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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 118

Geological Investigations by the Australian National Antarctic Research Expeditions, 1965

BY

D. S. TRAIL, I. R. MCLEOD, P. J. COOK, AND G. R. WALLIS

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SUMMARY

Early in 1965, Bureau of Mineral Resources geologists, seconded to the Australian National Antarctic Research Expeditions, used ship-based helicopters to survey the coastal region in Mac.Robertson Land and Kemp Land, Antarctica.

In Mac.Robertson Land and Kemp Land, charnockite forms the bulk of exposures between longitudes 61°E and 64°30′E, and crops out within the banded gneiss, and at Magnet Bay and Wheeler Rocks. It is principally feldspar and quartz with minor pyroxene, generally uniform, poorly foliated, and even-grained, but porphyroblastic in places. Banded gneiss is predominant between longitudes 56°30′E and 60°E, north of latitude 67°30′S. Bands, up to 10 metres wide, of light-coloured foliated quartz-feldspar gneiss alternate regularly with dark rather massive pyroxene-feldspar gneiss. Quartz-feldspar gneiss forms most exposures examined west of longitude 56°30′E and north of latitude 67°10′S. It is medium-grained and moderately foliated to massive, with thin discontinuous banding in parts. Its boundary with the banded gneiss is possibly transitional. Biotite-garnet-quartz-feldspar gneiss, commonly containing sillimanite and with migmatitic granite, occupies the coast around Taylor Glacier, between the main area of charnockite and the area of banded gneiss. It is typically medium-grained, well foliated, and thinly banded. It appears to be interbanded locally with both charnockite and banded gneiss. Garnetiferous gneisses are a heterogeneous unit forming nunataks at about longitude 56°E, latitude 67½°S. The rocks are principally variants of pyroxene-feldspar gneiss, quartz-feldspar gneiss, biotite-bearing gneiss, and quartzite, with more or less garnet; they range from well banded and well foliated to massive, and may grade into the quartz-feldspar gneiss. The isolated Hansen Mountains are made up of foliated migmatitic granite and biotite-quartz-feldspar gneiss, garnet quartzite, and thick bands of impure marble. Casey Range is predominantly finely banded, fine-grained to medium-grained biotite-garnet-pyroxene-quartz-feldspar gneiss and quartzite, commonly with sillimanite; its relation to the other units is not known.

Basic and ultrabasic dykes cut charnockite, banded gneiss, garnetiferous gneiss, and quartz-feldspar gneiss. Some are foliated and poorly banded; many are metamorphosed. The basic dykes are pyroxene-feldspar rocks, the ultrabasic are predominantly pyroxene. Some are cut by massive pegmatite.

East of longitude 60°E, foliation trends approximately north; the predominant trend west of this meridian is about east-south-east. Large and small near-isoclinal folds are common in the banded rocks. Mylonitic rocks are common throughout the charnockite. Only minor occurrences of metallic minerals were found.

The prominently banded rocks are probably metasediments or metavolcanics. The massive and uniform charnockite and quartz-feldspar gneiss may be metamorphosed igneous rocks or thoroughly recrystallized metasediments. The first discernible metamorphism took place under granulite facies conditions. Later, the rocks were folded, basic dykes were intruded, and some recrystallization occurred under almandine-amphibolite facies conditions.

Samples of sea-floor sediment were obtained at localities unevenly distributed on the continental shelf between longitudes 57°E and 78°E. Much of the ruditic fraction in the one terrestrial glacial deposit examined is absent in the marine sediments. The arenite: lutite ratio averages about 1:1 in marine and possibly lacustrine samples.

INTRODUCTION

The Australian National Antarctic Research Expeditions (ANARE) station Mawson was established in early 1954. A reconnaissance geological survey of the region accessible from Mawson was begun that year by a geologist of the Bureau of Mineral Resources attached to ANARE. This reconnaissance was continued in succeeding years, and in 1961 the wintering geologist commenced systematic geological mapping at a scale of 1:250,000.

It was apparent that, with only the surface transport which was available, travelling would take a very large part of the geologist's time as the mapped area extended farther from Mawson. Another difficulty was that at least one month of summer, the best time for field work, could not be used, because station personnel were relieved at that time. Consequently the 1962 and later parties did not include a geologist.

Those connected with the geological and topographic survey work were agreed that men and facilities could be used most efficiently by mounting a largely self-contained expedition during the summer. But only one ship was then available each summer to relieve four stations, and these operations did not allow sufficient time for such a project.

In mid-1964, the Antarctic Division of the Department of External Affairs (which provides the logistic support for ANARE) learnt that it could charter a second ship for 3 months. An intensive field operation was planned, using several geologists and surveyors, and helicopter transport. The ship's prime function was to relieve Mawson and Davis, but the programme allowed 5 weeks for field work. The main aspect of the geological work was to be extension of the 1961 mapping to the west and south. Other work planned was collection of specimens for isotopic age measurement and palaeomagnetic work, and collection of sea-floor sediment samples. To do this work, the four authors of this Report were seconded to ANARE from the Bureau of Mineral Resources. Wallis is employed by the Department of Mines, New South Wales. His services were made available through the courtesy of the Under-Secretary of that Department, who sanctioned his temporary transfer to the Bureau of Mineral Resources for 4 months.

As much geological work as possible was to be done in the Vestfold Hills while the ship was at Davis, the ANARE station there. (In fact, only two days' work was possible.) The detailed results of this will be reported elsewhere.

The Report is a preliminary one only, modified from an unpublished report by the same authors (McLeod et al., 1966). With a few exceptions, descriptions of thin-sections of specimens are not yet avilable, and petrographic names are based on hand-specimens. The Report deals only with the 1965 mapping, although results of the earlier work, especially that of Trail in 1961, have been used extensively as background information, and are shown on the geological map (Pl. 7).

At the time of writing, study of the samples of sea-floor sediments is not complete, and any conclusions drawn must be regarded as provisional.

Method of Working

Transport in the field was provided by three Bell H47-G2 helicopters, on charter from a Sydney air-charter firm. The DHC-2 Beaver aircraft owned by ANARE was used for trimetrogon photography and to build up fuel dumps for the helicopters; when possible, it was also used to move the field parties. Unfortunately, soon after work began in the Edward VIII Gulf area, the Beaver broke through the sea ice while taking off, and was unusable thereafter. The work was greatly affected by the lack of this aircraft.

The ship was the base for all operations, except those in the vicinity of Mawson. It was moored to the edge of fast ice or large floes near the Jagar Islands, north-east of Edward VIII Gulf, and the aircraft operated from the ice. Weather forecasts were provided by an officer of the Bureau of Meteorology (Mr N. T. Lied), who used data radioed from Mawson (which is a 'mother' station in the Antarctic weather reporting network) and synoptic charts received by 'Seafax' equipment on the ship.

The intention was that the geological work would be done from field camps, which were to be moved from place to place by helicopter. The larger rock exposures were to be traversed on foot, and the smaller and outlying nunataks visited by helicopter. This plan was not adhered to for two main reasons. Firstly the loss of the Beaver aircraft, coupled with the low range, ceiling, and weight capabilities of the helicopters, left inadequate transport; secondly, the time available for work in the Edward VIII Gulf area was reduced by the unusually late break-up of the sea ice and prolonged bad weather. Consequently, although six geological camps were established, much of the work was done by helicopter traverses from the ship, which allowed only a short time on each outcrop.

During the mapping, samples were collected for isotopic age measurements and palaeomagnetic work.

Samples of sediment from the continental shelf were collected as opportunity allowed. Procedures used in this work are described on page 43.

Previous Work

The first geological work in the region was by the British, Australian and New Zealand Antarctic Research Expedition (BANZARE), which in 1930 briefly examined Proclamation Island (200 km west of Cape Boothby) and Cape Bruce (Tilley, 1937). Bertha Island, in William Scoresby Bay, was visited by the Discovery Expedition in 1936 (Rayner & Tilley, 1940).

Mawson was established by ANARE early in 1954, and B. H. Stinear started a reconnaissance of the geology of the region in that year (Stinear, 1956). In the next two years P. W. Crohn reconnoitred the Framnes Mountains and the coastline from Mawson to the Oygarden Group, near Edward VIII Gulf (Crohn, 1959). Stinear visited Galten Island in 1957, and in 1958 I. R. McLeod examined some of the nunataks between Leckie Range and the Framnes Mountains (McLeod, 1959). Outcrops along the northern side of, and west of, Edward VIII Gulf were examined by R. A. Ruker in 1960 (Ruker, 1963).

Systematic mapping, at a scale of 1:250,000, was begun by D. S. Trail in 1961. His work covered the northern Framnes Mountains and most of the coastal outcrops between the Robinson Group, east of Mawson, and Kloa Point, north of Edward VIII Gulf (McCarthy & Trail, 1964; Trail 1967). The 1965 survey extended this mapping.

The Soviet Antarctic Expedition briefly visited the Oygarden Group in 1957 (Ravich & Voronov, 1958), and Mawson in 1959.

The earliest known sampling of bottom sediments in the vicinity of Antarctica was carried out in 1873–1876 by the British 'Challenger' Expedition (Murray & Renard, 1891). In 1898–1899 the German 'Valdivia' Expedition (Murray & Philippi, 1908) carried out oceanographic work between Bouvet Island, Enderby Land, and Archipel de Kerguelen. In 1901, a second German Expedition in the 'Gauss' carried out bottom sampling in the Davis Sea (Drygalski, 1904; Philippi, 1912). The 1911–1914 Australasian Antarctic Expeditions undertook oceanographic work from Australia to Antarctica between longitudes 170°E and 90°E and collected over a hundred bottom samples, mainly to study the recent micro-organisms (Chapman, 1922). An oceanographic programme was initiated by the Discovery Committee (of Great Britain), and between 1925 and 1939 a total of fifteen oceanographic cruises were made, mainly off West Antarctica. Samples of bottom sediment were collected on some of these cruises (Mackintosh, 1936; Deacon, 1939).

In the past decade a considerable amount of oceanographic work has been carried out by the Soviet and United States expeditions. Activities by the United States have been concerned mainly with the waters off West Antarctica. The Soviet work has included the waters of the sector between Enderby Land and Davis (Zhivago & Lisitsyn, 1957; Lisitsyn & Zhivago, 1958).

The bottom sampling dealt with in this report is the first work of its type carried out by Australia in Antarctic waters for many years.

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The Officer-in-Charge of the Antarctic Mapping Branch of the Department of National Development, D'A. T. Gale, and his staff readily supplied maps and other cartographic information. Dr K. A. W. Crook, of the Australian National University, kindly made sedimentological equipment available and offered valuable advice related to study of the sea-bottom sediment.

GEOMORPHOLOGY

THE geomorphology of parts of the area covered in 1965 has been described by McLeod (1959) and Crohn (1959).

The coastal slope of the continental ice sheet occupies most of the area. Most of the Enderby Land peninsula appears to maintain an independent ice sheet, and small independent ice caps have been identified by Crohn covering King Edward Plateau and Law Promontory. Several large islands carry ice caps or small glaciers.

ICE

In 1965 it was observed that the Hansen Mountains appear to present a formidable barrier to the northward flow of the continental ice sheet. The ice is banked up behind the eastern Hansen Mountains in particular to a height of 50 to 100 metres, and where it flows through these mountains, commonly forms steeply sloping ice falls.

A thick blanket of poorly compacted snow lies on large parts of Mount Storegutt, Mount Mueller, Twin Peaks, and other nunataks in their vicinity, on slopes up to 30° from the horizontal. In places it is discharged from the slopes by small hanging glaciers. Broad patches of poorly compacted snow, up to a few kilometres across, also occur on the ice sheet in this vicinity; on harder snow, sastrugi are small or absent and no blue ice was observed, through blue ice is exposed at Mount Kernot and Rayner Peak. The accumulation of snow probably results from the diversion and slowing up of the north-flowing katabatic wind by the northward-rising slope of the ice sheet covering the Enderby Land peninsula.

A similar blanket of snow covers the north-western part of Mount Banfield in the Hansen Mountains. This may have been deposited in a wind shadow produced by the abrupt rise of the south-east side of the mountain.

No large mountain glaciers exist in the coastal exposures or in the inland nunataks examined in 1965, though restricted snow basins feed small glaciers on many higher peaks, and a very small 'misfit' glacier occupies part of a large cirque, about 500 metres in diameter and almost 500 metres high, on the west side of Mount Elliott in the Framnes Mountains.

The many ice streams prominent on the coast are of two types: those which terminate in promontories, and those which terminate in embayments in the ice coast.

The ice streams which terminate in promontories, such as Jelbart, Taylor, and Hoseason Glaciers, have surfaces which rise above the general level of the ice sheet near the coast and which merge with the ice sheet only a few kilometres from the coast; farther inland the ice stream cannot be delineated. These ice streams appear to be constricted in narrow rock valleys, whose walls are exposed at Hoseason and Taylor Glaciers. They are over-supplied with ice and the addition of relatively little more would cause them to overflow and possibly expand at the coast in a large bulge similar to that formed by the ill defined Scoble Glacier, perhaps producing a spectacular local advance of the ice sheet.

The ice streams which terminate in embayments, such as Dovers, Robert, and Wilma Glaciers, have surfaces depressed below the general level of the ice sheet, and can be traced many kilometres inland. They occupy wide and probably deep rock valleys which could carry very much larger quantities of ice than they carry at present.

The constrictions in the valleys of the ice streams terminating in promontories may only be local. However, the absence of well defined drainage channels and drainage basins inland from these glaciers suggests that their valleys are narrow and short, and that they are less mature and relatively minor features compared to the major drainage channels occupied by the ice streams terminating in embayments.

Landforms

Nunataks

Most large nunataks more than a few kilometres from the coastline are peaks or sharp ridges. A few, such as Anniversary Nunataks, Mount Twintop, Baillieu Peak and Mount Pasco, have more gentle, rounded forms.

Cirques

Large cirques, either dry or partly buried by the continental ice sheet, are common in the Framnes Mountains, and buried cirques appear to be outlined by ridge systems in the Nansen Mountains and at Mount Kernot. Bird Ridge has the form of a huge cirque, 7 kilometres across, but it may be a step in the rock surface which has been preferentially eroded by the ice sheet, a pseudo-cirque as described by Gunn & Warren (1962, p. 62).

The rarity of well developed cirques in the higher coastal exposures is striking. Only small cirques are evident on Ufs Island and Kemp Peak. The steep head of the valley east of Stump Mountain may be a cirque or a pseudo-cirque. Its floor is mantled by an apparently thin cover of moraine, some of which has a core of ice. Small amphitheatre valleys on some of the larger islands probably also represent cirques, but generally conditions appear to have been unfavourable for the development of sizable cirques near the present-day coastline.

Coastal erosion surface

An old erosion surface is described by Crohn (1959) as rising from about 35 metres above sea level at Mawson to about 60 metres at Taylor Glacier and about 110 metres at Stefansson Bay (Pl. 1, fig. 2). The many concordant summits on Broka and Havstein Islands, shown as 120 to 140 metres above sea level by Hansen (1946), may represent the westward extension of this surface. Summit plateaux on many islands in the Oygarden Group, and on coastal exposures round the head of Edward VIII Gulf, are shown by Hansen as generally about 110 metres above sea level; these summits may represent a level or gently falling extension of the surface west of Broka Island. Kidson Island has a broad plateau summit estimated by Hansen as 90 metres above sea level, and may be an outlying representative of the erosion surface. The Jagar Islands, whose plateau summits lie about 45 metres above sea level, may also be outlying representatives of the surface.

The southern edge of the erosion surface continues southwards under the ice sheet, for the high rock masses forming Ufs Island, Kemp Peak, Mount Whiteside, and the higher hills of Alphard and Shaula Islands are surrounded by the erosion surface and appear to be monadnocks. They are strike ridges probably formed by particularly resistant rocks. Stump Mountain, Hayes Peak, Tschuffert Peak, and Solitary Nunatak appear to be similar features.

Weathering

On most exposures examined in 1965 the effects of weathering are generally slight. Most rocks are somewhat discoloured on exposed surfaces by patchy iron staining and in a few samples biotite appears to be altered by weathering, but many rocks, particularly those from which ice has recently receded, are quite fresh. Even fragments in moraine are rarely much weathered, and, compared to material described from McMurdo Sound by Péwé (1960), none of this moraine appears to be very old.

'Honeycomb weathering', which is probably a product of wind erosion, occurs in places (Pl. 3, fig. 1), but the cavities are rarely more than a few centimetres across; large cavities like those recorded in the Sor Rondane (van Autenboer, 1964) and in the region of McMurdo Sound (Caillieux, 1962) were not found. The 'honeycomb weathering' tends to be best developed in large areas of exposed rock, such as Stillwell Hills, whose weathering provides sand for wind erosion. It also tends to be better developed in the coarser-grained rocks.

Large exposures of weathered rocks permeated and heavily stained red and yellow by limonite occur within a subcircular area about 3 kilometres in diameter extending from the north end of the Stillwell Hills to Ives Tongue. Most of the weathered rocks are garnet quartzite and biotite-garnet-quartz-feldspar gneiss, though graphite and sillimanite are prominent in gneiss on Ives Tongue.

The degree of weathering varies considerably. In some heavily stained rocks, garnet is comparatively fresh; in other rocks with little staining, garnet has weathered out. Generally biotite is much weathered or has been removed by weathering. Feldspar is commonly dull but is nowhere evidently kaolinized. Large lenses of fresh pyroxene-feldspar gneiss are common in the weathered rocks. The heavy staining and perhaps the weathered appearance of the rocks may result mainly from the decomposition of some mineral particularly susceptible to oxidation, most probably disseminated iron sulphide.

Bands, up to several metres thick, in quartz-feldspar gneiss at Wallis Nunataks, Cook Nunataks, and Mount Mueller, and in biotite-bearing gneiss at Painted Hill in the Framnes Mountains, have weathered and stained surfaces similar to the rocks described above. This staining is again possibly a result of the oxidation of disseminated iron sulphide minerals. Desert varnish was found on the rocks of the outcrop at latitude 66°57'S, longitude 56°14'E, south of Downer Glacier.

Quaternary Deposits

Moraine is relatively scarce on coastal exposures and on inland nunataks examined in 1965. A few raised beaches were noted, none more than 10 metres above sea level. Patches of rock detritus occur in places, accumulated by surface creep locally assisted by intermittent stream action, and fine-grained sediment is accumulating in lakes in the coastal exposures.

Lake Sediment

The beds of small dried-up ponds in the northern Stillwell Hills are composed of poorly sorted green silty and pebbly sand ranging from fine to very coarse. Similar sediment is probably accumulating in the lakes among these hills and in other large coastal exposures and islands; in the lakes the degree of sorting is probably higher than in the ponds.

Stream Sediment

Streams were observed only in Stillwell Hills, in January 1965. They range up to 20 metres in width, but are rarely more than a few centimetres deep. Their sources are generally lakes and they follow more or less braided courses among moraine flooring broad valleys.

The streams remove the relatively fine fraction—silt, sand, and small pebbles—from the moraine and redeposit some of it among moraine where the stream velocity drops. However, much of the load is deposited as small fans where the streams enter lake or sea.

On the floors of gently sloping gullies in Stillwell Hills, elongated bodies of coarse sand and small pebbles, more than 10 metres long and between 15 and 50 centimetres in width, wind downhill around and between boulders. The tops of these bodies are raised up to 15 centimetres above the general level of the rock detritus on the gully floor. They appear to be miniature eskers and no doubt were deposited by meltstreams running in the gullies when they were choked by snow.

