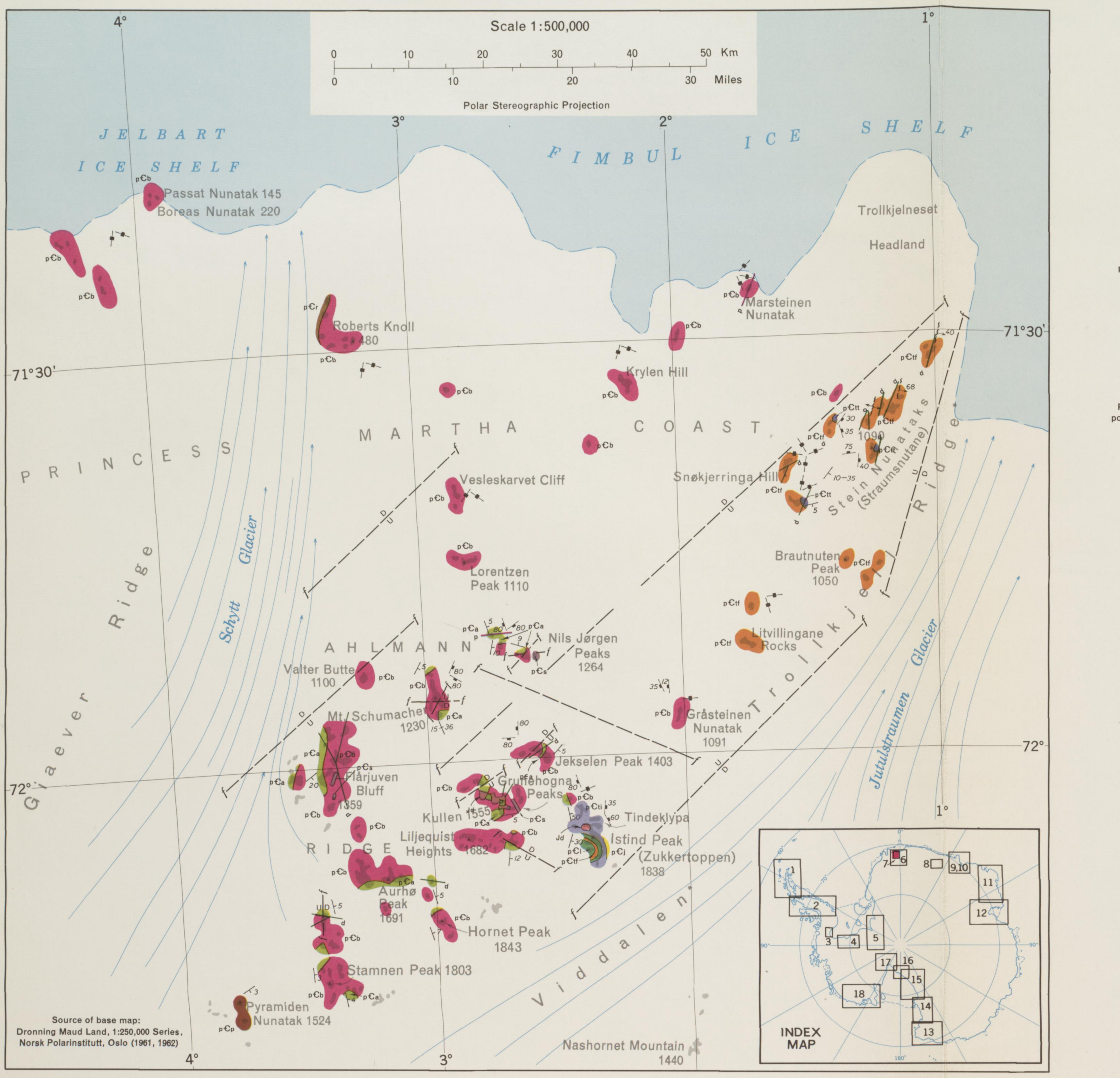

EXPLANATION

Jurassic(?) or younger
- Jd — *Dolerite sills*
- d — *Dolerite or basalt dike*
- p — *Peridotite dike*

