AGSO

EARLY GEOLOGICAL RESEARCH IN ANTARCTICA: THE SOUTHERN PRINCE CHARLES MOUNTAINS 1958 TO 1962

EDITED BY

D. THOST

RECORD 1996/27

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GEOLOGICAL SURVEY
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The southern Prince Charles Mountains 1958 to 1962

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DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

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Contents

INTRODUCTION TO THE COLLECTION OF EARLY BMR RECORDS

This Record is essentially a re-issue of three early BMR Records describing fieldwork undertaken in the southern Prince Charles Mountains (sPCM). The Records of McLeod (1959) and Ruker (1963) have been edited to present only their observations from the sPCM. The original "summary" from each record is included, and this gives an indication of the other areas visited, and extra studies carried out, which are not relevant to the sPCM work. Apart from the occasional comment added as a footnote or in square brackets, editorial changes were generally confined to correcting typos, and the metrification of distances, heights, and temperatures.

The rationale behind this re-issue is that the Australian Antarctic Division is planning to re-visit the sPCM for the first time in 20 years, and much of this very early work never progressed past the "Record" stage: essentially unpublished and inaccessible to aspiring workers in the region. While this compilation is also a record, our ability to run off more than a few copies will make it more available to those who are interested.

While much of this early work presents little detailed scientific information to the specialist in metamorphic petrology, structural geology or geomorphology, it describes the areas visited and interesting features, and is of significant historical interest. For example, Ian McLeod was the first to observe the tidal nature of Beaver Lake. Parts of the text will sound very familiar to those who have been fortunate enough to visit any part of Antarctica: David Trail notes that:

> *"In any wind, note-taking is difficult, and through the day the geologist normally makes very brief notes, which are expanded in the shelter and warmth of the tent in the evening. The examination of samples by hand lens in the field is very difficult, since the lens almost always becomes coated with ice."*

Some things never change. His acknowledgements are probably unique in the personal debt he pays to the dogs - a moving reminder of an era in the history of Antarctic exploration that we will probably never see again. I somehow doubt that modern field geologists will bond with their "Quads" with such emotion! The acknowledgements have been retained more for their historical interest than for anything else: in many instances, they mention the people after which the mounts, nunantaks and glaciers of the region have been named.

The Records are of use in noting who has been where, when. Although not mentioned in the text, all you mountaineer types should note that David Trail, David Keyser and Jim Seavers made the first ascent of Mt Menzies, the highest mountain in this sector of Australian Antarctic Territory, on the 19th of December, 1961. They left their camp at about 1pm, arrived near the summit just before midnight (David Trail was the only one to actually summit), and returned to the camp at 5am on the 20th. Route descriptions across the Fisher Glacier by Ruker and Trail may be of considerable interest to those contemplating a similar trip using Quads.

It was not possible, or necessary, to reproduce all the figures included in the original records. In places, the text has been supplemented with oblique aerial photographs. The original records and figures are available for inspection at the AGSO library, and can also be re-ordered from the AGSO Sales Office. The results of more detailed geological work undertaken during the summers of 1972-74 are reported by Tingey & England (1973), England & Langworthy (1975), and Tingey et al. (1981).

I hope this compilation will prove of some use not only to those who are contemplating a trip to the sPCM, but also to those with an interest in the history of this spectacular regions' early exploration.

Doug Thost
September 1996

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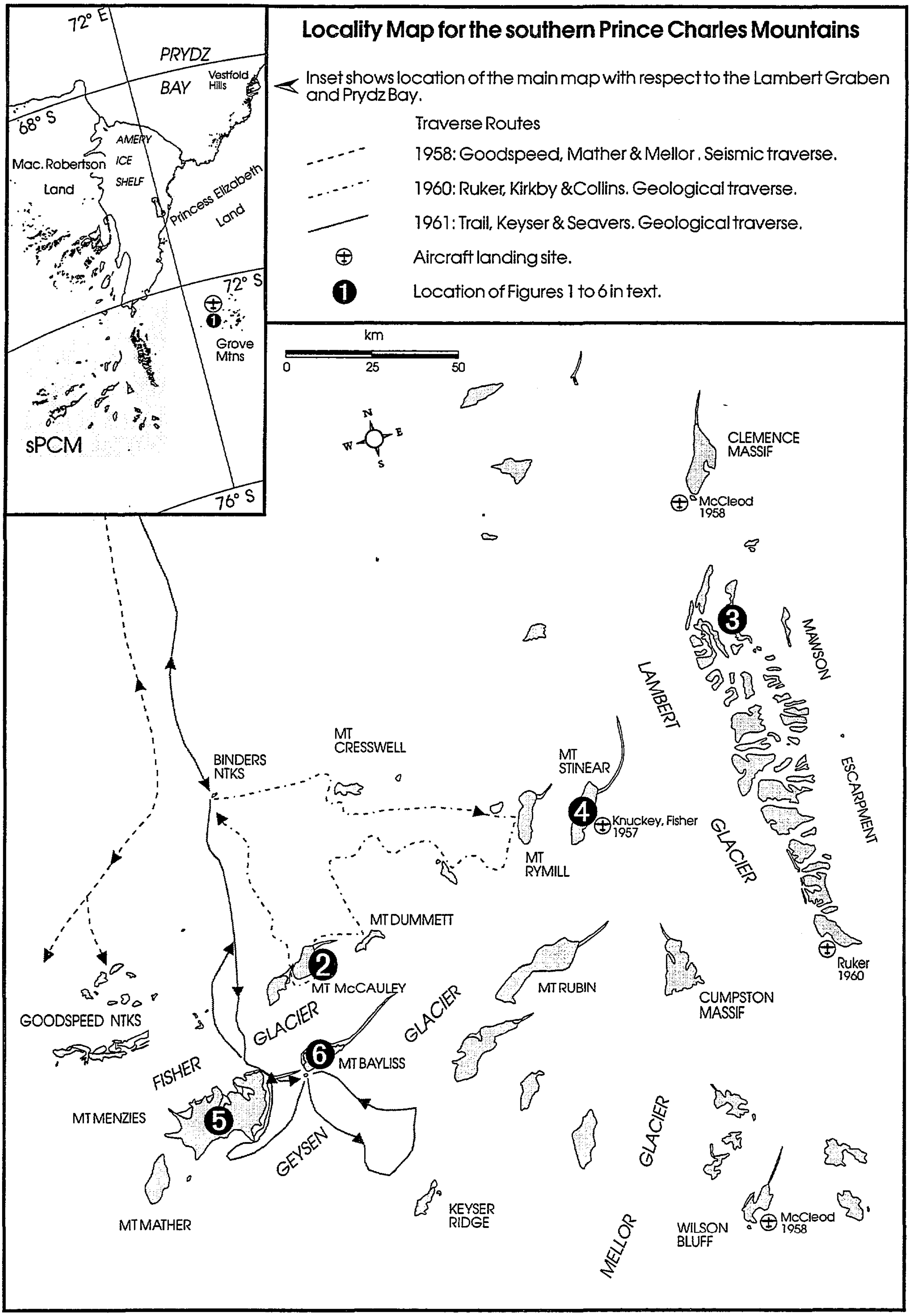

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REPORT ON GEOLOGICAL AND GLACIOLOGICAL WORK

BY THE

1958 AUSTRALIAN NATIONAL ANTARCTIC RESEARCH EXPEDITION

(abridged, 1996)

by

I. R. McLeod

Records 1959/131.

SUMMARY

The work described in this report is a continuation of that carried out in the previous years. The rocks generally are similar to those described in the earlier reports, viz. granite gneisses and migmatites, quartz-feldspar-garnet gneisses and quartz-feldspar and pyroxene gneiss; with extreme metamorphism these last two grade into charnockitic gneiss; dolerite and metamorphosed basic dykes cut these gneisses. Quartz-mica schists occurring in the southern Prince Charles Mountains have a notably lower metamorphic grade than the other rocks in the sector. The Permian sediments at Beaver Lake were also examined. Evidence of block faulting was found throughout the area. Raised beaches were found at Amundsen Bay. Highly saline lakes in the Vestfold Hills are due to concentration of seawater in basins isolated by a fall in the sea level. Analyses are given of water samples collected at intervals from these lakes, and of water from Beaver Lake, which is shown to be [tidal, and an extension of Prydz Bay]. Measurements of snow and ice accumulation and ablation were continued, and a detailed account kept of sea ice conditions. Using measurements of the rate of flow of ice, along a line of known thickness, calculations are made of the mass economy of the plateau.

INTRODUCTION

This report embodies the results of geological and glaciological work by the writer while based at Mawson as a member of the 1958 Australian National Antarctic Research Expedition. The work was a continuation of that carried out since 1954, and consequently this report is, to some extent, supplementary to those by Stinear (1956) and Crohn (1959).

During the year, the writer made field trips to the following places, involving 126 days in the field, and 80 hours of flying time: a traverse north of the Framnes Mountains to measure ice thickness; the east end of the Robinson Islands and the Auster Emperor penguin rookery; Mt Horden; Beaver Lake, and several points in the Prince Charles Mountains; Grove Nunataks; Amundsen Bay, Nye Mountains and Perov Nunataks; and a sledging journey of 656 kms from Amundsen Bay to Mawson. Geological observations were also made from the aircraft during various flights. In addition to these journeys, a number of one-day trips were made to Mt Henderson and the islands within a few kms of the camp.

During the voyage to Mawson, landings at Lewis Island and at several points in the Larsemann Hills allowed examination of the geology at these places.

PREVIOUS WORK

With the exception of Beaver Lake, none of the inland areas had previously been visited. Reports of earlier geological work by ANARE personnel are those by Stinear (1956) and Crohn (1959) (who also lists earlier work). Segnit (1957) has described a sapphirine bearing rock from Mawson. Brief accounts of work by Soviet Antarctic Expeditions are given by Ravich (1958) and Ravich & Varanov (1958). Earlier glaciological work is described by Loewe (1956a, b) and Mellor (1958, 1959).

LOCALITIES VISITED IN THE SOUTHERN PRINCE CHARLES MOUNTAINS

CLEMENCE MASSIF

This is a large ridge of rock rising 1190 m above the Lambert Glacier, which is here about 90 m above sea level. A landing was made beside the small nunatak 4.8 kms south of the massif.

The rocks are migmatitic, mainly pink medium grained granitic gneisses with scattered large feldspars and a rather irregular small scale banding due to concentration of biotite, the total content of which varies considerably from place to place. The typical rock is made up of antiperthitic oligoclase, quartz, potash feldspar, biotite, magnetite and apatite; the plagioclase is partly altered to muscovite and calcite.

With an increase in biotite and decrease of quartz and potash feldspar this granitic rock grades into a dark fine to medium grained well foliated hornfelsic looking rock, forming scattered bands a foot or so wide.

A number of veins and lenses of coarse red graphic pegmatite occur, up to 3 m wide, containing perthite-quartz intergrowths several centimetres across, biotite plates, and rarely, garnet. These pegmatites are usually more or less concordant with the gneisses, but near the southern end of the nunatak, a vein occupies a shear, and the adjacent gneiss is highly contorted.

The strike of the rocks ranges form 350° to 010°; dips increase from 10° to the west at the north-eastern end to 40° in the central and southern parts of the nunatak.

From the air, the main Clemence Massif is seen to consist of banded rocks very like those of the nunatak, with a similar strike of 340° and dip of 40° west. Irregular pink pegmatite masses also occur.

A small nunatak a few kms south-east of the massif consists of banded light-brown and dark-brown rocks striking east-west and dipping north at 60°.

WILSON BLUFF

South of the junction of the Mellor and Lambert Glaciers are a number of flat-topped massifs, each several kms in extent. The south-western most of these, Wilson Bluff, is marked by a long trail of moraine running off to the north-east.

The rocks of the Bluff are dominantly medium-grained finely banded quartz-biotite schists, with varying amounts of plagioclase (andesine-labradorite) and muscovite. Fibres of cummingtonite are common in places. A number of lenses, several centimetres thick, contain dark green amphibole with some feldspar and rare garnet. Small stumpy prisms of tourmaline occur along some layers, especially in the more feldspathic rocks. At the north-east corner of the massif is a horizon, 4.6 m thick, of almost pure quartzite.

Cutting these schists are numerous irregular veins and masses of coarse pink graphic pegmatite, up to 3 m wide. They generally transgress the foliation of the schists, but some thin concordant ones do occur. Most contain scattered plates of biotite, more rarely muscovite, and in some cases, small crystals of red garnet; tourmaline crystals occur along both edges of one.

Near the south eastern corner of the massif, these irregular pegmatite masses are cut by straight veins, a metre or so wide, of similar pegmatite, but zoned, with concentrations of quartz and biotite in the centre. These veins strike 020° and dip west at 80°. A few thin concordant veins of white alaskite with rare garnet and biotite occur, and seams of quartz are common in places; these two generally occur only in plicated portions of the schists.

The general strike of the schists is east-west, with dips of 10° to 20° to the south. Near the south-east corner are a number of recumbent folds, each about 3 m across with the axial surface dipping south at about 10°.

Small plications occur in places, especially near the lenses of green amphibole. Near the western end, the dip on either side of the valley increases to 30°; this valley may mark a north-west striking fault downthrown on the eastern side.

A notable feature of the moraine along the northern side of the massif, and forming the long tail extending to the north-east, is the small size of the debris. Except at the foot of the massif, boulders more than a 30 cm across are not common, and most of the fragments are less than 8 cm in diameter.

Many have almost a water-worn appearance, with rounded edges to the facets and slightly convex faces. Pegmatitic and quartzitic types are predominant, with a few examples of mica schist and fine grained biotite-rich hornfels.

GROVE NUNATAKS

The grove Nunataks are a group of isolated peaks extending about 48 kms from north to south and 32 kms from east to west. The altitude of the plateau of the landing area (which is a depression west of the main group of peaks: Fig. 1) is 1830 m; the highest peaks rise almost 300 m above this. Immediately east of the group, the plateau rises steeply in a series of terraces for over 300 m.

The nunataks are very rugged, with vertical sides and jagged summits. There do not appear to be any old erosion surfaces comparable to those in the Prince Charles Mountains.

The rocks forming these nunataks are migmatitic gneissic granites, with a few bands of hornfels. In the nunatak north-east of the landing area (ie at the north-west end of the main group) hornfels and granite occur in about equal amounts, as alternating bands up to 6 m thick. The hornfels is variable in composition, ranging from a dark coloured fine to medium-grained biotite rich rock to a light coloured medium-grained almost granitic rock with only minor biotite. In places, small feldspathic porphyroblasts occur. The rock is moderately well foliated; a rather irregular banding may also be developed. The most common type is intermediate between the two extremes. It is a light pinkish-grey fine to medium-grained rock, with a rather wispy banding of the light and dark minerals and made up of a fine-grained mosaic of perthite, quartz and oligoclase, with lesser amounts of hornblende, biotite and magnetite, and accessory apatite and zircon. Perthite porphyroblasts in this mosaic contain small rounded blebs of quartz, many in optical continuity.

The granite is a reddish coloured medium-grained rock, containing creamy iron stained feldspar and dark smoky quartz, with smaller amounts of biotite and hornblende and accessory zircon. Potash feldspar phenocrysts may, in cases, form up to 50% of the rock; alignment of these produces a marked foliation. Both microperthite and oligoclase occur in the groundmass. Patches of myrmekite are common, and some of the perthite also contains micrographic quartz. Most of the minerals show marked undulose extinction.

Despite the variation in appearance of the hornfels, the contact between granite and hornfels is quite sharp, and usually more or less parallel to the foliation of both. But in places, the granite cuts across the hornfels, forming veins, or leaving lenses of hornfels in the granite, according to the relative proportions of the two.

At the southern corner of the nunatak, a small mass of dark hornfels has a very irregular foliation, orientated quite differently to that of the rest of the mass.

Cutting both the granite and the hornfels is a series of veins of pink medium-grained granite, made up of potash and some plagioclase feldspar, quartz, and a little biotite. A few phenocrysts of feldspar, slightly coarser than the matrix, occur. These veins are straight, sharp edged (in some cases there is an increase of grain size along the edge) and steeply dipping.

The small nunatak south of this one has a similar dip, but the cross-cutting granite veins are much less common.

The largest nunatak of the group has some bands of dark biotite-rich hornfels; but most of it is porphyritic granite like that just described. Cutting irregularly through this are veins and masses (commonly anastomosing) of a second type of porphyritic granite, distinguishable form the first type by uts massive texture flesh-coloured feldspar, clear quartz and rarity of ferromagnesian minerals (mostly biotite). The contacts between the two types are sharp.

Near the western corner of this nunatak is a dyke-like body of brown aplite with blebs of hornblende. It is almost vertical, widening and curving towards the base, and has smooth sharp edges. It cuts the main mass of granite, but is cut by the granite veins. One rectangular sharp-edged inclusion of porphyritic granite was seen. The strike of the rocks in this main group is uniformly 105°, with dips of 30° to 40° to the north.

From the air most of the other nunataks also appear to be granite and biotite hornfels. Strikes are variable, and dips usually at moderate angles in the south east quadrant.

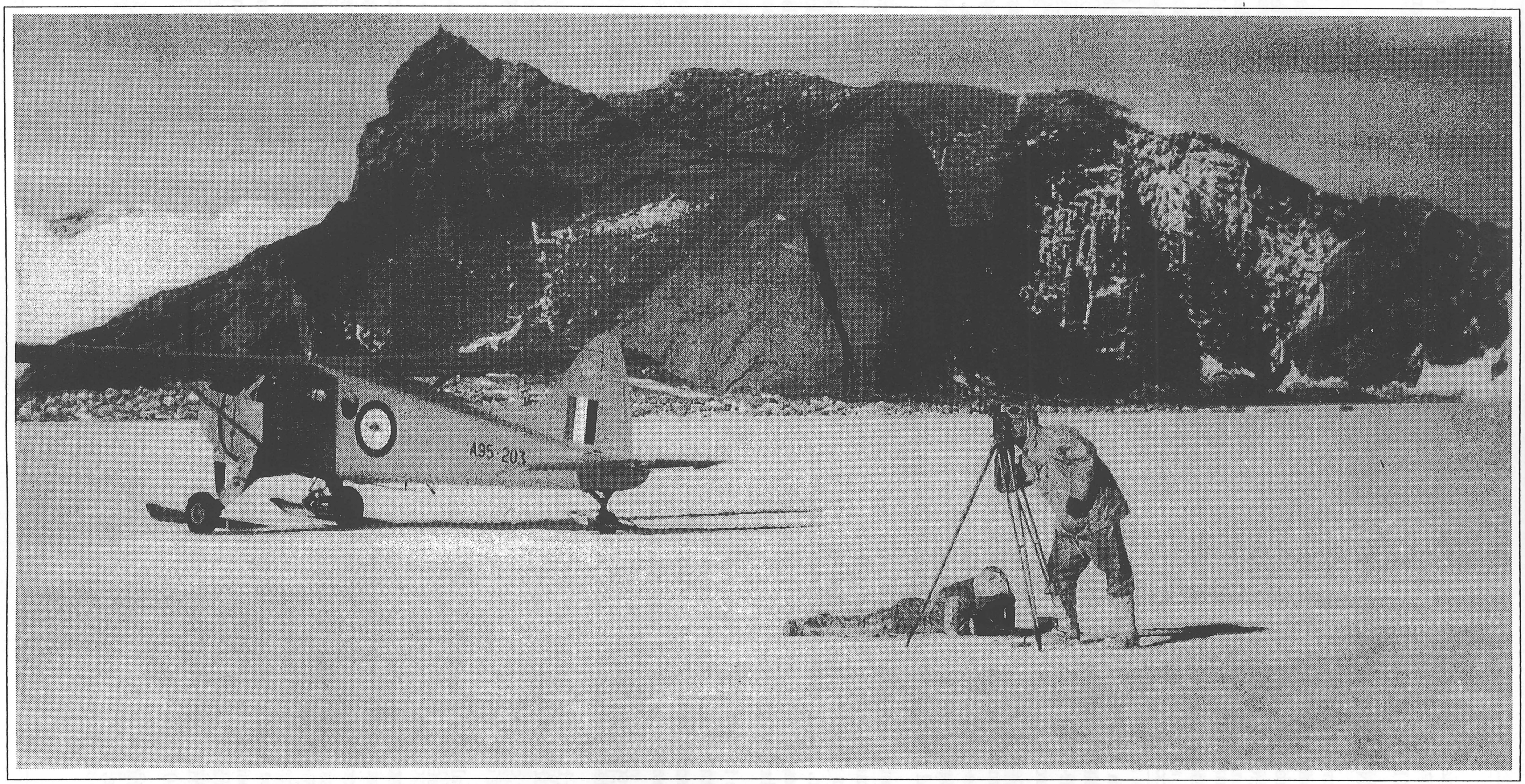

Fig. 1. One of the main peaks of the Grove Nunataks, looking east. The rocks are mainly gneissic granites, with migmatites on the right. To the left of the massif, a steep scarp in the ice is due to damming by the mountains. An extensive moraine deposit occurs along the front of the mountain.