These miniature eskers are not regularly repeated, and do not therefore constitute a pattern, but two or three may occur together in a broad gully.

Raised Beaches

A well formed raised beach was observed from a distance in an inlet a few hundred metres west of the crest of Chapman Ridge (Pl. 1, fig. 1). The beach at the head of the inlet corresponds with a distinct notch cut in slabby rock forming a promontory at the entrance to the inlet. This is about 10 metres above present sea level. The beach is probably composed of coarse sand and pebbles and is about 15 metres wide. Probable raised beaches were seen from the air at several other places in the hills and islands in the vicinity of Taylor.

The sea has levelled the top of a fan-shaped deposit of sand, pebbles, and boulders at the mouth of a small valley in the northern Stillwell Hills (Pl. 1, fig. 2). The flat top of the fan is about 6 metres above sea level, and a narrow bench is cut in the fan about 5 metres above sea level. Since the fan lies at the head of a well sheltered inlet, wave action probably took a considerable time to form the platform, about 20 metres wide, forming the top of the fan. The formation of the narrow bench 1 metre below the top of the fan probably occupied a short pause during the fall of sea level.

Rock detritus

Large accumulations of rock detritus occur as scree at the bases of most steep slopes. Only the absence of erratics distinguishes this material from moraine. Relatively fine rock detritus, mostly of pebble size, apparently formed by *in situ* weathering, covers most gentle slopes on Ives Tongue, and in depressions there the finer fraction has been concentrated by intermittent stream action.

A plateau summit examined in Anniversary Nunataks is covered by small boulders to a depth of about 1 metre. A few erratics occur among these, but weathering bedrock nearby appears to be forming the same type of detritus, and the deposit is probably a boulder field, developed *in situ*. Boulders covering the saddle on Mount Twintop appear to reflect the distribution of particular underlying rock types; this debris, also, is probably a boulder field.

Moraine

Crohn (1959) subdivides moraine deposits into an older high-level group deposited when the surface of the ice sheet stood at a much higher level than it now does, and a younger group lying close to the present margins of the ice sheet and evidently recently deposited by it.

Younger moraine noted in 1965 included patches up to several metres thick along the west side of Stillwell Hills immediately adjacent to Dovers Glacier. This moraine is light grey and has a fresh appearance resulting from the presence of a matrix of fine sand, silt, and clay. A large body of light grey younger moraine, about 500 metres long, occurs on ice adjacent to the southern margin of the area of rock exposures at Campbell Head. It is probably a shear moraine deposited from the base of the ablating ice sheet as the sheet rides up a ramp of stagnant ice on the upstream side of the bedrock exposure, as described by Hollin (1962) from Wilkes.

Ice-cored moraine was found in 1965 only in a valley at the east side of Stump Mountain. The moraine is mainly formed by subconical ice-cored mounds about 50 centimetres high and 2 metres across. On steep-sided mounds, some ice is exposed, but generally the ice cores are mantled by material ranging from sand to small boulders, forming a deposit on the ice between 5 centimetres and 30 centimetres thick. One large mound 20 metres in diameter and 3 metres high has a central depression 5 metres in diameter and 1½ metres deep drained through a breach on the north side of the mound. The central depression contains some silt-size material among the moraine on its floor.

Older moraine, in the area examined in 1965, generally occurs as scattered boulders on the slopes and on the summits of exposures both along the coast and in the inland nunataks. Large accumulations of moraine were observed only on the floors of abandoned cirques in the Framnes Mountains. McLeod (1959) records extensive terraces of high-level moraine in Leckie Range. No deposits here approach in extent or thickness the great accumulations of moraine present at high and low levels in the Prince Charles Mountains (Crohn, 1959; Trail, 1964).

Rock detritus flooring valleys in Stillwell Hills and near Stump Mountain appears to be old moraine to which scree shed from the valley walls has been added. It has also been reworked in places by streams originating in small lakes dammed back by the detritus. Bedrock is commonly exposed on the valley floors and generally the moraine cover is probably little more than a few metres thick.

This moraine is generally unpatterned. In one valley in the northern Stillwell Hills, a small group of hummocks on otherwise unpatterned material ranges up to 3 metres high and 10 metres across. They have no ice cores. The large hummocks are composed predominantly of angular boulders up to 1 metre long, and the small hummocks, less than 50 centimetres high, are composed of clay and have cracked apexes. These hummocks may be relics of larger ice-cored structures.

Patterned Ground

Since patterned ground develops only on unconsolidated deposits and these are few and small in the area examined, few observations of patterned ground were made in 1965.

The most common type found is a polygonal pattern of cracks or narrow depressions, typically several centimetres wide by a few centimetres deep, outlining polygons ranging from 2 metres to 10 metres and more across (Pl. 2, fig. 1).

The deposits on which these cracks develop are generally poorly sorted mixtures of coarse sand, pebbles, and small boulders which have accumulated as moraine, as scree, or as products of *in situ* weathering. The cracks forming the pattern generally contain only pebbles and small boulders; the finer fraction is missing. Where large boulders lie on the surface of a deposit the cracks pass round them rather than under them.

In places, particularly on the floors of narrow sloping depressions in the rock surface in which detritus has accumulated, subparallel cracks are present but do not outline polygons. These cracks resemble stream channels and the fine fraction has probably been washed out of them.

Polygonal patterns of cracks were recorded in moraine in North Masson Range, in rock detritus on Mount Hordern and Mount Twintop, in scree on the west side of Casey Range, and on rock detritus in Stillwell Hills and on Ives Tongue.

A second type of pattern observed is the smaller stone circle, observed in Stillwell Hills and on Stump Mountain (Pl. 2, fig. 2). On Kemp Peak, stone circles occur mainly in the beds of dry ponds. Rings, about 15 centimetres thick, of pebbles and cobbles enclose circular patches, about 50 centimetres in diameter, of silt, coarse sand, and small pebbles. The marginal rings are depressed a few centimetres and the higher fine-grained centres have empty radial cracks. Excavation of a circle revealed that coarse marginal material grades downwards into sand and small pebbles (similar to the material in the centre at the surface) at a depth of 30 centimetres. The fine central material passes abruptly at a depth of one centimetre into finer material—coarse sand and silt with few pebbles—which continues to a depth of 15 centimetres. All the material immediately below the surface is saturated with water, and in January this was not frozen at a depth of 30 centimetres.

The stone circles found on Stump Mountain are of similar size to those on Kemp Peak, but are composed of coarser material. They have centres of small pebbles surrounded by rings of small cobbles. Stone circles of this type were found also on gently sloping ground in Stillwell Hills, where their raised centres produce a succession of small terraces, running across the slope.

A few ill defined large fine-centred circles which occur among the thin mantle of debris covering a plateau summit in Anniversary Nunataks in the Framnes Mountains range up to 1½ metres in diameter and contain small pebbles in the centre and boulders in the marginal ring. These circles may be related to low terraces on this material, running along the contours of the gentle slope.

Circular patches of pebbles, between 20 centimetres and 50 centimetres in diameter and raised a few centimetres above the general level of unsorted rock detritus, were found on some islands, up to 40 metres above sea level. They are the nesting sites of skuas or of Adélie penguins and where abundant may be confused with patterned ground.

The large polygons are ice-wedge or sand-wedge polygons, described in Victoria Land by Péwé (1959) and Black & Berg (1964). Since they mostly occur in saturated ground the small stone circles are presumably formed by an ice-wedge mechanism.

GEOLOGY

Regional Geology

On a broad lithological basis, the rocks of the sector can be divided into eight units, according to the predominance of a particular rock type, or the widespread association of particular rock types (Pl. 7). Each unit contains numerous textural, mineralogical, and petrological variants, and a particular specimen could possibly belong to several of the units: the classification depends on overall field characteristics rather than detailed petrology.

The units, and their characteristics, are:

Charnockite: Massive to poorly foliated, medium-grained to coarse-grained, granulitic textured; principally feldspar and quartz and minor pyroxene.

Banded gneiss: Regularly alternating bands, up to 10 metres thick, of light-coloured foliated quartz-feldspar gneiss and dark-coloured rather massive pyroxene-feldspar gneiss; overall, the pyroxene-feldspar gneiss forms about 20 to 30 percent of the unit.

Quartz-feldspar gneiss: Medium-grained moderately foliated to massive, with thin discontinuous banding in parts; predominantly quartz and feldspar; in hand-specimen does not have the granulitic texture and dark colour of the charnockite.

Gneiss of Taylor Glacier: Predominantly medium-grained well foliated thinly banded biotite-garnet-quartz-feldspar gneiss, with migmatitic granite bodies; sillimanite commonly present.

Garnetiferous gneisses: Heterogeneous unit, the components ranging from well banded and well foliated to massive; principally variants of pyroxene-feldspar gneiss, quartz-feldspar gneiss, biotite-bearing gneiss, and quartzite; garnet common in many varieties.

Gneiss, marble, and migmatite of Hansen Mountains: Foliated migmatitic granite and biotite-quartz-feldspar gneiss, garnet quartzite, and thick bands of impure marble.

Pyroxene-quartz-feldspar gneiss of Casey Range: Finely banded fine-grained to medium-grained biotite-garnet-pyroxene-quartz-feldspar gneiss with sillimanite in places, and quartzite.

Basic and ultrabasic dykes: Fine-grained to medium-grained, with dyke form; some foliated and poorly banded; composed of pyroxene or feldspar and pyroxene; many metamorphosed.

Charnockite

The charnockites of Mac.Robertson Land have been described and discussed by Stinear (1956), Crohn (1959), McLeod (1959, 1964b), and McCarthy & Trail (1964); Stinear and Ruker found charnockite in western Kemp Land (Ruker, 1963).

Geologists of the Soviet Antarctic Expedition have sampled the charnockite at Mawson for isotopic age determination (Ravich & Krylov, 1964). The ages of four samples were measured as 490, 535, 555, and 650 m.y.

Here the term charnockite is applied, following Holland (1900), to 'great masses of rock whose two leading characteristics are a granulitic structure and the invariable presence of a rhombic pyroxene amongst the constituents'. However, charnockite is here restricted to those rocks which show little small-scale or large-scale textural or compositional variation. They are separated from the banded gneiss, described below, which is composed of alternating bands of radically different compositions, although many individual bands are granulitic rocks with rhombic pyroxene.

The charnockite is subdivided into *even-grained charnockite*, a type which fits closely the description by Holland (1900), and *porphyroblastic charnockite*.

The earlier work has shown that the charnockite is essentially composed of hypersthene, quartz, and feldspar; it may also contain garnet or biotite; hornblende is uncommon. Its feldspar content is at least 30 percent plagioclase, which ranges from oligoclase-andesine in rocks containing much potash feldspar to labradorite-bytownite in rocks without potash feldspar. The potash feldspar is almost invariably perthitic orthoclase.

The grainsize of the charnockite ranges from medium to very coarse. Quartz and feldspar are equigranular in the even-grained charnockite, and hypersthene and other dark minerals are generally smaller. In the porphyroblastic charnockite, rectangular feldspar crystals, generally between 10 and 50 millimetres long, lie in a groundmass resembling the even-grained charnockite. Both types commonly have a marked foliation, conferred by stringers and lenses of dark minerals and small lenses of felsic minerals; the feldspar porphyroblasts commonly have their long axes oriented parallel to the foliation.

The even-grained charnockite was called charnockitic granular gneiss by Crohn (1959). It has been renamed to separate it more emphatically from the other gneisses.

In Mac.Robertson Land, charnockite forms 90 percent of the bedrock exposures in an area of 10,000 square kilometres around Mawson. Most of this area is covered by ice or sea, but the charnockite appears to extend at least 130 kilometres from Howard Bay in the west to Austskjera in the east, and 80 kilometres from Nelson Rock in the north to Brown Range in the south. The only large exposure of significantly different rocks within the area is formed by the sillimanite-bearing and garnet-bearing gneisses of the Casey Range. Ten other small exposures of biotite-bearing and garnet-bearing gneisses are known within the charnockite outcrop.

Where it is exposed in association with large bodies of significantly different rocks, as at Ufs Island and Chapman Ridge, the charnockite forms high peaks and ridges and the other rocks floor the valleys. Therefore, in the Framnes Mountains in particular, a large proportion of the low-lying bedrock covered by ice within the charnockite outcrop may be composed of other rocks.

Framnes Mountains

All previously unvisited nunataks in the Framnes Mountains were inspected from the air in 1965, and wherever possible representative exposures were examined on the ground. Gneiss outcrops were examined from the air at Phillips Ridge and the nunatak west of Mount Coates, but could not be visited.

Porphyroblastic charnockite with a coarse-grained matrix forms the exposures in the south-east of the Framnes Mountains. It is mostly massive or poorly foliated; a foliation is conferred at Anniversary Nunataks by prominent lenses, typically 2 metres long and 1 metre thick, of fine-grained rock with biotite-rich margins; and at Wakeford Nunatak, a few thin lenses of fine-grained garnet-feldspar rock typically 3 metres long by 30 centimetres thick, and parallel bands of mylonitic crush-rock about 2 millimetres thick, produce a poor foliation. Small light green patches of copper stains occur on this nunatak.

The nunataks forming the south-west part of the Framnes Mountains are composed of even-grained charnockite, ranging from fine-grained to coarse-grained in texture. The rock is commonly massive, but may be foliated. At Mount Tritoppen it contains bands rich in quartz and feldspar, in some of which the quartz has a marked preferred orientation parallel to the foliation of the enclosing charnockite. Diopside forms up to 15 percent (but mostly only 2 or 3 percent) of some bands in the charnockite at Mount Tritoppen.

The even-grained charnockite at Mount Twintop is rich in quartz and poor in pyroxene. Quartz forms up to 50 percent of the rock, and small lenses, lenticles, and schlieren of quartz, up to several centimetres thick, are common. In one exposure, bands of pyroxene-rich charnockite, up to 7 metres thick, alternate with bands of quartz-rich rock tens of metres thick. One distinct band of feldspar-pyroxene rock is at least 60 metres thick, and contains thin irregular veins and patches of quartz and feldspar. Green copper stains are common along the contact of this band with the charnockite. Zones of mylonitic crush-rock up to 20 centimetres thick parallel the strike of the rocks.

At Brown Range, the charnockite contains fine-grained stringers, attenuated lenses, and bands, of pyroxene-rich material. Boudinage is common in the bands; the boudins are about 50 centimetres long.

Baillieu Peak and neighbouring nunataks

Baillieu Peak and the six nunataks within 25 kilometres of it on its eastern side are all composed predominantly of even-grained charnockite.

The charnockite forming Baillieu Peak contains a few bands of pyroxene-rich rock up to several metres thick. The only contact seen of this rock with the normal charnockite is sharp. The charnockite also contains patches of coarse-grained garnet-biotite-quartz-feldspar rock a few metres across, zones of mylonitic crush-rock between 15 and 30 centimetres thick, and one thick vein of coarse-grained quartz-feldspar rock with feldspar crystals up to 25 millimetres long. Small discontinuous quartz-feldspar veins, up to 5 centimetres thick, are commonly sigmoidal or hook-shaped, and in one place outline tight irregular folds, a few centimetres in amplitude, whose axial planes coincide with the foliation of the charnockite. The fold axes pitch 40° southwards and the foliation dips 80° eastwards.

The Satellite is formed by feldspar-rich garnet charnockite containing many lenses of pink garnet-feldspar pegmatite, typically 1 metre by 30 centimetres, with a marked preferred orientation. In places the pegmatite has a migmatitic relationship with the charnockite; irregular patches of one rock type are surrounded by the other, and a complete gradation exists between the two. Similar pink lenses were observed from the air on the small nunatak 2½ kilometres north of Pearce Peak.

At Moyes Peak and Pearce Peak the foliation is marked by streaks of rock rich in feldspar or rich in pyroxene, ranging up to 30 centimetres long by 10 centimetres thick. Many of these streaks appear to be the cores of disrupted small-scale isoclinal folds, whose axes plunge in the dip of foliation. Biotite-quartz-feldspar rock also forms irregular patches. The small nunatak 1½ kilometres south-east of The Satellite is similar to these peaks.

A small nunatak 5½ kilometres north-west of Mill Peak is composed of biotite charnockite, which weathers red in contrast to the normal yellow-brown charnockite, and which contains, in an inaccessible part, prominent white bands up to 3 metres thick. Lenses of mylonitic crush-rock, up to 1 metre long by 30 centimetres thick, are common here.

Outlying islands

The outlying islands off Holme Bay are predominantly charnockite, with the exception of Nelson Rock, which is composed of garnet-quartz-feldspar rock with the texture of coarse-grained, even-grained charnockite. It contains many lenses with a marked preferred orientation, ranging up to 2 metres long by 30 centimetres thick; dark lenses are pyroxene-bearing and appear to be composed of even-grained charnockite; the light-coloured lenses are broadly similar to the host rock.

At Sawert Rocks, feldspar porphyroblasts are so numerous that they are intergrown and form the bulk of the rock; the matrix in their interstices is dominantly garnet and quartz, with small grains of pyroxene associated with the garnet. A band, 20 metres long by 15 centimetres thick, of coarse-grained quartz-feldspar rock with blue quartz cuts the massive charnockite.

Most outlying islands, including Ryrie Rock, between the group 18 kilometres north-north-west of Einstoding Island and the string extending 15 kilometres north-north-west from Stevenson Island, are composed of even-grained charnockite with a clear foliation produced by stringers and lenses of pyroxene-rich rock and by quartz-feldspar lenses. The lenses are generally a few centimetres long, but some reach 2 metres. Garnet or biotite occurs in the charnockite on a few islands, and the westernmost charnockite island, about 18 kilometres north of Taylor Glacier, contains coarser patches with garnet, biotite, and possible hornblende. Thin veins of mylonitic crush-rock are common throughout these islands.

On many islands, the charnockite contains bands and discordant veins, up to 1 metre thick, of yellow-brown coarse-grained quartz-feldspar rock, which form a network in places. Locally these veins carry garnet or pyroxene. In one exposure on Stevenson Island the veins outline isoclinal folds, one of which has its axial plane parallel to the foliation in the charnockite; the axial planes of the others were not determined.

Also on Stevenson Island, the charnockite and quartz-feldspar veins are cut by veins and sheets of red quartz-feldspar granite, which ranges from fine-grained to very coarse-grained. Islands examined from the air north and north-north-west of Stevenson Island appear to be formed by similar interrelated rocks.

Though Kidson Island is surrounded by charnockite exposures, it differs significantly from them in colour and mineralogy. It is composed of grey quartz-pyroxene-feldspar gneiss, with some clusters of garnet, which contains bands of massive biotite-garnet-quartz-feldspar rock with possible cordierite in places.

One of a group of small islands about 10 kilometres north of Taylor Rookery is composed of pyroxene-biotite-quartz-feldspar gneiss in which the biotite is much more abundant than the pyroxene; a nearby island consists of garnet-quartz-feldspar gneiss.

A group of small islands about 10 kilometres north of Campbell Head is composed of dark grey fine-grained garnet-pyroxene-quartz-feldspar gneiss, with a few bands of light grey quartz-feldspar rock. The foliation in these rocks, defined by textural bands between 1 centimetre and 10 centimetres thick and by stringers of dark minerals, is tightly folded in places.

