones (D.4870.1, 4878.1) is almost identical to that of a sandstone (D.4879.1) from the conglomerate beds. All of them contain a large proportion of volcanic material which was almost certainly derived from the Upper Jurassic Volcanic Group.

Numerous unidentifiable stems and pinnae were found at the top of a graded conglomerate-sandstone bed on the north-west side of Pedersen Nunatak, but they are of no value for stratigraphical purposes.

The absence of fossils and the almost certain lateral variation in lithology make direct correlation impossible. Since sedimentation on the north-west side of James Ross Island began with coarse conglomeratic sediments of Lower to Middle Campanian age, it is probable that the conglomerates from Sobral Peninsula and Pedersen Nunatak are also of that age.

Provenance

The source of these sediments must have been mainly the Upper Jurassic Volcanic Group. The small proportion of quartz in the sandstones, except at Pedersen Nunatak, is remarkable considering the predominance of acid volcanic fragments, but it is possible that the size of the phenocryst fragments precluded deposition in these beds. Most of the plagioclase in the sandstones was derived from pyroxene-andesites and some probably came from crystal tuffs, particularly at Pedersen Nunatak. The conglomerates also indicate a similar provenance, because the pebbles are mainly of rocks similar to the andesites and crystal tuffs near Muskeg Gap, but there are also some pebbles of schists and sandstones similar to those of the Trinity Peninsula Series. The characteristics of the pebble-forming sandstones are closest to those of sandstones from north-west Trinity Peninsula (Elliot, 1965, p. 4). The plagioclase in the Trinity Peninsula Series schists and sandstones (p. 5, 7) is different from that in the sandstones near Mount Lombard. Additional evidence of the source of the plagioclase is provided by a pyroxene-andesite pebble which contains euhedral phenocrysts of andesine ($Ab_{58}An_{42}$) similar to those in the sandstones at Sobral Peninsula.

Thus the provenance was mainly the andesites and crystal tuffs of the Upper Jurassic Volcanic Group and subordinately the Trinity Peninsula Series.

ANDEAN INTRUSIVE SUITE

Plutonic rocks of the Andean Intrusive Suite occur near Drygalski Glacier and at inaccessible outcrops near Mount Elliott. The age of the intrusions cannot be inferred precisely; the only contacts are with the Trinity Peninsula Series, which is probably Carboniferous (Adie, 1957, p. 2), and with intrusions of Jurassic age (p. 10, 14). Adie (1955, p. 4) has presented evidence for a late Cretaceous to early Tertiary age but recent age determinations by the K/A and Pbα methods (Halpern, 1964; Scott, 1965) give a slightly wider time range. The occurrence of a gabbro of possible Lower Jurassic age (p. 10) casts doubt on the age of any intrusion which cannot be proved to be post-Jurassic. The age of the intrusions is discussed on p. 41.

The composition of the intrusions varies from gabbro to granite, although intermediate members are uncommon. Quartz-diorite and granite intrude gabbro but other relationships of the rocks are unknown.

The assimilation of sedimentary rocks is shown by the presence of garnet and andalusite crystals, and of partially assimilated basic xenoliths in the granites. The granodiorite at Bekker Nunataks encloses rafts of rocks similar to the nearest outcrops of the Trinity Peninsula Series. These rafts are 1 to 30 ft. (0·3 to 9·1 m.) thick and more than 100 ft. (30·5 m.) long (Fig. 5d).

The intrusions have thermally metamorphosed the rafts (p. 9) and the Trinity Peninsula Series at the contacts (p. 8-9). One Jurassic dyke (p. 14) and a gabbro (p. 10) also show the effects of an adjacent intrusion. Metamorphism of the country rocks does not exceed the hornblende-hornfels facies.

TABLE II. MODAL ANALYSES OF 16 PLUTONIC ROCKS FROM THE NORDENSKJÖLD COAST

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Quartz	1·3	0·1	—	5·1	1·1	8·6	8·8	8·0	7·2	33·6	26·5	44·1	40·1	33·0	32·5	35·8
Orthoclase	—	—	*	—	—	—	*	*	—	3·1	36·1	18·3	23·6	33·8	43·7	49·4
Microcline	—	—	—	—	—	—	—	—	—	7·4	12·8	14·0	7·4	—	—	—
Plagioclase	54·3	50·4	51·0	57·0	51·8	69·0	72·8	69·9	61·3	41·4	16·7	20·0	23·7	30·8	21·6	13·2
Granular albite	—	—	—	—	—	—	—	—	—	0·5	1·7	0·8	1·6	0·6	0·6	—
Olivine	—	0·1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hypersthene	2·0	—	*	1·0	—	—	—	—	—	—	—	—	—	—	—	—
Augite	9·0	5·1	0·6	12·1	2·1	0·2	*	—	0·3	—	—	—	—	—	—	—
Brown hornblende	7·2	18·5	36·9	—	31·1	7·4	2·1	2·2	19·9	—	—	—	—	—	—	—
Green hornblende	12·9	10·4	6·0	7·7												
Actinolite	—	11·5	1·6	3·2	8·2	1·9	1·1	2·7	0·5	—	—	—	—	—	—	—
Muscovite	—	—	—	—	—	—	—	—	—	0·4	0·6	*	0·4	0·3	—	—
Biotite	0·4	*	*	6·2	0·3	9·7	12·9	13·3	0·1	13·0	5·0	2·0	3·2	1·4	1·5	1·1
Chlorite	0·6	2·6	1·0	0·1	3·4	0·3	0·3	0·8	6·1	0·6	0·5	0·8	*	0·1	*	0·3
Iron ore	9·9	0·8	2·7	6·7	1·4	2·7	1·9	3·1	4·2	—	—	*	*	—	0·1	0·2
Accessory minerals	2·4	0·5	0·2	0·9	0·6	0·2	0·1	*	0·4	*	0·1	*	*	*	—	*
Plagioclase composition	An_{56}	An_{78}	An_{54}	An_{46}	An_{61}	An_{56}	An_{43}	An_{50}	An_{58}	An_{36}	An_{28}	An_{28}	An_{24}	An_{24}	An_{22}	An_{23}

* Present but not recorded.

1.	D.4817.1	Hornblende-gabbro; south-west of Drygalski Glacier.
2.	D.4819.1	Hornblende-gabbro; south-west of Drygalski Glacier.
3.	D.4822.2	Hornblende-gabbro; south-west of Drygalski Glacier.
4.	D.4822.1	Quartz-diorite; south-west of Drygalski Glacier.
5.	D.4823.1	Hornblende-gabbro; south-west of Drygalski Glacier.
6.	D.4823.2	Quartz-gabbro; south-west of Drygalski Glacier.
7.	D.4823.3	Quartz-diorite; south-west of Drygalski Glacier.
8.	D.4823.6	Quartz-diorite; south-west of Drygalski Glacier.
9.	D.4823.7	Quartz-hornblende-gabbro; south-west of Drygalski Glacier.
10.	D.4844.1	Granodiorite; Bekker Nunataks.
11.	D.4802.1	Granite; north-west of Bekker Nunataks.
12.	D.4814.1	Granite; south-west of Fender Buttress.
13.	D.4835.1	Adamellite; west of Tillberg Peak.
14.	D.4841.1	Adamellite; Tillberg Peak.
15.	D.4820.1	Granite; south-west of Drygalski Glacier.
16.	D.4826.1	Granite; south of Drygalski Glacier.

Basic intrusions

The older basic rocks form one large intrusion south-west of Drygalski Glacier and a few outcrops east of that intrusion. The main rock type is hornblende-gabbro but there is also a little quartz-diorite. A thermally metamorphosed schist (p. 9) suggests that the small gabbro and quartz-diorite outcrops form part of a larger intrusion, but the relationships to the main intrusion are unknown.

The main gabbro intrusion

Field description. The main intrusion is banded and at least 3,000 ft. (915 m.) thick (Fig. 12a). Accessibility is poor and the true composition and cause of the banding are not known. The banding dips gently westwards in the outcrops at stations D.4819 and 4824, but across the glacier to the south, the dip is apparently steeper and diminishes westwards (Fig. 12b). The distribution of outcrops suggests that the intrusion might be circular.

The banding is an alternation of light and dark layers which are at least 30 ft. (9·1 m.) thick. The light bands form only a small proportion of the total exposed rock. At the base of the main outcrop about 30 ft. (9·1 m.) of a vertical rock face are accessible (D.4824; Fig. 12c). The part of the rock face examined is lighter in colour than the majority of the exposed rock, but rather darker and not weathered in the same way as the overlying light band (Fig. 12c). The lighter colour of the rock examined, which is a hornblende-gabbro (D.4824.1), is caused mainly by intense weathering. The dark band could only be examined from a few feet away and it appeared to be finer-grained, comparatively unweathered and without the coarse white plagioclase segregations of the hornblende-gabbro. Rocks which fit this description are dioritic rather than gabbroic. It is probable that the overlying light band has a more acid composition and it may be comparable to the microgranite at another outcrop (D.4823). Compared with the adjacent gabbros, this microgranite is conspicuously paler and weathers differently; the light bands in the gabbros have similar properties. Possible interpretations of this microgranite are given on p. 23.

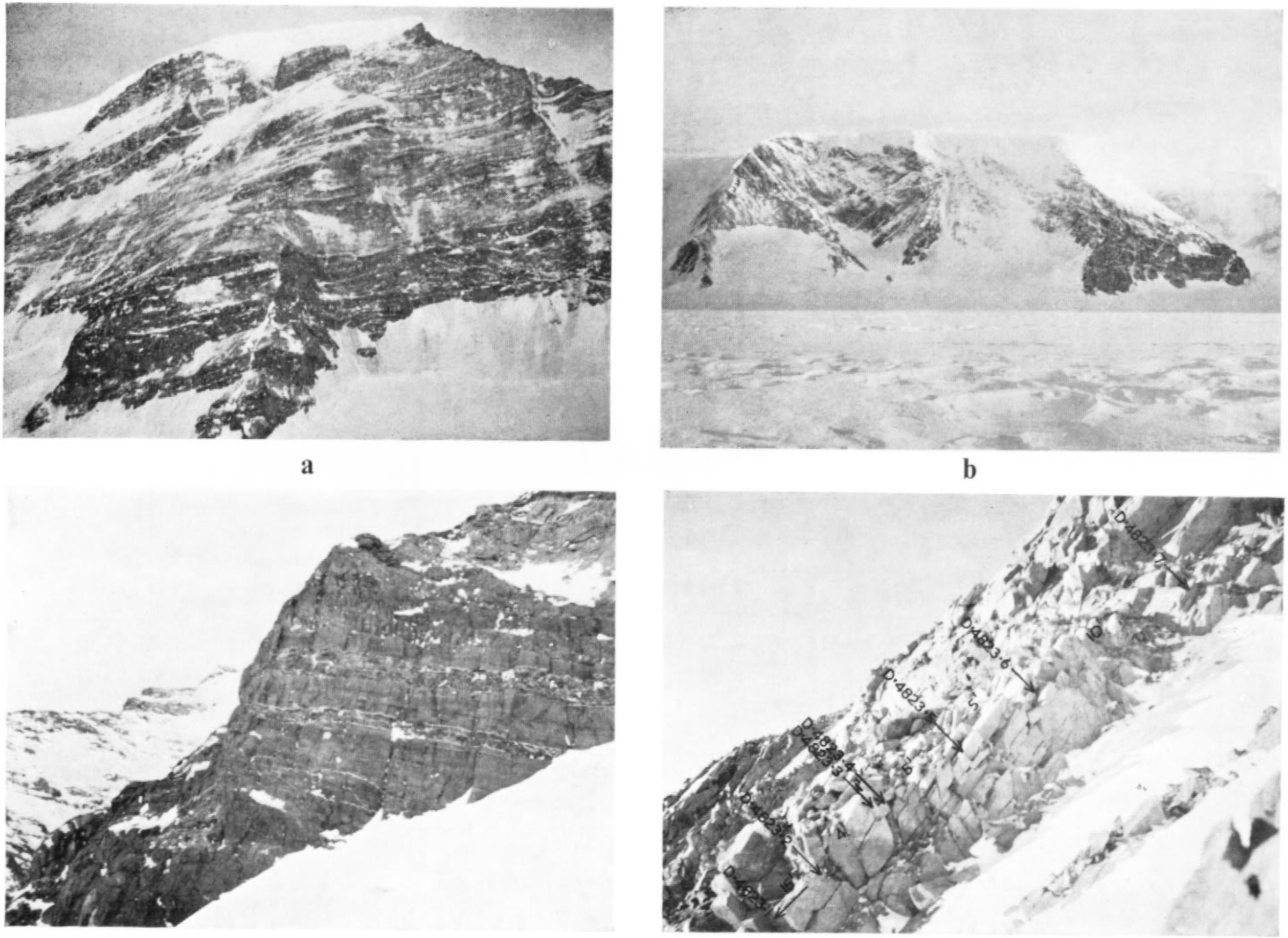
Quartz-diorite also occurs with the gabbros and at one outcrop (D.4822) it is the main rock type; there is subordinate hornblende-gabbro and a very small proportion of microgranite but the contacts are not sharp and the changes are apparently gradational. Elsewhere, quartz-diorites are rich in plagioclase and either isolated (D.4829; p. 23), adjacent to a microgranite (D.4823; p. 23), or associated with rocks interpreted as the simultaneous intrusion of acid and basic magma (D.4818, 4828; p. 24, 26). The quartz-diorites, including the plagioclase-rich types, are the products of differentiation.

