COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

BULLETIN No. 52.

A CONTRIBUTION TO THE GEOLOGY AND GLACIOLOGY OF THE WESTERN PART OF AUSTRALIAN ANTARCTIC TERRITORY

BY

P. W. CROHN.

Issued under the Authority of Senator the Hon. W. H. Spooner, Minister for National Development.
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Minister: SENATOR THE HON. W. H. SPOONER, M.M.

Secretary: H. G. RAGGATT, C.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

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PREFACE.

This Bulletin describes the results of geological and glaciological investigations carried out in MacRobertson Land and adjoining portions of the Australian Antarctic Territory in 1955 and 1956. The work was planned and carried out by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, and was made possible by the Australian National Antarctic Research Expeditions (A.N.A.R.E.), which established a scientific research station at Mawson, MacRobertson Land, in 1954. Geological equipment used in the investigations was supplied by the Bureau of Mineral Resources, but transport, living accommodation and general facilities were provided by A.N.A.R.E., which is responsible for the general administration of the research station.

Laboratory work connected with these investigations was carried out in the Geology Department of the University of Melbourne during 1957, and the results of this work are being submitted in partial fulfilment of the requirements for the degree of Ph.D. at that University.

SUMMARY.

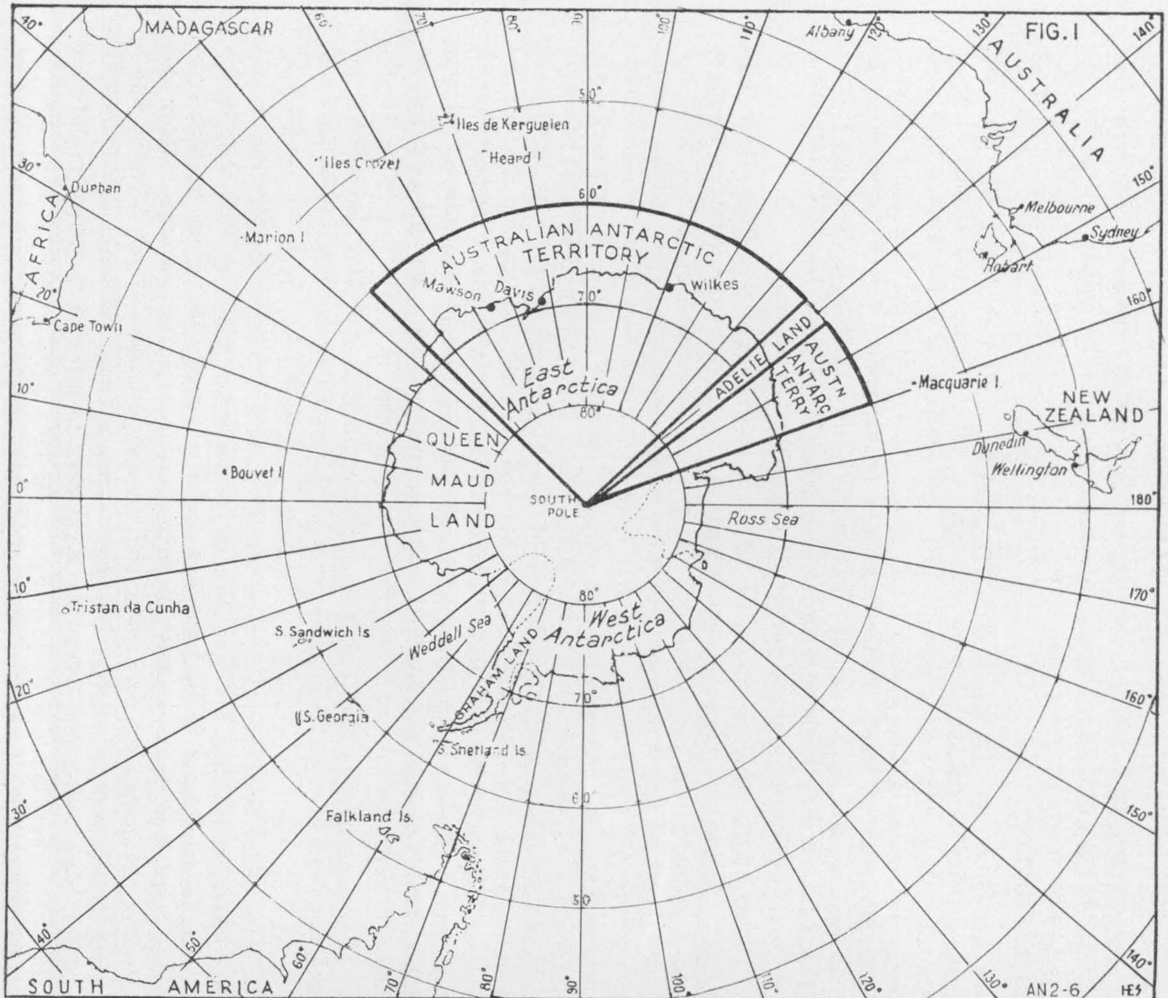
Reconnaissance surveys based on the A.N.A.R.E. Station at Mawson (lat. 67° 36′ S., long. 62° 53′ E.) have covered Enderby Land, Kemp Land, MacRobertson Land and Princess Elizabeth Land between latitudes 67° and 74° South and longitudes 50° and 80° East.

Less than one percent of this area consists of rock outcrops, the remainder being covered by permanent snow and ice. Coastal outcrops and islands occur at Amundsen Bay, in the King Edward VIII Gulf—Stefansson Bay—Mawson area, and in the Larsemann Hills—Vestfold Hills area. Parts of the coastline show evidence of submergence, on which is superimposed a smaller uplift. Inland ranges occur in Enderby Land and to the south of Mawson. The latter, comprising the Prince Charles Mountains and their southern extension, rise to heights of more than 9,000 feet above sea level, and their northern portion is extensively block-faulted.

Most of the outcrops consist of basement rocks of probable Precambrian age. Rocks of sedimentary origin are now represented by garnetiferous quartzite, hornfels, quartz-feldspar-garnet gneiss, and granular gneiss. The dominant igneous rocks are granitic gneisses and hybrid gneisses with minor aplite, pegmatite, gabbro, norite, pyroxenite, and hypersthenite. Several large bodies of charnockitic granite intrude other rocks of the basement complex, and are regarded as products of palingenesis. In several areas, the complex is intruded by dolerite dykes, believed to be of Mesozoic age, and by minor basalts, which may be late Tertiary or Recent. At the Amery Locality, about 250 miles south-east of Mawson, an area of about 200 square miles consists of flat-lying Permian arkosic sandstones and grits with minor pebble beds and coal seams. These are tentatively correlated with the Beacon Formation of Victoria Land. Both high-level and low-level moraines have been noted, and the latter include lateral, medial, terminal, and ground moraines.

No mineral deposits of economic importance have so far been discovered in the area, but traces of copper, iron, manganese, coal, and radioactive minerals are recorded.

Measurements of ablation, accumulation, horizontal movement, névé densities, and névé temperatures were obtained and the mass and heat economy of the ice cap was investigated. Near Mawson, blue ice predominates in the ablation zone, which extends to a height of about 2,400 feet above sea level. Melt-water streams, cryoconite holes, flow structures and crevassing were observed in this zone. Above this elevation, accumulation predominates and the plateau consists largely of névé, with a strong development of sastrugi and depositional layering. However, local areas of blue ice, often with severe crevassing, occur close to many of the larger inland rock exposures. These inland portions of the ice cap are drained by several major glaciers, the largest being the Lambert Glacier, more than 200 miles long and up to 30 miles wide, which feeds the Amery Ice Shelf, 250 miles east of Mawson.



Bureau of Mineral Resources, Geology & Geophysics. Nov 1957

INTRODUCTION.

The Antarctic Continent has an area of approximately 5,400,000 square miles, of which the Australian Antarctic Territory occupies about 2,400,000 square miles.

Topographically and geologically, the continent falls into two main sub-divisions. The larger of these, commonly referred to as East Antarctica, consists of a shield area largely composed of Precambrian igneous and metamorphic rocks, with a local cover of flat-lying Palaeozoic and Lower Mesozoic sediments. It occupies the area roughly south of Australia, the Indian Ocean and South Africa, and includes the whole of the Australian Antarctic Territory. In the smaller sub-division, West Antarctica, fold mountains are strongly developed, and the region appears to be structurally related to the Andean Belt of South America.

The junction of these two dissimilar structural units is marked by two deep embayments, occupied by the Ross and Weddell Seas, and the boundary of the East Antarctic Shield in this area is largely controlled by strong block faulting (text-fig. 1).

LOCATION AND EXTENT OF AREA.

The area to be described in this Bulletin comprises the coastal and nearer inland portions of the Australian Antarctic Territory between 45° and 80° E. For descriptive purposes, this area is generally divided into sectors, bounded by meridians of longitude as follows:—

Enderby Land—45° to 55° E.
Kemp Land—55° to 60° E.
MacRobertson Land—60° to 73° E.
Princess Elizabeth Land—East of 73° E.

THE AUSTRALIAN NATIONAL ANTARCTIC RESEARCH EXPEDITIONS.

The work described in this Bulletin was carried out during a two-year stay at the Australian National Antarctic Research Expeditions' station at Mawson (January, 1955, to February, 1957). This station is situated on the coast of the Antarctic Continent at 67° 36′ S. lat., 62° 53′ E. long., and was first manned in 1954 by a party of ten men with R. Dovers as Officer-in-charge. In 1955 the base was manned by a party of fifteen under J. Bechervaise, and in 1956 by twenty under W. Bewsher. The entire expedition was under the leadership of Mr. P. G. Law, Director, Antarctic Division, Department of External Affairs.

At the end of 1956, the establishment at Mawson consisted of 30 separate buildings, including engine room and workshop, aircraft hangar, administration building, meteorological, cosmic ray, biological, magnetic, and seismic observatories, living and sleeping quarters, store huts, &c. (Plate 1, fig. 1). All buildings were supplied with electric light and power, and daily radio communication was maintained with Perth, Cape Town, Marion Island, and Iles de Kerguelen.

FIELD WORK.

(Plates 2 and 3.)

At the beginning of 1955, transport facilities consisted of three "weasels" and two teams of ten dogs each. In the course of this year, the following trips were undertaken: a dog sledge trip to the Byrd Head and Taylor Glacier areas, 50 miles west of Mawson; one depot-laying and one exploratory trip by weasel to the northern portion of the Prince Charles Mountains, 200 miles south-south-east of Mawson; a weasel trip to the Masson, David, and Casey Ranges, 15 to 20 miles south and south-west of Mawson.

In addition islands and outcrops within 15 miles of Mawson were visited, and some time was spent in glaciological work close to the station. Altogether, 80 days were spent in the field during 1955, to which should be added four days spent on landings from M.V. *Kista Dan* at Vestfold Hills and Lichen Island in Sandefjord Bay during the initial voyage to Mawson.

At the beginning of 1956, a new " weasel " was supplied to replace one abandoned on the return journey from the Prince Charles Mountains in 1955, but the effective supply of dogs was reduced to one team of eight, as 25 dogs were transferred to the New Zealand Antarctic Expedition for use in the McMurdo Sound region. However, two aircraft, flown and maintained by members of the R.A.A.F. Antarctic Flight, under Squadron Leader D. Leckie, O.B.E., A.F.C., were stationed at Mawson during this year: a De Havilland Beaver with a cruising range of about 900 miles, and an Auster with a range of about 400 miles. In addition to carrying out extensive trimetrogon photography of the coast and of selected inland regions, these planes were available for exploratory flights and for the transport of field personnel and supplies from early April to late November of this year.

Field trips carried out during the autumn, winter, and spring of 1956 were as follows:—Weasel trips to the Masson Range, 15 miles south of Mawson, and to Einstoding Islands, 30 miles west of Mawson; dog trips to Douglas Island, 20 miles north-east of Mawson, and to the Masson Range and Mount Hordern, 25 miles south-south-west of Mawson. A considerable amount of time was also spent on various short trips and on glaciological studies close to the station.

Six major reconnaissance flights were made in the Beaver aircraft and field parties were landed by the aircraft at the following points:—King Edward VIII Gulf, 180 miles west of Mawson; Stefansson Bay, 120 miles west of Mawson; Byrd Head/Taylor Glacier area, 50 miles west of Mawson; Amundsen Bay, 350 miles west of Mawson; northern portion of Prince Charles Mountains, 200 miles south-south-east of Mawson.

An 850-mile trip was made to the Prince Charles Mountains between 19th November, 1956, and 10th February, 1957. The crevassed terrain within the ranges proved too dangerous for weasels and the actual exploration in this area was carried out entirely by dog sledge. During this time six astro-fixes were obtained by the surveyor, and 3,000 square miles of new territory were reconnoitred geologically.

The total time spent in the field in 1956 was 178 days.

FIELD PARTIES.

For extended journeys on sea-ice or inland plateau, two vehicles and five men were found to be the most satisfactory party. For shorter journeys, one vehicle or dog-sledge and two or three men were considered adequate. The geologist and surveyor took part in all the field trips listed above. An engineer generally accompanied field parties using weasels, and whenever possible a trained wireless operator was included. Parties landed by aircraft generally consisted of two or three men.

TERRAIN AND TRAVELLING CONDITIONS.

Inland from Mawson, blue ice gives way to névé at an altitude of about 2,400 feet, which is generally reached some 12 to 15 miles from the coast. Areas of blue ice ranging from a few hundred square yards to several square miles are also developed in the lee of most major inland rock outcrops, and a few isolated ice domes and ice ridges from the névé occur in areas where no rock outcrops are present.

These blue ice areas generally offer fairly smooth surfaces, but because of their proximity to mountain areas or to steep coastal slopes they are liable to be more or less severely crevassed. The most dangerous areas are generally the transition zones from blue ice to névé. In these areas, crevassing may assume dangerous proportions, but the snow bridges cannot readily be distinguished from the surrounding névé except by tedious probing with crow-bars. On level or gently undulating névé surfaces, away from mountain areas, crevassing need not generally be considered; but in such areas sastrugi up to 24 inches high make progress difficult. Fortunately the alignment of the sastrugi, parallel to the prevailing wind, is constant over large areas, and courses can often be planned to cut them at an acute angle.

Smooth sea ice offers an ideal surface for vehicle travelling or dog sledging and can generally be relied on in this area from early April until late November. The main obstacles are likely to be locally accumulated soft snow drifts in the lee of major headlands, and areas of old floes which have been tilted or rafted before being re-cemented by younger ice. However, experience has shown that sea-ice may break out at any time of the year, and on all sea-ice trips camp sites were selected only on islands or on land-based ice.

SURVEYING AND NAVIGATION.

Owing to the featureless nature of the plateau surface and the frequent poor visibility due to falling or drifting snow, most navigation was by dead-reckoning. In the weasels, the combination of astro-compass and speedometer was found to be very satisfactory. With the dog sledge, magnetic compass and pacing were used, and all courses were adjusted to astro-fixes whenever these were available.

On the main southern journeys, bamboo poles with pennants attached were left at 5-mile intervals as route markers and were also used for the measurement of surface accumulation and ablation.

CLIMATE AND DAYLIGHT CONDITIONS.

The mean annual temperature at Mawson for 1955 was 12.8° F. (minus 10.6° C.), and the mean wind speed for the year was 23 miles per hour (10.3 metres per second). The minimum temperature to the end of 1956 was minus 32° F. (minus 36° C.), recorded in August, 1956, and the maximum was plus 45.3° F. (plus 7.4° C.), recorded in January, 1956. To the same date, the maximum wind-run for a 24-hour period was just over 1,500 miles, equivalent to a mean speed of 62 miles per hour (27.7 metres per second), recorded in August, 1956.

In general, winds of more than 35 miles per hour were accompanied by drifting snow, and 30 blizzard days were recorded at Mawson during 1955. For statistical purposes, a blizzard day was defined as a day on which drifting snow reduced the visibility to less than 20 yards for at least six hours.

As the station is situated just south of the Antarctic Circle, the sun does not rise above the horizon for about three weeks at midwinter, but for three to four hours each day twilight is sufficient for outdoor work. In midsummer, on the other hand, 24 hours of daylight are experienced for several weeks.

WILD LIFE AND VEGETATION.

Wild life in this area is almost entirely confined to the coast. Weddell and crab-eater seals are very numerous on the sea-ice and coastal beaches from early November to late March, and a few individuals can sometimes also be met with in winter. A colony of sea elephants is found at Vestfold Hills in summer.

Adélie penguins are very abundant from November to March, and numerous rookeries, sometimes inhabited by many thousands of birds, are known. Emperor penguins are less numerous, and only two rookeries were known in this area, at Taylor Glacier and Stefansson Bay, during the author's stay.* These birds breed in midwinter and early spring and are the only wild life always present during the winter months. Snow petrels, Wilson's petrels, and skuas are the most important of the remaining dozen or so species that have been recorded from this part of the Antarctic. Occasional snow petrels and skuas have been encountered up to 200 miles from the coast, but none remains over winter.

The only vegetation known from this area consists of a few species of lichen and moss which lead a precarious existence in protected spots on rock outcrops. A few of the fresh and brackish water lakes contain algae.

MAGNETIC VARIATION.

Magnetic variation is approximately 58° W. at Mawson, 64° W. at the northern tip of the Prince Charles Mountains, 70° W. at Vestfold Hills and 49° W. at Amundsen Bay. Unless otherwise stated, all azimuths in this Bulletin refer to true north.

PREVIOUS WORK.

Before 1954, the only information available on the geology of this portion of the Antarctic consisted of two brief reports on collections made by Sir Douglas Mawson from Proclamation Island, Cape Bruce, and Scullin Monolith (Tilley, 1937), and one report on collections made from Scullin Monolith and Bertha Island in William Scoresby Bay (Rayner & Tilley, 1940). During 1954, the first A.N.A.R.E. party at Mawson, led by surveyor R. Dovers, made coastal exploratory trips to King Edward VIII Gulf in the west and to Scullin Monolith in the east and succeeded in penetrating inland to the Stinear Nunataks, about 160 miles south-south-east of Mawson. The geology of the areas investigated on these journeys has been described by B. H. Stinear (1956).

For purposes of comparison and contrast, reference will also be made to geological and glaciological investigations carried out in other parts of the Antarctic by a large number of parties of different nationalities. Among these, the most important are the British Antarctic Expedition (1907-1909) under Sir E. Shackleton; the British Antarctic Expedition (1910-1913) under Captain R. F. Scott; the Australasian Antarctic Expedition (1911-1914) under Sir Douglas Mawson; the Norwegian-British-Swedish Antarctic Expedition (1949-1952); and the Expeditions Polaires Françaises, Missions Paul-Emile Victor (1950-1952).

* Three more rookeries of Emperor penguins have since been reported: one about 35 miles east of Mawson, amongst grounded bergs, another at Cape Boothby, and the last on the coast between the Vestfold and Larsemann Hills.

MAPS.

Apart from general maps of the Antarctic Continent, two main sets of maps are available for the area under discussion. Australian-compiled map sheets on scales of 1 : 500,000 and 1 : 1,000,000 have been prepared for the whole of this area and are being constantly revised as new information comes to hand. Also an excellent set of Norwegian maps* on a scale of 1 : 250,000 is available for portions of the coastline, based on aerial photographs of the Lars Christensen Expedition (1936-1937).

PHYSIOGRAPHY.

SNOW AND ICE.

Probably rather less than one percent of the total area consists of rock outcrops, the remainder being occupied by permanent snow and ice.

In general, except where it abuts on to coastal rock outcrops, the termination of the ice-sheet consists of cliffs, mostly 30 to 100 feet high, which face the open sea and from which bergs and "bergy bits" calve off periodically.

Inland from the coast, the level of this snow and ice surface generally rises fairly sharply to about 2,000 feet above sea level in the first 10 to 15 miles. From there on, the rise is usually more gradual, and a height of about 6,000 feet may be reached 120 to 150 miles from the coast. The highest areas found lay in the vicinity of 69° 30′ S. lat., 51°–52° E. long., and 70° S. lat., 61° E. long. In both these areas, plateau heights of approximately 10,000 feet above sea level have been recorded, and there is some evidence that heights to the south of these areas begin to decrease again.

The main exceptions to these general trends occur around major glacier systems, commonly terminating at the coast in floating glacier tongues or areas of ice shelf. Of these, the most important are the Beaver Glacier, draining into Amundsen Bay, the Robert and Wilma Glaciers, draining into King Edward VIII Gulf, and the newly discovered Lambert Glacier System, which is the main source of the Amery Ice Shelf. The head regions of these glaciers, being areas from which ice is being removed at higher than average rates, lie at elevations considerably below those of the surrounding plaetau. The Lambert Glacier, which is one of the largest glaciers at present known, is at a height of only about 3,500 feet above sea level at 73° 45′ S. iat., 68° E. long., about 300 miles from the nearest point on the coast.

ROCK OUTCROPS.

The rock outcrops of the area can be subdivided into coastal features and islands, inland ranges, and inland low-lying areas.

Coastal outcrops and islands are almost entirely confined to three areas: Amundsen Bay, the King Edward VIII Gulf/Stefansson Bay/Mawson area, and the Larsemann Hills/Vestfold Hills area, each with its own distinctive features. In each area, sections of highly indented coastline and the presence of numerous islands indicate that it is an area of submergence. This is especially pronounced in the Larsemann Hills/Vestfold Hills area, with its numerous fjords extending inland as far as 10 miles, and would probably be equally obvious in the other two areas if similarly large ice-free areas were available for study. However, a more recent uplift is superimposed on this drowning in several areas, as will be shown below.

* HANSEN, H. E., 1946. Atlas of Parts of the Antarctic Coastal Lands. Oslo.

At Amundsen Bay, both islands and coastal outcrops show very rugged topography, and several peaks near the southern and south-eastern extremity of the bay rise more than 4,000 feet above sea level. In the area between King Edward VIII Gulf and Mawson, on the other hand, the tendency is towards the development of very numerous but generally less prominent rock occurrences.

In the immediate vicinity of Mawson, very few of the islands or coastal outcrops are more than 120 feet above sea level, but several have flat or gently undulating summit plateaux between 100 and 120 feet. Of the islands which rise above this level, Welch Island (430 feet) shows a broad, undulating terrace with a maximum elevation of about 110 feet above sea level. This terrace is about a quarter of a mile wide, and contains at least three closed depressions, occupied by salt pans, the largest of which is about 200 yards in diameter. The main peak of the island rises from the terrace with a sharp discontinuity of slope. On the largest of the Flat Islands, with a maximum elevation of about 170 feet, a slight suggestion of a comparable break of slope is also visible in the southern portion of the island. There is therefore very strong evidence in this area for the existence of an old erosion surface at a present elevation of 100 to 120 feet (Plate 1, fig. 2). In the area between the Jelbart and Taylor Glaciers, 45 to 55 miles west of Mawson, traces of a similar surface can be recognized at present elevations of 180 to 200 feet above sea level.

At Stefansson Bay, 120 miles west of Mawson, and at King Edward VIII Gulf, 180 miles west of Mawson, most of the islands and coastal outcrops consist of more or less isolated rocky knolls and hummocks, separated by lower-lying areas largely covered by permanent snow drifts or by morainic debris. The summits of these knolls also tend to lie at fairly constant elevations between 350 and 400 feet above sea level, but there are none of the flat-topped plateau-like summits so typical of the Mawson area; if this 350-foot level represents a portion of the same erosion surface, it has been much more modified than that corresponding to the 120-foot level at Mawson.

Taking all these localities into consideration, however, there appears to be sufficient evidence to postulate the existence of an old erosion surface along the coast of Kemp Land and MacRobertson Land, now falling eastwards with an average gradient of about 1.6 feet per mile. In the absence of fossiliferous beach deposits, the absolute age of the earth movements involved in the production of this surface cannot be deduced; but the maximum drowning may have corresponded to the depression of the continent under its load of ice during the glacial maximum (?Pleistocene), and the more recent emergence, which may still be in progress, may correspond to a partial recovery after the melting of some of this ice.

In the Vestfold Hills/Larsemann Hills area, on the other hand, the typical development consists of large areas of comparatively low-lying ground, amounting in the Vestfold Hills to at least 150 square miles, none of which is higher than about 750 feet above sea level. Remnants of two old erosion surfaces appear to be present in this area, one indicated by a group of summits at about 400 feet and the other by the tops of minor ridges at about 100 feet above sea level.

At Amundsen Bay, the coastal outcrops merge into the Scott and Tula Mountains, which typically occupy the transition zone from the steep coastal slopes to the more level inland portions of the ice-sheet. In the Mawson area, Mount Henderson and the Masson, David, and Casey Ranges lie about 10 miles from the coast (Plate 4).

Fig. 1.—Mawson Station, summer 1958, seen from M.V. Thala Dan at anchor in Horseshoe Harbour. Pipe-line in foreground is for pumping ashore bulk fuel supplies.

Fig. 2.—Looking north from Mawson. Welch Island on left. Note concordant summit levels of most islands.

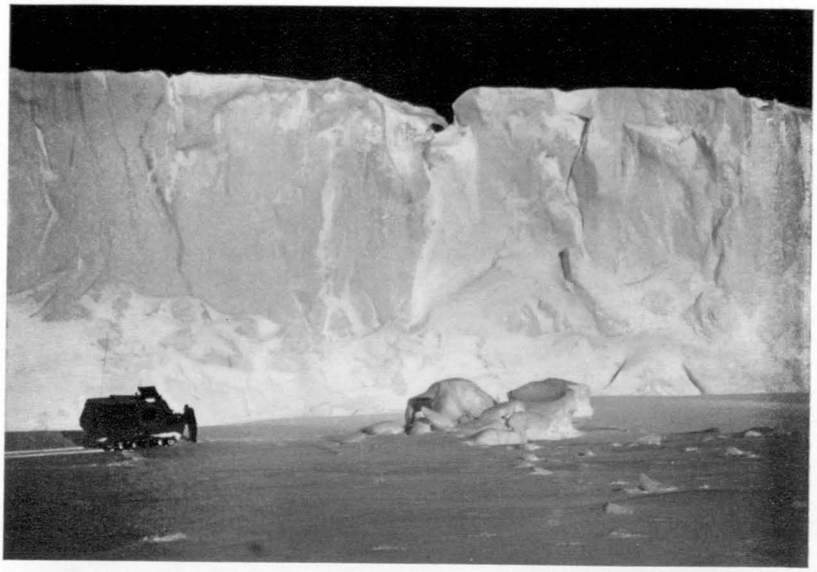


Fig. 1.—Weasel on sea ice. Coastal ice cliff in background. About three miles west of Mawson.

Fig. 2.—Beaver at Depot Island, Oygarden Group, King Edward VIII Gulf. Camp in foreground.

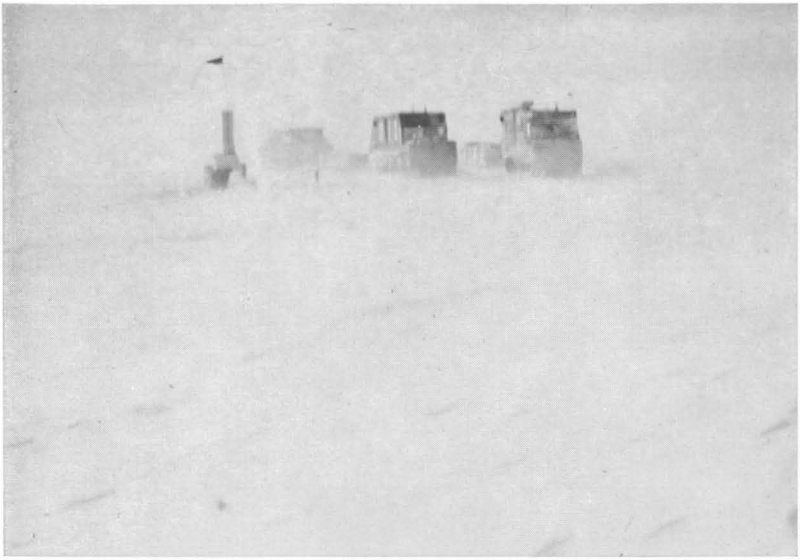


Fig. 1.—Weasels and Caravan at 50-mile Depot. Moderate drift. Wind estimated at 45 miles per hour.

Fig. 2.—Dog Team on sea ice near Taylor Glacier.

Looking inland towards Mount Henderson, Masson Range and David Range (left to right). Mawson Rock and Horseshoe Harbour in right bottom corner. Note " flow lines " in ice sheet.

Fig. 1.—Napier Mountains. Enderby Land.

Fig. 2.—Low-lying rock exposures near Amery Locality. Looking east.

PLATE 6

Fig. 1.—Shear zone in granite. Mawson Rock.

Fig 2.—Flat joints on southern portion of West Arm, Mawson.

Fig. 1.—Ground moraine and large erratics on Mawson Rock.

Fig. 2.—Ice-polished rock surface. Mawson Rock.

Fig. 1.—Tongue of Taylor Glacier. Emperor Penguin Rookery in angle to left of Tongue.

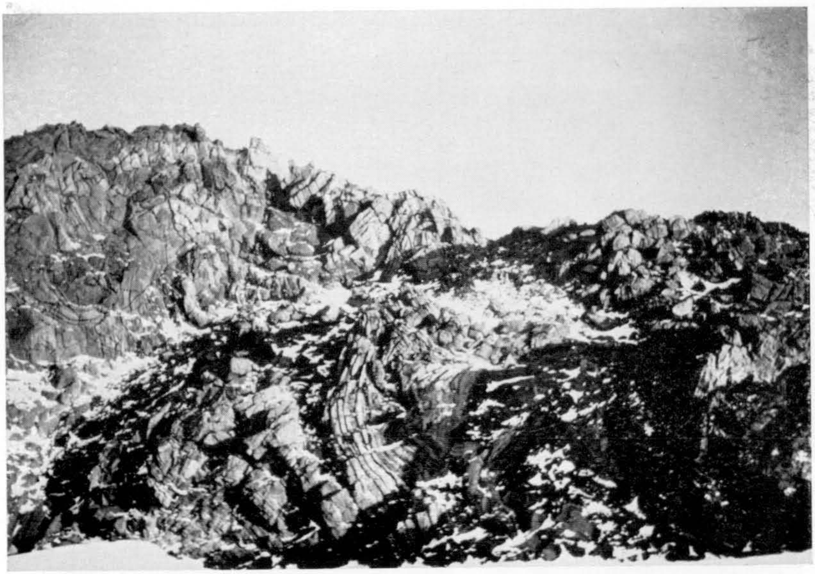


Fig. 2.—Contorted Metasediments. Oygarden Group, King Edward VIII Gulf.

True inland ranges, rising from the ice-sheet at distances of more than 40 or 50 miles from the nearest point on the coast, are concentrated in two main areas. The first of these comprises the Napier Mountains and Aker Peaks, rising to 7,000 feet above sea level and situated in the central portion of the Enderby Land peninsula (Plate 5, fig. 1). Secondly, there are the Prince Charles Mountains between 70° and 71° 30′ S. lat. and 64° and 68° 15′ E. long., and their southern extension to at least 73° 30′ S. lat., both with estimated maximum heights of the order of 8,000 feet above sea level.

Of these, only the Prince Charles Mountains are known in any detail. In them, the extent and alignment of rock exposures appear to be largely controlled by major faulting. This is most clearly indicated in the vicinity of Mount Loewe, where the Mount Loewe plateau, occupying an area of 50 square miles at an average elevation of about 3,500 feet above sea level, is terminated to the north and east by abrupt linear scarps with vertical drops of the order of 2,000 feet. Similar features, although less pronounced, can also be recognized in other parts of these ranges. In addition, many peaks within these ranges have flat-topped summits, often partly covered by moraine deposits, at levels up to 1,500 feet above the surrounding ice and snow surface. These flat summits are regarded as remnants of an old erosion surface. Their altitude ranges from 3,500 feet at Mount Loewe plateau to about 8,500 feet at Mount Bewsher, and these differences are probably also due to block faulting. To the east and south of this area, the distribution of rock exposures is less regular.

Between latitudes 70° 15′ and 70° 45′ S. and longitudes 68° and 69° 15′ E., an estimated total area of nearly 200 square miles, including the Amery Locality, consists of gently undulating, largely moraine-covered terrain at average elevations of less than 2,000 feet above sea level (Plate 5, fig. 2). This contrasts strongly with the rugged, deeply dissected Prince Charles Mountains themselves, from which it is separated by the scarp that forms the eastern edge of the Mount Loewe plateau.

On the eastern flank of the Amery Ice Shelf, a comparable but less concentrated group of rock exposures includes the Spayd Outlier, the Reinbolt Hills, and a number of minor outcrops, extending altogether from 70° 20′ S. lat., 71° 30′ E. long., to Mount Caroline Mikkelsen at the head of Sandefjord Bay.

To the south of the Amery Locality, widely spaced major massifs, some of them approaching 50 square miles in area, continue to line the west flank of the Lambert Glacier at irregular intervals to at least 73° 30′ S. lat.; height and relief increase to the south. At present, these features are only known from reconnaissance flights and trimetrogon photographs, and it is not certain to what extent they should be regarded as belonging to the southern extension of the Prince Charles Mountains. Further information may well prove some of them, at least, to be structurally distinct units.

Finally, a major concentration of rock exposures (Mawson Escarpment) is known from the eastern flank of the Lambert Glacier between 71° 45′ S. lat., 68° 30′ E. long., and 73° 15′ S. lat., 68° 30′ E. long. These form an almost unbroken chain, slightly convex to the west, almost 100 miles long and up to 10 miles wide. Numerous minor glaciers flow westwards from gaps in the Escarpment to join the Lambert Glacier, and many perfect cirques are exposed in this area.

SOIL.

Within the Prince Charles Mountains, several areas of heavy ground moraine or scree, resting on gentle or moderate slopes, tend to develop a hummocky appearance, due to the presence of low mounds of boulders and pebbles, separated by strips of finer-grained material. The mounds are 18 to 24 inches high and three to four yards from centre to centre. Many of the low-lying strips between the mounds are occupied by accumulations of drift snow and re-frozen melt water, giving a polygonal appearance reminiscent of columnar jointing when seen from a distance. How the mounds were formed is not known, but transport of the rock fragments by the alternate freezing and thawing of interstitial water probably plays a major part, and they may be related to the stone polygons described by numerous authors from the Arctic and occasionally also from the Antarctic (Shumskii, 1957). However, they differ from the normally described features in having their coarsest particles in the centre of the polygons instead of at the circumference.

In the vicinity of the Amery Locality, a different pattern is developed. Here, a gently sloping area of several square miles, composed of flat-lying sediments of the Amery Formation, is overlain by only light ground moraine. The surface material therefore contains an appreciably higher proportion of fine-grained material than is usual in corresponding deposits resting on basement rocks, e.g. in the Prince Charles Mountains. The coarser material has been concentrated into strips, a few yards to several chains wide and several hundred yards long, elongated parallel to the slope of the ground. The finer fractions occupy the rather narrower intervening strips. This feature is therefore a typical example of the "striped soil" described by previous authors (Nordenskjold and Mecking, 1928).

GENERAL GEOLOGY.

PRECAMBRIAN BASEMENT.

Basement rocks of probable Precambrian age form the bedrock of the greater portion of this area. The typical assemblages include varying proportions of rocks of sedimentary, igneous, and hybrid origin, without any indications of large-scale zoning or facies changes.

The least altered rocks of sedimentary origin are now represented by garnetiferous quartzite and by hornfelsic rocks carrying varying proportions of biotite, garnet, and pyroxenes. With increasing metamorphism and probably some metasomatic addition of material, the quartzite passes into quartz-feldspar-garnet gneiss, and this in turn grades into the contaminated phases of the granitic gneiss mentioned below. Similarly, the hornfelses grade into biotite-rich and quartz-rich granular gneisses.

Some closely related granular gneisses, including some charnockitic types, appear to have developed under similar conditions of metamorphism from pre-existing igneous rocks. The most widespread igneous rocks of the complex, however, are a series of granite gneisses, grading locally into banded hybrid gneisses and migmatites, again with a very abundant development of garnetiferous types. Bands and lenses composed largely or entirely of ferromagnesian minerals (ortho- and clino-pyroxenes, garnet, and magnetite, in various proportions) are very abundant in some areas. Quartz veins and pegmatite are also commonly present.

Finally, large bodies of charnockitic granite, with their own series of associated pegmatite and aplite, appear to cut all the previously mentioned rock types. They are related to the charnockitic granular gneisses, and are regarded as the most thoroughly reconstituted portions of the metamorphic complex, which have been partially mobilized and re-injected.

Diagrammatically, these relations between the main rock type of the area may be represented as follows:

Original rocks, or least metamorphosed representatives of group.	High-grade metamorphic equivalents, in part with metasomatic addition of material and partial mobilization.	Rocks with dominantly igneous characteristics, in part derived from pre-existing types by palingenesis.
Garnetiferous quartzite →	Quartz-feldspar-garnet gneiss →	
Hornfels →		Granitic gneiss
	Banded hybrid gneiss →	
Metasediments (undifferentiated) →		
	Biotite- and quartz-rich granular gneiss	
Pre-existing igneous rocks (not now preserved as such in this area) →	Charnockitic granular gneiss →	Charnockitic granite

The probable Precambrian age of this complex is suggested by analogy with the Ross Sea sector of Antarctica, where the presence of unaltered fossiliferous Cambrian limestones, found close to similar metamorphic rocks, sets an upper limit to the possible age of the basement complex.

UPPER PALAEOZOIC SEDIMENTS.

At the Amery Locality (70° 30′ S. lat., 68° 15′ E. long.), an area of probably not less than 200 square miles is underlain by a series of flat-lying arkosic and calcareous sandstones and grits, locally strongly cross-bedded and containing a number of pebbly horizons and at least two seams of coal, each with a maximum thickness of about 8 inches. The total thickness of the formation at this point is estimated at not less than 1,000 feet, and aerial reconnaissance suggests that the rocks may occur as much as 150 miles to the south.

The Amery Formation is faulted against the basement complex to the west. The age of the formation, based on the determination of pollen and spores contained in the coaly material, is Permian, and it is regarded as the equivalent of the lithologically and structurally similar beds of the Beacon Formation, recorded from other parts of Antarctica, notably from the Ross Sea area.

BASIC DYKES.

Basic dykes are known from widely separated localities. They are commonest in the Vestfold Hills, where several hundred of them are apparent; many of them are more than 50 feet wide and several miles long. Basaltic dykes have been found in the Prince Charles Mountains, where they cut various members of the basement complex, including the charnockitic granite, so that they are the youngest known igneous rocks of the area. Erratics of doleritic and basaltic composition have also been recorded from Amundsen Bay and Law Promontory.

The dolerites are tentatively correlated with the large, probably Mesozoic, sills that intrude the Beacon Formation in other parts of Antarctica, but the basalts may be Tertiary or even younger. Unfortunately no dykes have so far been observed in contact with the sediments of the Amery Formation.

MORAINE DEPOSITS.

Moraine deposits are associated with almost all major rock outcrops. In many areas, they can be broadly subdivided into an older high-level group and a younger group lying close to the present margins of the ice-sheet. The high-level deposits are especially prominent in parts of the Amundsen Bay area, on portions of the Masson and David Ranges, and on some of the flat-topped peaks of the Prince Charles Mountains. In all these areas, they are locally found at least 1,000 feet above the present level of the ice-sheet. Most of the very heavy deposits of the Vestfold Hills area and of the Amery Locality, now lying several miles from their respective ice fronts, should probably also be included in this group.

The younger deposits can be further subdivided morphologically. In inland areas, wherever the ice is moving past a rock outcrop, a pair of lateral moraines is normally developed on the flanks of the outcrop, merging on the downstream side to form a medial moraine. After a mile or two, however, these deposits are either buried under new accumulations of snow, or, in the ablation area, melt down into the body of the ice, forming cryoconite holes.

A slightly different pattern results in areas where local glaciers, originating within a range, receive only limited nourishment and do not persist far enough to join the main ice-sheet. In this case, a beautifully curved terminal moraine or series of moraines is formed if the front of the local glacier has been stationary for some time; or, if the retreat has been continuous, a more or less complete cover of ground moraine may extend over several square miles. Both the terminal and the ground moraine may rest either on rock or on stagnant ice and, if the cover on this ice is sufficiently heavy, will effectively protect it from ablation or erosion.