The pyroxene-bearing gneisses described from Kidson Island and the two island groups above differ from the charnockite in their grey colour and their finer grainsize. They resemble more closely rocks forming a large outcrop of hypersthene-bearing gneiss at Cape Bruce, sampled by Trail in 1961 and mapped in 1965, which is almost completely surrounded by the sillimanite-bearing gneiss predominant there.

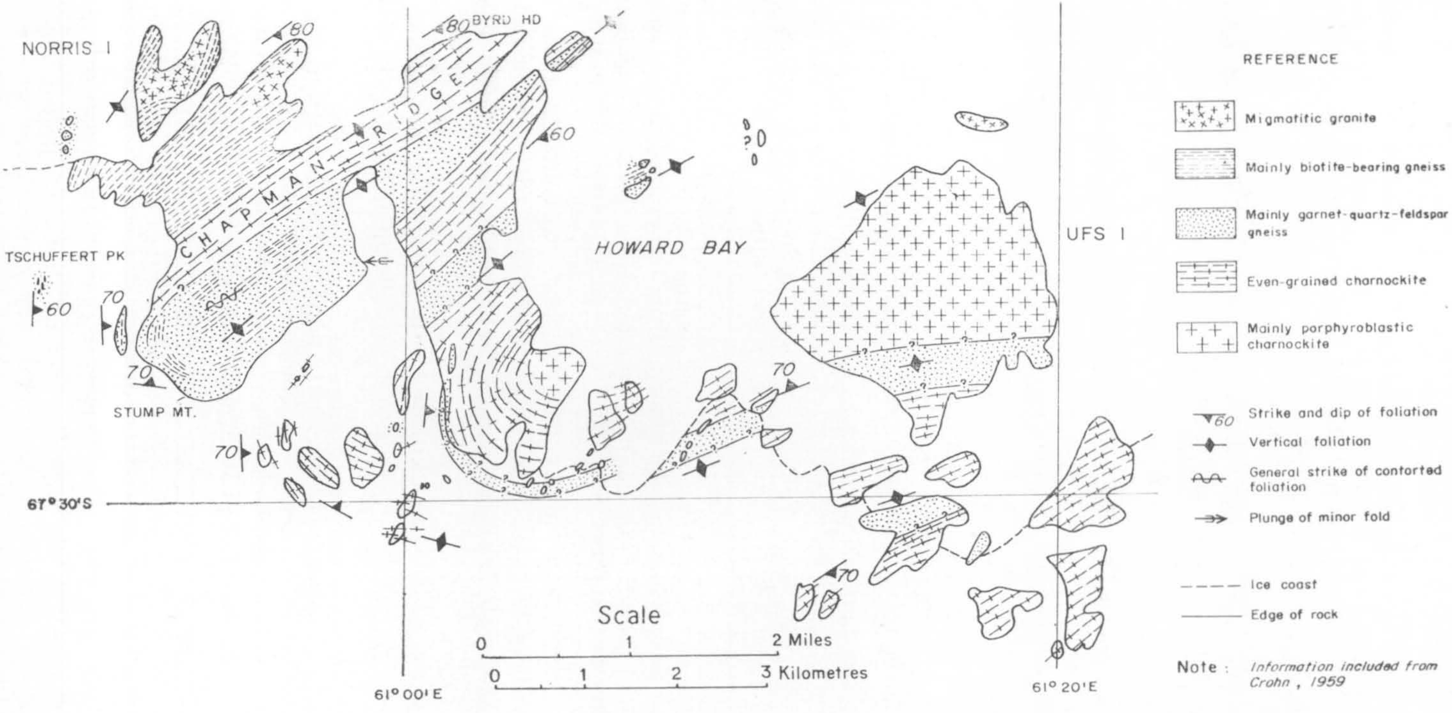

Figure 1. Interpretative sketch map of geological structure between Ufs Island and Norris Island, Mac.Robertson Land, Antarctica.

Ufs Island and Stump Mountain

In 1965 a traverse was made on foot across the transition between the pyroxene-bearing (charnockitic) rocks which predominate along the coast east of Ufs Island, and the biotite-bearing rocks which are abundant on the coast west of Stump Mountain (Fig. 1). Since Crohn (1959) had described the coastal exposures in this transition, the traverse was made along the inland margin of the rock area.

Even-grained charnockite (Crohn's charnockitic granular gneiss) predominates south and east of Stump Mountain, but it contains several exposures of garnet-quartz-feldspar gneiss which form distinct bands over 100 metres wide and a few kilometres long.

Across the hummocky plateau which forms the summit of Stump Mountain, ill defined bands of even-grained charnockite are interspersed with gneisses made up of various proportions of quartz, feldspar, garnet, and biotite; a single thick band of even-grained charnockite forms Chapman Ridge, a prominent escarpment extending 5 kilometres along the north-west side of the mountain from the summit to the sea at Byrd Head.

North-west of Chapman Ridge, the coastal exposures for 15 kilometres to the Scoble Glacier are composed predominantly of biotite-bearing, garnet-bearing, and sillimanite-bearing gneisses, among which pyroxene-bearing rocks are rare.

The *even-grained charnockite*, where weathered, is red or brown; where fresh, the rock is dark grey or black. It is generally a medium-grained pyroxene-quartz-feldspar rock, with garnet in a few exposures.

The charnockite is generally massive, but it commonly contains lenses and bands of yellow-brown quartz-feldspar rock (Pl. 3, fig. 1), which are a few centimetres thick in some exposures and up to a few metres thick in others; the thicker bands may be 20 metres long. The bands and lenses generally have a marked preferred orientation; some small lens-like bodies outline isoclinal folds; in some exposures thick bands branch and anastomose.

These quartz-feldspar rocks generally form less than 20 percent of any exposure. Their margins are well defined and contain some pyroxene, and grade into the finer charnockite.

Thin, branching zones of mylonitic crush-rock, generally a few millimetres thick, are common throughout the charnockite. In places, zones of brecciated charnockite up to 50 centimetres thick have a matrix of mylonitic rock. These zones generally have a preferred orientation and commonly cut across the quartz-feldspar bands, though in a few exposures they are parallel.

On the mainland south of Ufs Island, concordant bands of pegmatitic pyroxene-quartz-feldspar rock are common in the even-grained charnockite. Some of these bands contain feldspar porphyroblasts and resemble very coarse-grained porphyroblastic charnockite.

Garnet-quartz-feldspar gneiss is prominent in bands within the charnockite. It includes much of the quartz-rich and feldspar-rich gneisses recorded by Crohn (1959), and contrasts markedly with the charnockite because of its light brownish grey colour and its coarse grain. It commonly has a faint foliation or banding resulting from concentrations of the constituent minerals.

Mylonitic rocks are notably absent from the garnet-quartz-feldspar gneiss, though they may be abundant in adjoining charnockite.

Observed from a distance, most contacts of the garnet-quartz-feldspar gneiss with the charnockite appear to be sharp. The only contact exposure examined in detail in 1965 is on a bluff on the mainland 1 kilometre south-west of Ufs Island. It is shown diagrammatically in Figure 2. Within 2 metres of the well defined contact, the charnockite contains many lenses and bands, between 10 centimetres and 1 metre thick, of coarse-grained biotite-quartz-feldspar rock. Within 1 metre of the contact, the garnet-quartz-feldspar gneiss contains many ill defined lenses and bands, between 2 and 15 centimetres thick, of garnet-pyroxene-quartz-feldspar rock, which grade into the host rock. The rocks forming these lenses and bands each occur in the respective host rock in other places, but they are unusually abundant close to the contact.

Garnet-quartz-feldspar gneiss is also abundant on Stump Mountain. It forms light purple-grey bands, up to 20 metres thick, which outline structures in charnockitic rocks on the south-east side of the mountain. Towards Chapman Ridge, bands of light grey coarse-grained garnet-quartz-feldspar rock, several metres thick, contain bands and lenses of fine-grained garnet-biotite-quartz-feldspar gneiss up to a metre thick, which commonly outline open or tight folds.

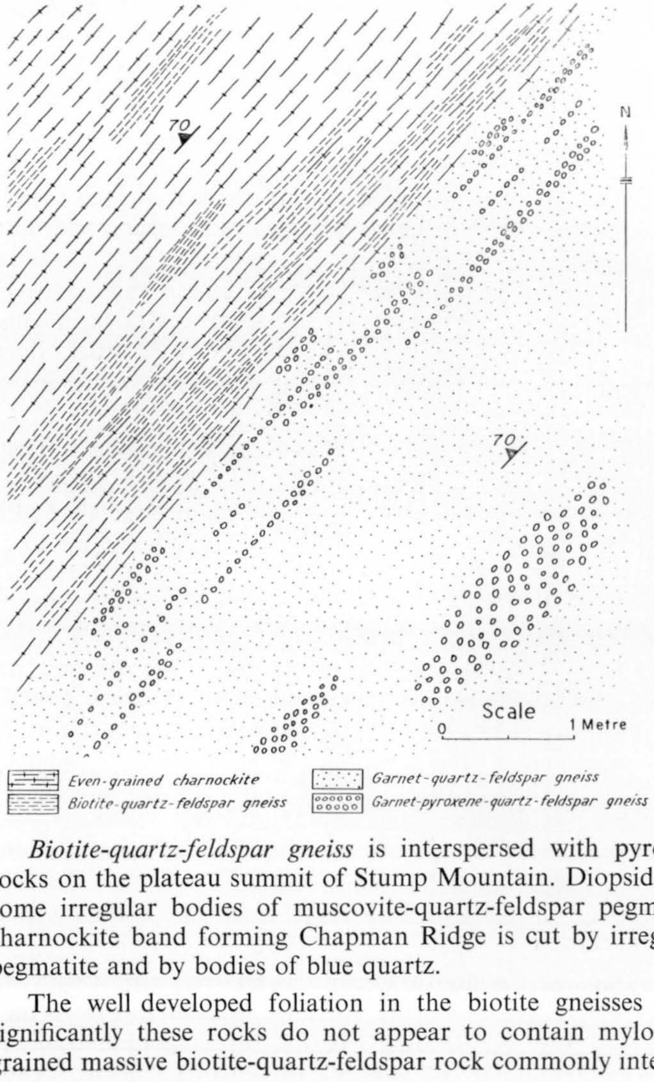

Figure 2. Diagrammatic sketch map of contact between even-grained charnockite and garnet-quartz-feldspar gneiss near Ufs Island, Mac.Robertson Land, Antarctica.

Biotite-quartz-feldspar gneiss is interspersed with pyroxene-bearing and garnet-bearing rocks on the plateau summit of Stump Mountain. Diopside is prominent in a few rocks, and some irregular bodies of muscovite-quartz-feldspar pegmatite are also exposed here. The charnockite band forming Chapman Ridge is cut by irregular dykes of red biotite-feldspar pegmatite and by bodies of blue quartz.

The well developed foliation in the biotite gneisses is commonly tightly folded, but significantly these rocks do not appear to contain mylonitic material. Patches of coarse-grained massive biotite-quartz-feldspar rock commonly interrupt the foliation of the gneiss.

Tschuffert Peak, 1½ kilometres west of Stump Mountain, is composed of rather massive quartz-feldspar rocks containing small quantities of garnet, biotite, and pyroxene. An ill defined foliation in these rocks is revealed by lenses rich in dark minerals, from a few centimetres to a few metres long. A few metres north-west of the summit of the peak, a tightly folded band of biotite-rich rock, between 1 metre and 5 metres thick, trends across the ill defined foliation, which is approximately parallel to the axial planes of the folds in the band (Fig. 3).

Biotite appears to increase in prominence westwards across Stump Mountain, though nowhere on the mountain is it the predominant dark mineral. The abundant evidence of deformation suggests that the original metamorphic relationship of biotite-bearing and pyroxene-bearing rocks has been greatly complicated and obscured by an episode of intense deformation which followed the metamorphism.

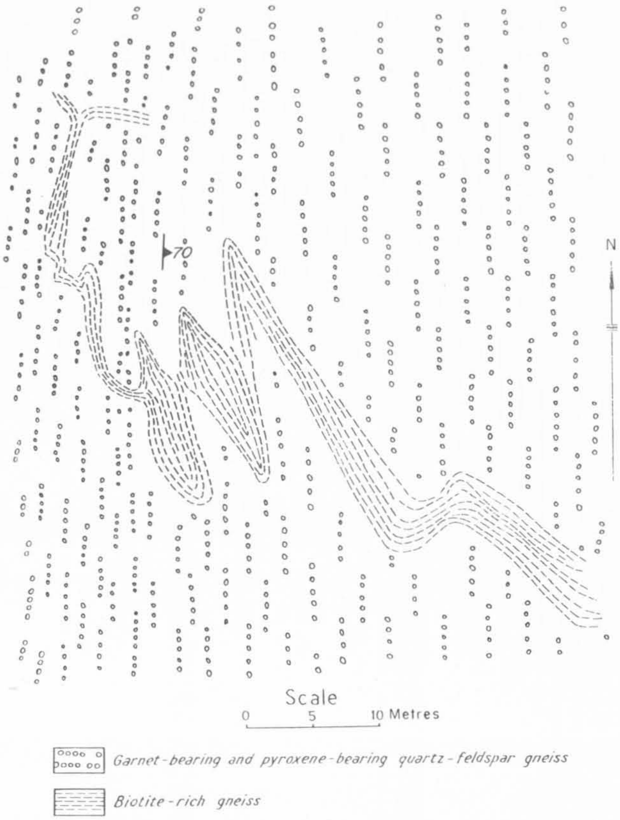

Figure 3. Sketch map of biotite-rich band transgressing foliation, Tschuffert Peak, Mac.Robertson Land, Antarctica.

William Scoresby Bay

Warnock Islands, adjacent to a long string of islands off William Scoresby Bay composed of banded gneiss, are formed by medium-grained even-grained charnockite with a foliation conferred by stringers and small lenses rich in dark or light minerals. This rock resembles many of the light bands in the banded gneiss, but the only concentrations of mafic material on the islands, which are up to 100 metres across, are a few lenses of relatively fine-grained granular rock, up to 1 metre long by 20 centimetres thick.

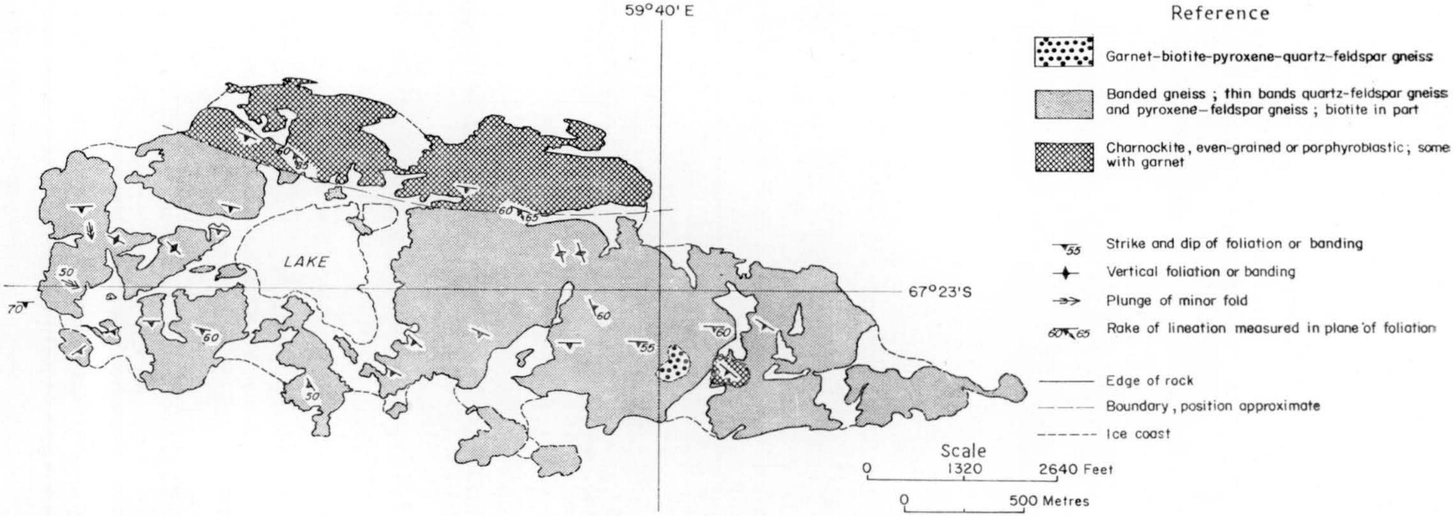

Figure 4. Geological sketch map, Bertha Island, Kemp Land, Antarctica.

Dales Island is predominantly composed of similar rock, with a better foliation formed by long stringers of pyroxene-rich material. Some of the charnockitic rocks here are very coarse-grained, with large pyroxene crystals. A few dark bands, less than 1 metre in thickness, are exposed low on the south face of Dales Island.

Well within the area of the banded gneiss, the northern part of Bertha Island (Fig. 4) is formed by fine-grained to medium-grained even-grained charnockite, with patches and blebs of coarse feldspar crystals which give the rock in places the appearance of the porphyroblastic charnockite; some exposures of porphyroblastic rock are between 50 and 70 metres wide. Stringers and small lenses of pyroxene-rich material produce clear foliation, though this is locally absent. Rare bands of pyroxene-rich rock range up to 30 centimetres in thickness. In some exposures garnet is scattered through the rock, or is concentrated in lenses a few millimetres thick and up to 3 metres long.

A subcircular mass of charnockite over 100 metres in diameter appears to cut the banded gneiss forming the remainder of Bertha Island. A large massive exposure on the coast about 4 kilometres east of Bertha Island carries the prominent rounded boulders and tors that distinguish the charnockite from the banded gneiss on Bertha Island. It also lies on strike with the northern part of Bertha Island, and is probably composed of charnockite.

Western Kemp Land

Two isolated groups of small exposures on the coast of western Kemp Land, Wheeler Rocks and the islands in Magnet Bay, are composed of even-grained charnockite. At Wheeler Rocks, coarse-grained lenses of brown feldspar, ranging from 1 centimetre to 8 centimetres in thickness and up to a few metres in length, make up about 30 percent of the rock. They alternate with bands of medium-grained charnockite, into which they grade. Vertical veins of similar feldspar, 1 centimetre thick and spaced about 70 centimetres apart, strike normal to the banding, and another feldspar vein 10 centimetres thick cuts the banding acutely and fingers along it. The charnockite also contains short streaks of pyroxene grains.

The islands adjoining the mainland ice at the south end of Magnet Bay are composed of similar charnockite. A large island, which could not be visited, displays numerous dark bands up to 2 metres thick, and also contains two dykes of grey rock, each about three-quarters of a metre thick.

At Galten Island, in Magnet Bay, the medium-grained charnockite has a foliation defined by stringers of coarse blue quartz ranging up to 6 metres long and 5 centimetres thick, and spaced a metre or so apart. The foliation direction ranges widely over the island. Well defined lenses, ranging up to 1 metre long by 30 centimetres thick, rich in pyroxene, biotite, or both, are scattered through the charnockite, but are generally parallel to neighbouring quartz stringers. The lenses are themselves foliated as a result of the preferred orientation of biotite or of small elongated aggregates of quartz and feldspar. W. Fander, of Australian Mineral Development Laboratories, describes a sample of charnockite collected by Stinear from Galten Island as composed mainly of quartz and orthoclase-perthite, with antiperthitic oligoclase and andesine. Poikiloblastic grains of hypersthene and some diopside commonly occur in groups with iron oxides, apatite, rare patches of brown hornblende, and a few rough grains of zircon.

