A Petrographical and Structural Study of the Rocks Around the Peridotite at Engenbræ, Holandsfjord, Northern Norway.

By

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With 13 text-figures.

Abstract. This study is a continuation of the work carried out by S. Skjeseth and the writer in 1952 (see 5). The present paper only deals with an extremely well-exposed surface 1 km square in front of the retreating Engenbræ glacier.

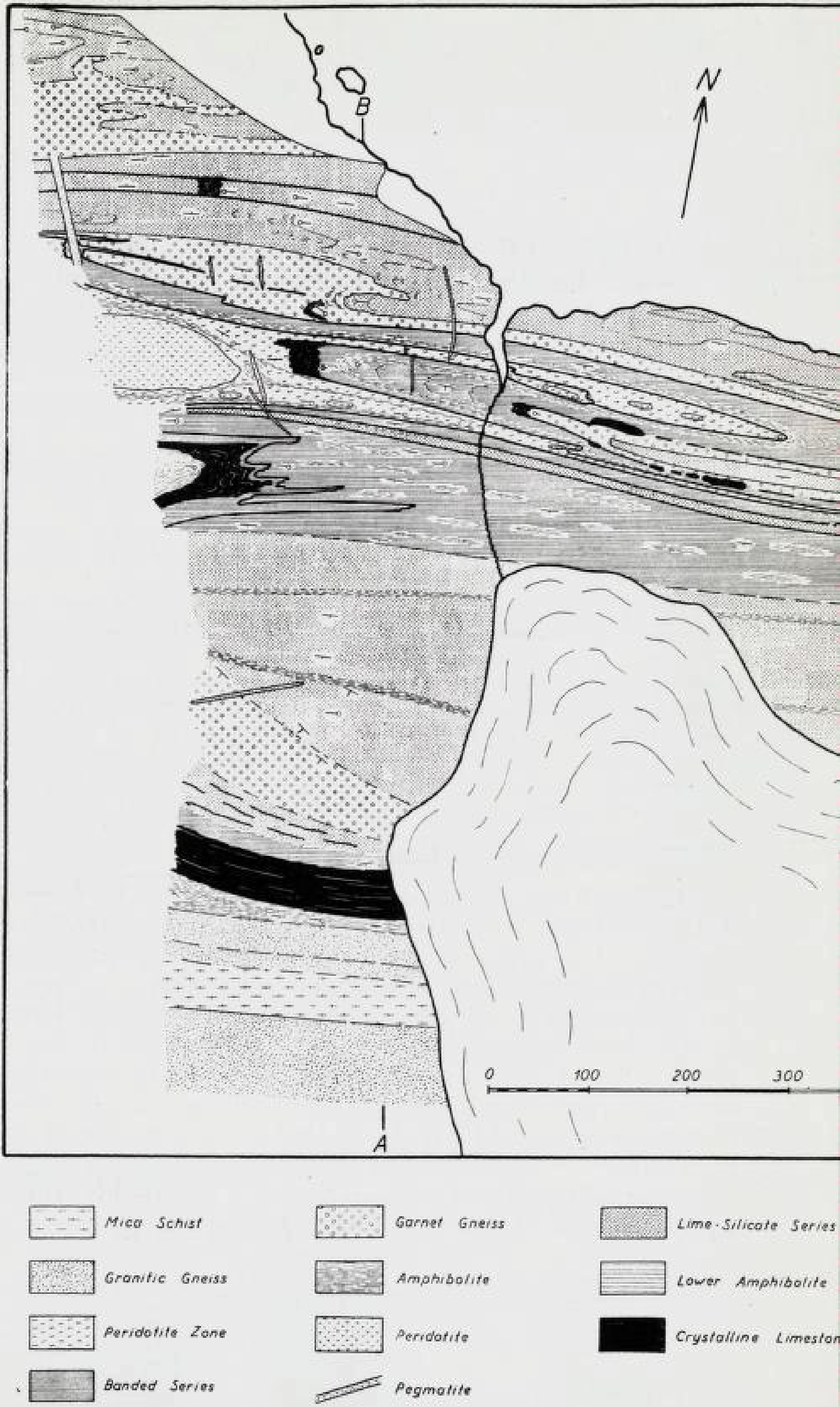
This surface is built up of a series of para-sediments metamorphosed under amphibolite facies conditions. The main components are: amphibolites (often with diopside and garnet), sillimanite-mica schists, lime-silicate gneisses, skarn, and crystalline limestone. The folding is intense with narrow and deep folds.

A mass of peridotite is situated in a banded series lying between an upper series of mica schists (granite) and a lower series of calcareous rocks. It is shown that the peridotite was emplaced at an early stage of the folding in a zone of strong deformation and that this mass has much disturbed the surroundings during subsequent phases of folding because of its greater rigidity.

Introduction.

In 1952 I took part in the detailed examination of the graphite at Renndalsviken, Holandsfjord in Northern Norway which was carried out by the Norwegian Geological Survey. As one of the results of this work a short description of the geology of the region was published by S. Skjeseth and the writer (5). In 1952 I had, through the kindness of Mr. S. Føyn, Director of the Geological Survey of Norway (NGU), the opportunity of studying the remarkably well-exposed outcrop in front of the retreating Engenbræ glacier, but having no topographical maps I could not at that time complete the examination.

After the return from Northern Norway it was possible to make a preliminary map based on air photographs and in the summer of


N
B
A
0
100
200
300
Mica Schist
Granitic Gneiss
Peridotite Zone
Banded Series
Garnet Gneiss
Amphibolite
Peridotite
Pegmatite
Lime-Silicate Series
Lower Amphibolite
Crystalline Limeston

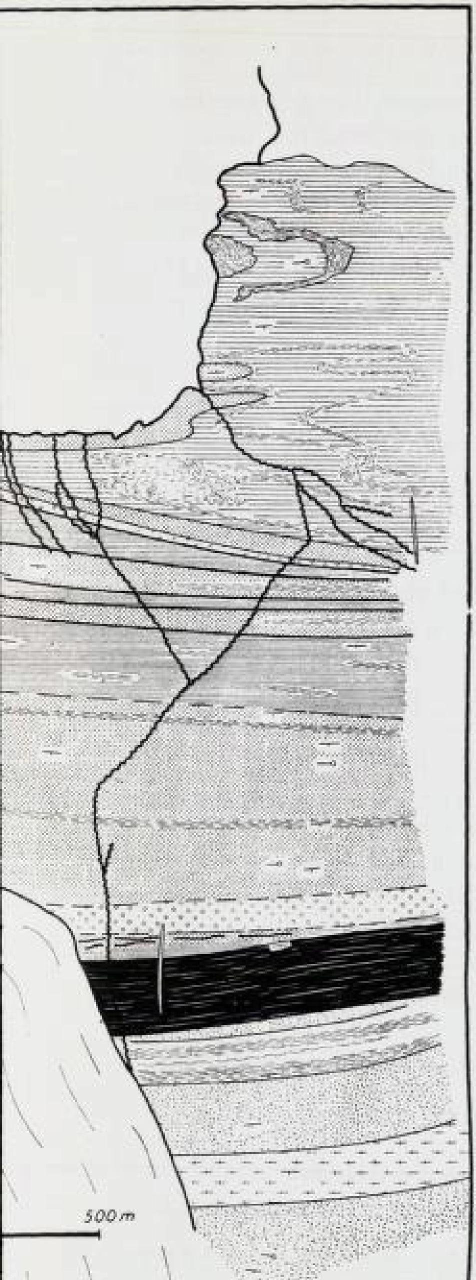


Fig. 1. Map of the Engenbræ Area based on air photographs.

Geologisk kort over området tegnet på grundlag af luftfotografier.

