The Precambrian schists and gneisses of Lakselv valley, northern Norway.

By

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With 2 text-figures and 2 plates.

Abstract.

The principal rocks of the Lakselv valley area are well-foliated hornblende schist and mica-quartz schists and lesser amounts of quartzite and marble. The hornblende schist overlies most of the mica-quartz schists and in several places is interlayered with them on a small scale. The structure of these layered rocks consists of several broad folds trending and plunging easterly. Most of these rocks probably represent sediments that were metamorphosed in Precambrian time under conditions of the epidote-amphibolite facies.

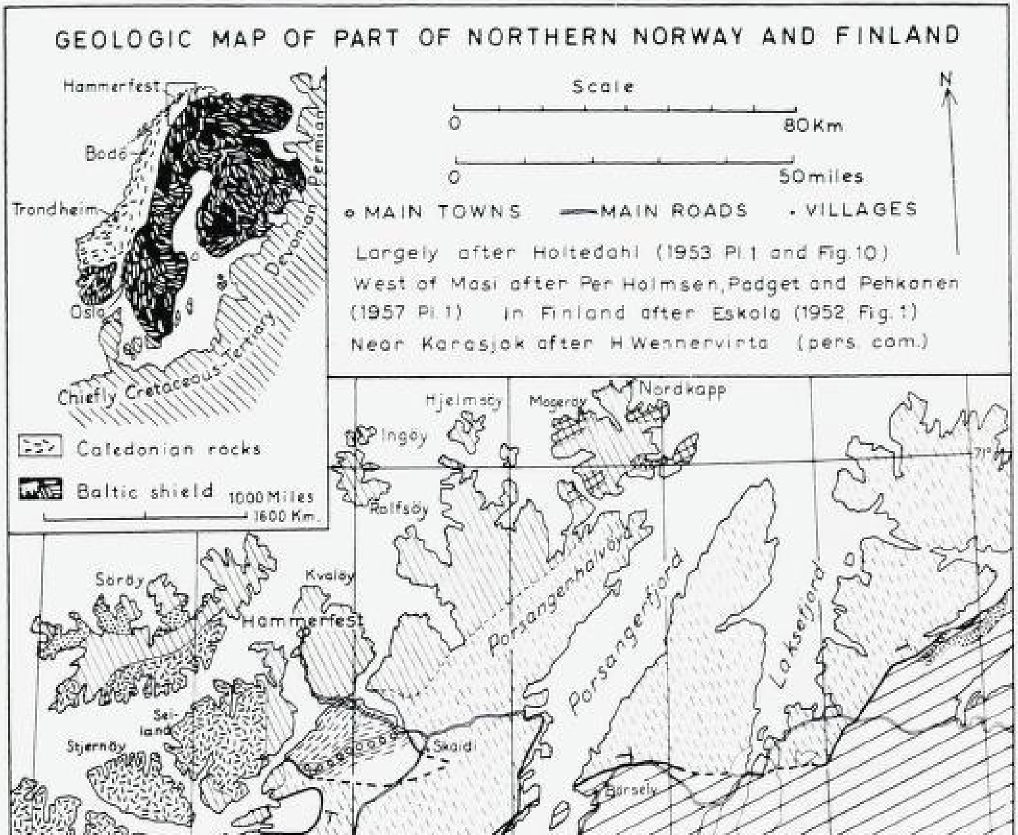
Some of the hornblende schist has been transformed to small masses of hornblende gneiss and diorite; and a large sill of quartz diorite and a small stock of granite have been emplaced. These rocks, which were originally more or less massive, have been metamorphosed to gneisses; this metamorphism obscures their original mode of emplacement.

More recently, horblende schist has been converted into chlorite schist in shear zones, and small sills of ultrabasic rock have been emplaced.

Introduction.

The Lakselv valley is at the head of Porsangerfjord on the north coast of Northern Norway (see Fig. 1). The rocks described in this report are the metamorphic rocks which occur in the Lakselv valley from Porsangerfjord on the north to near the hamlet of Skoganvarre on the south. Near the southern boundary the otherwise extensive outcrops in Lakselv valley become very scarce due to a blanket of moraine. The metamorphic rocks of the valley are overlain uncomformably in the abrupt valley sides by beds of Caledonian sedimentary rocks; the contact between these sedimentary rocks and the metamorphic rocks forms the east and the west limits of the mapping. This contact, slightly changed and extended near Mærddevarre and north as far as Porsangerfjord, was taken from a map by Holtedahl (1931, Fig. 2).

The area is accessible from the road around the head of Porsanger-



GEOLOGIC MAP OF PART OF NORTHERN NORWAY AND FINLAND

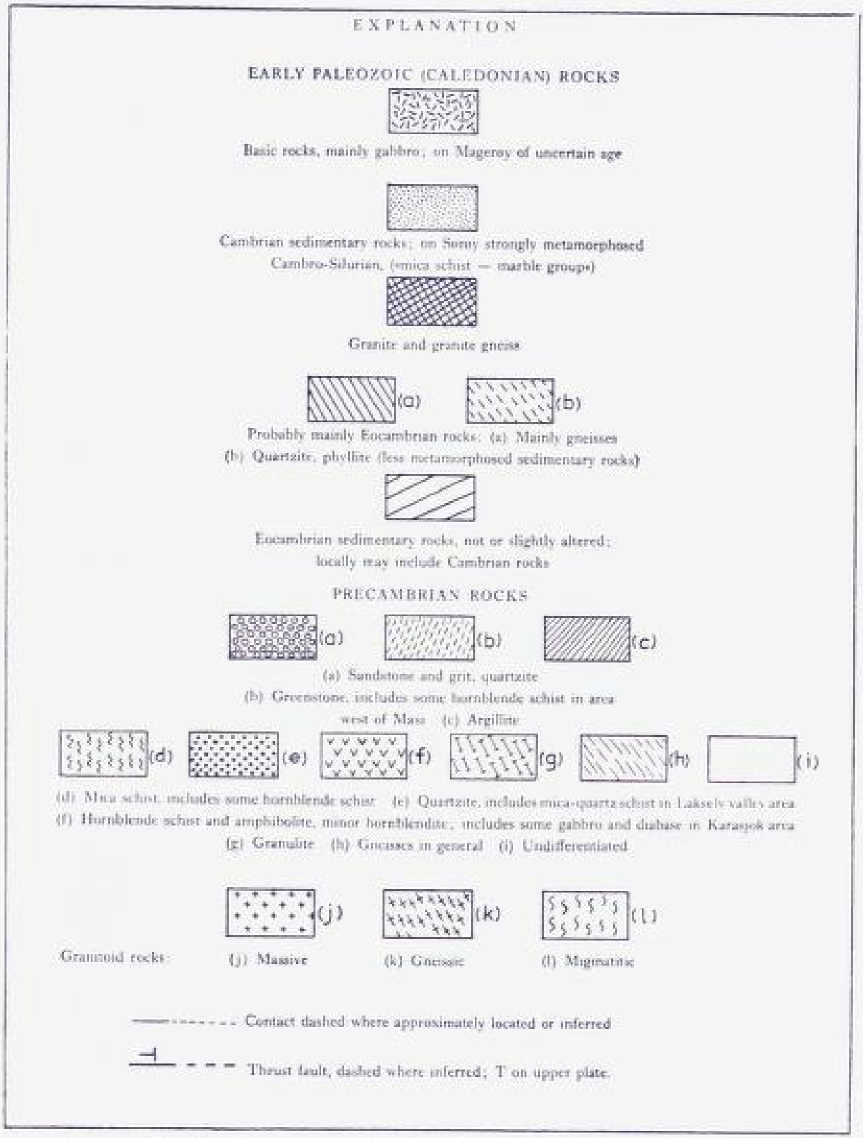


Fig. 1. Geologic map showing location of the Lakselv valley area.

Geologisk kart som viser beliggenheten av Lakselvdalens område.

fjord and from the road along the east bank of Lakselva ("the Salmon River"). Since Lakselva is too large to wade across, the west side of the valley is not so easily accessible. Settlement is limited to small farms and hamlets on the roads. Some migrating Samer (Lapps) winter their reindeer on the plateau south of the area and in the spring and in the fall they follow their herds through Lakselv valley on their way to and from summer pasture in coastal areas.

