Geology of Western Queen Maud Land[1]

E. F. Roots[2]

Introduction

Western Queen Maud Land forms the western part of the Atlantic sector of the continental mass of East Antarctica. It is bounded on the north by the Antarctic basin of the South Atlantic Ocean and on the west by the Weddell Sea to Ross Sea depression. The region inland from Princess Martha Coast (longitudes 2°E to 6°W) was investigated by the field parties of the Norwegian-British-Swedish Antarctic Expedition of 1949–1952 (Roots, 1952, 1953).

Princess Martha Coast is entirely ice shrouded and deeply embayed, with its irregularities smoothed by an almost continuous fringing ice shelf that extends the ice front to approximately the outer edge of the narrow continental shelf. From the inner border of the ice shelf, the ice surface rises in a series of broad north-trending ridges — Giaever Ridge, Ahlmann Ridge, Helle Slope — separated at intervals of about 100 km by more or less well-defined ice streams. The largest ice stream in the area is Jutulstraumen Glacier, which flows into and through the Fimbul Ice Shelf to form a prominent projecting floating ice tongue at the Greenwich Meridian. The general ice surface reaches an altitude of 1500 to 2000 m at the foot of a mountain range which runs roughly parallel with the coastline and 150 to 200 km inland. This range, represented by the Sverdrup Mountains and Kirwan Escarpment, truncates the rolling piedmont ridges and forms a major escarpment bounding the inland ice plateau. South of the range, nearly all of the ice surface is more than 2400 m above sea level.

Rock outcrops are abundant along the mountain range which forms the escarpment at the edge of the inland plateau. Here, the Gjelsvik Mountains, Sverdrup Mountains, and Kirwan Escarpment show sharp curving ridges, long sweeping buttresses, and massive rock walls with a local topographic relief exceeding 1500 m in places. Outcrops are also numerous in the Borg Massif, where flat-topped, blocky mountains and steep-sided buttes rise as much as 1000 m above the ice. North of the Borg Massif, the Ahlmann Ridge is characterized by a large number of horn-like and blocky nunataks, which become lower, smaller, and more scattered toward the north until near the coast many are only a few tens of meters across. On Giaever Ridge to the west, the ice blanket is pierced by fewer than a dozen widely-spaced nunataks, none of which rises more than 50 m above the present ice surface. Seismic sounding (Robin, 1958) along a line from the coast near 10°W to the inland plateau near the Greenwich Meridian at 74°S has shown the bedrock floor to be one of considerable relief. In the region of the Giaever Ridge, some areas are below sea level, while nearby, outcrops pierce the ice surface at altitudes of 1000 m. At the foot of the Kirwan Escarpment, 200 km inland from the shelf ice, the channel of the Penck Trough is 800 m below sea level. On the inland side of the range forming Kirwan Escarpment, where the rock surface drops almost to sea level, ice thicknesses of 2400 m have been measured.

General Geology

The oldest rocks in the area are those of the *Sverdrupfjell Group* (p€s), which comprises all of the Gjelsvik and Sverdrup Mountains and the Kirwan Escarpment between 2°E and 5°W, except for minor younger intrusions. Well banded, medium- to coarse-grained leucocratic felsic to intermediate quartz-microcline-oligoclase-biotite gneiss makes up more than three quarters of the exposed thickness of this group; the remainder consists of garnetiferous and amphibolitic gneisses, amphibolite, biotitic and pyroxenic schists, pegmatites, aplites and related rocks. Most are of granulitic facies; well developed augen gneisses are common, and locally the rock has the appearance of a high-grade migmatite in which some units possess a granitic texture. A thickness of at least 2000 m is exposed. The age of this group is unknown, but it is almost certainly older than that of the unmetamorphosed Cambrian limestone that has been dredged from the Weddell Sea to the west (Gordon, 1920; Hill and Oliver, 1964); and on Tunga Spur (73°54′S, 5°20′W) the group is overlain with angular unconformity by strata assigned to the Ahlmannrygg Group of presumably late Precambrian to early Paleozoic age. A Precambrian age is thus probable, and the group is considered to be a typical unit of the Antarctic Shield.

