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THE ARCADIA BORE, QUEENSLAND.

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AN OUTLINE OF THE GEOLOGY OF THE WESTERN PORTION OF AUSTRALIAN ANTARCTIC TERRITORY

by

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INTRODUCTION

This paper gives a brief description of the geology of the sector of the Australian Antarctic Territory between 45° and 80° east longitude. It deals mainly with the work of the Australian National Antarctic Research Expeditions since 1954, but work by the British, Australian, New Zealand Antarctic Research Expedition (1929-31), the Discovery Expedition (1935-36) and the Soviet Antarctic Expedition (1955-56) is also included. Several other expeditions have made landings in the sector but have not published any account of geological work.

PHYSIOGRAPHY

Rock exposures are common along parts of the coast between King Edward VIII Gulf and Mawson, and in the interior of the sector. The coastal exposures are mostly small islands or rocky headlands, and with few exceptions, do not rise to any great height. An old erosion surface falling from 125 metres at King Edward VIII Gulf to 35 metres at Mawson has been recognised; and in the Vestfold and Larsemann Hills, which are extensive rocky coastal exposures with deeply indented coastlines, remnants of two old erosion surfaces appear to be present at 125 and 30 metres altitude. In the Vestfold Hills are several saline lakes (up to 27% total solids, mainly sodium chloride), with water levels well below sea level, e.g. the surface of Deep Lake is 56 metres below sea level.

The mountains in the interior of Enderby and Kemp Lands, extending down to the coast around Amundsen and Casey Bays, are very rugged and deeply dissected. Evidence of block faulting can still be seen in several places, however. On the other hand the Prince Charles Mountains are characterized by extensive flat-topped massifs, some many square kilometres in extent. This old erosion surface has been greatly disrupted by block faulting, and now stands at heights ranging from 1000 to 2600 metres, whereas around the Amery Ice Shelf, similar exposures have summits only 60-200 metres above sea level.

There is an 8-metre raised beach at Amundsen Bay. Raised beaches also occur in the Vestfold Hills; molluscan remains on these are all of forms still living around the Antarctic coast, as are most of the microfossils.

Deposits of mirabilite occur in depressions in coastal outcrops, and around saline lakes.

On many of the inland rock exposures, moraine occurs at heights up to several hundred metres above the present surface of the ice sheet. Terraces of moraine at several heights along the sides of some of the mountains denote pauses in the lowering of the surface of the ice sheet.

REGIONAL GEOLOGY

PRECAMBRIAN(?) ROCKS

The rock at Mawson is a porphyritic charnockitic "granite", with a moderate foliation due to alignment of coarse perthitic potash feldspar phenocrysts. The rock is composed of potash feldspar, andesine, quartz, and hypersthene with accessory biotite, magnetite, garnet, apatite and sphene. The ratio of potash feldspar to plagioclase feldspar varies from place to place, so that granite, adamellite, and granodiorite can all be found. Inclusions are common, elongated parallel to the foliation; most are fine grained, and rich in hypersthene or biotite, or both; some are garnetiferous. Thin aplite veins cut by later pegmetite veins are widespread.

Most of the islands and coastal outcrops within 20 km of Mawson, and the Framnes Mountains south of Mawson, are charnockitic granite quite like the rock at Mawson. In a few places granular charnockite occurs, with the same mineralogy as the granite, but with a fine- to medium-grained, equigranular, granulitic texture. Inclusions are similar to those in the granite.

The charnockitic granite intrudes the granular charnockite, and is probably the result of mobilisation of the charnockite under conditions of extreme metamorphism. At Byrd Head, the granular charnockite itself has been found with an intrusive contact against meta-sediments.

Among these charnockitic rocks, minor amounts of other gneisses occur. These are generally migmatitic, with the igneous component represented by gneissic granite with or without garnet and biotite. The host rocks range from biotite-rich gneisses through biotite-bearing quartz-feldspar-garnet gneiss to impure quartzite; pegmatite and quartz veins are common.

Along the coastline west of Mawson are numerous rock exposures, consisting of charnockite and banded migmatite, with some charnockitic granite. Migmatite is most important in the Byrd Head-Cape Bruce area.

Along this coast the migmatitic host rocks contain potash or plagioclase feldspar, or both, and are characterised by abundance of garnet and biotite; amphibole or pyroxene may also occur, and sillimanite and cordierite are locally important. The granitic gneisses are composed of quartz, microperthite, and andesine, and most contain some garnet and biotite. Either microperthite or plagioclase may be predominant.

A widely distributed suite of quartz-feldspar-garnet gneisses, formed by metasomatism and partial mobilisation, appears as an intermediate stage between garnetiferous arenaceous metasediments and garnetiferous granite gneisses.