Geologic work occupied a period of eight weeks in the summer of 1957. Traverses were made from camps on the roads and from a camp at the north end of Gaggavatn. Parts of Norges Geografiske Oppmåling's 1: 100,000 quadrangle maps, Skoganvarre (V 5), Halkkavarre (W 5), Stabbursdalen (W 5), and Børselv (W 4), enlarged to 1: 50,000, were used as a base map. Aerial photographs were available for about half of the area, and these were not used as a base map but as an aid in mapping.

I was assisted in the mapping by Harald Skålvoll, and Hrobjartur Einarsson served as our camp assistant. We thank the staff of Lakselv Gjestgiveri for many special favors, and Mr. A. Sellevold of Geofysisk Malmleting, Trondheim, for his and his staff's cooperation and their help with local transportation. Miss D. Engelsrud drafted the illustrations. Suggestions on terminology were made by Professor T. Barth and Professor O. Holtedahl. I also discussed pertinant problems of Caledonian geology with Professor Holtedahl. Konservator H. Rosendahl helped me write the Norwegian in the report. I am indebted to the U. S. Educational (Fulbright) Foundation for bringing me to Norway for geologic study. For all this help I am most grateful.

Reports of previous workers in the Lakselv valley area deal largely with the sedimentary rocks on the sides of the broad valley or with the numerous copper prospects in the valley itself. Reusch (in Dahll and others 1891, pp. 62—65 and Reusch 1903, pp. 32—36) and Holtedahl (1918, pp. 131—132, 207—209) make brief mention of the crystalline rock types observed in the valley during reconnaissance surveys. Holtedahl (1931, p. 246) discusses the nature of the land surface developed on the Precambrian rocks, and Carstens (1931) describes the Lakselv valley metamorphic rocks in somewhat more detail than do the early reconnaissance workers. Considerable more-or-less detailed work has been done to investigate the copper prospects in Lakselv valley but except for the reports of Carstens (1931), Foslie (1933), and Færden (1952) most of the results of this work are in unpublished reports in the files of the government agencies, Norges Geologiske Undersøkelse and Geofysisk Malmleting.

The Lakselv valley area is a part of the large area of Precambrian rocks in Northern Norway (see Fig. 1), the geology of which is known largely from reconnaissance surveys. Holmsen and others (1957) describe in some detail the rocks north and west of Kautokeino, and Reusch (in Dahll and others 1891, pp. 29—35) describes the rocks in the Karasjok area. Eskola (1952) describes the granulites of Lappland, part of which occur in Norway only 20 km. east of Lakselv valley.

General geology.

The Caledonian sedimentary rocks which lie unconformably on the metamorphic rocks of Lakselv valley (see cross-section A-B on the geologic map), and which are mostly shale and sandstone, were not studied. Certain observations on them were made, however.[1]

On Vuollonjunne, which is a mountain just west of the southwest corner of the map area, there are lower Cambrian fossils in these sedimentary rocks (Holtedahl 1918, p. 129); the underlying metamorphic rocks in Lakselv valley are therefore Precambrian rocks. In Norway these rocks are known as "grunnfjell" and the term Pre-Eocambrian has been applied to them (for example Holtedahl 1953, Pl. 1).

[1] The actual contact between the sedimentary rocks in the Lakselv valley area and the underlying metamorphic rocks was observed in three places that have not been previously described and that are very well exposed: on the road to Børselv at an outlier which is 6¾ km. east of Brennelv; at the top of the spur north of the lakes which lie due east of Mærddevarre, a mountain on the west side of the valley; and at the bottom of the creek gorge 2 km. north of Mærddevarre. In all three places the bedding of the overlying sedimentary rocks, which are principally conglomerate and sandstone, is nearly horizontal, and the underlying schist or gneiss dips 20° to 40°; the contact is clearly an unconformity. The underlying metamorphic rocks are not noticeably wathered, the contact is sharp and along it there is no sign of dislocation. A basal conglomerate lies on the unconformity. It is only a few tens of centimeters thick and contains well-rounded quartz-rich pebbles and cobbles from about 1 cm. to 20 cm. in diameter in a matrix of coarse sandstone. The outlier on the road to Børselv is notably accessible and well-exposed, and it consists of a cluster of scattered patches of basal conglomerate on gneiss. Some of these pathes are literally single pebbles. In the immediate vicinity of Mærddevarre the rocks lying conformably above the basal conglomerate are sandstones and grits which contain a few thin layers of reddish shale. Observations on these rocks are summarized in the two stratigraphic sections shown in Figure 2.

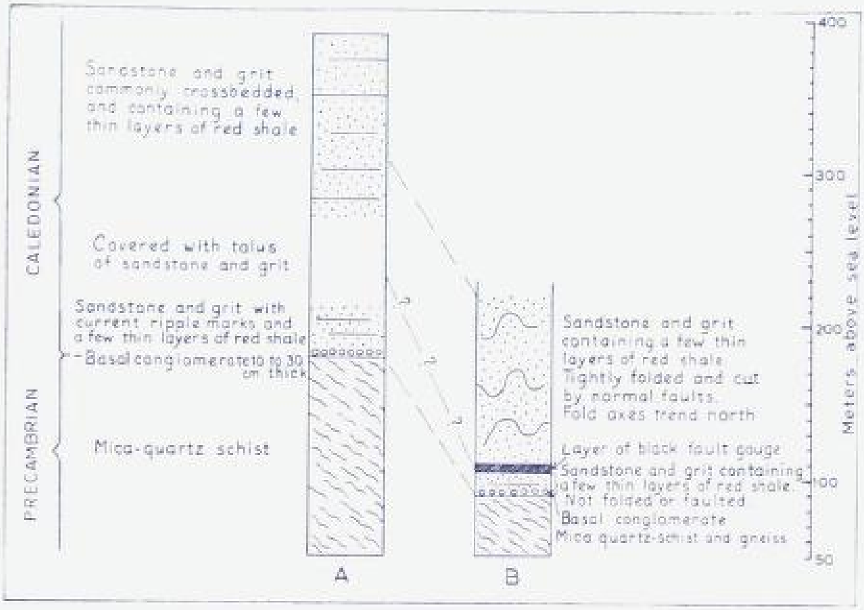


Fig. 2. Stratigraphic sections on the east side of Mærddevarre. Thicknesses approximate only.
A. One-half kilometer north of the summit of Mærddevarre.
B. Along creek 2 kilometers north of the summit of Mærddevarre.

Stratigrafiske snitt på østsiden av Mærddevarre. Bare tilnærmete tykkelser.
A. En halv kilometer nord for toppen av Mærddevarre.
B. Langs bekken 2 kilometer nord for Mærddevarre.

The most abundant metamorphic rocks in the Lakselv valley area are mica-quartz schists and hornblende schist, with a few layers of quartzite and marble in them. Small masses of more-or-less massive granitoid rock[1] have been emplaced in these rocks — a granite, a quartz diorite and a hornblende diorite formed by granitization of hornblende schist — but these rocks have all been metamorphosed to gneisses. A little chlorite schist has been formed from the hornblende schist in late shear zones and a few ultrabasic sills have been emplaced.

Most of the quartzitic rocks and the marble in Lakselv valley have been derived from sedimentary rocks, and since much of the horn-

[1] By granitoid rocks I mean the whole class of granular crystalline rocks of dioritic to granitic composition, i. e., as the terms granitic rock and granite are often used.

blende schist is interlayered with them on a small scale, much of the hornblende schist is also of sedimentary origin. Some of the hornblende schist probably has been derived from basic volcanic rocks.

The hornblende schist overlies most of the quartzitic rocks, but since the top and the bottom of the sequence is not exposed the thicknesses are impossible to determine. Exposed thicknesses, calculated from measumerents along the cross-section line A-B on the geologic map, are 1200 m. of quartzitic rocks and 6000 m. of hornblende schist. The rocks have been gently folded into several synclines and anticlines whose axes strike and plunge eastward.

Rock descriptions.

Mica-quartz schist and quartzite. More abundant than pure white quartzite are quartz-rich schists containing biotite, muscovite, and oligoclase (An_{25} to An_{30}, albite in a few places).

There are three main varieties of the mica-quartz schists: (1) muscovite-quartz schist, (2) biotite-quartz-oligoclase schist, and (3) quartz-albite schist. All these schists are fine-grained, and their foliation is caused by parallel flakes of mica which commonly are more abundant in some layers than in others, so that the rocks are finely (1 to 10 cm.) and regularly laminated. This lamination suggests that the original rock was a sediment, formed by alternating deposition of pure and impure quartz-rich material.

