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The Geology of the Caledonides of the Birtavarre Region, Troms, Northern Norway

BY

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SAMMENDRAG:

BIRTAVARRE-OMRÅDETS GEOLOGI

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AND 3 PLATES

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Introduction.

In the summer of 1952, the Geological Survey of Norway (Norges Geologiske Undersøkelse, or NGU for short) began an investigation of an area around Birtavarre (69° 50'N, 10°E of Oslo), Kåfjord i Lyngen, Troms (map, pl. 1). Several small mines were in operation 1899—1919 based on separate bodies of sulphide ore (chalcopyrite, pyrrhotite and sphalerite).

The investigation had as its main purpose the valuation of the known ore bodies and the search for new ones with a view to the possible restarting of mining activity in the area. The work formed a part of the government-sponsored plan for the economic development of northern Norway.

A detailed geological map was first prepared around the former mining area and the possible form, distribution and interrelationship of the known ore bodies deduced. In the summer of 1953 mapping was carried out over a wider area: also more intensively around and in the accessible parts of the mines. Concurrent with this work a geophysical survey was carried out by Geofysisk Malmleting (Trondheim) at the request of NGU. With the results of the latter survey to hand a programme of diamond-drilling to prove the ore resources was begun in the summer of 1954.

The present paper deals mainly with the stratigraphic and structural features of the Caledonides in which the ore bodies occur. As might be expected, information is more detailed from the area of sulphide mineralization. In fact the the work falls into three main grades of 'intensity'. Firstly, geological mapping over a wide area on both sides of Kåfjorddalen, (1 : 26500) embracing the Kåfjorddalen syncline (see Part 2) and the extension of its easterly limb towards Reisadalen. Secondly, the detailed mapping (1 : 500) of the mines (where accessible) and ore-bearing rocks where exposed at the surface. (The results of this intensive study will form the subject of a special publication by F. M. Vokes.) Thirdly, mapping of a reconnaissance nature in Mandalen, Reisadalen, where the main formational units established around Birtavarre can be easily distinguished and their distribution estimated fairly accurately from a study of critical profiles and from aerial photographs. In addition a study of a profile in Skibotndal from the base of the Caledonides upwards was made, enabling among other things, the beds around Birtavarre to be placed, both stratigraphically and structurally in the Caledonide sequence.

Historical.

No intensive geological work had been carried out in the area under consideration previous to the present survey. The geological background was therefore known in only the vaguest way and largely inferred from the works of earlier writers. Among the latter, Karl Pettersen is outstanding as being the first to give details of the geology of Troms. Much of his work is descriptive in character and arranged geographically. Thus information on the present region occurs in four sections of a larger report on Troms (1870), viz. Storfjordelv to Skibottenelv (pp. 42—48): Skibottenelv to Kåfjordelv i Lyngen (pp. 48—53): Kåfjordelv to Reisenelv (pp. 53—70): Reisenelv to Kvænangen (pp. 84—108). His results are also shown in maps, e. g. 1868, 2. Fastlandsstrækningen fra Storfjordbotten, nordover til Kvænangen: and in profiles, e. g. 1870, fig. 1. Profil fra Rigsgrændsen ned til Kaafjord Botten i Lyngen.

Later H. Reusch, a former Director of NGU, visited the area and drew attention to geomorphological features, particularly the deep, canyon-like valleys of Kåfjorddalen (1904, pp. 14—34). Further comments on these and on some glacial features have been recently published by J. A. Dons, a member of the present survey during the summer of 1952 (1953, pp. 188—190).

On the southern side of the area in neighbouring Finland, Hausen has described the Haldit gabbro in detail (1942 a) and given a full account of the overthrusting of the Caledonides in the Enontekiö area (1942 b).

Topographical.

As can be seen from the map (pl. 1) the area under consideration stretches from the Finnish border northwestwards to the sea as represented by Lyngen- and Storfjords. It includes several valleys arranged roughly parallel to each other and these are (from south to north) Skibotndal, Mandalen, Skardalen, Kåfjorddalen and Reisadalen. The first four become progressively deeper and more U-shaped towards the sea and represent a deeper dissection of the plateau surface of inner Troms, Finnmark and neighbouring parts of Finland and Sweden. This surface is on the average about 800 to 900 metres above sea-level in the area of investigation. Reisadalen is a much wider valley and opens into Reisenfjord (Kvænangen).

The more seaward parts of the area are frequently very barren, treeless and mantled in rock scree — the result of weathering in glacial and post-glacial times. Several glacial corries are present, the most spectacular being on Isa Varre, south-west of Kåfjord.

Retreating ice-sheets have locally left much glacial débris inland which mantles the solid rocks in a rather irregular fashion and softens the harshness of the topography. More clearly defined glacial deposits such as terminal moraines and sinuous eskers are occasionally discernible. They usually show up well in aerial photographs.

Numerous lakes occupy basins and hollows on the 'plateau' surface. They are drained by streams which merge into the rivers of the main valleys. In parts of their courses the main rivers and their larger tributaries flow along steep, canyon-like gorges. This is particularly characteristic for Kåfjorddalen and has been commented on elsewhere (Reusch, 1904; Dons, 1953).

Permanent habitations are largely confined to the valleys though a few nomadic Lapps spend the summer months in the area with their reindeer herds.

Part 1. Stratigraphy and Petrography.

Autochthonous Rocks.

While the main object of this paper is an account and discussion of the stratigraphy and structure of the allochthonous Caledonides, some remarks are here included for the sake of completeness on autochthonous rocks in the vicinity of Kilpisjärvi, Finland. (See also the writings of Hausen, 1942 b.)

Two main rock types are present, namely a dioritic gneiss and fine-grained shale belonging to the Hyolithus zone.

The gneiss dips at high angles (80°) and at one road-side locality a little north of Siilastupa (Kilpisjärvi), it is mylonitized.

The shales, forming the lowermost slopes of Saana mountain, overlie the gneiss. The contact is presumed to be one of angular unconformity, though it cannot be observed directly due to lack of exposures. The shales themselves were examined in more detail on the south-west facing slopes of Saana, close to Kilpisjärvi. In their lower part they are fine-grained, brownish, greenish and reddish in colour and relatively unmetamorphosed. A possible mould of *Hyolithus* sp. was found. Higher in horizon, light coloured layers and lenses of dolomite and calcite cut by a multitude of thin quartz veinlets occur. There is also a marked increase in tectonism upwards, the shales showing much slickensiding both on parting planes and on oblique planes of fracture. These tectonic effects on the shale are clearly 'drag' effects brought about by big movements connected with the 'Seve' thrust plane just above. The latter is now represented by a thick zone of mylonite.

From observations in the field and after drawing of the profile it seems likely that this thrust zone falls at a steeper angle to the north than the shale. The latter would then be progressively cut out in this direction. Exposures, however, are not good enough to prove the correctness of this deduction.

Allochthonous Caledonides.

Introduction.

A full and fairly detailed stratigraphic succession is given below of the Caledonides of inner Troms. The lower limit is a tectonic one, the 'Seve' overthrust, and the upper limit, beds of the Quartzite Series (see later, Part 2). Higher beds probably occur some distance to the west, close to the Lyngen gabbro massif, but outside the present area of investigation.

The beds are essentially layered schists with a general fall of about 15°—25° to the NNW. Younger beds therefore occur in this direction.

In the lower part of the succession the schists are dominantly quartzose and somewhat feldspathic. They resemble the sparagmitic rocks elsewhere in Norway and are therefore provisionally referred to as the Sparagmitic Schists. They have only been studied in Skibotndal as yet.

Above them comes a thick and more varied sequence of schists collectively known as the Birtavarre Series. In their upper part formational units can be discerned and have been mapped in detail over a wide area around Birtavarre, hence the name.

Lower down, however, they have suffered granitization in greater or lesser amounts. This occurs in a broad zone several hundreds of metres thick and roughly, but not exactly conformable with the stratigraphy.

It is therefore proposed to treat the Caledonide succession as follows:

Birtavarre Series
- a. non-granitized schists:
- b. granitized schists:

Sparagmitic Schists.

Most of the rocks have been involved in a fairly high degree of metamorphism and now appear to be in upper epidote-amphibolite or low amphibolite facies. There are, however, certain basic rocks which are only weakly metamorphosed. They appear to be intrusive and are thought to date from a period after the main phase of regional metamorphism.

No fossils were found.

Sparagmitic Schists.

The beds have only been studied in detail in connection with the construction of a profile along Skibotndal. Here they occur immediately above the basal mylonite zone at Kilpisjärvi and in an elongated inlier near Helligskogen.

The beds are typically grey, regularly bedded and jointed psammitic schists. On freshly broken surfaces a distinct colour banding is often visible and is apparently due to slight variations in the amounts of mica. Only occasional layers of muscovite schist are present. In detail, small-scale erosion surfaces are occasionally visible and traces of cross-bedding. Thin sections show an abundance of small quartz-grains with lesser amounts of feldspar (albite, microcline). Small but variable amounts of muscovite and occasional epidote-bearing layers are sometimes present. The rock shows strong granoblastic texture with all the grains firmly sutured together. The original clastic nature of the grains is, therefore, no longer apparent but it is possible that the rock was originally a somewhat feldspathic sandstone. Some of the feldspar is now slightly larger than the other grains and is to some extent of secondary growth.

In the field and in hand specimens the rock closely resembles certain metamorphosed sparagmites in the Opdal area, south of Trondheim. A chemical analysis (Table 5, p. 52) emphasizes the resemblance still further, particularly in the ratio of the salic to the femic constituents. Further comments are reserved till later (p. 53).

The relationship to the (granitized) Birtavarre Series was carefully studied in ground north-east of Helligskogen where exposures are fairly complete (see fig. 1.).

Attention is drawn to the conformable nature of the junction and the narrow transition zone in which sparagmitic-like layers are contained within micaceous schists.