Banded Gneiss

Banded gneiss is the informal name given by McCarthy & Trail (1964) to a unit which they distinguished, characteristically composed of alternating felsic-rich and mafic-rich bands. The unit, which is readily recognizable in the field, forms over 90 percent of the rock exposed on the coast between Tilley Nunatak and King Edward Ice Shelf, from where it extends north to Cape Boothby and south to Turbulence Bluffs. It is bounded on the west by the quartz-feldspar gneiss, on the south-west by the garnetiferous gneiss, and on the east by the sillimanite-bearing gneisses of Campbell Head. A few bodies of other rocks occur within the outcrop of the banded gneiss, generally biotite-bearing gneisses resembling the rocks exposed at Taylor Glacier, or charnockites. Metamorphosed basic dykes are common in the western part of the banded gneiss outcrop.

According to McCarthy & Trail, the banded gneiss is typically composed of dark bands of pyroxene-plagioclase rock alternating with light bands of quartz-feldspar gneiss (Pl. 3, fig. 2).

The plagioclase of the dark bands is commonly labradorite. The pyroxene is predominantly hypersthene, commonly accompanied by clinopyroxene; hornblende also occurs in some samples. Garnet, biotite, and quartz are common in some dark bands.

In the light bands, the feldspar is both orthoclase and more abundant plagioclase—commonly oligoclase or andesine. Dark minerals are minor constituents, mostly forming less than 10 percent of the rock, and rarely more than 15 percent. Pyroxene is almost ubiquitous, biotite and garnet are widespread, and hornblende occurs in some samples.

Exposures within the banded gneiss were first sampled in 1936 at Bertha Island (Rayner & Tilley, 1940), and in 1954 at several points by ANARE surveyor R. Dovers (Stinear, 1956). Crohn (1959) described the geology of several localities within the banded gneiss; and Ruker (1963) described a few exposures on the north side of Edward VIII Gulf. In 1965 the examination of previously unvisited exposures defined more accurately the limits of outcrop of banded gneiss and disclosed several bodies of other rock types.

Outlying islands off William Scoresby Bay

Bertha Island was mapped in some detail in 1965 (Fig. 4) because on air-photographs it appears to lack the banded rocks prominent in nearby exposures. The northern part of the island is composed of charnockite, described above. The remainder of the island is composed of banded gneiss in which the bands are too thin to show on air-photographs; most range from 1 centimetre to 50 centimetres in thickness. Pyroxene forms less than 15 percent of the light bands and between 50 and 90 percent of the dark. The contacts of the contrasting bands are distinct; any gradation occupies only a very small part of each band. The banded gneiss is separated from the charnockite by a depression running the length of the island.

The bands are also thin on Tillett Islands, ranging from 1 centimetre to 1 metre, and on Farrington Island and nearby islands, where their thickness ranges up to 3 metres. Pyroxene is not common in the light bands. Some dark bands on Tillett Islands have prominent blebs composed of large crystals of pyroxene and feldspar.

The islands near Endresen Island were not visited, but from the air appear to be composed of banded gneiss.

Stillwell Hills

The rocks of the northern and central Stillwell Hills were examined in some detail, and those of the southern part of the hills more briefly.

Typical banded gneiss makes up the central and southern parts of the hills. Similar rocks were found in the northern part of the hills, but here other types, principally varieties of quartzite, occur also (Fig. 5).

Light bands form between 60 and 90 percent of the banded gneiss. They are generally thicker than the dark bands, ranging from a few centimetres to 30 metres. Most dark bands are actually elongated lenses. The largest seen on the ground are several hundred metres long and 10 metres thick. Some bands in the southern part of the hills appeared from the air to be up to 200 metres thick; dark bands of such great thickness are unusual in the banded gneiss, and it is possible that they are actually made up of several dark bands separated by thin poorly defined light bands.

The light bands are predominantly medium-grained to coarse-grained quartz-feldspar gneiss with minor dark mineral; a few are fine-grained. Some are massive, but most have a foliation conferred by stringers of pyroxene or by small schlieren of quartz or quartz and feldspar. Some light bands are made up of thin quartz-poor bands alternating with quartz-rich bands, and others of alternating coarse-grained and medium-grained bands. Some thick bands in the southern Stillwell Hills contain large feldspar crystals and strongly resemble the porphyroblastic charnockite.

The dark bands are commonly massive, but many are made up of bands and lenticles, from a few millimetres to a few centimetres thick, distinguished by their dark mineral content, which ranges from 10 to 90 percent. Feldspar mostly predominates over the dark minerals; biotite, garnet, and diopside are locally common, and some bands contain a considerable proportion of quartz as lenses or vein-like bodies. Some thin bands are composed of biotite and garnet, and carry a network of green copper stains. Thin concordant lenses of very coarse biotite rock occur in the central Stillwell Hills.

Several lenses and dykes of pink massive biotite-quartz-feldspar pegmatite, generally several metres long, cut the banded gneiss of the central Stillwell Hills. The gneiss in places also contains small irregular bodies composed of iron-ore mineral and quartz. A discordant lens of light grey pyroxene-bearing rock, 30 metres long by 5 metres wide, which occurs 4 kilometres north of Kemp Peak resembles scapolite-pyroxene rocks seen in the Framnes Mountains and at Tilley Nunatak.

A distinctly different type of banded gneiss crops out over about 1½ square kilometres in the core of a large antiform whose axis lies about 1 kilometre north-west of Kemp Peak. This type is made up of white quartzite, forming about 10 percent of the outcrop, alternating with thick dark bands forming about 90 percent of the outcrop. Most quartzite bands are a few metres thick; a few range up to 25 metres. The quartzite is almost pure quartz, with some layers, a few centimetres thick, of probable sillimanite. Most of the dark bands are over 100 metres long and range from 10 metres to 70 metres in thickness. They are mainly composed of pyroxene-feldspar rock, though pyroxene predominates in places. Several contain thin bands of iron-ore minerals, garnetiferous in part, up to 50 centimetres in thickness and more than 50 metres long. These bands are generally close to the contact of the dark band with the quartzite. The bands containing iron-ore mineral, and the feldspar-pyroxene rock within 1 metre of them, commonly have a network of green copper stains following surface cracks.

The quartzite and pyroxene-feldspar bands commonly interfinger at their contacts, and the pyroxene-feldspar bands contain abundant garnet within half a metre of the contact. The quartzite within a few metres of one contact contains several lenses of dark pyroxene-feldspar rock, typically 1 metre thick and 2 metres long.

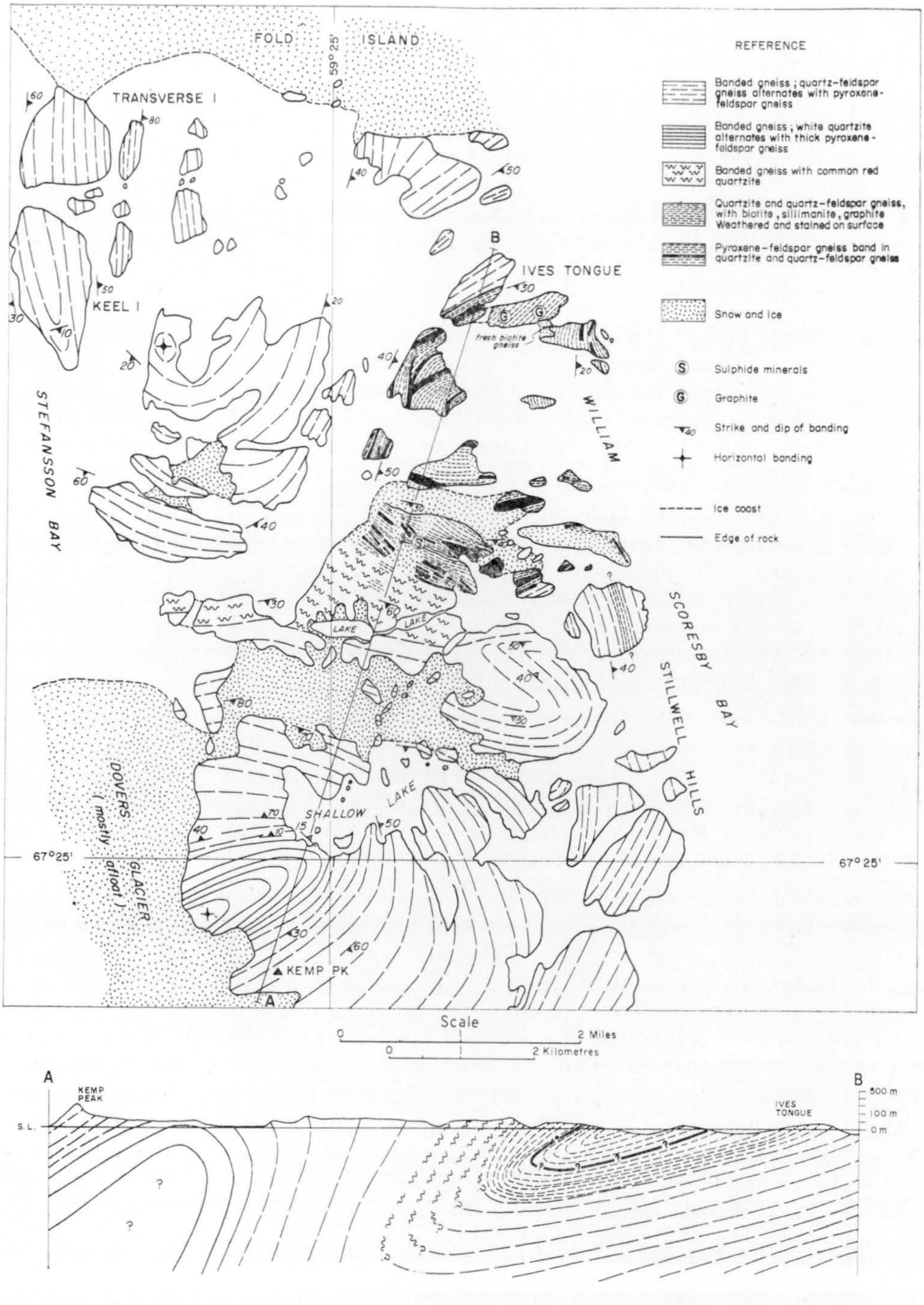

Figure 5. Geological sketch map, northern Stillwell Hills and adjacent islands.

In the northern Stillwell Hills (Fig. 5), thick reddish grey garnet quartzite bands are prominent in the banded gneiss about 4 kilometres north-north-east of Kemp Peak. A rock face 50 metres high is composed of 25 percent garnet quartzite, 50 percent light brown pyroxene-quartz-feldspar gneiss, and 25 percent dark grey and black pyroxene-feldspar rock. Garnet quartzite bands increase in thickness and in abundance towards the northern margin of the hills. Another distinctive type of light band in the northern part of the hills is a quartz-feldspar gneiss with brick-red feldspar and with garnet and biotite in places.

Massive light grey, red, and yellow weathered quartzite and quartz-feldspar gneiss predominate along the northern margin of the Stillwell Hills and on several small islands, all within a subcircular area about 4 kilometres in diameter. Banding is poorly developed in most exposures. Dark minerals are weathered in many of the rocks; garnet is predominant and biotite is common.

At the north end of the Stillwell Hills, thin bands of biotite-garnet rock and of very coarse-grained biotite-quartz-feldspar rock with iron oxides reveal the structure of the otherwise massive rocks. In Ives Tongue, the northernmost island in the subcircular area, the quartzite and quartz-feldspar gneiss contain combinations of garnet, graphite, sillimanite, and biotite. Graphite forms stringers and aggregates up to 2 centimetres across and makes up 2 percent of the rocks in places; sillimanite crystals form bands a few millimetres thick in the poorly foliated rocks. A sample of beach sand from Ives Tongue contains, in addition to amphibole and epidote and other minerals already mentioned, small quantities of wollastonite, tourmaline, and possible staurolite.

A few large lenses of little-weathered dark grey pyroxene-feldspar rock occur within the outcrop of the weathered quartzite and quartz-feldspar gneiss. The contact of one lens, 30 metres long by 15 metres thick, with underlying biotite-garnet-quartz-feldspar gneiss is sharp but tightly folded, and the lens contains bodies of very coarse-grained biotite-garnet-quartz-feldspar rock, typically 3 metres long and 1 metre thick, within 5 metres of its lower contact. These lenses become more common southwards towards the banded gneiss containing the red quartzite. As described above, reddish garnet quartzites in the banded gneiss increase in abundance northwards. It seems that there is a large scale transition from the banded gneiss with reddish garnet quartzite bands to the weathered and iron-stained quartzite and quartz-feldspar gneiss with bands and lenses of pyroxene-feldspar gneiss.

Green copper staining is common within the area of quartzite and quartz-feldspar gneiss and in the quartzite-bearing banded gneiss south of it. The staining is most common on the garnet quartzite, and occurs less commonly on the quartz-feldspar gneiss and rarely on the pyroxene-feldspar gneiss.

A few small yellow-brown exposures of fine-grained quartzite on the floor of a deep valley on the northern margin of the Stillwell Hills contain small crystals of metallic sulphides and oxides, and graphite (see p. 38).

Many of the quartz-feldspar gneisses resemble strikingly the garnet-bearing and sillimanite-bearing gneisses of Taylor Glacier, and the relative scarcity of dark bands within them suggests that the gneisses of the northern margin of the Stillwell Hills should be classed with the gneisses of Taylor Glacier rather than with the banded gneiss.

The graphite-bearing sillimanite-garnet-quartz-feldspar gneisses have not been recognized elsewhere in Kemp Land or Mac.Robertson Land. They have a marked mineralogical similarity to khondalites of Ceylon, described by Fernando (1950) as 'garnet-sillimanite schists with disseminated flakes of graphite', which also contain feldspar and are commonly associated with quartzites.

The degree of folding of the gneisses of the Stillwell Hills ranges from open to tight. Several large folds can be seen on air-photographs of the northern and central hills. Photo-coverage of the southern hills is too distant for structural interpretation; attitudes of banding in the south-east of the hills suggest the presence of a large-scale fold measuring many hundred metres from limb to limb.

Cosgrove Glacier to Gwynn Bay

Several exposures between Cosgrove Glacier and Gwynn Bay were visited for the first time in 1965, and others were inspected from the air to complete the geological examination of this stretch of coast, which was begun in 1961. Banded gneiss was found at all the exposures visited except Secluded Rocks and some small exposures near the southern corner of Stefansson Bay.

Pyroxene generally is not common in the light bands. In places it is accompanied by biotite, and in others by garnet. Some bands on the west side of Bell Bay are unusually rich in quartz. The light bands on Solitary Nunatak contain irregular quartz-feldspar veins, some of which are zoned, with quartz in the centre.

The thickness of the dark bands ranges up to 10 metres. Many, expecially the thicker ones, are themselves finely banded. The dark bands on Solitary Nunatak and Svart Mountain contain veins and schlieren of feldspar, up to 1 centimetre thick, and some on the west side of Bell Bay contain veinlets and bands of pyroxene and garnet between 1 and 5 centimetres thick. Quartz is a constituent of the dark bands in the north of Havstein Island and coastal outcrops in the south-west corner of Stefansson Bay, and some dark bands at the latter place are almost entirely pyroxene. A lens of diopside-biotite-quartz-feldspar gneiss containing possible sillimanite was found on the north part of Havstein Island.

The light bands in exposures along the west side of the Hoseason Glacier increase in number and thickness northwards. In the southernmost exposure they are rarely more than 2 metres thick and form less than 50 percent of the rock. Six kilometres to the north, light bands range up to 20 metres thick and form up to 80 percent of the rock. The dark bands are less than 3 metres thick in the northern exposures; some are over 10 metres thick in the south.

In the large southernmost exposure, the light bands are pyroxene-quartz-feldspar gneiss. The dark pyroxene-feldspar bands contain concordant small lenses of coarse garnet and stringers and discordant veins of pegmatitic pyroxene-feldspar rock. Zones of tight disrupted folds in the dark bands are veined by aplitic rock and are heavily stained by iron. Near-vertical dykes of almost pure pyroxene, about 3 metres thick, parallel the strike of the banded gneiss in this exposure, but cut across the relatively gentle dip.

A large exposure of banded gneiss on the west side of Gwynn Bay was examined in detail. The light bands are quartz-feldspar gneiss with biotite and garnet as their characteristic dark minerals, but pyroxene is also common; some light bands are pyroxene-feldspar quartzites. Garnet is common in the dark bands, and diopside is abundant in some. Both light and dark bands are themselves commonly composed of bands a few centimetres thick. Brick-red quartz-feldspar rock forms some light bands at the south end of the exposure. Bands of biotite-garnet rock up to 15 centimetres thick occur within some pyroxene-feldspar bands.

Dykes of biotite-quartz-feldspar pegmatite up to 2 metres thick cut or parallel the banding of the country rock. One dyke contains accessory iron-ore mineral in crystals up to 5 centimetres long intergrown with garnet in places, and crystals up to 3 centimetres long of a black glassy mineral which may be allanite. In one specimen examined the feldspar is probably orthoclase-microperthite with numerous dust-like crystallite inclusions, and rare patch-like inclusions of muscovite.

Many folds are outlined by the banded gneiss at Gwynn Bay. The dominant type of large-scale fold appears to be a tight synform. One such fold is outlined by a massive dark band 5 metres thick and its core is occupied by massive quartz-feldspar rock. In another tight fold of similar style both dark and light bands in the core contain discordant pods and irregular vein-like bodies of massive biotite-garnet-quartz-feldspar pegmatite. The existence of the massive rocks in the fold cores suggests that during the fold movements recrystallization was restricted to the cores. Similar partial recrystallization associated with folds was found in the Jagar Islands (Pl. 4, fig. 2).

The Secluded Rocks, several small exposures at the confluence of the Cosgrove Glacier and the Dovers Glacier, are formed by medium-grained grey biotite-quartz-feldspar gneiss, with bands up to 50 centimetres thick relatively rich in dark minerals, which outline tight folds in places. The gneiss contains a few green lenses, typically 1 metre thick, rich in epidote and diopside, discordant veins and concordant bands, up to 10 centimetres thick, of red granitic quartz-feldspar rock, and some light grey quartz-feldspar pegmatite. The rocks resemble strongly exposures in the vicinity of Taylor Glacier; the recurrence of the red granitic rock, which also occurs at Taylor, is striking.

An island in a group of small islands and coastal exposures near the south corner of Stefansson Bay (latitude 67°24′S, longitude 59°02′E) is composed of light grey banded garnet-biotite-quartz-feldspar gneiss containing veins of red coarse-grained granitic rock. Most veins are less than 30 centimetres thick; some range up to 50 centimetres; they are generally concordant but in places form a network. This gneiss contains some dark bands of pyroxene-feldspar gneiss in which streaks of white feldspar produce a foliation. One lens-like body of dark fine-grained to medium-grained rock contains large plates of biotite. Folds are common on this island.

The coastal exposure south of the island appears to be formed by banded gneiss, and the coastal exposure south-east of the island appears to be made up of both banded gneiss and light grey rock similar to the garnet-biotite-quartz-feldspar gneiss described above.

Cape Boothby to Turbulence Bluffs

The boundary between banded gneiss and quartz-feldspar gneiss is a relatively short distance west of a line from Cape Boothby through Cape Dalton to Turbulence Bluffs. Some light bands in the banded gneiss consist of a rock strikingly similar to some of the quartz-feldspar gneiss, and dark bands form only 5 percent of the banded gneiss in some exposures between Cape Boothby and Turbulence Bluffs. Even so, the two rock types can generally be separated with little difficulty because regularly repeated, well defined dark bands do not occur in the quartz-feldspar gneiss, and the light bands of the banded gneiss contain some pyroxene, which is rare in the quartz-feldspar gneiss.