The muscovite-quartz schist, which generally contains over 95 % quartz, also contains muscovite, a little biotite and oligoclase, a few opaque grains, a little chlorite as an alteration product of biotite, and a little sericite as an alteration product of oligoclase. Thin sections of some of these schists show small lenses of somewhat coarser-grained quartz in a fine-grained quartz-rich matrix, which may be relics of particularly large grains of detrital quartz. Some muscovite-quartz schist, in which the muscovite on foliation planes is coarser-grained than usual, are very lustrous. These foliation planes, though nearly parallel, are not exactly so: they cross and branch and in places fray out into massive quartzite. It appears that the medium-grained muscovite in these lustrous schists has formed in quartzite along small shear planes.

In the biotite-quartz-oligoclase schist the quartz and oligoclase are present in approximately equal amounts, though in many places oligoclase is slightly more abundant than quartz. The most common varietal mineral, other than biotite, may be either garnet, scapolite (dipyre) or calcite. Also present are small amounts of sphene, magnetite, apatite, zircon, allanite, muscovite and microcline. A little sericite, epidote and chlorite occur as alteration products of plagioclase or biotite, and in many places the alteration is rather intense.

Quartz-albite schist, containing 60 % to 70 % albite (An_5 to An_{10}) and quartz, occurs in a few places. In one place the varietal mineral in the albite-rich schist is tremolite. In most places the schist contains a little muscovite, epdote, sphene, apatite and chlorite.

Though interlocking grains are visible in most thin sections of the mica-quartz schists and quartzite, their typical micro-texture is granoblastic.

The sedimentary origin of most of the mica-quartz schist and the quartzite can be inferred from their appearance and field relations and from their composition. There rocks are nearly everywhere fine-grained, evenly laminated, and well-foliated, and when occurring in hornblende schist and gneiss they are in conformable layers 1 mm. to many meters thick. No cross-cutting or branching layers were observed. The high quartz content of the muscovite-quartz schist, and the presence of the quartzite, also suggest a sedimentary origin. The biotite-quartz-oligoclase schists, which contain abundant plagioclase, may originally have been beds of arkose or of acid tuff. The scarce and compositionally unusual quartz-albite schist cannot have been a typical sedimentary rock. Adjacent to the body of sheared and recrystallized granite, near the summit of Lævnjavarre, is some quartz-albite schist; even though there is no field or microscopic evidence that they formed by replacement, it is possible that sodium-rich emanations, related to the original granite, have replaced the adjacent rocks.

Hornblende schist, diorite and gneiss. In Lakselv valley there is some hornblende gneiss and hornblende diorite, which may also be called amphibolite, but far more abundant is hornblende schist. The hornblende gneiss and diorite occur in small irregular masses and layers that were too small to map and which grade into the hornblende schist. They appear to have been formed by granitization of the hornblende schist. The hornblende gneiss and diorite developed during an early period of metamorphism and granitization, and were converted into other hornblende gneisses by shearing and recrystallization during a later period of metamorphism.

The hornblende schist is generally fine-grained or fine medium-grained and black and its micro-texture is granoblastic. The mineral composition is rather variable: hornblende (25 to 50 %), plagioclase (mostly An_{20}, 10 to 30 %) and quartz (5 to 25 %). Most of the hornblende is a typical green to blue-green variety but pale-colored, actinolitic hornblende is fairly common. Garnet and epidote are the most abundant accessory minerals and garnet-hornblende schist containing up to 10 % garnet occurs in several places. Minor accessory minerals are sphene, apatite, zircon and opaque grains. Sericite and chlorite occur as alteration products. Much of the plagioclase in contact with epidote is more sodic than usual (An_{10} to An_{15}), but most of the plagioclase (An_{20}) and epidote appear to be in equilibrium with one another. Regional metamorphism of the hornblende schist apparently took place in the lower half of the temperature range represented by the epidote-amphibolite facies.

Most of the hornblende schist has a good cleavage, but some is particularly massive; this suggests that the original rock was a basic lava flow. No primary volcanic structures were noted, however, though Carstens (1931, p. 172) does mention having seen a volcanic slag structure in these schists. In many places, for example along the north shore of the northernmost Porsvatn and in the area north and east of Russevatn, thin layers of mica-quartz schist, quartzite and marble, which are certainly of sedimentary origin, alternate with thin layers of hornblende schist. Most of these layers range in thickness from a few millimeters up to a meter or two. The hornblende schist in such places must once have been a sedimentary rock — perhaps a limey mud. Another possible origin of the hornblende schist is in thin layers of basic tuff, but since it is acid volcanic rocks and not basic ones that furnish most present-day tuffs — particularly those deposited in thin layers — the possibility that much of the hornblende schist in Lakselv valley were tuffs is remote. The recurrence of layers and lenses of mica-quartz schist, quartzite and marble here and there in areas largely underlain by hornblende schist, for example north and south of Rittavatnan and near Silbbačokka, also suggest that the hornblende schist is predominately of sedimentary origin.

Hornblende diorite, formed by granitization of hornblende schist, occurs in several small irregular masses — for example 1½ km. east of the north end of Coalbmejavvre, 1 km. south of Aurevatn, and 1 km. west of Vuolajokluobbal. The diorite grades into hornblende schist through zones of hornblende gneiss or of hornblende schist which contains layers of hornblende gneiss a few centimeters to several meters thick grading into it. No dikes of hornblende diorite or of hornblende gneiss were noted. In the zones where diorite grades into schist are seams and layers of plagioclase which range in thickness from about 2 to 10 mm. Much of the hornblende gneiss in these zones contains a few augen of plagioclase about 5 mm. long and some irregular patches of more massive diorited rock. The hornblende diorite has an uneven grain size and contains very irregular clots of hornblende. Polished hand specimens, of the typical hornblende diorite and of hornblende gneiss containing patches of the diorite, are shown in Fig. 1 of Pl. I.

The main minerals in the hornblende diorite and associated gneiss are normal green to blue-green hornblende (paler and actinolitic locally), sodic plagioclase (An_5 to An_{20}), and epidote. Quartz is fairly abundant in most specimens. The principal accessory minerals are scapolite, sphene, apatite, magnetite and ilmenite, biotite, calcite and the alteration products sericite and chlorite.

The hornblende diorite and associated hornblende gneiss have been altered and recrystallized so that in thin sections details of the granitization process are obscure though not entirely obliberated. I judge the metamorphic origin of these rocks primarily from the field relations just described — their gradation into hornblende schist and the heterogeneity of the rocks themselves. The least granitized hornblende schist contains fine-grained granoblastic hornblende, in which are relics of plagioclase porphyroblasts. These plagioclase relics are marked by aggregates of fine-grained granoblastic epidote and plagioclase. In some places the original porphyroblasts of plagioclase, which are anhedral or subhedral and which have irregular borders, have not recrystallized to aggregates of plagioclase and epidote, but do contain many small inclusions of epidote; in other places part of such porphyroblasts has recrystallized and part has not. In somewhat more granitoid hornblende diorite and gneiss (see Fig. 1 of Pl. I) the granoblastic hornblende occurs in clots and there are a few subhedral grains of hornblende, presumably porphyroblasts, containing many small inclusions of plagioclase. In these rocks the epidote-plagioclase aggregates have a prismatic shape. The most granitoid and least altered hornblende diorite is a medium-grained rock. It contains irregularly-bounded and randomly-oriented laths of hornblende, which commonly contain many inclusions of plagioclase and which are probably metamorphic crystals. The plagioclase grains are unzoned laths in one place, but more commonly they have recrystallized into a fine-grained and granoblastic aggregates which retain the subhedral shape of the original crystal. The relative amounts of hornblende and plagioclase appear much the same as in the original hornblende schist; much of the transformation of the schist appears due to metamorphic segregation and to recrystallization.

The hornblende diorite and gneiss formed by granitization of the hornblende schist have been sheared and recrystallized to form hornblende gneiss. I have already mentioned a characteristic feature of this change: the recrystallization of the original plagioclase into a fine-grained granoblastic aggregate of epidote and plagioclase. Rims of fine-grained granoblastic hornblende around cores of sieve-textured hornblende show another characteristic: the recrystallization of hornblende porphyroblasts to fine-grained aggregates. In places there is a reaction rim between the epidote and plagioclase aggregates and the hornblende, consisting of fine-grained and granoblastic plagioclase and hornblende. Shearing has flattened the mineral aggregates and formed gneisses which contain streaks and lenses of granoblastic epidote and plagioclase in a matrix of granoblastic hornblende. The fine-grained aggregates of hornblende and larger sieve-textured grains show all stages of rolling and streaking out. Despite this obvious deformation the hornblende gneisses have no fragmental textures; they were completely recrystallized during and after deformation.