The main body of the sparagmitic schist however is here light coloured. In some places it shows fine banding and small angular unconformities believed to be of primary origin. Folds are rare and only of the order of a few centimetres when present.

Birtavarre Series. a. non-granitized.

In this group are included all the higher beds of the succession above the main zone of regional granitization.

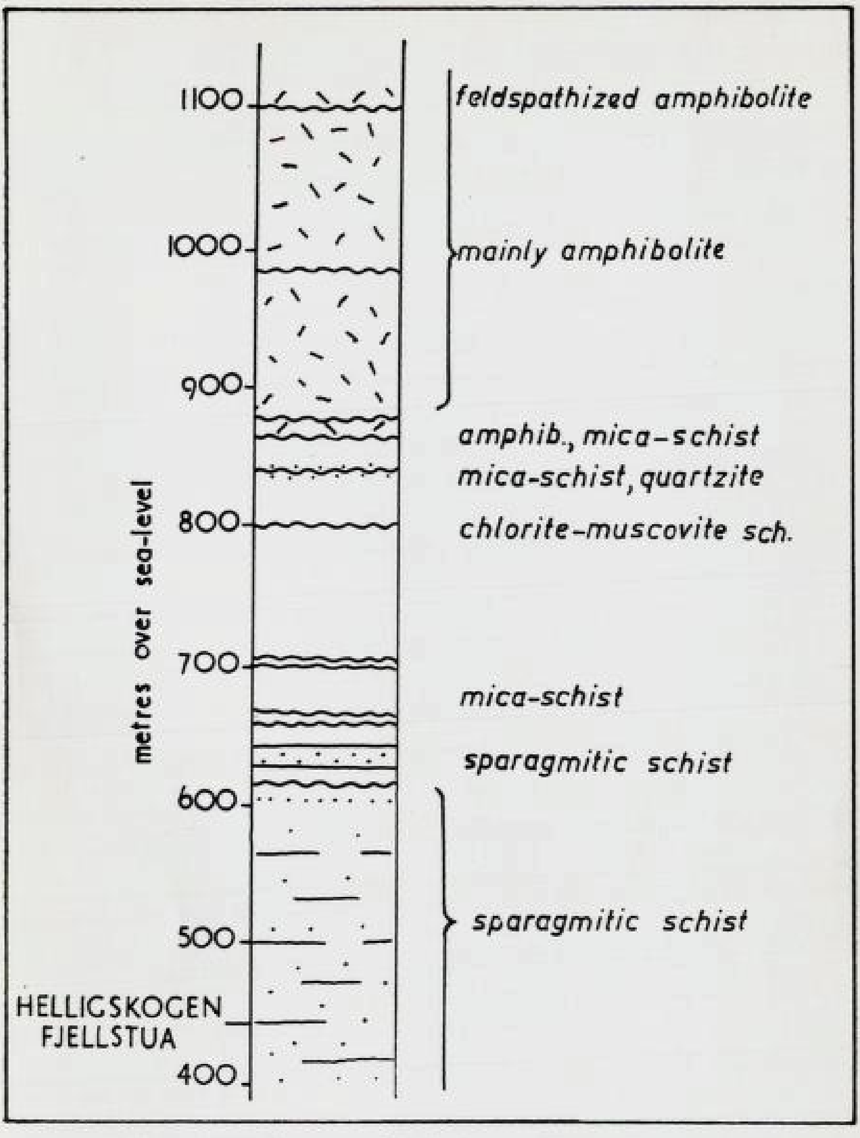

Fig. 1. Succession east of Helligskogen fjellstue, Skibotndal.
Lagrekken øst for Helligskogen fjellstue, Skibotndal.

A number of distinct units can be readily distinguished and these are in stratigraphical order:

VIII. Quartzite Series.
VII. Store Borsejok Series.
VI. Schists-with-thin-Limestones.
V. Green Beds.
IV. Ankerlia Series:
- Upper Brown Schist.
- Ankerlia Schist.
  - Upper Ankerlia Schist.
  - Banded Ankerlia Schist.
  - Lower Ankerlia Schist.
- Lower Brown Schist.

III. Guolas Limestone Series.
II. Nitsim Varre Series.
I. Big Limestone Series.

Granitization is generally absent except in a few narrow bands and in localized areas to be detailed below.

Each of the above subdivisions will now be described individually when the procedure is to select and describe a type locality then to note stratigraphic and petrographic variations of interest elsewhere. When tectonic features are especially characteristic of a particular formation these are briefly noted, though fuller descriptions are postponed till Part 2.

VIII. Quartzite Series.

This, the highest Series in the area, is chiefly characterized by the presence of numerous layers of white or grey quartzite separated by quartz-mica-schist. The two main outcrops occupy high ground on either side of Kåfjorddalen. That to the SW around Isavarre has been studied in a fair amount of detail as exposures are good though partially covered by surface scree. It is also possible to make out the stratigraphical succession here with greater ease especially to the south and west. North and east of Isa Varre, however, slopes are so steep as to be virtually inaccessible and the limits of the Series are deduced from a consideration of the dip and strike of the underlying beds at lower altitudes and from aerial photographs. It seems that the outcrop of the Series closes to the north (see map, pl. 1). Similarly, the outcrop NE of Kåfjorddalen between Nassa Varre and Mainarasja has been studied most fully on its S and E borders. Excursions across it to the west show first a flattening and in some places a reversal of the dip. The base of the Series then outcrops in the walls of Kåfjorddalen, but becomes indistinct northwards due to local granitization phenomena.

The lithology of the Series may be most conveniently studied to the SE of Isa Varre and NW of Store Borsejok Vann where no tectonic complications affect the lowermost 50 metres or so. Here the base is conveniently taken at the first layer of quartzite. This is about 3 metres thick and others varying from ½ to 4 metres occur above: one of 10 metres showed cross-bedding. The quartzites are interbedded with grey, fine-grained quartz-mica schists. Some show a banding due to the presence of more micaceous layers (lustrous on weathered surfaces) and contain, not infrequently, small porphyroblastic garnets. They are rather similar to some of the schists of the underlying Store Borsejok Series with which the Quartzite Series appears to be perfectly conformable. Dark basic rocks are rare: a few thin, lens-like bodies are present in the area west of Okselvdalen and seem to be occasionally discordant to the enclosing rocks: some show apparent chilled margins.

Of importance is the increasing tectonic disturbance upwards in the succession. This fact becomes evident about 50 metres above the base when occasional drag-folds are seen in the grey schists. These tend to increase in frequency upwards and involve greater thicknesses of rock. About 200—300 metres seem to be so affected though with varying degrees of intensity. Higher beds (the highest studied in the whole area) above this zone are more uniformly bedded and gently dipping.

The tectonic disturbance has brought about considerable recrystallization and re-orientation of the minerals grains. To some extent there is also a segregation of the micaceous minerals into small 'clots' or 'speckles' a few millimetres in size. These are typically ovoid in shape and elongated parallel to each other. They further emphasize the strong lineation which all the rocks show, especially the bedding surfaces of the quartzitic layers. Quartz grains in both the grey and 'speckled' schists and in the quartzites themselves invariably show 'strain' effects when studied in thin section. Garnets also appear to have been smeared out in some places and at one horizon feldspathic material (orthoclase) occurs as small augen and schlieren.

Passing to the other main outcrop NE of Kåfjorddalen we find a similar conformable relationship to the Store Borsejok Series but tectonic complications of the type outlined above occur much lower down in the succession. Speckled schists are very commonly developed and both lighter and darker types are recognizable. Towards the top of the more severely tectonized zone, conspicuous pegmatitic bodies of quartzo-feldspathic rock occur in the schists. These are well seen in the Mainarasja area where they are commonly several metres thick and up to 40 metres long (fig. 2). They are generally conformable to the schists but have irregular margins and frequently enclose portions of schist. Tourmaline is present as a minor mineral constituent and is frequently concentrated close to the junction with the schist. Quartz is commonly intergrown with perthitic feldspar or segregated into veins down the central part of the bodies. The schist fragments included in the body of the pegmatite show an absence of rotation while their margins have a highly 'corroded' appearance. This megascopic field evidence is thought to suggest that the schist layers have been partially replaced by the pegmatite. There is no evidence that the 'replacement' has taken place on planes of fracture.

Of lithological interest is the appearance down dip of a thickness (several metres) of lime-phyllite and calcareous meta-limestone with thin calc-silicate and biotite-rich layers. This is spectacularly exposed as a white-weathering rock on the steep mountain side overlooking Kåfjorddalen, SW of Nassa Varre. It is here locally much folded (fig. 39) along with the other (i. e. speckled) schists and quartzites. Stratigraphically, it appears to be either in the base of the Quartzite Series or a little above it. Similar white layers are visible in the steep valley wall opposite, but cannot be directly examined due to their inaccessibility. Through the binoculars, however, they also appear to be folded (see profile, fig. 40), and occur at about the same stratigraphical horizon. They thin out altogether to the SE and have not been found to outcrop away from Kåfjorddalen. Petrographically they are unlike any of the other limestones of the Birtavarre Series and are most likely to be explained as a local sedimentary facies of the Quartzite Series.

Fig. 2. Pegmatite (light-coloured) in the Quartzite Series, Mainarasja, Birtavarre.
Pegmatitt (lys) i Quartzite Series, Mainarasja, Birtavarre.