In the long trail of moraine extending west from the main nunatak, the following size distribution (by volume) was estimated:

Large boulders (> 1.8 m diameter)	15%
Boulders (15 cm to 1.8 m)	70%
Pebbles (2.5 to 15 cm)	10%
Screening and sand (<2.5 cm)	5%

Many of the larger boulders consist of tabular blocks, but the smaller ones tend to be equidimensional. The edges generally show a good degree of rounding. Granitic rocks predominate, with some hornfels, a few boulders of white quartz-feldspar-garnet gneiss (not seen in situ) and one of medium-grained green diopside (4572), with a small amount of pale-brown phlogopite.

Goodspeed Nunataks

These are a group of isolated hills, rising up to 300 m above the plateau, near the head of the Fisher Glacier, at about 73°S, 61°E. In January 1958, a number of specimens of moraine were collected by M. Melor from two localities, one from the hill on which the astrofix was located, the other from the ice north of this hill.

The samples from the second locality are all coarse-grained massive granitic rocks; most contain perthite, plagioclase, quartz and biotite. Other minerals include lepidolite, fluorite, beryl, tourmaline, zircon, muscovite and magnetite.

At the second locality, samples are of two types. One is a massive fine-grained light-brown, partly recrystallised sandstone consisting of a mosaic of quartz grains with flakes of muscovite fairly common, and rare magnetite, zircon, tourmaline and sphene. The second type is a grey porphyroblastic rock with elongated highly poikiloblastic biotite flakes in a fine-grained mosaic of quartz, sericite, biotite and magnetite, with rare apatite and calcite. The biotite porphyroblasts produce a pronounced lineation. In some samples, the porphyroblasts are rare or absent.

These quartzites and hornfelses are described as forming 92% of moraine which completely covers the surface of the nunatak. This predominance suggests that the underlying rock is lithologically similar, and that the granite fragments from the ice represent the rock responsible for the alteration.

Aerial Observations

During flights in this area, a number of rock exposures were examined from the aircraft. The rocks all appear to be metamorphic in origin, with transcurrent dykes of pink rock, probably pegmatites. Most are well banded, so that a reasonably accurate estimate of the attitude could be obtained.

Manning Nunataks (71°S, 71°40'E): An attempt to land here was abandoned when the aircraft broke through the crust of the melt lake when landing. The rocks are banded light grey (Acid gneiss?) with a few straight light coloured veins (probably pegmatite) running in different directions. The strike is WNW with dips of 60° to the south. Near the south-western corner the rocks are highly contorted and faulted.

Patrick Point (73°20'S, 67°25'E): Consists of light coloured metamorphics, with dark hornfels (?) bands. At the northern end the strike is about WNW, changing to NNW further south. Dip is 30° to 40° south. The hornfels bands display very tight folds.

Blake Peaks (73°55'S, 67°E): Are composed of banded metamorphics with low dips (about 5°) to the south or south-west, except at the south-western end, where there is a north-south strike and westerly dip of 50°.

Mawson Escarpment: This appears to consist of the same rock types along its entire length, viz. white and brown bands, with some irregular masses of white rock, probably pegmatite. Near the northern end, the strike is NNW and dip west at 20°. This attitude seems more or less constant along the whole escarpment.

Acknowledgments

The work embodied in this report was made possible only by the team-work of all members of the 1958 expedition. The writer would, however, like to specifically acknowledge the help of: the surveyor, Mr

G. A. Knuckey, who made the surveys associated with the glaciological work, supplied much basic data, and assisted in many other ways; Mr D. A. Brown and Mr E. Burnett, for their geological observations in the Framnes Mountains; the pilots of the RAAF Antarctic Flight, Sqd. Leader I. Grove and Flt Lt H. O. Wilson, for observations related to various aspects of the work; and the men at Davis, Messrs M. J. Flutter, P. B. Turner, E. A. Trigwell, L. Gardner and F. Elliot, who collected water samples and made glaciological observations. While the writer was absent in the field during part of the periods of sea ice formation and deterioration, a very full account of sea ice conditions was kept by Flt Lt Wilson, and Messrs R. A. Borland and R. Arnel continued routine glaciological observations.

The Officer-in-Charge, Mr I. L. Adams, at all times took an interest in the work, and to his encouragement and co-operation was due, in no small measure, the success of the year's operations.

During the preparation of the report, the writer was assisted by discussions with colleagues of the Bureau of Mineral Resources, especially P. W. Crohn, who read the manuscript, and with Dr Uwe Radok, of the Meteorology Department, University of Melbourne, who gave helpful advice on glaciological matters.

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GEOLOGICAL RECONNAISSANCE IN ENDERBY LAND AND SOUTHERN PRINCE CHARLES MOUNTAINS, ANTARCTICA.

(Australian National Antarctic Research Expedition 1960)

(abridged, 1996)

by

R.A. Ruker

Records 1963/154.

SUMMARY

During 1960 the Australian National Antarctic Research Expedition undertook two field trips to collect geological and geographical information in the interior of the Enderby Land Peninsula and in the southern Prince Charles Mountains. The rocks in Enderby Land (Napier Mountains) are charnockitic gneiss and quartz-feldspar-biotite gneiss grading into quartz-feldspar-pyroxene gneiss, and are intersected by amphibolite schist and pegmatite. Similar rocks have been recorded in neighbouring areas by I.R. McLeod and P.W. Crohn. Rocks in the southern Prince Charles Mountains (north of the Fisher Glacier) are of low metamorphic grade and are derived from sediments of a greywacke suite. At Mount Dummett and Mount McCauley they are intruded by a granite batholith. Sediments with Glossopteris fossils were found in moraine at Mount Rymill, and boulders of hematite in moraine at Mount McCauley. The sources of these erratics are unknown. In view of these findings it is advisable that future geological activity be directed towards exploring the mountains south of the Fisher Glacier. Four alternative routes across this glacier are suggested.

INTRODUCTION

In 1960 the Australian National Antarctic Research Expedition (ANARE) undertook two major field trips from Mawson in the Australian Antarctic Territory. The purpose was to collect geological and geographical information in Enderby Land and in the southern Prince Charles Mountains (Mac. Robertson Land). Geological reconnaissances were also made of the Mawson Escarpment in Mac. Robertson Land and along the coast west of Casey Bay in Enderby Land. These localities were not previously visited and reconnaissance knowledge was required. The information in this report was collected by R. J. Ruker, the overall programme was prepared by the Bureau of Mineral Resources, and the ANARE organisation provided camping and transport facilities.

GENERAL

The first of the two major field trips was planned to explore the mountains in the interior of the Enderby Land Peninsula. For this purpose a party of three men, consisting of a geologist, surveyor and radio operator, spent 58 days in the field and travelled 290 kms under adverse weather conditions. Two dog teams were used for the transport of supplies and equipment. The party landed from the ship *Thala Dan* on the coast 1 km east of Cape Batterbee, travelled inland to the Napier Mountains, then continued through the Akers Peaks, and ended the journey at Styles Bluff in King Edward VIII Gulf.

The second trip was designed to explore the southern Prince Charles Mountains. During the first phase of exploration a base camp was established 480 kms south of Mawson. This was accomplished after 45 days of travel by a party of 5 men who drove two tractor trains with equipment and supplies to an area suitable for aircraft landing at 72°30'S, 62°59'E. Extremely low temperatures were encountered (minimum temperature -55 °C) and the weather conditions permitted an average of one day of travel in two.

The second phase consisted of geological reconnaissance of the following mountains: Mount Cresswell, Mount Rymill, Mount Seddon, Mount Dummett, Mount McCauley, and Mount Scherger. A *Weasel* and a team of dogs were used for transport. The party of three men covered 320 kms in 30 days, travelling over a severely crevassed route.

A third phase envisaged crossing the Fisher Glacier and exploration of the area between Mount Menzies and Mount Rubin, but this phase was not carried out due to lack of time. An aerial reconnaissance was made over the Goodspeed Nunataks and one landing was made at Mawson Escarpment in the vicinity of 73° 13'S, 68° 15'E.

A geological reconnaissance of the Enderby Land coast close to the western boundary of the Australian Antarctic Territory was made from the M.S. *Thala Dan* in the period 10th to 24th February, 1961. A number of outcrops were visited by motor boat and rock specimens collected in each locality.

PREVIOUS WORK

The localities visited this year had not been examined before but geological information from neighbouring areas can be found in reports by McLeod (1959) and Crohn (1959). McLeod (1959) has studied the Tula Ranges and the Amundsen Bay area and Crohn (1959) reports on the King Edward VIII Gulf area and the Prince Charles Mountains. Descriptions of rocks collected at Proclamation Island are reported by Tilley (1937).

SAMPLES

Typical rock specimens were collected from examined outcrops and later sent to the Australian Mineral Development Laboratories for petrographic examination (Appendix 1). The hand specimens are stored in the museum of the Bureau of Mineral Resources [*now Australian Geological Survey Organisation*] in Canberra under registered numbers R8832-8878.

CONDITIONS OF TRAVEL AND MEANS OF TRANSPORT

Much time was consumed in overcoming travelling difficulties due to surface and climatic conditions. During the Enderby Land journey, deep snow and rafted sea ice made progress slow and the travelling rate was reduced to two days in three by blizzards and "whiteouts". On the journey to the southern Prince Charles Mountains the travelling conditions were also severe. To make full use of the available daylight hours the party left Mawson at the end of August and therefore endured extremely low temperatures. Crevassed areas were encountered in several places and two serious crevasse incidents occurred (Fig. 2). High drifting snow was common, and accounted for most of the unproductive days. The average rate of travel was one day in two over a period of four months.

During the year several means of transport were used. On the Endery Land trip, sixteen dogs pulled two sledges loaded with a total of 730 kg of equipment. The party lived in a tent. On the southern Prince Charles Mountains journey two D4 tractors were used to pull 5 two-tonne sledges each, loaded with fuel, equipment and living caravans. *Weasels* and tractors were partly equipped for polar travel.

ACCESS SOUTH OF THE FISHER GLACIER

Complete reconnaissance knowledge of the southern Prince Charles Mountains area should be gained by visiting the mountains south of the Fisher Glacier. This becomes necessary particularly after the finding of sediments with *Glossopteris* at Mount Rymill, and hematite at Mount McCauley in moraine of unknown provenance. The task of crossing the glacier was not carried out during 1960, but information which could be useful to future exploration is given here.

From the base camp established by the 1960 party four crossings are possible. They are described in order of personal preference, based on two air inspections from an average altitude of 600 m above the ground and of ground observation from a distance of up to 24 kms. The first route is between Mount Seddon and the western end of Mount Rubin. This route was observed during a reconnaissance flight (3rd December, 1960). Crevassing is present. The advantage of this route lies in the possibility of reaching Mount Seddon with heavy vehicles to establish the base camp close to the operative area.

The second route was observed during the reconnaissance flight on the 2nd December 1960 after a snowfall, and therefore should be negotiated with caution, and, if possible, following an air inspection. This route lies in a straight line connecting base camp with the mountain glacier flowing from Mount Menzies and is the most direct approach to the area south of Fisher Glacier. A belt of crevassing close to Mount Menzies may force detouring towards Mount Mather or Mount Bayliss.

The third crossing starts at the gap between Mount Dummett and Mount McCauley and ends at Mount Bayliss. This possible route was examined from the distance from Mount McCauley and should not be attempted without air inspection.

The fourth route would lead westward from Goodspeed Nunataks and cross the Fisher Glacier above its ice divide. Nothing is known about the area, and an air reconnaissance is necessary.

Fig. 2. Dogs and expeditioners contemplate Weasel No. 4, firmly entrenched in a well hidden crevasse near Mount McCauley. The peak right of centre is part of the granite batholith. Right and left background are metasediments.

REGIONAL GEOLOGY

The rock types encountered in Enderby Land and the coast west of Casey Bay have been previously found in adjoining areas and described by Crohn (1959) and McLeod (1959). They are high to medium grade metamorphic rocks. In the southern Prince Charles Mountains a suite of rocks of low metamorphic grade was found. It originated from a greywacke-sandstone assemblage and the generalised term quartzite has been used in this report. Other terminology used in this report is the same as applied by McLeod (1959).

The sporadic nature of the outcrops and the difficulty of correlating the rocks did not enable definition of formations and the following description is therefore made under geographic features.

SOUTHERN PRINCE CHARLES MOUNTAINS

BINDERS NUNATAKS

The base camp in the southern Prince Charles Mountains was established close to Binders Nunataks at 72°35'S, 62°58'E. The largest nunatak is 3.2 km long, 800 m wide and rises 61 m above the plateau level. Two small outcrops, not shown on the map, are present about one km to the north-west and west.

The large nunatak is almost entirely covered with moraine. A few square metres of quartz-feldspar-biotite gneiss were found *in situ* (Sample R8832). It is a distinctly schistose rock, medium to fine-grained and banded. Banding is due to the concentration of biotite and hornblende. Quartz veins up to 30 cm thick intersect the rock. Amphibolite dykes containing labradorite, quartz and biotite occur in two places (Samples R8833). In hand specimen this amphibolite is a black, hard, fine-grained rock with no evident schistosity.

The moraines are formed into mounds or polygons. They contain high grade metamorphic rocks of varied nature: granitic gneisses, quartz-garnet gneiss, amphibolite, gneiss with large staurolite and apatite crystals, silicified breccia-sandstone, and granite.

MOUNT CRESSWELL

This flat-topped mountain (72°47'S, 64°17'E) with steep moraine-covered slopes is approximately 10 square kilometres in area. On the northern side is an amphitheatre-like valley with six rows of lateral moraine. The flat top of the mountain represents the old erosion surface covered with mounded moraine. The feature is dominated by a peak rising 90 m above the general plateau surface.

Finely banded quartz-feldspar-biotite gneiss forms this mountain (Sample R8849). The rock is the same as that at Binders Nunataks. It is intersected by numerous pegmatite dykes up to 20 m thick. Quartz veins and a few amphibolite bands (Sample R8850) are present. The pegmatite is composed mainly of feldspar, quartz and muscovite, the latter in crystals up to 10 cm wide. Subordinate garnet and ferromagnesian minerals are concentrated in places.

The general strike of gneissosity is easterly, and the dip 30° to 70° to the north. A number of minor faults are present.

Fragments of moraine are several centimetres in diameter, angular and similar to the bedrock. A few allochthonous boulders of quartz-feldspar-garnet gneiss and quartzite were found in the lateral moraine on the north side of the mountain.

MOUNT RYMILL

This mountain is part of a range bordering the Fisher Glacier. It extends for 17.5 kms from north-east to south-west and is divided by an ice covered saddle. The general plateau level in the area is 820 m and the mountain rises 360 m above it. It features the flat-topped morphology characteristic of the southern Prince Charles Mountains.

The rock is black, grey and green greenschist in alternating bands (Sample R8838). It is a fine-grained, hard rock, slightly schistose and showing remnants of former bedding. In addition to quartz it contains biotite and lesser sphene and apatite.

The general strike of the bedding and schistosity is east with dips of 30° to 60° to the north. Faults with a small throw, striking north-east, were observed in the north-eastern part of the mountain.

The outcrop is surrounded by lateral moraine which terminates in a moraine tail towards the north-east. Among the materials constituting the moraine, of particular interest are sandy siltstone (R8848) containing numerous remnants of *Glossopteris* and other plants (White, 1962). The siltstone is brick-red, soft and fissile. Some boulders contain bands of sandstone. The original formation is therefore thought to be a sandstone-shale assemblage. The sandstone does not contain fossil remnants. Numerous fragments of grey and pale purple marble (Sample R8847) with a sugary texture were found. The occurrence of siltstone with *Glossopteris* and marble are restricted to the moraine at the base of the mountain at the north-western end of the saddle. The moraine on the upper slopes contains only high grade metamorphic rocks and detritus produced by nivation of local rock.

MOUNT BLOOMFIELD

The low-lying hill 4.8 km north-west of Mount Rymill which covers approximately 10 square kilometres, is composed of quartz-feldspar augen gneiss (Sample R8836). The rock is coarse-grained, closely jointed and intersected by numerous veins of medium-grained, pink pegmatite. The pegmatite is composed of quartz and orthoclase with minor garnet and muscovite. Numerous pebbles of sugary, white, fine-grained quartz occur in the moraine, which covers most of the outcrop and ends towards the north-east in a long moraine tail.

MOUNT SEDDON

Mount Seddon is situated 21 kms west of Mount Rymill and consists of three rounded peaks separated by snow covered saddles. The highest peak rises approximately 270 m above the plateau. The mountain is composed of calcite-sericite-quartz greenschist (Samples R8839 & R8840). This rock is hard, fine-grained and well stratified. It is probably a slightly metamorphosed greywacke.

The rock on the north-eastern side of the mountain is intruded by an amphibolite dyke several metres wide. Veins of amphibolite extend out from the dyke and intersect or follow the bedding planes. The structure is regular and the strike on the eastern side of the outcrop is east with an average dip of 60° towards the north.

MOUNT DUMMETT

This flat-topped ridge is 11 km long and is dominated in the east by a peak rising approximately 100 m above the ice plateau.

The eastern half of the mountain is composed of quartz-feldspar schist similar to the low grade metasediments found at Mount Seddon and Mount Rymill (Sample R8841).