Marble. Mapped layers of calcite marble in hornblende schist occur east of Porsvatnan and on Loftefjell. Elsewhere occur many thin layers too small to map — for example, the fine-grained and pink calcite marble occurring 1/2 km. west of the summit of Akkevarre and in road cuts near the south end of Nedrevatn. Most of the marble is white and fine to fine medium-grained. Just west of the summit of Akkevarre and near the summit of Lævnjavarre closely spaced and parallel seams of calcite marble 1 to 5 mm. thick occur in mica-quartz schist. These thin marble layers weather more than the schist, so that the outcrop shows a marked small-scale banding. The marble contains, in addition to calcite, a little tremolite and muscovite and some chlorite, apatite, sphene and opaque grains.

Biotite-hornblende gneiss. In the hornblende schist just east of Gaggavatn occurs a sill of fine to fine medium-grained biotite-hornblende gneiss of a light grey color. On the east the contact of the sill with the hornblende schist and gneiss is sharp and on the west contact many layers of the biotite-hornblende gneiss occur in the hornblende schist over a narrow zone. In several places the sill itself contains lenses and long conformable layers of the hornblende schist, and some of these are contorted, which suggests that the biotite-hornblende gneiss surrounding them was once plastic. In a small area about 4 km. south of the summit of Gaggagaissa is a mass, perhaps a layer, of migmatized hornblende gneiss bordered by the biotite-hornblende gneiss. Within this mass of gneiss are clots of hornblende and conformable lenses and layers of hornblende schist and hornblendite.

The biotite-hornblende gneiss contains common green to blue-green hornblende, dark brown and apparently iron-rich biotite, oligoclase (An_{15} to An_{20}), and quartz. Accessory minerals are allanite and epidote, garnet, apatite and sphene. Epidote is notably abundant and apparently is in equilibrium with the oligoclase. The micro-texture of the rocks is porphyroblastic and indicates that a considerably more massive and coarser-grained rock — a biotite-hornblende-quartz diorite — has been deformed and recrystallized. The porphyroclasts are medium-grained plagioclase grains, some of which have normal zoning and nearly all of which have bent twin lamellae, indicating that they have been deformed. Ragged hornblende grains also occur as rounded and rolled-appearing porphyroclasts. The matrix consists of fine-grained and granoblastic quartz and plagioclase, parallel flakes of biotite bending around the porphyroclasts, and angular, somewhat fragmental-appearing hornblende.

There is not enough data available to decide whether the sill of biotite-hornblende gneiss is an intrusive magmatic sill or one formed by granitization. The sharp contacts of the sill, its homogeneity, the scarcity of inclusions in it, and the scarcity of particularly deep-seated plutonic rocks in Lakselv valley (gneisses, migmatites, granitoid rocks), suggest that the sill was originally a magmatic quartz diorite intrusion later metamorphosed under conditions of the epidote-amphibolite facies. The fairly common occurrence of accessory garnet, of epidote in equilibrium with plagioclase, of tabular and conformable inclusions of hornblende schist and of the rather gently dipping foliation of the sill approximately conformable to that of the enclosing hornblende schist, may all indicate that a sill of massive quartz diorite was formed by granitization of hornblende schist and later was metamorphosed.

In any case, the biotite-hornblende gneiss now is a metamorphic rock formed by recrystallization of a more massive one.

Granite gneiss. On the west slopes of Lævnjavarre, and further west on the lower slopes of Jorgastakgaissa, occurs a small mass of granite gneiss. About 5 km. east of Lævnjavarre is a smaller related mass of more massive granite gneiss and granodiorite gneiss. The distinctive red the pink color of the rocks is caused by the pink microcline in them and by minute and closely-spaced fractures in their feldspars coated with iron oxide. In most places the granite gneiss is fine-grained, and has a pronounced streaky appearance (see Fig. 2 of Pl. I) but only a poor foliation.

The contacts of the granite gneiss are gradational into mica-quartz schist and quartzite which contain streaks of red microcline. Seams of red microcline, $^1/_2$ mm. or less in thickness which cut the rocks of Lakselv valley in many places are presumably related to the granite gneiss. In the field the gradation of granite gneiss into the quartzitic rocks was interpreted as evidence that the granite gneiss had formed from them by granitization. The gneissic structure of the granite gneiss was interpreted as a relict feature. Near Stellingvatn, however, the granite gneiss in several places is medium-grained, homogeneous and more or less massive, which suggests that the granite gneiss has an igneous origin. On Lævnjavarre an unoriented inclusion of coarse-grained gneissic granite (10 cm. by 20 cm.) is enclosed in a small local body of massive granite. Thin sections show clearly that the gneissic structure of most of the granite gneiss is not a relict feature but a secondary feature, formed by intense shearing and recrystallization of a more massive granite.

A thin section of the massive phase of the granite gneiss, rocks far less abundant than the gneissic phase, is not of granitic rock but of a granodioritic one. The massive phase is medium-grained and most of its crystals are anhedral. Irregular grains of oligoclase (An_{15} to An_{20}) and microcline 1 to 3 mm. in diameter are enclosed in a fine-grained matrix composed of interlocking grains of quartz and somewhat finer-grained and granoblastic microcline. The large plagioclase crystals are intensely altered to sericite and epidote. The biotite, the principal varietal mineral, has an olive-brown color and is partly altered to chlorite. The principal accessory minerals are muscovite and sphene. The anhedral shape of most of the minerals of the more massive phase of the granite gneiss suggest that it is a metamorphic rock, but its massive and homogeneous appearance, and the occurrence of most of the microcline and quartz interstitial to a few large grains of microcline and to grains of plagioclase, suggest an igneous origin.

In the granite gneiss, which is believed to have formed by shearing and recrystallization of a more massive phase, the larger crystals of plagioclase and microcline are spherical or lens-shaped and are enclosed in a granoblastic and fine-grained matrix of microcline and quartz. Cutting this matrix, and in places cutting the larger crystals as well as bending around them, are zones of finer-grained microcline and quartz containing abundant muscovite. I interpret these as recrystallized shear zones. The granite gneiss contains long streaks of quartz and of epidote and sericite. In some of the granite gneiss there remain only few rounded feldspar porphyroclasts that have escaped the shearing and recrystallization, and these are contained in a fine-grained matrix of feldspar and quartz, made schistose by small, parallel flakes of muscovite and biotite.

Some features have been mentioned which indicate that the granite that was sheared and recrystallized was an igneous rock. Does the bending of foliation and contacts around the east end of the granite gneiss mass on Lævnjavarre indicate that the original granite was forcibly intruded? This bending forms the nose of a plunging anticline which is complementary to synclines on either side, so it appears related to regional deformation and not to local wedging-aside caused by an intrusion.

Chlorite schist. Throughout the Lakselv valley area occur thin zones of chlorite schist clearly derived from the hornblende schist by shearing and retrograde metamorphism. The largest zone, and the only one appearing on the map, occurs just west of Algasvuovdde. Road cuts near the outlet of Porsvatnan show the typical features which indicate that the chlorite schist was derived from the hornblende schist: (1) chlorite schist, which has excellent foliation highly contorted in many places, contains conformable lenses of the hornblende schist from 0.5 m. to several meters long, and (2) small seams of chlorite schist branch from the larger zones of chlorite schist and cut the adjacent hornblende schist and the larger lenses. In one place, immediately adjacent to the contact of chlorite schist and quartzite, lenses and angular pieces of the more competent quarzite, which are obviously broken away from the adjacent quartzite bed, are partly or wholly surrounded by chlorite schist. Cutting the quartzite are zones of shearing 1 to 3 cm. thick containing medium-grained muscovite, which can be followed across the contact of the quartzite bed into well-foliated chlorite schist. The micro-texture of a thin section of chlorite schist, in which fragmental-appearing hornblende grains occur in a schistose matrix of chlorite, supports the conclusion the chlorite schist is derived from the hornblende schist by shearing.