Pegmatite veins are common and quartz veins and reefs occur in places.

At King Edward VIII Gulf, migmatites are rare. The rocks are garnetiferous feldspathic quartzite, and gneisses rich in garnet and amphibole, with some lenses of metamorphosed calcareous rocks. Much of the amphibole can be seen to have formed from pyroxene, suggesting a second episode of metamorphism. There are a number of layers of garnet and magnetite rich rocks, of metasomatic origin. Several metamorphosed basic sills also occur.

Around the coast of the Enderby Land Peninsula outcrops are rare. The rocks are charnockite with some bands of pyroxenite, and, at Proclamation Island, garnet granulites in which the garnet is pseudomorphed by biotite, kyanite, andalusite and cordierite, again pointing to a later metamorphism. Granite gneisses occur at Mt. Biscoe.

Migmatite is the most common rock in the southern part of Casey Bay, and in the Nye Mountains. Several thick bands of hornblende anorthosite, with biotite replacing the hornblende, may be re-crystallised igneous rocks. Remnants of pyroxene grains can be seen in the host rocks which grade into garnetiferous granite gneisses.

Thus it appears that at several places between King Edward VIII Gulf and Casey Bay, there is evidence that a second metamorphism of quite high grade has been superimposed on the earlier metamorphic rocks.

Around the shores of Amundsen Bay, and in the Tula and Scott Mountains, the characteristic rock is quartz-feldspar gneiss, composed of blue or brown quartz and brown strongly perthitic feldspar, with brown garnets in places, and a few small lenses of coarsely crystalline enstatite. Interbedded with this gneiss are numerous layers of medium grained, equigranular, rather massive pyroxene gneiss, containing antiperthitic oligoclase, hypersthene and clinopyroxene. A few layers of white quartz-feldspar-garnet gneiss, and of hypersthenite, occur also. These gneisses appear to have been derived, possibly with some metasomatism, from a sequence of arkosic and impure peletic sediments in which were layers of igneous rocks. Metamorphosed basic dykes and sills occur in several places.

South-east of the Tula Mountains, the quartz-feldspar gneiss becomes more granular and darker coloured, and at the Knuckey Peaks dark coloured charnockite occurs, quite like that near Mawson, but, (excepting some horizons) with only a small amount of hypersthene. It is likely that this charnockite is the extreme result of alteration of rocks similar to those from which the quartz-feldspar and pyroxene gneisses were formed.

At the Leckie Range and Mt. Channon are quartz- and feldspar-rich gneisses with a large-scale banding due to concentration of garnet and/or biotite. At the Leckie Range, these rocks have a strong lineation. Here also, thin quartz-feldspar veins along the foliation may be the result of partial mobilisation of the gneisses. These veins are intersected by metamorphosed basic dykes (which do not have any macroscopic lineation), which are in turn invaded by thin pink granite veins.

Between Mawson and Sandefiord Bay, 300 km. to the east, the only major rock outcrops are the Scullin and Murray Monoliths. The first of these is composed of coarse grained granitic gneiss with bands of pyroxene granulite.

Around the eastern shores of Prydz Bay, quartz-feldspar-garnet gneisses are common, with layers rich in sillimanite, biotite or garnet. Bands of pink or creamy coloured massive granite, commonly quite coarse grained, intrude the gneisses. In places, both the gneisses and the granite are rich in magnetite. Some amphibole, biotite-, and magnetite-rich lenses may be of metasomatic origin. Several exposures of charnockite occur.

The Vestfold Hills are made up of banded quartz-oligoclase-amphibole (or pyroxene) gneisses and granulitic quartz-feldspar-garnet gneisses, with biotite or sillimanite; charnockite and some granite gneisses occur also.

The outcrops from Depot Peak to the Prince Charles Mountains and in the Hansen Mountains are partly migmatised rocks, made up of varying proportions of feldspar, quartz, biotite, and garnet, with sillimanite in places. Aplite and garnetiferous quartz-feldspar pegmatites are common. Similar rocks occur in the western parts of the Athos, Porthos, and Aramis Ranges. In the eastern parts of these ranges, in the Grove Nunataks and in mountains along the Lambert Glacier, igneous material is predominant, so that the rocks appear as granitic gneisses with bands of dark hornfelsic rock. At the Grove Nunataks there are two types of gneissic granite, one younger than the other. Porphyritic charnockitic granite, quite like the rock at Mawson, occurs at Mt. Loewe and Jennings Promontory.

Wilson Bluff, near the head of the Mellor Glacier, is made up of quartz-biotite schist containing varying amounts of muscovite, andesine-labradorite, cummingtonite, and, rarely, garnet. Tourmaline occurs along some horizons. These rocks represent the lowest metamorphic grade yet encountered in the sector.

