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THE BRITISH NORTH GREENLAND EXPEDITION 1952–54

A GEOLOGICAL RECONNAISSANCE THROUGH SOUTH GERMANIA LAND, NORTHEAST GREENLAND

LAT. 77°N, LONG. 18½°W TO 22°W

BY

P. J. WYLLIE

WITH 29 FIGURES IN THE TEXT
AND 1 PLATE

KØBENHAVN
C. A. REITZELS FORLAG
BIANCO LUNOS BOGTRYKKERI A/S
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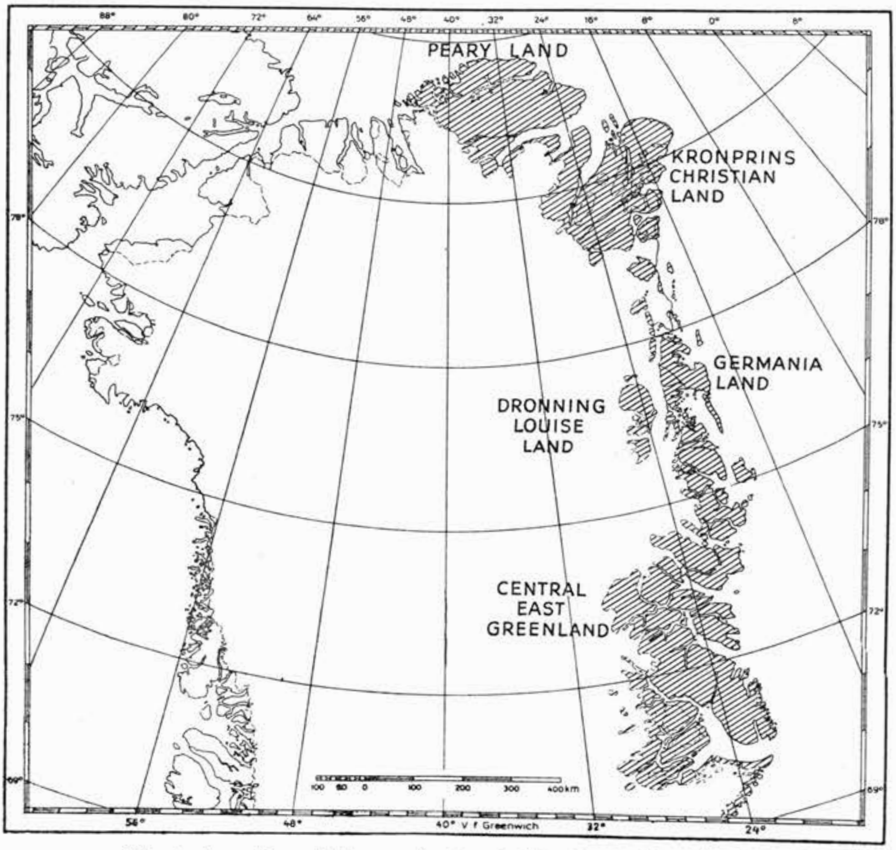

Fig. 1. Location of Germania Land, Northeast Greenland.

INTRODUCTION

For two years, between 1952 and 1954, the British North Greenland Expedition (under the leadership of Commander C. J. W. SIMPSON, D.S.C., R.N.) operated from a base hut on the shore of Britannia Sø in Dronning Louise Land (SIMPSON, 1955). This dissected, mountainous land lies within the margin of the ice sheet in north-east Greenland (Fig. 1), extends from latitude 75°50′ N to 78° N, from longitude 23° W to 27° W, and covers an area of approximately 12,000 square kilometres. The writer served as a geologist with the Expedition and, during the first year, assisted J. D. PEACOCK in a reconnaissance survey of the area. In the second year, assisted mainly by Lt. A. B. ERSKINE, R. N., the writer extended and consolidated the field work begun during the first year.

During March, 1953, conditions for travelling and working along the edge of the ice cap were severe. Strong winds and low temperatures forced us to spend more than 75 % of our time lying-up and we were unable to complete much useful work during this month. A small team (under the leadership of LAUB) from the "Alabama" Expedition which attempted to sledge round Dronning Louise Land in April 1910 encountered conditions so severe that they were forced to turn back (MIKKELSEN, 1922). We planned to avoid another month of constant lying-up during March 1954 by sledging eastwards across Storstrømmen and extending our work through the coastal mountains of Germania Land—away from the zone of unstable atmospheric conditions bordering the ice cap. The results of such work would provide a wider regional picture than we could obtain by restricting our observations to Dronning Louise Land (Fig. 2).

Storstrømmen, 40 kilometres of rough glacier ice, has been crossed several times by snow-tractors, dog sledges and men on foot. It is a formidable barrier to travellers (MIKKELSEN, 1922; SIMPSON, 1955) but we hoped that our crossing to the coast would not be too difficult. There had been an unusually heavy snowfall during the winter, and this helped considerably by filling many of the hollows between the large ice hummocks on the Storstrømmen surface and, as we both drove a dog team, each sledge was loaded with only 500 lbs. for our month's journey. Since we would encounter an irregular glacier surface, we took robust Greenland sledges rather than NANSEN sledges and carried ski runners for use on the coast. The crossing this time presented no difficulties and we were sledging on Sælsøen on the morning of the third day after leaving base—much earlier than we had dared to hope.

A reconnaissance traverse was made first along Sælsøen, which presents cliff exposures approximately across the regional strike for 50 kilometres; then the traverse was extended for a further 50 kilometres eastwards along the south coast of Germania Land to Danmarkshavn. Danmarkshavn now a weather station, previously the base of the Danmark Expedition, 1906—1908 (AMDRUP, 1913). The old base hut of this Expedition still stands, together with a cross in remembrance of MYLIUS-ERICHSEN, the leader of the Expedition, who died during his famous journey to the north. I would like to acknowledge here, most gratefully, the excellent Danish hospitality extended to Lt. ERSKINE and myself during our brief stay at Danmarkshavn.

The low glaciated hills forming the coast between Sælsøen and Danmarkshavn were so heavily covered with snow that little work was possible (Fig. 24). The cliffs bordering Sælsøen, however, presented excellent exposures. Talus slopes obscured the rocks at the bases of many cliffs (Fig. 8) and sloping ground between the cliffs was mantled by

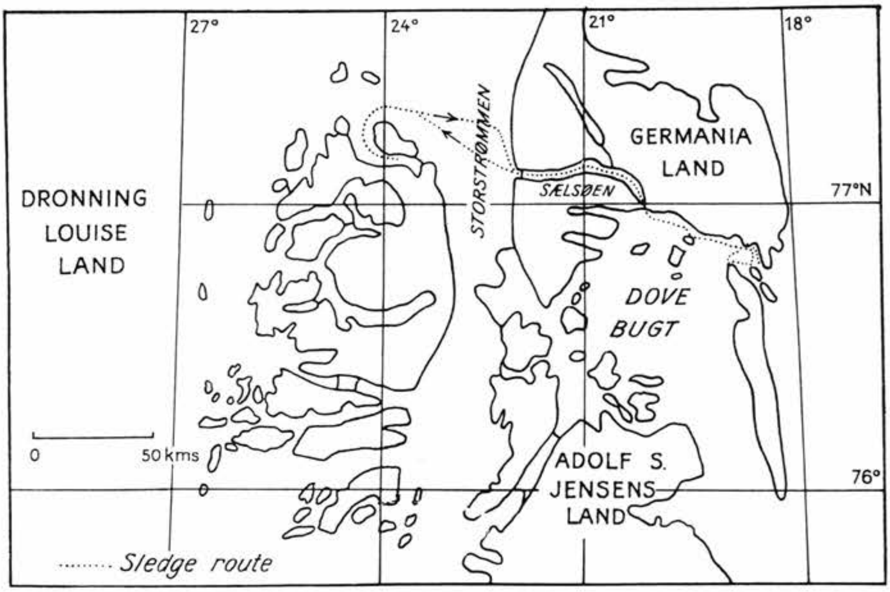

Fig. 2. Dronning Louise Land and Germania Land.

scree, glacial debris and snow (Fig. 6), but most of the rocks exposed in the cliffs were readily accessible.

As it was early in the season the sun was very low and it was only for a short time each day that rock faces in the deep cleft occupied by Sælsøen were illuminated. The lighting was poor for coloured photography. In addition, the low temperatures caused frequent mechanical failure of the camera shutters, and many pictures were ruined either by irregular opening of the shutter or by failure to open at all.

In Sælsøen and on the coast near Danmarkshavn we saw several small herds of muskoxen. They were all in poor condition; the heavy snowfall which had helped us to cross Storstrømmen made it difficult for them to find food. Dead muskoxen were found at three places on the lake edge. They had died either of starvation, or by falling from the hillside. Near the carcases there were many fox tracks, for the foxes profited from the misfortune of the muskoxen. In the centre of Sælsøen we found the tracks of two bears followed by the tracks of a fox. Later we discovered more tracks near the moraines marginal to Storstrømmen but we were not fortunate enough to sight a bear.

Very little work has been done previously in this area. Jarner of the Danmark Expedition (Amdrup, 1913) appears to have confined his attention to fossiliferous strata in Dove Bugt, and he did not publish his results. J. Ravn examined the collections of Jarner (Ravn, 1911).

LAUGE KOCH reached Danmarkshavn on his great sledge journey of 1927 (KOCH, 1929). He wrote (page 66):—"Round Danmark Harbour I found gneiss. The samples of rocks collected by the Danmark Expedition in more northerly regions are too insufficient to warrant a close definition of the geological conditions farther north along the coast". ....."With all reservation I therefore put forward the conjecture that the central portion of the Caledonian folding range forms the coast northwards from Gael Hamkes Bay, ..." He reports that the northern part of Store Koldewey island consists of highly metamorphosed rocks, especially gneiss (page 66). Reference is also made to Neocomian and Portlandian erratics found near Danmark Harbour (page 163).

F. BRONNER, a member of the 1938 LOUISE BOYD Expedition, spent a few days at some points on the south coast of Germania Land, but only his brief reference to eclogites injected into the schist country rock near Danmarkshavn is relevant to this paper (BOYD, 1948, p. 216).

The members of the Mørkefjord Expedition, 1939, were so intent on pushing northwards that there was no time for local geological work (KUUTH, 1941).

The present contribution to the geology of the area is essentially a reconnaissance report. It includes a record of observations in an area virtually unknown geologically together with comments on, and discussion of, the theoretical implication of some of the facts discovered. As this area is probably unlikely to be surveyed in further detail for many years to come, the writer regarded it as an obligation and a privilege to submit his observations and conclusions for publication. He trusts they will be of some value to his Danish colleagues.

University of St. Andrews, 1956.

I. GEOMORPHOLOGY

Topography.

J. P. Koch (1916) has described the topographic forms of Germania Land at some length. The whole of Germania Land was covered by the ice cap at one time, and he writes: "... the landforms created by the ice may be referred to two types, very different in aspect. The moutonneed (rounded) rocks corresponding with the localities where the motion of the ice has been strongest, and the plateau, corresponding with the stretches where the motion of the ice has been very slight. Between these types there are, however, also transition forms." The plateau (reaching 700 metres above sea level) is extensive in south west Germania Land (Fig. 3). It slopes gently westwards near Storstrømmen, and more steeply eastwards at the east end of Sælsøen. Here transition forms occur between the plateau and the "moutonneed" hills of the low coastal area (Fig. 4).

Thus J. P. Koch attributes the plateau landform to ice erosion. There is a similar surface in Dronning Louise Land — the highland erosion surface (Lister and Wyllie) — which slopes downwards gently to the E. N. E. from 1850 to 1000 metres above sea level. The plateau of Germania Land is almost certainly part of the same surface and is separated from it by Storstrømmen. All geological structures are truncated by the highland erosion surface of Dronning Louise Land, and by the plateau landform of Germania Land. This fact suggests the operation of an erosion cycle. The land must have been worn down almost to sea level, and then raised relative to the sea. Thus the surfaces probably form parts of a raised peneplain.

Similar uplifted erosion surfaces are known from all parts of East and North Greenland. R. F. Flint (1948, p. 92) has reviewed the relevant literature and states that "the time of formation of this latemature surface has not been definitely determined". H. G. Backlund (1930) has inferred that the surface on Clavering Ø is pre-Eocene; L. R. Wager (1932) considered that the surface is later than the Tertiary igneous activity in south-east Greenland; and C. Teichert (1935) suggested a possibly mid-Tertiary age, without citing supporting evidence.

Fig. 3. View westwards from MR 688495 (north side of Sælsøen). The plateau landform.

The "moutonneed" and transition forms of J. P. KOCH are certainly the result of modification of existing landforms by ice erosion but the plateau landform probably existed before glaciation.

Glacial Deposits.

There are many moraines bordering Storstrømmen and the glacier entering Sælsøen but elsewhere well-formed moraines are few. In certain localities bordering Sælsøen irregular heaps of glacial debris are preserved. For example, the valley between Annekssøen and Sælsøen is filled with such heaps, many of which have been terraced by the action of water. On most hillsides there is a variable cover of till. In addition to numerous boulders of gneiss, the deposits contain many rounded boulders of quartz-dolerite and coloured quartzite. These rocks must have been transported by the ice from the western parts of Dronning Louise Land because they outcrop at no place nearer than this. The terraces bordering Sælsøen are composed of a similar variety of boulders and therefore must have been formed of reworked glacial debris.

At the east end of the lake, between Trekroner and Tvillingnæs, there is a broad valley containing thick deposits of till. Canyons over 30 metres deep are cut through this till without exposing bedrock. Thus great quantities of material must have been carried eastwards by the glacier which formerly occupied Sælsøen. The fact that so little of this material is preserved as lateral moraines in Sælsøen area suggests that the bulk of it was transported as englacial moraine, but the evidence of this is probably obscured by the Lake.

Strand lines and Related Features.

There are many strand lines suggesting post-glacial uplift of the land. According to J. P. Koch (1917, p. 441): "Through observations of

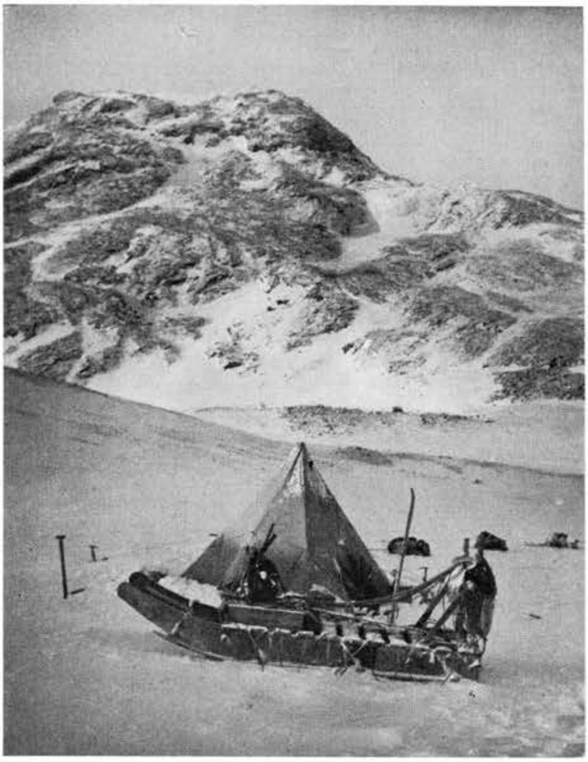

Fig. 4. Mountains of transition form (north east side of Sælsøen, MR 725482).

the heights of strand lines above the sea, it has been possible to form a clear conception of the fact that Germania Land after the European-North-American period has risen about 400 m. ... The traces, left by the sea, are generally confined to more or less effaced strand lines and to the appearance of shells; as regards the landforms these traces of the sea are of no real importance. Only in a single locality, in the hollow between Moskusoksefjeldene and Sælsøen, does there appear a plane 20 km. long and about 10 km broad, which has been formed below the sea by the melting off of the ground moraine from the floating inland ice."

Many strand lines and terraces were noted alonside Sælsøen, but they have not yet been correlated with former sea levels (Fig. 5). When

Fig. 5. View eastwards from MR 695491 (north side of Sælsøen). 45 metre terrace.

Sælsøen was occupied by a glacier there was ample opportunity for the development of terrace features by ice dammed lakes and marginal streams. Shells found in situ are the only certain criteria of a marine shore feature and none were found in Sælsøen. The heights of the terraces above the frozen surface of the lake were measured with an aneroid barometer. Readings were taken at lake level, at each terrace going up the hillside, again going down the hillside, and finally at lake level. An accuracy of ± 5 metres is all that can be claimed. The results are given in Table I, assuming that the surface of Sælsøen is 5 metres above sea level (J. P. KOCH, 1917, p. 445).

The only persistent terrace level, which is not constantly developed at the same height, lies between 40 and 50 metres above sea level. This may well be a marine shore feature but proof is not available. The high level terraces were found in localities which would have been favourable for the formation of ice dammed lakes when Sælsøen was occupied by a glacier and their origin is attributed to the work of such lakes.