Ultrabasic rocks. The small bodies of ultrabasic rocks shown on the map just east of Skoganvarre, on Coalbmejavrre, and west of Vuolajokluobbal, are apparently sills. The largest sill, that near Skoganvarre, has sharp contacts. No inclusions were noted in any of the ultrabasic masses and the map and field observations show no signs of dilation around the ultrabasic bodies themselves. The rocks are badly sheared in many places. A thin section of the sill near Skoganvarre consists principally of chrysotile, which is an alteration product of the original pyroxene, and tremolite, which is an alteration product of the original brownish hornblende. Only traces of the original minerals have survived the alteration, but the original rock may have been a pyroxene hornblendite. Biotite, both light brown and emerald green in color, occurs as an alteration product of hornblende. The tremolite contains many opaque inclusions and in most places these are lacking in a zone adjacent to altered pyroxene grains. Thin sections of other ultrabasic rocks show a felted mat of chrysotile and tremolite and give no clear indication of the mineral composition or texture of the original rock.

Quartz veins, quartz and calcite veins containing some sulfide minerals and pegmatite pods occur in the Lakselv valley area but they are very scarce. Most of the prospect pits in the area (see the geologic map for their approximate location) are in zones of slightly sheared hornblende schist or mica-quartz schist that are weakly impregnated with sulfides and are somewhat oxidized. Most of the zones are conformable to the foliation and banding of surrounding rocks.

Structure.

General. Almost all the rocks in the Lakselv valley area have a good foliation, caused by the preferred orientation of micas and hornblende, and in places enhanced by lenses of feldspar and quartz in a matrix of fine-grained, recrystallized material. In most places the rocks cleave parallel to this foliation, and contacts and banding are everywhere parallel to it. In some of the hornblende schist the hornblende prisms in the foliation planes are parallel and produce a good lineation. Some of the lustrous muscovite-quartz schists, having a crinkled foliation in which all the small fold axes are parallel, are well-lineated. Well developed lineation is not a conspicuous feature of the rocks, however, but where it was noted it is approximately parallel to the axes of the major folds.

Folds and faults. The several open folds which occur in the Lakselv valley area, and whose axes plunge in a general easterly direction, are shown on the geologic map in the accompanying cross-sections. The two best defined ones are the anticline on Lævnjavarre and the adjoining syncline to the north. The easterly plunge of these folds is clearly shown by the traces of the individually-mapped marble and hornblende schist layers and by the trend of the contact between the larger masses of mica-quartz schists and hornblende schist.

In these folds, and in the less clearly defined ones further south, the hornblende schist occurs in the troughs of the synclines and the mica-quarts schists in the cores of the anticlines; the mica-quartz schist underlies the hornblende schist and the source material for it is older. The dips of the foliation and banding of the rocks are steep and contorted in only a few places so that it is unlikely that the folds are overturned. Though most of the mica-quartz schists are older than the hornblende schist, the two rocks are obviously contemporaneous in some places — for example east of Brennelva are mappable layers and lenses of mica-quartz schists in hornblende schist, and in many other places the two rocks are interlayered on a small scale.

Since the top and the bottom of the sequence is not exposed it is impossible to estimate thicknesses. Exposed thicknesses, calculated from measurements along the cross-section line A-B on the geologic map are 1200 m. of quartzitic rocks and 6000 m. of hornblende schist.

The anticline on Lænjavarre appears to be related to the regional stress which formed the other folds of the area, although the occurrence near the core of this anticline of a mass of red granite gneiss suggests that the anticline may be local feature formed by the shouldering aside of the rocks by an intrusive granite — a granite that later was metamorphosed to a granite gneiss, thus blurring the original contacts and making them gradational. It is also possible this anticline was formed by regional stress and that the original granite was formed by replacement in the low pressure region near the crest of the fold. Metamorphism has so altered the original granite that it is not possible to decide whether it was an intrusion or a replacement body.

Perhaps the granite gneiss core of the anticline on Lænjavarre is a "mantled dome" (Eskola, 1948) i. e. a relic of the granite basement upon which the supracrustal source material of the mica-quartz schists and hornblende schist was deposited. The anticline on Lævnjavarre could be the result of doming up of the original basement during an orogeny. Since there is no distinctive layer mantling the granite gneiss on Lævnjavarre, it is impossible to find good support for the mantled-dome hypothesis. The occurrence of small seams of microcline, presumably related to the granite on Lævnjavarre, indicate the granite is not an old basement but is younger than the surrounding rocks.

Holtedahl (1931, p. 246) concludes that in Lakselv valley the surface of the Precambrian rocks upon which the oldest Caledonian sedimentary rocks were deposited was approximately flat and dipped gently northwest. He deduces, from structures in the Caledonian sedimentary rocks in Lakselv valley, that this surface was bowed up in early Caledonian time into an anticline along the line of summits Čappelvarre-Lævnjavarre-Loftefjell. Such an anticline would be a Caledonian rejuvenation of the anticline in the rocks of Lævnjavarre that formed in the Precambrian, and this coincidence indicates that the forces applied to the area in early Caledonian time were the same as those applied to it in earlier Precambrian time.

Four of the principal faults in the Lakselv valley area appear on the geologic map. The one near Akkevarre is clearly marked by brecciation and by contortion and abrupt changes of foliation attitudes near it; the other three are marked by similar features and in addition they abruptly terminate or offset contacts. Parts of all these faults follow valleys or abrupt changes in slope. No accurate estimate of the true direction or amount of displacement is possible and no mylonite is associated with them. The zones of chlorite schist represent fault zones which are nearly parallel to the foliation and banding of the enclosing hornblende schist. They may have formed during the Caledonian deformation that deformed the Precambrian surface along preexisting folds, as just described, or during an earlier period of Precambrian deformation.

Economic geology.

On the geologic map the location of the principal prospect pits in the Lakselv valley area shown. These have been transferred from a map compiled by Poulsen (1958). There is no marked relationship between the location of these prospect pits, which represent a certain amount of copper mineralization, and the principal rocks, folds and faults of the area. Some of the prospects are along zones of slightly sheared oxidized rocks which parallel the general trend of the foliation, but these zones do not appear to form any stratigraphic horizons such as might indicate that the mineralization was syngenetic. The widespread and apparently random distribution of the prospect pits and of the oxidized zones suggests, on the other hand, that the mineralization is epigenetic.

Vokes (1956) classifies the epigenetic copper mineralization in Precambrian rocks of Northern Norway in two groups. One type of mineralization is of chalcopyrite, pyrite and pyrrhotite in veins of quartz and calcite. The other type is an impregnation by bornite, chalcopyrite, neodigenite and, in places, chalcocite in broad zones. Both types of copper mineralization occur in the Lakselv valley area (Foslie, 1933, Carstens, 1931 and Færden, 1952). Quartz veins containing sulfides, both with and without calcite occur in several places — for example prospect No. 1 located 1 km. south of Brennelv. The long zones of oxidized rocks which contain weak impregnations of sulfide minerals and quartz, probably belong in Vokes' second subdivision.

The radioactivity of some of the veins and zones containing sulfide minerals and of the major rock types of the area were measured by F. J. Skjerlie during the summer of 1957. Skjerlie reports (1957, Norges Geologiske Undersøkelse unpublished report) that no significant radioactivity was found.

Since a few small veins of quartz containing sulfides occur in some of the chlorite schist, the shearing and mineralization in the oxidized zones may be related to the deformation that formed the chlorite schist.

It is possible that careful study of the veins and zones that contain sulfide minerals might lead to the discovery of an ore deposit, but analysis of the general geology of the area, which is now reasonably well known, gives no indication that such a discovery is to be expected.

Comparison with other areas.

Three excursions were made to compare the Precambrian rocks of the Lakselv valley area with those in nearby areas that are also presumed to be of Precambrian age.

The rocks seen during a visit to the tectonic window west of Skaidi (see Fig. 1) — sandstones conglomerates, greenstones, slates and quartzites (Raipas formation) — are clearly much less metamorphosed than the metamorphic rocks in the Lakselv valley area. They bear a much greater resemblance to the Caledonian rocks on the sides of the Lakselv valley than to the metamorphic rocks in the valley itself.

The rocks seen on traverses east and southwest from Skoganvarre, however, (see lines of symbols on Fig. 1) have many similarities to the Precambrian metamorphic rocks in the Lakselv valley area. Good outcrops were found only just east of the Lakselv valley map boundary and in the granulites ca. 20 km. further east. The biotite-hornblende gneiss layer west of Gaggavatn continues south-eastward out of the map area, and east of it are hornblende schists containing abundant garnet in most places and streaks and clots of hornblende gneiss. These hornblende-rich rocks, that strike roughly north along the traverse line, continue to the contact with granulites which was mapped by Eskola (1952, Fig. 1). Small masses of ultrabasic rocks, gabbro, granite gneiss, and a few dikes and pods of pegmatite also occur between the granulites and the Lakselv valley area. The hornblende-rich rocks appear very similar to the hornblende schist of the Lakselv valley area, but mica-quartz schists and quartzite were not seen in them.