The western part of the mountain is granite. This rock contains muscovite, biotite and locally concentrated small crystals of garnet. Veins of quartz and coarse-grained pegmatite containing feldspars, quartz and muscovite, extend out from the granitic mass. An isolated outcrop of yellow, coarse-grained marble (Sample R8842) was found in the vicinity of the granite intrusion. Under the microscope it is seen to contain crystals of calcite, quartz, muscovite and kyanite and probably originated by contact metamorphism.

MOUNT MCCAULEY AND MOUNT SCHERGER

These two outcrops are the most prominent topographic features in the western part of the mountains north of the Fisher Glacier. They rise approximately 300 m above the plateau and are separated by a valley of stagnant ice. Both are topped by flat, moraine covered terraces. In the north-eastern part of Mount McCauley the terrace has been lowered several tens of metres by faulting.

Quartz-feldspar schist similar to the rock found at Mount Rymill, Mount Seddon and Mount Dummett forms the major part of the outcrops. The south-western part of Mount McCauley is granite. It is a medium-grained rock containing quartz, feldspar, biotite, muscovite and local concentrations of garnet. Numerous veins of quartz extend from the granitic mass of quartz and follow joints or bedding planes. Black vein-like and dyke-like bodies of contact metamorphosed sediment containing biotite and chlorite are also very numerous in the quartz-feldspar schist (Sample R8846). In a wide area around the granitic intrusion the metasediments have lost their original texture and structure and are now represented by hornfels and migmatite.

The structure of the intruded rock is complicated by folding, jointing and faulting and the strike and dip shown on the map are local features which do not express a structural trend.

On the north side the two mountains are joined by lateral moraine and a moraine tail 13 km long extends from the eastern corner of Mount McCauley. The mountain's slopes are also covered with moraine. The lateral moraine on the south side and in the valley between Mount Scherger and Mount McCauley contains high grade metamorphic rocks of igneous and sedimentary origin.

The moraine which joins the north sides of the mountains and the moraine on the northern and eastern slopes of Mount McCauley are different in that they contain a great quantity of sedimentary rocks of low metamorphic grade. Sandstone breccia (Sample R8843) and silicified sandstone (Sample R8844) are common. In this type of moraine were found boulders of hematite (Sample R8845) a few metres in diameter. The boulders are very well rounded and are found high up the slope of the mountain. Well-rounded fragments of jaspilite are also present. This rock is fissile and strongly lineated and has a high content of hematite. Provenance of these erratics cannot be suggested. The present direction of ice flow would indicate the Goodspeed Nunataks as the likely area of origin but aerial observation does not support this hypothesis[1].

MAWSON ESCARPMENT

This scarp is on the east side of the Lambert Glacier between 72°30'S and 73°40'S. It is composed of a series of steep rock faces 210 m high topped by the flat, moraine covered Law Plateau. The rock faces are dissected by cirque glaciers and short glaciers draining from the plateau into the Lambert Glacier (Fig. 3).

The escarpment was visited close to the southern end in the vicinity of 72°33'S, 68°45'E. In this area the country rock is a hornblende-feldspar-quartz gneiss (Sample R8855). It is a medium to coarse-grained rock with bands rich in amphibole. A closely-spaced network of amphibolite bands (Sample R8856) intersects the rock along two preferential directions, east-north-east and north-north-east. In the vicinity of the bands, the intruded rock is metamorphosed to a garnetiferous hornfels (Sample R8854). In one locality the hornfels has attained a thickness of 15 m and a dark red scree is developed on the slope.

The rocks are intensely folded but a general strike towards the north-north-east dominates, with dips from 40° to 60° towards the west. At the foot of the Mawson Escarpment a wide lateral moraine is carried by the Lambert Glacier. Local rocks contribute most of the material but well-rounded boulders of pegmatite and granite were also found.

AERIAL OBSERVATIONS

The Goodspeed Nunataks, Mount Menzies and Mount Rubin were examined during traverse route reconnaissance flights in the southern Prince Charles Mountains.

The Goodspeed Nunataks are formed by a number of hills rising several tens of metres above the plateau surface. In places a group of hills encircles areas of stagnant ice which are considered safe for landing and travelling.

The outcrops appear to be formed by rock similar to the quartz-feldspar-biotite gneiss found at Binders Nunataks. Aerial observation does not suggest the presence of sedimentary rocks in this area.

Extensive moraine deposits form long serpentine patterns between the outcrops. The quantity of moraine compared with the relatively small areas of rock in situ is a striking feature.

Mount Menzies is the highest mountain in the Australian sector of Antarctica. It rises to a height of about 3300 m above sea level, and is at least 1500 m above the surrounding plateau. It is formed by numerous rugged peaks and from the north side two mountain glaciers flow into the Fisher Glacier. The northern side of the mountain was examined from the air. It is probably composed of metamorphic rocks, banded light grey, pink and black. A few dark-coloured dykes intersect the bedding. Some of the light coloured rocks in the upper part of the mountain could be sediments. Viewed from the north, the bedding appears nearly horizontal but the strike could be east with dips to the south.

Mount Rubin is situated along the south side of the Fisher Glacier between 65° E and 66° E. It is a long, flat-topped mountain rising a few hundred metres above the glacier and is covered with mounded moraine. The rocks are dark coloured and well bedded, similar to low grade metasediments of the

[1] Subsequently located in situ at Mt Ruker and Mt Stinear. See, for example, M. G. Ravich *et al.*, 1982, In C. Craddock (ed.), Antarctic Geoscience, p. 853-858.

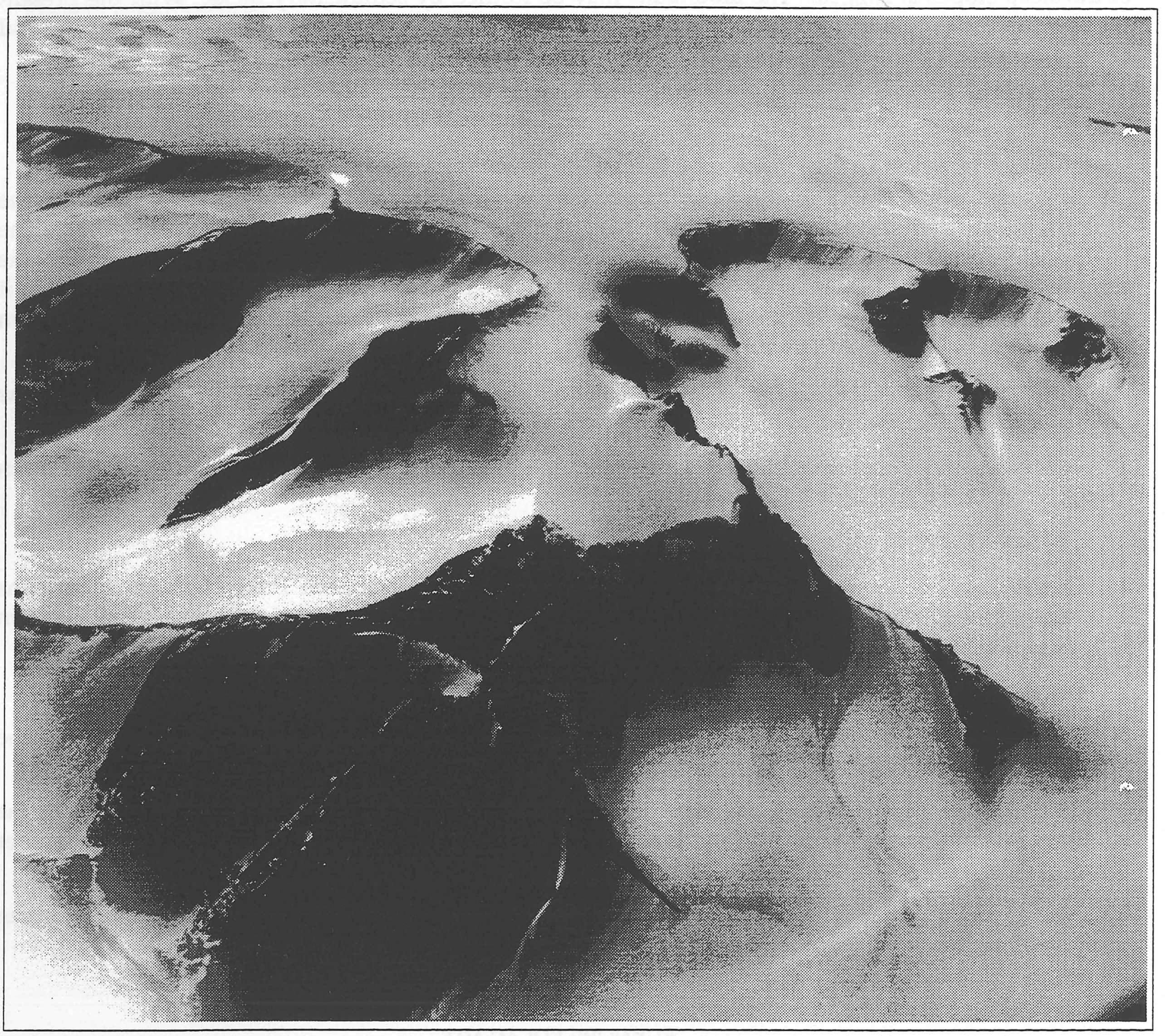

Fig. 3. Abandoned cirques along the north-western margin of the Mawson Escarpment. Oblique aerial photograph taken looking north-east, in the vicinity of 72°40'S, 68°20'E. Airphoto ANT47Run 27 7100L, acquired on the 28th November, 1956.

greywacke-sandstone suite found in outcrops north of Fisher Glacier. In some places the strike is east with dips to the north.

Mount Maguire and Blake Peaks are situated between the Mellor and Lambert Glaciers. The interpretation of the air photographs taken in 1960 reveals a textural and tonal pattern substantially different from the neighbouring outcrops. Horizontal bedding is clearly outlined and the morphology of the steep slopes is rugged. The mountains may be formed by sedimentary racks. With the present transport facilities it is impossible to reach the mountains but ground examination by helicopter would be necessary to complete the reconnaissance knowledge of the area.

CONCLUSIONS

The extensive field activity of the ANARE party occupying Mawson in 1960 has contributed to the reconnaissance knowledge of areas which have not been visited before by ground parties. The geological information which was collected is part of a general plan of reconnaissance activity for the compilation of a geological map of the Australian sector of Antarctica at a scale of 1:250,000. As such it is the continuation of the work done by B. Stinear, I. R. McLeod and P. W. Crohn. The contributions in the geological field are here summarised:

1. The reconnaissance knowledge of the mountains in the interior of Enderby Land completes the geological reconnaissance of this part of Antarctic territory.
2. Geological and route information concerning the mountains north of Fisher Glacier has been collected for the first time by a ground party.
3. Mawson Escarpment has been examined from the ground.
4. Siltstone with *Glossopteris* has been found in moraine in the southern Prince Charles Mountains although the place of origin is undetermined; it is the first time that macrofossils have been found in this sector of Antarctica.
5. Hematite has been found in moraine at Mount McCauley but the place of origin is unknown.
6. The presence of low-grade metasediments intruded by a granite batholith has been recorded in the mountains north of Fisher Glacier.

In addition to geological results, the expedition has collected information on route possibilities in the southern Prince Charles Mountains and has proved that travel is possible early in the Austral summer season, under very low temperatures, giving full use of the daylight hours.

This years work suggested that in planning future geological reconnaissance work first priority be given to the exploration of the mountains south of the Fisher Glacier.

ACKNOWLEDGMENTS

The ANARE organisation has made this work possible and has provided excellent equipment for field activity. I want to acknowledge in particular the enthusiastic assistance of Mr. Hendrik Geysen, the Officer in Charge at Mawson in 1960, who has given full support to field activity at all times and led the journey to the southern Prince Charles MountainsWithout his drive the results achieved would not have been possible. Sqd. Ldr J. Kitchenside and his RAAF crew spent much of their effort in supporting the ground exploration. S. Kirkby and N. Collins were valued members of the exploratory parties and their previous experience in Antarctic travel proved indispensable. Radio operators I. Bird, I. Machin, and Ken Bennett contributed to the success of field activities.

I wish to acknowledge the advice and suggestions offered to me by I. McLeod, P. W. Crohn and B. Stinear of the Bureau of Mineral Resources. Moreover I want to mention the assistance of the Officer in Charge of the Antarctic Mapping Centre, D. T. Gale, and N. Harding of his staff for the assistance with maps and aerial photographs.

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APPENDIX 1

PETROGRAPHIC DECRIPTIONS BY THE AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES OF ROCK SAMPLES COLLECTED BY ANARE 1960-61.

by

W. R. McCarthy

SOUTHERN PRINCE CHARLES MOUNTAINS

Binders Nunataks

R8832: T.S. 7238

The rock is a garnet-biotite-hornblende-feldspar quartz gneiss, assigned to the almandine amphibolite facies of Fyfe, Turner and Verhoogen (G.S.A. Memoir 73, 1958, p. 228). Foliation is fair and visible both in hand specimen and thin-section. In thin section, the biotite shows foliation and quartz and feldspar have a tendency to be elongated parallel to foliation. Evidence exists for a probable polymetamorphic history of the rock. It is evident that the first period of metamorphism was synkinematic and reached the biotite grade. A second later period of thermal (regional rather than local) metamorphism is likely for the following reasons:

1. Large garnet porphyroblasts have inclusions of biotite (formed during synkinematic period) and the garnets push aside the foliated biotite.

2. A second, non-aligned, generation of biotite is present.

3. Hornblende shows no preferred orientation and is not present as inclusions in garnet - thus is probably not synkinematic.

Quartz (about 50%), labradorite (An_{58} and about 35%), and biotite (about 10%) are the major constituents. Green hornblende, and garnet (with inclusions of biotite, feldspar, and quartz are present in about equal quantities, and form about 5% of the rock. Some biotite has altered to chlorite.

Accessory zircon (many grains are rounded) and apatite are common.

R8833: T.S. 7239

This is a garnet-hornblende gneissic amphibolite and assigned to the almandine amphibolite facies. Hornblende, the major constituent (about 60%), shows a fair crystal parallelism and gives the rock its structure. Feldspar, andesine and quartz - except for accessories - comprise the remainder of the gneiss. Garnet is present as porphyroblasts with inclusions of hornblende, plagioclase and quartz The garnet is extremely corroded and often is present only in the centre or side of large circular areas now occupied by finer crystals of feldspar, quartz, hornblende and sometimes sericite and biotite. It is then thought that the garnet once filled a larger portion of the circular areas and because of some disturbance of metamorphic equilibrium (i.e. heat, pressure, metasomatism) that a portion of it has recrystallised into other minerals more conformable with new conditions. Some of the garnet porphyroblasts show alignment with structure.

Sphene occurs associated with skeletal opaques and some crystals show an elongation parallel to structure. Apatite and zircon occur in accessory amounts.

R8834: T.S. 7240

This is a garnet-hornblende amphibolite with poor foliation and assigned to the almandine amphibolite facies. Hornblende shows a fair crystal parallelism and biotite a fair foliation. The specimen shows a complex metamorphic history; several periods of metamorphism are evident.

During the first period, the rock developed its schistosity with biotite and hornblende giving the foliation, biotite being rather rare at this stage. Porphyroblastic garnet developed at this time. Several quartz vein-like bodies cut the rock parallel to foliation and were formed during the initial metamorphism. Next, a period of fracturing followed - shown by fractures in garnet. A final period of metamorphism, which appears to be primarily thermal, resulted in crystallisation of hornblende and biotite within fractures in garnet, new unoriented biotite, and partial conversion of some hornblende to biotite. Another alteration, the sericitisation of some of the feldspar, was contemporaneous with the thermal metamorphism or is a late retrograde feature. Hornblende, quartz and garnet are major constituents; biotite and feldspar minor constituents.

Accessories are zircon, apatite, sphene and metallic opaques. Metallic opaques are common, have lath and rod habit, occur in skeletal aggregates, are associated with sphene, and are probably Ilmenite.

R8835: T.S. 7241

This is a feldspar-quartz-amphibole hornfels and assigned to the hornblende hornfels facies. The constituents are hornblende (about 55%), plagioclase (about 30%) and quartz (about 15%). Texture is granoblastic and all minerals have a tendency to develop equant grains and crystal faces and show the following decreasing order of idioblastic habit - hornblende, plagioclase, and quartz. Hornblende has an average diameter of 0.18 mm, and quartz and feldspar average 0.37 mm. No relict igneous textures are visible although the plagioclase (andesine) is generally zoned. Consequently, the rock appears to have formed by regional thermal metamorphism.

Mount Cresswell

R8849: T.S. 7255

This is a biotite-feldspar-quartz gneiss and assigned to the almandine amphibolite facies. The rock has crystallisation foliation with both feldspar and quartz showing elongation parallel to foliation. Biotite forms about 7% of the rock and gives it a fair foliation. Quartz forms about 50% of the rock, is xenoblastic, ranges in grain size from 1.7 mm. to 0.14 mm. and averages 1.2 mm. Feldspar has anhedral to xenoblastic habit, is andesine, and ranges from 0.7 mm. to 0.2 mm. and averages 0.4 mm.

Zircon as fine crystals is a rare accessory.

R8850: T.S. 7256.

The rock is an epidote-chlorite-hornblende hornfels and assigned to the hornblende hornfels facies. No structure is apparent and the rock has sub-granoblastic texture. The ferromagnesians tend to be concentrated in patch-like bodies with feldspar interstitial to them. The rock is medium to fine-grained and the minerals arranged in decreasing order of idioblastic tendency are: hornblende, epidote, chlorite, and feldspar. Feldspar is very dirty appearing in plain light because of many fine inclusions, shows little twinning and is andesine (An_{32}). Chlorite is penninite and generally has spherulitic habit.

The mineral assemblage is apparently unstable and a portion of the epidote and all of the chlorite appear to have formed retrogressively from hornblende.

Sphene is a common accessory and occurs as coarse to fine xenoblastic grains. Opaques and apatite occur as rare accessories.

Original rock type is not determinable from thin section. However it is more likely that this is a metamorphosed basic igneous rock than a metasediment.

R8851: T.S. 7257

The rock compares in all regards to R8834 except for the following differences: Garnet of R8851 is more coarse, no quartz vein-like bodies cut the rock, and the feldspar of R8851 is little altered.

R8852: T.S. 7258

This is a garnet-muscovite-tourmaline pegmatite. Tourmaline is present as idioblastic crystals, garnet is subhedral, and quartz and feldspar have fine crenulated borders. Feldspar is microcline and albite-oligoclase; the feldspar has inclusions of quartz and a portion shows incipient sericitisation.

Petrogenesis is not determinable from the thin section, but quartz inclusions in feldspar, feldspar with crenulated borders, and the presence of garnet would suggest that a metamorphic genesis be considered.

R8853: T.S. 7259

This is a feldspar-quartz pegmatite with graphic intergrowths of quartz and feldspar. The feldspar is albite and microcline. Quartz is present as thin laminae-like bodies which parallel the (001) cleavage of the feldspar.