Garnet occurs in the light bands at Cape Dalton and the outcrops 10 kilometres to the west, in the dark bands on the Jagar Islands, and in both at Abrupt Point. Some of the dark bands on the Jagar Islands also contain biotite. Dark bands made up almost entirely of pyroxene with little feldspar were found at Jagar Islands, Abrupt Point and Turbulence Bluffs. One such band on Jagar Islands contains 60 percent pyroxene, 30 percent iron-ore mineral, and 10 percent garnet.

A specimen from a light band on the Jagar Islands is a medium-grained hypersthene-plagioclase-quartz-alkali-feldspar granulite. The rock probably formed under granulite facies conditions, but there are indications that it has been slightly adjusted to lower metamorphic conditions, as some of the hypersthene appears to have been partly converted to hornblende. Estimated mineral proportions are: traces of blue-green coloured hornblende, clinopyroxene 1 percent, hypersthene 9 percent, andesine 17 percent, quartz 28 percent, and alkali feldspar (probably orthoclase-microperthite) 45 percent. Accessories observed are zircon, apatite, and opaques, and a single grain of possible allanite. Some of the plagioclase is antiperthitic. Occasionally it has inclusions of carbonate, and less frequently mica. Some wisp-like bodies of mica appear to have formed adjacent to, or as a replacement of, hypersthene.

A small part of the north-western side of Abrupt Point is composed of grey well banded biotite-quartz-feldspar gneiss and biotite-pyroxene-quartz-feldspar gneiss with some bands of feldspar-pyroxene gneiss. The rocks are medium-grained, and scattered garnet occurs in all types. Pegmatite in these grey gneisses forms concordant and discordant veins in zones up to 20 metres thick; one irregular discordant body of white pegmatite is 6 metres thick.

The rocks on Georges Island resemble from the air many exposures of banded gneiss, but they are composed predominantly of garnet-biotite-quartz-feldspar gneisses in which the banding results from variations in the dark mineral content; the bands are poorly defined. Some of the gneisses probably contain pyroxene. The gneisses are grey and pink, and typically medium-grained; schlieren and veins of coarse-grained material are common; the veins range up to 10 centimetres in thickness and some cut the foliation. The banding in similar gneiss on the southern large island is more clearly defined, and at least three dolerite dykes, up to 6 metres in thickness, sharply cut the banding; the dykes carry green copper staining.

On the northern large island, many veins of quartz and of biotite-quartz-feldspar pegmatite, ranging up to 1 metre in thickness, cut an irregular metamorphosed dolerite dyke about 10 metres thick. The foliation of the gneiss adjacent to the pegmatite bodies is disturbed and the pegmatites contain blocks of gneiss up to 1 metre across.

In addition to the two occurrences described above, mica-quartz-feldspar pegmatites were found in the banded gneiss at most of the exposures visited. The width of the veins ranges up to 6 metres. They are generally massive, and many are straight, with no sign of deformation.

The banded gneiss between Cape Boothby and Turbulence Bluffs contains numerous metamorphosed basic dykes, which range up to 10 metres in thickness. Several of the dykes are themselves cut by mica-quartz-feldspar pegmatites. Some of the dykes, such as a large one in the Jagar Islands, are faintly foliated parallel to their margins, even where the margin is discordant to the foliation of the gneisses. The large dyke proved on petrographic examination to be a massive medium-grained biotite-quartz-hornblende-pyroxene-plagioclase rock, with a hornfelsic or granulitic texture. Estimated proportions of the mineral constituents are: biotite 1 percent, quartz 3 percent, hornblende 5 percent, clinopyroxene 15 percent, orthopyroxene 15 percent, and plagioclase 60 percent. Accessories observed were apatite and opaques (forming perhaps 2 percent of the rock). The anorthite content of the plagioclase is in the range 40–70 percent. No alkali feldspar, other than some patch-like bodies in several of the plagioclase grains, was observed.

A second specimen has a similar composition except that it contains more hornblende, less orthopyroxene, and no biotite, some of the plagioclase is antiperthitic, and accessory zircon is present.

In many places the dark bands outline intense isoclinal folding. In several examples, the limbs of folds with an amplitude of several metres are only 10 to 20 centimetres apart, and parallel for most of their length. Some thin folded dark bands resemble ptygmatic veins, but their general trends are broadly concordant with the poorly foliated coarse-grained light rocks which contain them (Pl. 4, fig. 1). A few of these thin dark bands are bordered by very coarse-grained massive felsic material which also appears to outline folds. Other small-scale folds are cut by similar massive felsic material (Pl. 4, fig. 2), which suggests partial recrystallization of the rock.

Quartz-Feldspar Gneiss

The area of outcrop of the unit called quartz-feldspar gneiss extends from the King Edward Ice Shelf, at the western end of Edward VIII Gulf, westwards to beyond the limit of the survey, and southwards to the garnetiferous gneisses cropping out around the upper parts of the Robert and Wilma Glaciers. The unit probably continues west through Enderby Land to the Tula Mountains and Amundsen Bay, where similar rocks were described by McLeod (1959). The rocks at Twin Peaks are considered to be intermediate between the quartz-feldspar gneiss and the garnetiferous gneisses; they are described under the latter heading.

As the name implies, the unit is dominantly quartz-feldspar gneiss. Pyroxene and garnet occur in small amounts, and biotite is a minor constituent. Other rock types present include feldspar-pyroxene gneiss, pyroxene rock, garnet-pyroxene rock, garnet quartzite, and biotite-rich rocks; stringers and veins of pegmatitic rock occur locally.

The typical quartz-feldspar gneiss is a predominantly medium-grained light grey to white rock, mostly stained red, brown, or yellow by iron oxides. It is massive in some outcrops, but is more commonly foliated or banded to various degrees. Subspheroidal weathering is widespread.

The rock is composed mainly of quartz and feldspar; in places the composition approaches that of a quartzite. Minerals other than quartz and feldspar are rare or absent in much of the quartz-feldspar gneiss, but many outcrops contain a little (less than 5 percent) dark mineral, principally pyroxene and garnet, and rarely biotite. Pyroxene is finely disseminated in some occurrences, but is more common as thin stringers or trails of grains. The pyroxene content is minor, but exceeds the garnet in the unit as a whole. Where garnet occurs, it is locally more abundant than the pyroxene; it is present commonly as disseminated grains. Biotite mostly forms thin streaks of flakes in the gneiss.

The foliation and small-scale banding of the quartz-feldspar gneiss is the result of several features, which include: elongation of the quartz grains, presence of small lenticular fine-grained quartz aggregates, variation in the proportions of quartz and feldspar, alternation of different grainsizes, and streaks of dark minerals. Most of the small-scale banding is thin and discontinuous. Where minerals other than quartz and feldspar are rare, the rock tends to be massive. In a few places, such as the nunataks south of the Downer Glacier (latitude 66°57′S, longitude 56°14′E), otherwise massive quartz-feldspar gneiss contains irregular vein-like patches of coarser-textured rock. Except for the different grainsize, the patches seem identical with the enclosing rock, and grade into it.

A large-scale banding results from alternations of other rock types with the quartz-feldspar gneiss. Most bands possess well-defined margins; many are themselves banded. Most common of these other types are feldspar-pyroxene gneiss and pyroxene rock, which form bands ranging in thickness from a few centimetres upwards. Some are garnetiferous, and some contain a few percent of opaque minerals. In some places, such as the nunatak near the junction of the Seaton and Wilson Glaciers, pods of pyroxene rock, a metre or so across, may have formed by disruption of bands by intense folding. Other minor banding in exposures near this is produced by bands of medium-grained to coarse-grained garnet-pyroxene rock alternating with bands of finer-grained biotite-rich rock. The bands range from 15 to 30 metres thick.

Bands of biotite-quartz-feldspar gneiss about a metre wide occur on several nunataks in the vicinity of Mount Storegutt. On Mount Mueller, lenses of garnet quartzite range from 15 centimetres thick and 30 centimetres long to over 15 metres thick and 150 metres long. These lenses are associated with bands of medium-grained pyroxene-garnet-quartz-feldspar rock.

In only a few places were the bands in the quartz-feldspar gneiss traced over any distance. Observations where this was done suggest that they are actually lenses rather than persistent bands. For example, on Mount Mueller, bands of black massive medium-grained pyroxene-rich rock associated with thicker bands of quartz-feldspar gneiss are 2 to 7 metres thick and range from less than 15 metres to 60 metres long.

Pegmatite rocks form pods, or veins up to 3 metres thick, in the gneisses, and in places form a network of veins about a centimetre thick. Some veins are concordant and some discordant. Mineralogically they are generally composed of pink and white feldspar and quartz, with biotite flakes up to a centimetre across in some localities.

Bird Ridge, near the boundary between Kemp and Enderby Lands, was only inspected from the air since it was not possible to land on it. It is composed of red rocks in bands up to 150 metres thick, and bands, approximately 15 metres thick, of white and light grey rock, probably quartzite, and a very few bands of black rock. The thick beds have the appearance of iron-stained quartz-feldspar gneiss.

The quartz-feldspar gneiss unit as a whole is weakly to moderately jointed; normally the joints dip steeply and strike in random directions. The strike of the gneisses is generally east-west, with minor variations, especially around Mount Storegutt, and the nunataks east of Mount Pasco.

Most of the banded outcrops of the quartz-feldspar gneiss unit show tight isoclinal folding. The extent of this folding in the homogeneous outcrops was not ascertainable. A lineation is shown up in some places by elongated quartz grains or small aggregates of quartz.

Gneisses of Taylor Glacier

The gneisses of Taylor Glacier are typically well foliated biotite-garnet-quartz-feldspar gneiss, in which the foliation is tightly folded. Sillimanite-cordierite-bearing gneiss is prominent between Cape Bruce and Campbell Head.

Exposures of these gneisses, which extend from Norris Island to Campbell Head, were examined in 1965 near Hayes Peak and at the southern margin of the exposures extending south from Campbell Head. Hayes Peak is composed of reddish grey biotite-bearing and garnet-bearing quartz-feldspar gneisses which contain large patches of coarse massive granitic rock of similar composition to the gneisses.

At the south-west corner of the area of exposed rock behind Campbell Head, bands of white quartzite alternate with dark bands of gneiss and massive rock composed of various proportions of garnet, biotite, pyroxene, quartz, and feldspar. Though large-scale banding in these exposures is evident from the air, the rocks, seen in detail on the ground, are tightly and irregularly folded and contorted.

Aerial observation revealed that light grey hypersthene-bearing gneiss, sampled in 1961, crops out as a narrow north-trending band between Cape Bruce and the west side of the Taylor Glacier. This rock appears to be underlain and overlain by the reddish sillimanite-bearing gneiss which predominates at Cape Bruce.

The boundary relationships of these gneisses with the charnockite are described in the section on charnockite. Their boundary with the banded gneiss may also be gradational. Sillimanite-bearing gneiss is interbanded with banded gneiss at Tilley Nunatak, and bodies of gneiss similar to the gneiss of Taylor Glacier occur in banded gneiss on the south-western side of Stefansson Bay, and at Striated Nunatak and Secluded Rocks.

Garnetiferous Gneisses of Mount Kernot, etc.

The unit called here 'garnetiferous gneisses' crops out as nunataks near the head of the Robert and Wilma Glaciers at about latitude 67½°S, longitude 56°E. Mount Kernot and Rayner Peak are the largest of these nunataks, standing some 160 metres and 320 metres respectively above the ice surface. The rocks forming Twin Peaks (latitude 67°20′S, longitude 55°30′E), described in this section, are intermediate in character between the garnetiferous gneisses and the quartz-feldspar gneiss.

The garnetiferous gneisses are a heterogeneous unit characterized by a variety of rock types and by the presence of garnet as a common mineral. The various rock types form bands which are generally from 1 to 5 metres thick; some range up to 15 metres. The most common types are variants of feldspar-pyroxene and pyroxene-feldspar gneiss, quartz-feldspar gneiss, biotite-bearing gneiss, and quartzite. Garnet is a constituent of most rock types, in amounts ranging from minor to predominant.

The pyroxene-feldspar gneiss is a moderately foliated granulitic equigranular rock, commonly containing thin bands or lenses (mostly only one or two grains wide) of either feldspar or pyroxene, and massive in places, with no foliation. The feldspar content differs greatly from place to place; in parts it is only small, and the rock is almost entirely pyroxene or garnet and pyroxene. On the whole the garnet content ranges from rare to common. In some of the garnet-pyroxene rocks it is concentrated in closely spaced ellipsoidal aggregates up to 7 centimetres across, containing 75 percent or more garnet. Green diopside is common in many of the garnet-pyroxene rocks. On parts of Mount Kernot, the pyroxene-feldspar gneiss contains quartz-feldspar bands up to half a centimetre thick. Near the north-east corner of Mount Kernot, and on the nunatak at latitude 67°22′S, longitude 55°44′E, feldspar-pyroxene gneiss contains irregular pink quartz-feldspar schlieren up to 10 centimetres wide and 2 metres long. The grainsize of these schlieren is variable; it tends to be coarser in the wider ones. Some of the coarser schlieren contain scattered crystals of black pyroxene.

The quartz-feldspar gneiss is a creamy-coloured rock with a rather uneven grainsize. Foliation is mostly poor, but parts display a good banding because of variation in the proportions of quartz and feldspar. The banding is commonly accentuated by dark minerals, mainly garnet or garnet and biotite. Garnet, when present in minor amount, is mostly disseminated through the rock; when more common, it occurs in bands up to a centimetre wide. Biotite, which is usually accompanied by garnet, tends to give a discontinuous streaky banding. Some bands in the rock, up to 2 or 3 centimetres wide, are rich in pyroxene.

The biotite-bearing gneisses are variants of the garnetiferous quartz-feldspar gneiss, and to a lesser degree, the garnetiferous pyroxene-feldspar gneiss. Normally the biotite and biotite-plus-pyroxene contents do not exceed 5 and 20 percent respectively. The biotite tends to be concentrated in bands through the rock, and most biotite-bearing types have a good foliation. The biotite-bearing rocks are best developed at Striated Nunatak (Pl. 5, fig. 2) and the nunatak north-west of it on the other side of the Robert Glacier. At both places the rocks are fine-grained to medium-grained pyroxene-garnet-biotite-quartz-feldspar gneiss interbanded with minor garnet-pyroxene-biotite-feldspar gneiss. The predominant quartz-feldspar gneiss is itself prominently banded, the bands ranging up to half a metre in thickness. A few bands of garnet-pyroxene rock occur at both places. Biotite is also common at Else Nunataks, where the rock is predominantly fine-grained foliated garnet-biotite-quartz-feldspar gneiss with subordinate medium-grained feldspar-pyroxene gneiss. The garnet tends to be concentrated in bands or lenses up to 5 centimetres wide, but otherwise the rock is not markedly banded because of variation in the mineral content. A strongly banded appearance is produced, however, by veins of quartz up to 2 centimetres wide which are parallel to the foliation.

Bands of quartzite were found on Mount Kernot and Rayner Peak. The rock is massive and very well jointed, breaking into small rectangular blocks. The quartz is clear, giving the rock a greyish colour. Other minerals—mainly feldspar and garnet—are rare.

Coarse-grained pegmatitic quartz-feldspar veins, mostly less than a quarter of a metre wide, occur locally, especially in the pyroxene-feldspar gneiss.

The foliation of the rocks is parallel to the banding caused by alternation of the different rock types. Although the strike seems to be constant on each nunatak, large exposures reveal that the rocks are commonly folded into very tight isoclinal folds with an amplitude many times their wavelength. Near the western corner of Rayner Peak, a large open fold plunges east at about 30°.

Lineation was seen in several outcrops. It is caused either by elongation of the mineral grains or small lenticles of grains of the same mineral, or by small crenulations in the foliation. The latter type is particularly marked on Rayner Peak, in garnet-quartz-feldspar gneiss at its junction with garnet-pyroxene rock. Where lineation and isoclinal folding were seen together, the lineation is parallel to the fold axes.

Only one outcrop of Twin Peaks was accessible in the time available; this was at the base of the cliffs near the south-east corner of the mountain. This outcrop is garnetiferous-quartz-feldspar gneiss. A thick band of probable quartzite, near the north-west corner of the mountain, was inaccessible. The few observations which could be made suggested that the rocks on Twin Peaks represent an assemblage intermediate between the garnetiferous gneiss and quartz-feldspar gneiss units.

A dyke of metamorphosed basic rock, near the summit of Rayner Peak, is 1½ to 3 metres wide. It strikes about 050° and dips south-east at 80°. Two specimens were collected by surveyor M. Corry; one is a coarse pegmatitic rock containing crystals of diopside up to 5 centimetres across, quartz, and feldspar; the other is a medium-grained equigranular foliated garnet-diopside feldspar gneiss. According to Mr Corry, there were two bands of each type over a width of 1½ metres. The remaining width of the dyke was obscured by rubble.

Gneiss, Marble, and Migmatite of the Hansen Mountains

Fram Peak, the largest nunatak in a small isolated group north of the Hansen Mountains, has been described by McLeod (1959). In 1965 further investigation of Fram Peak and nearby nunataks and a rapid reconnaissance of the Hansen Mountains revealed that the geology of the entire range is substantially similar to that of Fram Peak.

McLeod (1959) records that Fram Peak is composed of migmatite formed by red granite and dark brown biotite-quartz-feldspar gneiss. In 1965, a detailed examination of Fram Peak added little to McLeod's observations. He describes the granite in thin section as a medium-grained mosaic of quartz and feldspar (potash feldspar and oligoclase-andesine) with clinochlore and rare biotite, magnetite, zircon, and apatite. It has a megascopic foliation produced by stringers of quartz, and by large feldspar crystals which are abundant in places and have a marked preferred orientation. Where best developed, the foliation produces a flaggy parting.

The granite contains bands, up to 5 metres thick, of coarse-grained quartz-rich rock stained yellow and dark brown by iron. These bands carry a lustrous dark mineral, forming less than 2 percent of the rock, which I. R. Pontifex of the Bureau of Mineral Resources identified as graphite.

The dark brown biotite-quartz-feldspar gneiss is most abundant in an ill defined zone about 50 metres thick, where it forms lenses up to several metres long and 2 metres thick. The gneiss has a migmatitic relationship with the surrounding red granite; the margins of the lenses are indefinite; many irregular patches of each rock type occur within the other; ill defined tongues of each type penetrate the other; all gradations in composition exist between the two types.

Fram Peak is a bulky monolith connected by a narrow rock saddle on its north-eastern side to a high rock ridge which extends north-eastwards for about 500 metres. The high ridge is predominantly composed of biotite-quartz-feldspar gneiss, fine-grained to medium-grained, with abundant lenses and stringers of red fine-grained to very coarse-grained granite ranging from a few millimetres to a few metres thick. In the south-eastern face of this high ridge a concordant band of marble between 20 and 30 metres thick is exposed. This band strikes into the narrow rock saddle, where it interfingers with the migmatitic rocks. On the south-west side of the saddle, the marble is separated from the granite by a fine-grained to medium-grained quartzite, into which the granite grades. The quartzite has a fine flaggy parting and a strong lineation, possibly representing slickensides. McLeod (1959) describes it as a phyllonite occupying a shear zone.