At one outcrop (D.4824; Fig. 12c) the main intrusion is cut by 1–3 ft. (0·3–0·9 m.) thick sills of an acid rock which encloses numerous basic xenoliths. These sills are parallel to the banding in the intrusion but at other outcrops of xenolith-bearing sills (p. 24) there is no such relationship.

The margins of the main intrusion are cut by a few acid intrusions (p. 29) and a number of basic dykes, which are described on p. 29-30; at inaccessible outcrops it is cut by sills and intruded by granite masses.

Petrography. A medium-grained *hornblende-gabbro* forms most of the outcrops at the base of the plateau edge. The hornblende-gabbro shows some variation which depends mainly on the grain-size and the degree of alteration of the ferromagnesian minerals. The essential minerals are plagioclase, pyroxene and amphibole in varying proportions, and ranging in size from 1 to 7 mm. The texture varies from ophitic to hypidiomorphic granular, though it is usually between the two extremes. Modal analyses of hornblende-gabbros are given in Table II (analyses 1–3).

The euhedral to subhedral plagioclase crystals are separate or enclosed in ferromagnesian minerals. Primary twin lamellae and synneusis twins (Vance, 1961, p. 1099, 1107) are rare, and multiple albite twinning is dominant. Shearing stress after crystallization was not intense because polysynthetic glide twinning is uncommon. Patchy extinction and zoning occurs in a few crystals and the composition range is remarkable for showing several preferred values. The cores of zoned and patchy crystals are $Ab_{22}An_{78}$–$Ab_{29}An_{71}$, the next major zone and other parts of patchy cores are $Ab_{40}An_{60}$–$Ab_{46}An_{54}$ and the outer zones are $Ab_{52}An_{48}$–$Ab_{55}An_{45}$



a b

c d

Fig. 12.

though they may be zoned to acid andesine (Fig. 6f). Crystals without patchy cores tend to have more numerous twin lamellae which have a more even width; the composition range is $Ab_{39}An_{61}$–$Ab_{47}An_{53}$. The characteristics of the twinning are closer to the criteria for the recognition of secondary lamellae than those of primary lamellae (Vance, 1961, p. 1103).

There is little sign of externally applied stress and, since Laves (Smith, 1962, p. 256) states that secondary twinning without high external stress can only take place at high temperatures, the patchy replacement must also be a high-temperature effect. The stress causing twinning in the patchy crystals could be the result of contraction on cooling or the ordering of the structure on the inversion from high-temperature albite to a low-temperature feldspar. Thus the observed features may have been caused by simultaneous replacement and internal stress during the fall in temperature accompanying crystallization.

Hornblende, the dominant ferromagnesian mineral, forms subhedral and ophitic crystals. It is pleochroic from $\alpha =$ pale brown to $\gamma =$ dark brown or greenish brown, though there are all shades to bluish green. The types grade from one to the next (D.4817; $\gamma : c = 23°$–$13°$), but the green and bluish green varieties may only be the result of hydrothermal alteration. A little of the brown hornblende is primary but most of it has been derived by the magmatic alteration of pyroxene which forms the cores of many crystals (Fig. 13a). Some of the hornblende is altered to chlorite and a little epidote, iron ore and sphene. Alteration to actinolite is rare.

Most of the pyroxene forms cores of hornblende crystals but there are some unaltered crystals (D.4817.1). Orthopyroxene, which is subordinate to clinopyroxene, is a pleochroic hypersthene ($\alpha =$ pale pink, $\gamma =$ colourless). Some crystals are traversed by cracks that form foci for the development of serpentine minerals which completely replace a few of them (D.4817.1). Serpentinization of the orthopyroxene ante-dates the rimming and rare replacement by hornblende. Later hydrothermal alteration has replaced the hypersthene by rounded aggregates of actinolite, chlorite, iron ore and fibrous talc (D.4819.1; Fig. 13b).

The clinopyroxene is a colourless augite ($\gamma : c = 44°$) which forms subhedral or large (up to 7·0 mm.) ophitic crystals enclosing plagioclase. The diallage structure of iron ore flakes parallel to (100) is common. Magmatic alteration to hornblende is extensive and the contact between the two minerals is irregular (Fig. 13a). Later hydrothermal alteration of the augite has generated actinolite-chlorite-iron ore aggregates, some of which are enclosed in hornblende. The distinction between these aggregates and those derived from orthopyroxene depends on the absence or presence of talc and the form of those aggregates which are surrounded by hornblende.

Olivine occurs in only one rock (D.4819.1) and, since its $2V_\gamma$ is close to 90°, it is magnesium-rich. It is enclosed in augite (Fig. 13c) and the crystals are rimmed by iron ore; some are altered to iddingsite, talc and a colourless amphibole. The crystals and pseudomorphs are separated from the augite by a narrow rim of pale green amphibole.

Ilmenite and titaniferous magnetite grains are separate or enclosed in ferromagnesian minerals. Several gabbros have interstitial primary graphic quartz and alkali-feldspar but others have metasomatic alkali-feldspar (p. 23). The accessory minerals are abundant apatite and a little sphene and zircon.

The *quartz-diorite* (D.4822.1) is a fine-grained equigranular rock composed of hypidiomorphic crystals (0·2–1·0 mm.) of plagioclase, pyroxene, amphibole and biotite. A modal

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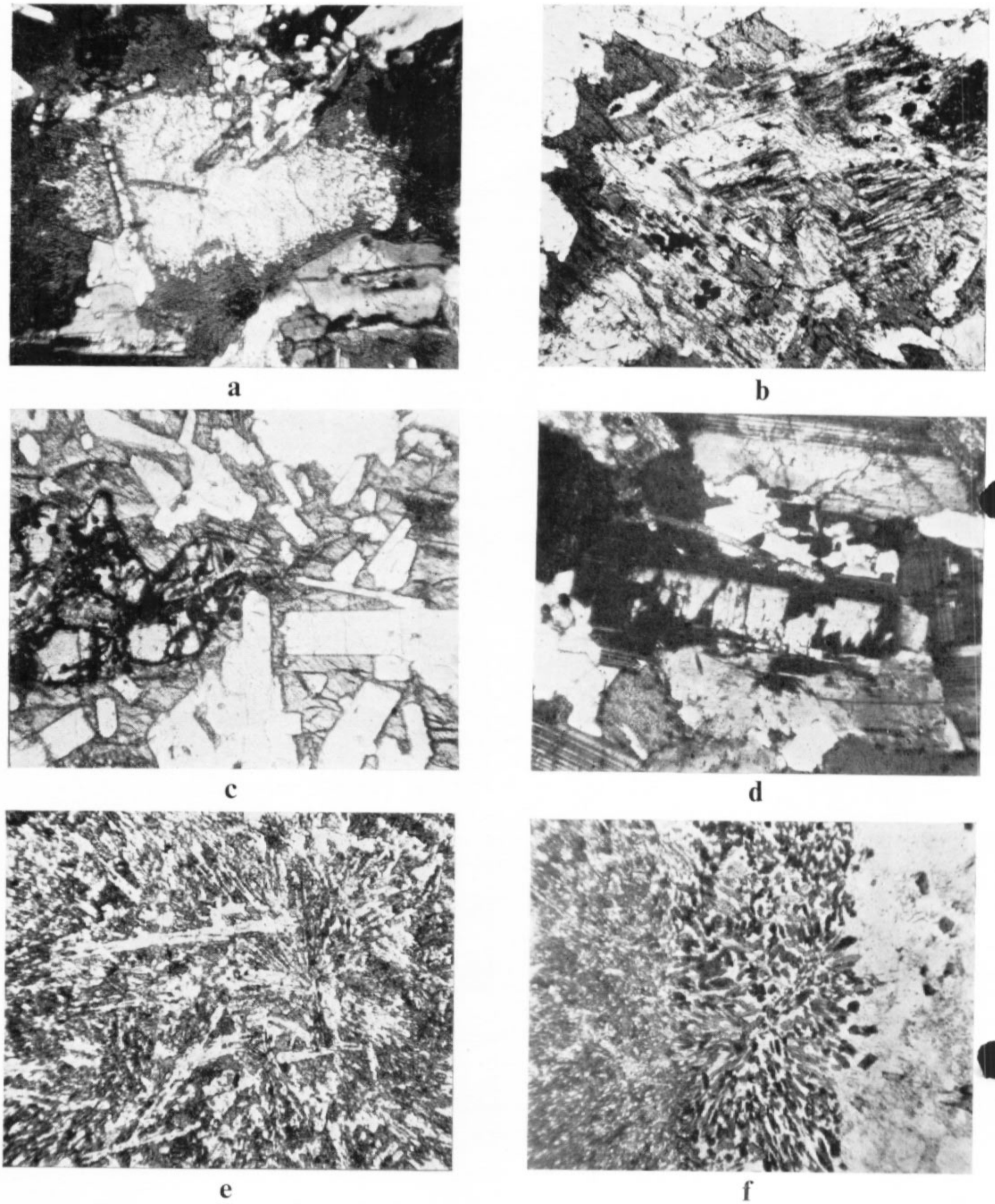
Fig. 12. a. Plateau edge showing the gabbro with light bands which dip gently westwards; station D.4824 is in the centre at the base of the rock face which is about 3,000 ft. (915 m.) high; view looking north-west; south-west of Drygalski Glacier.

b. Plateau edge, 3,000 ft. (915 m.) high, showing the gabbro dipping westwards; station D.4822 is at the base of the rock face at the right-hand side; view looking south-west; south-west of Drygalski Glacier.

c. Gabbro with xenolithic sills parallel to the banding which is shown by the prominent light band at the top; the rock face just above the snow at the left-hand side was examined; the height of the rock face visible is about 60 ft. (18·3 m.); view looking west; south-west of Drygalski Glacier (D.4824).

d. Station D.4823 showing the gradation gabbro–microgranite–gabbro; the microgranite is the shattered pale rock in the centre; location of specimens and distance apart are shown; view looking south-east; south-west of Drygalski Glacier.



a b c d e f

Fig. 13. a. Hornblende (dark grey) replacing pyroxene which ophitically encloses plagioclase laths; south-west of Drygalski Glacier (D.4823.1; X-nicols; ×30).

b. Secondary minerals pseudomorphing orthopyroxene which has been rimmed by hornblende (dark grey); south-west of Drygalski Glacier (D.4819.1; ordinary light; ×35).

c. Altered olivine crystals within augite which is ophitically intergrown with plagioclase; south-west of Drygalski Glacier (D.4819.1; ordinary light; ×35).

d. Replacement of the core of a plagioclase crystal by feldspar of rim composition (in extinction); south-west of Drygalski Glacier (D.4823.7; X-nicols; ×35).

e. Sub-variolitic texture of plagioclase laths and granular amphibole in the chilled margin of a basic xenolith; south-west of Drygalski Glacier (D.4819.3; ordinary light; ×35).

f. Reaction zone of biotite and alkali-feldspar between chilled basic magma (left) and acid magma (right); south-west of Drygalski Glacier (D.4819.3; ordinary light; ×35).

analysis is given in Table II (analysis 4). The more strongly zoned plagioclase crystals have a composition range of $Ab_{54}An_{46}$ to $Ab_{79}An_{21}$. The augite ($\gamma : c = 40°$) nearly always encloses iron ore and is altered to brownish green hornblende. The hypersthene, which is free from iron ore and is rimmed but not replaced by hornblende, exhibits later alteration to fibrous actinolite, iron ore and a little yellowish green chlorite. The brownish green hornblende ($\gamma : c = 18°$) passes marginally to green or blue-green varieties. The biotite, some of which rims iron ore, has been slightly altered to penninite. The primary iron ore is magnetite. Quartz is interstitial and strain effects are uncommon. Accessory apatite prisms are common.

Metasomatized rocks

Gabbros. The metasomatic introduction of alkali-feldspar is widespread but extensive at only one locality (D.4828). The source of the metasomatizing solutions was either the late acid residuum from the crystallization of the gabbros or the later acid phase of the Andean Intrusive Suite.

