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PRELIMINARY NOTE ON THE GEOLOGY OF WESTERN DRONNING MAUD LAND

BY

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PRELIMINARY NOTE ON THE GEOLOGY OF WESTERN DRONNING MAUD LAND

BY

E. F. Roots

With 1 map.

Abstract. A series of northeast-trending mountain ranges, with a rock-surface relief of more than 2500 metres, projects through an ice mantle that is in places 1500 metres thick to form the rock massifs and nunataks of western Dronning Maud Land. The oldest rocks found in these ranges belong to a metamorphic complex that probably underlies much of this part of Antarctica. Unconformably overlying the metamorphic complex is an assemblage of flat-lying, clastic sediments; this in turn locally includes, or is overlain by, volcanic rocks. The sediments have been intimately invaded by large sills and dykes of diorite and gabbro. The youngest known rocks are small basalt-dykes.

Since the metamorphism of the basement complex, the area has been essentially stable, and has suffered only minor, vertical movements.

Introduction.

The field parties of the Norwegian-British-Swedish Antarctic Expedition 1949—52 visited the outcrop areas of western Dronning Maud Land between Long. 02° E. and 12° W. of Greenwich, and Lat. 71° 08′ S. and 73° 40′ S. Within this region the main rock exposures are confined to an area of approximately 60,000 square kilometres lying east of Long. 09° W. Here a series of nunatak-studded snow ridges, low escarpments, and small dissected mountain ranges are aligned in a general northeast-southwest direction; the mountainous terrain extends beyond the area investigated. This area of inland mountains was discovered and first photographed by the Deutsche Antarktische Expedition 1938—39; and the Norwegian forms of some of the names given by that expedition to prominent topographical features are used in the present note.

Physiography.

On the basis of its topography, the area investigated may be divided into three main units. Northwest of an irregular line running south-southwest from near the nunataks Boreas and Passat (71° 18′ S., 04° 00′ W.), the country is almost completely covered by ice, which rises in a series of gentle, northeast-trending undulations from the floating ice shelf along the coast to a maximum altitude of about 1500 metres. There is very little exposed rock in this region. The few nunataks, all on the crests of the snow ridges, are rarely more than 1 square kilometre in area, and with the exception of Kraulfjella, none project more than 150 metres above the surrounding snow surface. Seismic soundings in this area, however, show the ice mantle to be as much as 1000 metres thick; and the present-day nunataks are seen as merely the exposed points of a rugged rock-surface topography of considerable relief.

To the east of this large area of very sparsely-scattered nunataks, between Lat. 71° 30′ S. and 73° 00′ S., lies a relatively compact group of mountain blocks and nunataks. In the southern part of the group, flat-topped tabular masses as much as 30 square kilometres in area, bounded by sheer rock walls, rise more than 1000 metres above the general snow level to altitudes of more than 2700 metres. Towards the north the blocky massifs are progressively more dissected, and degenerate into thin ridges and sharp horns, and eventually into disconnected lines of nunataks. Some of these lines of nunataks are crescentic or horseshoe-shaped in plan, enclosing basins as much as 15 kilometres across; and seismic sounding of one basin has shown it to have the form of a great cirque, more than 600 metres deep.

The individual groups of mountain blocks and nunataks within this area have remarkably linear arrangements, each oriented northeast parallel to the main trend of outcrops. The pattern is particularly pronounced at the southern end of the area, where blocky massifs and horn-like nunataks occur in parallel rows, separated by ice-filled corridors that appear to be partly of tectonic origin.

The area of blocky mountains and horns is bounded on the southeast by a trough, nowhere less than 40 kilometres wide, occupied by a great northeast-flowing ice stream whose relatively flat and terraced, but heavily crevassed, upper surface is 200 to 400 metres below the ice level on each side. The upper (southwest) section of the trough has been named Pencksøkka. A seismic profile across it has shown the rock floor to be below sea level in places, as far south as Lat. 72° 50′ S., and about 200 km. inland from the inner edge of the floating ice shelf. The floor of the trough is not smooth, but contains, in profile, several peak-like features that are probably parts of narrow ridges aligned parallel to the long axis of the trough; several of these ridges can be related to belts of crevasses on the surface, and three outcrop as rock islands in the ice stream. There is some evidence to suggest the presence of a considerable thickness of poorly-consolidated material on parts of the trough floor.