The observations of R. F. FLINT (1948, p. 191) in the Fjord Region of East Greenland suggest two water planes, probably marine, at 65 to 75 metres, and 30 to 35 metres above sea level.

In north Greenland, LAUGE KOCH (1928, p. 517) has found marine shells up to 210 metres above sea level, and driftwood up to 165 metres. He also stated that, "Above 210 metres there are, in several places, suggestions of shore lines".

Table I. The heights above sea level of strand lines and terraces alongside Sælsøcn.

Map references	Height of strand lines in metres
West	
642480[1])	24. 51.
649487	42. 245. 270
660485	42.
695491	45. 82. 157. 210.
718482	45. 48. 51.
722481	45. 48. 51.
733478	45. 48. 51.
733478	54. 73.
725474	51. 57. 60.
East	

[1]) The south shore of Sælsøen. The other measurements were recorded on the north shore.

D. Laursen (1944 and 1950) has studied in detail the marine quaternary deposits of west and north-west Greenland. He concluded that on the northern coast of Nugssuaq (71° N) the upper marine limit is 230 metres above the present sea level. This becomes lower, the farther south one goes.

The observations in Sælsøen are so limited that any attempt at correlation would be futile. It is worth noting, however, that J. P. Koch's suggested uplift of 400 metres is high in comparison with that suggested for other parts of Greenland and that no strand lines at that height were seen alongside Sælsøen. In any area where glacial action was vigorous, correlation of terraces and strand lines with former sea levels must be made only with great caution.

II. REGIONAL SETTING

The geology of Germania Land was practically unknown, but by extrapolation of results obtained north and south and west of the region much could be deduced concerning its probable geological history. It has become clear that the rocks of Germania Land were involved in the Caledonian orogeny of East Greenland.

LAUGE KOCH (1929, p. 286) believed that the East Greenland geosyncline extended northwards from Scoresby Sund to Nordostrundingen. During Greenlandian and Cambrian times a thick series of strata was deposited in the geosyncline under varying conditions. These deposits were strongly folded in Caledonian time with the formation of a great mountain chain. A western marginal zone of folding extends from Scoresby Sund northward, "no doubt continuing, partly concealed by the inland ice, to Dronning Louise Land and probably still further northward". East of this marginal folding zone vast areas of granite extend parallel to the axis of folding. LAUGE KOCH recognised the Caledonian folding with certainty from Scoresby Sund to Danmarkshavn and he considered that large areas of gneiss, particularly in the northern part of this region, belong to the central zone of folding. Further south also certain granitic and gnesissic areas, previously believed to be Archean, were assumed by KOCH to be products of the mountain building movements. Thus he concluded that the rocks of Germania Land formed part of the central folding zone of the Caledonian orogeny. Much of his brilliant pioneer work has been verified by recent detailed mapping.

The Central East Greenland Caledonides between latitudes 72° N and 74° N have now been studied intensively by geologists working under KOCH's direction. BACKLUND (1932) and WEGMANN (1935) investigated the geology of Central East Greenland and concluded that large parts of the Central Metamorphic Complex are made up of Metamorphosed Greenlandian sediments. WEGMANN also concluded that the supercrustal transformation of the East Greenland Geosyncline is such a deeply penetrating interruption of the Greenlandic shield that it must be considered as a major tectonic element in the earth's crust. J. HALLER (1955), by taking into consideration the results of all recent publications, presents a clear picture of the structure of the "Central Metamorphic Complex" of this region. The granitic and gneissic areas of the Central Metamorphic Complex have now been shown in detail to consist of metamorphic and metasomatically transformed sediments of Greenlandian age, affected by the Caledonian folding.

Expeditions under the leadership of LAUGE KOCH have also investigated that part of the East Greenland geosyncline lying between latitudes 80° and 81° N and longitudes 20° and 23° W in Kronprins Christian Land. Here we are at the western border of the Caledonian chain in East Greenland (FRÄNKL, 1954) and the metamorphism of the pre-Cambrian and Cambrian sediments is weak compared with that of the sediments in the main orogenic focus of Central East Greenland. But tangential movements are stronger here along the border of the Caledonian chain, and the main tectonic feature of Kronprins Christian Land is a great nappe, formed mostly of pre-Cambrian sediments, which is overthrust upon Silurian rocks. FRÄNKL considers that the overthrusting was part of the Caledonian movements.

Thus, to LAUGE KOCH's conception of the East Greenland geosyncline has been added geological detail for the regions of Kronprins Christian Land and Central East Greenland. This detail gives support to his conclusion that the gneissic and granitic rocks of the Dove Bugt area belong to the central folding zone of the Caledonian orogeny. However, there remain large gaps in our knowledge of the geology of East Greenland between these two regions.

Germania Land is the only large ice-free coastland between latitudes 76° N and 80° N and the mountains of Dronning Louise Land extend further westwards into the ice sheet than any neighbouring land mass. Germania Land and Dronning Louise Land together extend from latitude $18^1/_2$° W to 27° W, a distance of over 200 kilometres; this is longer than any cross section of the Caledonian mountain chain yet investigated and it occupies a central position in the area of North-east Greenland in which our geological knowledge is seriously deficient. Without geological information from western Dronning Louise Land to eastern Germania Land any hypothesis concerning the East Greenland geosyncline as a whole must also be deficient.

Since the purpose of the traverse was to extend eastwards the regional picture obtained by work in Dronning Louise Land, a summary of the geology of this region has more direct bearing on the present paper than the geology of those to the north and south.

The western half of Dronning Louise Land is formed of a north-south zone of Archean gneisses and the eastern half of folded schists of obvious sedimentary origin. Lying with marked unconformity on the Archean basement is a series of coloured quartzites and quartzitic sandstones intruded by dykes and sills of quartz-dolerite. The sediments, of limited extent on the western nunataks and mountains, are only slightly recrystallised and were deposited near the western foreland of the geosyncline (Peacock, 1956a). Evidence of increasing metamorphism eastwards noted in the field is confirmed by petrographic study. Four zones of increasing metamorphic grade may be distinguished in the gneisses and schists (Peacock, manuscript, 1956). In the eastern parts of the area, the schists locally may be transformed into gneisses.

From this evidence we may conclude that the rocks of southern Germania Land, further away from the western foreland and in the direction of increasing metamorphism, were formed near the central part of the East Greenland geosyncline. This conclusion is strengthened by evidence from the north (Kronprins Christian Land) and from the south (Central East Greenland). It seems, therefore, that the rocks exposed in Germania Land were once the roots of the central ranges of the Caledonian mountain chain, now deeply eroded. Such rocks would be so intensely folded and so highly metamorphosed that we would expect to find evidence of considerable granitic activity.

We may now examine the results obtained from the reconnaissance traverse and see to what extent they corroborate this conclusion first reached by Lauge Koch (1929, p. 286).

III. FIELD OBSERVATIONS

General Geology.

Only a limited range of rock types, compared with the variety in Dronning Louise Land, was found along the entire length of the traverse (100 kilometres). They comprise migmatites, granitic gneisses, paragneisses and schists, with a few outcrops of basic and ultrabasic rocks, and bear little resemblance either to the Western Gneisses or to the Eastern Schists of Dronning Louise Land.

Massive granitic rocks of uniform character are exposed in several areas alongside Sælsøen and grade into foliated but still massive granitic rocks surrounded by broad zones of migmatite with regular or highly contorted light and dark bands. Migmatites constitute the greater part of the rocks examined in the traverse. They occur in a variety of forms including typical injection gneiss, permeation gneiss and augen gneiss (e. g. PHEMISTER, 1948, p. 29). The granitic and sedimentary material are often so intimately mixed that they cannot be distinguished in the field. Small veins and bodies of pegmatitic material are commonly associated with the granitic gneiss and migmatite. In one place, pegmatite dykes 10 metres wide cut the paragneiss.

Schists and paragneisses, restricted in extent, occur between the exposures of granitic gneisses and migmatites. No calc-silicate rocks were found. The schists (including garnet-biotite schist, garnet-biotite-quartz schists, garnet-plagioclase-quartz schists and garnet-amphibole schists) occur mainly at either end of the traverse; i. e. near Storstrømmen and in south east Germania Land. Paragneiss (garnet-quartz-biotite-plagioclase gneiss with a variable content of amphibole) is more widely distributed and was recognised at several places along the traverse. Paragneiss of this composition also forms the sedimentary portions of the migmatites. Staurolite, kyanite and sillimanite were not found in any of the rocks.

The occurrence of amphibolites is restricted. Thin bands of garnet-amphibole schist have already been mentioned. The only large outcrop of basic rock caps Trekroner, the mountain at the east end of Sælsøen.

Here, coarse grained garnet-amphibolite is in contact with granitic gneiss, and the steep rock faces north of the mountain display a variety of injection phenomena. Elsewhere, small masses and lenses of amphibolite are incorporated in the migmatites.

There are several small outcrops of ultrabasic rock, each with a different mineral assemblage, widely spaced along the traverse.

The cliff exposures of Sælsøen are extensive and one might therefore expect to find large scale structures clearly displayed. But major structures were not evident, no folds were discovered (although it is clear that the rocks have been highly folded) and few junctions between different rock types were found.

The strike of the foliation planes varies locally. The mean strike was measured at 28 points in Sælsøen area and at 9 points from Hvalrosodden to Danmarkshavn. There are thus insufficient points for a statistical analysis of the strike of the foliation planes. However, the poles of measured foliation planes when plotted on an equal area projection occupy a zone extending from W.N.W. to E.S.E. This indicates that the regional strike is N.N.E.—S.S.W. The prevailing dip is westerly but many foliation planes dip to the east. In south-east Germania Land the strike is more often N.—S. and the dip is more nearly vertical. Although an accurate statistical analysis of the attitude of the foliation planes is impossible with available data, the fact that the few measurements recorded show such limited variation suggests that the regional strike is constant for the length of the traverse (100 kilometres).

The axial planes of minor folds are invariably parallel to the foliation of the gneisses. So although no major structures were distinguished we may conclude that major fold axes follow the regional strike of the gneisses, i. e. N.N.E.—S.S.W. It has not been possible to divide the region into distinct structural units.

44 joint measurements were recorded between Storstrømmen and Danmarkshavn, 35 of them in Sælsøen area. These measurements also are too few for an accurate statistical analysis. But when the poles of the 35 joints are plotted on an equal area projection concentrations are obtained in three small areas. These correspond to three near vertical joints striking E.—W., N.W.—S.E. and N.N.E.—S.S.W. It is notable that the latter joint is parallel to the regional strike and approximately bisects the obtuse angle between the other two joints. Of the 9 joints measured between Orienteringsøerne and Danmarkshavn, 5 conform to this pattern. Although, statistically, little reliance can be placed on this result the fact that so few measurements recorded over a great distance do conform to a definite joint pattern suggests strongly that this system of joints is prevalent in south Germania Land.

Since the geology of Germania Land is so imperfectly known detailed descriptions of the outcrops examined are given below. Detailed mapping was not possible in the time available. It is difficult to construct a geological map from the results of a single traverse and the task has been made even more difficult by the similarity of the rocks found and by the fact that no structural units could be distinguished. Plate 1 B gives the distribution of the rocks described. A four kilometre grid was used in the field to locate the outcrops and the same grid system is used in this paper. It offers a simple method of describing a region with so few place names. The symbol MR 698487 refers to map reference point 69.8 east, 48.7 north on this grid (Plate 1 A).

Descriptions of Outcrops from West to East.

The west of Sælsøen. The many low, glaciated hillocks (the "moutonneed" form of J. P. Koch) bordering Storstrømmen gain height rapidly eastwards until they reach the altitude of the plateau surface (700 metres above sea level). The smoothed hillock outcrops, weathering light grey or pale pink, are composed of medium-grained paragneiss and schists containing quartz, oligoclase, biotite, amphibole, and garnet; locally, pale green epidote was seen. The proportions of the component minerals vary in quite small areas. Those rocks containing a high proportion of biotite and amphibole, are schistose. In the more massive rocks, the platy minerals are distributed more evenly and the foliation is poorly developed. Parallel to the foliation planes there are coarser-grained, pale quartzo-feldspathic bands which are sometimes folded on a small scale.

South side, MR 649479. For 7 kilometres to the east from Storstrømmen, the land rises gently from the south side of the lake. Few outcrops were noted through the covering of glacial debris, scree and snow (Fig. 6). The next outcrop visited was below the jagged cliffs at MR 649479. The massive gneisses, probably mainly of sedimentary origin, at the base of the cliffs were examined from west to east for $1^1/_2$ kilometres. They contain oligoclase, microcline, quartz, biotite, black amphibole and garnet.

At MR 648480, the western end of the exposure, the gneiss is very light grey in colour. Foliation is marked by flat lenticles of quartz (a striking and persistent feature of the gneisses here, they are commonly 1 cm in diameter and 1 mm thick), lines of bright pink garnets and a few small shreds of biotite. The rock is massive and uniform in composition with no colour banding.

Near the west end of the exposure there is a band of black ultrabasic rock. Neither foliation nor lineation was detected. Its edges are concordant with the foliation of the gneiss, the junction is abrupt, and there is no marginal variation. Since the outcrop was partly obscured by snow and scree the junction could not be traced far. The rock is medium grained, very tough, and is composed mainly of equant crystals of black amphibole without felsic components (microscopic examination revealed olivine, magnetite and green spinel in addition to the amphibole). There are a few fine grained white veins trending parallel to the edges of the band but no specimen was collected from these. They are generally about 5 cms wide, but one 20 cms wide was recorded.

Fig. 6. View eastwards from near Storstrømmen (MR 626481). Note the snow covered slopes obscuring outcrops. In the centre is a grounded iceberg calved from the glacier.

Passing eastwards along the base of the cliff, more clearly defined foliation planes in the gneiss result from increase in the proportion of dark minerals. The gneiss develops a regular pink and grey banding, with the bands varying in width. In places they are only a few centimetres apart but elsewhere they are about 1 metre wide. The pink bands grade into the grey with gradual increase in the quantity of biotite. Garnets, larger than in the light coloured gneiss at the west end of the exposure, often reach about 1 cm in diameter; they contain many inclusions. Prisms of black amphibole occur in the dark bands.

At the east end of the exposure, MR 651477, the proportion of pink microcline is much reduced. The cliff face is formed of dark and light grey banded gneiss, with some rusty staining. The rock is medium grained, with foliation well defined by the fine colour banding and by the flakes of biotite. Locally, prisms of black amphibole (reaching about 1 cm in length) bearing no relationship to the foliation are sparsely scattered through the rock. No lineation was detected. The proportion of bright red garnets in the gneiss of this area varies considerably from one band to another. There is much flow folding with thickening of the acidic portions in many places. The axial planes of the minor folds have the same strike as the foliation planes (Fig. 7).

East of MR 651477 extensive talus slopes are present beneath the cliffs and the rocks were not examined. The steep rock faces, divided by deep gullies formed by frost wedging along joint planes, appear to be composed of gneisses similar to those already described. The cliffs do not extend far to the east from this point, but are replaced by a steep hillside covered with scree and snow.

North side, MR 640481 to MR 647486. On the north side of the lake the glaciated hills close to the Storstrømmen give way, within 3 kilometres of the glacier, to a steep cliff. It rises sharply from the terraces of re-sorted glacial debris which border the west end of the lake, forming a prominent feature extending for over 3 kilo-

Fig. 7. Small isoclinal fold in paragneiss (south side of Sælsøen, MR 651477).

Fig. 8. Cliff formed of massive granitic gneiss on the north side of Sælsøen (MR 644485). Note the terrace in the west and the talus slopes in the east.

metres (Fig. 8). At its east end, the terraces are not present and steep talus slopes fall directly to the lake. Large joint faces control the cliff face.

The cliff has a uniform colour, weathering light pinkish-grey with a few darker lines marking a faint foliation dipping to the east. A massive, medium to coarse-

Fig. 9. View westwards from glaciated outcrops above Sælsøen at MR 651485.

grained granitic rock forms the cliff. It is pink in a hand specimen and more uniform in composition than the gneisses from the south side of the lake, Microcline, quartz and biotite constitute the bulk of the rock; there are a few small needles of black amphibole and garnet is locally present. The rock has a fairly even texture, but a faint foliation is produced by orientated biotite flakes and, rarely, by a slight increase in its proportion, biotite forms a darker band parallel to the foliation. Some of the quartz crystals are flat lenticles parallel to the foliation, but this feature is not as well developed as in the gneisses at MR 684480 on the south side of the lake.

At MR 643485 there is a wide, dark band in the cliff traversed by thin veins of pink granitic rock. It was examined at a small boss outcropping on the lake shore below the talus slopes. The dark band contains feldspar, quartz, black amphibole and biotite. From a short distance, it appears dark grey in colour. It is a composite gneiss containing many bands and lenses of almost black rock traversed by ramifying veins of granitic material. The black rock is composed of amphibole with a very small proportion of felsic minerals.

The east end of the cliff forms the west side of a large embayment in the shore of the lake. A stream flowing through a high level valley from a small lake in the hills divides the steep cliff from the less steep slopes which form the east side of the embayment.