The contact with the granulites appears to be gradational over several kilometers for layers of fine-grained garnet-quartz-feldspar granulite occur in the hornblende schist and gneiss west of the main contact. Eskola (1952, p. 166) mentions that layers of hornblende-rich amphibolite facies rocks do occur within the granulites of Lappland and a similar anomalous mixture apparently occurs east of Lakselv valley. The epidote-amphibolite facies rocks of the Lakselv valley area appear to grade eastward into amphibolite and granulite facies rocks through a zone which is about 20 km. wide.

The rocks observed within the main area of granulite were largely "granitic granulites" containing layers and fragments of darker and garnet-rich granulite (see Eskola, 1952, p. 138 and Fig. 9).

The outcrops on the traverse from Skoganvarre to Masi are extremely scarce. Just southwest of Vuolajokloubbal is a massive granitoid rock which in places is pink and cut by red pegmatites; it may be related to the red granite gneiss on Lævnjavarre. Similar granitoid rocks — some massive, some gneissic, and some enclosing dark swirled layers and dark unoriented inclusions — continue to the immediate vicinity of Masi. This large mass of granitoid rock is certainly the same as the batholithic mass schown on Dahll's Geologiske Kart over det Nordlige Norge (1891). No critical observations of this batholith were made to indicate its origin. Near Masi occurs massive white quartzite and hornblende schist very smilar to some of the quartzite and to the hornblende schist in the Lakselv valley area.

Summary of geologic history.

The geologic history of the Lakselv valley area begins in the Precambrian with the deposition of quartz-rich sediments. These were overlain by and locally alternated with limey muds, a few limestone layers, and probably some flows of basic lava. Later, during a Precambrian orogeny, these supracrustal rocks were metamorphosed, under conditions of the epidote-amphibolite facies, to mica-quartz schists, hornblende schist, quartzite and marble. In a few places small irregular masses of the hornblende schist were transformed, largely by recrystallization and metamorphic segregation, to hornblende gneiss and hornblende diorite. All the rocks were deformed into east trending and plunging folds. A small mass of granite, possibly related to the batholith that occurs just southwest of the area, was emplaced in the core of an anticline and a sill of biotite-hornblende-quartz diorite was emplaced in the hornblende schist. The mode of emplacement of these masses was obscured by a later metamorphism during which the granite was sheared and recrystallized to a granite gneiss, the hornblende diorite to hornblende gneiss, and the quartz diorite to biotite-hornblende gneiss. Uplift and erosion may have separated these two periods of metamorphism but there is no evidence to show this.

The area was then uplifted and in several shear zones the hornblende schist was converted to chlorite schist. The formation of the quartz and calcite veins that contain a little copper mineralization and the formation of the shear zones weakly impregnated by sulfides is probably related to this period of deformation. Small sills of ultrabasic rocks were then emplaced.

The Precambrian metamorphic rocks were eventually exposed. A more-or-less flat surface was cut on them by erosion, and in Early Cambrian time it sloped gently northwest and received a blanket of sediments. Later, in Caledonian time, this surface and the overlying sedimentary rocks were bowed up into an anticline by rejuvination of an anticline in the underlying Precambrian basement.

Sammendrag.

Den prekambriske skifer og gneis i Lakselvdalen, Nord-Norge.

Hovedbergarten i Lakselvdalen, Finnmark, fra Porsangerfjord i nord til Skoganvarre i syd, er prekambrisk hornblende-skifer og glimmer-kvarts-skifer og litt marmor og kvartsitt. På sidene av dalen ligger kaledonske sedimentære bergarter med vinkel-diskordans over disse prekambriske metamorfe bergarter.

Hornblende-skiferen er finkornet til middelkornet og mineralinnholdet er varierende — hornblende (for det meste alminnelig grønn hornblende, men også aktinolitisk), 25—50 %; oligoklas, 10—20 %; og kvarts, 5—25 %. Granat-hornblende-skifre er ganske alminnelige. Epidot forekommer også i hornblende-skiferen og dens forekomst sammen med oligoklas viser at regionalmetamorfosen foregikk under betingelser for epidot-amphibolitt-facies. Siden tynne lag av kvartsitt, marmor og glimmer-kvarts-skifer — bergarter for det meste av sedimentær opprinnelse — forekommer i tynne lag skiftende med hornblende-skiferen, er noe av hornblende-skiferen også av sedimentær opprinnelse. Noe av hornblende-skiferen kan være metamorfe basiske lavaer.

Tre hovedtyper av glimmer-kvarts-skifre forekommer: 1. rike på muskovitt, 2. rike på biotitt og oligoklas og sjeldnere 3. rike på albitt. Muskovitt-kvarts-skifrene er meget kvarts-rike og svarer sannsynligvis til uren kvarts-rik sediment. De biotitt- og oligoklasførende kvarts-skifre kan en gang ha vært lag av sur tuff eller arkose.

Blant hornblende-skifrene er noen få små masser av middel- til grov-kornet hornblende-dioritt, som er heterogene, mange steder gneisiske. Hornblende-dioritten går over i skiferen og synes å være dannet av den ved granitisering. I glimmer-kvarts-skiferen på Lævnja-varre er det en liten masse av granitt-gneis, og i hornblende-skiferen på vestsiden av Gaggagaissa er det en lagergang av biotitt-hornblende-gneis. Gneis-strukturen i disse bergarter kommer av skjæring og re-krystallisering av tidligere mere massive bergarter, hvis genesis derved er blitt uklar. Skjæring (shearing) og rekrystallisering har også dannet gneis av hornblende-dioritt.

I skjær-sonene er noe av hornblende-skiferen omdannet til kloritt-skifer. Små kvarts-årer og litt sulfid-mineralisering forekommer i noen av disse skjær-soner. Denne mineralisering og skjæring kan også være årsaken til dannelsen av soner av litt "sheared" bergarter, som er noe oxydert og som har mange kopper-skjerp.

Ultrabasiske bergarter, som opprinnelig kan ha vært pyroxen-hornblenditer, men som er omformet til chrysotil og tremolitt, forekommer i små lagerganger.

Strukturelt består bergartene i Lakselvdalens område av noen brede folder med strøk og aksefall østlig. Foldningen foregikk i prekambrisk tid, men etter at de metamorfe bergarter var erodert, og et lag av kaledonske sedimenter var avleiret diskordant på dem, ble en av antiklinalene fornyet og overliggende sediment deformert. Siden det meste av glimmer-kvarts-skifrene forekommer i kjernene av antiklinalene, ligger de under hornblende-skiferen og er eldre.

Litt epigenetisk sulfid-mineralisering forekommer i Lakselvdalens område i årer av kvarts, med eller uten kalkspat, og i lange soner av litt "sheared" og oxsydert skifer. Svovelkis, magnetkis, kopperkis og broket kopper er de viktigste sulfid-mineraler. Ingen avvikende radioaktivitet ble funnet i disse årer eller soner eller i hovedbergarten. Det er mulig at inngående studier av årene og sonene som inneholder sulfid-mineral kan føre til oppdagelse av brytbar malmforekomst, men den generelle geologiske analyse av området, som nå er forholdsvis godt kjent, tyder ikke på at vi kan vente en slik oppdagelse.

En rekognoseringstur viste at øst for Skoganvarre er de fleste bergarter hornblende-skifre og -gneis. De strekker seg 20 km mot øst, hvor de skifter med og er i kontakt med granulitter. Like sydøst for området er det en batholith som kan være i samband med granitt-gneisen i området.

References Cited.

Carstens, C. W., 1931. Die kiesvorkommen im Porsangergebiet: Norsk Geol. Tidsskr., Bind 12, pp. 171—177.

Dahll, T. Om fjeldbygningen i Finmarken og guldets forekomst sammesteds, *in* Dahll, T. and others. Det nordlige Norges geologi, Norges geologiske undersøkelse, no. 4, pp. 1—21.

Eskola, P. E., 1948. The problem of mantled gneiss domes: Jour. of the Geol. Soc. of London, v. 104, pp. 461—467.

— 1952. On the granulites of Lappland: Am. Jour. of Sci., Bowen Volume, pp. 133—177.

Færden, J., 1952. Porsangerfeltets koppermalmforekomster: Tidsskr. for Kemi og Bergvesen, 12 årgang, pp. 16—18.

Foslie, S., 1933. Copper deposits of Norway, *in* Copper deposits of the world, XVI Internat. Geol. Cong., Washington, pp. 605—614.