All these patterns (lateral, medial, terminal, and ground moraines) have been observed in the Prince Charles Mountains and on a smaller scale also in the Henderson, David, Masson, and Casey Ranges.

On coastal outcrops and islands, any moraine deposits are generally due to material deposited from the basal layers of the main ice-sheet itself. At Mawson and at Ring Rock, 5 miles west of Mawson, sharply defined terminal moraines now occur a short distance inland from the present ice-rock contact, but are probably rock-based, the intervening ice being formed from local accumulations of drift snow. At Mawson, a rather patchy ground moraine also covers the southern portion of the outcrop area itself.

REGIONAL GEOLOGY.

MAWSON ROCK.

Mawson Station lies on the more easterly of two small rock outcrops which are situated at 67° 36′ S. lat., 62° 53′ E. long. The two outcrops occupy areas of about 40 chains by 20 chains (main Station area, including East Arm) and 30 chains by 5 chains (West Arm). Both are elongated in a north-south direction, enclosing the sheltered inlet of Horseshoe Harbour between them, and they reach a maximum elevation of about 110 feet in the southern portion of the main Station area. They are collectively referred to as " Mawson Rock ".

The country rock of this area (thin section No. 3902, B.M.R. collection) consists of a porphyritic gneissic charnockitic granite, subsequently referred to in this Bulletin as the " Mawson Granite " (see also Stinear, 1956). The phenocrysts consist of orthoclase, up to 3 cm. long, containing minor inclusions of quartz and showing incipient alteration to sericite along cleavage planes. Andesine, Ab_{65}, is about as abundant as the potash feldspar and occurs typically as subhedral crystals, up to 5 mm. long, although the twin lamellae of some of the grains are strongly deformed. Quartz occurs as mosaics of roughly equidimensional grains, averaging 0.5 mm. in diameter, and strongly pleochroic hypersthene, with very irregular outlines, attains a size of 1 mm. Biotite is restricted to minor zones of shearing, where it is associated with very fine-grained aggregates of reconstituted quartz and feldspar. Magnetite, apatite, and sphene are the most prominent accessory minerals.

A slight to moderate foliation is brought out in the field by a marked parallelism of the long axes of the phenocrysts and by the presence of elongated schlieren, slightly enriched or impoverished in the ferromagnesian constituents. The foliation trends very uniformly 15° to 30° and dips east at angles of 60°–80°. No lineation is apparent in the hand-specimen or in the field.

Numerous xenoliths are scattered throughout the area, ranging from a few inches to 100 feet in length and up to 30 feet in width. They are also commonly elongated parallel to the foliation of the country rock, but their contacts are usually sharply defined and no distinctive border zones are developed. Petrologically, they range from fine-grained dense hornfelsic rocks to medium-grained granular quartz-feldspar rocks with variable amounts of biotite or hypersthene or both (thin sections No. 3901 and 3904.) Several garnetiferous rocks are also present, including one from near the Meteorological Observatory (thin section No. 3903), characterized by the presence of garnets up to 5 mm. in diameter. This rock also contains very abundant intergrowths of quartz and an unidentified white mica, which replace original quartz and feldspar.

Aplite veins and lenses, up to three feet wide, are fairly widespread and typically follow winding courses, suggesting that they were emplaced before the country rock was completely consolidated. Some of them, e.g., thin section No. 3906, carry a pale green clinopyroxene instead of the prevalent hypersthene, and are also very rich in sphene. Pegmatite typically occurs as slightly smaller bodies—veins up to 6 inches wide and occasional lenses up to 18 inches wide. They cut the aplite dykes wherever the two come into contact. These pegmatites are mostly orthoclase-rich, typically with subordinate biotite, hypersthene, or both, some with quartz and a few with garnet. A few quartz veins and lenses of graphic granite are also present, but are generally less than 6 inches wide.

In the central portion of West Arm, a dyke-like body of fine-grained to medium-grained granular banded rock, about 5 feet wide, strikes at 50° and dips south-east at 80°. Being less resistant to erosion, this dyke lies in a channel several feet below the level of the adjacent country rock. It has been described as a hypersthene granulite by Stinear.

The area is also traversed by several shear-zones, up to 3 feet wide, which in places intersect and displace both aplites and pegmatites. These shear zones also typically follow very meandering courses and occasionally combine to form anastomosing networks (Plate 6, fig. 1). A typical specimen from such a zone (thin section No. 3905) consists of bands and seams of mylonite, composed essentially of minute granules of recrystallized quartz, untwinned feldspar, hypersthene, biotite, and iron oxide (? magnetite), and encloses lenses and angular fragments of the country rock in various stages of disintegration.

Jointing is very unevenly developed in the area. Widely spaced sub-vertical joints are commonly present and tend to fall into two sets, one roughly parallel and the other normal to the strike of the foliation. In addition, a more closely spaced set of meridional joints, dipping west at 10° to 15°, is present in parts of West Arm and the south-west portion of the main Station area (Plate 6, fig. 2).

Superficial deposits in the area consist of numerous erratics and traces of rock flour which extend over a total area of 20 by 10 chains in the south-eastern portion of the main Station area. Within this area, a section of 10 by 3 chains consists of till, which completely obscures the bedrock (Plate 7, fig. 1). Within this till deposit, the following size distribution (by weight) was estimated:—

	Per cent.
Large boulders (diameter greater than 6 feet)	20
Boulders (diameter 6 inches–6 feet)	50
Pebbles (diameter 1 inch–6 feet)	15
Screenings (diameter $\frac{1}{16}$ inch–1 inch)	10
Sand (diameter $^1/_{64}$ inch–$\frac{1}{16}$ inch)	$2\frac{1}{2}$
Rock-flour (diameter less than $^1/_{64}$ inch)	$2\frac{1}{2}$

In exposed positions, most of the material below boulder size has been removed by wind action. The sand and rock-flour fractions are generally restricted to a 3 to 6-in. layer immediately overlying the bedrock.

The material classified as large boulders consists almost entirely of gneissic granite similar to the country rock at Mawson. The shape of the boulders is very irregular, commonly controlled by joint planes and generally angular, with the corners and edges rounded off for only 1 or 2 inches. These angular shapes, however, are undoubtedly due, at least in part, to frost action after the emergence of the material from the ice.

Approximately 60 per cent. of the material of boulder size also consists of Mawson Granite. About 15 per cent. are other types of gneissic granite, including one rather prominent type in which the feldspar phenocrysts weather white. Another 15 per cent. are quartzite and garnetiferous quartzite, and the remaining 10 per cent. are aplite, pegmatite, hornfels, rare vein quartz, and some sheared rocks. In shape and degree of rounding the boulders of Mawson granite are similar to the large boulders described above. The other rock types are generally more nearly equidimensional and better rounded, the edges and corners generally being worn back to a condition about half-way between polyhedral and ellipsoidal shapes.

Among the material of pebble size, counts were carried out on two samples, giving the following distribution by number of particles:—

—	Sample 1.	Sample 2.
	Per cent.	Per cent.
Mawson Granite	39	45
Other granitic rocks	37	24
Aplite, pegmatite, reef quartz	11	7
Quartzite, hornfels, garnet quartzite	8	16
Hybrids, biotite-rich segregations, &c.	3	7
Mylonite and other sheared rocks	2	1
Total number of particles in sample	152	142

The shape of these particles is generally very irregular and the degree of rounding very slight.

The sand and rock-flour fractions were not examined in detail.

Among the scattered erratics outside the limits of the till deposit, the distribution of rock types and their degree of rounding are closely comparable to those of the boulder and large boulder fractions described above.

A terminal moraine, still forming, extends parallel to the present ice-rock contact of the main Mawson rock outcrop and about 1 chain south of it. This is less well exposed, since its basal portion is still embedded in ice, but as far as could be ascertained, the material of this moraine does not differ in any significant detail from that described above.

Very few of the erratics show significant striations or faceting, but at several points in the southern portion of the main Station area the bedrock itself is slightly polished and striated, including one point with two intersecting sets of striations, striking 310° and 340° (Plate 7, fig. 2).

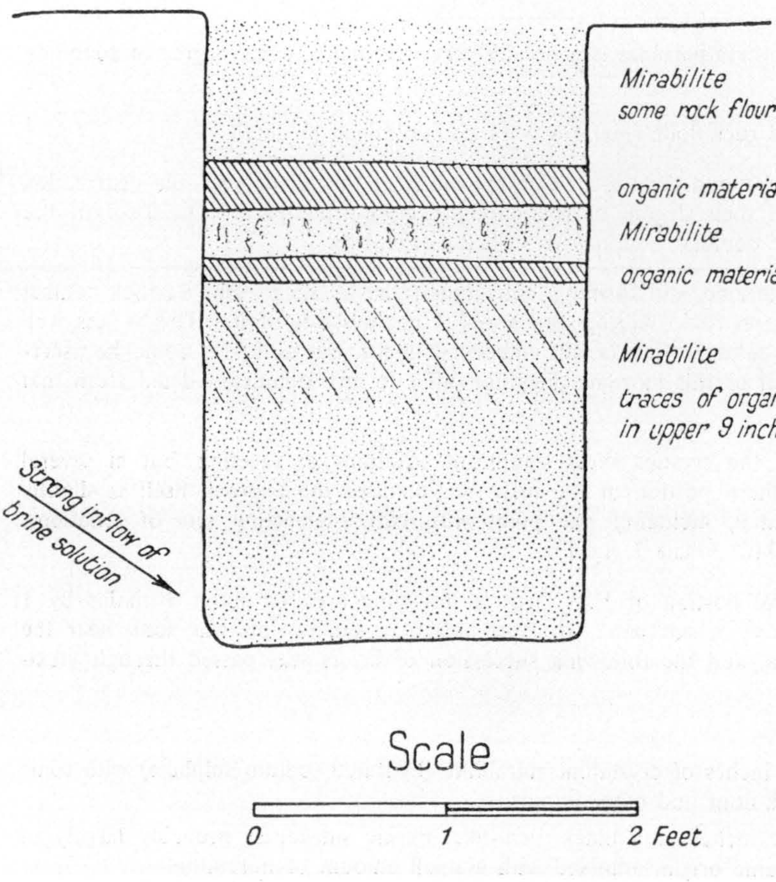
On the central portion of East Arm, a low-lying area of about 3 chains by 1 chain is occupied by a salt pan. In April, 1956, a shallow pit was sunk near the centre of this area, and the following succession of layers was passed through (text-fig. 2).

Surface.

1. Nine inches of crystalline mirabilite (hydrated sodium sulphate) with some rock-flour and other impurities.
2. Three inches of a black, peat-like, plastic substance, probably largely of organic origin, admixed with a small amount of mirabilite.
3. Three inches of almost pure mirabilite, consisting of crystals up to half an inch across and 2 inches long, all elongated vertically.
4. One inch of the black, peat-like substance noted in 2 above.
5. Twenty-four inches of crystalline mirabilite, the upper 9 inches showing a slight admixture of dark-coloured material, probably of organic origin; the remainder almost pure.

SALT PAN ON EAST ARM, MAWSON FIG. 2

26/4/56



It had originally been intended to sink the pit to bedrock, which was estimated, from the general configuration of the ground, to lie at a depth of some 6 to 8 feet; but a strong inflow of concentrated brine solution below a depth of 2 feet 6 inches from the surface made this impracticable.

A sample of layer No. 2 was submitted for further examination to Dr. L. Baas-Becking, Bureau of Mineral Resources, and the following extracts are quoted from his report:—

Microscopic examination showed that, apart from the sodium sulphate crystals, the material contained iron oxide, feather fragments and orange and green cysts about 10μ in diameter.

Cultures were made on the following media:—

1. Sulphate reduction—
   - (a) starch, 3 per cent. NaCl: highly positive in nine days.
   - (b) glycerol, 3 per cent. NaCl: negative.
   - (c) steel wool, 3 per cent. NaCl: negative.

   This shows that apparently only the heterotrophic form was present.
2. Thiobacteria—

   Thiosulphate, 3 per cent. NaCl: positive in eleven days.
3. Algae—

   Acetate, 15 per cent. NaCl: positive in six weeks in the light.

A green flagellate, *Dunaliella* sp., developed, 8μ long, flat, allied to *D. peircei* L.B.B., but apparently a new species. This form was transferred to 3 per cent. NaCl, and in one month yielded a copious culture. Its optimum growth, however, was in 10 per cent. NaCl. Several blue-green algae developed in both 3 per cent. and 15 per cent. NaCl. A very small-celled *Aphanothece* seems the commonest. There are also colonies of olive-coloured spherical cells, 15μ in diameter, which resemble *Gloeothece,* but this genus has only been described from fresh water. A large *Aphanothece* with cells of 6 x 8μ occurred in one culture containing 3 per cent. NaCl.

A zoogloea of small (1μ) rod-shaped bacilli accompanied both *Dunaliella* and the blue-greens. Ciliates and colourless flagellates were observed in all solutions. It may be concluded that the material is teeming with life, some of it indicative of the presence, at times, of a high salt concentration. Except for the absence of arthropods, it does not differ from other concentrated tide-pool material collected in milder climates.

COASTAL OUTCROPS AND ISLANDS CLOSE TO MAWSON.

The area within about 10 miles of Mawson, extending roughly from Nost Island and Arrow Island in the west to the Canopus Islands in the east, contains about ten coastal outcrops and more than 100 islands, ranging in size from almost a square mile down to a few square yards. The most important of these are Flat Island, Van Hulssen Island, Welch Island, and Klung Island.

The dominant rock throughout the greater portion of this area is a porphyritic gneissic granite, closely comparable to that already described from Mawson itself. The foliation, indicated by the alignment of the long axes of the feldspar phenocrysts and xenoliths, generally strikes between 360° and 30°, but strikes up to 60° have been recorded from the north-eastern part of Welch Island and from the main island of the Flat Islands. On the other hand, strikes of 330° are typical of the most southerly large island of this group. The dips are generally east at angles of 60° to 80°, but steep westerly dips predominate in parts of the Klung Islands and Flat Islands.

The proportions of feldspar phenocrysts and of xenoliths vary considerably from one outcrop to another, but actual contacts between different phases of the country rock can rarely be observed. On the Flat Islands, occasional patches of non-porphyritic granite occupy areas up to 200 yards across and merge gradually into the porphyritic phase. On a small unnamed island immediately east of the East Arm of Mawson, two phases can be distinguished by slight differences in their feldspar-phenocryst content and in their patterns of weathering; the more feldspathic phase occurs to the east. Part of the contact here is sharp and part gradational, but even where the contact is sharp, the trend of xenoliths across it is undisturbed, and the relative age of the two phases cannot be determined. On the most northerly island of the Canopus Islands, there is a similar contact between two such phases, but the more feldspathic type occurs on the western side.

Pegmatite and aplite are widespread, but are generally restricted to seams and lenticular bodies with a width of only a few inches. One of the largest is a pegmatite dyke in the northern portion of the largest of the Flat Islands, which strikes at 300° and can be traced for several hundred yards with an average width of 3 feet. Others, with similar strikes and widths up to 5 feet, but mostly shorter, occur on the most southerly large island in the group.

This island also contains several dykes of a medium-grained granular rock, occasionally with banded structures, which shows affinities with the banded dyke rock previously described from the West Arm of Mawson. In thin section, a typical specimen (No. 3913) was found to consist of orthoclase, quartz, and subordinate andesine, all as roughly equidimensional grains, averaging 0.5 mm. in diameter and partly with interlocking boundaries. Very irregular grains of hypersthene and garnet, a few of which have rims of biotite, tend to be concentrated into individual bands. The largest of these dykes attain widths of 50 feet, and they also strike at 300°. The pegmatite cuts through these granular dyke rocks wherever they meet.

Shears and major joints occur in most outcrops and can sometimes be grouped into well-defined sets with constant trends. In the islands immediately north-east of Mawson itself, two prominent sets of more or less vertical joints trend north and east. Locally, a third set striking east and dipping north at 20° is also developed. On the largest of the Flat Islands, the dominant joints strike at 300°, roughly normal to the foliation of the country rock, and dips are generally within 20° of vertical. On Welch Island, the strike is about 300° and dips are more variable. However, on some other islands, neither shearing nor jointing shows any regularity at all. Where dyke rocks are present in any abundance, as on the southern of the Flat Islands, the major shears can be seen to cut all rock types, including the pegmatite.

Xenoliths are variably distributed. They rarely constitute more than 10 per cent. of the rock, and few exceed 30 feet by 10 feet in horizontal section. Fine-grained to medium-grained granular hornfels generally predominates. The first coastal outcrop to the west of Mawson, where a major contact between granite to the east and hornfels to the west is exposed, is an exception. The sediments here strike north and dip east at 60° to 70°, and the granite near the contact is crowded with xenoliths, most of them elongated parallel to the original bedding. The actual contact zone shows strong lit-par-lit structure, but the granite itself is only very slightly gneissic. Since the granite re-appears at Ring Rock, about 4 miles to the south-west of this exposure, these sediments must be a roof pendant or major inclusion.

A very different association of rock types occurs in the group of small islands situated 1¾ miles south-west of Mawson. The north-western island of this group is composed of alternating belts of coarse-grained light-coloured quartz-feldspar gneiss and finer-grained dark-coloured granular gneiss. The banding generally trends between 70° and 90° and the dips are dominantly southerly at about 60° to 80°.

The remaining islands of the group consist largely of granite gneiss, mostly with marked banding. Minor amounts of sedimentary material, including some lenses of almost pure garnet-biotite rock, occur as inclusions. A typical specimen of the gneiss (thin section No. 3916) consists of orthoclase and andesine as crystals up to 1 cm. long, associated with mosaics of smaller quartz grains. Garnet occurs as irregular grains up to 1 cm. across, containing numerous inclusions of quartz and feldspar and altering to biotite along cracks. Hypersthene is present as very irregular crystals, up to 1 mm. across, and biotite as flakes of similar size, commonly strongly deformed. The strike of the banding ranges from 320° to 270°, and the corresponding dips from 70° south-west to about 45° south. Veins and irregular small bodies of bluish quartz and pegmatites are fairly numerous throughout this group, and the whole assemblage is much more closely comparable to that from the Taylor Glacier area (see below) than to any of the nearer outcrops and islands. There is some shearing, especially on the most easterly island of the group, and the whole group should probably be regarded as an in-faulted block, since the rock types represented within it appear to have originated in a very different environment from that responsible for the previously described occurrences of hornfels, outcropping less than half a mile to the east of the most easterly island of this group.

Moraine Deposits.

A few erratics are present on nearly every outcrop and island examined, but glacial polishing and striations have only been noted on some of the coastal outcrops close to the present rock-ice contact. In addition, there is a very prominent terminal moraine at Ring Rock, which is a coastal outcrop of about a quarter of a square mile situated about 5 miles south-west of Mawson. On the inland side of this outcrop and at an average distance of some 10 chains from it lies a line of moraine deposits about a quarter of a mile long, 100 yards wide, and rising about 60 feet above the ice, the highest portion being about 300 feet above sea level.

Taking the average over the whole deposit, the following size distribution (by weight) was estimated:—

	Per cent.
Large boulders (diameter more than 6 feet)	20
Boulders (6 inches to 6 feet)	60
Pebbles (1 inch to 6 inches)	10
Screenings ($\frac{1}{16}$ inch to 1 inch)	6
Sand ($^1/_{64}$ inch to $\frac{1}{16}$ inch)	2
Rock-flour (less than $^1/_{64}$ inch)	2

The large boulder fraction consisted almost entirely of porphyritic gneissic granite, similar to that forming the bed-rock at Ring Rock and at Mawson itself.

Among the boulder fraction, the following distribution according to rock-types was estimated (by weight)—:

	Per cent.
Mawson Granite	30
Other granitic rocks	30
Aplite and pegmatite	4
Quartzite, &c.	30
Hybrids, mica schist, &c.	5
Sheared rocks	1

Among the pebble fraction, a count of 166 particles gave the following distribution of rock types (by number of particles):—

	Per cent.
Mawson Granite	49
Other granitic rocks	11
Aplite and pegmatite	4
Vein quartz	2
Quartzite and arenaceous metasediments	20
Hornfels and biotite-rich metasediments	13
Ironstone	1

No attempt was made to estimate the origin of particles below pebble size.

The degree of rounding of the larger size groups was generally closely comparable to that recorded from Mawson (p. 22). Among the pebble fraction, very angular forms tended to predominate, but hornfels particles were generally slightly more rounded than other rock types.

SHORE PLATFORMS.

On Welch Island, a very prominent topographic feature is a broad undulating terrace whose highest point is about 110 feet above present sea level. This terrace attains a width of a quarter of a mile and contains at least three salt pans, the largest of which is about 200 yards across. The salt pans are filled to an unknown depth by a mixture of mirabilite, common salt, guano, and rock-flour, and are in every way comparable with that previously described from the East Arm of Mawson. The main peak of the island (about 430 feet) rises from the terrace with a sharp discontinuity of slope.

On the largest of the Flat Islands, with a maximum elevation of about 170 feet, a slight suggestion of a comparable break of slope is visible in the southern portion of the island. None of the other islands in this area rises above 120 feet, but some of them have flat or gently undulating summit plateaux at levels between 100 and 120 feet. There is therefore very strong evidence in this area for the existence of an old erosion surface at a present elevation of 100 to 120 feet (see p. 16).

DOUGLAS ISLANDS, CHILD ROCKS, AND ROBINSON GROUP.

The Douglas Islands, Child Rocks, and Robinson Group comprise some 40 small islands, extending eastwards from a point about 15 miles north-east of Mawson. To the east, they extend towards Safety Islands and Austskjera, but to the south-west are separated by a gap of some 6 miles from the nearest of the Canopus Islands.

Douglas Island is shown on the Hansen map in a position about 8 miles north of the Child Rocks, but a dog-sledge trip in July, 1956, failed to reveal any traces of islands in this position; two small uncharted islands about 4 miles south of the position are believed to be the "Douglas Islands" as originally defined. Each is about 10 chains long, 5 chains wide, and about 40 feet high, and both are elongated in a north-westerly direction.

The country rock of all the islands examined in this area is a garnetiferous porphyritic gneissic granite, similar to that occurring at Mawson, except for a rather higher proportion of ferromagnesian minerals, which include garnet, biotite, and augite. In thin section (No. 3912), andesine, Ab_{60}, and orthoclase are seen to be equally abundant. Quartz, hypersthene, and biotite tend to be concentrated into small rather irregular clots, and magnetite is a common accessory. Some xenoliths of hornfels and garnetiferous quartzite are present on all the islands, but are not as conspicuous as at Mawson.

The foliation, made visible in the hand-specimen by the parallel alignment of the tabular feldspar phenocrysts, generally strikes between 320° and 360° and dips to the west and south-west at angles from 70° to vertical.

Several of the islands are traversed by aplite and pegmatite dykes of varying strike and dip. Generally, the aplite dykes are 3 to 6 inches wide. The pegmatite dykes are up to 36 inches wide; some are sharply marked off from the country rock and follow straight courses, but others grade into the country rock and follow winding courses. The composition of both is relatively simple: essentially quartz, very coarse orthoclase with incipient sericite, subordinate andesine (Ab_{65}), irregularly distributed garnet, minor biotite, and very rare small grains of monazite (thin section No. 3917). The more southerly of the pair of small islands at the extreme western end of the group is also traversed by a dyke of a medium-grained rock, about 6 feet wide, which strikes about east-west and dips vertically. This appears to be closely comparable to the " granulite dyke " from the West Arm of Mawson.

ROOKERY ISLANDS AND GIBBNEY ISLAND.

The Rookery Islands consist of about 30 islands, some 10 miles due west of Mawson, the largest of which has an area of some 10 by 40 chains and rises 200 feet above sea level.

The dominant rocks throughout this island group are granitic gneisses and granular gneisses, including some charnockitic types, all with more or less pronounced banding. Enclosed bands and lenses of hornfels are very abundant and range up to several chains long and 4 or 5 feet wide. In addition garnetiferous quartz- and feldspar-rich gneisses form lenses up to a chain wide and several chains long, especially on some of the smaller islands near the eastern edge of the group. These lenses are generally concordant with the foliation of the adjacent granitic and granular gneisses and commonly grade into them, so that their age relations could not be satisfactorily established. A relatively large area in the south portion of the main island of the group is occupied by a very distinctive medium to coarse pink garnetiferous granitic gneiss.

Under the microscope, the granular gneiss is found to be composed essentially of quartz, orthoclase, and andesine, together with slightly less abundant hypersthene, biotite, and magnetite. All the minerals have very irregular outlines and many have interlocking boundaries (thin sections Nos. 3909 and 3911).

In a typical specimen of the hornfels (thin section No. 3915) the grain-size is slightly smaller, orthoclase is absent, and ferromagnesian minerals more abundant. The ferromagnesians are hypersthene, biotite with very strong pleochroism, pale yellow to deep reddish brown, and abundant hornblende, pleochroic pale greenish brown to dark greenish brown. All tend to be concentrated in bands, and grains of biotite and hornblende tend to lie parallel.

The typical granitic gneiss, garnetiferous quartz-feldspar gneiss, and pink granitic gneiss (thin sections Nos. 3907, 3908, and 3910) consist of coarsely crystalline orthoclase, slightly less abundant and partly recrystallized quartz, and subhedral oligoclase-andesine, together with coarse garnets, up to 5 mm. across, some magnetite, and minor biotite. The feldspars are extensively sericitized and replaced in part by fibrous aggregates of incipient sillimanite and in part by myrmekitic quartz-feldspar intergrowths. The pink colour of some members of this group is due essentially to the presence of finely divided iron oxides within the potash feldspar.

The only defined dykes noted in this area consisted of a few quartz-feldspar pegmatites up to 6 feet long and 3 inches wide, but numerous pegmatitic phases are associated with both the granitic gneiss and the garnetiferous quartz- and feldspar-rich gneisses. Generally, their mineralogical composition is similar to that of the surrounding country rock; their contacts are gradational, and their boundaries, though irregular, are roughly concordant with the surrounding foliation.

Some of the bands of granular gneiss within this area also contain traces of metallic minerals, identified as pyrite, ilmenite, and chalcopyrite by Mr. W. M. B. Roberts (Bureau of Mineral Resources). These minerals occur as disseminated grains; the largest ilmenite grains are 0.8 mm. across, and the sulphides 0.2 mm.

The foliation and banding throughout this island group strike generally within 10° of true north and dip east at angles of 60° to vertical, except in the north-western island of the group, where the strike has changed to 25° and the dip has flattened to 55° east. Flatter dips, of the order of 30° to 35° east, have also been noted in a few localities on the northern portion of the main island.

At Gibbney Island, some 5 miles west-north-west of the Rookery Islands, the assemblage of rocks and their foliation and banding are very similar to those predominating at the Rookery Islands.

STANTON GROUP.

About 10 miles west of Gibbney Island, the isolated small island of Tongue Rock and the nearby coastal outcrop of Low Tongue consist of garnetiferous gneiss similar to that described from the Rookery Islands. The banding here is vertical and strikes 360°.

At Oldham Island, about 8 miles farther west again, the general assemblage is also very similar to that of the Rookery Islands. Granular gneiss and banded leucocratic gneiss with numerous basic schlieren are the dominant phases, together with a few lenses and veins of a coarse-grained porphyritic gneissic granite, mostly elongated parallel to the banding of the surrounding country rock, but in places cutting across it at various angles. The banding and foliation strike roughly north and show dips ranging from 45° west through vertical to 60° east; minor contortions mostly pitch west at about 45°.

The remaining islands of the Stanton Group, extending for about 8 miles to the west and south-west of Oldham Island, although not examined in detail, are believed to consist essentially of similar rock types.

EINSTODING ISLANDS.

The Einstoding Islands, situated about 3 miles north of Oldham Island, consist of three islands, each about 100 yards across, separated by narrow channels and aligned approximately east-west. The highest points are about 40 feet above sea level. Here, the country rock consists of a porphyritic granite, with faint gneissic structures, garnetiferous in part and indistinguishable in the hand-specimen from the Mawson

Granite (p. 21). Microscopically, the only difference consists of the presence of traces of secondary green amphibole, partly replacing hypersthene, in the Einstoding Islands rock (thin section No. 3918).

The foliation, where discernible, strikes about 300° and dips vertically. Xenoliths are rare, but one body of hornfels, several chains long and intersected by numerous narrow veins of granitic composition, was noted on the central island. Pegmatite dykes are very abundant, mostly of a similar composition to the country rock and commonly grading into it at their margins. They may be several chains across, commonly with very irregular outlines, although one well-defined dyke, about 6 inches wide, was also noted.

ISLANDS AND COASTAL OUTCROPS BETWEEN JELBART GLACIER AND TAYLOR GLACIER.

The stretch of coastline 45 to 55 miles west of Mawson contains about 5 square miles of exposed rock, made up of islands, coastal outcrops, and inland occurrences within 3 or 4 miles of the coast (Plate 8, fig. 1). At Stump Mountain, 2½ miles south-west of Byrd Head, the inland rocks reach a maximum height of about 1,200 feet above sea level, and the main peak of Ufs Island reaches approximately the same height. Most of the headlands and all the more outlying islands, however, are considerably lower than this, and in places summit levels can be seen to lie 180 to 200 feet above sea level. (Compare similar concordant levels at about 100 to 110 feet above sea level around Mawson.)

In the area south-west of Byrd Head, several lakes lie in flat-bottomed valleys largely covered by morainic material and general rock debris. They all lie about 150 feet above sea level, and the largest of them measures about 600 yards by 200 yards. They were frozen over at the time of examination (August, 1956), and their depths are not known. The general trend of both valleys and ridges conforms fairly closely to the average strike of the foliation of the rocks in this area, which is close to 60°, and the trend is continued northwards in groups of islands aligned parallel to this direction.

On the higher ridges to the south and west of Byrd Head, and on many of the islands of the Colbeck Archipelago, the most abundant rocks are medium to coarse even-grained granular rocks with slight gneissic tendencies, closely comparable to the granular gneiss of the Rookery Islands. The granular gneiss encloses numerous bands and lenticular bodies of hornfels, a few of which are several chains wide and which consist of the usual orthoclase, oligoclase-andesine, quartz, hypersthene, biotite, and magnetite, with the addition of deep green amphibole (thin section No. 3925), cordierite (No. 3926), or a pale green clinopyroxene (No. 3927). In addition, the gneiss contains a few inclusions of quartzite and garnetiferous quartzite and a few inclusions or segregations composed almost entirely of ferromagnesian minerals—biotite, garnet, hypersthene, clinopyroxene, and amphibole, in various proportions. At major contacts with the metasediments, the granular gneiss is intrusive, although its boundaries and foliation are generally broadly conformable to the banding of the hornfels.

Within this complex, other rocks become prominent in several zones, the most important being a series of pink quartz- and feldspar-rich gneisses with minor garnet and biotite, again closely comparable to the corresponding rocks already described from the Rookery Islands. These also are intrusive into the metasediments; lit-par-lit structure is developed in places, but they are regarded as reconstituted and partially mobilized sedimentary rocks rather than true igneous intrusions (see p. 72). The gneiss consists of perthitic orthoclase, ranging in average grain-size from about 2 mm. to more than 1 cm. in different specimens, together with quartz, typically as mosaics of very much smaller grains, and subordinate amounts of oligoclase-andesine, sometimes with anti-perthitic texture. Some garnet is invariably present, but biotite and magnetite are very subordinate (thin sections Nos. 3928, 3929 and 3931). A rather unusual rock from the same area (thin section No. 3930) may also belong to this group. It is composed of a mosaic of strongly elongated quartz grains in parallel alignment; some of the individual grains measure 5 mm. by 0.5 mm. The only other minerals are a few lenticular remnants of strongly deformed and sericitized plagioclase (? oligoclase), also with a maximum length of about 5 mm., a very subordinate amount of biotite, and some minute granules of amphibole and pyroxene. Locally, these gneisses appear to grade into pegmatitic phases of similar mineralogical composition (see below).

The main areas in which these quartz-rich and feldspar-rich gneisses assume significant proportions are in the immediate vicinity of Byrd Head, along the coastline to the south of this point, on a number of headlands 2 or 3 miles south-west of Byrd Head, and on some of the more westerly islands of the Colbeck Archipelago. Similar rocks have also been encountered in the Allison Islands, immediately west of the Jelbart Glacier. Near the Taylor emperor penguin rookery, these rocks are lacking, and instead banded gneisses of obviously hybrid origin, characterized by the presence of garnet and abundant biotite (thin section No. 3924) are very strongly developed.

Veins of pink pegmatite, up to 5 feet wide, are widespread throughout the Byrd Head and Colbeck Archipelago area, where they cut across the foliation of the gneiss at various angles. They are most abundant in the immediate vicinity of some of the zones of pink gneiss described above, but they have not been observed in contact with charnockitic granite (see below). Mineralogically, the pegmatite is generally simple, consisting essentially of orthoclase and quartz (which commonly shows evidence of recrystallization), together with minor biotite and magnetite. Alteration products may include sericite, chlorite, and traces of calcite (thin sections No. 3921 and 3922). A specimen from the western Colbeck Archipelago (thin section No. 3923), in addition to orthoclase and subordinate quartz, contains numerous prismatic crystals of sillimanite, up to 5 mm. long and 1 mm. thick, as well as a number of subhedral garnets, up to 1 cm. across, crowded with inclusions of quartz and magnetite and altering to biotite along cleavage planes. This rock is best described as a contaminated pegmatite.

In the Byrd Head and western Colbeck Archipelago areas minor occurrences of chrysocolla are associated with the pegmatite dykes; they form superficial stains, generally only a few inches across, on exposed faces and joint planes of pegmatite and occasionally on gneiss. Small reefs of medium to coarsely crystalline quartz are also present in this area. Similar pegmatite dykes are also prominent near the Taylor rookery, where they locally become the dominant rock and enclose large lenticular bodies of biotite hornfels and garnetiferous biotite hornfels. They are not generally foliated, and their contacts with the surrounding gneiss and with the hornfels inclusions are generally sharp and transgressive.

A very different rock assemblage predominates in the northern and western portions of Ufs Island and on the adjacent portions of the mainland, which are occupied by porphyritic gneissic charnockitic granite, very similar to that previously described from Einstoding Islands and from Mawson. Its contact with the metasediments passes a few chains south-east of the isolated knoll which rises to a height of about 600 feet on the south-western portion of the island. At this point, the contact trends roughly parallel to the banding of the metasediments, which strikes about 60° and dips nearly vertically. Near the contact, these metasediments are traversed by a network of granite veins, each a few inches wide, and contain scattered feldspar porphyroblasts. Close to the contact the long axes of xenoliths and feldspar phenocrysts in the granite are aligned parallel; but in other portions of the mass this parallelism is only feebly developed or altogether absent. It re-appears, however, on the most northerly tip of the island, where its strike is 320° and dip more or less vertical, possibly indicating the proximity of another contact some distance out to sea.

The south-western extension of this granite can be traced on to the mainland at two points. One belt, about 100 yards wide, occurs on an isolated headland about half a mile south-west of the western tip of the island, and a second belt, about half a mile wide, is situated about two and a half miles due south of Byrd Head. Both appear to be roughly concordant with the strike of the surrounding metasediments, which is again about 60°, and, wherever any foliation was noted, it also conformed approximately to this direction.

In addition to the localities listed above, at least two bands of charnockitic granite occur within the Colbeck Archipelago; their relations to the surrounding gneiss are similar to those described above from Ufs Island.

All the rocks of this area are liable to be intersected by shear zones with an average width of six inches, in which minor breccia and pseudo-tachylite are developed. The shear zones appear to be especially numerous near Taylor rookery, where they dip more or less vertically; strikes at right angles to the banding of the country rock predominate slightly.

The dominant trends throughout the area, including the foliation of the gneisses, the banding of the metasediments, and the elongation of the granite belts, follow directions between 60° and 75°. Dips generally are within 15° of vertical, with a slight predominance of steep south-easterly dips. The main exceptions occur along a half-mile stretch of coastline some two and a half miles south-west of Byrd Head, on some of the more westerly islands of the Colbeck Archipelago, approximately north of this area, and in the immediate vicinity of the Taylor rookery. In these localities, the dominant strikes are generally 15° to 30°, again with more or less vertical dips. At the southern extremity of the area south-west of Byrd Head, this change in strike is very abrupt and may have been brought about, at least in part, by faulting. In the Taylor rookery area, pronounced minor folds are developed locally; most of them pitch east at angles between 45° and 90°.

There is no evidence of recent polishing by ice at the Byrd Head or Taylor Glacier localities, but surfaces on several of the lower-lying islands of the Colbeck Archipelago are well polished and somewhat striated. Moraine deposits and erratic boulders, on the other hand, are poorly represented on any of the islands except the southern portion of Ufs Island, and are almost confined to some of the larger coastal outcrop areas.

TAYLOR GLACIER TO STEFANSSON BAY.

The area between the Taylor Glacier and Stefansson Bay, some 40 miles to the west, contains a number of prominent coastal outcrops and islands, but they could not be examined during the 1955 and 1956 field seasons. However, collections in this area had previously been made from Cape Bruce (B.A.N.Z.A.R.E., 1930-1931), Bertha Island ("William Scoresby", 1936), and Oom Island and Hobbs Islands (A.N.A.R.E., 1954).

The Cape Bruce collection has been described by Tilley (1937). It includes garnetiferous cordierite and sillimanite paragneisses, garnet-plagioclase orthogneiss, and some sheared rocks intersected by pseudo-tachylite veins similar to those described above from the Taylor rookery. Some rocks described as granite and granodiorite gneiss appear to correspond to the garnetiferous gneisses from Rookery Islands and Byrd Head, and quartz-feldspar-garnet gneiss, regarded by Tilley as a hybrid, also has its counterpart in the Byrd Head area.

The Bertha Island collection (Rayner and Tilley, 1940) indicates that the dominant rock at this locality is a medium-grained foliated gneiss composed of quartz, microperthite, hornblende, and garnet, with subordinate andesine, hypersthene, and clinopyroxene. This corresponds to a rock which is also very widespread around Keel Island, a few miles to the west (see below), except that hornblende is there generally replaced by biotite.

Small outcrops of hypersthenite and garnetiferous hypersthenite are also recorded, corresponding to similar rocks at King Edward VIII Gulf (see below). However, some specimens of metamorphosed gabbro and norite, composed of augite, hypersthene, hornblende, and labradorite, with secondary garnet developing at the expense of the other ferromagneslan minerals, do not appear to have any counterparts among the rocks encountered during the 1955 and 1956 field seasons.

An erratic calc-silicate rock rich in diopside and scapolite is also recorded.

STEFANSSON BAY AND LAW PROMONTORY.

On the east side of Stefansson Bay, many islands and coastal outcrops extend over an area of five by fifteen miles from Cape Wilkins on Fold Island in the north to Stanley Kemp Peak in the south. The central part of this area was examined geologically in 1956. On the west side of Stefansson Bay, another series of islands and coastal outcrops occurs at irregular intervals around the flanks of Law Promontory. Of these, the Law Islands and the Broka-Havstein Group had already been visited by R. Dovers and G. Schwartz in 1954. During 1956, two small outcrops near the south-eastern tip of Law Promontory, and Kring Islands off its north-western coast, were also visited.

These rock exposures, with the exception of Fold Island, parts of Broka Island, and Stanley Kemp Peak, consist of more or less isolated rocky knolls and hummocks, separated by lower-lying areas largely covered by permanent snow drifts or morainic debris. Most of the summits of the knolls lie between 350 and 400 feet above sea level, but there are none of the flat-topped plateau-like summits which are so typical of the Mawson area.

The morainic material occupying the intervening low-lying areas consists largely of poorly sorted boulders up to several feet across and commonly including at least a small proportion of rock types not occurring in situ close to the moraine.