The third physiographic unit lies east and southeast of Pencksøkka. The northern part of this unit consists of a nearly continuous series of mountain ranges — Paulsenfjella, Barkleyfjella, Krügerfjellet, Hermannfjella, Gockelkammen — and a group of outlying massifs, Gburektoppane. The ranges rise abruptly as much as 1500 metres above the flanks of the Pencksøkka ice stream and the coastal foreland to the north, and about 500 metres above the rolling surface of the 'inland ice' to the south. The highest known peak is approximately 2830 metres above sea level. In distinct contrast to the blocky form of the mountains northwest of Pencksøkka, these ranges are irregular in plan and profile, characterized by sharp, smooth, sweeping ridges and long curving buttresses, and by a mixture of gentle slopes and steep cliffs that face in almost every direction. The overall pattern of these ranges continues the general northeast trend of the country; but within each mountain group there is no evidence of directional control of the land forms. Across a large north-flowing glacier east of Paulsenfjella and Barkleyfjella, mountains of similar character continue eastward beyond the area investigated.

Southwest from Gockelkammen, this physiographic unit is continued by Neumayerveggen and the southeast wall of Pencksøkka. Neumayerveggen is an irregular, nearly continuous cliff about 50 kilometres long and up to 300 metres high. Its line is continued to the southwest for at least 150 kilometres by an ice-covered escarpment through which groups of nunataks or small mountains project at intervals of 10 to 25 kilometres. From the top of the escarpment, the ice surface rises gently until, 100 kilometres south from the brink, it reaches an altitude of 2700 metres above sea level. A seismic profile shows the escarpment to be not the edge of a great plateau, but rather the crest of a nearly-buried mountain range, similar to that to the northeast, which has dammed back the north-flowing ice. Inland from this range, the underlying rock surface is rolling, and, as far as present knowledge goes, ever more deeply buried by ice.

Almost every mountain massif, and many of the large nunataks, show a rolling upper surface that is quite out of harmony with the steep frost-shattered cliffs and thin, serrated ridges, and is clearly the result of an earlier erosion cycle. Where it is best preserved, this old erosion surface suggests a land form and slope pattern different than that produced by glacier or icecap action; and it seems probable that the land surface, prior to its present occupation by ice, was developed mainly by normal stream action. There is evidence, in the form of erratics and striae, that even the highest mountains have been covered by the general ice sheet; the movement of this ice cover must have been largely controlled by the earlier drainage pattern, and the ice itself must have, in most places, considerably modified the pre-existing land surface. The alpine topography now characteristic of this area must have developed by frost action mainly during and since retreat of the ice to about its present position; and the modern land forms are more or less in harmony with the present-day ice levels.

General Geology.

General Statement.

Two distinct rock assemblages are exposed in western Dronning Maud Land, separated by Pencksøkka and the ice stream flowing north from it to the ice tongue at about the Greenwich meridian.

The nunataks east and south of this ice stream, including Gburektoppane, the range from Paulsenfjella to Gockelkammen, Neumayerveggen and the line of escarpments reaching at least 120 kilometres southwest from it, are composed of a related complex of metamorphic rocks, mainly banded gneisses, amphibolites, schists, and pegmatites. The structure of this complex is variable; over large areas, the foliation of the gneisses is gently-dipping and nearly plane, and in other places deformation has been intense.

A group of small nunataks of granitic gneiss and pegmatite, possibly related to this complex, outcrops among the sediments and sills west of Pencksøkka.

West and north of Pencksøkka and its north-flowing ice stream, the mountains are dominantly a nearly flat-lying series of strongly indurated siltstones, greywackes, and conglomerates, invaded by sills and occasional dykes of dioritic and gabbroic composition. An area in the northeastern part of this region consists of propylitized andesitic flows.

A small mass of similar sediments has been preserved at the southwest end of the southwest wall of Pencksøkka, overlying rocks of the metamorphic complex.

Small basaltic dykes are scattered sparsely throughout the whole area.

Metamorphic Complex.

The metamorphic rocks exposed east and south of Pencksøkka range from chloritic slate and schist to migmatite and granitic pegmatite, and from amphibolite to the most acid gneiss, but about 80 % of the total consists of banded gneisses of acidic to intermediate composition and very simple mineralogy. The most common gneisses are medium-grained, cleanly banded rocks consisting almost entirely of quartz, potash feldspar (mainly microcline), sodic plagioclase (commonly albite-oligoclase $Ab_{94}An_6$ to $Ab_{80}An_{20}$), and biotite. Garnetiferous (grossular) and amphibole-rich gneisses are also widespread; the latter grade into amphibolites, which are ubiquitous as thin layers and pods throughout all the gneisses, and which are the main constituent of a few assemblages as much as 300 metres thick. The common amphibole is a black, relatively iron-rich hornblende, pleochroic green in thinsection; but some rocks contain tremolite-actinolite. Thin layers of biotite-schist, amphibole-biotite-schist, and diopside-amphibolite are fairly common. Minor lithological varieties contain sericite and muscovite, epidote or clinozoisite, or chlorite as essential minerals. Accessory minerals include apatite, sphene, allanite, zircon, magnetite, specularite, and a few metallic sulphides.