Mount Rymill

R8838: T.S. 7244

This is a fine-grained, dark coloured, epidote-biotite - feldspar-quartz greenschist and assigned to the greenschist -facies. Schistosity is poor - almost incipient - and shown by thin concentrations of biotite. The matrix is quartz and feldspar with an average diameter of 0.051 mm. Several incipient porphyroblasts of partially fused feldspar grains reach a diameter of 0.56 mm. Concentrations of opaques and biotite rimming a core of sphene are common. Epidote minerals are present as minor constituents and occur as extremely fine-grained, disseminated crystals.

Apatite is a common accessory; zircon occurs rarely.

R8847: T.S. 7253

This is a fine-grained marble. The matrix of the rock is composed of recrystallised calcite and calcite grains which show no apparent recrystallisation. Several cross-cutting bodies containing coarsely crystalline calcite occur. Grain size ranges from 0.05 mm. in the matrix to 1.12 mm in the cross-cutting body. Most of the calcite has fine scattered inclusions. A few grains of quartz and flakes of muscovite are the only additional minerals in the rock.

A magnesium test was positive which proves that a portion of the calcite referred to above is dolomite or magnesium rich.

R8848: T.S. 7254

This is a stilpnomelane-goethite-quartz schist and assigned to the greenschist facies - an iron-magnesium assemblage. All minerals have a grain size of loss than 0.0625 mm. Quartz and stilpnomelane are major constituents and interstitial goethite is common. Stilpnomelane and angular quartz grains, with parallel elongation give the rock its schistosity. Quartz is angular or lens like - a few grains are subrounded - stilpnomelane has acicular habit.

R8866: T.S. 7272

This is a mica-quartz-feldspar schist and assigned to the almandine amphibolite facies. Schistosity is poor and the rock has an incipient crystallisation foliation; quartz and feldspar show a poor grain elongation parallelism. Feldspar is primarily microcline with some oligoclase and forms about 30% of the specimen; it has an average diameter of 0.72 mm. Much of the feldspar has been sericitised; the sericitisation is thought to result from K metasomatism. Most grains of feldspar and quartz are ringed by coarse-grained sericite which occasionally concentrates in lenses to give a rude foliation to the rock.

Zircon, tourmaline, chlorite, and opaques are accessories. Biotite occurs as sheet-like poikiloblastic crystals in accessory amounts.

Mount Bloomfield

R8836: T.S. 7242

This is an epidote-hornblende-biotite-quartz-feldspar augen gneiss and assigned to the almandine amphibolite facies. Schistosity is shown by linear zones of crushed fragments; mainly quartz and feldspar with an average diameter of 0.026 mm and by linear zones of ferromagnesians. Often the two zones are distinct, but zones containing a mixture of ferromagnesians, quartz, and feldspar are common. Linear zones of crystalline quartz also are present. The ferromagnesian zones contain fine-grained biotite (generally showing no preferred orientation) green uralitic appearing hornblende, sphene, epidote minerals, and accessory minerals. Two types of augens are evident, one of sericitised and epidotised plagioclase, and the other of microcline. Between augens and linear zoned material, quartz and microcline (with an average diameter of 0.55 mm), scattered ferromagnesians, and accessories are found.

The rock has had a complex evolutionary history. Two generations of minerals are evident; the first: augen plagioclase, epidote (distinguishable from later formed epidote by its pleochroism, low birefringence, and clastic appearing grains), and finer grained biotite and hornblende; the second: microcline, sericite, epidote, green uralitic hornblende, coarser biotite, quartz, and sphene. The second generation of minerals formed during a period of medium grade dynamic metamorphism accompanied by K metasomatism. Before dynamic metamorphism the rock was probably a granitoid rock and most likely metamorphic as it contained epidote. Thus it appears that two periods of metamorphism have formed the present mineral assemblage.

Potassic metasomatism is thought to have accompanied the second period of metamorphism because the relict plagioclase indicates that it was the stable feldspar of the granitoid rock whereas the only feldspar to form during the last crystallisation was microcline. The sericitisation of plagioclase was most likely a result of K metasomatism.

Accessory minerals, zircon and apatite, are common; some of the zircon is present as broken crystals; most apatite is euhedral

Mount Seddon

R8839: T.S. 7245

The rock is a calcite-sericite-quartz schist and assigned to the greenschist facies. Schistosity is fair and shown by sericite and sub-aligned quartz clasts. Calcite occurs as xenoblastic, poikiloblastic crystals with inclusions of quartz; calcite crystals have an average diameter of 1.12 mm. Rare clastic grains of feldspar are present. Quartz occurs as angular to sub-rounded grains which have an average diameter of 0.13 mm.

Accessories are tourmaline, zircon, sphene, and opaques. Opaques occur as scattered grains which assume a rude parallelism with schistosity and as patchy aggregates. Green biotite is present in accessory amounts.

R8840: T.S. 7246

This rock can be compared to R8839 in all regards except for the following differences. Small porphyroblasts of quartz which are rimmed by directionless green biotite are scattered through the rock; similar shaped bodies of biotite occur with no quartz centres. No calcite porphyroblasts occur. This rock shows that P/T condition reached during its metamorphism, as compared to R8839, was slightly higher; this is indicated by its more abundant biotite.

Mount Dummett

R8841: T.S. 7247

The rock is an epidote-hornblende-quartz-feldspar amphibolite and assigned to the greenschist facies. In previous classifications the rock would have been assigned to the epidote-amphibolite subfacies; now it belongs to the highest portion of the greenschist facies. Structure is shown by parallel zonal concentrations of hornblende and epidote and by parallelism of elongated epidote, hornblende and less frequently microcline. Texture is sub-granoblastic and grains have a range in size from 0.37 mm. to 0.15 mm; quartz shows the complete grain range while the other constituents are coarser than 0.20 mm. Feldspar is generally microcline with some sodic plagioclase.

Sphene, zircon, and apatite are present in accessory amounts. Opaques are scattered through the specimen as anhedral to subhedral grains.

Several vein-like bodies of epidote cut the rock. Some of the feldspar is sericitised especially when near zonal concentrations of epidote.

R8842: T.S. 7248

This is a tremolite-quartz-calcite marble and assigned to the greenschist facies. The rock has definite structure; quartz, and calcite grains are elongated and show parallel orientation; quartz and calcite grains are concentrated in separate zones which parallel the grain elongation. both quartz and calcite occur as xenoblastic grains, quartz ranges in size from 1.15 mm. to 0.04 mm. calcite from 1.15 mm to 0.06 mm. Quartz and calcite are present in about equal quantities and form approximately 98% of the rock. Tremolite occurs as fine acicular crystals with a random distribution.

Mount McCauley

R8843: T.S. 7249

The rock is a sericite-biotite-quartz schist and assigned to the greenschist facies. Schistosity is good; it is quite wavy as it passes around augen-like quartz grains or crystalline quartz aggregates. Two fractions of quartz form the major portion of the rock, one ranging from 0.75 mm to 0.08 mm, and the other fraction is less than 0.0625 mm. Quartz is angular to sub-rounded and occasionally a grain of feldspar occurs with the finer fraction. Sericite and fine, green to brown coloured biotite are present with fine quartz; chlorite occurs rarely in the fine fraction. Fine grains of calcite are scattered through the finer fraction.

Accessory tourmaline, zircon and opaques occur rarely.

R8844: T.S. 7250

This is a recrystallised feldspathic quartzite. No structure is visible. Altered feldspar (about 35%) and quartz (about 65%) are the major constituents. Grains are well sorted and have an average diameter of 0.16 mm. Feldspar is microcline and plagioclase; it shows varying degrees of sericitisation from unaltered to completely sericitised grains. Secondary overgrowths of silica have destroyed much of the sedimentary texture. Rare biotite with equant habit is present. This would be classified by most petrologists as a metamorphic quartzite.

Accessory apatite and zircon occur as rare crystals.

R8845: T.S. 7251

The ore minerals of this rock are hematite and magnetite present in 9 to 1 ratio; hematite is the more abundant. Both are finely crystalline and hematite is xenomorphic while magnetite occurs as rounded inclusions in hematite.

Thin section examination reveals that muscovite and quartz, present in fine, parallel laminae, occur as gangue in the ore.

R8846: T.S. 7252

The rock is a goethite-tremolite-muscovite-stilpnomelane schist and assigned to the greenschist facies - an iron and magnesium rich assemblage. Banding is apparent and occurs because muscovite and tremolite are present in lighter coloured bands with less stilpnomelane and goethite. Stilpnomelane and muscovite are the most common acicular minerals and show a slight tendency to be elongated normal to the banding. Geothite fills interstitial spaces. All acicular minerals are less than 0.0625 mm.

Euhedral to subhedral opaques are scattered through the matrix and some reach a diameter of 1.12 mm.

Mawson Escarpment (68°15'E, 72°33'S)

R8855: T.S. 7261

This is a fine-grained, biotite-hornblende-feldspar quartz gneiss and assigned to the almandine amphibolite facies. Structure is fair and shown by hornblende and biotite generally present in thin linear zones and feldspar and quartz which have poor crystallisation foliation. Quartz forms about 45% of the specimen and ranges in grain size from 0.72 mm to less than 0.0625 mm. Feldspar is microcline and andesine, has xenoblastic habit, ranges in diameter from 0.72 mm. to less than 0.0625 mm, averages 0.3 mm, and forms about 50% of the specimen. Biotite and hornblende form about 5%. and are finer than 0.2 mm in grain size.

Apatite and zircon are rare accessories and occur as extremely fine crystals.

R8856: T.S. 7262

This is a quartz-chlorite-feldspar-hornblende amphibolite. The texture is crystalloblastic and all minerals have an unaltered appearance. No structures, igneous or metamorphic, are present. Sedimentary relict clastic minerals do not occur. The original rock type does not appear to be determinable from thin-section examination. Due to its recrystallised nature original grain size is not determinable. If this was an igneous rock, it would have been an ultrabasic (pyroxenite perhaps) which has recrystallised in situ by a thermal metamorphic retrograde of pyroxene to hornblende and chlorite. Andesine is present in patches between ferromagnesians and forms about 40% of the rock. Quartz is present in interstices amongst andesine and as fine grains in the ferromagnesians.

Accessories are opaques - skeletal appearing and associated with sphene - and apatite.

THE 1961 GEOLOGICAL RECONNAISSANCE IN THE SOUTHERN PRINCE CHARLES MOUNTAINS, ANTARCTICA.

by

D. S. Trail

Records 1963/155

SUMMARY

The Prince Charles Mountains are located in Australian Antarctic Territory, in Mac. Robertson Land between 240 and 800 kms south of Mawson. The mountains are grouped around an 800 km long meridional depression in the continental ice cap formed by the Lambert Glacier and the Amery Ice Shelf. In 1961 an Australian National Antarctic Research Expeditions party from Mawson extended the reconnaissance geological survey of these mountains to Mount Menzies and Mount Bayliss, south of the Fisher Glacier. Inland ice in Mac. Robertson Land mostly drains into the great trough containing the Lambert Glacier. In the southern Prince Charles Mountains ice-flow north of the Fisher Glacier is complex. The Fisher Glacier and the Geysen Glacier are well defined. The south side of Mount Menzies maintains active mountain glaciers. Most high nunataks have flat or gently rounded summit plateaux; some nunataks are fringed by moraine-covered benches or rock benches. Large cirques originally formed by mountain glaciers on Mount Menzies are now abandoned or have been flooded by the ice cap. Unpatterned moraine appears to be younger than the widespread patterned moraine, which may have formed by the ablation of masses of moraine-charged ice. The cirques of Mount Menzies may have been formed before the formation of the continental ice cap. The height of the ice cap has fluctuated greatly; it once stood between 610 m and 1220 m higher than its present level. Mountain glaciers have also formed and have wasted away at various times on Mount Menzies. The glacial features are controlled primarily by precipitation, and this in turn may be controlled by the position of the ice coast. Mount Menzies is composed of quartzite containing bands of quartz-rich schist and amphibolite; all rocks are in the greenschist facies of metamorphism. Mount Bayliss is composed of sub-horizontal layers of quartzite, sheared granite, and amphibolite. At a nearby small nunatak, quartz reefs are developed in a contact between granite and marble. Thermal metamorphism is prominent, probably as a result of the emplacement of the granite. Later shearing has affected all rocks at Mount Bayliss. Among the amphibolites there is no structural distinction between metamorphosed impure limestone and metamorphosed basic igneous rocks. The quartzite was probably derived from a land mass composed mainly of Precambrian gneiss. The low-grade [?] may have been metamorphosed in Lower Palaeozoic times. Mac. Robertson Land has probably persisted as a landmass since the Lower Palaeozoic. Permian sediments have been found by Crohn (1959) and Ruker (1963). Boxworks in quartz reefs at Mount Bayliss and fluorite in granite intruding the low-grade metamorphic rooks suggest that metallic minerals may be associated with these granites. Further exploration in these mountains should be carried out between November and February by ground parties with air support or by parties using air transport.

INTRODUCTION

GENERAL

The Prince Charles Mountains are located in Mac. Robertson Land in Australian Antarctic Territory between latitudes 69°30'S and 74°30'S, and longitudes 60°E and 70°E between 240 kms and 800 kms south of Mawson. They are grouped around an 800 km long meridional depression in the continental ice cap formed by the Lambert Glacier and the Amery Ice Shelf. The mountains are nunataks (rock masses surrounded by ice, up to 130 square kms in area). The higher nunataks rise between 1220 and 2600 m above sea level. Mount Menzies is exceptional and exceeds 3300 m.

The Prince Charles Mountains were discovered in December 1954, by R.G. Dovers, B. H. Stinear, and R. O. Summers, of the Australian National Antarctic Research Expeditions (ANARE) who travelled 240 kms south from Mawson to the northern outliers named the Stinear Nunataks. Since then ANARE exploration of the Prince Charles Mountains has progressed steadily by direct examination and by aerial photography.

The long meridional depression reaching from the sea to the southern Prince Charles Mountains, produces an inland extension of climatic effects normally found adjacent to the Antarctic coast. In December and January cumulus cloud and falls of snow are frequent in the southern ranges 640 kms from the sea; at 2450 m on the Mac. Robertson Land ice cap 320 kms nearer the coast, the precipitation of ice crystals from cirrus clouds was seen on several days. Temperature is also more a function of altitude than latitude in summer. In the southern ranges in December, temperatures between -15 °C and -20 °C were normal at altitudes between 1220 m and 1850 m. At 2150 m on the Mac. Robertson Land ice cap, temperatures between -18 °C and -30 °C were common in December and January.

As observed by Mather (1962) there is a progressive change in the direction of the katabatic wind between Mawson and the southern ranges of the Prince Charles Mountains, The wind direction is south-south-east at Mawson, south on the ice cap about 190 kms south of Mawson, and south-west in the southern mountains. Wind velocity appears to decrease south-wards from Mawson, and north of the Fisher Glacier light winds probably prevail. On the Fisher Glacier and among the mountains south of it a strong south-westerly katabatic wind blew on most days between 16th and 29th December, 1961. This wind sprang up suddenly at 2100 GMT (0100 Zone Time), and blew at speeds between 15 and 30 knots until 0700 GMT after which the wind steadily decreased.

Poor visibility frequently prevents oversnow travel in the Prince Charles Mountains. It is caused by overcast sky producing a "whiteout", in which snow surface features cannot be distinguished, or by large quantities of snow drifting in a strong wind and producing a dense drift haze. A geologist may well be able to work on a rock surface under such conditions.

De Havilland *Beaver* aircraft operating from Mawson or Davis have landed at several points in the Prince Charles Mountains on flat areas of snow or ice. Proved landing grounds are located at Jetty Peninsula, Beaver Lake, Grove Nunataks, Clemence Massif, Fisher Massif, Mawson Escarpment at 73°33'S, Mount Stinear, and Wilson Bluff. *Beaver* and *DC-3* aircraft have landed at Binders Nunataks on a snow airstrip prepared by a bulldozer.

In 1954, 1955, and 1956, light tracked vehicles (*Weasels*) reached the northern outliers of the Prince Charles Mountains along a route running south-south-east from Mawson via Depot Peak and the Stinear Nunataks. Crohn (1959) records that the terrain within the northern ranges is too dangerous for vehicles; in 1956 exploration there was carried out entirely by dog sledge.

Tractor trains, composed of *D4* Caterpillar tractors pulling several heavy sledges, reached the southern ranges of the Prince Charles Mountains in 1957 and 1960. Both parties travelled south from Mawson along the 62nd meridian and both experienced great difficulty with crevasses within 32 kms of the mountains. In 1960 Ruker (1963) made a geological traverse along the north side of the Fisher Glacier. He used a *Weasel*, with a dog team for emergency transport. The *Weasel* broke through a crevasse at Mount Scherger and was recovered with great difficulty. Ruker suggests that tractor trains may be able to reach Mount Seddon, on the north side of the Fisher Glacier, and that light vehicles or dog sledges may be able to cross the Fisher Glacier to Mount Rubin from Mount Seddon. Following a reconnaissance map prepared by Ruker a dog sledge route was found across the Fisher Glacier from Binders Nunataks to Mount Menzies in 1961. This route may be suitable for light tracked vehicles.

A caravan with a depot containing small quantities of man food and petrol was located in 1961 at a small rock outcrop about one km north-west of the west end of the largest of Binders Nunataks. The depot was on the small outcrop, the caravan is 30 m north-east of it. The caravan was buried in snow but provided excellent shelter. It was poorly ventilated and the danger of carbon monoxide poisoning was very great, when a stove or heater was burning.

A small depot of dog food and man food was left in 1961 on the ice cap along the route from Mawson to the southern ranges of the Prince Charles Mountains, at 70°33.3'S, 62°29.8'E, about sixty kms west of the west end of the Porthos Range. About five kms south of this depot were two snow cairns spaced about a km apart, each containing a small quantity of dog food.

A large fuel dump containing kerosene and petrol was left in 1961 on the ice cap at 68°48'S, 62°07'E. On the north side of this fuel dump a snow cairn contained a small amount of dog food and a very small amount of man food.

Between Mawson and the depot at 70°33.3'S the track of the 1961 tractor party was marked by drums, snow cairns, and flags spaced at intervals ranging from 800 m to 8 km. Between this depot and Binders Nunataks the track of the 1961 dog party was marked by snow cairns and flags at intervals ranging from 1.6 km to 6.5 kms. Of these markers, only some drums and some bamboo flagstaffs will remain for any length of time.

FIELD WORK

Personnel of the Australian National Antarctic Research Expedition manning Mawson base in 1961 were directed to travel by tractor train to the southern ranges of the Prince Charles Mountains in October of that year, and to use light tracked vehicles to explore the mountains south of the Fisher Glacier.

In April 1961, during a fuel-dumping operation in connection with this program, the two *D4* tractors at Mawson were immobilised 80 kms south of the base, and were abandoned for the winter. The plan for the journey to the Prince Charles Mountains was shelved.

On the recovery of these tractors in October, 1961, the Officer-in-Charge at Mawson was directed to use them to recover a third *D4* tractor abandoned for lack of fuel, 320 kms south of Mawson, by the 1960 party on returning from the Prince Charles Mountains.

D. Keyser (radio operator) suggested that the tractor party might support a dog-sledge party which could then reach the 1960 depot at Binders Nunataks, on the northern fringe of the southern Prince Charles Mountains.