On the southern part of Fold Island, a small ice-cap has developed (maximum height about 800 feet), which obscures all rock outcrops over an area of 15 or 20 square miles. Parts of this ice-cap appear to be moving towards the coast, for crevassing is visible at several points. The ice-cap on Law Promontory (maximum height about 1,500 feet, area approximately 120 square miles), also appears to be an independent unit, nourished entirely by precipitation on its surface, as it rises several hundred feet above the highest point of the neck which connects it with the mainland. Intense local crevassing and minor glacier tongues indicate that parts of this ice-cap are moving coastward. A rather smaller ice-cap is also present on Broka Island. This area therefore has considerably higher annual accumulation than the Mawson area, or a correspondingly lower ablation, since in the Mawson area no excess of accumulation over ablation has been noted below 2,400 feet.

On most of the other outcrops in this area, such as Keel Island and Transverse Island, the snow and ice cover is restricted to permanent drifts which extend to leeward and occasionally to windward of the more prominent rocky knolls and hummocks. Some drifts are composed of blue ice with a seasonal cover of new snow; others are composed, at least in part, of névé. No signs of crevassing were seen at any of these drifts, so they are probably stationary. Occasional depressions in the rock surface and valleys dammed by these drifts are occupied by small melt-water lakes.

The bed-rock at Keel Island and the adjoining islands and coastal outcrops is generally similar to that already described from the Byrd Head/Taylor Glacier area. Medium-grained granular gneiss rich in quartz and feldspar, and probably of igneous origin, is dominant. Biotite and garnet are the main accessories. The foliation is generally brought out by the presence of parallel bands, lenses, and schlieren enriched in ferromagnesian minerals, dominantly biotite, which are locally so abundant that they give a banded appearance to the rock as a whole. More massive inclusions of fine to medium grained hornfels are also present, and in the northern portion of the coastal outcrops, some 2 miles east of Keel Island, arenaceous metasediments locally become dominant.

On Keel Island the strike is approximately north-south, and the dip east at about 45°. On the mainland, some 2 or 3 miles south-east of Keel Island, the attitude of the banding is more variable. Most dips in this area are to the east, south, or west at low angles, mostly between 15° and 30°. Locally, a slight lineation was also noted, lying in the plane of the foliation and striking roughly north-south.

Both pink and grey pegmatites are present in the area, generally composed of quartz, feldspar, and biotite only, a few also with garnet. On Keel Island most are less than 12 inches wide, but bodies up to 10 feet wide are not uncommon on the mainland, some 2 or 3 miles south-east of this island. They commonly cut across the foliation of the surrounding country rock and are not foliated themselves, but some of their contacts with the surrounding gneisses are gradational.

Some coarsely crystalline veins and lenses of reef quartz up to 18 inches wide are also present on the mainland, but not on Keel Island. A lenticular mass measuring some 10 feet by 18 inches, on the central portion of Keel Island, was found to consist of a quartz-epidote rock, with traces of iron oxide (? magnetite), and remnants of plagioclase and amphibole, now largely replaced by sericitic aggregates and by chlorite-epidote mixtures respectively (thin section No. 3933).

Traces of superficial copper staining were noted at one place on Keel Island and five or six places on the mainland to the east, associated with quartz veins, pegmatite, and apparently normal gneiss. The secondary mineral is a hydrated copper silicate of the chrysocolla group, and at least one of the occurrences is associated with traces of disseminated chalcopyrite, described by Mr. W. M. B. Roberts as forming small areas, up to 0.3 mm. across, mostly in the garnets.

On the small coastal outcrop on the mainland, opposite the south-eastern extremity of Law Promontory, about 12 miles west of Keel Island, the dominant rock is a medium-grained, even-grained granular gneiss, similar to those already described from Keel Island itself. Perthitic orthoclase, quartz, and oligoclase, together with minor hypersthene and subordinate magnetite, are the typical constituents (thin section No. 3936).

These rocks are only feebly gneissic and are believed to be largely of igneous origin, comparable to the charnockitic gneiss described from Rookery Islands, &c. Lenticular inclusions of fine to medium-grained dark-coloured hornfels are very abundant; a few are as much as 60 feet across. A typical specimen (thin section No. 3937) consists of roughly equidimensional andesine, hypersthene, and a bright green non-pleochroic clino-pyroxene, together with slightly larger, less regular amphibole, pleochroic greenish brown to deep brown, and subordinate magnetite.

The foliation of the gneiss and the long axes of the inclusions run more or less north-south with dips ranging from 70° to vertical. The boundaries of the inclusions are generally sharp, and a few are offset by minor shears. More rarely, the granular gneiss passes into zones of hybrid gneiss in which coarse-grained biotite-rich bands, generally a fraction of an inch thick, alternate with bands of the normal country rock. Some very complex small-scale folding is associated with some of these hybrid zones.

Veins and irregular bodies of pegmatite, generally 12 to 18 inches wide, are very abundant; some are aligned parallel to the foliation of the surrounding country rock, but most cut across it at various angles.

In addition, a single erratic boulder of an altered basaltic rock was found at this locality (thin section No. 3938). This rock is now composed essentially of aggregates of small chlorite flakes, calcite grains, and finely divided iron oxides, but the outlines of original phenocrysts of feldspar and ferromagnesian minerals are still marked by differences in the proportion of light to dark minerals. A few scattered grains of deep brown iddingsite are also present.

Metallic minerals at this locality were found in an area some 2 to 3 feet in diameter in which exposed faces and joint planes in a hornfels inclusion have been superficially stained by limonite, manganese oxides, and secondary copper minerals (? chrysocolla).

The outcrop on the south-east tip of Law Promontory itself, some 4 miles east-north-east of the above, consists of essentially similar rocks. The foliation and the long axes of any inclusions again trend approximately north-south, but dips are dominantly to the west at angles of about 45°.

On Kring Islands, off the north-western coast of Law Promontory, the dominant rocks are arenaceous metasediments, grading into garnetiferous quartzite on the one hand and into biotite and amphibole hornfels on the other. Strikes lie between 45° and 90°, with southerly dips of 15° to 45°. These metasediments are intersected by numerous bodies of pink and grey pegmatite, generally with irregular outlines, which cut across the banding at various angles. Traces of superficial staining by secondary copper minerals were noticed at several points.

KING EDWARD VIII GULF AND OYGARDEN GROUP.

To the west of Law Promontory, closely spaced coastal outcrops and islands persist for another 50 miles to the mouth of King Edward VIII Gulf. Some of these, including Mule Point, Kvars Promontory, Abrupt Point, and parts of the Oygarden Group, were visited by Dovers in 1954, but only one area was examined during the 1956 season. This was the western portion of the Oygarden Group, in the vicinity of 66° 56′ S. lat., 57° 20′ E. long., 180 miles west of Mawson. Physiographically, this area is very similar to the Stefansson Bay locality. The highest points of most of the islands are 350 to 400 feet above sea level, and most of the lower portions are occupied by moraine deposits and permanent drifts, generally composed of blue ice with only a superficial cover of new snow. Melt-water lakes are very numerous and a few reach a width of 40 to 50 yards.

The dominant rocks in this area are highly metamorphosed sediments. Garnetiferous quartzite predominates, generally containing minor amounts of orthoclase and oligoclase-andesine, and sometimes cordierite (thin section No. 3940), or sillimanite (thin section No. 3943). With increasing alumina content, this grades into rocks locally containing up to 50 per cent. of sillimanite (thin section No. 3941); others tend towards biotite hornfels and garnetiferous biotite hornfels. Among the igneous rocks of the area, most conform to the banding of the surrounding metasediments. One very striking rock, encountered on Shaula Island and Alphard Island, consists largely of andesine and pale green clinopyroxene, both as roughly equidimensional grains with an average diameter of 2 mm. Subordinate hypersthene is present, as well as a small quantity of amphibole, pleochroic yellowish brown to deep greenish brown, typically forming rims around some of the pyroxene grains. Rather smaller garnets, generally subhedral, and minor iron oxide are also present (thin section No. 3942). This rock shows slight banding in the hand-specimen, and may be called a garnetiferous gabbro-gneiss.

By contrast, a number of bands on Alphard Island and Depot Island are believed to represent the recrystallized equivalents of originally fine-grained basic igneous rocks. A typical specimen (thin section No. 3950) now consists largely of hypersthene, minor quartz, some unidentified feldspar, and very subordinate magnetite, all as irregular grains of less than 0.1 mm. average grain size, except for a few hypersthene phenocrysts up to 2 mm. The rock is cut by narrow quartz-calcite veinlets and contains numerous disseminated specks of opaque minerals, identified by Mr. W. M. B. Roberts as ilmenite, magnetite, pyrrhotite, chalcopyrite, and a mineral which could be marcasite. Mr. Roberts states that pyrrhotite is the most abundant opaque mineral; it forms irregular masses ranging up to 2.0 mm., and contains a small quantity of chalcopyrite as intimate intergrowths. Ilmenite is widely distributed in the section, but in very small grains, the largest measuring 0.25 mm. Magnetite is a very minor constituent, only one grain being observed. The mineral tentatively named marcasite occurs as small irregular grains of fairly high reflectivity and hardness and could be the result of breakdown of pyrrhotite to marcasite and pyrite, the skeletal form being due to removal of pyrite.

The only rocks which commonly cut across the foliation and banding of the metasediments are a series of pegmatite dykes and quartz veins, generally less than 6 inches wide. The pegmatite dykes are somewhat variable in composition and many of them carry some biotite or garnet or both. One specimen from the Sirius Islands (thin section No. 3944), in addition to quartz and oligoclase, both of which show some evidence of recrystallization, contains crystals of amphibole, pleochroic pale yellowish brown to deep greenish brown, up to 3 cm. long, which are rimmed in part by biotite, pleochroic pale yellowish brown to very deep reddish brown. Some smaller subhedral garnets, minor magnetite, and accessory zircon are also present.

This area also contains rocks composed largely or entirely of ferromagnesian minerals, including ortho- and clino-pyroxenes, amphibole, biotite, garnet, and magnetite. These typically occur as lenses and bands from a fraction of an inch to several feet wide, generally conformable to the banding of the surrounding rocks, but their origin is not always clearly recognizable. In general, the pyroxene-rich rocks are thought to be of igneous origin, and the magnetite-rich and garnet-rich rocks are regarded as being largely of sedimentary origin.

Among the pyroxene-rich rocks, some are composed entirely of pale green clino-pyroxene as roughly equidimensional grains, up to 5 mm. in diameter (thin section No. 3945). Others contain in addition some 10 per cent. of hypersthene as smaller and less regular grains (thin section No. 3947). Still others consist dominantly of hypersthene as subhedral equidimensional grains with an average diameter of about 2 mm., together with about 10 per cent. of amphibole, pleochroic almost colourless to dark brown, occurring as less regular grains and in part enclosing the pyroxene. Very subordinate biotite flakes, up to 1 mm., pleochroic pale yellow to deep reddish brown, are also present (thin section No. 3946).

Among the garnet-rich and magnetite-rich rocks also, the proportions of the various minerals present vary considerably between specimens. One specimen (thin section No. 3948) consists essentially of subhedral grains of hypersthene, averaging about 2 mm. in diameter, together with magnetite of about the same grain size. The magnetite occurs partly as subhedral crystals, some of which enclose the pyroxene, and partly as interstitial grains. According to Mr. W. M. B. Roberts, this magnetite is slightly anisotropic and at high magnifications shows exsolution lamellae of a non-opaque mineral along the (100) and (111) directions. The exsolving mineral is probably the iron spinel hercynite. A rather different assemblage is found in thin section No. 3949. This consists largely of clear quartz and garnet, both as rather irregular grains up to 5 mm., together with a few clots of rather smaller hypersthene grains and some small needles and larger irregular grains of amphibole, pleochroic pale greenish-brown to deep green. Magnetite is present as rather irregular grains up to 2 mm., and may be associated with hypersthene or intergrown with quartz. In both these rocks, the proportion of magnetite may locally exceed 50 per cent. by weight, but such magnetite-rich phases are generally restricted to lenses or bands only a few inches wide.

Superficial staining by secondary iron, manganese, and copper minerals can be seen in several places. The iron staining (mostly limonite) locally extends over areas of 40 to 50 feet by about 10 feet, and appears to be largely derived from the previously described fine-grained igneous rocks carrying magnetite and traces of disseminated sulphides. The manganese stains are much smaller, and generally consist of thin coatings on exposed faces, joints, and minor shears. Staining by secondary copper minerals occurs similarly, but individual occurrences rarely exceed 5 by 2 feet. They have been found in a wide variety of rocks, including hornfels, quartzite, pegmatite, and reef quartz, but only traces of sulphides were found in association with any of them.

Structurally, the metasediments of this area generally show large-scale banding, which appears to be a direct reflection of the original bedding (Plate 8, fig. 2). Some of the more micaceous phases are also foliated by the parallel alignment of mica flakes and other elongated mineral grains. Foliation is invariably parallel to the banding in the immediate vicinity.

East-west strikes predominate on all the islands examined, and are reflected in the elongation of most of the islands themselves. On Depot Island and on the northern part of Shaula Island, the dips are dominantly to the south at angles of about 60°, but some minor folding is present. This includes more or less symmetrical folds with horizontal axes, spaced about 1 to 2 chains apart, and a few smaller, almost isoclinal structures, pitching west at angles of up to 70°. The Rigel Skerries appear to consist of a major syncline pitching west at 20° to 30°, with dips averaging 60° on the southern limb and 45° on the northern limb. The western portion of Alphard Island and the unnamed island about 1 mile east of Depot Island both show considerable variation in dip and strike, due to complex structural patterns. The major units appear to be open synclines and anticlines, spaced at intervals of a few hundred yards, and separated by areas containing complex drag-folds, in part almost isoclinal. The axes of all these structures pitch west at moderate angles, mostly between 15° and 40°.

ENDERBY LAND.

The main Enderby Land peninsula, between King Edward VIII Gulf at 57° E. long. and Amundsen Bay at 50° 30′ E. long., contains several coastal outcrops and a major group of inland ranges, rising in part to heights of more than 6,500 feet above sea level; but the only geological information available on this sector is contained in a report on rocks collected from Proclamation Island by the B.A.N.Z.A.R. Expedition, 1929-1931 (Tilley, 1937).

The dominant rock at this locality is reported to be an acid charnockite, consisting of quartz, microperthite, subordinate myrmekitic andesine, hypersthene, and hornblende or biotite, together with accessory apatite, magnetite, and zircon. The hypersthene may be mantled by clinopyroxene or partly altered to amphibole and biotite. A variant in which andesine or andesine-antiperthite predominates over potash feldspar was also recognized. These rocks appear to correspond very closely to the hypersthene-bearing granular gneiss from Rookery Islands, Law Promontory, and other localities in MacRobertson Land.

Tilley also records a group of biotite pyroxenite, hypersthenite, and hornblende hypersthenite, which he refers to as ultrabasic members of the charnockite suite. However, the equivalents of these rocks have also been met with at King Edward VIII Gulf and at Amundsen Bay; at neither locality are they associated with the more normal acid members of the suite. Their relation to the charnockites is therefore regarded as doubtful.

Other rocks recorded from Proclamation Island include garnet granulite, sometimes with minor sillimanite, which is regarded as an extensively recrystallized igneous rock by Tilley and which compares closely with the garnetiferous gneisses of the Byrd Head and Amundsen Bay areas. Hornblende gneiss, garnet-sillimanite gneiss and garnet-hypersthene gneiss are recorded as erratics only, along with boulders of metamorphosed dolerite, some still preserving traces of ophitic texture.

AMUNDSEN BAY AREA.

During a brief examination in November, 1956, it was found that the area shown as " Amundsen Bay " on earlier maps actually consists of two bays (Amundsen and Casey Bays), separated by some 20 miles of low ice plateau. Only the more easterly of these bays (Amundsen Bay) was examined during this visit. It extends north-westerly for 30 miles, with a maximum width of about 15 miles. Near its southern and south-eastern limits, at approximately 67° 15′ S. lat., 50° 30′ E. long., a series of major rock peaks, forming part of the Scott Mountains, rises abruptly to heights of more than 4,000 feet above sea level, and it is estimated that, over a total length of some 20 miles, about 50 per cent. of the coastline in this area is made up of rock outcrops. Several glacier tongues extend into the bay from gaps in this range. The largest of these, belonging to the Beaver Glacier, extends from the eastern extremity of the bay in a general west-north-westerly direction and is about 15 miles long and 5 miles wide (Plate 9).

In general, the major bedrock exposures present an extremely rugged appearance, due to the presence of several sets of more or less vertical joints, many of which give rise to cliff faces several hundred feet high. At lower altitudes extensive glacial deposits give rise to a hummocky topography and locally have dammed back melt-water lakes up to some 200 yards by 100 yards in extent. On the down-wind side of some of these lakes, a heavy superficial encrustation of carbonates was noted on exposed boulders, apparently formed from material carried there by spray from the lake. The lower limit of this encrustation lay about 20 feet above the level of the lake at the time of the visit, suggesting that the level varies considerably from time to time. To the west of this area, a closed depression below sea level was noted from the air, apparently due to over-deepening of a valley by glacial action in the fairly recent past.

The dominant rocks of the area are highly metamorphosed sediments, originally mainly arenaceous. They generally show fine banding, due to the alteration of layers with varying proportions of ferromagnesian minerals, and grade on the one hand into quartzite and garnetiferous quartzite and on the other hand into biotite-rich hornfels (Plate 10). One rather unusual variant (thin section No. 3956), consists largely of interlocking grains of quartz, the largest of which are one centimetre across, together with aggregates of white mica, biotite, and sillimanite, which are made up of grains up to 0.1 mm. in diameter, and appear to replace original feldspar. Traces of disseminated pyrite are also present.

With the addition of some igneous material, possibly by metasomatism, these metasediments grade into banded gneiss rich in quartz and feldspar, similar to those from Byrd Head and Rookery Islets. Thin section No. 3951, regarded as typical of this group, now consists almost entirely of quartz as elongated interlocking grains, up to 1 cm. by 2 mm., together with slightly smaller irregular grains of perthitic orthoclase and subhedral oligoclase, the latter as strongly zoned, rather clouded grains. Garnet is present as irregularly distributed small clots. In the western portion of the area, even more intense metamorphism appears to have affected a few of these rocks, and several bands with feldspar porphyroblasts were noted. Bands and lenses very rich in pyroxene, similar to those from King Edward VIII Gulf, are present, including one specimen, obtained as an erratic only, composed of hypersthene with only a trace of interstitial plagioclase (? labradorite) (thin section No. 3955).

Among the rocks of undoubted igneous origin, two main types can be distinguished. One is represented by several intrusive masses, up to 3 chains by 1 chain in extent, near the south-eastern extremity of the Bay. These rocks are generally rather strongly weathered and poorly exposed, but appear to be roughly conformable to the bedding of the surrounding metasediments. Under the microscope, a typical specimen (thin section No. 3953) is seen to consist of hypersthene and strongly zoned, slightly cloudy plagioclase (?andesine), both as rather irregular grains averaging about 2mm. in diameter. A few small biotite shreds, pleochroic almost colourless to pale reddish brown, are associated with the hypersthene. This rock appears slightly gneissic in the hand-specimen but not in thin section, and may be called a norite gneiss.

In addition, the area contains some cross-cutting veins of pegmatite and graphic granite, generally less than 6 inches wide. Many of these are rich in feldspar (? microcline-perthite), which generally shows a distinct bluish tinge, and some also contain minor amounts of hypersthene, sometimes as crystals more than 5 mm. long, intergrown with quartz (thin section No. 3952).

Finally, there are again several magnetite-rich bands within this complex. A few of these reach a width of 2 feet and locally contain more than 50 per cent. by weight of magnetite, the remaining constituents being quartz and hypersthene (thin section No. 3954). The majority were found within a few chains of the norite intrusions described above, and are probably genetically related to them.

Superficial staining by secondary copper minerals was noted in a few places, and several altered dyke rocks contain traces of disseminated sulphides and oxides, similar to thin section No. 3950 from King Edward VIII Gulf. Mr. W. M. B. Roberts states that magnetite is the most abundant opaque mineral, forming subhedral crystals up to 1.6 mm. across and containing exsolution lamellae of ?hercynite along the (100) direction and of ilmenite along (111). Pyrrhotite is next in abundance, occurring as small irregular masses, most of which appear to be undergoing some degenerative process along the cleavage; this may be a break-down to marcasite and pyrite. Chalcopyrite is intimately intergrown with pyrrhotite, in which it forms small irregular areas, ranging up to 0.06 mm. in size.

In addition to these rocks, two types of fine-grained basic igneous rock were found in this area as erratics. One of these corresponds in composition to a basalt or fine-grained dolerite, composed of laths of slightly zoned, rather clouded andesine-labradorite, up to 2 mm. long, and subhedral to irregular augite, up to 5 mm. across, typically much twinned and commonly enclosing the plagioclase. Small granules of green amphibole and flakes of biotite are present, generally rimming the augite. Magnetite forms euhedral to subhedral crystals, up to 0.2 mm. in diameter (thin section No. 3957). The other rock (thin section No. 3958) is composed essentially of small prisms and irregular grains, up to 1 mm., of ?soda-rich amphobile, pleochroic pale yellowish brown to deep brownish green to deep bluish green, together with subordinate quartz, some irregularly distributed clots of strongly zoned, untwinned plagioclase (?oligoclase), and magnetite. It is the only amphibolite encountered in the entire area. No rocks corresponding to either were seen in situ, but inspection from the air indicated the presence of a body of dark-coloured rock, several hundred feet thick, in the upper portion of one of the main peaks of the Scott Mountains, approximately 20 miles east-north-east of this area, and this is tentatively interpreted as a sheet of basalt or dolerite overlying a basement of metamorphic rocks.

Structurally the area appears to be relatively simple. On Observation Island (67° 01′ S. lat., 50° 24′ E. long.) the metasediments were found to strike approximately east-west, and to dip south at an average angle of about 70°. On Beaver Island, some 15 miles south-east of this point, and on nearby portions of the mainland, the dominant strikes are approximately 120°, with northerly dips of 40° to 50°. Local deviations of strike to 150° and even to 180° were noted, and generally appeared to be associated with a steepening of the dip.

Glacial deposits are very widespread on most of the islands and coastal outcrops of this area. On Beaver Island, which rises to a height of about 2,200 feet on the southern flank of the Beaver Glacier Tongue, morainic material practically obliterates the bedrock to within 500 feet of the summit. This material is noticeably richer in fine fractions (sand and rock-flour) than any of the deposits examined in the Mawson area, but owing to the extreme variability of its composition from point to point, no quantitative estimate of its constitution was attempted. On the mainland to the south of this point, bedrock generally crops out in a series of strike ridges, the intervening valleys being filled by morainic material. The presence of the finer fractions was less marked in this area than on Beaver Island. Arenaceous metasediments, similar to those occurring in situ in this area, make up the greater portion of the erratics from these localities, but granitic and pegmatitic rocks are well represented and rare reef quartz and basalts and fine-grained dolerites also occur.

COASTLINE EAST OF MAWSON.

Between Austskjera and Cape Darnley, from 20 to 180 miles east of Mawson, the coastline consists almost entirely of ice cliffs, interrupted only by the abrupt outcrops of the Scullin and Murray Monoliths. Both these features, situated in the vicinity of 67° 45′ S. lat., 66° 45′ E. long., rise to heights of more than 1,200 feet above sea level. They had been visited by three previous parties (B.A.N.Z.A.R.E. 1929-1931, "William Scoresby", February 1936, and A.N.A.R.E. 1954), and were not visited in 1955 or 1956.

Rayner and Tilley (1940) record gneiss rich in microperthite crystals up to an inch long, the remaining minerals being quartz, garnet, biotite, and subordinate oligoclase-andesine. Stinear (1956) also describes the dominant rock as a coarse-grained quartz-microperthite gneiss, and in addition records a number of minor occurrences of pyroxene granulite and of pink and grey granite-gneiss.

At Cape Darnley, the coastline swings abruptly to the south towards the Amery Ice Shelf, which occupies an area of about 10,000 square miles between 68° 30′ and 71° 00′ S. lat., and 68° 30′ and 74° 15′ E. long. From Sandefjord Bay, 69° 40′ S. lat., 74° E. long., the coastline again trends in a roughly north-easterly direction towards the Vestfold Hills at 68° 30′ S. lat., 78° E. long., and this region contains some of the largest areas of exposed rock so far known from the whole of Antarctica: Mount Caroline Mikkelsen and other isolated outcrops at the head of Sandefjord Bay, the Larsemann Hills, the Rauer Group, and the Vestfold Hills.

THE VESTFOLD HILLS.

The Vestfold Hills were previously visited by Mikkelsen in 1935, Lincoln Ellsworth in 1939, and A.N.A.R.E. in 1954. In 1955, brief visits were paid to the Vestfold Hills and Lichen Island, off the Bolingem Islands, but more detailed work is now being carried out in this area, so that the following account should be regarded as a preliminary report only.

About 150 square miles of rock are exposed at the Vestfold Hills, between 68° 25′ and 68° 40′ S. lat., and 77° 50′ and 78° 35′ E. long. Relief is of the order of 400 feet, and the area is characterized by numerous isolated hummocky hills, somewhat modified in shape by joint and shear directions of the country rock. The major valleys trend roughly east-west, parallel to the predominant strike of the rock foliation, and are filled to various depths by glacial drift and moraine. In the central coastal portion of the area, this morainic material also covers the hills, and no country rock at all is exposed. Elsewhere, only scattered erratics occur on the upper portions of the hills, and few of these show any evidence of faceting or striations. Lakes and fjord-like inlets are very prominent features of the landscape, but there are no defined stream channels and many of the lakes appear to have no surface outlets (Plate 11). Some evidence that two old erosion surfaces are present in this area is afforded by the summits of the highest hills at about 400 feet above sea level and the tops of minor ridges at about 100 feet above sea level. Further work is required, however, to work out these relationships in detail.

The country rock consists largely of medium-grained gneiss, some of which is banded. Under the microscope, a typical specimen (thin section No. 3959) shows light-coloured bands consisting dominantly of quartz and oligoclase, alternating with dark-coloured bands composed mainly of brownish-green amphibole, in part replacing hypersthene, and subordinate deep brown biotite. In spite of the strong banding, individual mineral grains are only slightly elongated.

The dominant strike of both foliation and banding is 90°, with vertical to steep northerly dips, but the strike locally ranges from 45° to 135°. No significant lineation was noted, but extensive zones of slight shearing, some 100 feet wide, cut these rocks at various angles, with a slight preference for trends close to 360°.

Numerous narrow seams of bluish quartz and glassy quartz are present, generally sub-parallel to the foliation, as well as occasional larger lenticular or irregular bodies of granite-pegmatite, pyroxene-bearing pegmatite, quartz-garnet rock, and quartz-epidote rock, some of which carry traces of disseminated sulphides (pyrite and ? arsenopyrite). Segregations or inclusions of almost pure epidote or almost pure pyroxene 2 or 3 feet across also occur.

In addition, there are several bodies of biotite granular gneiss and pyroxene granular gneiss, the largest of which are at least half a mile across. Quartz, oligoclase, minor orthoclase, hypersthene, cordierite, and magnetite are the main constituents of one typical member of this group (thin section No. 3960). Their relations to the banded gneiss were not obvious in the field, but they appear to be related, at least in part, to the charnockitic granular gneiss of the Mawson area and may therefore represent severely metamorphosed igneous rocks.

One of the most prominent features of the area is the large number of basic dykes, which range up to 50 feet in width; some of them can be traced for at least a mile. Fine-grained dolerite is the dominant rock. A typical specimen (thin section

No. 3962) consists of laths of andesine-labradorite and subhedral grains of augite, both up to 1 mm. in size and occasionally showing ophitic texture, in a matrix of smaller plagioclase laths, interstitial granules of augite, and minor amounts of iron oxide (?magnetite), green amphibole, and biotite. The dominant strike direction of these dykes is between 340° and 20°, with a minor set approximately at right angles to this, and a few dykes oblique to both. Dips are generally within 20° of vertical. The dykes typically cut across shear structures in the country rock, but some are themselves faulted and show slight local shearing. On the other hand, they do not contain any quartz veins or other indications of younger magmatic activity. No petrological or structural differences could be detected between the various sets of dykes of different strikes, and no consistent age relationships exist at intersections (Plate 12, fig. 1).

The erratics and boulders of the moraine deposits generally belong to one or other of the rock types already described, the main exceptions being a few specimens of a contorted garnet schist and of a mica schist with porphyroblastic feldspars, neither of which corresponds to any rock seen in situ in this area.

LICHEN ISLAND.

Lichen Island (69° 20′ S. lat., 75° 32′ E. long.) is situated some 12 miles west of the Larsemann Hills. The island measures 350 yards by 120 yards, elongated east-north-east, and reaches a maximum elevation of about 60 feet. At the time of the visit (February 1955), the island was completely surrounded by fast ice, with a pronounced tide crack, and its relatively low-lying central portion was covered by snow drifts.

In contrast to the Vestfold Hills, Lichen Island is free from erratics and glacial drift. The country rock consists largely of medium-grained biotite paragneiss, which locally grades into biotite hornfels, and is intruded by quartz-feldspar orthogneiss with occasional clots of garnet.

A typical specimen of the orthogneiss (thin section No. 3964) consists of very abundant quartz, slightly less abundant andesine, and subordinate orthoclase, together with scattered subhedral garnets up to 5 mm. in diameter, and some small lenses composed of amphibole grains, pleochroic yellowish brown to reddish brown to bluish green, also up to 5 mm. in length. Small amounts of biotite, magnetite, hypersthene, apatite, and zircon are present, all as grains 0.1 mm. or less in diameter.

A typical specimen of the paragneiss (thin section No. 3965), on the other hand, in addition to quartz, andesine-labradorite, and some orthoclase, contains abundant irregular grains and prisms of hypersthene, flakes of strongly pleochroic biotite, and relatively abundant magnetite, all up to 1 mm. in length. These ferromagnesian minerals show a marked parallel elongation, and tend to be concentrated into bands or lenses.

The paragneiss is markedly foliated parallel to the original bedding, and intensely contorted into irregular folds of very variable amplitude. The fold axes, however, are remarkably parallel, with strikes of 225° to 255° and south-westerly pitches of 20° to 35°. Parallel to these fold axes is a marked lineation due to the presence of micro-folds and of elongated clots of various mineral constituents. The orthogneiss intrusions are generally also elongated parallel to the direction of this lineation, and their boundaries are generally concordant with the foliation. They also show some foliation and lineation themselves, although less pronounced than in the paragneiss.

A few veins of glassy quartz with a thickness of two to three inches and a length of up to 20 feet were noted, but no basic dykes.

FRAMNES MOUNTAINS.

The outcrops which are collectively referred to as the Framnes Mountains comprise Mount Henderson and the Masson, David, and Casey Ranges, all of which lie between 67° 40′ and 68° 10′ S. lat., 62° 10′ and 63° 10′ E. long., roughly ten to thirty miles south and south-west of Mawson. In each range, one or more of the higher peaks reaches a height of more than 3,000 feet above sea level, and the height above the surrounding plateau, except for the Casey Range, is of the order of 1,500 to 2,000 feet (Plate 12, fig. 2; Plate 13).

The average level of the plateau itself rises from about 1,500 feet at the northern tips of the ranges to more than 3,000 feet near Mount Hordern, which forms the southern extension of the David Range. In the northern portion of the area, the plateau consists largely of blue ice, with local snow cover mostly to windward of the major rock exposures and occasionally in their lee (Plate 14, fig. 1). Above about 2,000 feet, however, névé becomes increasingly important until, above 2,400 feet, blue ice is restricted to small areas in the immediate vicinity of rock outcrops and to isolated ice domes and ice ridges. The areas close to major rock exposures are also commonly marked by moderate to severe crevassing. Another strongly crevassed zone, about half a mile wide, occurs about half-way between Mount Henderson and the northern tip of the Masson Range, and a series of heavily crevassed ice-domes and ice-ridges occupies a belt some three miles wide along the eastern flank of the Casey Range. All of these are believed to owe their origin to irregularities in the buried bedrock topography.

The average level of the plateau on the east flank of all ranges is some 300 feet higher than that to the west. This is partly due to the piling up of major drifts by the prevailing south-easterly winds, but also to the general trend of the ranges, 20° east of north, which tends to obstruct the northward flow of ice along their eastern flanks and cause it to override the rock to some extent.

A strong moraine trending northwards from the northern tip of the Masson Range is a medial moraine, at the confluence of the ice-streams from the east and west flanks of the range (Plate 14, fig. 2). A similar feature was noted at Mount Hordern. In addition, the ice around the northern tips of all the ranges shows numerous "flow-lines", which consist of slightly raised or depressed bands in the ice, from a few inches to a few feet wide, and commonly at least several hundred yards long. These conform closely to the direction of movement and are probably due to deformation of the ice mass during its passage through the various gaps between these mountain ranges. Their probable origin and significance will be more fully discussed in a later section.

MOUNT HENDERSON.

The main mass of Mount Henderson, eight miles south-south-east of Mawson, occupies an area of $2\frac{1}{2}$ by $1\frac{1}{2}$ miles and reaches a maximum height of about 3,600 feet above sea level. A small outlier about half a mile square lies about one mile south of the main mass and is the site of Mount Henderson depot and meteorological station. The bedrock of both these outcrops consists of the same porphyritic gneissic granite that has already been described from Mawson, complete with xenoliths of sedimentary origin, shear-zones, aplite and pegmatite dykes, &c. The dominant foliation, however, trends roughly north-west and dips steeply to the north-east.

MASSON RANGE.

The Masson Range, ten to twenty-five miles due south of Mawson, consists of three separate groups of peaks and several outlying nunataks, scattered in all over an area of 15 by 5 miles. Only the most northerly of these groups, occupying an area of about four by two miles, was examined.

The northern part of this group consists of a series of metamorphosed sediments, ranging in composition from biotite-rich hornfelsic rocks, through quartz-feldspar-biotite and quartz-feldspar-garnet rocks, to only slightly impure quartzite. The original bedding is clearly preserved and shows strikes of 60° to 80° and south-easterly dips of 50° to 70°. Thin section No. 3971, belonging to this series of quartz-feldspar-garnet rocks, is composed essentially of quartz and strongly perthitic orthoclase, as interlocking grains to 2 mm. across, together with smaller, less abundant subhedral crystals of rather strongly zoned plagioclase with average composition of andesine. Pink garnet occurs as irregular grains, up to 2 mm., commonly with inclusions of quartz. Biotite and ilmenite, altering to leucoxene, are present in traces.

The sediments are intruded by garnetiferous granite gneiss, aplite, pegmatite, quartz veins, and a very distinctive series of banded quartz-feldspar-pyroxene rocks, all of which generally conform fairly closely to the banding of the surrounding sediments. Microscopically, a typical specimen of the garnetiferous gneiss (thin section No. 3967) consists of quartz as irregular grains to 2 mm., rather clouded perthitic orthoclase as rather smaller grains, and very subordinate grains of zoned, untwinned plagioclase, about 0.2 mm. in diameter. Very irregularly, garnets, up to 5 mm. in diameter, are scattered through the rock and contain minor inclusions of quartz and magnetite. There are also a few independent grains of magnetite.

Among the aplites and pegmatites, in addition to the normal quartz-feldspar-rich phases, an unusual type is represented by thin section No. 3969. This rock consists largely of interlocking quartz grains, up to 1 cm. in diameter, commonly with strongly undulose extinction. Subordinate unidentified plagioclase is now completely replaced by fine-grained sericitic aggregates, and the only other mineral is a clinopyroxene, occurring as rounded to subhedral grains, up to 1 mm. in diameter, commonly enclosed by quartz.

The banded pyroxene-bearing rocks are represented by thin section No. 3970. The dominant light-coloured mineral is andesine, occurring as subhedral grains to 5 mm., together with subordinate quartz as smaller grains, often enclosed in the feldspar. The ferromagnesian mineral is a pale green clinopyroxene, occurring as irregular grains, also up to 5 mm., and occasionally as smaller grains enclosed by feldspar. The banding is very obvious in the hand-specimen, but not in the thin section.

A few small surface stains of secondary copper minerals of the chrysocolla type were noted in this area. Some of these are associated with narrow seams of quartz, and others appear to have originated from specks of sulphides disseminated through the country rock.

About one and a half miles from the northern tip of the range, the sediments give way to a porphyritic granite, very similar to the rock from Mawson, except for the almost complete absence of xenoliths and the comparative scarcity of dyke rocks. A very faint vertical foliation is present, generally trending between 360° and 30°; but the contact of the granite with the sediments is obscured by a series of minor shear-zones (Plate 15, fig. 1).

In the south-west portion of this outcrop area, the granite encloses a lenticular complex of sedimentary rocks, red aplite, and pegmatite, with a total width of some 100 yards. Both the general outline of this lens and the banding and foliation of the rocks within it conform to the foliation of the surrounding granite. Nearby, the granite contains some quartz seams, generally only a fraction of an inch thick, some of which show traces of a mauve to purple mineral on exposed surfaces. This mineral has been identified by Dr. Norrish of the C.S.I.R.O. Clay Minerals Section as leucophosphite, a phosphate of iron, potash, and alumina.

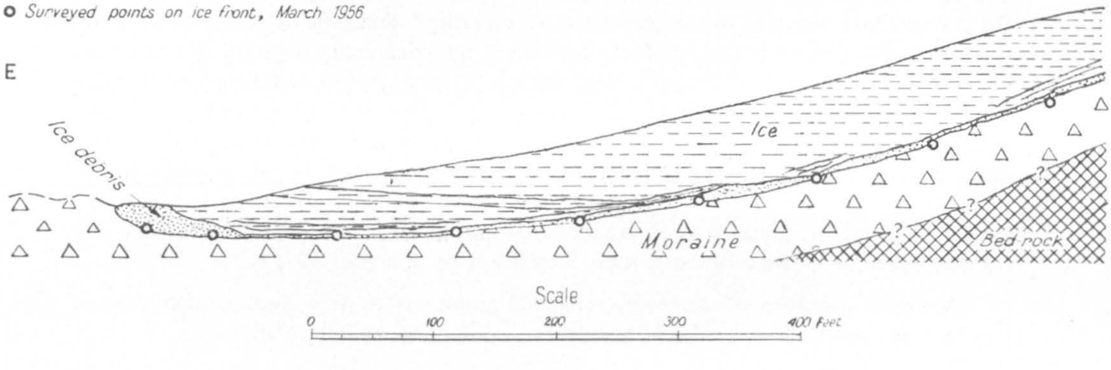
Glaciologically, the Masson Range is of interest in providing very clear evidence of the former greater extent of the ice-sheet in this area. Several erratics were found within 20 feet of the summit of one of the southern peaks of this group, 600 feet above the present level of the plateau. Just to the east of this peak, a large valley with a floor heavily covered by moraine and a pronounced U-shaped cross-section trends roughly north-south, and its floor lies some 400 feet above the present plateau surface.

Evidence of more recent recession of the ice is provided by a small valley on the extreme western flank of the range. This valley, open at both ends and about a quarter of a mile long, also trends roughly north-south and separates an isolated rock bastion from the main range. The U-shaped cross-section and heavy ground moraine and lateral moraines show that it was formerly occupied by a transection glacier flowing from south to north (Plate 16). The central portion of the valley is now occupied by a lake, some 100 yards by 150 yards in extent, which appears to fill a rock-basin due to over-deepening, as several outcrops of bedrock project from the valley floor to the north. Slight remnants of glacial polish can still be seen on one of these outcrops. The present glacier front at the south end of the valley consists of an ice cliff 40 feet high. The basal 3 feet are heavily charged with rock debris, and a number of dirt bands also occur at higher levels (Plate 15, fig. 2; text-fig. 3). To the north, the valley terminates against a projecting lobe of the ice-sheet from the west, but no cliffs are present at this end, except where the ice abuts against rock faces at the valley sides.

ICE CLIFF, MASSON RANGE

FIG. 3

South end of small valley on West Flank



The erratics from this locality were not systematically examined, but two rather striking rocks were noted. One is a pink quartz-feldspar pegmatite containing scattered crystals of slightly magnetic lead-grey ilmenite, associated with subordinate rutile. The other is the only specimen of a metamorphosed limestone so far recognized from this area (thin section No. 3974). This rock consists of about 70 per cent. calcite as interlocking grains, averaging 1 to 2 mm. in diameter, about 25 per cent. of forsterite as rounded grains, up to 2 mm., in part altering to fibrous aggregates of antigorite, and some 5 per cent. of pale blue spinel as similar rounded grains. A few flakes of white mica (phlogopite) are present in the hand specimen but not in the thin section.