VII. Store Borsejok Series.

The Series forms a broad continuous outcrop across the area from Mandalen to Samueldalen and is also known from Skibotndal. It is typically developed around Store Borsejok Vann, hence the name. Here, as elsewhere, the beds are gently dipping. The lowermost ones are largely quartz-biotite schists with a few grey, graphitic layers (2—3 metres thick). They succeed some lime-schists of the underlying Schists-with-thin-Limestones conformably and are themselves succeeded by a thickness of muscovite-biotite schist. The latter is especially well exposed around Store Borsejok Vann and includes a thick lens of white vein quartz which has been brecciated and has a sulphide impregnation. The highest beds of the Series form the rather abrupt slope on the NW side of Store Borsejok Vann. They contain a few dark, graphitic schists towards the base but are for the most part well-bedded and jointed quartz-mica schists. Thinner mica-schist laminae give added schistosity to the Series and in association with the well marked jointing promote the development of a blocky scree. There are also layers of lustrous muscovite schist several metres thick which weather more easily and give rise to distinct 'steps' in the topography. Thin concordant layers of green, schistose amphibolite are also common in some places. They are frequently garnet-bearing and have more coarsely crystalline parts where plagioclase (An_{38}, An_{50}) is conspicuous in association with green hornblende. Finally, white, grey or purplish lenses of vein quartz concordant to the schistosity and the bedding are commonly present. They are usually about a metre in length and from 10 to 20 cms thick. The top of the Series is marked by the appearance of the first quartzitic layers of the Quartzite Series.

When followed laterally it is evident that the lithological types continue though varying in thickness. Thus the graphite schists are expanded in thickness at little north of Kilen and disseminated pyrite is common. Again, the muscovitic schist forming the middle part of the Series become thinner westwards but continues strongly to the NE across Kåfjorddalen. The quartz-veining, so common in some of the schists, is also present in Kjerringdal and can be seen in the steep inaccessible walls of Mandalen and Skardalen. Here its lowest appearance in the succession apparently coincides with the base of the Series.

The Series is remarkably little folded. Towards the base the layers are often sheared and slickensided.

To the W and N of Njuorjo Javre, the junction between the lowermost Store Borsejok Series and the Schists-with-thin-Limestones is difficult to follow due to the increasing similarity of the schists of each.

When followed down to the NW the Series is seen to outcrop extensively in the walls of lower Kåfjorddalen and Kåfjord. A number of random observations showed the persistence of the same muscovitic and quartz-mica schists with thin layers of green, garnetiferous amphibolite.

There is, however, a conspicuous development of granitization in a more northerly direction. Thus in a roadside exposure about 50 metres north of the store near the head of Kåfjord, large feldspathic augen arranged in lines and more irregular schlieren are typical through 15—20 metres. Similar features were seen in corresponding beds on the opposite side of Kåfjord.

A profile was also examined from a point on the fjord, about 1 km SE of Trollvik up the mountain slope in a NE direction. At first typical Store Borsejok schists were met with, but higher up quartzo-feldspathic pegmatites appear in irregular lenses. Quartz commonly lies towards the centre and mica is abundant. The rock as a whole becomes more massive upwards and regular schistosity disappears. Recrystallization of the component minerals has taken place with increase in grain size. Locally, the rock is in the condition of a granitic gneiss.

Granitization of this type continues upwards till more weakly granitized quartzitic schists, characteristic of the upper part of the Quartzite Series, are met with. Thus it would seem that the upper part of the Store Borsejok and lower part af the Quartzite Series are granitized so that the junction between them is no longer clear and distinct.

A body of more homogeneous granite and granite-gneiss is present in upper Trollvikdalen. It appears to lie in the stratigraphic horizon of the Store Borsejok Series. A brief reconnaissance indicates that it has an oval-shaped outcrop and is cut by a large number of pegmatite veins rich in quartz, feldspar, muscovite but barren of other minerals. These are often fairly flat-lying and have sharp contacts with the granite. They also occur in the schists but seem to lose their regularity with increasing distance from the granite proper.

It seems possible that the granite represents a more complete stage of granitization of the Store Borsejok Schists than that seen in the profile, though the latter may very well be a lateral manifestation of the process.

The presumed relationships are shown rather diagrammatically in fig. 3, where the general parallelism of the granitization with the layering of the schists is indicated.

VI. Schists-with-thin-Limestones.

The Series owes its name to the presence of several thin, crystalline limestones interlayered with mica- and quartz-mica schists. It is most typically developed in the Moskogaissa area, west of Ankerlia where it crowns both Store and Lille Moskogaissa. The formation can be followed at intervals W and NW to Cappis Javre and NE to Kilen and beyond.

The thickest and most characteristic development of the Series is to be found on Store Moskogaissa where several profiles show that two-mica schists (often weathering brown) and quartz-mica schists succeed the Green Beds conformably. Several thin metalimestones are frequently present close to the junction which is slightly transitional: thus, limy layers are interbedded with green schistose rock.

Higher up in the succession there is considerable variegation in the layers. Apart from the mica- and quartz-mica schists mentioned above, there is a conspicuous layer (about 3—4 metres thick) of hard white quartzite, often slightly biotitic. This can be followed rather extensively and gives a good mapping line. The meta-limestones are usually thin (10 cms to 1 metre), weather to a brown colour, and can be followed for only limited distances. The highest limestone (the 'main' limestone), however, is nearly 3 m thick and appears to be more persistent. There are also several layers of amphibolite, and a wedge-like body of dolerite exhibiting a massive and well-jointed appearance and giving rise to a blocky scree on the summit of Store Moskogaissa. It also shows evidence of chilling against the schists and thin layers of the latter are interleaved with it. In thin-section a sub-ophitic texture is retained though the pyroxene is altered in various degrees to green hornblende. Several smaller bodies of dolerite are present in the Series elsewhere, though they are usually smaller in size and contact effects (such as chilled margins) are less obvious. These dolerites are remarkably directionless as regards texture and appear to have escaped the main phase of regional metamorphism. They were presumably intruded later. Similar rocks are also developed to the north (Lille Moskogaissa, Lime-Schist Mountain) with the addition of a thickness of 10 metres of lime-schist. This occurs in the uppermost part of the Series and consists of thin, alternating layers (2—3 mm thick) of lime- and quartz-schist. It weathers brownish and surfaces oblique to the bedding show a fine ribbing, the ribs being the more quartzitic layers.

On Store Moskogaissa there was little evidence of granitization as represented by secondary quartzo-feldspathization except for some pegmatitic material associated rather irregularly with the white quartzite. Northwards, however, it appears to become progressively more marked and forms a broader zone towards the middle of the Series a little west of Lille Borsejok Vann. Here, conspicuous augen and schlieren of feldspar (plagioclase. An_{36}, An_{38}) are common through 10—15 metres and though the schistosity is still retained to some extent the rock has been 'welded' together and now weathers into more rounded surfaces compared with the scarp-like outcrops of non-granitized schists above and below. Further in-

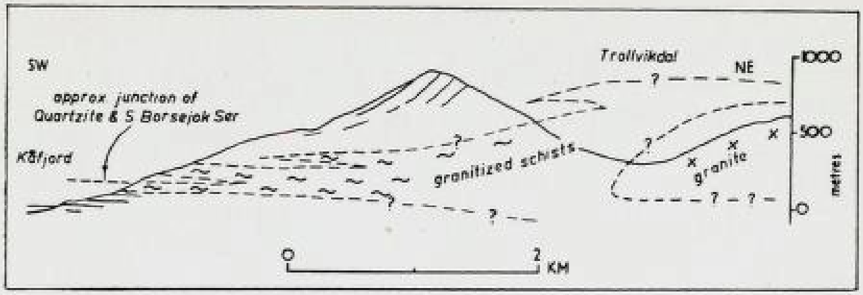

Fig. 3. Profile to show deduced relationship of granite (Trollvikdal) to granitized schists (Kåfjord).

Profil som viser den antatte forbindelse mellom granitt (Trollvikdal) og granittiserte skifre (Kåfjord).

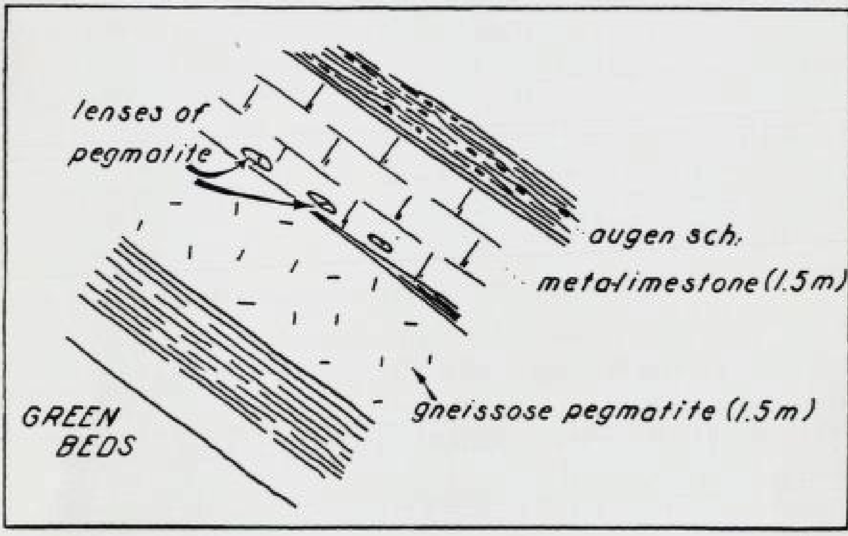

Fig. 4. Relation of gneissose pegmatite to containing beds, close to outflow from Lille Borsejok Vann. Drawn from field-sketch.

Forholdet mellom gneisaktig pegmatitt og skifrene like ved utløp av Lille Borsejok Vann. Tegnet etter dagboksskisse.

crease in the degree of 'gneissification' and in the thickness of beds involved takes place down dip towards Kilen.

Mention must be made here of sheet-like bodies of granitic and gneissose pegmatite present in the schists. They are usually about 1.5—2.0 metres thick, have slight swells and pinches and are only rarely discordant to the bedding. Contacts with the containing schists are usually sharp and detached flakes of the latter are occasionally seen in the body of the pegmatite (fig. 4). Mineralogically the pegmatite consists of quartz, oligoclase, (An_{20}-$_{30}$) microcline (microperthite), biotite, muscovite, with occasional small garnets, zoisite and black tourmaline needles. The micas are often orientated parallel to each other, so as to give the rock a crudely foliated appearance.