The gabbros at a number of outcrops have primary graphic quartz and alkali-feldspar, but the non-graphic alkali-feldspar (D.4818.2, 4828.2) and the replacement of plagioclase (D.4824.1, 4828.5) which may also exhibit strong marginal zoning ($Ab_{46}An_{54}$–$Ab_{86}An_{14}$; .4828.2) suggest that there has been metasomatism. Where plagioclase has been replaced, there is extensive replacement of the ferromagnesian minerals by actinolite-chlorite aggregates (D.4817.6, 4824.1); the bluish green colour of the rims of some hornblende crystals may also be a result of metasomatism.

Quartz-diorites. One isolated outcrop (D.4829.1) exhibits metasomatic effects. The rock has a very high proportion of plagioclase ($Ab_{67}An_{33}$) which has been marginally replaced by alkali-feldspar. The green hornblende is accompanied by actinolite aggregates which replace either pyroxene crystals or the hornblende. The alteration to actinolite and the replacement of plagioclase by alkali-feldspar were probably caused by the adjacent granite.

At another outcrop (D.4823) there is a gradation, without visible contacts, from hornblende-gabbro to porphyritic microgranite and back to hornblende-gabbro in a distance of 50 ft. (15·2 m.) (Fig. 12d). Modal analyses are given in Table II (analyses 5–9). Although there are no visible contacts between the rock types, there is an abrupt change from quartz-diorite to microgranite when traversing up the outcrop. The marginal rock at the lower side is a typical hornblende-gabbro (D.4823.1). It is succeeded by a quartz-gabbro (D.4823.2) which has an intergranular rather than an ophitic texture and an unusual mineralogy. The proportions of augite and amphibole are reduced and those of biotite and quartz are increased. The plagioclase is zoned from $Ab_{44}An_{56}$ to $Ab_{70}An_{30}$. On either side of the microgranite there are quartz-diorites (D.4823.3, 6) in which pyroxene and amphibole are again reduced and biotite increased. The slightly orientated plagioclase is zoned from $Ab_{50}An_{50}$ to $Ab_{78}An_{22}$. Quartz is interstitial together with small oligoclase and rare alkali-feldspar crystals. In the field there is no sign of the abrupt change from quartz-diorite to microgranite which takes place over 1 ft. (30 cm.) on the lower side and 5 ft. (1·5 m.) on the upper side of the acid rock. The microranite (D.4823.4, 5) has oligoclase phenocrysts set in a fine-grained matrix of quartz, alkali-feldspar (mostly microcline), plagioclase ($Ab_{84}An_{16}$) and accessory dark minerals. The highest rock in the sequence is a quartz-hornblende-gabbro (D.4823.7) which has an intergranular texture. The plagioclase crystals are zoned from $Ab_{42}An_{58}$ to $Ab_{69}An_{31}$. Amphiboles are the main ferromagnesian minerals, and biotite and chlorite are minor constituents. The mineral proportions lie between the lowest two of the sequence.

The microgranite apparently dips westwards, conforming with the banding in the gabbros. The sills, which are parallel to the banding in the gabbros (Fig. 12c), indicate a plane of weakness in that direction. The textures suggest that the diorites were derived by the differentiation of the gabbro and that they are not metasomatized gabbros. The microgranite is not a quartzo-feldspathic residuum developed by differentiation from the gabbro, because of the porphyritic texture and the 3,000 ft. (915 m.) of intrusion above the level of the acid rock.

It is possible that the porphyritic microgranite is a later hypabyssal intrusion emplaced during the cooling of the gabbro. The temperature of the gabbro was high enough to prevent chilled margins and there was reaction between the microgranite and the diorites. The modal analyses show the changes in the proportions of the minerals. There is strong zoning in the plagioclase crystals and some replacement of their cores by feldspar of rim composition (Fig. 13d). There is also a marked increase in the proportion of biotite at the expense of pyroxene and amphibole. Interstitially there is an increase in quartz, and also oligoclase and rare alkali-feldspar crystals. This implies the introduction of potash to generate the interstitial alkali-feldspar and the biotite from pyroxene and amphibole, and silica and soda to form interstitial quartz and oligoclase, and the more acid rims on the plagioclase crystals. These are the changes to be expected when granitic magma comes in contact with diorite. If crystallization of the diorite had not been completed, then the interstices would have formed ideal channels for metasomatizing solutions.

Simultaneous intrusion of basic and acid magma

Xenolith-bearing sills. At several outcrops of the main intrusion there are xenolith-bearing sills which vary from a regular 1–3 ft. (0·3–0·9 m.) in width (D.4824; Fig. 12c) to sills at least 15 ft. (4·5 m.) thick with irregular boundaries (D.4818, 4819; Fig. 14a). The field relations, textures and mineralogy show that the basic xenoliths and the acid host rock were intruded simultaneously as basic and acid magma.

The inaccessible sills (Fig. 12c) have rounded and angular xenoliths both sparsely and tightly packed together. At one accessible outcrop (D.4819) the randomly distributed xenolith[illegible] (up to 2 ft. (0·6 m.) long) are either rounded or angular, and in detail the margins may be highly irregular. The acid material forms a network which may be as narrow as 1 mm. between xenoliths but elsewhere may form the bulk of the rock.

The xenoliths (D.4819.3) comprise a few phenocrysts of plagioclase ($Ab_{41}An_{59}$) and pyroxene, the latter replaced by colourless to green amphibole aggregates, in a groundmass of plagioclase laths ($Ab_{44}An_{56}$), green hornblende, biotite and a little iron ore. The groundmass has a sub-variolitic texture of acicular plagioclase and intergranular amphibole and biotite (Fig. 13e); this is particularly marked near and at the margins, where the texture may be variolitic, except in one instance where it is sub-trachytic parallel to the contact. The grain-size diminishes within 3·0 mm. of the contact which is fairly sharp, although there may have been later reaction between the fine-grained contact and the acid material (Fig. 13f). This reaction has developed biotite at the expense of amphibole and iron ore, and replaced plagioclase by alkali-feldspar; the reaction zone is 1·0–3·0 mm. wide. The abundance of hydrous minerals within the xenolith shows that there was some transfer of material from the acid magma before or during crystallization. It is unlikely to have been later, because quartz released on the generation of hornblende from pyroxene is absent, and hence it must have been incorporated in the crystallizing groundmass minerals.

The acid component has a granitic texture and composition. There are approximately equal proportions of quartz, orthoclase and plagioclase ($Ab_{75}An_{25}$) together with a little interstitial mica. There is some development of poekilitic quartz and some growth of plagioclase perpendicular to the contacts in a type of comb structure but there is no chilling of the acid rock against the basic rock. The granite also encloses finer-grained plagioclase-biotite clots which are the remnants of absorbed basic material.

One of the other outcrops (D.4818) is megascopically similar, but microscopically the acid component is a plagioclase-rich quartz-diorite and the basic component is coarser-grained, has more phenocrysts and has neither as well-developed a chilled margin nor a sub-variolitic texture. At another locality (D.4825) the acid rock forms only a very small proportion of the outcrop; the microscopic properties are similar but not so well developed. The basic component is a plagioclase-hornblende-hornfels and the acid component is a plagioclase-rich tonalite.

Fig. 14. a. Xenolithic sill showing thin veins of acid rock separating larger masses of basic rock; the height of the rock face is about 8 ft. (2·4 m.); south-west of Drygalski Glacier (D.4819).

b. Trinity Peninsula Series sediments which dip steeply to the north-west; view looking north with station D.4812 just to the right of the photograph; the plateau edge is 3 miles (4·8 km.) distant; west of Fender Buttress.

c. Small asymmetric folds in the Trinity Peninsula Series; the height of the rock face is about 10 ft. (3 m.); view looking south-west; near Cape Worsley (D.4850).

d. Complex disharmonic folding in the Trinity Peninsula Series; a 3 ft. (0·9 m.) ice-axe is at the lower end of the snow slope; view looking south-west; near Phoenix Peak (D.4862).

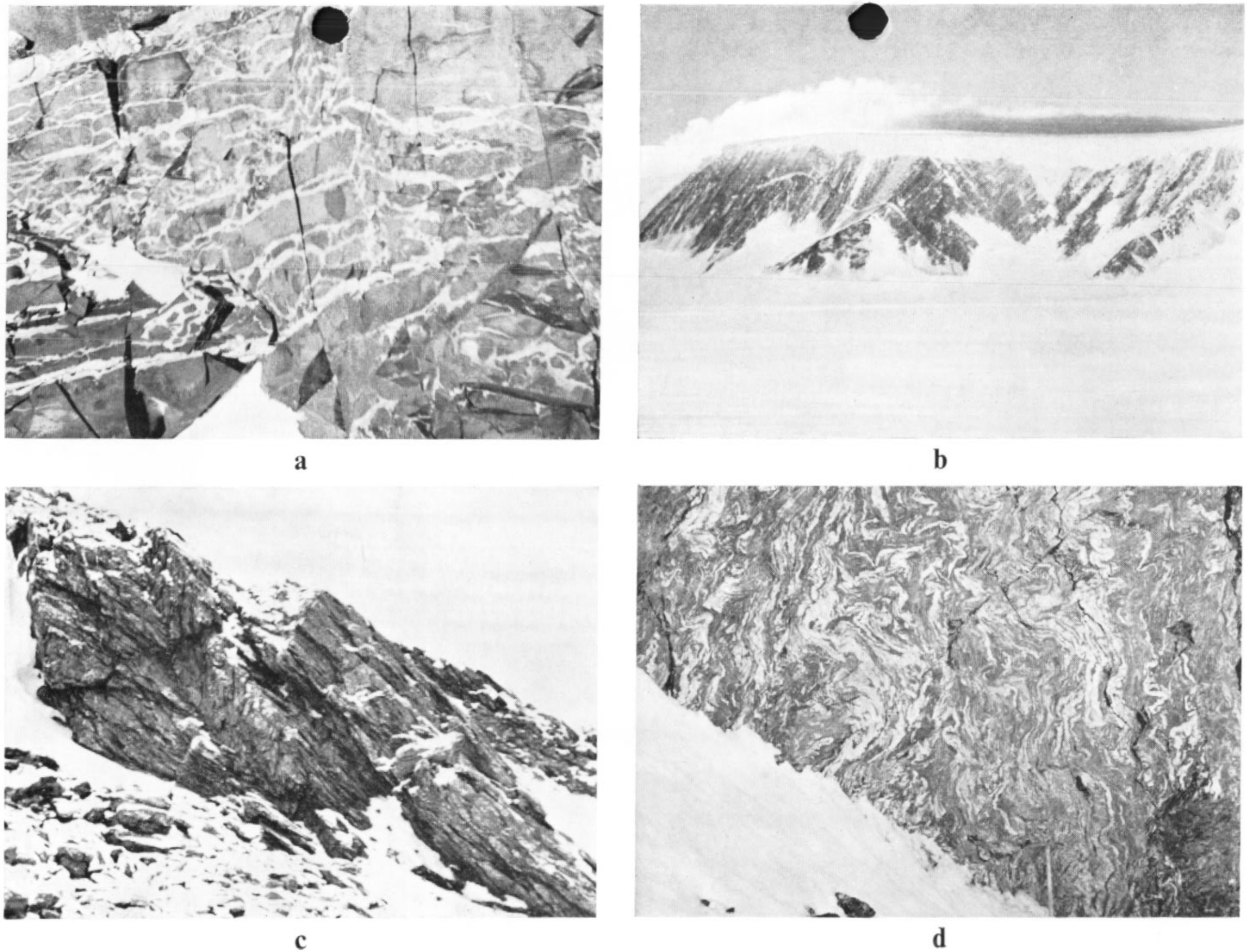


Fig. 14.

The xenoliths are too tightly packed in many of the sills for their emplacement as crystallized material, and the textures and mineralogy exclude their derivation from the wall rocks. The fine-grained margins, variolitic texture and skeletal plagioclase are the criteria for the chilling of basic magma against acid (Bishop, 1963, p. 291) and the contact zones are best explained as reaction between acid magma and solid basic rock. Thus the xenolith-bearing rocks are the result of the simultaneous intrusion of acid and basic magma, with some transfer of material to account for the mineralogy of the basic component and with later reaction between the chilled margin of the basic rock and the still liquid acid magma.

Other rocks. Rocks at one other outcrop (D.4828) have features which resemble those described above. The main mass of the basic rocks is a metasomatized quartz-bearing hornblende-gabbro (p. 23) but the junction with the quartz-diorite exhibits effects that suggest the simultaneous emplacement of two magmas. The quartz-diorite has an irregular contact which veins the gabbro and it does not have a chilled margin. The margin of the gabbro is a plagioclase-hornblende-hornfels, which, like the hornfels at station D.4825, has neither a variolitic texture nor skeletal plagioclase. The mineralogy and texture suggest a metamorphic rock but the absence of a chilled margin to the quartz-diorite implies there has been simultaneous intrusion.

Acid intrusions

The younger acid rocks can be divided into two distinct groups on their megascopic and microscopic characteristics. The group north of Drygalski Glacier is white and coarse-grained, whereas the group south of Drygalski Glacier is pink and medium-grained. The slower cooling of the first group of rocks, which caused the coarse grain-size, also facilitated the inversion of orthoclase to microcline which is relatively uncommon in the second group. A third group may be represented by an inaccessible buff-coloured intrusion south of Drygalski Glacier between stations D.4825 and 4826. Hypabyssal rocks have not been recorded cutting the acid intrusions.