The *Juletopper Intrusions* (p€j) are coarse-grained, non-banded granite gneiss and pegmatite, comprising an isolated group of small nunataks on Ritscher Upland. Their relationship to other rock units is not known, although the rocks are lithologically similar to some of the more granitic parts of the Sverdrupfjell Group.

The *Heksegryte Intrusions* (p€h) are tabular bodies of sheared, slaty amphibolite that cut the Sverdrupfjell Group in Kirwan Escarpment. The *Tvore Intrusions* (p€t) are roughly equidimensional bodies of coarse-grained oligoclase-hornblende syenite that cut the Sverdrupfjell Group in the Neumayer Cliffs and in the Gburek Peaks. No intrusions similar to these have been found cutting the non-metamorphosed rocks, and the intrusions themselves have been subject to metamorphism; they are probably Precambrian.

Fine-grained metasedimentary rocks of the greenschist facies, mainly gray and green slates, chloritic and sericitic phyllites, and minor quartzite, comprise the *Pencksokk Formation* (p€p), which forms isolated nunataks in Penck Trough and Jutulstraumen Glacier. A stratigraphic thickness of about 250 m is exposed. The age and stratigraphic relationship of this formation is not known; the rocks resemble some of the less metamorphosed members of the Sverdrupfjell Group in Kirwan Escarpment and in the Gburek Peaks. However, quite similar rocks could be produced by metamorphism of a pelitic assemblage from the Ahlmannrygg Group exposed to the northwest.

All of the sedimentary rocks exposed in the Borg Massif and on Ahlmann Ridge, except for volcanic sediments in the northeast corner, have been assigned to the *Ahlmannrygg Group* (p€a). The group is composed entirely of clastic strata which are barren or exceedingly poor in organic remains, and consists in large part of a repetitive assemblage of well banded gray, green, and buff quartzite, siltstone, mudstone, and mudstone-fragment conglomerate without distinctive horizon markers. Correlation between widely scattered outcrops is difficult, and interpretation of the structural details or the stratigraphic sequence is very speculative. It appears that a thickness of more than 1600 m of the rocks is exposed in the map area. The base of the group, at least locally, appears to be represented by banded yellow and gray quartzites and thin mudstone-fragment conglomerate beds that lie with angular unconformity on the smooth, apparently eroded surface of Sverdrupfjell Group strata on Kuven Hill and Tunga Spur of Kirwan Escarpment; but the relationship of these beds to the remainder of the group is not known. Four conformable formations have been recognized in the Borg Massif. They are, beginning with the oldest:

Fram Formation (p€af)—more than 550 m thick; well-bedded brown, red, yellow, and gray quartzites, black siltstones and mudstones, with the proportion of mudstone increasing from less than 10 percent in the lower exposed beds to 50 percent at the top.

Lower Borg Formation (p€abl)—about 300 m thick; conspicuously banded brown, purple, buff, gray, and green quartzites and quartzitic graywackes, with black and brown mudstones, siltstones and minor shale.

Upper Borg Formation (p€abu)—about 200 m thick; fine-grained gray, green, and buff quartzites, with about 15 percent thin-bedded black mudstones and siltstones, and occasional beds of angular conglomerate.

Raudberg Formation (p€ar)—more than 500 m thick; a uniform series of beds of red fine-grained quartzite, with thin layers of breccia of brown and purple mudstone, and occasional thick sheets of quartz-pebble and mudstone-fragment conglomerate.

Elsewhere, south of 73°00′S, and on the Ahlmann Ridge north of 72°10′S, it has not been possible to correlate formational units from nunatak to nunatak, and the sedimentary rocks have been mapped as undifferentiated *Ahlmannrygg Group* (p€a).