Good outcrops of the pegmatite are seen on the SE slope of Lille Moskogaissa where a single layer, 2 m thick weathers into massive blocks. It is apparently located in the upper part of the Green Beds. To the south, on the south-east slope of the 'Lime-Schist-Mountain', a similar sheet is present in the Green Beds (here much reduced in thickness) and others in some amphibolite believed to be the lateral equivalent of higher parts of the Green Beds as developed to the south (see fig. 5). Northeastwards, pegmatite can be followed at intervals towards Lille Borsejok Vann. Here a good exposure near the outflow of the lake shows it to lie in the basal layers of the Schists-with-thin-Limestones (fig. 4). It appears therefore to be slightly discordant stratigraphically though this is partly due to lateral variation in the rocks themselves.

The series as a whole continues towards Cappis Javre but becomes cut out there due to thrusting. This will be further dealt with in Part 2. It may also be mentioned that thin, crystalline limestones occur in some schists a little below the base of the Store Borsejok Series in Kjerringdal (a western tributary to Mandalen). These could be the stratigraphical equivalents of the Series though none of the other characteristic beds are present.

When traced northeastwards across Kåfjorddalen and beyond, important changes take place. The white quartzite and the lime-schist and most of the limestones except the highest one, disappear. The latter also dies out between Kilen and Skaide. There are no unmetamorphosed dolerites but an even greater abundance of amphibolite occurs a little west of Njuorjo Javre. Furthermore the mica- and quartz-schists resemble those of the Store Borsejok Series in a general way and a normal stratigraphic junction between the two series becomes increasingly difficult to distinguish. The lower limit of the Series against the Ankerlia Schist is, however, quite sharp and distinct and is apparently a tectonic one. The gneissic rocks

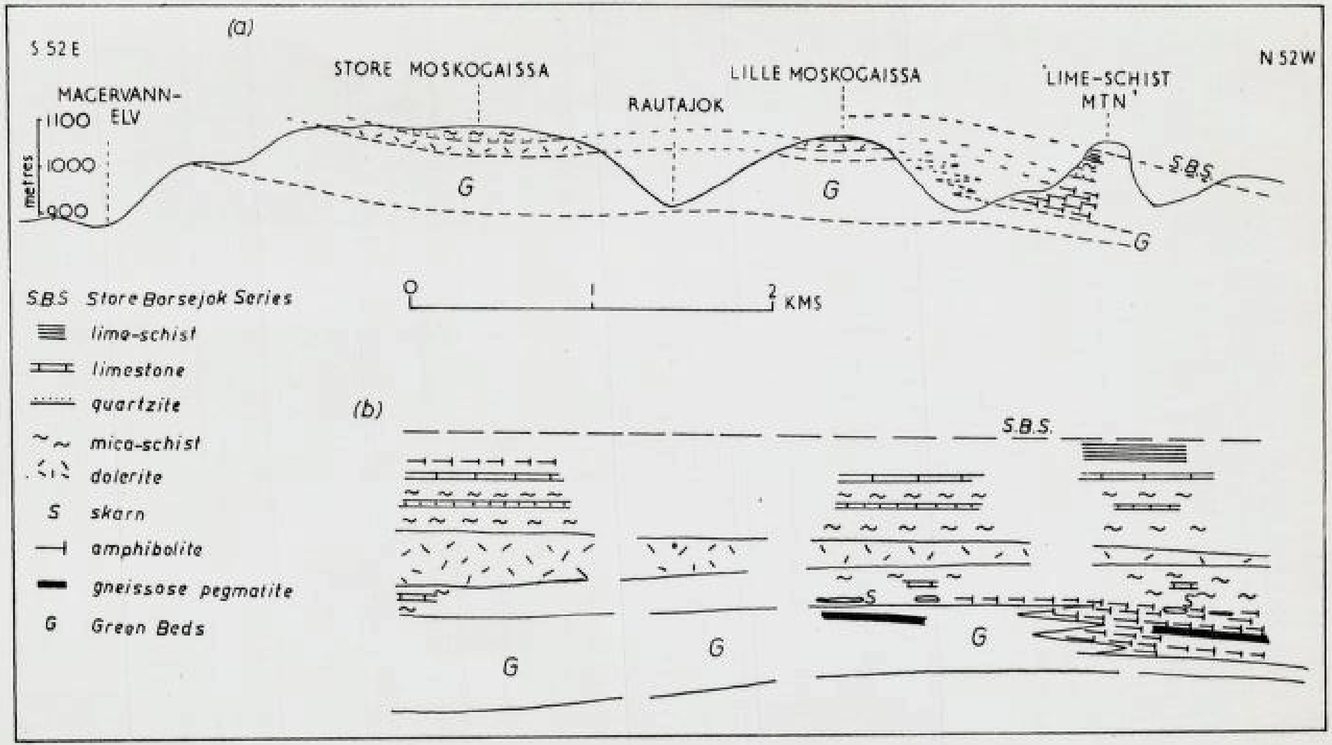

Fig. 5. (a) Profile showing Schists-with-thin-limestones in the Moskogaissa area; (b) diagrammatic representation of the above.
(a) Profil som viser Schists-with-thin-limestones i Moskogaissaområdet; (b) skjematisk fremstilling av profilet.

are strongly developed at Kilen but become weaker towards Skaide. They are reduced to a layer of augen gneiss (0.5 m) in a profile west of Njuorjo Javre (see profiles, fig. 6). North of this locality there are often larger or smaller amounts of quartzo-feldspathic material occurring as eyes, lenses and thin, impersistent schlieren in the schists. It seems to coincide with certain small-scale slipping and shearing of the rocks along schistosity planes.

It is common to find small, isolated pockets of rusted rock due to the weathering of small quantities of sulphides such as pyrrhotite. Tourmaline is also often conspicuous in narrow, irregular zones bordering some of the quartzo-feldspathic material or even contained within it.

There are several indications of small-scale tectonic movements in the Series. They include the development of slickensiding and shearing on schistosity planes in the area north of Njuorjo Javre and are part of a more extensive zone of small-scale movements affecting higher parts of the Series (and the lower part of the overlying Store Borsejok Series) south-west of Kåfjorddalen. The highest (main) limestone is severely folded in the Mattisaksla region where adjacent schists and amphibolites are also involved (fig. 7).

V. Green Beds.

These Beds are restricted in their occurrence to the area SW of Kåfjorddalen and derive their name from the greenish colour on both weathered and broken surfaces. The main mass of the Series occurs in the upper part of the Rautajok valley and good exposures are visible here and further south around Magervann. The upper and lower limits are also rather sharply defined, the green colour being absent from the schists immediately above and below.

Where typically developed as in the upper Rautajok sections, the main rock is a green schist which weathers to form smooth hill slopes covered by a platy scree and supporting a mossy vegetation. The schist itself is largely made up of green prismatic hornblende and plagioclase of high andesinic composition (An_{47}-$_{50}$). In some zoned grains the margins have An_{20}-$_{30}$. Smaller amounts of (clino-) zoisite, epidote, biotite and sphene are also present. Strong parallel orientation of the prismatic minerals gives the good schistosity of the rock. Surfaces of splitting invariably show well developed lineation as a grooving and striation.

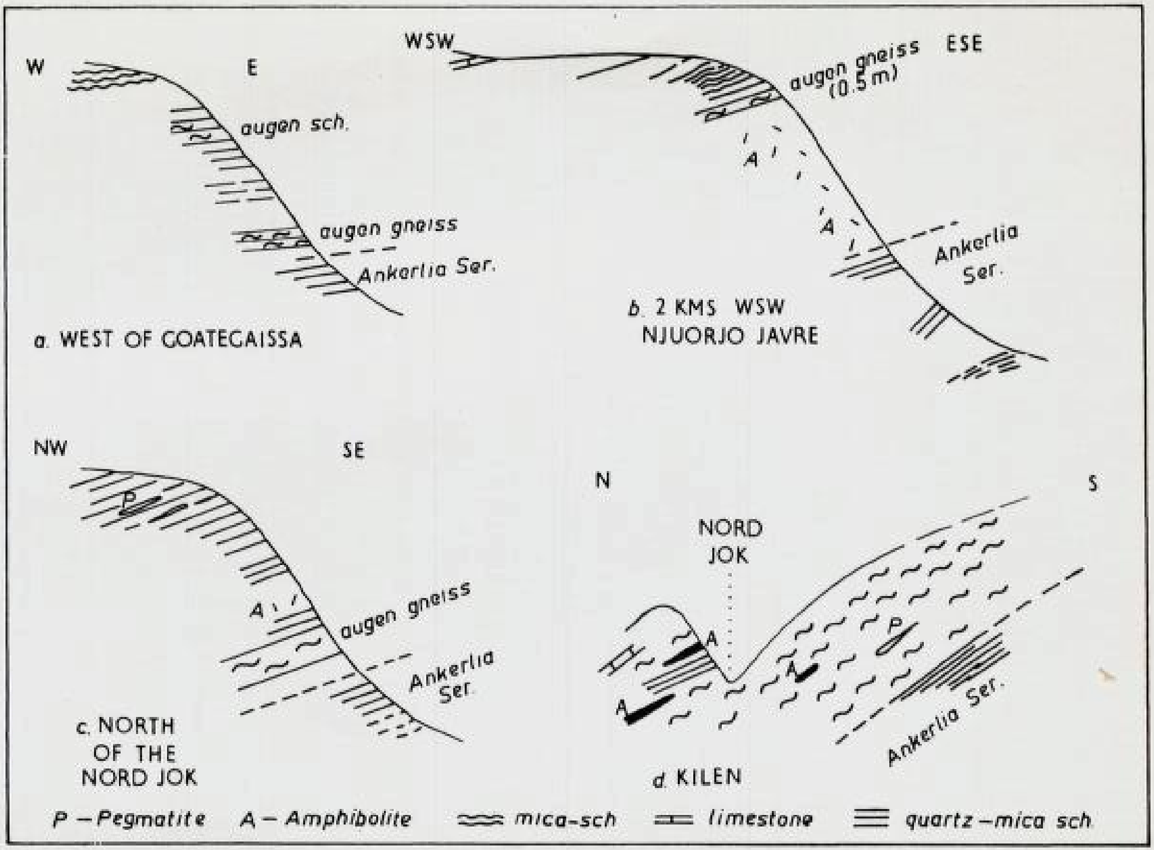

Fig. 6. Profiles (each about 150 m high) through Schists-with-thin-limestones, from Kilen eastwards.
Profiler (høyden ca. 150 m) gjennom Schists-with-thin-limestones fra Kilen mot øst.