The distribution of garnets is unusual. Within some large areas, apparently haphazardly distributed and totalling nearly one-sixth of the outcrop area, rocks of almost all lithological types from acid gneisses to amphibolites are garnetiferous; outside these areas, although the bulk composition, texture, and general mineralogical development appears similar, garnets are rare. Most of the garnets appear as small porphyroblasts, less than 5 mm. diameter, euhedral in the acid rocks, where they are usually surrounded by a zone free of other ferromagnesian minerals, and anhedral in the basic rocks; but well-formed dodecahedrons up to 10 cm. diameter have been found. All garnets tested to date are of the variety grossular, with a refractive index of about 1.75; but the exact composition, and the range of composition in different rocks, has not been determined.

Intercalated with the banded gneisses are many varieties of porphyroblastic gneisses and gneisses with clots and segregated pods and layers of distinctive minerals. Potash feldspar, plagioclase, garnet, amphibole (hornblende), magnetite, biotite, muscovite, and quartz have each been observed as porphyroblasts in different gneisses, but the tendency toward porphyroblastic texture reaches its greatest development in a distinctive and widely distributed, though relatively uncommon, augen-gneiss composed largely of prisms of grey plagioclase (oligoclase) as much as 15 centimetres long. Another unusual and widespread rock type is a fine- to medium-grained quartz-microcline-albite-hornblende-biotite gneiss with conspicuous octahedral porphyroblasts of magnetite 2 to 3 mm. diameter. The rocks characterized by clots and layers of segregated minerals appear to form a complete series from normal banded gneisses with small, irregularly scattered clumps of quartz and feldspar grains, through glomeroporphyroblastic gneisses and gneisses in which most of the acidic material is in irregular, partly-connected pods and lenses, to 'migmatites' in which the original banded rock has been transformed to a poorly foliated, granitic material. In places there appears to be a further development from migmatite to irregular anatectic bodies and pegmatites.

Pegmatitic, and to a lesser extent aplitic, material is associated with the gneiss on nearly every exposure. On many nunataks pegmatites make 2 to 10 per cent of the rock volume. All of the pegmatites are of simple mineralogical composition, comprising the same minerals as the average country rock. Almost all are very acidic in composition, and are composed mainly of quartz and potash feldspar, with greater or lesser amounts of plagioclase and muscovite; biotite and amphibole are, for the most part, minor accessories. Garnets are common in some bodies. Three unusual dykes in Neumayerveggen are composed of grossular, diopside, calcite, and quartz. The texture of most of the bodies is typically pegmatitic, with an intimate intermixture of very coarse (in places more than 1 metre) and fine grains, of euhedral and anhedral outlines. 'Graphic' and myrmekitic quartz-feldspar intergrowths are common. Many of the pegmatites are symmetrically banded, with successive layers differing in texture or composition or both, parallel to their borders. The pegmatites occur mainly as cross-cutting, sharp-bordered bodies of small dimensions: masses larger than 10 metres across are rare. Some of the pegmatites have been emplaced by replacement of the gneisses and amphibolites to form irregular, contorted bodies, or crudely tabular masses and networks that may represent enlarged joints or fracture zones; others are obviously simply fillings of pre-existing fractures. The 'replacement' pegmatites are older than the 'fracture-filling' pegmatites, and usually differ from them by a predominance of white albite-oligoclase over salmoncoloured microcline. In many places there appears to be a complete gradation between the cross-cutting 'replacement' pegmatites and the leucocratic layers in typical banded gneiss, and it is possible that these bodies have developed contemporaneously with the main metamorphism of the rocks, as anatectic differentiates of the surrounding gneisses. Although many bodies are indeterminate, no field evidence of a gradation or direct relationship between the 'fracture-filling' pegmatites and any other rock type has been found.

Aplitic material is relatively rare, and is found mainly in small dykes and stringers associated with, but commonly later than, the 'fracture-filling' pegmatites. In many places a pegmatite-healed fracture has been reopened to admit a thin aplite dyke that splits or borders the pegmatite body for tens of metres.