Precambrian(?), possibly younger
- p€s — Jorgen syeno-diorite[1] *Plugs and veins*
- p€r — Roberts Knoll peridotite
- p€b — Boreas dolerite *Tholeiitic, dolerite sills*; Borg Metamafics *Altered dolerite and diorite sills*
- p€tf — *Mafic to intermediate lava flows, some with pillows* (Trollkjellrygg Group[2])
- p€tt — *Tuffs* (Trollkjellrygg Group[2])

Precambrian(?), possibly Paleozoic
- p€i — Istind formation
- p€tl — Tindeklypa formation

Unconformity

Precambrian(?)
- p€j — Jutul volcanics *Mafic to intermediate lava flows, altered and sheared* (Ahlmannryggen formation)
- p€a — Nils red beds; Grunehogna arenite; Schumacher cyclic sediments (Ahlmannryggen formation)

Unconformity (?)

- p€p — Pyramiden beds

[1]Stratigraphic names used are informal and tentative
[2]The conglomerate and quartzite found elsewhere as part of the Trollkjellrygg Group are not found in this map region

Geologic contact, dashed when inferred
Fault with sense of displacement, dashed where inferred
Strike and dip of bedding
Strike and dip of joint
Strike of vertical joint
Strike and dip of shear plane
Strike of vertical shear plane
Bedrock exposure
Approx. coastline
Ice-flow lines
Ice shelf
Elevations in meters
*Names used are those approved by the United States Board on Geographic Names unless marked with an asterisk

Geology of the Ahlmann Ridge, Western Queen Maud Land

Dirk C. Neethling[1]

Introduction

The Ahlmann Ridge lies about 160 km south of the South African Antarctic base, SANAE, between the polar plateau and the Fimbul Ice Shelf. The outcrops form disconnected lines and groups of highly dissected horns, arêtes and glacially scoured massifs.

The geology of the area was previously investigated by the Norwegian-British-Swedish Antarctic Expedition in 1949–1952, and Roots (1953) has established that this part of western Queen Maud Land consists of two geologically distinct regions: (1) a complex of metamorphic rocks, consisting chiefly of banded gneiss, amphibolite, schist, and pegmatite, and (2) an assemblage of flat-lying clastic sedimentary rocks and andesitic volcanics invaded by large sills and dikes of diorite and dolerite. The sedimentary-volcanic sequence occurs mainly in the Ahlmann Ridge and Borg Massif (Sheet 6 of this folio) and is separated from the older metamorphic complex by north-flowing glaciers, the Schytt Glacier to the west and the Jutulstraumen Glacier to the east.

Glacial Geology

Active scarp recession and the formation of sharp-edged structural terraces are the dominant processes in the present cycle of glacial erosion. The ice-shorn southern slopes of some nunataks indicate a past ice movement toward the north-northwest, which coincides closely with the flow direction of the present day ice sheet. Morainic debris dating from the maximum of the present cycle of Quaternary glaciation indicates that the ice sheet did not exceed 1160 m above sea level at a distance of 250 km from the present coast line.

Sedimentary and Volcanic Rocks

Correlation within the sedimentary sequence of the Ahlmann Ridge is rendered difficult by the absence of marker beds, intensive block faulting, dislocation of strata by the intrusion of thick sills, and the advanced stage of glacial denudation. The unfossiliferous nature of most of the sedimentary units, the unsuitability of many of the altered intrusive rocks for radiometric dating, and the complexity of volcanism during early and late stages of deposition add to the difficulty. However, the following tentative stratigraphic sequence, in ascending order, is inferred.