1954 I went to Engenbræ again supported by a grant from the University of Copenhagen in order to complete the work.

I wish to express my gratitude to Director Føyn and to state geologist S. Skjeseth for much kind help, to my friends at Holandsfjord, especially the Dahl family at Fondal and Mr. O. Solhaug at Renndalsviken for hospitality and invaluable support, and to the University of Copenhagen for the grant which enabled me to go to Northern Norway in 1954.

Thanks are also due to Mr. Knut Dahl for valuable help in the field and for the photo fig. 2, to Miss Ragna Hansen for drawing the map and to Mr. P. Padget, M.Sc. for kindly correcting the English of the manuscript.

General Geology.

The geology of the region has already been described by S. Skjeseth and the writer (5). The present study only deals with the limited area in front of the Engenbræ glacier. The location of this area may be seen on the maps in (5, fig. 2) and in (4).

In order to place the Engenbræ area in the geological structure of the region reference will be made to the sections in Fondal (the valley immediately to the west of Engenbræ (cf. 5, page 156). In the south in Fondal is a fairly complex anticline the Fondal anticline, which to the north is followed by a synclinorium in the granite mountains Kløfttind and Middagstind. Then follows a zone of complex deep folding in Stortind and Rødtind with the graphite anticlinorium most northerly.

At Engenbræ the eastern continuation of the Fondal anticline occurs to the south; then towards the north the granite syncline, and furthest north the eastern continuation of the amphibolite and peridotite zone from Stortind and Rødtind.

The Surface in Front of the Glacier.

A few years ago the glacier almost reached the fiord (cf. plate VII, in (4)) but during the last decades it has retreated very rapidly so that a small lake and a surface about 1 square km are now exposed in front of the glacier (fig. 2). Thus seen from a glaciological point of view there is in front of the glacier first the rock surface on which the glacier rests, then the depression with the lake excavated by the

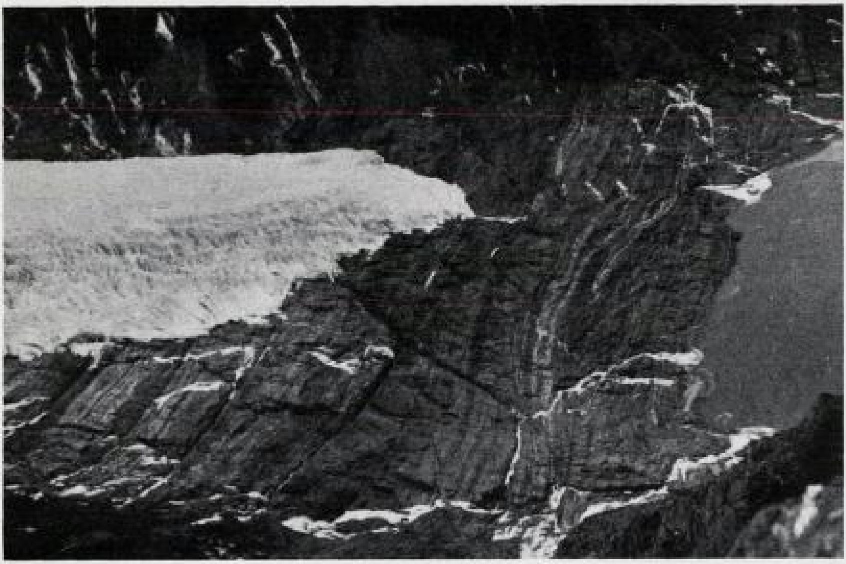


Fig. 2. The surface in front of Engenbræ seen from the mountains to the east. Note that the layers run across the surface from side to side on the left while there are closures to the right. Top right, closure of the marble and just above it the peridotite. One of the synclines of the peridotite zone is seen centre right, just left of the outflow of the river. (Knut Dahl phot.)

Den iseroderede flade foran Engenbræ set fra fjeldene øst for. I venstre side af billedet løber lagene tværs over fladen fra side til side, i højre side ses lukninger af folderne. Øverst tilhøjre lukning i marmor og oven for den igen peridotiten. Den nordligste af synklinalerne i peridotitzonen ses til højre i billedet, til venstre for gletscherelvens udløb. (Knut Dahl phot.)

ice, and in front of this again the moraines often built up of huge boulders.

The surface offers excellent opportunities for the study of the rocks and of the structures since it is not yet covered by vegetation. Apart from the numerous glacial striations the only traces left by the glacier are a few boulders and pebbles. In places, especially near the lake, crevaces and hollows may be covered by sand.

The surface in front of the glacier is built op of a rock complex comprising amphibolites, lime-silicate gneisses, mica-schists, crystalline limestones, skarn, peridotite, and several types of strongly deformed rocks. The folding is very intense.

The central part of the surface is the eastern continuation of the amphibolite-peridotite zone from Stortind and Rødtind and this zone also has amphibolite and peridotite here, although a garnet-biotite gneiss is the most prominent rock. A fairly large mass of peridotite is found in the most western part of the area under consideration and this is undoubtedly the continuation of the peridotite from Rødtind. Towards the east several smaller ultrabasic masses are found in two narrow synclines occupied by the above-mentioned garnet-biotite gneiss. These two synclines converge at the large peridotite and the anticline thereby formed is dominated by two closures with concentrations of marble, the layers of marble surrounding the peridotite zone being especially thick towards the hinges of the folds (fig. 3). Locally there is a change in direction of plunge of the fold axes in this zone so that the anticline may be changed to a syncline with steep axes of folding.

The area north of the peridotite zone is, towards the west, made up of lime-silicate gneisses with intercalated beds of sillimanite gneiss, crystalline limestone, and strongly deformed rocks. The eastern part of this area has folded bands of amphibolite in a matrix of deformed lime-silicate gneiss.

South of the peridotite zone there is to the west a syncline with limestone; towards the east occurs a banded series of lime-silicate gneisses, more or less granitized, with layers of mica-schists and amphibolites.

South of this follows another lime-silicate series and then a thick layer of limestone which is separated from the granitic gneiss of the granite synclinorium by an amphibolite-banded series.

Stratigraphy and Petrography.

In the previous paper (5, page 163) the following stratigraphical succession from the Fondal anticline was described from bottom upwards: micaschists, lime-silicate gneiss with amphibolite, banded series of lime-silicate gneiss with thin layers of sillimanite gneiss, then limestone, lime-silicate gneiss with bands of amphibolite, mica schist with bands of amphibolite, mica schist, graphite schist, quartzite and mica schists. The upper part of the series was granitized.

A corresponding series is found at Engenbræ, although a part of the sequence is lacking there. We have from bottom upwards:

lower amphibolite series,
lime-silicate series,
garnet gneiss,
lower crystalline limestone,
banded series,
upper crystalline limestone,
amphibolite-banded series (peridotite),
granitic gneiss and mica schists.

In the following pages the rocks will be described in this order.

Lower Amphibolite Series.

This series is best studied in the north-eastern part of the area. The main rock is a garnet-biotite rock rich in quartz veins. It has layers of calcareous origin such as crystalline limestone, lime-silicate gneiss, and also more quartzitic beds and spotted layers with sillimanite. In this garnet gneiss strongly folded bands of a diopside-bearing garnet amphibolite occur. The amphibolite has thin folded layers of limestone and of diopside skarn. The latter are often broken (with cross joints) where folded (fig. 4). Small thin layers of «outrolled» garnet may be present.

The style of folding of the amphibolite closely resembles that of the enclosing lime-silicate gneiss, leaving little doubt as to the origin of the amphibolite. There is a gradual transition from the amphibolite to the garnet gneiss. The latter is identical with the garnet gneiss which encloses the amphibolite in the core of the Fondal anticline.

The garnet gneiss (no. 49c) consists of a brown biotite in parallel flakes, quartz, plagioclase (28 % anorthite) and ore. Garnet is present in scattered grains. In some horizons the gneiss resembles closely the lime-silicate rocks which will be described in detail from higher levels of the series.