In a profile along the upper Rautajok numerous boudins from 1 to 1½ metres thick of a less perfectly schistose rock were noticed. They are conformable to the enclosing green schist which is wrapped around them. A white mineral is often porphyroblastically developed and consists of andesinic plagioclase (An_{48}) with a little (clino-)zoisite — probably the result of saussuritization of a more calcic feldspar. The Green Beds are interpreted as basic extrusives extruded contemporaneously with the deposition of the sediments (see also discussion under 'Basic intrusive rocks'). They have later been involved in the regional metamorphism and are now in high epidote-amphibolite or low amphibolite facies. No traces of original lava structure remain.

No trace of the Green Beds could be found on the NE side of Kåfjorddalen. In fact, they disappear very rapidly when followed in this direction and pass laterally into amphibolite with thin skarn layers (garnet-diopside) north of Lille Borsejok Vann. Here also thin layers of green schist are interbedded with brown schist (i. e. Upper Brown Schist). Near Cappis Javre and southwards, Brown Schist (upper and lower) has replaced most of the Ankerlia Series. It also contains thicknesses of green schist which are thought to represent lateral equivalents of the Green Beds. Like them they are interpreted as volcanic horizons (lavas or tuffs) deposited marginally to the main area of basaltic extrusion and with sediments now referred to as Brown Schist.

The Green Beds as a whole show little evidence of tectonic disturbance beyond the development of the marked lineation. Folds and thrusts are remarkably absent except in the Cappis Javre region where special tectonic disturbances have brought about some cross-folding, doming and local brecciation (see also Part 2).

IV. Ankerlia Series.

The Series includes a very considerable thickness of schists which may be divided as follows:

c. Upper Brown Schist;
b. Ankerlia Schist;
  Upper Ankerlia Schist;
  Banded Ankerlia Schist;
  Lower Ankerlia Schist;
a. Lower Brown Schist.

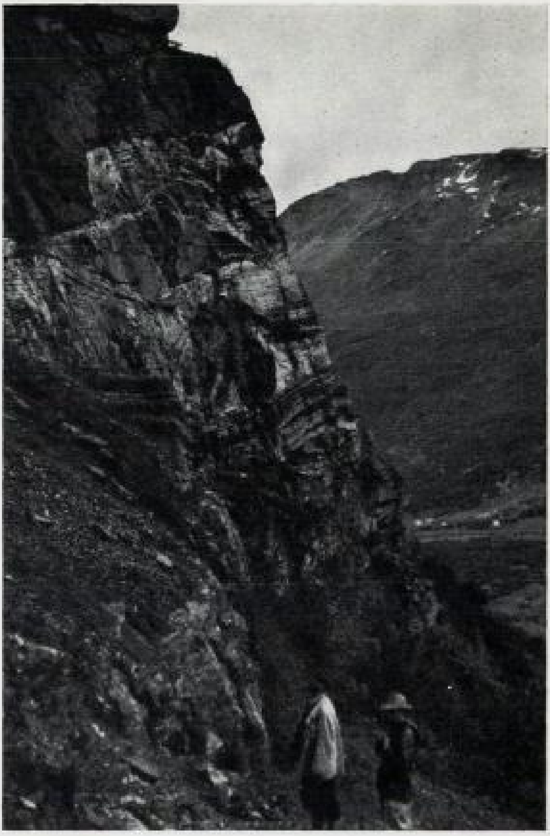

Fig. 7. Amphibolite associated with crystalline limestone (light-coloured), Schists-with-thin-limestones, Mattisaksla, Birtavarre.
Amfibolitt sammen med krystallinsk kalk (lys), Schists-with-thin-limestones, Mattisaksla, Birtavarre.

It should be emphasised that the Ankerlia Schist contains all the known ore bodies in the area and special attention has therefore been paid to its petrography, distribution and structure. The Lower and Upper Brown Schists are very much alike, both petrographically and lithologically and represent a single sedimentary facies. They are clearly distinct from the Ankerlia Schist between.

a. Lower Brown Schist. Beds of this subdivision outcrop over a wide area with their maximum thickness (of the order of 700—800 metres) between Akki Javre and Sabetjok. The base is conveniently taken at a conglomeratic horizon which is well exposed south of Akki Javre. It is typically monomictic, the pebbles being almost entirely of grey, fine-grained quartzite. They are distributed through about 4 metres (fig. 8), and have been pulled out or stretched during the regional metamorphism (NW—SE). They have ratios of 2 : 6 : 1 and 2 : 8 : 1. The largest fragment had a length of 50 centimetres but most are much smaller. The matrix is now a mica-hornblende schist containing a little free calcite. Above the conglomerate a fairly continuous succession of Lower Brown Schist can be followed to the NW. The principal rock type is a brown weathering quartz-mica schist which is greyish on freshly broken surfaces. It consists entirely of fine-grained quartz, calcite (slightly ankeritic), biotite, (clino-)zoisite and a little plagioclase (An_{40}): green hornblende occurs porphyroblastically and often contains numerous inclusions.

There are also several thin layers, up to ½ metre in thickness, of a lustrous mica-schist. These contain large prismatic crystals (to 1.5 cms) of hornblende, often showing 'sieve' texture in thin section. Small garnets are also commonly developed. Other minerals include biotite, calcite, fine-grained quartz and a little plagioclase. Such beds are only found between Akki Javre and Sabetjok where the Lower Brown Schist as a whole is thickest. Even so they represent only a small fraction of the total and disappear laterally. The Schist continues strongly to the north and forms part of the western wall of Reisadalen. Here it becomes thinner and finally disappears in the very north of the area surveyed, around Hallern. West of Kåfjorddalen it also becomes thinner and merges with the Upper Brown Schist though occasional 'ribs' of Ankerlia Schist are present in between. In general, the beds are rather monotonous petrographically and structurally. Only a few thin amphibolitic bodies are known to occur.

The junction of the Lower Brown Schist with the Ankerlia Schist is a conformable one. In the region of Miesavarre, a little SW of Sabetjok there is also a narrow transitional zone in which layers characteristic for each alternate with one another through 10 metres. More extensive mapping over a wide area has shown that this transitional zone increases in thickness to the north and east. It is also seen in two inliers — a small one in the canyon of the Sabetjok close to its confluence with the Guolle Jok and another in the Guolle Jok itself, a little north of Ankerlia. They are not shown on the maps (plates 1—2) where beds of the transitional zone are included for convenience with the Ankerlia Schist.

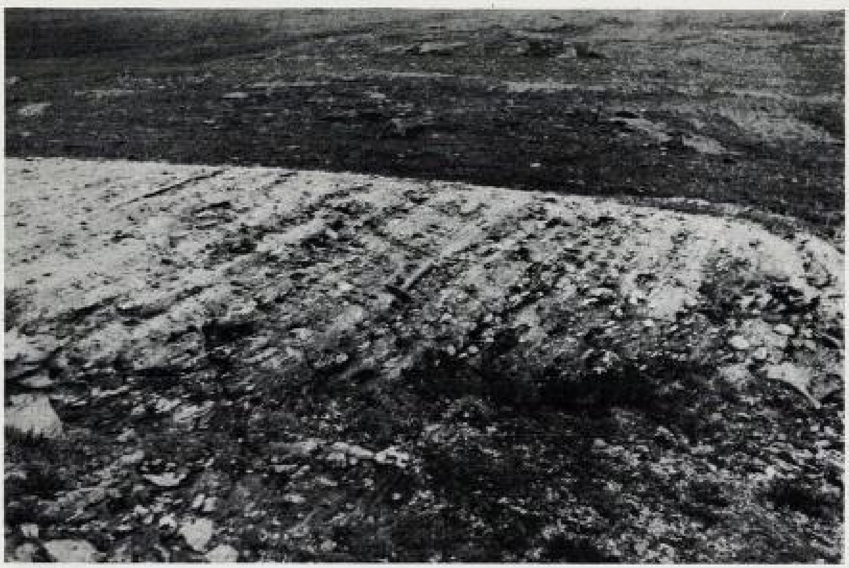

Fig. 8. Conglomerate, near Akki Javre; at base of Lower Brown Schist.
Konglomerat ved Akki Javre, ved bunnen av Lower Brown Schist.

The zone is also well exposed north of the Gætke Javre and in Reisadalen.

b. Ankerlia Schist. As indicated above the Ankerlia Schist is sandwiched between the Lower and Upper Brown Schists. It attains its maximum thickness in the region of Ankerlia where about 700—800 metres of bedded schists are exposed in the steep walls of the canyons of the Sabetjok, Guolle Jok and Rautajok. It also outcrops over a wide area on both sides of Kåfjorddalen.

A convenient type-section for the Schist is the track from Ankerlia up to Moskogaissa — a difference in height of about 800 metres. Exposures are frequent and it is possible to effect a three-fold stratigraphical division as follows:

Upper Ankerlia Schist,
Banded Ankerlia Schist,
Lower Ankerlia Schist.