North side, MR 648486 to MR 654482. This is the east side of the embayment, and there are many smoothed outcrops on the hillside (Fig. 9). They are composed of a coarse grained pink granitic rock, very similar in appearance to the rock forming the cliff to the west. The mineral components are microcline, some plagioclase feldspar, quartz and biotite. Numerous garnets, 0.5 cms in diameter, were noted at one outcrop. The biotite, in many places, produces a faint foliation. Coarse pegmatite was seen in many of the outcrops but only in one place was its relation to the normal granitic rock established; here the junction is gradational.

At MR 654482 the steep slopes forming the eastern side of the embayment give way to a high cliff extending eastwards for 6 kilometres, decreasing in steepness, and becoming less prominent.

North side, MR 654482 to MR 665485. The cliff for 1 kilometre east of MR 654482 is controlled by joint planes and has weathered in a blocky fashion. Much of its base is obscured by talus slopes. The rock, composed of light and dark portions, is massive and pink weathering. The light portions contain microcline, quartz, a little biotite and some black amphibole needles; the finer-grained dark portions are richer in biotite and amphibole. The light and dark portions do not show a regular foliation when viewed from a short distance, but from further away the orientation of pink granitic bands indicates a faint foliation dipping to the east.

At MR 660485 the cliff is less steep, and there is more scree covering the rocks. An outcrop not far above the lake surface consists of a compact amphibole schist. It grades into a medium grained, well foliated biotite-amphibole-feldspar-quartz schist, containing a few amphibole-rich bands of varying thickness. There are coarser grained granitic folia, and some irregular granitic patches with local development of flow folding. No pronounced lineation was detected in the schists. The cliff above the screes appears to be composed of massive gneiss weathering similarly to the gneisses described at MR 654482.

From this point to MR 665485 there are few outcrops, because the slopes rising from the lake are almost completely covered with scree. At MR 665485 steep rock faces again become prominent, and a fine cliff extends from there to the Midternaes building.

South side, MR 665480 to MR 679485. Rising steeply above extensive talus slopes is a high cliff, steeper at either end than in the centre. Vertical clefts and gullies in the cliff face give it a rugged appearance which, together with its length of 6 kilometres, make it one of the more impressive features of Sælsøen area. The rocks weather pink and light grey and, particularly towards the top of the cliff, there is a faint light and dark banding. Outcrops of migmatite were examined at lake level at each end of the cliff.

The outcrops at MR 665480 weather out in large blocks controlled by joint planes and display pink granitic veins and bodies of all shapes and sizes. Garnetiferous biotite schist with thin quartzo-feldspathic bands is present, the garnets reaching 0.5 centimetres in diameter. Amphibole occurs in the schist, and sometimes forms dark lenses within the granitic rock. The coarse grained granitic rock contains microcline, quartz, biotite and amphibole. The granitic veins tend to follow the foliation of the thin schistose band but the schist is so distorted by the coarser granitic rock that no satisfactory measurement of the attitude of the foliation planes could be made. Gradations exist between all the rock types and no abrupt junction was found. In places, the schistose and granitic portions are so intimately mixed that the rock is almost uniform, with a faint, irregular foliation marked by crumpled, discontinuous layers rich in biotite.

At the east end of the cliff, the outcrop at MR 679485 is composed of migmatites similar to those described at the west end. The foliation planes of the dark portions are still complicated by the pink granitic veins but, on the whole, the structures here are more orderly. There is much less schistose material and there are many more of the amphibolite lenses and nodules of varying sizes. The lenses, sometimes

Fig. 10. Migmatite containing small amphibolite lenses veined by granitic material (south side of Sælsøen, MR 679485).

including a little biotite and small garnets, are cut by narrow granitic veins (Fig. 10). Microcline, quartz and biotite constitute the massive, medium grained granitic rock; garnets are sometimes present. There are also coarser grained veins composed of microcline, quartz and large black amphibole prisms.

East of this area, there is a relatively low lying promontory separating the cliff from the lake and many smoothed outcrops are exposed through the scree and glacial debris.

South side, MR 684488 to MR 688487. Glaciated outcrops of red augen gneiss were examined at the west end of this exposure. The rock is generally coarse grained with well developed, close-set pink and grey banding. The gneiss contains microcline, quartz, biotite and amphibole; garnet was not found. Along the foliation planes are set large crystals of microcline, sometimes almost euhedral, attaining a length of about 5 centimetres. In places where the gneiss is medium grained microcline porphyroblasts are absent. In some outcrops no foliation is present. Here the grain size is coarser and the porphyroblasts of feldspar tend to be more nearly euhedral than elsewhere. Often there are, particularly in the latter areas, confused masses of pink microcline in which no crystal form can be distinguished. One such mass was noted in sharp contrast to well foliated medium grained gneiss; the change occurred abruptly across a joint plane, indicating that there has been some movement along the joint. Flow folding is developed in many places, sometimes to such an extent that a confused tangle of pink and grey lines is all that can be seen. The foliation planes are generally distinct but their strike varies irregularly.

Similar rocks continue to outcrop eastwards across the low promontory. At MR 687488 the rocks again rise steeply from the lake. The rock faces here are controlled by a prominent E.—W. joint (Fig. 13). The gneiss is often medium grained, and darker in colour than the red augen gneiss to the west. There are coarser grained

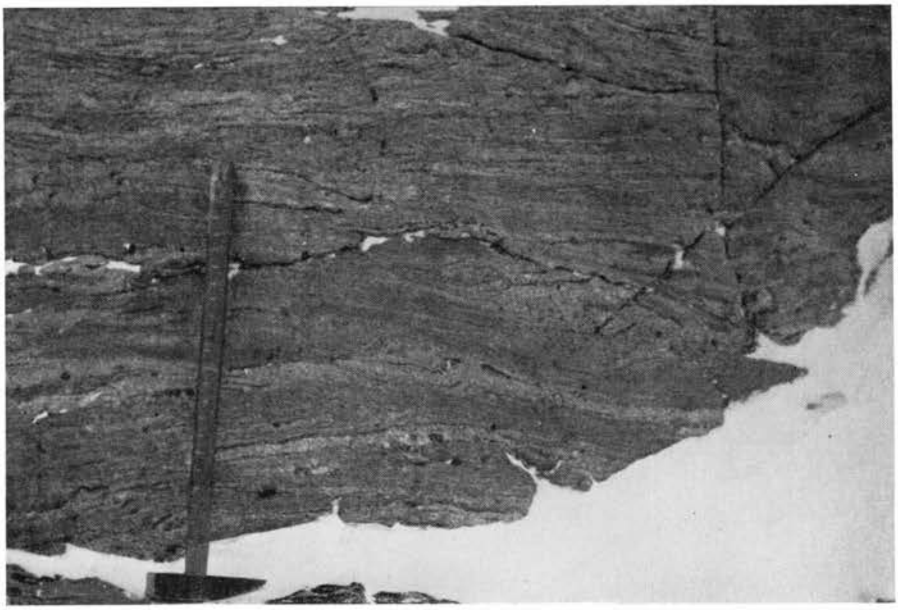

Fig. 11. Migmatite and augen gneiss (south side of Sælsøen, MR 688488). The shaft of the hammer is marked in inches.

Fig. 12. Migmatite with contorted granitic veins (south side of Sælsøen, MR 688487).

pink granitic bands traversing the gneiss and these show small scale folding (Fig. 11). The rock contains no feldspar porphyroblasts and the change from the red augen gneiss to this darker medium grained gneiss is gradational.

Feldspar augen occur again at MR 688487, but here they are grey and rarely pink. Otherwise, the gneiss is very similar to the red augen gneiss described above. The rock is generally well foliated, but contains also granitic veins showing flow folding and minor contortions (Fig. 12). The strike of the foliation planes is constant but the dip is variable. Eastwards, this rock grades into a pinker gneiss, with smaller augen and more pronounced separation into narrow pink acidic folia and dark biotite-rich folia.

The cliff continues eastwards from MR 688487 with deep gullies separated by impressive buttresses (Fig. 14). The rock types forming the cliff appear similar to those described above. At MR 700481 the cliff ends next to a broad valley whose moraine covered floor is considerably higher than lake level.

North side, MR 672486 to MR 687495. At MR 672486, bare rock exposures replace the debris-mantled slopes to the west and a high cliff is formed. This decreases in height until it reaches the Midternæs building, 7 kilometres further east, where a broad valley carries a stream from a mountain lake in the north. Faint colour banding is visible in the cliff.

The steep outcrops at the west end of the cliff tend to be rounded, with vertical joint faces (approximately perpendicular to the lake edge) exposed at regular intervals. Massive, medium to coarse grained migmatite, containing microcline, plagioclase feldspar, quartz and biotite outcrops at MR 762486. A foliation is marked by pink and grey bands, the pink granitic bands showing pinch and swell. The dark portions contain black amphibole and few garnets (0.5 cms diameter) in addition to the granitic minerals. Locally, where thin veins of microcline and quartz swell into lenticles, this rock type grades evenly into a dark grey augen gneiss with pink augen of microcline studded in a grey rock. Pink granitic veining approximately parallel to the foliation is prominent higher in the cliff where the foliation is much less distinct.

At the top of the cliff there is a wide band of uniformly light coloured rock, with edges concordant with the foliation of the migmatite. This band could not be traced down to the base of the cliff. Gneiss similar to the rocks described above, with minor variations, outcrop as far as the point MR 677488. Occasionally there are narrow (0.5 cm) pink granitic veins intersecting the foliation planes at small angles (of the order of 20°).

Outcrops of biotite-amphibole schist, with foliation planes almost horizontal, occur at the bottom of the cliff at MR 677488. The schists contain several thin granitic veins and, higher in the exposure, some thicker concordant granitic bands. Below the schist there is a medium grained, massive band of garnet-biotite-quartz feldspar paragneiss. The small proportion of biotite and flattened quartz crystals mark a well-developed foliation. A few yards to the west is a more massive rock,—plagioclase-quartz-biotite paragneiss with a few very small garnets,—passing below the rocks described above. The foliation is marked by biotite, and also by wider bands of lighter and darker portions. There is one band, 1 ft. wide, of dark green-black amphibolite. The relation of these schists and paragneisses to the migmatites and granitic rocks was not established.

Scree slopes and a fresh snow cover obscured the bottom of the cliff until MR 681491 was reached. Here, a large rocky promontory extends into the lake. The gneiss weathers in yellow and grey bands but close examination failed to reveal any difference between the bands weathering in different colours. The grey bands are composed of plagioclase feldspar, quartz and biotite; the yellow-weathering bands have similar mineral composition and are concordant with the grey bands. Cross cutting veins of pink pegmatitic materials are present. The strike of the foliation

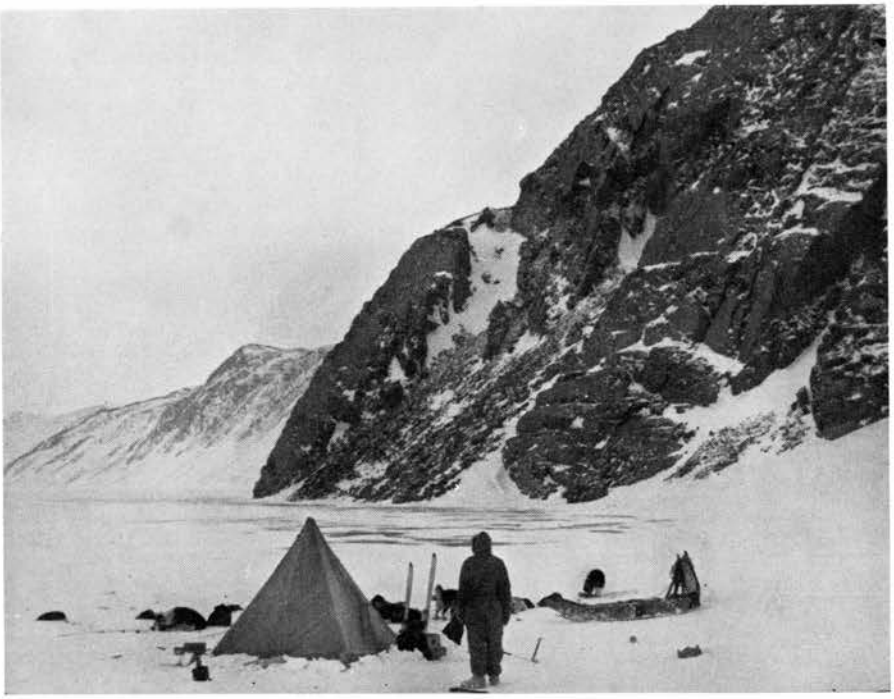

Fig. 13. View eastwards from MR 688488 (south side of Sælsøen). The rock faces are controlled by an E. — W. joint plane.

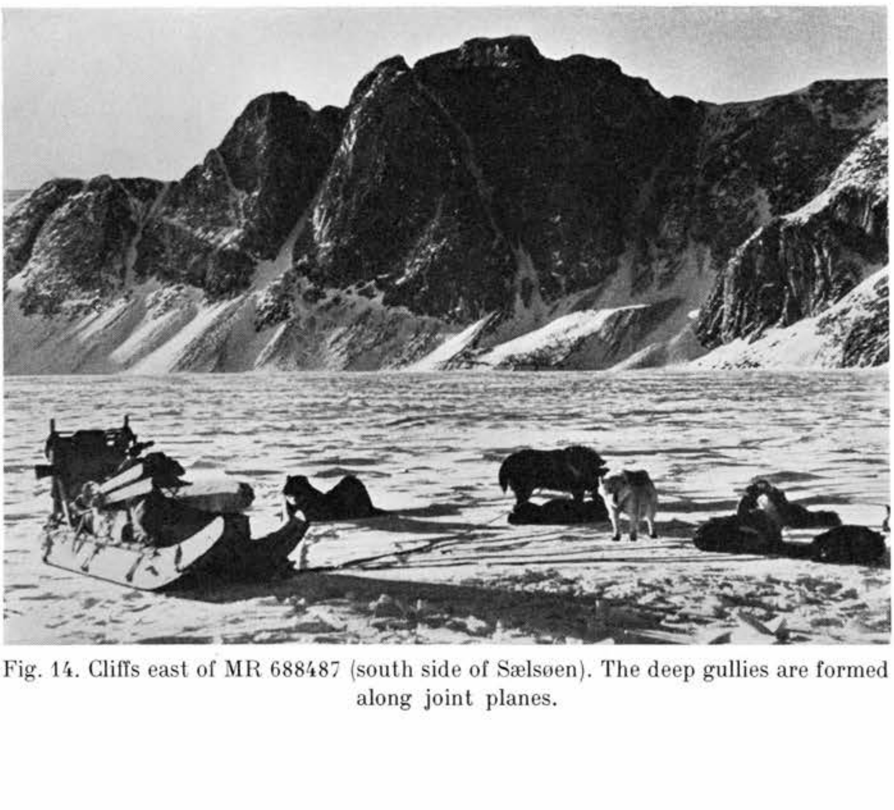

Fig. 14. Cliffs east of MR 688487 (south side of Sælsøen). The deep gullies are formed along joint planes.

Fig. 15. Lens of amphibolite enclosed by paragneiss (north side of Sælsøen, MR 681491).

planes appears constant but the dip is variable. An almost vertical, 2 metre wide vein of pegmatite contains microcline, quartz, biotite books, and some large scale graphic intergrowths. The edges of the pegmatite were not examined closely but they appeared quite sharp, although very irregular. The gneiss near the pegmatite seemed disturbed, with very variable dip.

There is also a large concordant lens of amphibolite, at least 20 metres long and 5 metres wide, enclosed in the gneiss (Fig. 15). It is a medium grained rock, containing black amphibole, some biotite and a very small proportion of light minerals. A small mass of calcite (10×1 cm) was found within this rock. The foliation of the gneiss seems to flow around the lens. Small masses of fine crystals of dark green epidote occur along joint planes.

The last outcrop visited in this exposure was a small one below the lower cliff at MR 687495. The rock here weathers out in great blocks controlled by joint planes. Microcline, quartz and biotite are the only minerals seen and they constitute a massive, medium to coarse grained red gneiss. It is divided into narrow red and grey bands with some coarser bands of feldspar and quartz which are also wider (Fig. 16).

North side, MR 696491 to MR 699489. At the west end of the exposure (MR 696491) small glaciated outcrops of foliated, pink and grey weathering, medium grained paragneiss occur above the terraces. The fresh rock, white and grey, is composed of oligoclase, quartz and biotite, with foliation produced by a variable content of biotite. There is some flow folding in the gneiss and many lenses and stringers of white, almost biotite-free material parallel the foliation. Narrow rims with a concentration of biotite border some of these white tongues and bands (Fig. 17).