The matrix of the amphibolite (no. 49b) consists of parallel, somewhat corroded prismae of a dark green hornblende; in addition quartz, a zonal plagioclase (about 35 % anorthite), and calcite occur. Accessories are ore, sphene, and apatite. Biotite may be present. Garnet is found in scattered grains and so is diopside in some parts of the rock. Diopside may, as mentioned above, also occur in true layers.

As an example of the skarn varieties of the amphibolite sample no. 49a may be mentioned. It is a rock with large green prismae of hornblende with inclusions of sphene and intergrown by scapolite and brownish-red biotite. The hornblende may be bleached against the scapolite. Diopside occurs in large, somewhat uralitized grains. In some parts of the rock calcite and biotite are present in a considerable amount. The hornblende is glomeroblastic.

The Lime-Silicate Series.

Above the amphibolite follows a layer of lime-silicate gneiss with a bed of limestone, then a sillimanite-bearing mica-gneiss, then a banded complex with thin layers of garnet amphibolite, sillimanite gneiss, limestone and a white muscovite quartzite, and then the predominant rock of this horizon, namely, a layer of lime-silicate gneiss. Because of the pinch and swell structure of this series the thickness of the individual beds varies from place to place; some layers may in places be totally lacking. It has therefore not been possible to establish the stratigraphical sequence with certainty and there will be made no attempt here to subdivide the upper layer of the lime-silicate gneiss by means of the intercalated beds of other rocks.

The main rocks of this series will be described below:

Lime-silicate gneiss. This is a light-gray, medium-grained rock which has thin, dark layers rich in biotite, thin layers of pure calcite, and thin layers of pure quartz. There are very often rusty-coloured layers of two types. The one is a sillimanite-bearing mica schists, the other is a graphite- and ore-bearing quartzite.

The structure of this rock is very similar to that of the less metamorphosed marly rocks of the Trondheim area further south which I saw when visiting Professor H. Ramberg at Åsenfiord in 1954. At Åsenfiord these rocks are deformed by «slip folding», that is by lamellar gliding so that the thin sandy- and limy layers are folded. A strong secondary schistosity is developed along the slip planes. At Engenbræ the deformation has progressed a stage further (the metamorphism is correspondingly more pronounced) and the secondary schistosity has been folded (fig. 5).

The following minerals are almost always present in these rocks: diopside, hornblende, biotite, sphene, quartz, plagioclase, microcline and calcite. Some of the rocks may have large porphyroblasts of

Fig. 3. The peridotite zone seen from the peridotite towards the east. Foreground: closure in marble. Centre: Northern syncline of the peridotite zone with larger ultrabasic mass (black). Centre right: easternmost closure in limestone and to the right the southern syncline. Top left: folds in lower amphibolite.

Peridotitzonen set fra peridotiten mod øst. I forgrunden lukning i marmor, i midten fra venstre til højre: nordlige peridotitsynklinal med sort ultrabasisk masse, i midten lukning i kalksten og til højre sydlige synklinal. Øverst til venstre folder i nedre amfibolit serie.

Fig. 4. Lower amphibolite in the north-eastern part of the area. Amphibolite in garnet gneiss. At the hammer: folded and broken layer of diopside.

Nedre amfibolit fra den nordøstlige del af området indesluttet i granatgnejs. Ved hammeren ses et foldet og sønderbrudt diopsid lag.

Fig. 5. Anticline in lime-silicate gneiss. The northwestern part of the area.

Antiklinal i kalksilikatgnejs i den nordvestlige del af området.

garnet and irregular grains of scapolite. Epidote minerals are very rare. Accessories are: apatite, graphite, zircon and ore.

The diopside is often found in fairly large grains which may be very fresh, but it is generally present in smaller corroded and uralitized grains intergrown by plagioclase and biotite. It may be glomeroblastic.

Hornblende is often associated with diopside as an alteration product of the latter, but it may be present in independent grains as well. It is normally of a faint green colour in thin section, but may occasionally be of a dark green colour as in the amphibolites.

Biotite (brown) is present in most rocks, but may be confined to the dark layers. In accordance with the terminology of V. M. Goldschmidt (1, page 8) these rocks should properly be termed lime-mica schists. The biotite has pleochroic haloes around small inclusions of zircon and it may be intergrown with secondary chlorite.

The biotite is present in small parallel flakes, often bent, and the schistosity thereby produced often cuts the linear arrangement of the diopside, indicating two periods of deformation. The biotite is most probably associated with the secondary cleavages mentioned above.

Sphene is invariably present, locally in a considerable amount in fairly large, irregular grains, but most often in small corroded grains. It may be twinned.

Quartz is the most prominent salic mineral and it may form layers of large irregular grains with wavy extinction. It is also a component of the groundmass of the rocks and represents most probably their original SiO_2.

Conformable replacement quartz veins are common in some horizons. The veins are associated with the secondary schistosity and may have parallel stripes of biotite. They may be folded where present in the closures of the folds.

Plagioclase may occur in large grains. The composition has (by means of the universal stage) been found to vary from rock to rock. An anorthite content of 30 to 40 % seems to be normal (as in no. 1—18/7), but values as high as 65—70 % have also been found (e.g. in no. 1—21/7). Twinning according to the pericline-, albite-, and complex albite-ala laws has been noted. The twinning may be irregular with lamellae wedging out. Inverse zonal structure has been seen.

Microcline is present in most rocks.

Calcite is present, in part in coarse-grained layers, in part in small interstitial grains between the silicate minerals.

Garnet is found in many rocks, most often as diablastic grains in aureoles of quartz and plagioclase and surrounded by the biotite.

Scapolite is present in some rocks and seems always to be of a replacing nature growing at the expense of the other Ca-minerals.

Tourmaline may occasionally be present.

The lime-silicate rocks are often granitized in the southern part of the area with the formation of a bluish-grey gneiss with quartz, plagioclas and biotite as the main components.

Mica-schist. The spotted mica schists are identical with the ones mentioned in (5). They are rusty coloured rocks occurring in thin layers and they have most often a well developed schistosity because of the parallel arrangement of the flakes of biotite. There are no traces of the zig-zag folding described in (5). This rock type is of the same appearance in all members of the stratigraphical sequence mentioned on page 77 and the following description is therefore valid for mica schists of all horizons.

The rocks are medium-grained with more coarse-grained layers (often rich in quartz).

The components are: quartz, plagioclase, (microcline), biotite, (muscovite), sillimanite and perhaps cordierite. Garnet and kyanite may be present. The accessories are: graphite, apatite, ore, tourmaline and zircon.

The great amount of quartz indicate that the original rocks were rich in sandy material. The quartz has undulatory extinction.

The plagioclase has alternating broad and narrow twin lamellae (the pericline and albite laws have been observed) and the anorthite content is about 30 %.

The potassium feldspar is only found in insignificant amounts when present.

The biotite is brown and forms thin layers made up of small irregular flakes (often bent). It may have inclusions of zircon and is more or less altered into chlorite with a simultaneous separation of tiny black needles.

Muscovite is found partly as independent flakes, which may be remnants of former layers of muscovite, partly as transformation products of sillimanite.

Sillimanite is most often found in aggregates of small thin fibres, more rarely in independent small grains. It is separated from the surroundings by muscovite (cf. 5, page 163). In some rocks large irregular grains of kyanite are present, in others it occurs as inclusions in muscovite.

Garnet in diablastic grains may be an important constituent of these rocks, but is most prominent in the rocks poor in sillimanite.

Cordierite has not been identified with certainty.

The examined specimens are: no. 2—21/7 from the lime-silicate series and nos. 4—15/7a and 8—14/7a from the banded series.