In the Istind Peak area, what are thought to be some of the stratigraphically highest strata include about 250 m of andestic and basaltic flows, brown and red angular conglomerate, variable graywacke, agglomerate, fanglomerate, and sedimentary or volcanic breccia. Identifiable fossils are absent or exceedingly rare in the Ahlmannrygg Group. Silty shales and mudstone-fragment conglomerate from several places, notably the Nils Jorgen Peaks, have yielded molds and casts that resemble lamellibranchs and possibly cephalopods, but all found have been too poorly preserved to permit identification, if indeed they are of organic origin. On the basis of algae (*Rifenites*) and spores from exposures west of Penck Trough, a late Precambrian to early Paleozoic age has been suggested (Klimov *et al.*, 1964; Ravich, 1966). Parts of the group have a lithological resemblance to parts of the late Paleozoic Beacon Group of the Transantarctic Mountains to the southwest; but on the whole the Ahlmannrygg Group is of a more argillaceous and graywacke facies, is more heterogeneous in mineralogy and texture, and has been derived by comparatively rapid erosion from a less-weathered provenance than has the Beacon Group; it is also more conspicuously metamorphosed, although the relatively greater development of metamorphic minerals and textures may be due to the relative impurity of the rocks rather than to a higher degree of metamorphism. The Ahlmannrygg Group may be related to the Turnpike Metamorphics of the Shackleton Range (Stephenson, 1966) or to the Patuxent Formation of the Pensacola Mountains (Schmidt *et al.*, 1964), but there is as yet no positive evidence upon which to base a correlation between these units.

Sills of the *Borg Intrusions* (p€b) have intimately invaded the sedimentary rocks of the Ahlmannrygg Group throughout its entire known extent. Because they are more resistant to erosion than the rocks they intrude, these sills form most of the nunataks and cliffs of Ahlmann Ridge and Giaever Ridge, and cap all the block mountains of the Borg Massif; they therefore appear to be much more abundant than they probably are in the stratigraphic section. Most of the sills are lenticular (although some individual bodies can be followed for more than 20 km), and thus an estimate of the composite thickness of sills would be meaningless. Nevertheless, in any extensive section of the Ahlmannrygg Group, Borg Intrusions make up more than 25 percent and commonly more than 60 percent of the total vertical exposure.

The typical rocks of the Borg Intrusions are feldspathic diabasic gabbro, with variations ranging from syeno-diorite to a mafic gabbro-pyroxenite. Most of the sills are large, more than 15 m thick, with individual bodies ranging to 200 m thick and covering at least 200 km². About half the sills are undifferentiated except for thin chilled contacts and a gradual diminishing of the otherwise ubiquitous ophitic texture in the upper part. The remainder are conspicuously differentiated, with the pattern of differentiation ranging from a simple one grading from a peridotitic layer at the base to quartz-microcline micropegmatite at the top, to complex rhythmic or non-rhythmic feldspar-pyroxene banding with evidences of crystal sorting and movement. Most sills follow bedding planes closely, reaching other stratigraphic horizons by abrupt steps or jumps. Cross-cutting dikes are comparatively rare, although three excellent examples are known of large feeder dikes, which are symmetrically differentiated from walls to center with a mineralogical sequence similar to the differentiated sill they have supplied. A few sills are so strongly lenticular that they have arched the overlying sedimentary rocks in the manner of typical laccoliths.

The only certainty regarding the age of the Borg Intrusions is that they are younger than the strata of the Ahlmannrygg Group. Their relation to the Trollkjell volcanic rocks is not known. The relationship of the Borg Intrusions to the Ahlmannrygg Group has been compared with the relationship of the Jurassic Ferrar dolerites to the Beacon Group in the Transantarctic Mountains (Reece, 1958); but these relationships are also similar to that of the pre-Devonian diabase of the Pensacola Mountains to the Patuxent Formation it intrudes (Schmidt *et al.*, 1964). Radiometric dating of an intrusion at the north end of Giaever Ridge indicates a Precambrian age (Neethling, Sheet 7, this folio). This intrusion is believed to be related to the Borg Intrusions, although it is not typical of them.

Andesitic to basaltic flows and minor tuffs comprise a distinct unit, the *Trollkjell Group* (p€tk) on Trollkjell Ridge* at the northeast corner of the Ahlmann Ridge. The flows, mainly 3 to 20 m thick, are aphanitic to fine-grained, in part porphyritic, and strongly amygdaloidal. Pillow structure is well developed, and one mass at least 80 m thick is composed entirely of lava pillows. These rocks have not been observed in contact with any other group. Their age is not known.