DAVID RANGE.

The David Range, 5 miles west of the Masson Range, is 8 miles long and 1½ miles wide, elongated 20° east of north. To the south, Mount Hordern, Mount Tritoppen, and other outlying groups of peaks, which stretch for almost another 20 miles, extend the range. Just south of the highest point of the range (Mount Elliott, 3,800 feet approximately) a low gap is occupied by a transection glacier, about a quarter of a mile wide, flowing from east to west. Other small glaciers, all flowing west, originate at various other saddles in this range and have given rise to a series of terminal moraines at their junctions with the main ice-sheet. A lateral moraine also extends for several miles along the foot of the range (Plate 17, fig. 1).

The greater portion of the main range consists of a gneissic granite in which the foliation strikes very uniformly at 20° and dips east at 60° to 80°. Some of the more porphyritic phases look like the rock from Mawson and have a similar mineral composition (thin section No. 3966). Locally, these grade into medium-grained even-grained phases and into hybrid gneiss with strong banding. A few pegmatite veins and lenses up to 5 feet wide are also present. Elsewhere, shearing and recrystallization of the massive granite have resulted in the production of augen gneiss in which lenses with a width of up to 5 mm., composed of roughly equal amounts of quartz, orthoclase, and andesine, are separated by layers composed of smaller grains of the same minerals, together with hypersthene and minor amounts of greenish-brown amphibole, deep reddish-brown biotite, relatively abundant magnetite, and some apatite (thin section No. 3968).

On the western flank of the range, several belts of hornfels and quartz-feldspar-garnet rock (reconstituted impure arenaceous sediments) have a combined width of several hundred yards. The banding of the sediments within these belts conforms broadly to the foliation of the nearby granite. The major contacts between them and the granite, however, are mostly obscured by shearing. Some of these shears are tight structures, marked by seams of dense mylonite; others, notably a group in the saddle about half a mile south of Mount Elliott, have produced systems of minor fissures filled by secondary minerals, including a flesh-pink zeolite of the stilbite group. In this area, the sheared rocks consist essentially of chloritic and sericitic aggregates with some granules of iron oxide (?magnetite), and fragments of larger mineral grains. The zeolite veinlets reach a width of several centimetres; some of them appear to be replacements of the sheared rock, and others appear to have filled open cavities and contain euhedral crystals up to 5 mm. long (thin section No. 3972).

A single specimen of somewhat sheared granite from this locality also showed very thin encrustations of oxides of manganese, coating minor joint planes.

Beaver Glacier Tongue, Amundsen Bay.
Tula Range in background. Looking north-east.

Contorted Metasediments. Scott Mountains.
Amundsen Bay area.

Fig. 1.—Fjord at Vestfold Hills. Note concordance of summit levels and presence of dykes.

Fig. 2.—Fjord in Vestfold Hills. Note concordant levels of ridges in background.

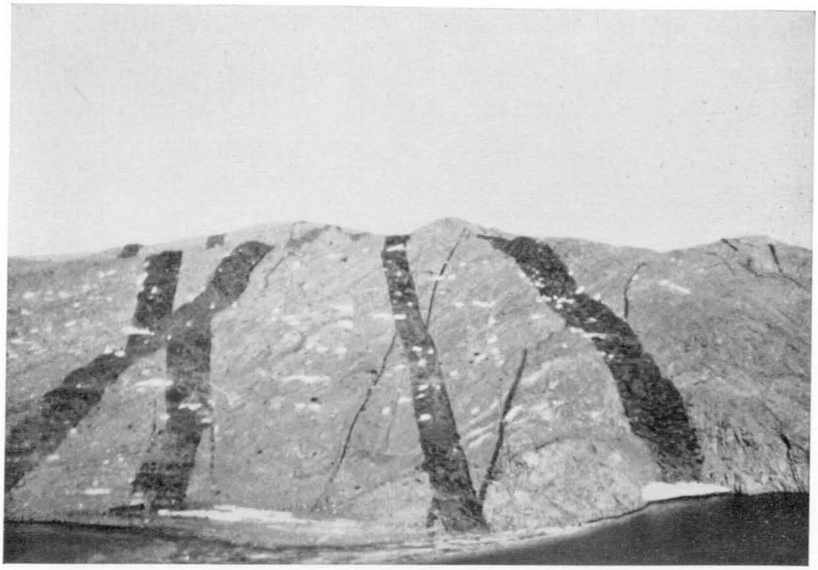


Fig. 1.—Dolerite dykes. Vestfold Hills. Thickness of individual dykes up to 50 feet.

Fig. 2.—Masson and David Ranges, looking south-west. Mount Hordern at extreme left.

Looking inland towards Masson Range (left) and David Range (centre).
Ring Rock in foreground.

Fig. 1.—Weasel on blue ice surface near Mount Henderson.

Fig. 2.—Ice streams near Masson Range. Looking north.

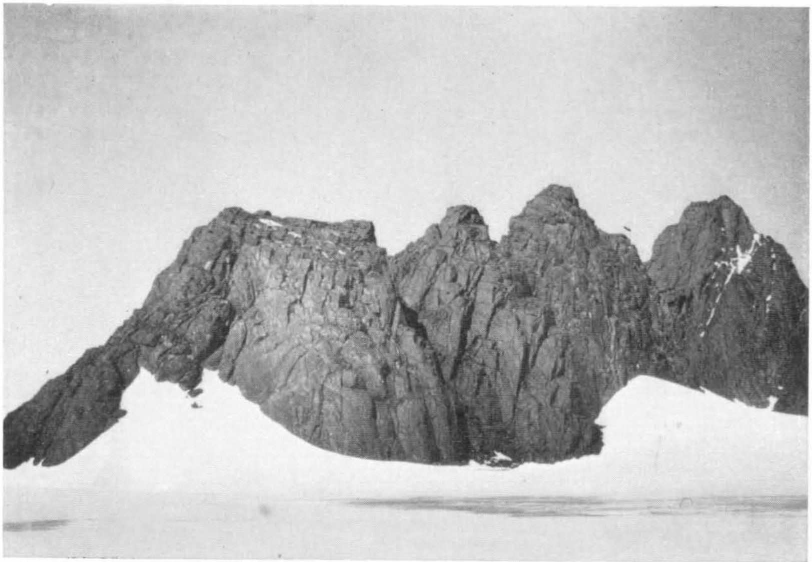


Fig. 1.—Granite cliffs, Masson Range. Height of rock faces about 800 feet. Note snow drifts at foot of cliffs.

Fig. 2.—Dirt bands in ice cliff. Masson Range.

Fig. 1.—Recently abandoned glacier valley. Masson Range.

Fig. 2.—Retreating glacier front at north end of valley shown above.

Fig. 1.—Lateral moraine on west flank of David Range.

Fig. 2.—Wind-scour on south-east flank of Casey Range.

MOUNT HORDERN.

Mount Hordern lies about 4 miles south of the end of the main range and rises nearly 5,000 feet above sea level; it consists largely of porphyritic gneissic granite, similar to the Mawson Granite.

Foliation generally strikes 340° and dips east at about 75° Extensive shearing was noted in some areas, generally conforming fairly closely to this foliation, and has given rise to augen gneiss which locally grades into almost schistose rock. In places where the trend of the shearing and of the foliation do not coincide, pseudo-tachylite veins are developed.

An included belt of metasediments, dominantly garnetiferous quartzite, was noted on the west flank of the northern peak of the mountain; its maximum width is about 50 yards. Its outline and the trend of the banding preserved within it conform closely to the foliation of the surrounding gneiss. Minor pegmatite veins, garnetiferous in part, intersect the belt at various angles.

The mountain is surrounded by blue ice to the east, north, and west, and is bordered on these sides by depressions up to 250 feet deep, due to the combined effects of wind scour and radiation from the dark rocks. On the south-east side, major snow drifts lead on to the rock. Lateral moraines are developed on each flank of the mountain and merge at its northern tip into a medial moraine which then trends 350°. At the point where the two lateral moraines merge, the deposit is 25 to 30 feet high and 60 to 80 yards wide. The surface of the moraine consists largely of hummocks, averaging three or four yards in diameter, which differ considerably in composition according to size and rock type.

The following figures are estimated averages for the deposit as a whole (by weight):—

	Per cent.
Large boulders (diameter more than 6 feet)	15
Boulders (diameter 6 inches to 6 feet)	40
Pebbles (diameter 1 inch to 6 inches)	25
Screening (diameter $\frac{1}{16}$ inch to 1 inch)	10
Sand and rock-flour (diameter less than $\frac{1}{16}$ inch)	10

The large boulders consist almost entirely of the local porphyritic gneissic granite and are angular or only very slightly rounded.

The boulder and pebble fractions are estimated to contain the following rock types (by weight):—

	Per cent.
Local porphyritic gneissic granite	70
Other granitic rocks	8
Aplite, pegmatite, &c.	8
Quartzite and garnetiferous quartzite	10
Other metasediments	3
Mylonite and other sheared rocks	1

The fragments of the local gneissic granite are angular or poorly rounded, like the large boulder fraction, but all the other rock types are more rounded, some into almost perfect ellipsoids.

In the screenings, sand, and rock-flour fractions, angular fragments again predominate. The original rock types from which these fragments were derived are not always identifiable, but it appears that the proportion derived from the local gneissic granite is higher in these size groups than in the boulder and pebble fractions.

Some of the rocks encountered in this deposit, notably among the groups listed as "other granitic rocks" and "metasediments", were not seen in situ anywhere on the accessible portions of the mountain, but occasional erratics of comparable composition were found among the scree gullies and on saddles at heights of several hundred feet above the present ice-rock contact. These boulders and pebbles, therefore, are probably derived from an earlier cycle of moraine deposition, at a time when the level of the ice stood considerably higher than it does now. Unfortunately it was not possible, in the time available, to ascertain whether a definite upper limit exists for the occurrence of these erratics.

CASEY RANGE.

The Casey Range, about ten miles west of the Masson Range, is three miles long and half a mile wide, and elongated in a direction 20° east of north. To the south, it is extended by a line of nunataks stretching intermittently for at least another six miles.

The main range is composed entirely of a complex of gneisses of mixed sedimentary and igneous origin. Fine-grained hornfelsic rocks, banded quartz-feldspar-garnet rock, and extensively recrystallized garnetiferous quartzite are the dominant sedimentary constituents. They are generally clearly banded; bands strike 20° and dip at 60° to 65° to the east. The sediments alternate with veins and lenticular bodies of garnetiferous aplite, pegmatite, and glassy quartz, the boundaries of which are generally conformable to the banding of the adjoining sediments.

A specimen from the contact of one of these pegmatites, represented by thin sections Nos. 3973 and 3973A, consists largely of elongated prismatic and tabular crystals of sillimanite, up to 1 cm. long, in part intimately associated with irregular grains of cordierite. The other minerals are subhedral squat crystals of andesine, up to 2 mm.; irregularly distributed pale brown garnet with some included biotite, up to 5 mm.; deep green spinel and magnetite, both as irregular grains, in part very delicately intergrown with each other, also to about 5 mm.; minor biotite; and some zircon.

Traces of pyrite and chalcopyrite occur in some of the smaller quartz seams, and also as disseminated crystals in some of the massive rocks. As a result, some exposed faces show comparatively extensive staining by secondary copper minerals, although very little copper is present in the bulk of the rock.

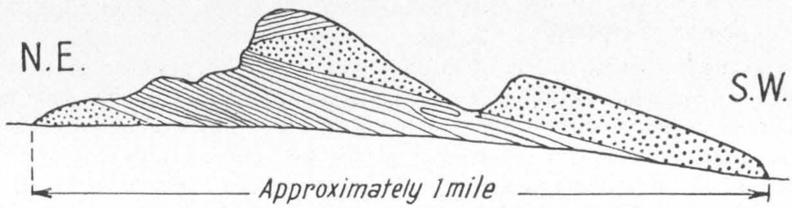
DEPOT PEAK.

To the south of the Framnes Mountains outcrops are completely lacking until Depot Peak is reached, about 120 miles south-south-east of Mawson.

This peak (6,080 feet above sea level), situated at 60° 05′ S. lat., 64° 43′ E. long., consists of a rock ridge a mile long, trending roughly south-west for the greater portion of its length and swinging to the south-east at its southern end. The western faces are largely cliffs, falling 400 feet sheer into a wind-scoured moat of blue ice, but the eastern slopes, except for that leading to the central summit, are largely covered by angular rock detritus and are accessible from major snow drifts.

The rocks are dominantly medium-grained, even-grained dark-coloured gneiss, composed of quartz, feldspar, biotite, and garnet in various proportions, and typically show slight to moderate banding and foliation. In the lower portion of the exposure, the foliation strikes north-west and dips south-west at 10° to 30°, but near the main summit, which is not readily accessible, the dip appears to be north-easterly at about the same angle, suggesting the presence of a recumbent fold (Plate 18, fig. 1). The probable core of this fold and the basal north-east portion of the whole exposure are occupied by major bodies of light-coloured gneiss, consisting of quartz, feldspar, and garnet in various proportions. This is a medium-grained to coarse-grained rock, mostly granular. Its contacts are generally sharp and conform to the foliation of the adjoining dark-coloured gneiss on a broad scale, although they may cut across it on a small scale. The marginal portions of the light-coloured gneiss frequently show banding, also broadly parallel to that of the adjoining dark gneiss, but the interior portions locally show lineation striking north-west and plunging south-east at about 20° (Plate 18, fig. 2; text-fig. 4).

FIG. 4



DEPOT PEAK

Gneiss Complex (see text)

A specimen from the marginal portion of this mass (thin section No. 3975) consists of a mosaic of quartz, perthitic orthoclase, and andesine, all as rather irregular grains, averaging about 0.5 mm. in diameter. Scattered irregularly-shaped garnets, containing a few relatively large inclusions of magnetite and biotite, reach a diameter of 5 mm. Magnetite and deep red-brown biotite also occur as independent crystals and flakes up to 0.5 mm. Sillimanite needles and prisms, also up to 0.5 mm. long, are very abundant, and there are a few irregular grains of cordierite, showing pleochroic haloes around small, unidentified inclusions.

Local off-shoots from these bodies of light-coloured gneiss form meandering veins of varying thickness (generally less than three feet), which cut through the adjoining dark gneiss at various angles. In addition, pegmatite veins, up to twelve inches wide, and composed largely of feldspar with subordinate quartz and some biotite, cut across both light and dark gneisses. Others form lenses, measuring up to five by three feet, in the dark gneiss, and many have border-zones enriched in biotite, garnet, and in places sillimanite.

The origin of this complex of light-coloured gneisses with their associated pegmatites is not entirely clear, but the field relations suggest that we may be dealing with an originally sedimentary rock, which has been reconstituted and partially mobilized so as to produce the local intrusive characteristics described above.

STINEAR NUNATAKS.

The Stinear Nunataks comprise about twelve or fifteen distinct peaks and ridges around 69° 40′ S. lat., 64° 42′ E. long., about 40 miles south of Depot Peak. Peak Seven, near the western extremity of this group, represents the most southerly point reached by the 1954 A.N.A.R.E. party under R. Dovers. It and some of the other nearby outcrops were revisited in 1955 and 1956. Peak Seven itself (6,930 feet) is readily accessible by a major snow drift from the north, but drops southwards for several hundred feet to a lower level of the plateau. The remaining members of the group, culminating in Summers Peak (7,300 feet), form a gentle arc, convex to the south, which extends eastwards for 8 miles from Peak Seven (Plate 19, fig. 1). Minor glaciers flow in a north-easterly direction from various gaps and saddles in the western portion of this arc, and have given rise to a terminal moraine, at least a mile long, which trends 330°. To the north-east of this moraine, an area of several square miles of blue ice is exposed.

Peak Seven itself consists largely of medium-grained banded granular gneisses of mixed sedimentary and igneous origin, in which the banding strikes roughly 300° and dips south-west at angles of 70° to 80°. A few seams and lenses of quartz-feldspar pegmatite are present, some with subordinate garnet, and are generally conformable to the banding of the surrounding country rock. Border-zones enriched in biotite or garnet or both, and occasionally in sillimanite, are again associated with some of these pegmatites.

About 1½ miles east of Peak Seven, a series of good exposures was examined on a somewhat lower ridge, trending north-south, with its highest point at its southern end. This ridge drops to the east in a series of cliff faces up to 300 feet high, but the western slopes, except at the extreme northern end, are largely covered by angular rock debris and are readily accessible.

In the southern portion of the ridge, the dominant rock type is a hybrid gneiss with foliation striking 320° and dipping south-west at about 80°. A typical specimen from this area (thin section No. 3976) consists essentially of irregular orthoclase grains, up to 1 cm. in diameter, crowded with inclusions of biotite, sillimanite, and occasional garnet. The garnet also occurs independently as euhedral crystals to 5 mm. in diameter. Quartz is present in traces. The biotite and sillimanite inclusions in the feldspar are aligned in parallel bands which cut across the boundaries of the host grains, which are therefore of secondary origin.

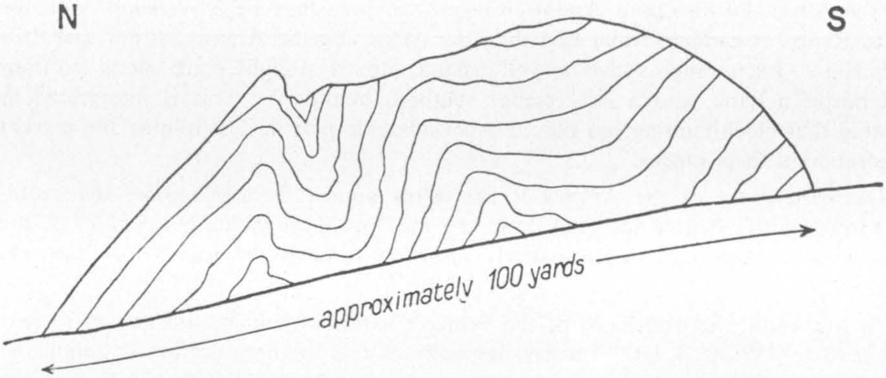
Numerous bands of quartz-feldspar-garnet pegmatite and aplite are present, mostly trending parallel to the foliation of the country rock, and a few are bordered by zones rich in biotite, garnet, and sillimanite. In thin section (No. 3977), one of these rocks was found to consist largely of rather cloudy orthoclase as irregular grains up to 5 mm., and similarly irregular garnet up to 1 cm., both with minor inclusions of quartz, biotite, sillimanite, and magnetite. Sillimanite also occurs as prisms and needles up to 1 mm. long and tends to be concentrated in narrow bands which may represent original zones of minor shearing.

Some residual bands of quartzite and siliceous hornfels are also present, generally elongated parallel to the foliation, as well as a few schlieren rich in biotite or garnet or both. In the northern portion of the ridge, these sedimentary bands predominate, and there is evidence of folding about north-west-trending axes (Text-fig. 5).

FIG. 5

RIDGE EAST OF PEAK 7

(folded metasediments)



Another isolated rock peak was visited about a mile south-east of this ridge and 3 miles north-west of Summers Peak. The dominant rock here is a medium-grained to coarse-grained garnetiferous granite gneiss with foliation striking 320° and dipping 10° either side of vertical. Seams and lenses of pegmatite and bands of quartzite and banded hornfels are again present.

ANARE NUNATAKS.

The Anare Nunataks comprise a group of small isolated outcrops at 69° 57′ S. lat., 64° 37′ E. long., about 20 miles south of Peak Seven. Two of these outcrops were visited in 1955.

The more easterly outcrop consists largely of banded gneisses of mixed sedimentary and igneous origin. The banding strikes at 330° and the dips are variable, mainly to the south-west at steep angles. Intrusive quartz-feldspar-garnet pegmatite and coarse-grained aplite are very abundant, and their contacts mostly conform to the banding of the country rock.

About 1½ miles west of this exposure, a slightly higher ridge trends approximately north-south, with 400-foot cliffs facing west, but accessible slopes to the east. It consists largely of medium-grained, even-grained granitic gneiss, composed of quartz, pink feldspar, and biotite. A faint foliation, due to the parallel elongation of streaks rich in biotite, strikes at about 300° and dips steeply to the south-west. This gneiss is intruded by numerous quartz-feldspar-garnet pegmatite dykes and coarsely granular aplite dykes, the largest of which are 100 feet wide. The dykes generally strike parallel to the banding of the country rock.

Still farther west, the general level of the plateau continues to rise, and the presence of several major ice domes indicates the existence of rock ridges close to the surface even in areas where no actual exposures occur.

NORTHERN PORTION OF PRINCE CHARLES MOUNTAINS.

The northern portions of the Prince Charles Mountains, situated roughly between 70° and 71° 30′ S. lat., and 64° and 68° 15′ E. long., consist of three fairly well defined ranges with general east-west trends. From north to south these are referred to as the Athos, Porthos, and Aramis Ranges. In plan they lie *en échelon,* with the Porthos Range extending farther east than the Athos and the Aramis farther east than the Porthos. Each range shows a well-defined, almost straight scarp along portions of its northern flank, and a less regular southern boundary. This is interpreted as indicating that block-faulting has played a considerable part in determining the present configuration of these ranges.

The eastern tip of the Aramis Range abuts almost directly against the south-west corner of the Amery Ice Shelf, and the ice flow throughout this portion of the ranges is in a general east-north-easterly direction towards the ice shelf (Plate 19, fig. 2).

To the south, the extensions of the Prince Charles Mountains are known to persist at least to 73° 30′ S. lat. The physiography of this southern portion is dominated by the Lambert Glacier, which flows from the vicinity of 74° 30′ S. lat., 67° E. long., in a roughly northerly direction, and enters the Amery Ice Shelf just east of the eastern tip of the Aramis Range. Major groups of peaks crop out on both flanks of this glacier, as described in a previous section, but their full extent and exact distribution are not yet known, as the only information so far available on this area is derived from reconnaissance aircraft flights and trimetrogon photographs.

In the northern portion of the ranges, the heights of both the plateau and the peaks generally increase to the south and west. Several peaks in the western portion of the Aramis Range are estimated at 8,500 feet above sea level, but to the west of this area the plateau continues to rise to heights above 9,000 feet and obliterates all rock outcrops. South of 71° S. lat., the height decreases slightly because drainage from this area into the headwaters of the Lambert Glacier is at fairly low elevations.

At the south-west corner of the Amery Ice Shelf, in the vicinity of 70° 30′ S. lat., 69° E. long., ice heights down to 200 feet above sea level have been recorded. Gradients up the Lambert Glacier are very gentle, and the height in the vicinity of 73° 45′ S. lat., 68° E. long., the farthest point so far reached on reconnaissance flights, is only about 3,500 feet above sea level.

Many outcrops in the Prince Charles Mountains have flat-topped summits, whose area ranges from a few acres to some 50 square miles, and which may be occupied in part by moraine deposits, permanent snowdrifts, or lakes. In many of the larger ones, e.g., the plateau to the south of Mount Loewe, the highest peaks of the area may rise for several hundred feet above the general level of the plateau. Their heights range from about 3,500 feet above sea level in the Mount Loewe area to about 8,500 feet at Mount Bewsher. Since they truncate all geological structures, these plateaux must be assumed to be the remnants of an old erosion surface, and their presence at various elevations further supports the suggestion of block faulting in this area.

Most of the area between the outcrops consists of névé, generally covered by sastrugi from a few inches to a foot high. The sastrugi lie parallel to the prevailing wind (between 190° and 210°). Blue ice is exposed near most of the larger rock outcrops and in many areas where the movement of the ice appears to be impeded by buried rock ridges, giving rise to isolated ice domes and ice ridges, generally with fairly severe crevassing.

In the descent towards the Amery Ice Shelf along the Nemesis Glacier, blue ice was first encountered at about 3,500 feet above sea level, which is more than 1,000 feet higher than in the Mawson area. Below 2,000 feet, many indications of very severe ablation were noted. These include melt-water pools and channels, needle ice, and the disintegration of the surface layer of the ice into granules with an average diameter of a quarter of an inch in the higher portions of this glacier, rising to half an inch in the lower portions.

Local drifts are associated with many of the larger rock exposures; some are largest on the windward and some on the leeward side. Wind scours 200 feet deep are not uncommon between these drifts and the rock faces, and many of them are surmounted by large cornices.

The ice streams between and around the three northern ranges of the Prince Charles Mountains show extensive and very severe crevassing. The most strongly affected areas appear to be those within 2 or 3 miles of the northern flanks of each range and all areas where the gradient is locally steepened in the direction of flow. Some quite extensive crevassed belts, however, do not appear to be related to any visible topographic features. Generally speaking, the disturbances in névé result in the development of sets of nearly straight crevasses, many very long and all long relative to their width; lengths of several hundred yards and widths of 20 to 30 feet are not unusual. Crevassing in blue ice more commonly results in a network of smaller cracks and very irregular holes, which may occupy as much as 30 to 40 per cent. of the surface of the whole disturbed zone.

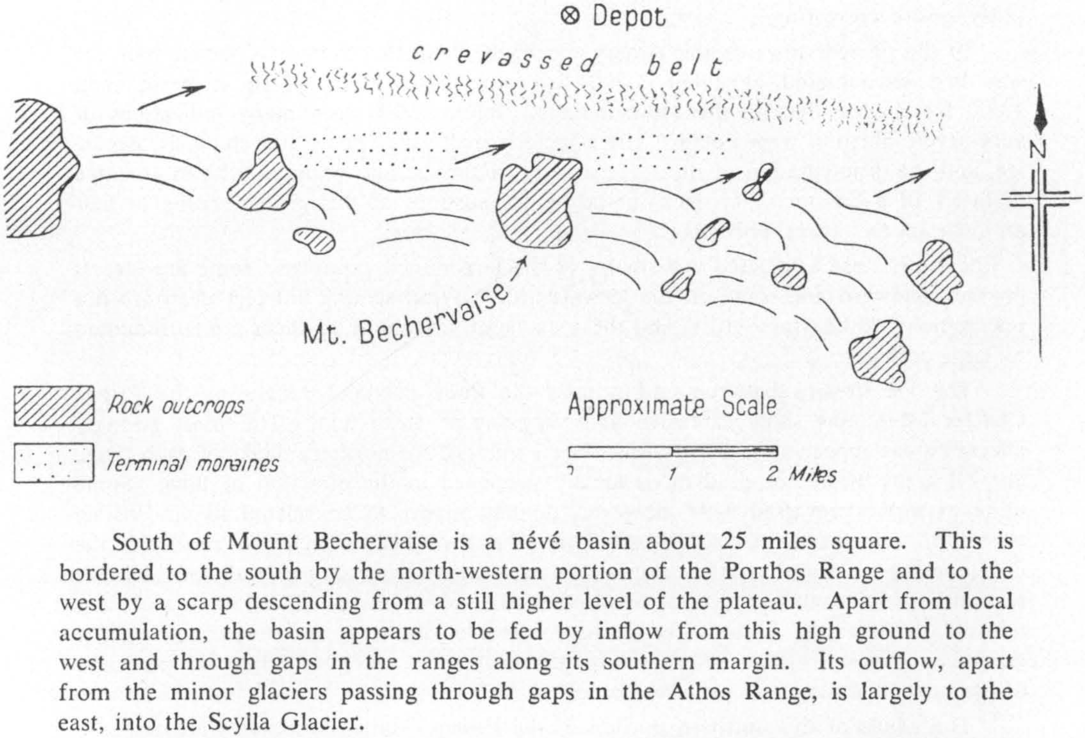
The whole of this northern portion of the Prince Charles Mountains is composed of basement rocks: granitic gneiss, hybrid gneisses, and highly metamorphosed sediments, all intersected by fairly numerous pegmatite and quartz veins and by a few basic dykes. Reconnaissance flights suggest that these rocks also persist in the western part of the southern extension of the ranges, e.g., in the vicinity of 73° S. lat., 63° to 65° E. long.

Western Portion of Athos Range.

The dominant peak in the western portion of the Athos Range is Mount Bechervaise (7,000 feet approximately), situated at 70° 12′ S. lat., 64° 45′ E. long. It was first visited in 1955, and the 200-mile Depot was established about 2½ miles to the north (Plate 20; text-fig. 6). For about 10 miles on either side of this mountain, the Athos Range consists of very closely spaced peaks. The general level of the plateau south of the range is about 300 feet higher than that to the north, and minor glaciers flow in a general north-easterly direction through the various gaps in the range. Within half a mile from the northern rock faces of the range, these glaciers terminate in moraines which trend approximately east-west and are succeeded to the north by a strongly crevassed belt of blue ice up to 2 miles wide.

FIG. 6

SKETCH OF MT. BECHERVAISE AREA



South of Mount Bechervaise is a névé basin about 25 miles square. This is bordered to the south by the north-western portion of the Porthos Range and to the west by a scarp descending from a still higher level of the plateau. Apart from local accumulation, the basin appears to be fed by inflow from this high ground to the west and through gaps in the ranges along its southern margin. Its outflow, apart from the minor glaciers passing through gaps in the Athos Range, is largely to the east, into the Scylla Glacier.

The rocks of Mount Bechervaise and the immediately adjoining exposures (within a radius of 3 or 4 miles of the 200-mile Depot) are largely banded gneisses of mixed sedimentary and igneous origin, many of which contain garnet, sillimanite, and some scattered flakes of graphite up to 1 mm. in diameter (thin section No. 3989). The banding generally strikes east-west and dips south at an average angle of 60°, except in the north-west portion of Mount Bechervaise itself, where a major syncline is exposed.

Younger intrusions of quartz-feldspar pegmatite and coarse-grained aplite are represented by veins and lenses, sometimes transgressing the banding of the gneiss. In the south-east portion of a small unnamed peak about 1½ miles east of Mount Bechervaise is a group of about six basic dykes, averaging 2 feet in width, which strike north-east and are approximately vertical; but their outcrops were not accessible at the time of the examination.

A system of major joints, striking approximately north-south and dipping west at 85°, has been responsible for a number of spectacular cliff faces, and there are occasional minor shear zones, some of which, at least, are parallel to the banding of the adjacent country rock, and which generally show extensive staining of the shear planes by hydrated iron oxides.

EASTERN PORTION OF ATHOS RANGE.

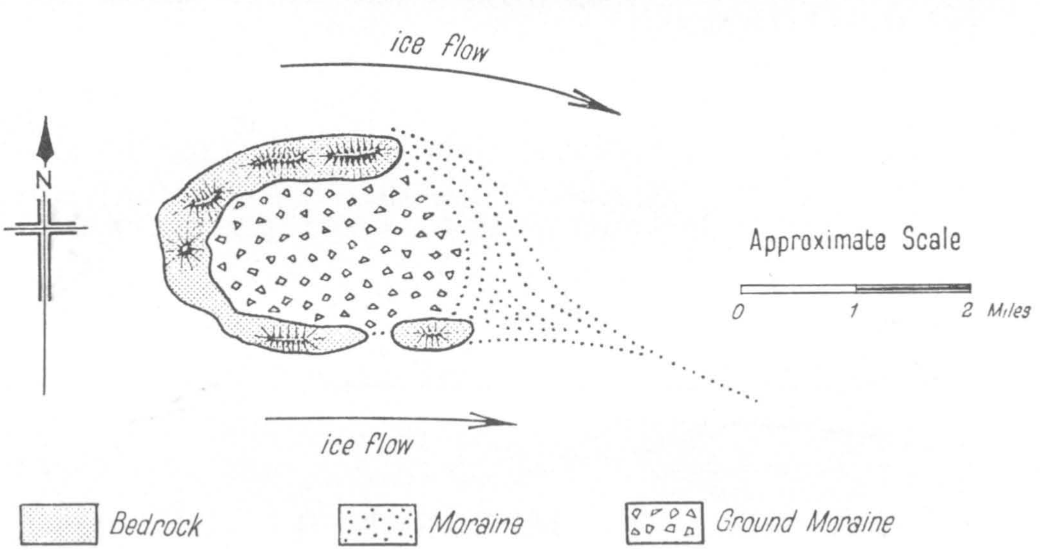
The absolute height of the main peaks gradually decreases towards the eastern end of the Athos Range, although their height above the surrounding plateau is still of the order of 1,000 feet. The range also broadens somewhat in the north-south direction and the general slope of the plateau is reversed, being higher to the north of the range than to the south.

Only one outcrop in this area was visited: Mount Jacklyn (about 35 miles east of Mount Bechervaise), which rises roughly 1,000 feet above the surrounding plateau and forms part of a horseshoe-shaped ridge, believed to be the rim of an abandoned cirque. The floor of this cirque is heavily covered by morainic material, which passes into a series of lateral moraines on the east flank of the peak and thence into a medial moraine tailing off in a general easterly direction. The 250-mile Depot is situated near this moraine, about 2½ miles east of the peak (Plate 21, fig. 1; text-fig. 7).

The dominant rock of Mount Jacklyn is a granitic gneiss with roughly horizontal foliation. This is intersected by minor pegmatites and shows traces of silicification on occasional joint planes. A few inclusions of hornfels and quartzite are also present, generally concordant with the foliation.

FIG. 7

SKETCH OF MT. JACKLYN



WESTERN PORTION OF PORTHOS RANGE.

The western portion of the Porthos Range contains some very prominent outcrops, generally with flat-topped summits, several of which rise more than 2,000 feet above the surrounding plateau. Mount Kirkby, about 25 miles south-south-east of Mount Bechervaise, is the only one of this group which was examined in detail.

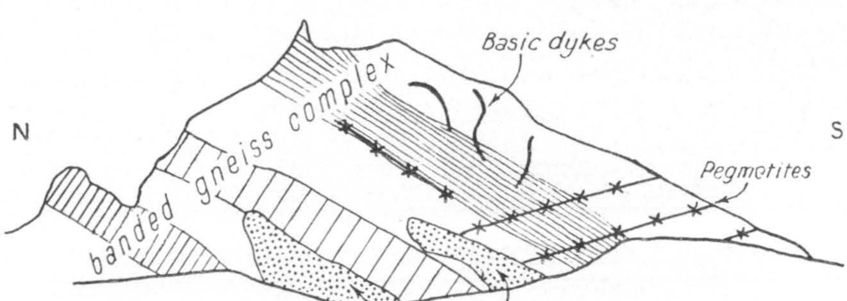
It again is composed largely of banded gneisses, including both granitic and sedimentary types, the latter corresponding roughly to arenaceous hornfels in composition. The banding generally strikes between 80° and 100° and dips 20° either side of vertical (Plate 22, fig. 1). The gneisses are intruded by pegmatites and quartz reefs, which are mostly less than 3 feet wide, but may reach 10 feet. Most of these conform to the banding of the surrounding gneiss, but a rather prominent set occupies joint planes which strike 60° and dip 80° south-east.

At the extreme north-west tip of the mountain, a gap in an east-trending ridge has clearly been recently occupied by a minor transection glacier flowing from south to north. The snout of this glacier now lies about 25 yards south of this gap, and the intervening area is occupied by deposits of morainic material.

CENTRAL PORTION OF PORTHOS RANGE.

The central portion of the Porthos Range contains a large number of somewhat smaller peaks, rising on the average not more than 1,000 feet above the surrounding plateau and culminating in points or saw-tooth ridges rather than in plateaux. Mount Gardner, about 15 miles east of Mount Kirkby, is typical of this group. It is composed of banded gneiss, largely of igneous origin. On the north-east ridge of the peak, the banding strikes 70° to 80° and dips 70° north to vertical, but in the south-western portion the strike averages 45° and the dip 65° south-east. Pegmatite veins up to 10 feet wide occupy flat-dipping joints, and others conform to the banding of the gneisses. Basic dykes, also up to about 10 feet in width, follow meandering courses which cut across the banding of the gneiss. They were seen only from a distance, being restricted to the upper portion of some major cliff faces and not readily accessible (Text-fig. 8).

FIG. 8



MT GARDNER
(LOOKING EAST)

Microscopically, a typical specimen of the gneiss (thin section No. 3979) contains quartz, perthitic orthoclase, and oligoclase, all as irregular grains up to 2 mm., together with roughly equal amounts of hypersthene and a pale green clinopyroxene, slightly less abundant greenish-brown amphibole, subordinate biotite, relatively abundant magnetite, and accessory apatite. The banding is only faintly apparent in thin section.

In the dark-coloured bands (thin section No. 3981), orthoclase is absent, quartz is present only as subordinate interstitial grains, and the proportion of ferromagnesian minerals, notably the amphibole, is greatly increased.

About 2 miles south-east of this peak, a minor east-flowing glacier has given rise to a very fine series of arcuate terminal moraines more than a mile long and about half a mile in total width.

Eastern Portion of Porthos Range.

Towards the eastern end of the Porthos Range, the level of the surrounding plateau drops fairly rapidly and shows very severe crevassing both north and south of the range. The area is accessible, however, by a route fairly high up on the southern flank of the range.

Mount McCarthy, about 15 miles east of Mount Gardner, is the dominant feature of this area, and lies about a mile from the tip of the range. The dominant rock is again a gneiss of igneous origin with minor aplitic and pegmatite phases and occasional hornfels inclusions. Both banding and foliation are present, parallel to each other, striking 80° to 90° and dipping 70° north to vertical. Some extensive zones of low-grade shearing lie roughly parallel to the foliation. A few pegmatite and quartz veins are present, generally less than 9 inches wide; they cut across the foliation at various angles.

Western Portion of Aramis Range.

The general trend of the western portion of the Aramis Range is south-west to north-east, but it is less well defined than either of the two ranges described above. It consists of isolated peaks, some of them of considerable size, spaced at intervals of about five miles over a total area of some 15 by 25 miles. In this area the plateau rises to its highest elevation within the northern portion of the Prince Charles Mountains.

Mount Bewsher was the only member of this group visited. It is a prominent flat-topped peak, situated at 70° 55′ S. lat., 65° 45′ E. long. It rises to a height of about 1,000 feet above the surrounding plateau or about 8,500 feet above sea level, and is notable for the very large and complicated system of wind-scours on its flanks. It is composed essentially of highly metamorphosed sedimentary rocks, including hornfels, quartzite, garnetiferous quartzite, &c. The original bedding is still clearly discernible, striking 90° and dipping within 20° either side of vertical.

These rocks are intersected by numerous pegmatite veins composed dominantly of quartz and feldspar, commonly graphically intergrown. Subordinate garnet and biotite are present in places. Of the two main sets of veins, one is roughly concordant to the bedding, and the other strikes approximately 315° and dips north-east at about 15°. The widths of the veins are generally of the order of two or three feet, with a few up to 20 feet.

Thin section No. 3984, belonging to one of these vein rocks, consists largely of perthitic flesh-pink microcline, much of it more than 1 cm. long, and mosaics of interlocking quartz grains. A few small grains of plagioclase (?andesine), almost completely replaced by micaceous aggregates, occur as inclusions in the microcline.

CENTRAL PORTION OF ARAMIS RANGE.

In the central portion of the Aramis Range, the peaks are closer together, but the width of the range is still ten to fifteen miles. Mount Hollingshead, situated about twenty miles south of Mount Gardner, is typical of this group (Plate 21, fig. 2; plate 22, fig. 2).

The greater part of Mount Hollingshead is composed of granitic gneiss with minor aplitic and pegmatitic phases (Plate 23, fig. 1). The foliation is not always apparent in the hand-specimen, but several included bands of hornfels and garnetiferous quartz-feldspar rock trend approximately 315° to 330° and dip 60° to 75° north-east. Several zones rich in pegmatite and reef-quartz stringers also trend parallel to this direction, although the individual veins commonly cut across it. Shearing is widespread and many of the zones also conform to this trend. Many joint planes and minor faults are silicified.

An unusual specimen from this area consists of a rock composed essentially of irregular grains of neutral-coloured clinopyroxene and oligoclase-andesine, both up to 5 mm. in diameter and commonly intimately intergrown. Scattered subrounded to subhedral grains of green spinel, up to 1 mm., form inclusions in the feldspar but not in the pyroxene (thin section No. 3982). This rock is believed to represent an inclusion of a calc-silicate rock in the surrounding gneiss.