The *Lower Ankerlia Schist* includes a series of dark bluish and greyish schists containing a multitude of thin white quartz seams and veinlets (fig. 25). Most are concordant to the schistosity but some are slightly discordant. Lower in the succession and in the vicinity of Ankerlia, some highly muscovitic schists, often garnetiferous and hornblende-bearing, are much folded. There are also several boudins of an amphibolite with porphyroblastic (clino-) zoisite. The base of the Schist is transitional down into the Lower Brown Schist.

The *Banded Ankerlia Schist* is especially characteristic on account of the numerous white bands ranging in thickness from a few millimetres up to 3—4 cms, interlayered with the more normal dark greyish and bluish grey schist. The bands themselves occur through about 200 metres and may be closely or widely spaced. They usually have sharp lower margins but slightly gradational upper ones and this is thought to be graded bedding inherited from the original sedimentary condition of the rock. If so, it indicates that the beds are not inverted.

In thin section the bands are seen to be richer in quartz than the containing schist and have only small amounts of hornblende and biotite and (clino-) zoisite. There is also some spectacular drag-folding in a zone roughly coincident with the Banded Ankerlia Schist. Pronounced lineation and complicated flowage-folding are also developed (see also Part 2).

The *Upper Ankerlia Schist* includes a series of well bedded quartz-hornblende-(clino-)zoisite and biotite-rich schists. The more quartzitic layers are generally more thickly bedded and less folded while layers with biotite show much incompetency. In the lowermost 35 metres small-scale crumpling, disharmonic folding and shearing oblique to the bedding are evident. Higher beds show cross-folding and several rust zones are also present conformable to the bedding though only the uppermost one at Moskogaissa has yielded much ore.

The Ankerlia Schists continue strongly towards Reisadalen but becomes progressively reduced in thickness to the south and west. Thus in the region of Magervann a lateral transition to the schists of the Brown Schist type is evident: numerous layers of the latter interdigitate with the Ankerlia Schist (fig. 9) and represent a lateral change in sedimentary facies. (On the maps., pls. 1—2, transitional beds are included with the Ankerlia Schist.) Thin beds of Ankerlia Schist type, however, continue for longer distances and one of these is to be found between layers of Brown Schist in a section in the

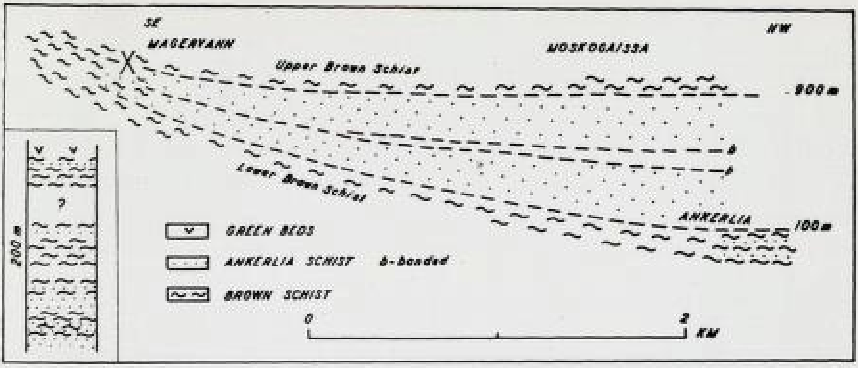

Fig. 9. Profile along the SW wall of Kåfjorddalen to show interdigitation of Ankerlia Schist with Brown Schists (partly schematic). Inset lower left, a vertical section in the transitional zone (cross in profile).
Profil langs SV veggen av Kåfjorddalen som viser faciesforholdene mellom Ankerlia Schist og Brown Schists (delvis skjematisk). Nederst til venstre på figuren, snitt gjennom lagserien i overgangssonen ved Magervann (kryss i profil).

upper Rautajok. Banded Ankerlia is present in the most westerly part of the area, namely, in Kjerringdal, a tributary of Mandalen. Between Kåfjorddalen and Reisadalen it was used as a most important mapping horizon and continues out of the area to the north.

A chemical analysis of a typical specimen from the Upper Ankerlia Schist is given in Table 6, p. 55. Attention is drawn to the relatively high proportion of lime in relation to soda and potash and this probably accounts for the common occurrence of lime-bearing silicates such as hornblende, (clino-)zoisite, sphene and occasionally a little diopside. The feldspar is normally andesinic (An_{40}) but in certain zoned grains the margins are less calcic (An_{25}). For further discussion see under 'Remarks on the sedimentary facies'.

Amphibolites are especially common in the Upper Ankerlia at Moskogaissa where they lie a little below the ore horizon and also at a slightly lower horizon near Magervannelv to the south. At the latter locality they occur in elongated lens-like bodies concordant to the schists which are domed around them. A particularly large mass with occasional thin schist layers occurs some 100—120 metres below the ore horizon at Skaide. The different bodies differ slightly in texture but are commonly composed of greenish or brownish hornblende, andesinic plagioclase, (clino-)zoisite, with smaller amounts of sphene, biotite and iron ore. A little scapolite was seen in a thin section of one of the lenses at Magervannelv as well as green hornblende replacing diopside. The main amphibolitic bodies are shown on the map of the Kåfjorddalen area (pl. 2).

A further petrographic feature is the occasional development of pegmatitic material — largely feldspar and quartz, in some of the schistose layers. In one case a little north of the mine 117 (Moskogaissa) it is developed in a local thrust-plane where the beds are crumpled and show physical discordance. In some localities, for example, north of the Skaide Jok it is complexely folded with the schists and appears to be in part replacing them. In other occurrences the replacement does not seem to be related to any obvious tectonic feature. Irregular rims of biotite are often found marginal to the quartzo-feldspathic material.

c. *Upper Brown Schist.* This resembles the Lower Brown Schist in many details.

It consists of fine-grained quartz, biotite, a little hornblende, plagioclase, ankeritic calcite. The latter leaves a brown iron oxide residue on weathered surfaces thus giving the schist its typically brownish colour.

The Upper Brown Schist though thinner than the Lower is nevertheless conspicuous in the steep east-facing slopes of Lille and Store Moskogaissa where it tends to be rather more regularly bedded and jointed and frequently shows a pitted weathering surface due to leaching of the carbonate. Here it underlies the Green Beds and is also exposed in two inliers, one in the upper Rautajok and the other SE of Cappis Javre. It is little disturbed tectonically in contrast with the Ankerlia Schist immediately below. To the W and NW the beds merge with the Lower Brown Schist and the facies continues strongly towards Mandalen.

At Moskogaissa diamond-drill boring in the summer of 1954 along the foot of Lille Moskogaissa has shown a more or less conformable downward passage from Upper Brown Schist into Ankerlia Schist. There is a rather broad zone, 70—80 metres thick, in which the beds are much colour-banded and locally contain much amphibolite interlayered in a rather irregular way.

The north-easterly continuation towards Skaide is rather different. Thus immediately north of Moskogaissa there is an interbedding of brown and greenish schists to the exclusion of the Upper Brown Schist and at the same horizon thinly banded schists are also exposed near Kilen, Skaide and Njuorjo Javre. The lighter greenish bands are more typical of the Ankerlia Schist. Some slightly thicker layers of brown schist around Skaide mine may be the local representatives of the Upper Brown Schist there.

III. Guolas Limestone Series.

This highly distinctive series was first recognized in the Guolas Javre region where layers of meta-limestone are interlayered with a variety of other petrographic types. It seems to show its greatest thickness here also (about 200 metres) but continues strongly both SE to Reisadalen and W and NW to Cappis Javre and Skardalen. It has proved of great value in the regional mapping of the area. In all cases it seems to be conformable to underlying beds.

In the Guolas area the meta-limestone is typically white, crystalline and frequently much folded on a small-scale. It weathers to a grey or brownish colour and may contain thin bands of mica-schist which help to delineate the folding. Numerous thin layers of a muscovite- and hornblende-schist, are interbedded with the limy layers. The rock then tends towards a lime-phyllite.

Green hornblende needles are common in the limestone: they may occur separately without any regular orientation but are commonly aggregated into layers when parallel or sub-parallel alignment is achieved. In the area a little SE of Akki Javre a large number of elongated rod-like units (1—3) cm across) of a dark (basic) rock are orientated parallel to each other and to the regional lineation. They consist of green hornblende, biotite, epidote, calcite and a little quartz and appear to be parts of once continuous layers later 'boudined' by tectonic forces.

Also interbedded with the meta-limestone are layers of lustrous muscovite-garnet schist or muscovite-garnet-hornblende schist which may attain a thickness of 15 metres. This association serves to distinguish the Guolas Limestone Series from the other limestone formations.

Dark green basic rock is especially common near Guolas Javre and probably accounts for the enhanced thickness of the Series in this area. In general it occurs as concordant layers as may be seen in a series of good exposures in the conspicuous promontory at the west end of Guolas. Here the meta-limestone is coarsely crystalline along its border with the basic rock.

Some of these rocks have a distinctive greenish cast and were called 'Greenstones' in the field. Of special interest is a small area a little south of Akki Javre, where pillow structures are developed. The pillow-like units are drawn out parallel to the general stretch direction of the rocks but in cross-section are oval in shape and occasionally show a concentric banding (fig. 10). Calcite is freely distributed in between the pillows. Thin sections of a pillow show an abundance of green hornblende with 'sieve' texture suggesting its secondary origin. Other minerals, forming a finer-grained matrix include brown biotite, zoisite, andesinic feldspar, a little calcite and granular sphene.

Such pillow structures were not found elsewhere in the area and if of primary origin, as seems most likely, represent a rather unusual case of preservation considering the grade of metamorphism.

The series is strongly developed elsewhere though continuity of exposures east and west is poor due to the continuous cover of glacial débris. Where observed, however, the beds retain their general thickness and character.

In Reisadalen (e. g. Linda Varre) a great deal of basic amphibolite is interlayered with the limestone. It occurs in bodies up to 4 metres thick but of varying shapes and sizes.

The series becomes thinner northwards but can be followed without difficulty.