PYRAMIDEN BEDS[2]

A 200-m thick sequence of well-bedded, greenish-gray subgraywacke and siltstone with intercalated dark shaly layers and rare monomict conglomerate with elongated quartz pebbles crops out at Pyramiden Nunatak (Pollak, 1967). These sedimentary rocks are extensively altered with the development of as much as 64 modal percent of actinolite, chlorite and epidote; thin layers of copper and iron sulphide and hematite also occur parallel to the bedding planes of a malachite-stained sandy shale (Pollak, 1967). Similar zones of subgraywacke stained with copper carbonate and containing a little disseminated pyrite and chalcopyrite occur at Jekselen Peak (Neethling, 1964). Because of the more extensive metamorphism of the Pyramiden beds, the apparent unconformable relation to overlying cyclic sedimentary rocks (Pollak, 1967), and possible structural continuity with the Borg Massif (Sheet 6 of this folio), these sedimentary rocks are provisionally assigned to an older and pre-Ahlmannryggen formation.

[1]Antarctic Division, Geological Survey, Pretoria, South Africa.
[2]The stratigraphic names used here are informal and tentative.

AHLMANNRYGGEN FORMATION

This slightly metamorphosed formation includes a lower part consisting of interbedded dark siliceous siltstone and arkose conformably overlain by arenaceous beds and minor black shale and clastic red beds. Andesite-basalt lava occurring in the Tindeklypa area is tentatively included in the upper part of this formation.

Schumacher cyclic sediments. Repetitive sequences of siliceous siltstone and arkose with rare intraformational sharpstone conglomerate constitute the lower part of the Ahlmannryggen formation. Beds of dark gray siliceous shale have a conchoidal fracture and develop a characteristic reddish-orange encrustation upon weathering. Tripartite sedimentary cycles, consisting of interbedded arkose, silty arkose, and siltstone, range in thickness from 10 cm to 1.5 m. Sedimentary structures such as slumped bedding and convolute folds are present; scour of siltstone bedding surfaces and micro-intraformational corrugation of paper-thin silty laminae have also been observed (Neethling, 1964). Pelitic sedimentary rocks, apparently dominating in the lower part, gradually yield upward to more arenaceous beds; rare pure recrystallized quartzite in the upper part apparently indicates a period of erosion and deposition of mature sands as well as an abrupt change in depositional environment.

Strata of this unit crop out over a large area and are found at Mount Schumacher (Neethling, 1964), Flårjuven Bluff (Langenegger, 1964), and to the southwest and southeast of Aurhø Peak (Pollak, 1967). A total thickness of 400 m is exposed.

Grunehogna speckled arenite. Impure feldspathic quartz arenite, parted by minor bands of dark shale, occurs in domed and faulted outcrops at the southern end of Mount Schumacher and at Grunehogna Peaks (Neethling, 1964). This sequence apparently has a gradational contact with the underlying cyclic sedimentary rocks. The upper part becomes more reddish in color and is overlain at Grunehogna Peaks by a polymict jasper conglomerate (Langenegger, 1964). The structural relation of the Grunehogna arenite to the supposedly overlying Nils red beds has not yet been confirmed in outcrop.

Nils red beds. Red quartzo-feldspathic mudstone, separated by minor bands of pale sub-arkose and characterized by intraformational mud-pebble conglomerate and rare marlstone, comprise the lower 40 m of the sedimentary sequence exposed at Nils Jørgen Peaks (Neethling, 1964). The angular and discoidal phenoclasts of red mudstone and rare greenish chert, which constitute the rudaceous beds, are embedded in an ill-sorted, epidotized, arkosic matrix, which is impregnated with specularite. Red arkose, bearing a close lithologic resemblance to these beds, underlies the Tindeklypa boulder beds at the type locality (Butt, 1962) and is provisionally correlated with the Nils red beds.

Jutul volcanics. The existence of pre-Tindeklypa volcanic activity is indicated by the occurrence of a conglomerate consisting of well-rounded pebbles of lava and vein quartz in the basal part of boulder beds exposed at Tindeklypa on the western side of the Jutulstraumen Glacier. An outcrop of altered sheared lava, occurring about 350 m below the Istind formation at Istind Peak, has also been reported by Butt (1962). A sheet of andesite-basalt interbedded with the lower part of upper Precambrian to Paleozoic (?) sedimentary rocks (Klimov *et al.*, 1964) has also been described from an unnamed locality in western Queen Maud Land, which strongly resembles the geologic description of the Tindeklypa–Istind area.