Holmsen, P., Padget, P., and Pehkonen, E., 1957. The Precambrian geology of Vest-Finnmark, Northern Norway: Norges geologiske undersøkelse, no. 201.

Holtedahl, O., 1918. Bidrag til Finnmarkens geologi: Norges geologiske undersøkelse, no. 84.

— 1931. Additional observations on the rock formations of Finnmarken, Northern Norway: Norsk Geol. Tidsskr., Bind 11, pp. 241—279.

— 1953. Norges geologi: Norges geologiske undersøkelse, no. 164, Bind 1.

Reusch, H., 1891. Iagttagelser fra en reise i Finnmarken 1890, *in* Dahll, T., and others, Det nordlige Norges geologi. Norges geologiske undersøkelse, no. 4, pp. 22—111.

— 1903. Fra det indre av Finnmarken: Norges geologiske undersøkelse, no. 36.

Poulsen, A. O., 1958. Norges gruver og malmforekomster, Nord-Norge: Norges geologiske undersøkelse, no. 204.

Vokes, F. M., 1956. Some copper sulfide paragenesis from the Raipas formation of Northern Norway: Norges geologiske undersøkelse, no. 200, pp. 74—111.

Plate 1

Fig. 1. Polished surfaces of hornblende diorite (left) and hornblende gneiss (right). Note the patches of diorite in the gneiss and the irregular crystal borders in the diorite.

Polerte overflater av hornblendedioritt (til venstre) og hornblendegneiss (til høyre). Merk flekker av dioritt i gneissen og irregulære krystallbegrensninger i dioritten.

Fig. 2. Polished surface of granite gneiss. Note the streaked-out appearance of the gneiss and the scattered porphyroclasts of feldspar. The dark streaks are chlorite and biotite.

Polert overflate av granittgneiss. Merk at gneissen er strukket ut og de spredte porfyroklaster av feltspat. De mørke streker er kloritt og biotitt.

Pl. I.

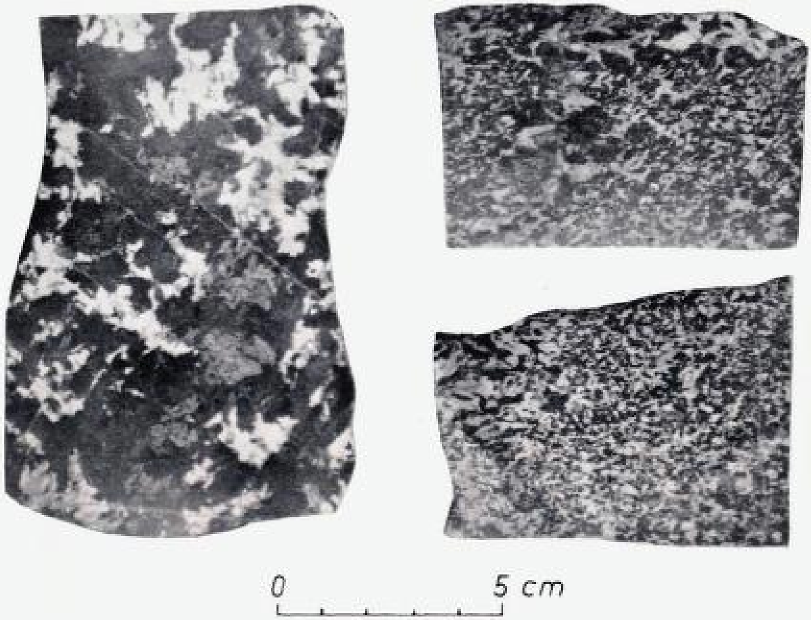


Fig. 1.

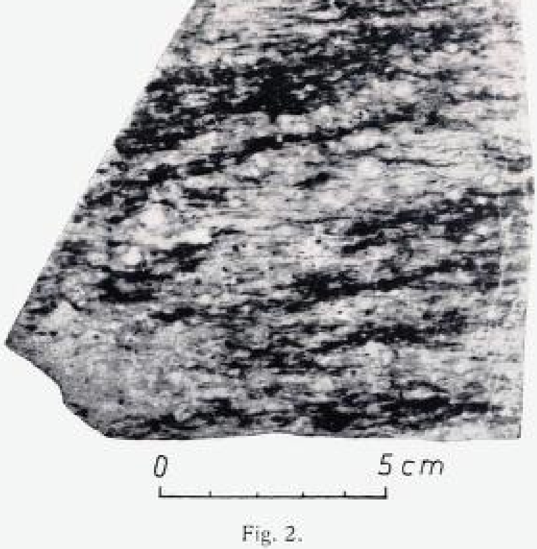


Fig. 2.

GEOLOGIC MAP of the LAKSELV VALLEY AREA NORTHERN NORWAY

EXPLANATION

PLEISTOCENE AND RECENT

Moraine and terrace gravels, minor alluvium and bog deposits

Unconformity

CALEDONIAN ROCKS

Sandstone and shale, minor conglomerate and quartzite

Unconformity

PRECAMBRIAN

Ultramasic rocks, largely altered to serpentine

Chlorite schist in shear zones

Granite gneiss, commonly red and fine-grained, contacts irregular and gradational

Marble layer

Quartzite or mica-quartz schist layer

(a) (b)

(a) Biotite-hornblende gneiss
(b) Hornblende schist, thickness of interlayered marble, somewhat exaggerated, interlayered quartzite and mica-quartz schist diagrammatic. Includes a little chlorite schist in shear zones and a little amphibolite of medium to coarse grain.

Hornblende schist layer.
Mica-quartz schist and quartzite, interlayered hornblende schist diagramatic

SYMBOLS

Contact (dashed where approximately located)

Indefinite contact (includes gradational contacts, inferred contacts and indefinite contacts of superficial deposits)

Concealed contact

Fault showing relative movement (dashed where approximately located)

—? — —? Probable fault

Strike and dip of foliation and gneissic banding (400° = circle)

Strike of vertical foliation and gneissic banding

Horizontal foliation and gneissic banding

Strike and dip of bedding (400° = circle)

xxxxxx Zones of oxidized rocks slightly sheared and impregnated with a little calcite, quartz and sulphides

•10 Prospect (location uncertain for most)