In the Cappis — Abnilasvagge region more folding is present when the axes are parallel to the regional lineation. Basic rocks are clearly wedged in between the limestone layers which they have locally corroded. There is also a tendency for the uppermost layers to be more folded. It is suggested that they have acted as a more plastic basement for the slight southward movement of the block of Lower Brown Schist.

The most northerly outcrop of the series is in the upper part of Skardalen (outside Reisadalen) and the most westerly, near Brennfjell, Skibotndal.

II. Nitsim Varre Series.

The series is so named because of its typical occurrence on some high ground between Abnilasvagge and Lilledal called Nitsim

Fig. 10. Cross-section of pillows in greenstone, Guolas Limestone Series, near Akki Javre.
Tverrsnitt gjennom «puter» i grønnstein, Guolas Limestone Series, ved Akki Javre.

Varre. It also outcrops on the south- and west-facing slopes of Abnilasvagge and extends southwards but with narrowing outcrop, towards Godde Javre. In the Guolas region and further NE it is visibly reduced in thickness.

In its typical condition on Nitsim Varre it is clearly conformable with the underlying Big Limestone Series and consists of white quartzite, often quite thickly bedded but sometimes flaggy, interbedded with dark, pelitic schists similar to those of the Big Limestone Series. The quartzites are distinctly fine- and even-grained and often brown on weathered surfaces due to the weathering of finely disseminated sulphide minerals. Lineation, as a grooving, is developed on bedding surfaces. In addition, many dark, basic, intrusive-looking bodies are present. They are commonly sill-like and some are several metres thick. On Nitsim Varre itself and especially in the ground above Lilledal, they are particularly abundant: dyke-like sheets were also seen here cutting across the bedding.

Many of the basic rocks appear to be fine-grained basaltic types and are only weakly schistose. Some mineral alteration (e. g. hornblende after pyroxene) is usually evident.

In the Guolas area a thick body of well-lineated amphibolite occurs in the lower part of the Series. It contains distinct lenses (6—7 m $\times$ 1—2 m) of granitized schist, the main part of which lies immediately below in this region. There is no sign here of the Big Limestone Series in its typical development and amphibolite is common all the way to Reisadalen in the base of the Nitsim Varre Series. It is not yet certain whether all the basic rock of the Series belongs to the same phase of intrusion since there are differences in both texture and in the degree of mineral alteration. It is clear that the basic rock is especially abundant in this Series and shows a special concentration near Nitsim Varre.

Some of the lowermost layers of the Series are somewhat granitized on Rasjanipa and then form the uppermost part of the granitized portion of the Birtavarre Series.

I. Big Limestones Series.

This Series, the lowermost of the non-granitized Birtavarre Series, is well exposed in the walls of Abnilasvagge where it reaches its maximum thickness. It is made up of numerous gently dipping layers of white or grey weathering meta-limestone which vary in thickness from 5 to 30 m interbedded with dark, pelitic schists. The limestone itself is usually rather crystalline and almost pure $CaCO_3$ except for a few thin bands of calc-silicate rock. Sometimes the lowermost parts of the limestone layers are rather darker and impure due to the presence of mica and disseminated graphite. The schists interbedded with the limestones are frequently sulphidic.

Dark, basaltic intrusive bodies are also commonly present. They are often fresh and only weakly schistose in hand specimens: those in the limestones are of various shapes and sizes some being ball-like, others elongated lenses. The limestone tends to be warped around them but sometimes the basalt seems to have corroded its way into the limestone for some distance. On weathered surfaces they are often brownish due to the oxidation of finely disseminated iron-bearing sulphides such as pyrrhotite.

Lineation is commonly developed on bedding planes in the limestone both as grooving and striation as well as small-scale folding and overfolding. The interbedded schists are also often folded in a complicated fashion with a tendency to overfolding to the south.

The base of the Series in Abnilasvagge is rather inadequately known due to the poorness of the exposures in the floor of the valley. There appears to be, however, a rather irregular area of granitization in which the darker schistose beds contain porphyroblastic feldspar augen. Such beds are thought to represent the upper part of the granitization zone which outcrops extensively to the south (see below, p. 44). The problem is further complicated by some apparent faulting with appreciable displacement of beds and by discrepancies in the thickness of the Series when studied on the south and north slopes of Abnilasvagge.

The development south of Abnilasvagge shows further features of interest for it seems that the limestones become progressively thinner and less numerous. This is especially clear on the east and north-east side of Olmaivoabmirasja where several individual layers first become thinner and finally disappear.

The changes in the rocks southwards are, therefore, of a primary (depositional) character. The relationships are shown in the profile (fig. 15). It is concluded that the limestones in Abnilasvagge are largely replaced laterally southwards by more psammitic schists.

There is no evidence that the schists continue in this typical condition as seen in Abnilasvagge for any great distance eastwards (towards Reisadalen) or westwards (towards Skibotndal). Some psammitic schists exposed in the Geira Jok (Reisadalen) contain one thin layer of crystalline meta-limestone at a stratigraphical horizon equivalent to the Big Limestone Series in Abnilasvagge.

The non-granitized Birtavarre Series in lower Skibotndal.

In the construction of the profile from Kilpisjärvi (Finland) north-northwestwards along Skibotndal, a great deal of granitized schist was first met with. At Lulle a granitic gneiss was apparently succeeded upwards first by less strongly granitized schists and these by non-granitized schists.

In the lowest part of the latter several thin layers of crystalline limestones were seen to be interbedded with garnet-mica schists, the whole bearing a strong resemblance to the Guolas Limestone Series known to occur further east. This is an important stratigraphical link and is further strengthened by the existence of Brown

Schist above which is in turn succeeded by schists reminiscent of the Store Borsejok Series, in the region of Brennfjell. Hereabouts a conspicuous layer of tough, massively weathering amphibolite — much recrystallized, occurs between the Brown Schist and Store Borsejok Series.

Further investigations were made NNW towards Skibotn and on Agjeg mountain in the hope of finding the Quartzite Series. No quartzite, however, of the type known from the Series around Birtavarre was found. On the other hand, a considerable thickness of quartzitic mica-schist occurs at about the anticipated horizon and may be the lateral equivalent in this region.

Field relationship in the lower part of Skibotndal are given in fig. 11 (based on field-sketches).

Attention is drawn to the existence of conspicuous amounts of kyanite, staurolite and garnet in some of the layers of mica-schist believed to belong to the Store Borsejok Series. These and especially the quartzitic mica schists above, frequently contain sizeable lenses of pegmatitic rock rich in muscovite and biotite micas.

A new feature is the conglomeratic horizon (see map, pl. 1), at least 15 metres thick in which the pebbles are greatly drawn out along one axis (NW—SE) and flattened on another. Typical dimensional ratios are 20 : 2 : 1 or 24 : 2 : 1. The constituent pebbles are mostly dark grey quartzites, brown weathering quartzitic mica-schist and a lesser number of a coarsely crystalline skarn rock. The latter contains abundant biotite along with diopside, scapolite, zoisite and lesser amounts of titanite, calcite and quartz. No corresponding conglomerate is known from the Kåfjorddalen area and it seems likely that it belongs to a horizon higher than anything seen there.

Even higher beds probably form the summit part of Agjeg. No direct study of these was made but loose blocks of hard, mica-kyanite schist and garnet-mica-schist were studied on the SW-facing slopes. They are cut by pegmatitic veins rich in mica and tend to weather into massive units.

The stratigraphical succession is therefore somewhat simpler in Skibotndal than, for example, around Moskogaissa. Thus there is no representative of the Schists-with-thin-Limestones, typical Ankerlia Schist or of the Green Beds.

Indications of such changes were found when mapping southwestwards from Moskogaissa in the direction of Skibotndal.

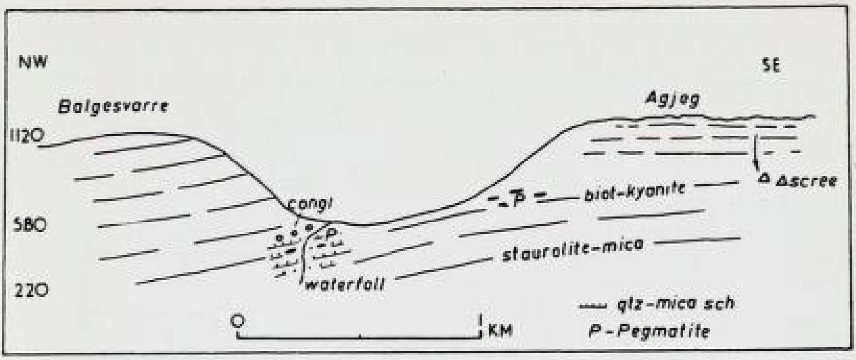

Fig. 11. Field relations of non-granitized Birtavarre Series in the vicinity of Agjeg, lower Skibotndal.
Ugranittisert Birtavarre Series i nærheten av Agjeg, nedre Skibotndal.

The Birtavarre Series. b. granitized.

The lowermost part of the Birtavarre Series is made up of quartz-, quartz-mica-, mica- and epidote-schists. Small boudins of dark basic amphibolite occur throughout but locally thicker sheets of amphibolite form important parts of the succession, e. g. south of Rasjanipa, on the higher ground north-east of Helligskogen. Limestones are generally absent or confined to thin bands when calc-silicate minerals, e. g. epidote, zoisite are common along with crystalline calcite.

The granitization is represented by feldspathic and quartzo-feldspathic material in greater or lesser amounts. It occurs in a variety of ways, as augen, as more indefinite schlieren, as coarse-grained pegmatitic bodies with both parallel and discordant relationships to the layering of the rocks.

These features are mainly confined to a broad zone, several hundred metres thick which, as will be demonstrated below, is roughly but not exactly parallel to the stratigraphy.