Further to the west, steep cliffs rise from the glaciated outcrops. The rock forming them is massive, medium to coarse grained, and of fairly uniform character. It is an even-textured granitic gneiss, light pink in colour, containing microcline,

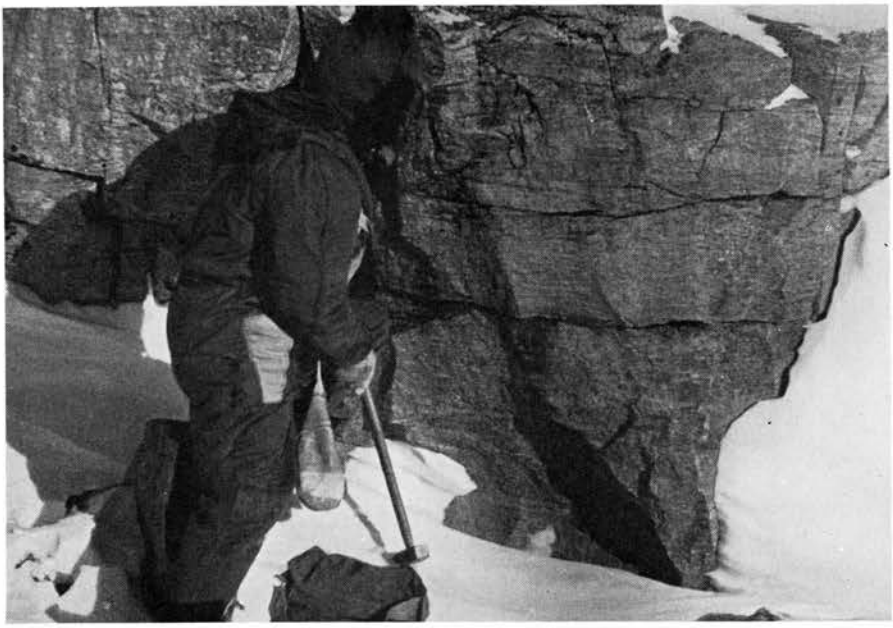

Fig. 16. Poorly foliated granitic gneiss (north side of Sælsøen, MR 68495).

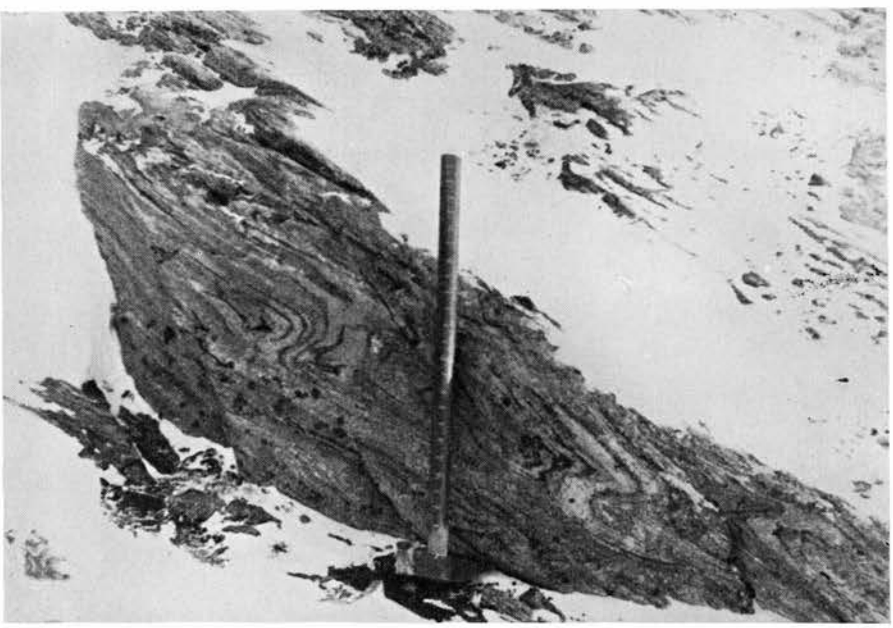

Fig. 17. Foliated paragneiss with minor folding (north side of Sælsøen, MR 696491).

quartz and biotite; a few garnets were found. In some parts, by concentration in bands, the biotite imparts a fine foliation to the rock. There are several even-textured granitic veins of later age, and some pegmatitic veins. In one pegmatite vein, about

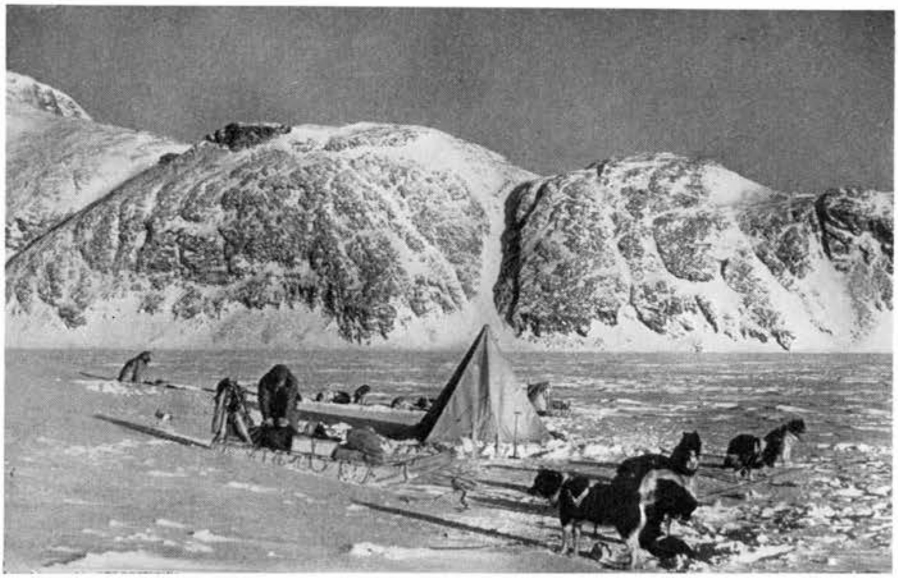

Fig. 18. Glaciated mountains formed mainly of paragneiss (north of Sælsøen, MR 723483).

50 cm in width, large pink feldspar crystals, with 10 cm edges are set in clear, grey quartz. Small bodies of compact amphibolite occur in the gneiss and granitic veins pass through them. Close to, and parallel to their margins there are often narrow granitic veins.

The cliffs to the west of MR 699489 are also uniform and massive, suggesting that these too are composed of the uniform granitic rock. Gullies in the rock face are controlled by prominent vertical joints. This cliff extends to MR 704489, where the valley from Annekssøen reaches Sælsøen.

South side, MR 706481 to MR 725474. The rock at the west end of this exposure is a massive, medium grained red granitic gneiss composed of microcline, quartz and biotite. The biotite is distributed fairly even through the gneiss, but slight concentration into bands produces a well defined foliation. Towards the east, the red gneiss is replaced by a grey paragneiss. The change is gradual. Numerous veins of the red gneiss pass into the grey rock, showing a variety of folding and flow features. The proportion of pink veins in the grey paragneiss decreases eastwards until the outcrops are of almost homogeneous grey gneiss. This contains less biotite than the red gneiss, and is composed of oligoclase, a small proportion of microcline, quartz, biotite, and a little amphibole. A faint foliation is produced by the mafic minerals, and a few bands are pink due to increase in the proportion of microcline. Many lenses and thin, discontinuous bands of dark, fine-grained material containing biotite and black amphibole trend parallel to the foliation of the paragneiss.

The low cliffs to the east of this point are set well back from the shore of the lake and their base is obscured by terraces and screes. At MR 725474 low cliffs of brown weathering gneiss are readily accessible. The outcrops near the lake edge are composed of coarse-grained granitic gneiss with microcline, clear quartz, and small biotite flakes. Black amphibole occurs frequently in clots parallel to the poor foliation; garnets are rarely seen. The microcline has a deeper red colour than that

Fig. 19. Metamorphosed breccia above and below an overhanging fault plane (north side of Sælsøen, MR 724483).

found elsewhere. The proportion of mafic minerals in this rock is less than in the granitic gneisses found farther west in Sælsøen and the foliation planes marked by them are more widely spaced.

Similar rocks form the low cliffs extending to the south east as far as MR 413460.

North side, MR 722483 to MR 725482. There are few outcrops emerging through the cover of glacial deposits on the hillsides east of the wide valley passing to Anneks-søen. Free rock faces occur again on the hills bordering the north eastern end of Sælsøen. These hills do not present steep cliffs to the lake in the same way as the mountains further west. They are set farther back from the lake, rising as separate hills with rounded contours, and represent the transition form of J. P. Koch (Fig. 18).

Most of the outcrops at the base of the hills by MR 722482 are composed of medium grained garnet-biotite schist, with bands of garnet-quartz-biotite schist. The pink garnets are translucent. This is the only place in Sælsøen area where extensive outcrops of schists were found. A few coarser grained bands are composed of quartz and milky white feldspar, with innumerable garnets of all sizes up to 2 cms in diameter. There is considerable segregation of quartzo-feldspathic material in bands and irregular masses and there are some cross cutting coarser grained granitic veins up to 30 cms in width. Wide pegmatite dykes outcrop higher on the hillside. The strike of the schists is fairly constant, but the dip is variable over the length of the outcrop examined. Almost a kilometre further east there are outcrops of foliated grey paragneisses. Their junction with the schists was not seen.

At MR 724483 there is evidence of a dislocation. An overhanging surface is furrowed by parallel grooves, 20 cms apart, with a depth of 5 cms. Smaller slickensides run parallel to the larger grooves. Below the grooved surface, the rock has the appearance of breccia (Fig. 19). Studded in a black, fine grained matrix of amphibole and biotite are large, white almost euhedral crystals of feldspar up to 4 cms in length, together with rounded masses and flat lenses of vein quartz. The structure of the dark matrix suggests flow round the light fragments. Blocks of banded gneiss are also present in the matrix, the largest being 50×20 centimetres. This is visible in Fig. 19. The light and dark finely banded gneiss of the block appears to grade into the matrix across a fairly sharp junction; the banding is along its greater length coinciding with the suggested direction of flow of the matrix around the fragments. The outcrop was small and detailed evidence of the dislocation was not obtained. A short distance to the west, below this outcrop, normal grey paragneiss was found.

Still further to the east, at MR 725482, there is a large, vertical pegmatite dyke cutting through grey paragneiss. The dyke, which is about 8 metres wide, contains large pink feldspars, clear grey quartz, books of muscovite and biotite, and a few lustrous prisms of tourmaline. Crystal edges of feldspar 20 cms long were measured. The strike of the dyke is in line with the two wide, pink bands outcropping on the hillside to the west above the schists previously described. The northern margin of the dyke is a fairly sharp line, but not straight for more than a few metres; very large crystals continue right to the edge of the dyke. Felsic bands in the adjacent gneiss, aligned obliquely to the dyke margin, appear not to be cut by, but derived directly from the pegmatite. The southern margin of the dyke has a finer-grained border. For about 30 cms from the margin the dyke is formed of a normal coarse grained granitic rock; this is replaced along a fairly sharp line by very large crystals. Within 10 cms from the margin, there is a concentration of tabular biotite with (001) vertical, and normal to the edge of the dyke.

The paragneiss is well segregated into light and dark bands and is contorted on a small scale near this margin of the pegmatite dyke. Vertical exposures of the gneiss show minor folding, with confused structures; horizontal exposures show well developed bands of granitic material with constant strike. Biotite is a prominent constituent giving the rock a darker colour than most of the gneisses described previously. The other minerals are oligoclase-andesine, quartz and garnet. Black amphibole is locally common. The proportion of garnets, reaching 0.5 cms in diameter, is variable. In the gneiss there are a few lighter coloured bands, medium grained and richer in garnet and quartz.

A low glaciated island near the lake shore at MR 723481 was examined. The paragneiss outcropping on the island is medium grained with pale grey feldspar, quartz, biotite, garnet and, in some places, amphibole. Light and dark bands within the gneiss grade into each other with transitional junctions and some of the lighter bands are of much coarser grain size. These resemble a pegmatite outcropping a short distance away. The pegmatite which contains large blue-grey feldspars, quartz and tabular biotite, outcrops extensively on the island.

In addition to these rocks two ultrabasic types were found. The first is compact, deeply weathered and black, composed largely of amphibole (Microscopic examination reveals also clinopyroxene and magnetite). It is normally medium grained but locally the grain size increases. In places, thin bands of epidote impart to the rock a foliation in the same plane as that of the neighbouring gneiss. The weathered surface of the second, a short distance away, shows large elongated brownish minerals (5 mms)

Fig. 20. Contorted migmatite near Tvillingnæs (MR 733478).

in a black medium grained groundmass. The large crystals are crudely lineated and mark a poor foliation conforming with that of the gneiss (Microscopic study reveals large hypersthene crystals set between smaller amphiboles, with some olivine, green spinel and magnetite).

The whole outcrop is deeply weathered and frost shattered and, despite a diligent search over the snow covered rocks, the relations between the four rock types were not clearly determined. In one place it seemed that the margin of the ultrabasic rock is concordant with the foliation of the gneiss and, as has been mentioned above, when pegmatitic rocks form narrow bands within the gneiss their contact is concordant and transitional. No contact between ultrabasic rock and pegmatite was found.

North side, Tvillingnæs, MR 733478 to MR 739478. In the neighbourhood of the Tvillingnæs building, there are many low glaciated slopes rising gently from the lake to the hills above them. The rock surfaces weather pink and grey and are formed, at MR 733478, of migmatite. The gneiss is medium grained containing microcline, quartz and biotite; much larger prisms of black amphibole are often present and garnets are scattered irregularly through the rock; there is also some muscovite. Narrow close-set bands of granitic material separate bands rich in mafic minerals; horizontal surfaces generally show distinct parallel banding but vertical surfaces often show contorted flow features with the axial planes of the minor folds parallel to the strike direction. Fig. 20 illustrates such a vertical face: the granitic veins, the dark bands and small bodies of dark material are visible. Biotite-rich folia, granitic veins and flat lenticular quartz crystals mark the foliation. The granitic component does not invariably form continuous veins. Frequently, the veins end in blunt tongues against the gneiss and from these wider tongues extend narrower granitic veins separating thin layers of mafic minerals. The alternating dark and light bands may be less than 1 mm in width. The two components of the migmatite

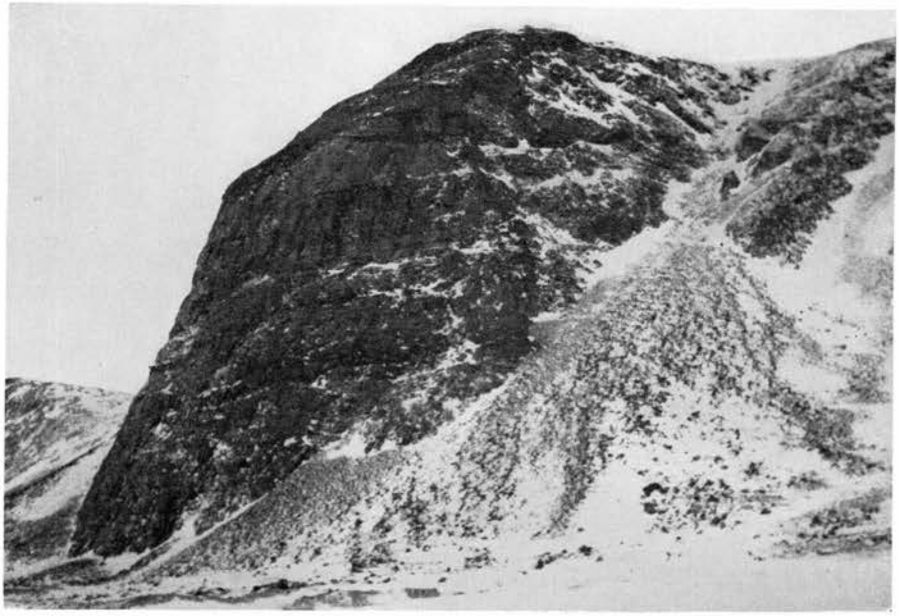

Fig. 21. The north east side of Trekroner viewed from the north. The mountain is capped by garnetiferous amphibolite.

are thus intimately mixed down to the finest scales. One thin band of fine to medium grained biotite and amphibole schists was found containing biotite, amphibole, garnet, quartz and pale grey feldspar. This series grades into highly contorted migmatite, which in turn grades into a 4 metre wide band of massive schist containing garnet, biotite, grey feldspar and quartz.

Passing eastwards from Sælsøen, between Tvillingnæs and Trekroner, is a broad valley containing thick deposits of till which completely cover the bed rock. A network of deep canyons passes through this valley. At one time, the canyons must have carried water from Sælsøen to Dove Bugt but they are now dry. Lakseelven alone now carries the overflow from Sælsøen during the summer. On the north side of the valley there are several glaciated hillocks emerging through the glacial debris below the mountains and they show exposures similar to those described at Tvillingnæs. At MR 739478 there are outcrops of deeply weathered pegmatite with graphic intergrowth between clear quartz and pink feldspar. Another outcrop consists of massive schistose rock with many granitic veins, both concordant and cross-cutting, passing through the schist.

On the south side of this valley, like a sentinel at the east end of Sælsøen, the mountain Trekroner rises steeply from the till and scree (Fig. 21).

Trekroner. The north-east and eastern sides of Trekroner were first examined and then the slopes is the south overlooking Sælsøen.