D. Trail (geologist), D. Keyser, and J. Seavers (assistant cook), with two five-dog teams, reached this depot on 12th December 1961, and using a route map prepared by Ruker (1963) crossed the Fisher Glacier and mapped the geology of Mount Bayliss and Mount Menzies. They spent five days in attempts to reach Keyser Ridge 64 kms south-east of Mount Menzies, and Mount Ruker and Mount Rubin, 95 kms east of Mount Menzies. Both attempts were stopped by a continuous zone of large crevasses occupying the south-eastern side of the Geysen Glacier.

The party turned on 26th December and retraced their outward route, arriving at Mawson on 27th January, 1962.

In crossing the ice cap and in route-finding among the mountains the party used 1:500,000 scale maps compiled by the Division of National Mapping. These maps are based on Royal Australian Air Force trimetrogon photography tied to astronomical observations by ANARE surveyors. One run of trimetrogon photographs was available to the field party. Information obtained in the field was plotted, on return to Australia, on large scale sketch maps drawn from further RAAF trimetrogon photography made in 1960.

While travelling on the ice cap, the dog sledge party steered by the sun. In poor visibility the party steered by the *sastrugi* (low, closely packed wind-cut snow ridges, parallel to the prevailing wind-direction) which are locally constant in direction. The course was checked hourly by a careful magnetic compass reading. The lack of a distance recorder on the dog sledge caused great inconvenience. Observations of the sun were made each suitable day with a bubble sextant, for latitude by meridian passage, and for longitude by position line. Neither the magnetic compass nor the bubble sextant was dependable. An astrocompass and a light theodolite would probably be more suitable for navigation.

A geologist intending to work in Antarctica should learn to use a light theodolite for celestial and distant terrestrial observations.

On gentle slopes in the Prince Charles Mountains, bedrock is commonly concealed under a thick blanket of moraine. Steep slopes provide excellent exposures, but these may be inaccessible because of disturbed ice lying against them.

In any wind, note-taking is difficult, and through the day the geologist normally makes very brief notes, which are expanded in the shelter and warmth of the tent in the evening. The examination of samples by hand lens in the field is very difficult, since the lens almost always becomes coated with ice.

PREVIOUS WORK

The geological reconnaissance of the northern ranges of the Prince Charles Mountains is reviewed by Crohn (1959).

In 1957, M. Fisher (surveyor at Mawson) was landed at Mount Stinear in the southern Prince Charles Mountains (Fig. 4). From the moraine along the eastern side of the mountain he collected samples of massive biotite granite, amphibole gneiss, mica schist, and slate.

At the southern limit of an oversnow seismic traverse from Mawson in January 1958, M. Mellor (glaciologist) collected samples of massive granite, metamorphosed sandstone, and hornfels, from

Fig. 4. Mount Stinear. looking south. Flat topped massifs bounded by steep cliffs are characteristic of the southern Prince Charles Mountains. The cliffs in this oblique aerial view are about 800 metres high. Airphoto ANT71 Run 202 9125R, acquired 1st March 1959.

moraine at the Goodspeed Nunataks, the north-western outliers of the southern Prince Charles Mountains. The samples are described by McLeod (1959).

Later in 1958, McLeod (1959) landed at Wilson Bluff, near the southern termination of the Prince Charles Mountains. He found outcrops of mica schist, quartzite, and amphibole-bearing rocks, quite unlike the gneisses which form the northern ranges of the Prince Charles Mountains.

In 1960 a field party from Mawson travelled by tractor to the southern Prince Charles Mountains. From their depot at Binders Nunataks, Ruker (1963) reconnoitred the mountains north of the Fisher Glacier.

Ruker found that Binders Nunataks and Mount Cresswell are composed of high-grade metamorphic rocks, typically biotite gneisses. Mount Bloomfield is sheared granite. The large mountains fringing the Fisher Glacier are dominantly composed of quartzite and mica schists, low-grade metamorphic rocks in the greenschist facies of metamorphism (Fyfe *et al.*, 1958). They are intruded by large bodies of massive granite and by amphibolite dykes. In moraine fringing Mount Rymill, Ruker discovered fragments of red sandstones and shales, with *Glossopteris* and other plant fossils determined as Permian by White (1962).

Ruker (1963) was flown to 73°33'S in the Mawson Escarpment, where he found high-grade metamorphic rocks, including staurolite schist.

PHYSIOGRAPHY

GENERAL

The form of the inland ice in Mac. Robertson Land is dominated by the huge meridional trough, over 480 kms long and 32 to 95 kms broad, which contains the Lambert Glacier and the southern part of the Amery Ice Shelf.

This trough so greatly facilitates the drainage of the inland ice to the sea that the surface of the continental ice cap is considerably depressed throughout Mac. Robertson Land. 480 kms inland, the surface of the Lambert Glacier lies only 150 m above sea level. The normal height of the continental ice cap at this distance from the coast is about 2450 m. Between 160 and 320 kms east and west of the Lambert Glacier the ice cap surface slopes gently towards it, and the overall depression in the ice cap runs southwards for at least 800 kms from the coast.

The form of the ice cap surface in Mac. Robertson Land suggests that the inland ice flows directly into the sea north of the 70th parallel only. South of this parallel the accumulated ice in Mac. Robertson Land, together with ice from western Princess Elizabeth Land and ice from south-eastern Kemp Land, flows radially inwards towards the Lambert Glacier and the Amery Ice Shelf. Broad, east and north-east trending rock valleys, occupied by the Fisher Glacier and other huge ice streams, supply ice to the Lambert Glacier along its western side. The west-trending rock ridge mapped by Goodspeed and Jesson (1959) under the ice west of Stinear Nunataks, about latitude 69°40'S, may dam the northward flow of the ice west of the Prince Charles Mountains and divert it towards the Lambert Glacier. The ice cap east of the Lambert Glacier is to some extent cut off from it by the north-trending range of mountains whose western face is exposed in the Mawson Escarpment.

The high rock walls of many glacier valleys are partly exposed above the ice cap as nunataks. Near the junction of the Lambert Glacier with the Amery Ice Shelf, the lowest part of the depression in the ice cap, many large nunataks form the northern ranges of the Prince Charles Mountains. The southern ranges of the Prince Charles Mountains are formed by the exposed tops of the rock walls containing the upper Lambert Glacier, the Fisher Glacier, and other large tributaries of the Lambert Glacier.

ICE CAP

The 1961 geological party crossed the inland ice between Mawson and the southern Prince Charles Mountains along the 62nd meridian, following the route taken by geophysical parties in 1957 and 1958, and by the geological party in 1960. The surface of the ice cap along this route has been described by Mather and Goodspeed (1959) and by Mather (1962).

From the sea at Mawson the blue ice surface of the ice cap rises for 32 to 48 kms through the marginal ablation zone to an altitude between 600 and 810 m. At this height and distance from the sea the ice surface passes under the cover of wind-compacted snow (névé) which forms the greater part of the ice cap surface in the accumulation zone.

The névé surface is almost everywhere cut by the wind into sastrugi, which range from a few centimetres to one metre in height. Where the wind has eroded a mound or dune of compacted snow, steep-sided ridges may rise two metres or more.

In 1961, between latitudes 69°S and 72°S, several km-wide patches of sastrugi up to 60 cm high appeared to be separated by equally wide patches of relatively smooth névé carrying sastrugi less than 30 cm high. The broad patches of high sastrugi probably correspond to the snow "waves" from two to six kilometres wide described by Dolgushin (1960) between Mirnyy and Pionerskaya.

As described by Mather (1962) the sastrugi direction changes from south-south-east near Mawson through south to south-west in the region of the southern Prince Charles Mountains. Mather attributes this systematic change to the diversion of the katabatic wind (the seaward-flowing current of dense cold air) into the deep trough of the Lambert Glacier.

From an altitude of 1220 m at the southernmost nunataks of the Framnes Mountains 72 kms south of Mawson, the névé surface of the inland ice along the 62nd meridian rises gently with an overall gradient between one in 150 and one in 300 to reach an altitude of 2130 m at 69°38'S, 248 kms south of Mawson. For the greater part of this distance, the névé surface is a succession of ill-defined and very gentle undulations. Crest to crest, the undulations are several kms apart and they rarely exceed 15 m in amplitude. About 68°30'S, between 112 kms and 128 kms from Mawson, a group of steep, north-facing, névé ridges and domes forms a step about 30 m high in the surface of the ice cap. The face of the step has a gradient of about one in 100. The crests of the domes and ridges carry large crevasses up to 6 m broad. This zone of disturbed ice is located on the northern edge of a depression in the rock surface, 900 m deep and 48 kms wide, mapped by Goodspeed and Jesson (1959). The southern edge of the depression is marked at the surface by a six km wide zone of low névé domes.

At 69°38'S the north face of a steep névé dome rises abruptly between 30 and 60 m; the crest of the dome is broken by huge crevasses over 15 m wide. For 56 kms south of this dome the névé surface is disturbed by steep domes and ridges with irregular hummocky surfaces and with large snow-filled crevasses on their crests. The névé surface is little disturbed in the broad valleys between the domes, but valley floor gradients are locally steeper than one in 100.

These domes and ridges overlie a high, steep-sided, west-trending rock ridge mapped by Goodspeed and Jesson (1959), which rises 900 m to approach within 300 m of the ice cap surface.

South of this disturbed zone the névé surface of the ice cap rises in gentle undulations from 2350 m to reach 2440 m at 70°15'S where it levels out as a gently undulating surface extending to 70°30'S.

From 70°30'S to 71°S the ice cap surface falls gently for 150 m, but the undulations in the surface are more clearly defined over this distance. They form a succession of broad hills and closed valleys. The crests of the hills are spaced between 5 and 8 kms apart; the hills rise between 15 and 30 m. The valleys are commonly elliptical; their long axes trend eastwards.

At 70°54'S a small névé dome marks the southern edge of a 450 foot rise in the rock surface, mapped by Goodspeed and Jesson (1959).

South of 71°S the snow-surface undulations increase in amplitude, exceeding 30 m, and their south-facing slopes steepen. Locally, gradients may exceed one in 100. Between 71°27'S and 71°40'S there are at least three distinct south-facing steps in the ice cap surface. They are spaced between 8 and 16 kms from each other; the highest falls about 60 m; gradients on the steps approach one in 50. In this area the undulations in ice cap surface, as Mather and Goodspeed (1959) observed, develop a distinct easterly slope, and the valleys between the swells visibly broaden and deepen eastwards towards the Lambert Glacier.

This markedly undulating, east-sloping surface continues to descend gently to 72°S where there is a sharp change. Here a steep, south-east-facing snow slope drops about 45 m into a narrow snow valley, closed at its north-east end, which descends and widens south-westwards. From the slope above this valley, Mount Menzies, Mount McCauley, and Mount Scherger are clearly seen in good weather.

The low south-east wall of the valley is a névé ridge with cracks and small crevasses on its crest. Southwards this ridge rises and broadens into a line of large névé domes, over 30 m high and more than 4.8 kms broad, carrying large crevasses; the line extends at least 21 kms south, towards the Goodspeed Nunataks.

This disturbed region overlies the north-west trending extension, mapped by Goodspeed and Jesson (1959), of the rock ridge which breaks the surface at Binders Nunataks and Mount Cresswell, the northern outliers of the southern ranges of the Prince Charles Mountains.

GLACIERS

Ground observations in the southern Prince Charles Mountains are augmented by information collected by Ruker (1963) and by airphoto interpretation.

From the western side of Binders Nunataks a succession of high and steep névé domes with large crevasses, runs southwards for 24 kms to merge with an elongated névé ridge which runs 40 kms south-westwards to the Goodspeed Nunataks. The south side of this ridge is about 60 m high, the north side is considerably lower. On its crest and on its south side the ridge has large crevasses. South of the ridge a broad basin of smooth névé, with a few small domes and patches of concealed crevasses, stretches 32 kms to the north side of the Fisher Glacier.

Between Binders Nunataks and the Fisher Glacier, and along the north side of that glacier to its confluence with the Lambert Glacier, ice flow is complex. A small glacier flows eastwards from the Goodspeed Nunataks to merge with the disturbed ice flowing south-eastwards between Binders Nunataks and the Goodspeed Nunataks and passing north of Mount Scherger and Mount McCauley. The Fisher Glacier is constricted between Mount Menzies and Mount Scherger. The distribution of crevasses around Mount Scherger, together with flow lines to the west, suggests that some ice from the constricted Fisher Glacier is diverted northwards around Mount Scherger.

The constriction in the Fisher Glacier is relieved east of Mount McCauley and Mount Bayliss, and ice from the 48 km broad area between Mount McCauley and Mount Cresswell flows into the Fisher Glacier between Mounts McCauley and Dummet, between Mounts Dummet and Seddon, and between Mounts Seddon and Rymill. The Fisher Glacier, greatly augmented by these northern tributaries and by its large south-eastern tributary the Geysen Glacier, is again constricted between Mount Stinear and Mount Rubin. The ice occupying the valley between Mount Rymill and Mount Stinear appears to be stagnant.

North of Mount Stinear the surface of the ice cap dips sharply down to the Lambert Glacier, and an enormous quantity of ice must here flow into the glacier along its western side from the ice cap north of Mount Cresswell.

The Fisher Glacier, the most prominent and most clearly defined tributary of the Lambert Glacier, has its source in the ice cap west of 60°E, over 2140 m above sea level. The glacier falls 1530 m in 190 kms to its confluence with the Lambert Glacier. Over most of its length the Fisher Glacier is about 40 kms broad; its breadth is reduced to 26 kms between Mounts Menzies and Scherger.

West of Mount Menzies, the upper part of the Fisher Glacier carries large areas of disturbed ice, domes, and ice falls with huge crevasses and seracs. The eastern limit of this disturbed area is marked by the large ice fall which runs for several kms south-westwards from Seavers Nunataks.

Within about 6 kms of the northern sides of Mount Menzies and Mount Bayliss, and probably of Mount Mather, the névé surface of the glacier has been stripped off by wind or by radiation to expose blue ice. North of Mount Menzies this blue ice zone is broken by large and small longitudinal crevasses (parallel to the direction of ice flow) and by potholes filled with soft snow. Ruker (1963) records that blue ice forms the surface of the north side of the Fisher Glacier east of Mount Scherger.

The proved dog-sledge route across the Fisher Glacier runs in a straight line from a point about 2.4 kms east of Seavers Nunataks to the north-east corner of Mount Menzies. This route crosses small and well-bridged longitudinal crevasses within a few kms of Seavers Nunatak, and runs over several kms of smooth névé to the edge of the blue ice zone north of Mount Menzies. In this zone the route runs for 5 or 6 kms over narrow longitudinal crevasses and rough, potholed blue ice, to south-sloping smooth blue ice within 1.6 km of the mountain.

A few kms east of this route steep longitudinal névé ridges develop along the north side and the centre of the glacier, as the ice is constricted between Mount Menzies and Mount Scherger. Large longitudinal crevasses in these ridges increase eastwards in size and number. Some are 20 m wide, others have their lips contorted upwards as steep névé hummocks up to 2 m high.

Between Mount Bayliss and Mount Scherger the longitudinal ridges unite in a mass of intensely deformed ice several kms broad, rising a few hundred metres above the margin of the glacier. The surface of the glacier is broken by lateral and diagonal crevasses over 30 m wide, and by high seracs. The uplifted area of disturbed ice ranges from 8 to 16 kms in breadth and occupies the centre of the glacier for at least 48 kms, from Mount Scherger to Mount Dummet.

The surface of the Fisher Glacier appears to be relatively little disturbed between Mount Rubin on the south and Mount Dummet and Mount Seddon on the north, and Ruker (1963) has suggested that the glacier may be crossed here. However, a zone of crevasses may exist along the north side of Mount Rubin.

Between Mount Rubin and Mount Rymill the Fisher Glacier, augmented by its south-eastern tributary, the Geysen Glacier, is again constricted and its surface is raised up in two broad areas of crevasses and seracs which converge eastwards into the area of intensely deformed ice which occupies the confluence of the Fisher, Lambert, and Mellor Glaciers.

The Geysen Glacier is the north-east flowing stream of ice located south-east of Mount Menzies and north-west of Keyser Ridge, which joins the Fisher Glacier at Mount Ruker. This glacier has its source in the ice cap south of Mount Mather at an altitude of over 2140 m. The surface of the glacier south of Mount Menzies is about 300 m higher than the surface of the Fisher Glacier north of Mount Menzies. As a result of its relatively steep gradient, the Geysen Glacier carries many extensive areas of disturbed ice.

West of Keyser Ridge a succession of névé domes with large crevasses extends northwards towards Mount Mather. A continuous 13 km broad zone of large lateral crevasses extends along the north-west side of Keyser Ridge to the north-west side of Mount Ruker where it broadens to merge with an area of large crevasses extending from the east end of Mount Bayliss. A broad névé dome with large crevasses is located about 5 kms south of the west end of Mount Bayliss.

Between Mount Menzies and Mount Bayliss a steep slope of undisturbed blue ice, about 300 m high, provides a safe route from the Fisher Glacier to the south side of Mount Menzies. There are a few small crevasses and potholes in the blue ice at the top of the slope.

Debris from the southern cliffs of Mount Menzies accumulates as lateral moraine on this slope and moves very slowly downhill to augment a broad area of moraine overlying almost stagnant ice at the north-east corner of the Mount Menzies massif. This area of moraine lies in an ice depression about 30 m lower than the southern margin of the Fisher Glacier. Some of the moraine has been caught up by the Fisher Glacier and has been drawn out across the foot of the slope as far as the broad area of stagnant moraine on the north side of Mount Bayliss.

Although this blue ice slope is steep, it appears to be composed of very slow-moving ice, probably cut off from the abundant supply of ice south of Mount Menzies by a submerged rock bar running between Mount Menzies and Mount Bayliss.

The stagnant ice occupying the outer part of the floor of the large abandoned cirque on the north side of Mount Menzies, is depressed about 30 m below the south margin of the Fisher Glacier.

A snowfield about 6 kms long, east to west, by 1.5 km broad lies high on the south side of Mount Menzies close below the summit. This snowfield feeds two glaciers. One is a 6 km-wide, steep mountain glacier which flows more than 900 vertical metres down the southern cliffs of Mount Menzies in a series of ice falls. It continues southwards from the foot of the mountain as a distinct upraised ice stream with large crevasses for at least 3.2 kms before it loses its identity in the great mass of ice flowing north-eastwards towards the Fisher Glacier. The other glacier fed by the snowfield flows gently eastwards for 6 kms along the broad east ridge of the mountain and terminates among the patterned ground at the south end of the east platform.

The present accumulation of snow on the south side of Mount Menzies is evidently great enough to feed these glaciers. However, one large and several small mountain glaciers previously occupying cirques on the north side of the mountain have been starved out of existence.

NUNATAKS

With the exception of Mount Menzies, the large nunataks in the southern ranges of the Prince Charles Mountains have flat or gently rounded platform summits.

Crohn (1959) records that platform summits are common in the northern ranges of the Prince Charles Mountains. Many nunataks around the inner edge of the Amery Ice Shelf have very flat tops.