Where granitized the mica schists are very rich in biotite and occasionally also in garnet; sillimanite and muscovite have disappeared.

Ore-graphite-quartzite. These rocks also occur in thin rusty-coloured layers and consist of quartz, a little plagioclase, biotite, muscovite, chlorite, graphite, ore and apatite. The rocks are fairly dense. (no. 3—20/7).

Limestone. Specimen no. 1—21/7 was taken in the middle of the anticline in the lime-silicate series in the north-western part of the area in the north limb of the limestone anticline indicated on the map. North of the limestone there is a transition zone to the lime-silicate gneiss. The border rock is white and quartzitic and will be described below. Locally there is a development of diopside skarn in the border.

The limestone (no. 1—21/7) is fine-grained and banded. It has patches of lime-silicate minerals, namely quartz, plagioclase, diopside, biotite, microcline, sphene, apatite and ore. It is rich in mica in some layers.

The white border rock is fine-grained with quartz and a colourless mica as the most important constituents, microcline, plagioclase and ore are found in minor amounts. Towards the lime-silicate rock there is a coarsening of grain size and biotite appears. This rock forms the western continuation of the anticline and is prominent in its closure. It also plays an important rôle in the central part of the narrow anticline east of the peridotite.

The southern limb of the limestone is rich in silicate minerals. It is somewhat deformed by flow (5, plate III, fig. 4).

No. 5—19/7 is another limestone from this series and was collected in the south-eastern part of the area. It is an example of a limestone with zones of crushed calcite. The twin lamellae of the larger grains of calcite are bent. Larger rounded grains of plagioclase and quartz occur in the calcitic matrix. Accessories are graphite, sphene, biotite, ore and apatite.

Strongly deformed zones. In the north western part of the area there are some zones consisting of a great number of strongly deformed rocks. Their exact stratigraphical position has not yet been established, but they most probably belong to the lime-silicate series and may correspond to the limestone series mentioned above. The rock components are: quartzite, banded limestone with folded and broken (boudined) layers of silicate minerals, thin bands of amphibolite which may be rich in garnet in their central parts, rusty zones (quartzitic as well as mica schists), and less well defined rock types. The origin of these zones is still problematic. Some parts of them might be interpreted as highly deformed conglomerates, but the writer is more inclined to regard them as being formed from limestones subjected to strong dynamic metamorphism. This view is supported by the behaviour of the limestones of these zones which clearly show a tendency to wedging out by flow leaving contorted bands of silicate minerals behind. A comparison of (5), plate III, fig. 4. and fig. 6 of the present paper may illustrate this similarity in deformation.

These zones contain skarn rocks as for instance no. 1—22/7 which is a diopsidic mass made up of large grains of diopside penetrated by hornblende, biotite, plagioclase and quartz. They are uralitized along the margins and may be crowded with fibrous alteration products, probably a colourless amphibole.

The plagioclase has irregular extinction and irregular twinning (the complex albite-ala law has been observed). The anorthite content is about 70 %.

The groundmass consists of a seriticized plagioclase, biotite, amphibole, calcite, scapolite and quartz. Here as in so many other rocks of the area the schistosity produced by the parallel arrangement of the flakes of mica cuts the linear arrangement of the diopside.

The Garnet Gneiss.

This is a sort of a mixture between lime-silicate gneisses and mica schists and it follows above the lime-silicate series. That is to say it is not present everywhere where one should expect to find it when regarding its place in the stratigraphy. The reason is that the rock shows a pronounced tendency to mechanical thinning and disappearance as it may be seen when following it along the strike direction across the area in question and it has not been found in the northern limb of the southern anticline.

Under the microscope the rock is seen to consist of quartz, plagioclase, biotite, amphibole, diopside (in part in large grains), garnet in rolled diablastic grains (with inclusions of quartz and surrounded by biotite), calcite, apatite, rutile, tourmaline, and ore. Some rocks like no. 2—20/7 have highly altered remnants of an unidentified mineral. In 6—15/7 the anorthite content of the plagioclase was determined to be 40 %. Muscovite is occasionally present.

Lower Limestone Horizon.

The layer of limestone overlying the garnet gneiss resembles the latter in its mechanical thickening and disappearance along the strike, which is seen especially well in the central part of the anticline east of the peridotite. There is there an alternation of disappearance and swelling and in places all carbonate material may have gone leaving white lumps of skarn behind.

The limestone (no. 1—25/7) is banded with alternating beds of calcite and white silicate minerals. These bands are broken and folded in a very intricate way (fig. 7) and it is the latter which mark the former site of the limestone where all the calcite has flowed away.

The calcite may occur in almost polygonal grains without translation lamellae, but lamellation also occurs.

The silicates are: diopside, amphibole, mica (all colourless), quartz, and plagioclase. The silicate bands are fine-grained showing traces of cataclasis.

The skarn (no. 53) consists of a colourless diopside, of small colourless fibres of amphibole, and a small amount of plagioclase, calcite and apatite.

The Banded Series.

The series overlying the limestone described above consists of lime-silicate gneisses (often highly deformed so that they appear as garnet gneiss), spotted mica-schists (fig. 9) and amphibolite in bands with or without garnet (the amphibolite bands appear to be most numerous in the upper part of the series), rusty zones, and skarn adjacent to the limestones at the base and at the top of the series.

Fig. 6. Strongly deformed zone in lime-silicate gneiss close to the anticline of fig. 5.
Stærkt deformeret zone i kalksilikatgnejs nær antiklinalen i fig. 5.

Fig. 7. Lower Limestone with layers of silicates. North of the peridotite.
Nedre kalksten med foldede silikatlag. Vestlige del af området nord for peridotiten.

Fig. 8. To the left: lower limestone. Centre broken and boudined light-coloured layer in gneiss.
Til venstre: Nedre kalksten, i midten brækket og boudineret lyst lag i gnejs.

The mica schists resemble the rocks described above (examples are nos. 8—14/7a and 4—15/7c and the *lime-silicate rocks* are also identical with the ones described from the lower series. They ought in some cases to be termed lime-mica schists because of their great content of mica. They may then lack diopside (as no. 8—14/7b does) and consist of large grains of garnet in a groundmass of quartz, plagioclase, amphibole, biotite, chlorite, apatite, ore and tourmaline. Some of the bands of lime-mica schist have as in no. 4—15/7a thin layers of calcite. This rock consists of quartz, plagioclase, microcline, diopside, sphene, apatite, biotite, scapolite, and ore. The calcitic layers have quartz, plagioclase, phlogopite, chlorite, sphene, apatite and in the borders diopside (uralitized), scapolite, sphene, and ore.

A third type of lime-silicate rock has compounds from the lime-silicates as well as from the mica schists and consists of quartz, plagioclase (35—40 % anorthite), biotite, diablastic garnet, diopside, a faintly coloured amphibole, muscovite, apatite, tourmaline, rutile, ore, chlorite, carbonate, and zircon. Here again the linear arrangement of the diopside is cut by the schistosity of the rock (no. 4—22/7).

A more intermediate type of rock is a garnet gneiss (no. 4—15/7) with large grains of garnet in a groundmass of quartz, plagioclase, biotite, muscovite, chlorite, and apatite. The garnets have many inclusions of quartz, ore, mica, and chlorite and they are enclosed by aureoles of quartz and plagioclase. The inclusions may be arranged in stripes as if the garnet is a replacing mineral, but there is also evidence that the garnet has been exposed to deformation since large grains have been «outrolled» during the formation of layers of garnet.

The bands of *amphibolite* are often rich in garnet and they may have conformable veins of quartz. The normal amphibolite (e.g. no. 9—14/7a) has the following components: quartz, plagioclase and a strongly green hornblende which is being replaced by biotite and chlorite; accessories are apatite and ore. The garnet porphyroblasts have caused a disturbance of the linear arrangement of the prismatic grains of hornblende. Associated with this rock a more banded amphibolite (no. 9—14/7b) occurs. It has layers rich in diopside and scapolite. This rock contains in addition to the minerals named above a good deal of sphene, biotite and calcite.