Rocks of lower metamorphic grade than the common banded gneiss have been found at three places within the area of metamorphic complex mapped. One of these occurences is an isolated nunatak in the Pencksøkka ice stream, entirely composed of low-grade rocks. At the other two places — southwest of Neumayerveggen and in the northern part of Gburektoppane — the low-grade rocks may be traced directly into higher-grade gneisses. The rock types at all three exposures are similar, and include green and grey slates, sericite and sericite-chlorite phyllites, flaky chlorite schists, and relatively pure to micaceous and feldspatic quartzites. Intermediate rock types, probably greater in observed outcrop area than the lowest-grade rocks, include biotite-rich schists and quartzites, light-coloured feldspathic quartzites, and several varieties of fine- to medium-grained rocks that are difficult to classify megascopically, and whose constituents include much epidote and green amphibole. Pegmatite bodies were not observed in these rocks, but quartz veins, commonly containing considerable epidote, chlorite, and pyrite, are ubiquitous.

The structure of the metamorphic complex is very varied. The foliation and banding, on a large scale, outlines fold-like structures that suggest moderate deformation of large thicknesses of rock. Large units may be found oriented at almost any angle, but dips of from 10° to 40° to the southeast or northwest, undulating but fairly constant over areas of 1 to 20 square kilometres, are most common. Outside this range, steep to vertical layering is more common than horizontal layering.

As is common in metamorphic complexes of this type, the smaller-scale structures, as outlined by individual lithological bands and by mineral foliation, are amazingly complex and intricate, with long zig-zag folds, twists, whorls, and crenulations often independent of the structures in nearby bands or layers. This small-scale deformation, at least, has clearly taken place wholly or partly contemporaneously with the metamorphic recrystallization of the main rock layers and the development of the 'replacement' pegmatites, many of which have 'ptygmatic' patterns.

There does not seem to be any evidence of significant overall differential rock movement accompanying or following the emplacement of the 'fracture-filling' pegmatites, which form plane or jagged angular sheets cutting indiscriminately through the intricate contortions of the older rocks. In places there is more than one generation of 'fracture-filling' pegmatites.

A crudely equidimensional body of coarse-grained, mainly nonfoliated hornblende syenite, covering about 15 square kilometres, outcrops among the gneisses and amphibolites of Gburektoppane. A similar body has been found on Neumayerveggen, where it has sharp, cross-cutting, intrusive contacts. The syenite varies considerably in composition and texture, but consists mostly of potash feldspar (orthoclase and microperthite) with lesser oligoclase and hornblende.

About 50 kilometres southwest of the west end of Neumayerveggen, numerous bodies of highly sheared or slaty amphibolite-like rock, 50 to 200 metres thick and as much as 3 kilometres long, cut the banded gneisses and amphibolites at various angles. The shearing or foliation of the interior of most of these bodies is parallel to their length, and independent of the attitude of foliation of the surrounding rock. The bodies may represent the remains of dykes that were emplaced prior to the main metamorphism of the complex.

The scanty evidence at present available suggests that these metamorphic rocks belong to a 'shield-type' basement complex which probably underlies much of this part of the Antarctic continent.

Granite Gneiss and Pegmatite Northwest of Pencksøkka.

Four small nunataks at about 72° 46′ S., 06° 45′ W. (approximately 170 kilometres west-northwest of Neumayerveggen) are entirely composed of coarse-grained granitic gneiss and pegmatite. The outcrops, which enclose an area of approximately 100 square kilometres, are very similar in appearance and composition. The dominant rock in each is a light golden-brown-weathering, white to pale buff coarse-grained non-banded gneiss, composed of colourless to smoky-white quartz, light grey to pale buff oligoclase, salmon-coloured microcline, muscovite, and biotite. A small amount of hornblende is present in some places. The gneissic foliation, poor and locally absent, is due mainly to the parallel orientation of mica plates.

Pegmatitic material constitutes about one quarter of the exposed rock in this area, and is found mainly as irregular masses with more or less gradational borders, rather than as discrete dyke-like bodies. The same mineral assemblage is present in the pegmatites as in the surrounding rocks, although several of the coarsest pegmatites are composed almost entirely of one or both of the feldspars, in crystals up to $\frac{1}{2}$ metre long, and quartz.

The whole assemblage closely resembles some of the more granitic portions of the metamorphic complex to the southeast.

Sedimentary Rocks.

The sedimentary rocks exposed north and west of the main area of the metamorphic complex constitute an entirely clastic, typically continental assemblage, varied in detail but essentially uniform over considerable lateral and stratigraphic distances. The commonest rock types form well-bedded repetitive sequences of medium- to fine-grained greywacke, siltstone, and impure sandstone, with minor shale, mudstone, and conglomerate. All of the rocks have been slightly metamorphosed, but most of the original sedimentary textures and structures have been preserved.