The platform summits lie at various levels up to 2600 m above sea level. The platforms are not simply concordant and they cannot be directly related to a simple, pre-glacial peneplain. Crohn (1959) suggests that faulting has produced the discordance of the levels.

Fisher Massif and Clemence Massif, nunataks at the edge of the Lambert Glacier, have broad flat benches developed well below their gently rounded summits.

Mount Menzies has broad moraine-covered benches on its east and west flanks. These are linked by a narrow, rock-floored bench cut along the north side of the mountain. These benches are roughly concordant with the broad, flat summit of Mount Bayliss, five kms east of Mount Menzies.

The east bench of Mount Menzies is composed of glacial debris, exposed to a depth of 45 m in one dry valley, banked between the main mass of the mountain and the low rock peaks along the north side of the platform. The platform has been built by the accumulation of glacial debris. The west platform was not visited; it appears to be similar from air photographs.

The flat summit of Mount Bayliss has large striae, seen on air photographs, running parallel to the present ice-flow direction. The upstream face of the mountain is rounded and the downstream face is abrupt and craggy, thus the mountain has the form of a *roche moutonnée;* a rock rounded by flowing ice.

The benches may be remnants of old valley floors. Since the floor of the Fisher Glacier probably lies well over 610 m blow the prominent bench on the north side of Mount Menzies, this interpretation involves the removal of an enormous mass of rock. However, the glaciers of the Prince Charles Mountains are among the largest glaciers in the world, and they may well be capable of eroding and transporting such quantities of rock.

In the European Alps similar benches have been attributed to erosion by tributary glaciers, confined to the side of their parent mountain by the lateral pressure of the great glaciers (Charlesworth, 1957). The benches of the Prince Charles Mountains may have a similar origin.

Mount Menzies is essentially an east-west trending rock ridge between 24 kms and 32 kms long. On its north side subsidiary ridges separated by cirques drop gently to the Fisher Glacier.

Along the south side of Mount Menzies the surface of the ice cap is at least 305 m higher than the surface of the Fisher Glacier. Subsidiary ridges on the south side of the mountain drop steeply between 900 m and 1520 m to the ice cap surface. A small nunatak 6.5 kms south-west the mountain is connected to it by a low ice ridge.

The most prominent feature on Mount Menzies is the great northern cirque which almost bisects the mountain (Fig. 5). This cirque is about 8 kms long by 2.5 kms broad, and its walls reach 1220 m in height. The cirque has been eroded by a large north-flowing mountain glacier originally located high on Mount Menzies. At present there is no significant accumulation of permanent snow in the cirque. It is floored mainly by patterned moraine, with a small strip of unpatterned moraine along the inner edge of a depressed area of stagnant ice, bordering the Fisher Glacier.

On the north-east side of Mount Menzies several small cirques are located at the heads of small glaciated valleys cut for the most part in the patterned moraine of the eastern platform; one valley cuts moraine at least 45 m thick. Most of these valleys contain large patches of névé. Moraine on their floors is unpatterned. The valleys commonly contain one or more heaps of moraine which stretch across their floors as steps or mounds up to 4.5 m high.

On the south side of Mount Menzies the pattern of the rock ridges reveals at least two large cirques, comparable in size to the great cirque on the north side, which are partly concealed by the present high level of the ice cap. The upper part of one, located below the summit of the mountain, contains the steep, active mountain glacier referred to above. The upper part of the other is empty.

The radiation of solar heat from the great area of dark rock exposed on the northern side of the mountain probably prevents the persistent accumulation of snow in all but the most sheltered situations, and the present prevailing wind direction also affects adversely the accumulation of snow on the north side of the mountain. On the south side, though previously eroded cirques are now occupied by the continental ice cap, the accumulation of snow is sufficient to maintain active mountain glaciers high on the mountain.

Fig. 5. The "great northern cirque" on Mount Menzies. View looking north-east. Airphoto ANT88 Run 1B 7107L, acquired 4th December 1960.

GLACIAL GEOLOGY

The glacial debris has been divided into unpatterned moraine and patterned moraine. Much of the unpatterned moraine has been moulded by glacial action into distinct forms - steep straight mounds, or long sinuous mounds - which nevertheless do not constitute patterned ground as defined by Washburn (1956).

UNPATTERNED MORAINE

Unpatterned moraine forms the lateral moraines of the active glaciers and is commonly found overlying bedrock up to about 30 m above and near the present ice surface. Unpatterned moraine is also found up to 900 m above the ice surface on some nunataks, on the floors of dry valleys previously occupied by mountain glaciers.

The unpatterned moraine overlying or adjacent to the active ice streams commonly forms long, low sinuous ridges, up to about 3 m high, roughly parallel to the direction of ice flow. In the dry valleys on some nunataks, straight steep-sided mounds of unpatterned moraine, up to 4.5 or 6 metres high, are elongated across the valleys. These are terminal moraines, and mark pauses in the recession of the mountain glaciers. In one shallow dry valley on Mount Menzies there are at least seven terminal moraines.

The unpatterned moraine is an unsorted accumulation of pebbles, cobbles, and boulders. Fine-grained material is notably rare. The fragments are mainly sub-angular; the largest are angular. They range up to 3 m in diameter; the majority are between 2.5 cm and 60 cm in diameter.

PATTERNED MORAINE

Moraine lying on the broad summit plateaux of many nunataks, and on the broad benches which flank many nunataks, and some moraine extending from these benches down gentle slopes to the present ice level, is commonly arranged in regularly spaced and similar sub-conical mounds approximating to the type of patterned ground defined by Washburn (1956) as unsorted nets.

Extensive areas of patterned moraine were superficially examined on Mount Bayliss and Mount Menzies. The patterned moraine was nowhere excavated and consequently cannot be fully described. The fragments forming the patterned moraine are not sorted, but clay-grade and silt-grade material is rarely present on the surface. Most of the fragments range from 2.5 cm to 60 cm in diameter; a few range up to 3.5 m in diameter. Fragments are dominantly sub-angular, a few are sub-round, and the largest fragments are angular.

The patterned moraine accumulations of these fragments form low cones, typically between 2.4 m and 6 m in diameter and between 60 cm and 120 cm high. The centres of the cones are roughly equidistant and each core is in contact with the surrounding cones. In a small area - a few hundred square metres - on the broad moraine-covered platform on the east side of Mount Menzies, relatively steep cones range up to 2.5 m in height; they are between 6 m and 10 m in diameter. The boundaries between neighbouring cones are almost everywhere obscured by the soft snow which accumulates in the intervening hollows. The material at the few boundaries seen did not appear to be markedly different from the material forming the cones.

Some cones are arranged in linear groups, some parallel, some at right angles to the slope of the moraine surface. These linear patterns may be picked out in one preferred direction by the accumulation of snow in wind-controlled stripes among the cones; this direction may be thus apparent rather than real.

The bottom of the long dry valley which forms the western limit of the moraine-covered platform at the east end of Mount Menzies, is covered by unpatterned moraine, partly concealed by snow. Where this valley debouches on to stagnant ice adjacent to the Fisher Glacier, about 2.6 square km of moraine derived from the valley has a roughly patterned surface. This area was observed at a distance of about 1.6 km and it was not examined in detail. It appears to be made up of irregularly spaced cones of moraine ranging between 60 cm and 10 m in height. The depressions between some cones are occupied by "ponds" of flat ice up to 45 m across. This roughly patterned moraine may be transitional between unpatterned and regularly patterned moraine. It suggests that patterned moraine may be produced by the ablation of stagnant, moraine-charged ice.

The patterned moraine in the Prince Charles Mountains may be further investigated by the study of aerial photographs, by excavation, and by the close examination of natural sections. Some of the areas of patterned moraine may lie on cores of very old stagnant ice.

Glacial History

The blanket of patterned moraine which covers most of Mount Menzies and Mount Bayliss appears to have been deposited by the receding ice-caps, since the distribution of the moraine is not evidently related to cirques or to valleys cut by mountain glaciers. The spread of the moraine blanket over benches and cirque floors demonstrates that the benches and cirques were formed before the deposition of the moraine blanket.

Mountain glaciers probably existed in Mac. Robertson Land long before the coalescence of the independent glacier systems formed the continental ice cap. The more prominent features formed by mountain glaciers, such as the very large cirques on Mount Menzies, may have been at least initiated during the long period of mountain glacier activity which preceded the formation of the ice cap.

As the cirques are cut into the summit plateaux and into at least one bench, the plateaux and benches may well be remnants of a pre-glacial landscape of rolling hills, whose tops are preserved as summit plateaux, and broad valleys, partly preserved as benches.

Following the formation of the continental ice cap, it rose, in the Prince Charles Mountains, to a height between 610 and 1220 m higher than its present level. It may have attained this height several times, and the height of the ice cap has probably fluctuated considerably. It has at least once dropped below its present level since patterned moraine extends beneath the ice in places.

The greatest vertical and lateral extent of the Antarctic ice cap probably coincided, as Hollin (1962) claims, with the world-wide drop in sea level during the Pleistocene. The recession of the sea and the lateral expansion of the ice cap reduced precipitation drastically in inland Antarctica, and the vertical recession of the ice cap inevitably followed.

This recession revealed many mountains which had been buried by the ice cap. Large masses of moraine-charged ice which had been stranded on the mountains ablated slowly to deposit thick blankets of moraine with patterned surfaces. Other large accumulations of moraine had been built up, during the flow of the ice, in the shelter of large rock features, duplicating on a large scale the crag-and-tail features of northern Europe (Charlesworth, 1957).

Vertical recession was probably accompanied by lateral recession at the coast, and the overall shrinkage in the ice cap was accompanied by an increase in height of sea level. The encroachment of the sea probably increased precipitation in the southern Prince Charles Mountains sufficiently to form mountain glaciers on Mount Menzies, the highest and largest nunatak, and eventually to bring the height of the ice cap some way above the lowest limit of the moraine deposited at the earlier recession.

The mountain glaciers of Mount Menzies completed the excavation of the great cirques on the north and south sides of the mountain, probably before the ice cap rose sufficiently to inundate the lower parts of the southern cirques. Then the ice cap margin responded, after an interval of several thousand years, to the increased precipitation in the interior, and the lateral expansion again reduced precipitation. The mountain glaciers on the north side of Mount Menzies receded step by step, leaving mounds of unpatterned moraine. Some masses of stranded moraine-charged ice, particularly on the floor of the great northern cirque, may have formed patterned moraine.

The large surface of rock and moraine now exposed on the north side of the mountain absorbs and re-radiates so much solar heat in summer that considerable quantities of snow cannot accumulate there permanently. Only the snowfield located high on the southern side of the mountain continues to nourish mountain glaciers, since this field receives little solar heat and appears to be favourably located for the accumulation of snow in the prevailing south-west wind.

GEOLOGY

The petrographic descriptions and the metamorphic histories of rocks from Mount Menzies and Mount Bayliss have been taken directly from descriptions of thin sections of these rocks by W.R. McCarthy of Australian Mineral Development Laboratories (Appendix 1).

MOUNT MENZIES

The rocks described were collected from the eastern part of Mount Menzies. This part is mainly covered by moraine at low levels and by nivation debris at higher levels. Good exposures are accessible at the north end of the eastern moraine platform, in the high cliffs of the south-east and south sides of the mountain and on its topmost 900 m.

Mount Menzies is composed of quartzite containing minor bands of quartz-rich schist and of amphibolite. Colour bands up to 300 m thick are evident in the cliffs of the mountain. They are almost all composed of quartzite; the colour depends on the accessory minerals. Black quartzite is coloured by iron-staining, greenish-grey quartzite contains chloritoid and white quartzite contains sericite. Pink quartzite is also prominent, but this rock was not sampled.

In hand-sample the quartzites are fine-grained, massive and tough; one sample has a pronounced lineation. Crystals of chloritoid, chlorite, sericite, and rarely garnet and biotite may be visible.

Lenses and thin bands of green-grey quartz-rich schist are locally common in the quartzite. On the north-east ridge of Mount Menzies, within a km of the summit, the quartzites alternate with bands of quartz-rich schists; the boundaries of the bands are gradational. Veins of milky quartz up to 15 cm broad are locally abundant in the quartz schists. Iron-staining is common.

Microscopic examination shows that the quartzites are composed of 90-97% recrystallised quartz. Chloritoid is the second most abundant mineral; chlorite is common and appears to have formed by the retrogressive alteration of chloritoid. Muscovite and sericite are common accessory minerals; in a few quartzites they are more abundant than chloritoid. Zircon and opaque minerals are present in small quantities.

One sample (R11362), from the summit area, is a garnet-muscovite quartzite. Muscovite and chlorite form about 10% of the rock and poikiloblastic porphyroblasts of garnet, probably spessartite, form about 1%. Corroded crystals associated with muscovite may be chloritoid. A few porphyroblasts of biotite are present; they have no preferred orientation. The biotite appears to have formed by replacement of muscovite.

The bands and lenses of schist in the quartzite are mainly chloritoid-quartz schist. In one sample (R11358) chloritoid forms 60% of the rock; the remainder is mainly quartz. Sericite, muscovite, and chlorite have apparently formed by the retrogressive alteration of the chloritoid.

Near the summit of the mountain a black, fine-grained hard, tough rock, commonly with a strong slaty cleavage, is interbanded with the quartzite. This rock was named slate in the field; it is a cordierite-chloritoid-muscovite-quartz schist (R11581). Fine-grained quartz is the most abundant mineral, chloritoid and muscovite each form about 15%. Under the microscope, the fine-grained muscovite reveals an excellent schistosity which is plicated. The axial areas of these plications contain porphyroblasts of cordierite. Lenses of quartz parallel the schistosity of the rock and other lenses possibly of goethite and of a golden-brown transparent mineral (?monazite) are present.

Near the summit of Mount Menzies bands of actinolite amphibolite are interbanded with the quartzite. The amphibolite is a black, fine-grained, hard and massive rock; its boundaries with the quartzite are concealed. McCarthy describes one sample (R11363) as an epidote-quartz-actinolite amphibolite, composed of 85% actinolite, 12% quartz, 2% epidote, and 1% feldspar. Opaques are common accessory minerals; zircon and apatite are rare. Some of the grains of actinolite have a preferred orientation, and augen-like lenses of quartz lie parallel to these.

MOUNT BAYLISS

The broad summit plateau of Mount Bayliss is mantled by patterned moraine (Fig. 6). The uniform composition of the moraine suggests that most of it is locally derived. Good exposures may be found in cliffs along all sides of Mount Bayliss. At the south-east corner a cliff section up to 150 m high and several kms long is exposed; this was not examined.

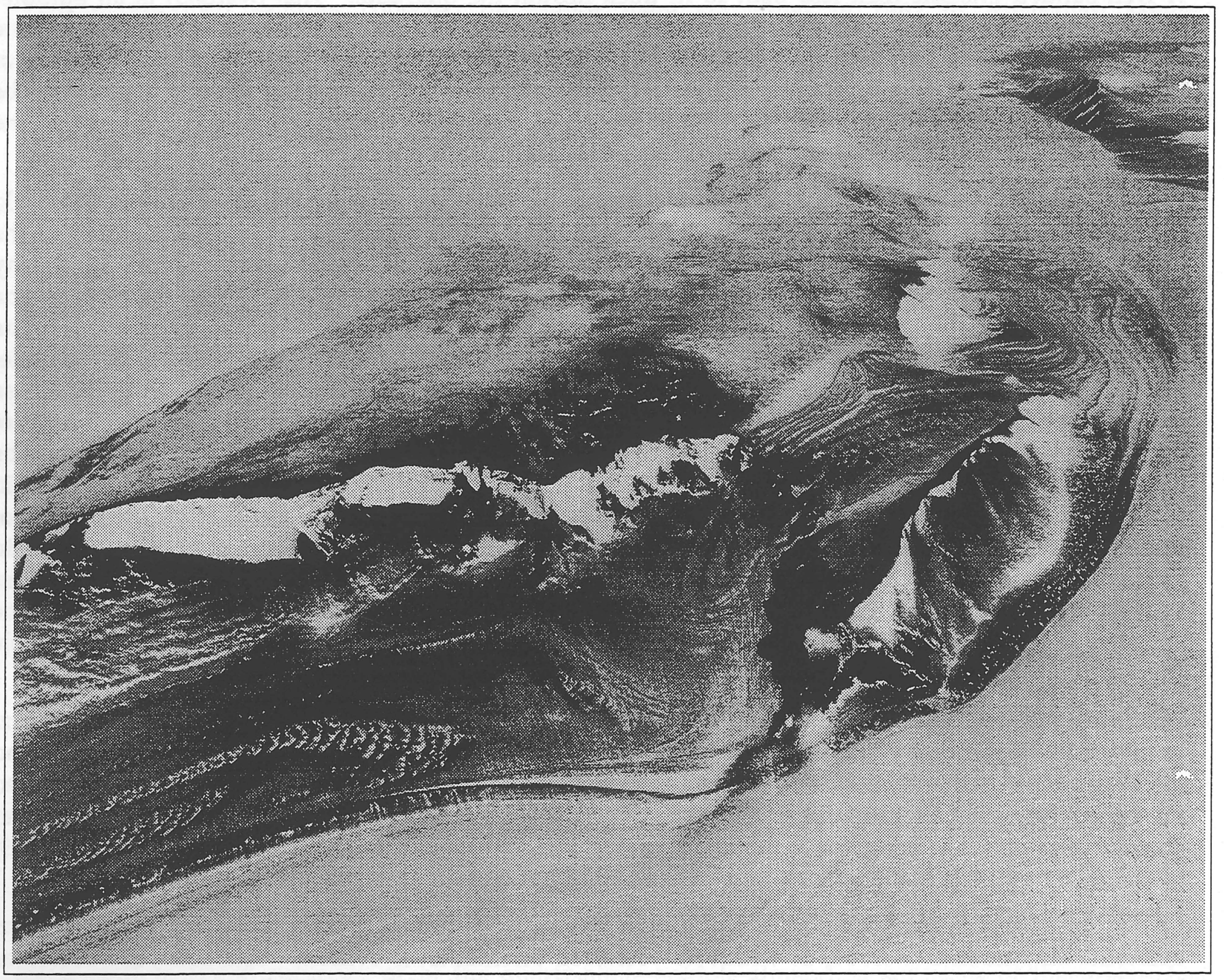

Fig. 6. View across Mount Bayliss, looking south-west. Note moraine patterns draped over escarpment at centre right. The south-eastern edge of Mt Menzies appears in the upper right of the photo. Airphoto ANT87 Run 1A 9108R, acquired 3rd December 1960.

In the low, irregular cliffs at the western end of Mount Bayliss, foliation is horizontal or dips gently northwards. The lowest rock is quartzite over 60 m thick. In hand-sample this is a light-green rock with large black spots of dark mineral; it is massive or poorly banded. The weathered rock resembles flaggy sandstone. It is composed of 85% quartz, and 5% muscovite, sericite, and biotite. Epidote, sphene, and apatite are accessory minerals. Shearing is prominent in thin section (R11364).