The marble is predominantly a mid-grey very coarse-grained friable rock, which McLeod (1959) describes as being composed of calcite (more than 50 percent of the rock), olivine (almost completely altered to serpentine minerals and magnetite), magnetite, pyrrhotite, pleonaste, and minor apatite. Small spherical segregations a few centimetres in diameter, scattered in the rock, contain combinations of olivine, magnetite, pleonaste, enstatite, apatite, and rare calcite and zircon. Larger aggregates are composed of olivine and biotite with some magnetite.

In the saddle, a large subcircular mass in the marble, about 5 metres across, is composed of dark green opaque, and light green translucent, minerals intergrown with biotite, calcite, and magnetite. Small clots of red garnet are restricted to the west side of the saddle.

Near the end of the ridge, a small group of nunataks extends 3 kilometres north-eastwards. They are predominantly composed of red-weathering granite similar to the granite of Fram Peak, but lenses and bands of dark brown biotite-bearing and pyroxene-bearing gneisses form about 20 percent of the exposures, and white quartzite bands form about 1 percent.

The granite is generally a medium-grained quartz-feldspar rock foliated by stringers of quartz a few millimetres thick; it contains some garnet or biotite, and iron-ore minerals may be associated with the quartz. The granite generally forms bands between 50 centimetres and 10 metres thick; a few bands are more than 50 metres thick.

The dark brown bands are quartz-feldspar gneiss rich in biotite, with some iron-ore minerals and pyroxene. They are fine-grained to medium-grained rocks with a foliation conferred by stringers of dark minerals alternating with stringers of quartz and feldspar, each a few millimetres thick. Most dark brown bands are between 50 centimetres and 5 metres thick; a few range up to 30 metres in thickness.

The difference in colour between red and dark brown rocks is mainly produced in weathering. The fresh granite is almost as dark as the fresh pyroxene-biotite-quartz-feldspar gneiss, since feldspar and quartz are dark brown where unweathered.

The quartzite bands are medium-grained to coarse-grained garnet-feldspar quartzite. Quartz is blue-grey and its concentration in stringers gives the rock a foliation; some thicker stringers contain iron-ore mineral. Almost all the quartzite bands are less than 1 metre thick. They are generally concordant, but some of them cut across the banding of the granite and the gneiss in places.

On the steep eastern side of the interrupted ridge, red and brown bands outline large-scale near-isoclinal folds. Erratic behaviour of the magnetic compass at one point on the ridge is probably caused by the iron-ore mineral common in all rock types.

The eastern Hansen Mountains are rock spires, hundreds of metres high, composed of red, white, and brown banded rocks commonly deformed into large isoclinal folds. White bands form about 30 percent of the exposed rock and red bands most of the remainder; brown bands are only prominent in a few exposures.

The rocks were examined at See Nunatak. The white bands here are garnet quartzite; the band sampled is medium-grained and poorly foliated. Red and reddish brown bands are coarse-grained biotite-quartz-feldspar gneiss, and contain a few dark brown lenses, up to 5 metres long by 2 metres thick, of medium-grained and fine-grained equigranular biotite-pyroxene?-quartz-feldspar rock. The stringers of dark minerals (garnet, biotite, or pyroxene) which define the foliation are intensely contorted, and large irregular patches of massive granitic coarse-grained biotite-quartz-feldspar rock produce a migmatitic appearance in places.

The white bands generally have sharp margins, but in places they appear to grade within a very small interval into the red bands.

Maruff Peaks, observed from the air, are composed predominantly of thick red bands alternating with white bands up to 20 metres thick. The banding outlines large isoclinal folds, up to about 100 metres in amplitude and 20 metres from limb to limb, whose axial planes appear to trend parallel to the strike of the banding. However, the southernmost peak is composed of thick black and thinner white bands, and carries a prominent steeply plunging lineation apparently at right angles to the trend of the isoclinal folding in the other peaks. In places the white bands appear to cut across the banding of the red and brown rocks and on one peak the white bands form a network.

Whiting Nunatak, also observed from the air, is formed by white, red, and brown bands, broadly similar to See Nunatak and Maruff Peaks.

The western Hansen Mountains appear from the air to be formed by more-massive rocks, but banding similar to that in the eastern Hansen Mountains is prominent in some nunataks, and thick, isolated bands of light grey marble occur in places.

Two nunataks were visited in the western mountains. One, the easternmost member of the Dwyer Nunataks, has a massive appearance when seen from the air, but is composed of finely-banded grey gneiss and coarse-grained red-brown gneissic granite; irregular pods and lenses of massive granite contain blocks of grey gneiss.

The grey gneiss is a fine-grained equigranular finely banded rock possibly composed of diopside and feldspar. It resembles in colour and texture fine-grained varieties of marble exposed at Fram Peak and the other nunatak visited in the western Hansen Mountains. The red-brown gneissic granite is probably essentially a biotite-quartz-feldspar rock, but abundant small dark crystals may be iron-ore mineral.

Banding and foliation in these rocks are intensely deformed into isoclinal folds and the rocks are markedly lineated, but the pods and lenses of massive granite appear to lack a preferred orientation.

The long rock ridge (the southernmost of the Dwyer Nunataks) about 5 kilometres south-south-west of Mount Banfield was also visited. It is composed of thick bands of dark brown rock and light grey rock outlining a pattern of open regular folds markedly different in style from the tight folding observed in other exposures in these mountains. Within the light grey rocks fine banding also reveals an unusual pattern of crinkly tight folds, several centimetres in amplitude and wavelength.

The light grey rocks are fine-grained marble composed predominantly of calcite and a green mineral, possibly olivine, with some iron-ore mineral. Calcite-rich bands up to 10 centimetres thick alternate with bands of similar thickness and poor in calcite. A few lenses and bands have a very coarse-grained texture and resemble the marble at Fram Peak.

The brown bands are composed of fine-grained poorly foliated biotite-garnet-quartz-feldspar gneiss with a small proportion of a lustrous mineral which may be graphite or iron-ore mineral. Lenses of felsic material up to 1 centimetre thick give the rock its poor foliation, which in places appears to have been disrupted by shearing.

The marble bands range up to 20 metres in thickness; the bands of biotite-garnet-quartz-feldspar rock are generally between 20 metres and 50 or more metres thick.

All the other exposures in the western mountains were examined from the air. Mount Corry and most exposures in the Dwyer Nunataks all appear to be composed of massive dark red rocks, but may contain a considerable proportion of the grey gneiss which occurs in the easternmost member of Dwyer Nunataks but which was not visible from the air. A light-coloured band traversing Mount Corry resembles, from the air, the marble band on Fram Peak.

The nunatak 2 kilometres south-south-east of Mount Banfield, the northern part of Mount Banfield, and Foley Nunatak are composed of interbanded white, grey, red, and dark brown rocks revealing a pattern of isoclinal folds which is most complex at Foley Nunatak. The bands range up to about 20 metres in thickness; at Mount Banfield, the grey and the white bands appear to cut the red and the brown bands in places, but generally all bands are deformed concordantly.

In the southern part of Mount Banfield, massive grey bands, up to 30 metres and more in thickness, cut across red and brown bands and contain large lenses of brown rock, up to 10 metres long by 2 metres thick. These grey bands also resemble the marble of Fram Peak.

Pyroxene-Quartz-Feldspar Gneisses of Casey Range

Finely banded rock with an overall composition of sillimanite-garnet-pyroxene-quartz-feldspar gneiss crops out along the whole of the Casey Range, to the south-west of Mawson. Crohn (1959) had previously visited the Casey Range and referred to the rocks as 'metasediment'.

The range consists of prominent north-south strike ridges with a precipitous western face and a steep eastern dip-slope. The range reaches a maximum altitude of 950 metres.

The major gneissic rock is composed of thin alternating dark and light bands up to half a metre thick (Pl. 5, fig. 1). Many of the bands maintain a very uniform thickness for considerable distances. At the northern end of the Casey Range, the dark and light bands form about equal amounts of the whole rock, but to the south the darker bands become thicker and form a higher proportion than the light.

The dark bands are fine-grained to medium-grained and are composed of 40–50 percent pyroxene; 20–30 percent feldspar and quartz; 5–10 percent biotite; and 10–20 percent garnet. Garnet is not common at the northern end of the Casey Range, but at places on Lucas Nunatak it is a major constituent of the dark bands, with crystals up to 1 centimetre in diameter. Sillimanite is very common in some of the dark bands of Lucas Nunatak.

The light bands are medium-grained to coarse-grained and are composed of an estimated 50 percent feldspar and 30 percent quartz with minor amounts of pyroxene, biotite and garnet. Petrographic examination of a specimen from a light band on Lucas Nunatak showed it to be a spinel-cordierite-plagioclase-sillimanite-biotite-quartz-garnet-feldspar gneiss, in which the major constituents are quartz, garnet, and alkali feldspar (probably orthoclase-microperthite).

In addition to the pyroxene-quartz-feldspar gneiss which forms 80 to 90 percent of the Casey Range, there are bands of light-coloured fine-grained to medium-grained garnetiferous quartzite, ranging from ½ to 6 metres in thickness. The proportion of garnet in the quartzite also increases to the south.

Small lenses of pyroxene are present, and minor developments of discordant veins of quartz-feldspar pegmatite also occur in places. Green copper-staining and brown or yellow iron-staining are common.

Relatively open folding (Pl. 5, fig. 1) occurs at the northern end of the Casey Range. On Lucas Nunatak, tight isoclinal folds with amplitudes of 5 metres and more have limbs only ¼ to ½ metre apart. Little faulting was seen.

A well-developed lineation is apparent in many of the dark bands, either because it is preferentially developed in the dark bands or because the presence of lath-like minerals such as sillimanite makes any lineation more obvious. The dip of the rocks is consistently 50° to 60° to the east throughout the range and the strike is approximately north. The lineation is in the plane of the banding and the plunge is subparallel to the dip.

The rock types of the Casey Range are not known from any other outcrops in the Mac.-Robertson Land or Kemp Land area and their relationship to the other rocks of the Framnes Mountains is unknown.

Basic and Ultrabasic Dykes

Dykes were examined in charnockite, banded gneiss, garnetiferous gneiss, and quartz-feldspar gneiss. Two types were found: an ultrabasic type composed almost entirely of pyroxene, and a doleritic type composed essentially of feldspar and pyroxene.

Dykes composed almost entirely of pyroxene occur in quartz-feldspar gneiss at Mount Storegutt and in banded gneiss at Gwynn Bay. In both places the dykes parallel the strike of the foliation of the gneiss, but cut across the dip of the foliation.

At Mount Storegutt, the pyroxene dyke, a body more than 7 metres thick, is medium-grained with seams 2 millimetres thick of very fine-grained black material. It contains irregular veins up to 5 centimetres thick of red feldspar pegmatite, and has a prominent network of green copper stains following surface cracks.

Several pyroxene dykes at Gwynn Bay average about 3 metres in thickness. Dark red iron stains and green copper stains occur on the banded gneiss within 50 centimetres of the contact of the dykes, and aplite veins cut the nearby gneiss. The pyroxene dykes contain many lenses, up to 2 metres long by 1 metre thick, of rock similar to the dark bands in the gneiss.

Doleritic dykes appear to be most abundant and are most easily recognized between Styles Bluff and the Jagar Islands; most of these dykes trend west-north-west. Doleritic dykes recognized east of these occurrences are commonly somewhat deformed and no strong preferred trend is evident, though many of them trend approximately westward.

A basic dyke in the charnockite forming Entrance Island at Mawson is about 2 metres thick; it branches and encloses lenses of country rock up to 1 metre thick and several metres long. Lenses in the adjacent country rock, up to 60 centimetres thick and 3 metres or so long, closely resemble the dyke. The dyke appears to be a sheared recrystallized dolerite. It is an even-grained granular aggregate of andesine-labradorite (forming about 60 percent of the rock) and clinopyroxene (30 percent), with small quantities of iron-ore mineral (about 1 percent) and possible quartz (1 percent). Biotite (5 percent) forms scattered large or small ragged plates. Elongated patches of very fine-grained granular material throughout the thin section examined are roughly parallel; they appear to be composed mainly of feldspar with a little quartz.

Basic dykes cutting banded gneiss at Jagar Islands range from 2 metres to 10 metres in thickness. One has a foliation conferred by wispy aggregates of feldspar and schlieren-like bands, defined by variations in dark mineral content, trending parallel to the margins of the dyke. It also contains veins, between 2 and 5 centimetres thick, of quartz-feldspar rock, and it has a poorly-defined vertical lineation. The doleritic rock forming the dyke is an equigranular medium-grained aggregate of andesine-labradorite (about 50 percent), clinopyroxene (18 percent), orthopyroxene (12 percent), and hornblende (12 percent), with small crystals of possible pyrite (5 percent) and quartz (2–5 percent). Rather diffuse stringers of dark minerals give the rock a foliation in thin section.

Another large dyke on the Jagar Islands is generally massive, medium-grained to fine-grained, and equigranular. In thin section it resembles the dyke rock described above, but it contains a little biotite, more pyroxene of both types, and less hornblende and quartz; stringers of dark minerals parallel the preferred orientation of markedly elongated plagioclase crystals. In places, the centre of the dyke contains lenses of feldspar-rich material typically 5 centimetres long by 1 centimetre thick, which trend parallel to the dyke margin.

The margins of the dykes have the same grainsize as the central parts. In one place a zone of small pyroxene crystals, 1 millimetre thick, occurs in the banded gneiss against the dyke.

Where the banded gneiss dips steeply, the dolerite dykes tend to strike parallel to the banding in the gneiss; the trend of one dyke swings through 20° to conform with the banding.

On two adjoining small islands in the Jagar Islands, a gently dipping sheet of pegmatite, about 1 metre in thickness, cuts two dykes. The contact of the pegmatite with dyke rock is sharp, but the pegmatite is relatively fine-grained along the contact. In the dykes, zones about 1 centimetre thick enriched in dark minerals border the pegmatite contacts, and bands of dark minerals a few millimetres thick and a few metres long parallel the pegmatite sheet a few metres from it.

Several basic dykes up to 7 metres thick cut the banded gneiss at Georges Islands, but foliation in the dykes runs parallel to the foliation in the banded gneiss. They are composed of rock similar to that forming the dykes at Jagar Islands.

At Turbulence Bluffs, a basic dyke about 3 metres thick in the banded gneiss is composed of fine-grained garnet-pyroxene-feldspar rock; it contains veins and schlieren of quartz-feldspar rock, some with garnet, and has a probable foliation trending about south-west.

The basic dyke cutting the garnetiferous gneiss at Rayner Peak is 1½ to 3 metres thick and is composed of coarse-grained bands and fine-grained to medium-grained bands between 30 and 50 centimetres thick.

A dyke about 5 metres thick cuts quartz-feldspar gneiss at the eastern end of Mount Mueller. It is composed of very dark equigranular medium-grained feldspar-pyroxene rock, with considerably more dark mineral than the metamorphosed doleritic rocks described above. The dyke is not evidently metamorphosed, and has remarkably straight walls and sharp contacts outlined by a very fined-grained selvage about 5 millimetres thick, which resembles a chilled margin. Within 1½ metres of the dyke the gneiss contains coarse-grained clots made up of various proportions of biotite, pyroxene, quartz, and feldspar, ranging up to 1 metre long by 15 centimetres thick.

STRUCTURE

Foliation

Foliation is present in all rock types described, though individual specimens or exposures of some types may be massive. The most common macroscopic elements of foliation are leaf-like aggregates of predominantly light or predominantly dark minerals, and since they characterize rocks as diverse as dolerite and marble they almost certainly have been formed as a result of deformation and metamorphism. The foliation parallels the banding everywhere except at Tschuffert Peak (Fig. 3). However, foliation and banding are themselves deformed by almost all folds seen, and in places they are interrupted by recrystallization (Pl. 4, fig. 2).

Two markedly different trends of foliation are evident in the map area. Foliation almost everywhere within the charnockite between Mawson and Byrd Head, in the gneisses of Casey Range, and in the gneisses exposed between Byrd Head and Campbell Head and at Tilley Nunatak and Solitary Island, trends approximately north. West of Tilley Nunatak, the predominant trends of foliation and banding in the banded gneiss, the quartz-feldspar gneiss, the gneisses of the Hansen Mountains, and the garnetiferous gneiss are between east and south-east, with the great majority trending about east-south-east. However, a northerly trend is again evident in the charnockite at Wheeler Rocks and Magnet Bay; foliation and banding on both sides of the boundary between quartz-feldspar gneiss and banded gneiss, from Cape Boothby to Schwartz Range, trend between north-east and east-north-east, that is, approximately parallel to the boundary. Trends of foliation and the distribution of rock types suggest that other major lithological boundaries, between banded gneiss and the gneisses of Taylor Glacier, and between the latter and the charnockite at Stump Mountains, trend approximately north-eastwards, though marked northerly trends evident in the Thorfin Islands suggest that the direction of the boundary may swing from north-east to north-north-west here.

Lineation

A macroscopic lineation, caused by parallel arrangement of mineral grains or small elongated aggregates of grains, was seen at several places. In most cases, the lineation is not well defined, and in some outcrops is evident only in parts of the rock.

At Rayner Peak, a strong lineation is produced by fine crenulations in quartzite beds. The crenulations are quite prominent on the top and bottom of the beds, where the softer rocks have been eroded away and the quartzite stands out.

Folds

Folds were observed in all rock types except the basic and ultrabasic dykes; in the charnockite, folds are common only near Stump Mountain and at Baillieu Peak, near the western margin of the large area of outcrop.

The folds generally deform the foliation, but the development of a new foliation parallel to their axial planes is nowhere evident. The folds in the biotite-rich band at Tschuffert Peak (Fig. 3) may be shear folds formed in the earlier deformation which produced the foliation.

Most of the folds observed are small-scale structures whose wavelength ranges from a few millimetres to 100 metres or so. Outcrop patterns suggest that large-scale folds, about 1 kilometre or more from limb to limb, are present in the banded gneiss at Stillwell Hills and in the charnockite between Stump Mountain and Ufs Island.

Where folds are best displayed, in banded gneiss and in the banded rocks of the Hansen Mountains and Mount Kernot, the predominant type appears to be a near-isoclinal overturned fold with a steeply dipping axial plane, but many variations in style are evident in small-scale folds in the banded gneiss (Pl. 4, figs 1 and 2). Some of these isoclinal folds have an amplitude many times their wavelength, with quite parallel limbs. Such folds are especially marked in the western part of the banded gneiss.

Both small-scale and large-scale folds observed in marble in the Hansen Mountains appear to differ in style from the majority of folds observed. Presumably this difference reflects a fundamental difference in the competence of the marble.

The trends of most observed fold axes agree broadly with local trends of foliation.

Mylonitic rocks

The occurrence of thin seams of mylonitic rock in almost every charnockite exposure suggests that the charnockite has been sheared rather than folded during deformation of the area. Mylonitic rocks also occur at Fram Peak (as phyllonite) and the Casey Range.

Faults

No large faults were observed. Undoubtedly they exist, but the absence of marker bands, and the apparent relation of foliation and banding, and even of topography, to fold structures in coastal exposures, such as the Stillwell Hills and Stump Mountain, suggest that the certain identification of faults is a matter for detailed mapping.

Economic Minerals

Small concentrations of economic minerals were found at several places, but none is of commercial importance.