The correlation of these volcanic rocks with the previously described sedimentary rocks has not yet been established. This volcanic activity appears to be confined to the Istind area.

TINDEKLYPA FORMATION

Unconformably overlying the Ahlmannryggen formation is an undifferentiated clastic deposit associated with interbedded andesitic volcanics in its upper part. This formation consists mainly of 300 m of unstratified rudaceous deposits of irregularly spaced, angular boulders of sedimentary rocks and smaller well-rounded pebbles of mafic, granitic and volcanic rocks in a graywacke matrix (Butt, 1962). The basal, stratified part of the boulder beds is an altered graywacke which consists of angular quartz, orthoclase and microcline; augite altered to serpentine; chlorite; rock fragments; and the heavy minerals zircon, apatite, and magnetite. Higher in the sequence red, partly recrystallized arkose is unconformably overlain by a lava-quartz conglomerate. As much as 30 percent calcite occurs in the conglomeratic matrix at the lower contact with a fine-grained mafic intrusive along the unconformity. An upward gradation from this lava-bearing conglomerate into massive boulder beds is evident. This rock, which is regarded as a possible tillite by Butt (1962), in turn grades upward into a poorly stratified polymict jasper conglomerate which represents a reworking of the underlying boulder beds.

The unconformable occurrence of a lithologic equivalent of this jasper conglomerate directly on Nils red beds at Nils Jørgen Peaks indicates a possible stratigraphic onlap to the northwest, and localized boulder bed deposition to the southeast. At Nils Jørgen Peaks the polymict conglomerate is only 2 m thick and consists mainly of ill-sorted angular to partly rounded pebbles of sedimentary rocks, vein quartz, greenstone, chert, granitic rocks and abundant red jasper (Neethling, 1964). The pebbles show some faceted edges and nicks and are commonly cut into regular slices by fine, close joints. The lower portion of the conglomerate contains rafts and plastic inclusions of the basal mudstone bed, and the subordinate quartzo-feldspathic matrix is well epidotized along with the presence of abundant specularite. Preliminary microscopic examination of the jasper fragments indicates possible recrystallized radiolarian structures.

ISTIND FORMATION

The Tindeklypa boulder beds are unconformably (?) overlain by 350 m of sub-horizontal, well-bedded, altered, brown, red and gray arkose and quartz-arenite of the Istind formation (Butt, 1962). Cross-bedding and ripple marks are well preserved. In thin section the sedimentary rocks appear metamorphosed and present a fine-grained, well-sorted clastic texture of recrystallized quartz grains, variable amounts of feldspar altering to sericite, minor amounts of ferromagnesian minerals and a limited suite of detrital minerals. Secondary calcite cement is common, particularly near dolerite intrusions; rare layers of siderite are also present (Butt, 1962).

TROLLKJELLRYGG GROUP (STRAUMSNUTANE VOLCANICS)

A sequence of mafic to intermediate lava flows with rare intercalations of tuff crops out over an area of 1600 km^2 in the Stein Nunataks (Straumsnutane) (Roots, 1953; Butt, 1962). Most of the lavas are amygdaloidal; the majority of the amygdules are composed mainly of quartz although others have a green chloritic, calcitic or feldspathic composition. Pillow structure in the lava and ripple marks in the tuff indicate partly subaqueous conditions during eruption (Butt, 1962). The localization of the volcanic rocks in the Stein Nunataks and an increase in dip to the south and southeast from 10° to 35° away from Snøkjerringa Hill may be indicative of the locus of eruption in this area. This increase in dip may, however, also be related to weathering and brecciation and to the apparent increase in deformation towards the Jutulstraumen Glacier. Regional metamorphism of the volcanics has been slight, and only the feldspar has been sericitized. Any significant alteration to greenschist facies rocks is the result of local phenomena such as intrusive dikes and quartz veinlets. Significant contact epidotization of the lava by rare doleritic intrusions is common (Butt, 1962).