The Upper Horizon of Limestone.

This horizon is developed in two widely different ways in the various parts of the area. It forms a thick layer in the southern part of the area and in the limestone synclinorium south of the peridotite, while it forms a well-banded series in the zone around the peridotite.

Fig. 9. Banded series south of the peridotite. The hammer rests on a layer with sillimanite spots.

Båndet serie syd for peridotiten. Hammeren ligger på et lag med spætter af sillimanit.

Fig. 10. Closure of marble east of the peridotite. The black rock in contact with the marble is skarn. As to the background compare fig. 3.

Lukning af marmor øst for peridotit. Den mørke bjergart ovenfor marmoret er skarn (sml. fig. 3).

The southern layer (no. 5—23/7) is very heterogenous and has thin bands of amphibolite, patches of lime-silicate rocks rich in plagioclase, quartz, diopside etc. and it may locally be altered to a considerable extent into lime-silicate rocks. Veins of quartz with large grains of diopside, hornblende, sphene, calcite and pyrrhotite are very common. So are calcitic veins in cross joints.

The thin bands of amphibolite consist of a green hornblende (with cores of diopside), plagioclase (30—60 % anorthite, inverse zonal structure), quartz, calcite, sphene, rutile, and ore. Bordering on the limestone there is a concentration of scapolite, plagioclase, and diopside. The scapolite replaces the hornblende and the plagioclase has a well-developed inverse zoning adjacent to the scapolite with 32 % anorthite in the core and 60 % towards the scapolite.

A fine-grained, white rock may occasionally be found in the border of the limestone. It is made up of: quartz, plagioclase, microcline, small flakes of biotite (and of muscovite), and very few grains of garnet and apatite.

The limestone in the synclinorium south of the peridotite is of the same appearance as no. 5—23/7 except for the fact that the flow within the layer is very pronounced (cf. 5, plate 3, fig. 3).

The stratigraphical equivalent of this limestone in the peridotite zone is a layered and banded series made up of marble, diopside, amphibolite, limestone and more gneissic rocks.

The marble (no. 2—14/7a) is pure white with thin layers of phlogopite. Under the microscope it is seen that the calcite has bent translation lamellae. There are scattered grains of amphibole, plagioclase, quartz, scapolite, sphene, and ore. The layers of mica are made up of small flakes of phlogopite. The marble has fine-grained, cataclastic zones.

In the border between the marble and the silicate rocks there are on both sides large grains of diopside. No. 2—14/7b has plagioclase (70—80 % An) and diopside with inclusions of calcite and scapolite in the border. In addition smaller and larger grains of sphene, often twinned, are present. Outside the border follows a silicate rock of diopside, scapolite, plagioclase (60 % anorthite), sphene, amphibole and with the scapolite replacing the plagioclase. Outside this rock follows a fine-grained amphibolite with a green hornblende and with subordinate amounts of plagioclase.

No. 5—18/7 was collected in the border between the marble and the garnet gneiss of the peridotite zone in the closure immediately to the east of the peridotite (fig. 10). Close to the marble the gneiss consists of a strongly green hornblende, plagioclase and quartz. About one centimetre from the border there is a zone rich in sphene and ore. Then follows diopside, with inclusions of the remaining minerals and apparantly growing at the expense of the hornblende. The diopside is uralitized by a colourless amphibole. Outside the diopside large grains of plagioclase (with inclusions of diopside and sphene) are present. This zone may border on the marble but is also seen to be separated from the latter by a zone of small grains of diopside.

The skarn. The bands of diopside skarn are generally broken during the formation of boudinage structures (cf. 5, plate 3, fig. 5 which gives a good impression of the banded limestone-skarn zone). The small masses of diopside are often embedded in a matrix of calcite, in more rare cases of biotite.

The skarn is as for instance no. 7—14/7 composed of diopside, epidote (often in big grains), amphibole, sphene, plagioclase and ore. The diopside is present in larger grains with irregular, often glomeroblastic extinction and occasionally with zoning. Calcite is never missing in these rocks.

The outer zones of the diopsidic masses vary from place to place. They may have a layer rich in diopside and scapolite in contact with the intercalated layers of limestone (the limestone is fairly pure but with scattered grains of diopside, quartz etc). In other cases their marginal parts are transformed into a mass of biotite. Finally it should be mentioned that they may have dark amphibolitic margins consisting of hornblende, biotite and plagioclase.

The thin layers of limestone may have fine-grained bands of amphibolite (i.e. no. 12—14/7) with green hornblende, plagioclase (30 % anorthite), quartz, calcite, sphene, apatite and ore. The borders with the limestone may be sharp, but with calcite penetrating the outer parts of the amphibolite. The calcite of the limestone is turbid, but it is quite clear close to the silicate rocks. The hornblende of the border may be filled with secondary minerals and it is often bleached. In this limestone diopside is lacking while amphibole is more prominent. Normally the limestone of this banded zone (i.e. the limestone layers of the silicate rocks, not the marble) have fairly large grains of diopside (with uralite). A colourless amphibole is common and is in part formed at the expense of the diopside. The remaining minerals of these limestones are: quartz, plagioclase, phlogopitic mica (often in layers of small flakes), sphene, apatite and ore.

The amphibolite is clearly of calcareous origin and may in some layers be true skarn rocks. Thus no. 11—14/7d is rich in diopside which occurs as corroded remnants in the hornblende (faintly green). The strongly banded rock has furthermore quartz, calcite (in part in pure calcite layers), sphene and ore. The more common amphibolite of this zone has a good deal of uralitized diopside, often as green layers. The groundmass is made up of a faintly green amphibole, and of plagioclase, calcite, scapolite and sphene.

No. 10—14/7 is also banded and is composed of green hornblende, biotite, diopside, plagioclase, sphene, apatite and ore. It has layers rich in calcite and with large grains of diopside. When garnetiferous the amphibolites may resemble the rocks described by Hernes (2) from the Molde peninsula.

The gneissic layers are most often fine-grained with the components: quartz, microcline, and in subordinate amounts plagioclase, chlorite, muscovite and biotite.

Upper Amphibolitic Series (Peridotite).

Above the marble-limestone series in the southern part of the area follows a series rich in bands of amphibolite; in the central part of the area the peridotite zone.

The banded zone is made up of thin bands and layers of amphibolite (in part with garnet), lime-silicate gneisses, mica schists (some of them with sillimanite, limestone, and light-coloured quartzitic layers. Skarn also occurs.

The rocks of this series resemble the rocks already described so closely that no further description will be given here. Instead the rock of the peridotite zone will be described.

The peridotite zone. By this term is meant the rock suite occupying the two narrow synclines of the central part of the area which join one another at the great peridotitic mass. (fig. 12).

The main rock of this zone is a garnetiferous biotite gneiss which will be further described below. This gneiss has inclusions of ultrabasic affinity, not only the big mass, but also a lot af smaller masses, mainly bronzitites and hornblendites. These masses may be rotated. Layers and bands of amphibolite (most often rich in garnet) are common. They are often broken so that beautiful boudinage structures are formed (fig. 11) and they are found in all stages of digestion, the end product being the garnet gneiss with corroded grains of hornblende and with the garnet porphyroblasts of the amphibolite crushed and rolled out to form monomineralic layers of garnet up to 3 centimetres thick.

In some parts of this zone the garnet gneiss is clearly derived from lime-silicate gneisses. Remnants of the latter with masses of diopside are found in the gneiss. Finally it should be mentioned that spots of sillimanite may be present locally.