Metallic minerals, mostly iron oxides and sulphides, were found in charnockite, banded gneiss, quartz-feldspar gneiss, gneiss and marble in the Hansen Mountains, and in pegmatite in the banded gneiss. Unless otherwise indicated, laboratory identifications of opaque minerals were made by I.R. Pontifex of the Bureau of Mineral Resources.

Graphite and sillimanite were found in gneiss at Ives Tongue and several exposures of sillimanite-bearing geniss were recorded in the Casey Range. Graphitic rocks were found at several places.

Sulphides

A small deposit of sulphide minerals at Entrance Island, near Mawson, was examined in detail. The minerals were identified by G. J. G. Greaves, of the Bureau of Mineral Resources, from samples collected in 1961. The sulphide minerals form pods, ranging up to 1 metre long by 30 centimetres thick, within a vertical zone of sheared charnockite about 4 metres long by 1 metre thick. The zone strikes due north, parallel to the foliation of the surrounding porphyroblastic charnockite. The pods are composed of massive flaky black marcasite and pyrrhotite, and contain thin irregular veins of chalcopyrite, from 2 to 5 millimetres thick, and rare flakes of molybdenite a few millimetres long. Chalcopyrite forms about 10 percent of the sample described by Greaves. Some of the sheared charnockite between the pods is impregnated with small sulphide crystals. In the exposure, the pods are completely coated by a dark yellow-brown encrustation, and in places they have weathered to a yellow-brown sandy clay which contrasts markedly in texture with the sand derived by weathering from the surrounding charnockite.

In the northern Stillwell Hills, thin stringers of metallic sulphide minerals occur in a small exposure of black fine-grained quartzite, part of a band in the weathered quartzite and quartz-feldspar gneiss which form the north end of the hills and the adjacent islands. Samples were found to contain a few percent of pyrrhotite, ilmenite, and graphite, and one percent or less of magnetite and chalcopyrite. The sulphide-bearing exposure is on the valley floor at the base of a slope formed mainly by light reddish brown weathered limonite-stained gneiss. The exposure is coloured dark yellow-brown by a thin but dense encrustation of limonite, and this continues over detritus and outcrops at the base of the slopes on both sides of the valley, forming a distinctively coloured zone a few metres high.

A few pebbles on valley floors in these hills carry a green crust, identified by I. R. Pontifex as copper chloride. A pebble examined by Pontifex contains no copper-bearing minerals, and the copper chloride presumably was deposited on it by the stream which flows along the valley floor in summer.

Iron oxide and related minerals

Boulders in the north-eastern part of the boulder field in the main saddle of Mount Twintop contain iron-ore mineral as thin bands and schlieren. The iron-ore mineral content is rarely more than 10 percent.

Small quantities of minerals resembling magnetite were found in pegmatitic rocks at the northern Stillwell Hills, Jagar Islands, and Gwynn Bay. G. J. Greaves, of the Bureau of Mineral Resources, has described samples collected from other pegmatites in the banded gneiss in 1961, in which ilmenite and titanhematite accompany magnetite.

In the central Stillwell Hills, magnetite and ilmenite, commonly accompanied by garnet, form bands up to 50 centimetres thick and in places over 50 metres long. A sample contained 70 percent magnetite and 30 percent of intergrown exsolution lamellae of ilmenite. The bands occur within the dark pyroxene-feldspar rocks which alternate with quartzite in the core of the large antiform 1½ kilometres north of Kemp Peak. They make up only a few percent of the thick dark bands which contain them, and they are generally separated by several metres of pyroxene-feldspar rock. The bands and the pyroxene-feldspar rock within 1 metre of them commonly carry a network of green copper stains following surface cracks.

In the Hansen Mountains, scattered aggregates of magnetite, containing up to 15 percent ilmenite in the sample examined, occur in marble at Fram Peak. The aggregates are up to 10 centimetres across. The granite, gneiss, and marble in these mountains commonly carry up to a few percent of small crystals of possible magnetite.

At Cook Nunataks, Wallis Nunataks, and Mount Mueller, dark yellow-brown weathered rocks, heavily stained by limonite, form bands up to several metres thick in the quartz-feldspar gneiss. Samples of the stained rocks appear to be somewhat shattered and the staining continues for at least several centimetres below the exposed surface. These rocks are generally rich in quartz and contain at least a few percent of iron-ore minerals weathered in varying degrees. A fresh unshattered rock at Cook Nunataks, associated with stained rocks, is composed of roughly 60 percent quartz and 40 percent possible magnetite. The magnetite(?) is disseminated among the quartz and in places forms stringers up to 1 centimetre thick. This rock forms numerous bands a few centimetres thick in the quartz-feldspar gneiss.

Other minerals

Graphite forms up to a few percent of some weathered quartz-rich coarse-grained rocks in the central and western parts of Ives Tongue. The graphite generally occurs as disseminated flakes a few millimetres in length, but the coarsest rocks contain aggregates of almost pure graphite up to 3 centimetres long. In one specimen, the graphite is accompanied by 5 percent of combined rutile, magnetite, and ilmenite.

A band of coarse-grained granitic rock at Fram Peak, several metres thick, contains a few percent of graphite.

In the Casey Range, sillimanite is locally an abundant constituent of the predominant pyroxene-bearing gneisses. Sillimanite forms thin layers in the graphite-bearing rocks at Ives Tongue, but the rocks are much weathered and heavily stained by iron.

Grains of a black glassy mineral occurring in a magnetite-biotite-quartz-feldspar pegmatite at Gwynn Bay were tentatively identified as a multiple oxide of a rare earth silicate, possibly allanite.

Guano

Examination from the air in 1965 confirmed the occurrence of small patches of guano adjacent to Adélie penguin rookeries in the Rookery Islands and on Gibbney Island. Investigation in 1961 showed that few of these patches are deeper than 50 centimetres, and individual patches range up to about 10 square metres in area.

Geological History

Original rocks

The original natures of the various rock types are masked by deformation and metamorphism, but many of them appear to retain some characteristics of supracrustal—sedimentary or volcanic—formations. In the banded gneiss, the garnetiferous gneisses of Mount Kernot etc., the pyroxene-quartz-feldspar gneisses of Casey Range, and the gneisses of Taylor Glacier, the great variations in composition from band to band and the similarities in composition of some bands to sedimentary or volcanic rocks, such as feldspathic sandstone or basalt, suggest that the gneisses with compositional banding are of supracrustal origin. Metamorphosed limestone is present in the Hansen Mountains, and diopside-rich rocks and some garnet-rich rocks in the banded gneiss are possibly derived from impure limestone. Sillimanite and cordierite are locally abundant in gneisses of the Casey Range and at Taylor Glacier, and graphite occurs at Ives Tongue. These minerals are generally held to suggest a sedimentary origin for the host rock.

In the banded gneiss, thin dark bands with a considerable quartz content may represent basic pyroclastic rocks contaminated by quartz, while thick sharply defined dark bands composed essentially of calcic plagioclase and pyroxene may be lavas or minor intrusive rocks.

The charnockite and the quartz-feldspar gneiss have wide distributions and strikingly uniform compositions. Both rock types show some local variations: lenses of mafic granulitic rock are abundant in the charnockite near Mawson; large bodies of gneiss similar to the gneisses of Taylor Glacier are common in charnockite in the Framnes Mountains; lenses of quartz-feldspar rock are abundant in the charnockite near Stump Mountain, and charnockite appears to be interlayered with garnet-bearing and biotite-bearing gneisses there. In the quartz-feldspar gneiss, lenses of pyroxene-feldspar gneiss, garnet quartzite, and biotite-bearing gneisses are locally abundant. Both the charnockite and the quartz-feldspar gneiss have structural resemblances to igneous rocks, and the charnockite has, to some extent, been mobilized (Crohn, 1959), but metamorphism and perhaps deformation have masked their original natures to such a degree that it is impossible to decide if they represent large masses of uniform sediments or of uniform igneous rocks, or if they have attained a uniform appearance by thorough recrystallization.

Metamorphic history

The abundance of sillimanite or pyroxene, and calcic plagioclase, in most of the major rock types indicates that the first discernible metamorphism took place under granulite-facies conditions. This metamorphism was presumably associated with the deformation which produced the widespread foliation.

The granulite-facies metamorphism appears to have been succeeded by an episode of deformation which tightly folded the foliation and banding in many gneisses, and which perhaps simultaneously produced widespread cataclasis in the charnockite. Some folds in banded gneiss, at Gwynn Bay and Jagar Islands, are cut by or contain recrystallized rocks, and discordant bands in folded gneisses in the Hansen Mountains also show that recrystallization has occurred after the fold movements. Potash feldspar and biotite appear to be the diagnostic minerals of this recrystallization, and suggest that it took place under the conditions of the almandine-amphibolite facies of metamorphism.

The recrystallization appears to mark a second episode of metamorphism, the effects of which are particularly evident where biotite-bearing and granitic rocks are abundant. Otherwise the effects are relatively slight; many of the mylonitic rocks in the charnockite are recrystallized, minor biotite occurs in charnockite in places, and hornblende occurs in some pyroxene-bearing members of the banded gneiss (McCarthy & Trail, 1964).

The recrystallized dolerite dykes in the western part of the banded gneiss outcrop are not disrupted by the deformation which preceded the second metamorphism, and the few massive pegmatites which cut some dykes are also not evidently deformed. The marked tendency of basic and ultrabasic dykes to conform with the strike of the gneisses suggests that they were injected at a late stage in the deformation. They were then probably recrystallized in the subsequent episode of metamorphism, during which the massive pegmatites were formed. The pegmatite bodies have no preferred orientation and were probably emplaced when the stresses of deformation had been completely relieved.

Ravich & Krylov (1964) have obtained isotopic ages ranging from 620 to 535 m.y. for rocks from Edward VIII Gulf and from 650 to 490 m.y. for rocks from Mawson. These dates are probably related to the later episode of metamorphism, though the wide spread of the ages suggests that the earlier episode may also be reflected in the results.

Late geological history

The formation of the coastal erosion surface is probably the first discernible event in the late geological history. Glacial erosion is not likely to form broad and level surfaces and, as Dietz (1963) has shown, marine erosion probably does not cut broad planes in hard rock. The very small tidal range on this coast would also limit the breadth of the platform which could be cut by wave erosion.

The coastal erosion surface is probably a peneplain formed by long-continued fluviatile erosion before glaciation. From this plain the preglacial land surface probably rose more steeply southwards and westwards and is perhaps represented by the summits of the higher nunataks inland. No evidence of block faulting has been found in the inland or coastal exposures.

With the onset of glaciation, the next recorded event is probably the formation of some cirques. Large cirques, partly buried by the ice sheet, in the inland nunataks evidently formed when the ice sheet was much lower than at present, and moraine scattered over the walls of large cirques in the Framnes Mountains indicates that these formed before the ice sheet, which deposited the moraine, reached its maximum height. The lack of large cirques in the higher coastal exposures suggests that the cirques in the inland nunataks were cut by mountain glaciers at a time when the climate nearer the sea was too mild to permit glaciers to form.

Glacial erosion, in the beginning by mountain glaciers and later by the ice sheet, was probably directed, at least in the highlands, by the preglacial drainage pattern. The lowering of sea level with the formation of the ice sheet may have initiated the dissection of the coastal erosion surface before the land sank under the weight of the ice.

The absence of islands seaward of the terminations of the large ice streams suggests that deep channels exist there; these ice streams probably cut their valleys to a base level controlled by a sea surface considerably lower than the present surface. When the ice sheet stood at its maximum height, the ice streams terminating in embayments carried much greater quantities of ice than they do now.

The ice streams which terminate in promontories are overcharged with ice even at present, yet channels also appear to exist seaward of them. The valleys of these glaciers are relatively narrow, and perhaps at the onset of glaciation they were immature valleys, which were rapidly deepened but not widened by concentrated glacial erosion.

Only one great fluctuation of the level of the ice sheet is evident in the costal region of Mac.Robertson Land and Kemp Land: it is recorded by the scattered moraine which occurs up to 300 metres above the present surface of the ice, according to Crohn (1959). The thick and extensive blankets of moraine evident in the Prince Charles Mountains (Trail, 1964) are absent here and this may indicate that glaciation has been less intense or even less prolonged.

The finer fractions which are evident in younger moraine have probably been removed from the scattered older moraine by wind.

The lack of fluvioglacial deposits suggests that rainfall was insignificant after the recession of the ice sheet, and even indicates that large quantities of meltwater were not channelled over the rock exposures. The absence of strandlines higher than 15 metres above present sea level suggests that wave action has reworked very little of the old moraine.

The rise in sea level that followed the melting of the ice cap appears to have been outstripped by the isostatic rise of the land relieved of its burden of ice, and the raised beaches of this coast probably reflect a complex interplay of rising land and rising sea, rather than a single period of higher sea level.

Evidence for multiple glaciation in Antarctica has been found principally in the McMurdo Sound region (Black & Berg, 1964). In Mac.Robertson Land and Kemp Land, the only major fluctuation of the ice sheet so far recognized is presumably the latest, which has obliterated any record of earlier fluctuations.

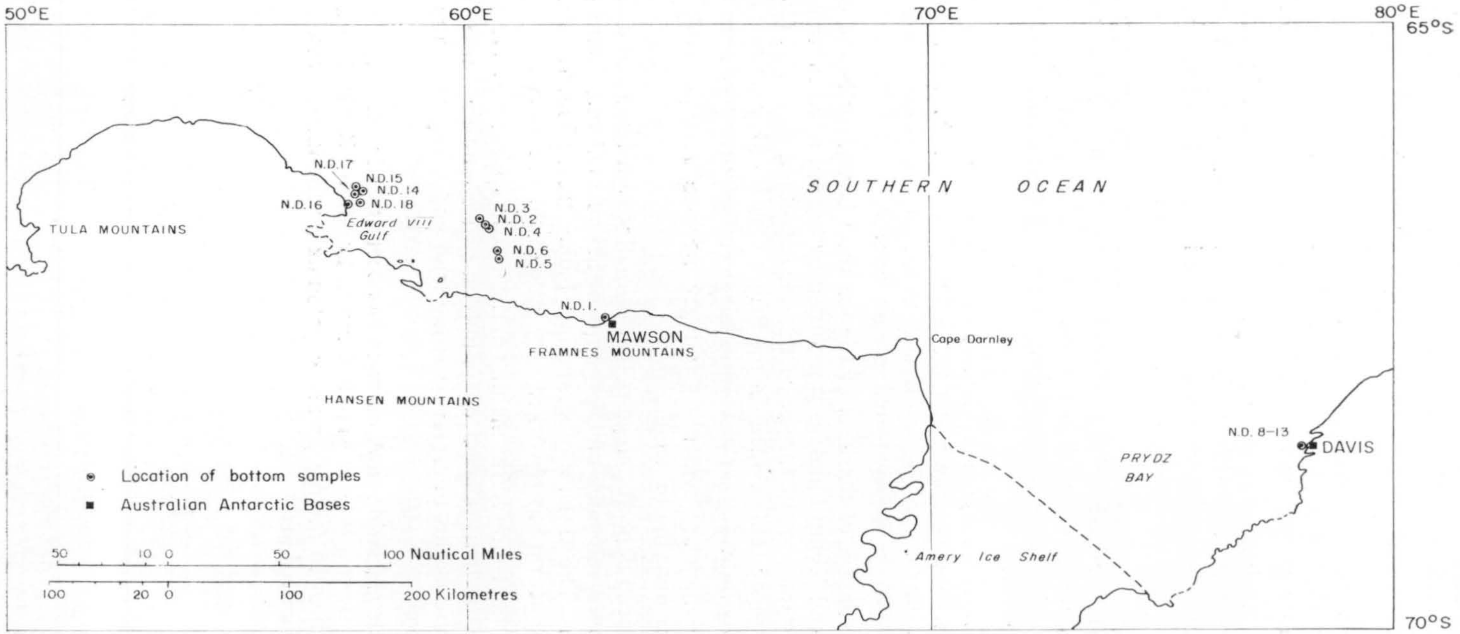

Figure 6. Location of sea bottom sediment sampling sites.

RECENT MARINE SEDIMENTS, CONTINENTAL SHELF

SAMPLING PROCEDURES

Bottom sediment samples were collected from sixteen localities on the continental shelf of Antarctica between latitudes 66°25′S and 68°34′S and between longitudes 57°20′E and 77°56′E (Fig. 6; Table 1). As there was no provision in the 1965 ANARE programme for systematic oceanographic work, bottom sampling could only be carried out when the ship was stationary in pack-ice or at anchor. This has inevitably resulted in an uneven distribution of samples.

The following sample numbering system was used: The letters ND refer to the ship, and the number to the locality. Where two cores were obtained at the same locality, the letters A and B are used (e.g. ND4B indicated the second core obtained at the fourth locality sampled). Where a core is divided into upper, middle, and lower, or upper and lower, parts, the numbers (1),(2), and (3), or (1) and (2), are added for each part, numbering downwards (e.g. ND4B(1)).

TABLE 1: SEA FLOOR SAMPLE LOCALITIES

Specimen number	*General location*	*Latitude*	*Longitude*	*Depth (feet)*	*Depth (metres)*	*Length of core (inches)*
ND1	Mawson approaches	67°36′S	62°51′E	655	200	1
ND2	North-west of Mawson	66°47′S	60°14′E	1550	475	10, 6
ND3	North-west of Mawson	66°47′S	60°13½′E	1200	365	5, 2
ND4	North-west of Mawson	66°48′S	60°18′E	1380	420	11
ND5	North-west of Mawson	67°04′S	60°42′E	1740	530	10
ND6	North-west of Mawson	66°59′S	60°47′E	1580	480	11
ND8	Davis approaches	68°33½′S	77°53′E	140	40	2
ND9	Davis approaches	68°34½′S	77°52′E	65	20	1
ND11	Davis approaches	68°34½′S	77°53′E	120	35	Bag sample
ND12	Davis approaches	68°34½′S	77°55′E	180	55	Bag sample
ND13	Davis approaches	68°34½′S	77°56′E	70	20	Anchor sample
ND14	Vicinity Cape Boothby	66°27′S	57°39′E	450	135	½
ND15	Vicinity Cape Boothby	66°25′S	57°36′E	540	165	10
ND16	Vicinity Cape Boothby	66°36′S	57°20′E	750	230	4
ND17	Vicinity Cape Boothby	66°36′S	57°31′E	790	240	½
ND18	Vicinity Cape Boothby	66°35′S	57°42′E	990	300	Rock chip

The method of bottom sampling used on the 'Nella Dan' was basically that used by the Bureau of Mineral Resources in their bottom sampling in north Australian waters.

Severe limitations were placed on the type of equipment which could be used, because 'Nella Dan' has not been designed specifically for oceanographic work. It was therefore impossible to use a large piston corer of the Kullenberg or Ewing type. An oceanographic winch was not available and therefore it was necessary to use one of the ship's mounted five-ton winches.

The corer used was a modified type of Phleger Corer (Pl. 6, fig. 2). A free fall of about 10 metres was achieved by means of a trigger arm with a 14-lb (6.3kg) trip-weight attached to one end by a 10-metre line. The corer was attached to the other end by 12 metres of wire rope (Pl. 6, fig. 1). There is theoretically no limit on the depth to which the corer may be used. The greatest depth of operation was 530 metres. A total of 550 metres of $\frac{1}{2}$-inch circumference 6/19 galvanized steel wire rope was available.

The sample was retained in the corer by a plastic film lining (Pl. 6, fig. 2). On removal from the corer, the sample was normally left in the plastic lining and put into a plastic bag which was then sealed, thus making the sample air tight for transport back to Australia.