Nunataks in the Ahlmann Ridge area expose two types of intrusions sufficiently distinct from the Borg Intrusions to be mapped separately. Most of the known bodies of these intrusions are too small to be shown on the present map. The Ahlmannrygg Group on Nils Jorgen, Grunehogna, and Jekselen Peaks and on Mount Schumacher is cut by small irregular stock-like bodies and dikes of gabbro, diorite, and syenite (p€n). These rocks have been named the *Nils Syeno-diorite* by Neethling (Sheet 7, this folio). At the northern end of the Ahlmann Ridge, Krylen Hill and Knotten Nunatak expose distinctive dikes of altered mafic or ultramafic rock (p€r) cutting bodies of the Borg Intrusions with sharp, serpentinized contacts. Similar rocks have been described from Roberts Knoll to the west, where they have been named the *Roberts Knoll Peridotites* (Neethling, Sheet 7, this folio).

The available evidence is compatible with a Precambrian or pre-middle Paleozoic age for all known rocks in the area.

Structure

Although highly contorted in detail, the formations of the Sverdrupfjell Group, on a regional pattern, dip at moderate angles to the southeast with their dip slope buried by the inland ice. The area known to be underlain by the group is bounded on the northwest by what seems to be a zone of faulting marked by Penck Trough and the valley of the lower Jutulstraumen Glacier. This depression, whose rock floor is 800 m below sea level where measured south of 73°00′S, appears to be a down-dropped block or a series of fault slices. Block movements along the east side of the northern part of this depression have tilted the rocks of the Gburek Peaks and Mount Roer at a variety of angles. Uplift of slices within the block has formed the nunataks exposing the Pencksokk Formation and has presumably contributed to the sheared and metamorphosed nature of their rocks.

The Borg Massif is an uplifted mass of nearly planar sedimentary rocks and sills that has been divided by northeast-trending normal faults into long sub-parallel blocks separated by steep-walled, straight, corridor-like valleys, and further broken by minor cross-faulting to produce a crudely rectangular pattern. There is no evidence of horizontal displacement as a result of the block faulting. The Ahlmannrygg Group strata on the whole dip gently to the east, and local variations appear to be caused more by the intrusion of lenticular sills than by a regional fault or fold structure.

The nunataks exposing the Trollkjell Group are too scattered to enable a determination of the overall structure to be made. Individual flows dip eastward at moderate angles, and lie on a ridge whose form suggests the presence of a major fault on the east side bounding the Jutulstraumen depression.

References

Gordon, W. T. (1920) Cambrian organic remains from a dredging in the Weddell Sea, *Trans. Roy. Soc. Edinburgh*, **52**, 681-714.

Hill, D., and Oliver, R. L., (1964) Archaeocyatha from loose material at Plunket Point at the head of Beardmore Glacier, in *Antarctic Geology, Proceedings of the First International Symposium on Antarctic Geology, Cape Town, 16-21 September 1963*, edited by R. J. Adie, pp. 609-622, North-Holland, Amsterdam.

Klimov, L. M., Ravich, M. G., and Soloviev, D. S. (1964) Geology of the Antarctic platform, in *Antarctic Geology, Proceedings of the First International Symposium on Antarctic Geology, Cape Town, 16-21 September 1963*, edited by R. J. Adie, pp. 681-691, North-Holland, Amsterdam.

Ravich, M. G. (1966) Geological structure of Antarctica, *Info. Bull., Soviet Antarctic Expedition*, No. 57, pp. 28-42.

Reece, A. W. (1958) Discussion following paper by L. C. King, 'Basic palaeogeography of Gondwanaland during the late Palaeozoic and Mesozoic eras,' *Quart. J. Geol. Soc. London*, **114**, 75.

Robin, G. de Q. (1958) Seismic shooting and related investigations, *Norwegian-Brit.-Swedish Ant. Exped., 1949–1952, Sci. Res.*, Vol. 5, Glaciol. III, Norsk Polarinstitutt, Oslo, 134 pp.

Roots, E. F. (1952) The Norwegian-British-Swedish Antarctic Expedition 1949–52, in *Science News*, edited by A. W. Haslett, No. 26, pp. 9-32, Penguin, London.

Roots, E. F. (1953) Preliminary note on the geology of western Dronning Maud Land, *Norsk Geol. Tids*, **32**, 18-33.