About half of the total stratigraphic thickness examined consists of thin beds of greywacke-siltstone. Most of this rock is dull grey, greenish, yellow-grey, or pale rusty brown on weathered surfaces, and grey, green, or yellowgreen where freshly fractured. Most beds are less than 10 centimetres thick. Cross-lamination, mainly on a fairly small scale within individual beds, is very common. Nearly all of these rocks appear to be relatively poor in quartz, and the coarser varieties (particles rarely more than 2 millimetres long) consist largely of broken grains of feldspar and sub-angular fragments of fine-grained, silty rocks in an indeterminate clayey matrix, the whole invariably containing chlorite and one of the epidote-group minerals. For the most part, size sorting within individual beds is excellent, and there is much contrast in grain size between adjacent layers. Some of the thicker (10 to 50 centimetres) beds grade, without distinctive interior lamination, from light-coloured sandy material at the bottom to dark brown shale at the top.

The shales and mudstones interbedded with the greywackes are dark grey, very dark brown to purplish-black, and commonly conspicuously red-weathering. Most are highly indurated, and a great variety of minor structures, such as ripple marks, mud cracks, raindrop impressions, gas pits, etc., are well preserved. The shales occur most commonly as thin partings between greywacke beds, or as irregular groups of beds mainly less than 5 metres thick scattered at rather wide intervals in the greywacke sequence. In a few places shale and mudstone are the dominant rock types in assemblages up to 50 metres thick.

Coarser clastic rocks are common, but make up a small proportion of the total stratigraphic thickness. The most abundant rock in this category is a distinctive and very widespread mudstone-breccia conglomerate consisting of angular fragments of dark grey mudstone in a greywacke and siltstone matrix. True pebble- and boulder-conglomerates are best developed in what appear to be the stratigraphically highest beds of the northeastern part of the area of outcrop of the sediments, where a section nearly 200 metres thick is composed mainly of conglomerate. Elsewhere the conglomerate usually occurs in single isolated beds up to 5 metres thick within thin-bedded greywacke-siltstone assemblages. These conglomerates, distinct from the ubiquitous mudstone-breccia conglomerates, consist of well-rounded pebbles and boulders of greenstone, chloritized volcanic rock or greywacke, white vein quartz, a great variety of cherty and jasperoid material, altered coarsely crystalline rock of dioritic or gabbroic appearance, feldspar porphyry, banded greywacke, siltstone, shale or hornfels, and indeterminate strongly hematitic matter. No pebbles of rock types representative of the metamorphic complex now exposed to the east have been found. The matrix of most of these conglomerates is a grey-green sandy or gritty greywacke. Almost all of the conglomerate beds are very strongly cemented, and joints run through, rather than around, the pebbles. Except in a few beds, only rare boulders are more than 30 centimetres diameter. Sorting is very poor to fair, and there is seldom a conspicuous lamination within the conglomerate layer itself. The beds are less lenticular than many conglomerates elsewhere; thin beds can be followed for many hundred metres without showing appreciable change, and some have been tentatively correlated across as much as 15 kilometres.

In the mountains immediately northwest of Penckssøkka an assemblage about 250 metres thick consists of shales, feldspathic sandstones, and minor pebble-conglomerate heavily impregnated with hematite, forming a conspicuous band of 'red beds' that may be followed for 60 kilometres.

All of the sedimentary beds have suffered slight to moderate metamorphism. The results of this process are manifest in the obviously crystalline or recrystallized character of the coarser greywackes and conglomerate, the hornfelsic appearance, hardness, and splintery fracture of the shales and mudstones, and in the widespread development of epidote, chlorite, and related minerals. The metamorphism has not obliterated the coarser sedimentary characteristics, and features such as lamination, cross-bedding, and ripple-marks have in many cases been emphasized by the recrystallization. The finer textures and structures, including recognizable organic remains, however, have been nearly completely destroyed.

The low-grade regional metamorphism has reached about the same degree of intensity wherever the sedimentary beds have been examined. In addition, sills and larger dykes intruding the sediments have metamorphosed the adjacent beds. This superimposed contact metamorphism is distinctly local and variable, and seldom affects beds more than 10 metres from the contact. Its most conspicuous feature is an irregular bleaching of the contact rocks and a development within them of pods and layers of epidote-group minerals, green amphibole, and feldspar, with lesser amounts of quartz, calcite, specularite, and a variety of minerals whose identity has not yet been determined. The metamorphism has been selective in its development: medium-grained greywacke beds have been most altered, and shales the least affected. Some layers in a finely laminated or cross-bedded series have been almost completely converted to epidote-amphibolite material, while adjacent layers are nearly unaffected.