The depth of the bottom at the sampling point was obtained from a Kelvin Hughes MS26G Echo Sounder.

Theoretically it is possible to obtain cores of up to 18 inches ($\frac{1}{2}$ metre) or more, but in fact the greatest length obtained was 11 inches (28 centimetres). A greater penetration could probably be obtained by arranging for a free fall of more than 10 metres, or by making the corer heavier.

Laboratory Technique

Most samples were first quartered; one quarter was used for micropalaeontological work; one quarter for geochemical analysis; one for sedimentological work; and one was retained.

The sedimentological work was done by P. J. Cook. Samples were compared with the United States Geological Survey Standard Colour Chart and then examined qualitatively under a binocular microscope. Core samples were then divided into lithological units where these were present; where no obvious breaks occurred, the core was generally subdivided arbitrarily into lower, middle, and upper portions. Samples were then dried at 40°C for several days.

Dry sieving was subsequently carried out for the range -2.0ϕ* to $+4.25\phi$ (equivalent to the range 5 mesh to 270 mesh) at intervals of 0.25ϕ. The sample from each 0.25ϕ interval was weighed to an accuracy of $\pm$ 0.0002 gm. The tendency of silt particles to aggregate was overcome by carefully brushing each sample in the sieve until it could be seen by microscopic examination that all silt particles had disaggregated and had fallen through the sieve. The fraction below 270 mesh was collected and the textural analysis of this fraction is at present proceeding, using a sedimentation balance.

Results of Sedimentological Work

Only very general conclusions can be drawn from the sedimentological results, for work is still proceeding. Comment is limited to the three major groups of grainsize, i.e. rudite, arenite, and lutite.

Table 2 gives a summary of the percentages of rudite, arenite and lutite in each sea-bottom sample analysed. The average texture of the bottom samples is:

Rudite	..	..	10.4 percent
Arenite	..	..	45.1 percent
Lutite	..	..	44.5 percent

This contrasts markedly with a typical moraine sample from Stump Mountain near Taylor Glacier, which has a texture of:

Rudite	..	..	44.7 percent
Arenite	..	..	48.7 percent
Lutite	..	..	6.6 percent

Thus a considerable decrease in the coarse ruditic fraction is indicated in the change from continental glacial to marine glacial deposits.

* a phi unit is equal to $-\log_2$ of the grain diameter in millimetres (Krumbein, 1934)

TABLE 2: GENERAL TEXTURAL PROPORTIONS OF RECENT MARINE SEDIMENTS FROM THE CONTINENTAL SHELF, ANTARCTICA

General number	*Specific number*	*Percentage Rudite*	*Percentage Arenite*	*Percentage Lutite*
ND1	ND1A	2.3	73.6	24.1
ND2	ND2A	2.1	60.8	37.1
	ND2A(1)	34.2	46.4	19.4
	ND2A(2)	70.1	15.7	14.2
	ND2B	0.2	65.5	34.3
ND3	ND3A	23.0	46.2	30.8
ND4	ND4A(1)	31.3	33.7	35.0
	ND4A(2)	8.8	46.1	45.1
	ND4B(1)	18.0	57.9	24.1
	ND4B(2)	9.7	58.3	32.0
	ND4B(3)	59.3	25.1	15.6
ND5	ND5(1)	1.2	45.8	53.0
	ND5(2)	0.8	49.3	49.9
ND6	ND6(1)	0.5	57.1	42.4
	ND6(2)	0.9	43.3	55.8
	ND6(3)	0.5	44.2	55.3
ND8	ND8	..	37.5	63.5
ND11	ND11	..	63.1	36.9
ND12	ND12 { random split	13.7	21.4	64.9
	ND12 { of one sample	..	28.9	71.1
ND14	ND14	..	55.4	44.6
ND15	ND15(1)	..	45.7	54.3
	ND15(2)	..	33.0	67.0
	ND15(3)	..	44.0	56.0
ND16	ND16(1)	..	38.5	61.5
	ND16(2)	..	39.5	59.9
ND17	ND17	3.4	42.5	54.1

The ruditic fraction of a fluvioglacial deposit was found to be intermediate between the marine and continental glacial samples—a sample from a lake in the Vestfold Hills had a textural value of:

Rudite	.. ..	29.8 percent
Arenite	.. ..	35.6 percent
Lutite	.. ..	34.6 percent

The arenite: lutite ratio is almost exactly 1:1 in both the average of marine samples and the lacustrine sample. There is considerable variation between the arenite: lutite ratios of individual marine samples, but the results suggest that in the finer size fractions the nature of the aqueous environment may have little or no influence on the degree of sorting.

A bottom sample from Deep Lake, one of the highly saline lakes in the Vestfold Hills, had the following texture:

Rudite	..	..	0.0 percent
Arenite	..	..	36.3 percent
Lutite	..	..	63.7 percent

These values support the theory (McLeod 1964a) that the saline lakes are landlocked arms of the sea, for fluvioglacial deposits would have a moderately high rudite content.

The sedimentological work will be discussed more fully in a later report.

Palaeontological Results

Quarterings of the sea bottom sediment samples were given a preliminary examination by Dr G. R. J. Terpstra, of the Bureau of Mineral Resources.

Marine faunal assemblages were found in samples ND1, ND4, ND5, ND6, ND8, ND11, ND12, ND15 and ND16. The samples contained Foraminifera, Ostracoda, Bryozoa, Radiolaria, sponge spicules, echinoid species and small Mollusca. The faunas generally were not very rich, except those in samples from localities ND4 and ND15, which contained a fair number of species.

No micro-organisms which would indicate a geological age older than Recent were observed in any of the samples.

Geochemical Results

The following average values for the abundance of chemical elements were obtained for the sea-bottom sediments, which were split into twenty-five samples of sand and gravel and twenty-five samples of silt and clay size:*

	V ppm	Pb ppm	Ni ppm	Co ppm	Cr ppm	P %	S %	CO_2 %
Sand-gravel ..	197	28	21	27	63	0.038	0.067	0.26
Silt-clay	122	118	23	4	103	0.072	0.328	0.29

These results are comparable with those obtained by Hirst (1962a, b) for modern sediments from the Gulf of Paria. Exceptions are the high vanadium and cobalt values in the average of the sand-gravel fractions. These may be due to the presence of abundant mafic minerals. The average quantity of lead present in the silt-clay fraction is considerably higher than that recorded by Hirst (1962 b). The reason for this is unknown; some contamination might have occurred during sieving, but this is considered unlikely. The carbon dioxide content of both fractions is relatively low, an indication of the absence of calcareous organisms in most of the samples. The average sulphur content of the sand-gravel fraction is low; it is, however, high in the silt-clay fraction, which is consistent with the anaerobic environment of some of the finer grained sediments.

* Analyses were conducted as follows:
  - Lead, nickel, cobalt, chromium: atomic absorption after perchloric acid digestion—accuracy of ± 5 percent of extracted metal ions.
  - Vanadium: combination of emission spectrographic, atomic absorption, and colorimetric on each sample—accuracy of ± 20 percent.
  - Sulphur: combustion—accuracy of ± 1 percent.
  - Phosphorus: spectrophotometric—accuracy of ± 10 percent of extracted ion.
  - Carbon dioxide: acid evolution—accuracy of ± 1 percent.

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Fig. 1. Raised beach and strandline, Chapman Ridge.

Fig. 2. Fan of rock debris, with typical Stillwell Hills topography.

PLATE 1

Fig. 1. Polygonal pattern of cracks in rock detritus, Ives Tongue.

Fig. 2. Stone circles on Kemp Peak.

PLATE 2

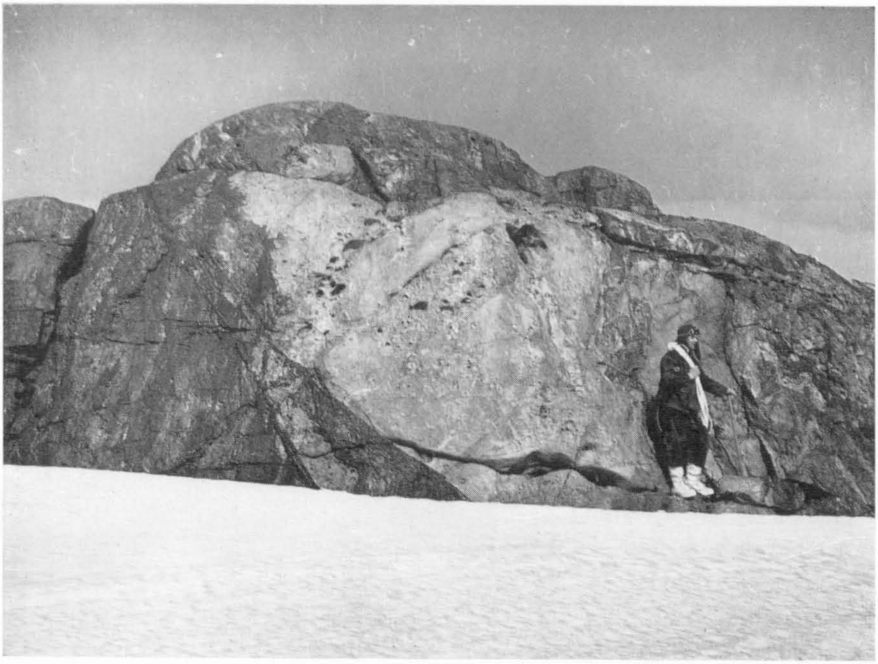

Fig. 1. Charnockite containing bodies of quartz-feldspar rock, with both rocks cut by seams of mylonite.

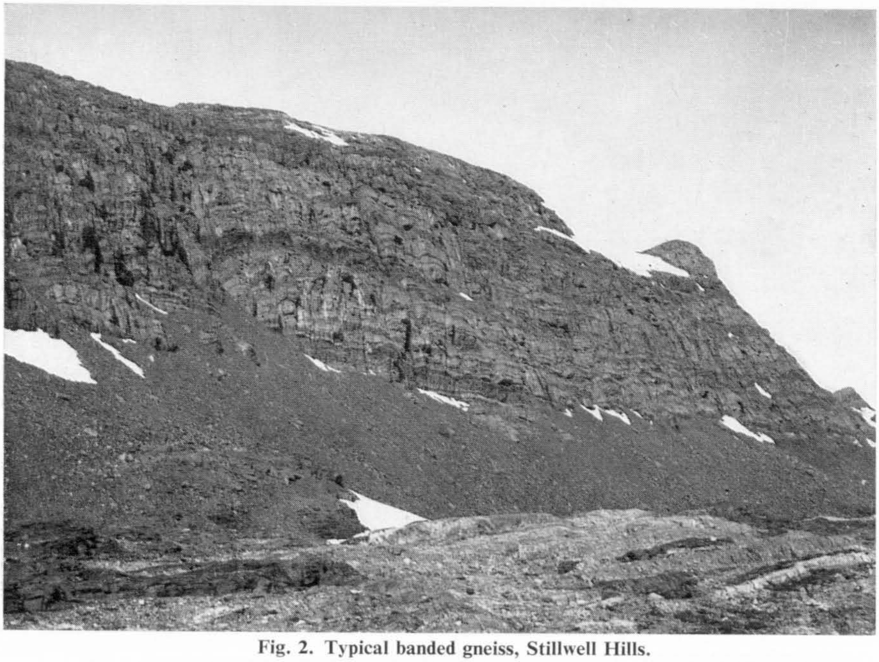

Fig. 2. Typical banded gneiss, Stillwell Hills.

PLATE 3

Fig. 1. Ptygmatic-like fold in banded gneiss.

Fig. 2. Fold in banded gneiss, cut off by recrystallization.

PLATE 4

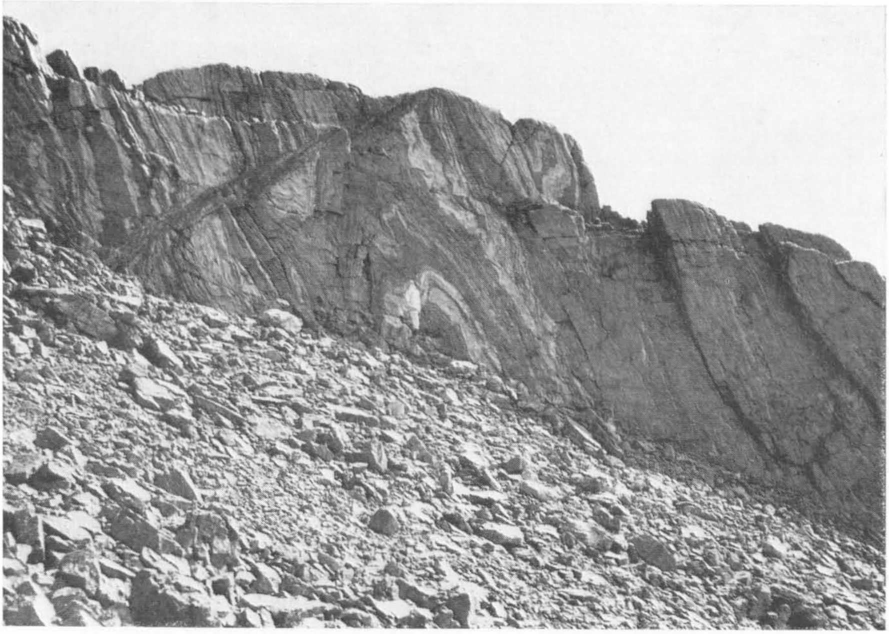

Fig. 1. Folding and thrusting in finely-banded gneiss, Casey Range.

Fig. 2. Glacial markings on pyroxene-garnet-biotite-quartz-feldspar gneiss, Striated Nunatak.

PLATE 5

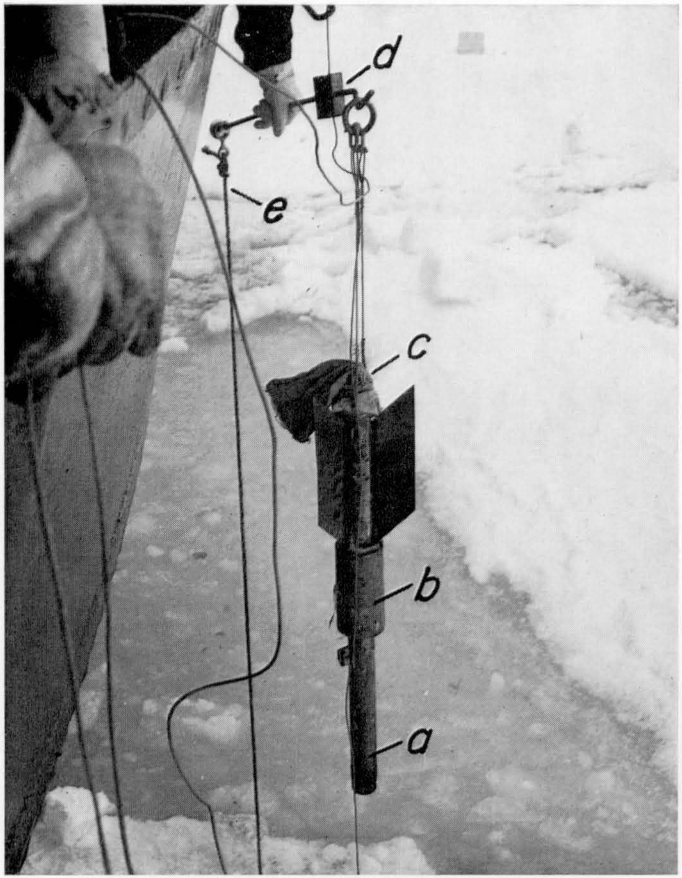

Fig. 1. Oceanographic bottom sampler being lowered through sea ice. a – core barrel; b – lead weighting; c – canvas bag for retaining excess sample; d – trigger arm; e – rope attaching trip-weight to trigger arm.

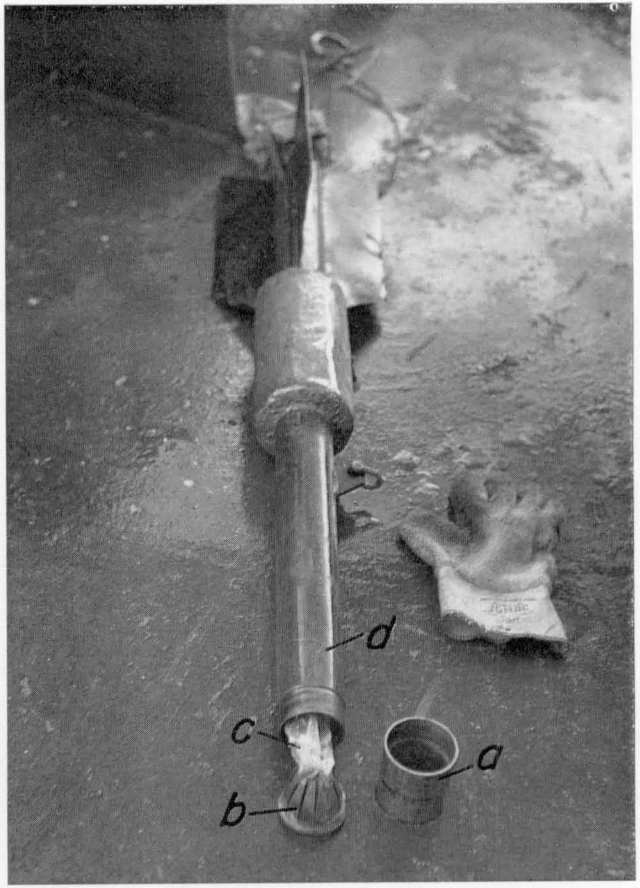

Fig. 2. Oceanographic bottom sampler. a – bit; b – core retainer; c – plastic tubing for retaining core; d – core barrel.

PLATE 6

Attached is a copy of plate 7 from B.M.R. Report No. 118 which was inadvertently omitted from the Report.


PLATE 7
GEOLOGICAL SKETCH MAP
MAC. ROBERTSON, KEMP, AND ENDERBY LANDS
SCALE 1:500,000
30 MILES
40 KILOMETRES
Porphyroblastic charnockite
Even-grained charnockite
Banded gneiss
Quartz-feldspar gneiss
Gneisses of Taylor Glacier
Garnetiferous gneisses of Mount Kernot, etc.
Gneiss, marble and migmatite of Hansen Mountains
Pyroxene-quartz-feldspar gneisses of Casey Range
Garnet-quartz-feldspar gneiss
Basic and ultrabasic dykes
Strike and dip of foliation
Vertical foliation
Horizontal foliation
Rake of lineation measured in plane of foliation
Direction and plunge of lineation
Anticline, showing plunge
Syncline, showing plunge
Plunge of minor anticline
Plunge of minor syncline
Plunge of minor folds
Doubly plunging minor folds
Minor folds, plunge zero
Rock feature
Ice coast
Front of ice shelf or glacier
Glacier
Station
Isotopic age determinations, sample sites
ENDERBY LAND
KEMP LAND
MAC ROBERTSON LAND
KING EDWARD PLATEAU
EDWARD VIII GULF
NAPIER MOUNTAINS
LAW PROMONTORY
STEFANSSON BAY
MAWSON
MAWSON COAST
THORFIN ISLANDS
HANSEN MOUNTAINS
DISMAL MOUNTAINS
ROBERT GLACIER
WILMA GLACIER
MT KERNOT
CASEY RANGE
FRAMNES MOUNTAINS