Thus the garnet gneiss of the peridotite zone contains remnants of the various components of the amphibolite-banded series to which it corresponds stratigraphically. It may be regarded as a tectonized equivalent of this banded series.

Some examples of the rocks of this zone will be given below.

No. 7—22/7 is rich in small crystals of garnet with well-

Fig. 11. Boudins of amphibolite in the garnet gneiss of the peridotite zone.
Amfibolitboudins i granatgnejs i peridotitzone.

Fig. 12. The west wall of the canyon of the glacier river. To the right: northern syncline of peridotite zone bordered by marble on both sides. To the left: central part of peridotite zone with folds in skarn, limestone and amphibolite.
Vestvæg af canyon med bræelven. Til højre ses den nordlige synklinal i peridotitzonen, på begge sider begrænset af marmor. Til venstre den centrale del af peridotitzonen med folder i lag af skarn, kalksten og amfibolit.

developed crystallographic outlines. They are almost free from inclusions, but show signs of cataclastic deformation. A faintly green hornblende is present in very corroded grains intergrown by plagioclase (40—48 % anorthite) and quartz so that the hornblende may be divided into several small grains of common optical orientation. Apatite and rutile are accessories. The green hornblende is often intergrown with a colourless amphibole and with chlorite.

The many corroded grains of hornblende in the rock mentioned above indicate that the rock has formerly been more amphibolitic. In no. 6—14/7 this is seen even better, since it has preserved amphibolitic bands giving a banded appearance to the rock. The groundmass consists of quartz and plagioclase (about 80 % anorthite). Corroded grains of a green hornblende are arranged in layers. The hornblende may have colourless spots. Garnet is present in minor amounts and the accessories are sphene, ore and zircon. Chlorite is a secondary mineral. Some parts of the rock are rich in biotite.

In nos. 4—14/7b and 5—14/7 there are amphibolitic bands in a mylonitic garnet gneiss. The components of the amphibolite are: green hornblende, plagioclase, diablastic garnet, biotite and ore. The very fine-grained gneiss which bears pronounced traces of cataclasis consists of quartz, plagioclase, biotite, scattered small remnants of hornblende and of numerous small grains of garnet which undoubtedly are formed by crushing of the porphyroblasts of the amphibolite.

While the small grains of garnet are scattered all over the rock in no. 5—14/7, they are arranged in layers about two centimetres thick in no. 14—6/7. The layers of garnet are made up of numerous tiny garnets. Parallel prismatic grains of a green hornblende are found in the layers of garnet and also in thicker independent amphibolitic layers. The amphibolite may have fairly large grains of garnet. Plagioclase and quartz are present in all layers and so are the minor components apatite, sphene and ore.

No. 4—14/7c is a garnet gneiss of an unmistakable lime-silicate appearance. It is made up of plagioclase (about 80 % anorthite), diopside (uralitized), apatite and sphene. There are a few large grains of garnet with inclusions of hornblende, plagioclase, calcite, epidote, and chlorite.

The peridotite is enclosed by a garnet gneiss very rich in layers of amphibolite. No. 4—20/7 may serve as an example. It has large well-crystallized garnets which may be rich in inclusions. The garnets are of a rolled appearance and may be crushed and rolled out in stripes. The groundmass consists of large prismae of a green hornblende, plagioclase (30—40 % anorthite), quartz, biotite in a few flakes, large grains of apatite, rutile, ore and chlorite. The plagioclase has irregular twinning and a pronounced zoning.

The Peridotite.

The central part of the body of peridotite is rich in olivine (2V is about (+) 90°) which is found in irregular, somewhat elongated grains. It is fairly fresh, but may be serpentinized, especially close to zones of dislocation. Chromite and magnetite are present in small grains. Bronzite is not abundant in the central part of the peridotite, but it increases in amount towards the borders of the mass. In the outer part it occurs in prismatic grains several centimetres long and often arranged in rosettes (no. 20—23/7).

As secondary minerals are found in addition to the serpentine mentioned above: hornblende, talc, carbonates (dolomite has been identified) and a colourless chlorite.

The bronzite of the marginal parts is subject to replacement by a faintly green, actinolitic amphibole(«smaragdite»), by talc and by carbonate. A phlogopitic mica may be present .(no. 10—25/7).

The bronzititic rock may have concentrations of chromite. The adjacent rock may then have green spinel. (no. 15—15/7).

The outermost part of the ultrabasic body is green or black, hornblenditic. It is made up of prismatic grains of a faintly green amphibole («smaragdite») often parallel arranged. There may be corroded remnants of bronzite. Some parts of these rocks are very fine-grained. There may be layers or patches of biotite and small concentrations of ore. Towards the interior of the peridotite the green amphibole is present in larger prismatic grains and it is eventually succeded by the prismae of bronzite (5—20/7). This transition from bronzitite to hornblendite is gradual; no. 17—14/7 shows an intermediate stage with corroded grains of bronzite in a matrix of amphibole. The bronzites may be divided into several small grains with a common optical orientation.

The fractures in the peridotite have veins of bronzite, «smaragdite», talc and carbonates.

There are many amphibolitic inclusions in the peridotite. They have the same orientation and are of the same appearance as the garnet amphibolite outside the peridotite. They consist of green hornblende, garnet, sphene, a small amount of plagioclase (which in no. 12—15/7a was found to have inverse zonal structure with about 40 % anorthite in the core and about 70 % along the margins. In addition quartz, apatite, zircon and ore may be present. Diopside may occur as porphyroblasts poikilitically enclosing all the minerals of the rocks. The amount of diopside increases towards the margins of the inclusions and so do the contents of clinozoisite and calcite. In some cases the margins of the inclusions are transformed to green rocks (with red spots) of an eclogitic appearance. They have the components diopside, clinozoisite, garnet, calcite and one or more of the following minerals: plagioclase, quartz, hornblende, sphene, apatite and ore. The garnet is only feebly diablastic.

In some of the inclusions the amphibolite is replaced by calcite and ilmenite along the borders and along fractures.

The peridotite is rich in bronzite and «smaragdite» where bordering on the inclusions. It here has green spots and «veins» and patches of carbonates. Under the microscope the bronzite is seen to be replaced by the amphibole and by carbonate, talc, chlorite and mica. The prismae of bronzite are often broken. Apatite, chromite, a green spinel, magnetite and pyrrhotite may be found. (nos. 14—15/7, 18—14/7 and 13—15/7).

The small ultrabasic masses enclosed in the garnet gneiss of the two narrow synclines of the peridotite zone vary in appearance from bronzitite to hornblendite. No. 1—2/9, one of the larger masses, is a bronzitite with bronzite, a green amphibole (colourless under the microscope), anthophyllite, talc and a Cr-spinel. The smaller masses may as no. 16—14/7 have corroded remnants of bronzite in a matrix of amphibole and carbonate, or they may be hornblendites consisting of a green amphibole (colourless in thin section) and anthophyllite. Some of these rocks may have a good deal of carbonate and biotite.

The Granitic Gneiss and The Mica Schists.

These rocks are only to be seen in the southern part of the area in question and since they are identical with the rocks described in the previous paper (5), they will only be mentioned briefly here.

The gneiss bears close to the underlying banded series traces of limestone- or lime-silicate structures so that it may be regarded as a granitized equivalent of these rocks. Normally, however, it is a veined gneiss rich in biotite and occasionally with garnet. This is the type of gneiss formed through granitization of the mica schist. Only the central part of the granite syncline is occupied by a more massive granite.

The mica-schist is coarse-grained with large flakes of biotite and muscovite; close to the granite small grains of garnet are found. It is rich in quartz veins. There are a few layers of quartzite, the most conspicuous one being in the veined gneiss formed at the expense of the mica schist.

Pegmatites.