The sedimentary rocks are almost undeformed; in most parts of the area examined the beds are nearly plane, dipping generally southeast at from 2 to 6 degrees. In a few places whole nunataks have been bodily tilted as much as 30 degrees in different directions.

Toward the southwest end of the line of nunataks forming the southeast wall of Pencksøkka, at 73° 53′ S., 4° 55′ W., a series about 30 metres thick of greywackes and siltstones that appear to be similar to the common sediments to the north lies directly upon the gently-rolling erosion surface of the metamorphic complex.

It is difficult to determine the total thickness of strata exposed. The scarcity of marker beds, the similarity of lithological types throughout the entire assemblage, the prevalence of thick, commonly lenticular sills, and the possibility of block faulting frustrates most attempts to equate beds in scattered groups of nunataks. A careful estimate must await the working out of individual sections and structures. The impression gained in the field is that certainly more than 700, and probably not more than 2000 metres of sedimentary rocks are exposed.

Very little information is available regarding the age of these rocks. The assemblage is essentially conformable in gross structure, but, like any typical continental or shallowwater series, contains innumerable erosional unconformities, any one of which could represent a time lapse of considerable magnitude. On the other hand the lithological similarity of all parts of the section, the frequent repetition of relatively coarse beds, and the fact that the most abundant rock is a greywacke that originally consisted of angular fragments of easily decomposed material, suggests that the entire thickness was deposited at a relatively rapid rate, during a more or less continuous period of erosion of comparatively near-by land masses. (Some of the rocks in the northeastern portion of the area appear to present contradictory evidence: discussion must be deferred until maps and more complete laboratory results are available).

No identifiable fossils could be found in these rocks. A deposit of mud-cracked shale, cross-bedded greywacke, and conglomerate indicates an environment that must have been distinctly unfavourable toward organisms; and any organic remains trapped in the rock have been subject to metamorphism. In several places the mudstone-breccia conglomerate beds look as though they may once have been partly shell beds, but the fragments are invariably too metamorphosed to be recognized as fossils.

Volcanic Rocks.

Small nunataks within an area of about 1100 square kilometres on the west side of the northern part of the ice stream flowing north from Pencksøkka are composed of altered flows of intermediate to basic composition. To the south, these rocks overlie and are in part intercalated with conglomerates and impure quartzites that appear to be part of the main sedimentary assemblage.

The flows are mainly green to dark grey-green, aphanitic to fine-grained rocks. A small proportion are porphyritic, with phenocrysts of ferromagnesian minerals (altered pyroxene) or, less commonly, feldspar. On the basis of their general appearance, it is suggested that most of these flows were originally andesitic. All have been more or less altered, with the development of much chlorite, epidote-group minerals, and amphibolite, to typical greenstones. Most of the flows are amygdaloidal; in places amygdules and gas-cavity fillings make up more than half the rock volume. Amygdules of white and pale blue chalcedonic quartz are most common, but fillings of chloritic or amphibole-like material, and calcite, are locally prominent.

Most of the flows or flow-units appear to be between 3 and 20 metres thick. Flow contacts are commonly conspicuous owing to a thin band of breccia between the flows, and a concentration of amygdules near borders. The upper parts of many flows are characterized by an arrangement of amygdules into strings and bands roughly parallel to the nearby contact, while the lower parts contain a zone of well-developed pipe amygdules about perpendicular to the contact.

The interior of most of the flows is devoid of amygdules.

One nunatak near the northwest border of the area containing exposures of these rocks contains a mass at least 80 metres thick composed entirely of lava pillows.

The nunataks exposing these rocks are too widely scattered to enable a determination of the overall structure to be made. On individual outcrops the flows dip eastward at angles ranging from 5 to 30 degrees.

Dioritic and Gabbroic Sills and Dykes.

Throughout its entire exposed area, the sedimentary assemblage has been invaded by sills. Because of its superior erosional resistance as compared with the sediments, sill material forms the dominant rock of many nunataks. Most of the sills are large; individual thicknesses range up to 200 metres or more, and some single bodies cover an area at least 20 by 10 kilometres.

