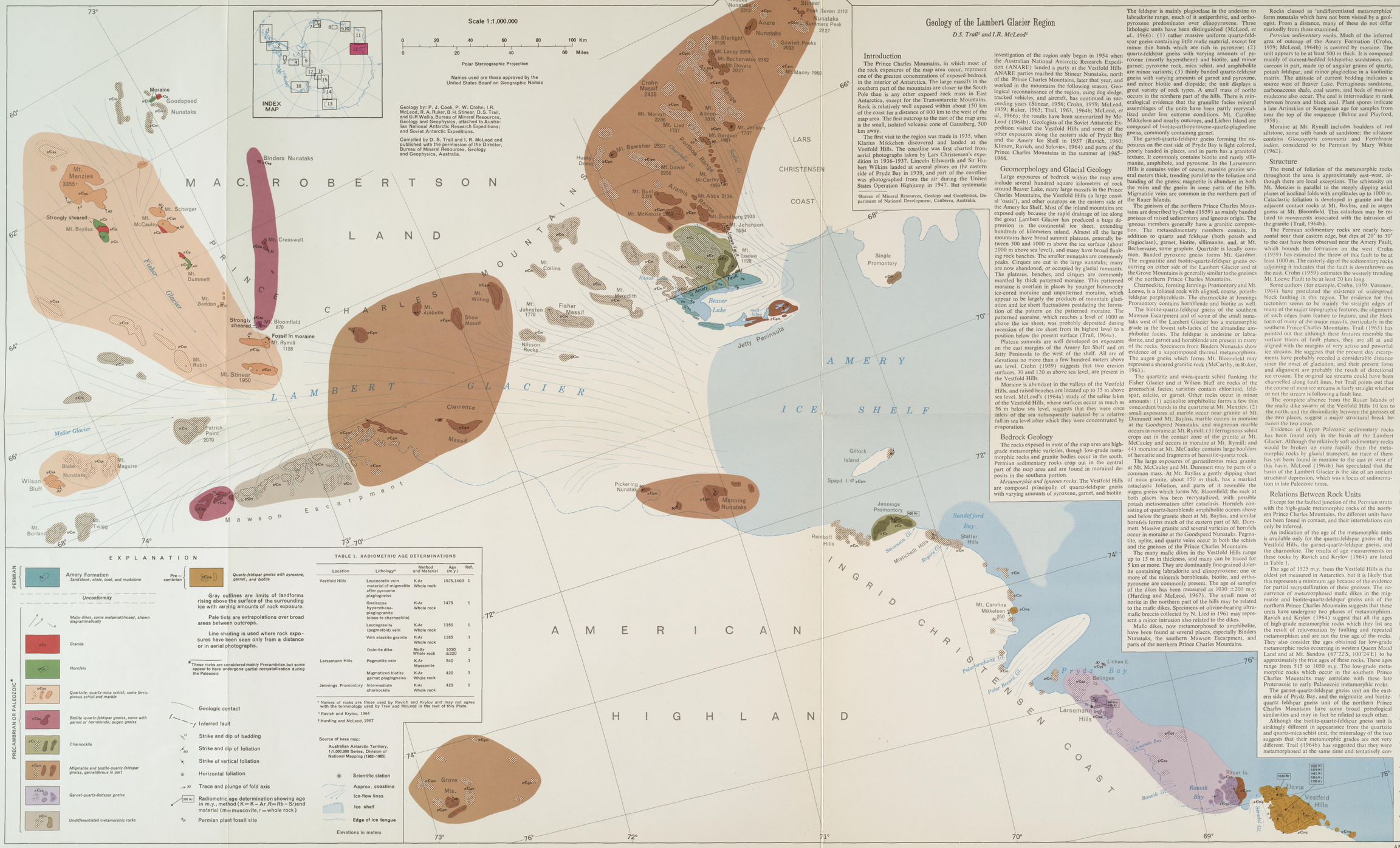

TABLE 1. RADIOMETRIC AGE DETERMINATIONS

Location	Lithology*	Method and Material	Age (m.y.)	Ref.
Vestfold Hills	Leucocratic vein material of migmatite after pyroxene plagioclase gneiss	K-Ar Whole rock	1525,1460	1
	Gneissose hypersthene-plagioclase granite (close to charnockite)	K-Ar Whole rock	1475	1
	Leucogranite (pegmatoid) vein	K-Ar Whole rock	1350	1
	Vein alaskite granite	K-Ar Whole rock	1185	1
	Dolerite dike	Rb-Sr Whole rock	1030 ±220	2
Larsemann Hills	Pegmatite vein	K-Ar Muscovite	540	1
	Migmatized biotite garnet gneiss	K-Ar Whole rock	420	1
Jennings Promontory	Intermediate charnockite	K-Ar Whole rock	420	1

* Names of rocks are those used by Ravich and Krylov and may not agree with the terminology used by Trail and McLeod in the text of this Plate.