Because of the absence of radiometric dating of these volcanic rocks, poor exposures, and the tentative form of the stratigraphic sequence, various ages and correlations have been advanced for the Jutul and Trollkjellrygg volcanics. Roots (1953) and Butt (1962) recognize only one group of volcanic rocks, a view that is supported by Von Brunn (1964), who also suggests that the volcanics are the effusive counterparts of the mafic intrusives, and possibly Jurassic in age. Klimov *et al.* (1964) refer to the Jutul (?) volcanics as interbedded with sedimentary rocks of Precambrian to Paleozoic age, but assign the activity to the earlier stages of sedimentation. However, contemporaneity of the Trollkjellrygg and Jutul volcanics has not yet been established, and the possibility of more than one period of volcanic activity during the deposition of the sedimentary rocks must also be considered.

Intrusive Rocks

Altered mafic rocks of doleritic and dioritic composition occur both as sills and dikes in the sedimentary sequence. Preliminary K-Ar dating of dolerite from erosional outliers of these sills (Von Brunn, 1962) exposed in the northern part of the region, indicate emplacement during the Precambrian (McDougall, in Neethling, 1968a?). Fine-grained, tabular dolerite and local syeno-diorite intrusives post-date these larger sills, and the dikes of dolerite, basalt, and rare peridotite appear to represent the closing stages of igneous activity in the area. Epidotization along joints and fracture planes in the intrusive rocks is ubiquitous and is commonly associated with intense hydrothermal alteration along with the formation of calcite and some copper and lead sulphides.

The following separate intrusive units have been tentatively established by consideration of degree of metamorphism, composition, and to a lesser extent, degree of differentiation and association with felsic rocks.

BORG METAMAFIC INTRUSIVES

Low grade regionally metamorphosed sheets of doleritic to quartz doleritic (Pollak, 1967) and dioritic composition intrude the sedimentary terrane on a grand scale. Their emplacement pattern is commonly transgressive, and shifting from one stratigraphic horizon to another occurs in many places. These sills, which may have thicknesses of more than 350 m, commonly have a differentiated syenodioritic upper part and a more mafic lower part. Basaltic selvages, sharp contacts, and minor assimilation of the wall-rock strata are characteristic. At Aurhø Peak a 60-m wide aureole of contact metamorphosed sedimentary rocks occurs at the intersection of feeder dikes (Pollak, 1967). Stratiform schlieren, pods of granophyric composition, and nests of dolerite-pegmatite are commonly present, especially in the upper part of the sills. Granophyric zones in the metamafics may represent transformed sedimentary rocks, and rheomorphic phenomena associated with the final stages of metasomatism could therefore be responsible for the felsic veins present in some of the poorly exposed outcrops. Cross-cutting veins of hornblende occur in the central zone of the composite Mount Schumacher sill. Petrographic examination of some of these altered mafic rocks, which are not necessarily representative of the metamafics as a unit, indicates a composition of 43-50 percent plagioclase (An_{52-60}), 30-50 percent augite, pigeonite, enstatite, hornblende, olivine, and biotite and 0.8-35 percent of myrmekite, quartz, and ore (Pollak, 1967). Intense sericitization of the feldspar and serpentinization of the pyroxene and olivine are characteristic (Butt, 1962). There is little evidence of differentiation, and chemical analyses of these rocks indicate that they are comparable with magma types of other tholeiitic provinces (Von Brunn, 1962).

BOREAS THOLEIITIC DOLERITE

The northernmost exposures in western Queen Maud Land, the Boreas-Passat area, consist of uniform medium-grained dolerite intrusives of typical tholeiitic composition (Von Brunn, 1962). The texture is ophitic to sub-ophitic and the grain size shows no variation in the outcrop area. The average modal composition is 54 percent plagioclase (An_{50-65}), 36 percent pyroxene (augite, pigeonite, and ortho-pyroxene); 5 percent micropegmatite and minor accessories which include iron oxide, biotite, and rare apatite. Olivine is absent (Von Brunn, 1962). The degree of alteration, although of a lower grade than that of the Borg metamafic intrusives, varies and depends on the extent of late deuteric and hydrothermal action (Von Brunn, 1962). K-Ar ages of 825 m. y. and 1010 m. y. determined for plagioclase and pyroxene obtained from dolerite from Boreas Nunatak, may also indicate post-emplacement thermal influence (McDougall, in Neethling, 1968a?). The present map provisionally includes the Boreas dolerite with the Borg metamafic intrusives.