A well-banded gneissic rock less than 15 m thick lies on the quartzite. This (R11365) is an epidote-biotite-hornblende-quartz-calcite-microcline amphibolite. Bands of quartz or bands of calcite, alternate with bands of ferromagnesian minerals and microcline. The microcline crystals contain inclusions of biotite, of large and cryptocrystalline opaque minerals, and of quartz. Green hornblende, which may be uralitic, and green biotite, are not confined to particular bands. Sphene is a minor constituent of the dark bands. Opaque minerals are common accessories and apatite is rare.

Foliated granite and augen gneiss, at least 150 m thick, overlie the amphibolite. The granite is a pink, medium-grained rock with foliation formed by stringers of biotite and stringers of quartz. Parts of the granite have large rounded augen of feldspar in a dark matrix of fine-grained quartz. McCarthy describes the thin section of this rock (R11371) as a cataclasite or cataclastic gneiss formed by the brecciation of a granitic rock. Microcline forms 50% of the rock and quartz 45%. Biotite and muscovite are scattered or concentrated in lenses with quartz and feldspar. The rock is composed of sub-parallel lens-like bodies containing one or more major minerals. One sample contains orthoclase and plagioclase in addition to microcline. Some of the plagioclase crystals are deformed and some others are recrystallised. Epidote and probable orthite are rare; some mica has altered to chlorite. Sphene may be a common accessory, zircon is rare. In one sample (R11371) irregular crystals of fluorite are contained in feldspar and quartz crystals, fine veins of fluorite cut a large orthite crystal, and large aggregates of fluorite lie adjacent to the veins. Towards the west end of Mount Bayliss the foliated granite is overlain by patterned moraine composed almost exclusively of amphibolite. Air photos of Mount Bayliss suggest that this moraine is locally derived, and overlies outcrops of amphibolite. The fragments in the moraine are all black rocks, fine-grained to coarse-grained, massive to well-foliated, many with visible fibrous amphibole, some with biotite.

Two samples are andesine-quartz-hornblende amphibolites (R11368, R11369); another is quartz-hornblende amphibolite (R11367). In these, hornblende forms between 60% and 75% of the rock and quartz between 20% and 37%. Andesine makes up 3% where present. Biotite and chlorite have formed by the retrogressive alteration of hornblende. Hornblende and quartz occur in alternating bands, and sheared minerals lie along the boundaries of the bands. In one hornblende amphibolite (R11369) tourmaline forms 1% of the rock as large or medium-sized crystals associated with hornblende.

One sample from the summit platform of Mount Bayliss is described by McCarthy as a biotite-quartz-actinolite amphibolite (R11366) in which no preferred orientation is evident. The actinolite occurs as large non-orientated crystals up to 7 mm long, and forms 70% of the rock. Proportions of the other constituents are chlorite 20%, quartz 10%, and biotite 3%. Quartz appears to have segregated in large and small bodies during the metamorphic growth of actinolite and biotite. Chlorite and calcite have probably formed by the retrogressive alteration of actinolite.

A small nunatak, about 2.5 square kms in area, lies less than 1.6 kms west of the western end of Mount Bayliss. At the north side of the nunatak a contact between marble and granite is exposed. The marble in hand sample is a yellow-brown to red, fine-grained to medium-grained rock which strongly resembles a bedded sandstone both in exposure and hand sample. The rock (R11352) is 90% calcite, 5% quartz, and the remainder muscovite, epidote, green biotite, and opaques concentrated in thin lenses.

The rock in contact with this marble(R11353) is a foliated granite similar to the foliated granite at the west end of Mount Bayliss.

The marble and the foliated granite are separated by less than 30 m of dark, flaggy, coarse-grained biotite-bearing rock (R11354). This contact rock is scapolite-biotite-calcite-epidote-hornblende-quartz hornfels. The assemblage biotite, scapolite, hornblende, quartz, and calcite, has been retrogressively altered to produce uralitic hornblende, epidote and chlorite, some of which is antigorite.

The marble and the contact rock contain many quartz veins and small reefs a metre or so wide. The quartz is translucent, or greenish-white, or dark brown. Some coarse, weathered ferruginous boxwork occurs among the quartz reefs and veins.

GOODSPEED NUNATAKS

These nunataks were not visited by the 1961 geological party. M. Mellor collected samples from rubble on one of the nunataks in January, 1958. Some of these samples, recrystallised sandstone and hornfels, and a sample of granite from moraine on the ice adjacent to the nunatak, have been described by McLeod (1959).

Two undescribed samples collected by Mellor were submitted in 1962 to Australian Mineral Development Laboratories for microscopic examination. One of the samples (R11600) is a partly brecciated marble composed of large calcite crystals with quartz in the interfragmental spaces of the brecciated parts. Silica has replaced some calcite along cleavage planes and thin vein-like bodies of silica cut the calcite crystals.

The other sample (R11599) is described by McCarthy as a calcite-pistacite-quartz hornfels. Quartz forms 70% of the rock; green biotite, muscovite, sericite, and chlorite are relatively abundant; biotite crystals range up to 1.2 mm. Pistacite (epidote), is present as euhedral to subhedral crystals. Calcite is common, generally intergranular, with a few larger poikiloblastic crystals. Opaque minerals, associated with the ferromagnesian minerals, are very abundant accessories. Zircon, apatite, tourmaline, and sphene are less common.

OTHER NUNATAKS

Previously unvisited features approached but not visited by the party are Seavers Nunataks, Keyser Ridge, and Mount Ruker. All these features have extensive cliffs of dark- coloured rocks in which neither banding nor differential erosion could be discerned at distances from 3.2 to 16 kms. The lower slopes of Keyser Ridge are covered by reddish patterned moraine.

ERRATIC

One dark, fine-grained rock collected on the summit of Mount Bayliss is quite unlike any rocks seen in outcrop in 1961. McCarthy describes the rock (R11370) as 60% orthoclase, 15% brown hornblende, 10% biotite, 5% riebeckite, 5% opaques, 3% calcite, and 2% quartz. McCarthy infers that 8-sided bodies of orthoclase are in fact altered leucite crystals, and he names the rock *leucitophyre*. At present no source is known for this rock. The nearest outcrop is Gaussberg in Wilhelm II Land about 1120 kms east of Mawson. However, basic dykes have been observed by Crohn (1959) in the northern ranges of the Prince Charles Mountains, and this rock may be derived from a basic dyke.

METAMORPHISM

McCarthy has assigned the rocks of Mount Menzies to the greenschist facies of metamorphism, as defined by Fyfe *et al.* (1958). According to Fyfe *et al.* (1958), chloritoid is a mineral typical of the quartz-albite-epidote-biotite subfacies or of the quartz-albite-epidote-almandine subfacies of the greenschist facies, though it may occur in the quartz-albite-muscovite-chlorite subfacies in rocks low in K_20 and high in $A1_20_3$ and Fe0.

As actinolite is the common amphibole in the amphibolite interbanded with these rocks, they are assigned to the quartz-albite-epidote-biotite subfacies. The only garnet found is, according to McCarthy, probably spessartite, which may occur in any subfacies of the greenschist facies.

The cordierite in one sample is anomalous for regionally metamorphosed rocks. However, the assemblage is correct for a member of the albite-epidote hornfels facies, and McCarthy suggests that the cordierite in this rock together with the common large, non-orientated flakes of biotite in other schists and quartzites, indicates that the rocks of Mount Menzies continued to undergo thermal metamorphism at a relatively high temperature after the relief of the stress accompanying regional metamorphism.

The rocks of Mount Menzies are metamorphosed sandstones and quartzites which originally contained a few beds of sandy or silty clay. The significance of the amphibolite among these rocks is uncertain. Ruker (1963) records intrusive amphibolite from Mount McCauley. The actinolite amphibolite sampled on Mount Menzies is composed of 85% actinolite, 12% quartz, and only 1% feldspar.

Possibly the actinolite amphibolite has been produced by the metamorphism of an impure, sandy limestone, with the copious effusion of carbon dioxide. It may be a basic intrusive. Another possibility is that the rock may be a water-lain crystal tuff contaminated by sand.

The metamorphic history of the rocks from Mount Bayliss is complex. Shearing is evident in most of these samples; in some the shearing post-dates the growth of minerals produced by thermal metamorphism, in others the metamorphic minerals are deformed by the shearing.

The main episode of thermal metamorphism is tentatively correlated with the emplacement of the granite which is now a cataclastic gneiss.

The sequence of events recorded in the Mount Bayliss rocks is possibly this:

1. A group of impure sandstones and limestones were metamorphosed in the greenschist facies in the same orogeny which metamorphosed the rocks of Mount Menzies.
2. Granite was emplaced in these rocks and they were thermally metamorphosed, some to the albite-epidote-hornfels facies and some to the hornblende-hornfels facies.
3. All these rocks including the granite were strongly sheared; in many the shearing produced foliation. The brittle style of the deformation is attributed to a relatively small depth of burial.
4. Thermal metamorphism persisted after the shearing and resulted in the growth of minerals typical of the albite-epidote hornfels facies in all rocks. Thus the low-grade rocks show a continuation of metamorphism throughout the shearing, while rocks in the hornblende hornfels facies have undergone retrograde metamorphism in which biotite and uralite have grown from green hornblende.

The samples described by McCarthy from the Goodspeed Nunataks are thermally metamorphosed limestone and impure limestone. These are probably related to thermally metamorphosed rocks from the locality described by McLeod (1959).

STRUCTURE

Exposures examined on Mount Menzies mainly display steeply dipping or vertical schistosity which strikes broadly east, and is expressed by aligned mica flakes or by partings in the quartzites. In many places this schistosity is sharply discordant to gently dipping or folded lithological boundaries seen in distant observations or in aerial photographs of the mountain.

The steeply dipping schistosity in quartzite exposed on the north-east ridge of Mount Menzies between the summit and a level 600 m below it, is developed parallel to the axial plane of a fold which can be made out in aerial photographs of the northern cirque. The amplitude of the fold is about 1500 m and its wavelength is also about 1500 m. The axis of the fold appears to plunge gently south-eastwards. A fold of similar trend and style with an amplitude and wavelength between 300 and 600 m is exposed in the south-eastern cliffs of Mount Menzies. The common schistosity on Mount Menzies is parallel to axial planes of these folds.

In the long west wall of the great northern cirque, below the west peak of Mount Menzies, bands of black rock a few hundred m thick are abruptly and irregularly truncated. The northern end of this wall provides a sectional view of some truncated bands, which appear to be attenuated and disrupted by intense plastic folding. This folding has a style and trend different from the folding described above, in the quartzites in the south wall of the cirque.

The deformation of the black bands may postdate the isoclinal folding, or the difference in fold style may reflect the difference in resistance to deformation between quartzite and the dark rocks. McLeod (1959) illustrates a cliff at Patrick Point where a band of black rock a few hundred m thick is deformed by plastic recumbent folding, although the band is surrounded by regularly banded and apparently more competent, light-coloured rocks.

Ruker (1963) describes discordant and intrusive amphibolites among low-grade metamorphic rocks at Mount McCauley and among high-grade metamorphic rocks at Mawson Escarpment at 73° 30'S. Some of these are evidently deformed minor intrusives but others have unusual mineralogical compositions; they contain relatively large quantities of quartz, or they are ultramafic or lamprophyric rocks.

Deformed intrusive amphibolites may be difficult to distinguish from originally concordant amphibolites which have been more intensely deformed than more competent quartz- rich rocks containing them.

The structure of Mount Bayliss is dominated by semi-brittle shearing on sub-horizontal planes which is probably later than the fold structures preserved at Mount Menzies, though folding and shearing could be contemporaneous.

The marked foliation evident in many rocks on Mount Bayliss originated in the shearing, and all the rock boundaries on Mount Bayliss appear to have been aligned with the shear planes in a simple sub-horizontal structure, though their inter-relationship before shearing may have been more complex. The intensity of the shearing suggests that a major thrust plane may be located at or near Mount Bayliss.

In Antarctica, mountains, the sides of mountains, and groups of mountains commonly form straight-line features. In the southern Prince Charles Mountains straight-line features may be seen in the alignment of the western sides of Keyser Ridge, Mount Ruker, and Mount Rubin, in the southern sides of Mount Bayliss and Mount Menzies, and in the straight sides of many large nunataks.

These straight lines resemble the surface traces of fault planes and block-faulting is commonly thought to be the principal control of outcrop distribution in Antarctica. However, the straight-line features in the southern Prince Charles Mountains are aligned on the margins of very active and powerful ice streams. The ice streams may have originally been channelled along fault lines, but the present day escarpments which form the sides of the mountains have probably receded a considerable distance since the onset of glaciation and their present form and alignment are probably the results of directional ice erosion. Most glaciers run straight, whether following faults or not.

Faults traced in the air photos of Mount Menzies run broadly east-west across the north side of the mountain and dip steeply northwards. These faults appear to displace dark banded rocks a few hundred m vertically. The trend of these faults is parallel to the valley of the Fisher Glacier, and sub-parallel to the observed schistosity.

GEOLOGICAL HISTORY

The quartzites of Mount Menzies were deposited as relatively pure sandstones containing a few beds of silty clay. The marbles and some amphibolites represent limestones formed when the deposition of sand was relatively slow. The great thickness of quartzite may have been derived from quartz-rich gneisses. Some amphibolites may be metamorphosed pyroclastic rocks.

These shelf sediments were presumably buried below a thick pile of similar or other sediments before they were metamorphosed in an orogeny. Fyfe *et al.* (1958) suggest a minimum depth of burial of 10 kilometres for the formation of greenschist facies rocks.

In the early stages of the orogeny, the quartzites were thrown into huge, relatively regular folds. At Mount Bayliss, the folding was followed by the emplacement of granite, and high temperatures prevailed after the relief of the stress associated with the folding.

Subsequent to the emplacement of the granite, while the temperature remained high, strong lateral pressure resulted in shearing at Mount Bayliss and in the formation of a foliation in many rocks there. This deformation may have been accompanied by the horizontal transport of large bodies of rock.

From determinations of both high-grade and low-grade metamorphic rocks in East Antarctica, Starik *et al.* (1960), and Deutsch *et al.* (1961) have obtained an age between 400 million and 500 million years for the latest metamorphism. The low-grade metamorphic rocks of the southern Prince Charles Mountains have probably been metamorphosed only in the latest, Lower Palaeozoic orogeny. The high-grade metamorphic rocks typical of the East Antarctic Shield have been repeatedly metamorphosed in successive orogenies dating from at least 1,500 million years ago, according to Starik *et al.* (1960).

Subsequent to the orogeny, much of the thick cover lying on the greenschist facies rocks was no doubt rapidly removed by erosion, but the area covered by the southern Prince Charles Mountains has probably existed as land for most of the time from the Lower Palaeozoic to the present day.

Sediments found by Ruker (1963), and the Amery Formation described by Crohn (1959) indicate that one or more depositional basins existed in Mac. Robertson Land in Permian times. The erratic of volcanic rock found on Mount Bayliss may be a product of the Jurassic or Tertiary igneous episodes recorded elsewhere in Antarctica. Little is known of the past metamorphic geological history of the southern Prince Charles Mountains before the onset of glaciation.

ECONOMIC GEOLOGY

The presence of ferruginous boxworks in quartz reefs and veins at the contact between granite and marble on the small nunatak at the west end of Mount Bayliss, suggests that metallic minerals are associated with the contact. Fluorite at another locality at Mount Bayliss, in foliated granite also suggests that metallic minerals may be present. Fluorite occurs in granite associated with hornfels of the Goodspeed Nunataks (McLeod, 1959). The granites emplaced in the low-grade metamorphic rocks of the Prince Charles Mountains should be examined and sampled for metallic minerals in future.

A quartzite sample containing visible crystals of a metallic mineral was collected from patterned moraine on the east platform of Mount Menzies. The sample was described by G. J. G. Greaves of the Bureau of Mineral Resources Laboratory, as iron-stained quartz containing 5% magnetite.

FUTURE WORK

The variety of rocks found in the Prince Charles Mountains suggests that the geological reconnaissance should be extended to cover the mountains between Mount Menzies and Wilson Bluff and the numerous unvisited mountains in the northern and central ranges.

The first requisite in planning this work is an aerial reconnaissance of the ice cap surface among the mountains selected for mapping. If crevasse-free routes are found, air-supported dog-sledge transport is strongly recommended for the mapping party. A dog-sledge party may travel in these mountains on many days when flying will be impossible.

Should the ice surface prohibit ground travel and require air transport, camps comprehensively equipped and stocked with sledging rations for two weeks should be established at the mountains visited. The geologists should then spend, ideally, between three and five days on each mountain, changing camp when the weather is suitable for flying. Skis, a manhauling sledge, and sufficient sledging rations should be cached at a conspicuous central feature in the mapping area to enable the party to walk to Mawson or Davis if the supporting aircraft are disabled. Air support from other expeditions should only be requested for the evacuation of an injured man, and it may only be available after an interval of many days.

The field party must maintain radio contact with base at least daily and possibly twice each day, to plan flying schedules and to transmit local weather information. A radio operator skilled in morse should accompany the geologist, and a third unskilled but enthusiastic assistant should complete the party. If a glaciologist or other scientist is included, the party must contain at least four men, since each field scientist must have at least one working companion.

Temperatures (between -30 °C and -9 °C) suitable for camping will be found below 1800 m altitude in the Prince Charles Mountains from November to February. In November and February, parties travelling on the ice cap between Mawson and the southern ranges should expect temperatures down to -40 °C at altitudes over 2100 m.

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APPENDIX 1

PETROGRAPHIC DESCRIPTIONS OF SAMPLES.

by

W. R. McCarthy

(Australian Mineral Development Laboratories)

Mount Bayliss, west Nunatak

R11352

The rock is a medium-grained marble. Several thin lenses of silicate minerals and opaques cut the rock. These lenses were laminae of sedimentary impurities which have recrystallised during metamorphism of the sample. The calcite crystals give the sample a granoblastic texture.

Calcite forms about 90% of the sample, and occurs as anhedral to euhedral crystals. Quartz is present as scattered, intergranular crystals which form about 5% of the sample. Muscovite, epidote, green biotite, and opaques are scattered throughout the rock, but the largest quantities are present in the lenses.

The present rock has formed by low grade metamorphism of an impure limestone.

R11353

The rock is a cataclasite or cataclastic gneiss. The sample has formed by brecciation of an earlier granitic rock. Large scale movements such as block or thrust faulting are generally associated with the genesis of this type of rock.

Microcline (50%) and quartz (45%) are the major constituents of the rock. Both are present as lens-like bodies which show a rude parallelism. Lenses are often of a single mineral (i.e. either microcline or quartz) but the quartz lenses generally have inclusions of microcline. Quartz is generally medium to coarse-grained and has a lenticular shape. Microcline is fine to coarse-grained and many crystals show strained extinction.

Both biotite and muscovite are present as scattered crystals and in lenticular concentrations with feldspar and quartz. Epidote and probable orthite are rare and associated with mica. A few very strained, bent, fractured plagioclase crystals of the pre-cataclastic granitic rock occur with the microcline. Some of the biotite and muscovite have retrogressed to chlorite. Apatite is present in accessory amounts and associated with fine-grained aggregates of epidote minerals.