In the eastern portion of Mount Hollingshead, hornfels, quartzite, and garnetiferous quartzite are the dominant rocks. They show a wide range of dips and strikes, due to intense crumpling about fold axes with very variable treads and often very steep pitches. The whole complex is again intersected by numerous quartz and pegmatite veins, many of them garnetiferous. Most of these roughly conform to the banding of the metasediments, but others cut across them at various angles. Many of them also show puckering (? ptygmatic folding) on a scale depending on the width of the vein (Plate 23, fig. 2). Thin section No. 3980, representing one of these veins, shows subhedral to subrounded garnets, up to 2 mm. in diameter, in a mosaic of interlocking quartz grains of very variable size.

EASTERN PORTION OF ARAMIS RANGE.

From the vicinity of Mount Hollingshead, the Aramis Range trends in a general east-north-easterly direction, and the area of some 15 by 25 miles near its eastern extremity contains one of the largest concentrations of major rock outcrops of the whole Prince Charles Mountains.

The area is characterized by the presence of large flat-topped massifs, and is bounded to the north and east by abrupt linear scarps, believed to be due to faulting. The Mount Loewe Fault, running east and west, forms the northern limit of the range for a distance of at least 12 miles in the vicinity of Mount Loewe and Mount Cooper. South of this fault, the Mount Loewe massif and its counterparts to the west rise to about 3,200 feet above sea level. North of the fault, no outcrops are known and the level of the snow and ice surface is only about 1,200 feet above sea level. Moreover, the ice is not crevassed and is therefore probably very thick, so that the rock floor may lie at sea level or even lower (Plate 24, fig. 1).

The range is terminated to the east by the Amery Fault, which runs very nearly north and south and can be traced for at least 25 miles. The 3,200-foot-high plateau of basement rocks to the west of the fault is brought into juxtaposition with flat-lying Upper Palaeozoic sediments cropping out at elevations of less than 1,200 feet above sea level. The sediments are probably at least 1,000 feet thick, and the total throw of the fault can hardly be less than 3,000 feet (Plate 24, fig. 2).

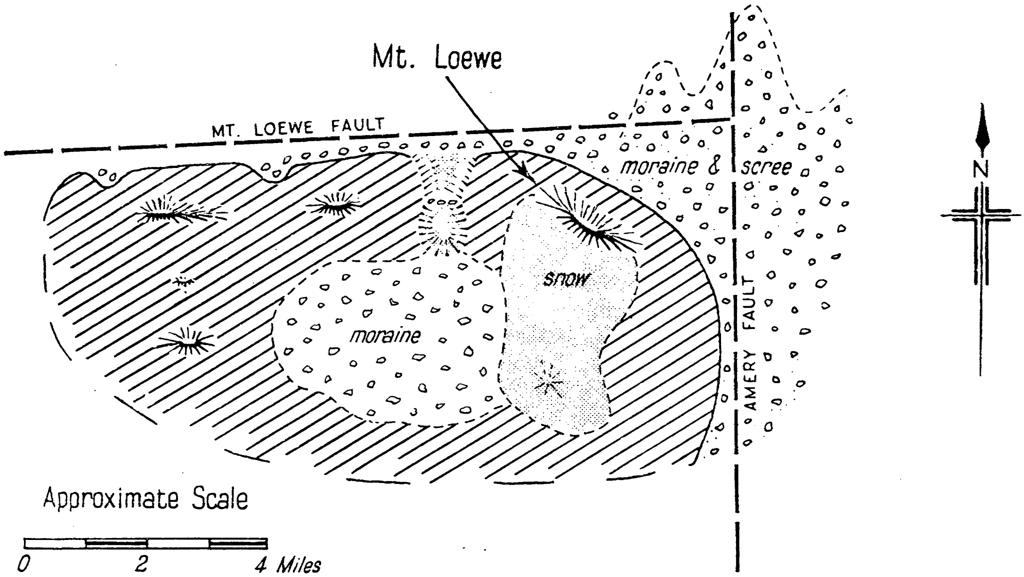
In the southern part of the area, a group of small peaks (surrounding Baseline Nunatak) near 70° 40′ S. lat., 67° 30′ E. long, rises to heights of 300 to 400 feet above the level of the surrounding plateau. They are composed dominantly of granitic gneiss and banded gneiss with vertical foliation striking approximately 90°. Quartz, perthitic orthoclase, minor unidentified plagioclase, cordierite, accessory biotite, magnetite, and zircon are the constituent minerals (thin section No. 3978). Subordinate included bands of hornfels, quartzite, and garnetiferous quartzite are generally conformable to the foliation of the gneiss. Minor aplitic and pegmatitic phases locally intrude the banded gneiss. The elongation of the ridges in a general north-south direction, on the other hand, appears to be controlled by a set of major joints at right angles to the foliation.

About ten miles north of this locality, the head of the Nemesis Glacier lies at an elevation of about 5,200 feet. This glacier, some 15 miles long and 5 miles in average width, flows east-north-east through a gap in the Aramis Range towards the low-lying area north of the Mount Loewe Fault. The outcrops on the north flank of its upper and middle portions are banded, with an average strike of 70° and moderate to steep northerly dips. They were not examined in detail, but appear to be largely composed of metasediments similar to those described from Mount Hollingshead. The large outcrops on the southern flank of this glacier and the small nunatak cropping out in the middle of the stream, on the other hand, are composed of a homogeneous strongly jointed rock, believed to be an extension of the granite of Mount Loewe, to be described below.

Mount Loewe is the most easterly peak of the Aramis Range, about 30 miles east-north-east of Mount Hollingshead. The summit consists of a knoll rising several hundred feet above an undulating plateau which covers an area of six by eight miles to the south and west of the peak. This plateau lies at an average elevation of about 3,200 feet above sea level, about 2,000 feet above the ice on its northern flank. To the north and east, the plateau is bounded by abrupt linear scarps, as already described (Plate 25; text-fig. 9).

FIG. 9

SKETCH OF MT. LOEWE



The northern part of the massif, including the summit of Mount Loewe itself, is composed essentially of a porphyritic gneissic granite not unlike that of Mawson. The foliation is indicated in the hand specimen by the parallel alignment of the tabular feldspar phenocrysts and generally trends about 300°, with steep dips either side of vertical. Occasional aplite and pegmatite veins, generally only a few inches wide, cut across the foliation at various angles. These also include a number of epidote-bearing rocks, such as thin section No. 3985. This consists of quartz and strongly sericitized orthoclase, both as irregular grains to about 5 mm., together with slightly smaller subhedral unidentified plagioclase. The epidote, occurring as small granules, forms veinlets and irregular aggregates within the quartz areas, apparently localized in minor shear-zones. In the hand specimen, the orthoclase of this rock is a bright red.

A few boulders of hornfels occur in the scree, but no outcrops were seen in situ. About a quarter of a mile west of the summit, a basic dyke with traces of epidote on joint planes trends roughly north and south. It has an average width of about 3 feet and can be traced for several hundred yards. Under the microscope, it can be seen to consist of abundant granules and small prisms of pyroxene, generally less than 0.2 mm. long, together with an interstitial mineral of lower refractive index and birefringence, probably a feldspar or feldspathoid. Numerous chloritic aggregates, up to 0.5 mm. across, probably represent the alteration product of original olivine phenocrysts (thin section No. 3986).

The central portion of the plateau, south-west of the summit of Mount Loewe, is extensively covered by moraine deposits, which include quartzite and other rocks not seen in situ in the immediate vicinity. This morainic material is locally very rich in clay or rock-flour and also contains a few well-rounded pebbles; so some of this material may have been derived originally from pebble beds in the Amery Formation (see below).

The valley which was used to gain access to the plateau from its northern flank consists of two steps, each occupied by a permanent drift, and separated by a small terminal moraine belonging to the upper drift. The upper drift occupies an almost perfectly horseshoe-shaped valley, which appears to be a cirque dating from a period of more vigorous ice activity.

AMERY LOCALITY AND RELATED OCCURRENCES.

The Amery Locality lies in the vicinity of 70° 30′ S. lat., 68° 15′ E. long.; the flat-lying sediments of the Amery Formation were first noted there. The Locality is part of a large horseshoe-shaped outcrop area, open to the north. Each lobe of the horseshoe has an estimated average width of some 6 to 8 miles; the length of the western lobe is estimated at 20 miles, that of the eastern one at 25 miles. The average elevation above sea level is of the order of 1,200 feet. Most of the western lobe and some parts of the eastern one are overlain by a deposit of morainic material including granitic, aplitic, and pegmatitic rocks, quartzite, garnetiferous quartzite, hornfels, and schistose rocks.

On the eastern flank of the western lobe, flat-lying arkosic sandstone and grit, locally strongly cross-bedded, crop out in a belt with an average width of quarter to half a mile and a length of some 3 to 4 miles. The series also includes a number of pebbly horizons containing well-rounded pebbles and boulders, dominantly of fine-grained compact quartzite. There are also two or possibly three narrow seams of coal and carbonaceous shale, each with a maximum thickness of about 8 inches (Plate 26). The general assemblage is strongly reminiscent of the Beacon Sandstone as described from other parts of the Continent. The exposed thickness at this locality is about 150 feet, but the beds probably underlie most of the area covered by the previously described moraine deposits and extend at least to the level of the ice occupying the low-lying interior of the horseshoe, giving a total thickness of the order of 1,000 feet. Aerial reconnaissance also indicates that the thicknesses exposed in more southerly localities, e.g., in the vicinity of 73° 15′ S. lat., 67° 15′ E. long., are of the order of 1,000 feet.

The horseshoe-shaped area abuts against the Prince Charles Mountains at an abrupt linear scarp, the Amery Fault. The interior of the horseshoe is filled by very rough ice, probably the weathered remnant of a glacier that formerly occupied the whole of the area. Near the ice-rock contact, however, a zone up to 1 mile wide, at a lower level than the central portion, is occupied by smooth ice, which appears to be re-frozen melt-water, occupying an area exposed by the recession of the original ice edge. (This has since been named "Beaver Lake.") Several true lakes lie within the moraine-covered area itself, the largest being of the order of 3 miles by 1 mile (Plates 27, 28, 29, 30).

Petrologically, a typical sandstone specimen (thin section No. 3987) consists of angular quartz grains and slightly more rounded feldspar, dominantly plagioclase, all with fairly uniform grain-size of about 0.5 mm. Subordinate white mica, rare garnet and spinel, and some limonite, replacing original ?magnetite, are also present. The matrix is composed entirely of interlocking grains of calcite with a grain size ranging up to 0.5 mm.

A typical specimen of grit (thin section No. 3988) again contains angular quartz and slightly rounded feldspar grains; the feldspar includes relatively fresh microcline, cloudy orthoclase, and subordinate unidentified plagioclase. Grain-size is more variable than in the sandstone and averages about 1 mm. Minor amounts of white mica, calcite, and limonite (?originally magnetite) are present. The matrix is less abundant than in the sandstone and consists almost entirely of sericitic aggregates.

Specimens of coal from this locality were submitted to the C.S.I.R.O. Coal Research Section for examination, and the following extracts are quoted from this report:

" The samples are of carbonaceous shale and coal, the rank of which was thought to be near the dividing line between brown and black coals. The coal present was chiefly clarite or intermediates tending towards clarite in composition. Spore exines were relatively abundant throughout. Vitrite bands wider than 100 microns were rare; some wider lenticles of fusinite and semi-fusinite occurred.

While most of the samples included some shaly material and some claritic intermediates, the proportions of these vary considerably. Quartz is quite common in the more mineral-rich bands.

The maceral contents of each of thirteen samples was estimated, giving the following results:—

	Per cent.	Per cent.
Vitrinite	5–50	Average 30
Exinite	5–20	Average 15
Inertinite	20–40	Average 30
Minerals	10–60	Average 25

Portion of one sample was macerated and found to contain considerable numbers of recognizable pollens and a small proportion of microspores. The following types were identified:—

	Per cent.
Florinites ovatus	16
Lueckisporites amplus	15
L. limpidus	13
Monocolpate pollen sp.	11
cf. *Florinites* sp.	10
Lueckisporites sp. A	8
L. sp.	4
Granulatisporites sp.	4
Lueckisporites fusus	3
Pityosporites sp.	2
Granulatisporites cf. *trisinus*	2
Apiculatisporites cf. *filiformis*	2
Lueckisporites cancellatus	1
Apiculatisporites cf. *levis*	1

Based on experience obtained with samples from Western Australia and New South Wales, the above is sufficient evidence to place these strata in the Permian System, but there is insufficient evidence to justify a definite allocation to any Stage. Although Lower Permian spore types were not found, the lack of many non-saccate Upper Permian species to corroborate the indication of Upper Permian given by the dominance of *Lueckisporites* leaves the placing of this sample in the Upper Permian

Fig. 1.—Depot Peak. Looking east. Maximum height of cliffs is about 400 feet.

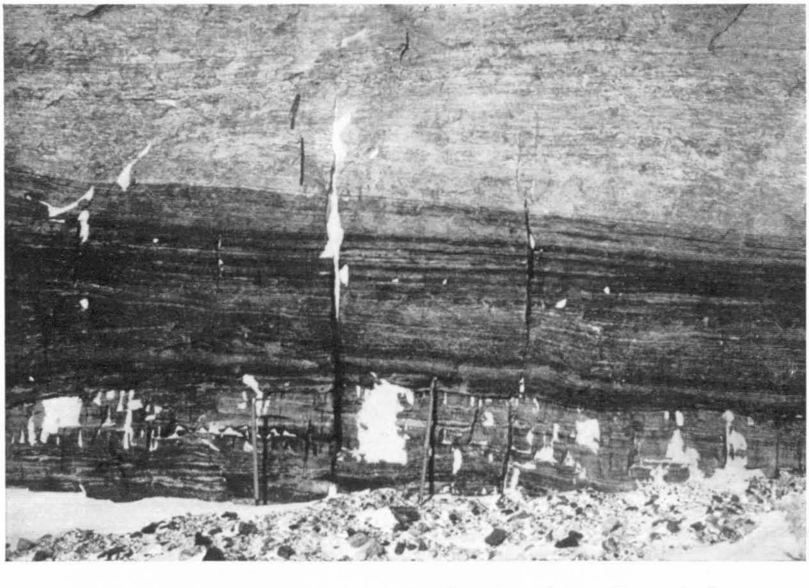


Fig. 2.—Contact of light- and dark-coloured gneisses. Depot Peak.

Fig. 1.—Stinear Nunataks. Looking south-east. Mount Macey in background.

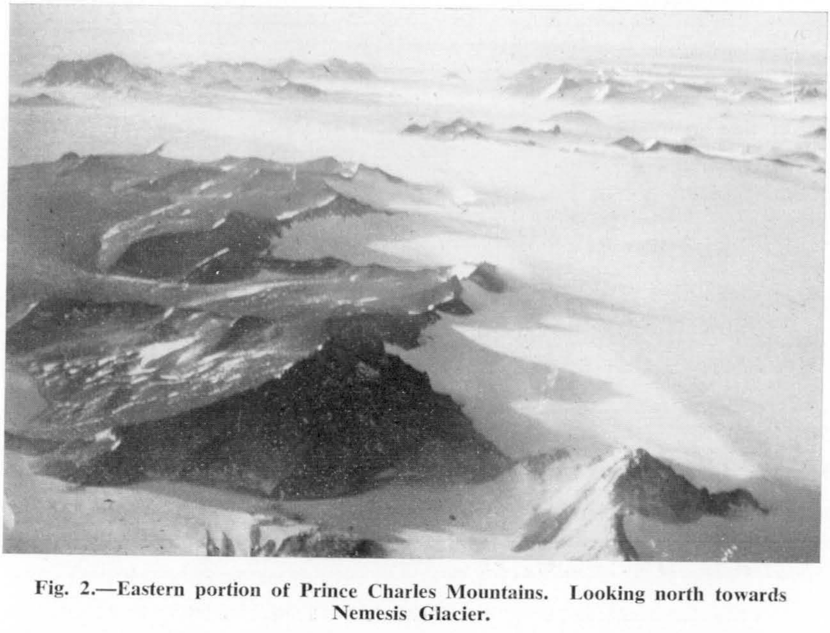


Fig. 2.—Eastern portion of Prince Charles Mountains. Looking north towards Nemesis Glacier.

Fig. 1.—Mount Bechervaise. Looking east.

Fig. 2.—Western portion of Prince Charles Ranges. Mount Bechervaise at extreme right. Looking south-east. Note terminal moraine of minor glacier.

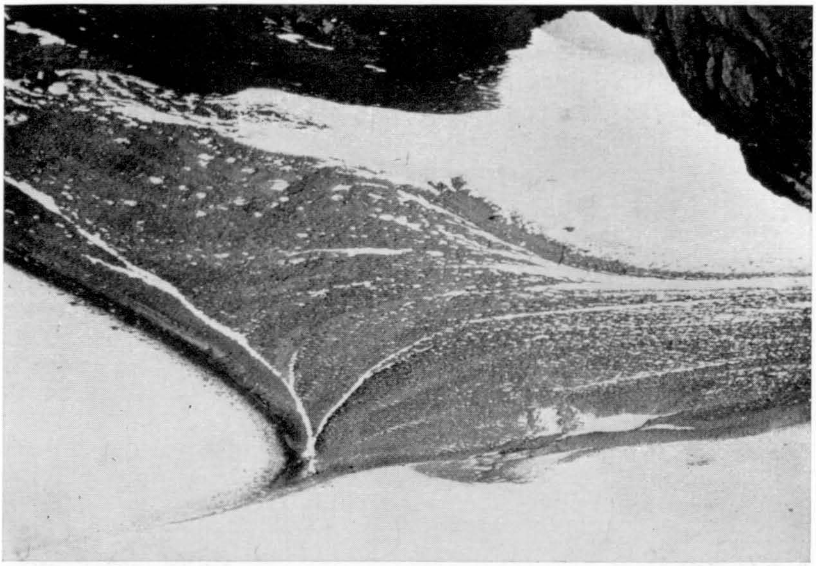


Fig. 1.—Terminal and lateral moraines, merging into medial moraine. Looking east from Mount Jacklyn.

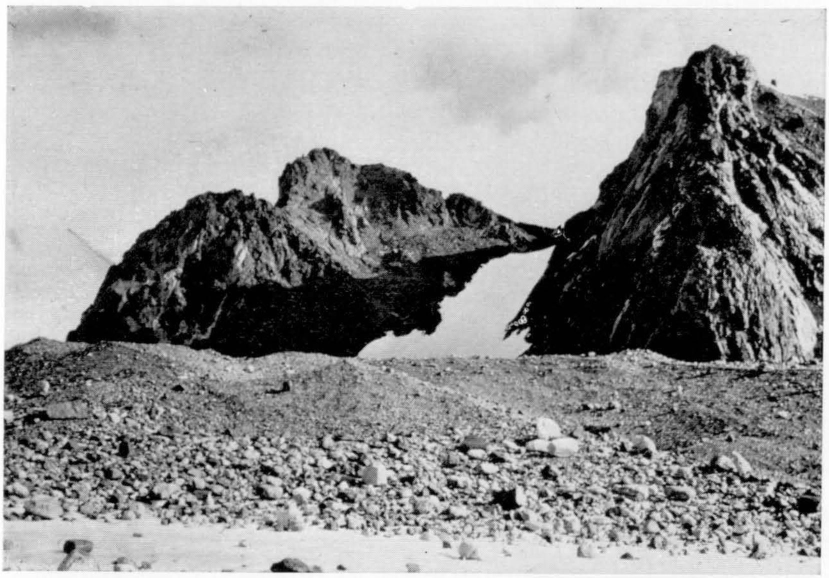


Fig. 2.—Lateral moraine. Mount Hollingshead.

Fig. 1.—Metasediments, vertical. Mount Kirkby.

Fig. 2.—Wind-scoured moat. Mount Hollingshead.

Fig. 1.—Granitic gnesis. Mount Hollingshead. Surveyors at work on summit.

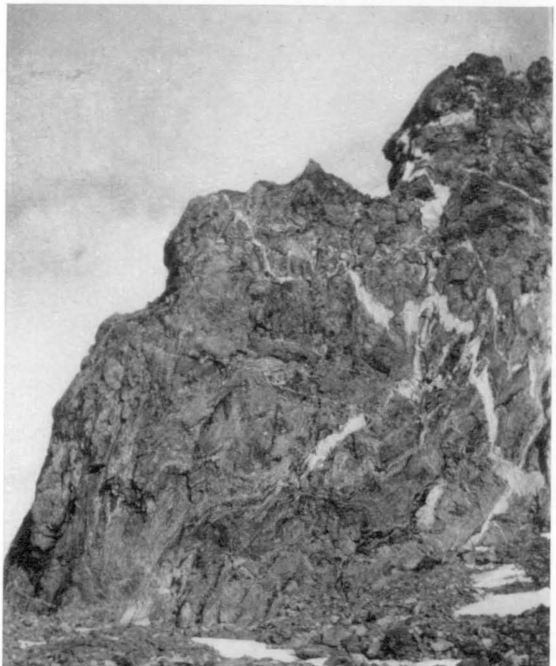


Fig. 2.—Rock bastion at east tip of Mount Hollingshead. Contorted meta-sediments with aplite and pegmatite dykes.

Fig. 1.—Looking west along line of Mount Loewe Fault.

Fig. 2.—Looking south along line of Amery Fault. Basement rocks to right, Amery Formation to left.

somewhat tentative. The type *Florinites* sp. bears some similarity to Virkki's[1] imperfectly described spore type No. 4 from the Artinskian of India and to No. 31 from 25 feet above the Talchir Boulder Bed, which is variously ascribed to the Upper Carboniferous and the Sakmarian.

Portion of the same sample was subjected to a limited chemical examination. On account of the small size of the sample, these results may only be regarded as typical and indicative of the coal type present and are not truly representative of the whole seam:

		Per cent.
Air-dried basis:	Moisture	5.48
	Ash	19.83
	Carbon	57.24
	Hydrogen	4.02
Dry, ash-free:	Carbon	76.64
	Hydrogen	5.38 "

The absence of shale and mudstone from this succession may be more apparent than real, as such bands would not be expected to crop out very strongly and may be represented in some of the obscured portions of the formation.

Reconnaissance flights and aerial photographs indicate that the Amery Formation is also represented among the outcrops flanking the Lambert Glacier to the south of the Amery Locality. Two of these occurrences are situated in the vicinity of 71° 30′ S. lat., 67° 30′ E. long., and in the vicinity of 73° 15′ S. lat., 67° 15′ E. long. To the south of these points, interpretation of air photographs is less conclusive, but additional occurrences may be present as far south as latitude 74°, 250 miles from the Amery Locality itself.

ECONOMIC GEOLOGY.

No mineral deposits of economic importance have so far been discovered in the area. However, traces of copper, iron, manganese, coal, and radio-active minerals occur at several places.

Copper.

Superficial staining on joint planes and exposed faces by secondary copper minerals of the chrysocolla group has been discovered at a number of widely separated points, most of which have already been referred to in the description of the individual outcrops.

At Byrd Head and on several islands of the Colbeck Archipelago, and on the mainland east of Keel Island, traces of secondary copper minerals occur in pegmatite and in apparently normal gneiss. On the small outcrop south-east of Law Promontory, chrysocolla staining is associated with hornfels, and on several islands of the Oygarden Group, in the King Edward VIII Gulf area, chrysocolla is associated with hornfels, quartzite, pegmatite, and reef quartz. Similar relationships hold on the mainland at the south-east extremity of Amundsen Bay.

At the Vestfold Hills, no indication of copper mineralization was seen in situ, but traces of secondary minerals were found in erratics, including fragments of glassy quartz, and a few disseminated grains of chalcopyrite were found in an erratic of feldspathic gneiss.

(1) Virkki, Chinna, 1945: "Spores from the Lower Gondwanas of India and Australia". *Proc. nat. Acad. Sci. India*, 15, 93–176.

On the northern tip of the Masson Range and the highest point of the Casey Range, a few narrow quartz seams, commonly less than an inch wide, carry minor amounts of pyrite and chalcopyrite, and a few grains of sulphides are disseminated through the nearby country rock. Secondary minerals are commonly associated with these occurrences.

Iron.

Small lenticular bodies of magnetite-rich material are known from Alphard Island and Rigel Skerries in the King Edward VIII Gulf area, and from the mainland near the south-east extremity of Amundsen Bay. The lenses may contain up to 50 per cent. by weight of magnetite, the associated minerals being quartz, garnet, and hypersthene, sometimes with minor amphibole and biotite. At both localities, these lenses occur within a highly altered series of metasediments. At King Edward VIII Gulf, the lenses are best developed near bands of pyroxenite and hypersthenite, which are irregularly distributed throughout the metasediments; at Amundsen Bay they appear to occur only near minor norite intrusives. They are probably, therefore, largely of metasomatic origin. None is more than 6 inches wide at King Edward VIII Gulf and 2 to 3 feet at Amundsen Bay.

Manganese.

A single specimen of slightly sheared charnockitic granite from the saddle about half a mile south of Mount Elliott shows encrustations of manganese oxides, about one sixty-fourth of an inch thick, on joints and exposed faces. Traces of similar encrustations have also been observed on Alphard Island in the King Edward VIII Gulf area.

Coal.

At least two thin seams of coal with average widths of the order of 8 inches are known to occur within the Amery Formation at the type locality (see p. 64). The formation was only briefly examined, and more detailed investigations would probably result in the discovery of additional coal seams, probably of greater thickness and possibly of better quality.

Radioactive Minerals.

Flat Islands.—A high reading was obtained over the southern island of this group during an airborne scintillograph survey carried out in 1954. The area was subsequently investigated by B. H. Stinear, and the following remarks are quoted from his report (Stinear, 1956):—

"The basement rock of this island consists of a massive coarse-grained garnetiferous variety of the typical charnockitic granite-gneiss of the area. Crossing the country rock in a general east-west direction are a few short, irregular pegmatite veins containing garnets, up to 9 inches in width. It was observed that some of these veins contained small quantities of radioactive material; field measurements with a ratemeter averaged over several veins from three to five times background count. The radioactivity of the veins has been checked in the laboratory and found to be due to thorium; microscopic examination of the sample has indicated that monazite is the mineral responsible."

Einstoding Island.—In September, 1955, a party from Mawson (not including a geologist), called at Einstoding Islands, en route to the Taylor rookery. Representative rock specimens were collected from the island by H. Oldham, including two specimens of a garnetiferous charnockitic granite-gneiss with large feldspar phenocrysts.

On closer examination at Mawson with the Philips Monitor and the Antarctic Ratemeter, these specimens gave average counts up to 25 per cent. above background.

The area was accordingly revisited in 1956, when an examination of the islands with the Philips Monitor gave very variable counts, averaging roughly twice normal background; but no defined bodies of above-average radioactivity could be recognized. Some of the highest counts appeared to be associated with pegmatite occurrences, but others could not be correlated with any particular rock types. Representative specimens were collected, and some of these, on further examination at Mawson, also gave counts up to 25 per cent. above background on the ratemeter. However, no radioactive minerals could be identified by inspection with the naked eye, and disseminated thorium minerals (probably monazite), similar to those from Flat Islands, are probably responsible for the high counts in this area.

Child Rocks.—Several islands in this group, situated some 15 to 20 miles north-east of Mawson, contain pegmatite dykes which give radioactive counts above background. The more southerly of the two relatively large islands about three miles east of the western extremity of the group is typical in this respect. Several pegmatites on this island, when tested with the Philips Monitor, gave counts of up to twice background, while others, indistinguishable from them in the hand-specimen, gave no significant counts. The highest counts were obtained from a pegmatite with transitional contacts and a meandering course, which occurs on the most easterly knoll of the island. This pegmatite, with an average width of about eighteen inches, was traced for about a chain, not counting occasional minor offshoots, and gave counts up to four or five times background. Individual specimens from this dyke, on further examination at Mawson, also gave counts of up to twice background on the Antarctic Ratemeter, but no radioactive minerals were visible to the naked eye.

The heavy mineral fraction of a specimen from this locality has since been examined by Mr. W. B. Dallwitz, Bureau of Mineral Resources, who identified garnet, a black opaque mineral, monazite, and rare zircon, and concluded that the monazite was responsible for the radioactivity of this specimen.

Two smaller islands, approximately two miles east-north-east of the above, showed similar features. The country rock throughout the group is a gneissic charnockitic granite, similar to that at Mawson.

William Scoresby Bay.—This locality consists of a ridge, about 2 miles long from north to south, and half a mile wide. The northern tip of the ridge, about two miles due east of Keel Island, rises to about 350 feet and has a slightly undulating summit. The ridge falls away gradually to the south.

Counts up to ten times background had been obtained from this area during an airborne scintillograph survey in 1956, and the locality was accordingly examined in some detail.

The dominant rocks are medium-grained arenaceous metasediments in which the original bedding is indicated by the presence of biotite-rich bands with a north-south strike and dips ranging from horizontal to 20° or 30° east. Very numerous bodies of pink pegmatite, composed essentially of quartz, feldspar, biotite, minor muscovite, and occasional garnet, intersect the metasediments at various angles, with a slight preponderance of east-west strikes and more or less vertical dips. Some dykes are 30 feet wide, and many of them give counts of the order of two to three times background on the Philips Monitor. However, intensity varies rapidly even within individual dykes and does not seem to correlate with any features visible to the naked eye. The highest individual counts, 200 to 250 counts per minute, were obtained on a pegmatite ledge just north of the most northerly summit of the ridge. On further examination at Mawson, however, individual specimens gave only slight increases on the ratemeter (20 per cent. above background). The high counts obtained in this area are probably due to the cumulative effects of very low-grade disseminated radioactive material, probably monazite, and no economic concentrations are present.

This conclusion has since been confirmed by Mr. W. B. Dallwitz, who has recorded monazite, subordinate black opaque mineral, and very rare zircon in a heavy mineral concentrate prepared from a composite sample from this locality.

Kring Island.—This locality, extending over an area about half a mile square, is situated on the southern portion of the north-eastern island of the Kring Islands, which lie some two miles off the north-west flank of Law Promontory. Counts of three to four times background have been recorded by the airborne scintillograph.

The dominant rocks are again arenaceous metasediments, grading into garnetiferous quartzite on the one hand and into hornfels rich in biotite or amphibole on the other. Strikes average between 45° and 90°, with southerly and south-easterly dips of 15° to 45°. Local traces of superficial copper staining were noted at several points, but did not appear to be associated with any special rock types or structural features. The metasediments are intersected by numerous bodies of pink and grey pegmatite, generally with irregular outlines, which cut across the bedding at various angles.

Average background counts of some 60 counts per minute were obtained in this area with the Philips Monitor. Counts up to twice this figure were obtained from some of the pegmatites, but none of these gave any promise of the presence of significant quantities of radioactive material. The examination of selected specimens with the Antarctic Ratemeter, resulting in counts of the order of 30 per cent. above background, confirmed this conclusion.

The heavy mineral concentrate from one of these specimens has since been examined by Mr. W. B. Dallwitz, who found it to consist of monazite, a little zircon, and probably ilmenite, and concluded that its radioactivity should be attributed to the monazite.

Kvars Promontory and Oygarden.—Counts of four to five times background were obtained with the airborne scintillograph on the northern portion of Kvars Promontory and on the north-western portion of Achernar Island, both in the King Edward VIII Gulf area, in July and August 1956. However, owing to rough surface conditions in these areas in spring and early summer, planes could not be landed sufficiently close to these localities to permit examination on the ground.

Part of the Oygarden Group, to the north-east of Achernar Island, had been previously examined (May 1956), and found to consist largely of arenaceous metasediments, including garnetiferous quartzite, biotite hornfels, and garnet-rich hornfels. Occasional lenses of a fine-grained compact dyke rock containing magnetite and traces of disseminated sulphides were present, as were occasional lenses of almost pure crystalline magnetite, up to three or four inches wide. These rocks were interbanded with subordinate medium-grained aplitic gneiss, possibly of hybrid origin, and the entire complex was intersected at various angles by quartz veins and pegmatites, generally less than six inches wide.

The setting of the radioactive localities at Kvars Promontory and Achernar Island is probably similar to this.

Ufs Island.—On Ufs Island, some 45 miles west of Mawson, counts up to three times background have been obtained with the airborne scintillograph. The highest counts were obtained from the isolated knoll which rises to a height of about 600 feet above sea level near the south-west extremity of the island.

The summit of this knoll is composed of porphyritic charnockitic granite wi h slightly gneissic texture, but its south-eastern slopes consist of originally sedimentary rocks, now largely altered to hornfels and granular gneiss. The banding of these metasediments, their contact with the granite, and the foliation of the granite all strike approximately 60° and dip more or less vertically. Numerous granitic veins, a few inches wide, were found within the metasediments within several chains of the contact, and occasional pegmatitic phases also occur.

No defined bodies of high radioactivity were found at this locality, but counts within the granite area tended to be somewhat higher than normal (80 to 100 counts per minute against an average of 60 for most rock exposures in this vicinity), and to vary rapidly and irregularly from point to point. The high counts obtained on the scintillograph are, therefore, probably due to the cumulative effects of very small quantities of radioactive material disseminated through portions of the rocks, and no significant concentrations of such material should be expected in this area.

Colbeck Archipelago.—Counts up to three times background have been obtained by the airborne scintillograph on a small island of the Western Colbeck Archipelago, about 3 miles north-east of the Taylor rookery.

About half of the area of this island group is occupied by fine-grained to medium-grained compact metasediments and medium-grained granular rocks composed essentially of quartz, feldspar, biotite, and minor amounts of other ferromagnesian minerals. These granular rocks include a number of charnockitic types and intrude the metasediments. Dominant strikes are about 010° and dips generally within 15° either side of vertical. Most of the remaining rocks of the area consist of a series of pink quartz and feldspar-rich gneisses with minor garnet and biotite, which also intrude the metasediments, although they generally conform to their regional trends. Locally, these gneisses are associated with pegmatitic phases of similar mineralogical composition, some of which show gradational boundaries, and also occasionally with irregular bodies of coarsely crystalline vein quartz. Traces of superficial copper staining were noted on a number of exposed faces and joint planes of some of these pegmatites and of some associated gneisses, but no sulphide minerals could be detected with the naked eye.

The exact source of the high counts recorded by the airborne scintillograph could not be traced on the ground, but counts somewhat above the average for this vicinity were noted from some of the pegmatites (80 to 100 counts per minute). It appears very probable, therefore, that one of these was responsible for the high count obtained, and that no significant concentrations of radioactive material should be expected in this area.

PETROLOGY.

CHARNOCKITIC GRANITE.

The typical porphyritic gneissic charnockitic granite which forms the country rock at Mawson and on the nearby islands and coastal outcrops is indistinguishable in the field and in thin section from similar rocks which have been encountered at Einstoding Islands, Ufs Island, the Masson and David Ranges, Mount Henderson, and Mount

Loewe in the north-eastern portion of the Prince Charles Mountains. Moreover, it corresponds very closely to rocks described as charnockites from Haswell Island in Queen Mary Land (Australian Antarctic Expedition 1911-1914, specimens Nos. 1095 and 1100), and hypersthene-feldspar gneiss from Stillwell Island in King George V Land (A.A.E. No. 979), and is thus an important constituent of the East Antarctic basement over a distance of some 2,000 miles.

Its mineralogy agrees well with that of the type charnockite described by Holland (1900), but it differs in having a pronounced porphyritic texture as well as containing numerous xenoliths of various sorts.

Wherever its contacts are exposed, it is unmistakably intrusive into all other rocks with which it comes into contact. There is therefore no reasonable doubt that the occurrences in MacRobertson Land have been emplaced in their present position in fluid form, and any subsequent metamorphism has been insufficient to destroy the original igneous textures and structures. This is in agreement with the igneous origin postulated by Holland for the Indian charnockites, but differs from Stillwell's 1918 interpretation in which he regarded the occurrences in King George V Land as having undergone complete reconstitution under conditions of deep-seated metamorphism.

CHARNOCKITIC GRANULAR GNEISS.

Charnockitic granular gneiss is another very widespread rock which has been encountered at Rookery Islands, Oldham Island, Byrd Head, Law Promontory, and the Vestfold Hills. It is closely comparable to the charnockitic granite in mineral composition, but lacks the porphyritic texture and the aplite and pegmatite dykes which generally accompany the granitic phase. However, at Byrd Head the gneiss also is intrusive into a series of metasediments with which it locally comes into contact. Its relations with the granitic phase have not been established beyond doubt, but at Oldham Island veins of the charnockitic granite appear to be intruded into the gneiss.

The rock corresponds very closely to the typical acid charnockite described by Holland, but the term charnockitic gneiss is preferred in order to maintain the distinction from the granitic phase. It also corresponds in every respect to the rocks described as acid charnockite from Proclamation Island (Tilley, 1937), and to the charnockite gneiss from Madigan Nunatak in George V Land (A.A.E. No. 798), and the hypersthene/alkali-feldspar gneiss from Stillwell Island (A.A.E. No. 947).

The primary igneous characteristics of the gneiss are much less obvious than those of the granite, and Stillwell's suggestion that they have undergone intensive metamorphism may be applicable. Nevertheless, their close resemblances to the granitic phase, both in thin section and in the hand-specimen, makes it unlikely that these two very similar rock types should have originated in widely different environments. A possible explanation may be found in Dunn's suggestion (1942) that the Indian charnockites are the product of extreme metamorphism of pre-existing igneous or sedimentary rocks, accompanied by palingenesis of parts of the complex. On this view, the charnockitic granites of MacRobertson Land might be regarded as the products of palingenesis which had been mobilized sufficiently to be re-injected into adjoining or overlying portions of the earth's crust, and typical igneous textures and structures developed. This charnockitic gneiss, on the other hand, may represent those portions of the original complex which, although extensively re-constituted in a physical and chemical environment similar to that which gave rise to the granitic phase, were not themselves entirely liquefied at any one time. Moreover, it seems likely that both pre-existing igneous and sedimentary or hybrid rocks are represented among the present granular gneisses, and this may account for the differences in mineral composition, structural features, and field relations of different bodies of these rocks. In general, the more obviously charnockitic phases suggest a primary igneous origin, whereas some of the associated quartz-rich and biotite-rich types may be derived from sediments or hybrids.

Both the charnockitic granite and the granular gneiss are thus thought to have originated in an environment at high pressure and temperatures, and low in volatile constituents, and under these conditions the difference between complete recrystallization in the solid state and crystallization from a magma or a re-melted pre-existing rock becomes of minor importance.

HORNFELS.

Rocks described as hornfels have been encountered at Rookery Islands, Byrd Head, Law Promontory, the Vestfold Hills, the Masson Range, and various points in the Prince Charles Mountains. Numerous examples also occur among the xenoliths enclosed in the granite at Mawson. They vary somewhat in mineral composition, but are generally readily identified in the hand-specimen by their dark colour, compact texture, banding, and abundance of biotite or amphibole. Pyroxene is generally also present, but is not usually obvious in the hand-specimen. Cordierite is present in one specimen only.

No exact equivalents to these rocks appear to have been described from other parts of Antarctica. They show some points of resemblance to the garnet-plagioclase-pyroxene gneiss from Cape Pigeon Rocks (A.A.E. No. 767), the hornblende-plagioclase-pyroxene gneiss from Cape Gray (A.A.E. No. 766), and the plagioclase-pyroxene gneiss from Madigan Nunatak (A.A.E. No. 775), all in King George V Land. They differ, however, in generally carrying a little quartz and orthoclase and having andesine rather than labradorite as the typical plagioclase. Since the gneisses from King George V Land are regarded as metamorphosed dyke rocks by Stillwell, the resemblance is probably due to similar conditions of metamorphism rather than similarity in the pre-existing rocks.

GRANITIC GNEISS.

Granitic gneiss is known from Rookery Islands, Keel Island, the Vestfold Hills, and various parts of the Prince Charles Mountains, as well as a small in-faulted block at the southern end of the Flat Islands, about 2½ miles west of Mawson. Similar rocks have also been recorded from Cape Bruce (Tilley, 1937). They are generally characterized by an excess of orthoclase, often perthitic, over plagioclase, and relatively abundant quartz. Garnet and biotite are the usual ferromagnesian minerals, but an amphibole-bearing variety occurs on Lichen Island in Sandefjord Bay. The abundance of garnet and the occasional presence of cordierite indicate some contamination by sedimentary material, but this is too slight to affect the essentially igneous characteristics of the rocks.