Individual sills differ in composition and texture, but all appear closely related. The average composition, based solely on megascopic evidence, probably ranges from feldspathic diorite to fairly basic gabbro. Diabasic texture is common. The thicker sills are almost invariably differentiated, with a thin basic or ultrabasic lower zone, a thick central zone of diorite or gabbro, usually medium-grained, and an upper zone, sometimes amounting to one-third of the total thickness, progressively more feldspathic toward a topmost band of highly feldspathic pegmatitic or micropegmatitic material. Most of the sills have chilled upper and lower contacts.

Many interesting and instructive features of differentiation, rhythmic banding, and internal structure are exhibited by the sills. Discussion of these features must be deferred until laboratory investigations have been made.

Most of the sill rocks are relatively fresh, except for a slight saussuritization of the feldspars. In a few places the rocks are epidotized. Fracture surfaces of parts of some sills and the adjacent sedimentary rocks are coated with aggregates of epidote, chlorite or amphibole, quartz, and feldspar, with minor specularite and copper carbonates.

Almost all of the sills are, on a large scale, concordant with the sedimentary beds across any one exposure; but the contacts are invariably transgressive in detail. The transgression of the sill from one group of sedimentary beds to another commonly takes place in a series of steps, with the contact alternately following the bedding planes of thicker, coarser or more siliceous beds, and then breaking directly through finer-grained, less competent beds to the next favourable horizon. In a few places transgressive portions of the sills have violently crumpled the ends of the truncated beds. Such deformation is very local, and has not been observed to extend more than 10 metres from the contact. Inclusions of sedimentary rock within the sills are rare. Those recognized are angular, sharp-bordered, and no more altered than the average contact beds.

Some of the sills are strongly lenticular, or have steep wedge-shaped terminations, over which the sediments are arched.

A few large dykes, up to 50 metres across, similar in composition to the sills, have been found cutting the sediments and sills. They are probably feeders to stratigraphically higher sills. Some of the thicker dykes are composite, or are differentiated between their borders and cores.

Basaltic Dykes.

Small dykes of dark brown-weathering, dark grey to black basaltic rock have been found in all main areas of rock exposures yet visited in Dronning Maud Land. Most are less than one metre thick. They are steep-dipping, commonly angular or irregular in plan, and nowhere numerous — usually several hundred metres or several kilometres apart. With the single exception of five bodies of andesitic aspect in Barkleyfjella, they are of uniform appearance over the whole area. Most of the dykes have chilled (in places nearly glassy) borders and a uniform, aphanitic or very fine-grained interior.

All of the dykes yet examined under the microscope are olivine basalts. Several are porphyritic, with olivine and less commonly pyroxene phenocrysts about one millimetre long, although this feature is not conspicuous in the hand specimens. Vesicular and amygdaloidal varieties have been found, but are rare; the amygdules are sodic plagioclase clinozoisite, apatite, calcite, and sericite.

Tectonics.

Little can be said, at this preliminary stage, regarding the crustal movements to which this portion of the Antarctic continent has been subjected. The metamorphic complex has been involved in what appears to have been a relatively mild orogeny prior to and contemporaneous with its metamorphism. A poorly exposed angular unconformity in Barkleyfjella may be evidence either of two periods of deformation separated by an interval of erosion, or of large scale thrust faulting from the south during a single orogenic cycle. By analogy with the geological history of the Ross Sea section of Antarctica (David & Priestley 1914; Fairbridge 1949) it might be presumed tentatively that the metamorphism of the complex was essentially complete by Cambrian times. Since then the area has been relatively stable. A prolonged period of emergence and erosion was terminated by an epeirogenic sinking of the western portion, at least, of the area into one or more shallow basins or gentle foreland slopes that received a variety of shallow-water and strandflat sediments. There was local volcanic activity during or following the period of sediment accumulation. Following burial (by material of which no trace remains) and slight regional metamophism, the sedimentary assemblage was invaded by numerous large dioritic and gabbroic sills, which have locally domed and differentially lifted the overlying beds. A system of semiparallel, northeast-trending major fractures developed about this time, and may have localized the emplacement of the sills. The last recorded crustal movement has been a general rise of the land, and different blocks, bounded by the northeast-trending fractures, have received slightly different amounts of uplift to form the units from which the present-day mountain ranges have been carved.