R11354

The rock is a scapolite-biotite-calcite-epidote-hornblende-quartz hornfels. The metamorphic assemblage does not appear to be representative of a single metamorphic facies. Two hornfels facies assemblages appear to comprise the rock. An earlier and higher grade of thermal metamorphism produced an assemblage of biotite, scapolite with some hornblende, quartz and calcite. The later and retrogressive metamorphism formed a second green, uralitic, hornblende and the abundant epidote of the rock. The uralitic hornblende has formed from the earlier hornblende and biotite. Epidote has formed by alteration of biotite and hornblende. Chlorite and antigorite are also present as retrogressive minerals formed by the alteration of ferromagnesians.

The original sedimentary rock was probably an impure limestone (laminae of siliceous and argillaceous material). Final interpretation of the retrogressive metamorphism will of course depend on the regional metamorphic history of the area. However, due to the close proximity of the cataclastic gneiss (R11353), the retrogressive alteration of this rock may be a product of the large scale deformation which formed the cataclasite.

Mount Bayliss

R11364

The rock has formed by metamorphism of an impure quartz arenite. It shows an incipient shear structure; shearing has been active and fine shears most frequently pass around quartz grains but often they combine into larger composite shears. Sericite forms an augen-shaped envelope around quartz grains and has crystallised around the composite shears. Scattered, large (some reach a diameter of 3 mm), poikiloblastic, porphyroblasts of biotite have grown post-deformation; they show no preferred orientation and often are normal to the shear orientation of sericite-muscovite. The biotite porphyroblasts have grown by incorporation and recrystallisation of sericite-muscovite. The structure of the rock and the growth of biotite porphyroblasts indicate that the rock has been subjected to an earlier synkinematic low-grade (greenschist facies) metamorphism and a later thermal metamorphism (albite-epidote hornfels). Whether thermal metamorphism followed immediately the synkinematic metamorphism or occurred much later is not determinable from this sample. The rock is a sheared, biotite-sericite-muscovite quartzite.

Mica forms 10-16% of the rock and quartz the remainder. Epidote is present as scattered crystals in accessory amounts, as is sphene and apatite. Several tentative identifications are noted. Altered porphyroblasts (two in number) of feldspar occur and another epidote mineral, zoisite, is present as microcrystalline grains generally included in sericite. Some of the mica has altered to chlorite.

R11365

This is a gneissic, epidote-biotite-hornblende-quartz-calcite-microcline amphibolite. The mineral assemblage has an unstable gross aspect. The instability and varied mineral assemblage indicate a polymetamorphic history. The gneissic structure of the rock is formed by laminae which are dominantly composed of quartz or calcite and alternate with ferromagnesian-microcline laminae. This structure may be interpreted as resulting from original sedimentary bedding or differentiation under stress conditions.

The general metamorphic history of the sample must be determined from a survey of nearby samples and regional metamorphic and field interpretation, as there is not sufficient conclusive information in this sample. A few features in the rook give some definite information about the metamorphic history. These are green uralitic-appearing hornblende and green biotite, which are not confined to particular laminae and indicate that thermal metamorphism was the last phase of the petrogenesis, and quartz laminae that have shouldered aside other laminae suggesting they are differentiation laminae. Microcline also appears to have crystallised during the thermal metamorphism and has inclusions of other minerals (biotite, opaques - large and cryptocrystalline, and quartz). Sphene is a minor constituent and occurs in the darker laminations. Accessories are apatite (rare) and opaques (common).

R11366

The rock is a biotite-quartz-actinolite amphibolite and is assigned to the hornblende hornfels facies. No structure is apparent; actinolite occurs as large (up to 7 mm in length) non-orientated, crystals. Estimated proportions of mineral constituents are biotite (3%), quartz (10%), chlorite (20%) and actinolite (70%).

During the metamorphic crystallisation of actinolite and biotite, excess silica was concentrated between these crystals and now occurs as quartz. The quartz inclusion in the rock appears to have formed by the same process. Actinolite crystals terminate as fibrous crystals which penetrate the quartz, of the inclusion and the matrix. Calcite is present as a segregated body at one extremity of the quartz inclusion, but this is more likely a product of the retrogressive alteration of actinolite to chlorite; generally it is associated With the chlorite and is not found with unaltered actinolite. Chlorite is not a primary meta-mineral, but has formed during retrogressive alteration of actinolite and biotite. Opaques are frequent accessories and occur as inclusions in actinolite or as intergranular bodies.

R11367

This is a quartz-hornblende amphibolite and is assigned to the hornblende hornfels facies. Hornblende is generally very coarse-grained (some crystals reach a length of 8 mm) and many crystals are poikiloblastic with quartz inclusions. Quartz occurs as elongated segregations between hornblende crystals or as inclusions in hornblende. Segregation quartz reached a maximum grain diameter of 0.65 mm and inclusion quartz is fine-grained. Chlorite and biotite comprise 5% of the sample and have formed by retrogressive alteration of hornblende. Hornblende forms about 75% of the sample and quartz about 20%. Opaques are a common accessory and occur as fine to medium-grained, xenoblastic to subhedral inclusions in hornblende.

R11368

This is an andesine-quartz-hornblende amphibolite and is assigned to the almandine-amphibolite facies. In thin-section, the structure of the rock is seen to be produced by alternating laminae of hornblende and quartz. Sheared minerals along the boundaries of the laminae and still thinner lenses of actinolite in quartz laminae make it quite evident that shearing, producing differential movement, has been an important process in forming the structure of the rock. Whether the laminae are inherited sedimentary bedding features or have formed by metamorphic differentiation accompanied by shearing is uncertain. It appears most likely that the rock has undergone regional synkinematic metamorphism and is thus assigned to the almandine-amphibolite facies. Thin stringers or bands of opaques parallel the structure and are generally included within the hornblende laminae.

Estimated proportions of mineral constituents are andesine (3%), quartz (37%), and hornblende (60%). Opaques are common accessories.

R11369

This sample compares in general mineralogy and fabric to rock R11368.

Several mineralogical differences are noted. Rock R11369 contains tourmaline which forms about 1% of the sample and is present as large or medium-sized crystals associated with hornblende. Hornblende forms about 75% of the rock. A part of the amphibole of the sample is probably cummingtonite. Biotite is a rare accessory. Chlorite, formed by retrogressive alteration of amphibole, comprises about 2% of the sample.

R11370

This is an extrusive rock. The rock has a pseudo-vesicular structure given by numerous orthoclase bodies which appear to be vesicular fillings. The orthoclase bodies sometimes have all or combinations of the following minerals as inclusions: calcite, sphene, quartz, and rare ferromagnesians. When closely examined most of these bodies are seen to have many straight sides and some have eight sided sections. It is then inferred by their shape and present composition that these orthoclase bodies were originally crystals of leucite which have altered to orthoclase. Alteration of leucite may have occurred either during the cooling of the lava or by subsequent processes.

Estimated proportions of mineral constituents are quartz (2%), calcite (3%), opaques (5%), reibeckite (5%), biotite (10%), brown hornblende (15%), and orthoclase (60%). Orthoclase has been identified by oils in the vesicle-like bodies and the matrix feldspar gives a positive staining test for potash feldspar and is thought to be orthoclase. Before alteration, the rock was a leucitophyre.

R11371

This is a cataclasite (cataclastic gneiss) which compares in structure and general mineralogy to rock R11353. Again large scale movements seem to be necessary for the intense deformation and recrystallisation of the sample.

The detailed mineralogy of this rock (11371) has some differences which are noted. Orthoclase is an important constituent of the feldspar and both deformed and recrystallised plagioclase are rare. Probable orthite is present as a large crystal and as scattered finer crystals. Fluorite is a common accessory mineral; its location is not confined, nor is it only associated with one mineral. It occurs as irregular, fine, crystals included in feldspar and quartz; a few fine vein-like bodies cut the large orthite (?) crystal and several larger aggregates of fluorite are adjacent to it. Sphene is a very common accessory mineral and associated with green biotite. Zircon is a rare accessory.

Mount Menzies

R11355

This is a sericite-chloritoid quartzite. No positive sedimentary features are present in the metasediment. Considerable recrystallisation has occurred as is evident by the habit of the quartz (anhedral to euhedral) and by the crystallisation of chloritoid. Quartz forms about 95% of the rock and ranges in crystal diameter from 0.23 mm to 0.56 mm. Chloritoid is found primarily in thin laminae; the genesis of these laminae is not certain (i.e. sedimentary or metamorphic). Sericite is present in the laminae and intergranular areas. Chloritoid is fine to medium-grained and is subhedral to anhedral. Sericite occurs as very fine, crystals or in medium-sized crystal aggregates.

While metamorphic structure is not certain in this rock, other chloritoid quartzites of this locality are assigned to the greenschist facies on the basis of structure and it seems likely then that this rock has been formed by the same type of metamorphism.

R11356

The rock is a chloritoid-chlorite quartzite. It resembles rock R11355 in all regards except for the following differences:

This rock originally contained a greater percentage of micas (about 10%). Chloritoid is still present but portions of it have now altered to chlorite (a green variety and penninite). No sericite is present. This sample contains several crystals of accessory zircon. Alteration of the chloritoid has left iron stains which coat crystals; staining apparently gives the rock its dark colour.

R11357

This is an epidote-actinolite-quartz amphibolite and is assigned to the greenschist facies. Structure of the rock is formed by lineated actinolite present in thin laminae and by alternating actinolite and quartz laminae The rock has been formed by synkinematic metamorphism of a sediment. Lineation of the actinolite is fair; the majority of crystals show a preferred orientation.

Estimated proportions of constituents are epidote (3%), actinolite (47%), and quartz (5%). Quartz ranges in grain diameter from 0.13 mm to less than 0.0625 mm. Epidote occurs as cryptocrystalline to fine-grained crystals which are intergranular to quartz

R11358

This is a chloritoid-quartz schist and is assigned to the highest portion of the greenschist facies. The rock has poor to fair structure which is shown by lineated chloritoid. The lineation of the sample shows minor plications. The rock has formed by the low-grade synkinematic metamorphism of a sediment deficient in K and Mg and rich in Al, Fe, and Si (an argillaceous quartz rock).

Estimated proportions of constituents are sericite, muscovite and chlorite (about 5%), quartz (35%), and chloritoid (60%). Quartz is fine to medium-grained, anhedral to subhedral, and is notable in that it has inclusions of opaques and probable micro-crystalline sericite. Chloritoid is fine-grained, shows blue pleochroism, and is subhedral to euhedral. Accessories are zircon (rare), sphene (rare), tourmaline (rare), and opaques (common).

Sericite, muscovite, and chlorite occur as retrogressive minerals formed by retrogression of chloritoid. Chlorite is penninite and occurs as large radiating porphyroblasts.

R11359

The rock is a sheared, fine to medium-grained quartz-feldspar-actinolite amphibolite. The structure of the sample is formed by shear planes; these planes are marked by fine lines of dust-like opaques and by parallel bodies of actinolite in which the dust-like opaques occur. The petrogenesis of the rock is not clear; it is complicated by several probable periods of metamorphism whose mutual relationships are uncertain. A tentative metamorphic history is presented below. It seems to be comparable with the petrogenesis of other rocks from this locality whose history is clearer. Crystallisation of actinolite with accompanying shearing, occurred during what is presumably the earliest metamorphism. Growth of poikiloblastic feldspar porphyroblasts, which partially destroy the elements of shearing, indicate that a period of thermal metamorphism followed synkinematic metamorphism (the porphyroblast and shearing relations are not certain). Texture of the sample between planar actinolite is hornfelsic and thought to have formed contemporaneous with porphyroblast growth.

Estimated proportions of constituents are quartz (4%), andesine (15%), and amphibole (80%). Opaques, as anhedral to subhedral crystals, are common accessories. Amphibole is actinolite and probable cummingtonite. Cummingtonite (?) appears to have formed during thermal metamorphism.

R11360

This is a chloritoid-quartzite. The rock compares very closely to samples R11355-356 in mineralogy and texture. All three rocks have been subjected to low grade metamorphism.

Quartz forms about 97% of the rock, chloritoid about 2% and the remainder is composed of opaques and chlorite. Chlorite appears to have formed retrogressively from chloritoid.

R11361

The sample is a chloritoid-sericite-muscovite quartzite. The rock is another of the Mount Menzies chloritoid quartzites but it has been subjected to more intense deformation than other quartzites of the locality the writer has described.

The quartz grains show a slight to fair parallel elongation. Muscovite often occurs in lens-like bodies which parallel the quartz elongation. Thicker, less abundant lenses of muscovite with some chloritoid transect the general quartz elongation. Sericite is a common intergranular mineral and present in the muscovite lens-like bodies also. Due to the complex nature of the structure and because sericite and chloritoid show preferred and non-preferred orientations, the metamorphic history of the rock is not clearly defined. It can be stated with certainty that the rock has undergone a low grade metamorphism. Zircon and opaques are present as accessories. Sericite and muscovite form about 7% of the rock, chloritoid about 3% and quartz about 90%.

R11362

This is a schistose, garnet-muscovite quartzite and is assigned to the higher portion of the greenschist facies; the petrogenesis of this sample is discussed further below. The unmetamorphosed sediment was an impure quartz arenite. Foliated mica minerals give the rock its foliation. The sample also shows a poor crystallisation foliation; quartz crystals are elongated.

Muscovite and chlorite form about 10% of the sample and are present in about equal quantities; quartz forms about 90% of the rock. Chlorite is penninite and has probably formed by retrograde alteration of muscovite. Garnet is present as poikiloblastic porphyroblasts, forms about 1% of the rock, and is probably spessartite. Several corroded, embayed crystals present with muscovite are tentatively identified as chloritoid. This may indicate that chloritoid was more abundant at a lower metamorphic grade and has progressively altered during metamorphism. Opaques are present as rare accessory minerals. Random porphyroblasts of biotite showing no preferred orientation have crystallised and formed by replacing some of the muscovite.

The unorientated aggregates of biotite complicate the petrogenesis of this rock. It is evident that the initial metamorphism has been a synkinematic one principally, but that biotite growth has occurred during a time when differential stress has been lacking or only weakly present.

Biotite replaces earlier synkinematic mica and thus crystallised under thermal conditions either during the waning stages of synkinematic metamorphism or during a later thermal metamorphism.

R11363

This is a fine to medium-grained, epidote-quartz-actinolite amphibolite. The rock has a low-grade metamorphic mineral assemblage. It has a rather vague structure, but the structural element does suggest that the rock has been metamorphosed under synkinematic conditions. The poor structure is formed by linear elements within the general aggregate of actinolite. These elements are parallel crystals of actinolite, aggregates of opaques and augen-like lenses of quartz.

Estimated proportions of mineral constituents are epidote (2%), feldspar (1%), quartz (12%) actinolite (85%). Accessories are apatite (rare), zircon (rare), and opaques (common). Opaques occur in lens-like to xenoblastic aggregates. Epidote is present as cryptocrystalline to fine-grained crystals which are intergranular to quartz. Quartz occurs as aggregates of fine to medium-grained crystals which generally have actinolite crystals extending into, or as inclusions within, the aggregates.

R11580

This rock is a sericite-quartzite and is assigned to the greenschist facies. The rock has formed by low grade metamorphism of a slightly argillaceous quartz arenite or siltstone. The sample has a poorly developed structure imparted by foliated sericite resulting from shearing stress. In some places the quartz shows crystallisation foliation.

Estimated proportions of mineral constituents are sericite (10%) and quartz (90%). The quartz has recrystallised into anhedral to subhedral crystals. The sample has an equigranular texture; quartz has an average diameter of about 0.19 mm. Sericite shows a range of crystal length from cryptocrystalline to 0.2 mm. Several lens-like aggregates of sericite cut the rock and opaques, present in accessory amounts, are associated with the sericite bodies. A few large crystals of chlorite are scattered through the rock. Rounded accessory minerals (tourmaline, zircon and apatite) attest to sedimentary origin of the rock.

From field relations, can this sample be correlative with the chloritoid quartzites of Mount Menzies? Mineralogically, the rock could be a lower grade equivalent of the chloritoid quartzites.

R11581

This rock is a cordierite-chloritoid-muscovite-quartz schist. The rock has an excellent schistosity formed by foliated, fine-grained muscovite. The muscovite is puckered and occasionally a secondary S-plane is developed by muscovite parallel to the axial plane of the plications. The original sediment was probably an argillaceous siltstone.

Fine-grained quartz is the major constituent; chloritoid and muscovite form about 30% of the rock and are present in about equal quantities. Cordierite occurs as fine to medium-grained porphyroblasts often with dust-like, opaque inclusions. The porphyroblasts generally have a structural location in the axial areas of the plications. Several lenses of quartz, probably segregation veinlets, parallel the schistosity of the rock. Several similarly shaped bodies formed by aggregates of goethite (?) and golden-brown, transparent minerals (monazite?) also are present.

Metamorphism of the sediment has been complex and its petrogenesis is perhaps not determinable from this single sample. However, several features of the history can be stated with certainty:

1. Initially the rock has undergone a synkinematic, low grade (greenschist facies) regional metamorphism.
2. As cordierite occurs only in regional metamorphism in higher grades, the sample has undergone a later period of thermal metamorphism. While time relations of these two periods of metamorphism cannot be stated emphatically, the relationships of chloritoid and cordierite with structure indicate that thermal metamorphism occurred during the waning stages of synkinematic metamorphism. About half of the chloritoid shows no preferred orientation; this appears to indicate that chloritoid began crystallisation during synkinematic metamorphism and completed its crystallisation during thermal metamorphism. The favoured structural location of cordierite, in the axial areas of the plications, indicates that stress was still active during the initial stages of cordierite crystallisation.

Goodspeed Nunataks

R11599

This is a calcite-pistacite-quartz hornfels. The rock has a very poor structure - some linear concentrations of opaques and pistacite are present. These concentrations are thought to be inherited sedimentary bedding features rather than structure formed by metamorphism with accompanying differential stress. The rock has a typical hornfelsic texture with poikiloblastic, directionless mica and non-orientated minerals present in a matrix of relatively equigranular quartz. The rock is thus assigned to the albite-epidote hornfels facies and is thought to have formed by thermal metamorphism of a fine-grained, impure quartzose arenite.

Quartz, as a mosaic of interlocking crystals, forms about 70% of the sample; mica is the next most important constituent. Mica is green biotite (most abundant), muscovite, sericite and chlorite (probably a retrogressive alteration product of biotite). Biotite forms the coarsest crystals of the rock (some reach a length of 1.2 mm). Pistacite, showing typical yellow pleochroism, is present as euhedral to subhedral crystals. Calcite is common and generally is intergranular although occasional larger, poikiloblastic crystals are seen. Opaques, showing varied shape and size and association with the ferromagnesians are a very abundant accessory mineral. Present as more rare accessory minerals are zircon, apatite, tourmaline and sphene.

R11600

This is a calcite marble which has been brecciated in places. Large calcite crystals (reaching a diameter of 10 mm) wholly comprised the rock before brecciation.

Fragments of the brecciated portions are extremely angular and little or no attrition has occurred. Intrafragmental spaces are filled with quartz which generally has a very elongated habit. Silica has also replaced part of the carbonate along cleavages and fills or replaces it along thin vein-like, cross-cutting bodies. The source of the silica for the silicification is an interesting problem - perhaps it is hydrothermal and the rock is a fault breccia. Calcite is the fluorescent mineral.

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