The north-eastern side of the mountain is shown in Fig. 21. The dark cap of the mountain is composed of coarse grained, massive, garnetiferous amphibolite containing lustrous prisms of greeny-black amphibole and large garnets. The rock at the northern end of the exposure, MR 738473, is a pink granitic gneiss, generally banded, with frequent flow folds. The granitic portions contain microcline, quartz

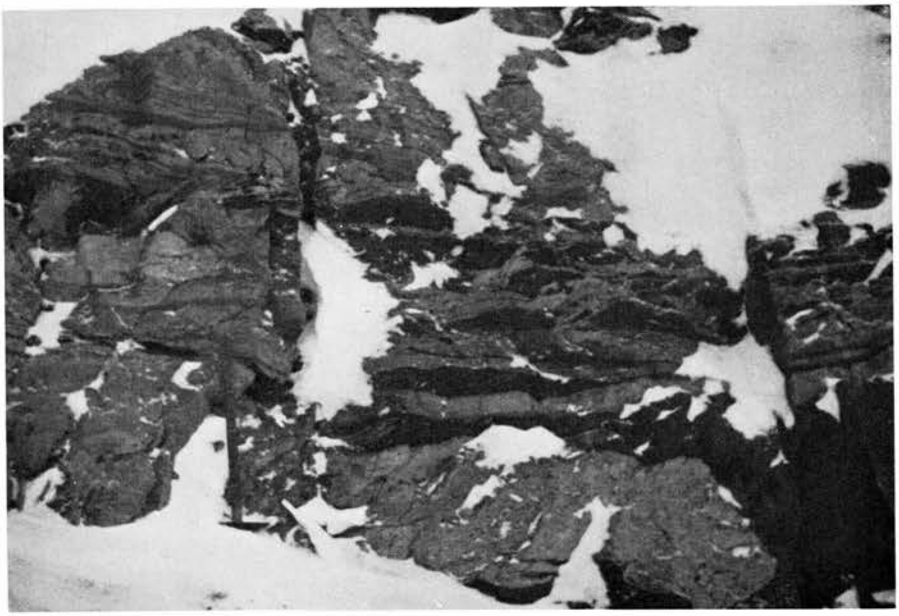

Fig. 22. Bands of granitic rock intruded into amphibolite at Trekroner (MR 740471).

and a few biotite flakes. The darker bands, marking a poor foliation, contain a higher proportion of biotite. A few thin bands consist of trains of amphibole prisms. No garnets were found. Veins of coarse quartzo-feldspathic material are present, without biotite, and these sometimes show ptygmatic folding. Between the granitic gneiss and the amphibolite cap is a variety of injection phenomena with granitic veins cutting and enclosing large and small bodies and lenses of medium grained, very tough amphibolite. Below the amphibolite, the cliff is formed of numerous approximately parallel bands of pink granitic rock, generally almost to the exclusion of the amphibolite. Figs. 22 and 23 illustrate the manner of injection at MR 740471. Thin granitic veins pinch out within amphibolite lenses, broader granitic bands form blunt tongues, and some veins show well-developed pinch and swell within the amphibolite. The granitic material here is clearly injected into the country rock in a manner distinct from the intimate mixing and permeation occurring in the migmatites found elsewhere in Sælsøen.

Schists were examined where they reach to the lake shore on the west side of the mountain, at MR 739464. The most widespread rock is a medium grained garnetiferous amphibole schist, with only a few lighter bands. The black amphibole occurs as equant crystals and the numerous garnets reach 0.5 cms in diameter. No lineation was distinguished. Towards the north, the schists. containing a higher proportion of quartz and plagioclase feldspar, become lighter in colour; the change from darker to lighter rocks is gradational. Garnet is less plentiful in the lighter schists but amphibole is still the most common mafic mineral; most of the lighter schists have rusty staining.

It has been noted that there were few good exposures between Hvalrosodden and Danmarkshavn owing to the nature of the hills and the heavy snow cover of the winter 1953—54 (Fig. 24). Brief visits were made to Nordre Orienteringsø, to Store Snenæs, and to the northern edge of Store Koldewey Ø.

Fig. 23. Bands of granitic rock intruded into amphibolite at Trekroner (MR 740471). Note the development of "pinch and swell' structure.

Nordre Orienteringsø, MR 781428. The rock exposed on the Triangle, the northern promontory of the island, is a contorted gneiss containing a considerable amount of pegmatitic material in veins and irregular bodies. There is also a large area of medium grained, even textured gneiss, composed of quartz, plagioclase feldspar, amphibole and biotite. The rock is dark grey and massive, with no foliation or lineation.

Store Snenæs, MR 798422. Here there are low rounded hillocks—the "moutonneed" form of J. P. Koch—composed of grey feldspathic paragneiss. Bands of biotite schist are separated by thinner bands composed of plagioclase feldspar and quartz. Some schistose bands attain a width of over 20 cms. Garnets are more common and larger in the darker portions. Amphibole prisms occur in the schistose portions.

Store Koldewey Ø, MR 817396 to MR 823395. Schists and gneisses of sedimentary origin outcrop for 2 kilometres across the strike of the rocks on the north side of Store Koldewey Ø. At MR 818395, massive, medium to fine grained, dark grey biotite paragneiss is exposed. The rock is finely banded into light and dark portions. Although the light portions are prominent because they mark the foliation they form only a small proportion of the gneiss. Plagioclase feldspar quartz, biotite, amphibole and garnet were distinguished. The garnets are generally small but they sometimes occur as large lenticles full of inclusions. One such lenticle was 2.5 cms long, and 1 cm wide.

Farther east, at MR 819396, a 4 metre band of light coloured garnet-muscovite-quartz schist was seen, grading into biotite schists. Fairly massive biotite schists are the most common outcrops found between here and the eastern end of the exposure. Black amphibole is plentiful in many places and sometimes the amount

Fig. 24. Approaching Danmarkshavn. The "moutonneed" coastal hills with heavy snow cover offer poor rock exposures.

increases sufficiently to form thin bands of amphibole schist, with subordinate biotite. Garnet is less common than further west. Towards the east end of the exposure, there is a considerable amount of pale pink material along the foliation planes, and a few augen and porphyroblasts of quartz and feldspar are developed.

Lille Koldewey, MR 836398. Only one point on this island was visited and outcrops of dark grey biotite schist were found. In the schist, there are thin segregation bands of quartzo-feldspathic material and a few thin veins of granitic and pegmatitic material, cross cutting and concordant. One narrow band, 30 cms wide, is very rich in actinolite. Garnets are not common in these rocks.

Danmarkshavn and vicinity, MR 844413. The schists and gneisses forming the glaciated hills and low outcrops around Danmarkshavn appear to be dominantly of sedimentary origin. True schists are widespread but in some places the addition of coarse grained granitic veins to the pelitic base has produced composite gneisses.

On the sea shore south of Harefjeld, at MR 838409, biotite schists with many thin quartzo-feldspathic segregation bands alternate with thin amphibole schist bands. Short prisms of black amphibole are often present in the biotite schists and garnets are very plentiful in places. Several dark lenses within the schists, up to 1 metre in length, are very rich in garnet and contain more amphibole than the surrounding schist. A short distance away from the shore dark fine grained schists contain large rounded crystals of pink feldspar and white feldspar (0.5 to 2 cms) and occasionally of quartz. The fine grained schists have poorly developed foliation planes. They enclose lenticles of black amphibole and large garnets up to 2 cms long, containing numerous inclusions. The strike and dip of the rocks in this area are very variable, and the rocks appear to be disturbed. It is possible that there has been faulting but this was not established.

The outcrops at the top of Harefjeld, MR 838413, are smoothed by glacial action and are traversed by polished grooves (15 cms wide and 7 cms deep) indicating the eastward direction of ice movement. The rock is medium grained and massive, with lenses and bands of amphibolite and biotite schist separated by irregular granitic folia. The granitic folia form either thin bands of the order of 1 mm separating pelitic folia of the same thickness, or less regular thicker veins, approximately parallel to the foliation, or small irregular bodies within the gneiss. There are also bands of medium grained eclogite, 1 to 2 metres wide, trending parallel to the foliation of the gneiss and showing gradational contacts with the gneiss. A specimen was not collected from the eclogite but the rock will be discussed in connection with the petrogenesis of ultrabasic rocks found in the area.

Similar gneisses are present on Termometerfjeldet, north of Danmarkshavn. The gneiss is medium grained, with some granitic bands of coarser grain size. It is dark grey in colour but the granitic bands weather pink. The granitic material is distributed more regularly between the pelitic portions than in the gneiss on Harefjeld. There is also less amphibole in these rocks.

The outcrops examined southwards from Danmarkshavn towards Kap Bismarck vary in type between the composite gneiss north of Danmarkshavn and the true schists of Lille Koldewey. Some of the schist bands are notable for their very high proportion of garnets.

Two rock types, differing from anything else found in the traverse, were collected on the low ground immediately to the north of the weather station at Danmarkshavn. Several medium grained bands of dark compact rock, about 1 metre in width, are concordant with and have sharp but gradational junctions with the gneiss. They are not foliated. The band nearest to Danmarkshavn contains bronzite, flakes of brown biotite, small crystals with a brilliant green colour and dull reddish brown garnet. No felsic mineral could be detected.

A little further up the hillside is a similar band, less deeply weathered. It contains a fair proportion of plagioclase feldspar, two green minerals, (the darker being an amphibole), biotite, and garnet of the same dull colour. These dull brownish garnets are distinct from the clear pink garnets found in the gneisses and schists.

IV. SCHISTS AND PARAGNEISSES

Field Relations.

Schists or paragneisses, representing metamorphosed sediments, outcrop along the whole length of the traverse. Most of them have been migmatised to some extent. Outcrops of schist are fewer and more restricted in extent than those of paragneiss. The schists exhibit gradational relations with contiguous schists and the chief mineral components, garnet, biotite, quartz and some amphibole are present in varying proportions. The paragneisses are banded on both a large and a small scale. Foliation planes are marked by micas in broad and narrow bands and frequently also by flat lenticular quartz crystals. Garnet-quartz-biotite-oligoclase paragneisses are the most widely distributed rocks of sedimentary origin and are apparently only slightly migmatised.

Before paragneiss could be distinguished with certainty from orthogneiss chemical and modal analyses would be necessary (Holmes, 1930, p. 435). The interpretation of a gneiss as of sedimentary origin must, in this report, rest upon its field occurrence and its mineralogical composition (by analogy with rocks of known sedimentary origin). It is sometimes difficult, when the granitic and sedimentary components are intimately mixed, to distinguish between paragneisses and some of the migmatised gneisses.

No stratigraphic succession could be established.

Petrography.

No specimens of schist were collected. The specimens of garnet-quartz-biotite-oligoclase-gneiss examined are mineralogically and texturally very similar to each other. There are variations in the proportions of quartz, biotite and oligoclase even within a single specimen. In no section examined was the proportion of biotite greater than 15 %.

Plagioclase feldspar occurs in large and small anhedral plates. Albite twinning is generally developed, often combined with pericline twinning. The twin lamellae sometimes occupy only part of a large crystal and may not be in continuity across it. Some of the crystals have been broken and slightly displaced (shown by displaced albite twin lamellae) and the crack has been healed by untwinned feldspar. Measurement of maximum extinction angles in the symmetrical zone and Becke line tests indicate a mean composition of about Ab_{75}. Andesine was found in one section.

Microcline. A few very small crystals of microcline with cross-hatched twinning are present in some sections.

Quartz invariably shows undulose extinction. Crystals may be large, small granules (frequently with mosaic texture suggesting partial granulation and recrystallisation), or they may appear elongated parallel to the foliation. In the elongated crystals the strain shadows near the position of extinction are parallel to the length of the crystal.

Biotite in shades of yellow and brown, with a green tint in basal sections (β), forms up to 15 % of the rock in some sections. It may form well developed laths concentrated in narrow bands or it may be fairly evenly disseminated through the rock. Pleochroic halos surround zircon inclusions.

Amphibole forms large, ragged plates, pleochroic in shades of green and yellowish brown.

Garnet is constantly present in large and small rounded grains. It is colourless to pale grey in thin section.

A variety of accessory minerals also occurs in the rocks.

Chlorite, generally intergrown with biotite, is sometimes present.

Clinozoisite was found in only two specimens. It occurs as colourless granules with anomolous greenish-yellow interference colours.

Muscovite in small irregular flakes is occasionally present.

Apatite is plentiful in small prisms with rounded outlines.

Zircon is often present in minute prisms with rounded edges.

Iron Ore is often present in small amounts, generally in grains with irregular outlines.

Calcite in small irregular grains was seen in one section.

Petrogenesis.

There can be little doubt that the garnetiferous biotite schists represent metamorphosed argillaceous sediments. Therefore, the thin bands of garnet-amphibole schists grading into the biotite schists have probably developed from impure calcareous sediments. These rocks are practically limited to outcrops at either end of the traverse.

Of more general distribution are the paragneisses. Layers and bands of garnet-quartz-biotite-oligoclase gneiss occur within and between outcrops of migmatite. They exhibit only small variations in mineralogical composition from place to place.

It could be inferred from the mineral assemblages of the gneisses and schists that they should be allocated to the amphibolite facies but the fabric of the gneisses, with long flat lenses of quartz orientated parallel to the foliation, is characteristic of the granulites (of German and Finnish petrologists) which are products of high grade, deep-seated regional metamorphism (TURNER and VERHOOGEN, 1951, p. 473). This fabric indicates that the gneisses belong at least to the upper amphibolite facies if not to the lower granulite facies. It is therefore surprising that neither kyanite or sillimanite was found. HARKER (1950, p. 229) refers to argillaceous sediments which are not rich enough in alumina to yield these most distinctive minerals of the highest metamorphic grade but it is possible that more detailed collecting and mapping would reveal the presence of sillimanite in south Germania Land.

In his study of certain Scottish gneisses HARRY (1953) ascribes oligoclase-biotite-quartz-gneiss and granitic gneisses (rich in microcline) to two aspects of the same metasomatic episode. He suggests that the two rocks were formed by the syntectonic advance along pelitic schists of two metasomatic fronts. "The earlier phase was essentially a Na, Ca, Mg metasomatism forming oligoclase-biotite-quartz gneiss ... this subsidiary front of feldspathisation and, to some small degree, basification was thus driven before a main wave of granitisation which was essentially a silica-potash metasomatism forming granitic gneiss". A different conclusion is reached by ENGEL and ENGEL in their study of the Grenville series of the northwest Adirondacks (1953). The major paragneiss of this region is a quartz-biotite-oligoclase gneiss exhibiting mineral assemblages of the amphibolite facies or higher metamorphic grade. It is either appreciably sillimanite-bearing or garnetiferous and it is widespread and uniform in composition forming thick monotonous zones much injected by granite. ENGEL and ENGEL (p. 1079) consider the possibility that the gneiss is a veinitic migmatite in which K_2O has been leached from the sediment leaving it enriched in Na_2O/K_2O, conceivably to form the potassic, granitic ichor which now forms the migmatising and granitising substances in the gneiss. If the potash-rich granitic ichor were derived from the sediment itself the many quartz-biotite-oligoclase layers become intermediate type rocks, that is, residues of a more felsic antecedent. This assumption has been discarded as untenable in the Adirondacks from considerations of volume relations, compositional features and paragenesis in the gneiss.

After examination and careful appraisal of detailed evidence, ENGEL and ENGEL conclude that either (1) the quartz-biotite oligoclase layers had essentially this composition at deposition, or (2) modifications, such as an increase in soda, were induced as the sediment was deposited or as a diagenetic process through the interaction of sediment and sea waters. The most likely parents are thought to be:— (1) Greywacke type sediments, or tuffs, (2) One of the common clay-weathering products with addition of Na_2O to the clastic particles.

The principal difficulties appear with the necessity to relate the postulated chemical composition of the sediment and its stratigraphical associations. The nearest analogue to the gneiss in terms of composition is greywacke which must be derived with a minimum of chemical weathering, and must be hastily transported and deposited, almost invariably with other sediments which reflect a highly unstable crustal environment (Pettijohn, 1943, p. 956). But thick, persistent uniformly layered marbles and clear quartzites lie stratigraphically above and below the gneiss and seem conformable with it. Moreover, several uniform carbonate zones occur as layers within the gneiss. These relations are best harmonized with the concept that the gneiss is derived from shales or argillaceous sandstones, themselves the product of moderate to intensive residual weathering and good sorting. The presence of greywackes in such an association is incongruous.

Similar difficulties arise when the other suggested parent rocks are considered. The authors conclude that "neither alternative is particularly compelling or more readily demonstrated than the other".

The stratigraphical associations which make the presence of greywacke incongruous in the Adirondacks are not found in Germania Land. Garnet-quartz-biotite-oligoclase gneiss is predominant in Sælsøen area and no quartzite or calc-silicate rocks were discovered. The most likely parent rock of the gneiss (by analogy with the sediments of the Grenville series) is a greywacke. Greywackes are believed to imply a minimum of chemical weathering with rapid erosion, transportation and deposition in an unstable environment. This is in harmony with the suggestion that Germania Land lies near the central folding zone of the East Greenland geosyncline.