Axis of plunging syncline

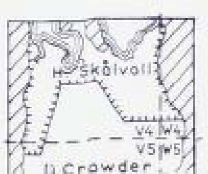
Axis of plunging anticline

SCALE

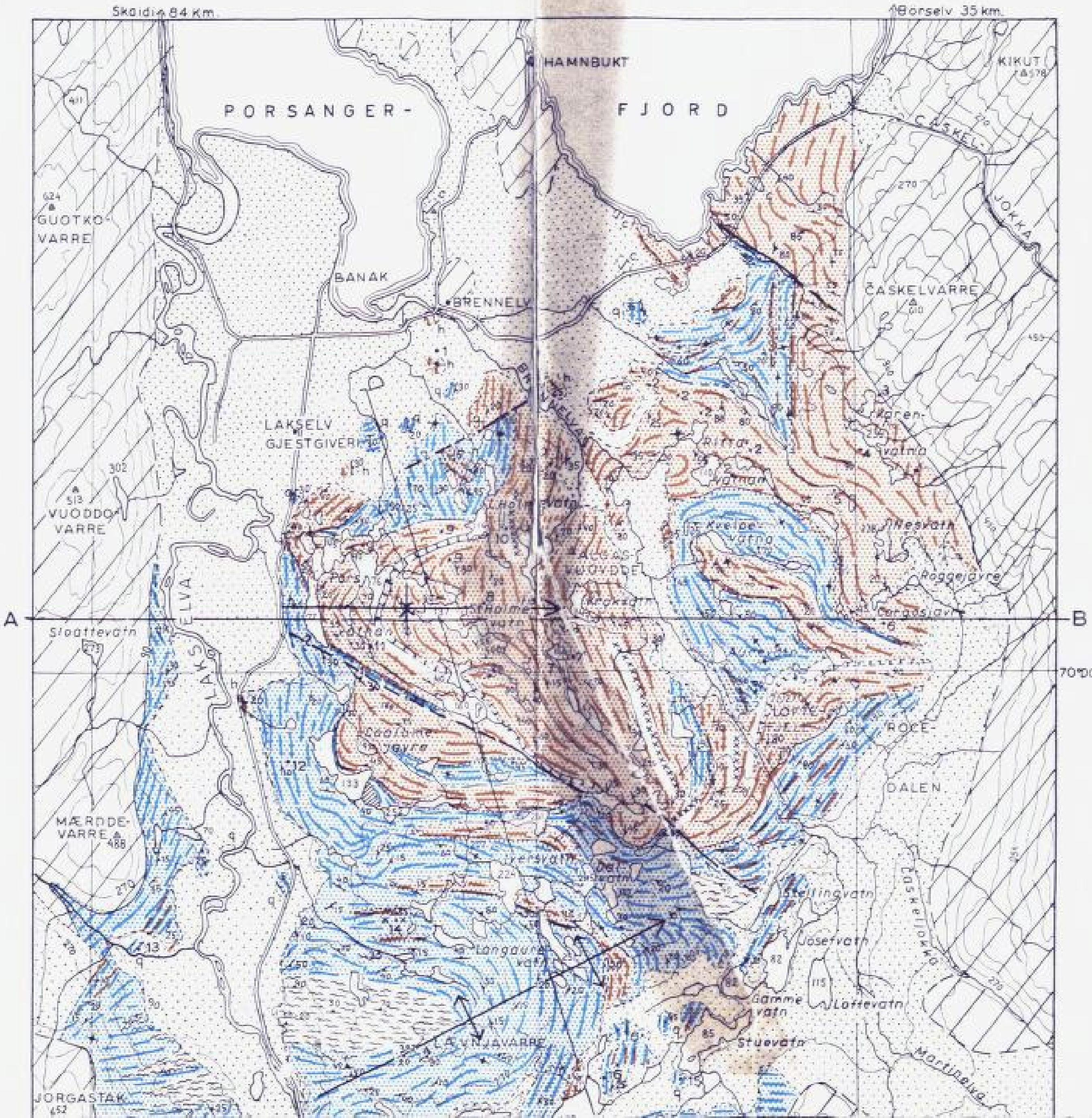
0 1 2 3 km

0 1 2 Miles

All elevations in meters



Base map from parts of Norges Geografiske Oppmålings 1: 100,000 quad-



Statens teknologiske institutt

Elevation of contour (interval 90 m)

Summit elevation

Lake elevation

Building

Road

rangle sheets:
Skoganvarre (V-5, 1933),
Halkkavarre (W-5, 1918),
Stabbursdalen (V-4, 1932), and
Børselv (W-4, 1916)
Geology by D. Crowder and H. Skålvoll, 1957

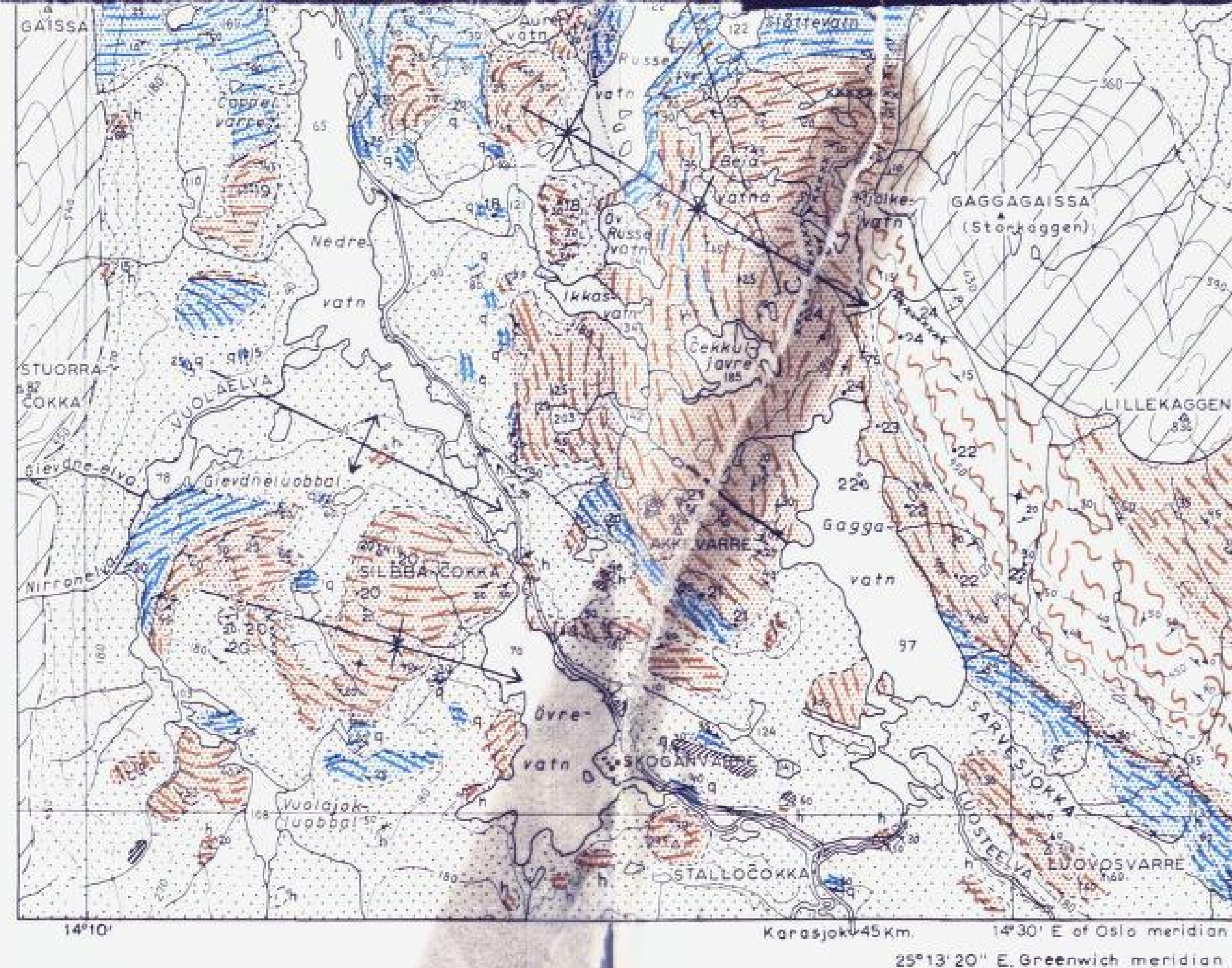
True North

6.0° (1950, 400° = circle)

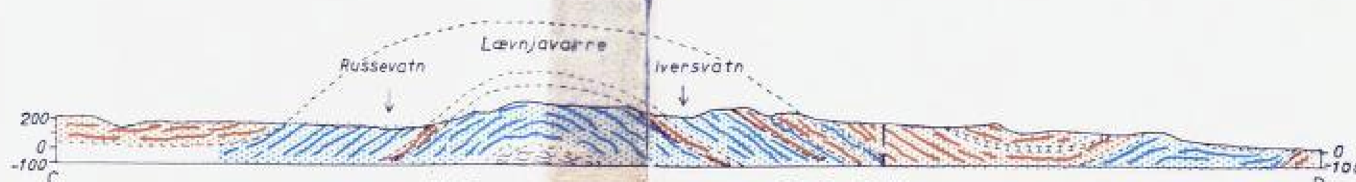
NAMES OF PROSPECTS

After Poulsen 1958. Cu = copper ores; K = pyrite and pyrrhotite; Fe = iron ores

1. Hueskar, Korkokuru .... Cu
2. Nedre Rittavann .... Cu
3. Karinhaugene .... Cu
4. Sorgusvann .... Cu
5. Sorgusdalen N. .... Cu
6. Sorgusdalen S. .... Cu
7. Fiskvann Store Kisgang .... K, Cu
8. Kagurijærvi .... Cu
9. Poikekuru — Langvassbekk Cu
10. Holmvann .... Cu
11. Sløykedal — Børsvann .... Cu
12. Revfossnes — Salmijærvi .. Cu, K
13. Salmijærvi .... Cu, K
14. Barbalas kisgang .... K, Cu
15. Toppajærvi .... K, Cu
16. Russevann .... Cu
17. Ørretvann .... Cu
18. Ingasvann .... K, Cu
19. Cappelvarre .... Cu
20. Silbbaçokka — Guotkonvarre .... K
21. Akkasvarre .... Cu
22. Gaggagaisa — Njonnas ... K
23. Gaggagaisa — Vuoppasvarre .... Fe
24. Gaggagaisa — Vuoppasvarre .... Cu



E-W CROSS SECTION ALONG A-B
(vertical scale double horizontal scale)



N-S CROSS SECTION ALONG C-D
(vertical scale double horizontal scale)