ROBERTS KNOLL PERIDOTITE

Ultramafic rocks of peridotitic composition, having a sharp contact but no chilled borders, occur below altered dolerite which is tentatively classified as Borg metamafics (Von Brunn, 1962). Veins of tremolite and serpentine are present locally. Augite ($Ca_{44}Mg_{49}Fe_7$) is subordinate to bronzite, the olivine (Fa_{14}) is mainly unserpentinized, and the composition of the plagioclase is An_{52-58}. These ultramafics are considered genetically related to the overlying dolerite. Their relationship to peridotitic dikes occurring in sedimentary and mafic rocks in the vicinity is unknown.

JORGEN SYENO-DIORITE

Medium-grained syeno-diorite occurs as cross-cutting plugs, and dike-like and irregular bodies in the Borg metamafics at Nils Jørgen Peaks, Grunehogna Peaks and Flårjuven Bluff. Irregular ferromagnesian-enriched, schlieren-like bodies exhibiting a vague linear parallelism of the hornblende (Neethling, 1964) and mafic inclusions as much as 30 cm in diameter are locally present (Pollak, 1967). Although the syeno-diorite may represent a late-stage differentiate of the Borg metamafics, it could also be related to and contemporaneous with the hornblende syenite intrusives in rocks of the metamorphic complex at Gburek Peaks and Neumayer Cliffs (Sheet 6 of this folio; Roots, 1953).

MAFIC AND ULTRAMAFIC DIKES

Dolerite, basalt, and rare peridotite dikes intrude the sedimentary rocks, volcanic rocks, tuffs (Butt, 1962) and all other mafic rocks in the area. The dikes generally dip at high angles and intrude along pre-existing faults in the sedimentary rocks or more commonly along joints and fractures in the igneous rocks (Neethling, 1964). Although chilled contacts are abundant, blocky and jagged borders, which may be associated with a stockwork of intrusive basaltic veins, are characteristic of the larger dikes (Neethling, 1964). Fine-grained dolerite feeder dikes cut across the Borg metamafics and occur as thin tabular intrusives in sedimentary roof remnants (Neethling, 1964; Langenegger, 1964). These late dikes and minor dolerite intrusives, which bear a close chemical and mineralogical relationship to the Ferrar Dolerites (Von Brunn, 1962), are considered Jurassic or even younger.

Structural Geology

Two sets of *en echelon* gravity faults, indicated by northeasterly and, to a lesser extent, northwesterly trending ridge patterns and lines of ice flow, have differentially elevated and tilted the rocks of the Ahlmann Ridge. Scarp recession has, however, obliterated most of the significant fault features; the inferred fault lines indicated on the map have been deduced mainly from the joint pattern, parallelism to small-scale faulting, and the large lithologic contrast of adjacent steep walls of the massifs. The Ahlmann Ridge therefore apparently represents a range formed by progressive step-faulting along narrow northeasterly trending zones with associated transverse dislocations, the former culminating in the major graben structures of the Schytt Glacier and the Jutulstraumen Glacier. A progressive increase in deformation, especially of the Trollkjellrygg volcanic unit, also implies a faulted contact with the basement rocks to the east (Butt, 1962).

The joints in the area are commonly steep and occur in two approximately perpendicular sets, the northeasterly direction being the more prominent. They are considered to have formed in the same stress field and are associated with the formation of the gravity faults. Brecciation and shear joints in the volcanics are probably due to local stress conditions associated with the increase in deformation to the east, but they might be indicative of an earlier deformation.

Although the strata of individual nunataks have been tilted in more than one direction, the prevailing strike of the rocks seems to parallel the local joint and fault directions, especially in the Ahlmannryggen formation. The dip of the Tindeklypa boulder beds and associated rocks is commonly steep (35°-50°); whether this is due to doming caused by nearby intrusives (Butt, 1962) or to faulting in the Istind area has not yet been established.