[1] Ravich and Krylov, 1964

[2] Harding and McLeod, 1967

Geology of the Lambert Glacier Region

D.S. Trail[1] and I.R. McLeod[1]

Introduction

The Prince Charles Mountains, in which most of the rock exposures of the map area occur, represent one of the greatest concentrations of exposed bedrock in the interior of Antarctica. The large massifs in the southern part of the mountains are closer to the South Pole than is any other exposed rock mass in East Antarctica, except for the Transantarctic Mountains. Rock is relatively well exposed within about 150 km of the coast for a distance of 800 km to the west of the map area. The first outcrop to the east of the map area is the small, isolated volcanic cone of Gaussberg, 500 km away.

The first visit to the region was made in 1935, when Klarius Mikkelsen discovered and landed at the Vestfold Hills. The coastline was first charted from aerial photographs taken by Lars Christensen's expedition in 1936–1937. Lincoln Ellsworth and Sir Hubert Wilkins landed at several places on the eastern side of Prydz Bay in 1939, and part of the coastline was photographed from the air during the United States Operation Highjump in 1947. But systematic investigation of the region only began in 1954 when the Australian National Antarctic Research Expedition (ANARE) landed a party at the Vestfold Hills. ANARE parties reached the Stinear Nunataks, north of the Prince Charles Mountains, later that year, and worked in the mountains the following season. Geological reconnaissance of the region, using dog sledge, tracked vehicles, and aircraft, has continued in succeeding years (Stinear, 1956; Crohn, 1959; McLeod, 1959; Ruker, 1963; Trail, 1963, 1964b; McLeod, *et al.*, 1966); the results have been summarized by McLeod (1964b). Geologists of the Soviet Antarctic Expedition visited the Vestfold Hills and some of the other exposures along the eastern side of Prydz Bay and the Amery Ice Shelf in 1957 (Ravich, 1960; Klimov, Ravich, and Soloviev, 1964) and parts of the Prince Charles Mountains in the summer of 1965–1966.

[1] Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, Canberra, Australia.

Geomorphology and Glacial Geology

Large exposures of bedrock within the map area include several hundred square kilometers of rock around Beaver Lake, many large massifs in the Prince Charles Mountains, the Vestfold Hills (a large coastal 'oasis'), and other outcrops on the eastern side of the Amery Ice Shelf. Most of the inland mountains are exposed only because the rapid drainage of ice along the great Lambert Glacier has produced a huge depression in the continental ice sheet, extending hundreds of kilometers inland. Almost all the large mountains have broad summit plateaus, generally between 300 and 1000 m above the ice surface (about 2000 m above sea level), and many have broad flanking rock benches. The smaller nunataks are commonly peaks. Cirques are cut in the large nunataks; many are now abandoned, or occupied by glacial remnants. The plateaus, benches, and cirques are commonly mantled by thick patterned moraine. This patterned moraine is overlain in places by younger hummocky ice-cored moraine and unpatterned moraine, which appear to be largely the products of mountain glaciation and ice sheet fluctuations postdating the formation of the pattern on the patterned moraine. The patterned moraine, which reaches a level of 1000 m above the ice sheet, was probably deposited during recession of the ice sheet from its highest level to a position below the present surface (Trail, 1964a).

Plateau summits are well developed on exposures on the east margins of the Amery Ice Shelf and on Jetty Peninsula to the west of the shelf. All are of elevations no more than a few hundred meters above sea level. Crohn (1959) suggests that two erosion surfaces, 30 and 120 m above sea level, are present in the Vestfold Hills.

Moraine is abundant in the valleys of the Vestfold Hills, and raised beaches are located up to 15 m above sea level. McLeod's (1964a) study of the saline lakes of the Vestfold Hills, whose surfaces occur as much as 56 m below sea level, suggests that they were once inlets of the sea subsequently isolated by a relative fall in sea level after which they were concentrated by evaporation.

Bedrock Geology

The rocks exposed in most of the map area are high-grade metamorphic varieties, though low-grade metamorphic rocks and granite bodies occur in the south. Permian sedimentary rocks crop out in the central part of the map area and are found in moraine deposits in the southern portion.