PEGMATITES

Pegmatites were found in most of the outcrops examined (except those of the Amery Formation). They can be divided into two groups:

(a) Coarse-grained discontinuous veins, irregular in width and direction, composed mainly of quartz and feldspar with accessory pyroxene, biotite, amphibole, or garnet.

(b) Very coarse-grained, straight, parallel sided veins, the wider ones zoned, containing mainly pink perthite and quartz (commonly graphically intergrown) with large biotite plates and some plagioclase. small amounts of garnet and minerals such as tourmaline and sphene may also be present. The width ranges from $\frac{1}{4}$ to 5 metres from vein to vein. Most have had no macroscopically observable effect on the adjacent rock, but in a few cases, although the edge of the pegmatite is quite sharply defined, the enclosing rock has been granitised for a distance of a metre or two from the pegmatite.

SEDIMENTS

Sediments of the Amery Formation outcrop along the western and southern sides of Beaver Lake in the north-east Prince Charles Mountains. Their western margin is downfaulted against metamorphic rocks along the Amery Fault. East of this fault there is approximately 500 sq. km. of sediments, but most of this area is covered by thick deposits of moraine. A thickness of over 500 metres is estimated for the sequence.

The sediments are mainly current-bedded feldspathic sandstones, calcareous in part, made up of rather angular, only moderately sorted grains. There are a few beds, a metre or so thick, of massive reddish-brown mudstone. Carbonaceous shale and coal seams also occur; the coal is intermediate in rank between brown and black coal. No identifiable macro-fossils have been found, but palynological work by Balme and Playford (1958) indicates an Upper Artinskian or Kungurian age.

Along the edge of Beaver Lake, the sediments are almost horizontal. Westwards the dip increases to 20° to 30° to the east near the Amery Fault.

Thermally metamorphosed sandstone which is very common in moraine covering a nunatak at 72°58' S. 61° E. may be related either to the Amery Formation or to the slightly altered sediments of Mts. Sandow and Amundsen, described by Voronov, Klimov, and Ravich (1959). Fragments of coarse massive granite also occurring in the moraine probably represent the metamorphosing agent.

DOLERITE DYKES

Dykes are very numerous in the Vestfold Hills, where they form two sets, one with members striking north-south, and a subordinate set trending east-west. Members of either set may intrude those of the other. Single dykes were found in several places in Enderby and Kemp Lands. Most of these ran approximately north-south.

Basalt dykes were seen in several places in the Tula and Prince Charles Mountains. In the former area, they occur in or near zones of shearing. These basalts may be related to the dolerites, but on the other hand could be the same age as the Tertiary volcanics of Mt. Gauss.

The age of the dolerites is not definitely known, but by analogy with similar rocks of the Ross Sea region and other parts of Gondwanaland, they are assigned a Jurassic age.

STRUCTURE

From Stefansson Bay to Mawson and south to the Stinear Nunataks, the rocks strike roughly north-south. Elsewhere, with few exceptions, the trend is approximately east-west. Dips are generally steep. Folds, with amplitudes up to several hundred metres, can be seen in many places; the degree of folding ranges from quite open to very tight.

Evidence of block faulting can be seen throughout the area. Fault scarps are common in the Prince Charles Mountains; although most have been modified by glacial action, their presence, even in the relatively soft sandstone, shows that there was extensive vertical movement during the late Tertiary, and possibly even more recently. Along many faults, the rocks have been mylonitised over widths of ten metres or so. Basalt dykes occur in or near some of these zones. The major fault lines fall into two sets, striking north-south and east-west. It is possible that these lines were initiated at least as early as the Palaeozoic, and that the Amery Formation was deposited in a downfaulted basin.

GEOLOGICAL HISTORY

The geological history of the region is only tentatively outlined here, and the sequence of events visualised will probably be greatly modified by further work. Also it is unlikely that the geological history would be the same for different parts of such a large area.

The generalised sequence of events is thought to have been:

(1) Metamorphism of a succession of sediments, with some lavas or sills, up to the granulite facies, with accompanying migmatisation.

(2) Intrusion of basic dykes and sills.

(3) Further metamorphism to at least the amphibolite grade, and possibly higher in places. The numerous parallel-sided pegmatite dykes may belong to this episode, or may be a later unconnected event.

(4) Deposition of freshwater sediments, possibly in downfaulted basins. The duration of deposition before and after Lower Permian time is not known.

(5) Widespread injection of dolerite dykes, probably during the Jurassic.

(6) Disruption by blockfaulting in late Tertiary times.

(7) Burial by ice, subsequent partial de-glacierisation, and eustatic sea level movements.

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