Consideration of the probable depositional environment of the rocks, the nature of the associated schists of sedimentary origin, the prevalence of and the constant mineralogical composition of the garnet-quartz-biotite-oligoclase gneiss leads to the hypothesis that the bulk of the original sediment deposited in Sælsøen area was greywacke.

V. GRANITIC GNEISSES AND MIGMATITES

Field Relations.

Four large masses of coarse grained, even textured granitic gneiss in Sælsøen area are massive, pink-weathering, and apparently of uniform composition. A poor foliation is marked by shreds and thin layers of biotite, and by flat quartz crystals. Locally, the foliation is accentuated by a higher proportion of mafic minerals.

At Trekroner (MR 740471), uniform granitic rock is in contact with coarse grained garnet-amphibolite, and sharp junctions exist between the two rocks. On field evidence, previously described and illustrated (Figs. 22 and 23), the intrusive nature of the granitic gneiss here is clearly displayed. The margins of the other granitic masses were not seen but, passing outwards, the centres of uniform granitic rocks are succeeded by migmatites, with granitic and sedimentary components mixed in all proportions and in a variety of ways. The veins of granite may be narrow, and finely interbanded (lit-par-lit) with the sedimentary component; they may be wider, both concordant and cross-cutting veins; or the two components may be so intimately mixed that they can barely be distinguished in the field (permeation gneisses). Augen gneiss is formed when the granitic material forms lenticles (of microcline, quartz or both) set along the foliation planes of the gneiss. The augen are often connected along the foliation planes by thin granitic threads. Gradations exist between the different types of migmatite, and sometimes all the varieties may be seen in a single exposure. The migmatites may be highly contorted. Horizontal exposures usually display a regular alternation of thin granitic bands and bands of sedimentary origin but a vertical exposure often displays highly contorted flow folding (Fig. 20).

Petrography.

(a) *The granitic gneisses* are composed of microcline, quartz and subordinate biotite. Garnet is locally present. Some plagioclase feldspar occurs in all exposures, and at MR 725474 amphibole also is an essential mineral. A brief description follows of the minerals of the granitic gneisses studied in thin section.

Microcline occurs in large and small crystals, with well defined cross-hatched twinning.

Plagioclase feldspar is present in small amounts. Very few crystals have well-developed multiple twinning. Measurement of maximum extinction angles in the symmetrical zone and Becke Line tests indicate a composition near Ab_{80}.

Antiperthite. Irregular blebs of twinned microcline occur in poorly twinned plagioclase feldspar.

Quartz in large and small crystals has undulose extinction. Crystals elongated parallel to the biotite flakes are common, accentuating the foliation.

Biotite crystals are usually well formed and are large in comparison with those of the paragneisses. The pleochroism is yellow to dark brown, and basal (β) sections are dark green. Crystals are often bent or broken. When broken, the fracture has been healed by recrystallised biotite. The crystals sometimes form thin trains passing through the section but when evenly distributed they are still parallel.

Garnet, in small rounded crystals, is distributed in sporadic fashion through the granitic gneisses. It is pink in thin section, contrasting with the colourless garnets of the paragneiss.

Amphibole is present in the granitic rock at the east end of Sælsøen. Both large and small grains have poor crystal outlines. The pleochroism is yellowish green to dark green.

Muscovite, in small flakes, is due to partial sericitisation of microcline, but it also occurs in larger laths. It is sometimes intergrown with biotite.

Apatite and *Zircon* are commonly present as small rounded crystals. Pleochroic halos form around zircon inclusions in biotite.

Iron ore is present as rare, irregular grains and, in some sections, as larger plates associated with garnet.

Myrmekitic intergrowths are common.

(b) *The Migmatites.* All the minerals described in the paragneisses and granitic rocks occur in the migmatites. The biotite has a red tint in some of the migmatites. In thin section it is often possible to distinguish the sedimentary portion (richer in biotite and oligoclase) from the granitic portion (richer in microcline) of the migmatite. Where such distinction can be made the boundaries between the granitic and sedimentary portions are not sharp and the crystals of the two portions are mutually interlocking.

Petrogenesis.

In Sælsøen area, abundant microcline appears to be confined to the granitic gneisses and migmatites. Therefore, it seems a valid inference that the granitic component of the migmatites, containing abundant microcline, was derived either from the granitic masses, or from the same source as the granitic masses. The rocks containing a high proportion of microcline are richer in potash and silica than the garnet-quartz-biotite-oligoclase paragneisss. But detailed field work and petrographical and chemical studies would be necessary before postulating, with any degree of confidence, a mechanism whereby the potash- and silica-rich material was introduced into the metamorphosed sediment. The presence of microcline is not, by itself, a certain criterion for the igneous origin of a gneiss (HARKER, 1950, p. 303).

One of the four centres of granitic gneiss in Sælsøen area (Trekroner, MR 740471) has sharp intrusive contacts with garnet-amphibolite and is bordered by a wide zone of injection gneiss. The intrusive contacts prove that this granitic mass was at least partially liquid at the time of emplacement. The other granitic gneisses are succeeded outwards by migmatites.

No evidence of special significance in relation to the problem of the origin of granite was discovered and it would serve no useful purpose to review the various possibilities here — they are sufficiently well known to all geologists (H. H. READ, 1944 et. al., N. BOWEN, 1947).

The outstanding structural feature of the migmatites is the concordance between the granitic material and the foliation planes of the paragneiss. The detailed way in which the granitic component of the migmatites follows the minor folds suggests that it was highly mobile at the time when major folding movements were in progress. High temperatures during the introduction and movement of material are indicated by the interlocking crystals at the boundaries between granitic and sedimentary portions.

We may conclude that the major folding movements of the Caledonian orogeny in South Germania Land were accompanied by the widespread movement of potash- and silica-rich material, under conditions of high grade dynamothermal metamorphism forming migmatites and large, uniform granitic masses.

VI. BASIC AND ULTRABASIC ROCKS

Field Relations.

(*a*) The only large outcrop of basic rocks is at Trekroner (MR 740471) where coarse grained garnet-amphibolite caps the mountain. No foliation planes were distinguished but its margin is concordant with the foliation planes of the adjacent quartz and mica schist.

The narrow bands of amphibole schist elsewhere associated with outcrops of mica schists are quantitatively unimportant.

(*b*) At Danmarkshavn there is a narrow band of garnet-pyroxene-amphibole-plagioclase gneiss which is concordant and has transitional contacts with the paragneiss.

Five outcrops of ultrabasic rocks were examined and these will be described separately. Their localities are:—

(*c*) The south side of Sælsøen, MR 648480.

(*d*) The north side of Sælsøen, MR 723481.

(*e*) The same location as (d).

(*f*) North of Danmarkshavn, MR 844413.

(*g*) Harefjeld, MR 838413.

The field relations of these rocks have already been described on pages 19, 32, and 38.

Petrography and Mineralogy.

The rocks are described in the order listed above.

(*a*) The garnet-amphibolite at Trekroner is composed of:—

Amphibole	approximately	50 %
Quartz	—	25 %
Plagioclase feldspar	—	15 %
Other minerals	—	10 %

Amphibole occurs in large crystals, pleochroic in shades of green and light brown, containing many rounded inclusions of quartz and less often of feldspar.

Quartz forms large and small crystals with undulose extinction.

Plagioclase feldspar occurs in large anhedral crystals with broad and narrow albite twin lamellae and some pericline twin lamellae. The crystals extinguish unevenly, but from approximate measurements of extinction angles and Becke line tests the mean composition is near Ab_{65}. Rounded quartz grains are enclosed by some of the large feldspar crystals.

Biotite appears as slender laths and very irregular basal plates; pleochroism is from brown to yellow.

Garnet forms large and very small rounded crystals, pale pink in thin section, with inclusions of amphibole and quartz.

Iron ore forms several small grains.

Apatite forms a few small prisms with rounded edges.

(*b*) The garnet-pyroxene-amphibole-plagioclase gneiss at Danmarkshavn is composed of:—

Oligoclase-andesine (about Ab_{70})	approximately	30 %
Clinopyroxene (pale grey green)	—	25 %
Garnet (pale grey)	—	20 %
Amphibole (pleochroic dark to light green) / Biotite (pleochroic dark to light brown)	—	15 %
Quartz / Magnetite	—	10 %

Small rounded crystals of feldspar are enclosed by the clinopyroxene. The amphibole forms irregular crystals and the biotite is nearly always closely related to it and, in several instances, appears to be forming at its expense. The garnets, in large rounded or slightly elongated crystals, are evenly distributed. All the garnets are traversed by well-developed parallel fractures. Between the coloured minerals are set equant crystals of twinned plagioclase with some clear quartz.

(*c*) The ultrabasic rock from MR 648480 is composed of 85—90 % amphibole. The other minerals present are olivine, magnetite and dark green spinel. Optical properties of the amphibole and olivine are:—

Amphibole: (+) $2H\gamma = 89°$, $Z \wedge c = 20°$. Pleochroism is X colourless, Y yellowish-green, Z green.

Olivine: (—) $2V\alpha = 83°$ corresponding to $Fo_{70}Fa_{30}$.

The amphibole occurs as equidimensional crystals containing numerous, small, orientated inclusions of magnetite. Between these crystals there are smaller anhedral olivines, without inclusions, varying in shape from rounded to rectangular. Many of them exhibit incipient alteration to brown serpentine. Rounded magnetite crystals are scattered through the rock and the spinel is present in small, irregular grains.

(*d*) The even textured medium-grained ultrabasic rock from MR 723481 is composed of about 80 % amphibole. The other minerals are clinopyroxene and magnetite. Optical properties of the amphibole and pale clinopyroxene are:—

Amphibole: (+) $2H\gamma = 88°$, $Z \wedge c = 17°$, the pleochroism is X colourless, Y brownish-green, Z yellowish-green.

Clinopyroxene: (+) $2H\gamma = 48°$, $Z \wedge c = 37°$.

Lines and isolated groups of clinopyroxene crystals occur between amphibole crystals. The clinopyroxene contains birefringent inclusions and fine lamellae. The small proportion of magnetite forms irregular grains or small rods orientated parallel to the cleavages of the ferromagnesian minerals.

(*e*) The porphyroblastic ultrabasic rock from MR 723481 contains more than 30 % of large orthopyroxene crystals set in a groundmass of medium-grained amphibole crystals exhibiting decussate structure. Accessory minerals are olivine, deep green spinel and magnetite. Optical properties are:—

Orthopyroxene: (—) $2H\alpha = 78°$. Pleochroism X pale pink, Y grey-green, Z colourless.

Amphibole: (—) $2H\alpha = 83°$, $Z \wedge c = 14°$. Pleochroism X colourless, Y green, Z brownish green.

Olivine: (—) $2V\alpha = 86°$ corresponding to a composition $Fo_{73}Fa_{27}$.

The small rounded olivines often appear similar in form to those in the outcrop at MR 648480. Some of the olivines are fresh, others are pseudomorphed by yellowish-brown serpentine. Green spinel forms large and small irregular crystals and magnetite forms rounded or elongated crystals. Magnetite also occurs as fine dust or small rods crystallographically orientated within the amphibole. The orthopyroxene contains many small hornblende inclusions and around the margins of the porphyroblasts quite large crystals are enclosed.

(*f*) The ultrabasic band just north of Danmarkshavn, MR 844413, is, a bronzitite. Microscopic study reveals the following minerals:—

Bronzite approximately 80 %.

Amphibole (+) $2H\gamma = 79°$. X pale green, Y brown-green, Z dark green. The amphibole is near edenite in composition.

Diopsidic pyroxene (+) 2V large; green.

Garnet, pale grey.

Biotite pleochroism reddish brown to straw yellow.

Magnetite and rutile.

The major part of the rock is composed of crystals of bronzite, with large garnets studded irregularly between them. There is generally an intergrowth of edenite and plagioclase feldspar between the garnets and bronzite forming at the expense of both minerals. Frequently, a small remnant of garnet is present in the centre of the intergrowth but the final stage of the reaction is illustrated by rounded patches of the intergrowth with no garnet remaining. The fingers of plagioclase and edenite respectively extinguish simultaneously. At the margins of the intergrowths, and sometimes within them, edenite forms larger, irregular crystals which may contain small inclusions of bronzite in optical continuity with each other. This confirms that the edenite is replacing bronzite as well as garnet. The green diopsidic pyroxene occurs as rounded crystals between the bronzite and rarely this too is marginally replaced by the edenite-plagioclase intergrowth. A reddish-brown biotite occurs in well-formed laths and irregular plates and, in some instances, appears to be forming from the edenite. Small crystals of magnetite and a few prisms of rutile are scattered through the rock.

The bronzitite and the bronzite separated from it have been analysed. A Frantz isodynamic separator was used for the separation and impurities were removed by handpicking. A clean fraction of bronzite was thus obtained. Optical properties of the bronzite have been determined on the universal stage and by examination of crushed fragments in immersion liquids. The Becke line method was used to determine the refractive indices in sodium light.

$\alpha = 1.674$, $\beta = 1.678$, $\gamma = 1.683$. The probable accuracy is ± 0.002. This corresponds to a composition $En_{83}Fs_{17}$ (Kuno, 1954, p. 40).

(—) $2V\alpha = 77°$. This is the mean of four indirect measurements. The probable accuracy is $\pm 2°$. This corresponds to a composition $En_{80}Fs_{20}$ (Kuno, 1954, p. 40).

Thus, the compositions determined by optical methods agree closely with the chemical analysis ($En_{81}Fs_{19}$, Table III).

Table II. Analysis of Bronzitite.
Analyst: W. H. Herdsman.

	Per cent	*Norm*	*Per cent*
SiO_2	54.26		
Al_2O_3	3.92		
TiO_2	0.12		
Fe_2O_3	1.34		
FeO	10.15		
MnO	0.15	Orthoclase	0.56
MgO	26.34	Albite	3.67
CaO	2.08	Anorthite	8.34
Na_2O	0.46	Diopside	1.54
K_2O	0.13	Hypersthene	82.10
H_2O-	0.09	Olivine	0.62
H_2O+	0.74	Magnetite	1.85
P_2O_5	Traces	Ilmenite	0.30
	99.78		98.98

Table III. Analysis of Bronzite.
Analyst: W. H. Herdsman.

	Per cent	*Formula on the basis of six oxygen atoms*		
SiO_2	55.60			
Al_2O_3	0.63			
TiO_2	Traces	Si^{4+}	1.976	2.00
Fe_2O_3	Nil	Al^{3+}	0.024	
FeO	13.06			
MnO	Traces	Al^{3+}	0.002	2.01
MgO	30.41	Fe^{2+}	0.387	
CaO	Nil	Mg^{2+}	1.621	
H_2O-	0.08			
H_2O+	0.20	The calculated composition of the bronzite is $En_{81}Fs_{19}$.		
	99.98			

(*g*) No specimen was collected from the eclogite at MR 838413. According to Bronner (Boyd, 1948, p. 216) it shows no trace of amphibolization.

Petrogenesis.

(*a*) There is insufficient evidence to decide whether the garnet-amphibolite of Trekroner is a metamorphosed sediment or a metamorphosed igneous rock. The thin bands of garnet-amphibole schists grading into mica schists are metamorphosed impure calcareous sediments (p. 40).

(*b*) The basic gneiss at Danmarkshavn is discussed in relation to the ultrabasic rocks found nearby (see below).

(*c*), (*d*) and (*e*) SØRENSEN (1953) describes ultrabasic rocks from Tovqussaq in west Greenland which are similar in many respects to the examples described above from Sælsøen. They occur as enclosures in amphibolite in precambrian gneisses. He concludes that such rocks are produced in situ by a process of metamorphic differentiation in zones of stress concentration. Evidence from ultrabasic rocks of other precambrian areas is consistent with his hypothesis. The ultrabasic rocks he describes are either enclosed in, or show transitions to amphibolitic rocks, or they are separated from gneiss by pegmatites. An exception is the occurrence of ultrabasic inclusions in the grey hornblende gneiss at Angmagssalik, east Greenland (WAGER, 1934); but here the gneiss also contains bands of amphibolite. The ultrabasic rocks are sometimes schistose and normally have thin reaction rims at their margins.

In Sælsøen area, amphibolite bands are rare and the ultrabasic rocks are not associated in any way with them. Nor were ultrabasic rocks seen in contact with pegmatite, although the outcrop near the east end of Sælsøen (MR 723481) has pegmatites nearby. In two places where a margin to the ultrabasic rocks was found the contact with gneiss was sharp and there was no marginal variation. No foliated ultrabasic rocks were found. These differences from the rocks described by SØRENSEN are recorded but it is not justifiable to consider them as evidence for or against his hypothesis. Much more field work would be necessary before the origin of these ultrabasic rocks could be profitably discussed.

(*b*), (*f*) anf (*g*) There are, in the vicinity of Danmarkshavn, three distinct rock types of similar appearance in the hand specimen and with similar field relations. These similarities are summarized. The rocks are dark, with a variable proportion of garnet. They are normally of intermediate grain size but this varies slightly within the bands which are concordant with the foliation of the gneiss and have transitional contacts with it. Their width is rarely more than one metre and they are not foliated. One of the bands is an "eclogite without trace of amphibolization" (BOYD, 1949, p. 216), another a bronzitite and the third a garnet-pyroxene-amphibole-plagioclase gneiss.