There are many pegmatites, most often associated with cross joints or diagonal joints. Some of them have an irregular course and may show beautiful replacement structures (5, plate III, fig. 6). Their thickness vary from a few centimetres to five metres, a thickness attained in a large pegmatite in the extreme north-western part of the area.

The pegmatites are made up of quartz, feldspar and mica. Tourmaline is very common. In one case sillimanite has been found in a pegmatite.

Not all of the pegmatites are indicated on the map.

At this place it should be mentioned that quartz veins are very common in this area. They occur in three ways: as pinch and swell veins in the mica schist, as diopside- and calcite-bearing veins in the limestone and as conformable (often folded) replacement veins with calcite and biotite in the lime-silicate gneisses.

Metamorphic Facies.

The parageneses listed above indicate that the metamorphism took place at amphibolite facies conditions. Thus epidote is only found in skarn and in inclusions of amphibolite in the peridotite. The amphibolites and the lime-silicate gneisses with anorthite contents of 30—40 % anorthite in the plagioclase have no epidote.

The sillimanite of the mica schist is always in one way or another associated with muscovite and is found in rocks poor in potassium feldspar.

The regressive metamorphism is slight; the plagioclase may occasionally be turbid and the biotite may be somewhat chloritized.

Tectonics.

In spite of the extremely beautiful exposures it is no easy task to unravel the structure of this area. Thus the «levelling» action of the glacier has literally resulted in a «removal of the axes of folding», and it is very difficult to obtain safe measurements of the fold axes, since observations are limited to only two dimensions in most parts of the area.

In the extreme south there are at the first glance no traces of folding. The layers run parallel from one side of the planed off surface in front of the glacier to the other, and one and the same layer may be followed straight upwards in the mountains on the sides of the plane for 1000 metres or more. The dip is almost everywhere steeply southwards. The strike is nearly constant.

In the central and northern parts of the area there are several closures of the folds so that the structure may be more easily determined in these places. Unfortunately it is only possible in a few cases to follow one and the same layer with certainty from the central zone north and southwards since most of the closures are situated outside the exposure. Another reason for this is the pinch and swell structure of many of the layers so that they may be lacking in some parts of the folds while being very thick elsewhere in the area.

Only by combining all the available data has it been possible to figure out how the sediments were deformed.

The folding is isoclinal with narrow and deep folds. The fact that some layers may be followed from the glacier right up to the top of the mountain Helgelandsbukken (1454 m) immediately to the east of the area in question shows that some of the folds have a vertical extension of about 1500 metres. The folds are slightly overturned with the axial plane dipping steeply to the south.

The section fig. 13 is a tentative representation of the structure of the area. Because of the difficulties in obtaining satisfactory measurements of the fold axes and because of the frequent change of plunge of the axes in some parts of the region, it has not been possible to construct an exact profile. A series of sections would be necessary in order to give a thorough explanation of the structure and even then there would be uncertain points. It has been considered to be most safe to construct a profile based on the «regional axis of folding» which has a slight westerly plunge (as to the variation of plunge of the axes see below when the peridotite is discussed). The correlations are indicated by dotted and stippled lines above and beneath the section. The vertical height of these connections is uncertain.

The section shows from the south to the north: Granite synclinorium with mica-schists (the reappearance of granite north of the thick granite in the south eastern part of the area indicates that there is a downfolding at this place). North of the granite follows the south limb of a fairly broad anticlinorium. The rocks have a gentle to steep southwesterly dip and the borders between the various rocks are folded in a drag-fold fashion. The series in the anticlinorium is from south to north (from the top downwards): upper amphibolite-banded series, thick layer of limestone, thin layer of banded series, lime-silicate with layers of limestone (corresponding to the lower layer of limestone), garnet gneiss, lime-silicate gneiss (with almost horizontal layers of limestone and with beds of spotted mica schist),

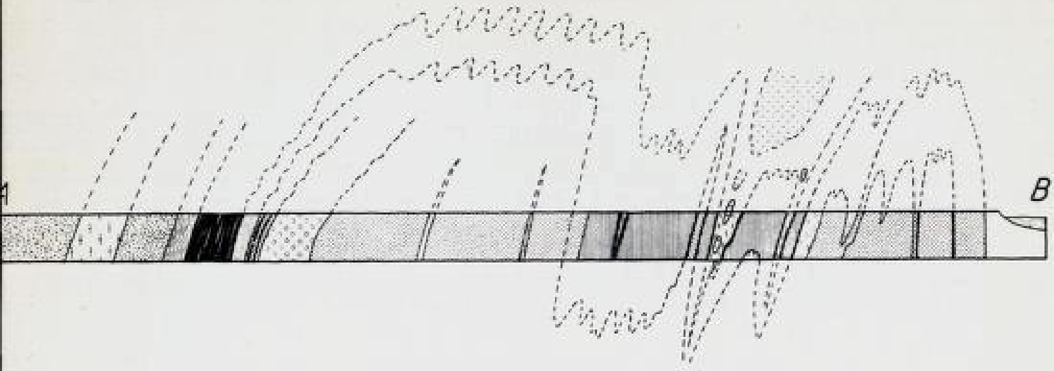


Fig. 13. Cross section of the western part of the area. (Cf. the map, fig. 1, and the text page 96.)

Tværsnit af den vestlige del af området (sml. kortet fig. 1 og teksten på side 96).

amphibolite, granitized lime-silicate gneisses and in the north limb of the anticline: amphibolite, lime-silicate gneiss and then the banded series. The lower layer of limestone and the garnet gneiss are lacking in this place (cf. page 83).

The following syncline is dominated towards the west by the upper limestone, towards the east by the banded series.

North of this synclinorium and after a narrow anticline follows the peridotite zone with its two synclines of garnet gneiss etc. and the interjacent zone made up of the banded series and dominated by two closures in marble and limestone.

North of the compressed folds of the peridotite zone follows a somewhat broader anticline (with narrow minor folds), then a syncline occupied by the garnet gneiss and furthest north the strongly folded zones in lime-silicate gneiss.

There are still problems to be solved as to the structure of the region. The main uncertainties are:

1) the missing layer of the garnet gneiss and limestone in the north limb of the southern anticlinorium. Now these two rocks show in other places a pronounced tendency to mechanical swelling and disappearance as especially well seen in the zone east of the peridotite (cf. the map. fig. 1). It seems as if these rocks preferably occur in the closures of the folds, the rocks may have been very plastic at some stages of the folding. This behaviour is not strange for limestone and marls. It is therefore believed that these rocks have flowed away from the steep north limb of this anticline;

2) the two layers of amphibolite in the southern anticlinorium. It has not been proved that these layers correspond to the lower amphibolite series which is exposed best in the north eastern part of the area and in the eastern ends of two narrow anticlines in the peridotite zone;

3) the structure in the shore just north of the glacier between the rivers. There is at this place a closed structure which could not be explained satisfactorily because of the difficulties in observing the fold axes. The structure might be explained by flat-lying axes towards the east and steeper ones towards the west (with westerly plunge).

4) the strongly deformed zones in the north western part of the area. As mentioned on page 83 these rocks might be formed where a layer of impure limestone has been subjected to intense deformation. The stratigraphical position of these rocks is uncertain since it cannot be decided whether the garnet gneiss ought to occur most northerly or not.

The behavior of the fold axes is as mentioned above most disturbing. When considering the area as a whole one may state that the «regional» axis of folding is directed east-west and with a slight, westerly plunge for the most part. Deviations from this general rule are found only locally and most often in the peridotite zone and in its eastern continuation at Rødtind and Stortind. It seems therefore to be admissible to conclude that the change in plunge of the axes is caused by the great rigid masses of peridotite (and amphibolite) in connection with the plastic behaviour of many of the rocks. It is therefore not surprising that most deviations are found in the limestones (and especially in their closures).