Although the structural history of the Ahlmann Ridge is at present obscure, earth movements appear to have been mainly vertical, and rejuvenation of fault structures along weak zones occurred. Block faulting may even have preceded the emplacement of the sills and/or eruption of the Precambrian (?) volcanics; eruptive activity is commonly associated with gravity faulting. The present surface features indicate relatively recent uplift along the old fault lines. This youngest diastrophism may be related to regional block faulting and the formation of the Transantarctic Mountains in Cenozoic time.

Geologic History

The piecing together of the geologic history for this part of western Queen Maud Land has been attempted, utilizing an even more fragmentary and tentative stratigraphic sequence than the present one (Neethling, 1964). The nature and sequence of events are modified here to some extent, but correlation and age of the different rock units have again been determined mainly from lithologic similarities and inferred structural relations. The separate rock units have not been found in contact except where specifically mentioned. The origin of the boulder beds and the correlation of the volcanic rocks constitute the most disputable interpretations. Although the sedimentary rocks of the Ahlmann Ridge form an integral part of the sedimentary cover of western Queen Maud Land, no correlation with the well-exposed sedimentary terrane of the Borg Massif to the south is attempted.

Flute casts and other substratal current markings occurring in graded, dominantly pelitic sediments may be indicative of an initial deep basin environment during the deposition of the lower part of the Ahlmannryggen formation in Precambrian (?) time. All other succeeding sedimentary features are characteristic of the shallow, oxidizing conditions of a near-shore or continental environment. The occurrence of intraformational conglomerate and mud-cracks and the presence of a red bed facies in the upper part of this formation indicate increasingly oxidizing and unstable conditions and intermittent emergence.

The formation of the overlying unconformable pyroclastic boulder beds during the late Precambrian (?) may have been associated with vertical faulting in the Istind–Tindeklypa area. Reworking of the boulder bed deposit during the closing stages of accumulation led to the formation of a polymict jasper conglomerate which transgressed to the northwest directly on sediments of the red bed facies. The characteristic red jasper pebbles of this conglomerate, which also occur in sedimentary rocks of pre-boulder bed age, seem to indicate a possible origin from emergent deeper parts of the basin where these siliceous rocks may have formed. An alternative glacial origin for the boulder beds has been advanced (Butt, 1962; Neethling, 1964), but the restricted lateral extent of the deposit, intercalated agglomerate, and its association with red bed clastics and volcanic activity seem to favor a graben-deposited facies (Pettijohn, 1956). Subsequent deposition (late Precambrian to Paleozoic ?) of the feldspathic Istind sediments under shallow water conditions appears to be the last recorded sedimentary event in the area.

Penecontemporaneous volcanism and the emplacement of stratiform mafic rocks and minor amounts of felsic rock during the Precambrian to Paleozoic (?) may have been associated with repeated vertical movements. The intrusion of basaltic dikes (Jurassic ?) apparently constitutes the youngest event in the area. All of the rocks in the area, with the exception of these dikes, have been partially recrystallized in the chlorite zone of regional metamorphism.

The Borg Massif (Sheet 6 of this folio; Roots, 1953) and the Ahlmann Ridge appear to have been subjected to mainly epeirogenic movements since deposition of the sedimentary cover on the crystalline basement. The region therefore comprises a stable platform consisting of a fault-margined block characterized by several phases of rifting (Neethling, 1968b?).

Regional Correlation

The low-grade regional metamorphism, the intrusion of Precambrian (?) mafic rocks and the lithological similarity to the Patuxent Formation in the Neptune Range of the Pensacola Mountains (Schmidt *et al.*, 1964) and the Mount Sandow Beds (Klimov *et al.*, 1964) suggest possible correlations for the rocks of the Ahlmann Ridge. However, in view of the tentative interpretation of the stratigraphic sequence and the considerable range in the apparent ages of the Precambrian mafic intrusives, the upper time limit of sedimentation in western Queen Maud Land has not yet been established. Continued deposition into the Paleozoic is therefore not excluded as a possibility.

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