SØRENSEN (1953) ascribes small eclogite bodies to metamorphic differentiation. Others, such as C. F. DAVIDSON (1943), reaffirm the conventional view that eclogites are high grade metamorphosed igneous rocks. BRONNER (BOYD, 1949) considers that the eclogites of Harefjeld "were injected into the country rock with a gradational contact".

The bronzitite of Danmarkshavn is less basic than the rocks from Sælsøen described above. On the basis of silica percentage it is almost an intermediate rock; the norm shows it to be just undersaturated with respect to silica (Table II). Yet many hypersthenites are known as ultrabasic charnockites (Picamuthu, 1953, p. 85) and Sørensen (1953) classifies apparently similar rocks as ultrabasic. Hypersthenites are known in charnockitic rock assemblages but neither the gneisses near Danmarkshavn, nor elsewhere in Germania Land so far as is known, have charnockitic affinities. Thus, the bronzitite cannot be related to a charnockitic suite of rocks. Rocks composed almost exclusively of hypersthene are described by Sørensen (1953, p. 27) and he includes them among the ultrabasic rocks produced by metamorphic differentiation.

The garnet-pyroxene-amphibole plagioclase gneiss bears the imprint of high grade regional metamorphism and retrogressive changes are indicated by the presence of biotite secondary after pyroxene. In contrast, the eclogite is without trace of amphibolization. Though it is not justifiable to discuss hypotheses of origin for these three rocks without further evidence the problem implied by the similar association of the different rocks is an intriguing one, worthy of more detailed research.

Fig. 25. Eastern Schists at Durham Klippe (south Dronning Louise Land).

VII. THE RELATION OF THE GEOLOGY OF GERMANIA LAND TO THE EAST GREENLAND GEOSYNCLINE

In the section "Regional Setting" it was concluded after consideration of the known geology of Kronprins Christian Land, Central East Greenland and Dronning Louise Land that the rocks exposed in Germania Land probably formed part of the central ranges of the Caledonian Mountain chain. The results of the reconnaissance traverse through southern Germania Land corroborate this conclusion. Original sedimentary rocks are now intensely folded and highly metamorphosed with the introduction of potash- and silica-rich material producing areas of gneissic granite and widespread migmatites. These are the rocks we would expect to find in the central parts of a fold mountain chain.

It was also pointed out that Germania Land and Dronning Louise Land together constitute a large land block occupying a central position in the area of North-east Greenland in which our geological knowledge is deficient, and that a traverse from western Dronning Louise Land to eastern Germania Land is longer than any cross section of the Caledonan mountain chain yet investigated. For this reason the geology of Germania Land is considered first in relation to the rocks of Dronning Louise

Land. The conclusions reached by consideration of the geology of this extended traverse will then be compared briefly with the known geology of regions to the north and south.

Relation to Dronning Louise Land.

The rocks of Dronning Louise Land comprise (PEACOCK, 1956a):—

(1) The Western Gneisses: a complex of granitic, augen, and flaser gneisses with subsidiary basic granulitic gneiss. The gneisses, of Archean age, extend in a broad north-south zone through the western half of the area

Fig. 26. Sandstones of the Trekant Series unconformable on the Western Gneisses at Curie Klippe (western Dronning Louise Land).

with prevailing strike of foliation planes N.N.E. — S.S.W. and general dip to the east. Crush belts commonly run parallel to the planar elements of the surrounding gneisses.

(2) The Eastern Schists and Gneisses: a series of rocks of sedimentary origin forming the eastern half of the region. Semipelitic schists are quantitatively the most important, with quartz, biotite, and epidote as

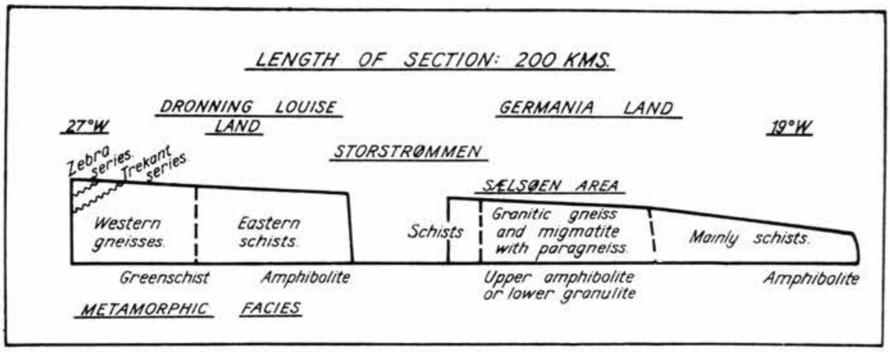

Fig. 27. Diagrammatic section through Dronning Louise Land and south Germania Land (77° N.).

the chief minerals. Limestone is rare. Gneisses may be formed by increase in feldspar content of some of the schists. The structures trend N.N.W. — S.S.E., with constant easterly dip; isoclinal folding is developed (Figs. 25 and 29).

(3) The Trekant Series: a series of quartzites and grits lies with marked unconformity on the Western Gneisses (Fig. 26). In the south they are almost flat-lying but there is strong folding in the north-west. The sediments cap the western mountains and form the outlying nunataks.

(4) The Zebra Series: quartzites and grits, sparingly distributed, lie unconformably on the Trekant Series.

Structures of the sediments trend N.N.E. — S.S.W. with a general dip to the west. Minor intrusions of quartz-dolerite occur in the sediments.

(5) Britannia Sø Series: mainly quartzites whose relations to the other rocks are conjectural.

Fig. 27 is a diagrammatic cross section through Dronning Louise Land and Germania Land showing the general relations of the major rock groups. The Western Gneisses represent the Archean basement which must form the floor of the geosynclinal trough. The sediments of the Trekant and Zebra series (Thule Formation and Greenlandian, Table IV) lie with marked unconformity on these old, predominantly granitic basement rocks bearing testimony to the great time interval between their formation and the deposition of the sediments. The relation between the Eastern Schists and the Western Gneisses has not been established but there is a well-defined line of petrographic discontinuity between the groups. This may be related in part to the evidence of thrusting discussed below. Peacock (1956a) tentatively correlates the Eastern Schists with the quarzitic sandstones of the Zebra Series (Table IV). The metamorphosed sediments of Germania Land also are probably mainly of Greenlandian age but no stratigraphic succession was established.

Regional Metamorphism. There is clear evidence in Dronning Louise Land of increasing metamorphism eastwards. On the basis of mineral paragenesis PEACOCK has divided the rocks into four metamorphic zones (Manuscript). The rocks of the western zone contain minerals formed during an earlier metamorphism of the Western Gneisses. The next zone, in the eastern exposures of the Western Gneisses, illustrates retrogressive effects produced by the metamorphism accompanying the folding of the Eastern Schists, that is, by the Caledonian orogeny. The other two zones in the Eastern Schists represent successive stages of metamorphism, reaching the lower amphibolite facies in the east. Here gneisses may be formed locally by increase in feldspar content. Varieties include grey augen gneiss, white feldspathic gneiss and gneissose pegmatite. A description of these feldspathised rock in northeast Dronning Louise Land has been published (PEACOCK, 1956b).

Eastwards from here for 30 kilometres extends Storstrømmen and the next rocks exposed, at the west end of Sælsøen, are schists not very different in appearance from the Eastern Schists. They differ however in bearing only a very small proportion of clinozoisite in contrast to the abundant epidote of the Eastern Schists, and they also contain thin quartzo-feldspathic bands. The rocks of the Sælsøen area belong to the upper amphibolite facies or lower granulite facies and are therefore of higher metamorphic grade than those of Dronning Louise Land. The evidence of slight granitic activity in some parts of eastern Dronning Louise Land culminates in Sælsøen area with the formation of large masses of granitic gneiss and widespread migmatites. At the eastern end of the traverse, on the north shores of Koldewey Ø and in the vicinity of Danmarkshavn, the schists and gneisses belong to the amphibolite facies and there is no sign here of the crystal fabric which characterises the granulite facies. A few crystals of clinozoisite are preserved in these schists. Granitic gneiss was not found and composite gneisses are rare. Thus these rocks appear to be less strongly metamorphosed than those of Sælsøen area. The paragenesis of the ultrabasic rocks indicates a higher metamorphic grade but there is evidence of retrograde metamorphism in one of them.

The broad picture of this extended traverse, therefore, illustrates increasing regional metamorphism eastwards from the unaltered sediments of western Dronning Louise Land, culminating in Sælsøen area with high grade metamorphism accompanied by widespread granitic activity and migmatisation. Eastwards from Sælsøen the degree of metamorphism apparently wanes and the amount of granitic material

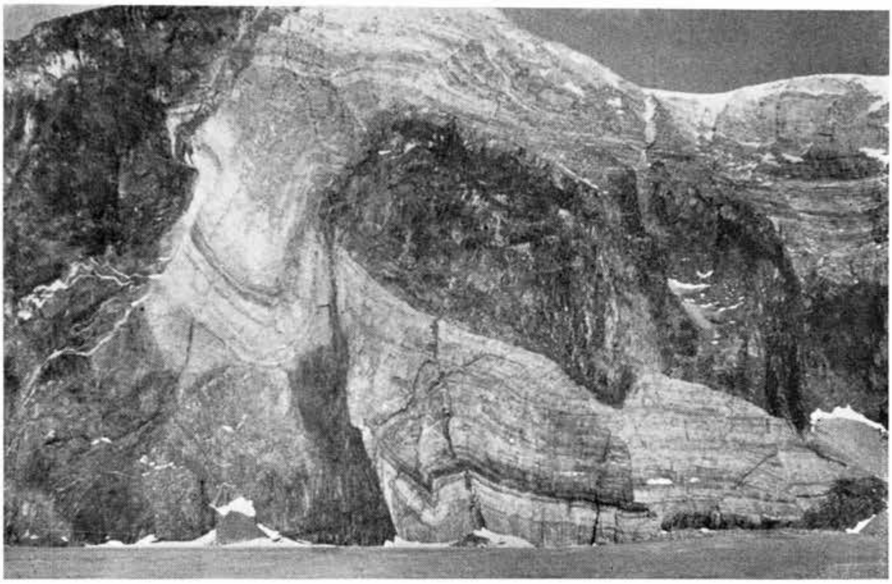

Fig. 28. Competent folding of the Trekant Series at Zebra Klippe (north west Dronning Louise Land). A sill of quartz-dolerite ends abruptly against a fault. Western gneisses are exposed below the sediments in the left of the picture.

decreases. This pattern of metamorphism is certainly an oversimplification of the true conditions. In such a long traverse there must be many minor variations in metamorphic grade (e. g. the outcrop of schists at MR 722482 surrounded by paragneisses and migmatites).

Evidence of retrograde metamorphism also indicates a more complicated metamorphic history than that outlined.

Tectonics. The way in which the rocks have yielded to stress provides some information regarding their position in relation to the main movements of the Caledonian orogeny. The sediments of western Dronning Louise Land are almost flat-lying in the south but in the north they have been folded in a series of open anticlines and synclines with axes trending N. N. E.—S. S. W. The regular form of the folds and evidence of slight dynamic metamorphism indicate that during folding the massive quartzites remained fairly rigid and yielded by shearing (Fig. 28). The isoclinal folds of the Eastern Schists, with axes trending N. N. W.—S. S. E., illustrate deep-seated plastic deformation which is magnificently displayed on some cliffs (Fig. 29). The folds are sometimes overturned towards the west, that is towards the basement rocks of the Western Gneisses. This fact suggests that the sediments have been compressed against the resistant block of old gneisses.

Further evidence of lateral compression towards the west is offerred by the zone of thrusting occurring near the boundary between the Western Gneisses and Eastern Schists in southern Dronning Louise Land. PEACOCK (1956a) describes briefly the outcrop of a thrust of unknown dimensions. The thrust plane, carrying Eastern Schists west-

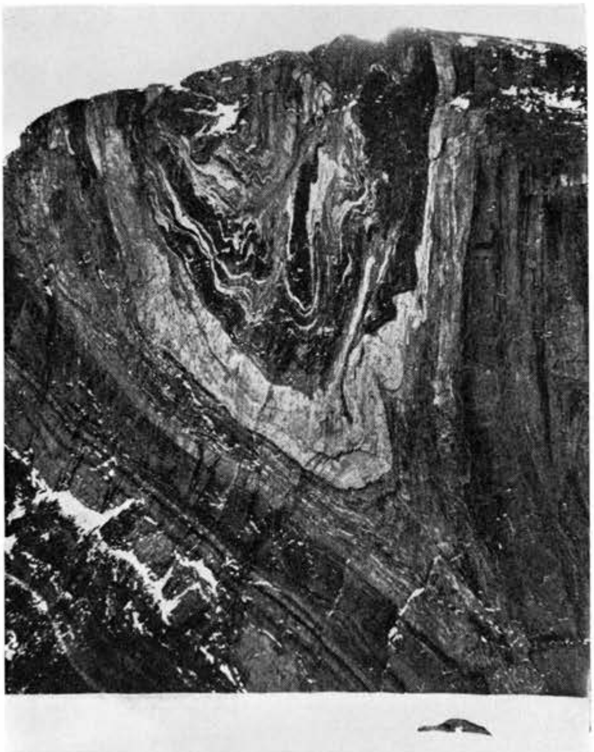

Fig. 29. Plastic folding in the Eastern Schists at Lodlineklippe (south east Dronning Louise Land).

wards, is marked by a thin band of flinty-crush rock. The thrusting must have occurred after the plastic folding at a stage when the rocks had become sufficiently rigid to yield to the horizontal stresses by rupture. Field work completed during the second year, 1953—54, indicates that the single thrust examined forms part of a thrust zone extending approximately N.—S. for at least 25 kilometres. The zone of thrusting is near to the line of petrographic discontinuity between the Gneisses and Schists but is not clearly related to it directly. The discontinuity occupies an ice filled valley and its position has not been located. In the northern half of Dronning Louise Land also the line of petrographic discontinuity follows broad, northerly trending glacier valleys. It might seem valid, therefore, to extend by feature mapping the 25 kilometre-long zone of thrusting established in the south for a further 100 kilometres (following the glacier valleys northwards through Dronning Louise Land) and thus to relate the petrographic discontinuity (following the same valleys) to thrusting. This is not considered justifiable for several reasons. (1) The discontinuity has not been definitely related to the thrust where this was examined. (2) No direct evidence of thrusting has been found in the northern half of Dronning Louise Land. (3) The writer has already shown that the factors controlling the directions of glacier flow in the northern half of Dronning Louise Land are the slope of the highland erosion surface and the regionally developed directions and planes of weakness in the underlying rock structure (LISTER and WYLLIE). The northerly directions of glacier flow correspond closely to the major structural directions determined by plotting average strike directions of the rocks. Thus, the course of the glaciers may be explained without invoking a great northerly extension of the thrust zone. If thrusting is proved to be the cause of the petrographic discontinuity, then the assumption that certain northward flowing glaciers have been eroded along the outcrop of an extended thrust zone may be justified.

The tectonic style of the gneisses of Sælsøen is clearly that of deep seated rocks. No major folds were discovered but the prevalence of small scale flow folding indicates plastic deformation of the rocks.

Flow folding is not common in the schists and gneisses of southeast Germania Land and, on the whole, the rocks here appear to be more rigid in character than the contorted gneisses of the Sælsøen area, but the evidence is scanty.

The different tectonic style of the rocks exposed along the traverse offers some support to the generalised outline of regional metamorphism given above. In the extreme west, where Caledonian regional metamorphism is negligible, the unconformable sediments are folded in a way suggesting that they were not very deeply buried. The plastic deformation of the Eastern Schists, however, indicates deep burial at high temperatures and the contortions and constant flow folding developed in the migmatites of Sælsøen area suggest deformation at even greater depths. This is in harmony with the distribution of metamorphic facies and the extensive development of granitic material in Sælsøen area. It would appear that the rocks of southeast Germania Land originated at smaller depths than those of Sælsøen area.

Sedimentary Environments. Information concerning the depositional environment in different parts of the geosyncline may be obtained from the nature of the original sediments.

The Trekant Series (composed of coloured quartzites and sandstones with rare thin beds of coloured shale) overlies basal breccias, conglomerates and arkoses. That the sandstones are shallow water deposits is proved by the repeated occurrence of current bedding and ripple marks. Exposure to the atmosphere at intervals is indicated by the occurrence of sun cracks in the shaly beds. The basal breccias and arkoses could have been formed in a continental environment and the predominant red colour of the sediments of the Trekant Series indicates that they too must have been exposed to the atmosphere at frequent intervals for long periods. An extensive, 15 metre-wide bed of conglomerate with extremely well rounded pebbles of quartzite and gneiss occurs near the base of the series. Its absence in the northern and southern parts of Dronning Louise Land is a clear illustration of the lateral variation occurring in these sediments. The Zebra Series lies unconformably on the Trekant Series and is composed of sandstones and grits interbedded with thin mudstones. These sediments also are shallow water deposits with recurring current bedding and ripple marks. These facts suggest that the sediments were deposited in shallow shelf seas on a stable platform west of the main trough of the geosyncline. During the long interval of Caledonian sedimentation and mountain building there must have been repeated fluctuations in the positions of the shore lines and in the depths of the seas with frequent exposure of the sediments to the atmosphere. Repeated shifting and reworking in the shallow seas produced the well sorted, cross-bedded and ripple-marked sandstones (cf. PETTIJOHN, 1943, p. 961).