North of Drygalski Glacier

Field description. The northern group of acid intrusions are light brown or grey in the field but white in the hand specimen. Bekker Nunataks are composed of granodiorite, whereas the outcrop to the north-west and the intrusion exposed in the plateau scarp south-west of Fender Buttress are granites. These rocks are intruded into the Trinity Peninsula Series and the granodiorite encloses rafts of the country rocks (p. 9; Fig. 5d). The contacts are sharp except where narrow veins have been injected parallel to the schistosity of the country rocks (D.4803). The form of the two intrusions of this group cannot be delineated, but there is evidence of considerable extension not far below the surface, because thermal metamorphic biotite is present in two sandstones from Fender Buttress (p. 8) and in the schists west of Ruth Ridge (p. 8). There is no sign of flow banding.

Petrography. The medium-grained *granodiorite* (D.4844.1) has a granitic texture and is composed of quartz, plagioclase, alkali-feldspar and biotite, all of which, except the alkali-feldspar, tend to occur in aggregates. A modal analysis is given in Table II (analysis 10). Individual grains are between 1·0 and 7·0 mm., and the aggregates of quartz crystals are up to 10·0 mm. across. Undulose extinction in the quartz crystals is uncommon. Oscillatory zoning is present in a number of single plagioclase crystals and it also shows that composite zoned crystals coalesced during growth. Multiple albite twinning in some crystals gives a composition of $Ab_{61}An_{39}$, whereas zoned crystals in which narrow albite twin lamellae are devoid of zoning, have a composition range $Ab_{62}An_{38}$–$Ab_{78}An_{22}$ (Fig. 15a). Broad primary twin lamellae are uncommon. Thin rims of albite separate some plagioclase and alkali-feldspar crystals. Both orthoclase- and microcline-microperthite are present and they are always surrounded by albite and myrmekite grains, both of which also replace them (Fig. 15b). Biotite crystals are common and a few are bent, indicating a little post-crystallization stress. There is a little accessory muscovite, apatite and allanite. The plagioclase–alkali-feldspar relationships are typical of the granites.

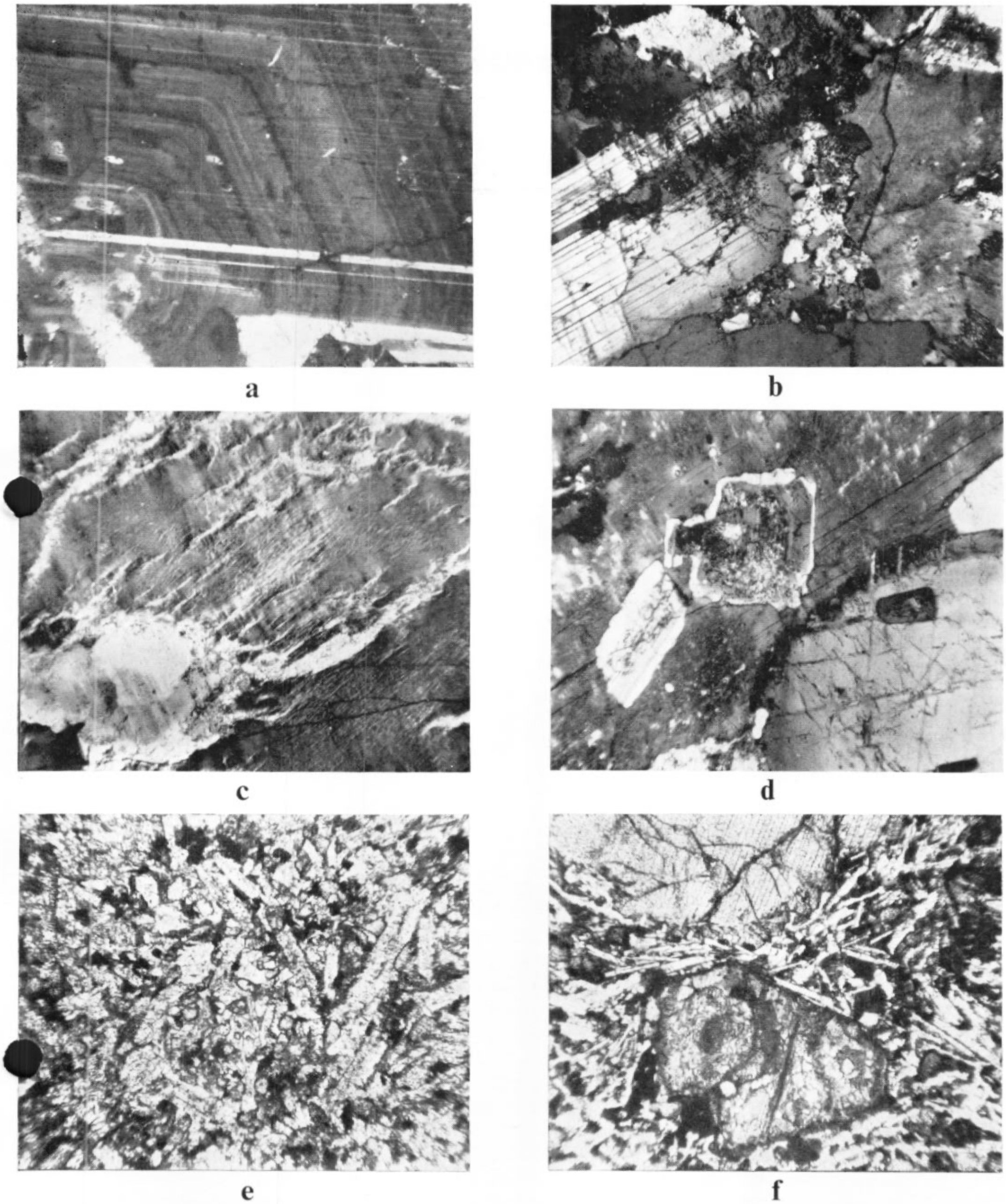


Fig. 15. a. A zoned plagioclase crystal with new unzoned twin lamellae (white); near Bekker Nunataks (D.4844.1; X-nicols; ×35).

b. Granular albite and myrmekite separating alkali-feldspar and plagioclase; near Bekker Nunataks (D.4844.1; X-nicols; ×35).

c. Film and braid perthite coalescing to albite-twinned patch perthite; west of Fender Buttress (D.4814.1; X-nicols; ×35).

d. An albite rim (white) on a plagioclase crystal within alkali-feldspar and an albite rim (in extinction) on a plagioclase crystal in contact with the latter; west of Ruth Ridge (D.4802.1; X-nicols; ×35).

e. Augite (high-relief rounded grains), altered plagioclase laths and interstitial chlorite and iron ore in a dolerite; south-west of Drygalski Glacier (D.4822.6; ordinary light; ×35).

f. An augite phenocryst (top) and an olivine pseudomorph (bottom) in a matrix of plagioclase laths, augite and iron ore; south-west of Fender Buttress (D.4816.3; ordinary light; ×35).

The coarse-grained *granites* (D.4802.1, 4814.1) have granitic textures and are composed of alkali-feldspar, quartz and plagioclase. Modal analyses are given in Table II (analyses 11 and 12). The grain-size is about 6·0 mm. but there are a few coarser crystals up to 13 mm. Some of the quartz crystals have a slight undulose extinction. Both orthoclase and microcline are microperthitic and the exsolved twinned albite crystals ($Ab_{90}An_{10}$) are in film, braid and patch-perthite intergrowths of which the first two, in a few cases, coalesce to give the third (Fig. 15c). Many of the individual crystals are separated by strings of small grains of albite ($Ab_{92}An_{8}$), myrmekite and a little quartz. The grains are 0·03–0·25 mm. across and the strings vary from single grains to aggregates 0·5 mm. wide. There is some late-stage replacement by myrmekite. Most of the plagioclase crystals are smaller than those of alkali-feldspar. Many of them have multiple albite twinning which is related to the zoning (Emmons, 1953, p. 41–54) in that where one is present the other is either not well developed or is absent, but this relationship could not have been caused by external stress, because there is little evidence of it in any other crystals. The oscillatory zoning is related to crystallographic form, whereas the normal zoning is related to resorption and crystallization round the corroded crystals. The composition range is $Ab_{68}An_{32}$ zoned to $Ab_{94}An_{6}$. Where it is in contact with alkali-feldspar, the plagioclase has either an albite rim with twin lamellae continuous from core to margin or is separated by granular myrmekitic albite ($Ab_{92}An_{8}$). A similar arrangement occurs in crystals poekilitically enclosed in alkali-feldspar (Fig. 15d) and some of those crystals are heavily sericitized and more basic ($Ab_{64}An_{36}$). The granular albite, myrmekitic albite and quartz which separate the alkali-feldspars, and the albite rims and myremekite between plagioclase and alkali-feldspar are attributed to late crystallization from the magma (Rogers, 1961). The accessory minerals include deep brown biotite, muscovite, rare apatite, magnetite and slightly pink garnet. The garnet ($n = 1 \cdot 813$), probably a member of the almandine-spessartine series, has a little alteration to chlorite. A contact specimen (D.4803.3) has, in addition, andalusite crystals which are partially altered to muscovite. The garnet and andalusite both indicate the assimilation of argillaceous sediment.

South of Drygalski Glacier

Field description. The southern group of acid intrusions are pink in the field and in the hand specimen. The Tillberg Peak intrusion is an adamellite, whereas the other intrusions to the west are granites. They are intruded into the Trinity Peninsula Series, the gabbro tentatively assigned an early Mesozoic age (p. 10) and the gabbros of the early basic phase of the Andean Intrusive Suite. The contacts are sharp (Fig. 16) and xenoliths have not been found. The form of the intrusions cannot be delineated; the intrusion at Tillberg Peak is overlain by Trinity Peninsula Series schists but elsewhere the accessible contacts are at least 2,000 ft. (610 m.) below the roofs of the intrusions. There is no sign of flow banding.

Petrography. The intrusion at Tillberg Peak is a slightly pinkish medium-grained (1·0–5·0 mm.) *adamellite*. Modal analyses are given in Table II (analyses 13 and 14). The microscopic properties of these rocks differ only slightly from those of the northern group. The intrusion adjacent to a contact (D.4835.1) is closest in mineralogy and texture to the other group of rocks. Microcline-microperthite forms a smaller proportion of the total alkali-feldspar and oscillatory zoning is inconspicuous in the plagioclase, much of which has multiple albite twinning. The composition is $Ab_{76}An_{24}$ zoned to $Ab_{95}An_{5}$. Other properties are similar.

Away from the contact the intrusion (D.4841.1) differs mainly in that microcline is absent and the orthoclase-microperthite is heavily sericitized. Multiple albite twinning is common in the plagioclase crystals which have normal zoning only and a composition range $Ab_{76}An_{24}$–$Ab_{84}An_{16}$. There is some replacement of the plagioclase by alkali-feldspar. Granular albite and myrmekite separate feldspar crystals as in the rocks of the northern group, but there are rare instances of replacement by alkali-feldspar which shows that the metasomatic alkali-feldspar was introduced after the crystallization of the intrusion.

The outcrops west of Tillberg Peak are pink medium-grained *granites*. Modal analyses are given in Table II (analyses 15 and 16). Microscopically (D.4820.1) there is a granitic texture composed of heavily sericitized alkali-feldspar (up to 7·0 mm.), quartz and some plagioclase. Microcline has not been observed and the alkali-feldspar is orthoclase which has film, patch and braid perthitic intergrowths. The exsolved plagioclase is albite ($Ab_{91}An_{9}$). There is a little

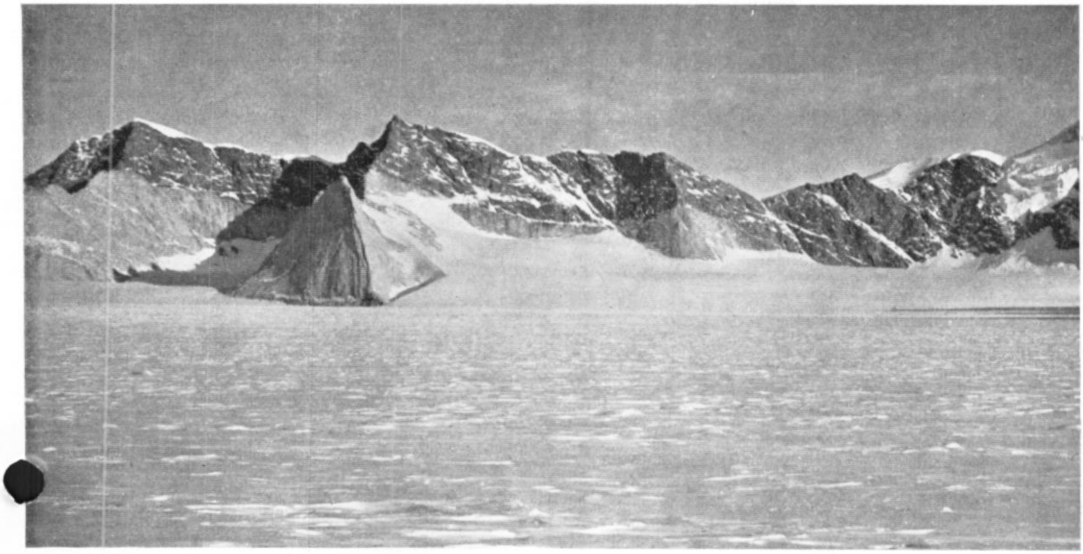


Fig. 16. The roof contact of an adamellite intrusion with the Trinity Peninsula Series; view looking south at a distance of 2 miles (3·2 km.); Tillberg Peak is 1 mile (1·6 km.) east of the viewpoint.

granular albite and myrmekite between the crystals. The plagioclase (up to 3·0 mm.) has multiple albite twinning and slight marginal zoning ($Ab_{78}An_{22}$–$Ab_{92}An_{8}$). Many of the plagioclase crystals enclosed in alkali-feldspar have an albite rim. Replacement of plagioclase by alkali-feldspar is not extensive. The accessory minerals are biotite and muscovite.