Schmidt, D. L., Dover, J. H., Ford, A. B., and Brown, R. D. (1964) Geology of the Patuxent Mountains, in *Antarctic Geology, Proceedings of the First International Symposium on Antarctic Geology, Cape Town, 16-21 September 1963*, edited by R. J. Adie, pp. 276-283, North-Holland, Amsterdam.

Stephenson, J. (1966) Theron Mountains, Shackleton Range, and Whichaway Nunataks, *Trans-Ant. Exped., 1955-1958, Sci. Rept.*, No. 8, Geol., Pt. 1, 79 pp.

[1]This text is based on a report in preparation for Volume 6 of the *Norwegian-British-Swedish Antarctic Expedition 1949–1952, Scientific Results.*

[2]Department of Energy, Mines and Resources, Ottawa, Canada.

*Unofficial name

EXPLANATION

STRATIFIED ROCKS

UPPER PRECAMBRIAN or LOWER PALEOZOIC

p€tk Trollkjell Group — *Andesite flows and pillow lavas; minor conglomerate, quartzite*

Ahlmannrygg Group — *Clastic, continental rocks, mainly quartzite, graywacke, siltstone, conglomerate*

p€a — *Undifferentiated clastic rocks*

p€ar Raudberg Formation — *Quartzite, red, fine-grained; minor mudstone breccia and quartz-pebble conglomerate*

p€abu Upper Borg Formation — *Quartzite, gray, green and buff; minor mudstone, siltstone, and conglomerate*

p€abl Lower Borg Formation — *Quartzite and graywacke, banded brown, purple, gray, white and green; mudstone, siltstone; minor shale*

p€af Fram Formation — *Quartzite, banded brown, red, and gray; siltstone; mudstone*

p€p Pencksokk Formation — *Slate, phyllite, chlorite, schist; minor quartzite. May include rocks which are metamorphosed equivalent of Ahlmannrygg Group*

PRECAMBRIAN ?

p€s Sverdrupfjell Group — *Quartz-feldspar-mica-amphibolite gneiss; quartzite, amphibolite; pegmatite, gneissic granitic rocks. May include rocks equivalent to Juletopper intrusions or Heksegryte intrusions*

INTRUSIVE ROCKS

p€r — *Peridotite*

p€n — *Miscellaneous gabbroic, dioritic, and syenitic rocks of unknown relationship*

p€b Borg Intrusions — *Sills and minor dikes of gabbro and diorite, in part highly differentiated*

p€t Tvore Intrusions — *Hornblende syenite*

p€h Heksegryte Intrusions — *Amphibolite*

p€j Juletopper Intrusions — *Leucocratic granitic gneiss*

INDEX MAP

Inferred geologic contact

Strike and dip of bedding or flow banding

Strike and dip of metamorphic foliation or layering

Horizontal bedding

Syncline

Animal fossil site

500 Ice surface contours (m)

Approx. coastline

Ice-flow lines

Ice shelf

Bedrock exposure

Elevations in meters

Sources of base map:

Dronning Maud Land, 1:250,000 Series, Norsk Polarinstitutt, Oslo (1961, 1962)

Scale 1:1,000,000

0 20 40 60 80 100 Km

0 20 40 60 Miles

Polar Stereographic Projection

GEOLOGIC CROSS SECTION

Borg Massif — Penck Trough — Kirwan Escarpment

A — B

Meters 3000 2000 1000 Sea level 1000 2000

Schytt Glacier; Ice; Pyramiden Nunatak; Borg Mountain; Høgsaetet Mountain; Raudberg Valley; Jøkulskarvet Ridge; Frostlendet Valley; Meteplassen Peak; Ryvingen Peak; Midbresrabben Hill; Neumayer Cliffs; Ice; Ice; Ice

p€abu p€ar p€abl p€af p€abl p€ar p€abu p€ar p€abu p€ar p€abu p€Ct p€s p€Cp

0 5 10 15 20 25 30 35 40 45 km

0 5 10 15 20 25 miles

Vertical exaggeration: x2.5

Rock formation symbols as on geologic map

Borg intrusives (map-unit p€b) shown in red

• Seismic determination of ice thickness