The above-mentioned is one indication of the possibility that the peridotite is older than the deformation responsible for the folding and metamorphism of the rocks. The study of the peridotite zone lends further support to this view.

Thus the many small metamorphosed ultrabasic bodies in the tectonized garnet gneiss of the peridotite zone indicate that a break down of the large mass of peridotite has taken place. Furthermore, the broken and partly digested remnants of garnet amphibolite, lime-silicate gneiss, skarn etc and the mylonitic appearance of the enclosing garnet gneiss with its layers of the crushed remains of garnet porphyroblasts clearly show that the movement around and along the peridotite was extreme. The upper amphibolite-banded series, to which the peridotite stratigraphically belongs, is transformed to this «mylonitic» zone close to the peridotite.

Further evidence is obtained from the upper layer of limestone which in the southern part has bands, layers and patches of amphibolite, skarn and lime-silicate rocks, but which around the peridotite appears as a banded series in which the components of the limestone are separated into bands according to their different physical properties, so that a series of marble, skarn, amphibolite, etc. is formed.

Thus all evidence favours the view that the peridotite was formed in an early stage of the folding.

The peridotite at Engenbræ is the eastern continuation of the peridotite zone from Rødtind and the two narrow synclines with fragments of ultrabasic rocks are the bottom of this zone. It is not surprising that this elongated rigid mass has caused serious disturbance in its surroundings in the subsequent phases of deformation and that simultaneously with the latter it has been broken down into several smaller masses.

The picture of the structure of the area arrived at above shows that the peridotite is situated in a series which is normally built up of bands of amphibolite, lime-silicate gneisses, mica-schist etc. The same banded series is found in the Fondal anticline where it borders on the granite of the Kløfttind-Middagstind synclinorium. It forms the bottom of the latter in the floor of the Fondal valley and appears again in the north limb of the synclinorium in the north side of Kløfttind and south of Rødtind. According to this interpretation it is this layer which forms the compressed anticline in Stortind. Here all traces of lime-silicates are lacking. This zone has been followed to the west to the north slope of Trolltind (cf. 5, fig. 2).

This amphibolite-banded zone is situated between a lower series rich in lime-silicate material and limestone and an upper series of mica schists. In many places the mica schist has been entirely granitized, so that the granite borders on the zone in question. In the previous paper (5) the granite was interpreted as the remnants of a former gneissic thrust sheet which during the folding had been folded with the sediments and in favourable places had grown at the expense of the latter. If this interpretation be correct then the amphibolite-banded zone is situated not far below the thrust plane.

Ultrabasic rocks have only been observed in a few places in this zone, namely in the Engenbræ-Rødtind zone and in small masses associated with the amphibolite north of Trolltind.

Thus the ultrabasic rocks of this region are associated with a banded series which stratigraphically lies between two series of rocks of very different mechanical properties, viz. mica schists and calcareous rocks. They may even have a certain connection with a zone of thrusting. This means that the peridotites are found in a zone which may have been the site of strong movement, either in the form of movement between layers of different competencies or in form of thrusting. The last-mentioned possibility in a way includes the first-named since the thrusting of the gneiss sheet over the mica schist may have resulted in an associated movement of the mica schist over the calcareous series.

We have thus in this area as in so many other mountain chains peridotites associated with zones of strong deformation (shear- or thrust zones) and formed in early stages of the folding. In the subsequent phases the original large masses were broken down to smaller ones and the parageneses of the rocks were transformed in conformity with the degree of metamorphism. At the same time the zones containing the ultrabasics may be folded so that the rigid masses occupy key positions in the structure while the enclosing rocks are folded in a more normal way and often have flowed away from the peridotites.

In the present area it is still possible to distinguish the primary nature of the sedimentary rocks, but all traces of thrusting have been obliterated. If the «mise en place» of the peridotite in one way or another is connected with the thrusting processes the zones rich in peridotite may be used in the attempt to explain the structural evolution of the region. This statement can, however, not be substantiated until all the peridotites of the region in question have been studied and their relationship to the structure established (cf. H. H. Hess, 3). When this has been done the peridotites may be useful tools in the study of the tectonic evolution of regions with stronger metamorphism as for instance many Pre-cambrian areas, where the peridotites are found in gneisses and amphibolites of uncertain origin.

In the previous paper (5) an attempt was made to discuss the structural evolution of the region under consideration and there is not much to add here.

The first phases of folding were characterized by thrusting of the sheets of granite and by the primary folding of the sediments (zig-zag folding of the schists, slip folding of the marly and calcareous rocks). The mise en place of the peridotite belongs to this phase.

There was later a second phase of folding which brought the sediments and sheets of granite to deeper levels of the crust resulting in an intensive metamorphism at amphibolite facies conditions. The traces of thrusting were obliterated by granitization and all discordances disappeared since the less competent rocks arranged themself conformably with the competent layers. The zones of peridotite were folded.

With decreasing tectonic activity and with decreasing metamorphism the pegmatites were formed, but as shown in (5), plate III, fig. 5 movement continued after the emplacement of the pegmatites.

In the latest stages of deformation crushing took place in limited zones, at Engenbræ especially in zones parallel to the strike of the layers and often along thin beds of mica schist.

The fractures and joints opened up during the last phases were in many cases filled by quartz and calcite.

Postscript.

In the present paper the structure of the Engenbræ area and the most important types of rock have been treated. There is, however, still much more work to be done on the rocks of this area. Especially does the metamorphism of the lime-silicate gneisses deserve a more detailed study, since the degree of metamorphism of the area is such that the original nature of the gneisses can be determined with a high degree of certainty and since, on the other hand, the metamorphism is so advanced that there are many similarities to the highly metamorphosed rocks of many Pre-cambrian areas. In this way the writer has found the clues to many problems in the Pre-cambrian of West Greenland at Holandsfiord.

It is my hope to be able to continue the work on this interesting region.

Sammendrag.

Bjergarterne omkring peridotiten ved Engenbræen, Holandsfjord.

Det foreliggende arbejde er en videreførelse af de undersøgelser, som i 1952 blev udført ved Holandsfjord i Nord-Norge af

S. Skjeseth og forfatteren. Allerede i 1952 kunne jeg gjennem venlig imødekommenhed fra Direktør S. Føyn arbejde på den udmærkede blotning, der ligger foran Engenbræen. I 1954 fortsatte jeg dette arbejde med økonomisk støtte fra Københavns Universitet.

Jeg er Direktør S. Føyn og Statsgeolog S. Skjeseth megen tak skyldig for den støtte N.G.U. har vist mit arbejde og ønsker også at udtale en varm tak til mine venner ved Holandsfjord for udvist gæstfrihed og hjælp.

Det undersøgte område opbygges af en stærkt foldet serie af glimmerskifer, amfiboliter (ofte med diopsid og granat), kalk-silikat gnejser og kalksten for at nævne de vigtigste bjergarter. Metamorfosegraden svarer til amfibolit facies. Folderne er snævre og dybe.

En stor peridotitlinse, der er en fortsættelse af peridotiten fra Rødtind, ligger i områdets vestlige del. Den er indesluttet i en båndet serie, der stratigrafisk ligger mellem en øvre glimmerskiferserie (+ granit) og en nedre kalkholdig serie.

Den båndede serie, der er rig på amfibolitbånd, er omkring peridotiten udvalset til en granatgnejs, der må opfattes som en «tektonit».

Det påvises, at peridotiten er «kommet på plads» i en tidlig fase of foldningen, og at den hører hjemme i en zone karakteriseret af kraftig bevægelse.

I de senere faser af foldningen er peridotitmassen blevet boudineret og den har på grund af sin stivhed været årsag til kraftig «mekanisk differentiation» i de indesluttende bjergarter.

Til slut gøres der rede for peridotitstrøgenes mulige betydning for studiet af den strukturelle udvikling i foldekæderne.

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