The other granites (D.4826.1, 4828.1) are more extensively replaced by alkali-feldspar and the primary orthoclase has neither rims of granular albite and myrmekite nor much exsolved plagioclase, though incipient exsolution is shown by coalescing and diverging braids of more heavily sericitized feldspar (D.4826.1). Much of the plagioclase ($Ab_{77}An_{23}$–$Ab_{85}An_{15}$; D.4826.1) has been almost completely replaced by alkali-feldspar.

Minor intrusions

A number of acid dykes and sills cut the gabbros but mainly at inaccessible outcrops. Two accessible dykes (D.4817.7, 4822.5), both of which are white medium-grained microgranites, have sharp contacts with the country rock, fragments of which are included as xenoliths (D.4822), but they are not xenolithic like a number of sills described with the gabbros (p. 24); it is for these reasons and their proximity to a granite (D.4820.1; p. 28) that they are included with the southern group of acid intrusions.

TERTIARY MINOR INTRUSIONS

Hypabyssal intrusions are not common on the Nordenskjöld Coast. They are basic and intermediate in composition and of varying mineralogy and affinities; they are probably all Tertiary in age but the evidence is not conclusive, because the ages of the intruded rocks are only inferred. There are no consistent strike trends in any group of dykes. Analyses of some of these rocks are included in a paper on geochemistry (Elliot, 1967).

Microgabbros

There are two dykes (D.4804.3, 4817.2) in this group; one (D.4804.3) intrudes the Trinity Peninsula Series and the other cuts the main gabbro intrusion south-west of Drygalski Glacier; they are 2 ft. (0·6 m.) and 5 ft. (1·5 m.) wide, respectively.

The hornblende-microgabbro (D.4817.2) which cuts the main gabbro intrusion (p. 19) is a fine- to medium-grained (up to 1·5 mm.) equigranular rock composed of plagioclase, hornblende and pyroxene. The plagioclase laths ($Ab_{32}An_{68}$–$Ab_{52}An_{48}$) are altered to saussurite, chlorite and epidote, and may have marginal replacement by metasomatic alkali-feldspar. The augite forms aggregates and single crystals, many of which have been magmatically altered to amphibole and now occur as cores to brown, greenish brown and green hornblende. The hornblende has suffered later hydrothermal alteration to actinolite and chlorite. There is much interstitial pale green penninite which has replaced other minerals, and magnetite-ilmenite intergrowths in which the ilmenite has been altered to leucoxene and sphene. Accessory apatite prisms are numerous.

The other dyke (D.4804.3) differs in that the plagioclase is more sodic ($Ab_{41}An_{59}$) and is marginally zoned to andesine ($Ab_{59}An_{41}$). The ferromagnesian minerals are replaced by fibrous actinolite, chlorite, calcite, sphene and quartz, but some biotite is present. A little interstitial quartz is primary but most of it is secondary like the pyrite, chlorite, sphene and abundant calcite.

Dolerites

One dyke (D.4822.6) in the main hornblende-gabbro and several 10 ft. (3 m.) wide intrusions in the Trinity Peninsula Series on the north side of Phoenix Peak are included in this group. These dykes have characteristics which can be matched in the altered microgabbros of the Argentine Islands (Elliot, 1964, p. 19).

Plagioclase phenocrysts (up to 1·5 mm.) are set in an intergranular matrix of plagioclase laths (0·1–0·5 mm.), unaltered augite grains, iron ore and interstitial chlorite (Fig. 15e). The few plagioclase phenocrysts ($Ab_{58}An_{42}$) are heavily altered to sericite, chlorite and calcite; the alteration may have destroyed the original composition. The matrix laths ($Ab_{42}An_{58}$) are similarly altered. The augite grains are unaltered, slightly brownish (D.4822.6 only) and have $\gamma : c = 40^\circ$ and $2V\gamma = 57^\circ$; the latter shows that they are not sub-calcic. A few crystals exhibit a subophitic texture with plagioclase. The iron ore is unaltered in one dyke (D.4822.6) but heavily altered to leucoxene in the other (D.4862.5). The interstitial chlorite is green penninite and there is also a little sphene, calcite and quartz.

The mineralogy is similar to that of spilites in that there is unaltered pyroxene together with altered plagioclase and interstitial chlorite. Battey (1956, p. 103) has pointed out that the quartz-dolerites and tholeiites of Scotland and the north of England have only one pyroxene, a slightly brownish augite which is not sub-calcic. Battey (1956, p. 104–05) has also suggested that spilites might be derived from a tholeiitic magma by the retention of volatiles, the consequent lowering of the temperature of crystallization and the modification of the phases present. It is believed that the unusual mineralogy of these dykes may also be caused by the retention of volatiles; the derivation of these rocks is discussed further in a paper on geochemistry (Elliot, 1967).

Porphyritic basaltic dyke

A 10 ft. (3 m.) wide porphyritic basaltic dyke (D.4817.5), which cuts the main gabbro intrusion, has several features in common with the dolerites. It has a few slightly altered plagioclase phenocrysts (up to 2·5 mm.) in a groundmass of plagioclase laths (0·1–0·3 mm.), augite grains, iron ore and a very fine-grained brown mineral with moderately high birefringence. The composition of the plagioclase phenocrysts is $Ab_{31}An_{69}$ and of the matrix laths is $Ab_{48}An_{52}$. The laths impart a sub-trachytic texture to the matrix. The augite is intergranular and unaltered, and the iron ore is also unaltered. The interstices are filled by the fine-grained brown serpentine mineral, a little quartz and much secondary calcite. Vesicles are filled by the serpentine mineral and calcite, and a little brown hornblende has been generated in the adjacent matrix at the same time. This dyke is similar to the dolerites and the altered microgabbros of the Argentine Islands (Elliot, 1964) in that unaltered pyroxene and iron ore are associated with an interstitial hydrous mineral.

Miocene dykes with alkali-basalt affinities

Two dykes, one basaltic (D.4816.3) and the other a dolerite (D.4875.2), have affinities to the James Ross Island Volcanic Group. They are of interest because rocks allied to that group are rare on the mainland side of Prince Gustav Channel and only nine olivine-dolerite dykes have been recorded from the area to the north-east (Aitkenhead, 1965, p. 20). These dykes may have been feeders for extrusive rocks and the absence of such rocks from the Nordenskjöld Coast and Trinity Peninsula, except for the two outcrops near Broad Valley (Aitkenhead, 1965, p. 19), may only be the result of erosion.

The olivine-basalt dyke (D.4816.3) occurs as a 3 ft. (0·9 m.) wide intrusion in the Trinity Peninsula Series near Fender Buttress. The outcrop is very small and almost covered in frost-shattered debris. The rock is fine-grained and black, but it has a pitted brown-weathered surface. Microscopically, olivine pseudomorphs and clinopyroxene form single crystals and aggregates in a groundmass of plagioclase laths (0·2–0·4 mm.), augite crystals, iron ore grains, interstitial very fine-grained orange-brown and greenish brown minerals (? iddingsite and bowlingite) and secondary calcite (Fig. 15f). Many of the olivine pseudomorphs (up to 4·0 mm.) are euhedral and a few are anvil-shaped; the outline of the pseudomorphs shows that there was little resorption of the original mineral. The olivine has been replaced by a carbonate mineral, talc, yellowish brown iddingsite, and a little antigorite and quartz. The unaltered augite (up to 2·0 mm. across) is faintly pink or pinkish brown and is probably titaniferous. Many of the single crystals have a narrow zoned rim on a rounded core and this rim crystallized at the same time as the groundmass pyroxene. The composition of the plagioclase is $Ab_{39}An_{61}$. A carbonate mineral, probably calcite, forms thin veins in the rock as well as filling vesicles and replacing other minerals.

The basaltic lavas and intrusions of the James Ross Island Volcanic Group are the only comparable rocks. The nearest representatives are the fissure eruptions of the Seal Nunataks and, although the dyke apparently strikes south-west to north-east, the outcrop lies near the trend of the nunataks. This dyke differs from most of the basaltic rocks from James Ross Island in having an only slightly titaniferous augite and olivine completely replaced, though Nelson (1966) has recorded carbonatized olivine in one dyke.

The dolerite dyke (D.4875.2) cuts the Upper Jurassic acid crystal tuffs and agglomerates on the north side of Muskeg Gap, which is comparatively close to James Ross Island. The dyke is at least 30 ft. (9·1 m.) thick but the actual contacts were not visible and the true thickness and attitude of the intrusion are unknown. The dyke is a fine-grained dark grey rock, which, in thin section, has the typical ophitic texture, composed of titanaugite enclosing plagioclase, of a dolerite. The pink titanaugite (up to 2·0 mm.) is neither zoned nor altered. The plagioclase laths (up to 1·5 mm.) are severely altered and the composition ($Ab_{69}An_{31}$) is most unlikely to be original. The alteration is to saussurite and a little dark green chlorite. The abundant ilmenite is almost completely replaced by leucoxene. Pale green penninite fills many interstices and there are also a number of well-crystallized plates of a pleochroic chlorite (α = straw, γ = pale green), which is probably replacing a pre-existing mineral. There are also vesicles filled by prehnite which in some instances is very fine-grained.

At Palisade Nunatak on James Ross Island there is an olivine-dolerite laccolith, some of which has a grain-size similar to the dolerite described here but it contains unaltered olivine (Nelson, 1966). The olivine-dolerites recorded by Aitkenhead (1965, p. 20) differ in having plagioclase phenocrysts and serpentine-calcite pseudomorphs after olivine. He has also noted severe carbonatization which is present in the basaltic dyke but absent from the dolerite (D.4875.2) discussed here.

Hybrid dyke

On the south side of Drygalski Glacier there is a 100 yd. (91·4 m.) wide dyke which has thermally metamorphosed the adjacent schists of the Trinity Peninsula Series. The rock has a sub-trachytic texture and is composed of phenocrysts of feldspar and ferromagnesian minerals set in a bluish grey aphanitic matrix.

The composition of the phenocrysts is remarkable. A high proportion are euhedral laths (0·5–4·0 mm.) of slightly altered labradorite ($Ab_{44}An_{56}$) which have thin rims of alkali-feldspar. There are a number of colourless augite phenocrysts (0·5–1·3 mm.) which are always rimmed by haematite and many have been altered to penninite and actinolite. Hornblende forms a few crystals (up to 1·5 mm.) which are pleochroic from α = straw to γ = bluish green and have $\gamma : c = 20°$; there is some replacement of the hornblende by the minerals of the groundmass. Pseudomorphs (up to 2·6 mm.), consisting of chlorite and actinolite and traversed by cracks from which the minerals grew, might have been derived from orthopyroxene. Those pseudomorphs composed of talc, phlogopite and iron ore were probably derived from olivine. Iron ore forms grains up to 1·0 mm. across and some are partially altered, showing that they were originally magnetite-ilmenite intergrowths; some grains are rimmed by biotite and others by haematite. Apatite prisms (up to 1·0 mm.) are common. The matrix has a grain-size about 0·1 mm. and it consists of plagioclase laths ($Ab_{73}An_{27}$) with interstitial quartz, alkali-feldspar, green hornblende, brownish green biotite and finely divided iron ore. Alkali-feldspar replaces both matrix and phenocryst plagioclase.