No exact equivalents of these rocks have been described from other parts of the Antarctic Shield. They differ from the typical granitic rocks of Queen Mary Land and King George V Land in their persistent content of garnet, but their degree of contamination is still appreciably less than that of the rocks described as garnetiferous gneiss from the latter area.

HYBRID GNEISS.

With increasing proportions of material of sedimentary origin, the granitic gneiss described above grades into hybrid gneisses, generally characterized by a more pronounced banding and a higher content of ferromagnesian minerals. Such rocks are among the most widespread throughout this portion of Antarctica. They have been recognized from the Stanton Group, the Byrd Head/Taylor Glacier area, the Vestfold Hills, the David Range, and numerous points in the Stinear Nunataks and the Prince Charles Mountains. Owing to their composite nature, they vary rapidly in mineral composition, so that either orthoclase or plagioclase may be the dominant feldspar, and the ferromagnesian minerals may include biotite, garnet, hornblende, and hypersthene. Clinopyroxene, cordierite, sillimanite, and graphite are also occasionally present.

No exact equivalents to these rocks appear to have been encountered elsewhere in Antarctica. The garnetiferous hypersthenic gneisses of Stillwell Island and Cape Pigeon Rocks in King George V Land are very similar to some of them in microscopic appearance and mineral composition (e.g., A.A.E. No. 785), but are described by Stillwell as dyke rocks of very limited extent, contrasting with the very extensive development of hybrid gneisses in MacRobertson Land.

SILLIMANITE GNEISS AND GARNET-SILLIMANITE GNEISS.

Two specimens from King Edward VIII Gulf and Amundsen Bay in which sillimanite becomes a major constituent are regarded essentially as recrystallized sediments.

Another group, from Depot Peak and the Stinear Nunataks, carrying garnet as well as sillimanite, is also regarded as being of dominantly sedimentary origin, but with some addition of material by metasomatic changes. This is especially marked in one specimen from the Stinear Nunataks, which contains large patches of orthoclase superimposed on an original oriented fabric, now represented by numerous biotite and sillimanite inclusions in parallel alignment, independent of the orientation of the feldspar. Much of the garnet in these rocks has perfect euhedral outlines. Similar rocks have also been described from Cape Bruce and as erratics from Proclamation Island (Tilley, 1937).

This group somewhat resembles the rocks described as garnet-cordierite gneisses and garnet-feldspar gneisses from Cape Gray and Garnet Point in King George V Land.

QUARTZ-FELDSPAR-GARNET GNEISS.

Quartz-feldspar-garnet gneiss is known from Rookery Island, Byrd Head, Amundsen Bay, the David Range, Depot Peak, and parts of the Prince Charles Mountains. Essentially, the rock consists of perthitic orthoclase, minor plagioclase, mosaics of recrystallized quartz grains, garnet, and minor biotite. It is related to the garnetiferous granitic gneiss and garnet-sillimanite gneiss described above and to the garnetiferous quartzite to be described below, but its field relations and structures distinguish it from all these groups. It is generally coarsely banded and occurs in association with rocks of undoubted sedimentary origin, but its contacts with the metasediments, although roughly conformable on a large scale, commonly cut across the bedding on a small scale. Also, the gneiss is commonly associated with minor pegmatitic phases of similar mineral composition, which cut across the bedding of the adjoining metasediments and the banding of the gneiss.

The gneiss is believed to represent the product of extreme metamorphism of a series of arenaceous sediments, partly mobilized. A similar origin has been proposed by Tilley (1937), for a comparable group of rocks from Cape Bruce.

No other rocks showing quite the same combination of features appear to have been described from Antarctica to date, but a number of erratics from Cape Denison (A.A.E. No. 270, 277, and 586) show similar mineral assemblages and similar appearance in the hand specimen.

GARNETIFEROUS QUARTZITE.

Where the original sediments have not been completely reconstituted or partially mobilized, the metamorphic product may be described as garnetiferous quartzite. The grain-size is slightly smaller and the feldspar content lower than those of the quartz-feldspar-garnet gneiss. Traces of cordierite or sillimanite may be present. The quartzite is developed in the King Edward VIII Gulf area, and a rock intermediate between this group and the quartz-feldspar-garnet gneiss is also known from the north tip of the Masson Range.

No equivalent rocks have been described from any other portion of East Antarctica.

NORITE, GABBRO, PYROXENITE, AND HYPERSTHENITE.

Norite and gabbro are not very widely developed in this area. A few examples of garnetiferous gabbo gneiss have been found in the King Edward VIII Gulf area (thin section No. 3942), and a coarsely banded rock of gabbroic composition occurs in the northern portion of the Masson Range (thin section No. 3970). The only other rock within this category is a norite gneiss from the Amundsen Bay area (thin section No. 3953). These all appear to be essentially of igneous origin, but unrelated to any of the more widespread rock-types.

Pyroxenite and hypersthenite, including some rocks very rich in magnetite, are known from the King Edward VIII Gulf and Amundsen Bay areas, the Vestfold Hills, and various points in the Prince Charles Mountains. They generally occur as sharply defined lenses and bands associated with a wider range of rock types. These field relations again suggest igneous origin, although their present mineral composition may be due to subsequent metamorphism. They differ from the equivalent basic and ultrabasic rocks of King Geore V Land in the invariable predominance of pyroxenes over amphiboles, and their nearest equivalents appear to be the rocks described as basic and ultrabasic members of the charnockitic series from Proclamation Island by Tilley (1937), and from Queen Mary Land by Nockolds (1940).

However, the rocks encountered during the present investigation do not normally occur in association with the more acid members of the charnockitic series, and show no textural or mineralogical resemblance to them, except for the presence of hypersthene in both groups of rocks. The correlation of the two groups is therefore regarded as very doubtful.

METASOMATIC ROCKS RICH IN GARNET AND MAGNETITE.

Under this heading are grouped together rocks rich in garnet and magnetite associated with one or more of the following: quartz, orthoclase, plagioclase, sillimanite, cordierite, hypersthene, amphibole, biotite, and green spinel. The main representatives are a contaminated pegmatite from the western Colbeck Archipelago, a contact specimen from a pegmatite dyke in the Casey Range, and a group of magnetite-rich rocks from the King Edward VIII Gulf and Amundsen Bay areas. They are comparable to the magnetite-garnet rocks from Cape Denison described by Coulson (1925), except for the presence of sillimanite, hypersthene, amphibole, and spinel, which have not been recorded in the Cape Denison Rocks. Coulson suggested, and the author agrees, that they were formed by the metasomatic alteration of sedimentary rocks.

BASIC DYKES AND METAMORPHOSED EQUIVALENTS.

A very well developed swarm of dolerite dykes and related rocks occurs in the Vestfold Hills, where several hundred of them are known in an area of some 150 square miles. Apart from this swarm, however, dolerite is only known as erratics from Amundsen Bay and from Proclamation Island (Tilley, 1937). A deuterically altered fine-grained rock, originally possibly a basalt, is known from the vicinity of Mount Loewe, and groups of basic dykes were noted in inaccessible positions on Mount Gardner and near Mount Bechervaise. A single boulder of a deuterically altered iddingsite basalt has also been found at Law Promontory. In the King Edward VIII Gulf area, bands of a fine-grained hypersthene-rich rock carrying relatively abundant pyrrhotite are regarded as metamorphosed dyke rocks. Finally, a single erratic of amphibolite has been found at Amundsen Bay.

The dolerite can be correlated with reasonable certainty with the late Mesozoic sills of King George V Land and Victoria Land and possibly with the sills and dykes of diorite and gabbro recorded by Roots (1953) from Dronning Maud Land. The basalt also appears to have fairly close counterparts in Dronning Maud Land, and may be related to the period of late Tertiary and Recent volcanic activity responsible for the lavas of Mount Erebus, &c., in Victoria Land and Gaussberg in Queen Mary Land. The altered dykes from King Edward VIII Gulf and the amphibolite erratic from Amundsen Bay, on the other hand, are probably related to the Precambrian complexes in which they occur, and may thus be correlated with the amphibolite and related types recorded by Stillwell and others from King George V Land.

CALC-SILICATE ROCKS.

Only two occurrences of calc-silicate rocks were noted in the area. One is a rock from Mount Hollingshead, in the Prince Charles Mountains, composed of diopside, plagioclase, and green spinel; the other is an erratic from the Masson Range, containing calcite, forsterite, white mica, and blue spinel. An erratic containing diopside, scapolite, labradorite, and quartz has been recorded from Cape Bruce (Tilley, 1937).

Although the mineral assemblages are not quite identical, they are similar to the calc-silicate rocks described by Tilley and Glastonbury (1940b, d, e) from erratics in Kin George V Land, and indicate the presence of original calcareous sediments at widely separated points in the Precambrian succession.

SEDIMENTS OF THE AMERY FORMATION.

The Amery Formation was laid down rapidly and in shallow water. Many features, such as the angularity of many of the particles of sand and grit, the presence of significant proportions of heavy minerals, especially garnet, the occurrence of interbedded pebble beds and coal seams, &c., are remarkably similar to occurrences of the

Beacon Formation described from King George V Land and Victoria Land (David and Priestley, 1907-9; Mawson, 1940a). Similarly, the correspondence of individual hand-specimens is very striking, e.g., with A.A.E. No. 1174 from Horn Bluff.

In Dronning Maud Land, Roots (1953) has also recorded an extensive series of flat-lying sediments, comprising greywacke, siltstone, and impure sandstone, with minor shale, mudstone, and conglomerate. They are overlain and in part intercalated with altered andesitic lava and intruded by a major group of diorite and gabbro sills and dykes. However, no fossils were found within them, so that their correlation with the Amery or Beacon Formation would be purely conjectural at this stage.

GENERAL CORRELATIONS WITH ADJOINING AREAS.

Only a few of the rock types encountered during the present investigation can be correlated with occurrences in other parts of Antarctica. Those that have close equivalents in Queen Mary Land, King George V Land or Victoria Land are the charnockitic granite, the charnockitic granular gneiss, the dolerite dykes, and the sediments of the Amery Formation. Certain resemblances to previously described rocks also appear in the pyroxenite and hypersthenite, the metasomatic garnet-magnetite rocks, the calc-silicate rocks, and some garnet-sillimanite gneisses. The most widespread types of igneous rocks, however, show more evidence of contamination and more marked gneissic structures than do the typical granites, &c., of other parts of Antarctica. At the same time, the metasediments of MacRobertson Land have undergone more intense alteration, often including some addition of igneous or metasomatic material and partial mobilization, than elsewhere in the Antarctic.

Comparison with rocks from Dronning Maud Land, studied by the Norwegian-British-Swedish Antarctic Expedition (1949-1952), is less conclusive, as the detailed results of this expedition are not yet available. However, the preliminary accounts (Roots, 1952 and 1953) indicate that the basement complex of this area consists largely of banded quartz-feldspar-biotite gneiss and gneissic granite with relatively abundant pegmatite phases. Garnetiferous rocks appear to be more localized than in MacRobertson Land and no charnockite has been recorded. There are, on the other hand, several areas of low-grade metamorphic rocks, including slate, phyllite, and chlorite schist, so that the metamorphism undergone by the basement complex in this area is both less intense and less widespread than in MacRobertson Land.

GLACIOLOGY.

SNOW AND ICE FEATURES AT AND NEAR MAWSON.

Near Mawson two entirely different zones in the continental plateau can be distinguished. The coastal zone, in which ablation predominates over accumulation, consists almost entirely of blue ice and extends to a maximum altitude of about 2,400 feet, which is generally reached between 16 to 20 miles from the coast. South of this, the inland zone, in which accumulation predominates, consists almost entirely of névé.

At Mawson itself, the plateau rises to a height of about 250 feet within a quarter of a mile of the coast, and then more gradually to about 1,200 feet at the foot of Mount Henderson, about six miles from Mawson. Close to Mount Henderson, the existence of buried rock ridges close to the surface of the ice-sheet is indicated by minor irregularities in the topography, but the general level continues to rise until the limit of the ablation zone is reached at an altitude of about 2,400 feet, about 18 miles from the coast.

The whole of this zone consists of blue ice, with the exception of a superficial seasonal snow cover and local drifts, whose distribution is controlled by rock exposures and minor topographic irregularities of the ice surface.

At Mawson, this ice abuts directly against rock and is slowly retreating, but at the coastline on either side the plateau ice persists to sea level and has given rise to cliffs from 10 to about 100 feet high. In all areas where such cliffs appear, it is obvious, if equilibrium conditions exist, that the replenishment due to the forward movement of the ice must be in excess of losses due to ablation, and it is estimated that this condition holds over some 85 per cent. of the coastline within 10 miles on either side of Mawson.

Snow and Ice Features between Mawson and King Edward VIII Gulf.

West of Ring Rock, the coastline consists largely of nearly stagnant ice cliffs for a distance of 25 to 30 miles. Beyond this, however, the numerous rock exposures of the Ufs Island/Byrd Head area, and the major glacier tongues of the Jelbart Glacier and the Taylor Glacier, break the monotony (Plate 8, fig. 1).

South-west of Byrd Head, the plateau rises rapidly to about 1,000 feet before levelling off, but only minor outfalls from this section of the plateau descend to sea level, and the area appears to be largely stagnant. Inland from the Taylor Glacier Tongue, on the other hand, a relatively low-lying area, 400 to 600 feet above sea level, extends inland for at least 5 miles. The surface of the ice in this area is extensively covered by hummocks and minor pressure ridges, up to 3 or 4 feet high. Numerous crevasses and minor cracks are present, spaced at irregular intervals, but few of these are more than 3 feet wide.

Throughout the Ufs Island/Byrd Head/Taylor Glacier area, major lee drifts occur on the flanks of most of the larger rock exposures. Most of these consist of blue ice, overlain by a few inches to a few feet of recent snow, and are thus permanent features.

West of the Taylor Glacier, a relatively featureless coastline again extends for about 30 miles, until the William Scoresby Bay/Stefansson Bay/Law Promontory area is reached. Major glaciers in this area include the Dovers Glacier and the Hoseason Glacier (Plate 31). In addition, this area contains two independent ice-caps: on Fold Island—area about 15 square miles, maximum height about 800 feet above sea level—and on Law Promontory—area about 120 square miles, maximum height about 1,500 feet. These are entirely nourished by precipitation on their surface, and part of the ice in each is moving towards the coast. This area therefore has a higher annual accumulation or lower ablation than the vicinity of Mawson, since no excess of accumulation over ablation has been noted below 2,400 feet in the Mawson area.

Very similar features occur in the King Edward VIII Gulf area, about 50 miles west of Law Promontory. The two main outlets from the mainland ice-sheet in this area are the Robert and Wilma Glaciers, draining into King Edward VIII Gulf (Plate 32). King Edward Plateau, in the eastern portion of the Enderby Land Peninsula, appears to be an independent ice-cap similar to Law Promontory. In addition, parts of all the larger islands in this area are permanently ice-covered. On most of the islands actually visited (e.g., Alphard, Shaula, Rigel and Sirius Islands), the cover consists only of permanent drifts which extend to leeward and occasionally to windward of the more prominent rocky knolls and hummocks. At the time of the visit (May, 1956) some of these drifts were composed entirely of blue ice, generally covered by a few inches or occasionally up to 3 feet of new snow; others were composed at least in part of névé. No signs of crevassing were seen on any of these drifts, so that the ice in them is stationary or hardly moving.

SNOW AND ICE FEATURES IN THE FRAMNES MOUNTAINS.

A general account of the snow and ice features of Mount Henderson and the Masson, David, and Casey Ranges has already been given in connexion with their geology. In this area, the general level of the plateau ranges from about 1,500 feet above sea level at the northern tips of the ranges to more than 3,000 feet in the vicinity of Mount Hordern. Blue ice predominates below about 2,400 feet and névé above this height. Among the minor features of this area, a retreating glacier front has been noted from a small transection valley in the Masson Range (Plate 16), and some very fine examples of wind scours and radiation moats occur on the flanks of many of the rock exposures (Plate 17, fig. 2).

SNOW AND ICE FEATURES IN THE VICINITY OF THE PRINCE CHARLES MOUNTAINS AND THEIR NORTHERN OUTLIERS.

Average plateau heights in the area occupied by the Prince Charles Mountains and their northern outliers (Depot Peak, Stinear Nunataks, Anare Nunataks, &c.) range from about 4,000 feet to more than 6,000 feet above sea level. Névé covers most of the area, and the only occurrences of blue ice are found around major rock exposures and on isolated ice domes and ice ridges associated with irregularities in the buried bedrock topography.

At Depot Peak, about a square mile of blue ice occurs north and north-west of the main rock ridge, but no major crevassed zones were seen. A wind-scoured moat about 50 feet deep occurs south-west and south of the mountain, but drifts lead right up to the rock on the eastern side.

In the Stinear Nunataks, a large belt of blue ice is exposed in a relatively low-lying area to the north of Summers Peak, and is bounded to the south-west by a group of ridges linking this peak with Peak Seven. Several minor glaciers drain in a north-easterly direction from these ridges, and a strong terminal moraine is developed where they abut against the main mass of blue ice in the basin. This moraine is notable for the fact that none of the boulders are embedded in the ice, except in the immediate vicinity of some of the larger rock exposures, indicating that the temperature is never raised sufficiently for any melting to take place. The ice is extensively crevassed, but insufficient time was spent in the area to work out the detailed drainage patterns.

No blue ice is exposed near Peak Seven itself, and a large drift extends right up to the summit ridge from the north-west.

The area adjoining the Anare Nunataks is also completely occupied by névé. Minor scours occur to the north and west of the rock exposures, but drifts lead up to the ridges on the south and east. Several major ice domes and ice ridges occur on the edge of the high country about 5 miles farther west, but no opportunity arose for examining them in detail.

At Mount Bechervaise, a strongly crevassed belt of blue ice with an average width of about $1\frac{1}{2}$ miles extends in an east-west direction for at least 10 miles along the north flank of the Athos Range. It is bounded to the south by the terminal moraines of several small glaciers flowing in a general north-easterly direction through various gaps in the range, and it grades to the north into névé through an intermediate stage of less heavily crevassed white ice. The regional drainage, away from the immediate influence of the rock exposures, is eastward as previously described. The rock exposures in this area are generally completely surrounded by wind scours up to 200 feet deep, many of which are surrounded by major cornices.

Similar relations hold along the north flanks of the Porthos and Aramis Ranges.

Near the eastern extremities of all three ranges, the level of the plateau generally decreases, and the Aramis Range, in the vicinity of Mount Loewe, actually abuts against the south-western extension of the Amery Ice Shelf at an elevation of about 1,200 feet above sea level. In this area, e.g., on the lower slopes of the Nemesis Glacier, the transition from névé to blue ice occurs at about 3,500 feet above sea level, which is considerably higher than in the Mawson area.

SNOW AND ICE FEATURES OF THE AMERY ICE SHELF AND THE LAMBERT GLACIER.

The Amery Ice Shelf, as far as is known at present, occupies an area of about 10,000 square miles between latitudes 68° 30′ and 71° 00′ S., and longitudes 68° 30′ and 74° 15′ E. The mean elevation is estimated at about 200 feet above sea level, and a series of spot heights of the order of 400 feet above sea level have been obtained by reconnaissance flights from its supposed junction with the continental ice to the south and west.

Along its south-eastern margin, a series of minor glaciers draining north-west are shown on American compilations from Operation Highjump air-photos—Rogers Glacier, Stevenson Glacier, Kreitzner Glacier, &c. These compilations also show the area between these glaciers and the Shelf itself as being occupied by the Baker III Glacier, which drains north-eastwards into Sandefjord Bay. However, it seems improbable that a major glacier should terminate at the head of a deep inlet rather than form a glacier tongue, and it is suggested that the "Baker III Glacier" is in fact the disturbed zone marking the junction of the Ice Shelf and the continental ice.

Along the north-western margin of the Shelf, air-photographs show a well defined scarp with possible rock exposures and minor glaciers (Plate 33), but the area of high land flanking the Shelf on this side is too small to contribute a great deal of ice to it. Its main supply of ice must therefore originate from the Lambert Glacier, which drains in a general northerly direction from 74° 30′ S. lat., 67° E. long.

To the east, the Lambert Glacier is bounded by an almost continuous line of major rock exposures, nearly 100 miles long (the Mawson Escarpment). To the west, it abuts against the southern extension of the Prince Charles Mountains and is joined by several important tributary glaciers emerging from various gaps within these ranges. At the farthest point so far reached on reconnaissance flights, 73° 45′ S. lat., the elevation of the glacier was only about 3,500 feet above sea level, giving it an average fall of less than 20 feet per mile (Plates 34, 35, 36, 37).

The Lambert Glacier is believed to join the Amery Ice Shelf, that is, to change from land-based to floating ice, at or near a line extending from 71° S. lat., 69° E. long., to 71° 20′ S. lat., 70° 15′ E. long., but more detailed studies are required for the really accurate determination of this boundary.

The projecting front of the Amery Ice Shelf and the low level of the Lambert Glacier both suggest very rapid removal of the ice by coastward flow, possibly in excess of the 500 yards per year measured on the Ross Shelf Ice by the British Antarctic Expedition 1910-1913 (Wright and Priestley, 1922). In the absence of suitable rock features for use as reference points, this could only be established by a series of astronomical determinations of position.

At present, information is also lacking on the accumulation-ablation relationships over the greater portion of the Lambert Glacier and the Amery Ice Shelf. In the eastern portion of the Prince Charles Mountains, close to the edge of the ice-shelf, ablation was found to predominate at elevations up to 3,500 feet; but this is undoubtedly due largely to the presence of large areas of exposed rock, which absorb more solar radiation, and steep slopes, giving rise to violent katabatic winds. These effects may therefore not persist for more than a few miles from the edge of the mountain ranges, and the greater portion of the Amery Ice-Shelf may, by analogy with the Ross Shelf and with similar features in Dronning Maud Land, be expected to show an excess of accumulation over ablation.

SURFACE FEATURES OF THE ABLATION ZONE.

Melt-water Pools and Streams.

Around Mawson, the blue ice of the ablation zone is commonly covered by a film of water during the middle of the day in the midsummer period (mid-December to late January). This gathers in depressions as shallow pools and runs off in melt-water streams which may reach widths and depths of 4 to 5 feet. Similar features also appear elsewhere along the coast, in the Framnes Mountains, and in the low-lying eastern portion of the Prince Charles Mountains. Many of the larger streams, however, originate on the flanks of major rock exposures, such as the stream on the north flank of Mount Loewe, which had incised its course to a depth of more than 15 feet in January, 1957 (Plate 38, fig. 1).

Cryoconite Holes.

These same areas commonly show numerous circular patches of clear ice, up to 18 inches or rarely up to several feet in diameter, which can generally be traced downwards to boulders or small pockets of gravel at depths of 2½ to 3 feet.

These features are due to the re-freezing of melt-water in the track of the gravel or boulders that sink through the ice owing to their absorption of solar radiation, and the ice in them generally shows radial structure, sometimes with the development of concentric zones.

To test the rate at which these structures develop, a dark-coloured boulder, about 6 inches across, was placed on the ice surface near Mawson at an elevation of 200 feet above sea level. No significant changes were noticeable between early August and mid-November, but between 14th November and 7th December the boulder sank a foot below the surrounding ice surface and the resultant hole was filled with melt-water, covered by a 2-inch crust of clear ice.

Surface Disintegration.

During the period of maximum ablation (late December to early January), the blue ice in all the ablation zones underwent a striking change. The surface layers to an average depth of 4 to 5 inches disintegrated into columnar granules about a quarter of an inch across and three-quarters of an inch long. A few patches, usually close to major rock outcrops, even showed granules up to half an inch in average diameter and up to 2 inches in length. The long axes of these granules were invariably vertical, and their contents of air bubbles about the same as that of the underlying solid ice. They were generally polygonal in horizontal cross-section, but were not bounded by regular crystallographic planes. Nevertheless, it appears probable that they represent single crystals, " disarticulated " along grain boundaries. Similar observations have been recorded by Wright and Priestley (1922).

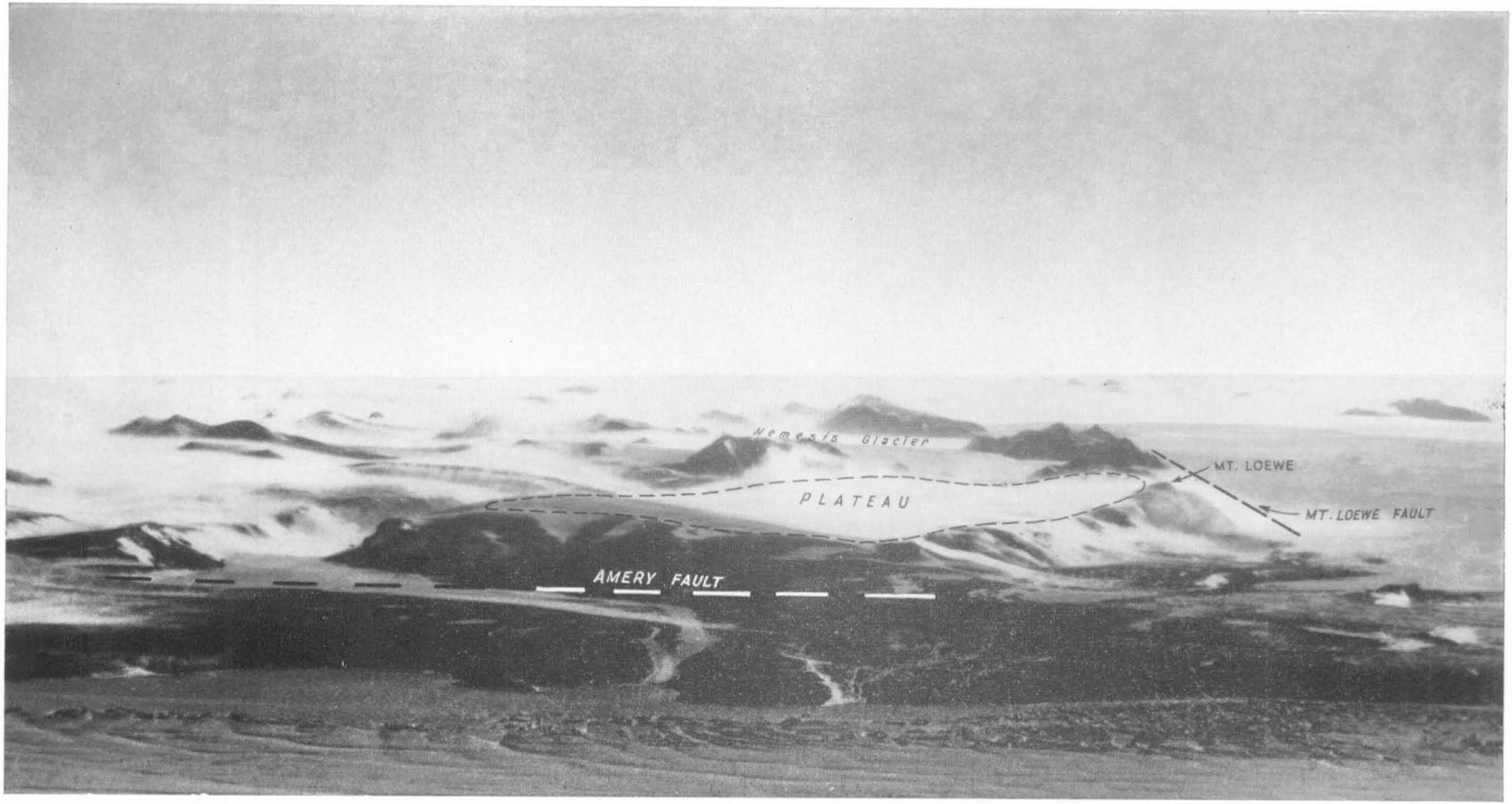
FLOW-LINES.

The term " flow-lines " is used in a purely descriptive sense to describe a very prominent structural feature of several blue-ice areas near the coast, among the Framnes Mountains, and in the low-lying portions of the Prince Charles Mountains. The flow-lines consist of numerous slightly raised or depressed bands of ice, from a few inches to several feet wide, and commonly several hundred yards long. In inland areas, they all conform closely to the direction of movement and appear to be restricted to areas of differential movement in the ice, such as the flanks of major ice streams, or to areas where the ice has been forced to flow through narrow gaps between rock outcrops.

Close to coastal outcrops, however, where the basal layers of the ice-sheet are exposed, as at Mawson itself, these lines may diverge appreciably from the direction of movement of the ice. They are therefore regarded as the traces, on the surface of the ice, of planar structures which dip at moderate or steep angles in the upper portion of the ice-sheet and flatten near its base (Plates 4 and 31).

Their limited distribution and the absence of any continuous layered structure in the original névé (see below) show that they are not developed from primary depositional features. On the other hand, they are not related to crevassing, as the remnants of old crevasses, filled by re-frozen melt-water, can often be seen intersecting them, but with entirely different orientation and appearance. The nearest analogy to these features appears to be the " blue bands " described from the Sorstrom Glacier, North Greenland, by Koch (1916), and regarded by him as due to the recrystallization of layers of ice adjoining longitudinal cracks on which differential movement of the ice is localized. This conception has been elaborated by Philipp (1920) who has shown that these bands are composed of ice with smaller grain-size and a smaller proportion of enclosed air bubbles than the main mass of the glacier. In valley glaciers, they are concentrated in the marginal and basal portions, where the differential movement is a maximum, and approximate to a U-shaped cross-section, conforming to the shape of the valley itself. Their thicknesses range from a few millimetres to about 50 cm. and they are spaced on the average from 1 to 2 metres apart. Philipp has shown from measured velocity profiles that the differential movement on each band may be as high as 30 cm. per year in temperate glaciers, but the figure in Antarctic conditions would be appreciably less than this. In addition, Philipp claims that several sets of intersecting " blue bands " may be produced if the shape of the confining valley undergoes a major change, but this condition has not so far been observed in MacRobertson Land.

Analogous structures have been observed in acid volcanic rocks (rhyolite and obsidian), where they consist of narrow zones, parallel to the final direction of movement, and marked by concentrations of crystallites and spherulites, due to



Plateau Area, south and west of Mount Loewe.

PLATE 25

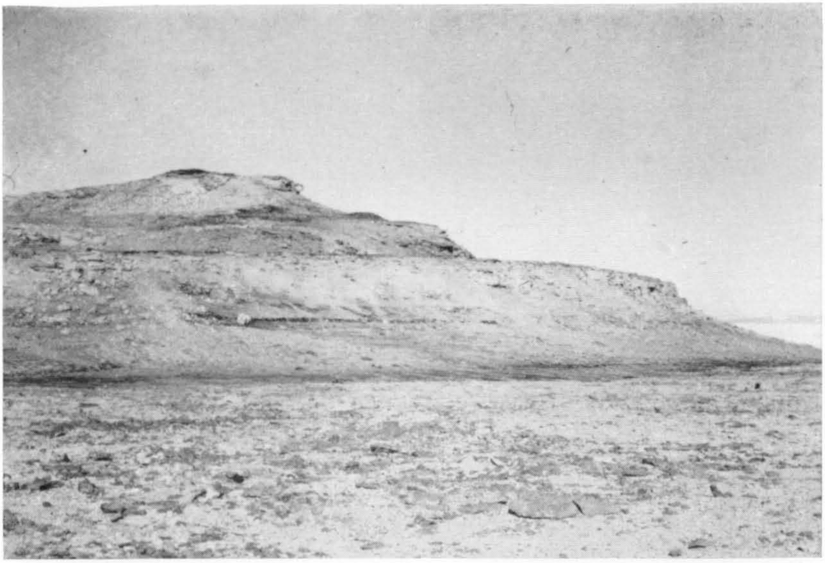


Fig. 1.—Sediments of Amery Formation at type locality. Resistant beds are calcareous sandstones. Thin coal seam about one third of way up cliff.

Fig. 2.—Close-up of sediments of Amery Formation. Outcrop of coal seam just below head of ice-axe.

Looking north-east over Amery Locality towards Amery Ice Shelf. " Beaver Lake " in distance, centre. Lake in middle distance, right, is situated at higher elevation and drains into " Beaver Lake ".

Looking west over Amery Locality towards Prince Charles Mountains. Mount Loewe on extreme left. North tip of eastern lobe of "horse-shoe" in foreground.

Looking west over Amery Locality towards Prince Charles Mountains. "Dead ice" in foreground. Taken from about five miles south of Plate 28.

Looking west towards Prince Charles Mountains. Amery Locality just out of picture, on right. " Beaver Lake " of re-frozen melt-water in middle distance. Taken from about five miles south of Plate 29.

devitrification. Philipp (1936) produces evidence that these structures are developed during the transition period from the lava, which would yield by continuous laminar flow, to the solid rock, which would yield along shear-planes inclined to the direction of deformation. During this transition period, the volcanics are believed to yield by discontinuous laminar flow parallel to the direction of deformation.

TRANSITION ZONE FROM BLUE ICE TO NÉVÉ.

The change from blue ice to névé is not usually abrupt, but is marked by a transition zone which may vary in width from a few chains to two or three miles. This zone is occupied by " white ice ", which is intermediate in appearance, hardness, and density between blue ice and névé. It originates by the percolation and re-freezing of melt-water through original névé, caused by the overlap of the zone of surface melting on to the accumulation zone. Under favourable circumstances, this is very clearly shown by the arrangement of white ice in layers in the névé, each layer corresponding to a surface exposed to melting.

Similar transition zones have been observed in North Greenland (Koch, 1916), and in Adelie Land (Loewe, 1956a).

SURFACE FEATURES OF THE ACCUMULATION ZONE.

The greater portion of the inland zone is covered by sastrugi of various sizes and degrees of regularity, locally alternating with dunes and other less regular forms (Plate 38, fig. 2). Between Mawson and the Stinear Nunataks, the direction of the sastrugi changes gradually from 150° to about 170°, but south of the nunataks it suddenly changes to 210° and locally reaches 230° in some portions of the Prince Charles Mountains. Where the sudden change of direction occurs, two sets of sastrugi are locally superimposed.

Patches of unusually large and irregular sastrugi occur at intervals throughout the areas visited, but these are probably reflections of local wind and weather conditions rather than permanent features. Thus the area between the 50-mile Depot and Mount Henderson was found to have been radically altered by ablation and wind-erosion between mid-November and early December, 1955, which undercut the sastrugi and locally exposed patches of the underlying surface with a characteristic rippled or pitted appearance, due to the presence of innumerable closely spaced shallow depressions from 1 to 3 inches in diameter.

Sastrugi also develop on the seasonal snow cover of the coastal zone, but winds of a certain minimum velocity appear to be essential to their formation. Thus areas of relative calm, such as portions of the Oygarden Group at King Edward VIII Gulf, were found to be largely covered by crescent-shaped dunes, from a few inches to some 20 feet in diameter and with a maximum height of some 6 to 9 inches. At this locality, sastrugi were only found in restricted areas of higher than average wind velocity, such as narrow channels in which funnelling effects were produced by the topography.

CREVASSING.

Major belts of crevassing are generally associated either with actual rock exposures or with topographic irregularities such as ice domes and ice ridges, indicating the presence of buried rock ridges close to the present surface of the plateau. Any sudden steepening of the slope of the plateau in the direction of movement is also commonly accompanied by crevassing.

The crevasses fall into several major groups, although all stages of transition and combination are possible. Those of the first type, due to tension alone, generally form at right angles to the direction of movement of the ice and show relatively smooth outlines. They are all much longer than wide, but may apparently be of any size: a few attain a width of more than 20 feet and a length of several hundred yards. This is the only type of major crevasse which is likely to occur on névé surfaces as well as on blue ice (Plate 39).

The second type, due to shear rather than tension, generally occurs in sharply defined belts, which are elongated roughly parallel to the direction of movement of the ice and mark areas of maximum differential movement. Within these belts, the individual crevasses are arranged en echelon with their axes inclined as much as 45 degrees to that of the belt as a whole. The individual crevasses are distinctly sigmoidal and they may be almost as wide as long. The width of individual crevasses of this type rarely exceeds three to four feet, but if they are closely spaced the intervening bridges may collapse, resulting in a compound crevasse which occupies the entire width of the original disturbed belt (Plate 40).

Related to this type, but distinct from it, are occasional areas notably close to the northern flanks of some of the larger rock exposures in the Prince Charles Mountains, which are traversed by a complete network of intersecting cracks from a few inches to 5 or more feet in width. These appear to be largely areas from which the main mass of the ice-sheet is moving away and which are not receiving sufficient local nourishment to replenish this loss. In extreme cases, these cracks and irregularly shaped holes may occupy 30 to 40 per cent. of the disturbed area, which may be several square miles in extent (Plate 41).

Finally, both on névé and on blue-ice surfaces, some areas contain numerous minor cracks, ranging from a fraction of an inch to 3 or 4 inches in width. Some of these grade laterally into areas of more severe crevassing, and the cracks may then be regarded as incipient true crevasses due to movement. Others, however, show no such gradation, and the cracks are then thought to be due to temperature changes or ablation effects which affect the surface layers of the ice only.

As individual crevasses pass out of the zones of active tension or shear they generally become filled with melt-water which later re-freezes. This produces bands of clear ice outlining the shape of the original crevasse, and these preserve their identity by contrast with the air-filled ice surrounding them and can thus frequently be observed in areas far from the original disturbance.

PLATEAU ELEVATIONS AND ICE DRAINAGE INLAND FROM MAWSON.

The general trend of plateau heights has already been discussed.