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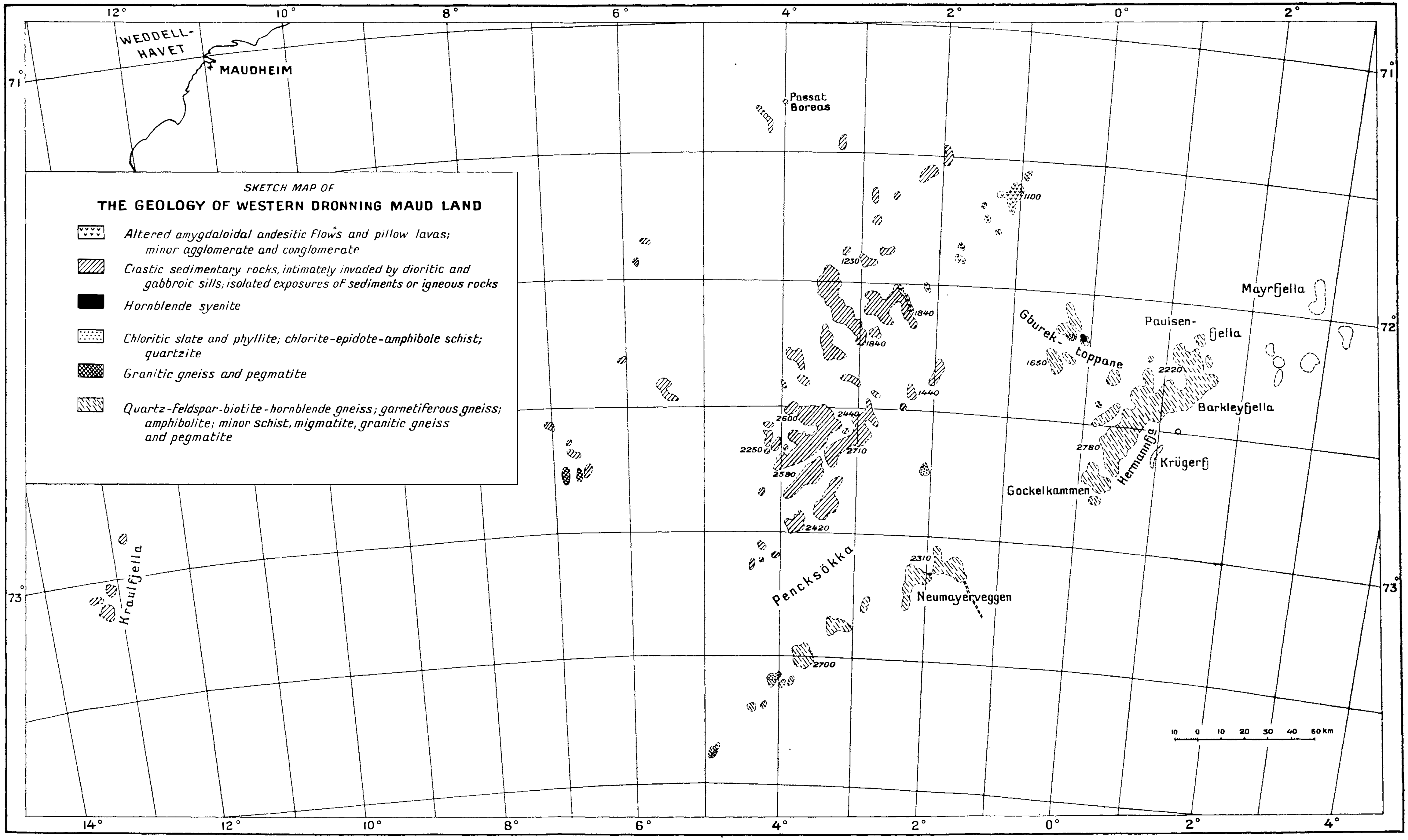

SKETCH MAP OF
THE GEOLOGY OF WESTERN DRONNING MAUD LAND
Altered amygdaloidal andesitic flows and pillow lavas; minor agglomerate and conglomerate
Clastic sedimentary rocks, intimately invaded by dioritic and gabbroic sills; isolated exposures of sediments or igneous rocks
Hornblende syenite
Chloritic slate and phyllite; chlorite-epidote-amphibole schist; quartzite
Granitic gneiss and pegmatite
Quartz-feldspar-biotite-hornblende gneiss; garnetiferous gneiss; amphibolite; minor schist, migmatite, granitic gneiss and pegmatite
WEDDELL-HAVET
MAUDHEIM
Passat
Boreas
Mayrfjella
Paulsen-fjella
Gburek-toppane
Barkleyfjella
Hermannfj.
Krügerfj
Gockelkammen
Pencksökka
Neumayerveggen
Kraulfjella
1100
1230
1840
1840
1650
2220
1440
2440
2600
2250
2710
2580
2780
2420
2310
2700
10 0 10 20 30 40 50 km
12° 10° 8° 6° 4° 2° 0° 2°
14° 12° 10° 8° 6° 4° 2° 0° 2° 4°
71° 72° 73°

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