The Eastern Schists are formed predominantly of semipelitic material. Absence of current bedding and ripple marks indicates deeper water here than on the stable platform to the west. Limestones are rare, only two thin bands being found. True quartzites are equally rare. The lack of sharp differentiation into psammitic and pelitic beds suggests rapid deposition and such deposition in deeper water indicates that these sediments were deposited in the subsiding trough of the geosyncline. The Eastern Schists have been tentatively correlated with the Zebra Series as sediments of Greenlandian age (Table IV). Thus the semipelitic schists constitute the Greenlandian geosynclinal facies and the Zebra Series constitute the Greenlandian platform facies.

It has been tentatively concluded that the bulk of the paragneisses in Sælsøen area represent metamorphosed greywackes. Greywackes are typical geosynclinal sediments requiring rapid weathering, transportation and deposition, with poor sorting in an unstable environment (PETTIJOHN, 1953). Limestones are absent also in this area.

In the eastern part of the traverse, as also in restricted areas alongside Sælsøen, there are outcrops of garnetiferous mica schists. These are metamorphosed pelitic sediments. Interbedded with them are thin schists representing metamorphosed impure calcareous and quartzitic sediments but these are quantitatively of minor importance. Such sediments could have been deposited in deeper water further removed from the source of clastic material.

Conclusion. The environments suggested by the original sediments agree, in general outline, with the tectonic style and metamorphic conditions prevailing in different parts of the traverse. The sediments deposited on the platform west of the main trough of the geosyncline have yielded to crustal stresses by competent folding and are unaffected by the regional metamorphism attributed to the Caledonian orogeny. In eastern Dronning Louise Land poorly sorted sediments collecting in a subsiding trough were deeply buried and pressed westwards against the stable Archean rocks of the western foreland (that is, the Greenlandic shield) with the formation of overturned isoclinal folds. The metamorphosed sediments of Sælsøen area are also products of rapid deposition in an unstable environment, confirming that they too were deposited in the subsiding trough of the geosyncline. Here we have the highest degree of metamorphism with introduction and transport of material on a large scale forming the granitic centres and migmatites. This we would expect in the most deeply buried and highly deformed parts of the geosyncline. In the extreme east we have some evidence of decreasing metamorphism and more stable conditions of sedimentation. This area could be either the axis of the geosyncline, furthest removed from the source of sediments, or a stratigraphical level higher than that exposed in Sælsøen area. The geology between this area and Sælsøen is not known well enough to reach any conclusion.

The absence of calcareous rocks throughout the section is striking but not unprecedented. JONES (1938) has noted the absence of significant limestones in the Lower Palaeozoic geosynclinal rocks of Great Britain.

It must be stressed that this conception of a wide subsiding trough, in which sediments from Archean mountains west of Dronning Louise Land accumulated, is very much oversimplified. Within the broad pattern of regional metamorphism there are almost certainly undiscovered variations. The varying depths to which the metamorphosed and folded sediments of the geosyncline have been eroded has not been considered and since rapid deposition doubtless continued throughout Greenlandian and Lower Palaeozoic times this is obviously of importance. It is possible also that deposition continued not in a single subsiding trough but in several different basins resulting from the subsidence of a large segment of the earth's crust (cf. JONES, 1938). Although such possible complications are mentioned they cannot at present be considered seriously in view of the limited evidence available from the reconnaissance traverse.

This attempt to relate metamorphic state and tectonic style to sedimentary environment is intended as no more than a tentative hypothesis.

Relation to Kronprins Christian Land.

In west Kronprins Christian Land arkoses and quartzites of the Thule Formation are penetrated by diabase and porphyrite dykes. Overlying these are dark greywackes, shales, sandstones and tillites of Greenlandian age succeeded by limestones and dolomites of Lower Palaeozoic age. After the deposition of the Thule Formation movements took place forming basins and ridges running more or less north-south. Greenlandian sediments were deposited in these basins and in the "real geosyncline" which lay to the east. During the main Caledonian movements Greenlandian sediments were pressed out of the most easterly of these basins and thrust westwards, forming a great nappe, upon Silurian limestones (FRÄNKL, 1954).

These sediments must have been deposited in shallow shelf seas lying west of the main trough of the geosyncline and they represent a platform facies. During the Caledonian orogeny the sediments were therefore neither greatly affected by vertical movements nor were they metamorphosed.

Table IV. Correlation table.

(PEACOCK, 1956 a).

North Greenland	West Dronning Louise Land	East Dronning Louise Land	East Greenland
Pre-Cambrian			
Greenlandian (in part)	? Zebra Series	Eastern Schists and Gneisses	Eremitdal and Alpefjord Series
Thule Formation	Trekant Series	— —	— —
Archean	Western Gneisses	— —	— —

They were, however, subject to lateral compression producing the overthrust towards the stable western foreland.

The sediments of the Trekant and Zebra Series in Dronning Louise Land have been correlated with the Thule Formation and Greenlandian sediments of Kronprins Christian Land (Table IV). The sedimentary environment in the two regions appears very similar. Although thrusting has not been discovered in the sediments of the platform facies in Dronning Louise Land, compression near the margin of the geosynclinal trough has produced a thrust zone carrying metamorphosed geosynclinal sediments (Eastern Schists) westwards towards the Archean foreland. Compression against the Archean block is also indicated by the overturning towards the west of isoclinal folds in the Eastern Schists.

Relation to Central East Greenland.

In Central East Greenland the oldest rocks exposed belong to the Eleanore Bay Formation and the Archean basement rocks have not been found. The lowest exposed strata are the Alpefjord and Eremitdal Series (Table IV) which show some resemblances to the Eastern Schists of Dronning Louise Land (Peacock, 1956a) and may also be correlated with part of the Greenlandian sediments carried westwards in the thrust nappe of Kronprins Christian Land (Fränkl, 1954). The Alpefjord and Eremitdal Series are mainly pelitic with thin quartzitic and calcareous bands but they show considerable lateral variation and are strongly metamorphosed in many areas. The overlying Quartzite, Multicoloured and Limestone-dolomite Series are more constant in detailed lithology (Fränkl, 1953).

The sediments affected by the Caledonian movements attain a thickness of more than 16,000 metres and since no basement is seen there may be another series of clastic sediments below the Greenlandian (Haller, 1955). A large proportion of the sediments has been transformed through granitisation and migmatisation. The migmatisation of the deeper lying sediments, that is the "mise en place" of the Central Metamorphic Complex represents the main phase of the Caledonian orogeny. The N.—S. fold systems of the sediments produced by vertical movements are closely associated with the migmatisation. Different plastic conditions in the basal migmatitic substratum (infrastructure) and the covering sedimentary series (super-structure) have given rise to large scale disharmonious folding and the rather stiffly folded sedimentary structures are separated from the plastically deformed migmatitic basement by a transitional zone of bottom shearing. The intensity of thermal metamorphism of the covering sediments varies according to local relations to the migmatite front. Continuous transitions westwards and eastwards from the Central Metamorphic Complex lead to the sedimentary parts of the Caledonian structure. Fragments of the sedimentary mantle frequently outcrop along zones of tectonic depression, surrounded by metamorphic and migmatised rocks.

Cross-bedding, ripple marks and sun-cracks occur repeatedly throughout the sedimentary series indicating that the sediments were deposited in shallow water. They are well sorted into pelitic and psammitic strata. Thus the deposits must always have originated near sea level and since the surface remained always on about the same level the substratum had to subside continually to accommodate the great thickness of sediments deposited. For several reasons it must be assumed that these sediments originated in the west (WEGMANN, 1935) and, in order to supply new sediments, the mountains beyond the western foreland must have been rising while the trough was subsiding.

In Central East Greenland there is exposed a wide section across the central folding zones of the Caledonian orogeny. The western foreland of the geosyncline lies west of the outlying nunataks and shelf sea deposits (the platform facies of Dronning Louise Land) are not found. The lowest exposed strata are mainly pelitic and probably correspond in part to the geosynclinal facies of Dronning Louise Land and the Sælsøen area. The succeeding strata are mainly well-sorted shallow water sediments and therefore cannot be considered as belonging to a normal geosynclinal facies of sedimentation. The migmatitic infrastructure may correspond to the migmatised rocks of the Sælsøen area but no trace of a covering sedimentary series (the shallow water deposits of the superstructure) was found in Germania Land. This may be due to different conditions of sedimentation in these widely spaced parts of the geosyncline, or it may be due to deeper erosion in Germania Land so that the sedimentary cover here has been removed.

Conclusion.

The conception of the East Greenland geosyncline obtained from the results of the extended traverse from western Dronning Louise Land to eastern Germania Land may thus be related successfully, in broad outline if not in detail, to the western foreland of the geosyncline in Kronprins Christian Land and to the central folding zones of Central East Greenland.

(1) The western foreland of the geosyncline passes southwards from Kronprins Christian Land, along the western borders of Dronning Louise Land and to the west of the nunatak zone of Central East Greenland.

(2) The central folding zone of the Caledonian mountain chain passes northwards from the Central Metamorphic Complex of Central East Greenland, through the Sælsøen area of south Germania Land and to the east of Kronprins Christian Land. FRÄNKL (1954) believes that the central folding zones of the Caledonian mountain chain lie to the east of Germania Land but the results of this geological reconnaissance confirm rather the original conclusions of LAUGE KOCH (1929, p. 286).

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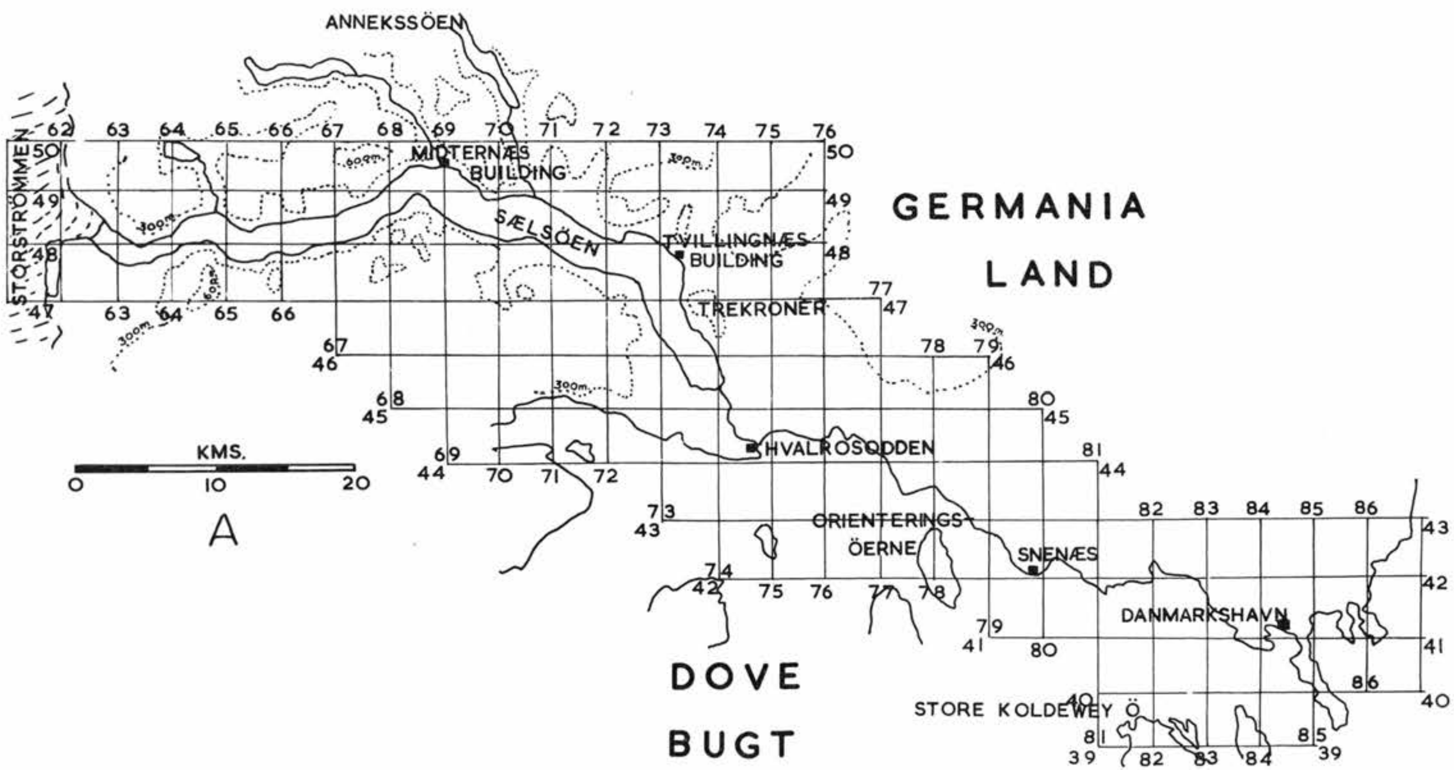
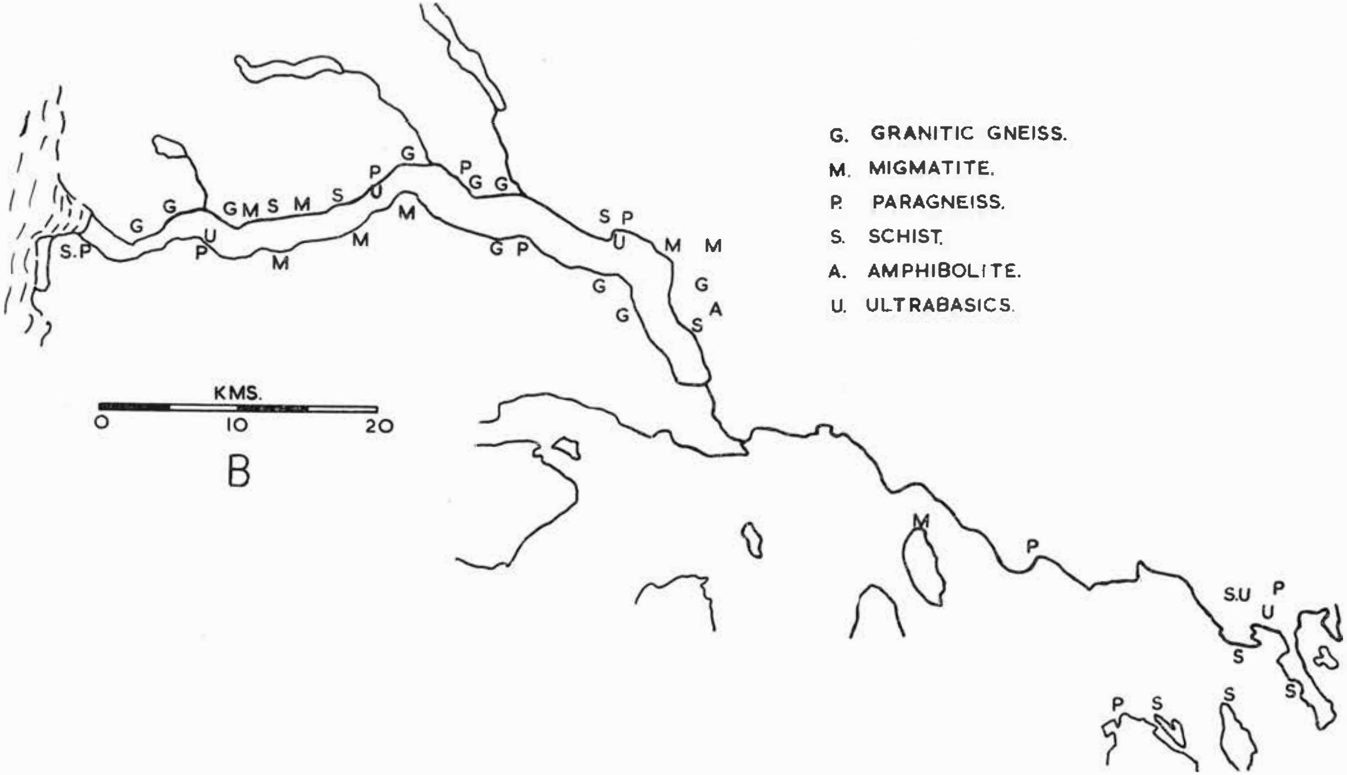
Færdig fra trykkeriet den 26. april 1957.

PLATES



Map of South Germania Land with four-kilometre grid.

MEDD. OM GRØNL. BD. 157. NR. 1. [P. J. WYLLIE].



Map of south Germania Land giving distribution of major rock types.