Between Mawson and the Stinear Nunataks, about 160 miles south-south-east of Mawson, the plateau rises steadily and the drainage is in a general north-north-easterly direction towards the coast (text-figs. 10 and 11). Some typical heights in this area are as follows:—

2,600	feet at	22	miles	from	Mawson.
3,600	,, ,,	48	,,	,,	,,
5,200	,, ,,	90	,,	,,	,,
5,600	,, ,,	120	,,	,,	,,
6,200	,, ,,	160	,,	,,	,,

FIG 10

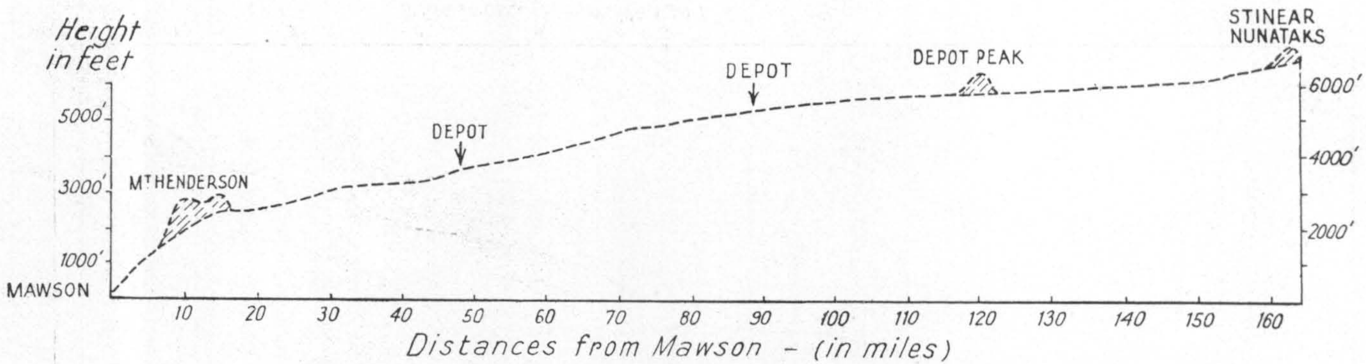
VERTICAL EXAGGERATION = X10

PROFILE : MAWSON TO HENDERSON DEPOT

Bureau of Mineral Resources, Geology & Geophysics · Nov 1957

AN2 -15

FIG. II



VERTICAL EXAGGERATION = X 25

PROFILE : MAWSON TO STINEAR NUNATAKS

Bureau of Mineral Resources, Geology & Geophysics. Nov. 1957 AN2-16 HES

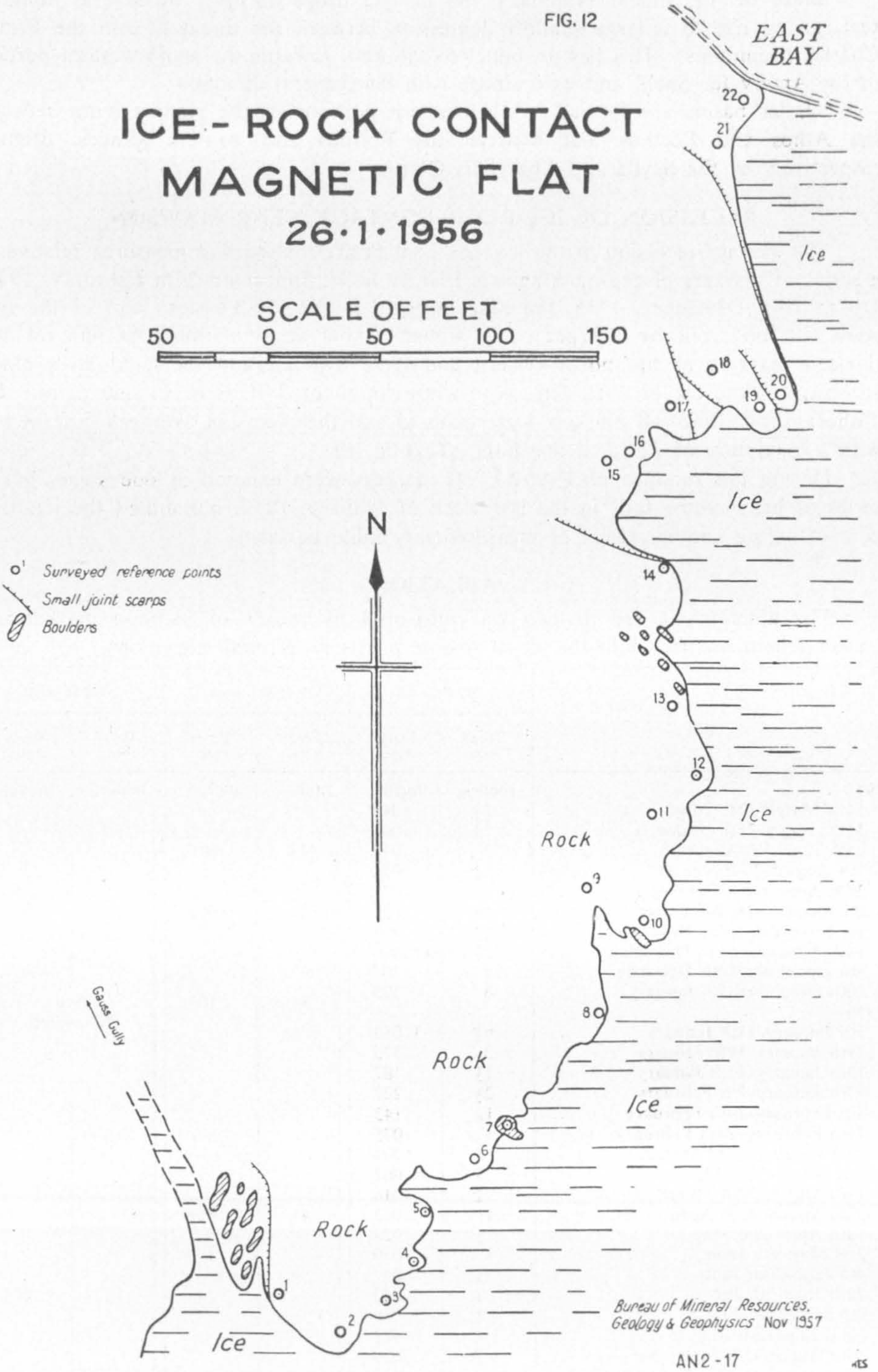


FIG. 12
ICE - ROCK CONTACT
MAGNETIC FLAT
26·1·1956
SCALE OF FEET
50 0 50 100 150
N
Surveyed reference points
Small joint scarps
Boulders
EAST BAY
Ice
Rock
Gauss Gully
Bureau of Mineral Resources,
Geology & Geophysics Nov 1957
AN2-17

South of the Stinear Nunataks, the plateau drops abruptly by several hundred feet, giving rise to a large shallow depression between the nunataks and the Prince Charles Mountains. This has an outlet to the east, towards the south-western portion of the Amery Ice Shelf, and its drainage is in that general direction.

Similar basins are formed by the western portions of the plateau lying between the Athos and Porthos and between the Porthos and Aramis Ranges, drained respectively by the Scylla and Charybdis Glaciers.

RECESSION OF ICE-ROCK CONTACT NEAR MAWSON.

The average recession of the ice-rock contact at Mawson was measured relative to a series of markers placed on Magnetic Flat by B. H. Stinear on 25th February, 1955. Up to 20th December, 1955, the nine markers at the south-eastern end of the line were still obscured by the preceding winter's snow accumulation, but nine of the thirteen markers at the north-western end were exposed and indicated an average recession of the ice of 2 ft. 6in., with a maximum of 7 ft. 6 in. at one point. By 26th January, 1956, all markers were exposed and the recession averaged 7 ft. 8 in., with a maximum of 22 ft. at one point (Text-fig. 12).

During the summer of 1956-57, all markers were exposed at one stage, but a series of heavy snow falls in the last week of January, 1957, obliterated the ice-rock contact before another series of measurements could be taken.

ABLATION.

The ablation on the plateau was measured by means of bamboo markers of known length, inserted into the ice at several points at different elevations.

—	200 ft. a.s.l.		1,400 ft. a.s.l.		2,000 ft. a.s.l.	
	Total loss.	Daily rate.	Total loss.	Daily rate.	Total loss.	Daily rate.
1955—	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
16th March–15th May	2½	.042	..	..		
15th May–25th June	1¼	.031				
25th June–7th August	1	.023	1½	.014		
7th August–30th August	¾	.032				
30th August–8th October	1	.025				
8th October–1st November ..	1¼	.054	2¼	.025		
1st November–14th November ..	¾	.054				
14th November–7th December ..	2¼ estimated					
8th December–20th December ..	2	.167				
20th December–5th January ..	6	.375				
1956—			3½	.103	Not Measured	
5th January–11th January	6½	1.083				
11th January–19th January ..	3	.375				
19th January–27th January ..	1½	.187				
27th January–7th February ..	2½	.227				
7th February–14th February ..	1¼	.143				
14th February–24th February ..	1	.075				
24th February–3rd March.. ..	¾	.094				
3rd March–11th March	½	.062				
11th March–27th March	¾	.046				
27th March–15th April	1	.053	4½	.019		
15th April–2nd May	½	.029				
2nd May–4th June	1	.030				
4th June–20th June	¾	.047				
20th June–9th July	¼	.013			1½	.009
9th July–22nd July	¼	.019				
22nd July–15th August	½	.021				
15th August–5th September ..	½	.024				
5th September–15th September ..	½	.050				

	200 ft. a.s.l.		1,400 ft. a.s.l.		2,000 ft. a.s.l.	
— —	Total loss.	Daily rate.	Total loss.	Daily rate.	Total loss.	Daily rate.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
15th September–12th October ..	½	.019				
12th October–3rd November ..	1	.045				
3rd November–19th November ..	1	.062				
19th November–29th November ..	1	.100	Not Measured			
29th November–8th December ..	1	.111			4	.027
8th December–20th December ..	5½	.458				
20th December–1st January ..	4	.333				
1957—						
1st January–12th February ..	Not Measured					

For the period June, 1955, to June, 1956, the total ablation at 200 feet above sea level thus amounts to 36 inches of ice, equivalent to 32 inches or 81 cm. of water. Of this amount, just over one-half was lost in the seven weeks from 20th December to 7th February. At 1,400 feet above sea level, the loss for the twelve months was 10½ inches of ice, equivalent to 9½ inches or 24 cm. of water. At 2,000 feet above sea level, observations do not quite cover a twelve-month period, but a slight extrapolation gives a value of 6 inches of ice, equivalent to 5½ inches or 14 cm. of water, for the year.

By assuming that the ablation changes uniformly between each pair of points for which measurements have been made, it is possible to derive an approximate value for the mean ablation for the whole zone between 0 and 16 miles from the coast. This value works out at 12.4 inches of ice per year, equivalent to 11.2 inches or 28.3 cm. of water.

The seasonal changes in the ablation rate and the decrease of ablation with altitude brought out by these figures do not reveal any unexpected features. The actual amount of ablation, on the other hand, appears to be considerably higher than that recorded from comparable localities elsewhere in the Antarctic. The German Antarctic Expedition (1901-1903) recorded ablation of 4 cm. in five winter months in the vicinity of Gaussberg (Phillippi, 1907). In Adélie Land, the Expéditions Polaires Françaises 1951-52 found ablation of 40 cm. between mid-December and mid-July at the coast; 13 cm. between late February and late November at 40 metres; 17 cm. between late January and early December at 100 metres and 15 cm. for the year at 450 metres above sea level (Loewe, 1956a). Each of these values is about half of those obtained at Mawson.

The height of the firn line, where the annual accumulation and ablation are equal, is about 2,400 feet at Mawson, compared with 500 metres (about 1,650 feet) in Adélie Land (Loewe, 1956a). Most other expeditions, such as the Norwegian-British-Swedish Expedition (1949-52) and the British and American parties in the Ross Sea area (Scott, Shackleton, Byrd, &c.) have been based on shelf ice where accumulation predominates over ablation right down to sea level.

HORIZONTAL MOVEMENT.

The horizontal movement of the plateau ice was measured by means of two series of markers set out along surveyed lines, each about 3 miles long, and laid out as nearly as possible at right angles to the direction of movement of the ice at that point. One of these extended from the west flank of Mount Henderson towards Mount Parsons in the David Range, about 8 miles from the coast, and the other extended eastwards along an azimuth of 94° 25′ from the south-eastern extremity of the outcrop on which the Henderson Depot is situated, about 10 miles from the coast (Text-fig. 13).

MARKERS WEST OF MOUNT HENDERSON.

Distance from west face of mountain in yards.	23rd May–30th August, 1955.		30th August–7th December, 1955.		7th December–27th January, 1956.		27th January–21st September, 1956.	
	Total movement.	Daily rate.	Total movement.	Daily rate.	Total movement.	Daily rate.	Total movement.	Daily rate.
	ft. in.	inches.	ft. in.	inches.	ft. in.	inches.	ft. in.	inches.
240 ..	0 8	0.08	1 4	0.16	..	..	..	..
390 ..	1 9	0.21	2 3	0.27	2 6	0 59	5 10	0.29
550 ..	5 0	0.60	5 1	0.61	2 5	0.58	12 6	0.63
1,225 ..	..	..	10 3	1.23	4 9	1.12	24 8	1.24
1,950 ..	..	..	11 9	1.41	5 2	1.21	28 6	1.44
2,700 ..	..	..	11 10	1.42	5 3	1.22	30 4	1.53
3,300 ..	..	..	12 2	1.46	5 0	1.18	29 5	1.48
4,350 ..	..	..	13 5	1.61	5 10	1.37	32 10	1.66
5,000 ..	..	..	14 9	1.77	6 4	1.49	36 3	1.83

MARKERS EAST OF MOUNT HENDERSON.

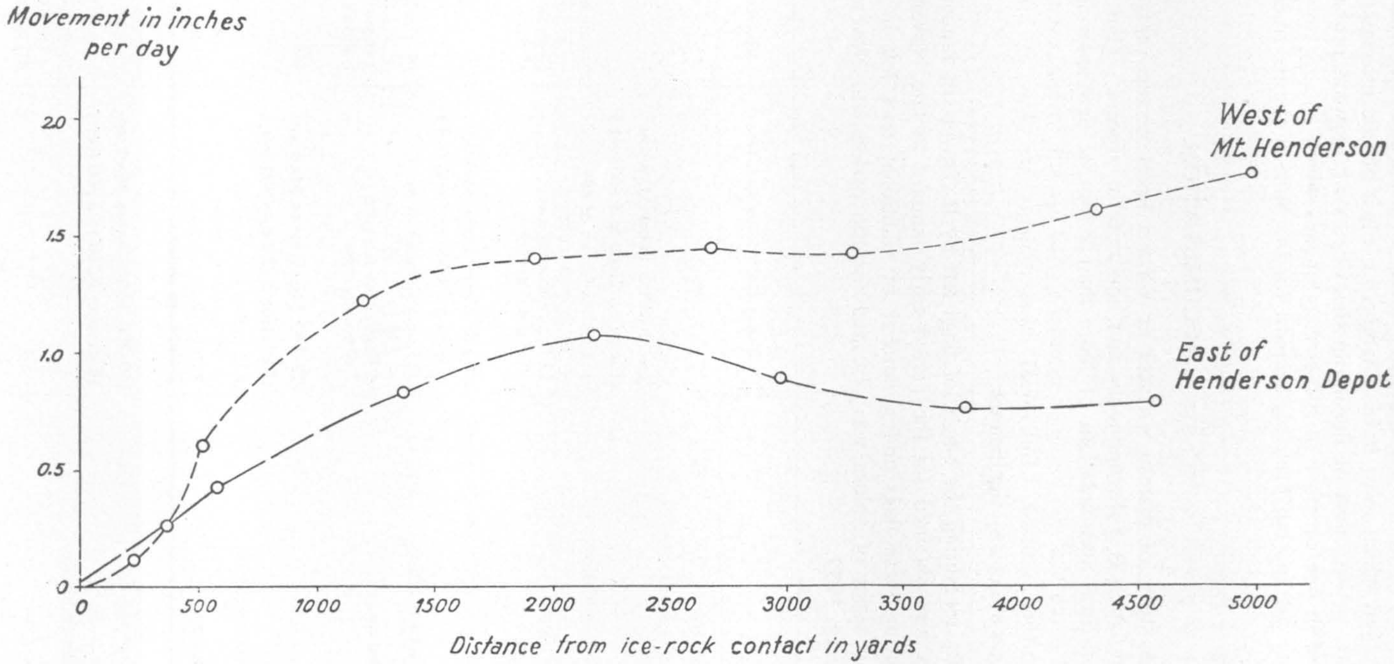
Distance from ice-rock contact in yards.	27th March–20th September, 1956.	
	Total movement.	Daily rate.
	ft. in.	inches.
600	6 4	0.43
1,400	12 7	0.85
2,200	16 1	1.09
3,000	13 4	0.90
3,800	11 5	0.77
4,600	11 10	0.80

The main trend apparent from these figures is, as would be expected, the marked reduction of movement in the ½-mile zone immediately adjoining the ice-rock contact.

The maximum rate of movement revealed by these measurements is of the order of 1¾ inches per day or just over 50 feet per year. This is less than the velocity of 30 cm. per day (350 feet per year) recorded by the German Antarctic Expedition from Gaussberg (Drygalski, 1906), but rather greater than that of 0.20 to 0.80 metres per month (8 to 32 feet per year) recorded by the Expéditions Polaires Françaises from Adélie Land (Perroud, 1952). All other measurements of rates of movement of Antarctic ice appear to have been made on defined glaciers or ice streams and are therefore not comparable with these results.

FIG. 13

SPEED PROFILES



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The low speeds in this area are undoubtedly due partly to the fact that measurements could only be made in the vicinity of rock outcrops which serve as reference points, but which must have a hampering effect on the movement of the ice in their vicinity. Also, most of the ice in the vicinity of Mawson probably finds its way to the sea in one or other of the glacier tongues which occupy only a small proportion of the coastline but probably account for the bulk of the ice transfer.

ACCUMULATION.

A study of plateau surfaces at various times of the year showed clearly that accumulation is a discontinuous and non-uniform process. Thus it is not uncommon to find local accumulations of more than a foot of new snow in areas where occasional patches of the previous summer's crust are still visible, even on level, apparently undisturbed ground. Individual measurements are thus of little value, and only averages are of any significance.

By measuring the height of flags left by R. Dovers in January, 1955, a series of values was obtained for the period early January to late November, 1955. By re-measuring these flags and a number of additional ones left in November, 1955, a second series of values was obtained for the period late November, 1955, to early February, 1957.

—	January, 1955–November, 1955.	November, 1955–February, 1957.
	16–50 Miles from Mawson. (Elevation 2,400 to 3,600 feet.)	
Mean accumulation	4.1 inches (mean of 18) ..	6.4 inches (mean of 18)
Range	+ 19 to − 5 inches	+ 27 to − 8 inches
Distribution	12 flags show increase .. 6 show decrease	13 show increase 5 show decrease
	50–120 Miles from Mawson. (Elevation 3,600 to 5,600 feet.)	
Mean accumulation	7.5 inches (mean of 8) ..	14.1 inches (mean of 4)
Range	+ 18½ to − 4½ inches ..	+ 21½ to − 2 inches
Distribution	6 flags show increase .. 2 show decrease	3 show increase 1 shows decrease
	120–160 Miles from Mawson. (Elevation 5,600 to 6,200 feet.)	
Mean accumulation	8.2 inches (mean of 9) ..	17.2 inches (mean of 6)
Range	+ 20 inches to zero	+ 25 to + 6½ inches
Distribution	7 flags show increase .. 2 show no change	All flags show increase
	160–200 Miles from Mawson. (Elevation 6,200 to 5,300 feet.)	
Mean accumulation	.. ..	20.9 inches (mean of 7)
Range	.. ..	+ 40 to + 5 inches
Distribution	.. ..	All flags show increase

Observations on the outward and homeward journeys during the 1956-1957 summer season indicated that, in this particular year, about 4 inches of the net accumulation between 16 and 50 miles and 5 inches of that between 50 and 200 miles were deposited in the summer months (late November to early February), mostly during a series of exceptionally heavy snow-falls during the last week of January, 1957, just before the final measurements of heights were made.

Averaging the values for the two-year period January, 1955, to early February, 1957, and assuming a mean specific gravity of 0.45, we thus arrive at the following annual figures:—

—	Snow.	Water equivalents.
	Inches.	
16–50 miles	5.2	2.3 inches (5.8 cm.)
50–120 miles	10.8	4.9 inches (12.4 cm.)
120–160 miles	12.7	5.7 inches (14.5 cm.)
160–200 miles	15.9 (extrapolated)	7.2 inches (18.3 cm.)
Average 16–200 miles	11.3	5.1 inches (13.0 cm.)

The period of observation is insufficient to establish the annual variation or the extent to which these values may be regarded as typical, but the measurements appear to indicate an accumulation somewhat below that recorded from most other parts of Antarctica. The following values may be used for comparison:—

Snow Hill Island—30 cm. snow (Nordenskjold, 1909).
Little America III—31 in. snow (Howard, 1948).
Ross Barrier—7½ in. water (Wright & Priestley, 1922).
Adélie Land—20-30 cm. water (Loewe, 1956a).
Queen Mary Land—60-75 cm. water (Shumsky, 1956).
Maudheim—36 cm. water (Schytt, 1953).

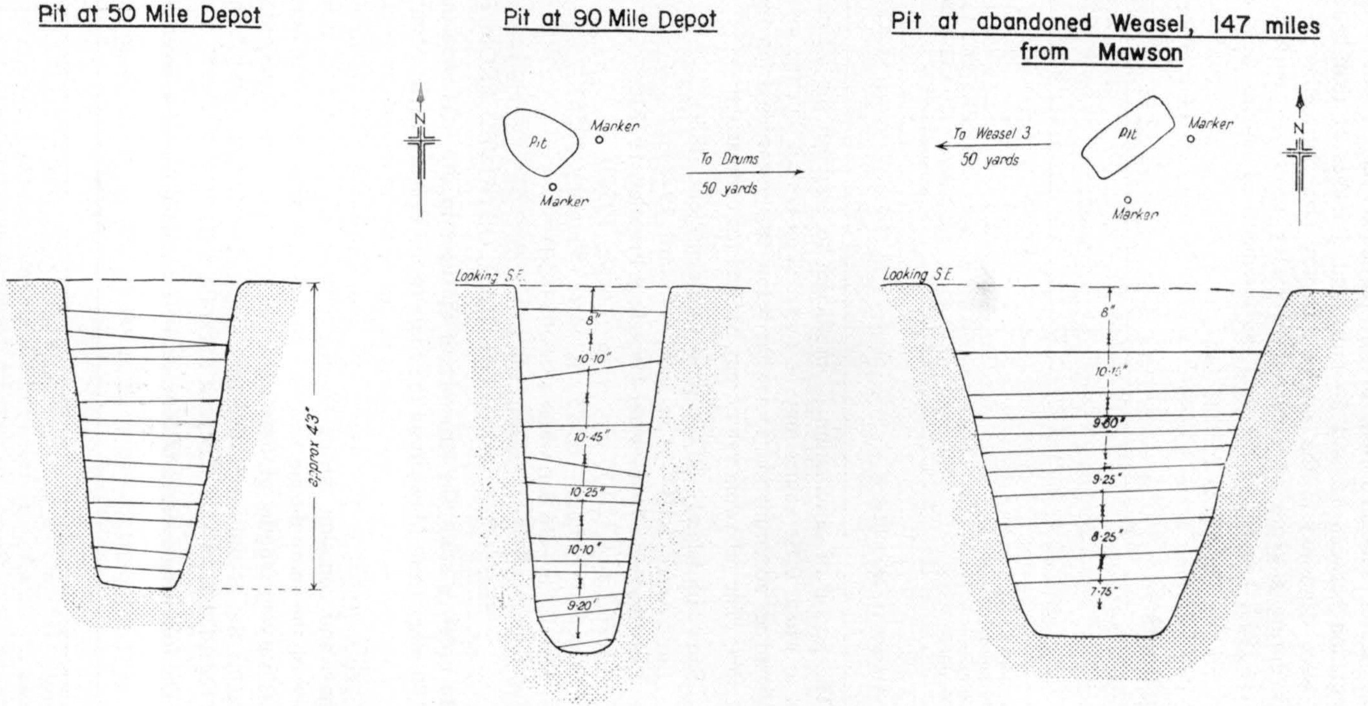
SECTIONS THROUGH NÉVÉ, OBTAINED FROM PITS.

In order to study the structure of the névé in situ, pits were dug at 50, 90, 147, and 180 miles from Mawson on the route to the Prince Charles Mountains. In each of these, a layered structure was apparent, due to the development of glazed crusts, which are readily visible to the naked eye and which are also apparent by their greater hardness and cohesion during digging. These are regarded as being formed on the surface of the snow during exposure to sun and wind, and their unequal development reflects varying lengths of time until the next layer was deposited. Each layer thus represents the accumulation due to a single snow-fall or blizzard, but is not normally to be regarded as an annual deposit (Text-fig. 14).

The following average thicknesses were obtained for these layers:—

—	Average.	Thickest Individual layer.
50 miles	3.9 inches (mean of 12)	9 inches
90 miles	5.0 inches (mean of 12)	12 inches
147 miles	4.9 inches (mean of 10)	9 inches
180 miles	4.1 inches (mean of 17)	9 inches.

SECTIONS THROUGH PITS IN NÉVÉ



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AN2-19

In each case, one or two of the layers could be seen to lens out in the sides of the pit, and a few others show dips of up to 10 degrees, emphasizing their irregular nature.

The crusts themselves do not consist of true ice layers, but merely of slightly welded and interlocking grains of névé, supporting the earlier conclusion that no actual melting occurs as far inland as the 50-mile Depot, even in mid-summer.

Two of the pits (at 90 and 147 miles) were also prepared for compaction measurements in future years by inserting bamboo splinters in the walls. The depths shown in Text-fig. 14 are measured from the top of one splinter to the top of the next.

Another pit was dug to a depth of 4 feet 8 inches at a point about 8 miles south of the head of the Nemesis Glacier, at an estimated altitude of 7,000 feet. No large-scale layering could be detected in this pit, but there is a suggestion of laminations with an average thickness of one-eighth of an inch, and some of these are cross-bedded, with dips of 5 to 10°. This difference is believed to be due to the influence of the Baseline Nunataks, some 2 miles south of this point, although the actual lee drifts associated with these peaks do not extend closer than three-quarters of a mile from this pit.

GRAIN-SIZE.

The average grain-size of névé from the plateau surface is of the order of one sixty-fourth of an inch (0.4 mm.). This was found to increase slightly with depth in the various pits, but random variations between the layers tend to obscure the trend. The most marked increase was noted in the pit 50 miles from Mawson, where an average grain-size of about one thirty-second of an inch (0.8 mm.) was reached at a depth of 4 feet. This was presumably due to more active recrystallization at this locality, due to warmer temperatures than occur farther inland.

For comparison, the following figures for average grain-size at other Antarctic localities may be quoted:—

Little America III.—1.0 to 1.5 mm. at 18 to 33 feet (Howard, 1948).
Adélie Land—0.5 to 1.0 mm. at 1 to 10 metres (Loewe, 1956a).
Maudheim—0.5 sq. mm. at 5 metres, 10 sq. mm. at 100 metres (Schytt, 1953).

DENSITY.

The specific gravity of several névé samples from the plateau surface ranged from 0.43 to 0.45, and a sample from a wind-packed drift of recent snow on Mawson Rock gave a value of 0.43. By comparison, two samples from the pit 90 miles inland gave specific gravities of 0.46 from 3 feet and 0.47 from 4 feet. These differences suggest a continuous increase of density with depth, but are hardly conclusive.

Only once could the density of a layer of freshly fallen snow before compaction by wind be measured; a specific gravity of 0.15 was obtained near Mount Bechervaise during the last week of January, 1957. However, after three days of winds from 50 to 60 miles per hour, much of this layer had been removed by drift and the remainder had been packed to the consistency of typical névé, so dense that a man walking on it in ordinary boots left prints less than half an inch in depth.

The following measurements of specific gravity from other Antarctic localities may be used for comparison:—

Little America III—0.404-0.416 from 18 ft.; 0.419-0.432 from 23 ft.: 0.542-0.548 from 28 ft.; 0.531-0.542 from 33 ft. (Howard, 1948).

Adélie Land—0.40-0.41 on surface at coast (maximum 0.53); 0.34-0.54 on surface inland (mean 0.43) (Loewe, 1956a).

Maudheim—0.50 on surface; 0.80 at 55 metres (Schytt, 1953).

NÉVÉ TEMPERATURES.

Loewe (1956a and b) has shown that temperatures taken in névé at a depth of 5 metres will be within about 2 Centigrade degrees of the mean annual surface temperature at that point, and that this difference is reduced to less than 0.5 degrees at 10 metres.

The greatest depth that could be conveniently attained during the 1955-1957 operations in MacRobertson Land was between 10 and 12 feet (3.3 to 4.0 metres). The following results were obtained in November, 1955 (Text-fig. 15):—

Distance from Mawson.	Elevation.		Depth.	Exposure. time.	Snow temperature.	Air temperature.
	Feet.	Metres.				
			Feet.	Hours.	Degrees C.	Degrees C.
50 miles	3,600	1,080	12	12	−23.6	−6
68 miles	4,400	1,320	10	12	−27.0	−21
90 miles	5,200	1,560	10	12	−29.5	−22
115 miles	5,600	1,680	12	36	−29.0	−15
130 miles	5,900	1,770	12	12	−29.6	−19

This compares with results previously obtained in MacRobertson Land (Loewe, 1956c)—

Height (metres) ..	820	1320	1580	1710	1850	2080
Temp. (degrees C.)	—20.8	—25.2	—27.2	—28.2	—30.6	—31.0

in Adélie Land (Loewe, 1956a)—

Height (metres) ..	755	1185	1545	1945
Temp. (degrees C.)	—19.2	—23.9	—28.1	—33.8

and in Dronning Maud Land (Holtzscherer and Robin, 1954)—

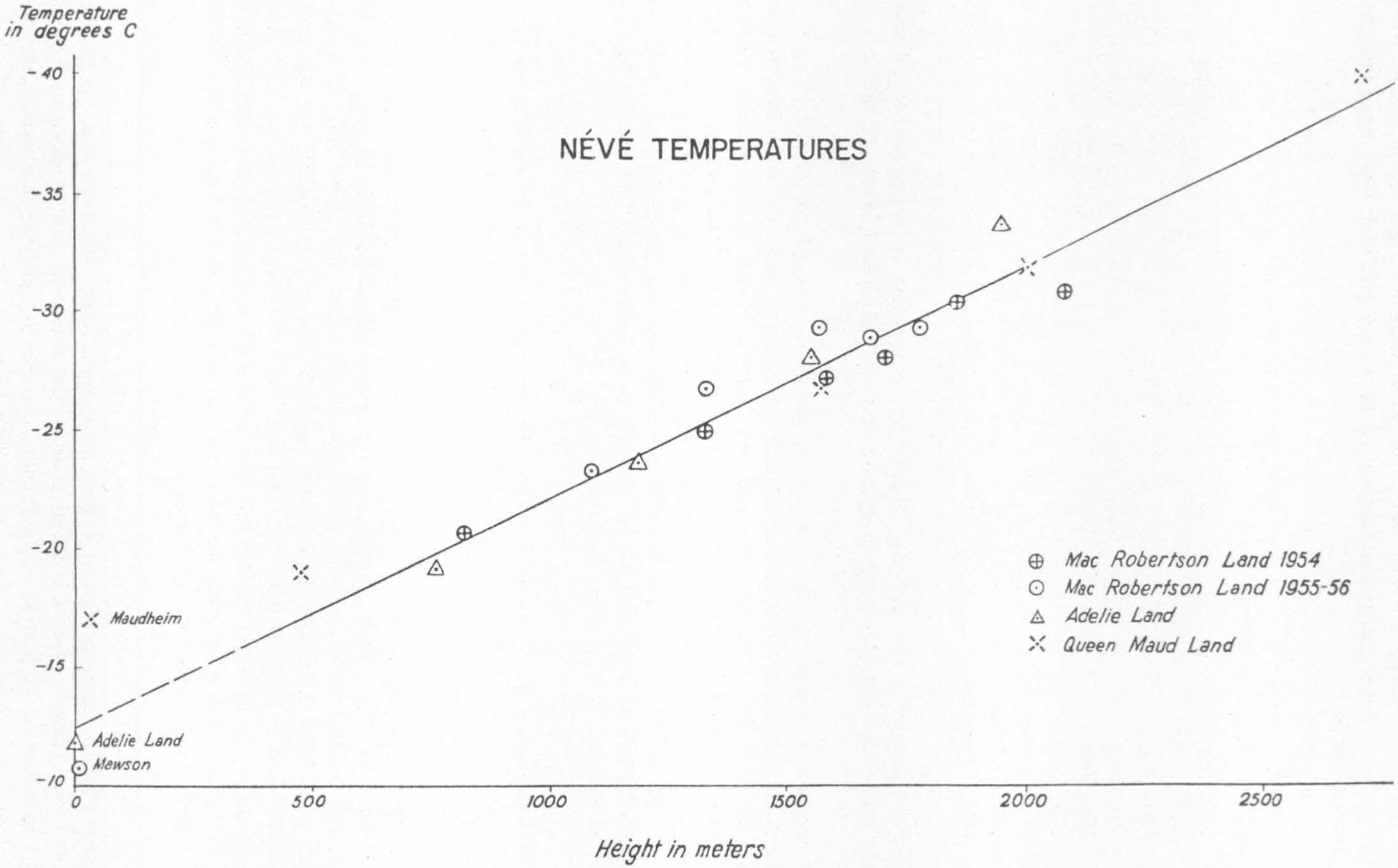
Height (metres) ..	37	480	1575	2000	2710
Temp. (degrees C.) ..	—17	—19	—27	—32	—40

SEA ICE.

1955.—In a normal year, the open sea at Mawson is frozen over from late March or early April until late December or early January, and the sea ice reaches a maximum thickness of about 5 feet in late September or early October.

In 1955, Horseshoe Harbour was completely frozen over on 4th March, and the sea just outside the harbour on 16th March. No open water remained in any of the tide-cracks after early April, and the ice gradually began to ride up over the beach, locally to a height of 6 to 8 feet above water level. Old leads also formed lines of weakness, even after repeated freezing, and the new ice tended to be thrust up over the old ice along them.

FIG 15



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In the immediate vicinity of Mawson, the snow cover generally was only an inch or two thick, and large areas of bare ice were exposed right through the winter. In other areas, however, drifts and sastrugi up to 3 or 4 feet high were not uncommon from July onwards.

The following thicknesses of ice were measured at a point about a quarter of a mile north of the tip of West Arm:—

20th March	3 inches
3rd April	15 ,,
27th April	27 ,,
5th June	20 ,,
15th July	39 ,,
27th August	54 ,,
25th September	60 ,,
20th October	57½ ,,
14th December	52½ ,,

These thicknesses are probably slightly less than those in areas farther off-shore, because long-shore currents tend to abrade and melt the basal layers of the ice.

Open water began to show again in the tide-cracks from the first week in December, and at the same time the ice itself became soft and extensively waterlogged. Open water was first seen on the north-west horizon, some 15 miles from Mawson, about 20th December. The nearer ice then proceeded to break out gradually, until, on 18th January, only the ice in Horseshoe Harbour and in the channels between some of the nearer islands was left (Plate 42, fig. 1). At the same time, wide belts of pack were still visible between 10 and 20 miles from shore. Horseshoe Harbour itself was entirely free from ice by 25th January, 1956.

1956.—During the autumn of 1956, the formation of sea ice was considerably delayed by a series of heavy gales which swept the coast around Mawson in late March, April, and early May.

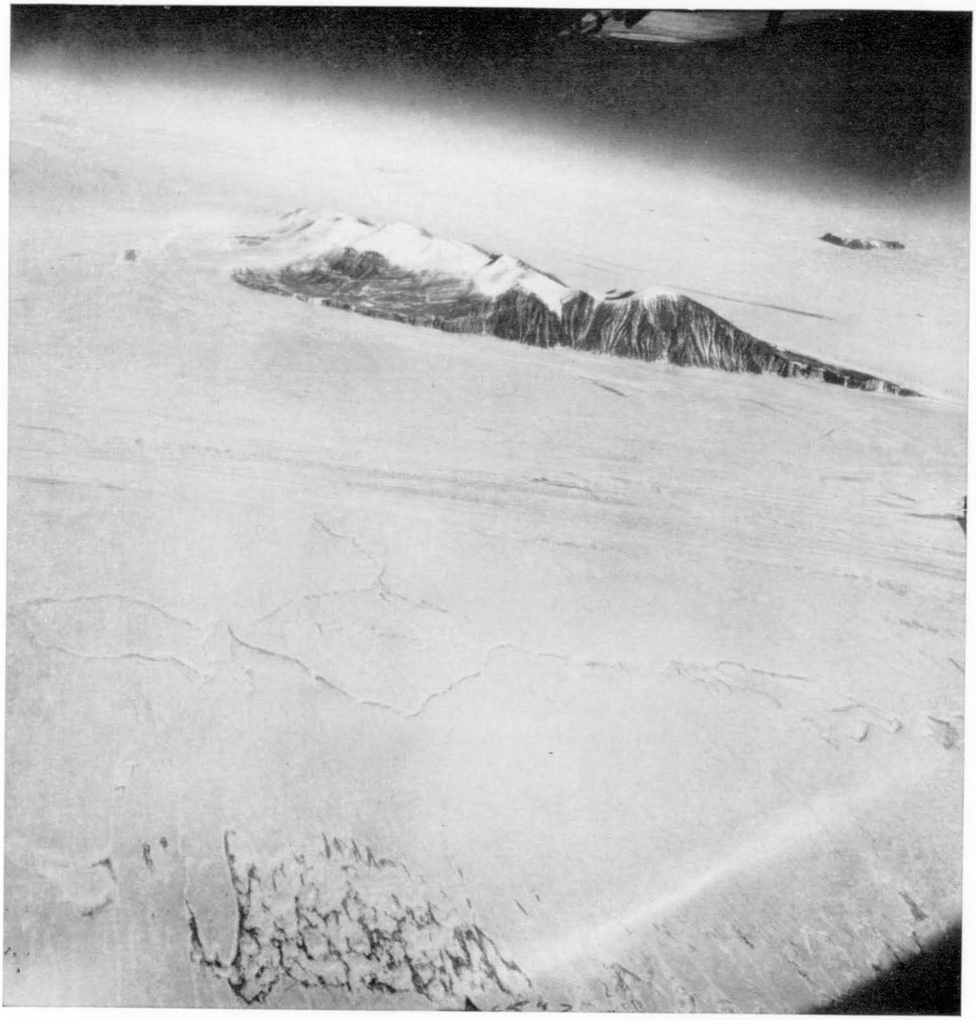
Local accumulations of thin ice were first noticed in sheltered areas on 14th March, but were completely swept away by strong winds on 18th March. By 25th March, this ice had re-formed to a thickness of 11 inches at a point 300 yards north of the tip of West Arm, but a break-out on 29th March removed all but the ice in the harbour and in parts of East Bay. Similar break-outs also occurred on 12th April, 29th April, and 13th May. After this last break-out, open water extended from the tip of West Arm to the northern horizon and reached the coast at points approximately 2 miles east and 5 miles west of Mawson.

On 22nd May, another partial break-out affected the ice which had re-formed in the interval, and again produced a tongue of open water between the tip of West Arm and Flat Islands. Local areas of open water were also noticed close to the coast about a mile east of the Station. The thickness within the harbour meanwhile continued to increase and had reached 36 inches on 27th May.

Tongue of Dovers Glacier, Stefansson Bay.

Junction of Wilma and Robert Glaciers, looking north. King Edward VIII Gulf area.

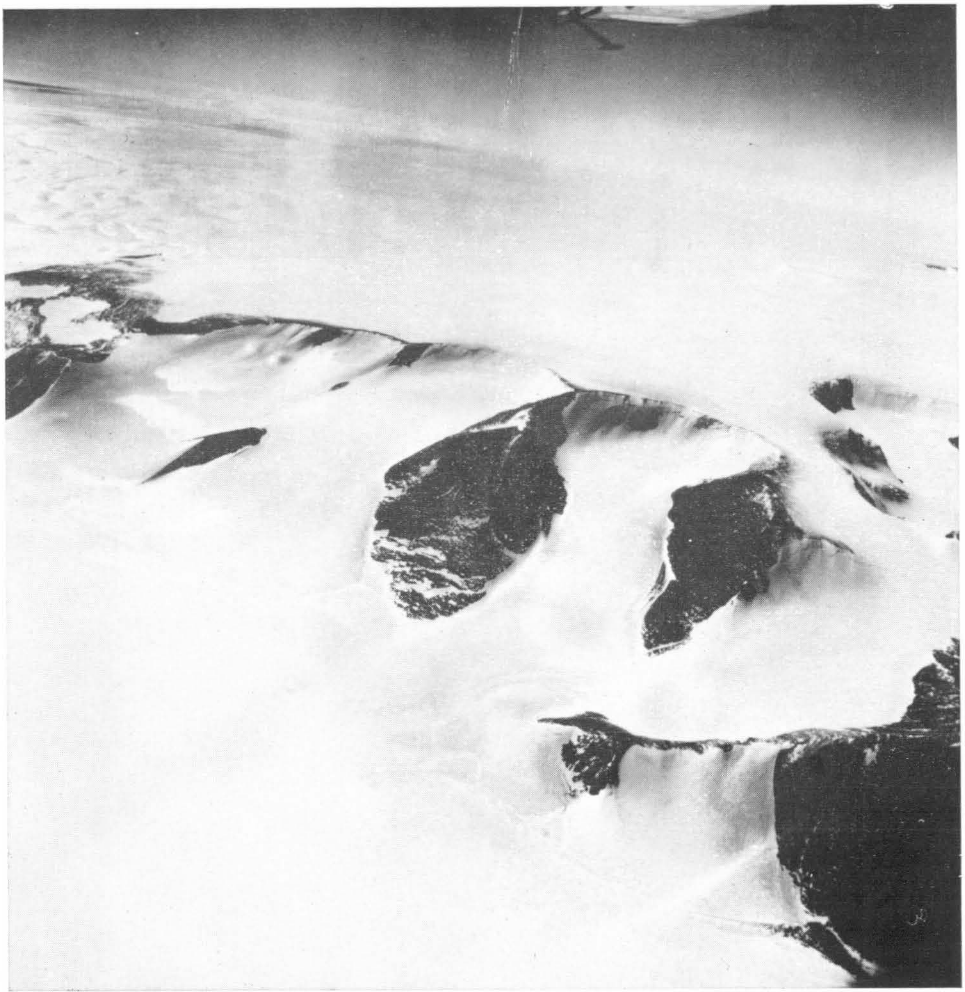
Western boundary of Amery Ice Shelf.