This dyke is a hybrid formed by the mixing of acid magma with either basic rocks or partially crystallized basic magma. The age of the dyke is problematical, because it intrudes the Trinity Peninsula Series only. Known periods of acid magma activity are associated with the Upper Jurassic Volcanic Group and the Andean Intrusive Suite. This dyke is more likely to be related to the latter, because of the greater proportion of basic rocks of that age and the occurrence of sills interpreted as the simultaneous intrusion of basic and acid magma (p. 24), though in this case the temperature of the basic component was too low for the development of chilled margins and other associated effects.

STRUCTURAL GEOLOGY

Trinity Peninsula Series

The sediments near Fender Buttress strike approximately north-east but, although the dominant dip is north-westwards, there are local dips towards the south-east. The reliability of the direction of younging deduced from sedimentary structures is not great. Since most of the exposed rock on the south side and to the west of Fender Buttress dips to the north-west (Fig. 14b), it is likely that all the dips towards the south-east are merely local and caused by folding. The presence of isoclinal folding is confirmed by the sediments at two outcrops (D.4807, 4816) which dip to the north-west and are overturned.

The only conclusive evidence of bedding in the metamorphosed sediments is at abrupt changes in rock type, such as from quartzo-feldspathic schist to greenschist. At such an outcrop (D.4845; Fig. 5c) the bedding coincides with the dip of the foliation and the overall dip of the quartz veins in the rocks. The reliable bedding gives high dip angles to the north-west; data based on less reliable bedding give similar values except south of Muskeg Gap where dips towards the south-east have been recorded. Elsewhere, there is no clear indication of bedding though the foliation also dips steeply to the north-west.

Well-defined folds were observed at only one outcrop, near Cape Worsley (D.4850). These are small asymmetric folds; the direction of the plunge (up to 30°) of their axes is between north and north-north-west, and the direction of the steep dip of the axial planes is between west and west-south-west (Fig. 14c). The axial-plane separation (Matthews, 1958) is from 5 to 18 in. (12·7 to 45·7 cm.) and the short-limb height is between 7 and 36 in. (17·8 to 91·4 cm.). The major limbs dip at about 45° in a direction slightly north of west and both the quartz veining and foliation are parallel to those limbs. These folds have the form of kink folds (Turner and Weiss, 1963, p. 114) in which flexural-slip folding is dominant. Very small disharmonic folds occur at almost all outcrops and at many of them they are complex and totally obscure larger-scale effects (Fig. 14d). These folds exhibit thickening and thinning of individual laminae, disharmonic relations between laminae and shearing which truncates the folds (Fig. 17a). The folding shows some features of both flexural-slip and slip or flow folds (Turner and Weiss, 1963, p. 473, 480) but the relations are dominantly disharmonic and there has been slip or flow of the less competent material; these folds are similar to the convolute folds described by Turner and Weiss (1963, p. 115). A simple example, illustrated in Fig. 18a, shows some of the relationships. The overall form is that of similar folding but in detail some laminae show flexural-slip folding and have a concentric form, whereas others show slip or flow folding, disharmonic relations and thickening in the hinge regions. At some outcrops the foliation is more regular, but within the rock there are zones of disharmonic folds exhibiting the same characteristics as described above (Fig. 17b). At these outcrops the fold axes vary in plunge and direction; generally the plunge is less than 30° and the direction is near either south-west or slightly west of north. At a number of outcrops (D.4848, 4857, 4859) there is a form of mullion structure, in which the rocks break up into rod-like bodies defined by intersecting foliations. Turner and Weiss (1963, p. 104) have cited this type of structure as an indicator of the hinge region of large folds and it is probable that the well-defined asymmetric folds (D.4850) are parasitic to larger folds.

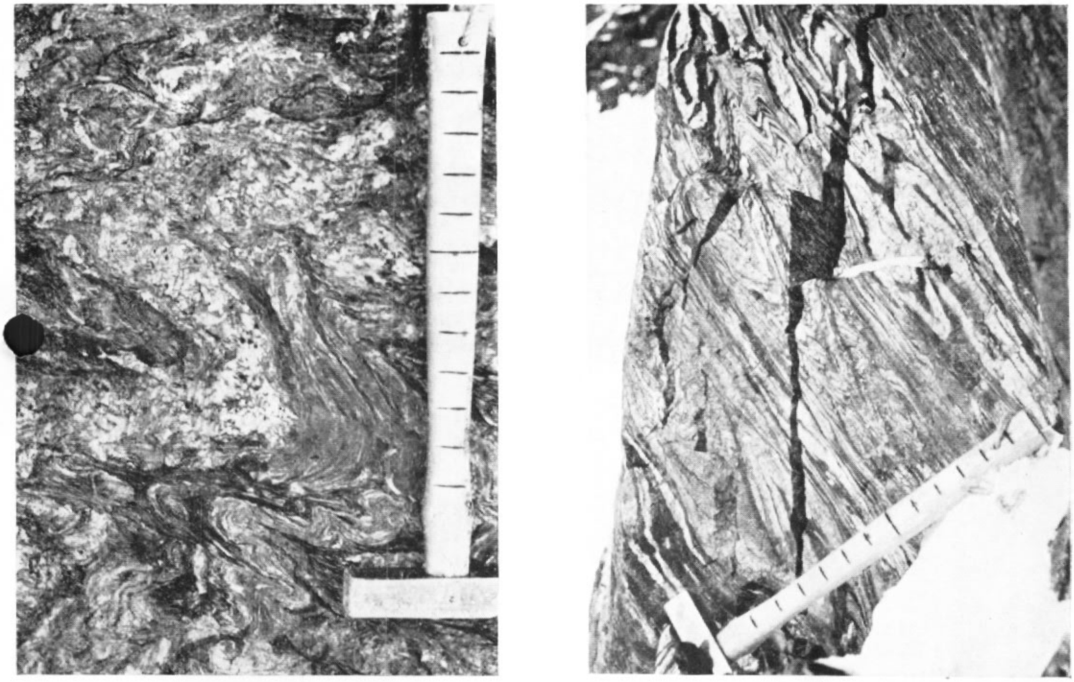


Fig. 17. a. Disharmonic folding in the Trinity Peninsula Series; the scale of the hammer is in inches; view looking south-west; south of Muskeg Gap (D.4869).
b. Disharmonic folding in the Trinity Peninsula Series; the scale on the hammer is in inches; view looking south; south of Drygalski Glacier (D.4827).

At one outcrop near Muskeg Gap (D.4868) there is clear evidence for two phases of folding. The rock, which before metamorphism may have been a laminated siltstone rather than an impure sandstone, exhibits disharmonic folding in two directions nearly at right-angles [illegible]ig. 18b and b′). Aitkenhead (1965, p. 55) has given a possible explanation of a second phase of folding nearly at right-angles to the first phase, which was sub-parallel to the depositional basin, on an extension of Hawkes's (1962) hypothesis on the structure of the Scotia arc. The disruption of the direct link between the Antarctic Peninsula and South America during the eastward migration of the Pacific crust would lead to the arcuate form of the Antarctic Peninsula and compression on its concave side.

Folding is shown by the attitude of some beds near Fender Buttress, the asymmetric kink folds and the variable dip direction south of Muskeg Gap. The mullion structures are also indicators of large folds and it is likely that there is considerably more folding than is apparent from the reconnaissance study of these rocks. On the slender evidence of the asymmetric kink folds, the increase in metamorphic grade from north-west to south-east and the apparent younging to the north-west of the beds near Fender Buttress, there is a major anticlinal axis to the south-east.

Faults are probably present in the Trinity Peninsula Series but they have been concealed by the repetitive lithology and absence of marker horizons; the only clear evidence of faulting which affects the Trinity Peninsula Series is confined to Muskeg Gap (p. 35).

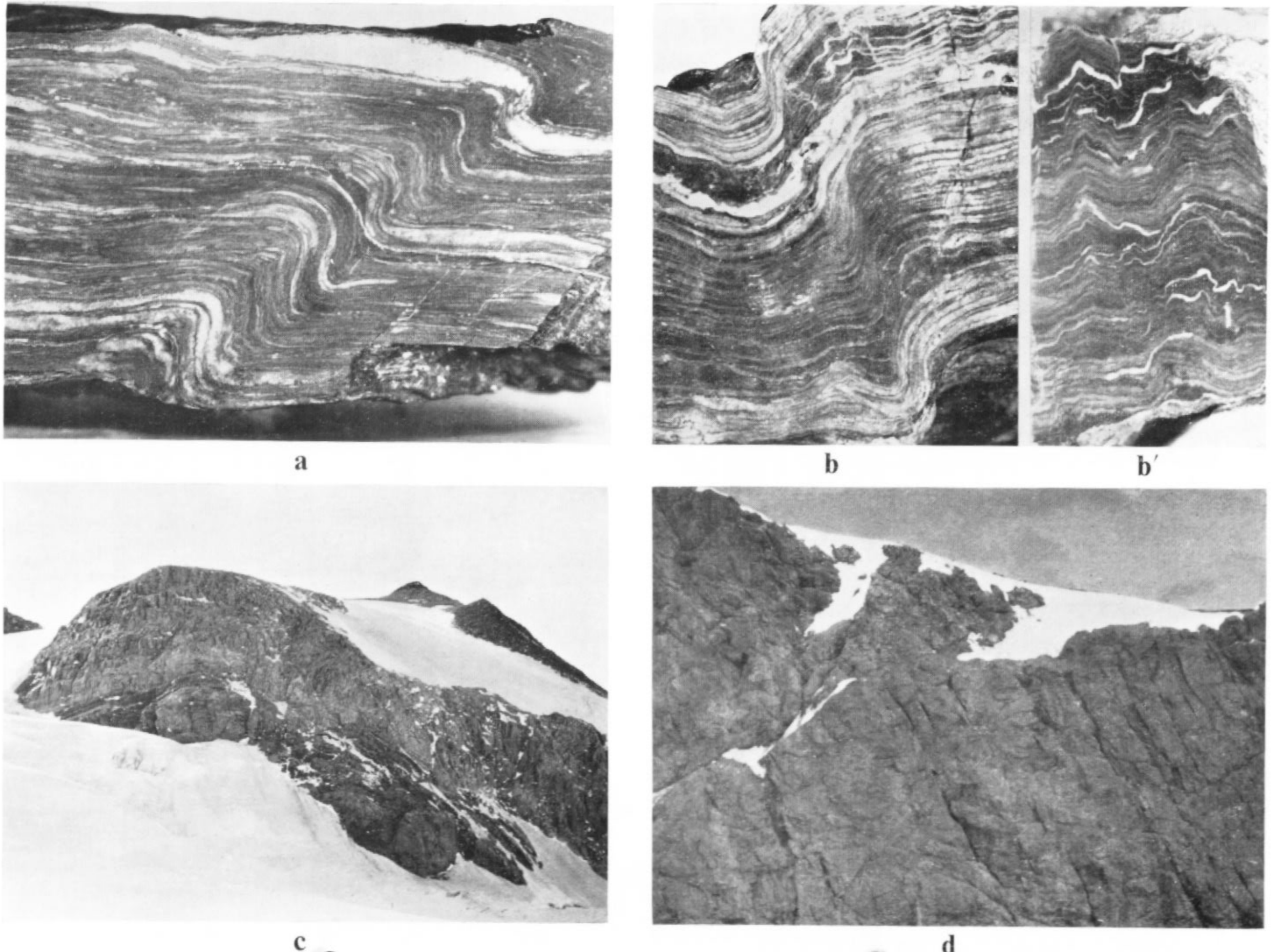


Fig. 18.

It is not possible to give a detailed account of the structure of the Trinity Peninsula Series. Near Fender Buttress most of the sediments dip steeply to the north-west. Isoclinal folding is present and it occurs in the Trinity Peninsula Series north-east of the Nordenskjöld Coast. Between Ruth Ridge and Larsen Inlet the metamorphosed sediments also dip steeply to the north-west at outcrops where the bedding can be proved. Although the foliation and overall dip of the quartz veins elsewhere give similar dip values, there is no proof that they coincide with the bedding as they do where the latter is clear. The absence of bedding and the complex disharmonic folding at most outcrops have prevented the detection of large-scale structures and this precludes anything but broad generalizations about the structure. Two phases of folding, the second at approximately right-angles to the major structural trend, are exhibited at one outcrop only. On the slender evidence of a major anticlinal axis to the south-east, these rocks are considered to form one limb of an anticlinorium.

Upper Jurassic Volcanic Group

There are few dip angles and directions in the rocks of the Upper Jurassic Volcanic Group near Muskeg Gap. The tuffites south-east of Phoenix Peak are well bedded (Fig. 8) and dip steeply towards the south-east. The dip of the bedding of the adjacent Trinity Peninsula Series cannot be determined here but south of Muskeg Gap the dip directions are towards both the north-west and south-east; unless there has been faulting, of which there is no surface expression, it is likely that the contact between the Jurassic rocks and the Trinity Peninsula Series is unconformable. The adjacent outcrops of the Jurassic rocks do not exhibit reliable bedding.