Metamorphic and igneous rocks. The Vestfold Hills are composed principally of quartz-feldspar gneiss with varying amounts of pyroxene, garnet, and biotite. The feldspar is mainly plagioclase in the andesine to labradorite range, much of it antiperthitic, and orthopyroxene predominates over clinopyroxene. Three lithologic units have been distinguished (McLeod, *et al.*, 1966): (1) rather massive uniform quartz-feldspar gneiss containing little mafic material, except for minor thin bands which are rich in pyroxene; (2) quartz-feldspar gneiss with varying amounts of pyroxene (mostly hypersthene) and biotite, and minor garnet; pyroxene rock, mica schist, and amphibolite are minor variants; (3) thinly banded quartz-feldspar gneiss with varying amounts of garnet and pyroxene, and minor biotite and diopside; the unit displays a great variety of rock types. A small mass of norite occurs in the northern part of the hills. There is mineralogical evidence that the granulite facies mineral assemblages of the units have been partly recrystallized under less extreme conditions. Mt. Caroline Mikkelsen and nearby outcrops, and Lichen Island are composed of biotite-orthopyroxene-quartz-plagioclase gneiss, commonly containing garnet.

The garnet-quartz-feldspar gneiss forming the exposures on the east side of Prydz Bay is light colored, poorly banded in places, and in parts has a granitoid texture. It commonly contains biotite and rarely sillimanite, amphibole, and pyroxene. In the Larsemann Hills it contains veins of coarse, massive granite several meters thick, trending parallel to the foliation and banding of the gneiss; magnetite is abundant in both the veins and the gneiss in some parts of the hills. Migmatitic veins are common in the northern part of the Rauer Islands.

The gneisses of the northern Prince Charles Mountains are described by Crohn (1959) as mainly banded gneisses of mixed sedimentary and igneous origin. The igneous members generally have a granitic composition. The metasedimentary members contain, in addition to quartz and feldspar (both potash and plagioclase), garnet, biotite, sillimanite, and, at Mt. Bechervaise, some graphite. Quartzite is locally common. Banded pyroxene gneiss forms Mt. Gardner. The migmatitic and biotite-quartz-feldspar gneiss occurring on either side of the Lambert Glacier and at the Grove Mountains is generally similar to the gneisses of the northern Prince Charles Mountains.

Charnockite, forming Jennings Promontory and Mt. Loewe, is a foliated rock with aligned, coarse, potash-feldspar porphyroblasts. The charnockite at Jennings Promontory contains hornblende and biotite as well.

The biotite-quartz-feldspar gneiss of the southern Mawson Escarpment and of some of the small nunataks west of the Lambert Glacier has a metamorphic grade in the lowest sub-facies of the almandine amphibolite facies. The feldspar is andesine or labradorite, and garnet and hornblende are present in many of the rocks. Specimens from Binders Nunataks show evidence of a superimposed thermal metamorphism. The augen gneiss which forms Mt. Bloomfield may represent a sheared granitic rock (McCarthy, in Ruker, 1963).

The quartzite and mica-quartz schist flanking the Fisher Glacier and at Wilson Bluff are rocks of the greenschist facies; varieties contain chloritoid, feldspar, calcite, or garnet. Other rocks occur in minor amounts: (1) actinolite amphibolite forms a few thin concordant bands in the quartzite at Mt. Menzies; (2) small exposures of marble occur near granite at Mt. Dummett and Mt. Bayliss, marble occurs in moraine at the Goodspeed Nunataks, and magnesian marble occurs in moraine at Mt. Rymill; (3) ferruginous schist crops out in the contact zone of the granite at Mt. McCauley and occurs in moraine at Mt. Rymill; and (4) moraine at Mt. McCauley contains large boulders of hematite and fragments of hematite-quartz rock.

The large exposures of garnetiferous mica granite at Mt. McCauley and Mt. Dummett may be parts of a common mass. At Mt. Bayliss a gently dipping sheet of mica granite, about 150 m thick, has a marked cataclastic foliation, and parts of it resemble the augen gneiss which forms Mt. Bloomfield; the rock at both places has been recrystallized, with possible potash metasomatism after cataclasis. Hornfels consisting of quartz-hornblende amphibolite occurs above and below the granite sheet at Mt. Bayliss, and similar hornfels forms much of the eastern part of Mt. Dummett. Massive granite and several varieties of hornfels occur in moraine at the Goodspeed Nunataks. Pegmatite, aplite, and quartz veins occur in both the schists and the gneisses of the Prince Charles Mountains.