Clemence Massif, on east flank of Lambert Glacier, vicinity 71° 45′ south. 68° 30′ east.

Outcrops on west flank of Lambert Glacier. Vicinity 71° 30′ south, 67° 30′ east.

Tributary glacier on east flank of Lambert Glacier, flowing through gap in Mawson Escarpment.



Cirques, east flank of Lambert Glacier. (Portion of Mawson Escarpment.)

Fig. 1.—Melt-water stream on north flank of Aramis Range.

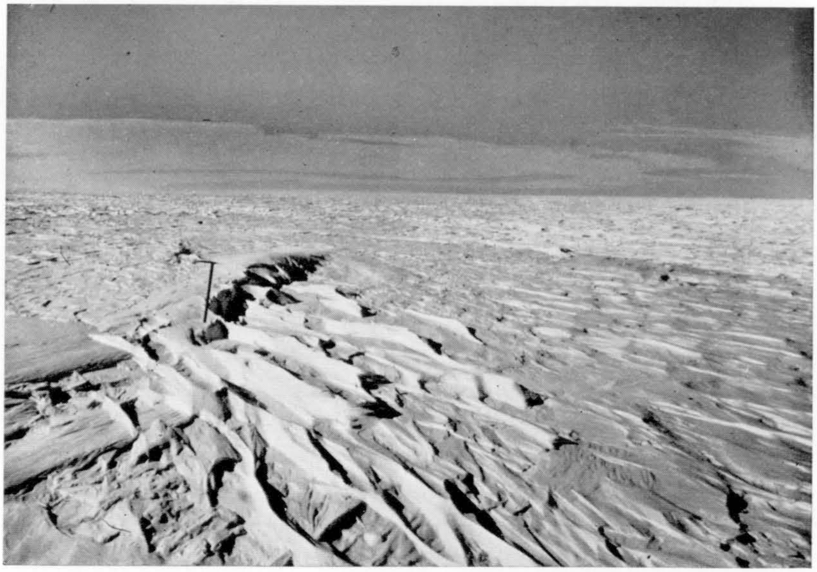


Fig. 2.—Sastrugi. Vicinity of 90-mile Depot.

Crevasse Pattern. Enderby Land, near head of Robert Glacier. Looking north.

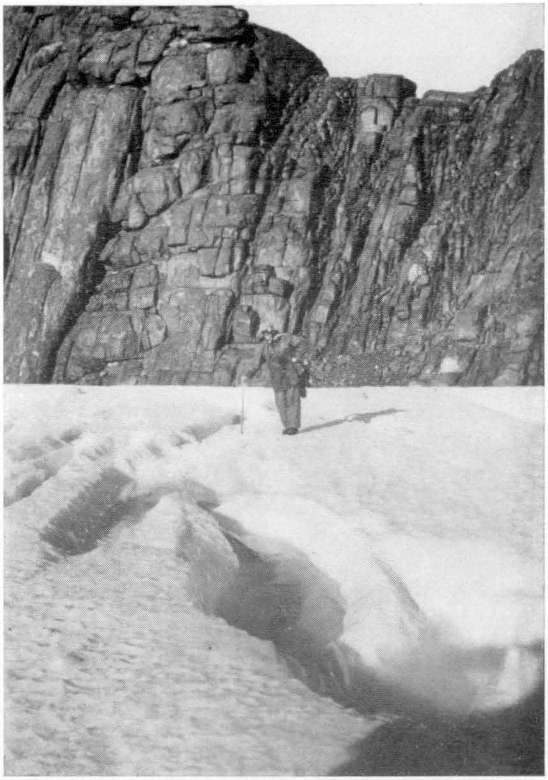
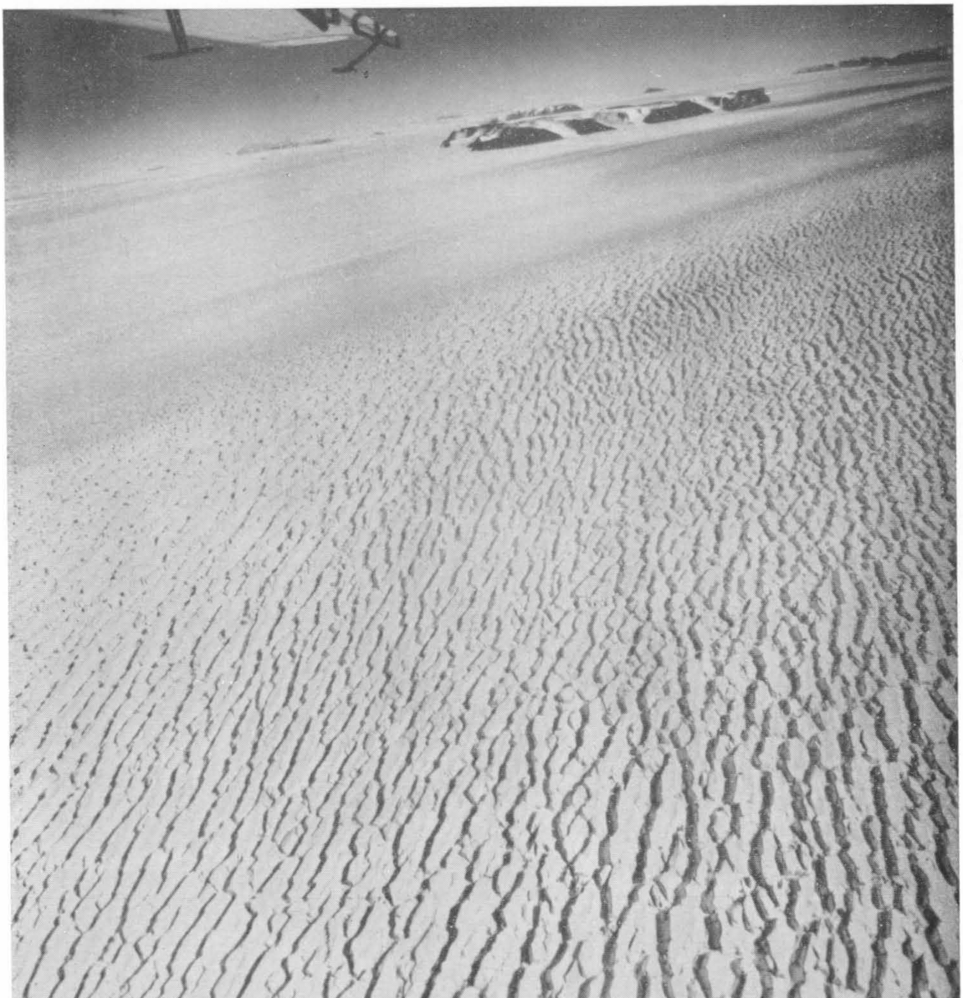


Fig. 1.—Crevassing in blue ice on flank of Masson Range.

Fig. 2.—Weasel 5 in crevasse about five miles south-east of Henderson Depot.



Crevasse patterns. Lambert Glacier.

Fig. 1.—Sea ice breaking up. Horseshoe Harbour, looking towards West Arm.

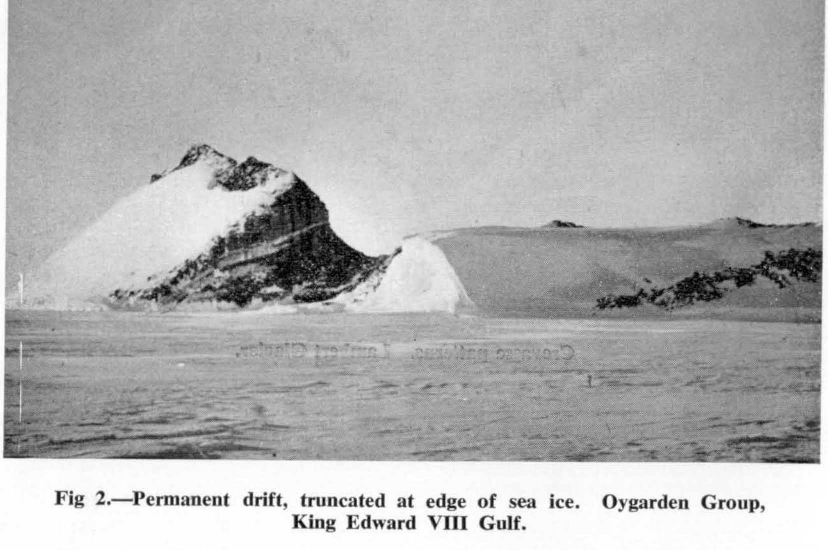


Fig 2.—Permanent drift, truncated at edge of sea ice. Oygarden Group, King Edward VIII Gulf.

From then on, the development of the ice followed the pattern of the previous two years, and the following thicknesses were measured at a point about 250 yards north of the tip of West Arm:—

6th June	15 inches
20th June	25 ,,
9th July	28 ,,
22nd July	33 ,,
15th August	38½ ,,
5th September	43 ,,
17th September	46 ,,
12th October	46 ,,
3rd November	42½ ,,
17th November	38 ,,
29th November	30 ,,

The maximum thickness reached this year was thus about one foot less than that observed in 1955.

The snow cover in 1956, as in 1955, was generally not more than an inch or two near Mawson, but drifts and sastrugi up to 3 or 4 feet high were noted in other areas, such as Stefansson Bay and King Edward VIII Gulf, especially after mid-winter.

One other important result of these early break-outs was the presence of several areas in which the earlier-formed floes had been severely rafted, tilted, and twisted before being re-cemented by younger ice. Two small areas of this type were situated to the south of Flat Islands and to the north-east of Tongue Rock, and another very much larger one extended from about 2 miles east of Einstoding Islands to the mainland in the south and to the Jelbart Glacier Tongue in the west.

Around Keel Island, visited in May, 1956, old bay ice could be seen in several places, much of it at least 3 feet above the level of the current season's ice, and therefore probably not less than 20 or 25 feet thick. This was especially noticeable near the emperor penguin rookery in the channel between Fold Island and Transverse Island, about 2 miles north of Keel Island, and in some of the inlets extending into the mainland, some 2 to 3 miles south-east of Keel Island.

In the Oygarden Group, visited about the same time, a number of lee drifts, extending from rocky bluffs on several of the larger islands, were abruptly truncated at the junction of the sea ice with the permanent ice-foot. Many of these drifts were composed entirely of blue ice, and had probably been built out on to semi-permanent sea ice over a period of many years, and truncated by a fairly recent break-out probably during the preceding summer (Plate 42, fig. 2).

Towards the end of the year, the deterioration of the ice again began with the development of lines of weakness and the appearance of open water in tide-cracks, starting in the last week of November. By the first week of January, the ice was no longer safe to walk on, and the final break-up occurred about a fortnight after this date. On 22nd January, Horseshoe Harbour and the adjoining sea were entirely clear of ice for the first time.

During the year, conditions out to sea were reported on a number of occasions by members of the R.A.A.F. Antarctic Flight as follows:—

16th July: Reconnaissance flight 80 miles north of Mawson at altitude 10,000 feet revealed no open water anywhere.

1st August: Open water from Cape Borley to a point about 10 miles east of Proclamation Island.

18th September: Open water from Magnet Bay to a point midway between Mount Biscoe and Proclamation Island.

20th September: Open water from Magnet Bay to a point about 15 miles east of Mount Biscoe.

25th September: Patches of open water in Mackenzie Bay and between Cape Darnley and Scullin Monolith.

10th October: Large areas of open water about 40 miles due north of Mawson.

11th October: Open water from a point 25 miles north of the mouth of Amundsen Bay to coast at Mount Biscoe, thence to coast at Magnet Bay, thence to a point 30 miles north of the Oygarden Group.

12th October: Large areas of open water in Prydz Bay and between Cape Darnley and Scullin Monolith.

24th November: Fast ice extending for 22 miles north of Mawson with heavy pack for about 200 miles beyond this.

4th January: Fast ice and heavy pack extending for a total distance of 90 miles north of Mawson.

MASS ECONOMY OF PLATEAU.

Between Mawson and the Stinear Nunataks, the total annual accumulation of névé on a strip 1 foot wide, running at right angles to the coast, is:

Length of strip in accumulation zone $\times$ mean accumulation $\times$ specific gravity.
$= 145 \times 5{,}280 \times 11.3/12 \times 62.5 \times 0.45$ lb.
$=$ 9,000 tons approximately.

The corresponding ablation will be:

Length of strip in ablation zone $\times$ mean ablation $\times$ specific gravity.
$= 16 \times 5{,}280 \times 12.4/12 \times 62.5 \times 0.90$ lb.
$=$ 2,200 tons approximately.

If the ice-cap is in equilibrium, the difference between these quantities, amounting to about 7,000 tons of ice per year per foot of coastline, would be accounted for by calving from glacier tongues and coastal ice cliffs.

The amount of ice passing across every foot of the measured speed profiles on the flanks of Mount Henderson can also be estimated by assuming an average thickness for the ice in this vicinity. Ignoring the measurements obtained within half a mile of the ice-rock contact, the average velocity of the western profile is 1.43 inches per day or 44 feet per year, and that of the eastern profile is 0.88 inches per day or 27 feet per year. The average ice thickness, from a consideration of the general topography in the vicinity, is expected to be of the order of 1,000 feet for the western line, corresponding to a bedrock elevation of about 400 feet above sea level, and 1,500 feet for the eastern profile, corresponding to a bedrock elevation of about 500 feet above sea level.

The quantity of ice passing across every foot of these profiles is, therefore:

Average thickness $\times$ mean speed $\times$ specific gravity.

$= 1{,}000 \times 44 \times 62.5 \times 0.90$ lb.

$= 1{,}100$ tons approximately for the western line.

And: $1{,}500 \times 27 \times 62.5 \times 0.90$ lb.

$= 1{,}000$ tons approximately for the eastern line.

These amounts are insufficient to account for the removal of all the névé being deposited inland, and even a doubling of the assumed ice thicknesses would not overcome the discrepancy. There may, however, be two explanations for this anomaly. Either something like 85 per cent. of all the ice reaching the coast near Mawson must do so as part of one of the fast-moving ice streams, such as the Forbes, Jelbart, and Taylor Glaciers, as suggested in a previous section; or the ice-cap is not in equilibrium and is actually being built up at the present time, as has been suggested by Loewe (1956a), on the basis of similar observations in Adélie Land. A great deal of additional work will be required to decide which of these alternatives is applicable in this area.

TEMPERATURE DISTRIBUTION IN THE INTERIOR OF THE ICE-SHEET AND HEAT ECONOMY OF PLATEAU.

The geothermal heat flux passing into the ice-sheet from the underlying rock is assumed to have a value similar to that observed in other parts of the earth's surface, i.e., about 40 calories per sq. cm. per year or 1.25×10^{-6} calories per sq. cm. per second.

The temperature gradient which must be maintained within the ice-sheet to permit this amount of heat to be conducted through it to the surface is:

heat flux/conductivity.

$= 1.25 \times 10^{-6}/0.005$.

$= 1°$ C. per 40 metres or per 130 feet approximately.

If no other factors are involved, the temperature of the ice-sheet will thus be below freezing throughout unless its thickness exceeds 3,000 feet at 50 miles inland (surface temperature —23.6° C., elevation 3,600 feet), or 3,850 feet at 130 miles inland (surface temperature —29.6° C., elevation 5,900 feet).

If at any point the temperature gradient is insufficient to allow the removal of the whole of the heat conducted across the rock-ice interface, the amount of resultant melting can be calculated. Thus, if one-half of this heat is used in melting the basal layers of the ice-sheet, this thickness is given by:

$\frac{1}{2} \times$ heat flux/(latent heat $\times$ specific gravity).

$= \frac{1}{2} \times 40/80 \times 0.90$.

$= 0.28$ cm. per year.

This is insignificant by comparison with the amount of accumulation and ablation taking place in the same period at the upper surface of the ice-sheet.

Heat is also absorbed within the ice-sheet, because the névé deposited at any point in the accumulation zone has a temperature equal to the mean annual air temperature at that altitude, whereas the ice lost by ablation and calving in the coastal zone has a temperature approximating to the mean annual air temperature at sea level. The difference is equal to the difference in height multiplied by the mean free air temperature gradient of approximately 1° C. per 100 metres.

This is partly counterbalanced by the fact that the potential energy liberated during this descent is also largely converted into heat.

The potential energy liberated by the descent of 1 gm. of ice for 100 metres is given by—

$$980 \times 100 \text{ ergs}$$
$$= 0.98 \text{ joules}$$

If this were entirely converted into heat, the resultant rise in temperature would be given by—

$$0.98/4.2 \times 1/ \text{ specific heat}$$
$$= 0.98/4.2 \times 1/0.5$$
$$= 0.46^\circ \text{ C.}$$

Actually, some of this heat will be absorbed by recrystallization, so that the resultant rise in temperature will be even smaller.

There is thus an overall heat deficiency within the ice-sheet, which will have to be balanced by the absorption of some of the heat transmitted across the rock-ice contact, and which will result in a reduction of the vertical temperature gradient within the ice-sheet.

A complication is introduced, however, by the fact that this generation of heat by friction is not distributed uniformly throughout the ice-sheet. Most of it will be concentrated in a comparatively thin layer near the base of the ice-sheet, and, to a first approximation, the amount generated at any one point will be proportional to the velocity at that point. According to Bull (1957) this is given by—

$2.4 \times k \times L$ calories per sq. cm. per year,

where: k = yield stress in bars = 1 approximately

and: L = lateral movement in metres per year.

This means that with velocities of the order of those observed at Mount Henderson (15 metres per year), the heat contributed from this source amounts to 36 calories per sq. cm. per year, or the same order of magnitude as the geothermal heat flux. In some of the major ice-streams, such as the Lambert Glacier, on the other hand, with possible speeds of several hundred metres per year, the heat received from this source may be as much as twenty times the geothermal heat flux. Similar conclusions have been obtained by Robin (1955) and Loewe (1956a).

ACKNOWLEDGMENTS.

In addition to personal observations, this Bulletin embodies the results of much team-work for which it is difficult to assign individual credit. The author is indebted to all members of the 1955 and 1956 A.N.A.R.E. parties, who contributed directly or indirectly to the success of the exploration programme. However, he would like to acknowledge specifically the assistance of the surveyors, Messrs. R. H. Lacey and S. L. Kirkby, who carried out the surveys for measuring the lateral movements of the ice and who provided many other basic data. The pilots of the R.A.A.F. Antarctic Flight, Squadron Leader D. Leckie and Pilot Officer John Seaton, also made available much valuable information from reconnaissance and photo flights, including flight logs with radar and pressure altimeter records, which made it possible to compute plateau heights in otherwise inaccessible areas.

The author is also indebted to the Officers-in-charge, Messrs. J. Bechervaise and W. Bewsher, and to the Director of the Antarctic Division, Mr. P. G. Law, for much encouragement and many valuable suggestions.

Finally, he wishes to record the part played in this work by the dogs of the Expedition, notably Butch, Mac, and Dee, who proved wonderful companions as well as fine working animals.

Since his return to Australia, he has benefited from extensive discussions on geological aspects with colleagues at the Bureau of Mineral Resources, the Geology Department of Melbourne University and the C.S.I.R.O. Mineragraphic Section. Dr. F. Loewe of the Melbourne University Meteorology Department and Dr. G. de Q. Robin of the Scott Polar Research Institute, formerly of the Australian National University, have been referred to for a number of discussions on glaciological problems. However, with the exception of a number of contributions on the opaque minerals, radioactive minerals, coal and recent organic matter, all of which are specifically acknowledged in the text, all laboratory work was carried out by the author himself and all conclusions are his own responsibility.

The photographs are produced in part from the author's Kodachrome transparencies and in part from trimetrogon photographs of the R.A.A.F. Antarctic Flight.

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PLATE 2

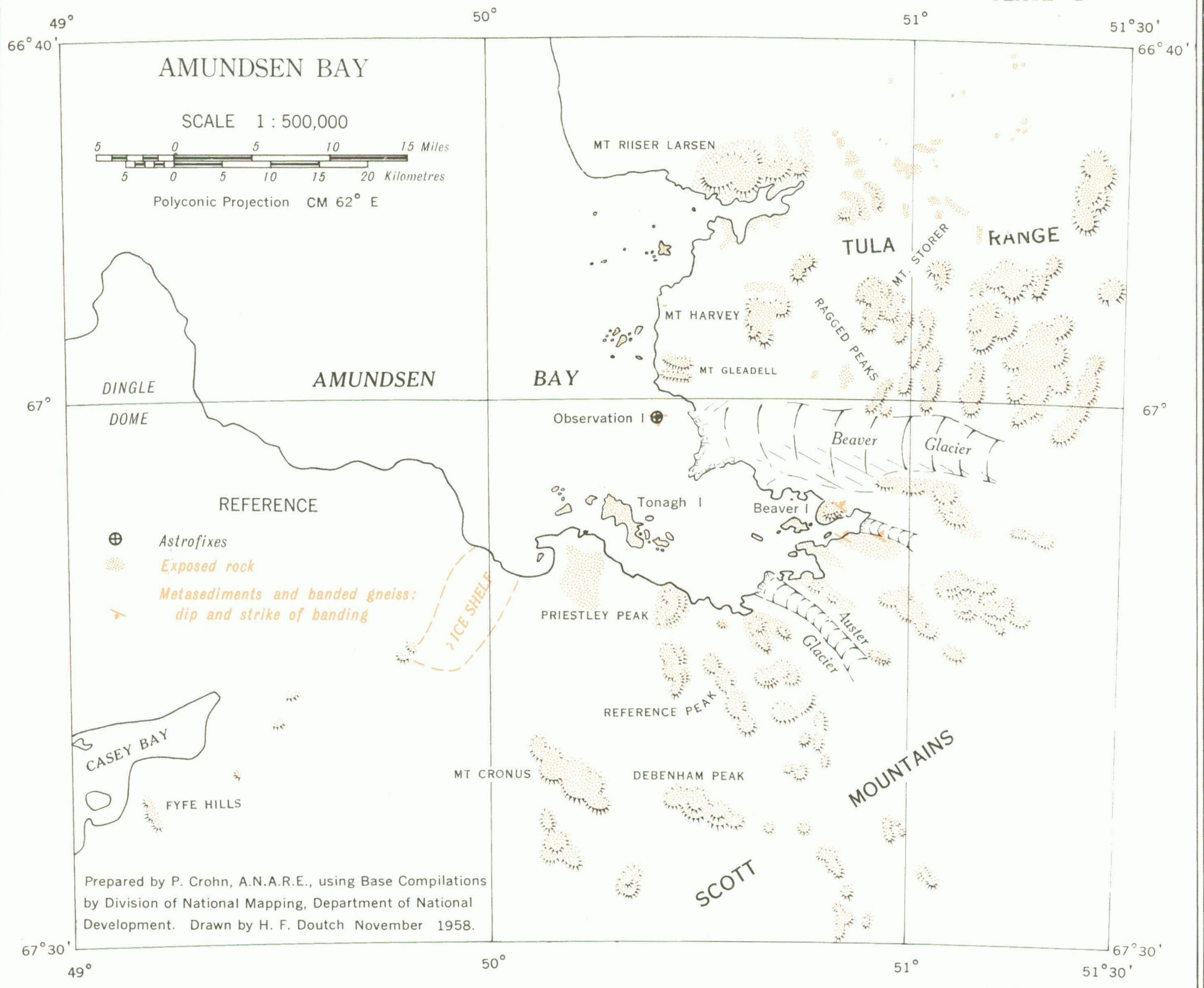

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PLATE 3
KING EDWARD VIII GULF TO MAWSON
SCALE 1 : 500,000
Miles
Kilometres
Altitudes in Metres
Polyconic projection CM 62° E
Prepared by P. W. Crohn, A.N.A.R.E.,
using maps of the Lars Christensen Expedition 1936-37, and Base Compilations to
September 1958 by Division of National Mapping, Department of National Development.
Drawn by H. F. Doutch.
REFERENCE
Ice form lines
Astrofixes
Metasediments and banded gneiss:
dip and strike of banding
vertical banding
variable dip & strike (structural)
Exposed rock
Charnockitic granite
Radioactive anomaly
INSET A
Oygarden Group
INSET B
William Scoresby Archipelago
INSET C
Colbeck Archipelago
INSET D
Insets based on maps of Lars Christensen Expedition.
SCALE 1 : 250,000
KING EDWARD VIII GULF
KING EDWARD PLATEAU
KING EDWARD ICE SHELF
Cape Gotley
Martin I
Georges Is
Cape Dalton
Abrupt Pt.
Oygarden Group
See Inset A
KVARS PROMONTORY
KVARS BAY
ROUND BAY
GWYNN BAY
STACK BAY
EAST STACK
Mule Pt.
Broka I
Havstein I
Kring Is
LONG SOUND
Hoseason Glacier
LAW PROMONTORY
Blackrock Head
Law Is
SVART MT
CIRQUE FJORD
STEFANSSON BAY
See Inset B
WILLIAM SCORESBY BAY
Tillet Is
Dales I
Warnock Is
Endresen Is
Hobbs Is
TILLEY BAY
TILLEY NUNATAK
Dovers Glacier
Scoble Glacier
See Inset C
Taylor Glacier
Jelbart Glacier
Einstoding Is
Stanton Group
Oldham I
Tongue Rock
Low Tongue
Douglas Is
Child Rocks
Robinson Group
Lars Anderson I
Thorgaut I
Safety I
Cape Daly
See Inset D
HOLME BAY
MAWSON
Forbes Glacier
MT HENDERSON
Western Speed Profile
Eastern Speed Profile
MT PARSONS
MT WARD
MT ELLIOTT
MT COATES
CASEY RANGE
DAVID RANGE
MASSON RANGE
RUSSELL NUNATAK
MCNAIR NUNATAK
FRAMNES MOUNTAINS
MT HORDERN
MT TRITOPPEN
MT TWINTOP
PEARCE PK
BAILLIEU PK
MILL PK
Southern Route
50 Mile Depot
Wilma Glacier
Robert Glacier
Seaton Glacier
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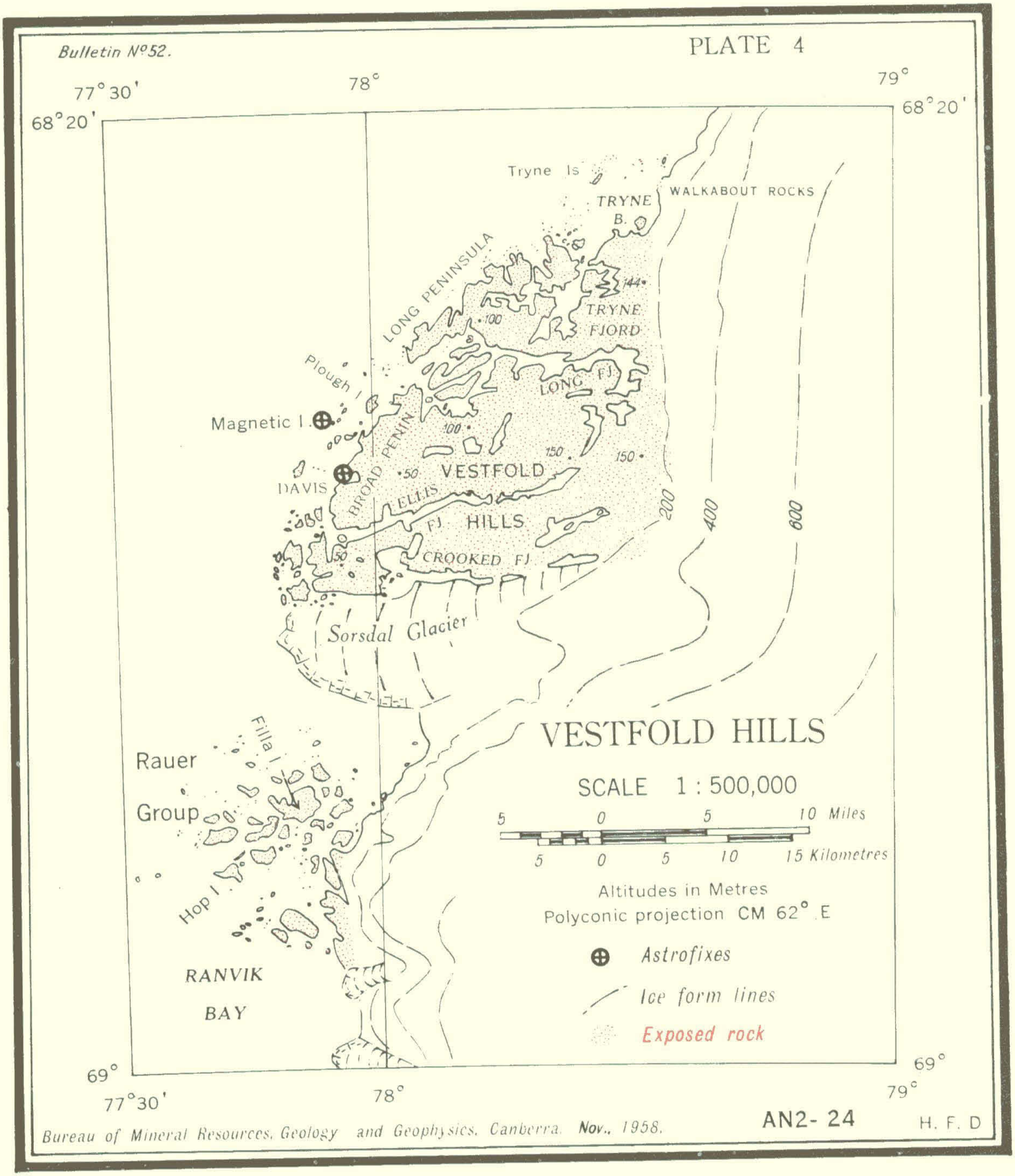
Bulletin Nº52.
PLATE 4
77° 30'
78°
79°
68°20'
68°20'
Tryne Is
TRYNE
B.
WALKABOUT ROCKS
LONG PENINSULA
144
TRYNE
FJORD
100
Plough I
LONG FJ.
Magnetic I.
100
BROAD PENIN
150
150
DAVIS
50
VESTFOLD
ELLIS
FJ.
HILLS
200
400
600
50
CROOKED FJ.
Sorsdal Glacier
Filla I
Rauer
Group
Hop I
RANVIK
BAY
VESTFOLD HILLS
SCALE 1 : 500,000
5 0 5 10 Miles
5 0 5 10 15 Kilometres
Altitudes in Metres
Polyconic projection CM 62° E
Astrofixes
Ice form lines
Exposed rock
69°
77°30'
78°
69°
79°
Bureau of Mineral Resources, Geology and Geophysics, Canberra. Nov., 1958.
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H. F. D

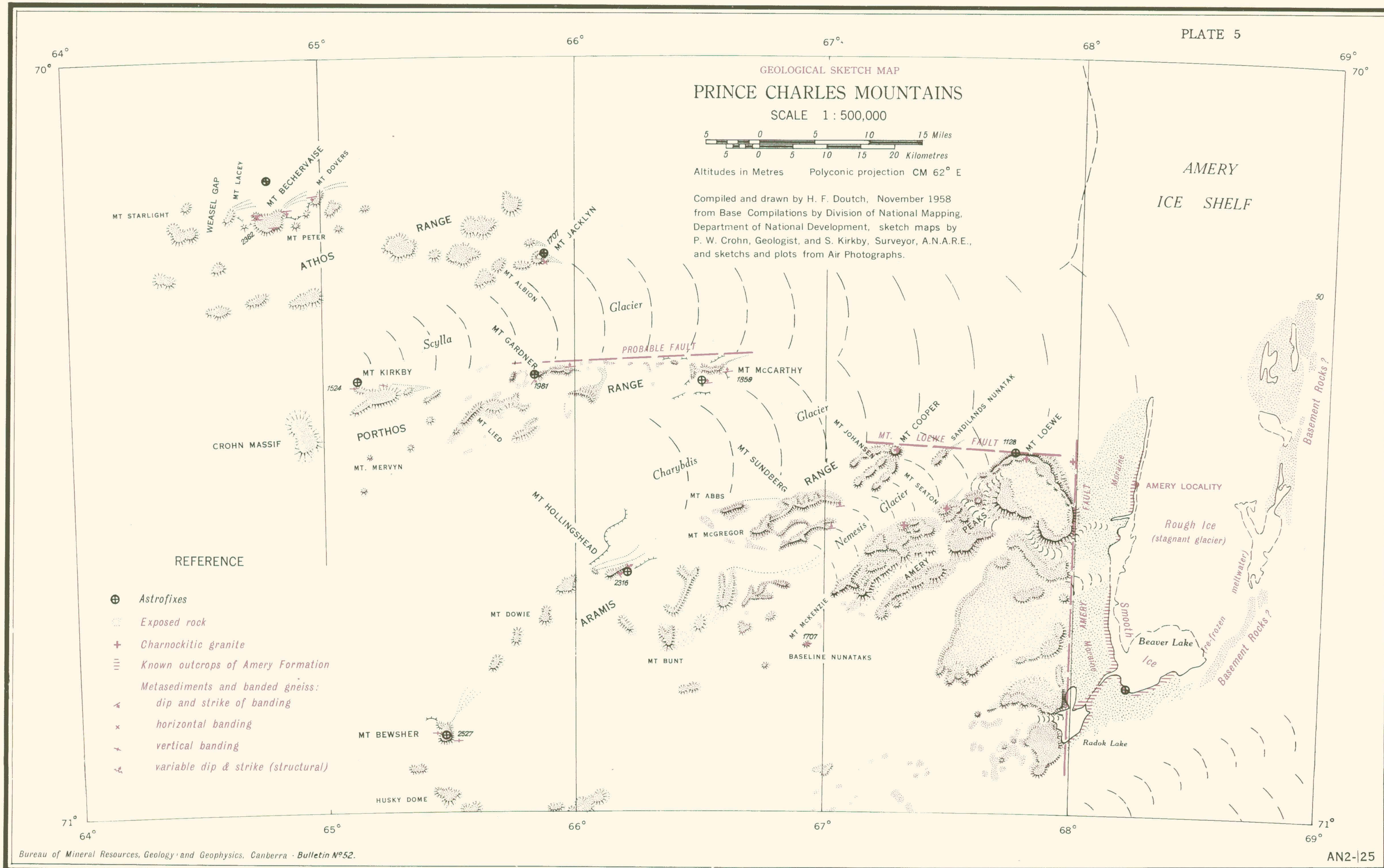

PLATE 5
GEOLOGICAL SKETCH MAP
PRINCE CHARLES MOUNTAINS
SCALE 1 : 500,000
5 0 5 10 15 Miles
5 0 5 10 15 20 Kilometres
Altitudes in Metres
Polyconic projection CM 62° E
Compiled and drawn by H. F. Doutch, November 1958 from Base Compilations by Division of National Mapping, Department of National Development, sketch maps by P. W. Crohn, Geologist, and S. Kirkby, Surveyor, A.N.A.R.E., and sketchs and plots from Air Photographs.
AMERY ICE SHELF
MT STARLIGHT
WEASEL GAP
MT LACEY
MT BECHERVAISE
MT DOVERS
2362
MT PETER
ATHOS RANGE
1707
MT JACKLYN
MT ALBION
Glacier
Scylla
MT GARDNER
PROBABLE FAULT
MT KIRKBY
1524
1981
RANGE
MT McCARTHY
1859
PORTHOS
MT LIED
CROHN MASSIF
MT. MERVYN
Glacier
MT JOHANSEN
MT COOPER
SANDILANDS NUNATAK
MT. LOEWE FAULT
1128
MT LOEWE
Charybdis
MT SUNDBERG
RANGE
MT ABBS
MT SEATON
Glacier
PEAKS
AMERY LOCALITY
Moraine
FAULT
Rough Ice
(stagnant glacier)
MT HOLLINGSHEAD
MT McGREGOR
Nemesis
AMERY
2316
ARAMIS
MT DOWIE
MT McKENZIE
1707
BASELINE NUNATAKS
MT BUNT
AMERY
Moraine
Smooth Ice
Beaver Lake
re-frozen
meltwater)
Basement Rocks ?
Basement Rocks ?
50
Radok Lake
MT BEWSHER
2527
HUSKY DOME
REFERENCE
Astrofixes
Exposed rock
Charnockitic granite
Known outcrops of Amery Formation
Metasediments and banded gneiss:
dip and strike of banding
horizontal banding
vertical banding
variable dip & strike (structural)
64° 65° 66° 67° 68° 69°
70° 71°
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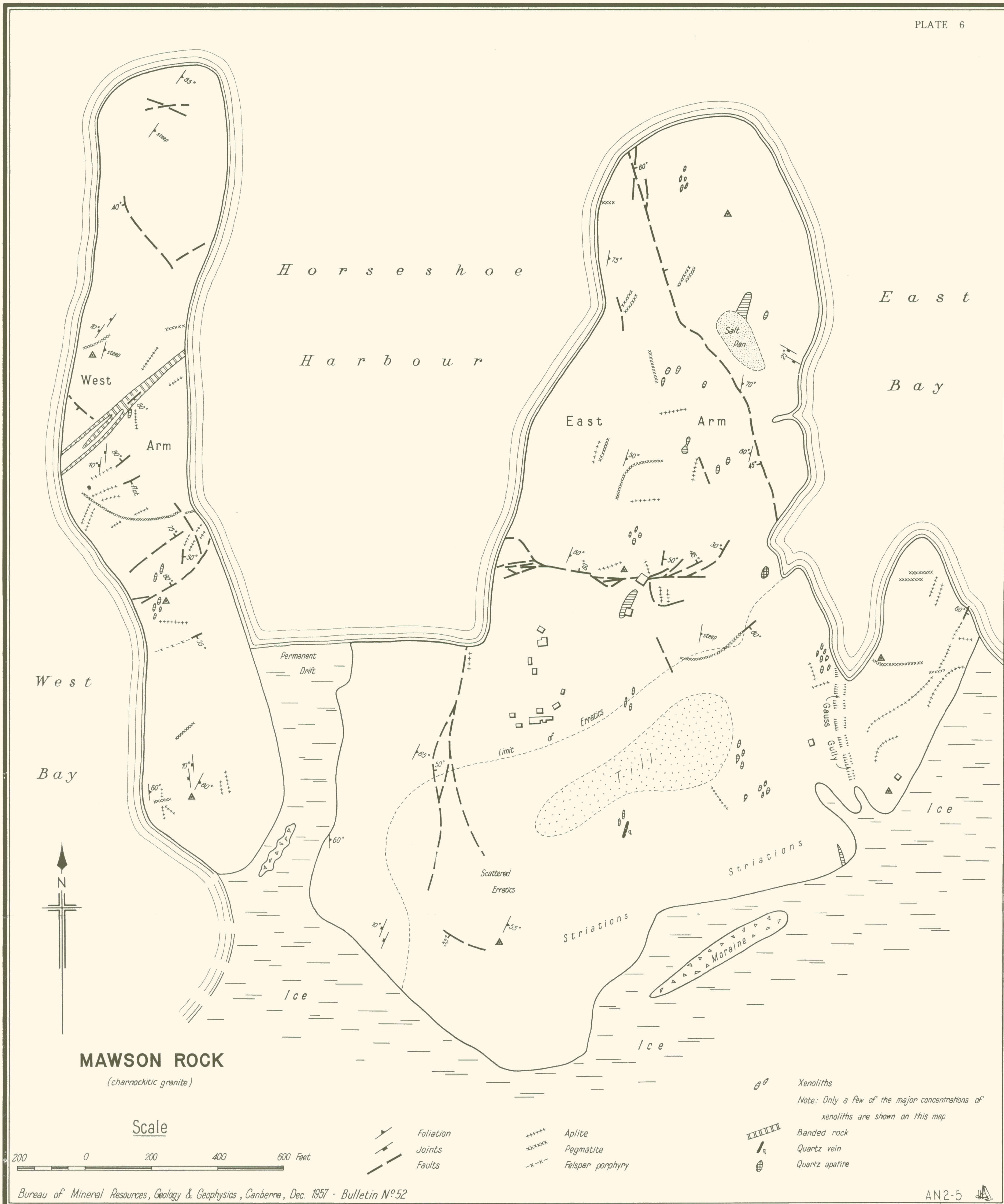

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