North of Muskeg Gap the lavas are autobrecciated and their bedding is shown only by abrupt changes in brecciation or by the oxidation of the tops of flows (D.4865); the bedding dips gently eastwards. An anticline with a north-east trending axis is visible in the south-west side of one nunatak (Fig. 18c); the bedding on the south-east side of the nunatak (D.4875), away from the visible part of the anticline, is towards the south-east.

The relative heights and dispositions of the rock types suggest that Muskeg Gap is the line of a fault, and that south of Nodwell Peaks the lavas are separated from the pyroclastic rocks to their east by another fault.

Cretaceous sediments

The sediments at the southern end of Sobral Peninsula form a shallow syncline which plunges gently south-westwards (Fig. 19A). The southern limb of the syncline dips more steeply than the northern one. Aerial photographs and field observations from a distance suggest that south-east of station D.4879 the rocks of the next two nunataks are near horizontal and that the nunatak at the south-east corner of Sobral Peninsula is composed of rocks dipping towards the north-west. On the extreme north-western point of the northern limb there is evidence of more intense deformation. The gently dipping northern limb overlies dynamically metamorphosed conglomerates which are in turn underlain by conglomerates, similar in lithology and composition to the overlying unmetamorphosed sediments, dipping at 80° to the west-north-west. A thrust-plane, which separates the metamorphosed conglomerates from the underlying sediments, is marked by a cleft which dips south-eastwards (Fig. 18d).

North-east of the steeply dipping conglomerates there are two outcrops of interbedded sandstones and shales. The sediments at one outcrop (D.4870) dip steeply towards the north-

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Fig. 18. a. An isolated similar fold which shows flexural-slip and slip or flow characteristics; south-east of Ruth Ridge (D.4845.1; × 1·2).

b and b′. Disharmonic folding in the Trinity Peninsula Series; Fig. 18b is approximately at right-angles to Fig. 18b′; south of Muskeg Gap (D.4868.2; × 1·2).

c. An anticline in the Upper Jurassic Volcanic Group; view from the south-west at a distance of about 0·5 miles (0·8 km.); north of Muskeg Gap (D.4874).

d. Thrust-plane (snow-filled cleft dipping to the left) separating metamorphosed conglomerates from the underlying conglomerates which dip steeply to the north-west; view looking south-west; north-west of Mount Lombard, Sobral Peninsula (D.4876).

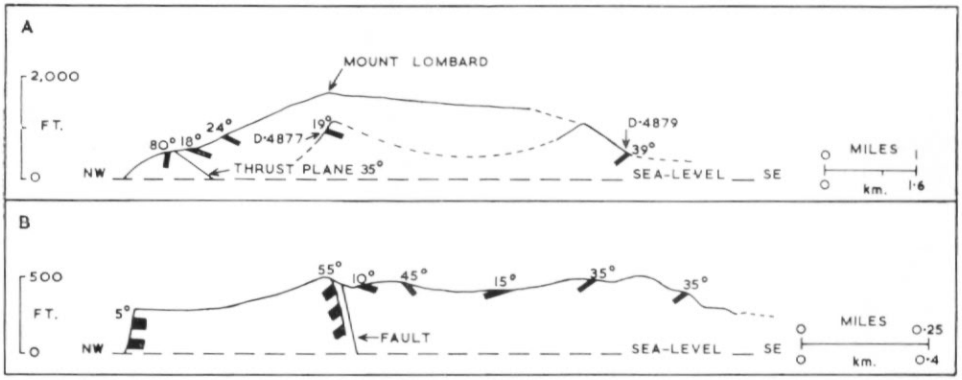

Fig. 19. A. A projected cross-section, seen from the south-west, of part of the southern end of Sobral Peninsula to show the attitude of the beds and the position of the thrust-plane.
B. A projected cross-section, seen from the south-west, of Pedersen Nunatak to show the attitude [illegible] the beds and the position of the high-angle fault. The cross-section can be observed in the field o[illegible] from the north-east.

west, whereas at the other outcrop (D.4878) the major limbs of the tightly folded sediments dip in a direction between south-east and south-south-east. The shales at the second outcrop are friable and the structures are picked out by the more resistant fine-grained sandstones; the folds are not clear but they appear to have short-limb heights of about 30 ft. (9·1 m.) and axial-plane separations of about 20 ft. (6·1 m.).

The change in lithology from the steeply dipping conglomerates to the adjacent sandstone-shale sequence (D.4878) suggests that a fault separates the two outcrops.

At Pedersen Nunatak the sediments form a shallow syncline, the axis of which strikes south-west (Fig. 19B). The north-western part of the nunatak is formed by one limb of another syncline striking in the same direction. A fault must separate the two synclines, because there is a change in lithology and attitude of the beds. On the evidence of thrusting near Mount Lombard, this is either a reverse fault or high-angle thrust.

The tectonic forces which caused the thrusting must also have induced the high dips in the two sandstone-shale sequences; it is possible that the Jurassic tuffites south-east of Phoenix Peak also acquired their high dip angle at the same time. There is no evidence of whether or not the anticline on the north side of Muskeg Gap is related to the structures described above.

Direct correlation between the structures at Pedersen Nunatak and Sobral Peninsula is not possible but clearly they are both expressions of the same tectonic force.

CONCLUSIONS

The only evidence of rocks older than the (?) Carboniferous Trinity Peninsula Series sediments is in the mineral and rock-fragment composition of the sandstones of that succession. A detailed provenance cannot be deduced but sheared granitic rocks together with some acid volcanic and metamorphic rocks formed the source of these sediments.

The Trinity Peninsula Series on the Nordenskjöld Coast has two different aspects; sediments crop out near Fender Buttress but elsewhere they have been transformed into low-grade schists. The sandstones, siltstones and shales near Fender Buttress form an unfossiliferous geosynclinal assemblage of sediments. The absence of fossils and the repetitive lithology prevent correlation between outcrops. The lithology, the few sedimentary structures and the microscopic texture of the sandstones suggest re-deposition of the coarse sediment by turbidity currents. The effects of regional metamorphism are confined to shearing and slight recrystallization, but in many of the sediments any mineralogical changes could well have been concealed by later thermal metamorphism. Sediments in other parts of the Nordenskjöld Coast have been completely recrystallized, except for a few schists with plagioclase blastophenocrysts. The rocks which are not affected by thermal metamorphism are mica-bearing quartzo-feldspathic schists, together with a few greenschists derived from basic igneous rocks, probably lavas. Many of the schist outcrops are traversed by numerous quartz veins and the schists themselves are highly siliceous. The quartzo-feldspathic schists belong to the quartz-albite-muscovite-chlorite sub-facies of the greenschist facies of regional metamorphism. The thickness of the metamorphosed sediments is estimated at (?) 35,000 ft. (10,665 m.) but it is not possible to take fully into account the effects of folding because of insufficient evidence.

The sediments near Fender Buttress dip mainly to the north-west but there are some beds dipping south-eastwards and isoclinal folding is present. The schists, where bedding can be proved, also dip towards the north-west and the foliation has a similar dip. The asymmetric folding near Cape Worsley, the increase in metamorphic grade from north-west to south-east and the apparent younging of the sediments to the north-west near Fender Buttress, are evidence for a major anticlinal axis to the south-east of the area. Two phases of folding, the second approximately at right-angles to the main structural trend, have been recorded at one outcrop.

Thermal metamorphic effects are slight away from intrusive contacts. The biotite-schists west of Ruth Ridge crop out between the sediments and the recrystallized schists, but they have been thermally metamorphosed and intermediate characters have been destroyed. The biotite-schists have plagioclase blastophenocrysts which show their derivation from impure feldspathic sandstones of the type present near Fender Buttress. These schists are crossed by numerous quartz veins, and the highly siliceous composition of the quartzo-feldspathic schists is probably the result of early quartz veins losing their identity on regional metamorphism.

A gabbro west of Tillberg Peak has been assigned a (?) Lower Jurassic age, because it is believed to be a post-tectonic intrusion associated with the regional metamorphism of the Trinity Peninsula Series, which is Upper Triassic–Lower Jurassic (199–176 m. yr.) in age.

Middle Jurassic sediments have not been found though the tuffites south-east of Phoenix Peak may be transition beds deposited at the onset of vulcanicity. Near Muskeg Gap the Upper Jurassic Volcanic Group comprises autobrecciated andesites, acid crystal tuffs and agglomerates. The relationships between the outcrops are not known, except that south-east of Phoenix Peak pyroclastic rocks succeed the tuffites which are unconformable on the Trinity Peninsula Series, and south of Nodwell Peaks the acid crystal tuffs are overlain by andesite lavas. On the available evidence, the age of the folding of the Upper Jurassic Volcanic Group could be either that of the emplacement of the Andean Intrusive Suite or that of the Tertiary thrusting on Sobral Peninsula. The volcanic rocks which are exposed near Tillberg Peak include acid crystal tuffs similar to those present at the only outcrop examined. The Upper Jurassic intrusions are microdiorites and porphyritic microgranites.

The former existence of Lower Cretaceous sediments on the Nordenskjöld Coast is shown by the angular shale fragments in the Upper Cretaceous conglomerates of Pedersen Nunatak. These Upper Cretaceous sediments are mainly conglomerates but there is a small proportion of finer sediment. The composition of the pebbles and the mineralogy of the sandstones show that the rocks were derived from the Upper Jurassic Volcanic Group and subordinately the Trinity Peninsula Series.

The late Cretaceous to early Tertiary Andean Intrusive Suite forms a number of large intrusions near Drygalski Glacier and several near Mount Elliott. The first area comprises an early basic phase of hornblende-gabbro and minor quartz-diorite, which forms one large intrusion and several small outcrops, and a later acid phase of at least three separate intrusions, which vary from granodiorite to granite. There are also numerous xenolith-bearing sills formed by the simultaneous intrusion of basic and acid magma. The distribution of metamorphic minerals suggests that some of the intrusions are more extensive than their surface outcrops indicate; the metamorphic grade does not exceed the hornblende-hornfels facies.

The Tertiary minor intrusions are described and their geochemistry is discussed elsewhere (Elliot, 1967). There is some evidence of faulting and strong thrusting near and on Sobral Peninsula, and it is probable that both are Tertiary in age. Pleistocene to Recent moraines are the youngest rocks on the Nordenskjöld Coast.

COMPARISON BETWEEN THE NORDENSKJÖLD COAST AND NORTH-WEST TRINITY PENINSULA

A general comparison between the Nordenskjöld Coast and north-west Trinity Peninsula (Elliot, 1965) is set out in Table III, and the succession is also discussed below in more general terms. The folded Trinity Peninsula Series sediments and the Andean plutonic rocks intruded into them form the backbone of north-east Graham Land, whereas the Upper Jurassic Volcanic Group and Cretaceous sediments lie on its flanks. The Trinity Peninsula Series crops out more extensively than other rock groups and the main differences between these two areas are the result of regional metamorphism. The banded hornfelses occur only in north-west Trinity Peninsula and the Jurassic rocks are so limited in extent in that area that comparisons cannot be drawn. The shallow-water Upper Cretaceous sediments of the Nordenskjöld Coast contrast markedly with the geosynclinal sediments (believed to be of a Lower Cretaceous age) of Cape Legoupil, north-west Trinity Peninsula. The Andean Intrusive Suite has the same general characteristics in both of these areas but on the Nordenskjöld Coast it differs in that the intrusions are larger, gabbros are present and external shearing-stress effects are slight. The Tertiary minor intrusions are discussed elsewhere (Elliot, 1967). Aitkenhead (1965) has described the geology of the area between the Nordenskjöld Coast and north-west Trinity Peninsula.

Trinity Peninsula Series

The Trinity Peninsula Series is a thick sequence of unfossiliferous sediments, together with a few greenschists. There are (?) 35,000 ft. (10,665 m.) of sediments on the Nordenskjöld Coast and at least 12,000 ft. (3,660 m.) in north-west Trinity Peninsula. The correlation of outcrops is not yet possible, because of the repetitive and monotonous lithology, and the absence of fossils.

The lithology of the sediments near Fender Buttress (p. 3) is comparable with that of north-west Trinity Peninsula, except for the absence of pebbly shales and a greater proportion of sandstone. The sandstones in north-west Trinity Peninsula are immature, bimodal plagioclase-arenites (Elliot, 1965, p. 7, fig. 5) and they form about half of the succession; thin-section analysis of the Fender Buttress sandstones has not been attempted, because of the corrosion of the sand-sized grains. Other sediments on the Nordenskjöld Coast (p. 5) have been metamorphosed but they were probably feldspathic sandstones and argillaceous beds. From the mineralogy of the sandstones near Fender Buttress their deduced provenance is similar to that of the sediments in north-west Trinity Peninsula. The severity of the metamorphism of the other Nordenskjöld Coast sediments precludes detailed provenance deductions.