The many mafic dikes in the Vestfold Hills range up to 15 m in thickness, and many can be traced for 5 km or more. They are dominantly fine-grained dolerite containing labradorite and clinopyroxene; one or more of the minerals hornblende, biotite, and orthopyroxene are commonly present. The age of samples of the dikes has been measured as 1030 ±200 m.y. (Harding and McLeod, 1967). The small mass of norite in the northern part of the hills may be related to the mafic dikes. Specimens of olivine-bearing ultramafic breccia collected by N. Lied in 1961 may represent a minor intrusion also related to the dikes.

Mafic dikes, now metamorphosed to amphibolite, have been found at several places, especially Binders Nunataks, the southern Mawson Escarpment, and parts of the northern Prince Charles Mountains.

Rocks classed as 'undifferentiated metamorphics' form nunataks which have not been visited by a geologist. From a distance, many of these do not differ markedly from those examined.

Permian sedimentary rocks. Much of the inferred area of outcrop of the Amery Formation (Crohn, 1959; McLeod, 1964b) is covered by moraine. The unit appears to be at least 500 m thick. It is composed mainly of current-bedded feldspathic sandstones, calcareous in part, made up of angular grains of quartz, potash feldspar, and minor plagioclase in a kaolinitic matrix. The attitude of current bedding indicates a source west of Beaver Lake. Ferruginous sandstone, carbonaceous shale, coal seams, and beds of massive mudstone also occur. The coal is intermediate in rank and this area may have escaped the repeated metamorphic episodes which affected much of East Antarctica up to the most recent widespread event which occurred about 480 m.y. ago. It is, however, noteworthy that the gneisses of the Vestfold Hills show evidence of recrystallization after the granulite-facies metamorphism; it is not known whether this recrystallization can be correlated with any of the other metamorphic events referred to below or to the intrusion of the dikes. It has already been suggested that the Vestfold Hills may be structurally distinct from the other rock units of the region. This suggestion is supported by the inferred great difference in measured ages between the gneisses of the Vestfold Hills and those of the nearby Rauer Islands, which can be correlated with the gneisses of the Larsemann Hills.

The lower grade metasedimentary rocks of the southern Prince Charles Mountains show the effects of at least two metamorphisms. The first event was a regional episode in which schistosity or foliation developed, presumably during the deformation which produced the isoclinal folds. This deformation was followed by the emplacement of granitic rocks, and possibly also of the mafic dikes. Mild deformation with locally severe cataclasis then occurred, and this was succeeded by widespread thermal metamorphism accompanied, or closely followed by, potash metasomatism and emplacement of granitic rocks, pegmatites, and quartz veins. The similarity of the cataclastic granite to the undeformed granite suggests that the last three of these events were phases of the one episode of metamorphism and granite emplacement.

The only possible link known at present between the events in the southern and northern Prince Charles Mountains is the presence of mafic dikes. The rocks of the northern Prince Charles Mountains had almost certainly undergone high-grade metamorphism before the dikes were emplaced there. If the dikes can be correlated between the two regions, the final, predominantly thermal, metamorphic event would have affected both regions, although there is no definite evidence of emplacement of granitic rocks after that of the mafic dikes in the northern Prince Charles Mountains. Trail (1964b) has tentatively correlated this latest event with the widespread event dated at 480 m.y. (Picciotto and Coppez, 1962). The measured ages of specimens from the Larsemann Hills and Jennings Promontory (Table 1) tend to support this correlation.

The next recorded event was the deposition of sediments, now represented by the Permian Treshwater Amery Formation. The chronological and geographic range of sedimentation is not known. Still later, possibly in Tertiary times, the sedimentary rocks were faulted down against the high-grade metamorphic rocks. The possibility of widespread block faulting has already been discussed.

Geologic History

The great variety of rocks in the region and the difference in metamorphic grades indicate a complex metamorphic history. The earliest metamorphism is represented by the rocks of the Vestfold Hills. The relatively great measured age of these rocks and the lack of evidence for metamorphism of the mafic dikes, whose age has been measured as 1030 m.y., suggest that this area may have escaped the repeated metamorphic episodes which affected much of East Antarctica up to the most recent widespread event which occurred about 480 m.y. ago. It is, however, noteworthy that the gneisses of the Vestfold Hills show evidence of recrystallization after the granulite-facies metamorphism; it is not known whether this recrystallization can be correlated with any of the other metamorphic events referred to below or to the intrusion of the dikes. It has already been suggested that the Vestfold Hills may be structurally distinct from the other rock units of the region. This suggestion is supported by the inferred great difference in measured ages between the gneisses of the Vestfold Hills and those of the nearby Rauer Islands, which can be correlated with the gneisses of the Larsemann Hills.

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