The pre-Upper Jurassic regional metamorphism of the sediments is the most important factor in a consideration of the differences between the two areas. In north-west Trinity Peninsula the metamorphism is expressed in the argillaceous beds as a slaty cleavage, and in the coarser beds as intergranular shearing and a little recrystallization of the matrix. South-west of Russell West Glacier there is more corrosion of the clasts and recrystallization of the matrix, and a few of the rocks have been transformed into schists though these are localized and possibly caused by faulting. The sediments near Fender Buttress are similar but the intensity of shearing, corrosion of the clasts and recrystallization of the matrix is greater, although some of the latter two features may have been caused by superimposed thermal metamorphism. The increase in metamorphic grade from north-east to south-west, detected in the less metamorphosed sediments, is present in the Nordenskjöld Coast schists when they are compared with outcrops to the north-east (Aitkenhead, 1965, p. 40). All the schists belong to the greenschist facies of regional metamorphism and they contrast markedly with the sediments to the north-west near Fender Buttress.

Near Pettus Glacier and Mount d'Urville, north-west Trinity Peninsula, the steep dip of the sediments is to the north-west and slightly west of north, respectively, but elsewhere, particularly near Misty Pass and north of Laclavère Plateau, the strike of the rocks is very variable and at some outcrops the beds are overturned. These sediments form the north-west limb of an anticlinorium. Disharmonic folding is present both in the schists and at outcrops near the core of the folding in Louis-Philippe Plateau. The sediments near Fender Buttress

Table III. Comparison of the rocks of north-west Trinity Peninsula and the Nordenskjöld Coast

		North-west Trinity Peninsula	*Nordenskjöld Coast*	
			Fender Buttress	*Ruth Ridge–Phoenix Peak*
Tertiary dykes	*Composition*	Dolerite (?) tholeiitic	Basic dykes (alkaline affinities) Porphyritic basaltic dyke (?) calc-alkaline Dolerites (?) tholeiitic Microgabbros (?) calc-alkaline	
Andean Intrusive Suite	*Distribution*	A few isolated outcrops but may be part of a larger intrusion	Extensive outcrops; at least four major intrusions	
	Composition	Tonalite to granophyre	Acid phase: granodiorite to granite Basic phase: hornblende-gabbro, a little quartz-diorite; rocks formed by the simultaneous intrusion of basic and acid magma	
	Stress	Much post-crystallization stress	Little external shearing stress	
Cretaceous sediments	*Lithology*	Geosynclinal sediments	Shallow-water, mainly conglomeratic	
	Age	(?) Lower Cretaceous	Upper Cretaceous	
Upper Jurassic Volcanic Group	*Intrusive rocks*	Quartz-plagioclase-porphyry dykes; porphyritic andesite dyke	Microdiorite and porphyritic microgranite intrusions	
	Volcanic rocks	Isolated acid crystal tuffs	Andesite lavas, acid crystal tuffs, agglomerates	
	Sediments		Tuffites	
(?)	*Lithology*	Banded hornfelses		
(?) Early Mesozoic	*Composition*		Gabbro	
Trinity Peninsula Series	*Lithology*	Sandstones, siltstones, shales, pebbly shales and greenschists	Sandstones, siltstones and shales	Mica-bearing quartzo-feldspathic schists, biotite-schists and greenschists
	Provenance	Sheared granitic rocks, intermediate to acid volcanic rocks, metamorphic and sedimentary rocks	Sheared granitic rocks, volcanic rocks and rare metamorphic rocks	Cannot be deduced but the schists are feldspathic
	Regional metamorphism	Intergranular shearing; local recrystallization	Intergranular shearing local recrystallization	Strong foliation; greenschist facies of metamorphism
	Structure	Steeply dipping; local minor folding	Steeply dipping; isoclinal folding	Steeply dipping; intense minor disharmonic folding

strike north-east but the dip direction, although variable, is mainly to the north-west and isoclinal folding is present. The schists in other parts of the Nordenskjöld Coast also dip steeply to the north-west where bedding can be proved and elsewhere the foliation has a similar orientation. The absence of bedding and the complex disharmonic folding have obscured large-scale structures, although there is some evidence for a major anticlinal axis to the south-east of the area, and the rocks would then form the north-west limb of an anticlinorium. Aitkenhead (1965, p. 53) has reported a synclinal axis between Alectoria Island and Mount Roberts, south-east of the northern end of Detroit Plateau, and that the axis can be detected in the outcrops north-west of Mount Wild. It is probable that the schists on the Nordenskjöld Coast are part of the same anticlinorium, of which the north-west limb has been observed on Alectoria Island and near Mount Wild. The sediments in north-west Trinity Peninsula are part of the north-west limb of the other anticlinorium north-west of the synclinal axis. It is therefore inferred that the folding of the sediments led, not to a single anticlinorium, but at least two arranged *en échelon.*

An Upper Triassic–Lower Jurassic age (199–176 m. yr.) has been determined by the K/A method for micas from the Basement Complex of the South Orkney Islands (Miller, 1960) and this has been inferred as the age of the deformation of the unconformably overlying Greywacke-Shale Series which has several characteristics in common with the Trinity Peninsula Series (Aitkenhead, 1965, p. 56). The folding of the latter can tentatively be given a similar age. One feature of this orogeny is the absence of syn-kinematic intrusions but it is possible that the gabbro intrusion near Tillberg Peak is post-kinematic in age. This inference could cast doubt on the age of any intrusion which cannot be proved to be younger than the Upper Jurassic Volcanic Group.

Banded hornfelses

The sequence of comparatively flat-lying banded hornfelses in north-west Trinity Peninsula (Elliot, 1965, p. 15) is important, because it is an additional formation to the stratigraphy. The banded hornfelses cannot be dated with any precision, but there is some evidence of their place in the stratigraphic column. The hornfelses have not suffered the same regional metamorphism as the adjacent Trinity Peninsula Series and, as large-scale thrusting is absent, they must be later than the probable early Mesozoic folding of those sediments. The hornfelses are cut by "quartz-plagioclase-porphyry" dykes which have petrographic affinities to many Upper Jurassic acid dykes. Unless there is more than one andesite-rhyolite volcanic association in Graham Land, they must be Lower or Middle Jurassic in age. There is also a 2,000 ft. (610 m.) succession of banded hornfelses on the south-east side of Detroit Plateau (Aitkenhead, 1965, p. 11), which is older than the adjacent Andean intrusion and differs from the Trinity Peninsula Series in the absence of sandstones, and the even and relatively undeformed nature of the bedding.

The suggested derivation from a thick sequence of alternating fine laminae of argillaceous and quartzo-feldspathic sediment requires a period of great stability in the Lower to Middle Jurassic. Outside the Antarctic Peninsula, pre-Upper Jurassic sedimentation is represented, probably, in the Cumberland Bay Series of South Georgia (Trendall, 1959, p. 44), which is a geosynclinal succession containing a high proportion of volcanic material; at Ablation Point, Alexander Island (Adie, 1964, p. 310-11), where it is probably estuarine and of Middle Jurassic age; and in the South Orkney Islands, where some Cretaceous conglomerates contain plant-bearing sandstone boulders also of Middle Jurassic age (Adie, 1964, p. 308). However, none of these successions is comparable with the banded hornfelses. In Trinity Peninsula, Middle Jurassic sediments have been found at Hope Bay and Botany Bay, where they are lacustrine and estuarine, respectively (Adie, 1964, p. 310–11). It is possible that the banded hornfelses are thermally metamorphosed sediments of that age and part of a different depositional basin, though the derivation of the Middle Jurassic sediments from the Trinity Peninsula Series implies a landmass in the areas where the banded hornfelses are found.

Jurassic rocks

In parts of north-east Graham Land other than the Nordenskjöld Coast and north-west Trinity Peninsula, there are lacustrine or estuarine sediments of Middle Jurassic age (Adie, 1964, p. 310–11). On the Nordenskjöld Coast there is evidence only of slight down-warping and the deposition of tuffite beds at the onset of vulcanicity.

Acid pyroclastic rocks form a few outcrops in north-west Trinity Peninsula and, although acid crystal tuffs crop out on the Nordenskjöld Coast, there is little evidence for useful comparison with the latter area's more varied lithology of tuffites, agglomerates, acid crystal tuffs and andesite lavas. The pyroclastic rocks and lavas near Muskeg Gap are comparable with the Upper Jurassic Volcanic Group north of Longing Gap (Aitkenhead, 1965, table III). The "quartz-plagioclase-porphyry" dykes south of Aureole Hills are equivalent to the porphyritic microgranite intrusions of the Nordenskjöld Coast, and intermediate rocks are represented by a porphyritic andesite dyke south-west of Poynter Col and the coarser-grained microdiorites near Tillberg Peak.

Cretaceous sediments

Sediments of Lower Cretaceous age have been reported from Cape Legoupil, north-west Trinity Peninsula (Halpern, 1964). These sediments contrast markedly with other Lower Cretaceous sediments, and in lithology, mineralogy and structural disposition they are more similar to the Trinity Peninsula Series.

Lower Cretaceous sediments are known from Alexander Island (Adie, 1964, p. 311) and Annenkov Island, South Georgia (Trendall, 1959, p. 4). The former existence of sediments of this age in northern Graham Land is indicated by the angular shale fragments in the Upper Cretaceous conglomerates of the Nordenskjöld Coast, but the disposition of the sedimentary basin can only be inferred to lie to the north-west of the conglomerate outcrops. Bibby (1966) has suggested the probability of now eroded Lower Cretaceous sediments comprising ferruginous sandstones, shales and mudstones, which were derived from Jurassic rocks.

Uplift terminated the Lower Cretaceous (Aptian) sedimentation elsewhere and was followed by down-warping on the east coast of Graham Land which has no preserved rocks of an age between the close of the Upper Jurassic vulcanicity and the Upper Cretaceous. Subsequent erosion of the uplifted area led to the deposition of the Upper Cretaceous (Lower to Middle Campanian) sediments of north-east Graham Land. Close to the uplifted areas the sediments were all shallow-water and conglomeratic but passing upwards and away from the land the sediments are finer-grained. The source of the Upper Cretaceous conglomerates of the Nordenskjöld Coast was mainly the Upper Jurassic Volcanic Group and subordinately the Trinity Peninsula Series, but there are also angular shale fragments of possible Lower Cretaceous age.

Andean Intrusive Suite

In north-west Trinity Peninsula, the Andean Intrusive Suite forms a number of isolated outcrops and the plateau edge near Aureole Hills, which may be part of a larger intrusion extending to the south-east side of Detroit Plateau (Aitkenhead, 1965, p. 17). The composition of the intrusions on the north-west side of the plateau is tonalite to granophyre, but the intrusions near Drygalski Glacier are mainly gabbro, adamellite and granite. The order of intrusion cannot be demonstrated in either area, but the hornblende-gabbro near Drygalski Glacier is definitely older than the adjacent acid rocks. Garnet crystals, which probably resulted from the assimilation of sedimentary rocks, have been found in the acid intrusions north-west of Bekker Nunataks and near Aureole Hills. Post-crystallization shearing stress has affected the intrusions in north-west Trinity Peninsula; stress effects are exhibited in the quartz and biotite, and the relationship of the twinning and zoning in the plagioclase is interpreted similarly. The plagioclase in the acid intrusions near Drygalski Glacier also has this twin and zone relationship but, as there is little sign of external stress in the quartz and biotite, it must have been caused by internal effects. Thermal metamorphism by the intrusions does not exceed the hornblende-hornfels facies and the thermal aureoles are not extensive.

The intrusions can be dated only as post-Upper Jurassic in age, though consideration of the Cretaceous sediments suggests further possibilities. The uplift following the Aptian sediments of Alexander Island and Annenkov Island, and preceding the Lower to Middle Campanian sediments of north-east Graham Land, may have been accompanied by magmatic intrusion. Halpern (1964, p. 336) has recorded a gabbro with an age of 100±20 m. yr. and Scott (1965,

p. 524) a diorite with an age of 94±8 m. yr., both of which are Lower-Middle Cretaceous ages. The stratigraphic break between the Upper Cretaceous sediments on Seymour Island (Adie, 1964, p. 311) and the overlying Lower Miocene sediments may also represent a period of uplift and intrusion. Ages corresponding to this period have been given by Halpern (1964, p. 336) for a quartz-diorite (75±8 m. yr.; late Cretaceous) and by Scott (1965, p. 524) also for quartz-diorites (52·5±2 and 45±5 m. yr.; Eocene). It is of interest to note that there were two Andean orogenies in South America, the first of Albian-Senonian age and the second Oligocene (Jenks, 1956, p. 203, 207).

ACKNOWLEDGEMENTS

I wish to thank members of the British Antarctic Survey station at Hope Bay during 1962 for their invaluable assistance with the field work. Thanks are due to Professor F. W. Shotton for making available the facilities of the Department of Geology, University of Birmingham, and to Dr. R. J. Adie for advice and criticism during the course of the work. I am grateful to members of the British Antarctic Survey and the Department of Geology, University of Birmingham, for stimulating discussion on many aspects of this work.

MS. received 30 March 1966

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