No stratigraphical subdivision of the schists within the zone of granitization has been attempted. The descriptions below are therefore arranged geographically and it may be seen that the information is rather fragmentary being derived from studies in several separated areas. In Skibotndal, the relationship to both the Sparagmitic Schists and higher Birtavarre Series is seen. A fairly systematic study was also conducted in the Rasjanipa — Olmaivoabmirasja area to the east while reconnaissance trips were made in the Guolas Javre, Gætke Javre and Reisadalen areas to the east and north-east. In each area the relationship of the granitized and non-granitized Birtavarre Series was studied.

i. Skibotndal.

A more or less complete section through the granitized schists can be followed in Skibotndal where, in a series of fresh road-sections, the beds are exposed to the best advantage.

From the profile it may be seen that granitized schists succeed the Sparagmitic Schists comformably. This has also been convincingly demonstrated in the region of Helligskogen (see fig. 1). In appearance, the lowermost layers are typically well banded with layers of white quartzo-feldspathic material (from a few millimetres to 4 centimetres in thickness) alternating with mica-rich layers. In a thin-section of a typical specimen from an exposure close to the 'lake' Garddebor Luobal, the darker bands are seen to consist of biotite, muscovite and some chlorite: the lighter bands are almost entirely feldspathic (microcline, microcline-microperthite, albite and orthoclase). In another specimen from a road-side exposure at Halsen, the separate layers are even more regular and sharply defined: the darker layers are largely composed of biotite with a little epidote, the lighter ones of quartz and potash feldspar. The latter (represented by orthoclase and microcline microperthite) frequently show porphyroblastic relationships to the other minerals and are often clouded with tiny inclusions.

Thin, epidote-rich layers are also fairly common. Other schists show a more intimate blending of quartzo-feldspathic material and mica minerals in thin section though the feldspar minerals are often slightly porphyroblastic and in more extreme cases are developed as conspicuous augen. This is well shown in the thin section of a specimen close to the north end of Galggo Javre where augen (up to 1 cm) of orthoclase with vein perthite structure, microcline and albite are especially common. The more fine-grained groundmass of biotite, epidote, muscovite and feldspar is to some extent warped around the augen.

Similar augen schists are common at other horizons in the series. The light feldspathic and quartzo-feldspathic material is

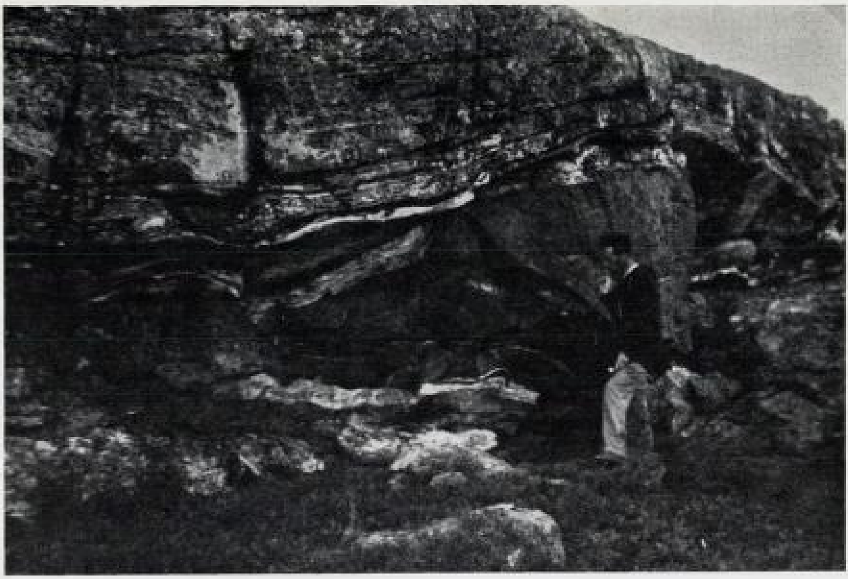

Fig. 12. Feldspar layers (white) replacing an amphibolite boudin in granitized schists, Birtavarre Series, east of Helligskogen (F. M. Vokes Photo).
Feltspatlag (lyse) som erstatter amfibolitt i granittiserte skifre, Birtavarre Series, øst for Helligskogen (F. M. Vokes foto).

sometimes present as more irregular lenses and layers and locally may be discordant to the schistosity when folding is present. In such cases it also replaces amphibolite in a rather irregular way. At a few horizons faint disseminations of sulphidic ore minerals (e. g. chalcopyrite) were noticed. These have no economic value.

When the layering is more regular the quartzo-feldspathic material is generally also regular and conformable.

In amphibolites it occurs in thin sheets parallel to the outlines of the boudins (fig. 12).

A further feature of interest in the Skibotndal profile is the apparent slight increase in quartzo-feldspathic material upwards. This is particularly evident a little NW of Halsen. A little further NW towards Lulle and higher in the succession, a thick zone of granite-gneiss appears quite suddenly. It seems to be generally conformable to the schists (see profile, pl. 3), shows good planar foliation, has conspicuous augen of pink and white feldspar and contains a few boudins of dark, basic amphibolite.

In thin-section, the chief feldspar is microcline, often with perthitic intergrowth of albite. Vein-, braid- and lobate-perthites can also be recognized. Lesser amounts of albite, quartz, biotite and sphene are usually present. It is also interesting to note the occurrence of a thin selvage of fine-grained quartz and biotite.

The gneiss is in the form of a rather thick sheet rooting down to the north-west and thinning to the south-east. It passes upwards rather abruptly into less strongly granitized schists and these in turn into the non-granitized part of the Birtavarre Series.

In all the granitized schists of the Skibotndal profile and also where studied laterally, lineation is very conspicuous, as parallel grooving and striation on all bedding and schistose surfaces as well as complex 'flowage' folding (fig. 13) in some places.

It is remarkably uniform in direction and imparts a definite 'grain' to the region which is clearly discernible on aerial photographs. There often seems to be a rough correlation between the amount of granitization and the intensity of the folding.

In Skibotndal, then, the granitized rocks occur in a broad zone which is roughly parallel and conformable with the schistosity and layering of the schists both above and below.

ii. Rasjanipa—Olmaivoabmirasja.

Lower beds of the granitized zone have not been followed for any great distance laterally. Higher horizons, however, have been studied in some detail north-east of Skibotndal and especially over a wide area around the mountains of Rasjanipa and Olmaivoabmirasja. Here, various additional features of interest were noted. Exposures are often good owing to the paucity of vegetation though the surface scree makes the going very wearisome.

In the first instance it should be pointed out that the schists are essentially similar to those from Skibotndal in the presence of feldspar and quartzo-feldspathic material in rather variable amounts but in some layers lower down it is only weakly present (e. g. close to Vann 6). The schists themselves also appear to be more variegated: distinct layers of quartzite, muscovite-schist and an occasional limestone and skarn rock were observed. Details of the rock succession are most conveniently expressed in a series of profiles (fig. 14). Of special interest is the presence of distinct zones of

Fig. 13. Granitized schists with flowage folding, Skibotndal.
Granittiserte skifre med «flyte»-folder, Skibotndal.

granite-gneiss with typical feldspar augen and strong planar foliation. These occur in only partially granitized schists. The relationships are particularly clear on the south side of Rasjanipa where two such zones are present. Each is about 20 metres thick and an attempt was made to map their distribution. They seem to follow the general bedding fairly closely but lose their identity northwards where they merge into a broader and less sharply defined zone of granitization.

In this same direction and higher in the succession more severe granitization has converted some of the schists into granite-gneiss with the development of very strong foliation planes. Some have behaved in an apparently more plastic manner and are folded in a rather complicated way. These effects seemingly affect definite layers in the succession but their lateral extent is often rather limited. Rasjanipa itself is of further interest since the granitization becomes rapidly weaker upwards towards the summit and the beds are more conveniently referred to the non-granitized Birtavarre Series.

Olmaivoabmirasja on the other hand has a 'crown' of granite or granite-gneiss. It is possible on the south-facing slopes to study clearly the transition through 30 metres or so from bedded, slightly granitized schists upwards into rock of almost granitic appearance and composition with only faint foliation. The limit of this granitic 'crown' can be fairly accurately deduced from aerial photographs since it gives rise to an area without the definite 'grain' of the surrounding region. The relationship of the granite to the schists is shown in the profiles (fig. 14).

As in Skibotndal, the schists show well-marked lineation both as a grooving and striation and as small-scale folding. The latter is not so common or as intense as in some of the Skibotndal sections but the fold-axes are parallel to the other linear elements and give the marked 'grain' to the country.

Thin sections of the granitized schists from the area show similar features to those from Skibotndal. The large augen in gneissic layers are commonly of alkali feldspar, e. g. albite (An_8), or microcline showing much perthitic intergrowth. Tiny inclusions are very common in some of the feldspars. Thin-sections of the upper granite-gneiss layer on the south side of Rasjanipa show large augen of albite and quartz: the groundmass is a fine-grained quartzo-feldspathic aggregate. Less regular veins of coarse-grained (pegmatitic), quartzo-feldspathic material are commonly present in the schists but are rather irregularly distributed.

The upper limit of the granitized schists is, in effect, the upper limit of granitization. Wherever studied it appears to be a fairly sharp junction, the quartzo-feldspathic material becoming progressively less abundant upwards in a transition zone at the most 20 metres thick. The outcrop of this narrow zone can therefore be mapped as a more or less definite line (at least on the scale of mapping adopted in the field (1 : 26500) when its relation to the non-granitized schists becomes apparent. It is then seen to be somewhat discordant to the stratigraphy when followed for any great distance. The upper surface of granitization appears to rise slightly to the south-east in relation to the stratigraphy in the region Rasjanipa—Olmaivoabmirasja—Abnilasvagge (fig. 15). Thus it occurs down in the Big Limestone Series to the north, in the top of this series east of Olmaivoabmirasja and in the lower quartzites of the Nitsim Varre Series on Rasjanipa. It should here be emphasized that the rapid thinning of the Big Limestone Series is largely one of original deposition: the limestones are apparently replaced

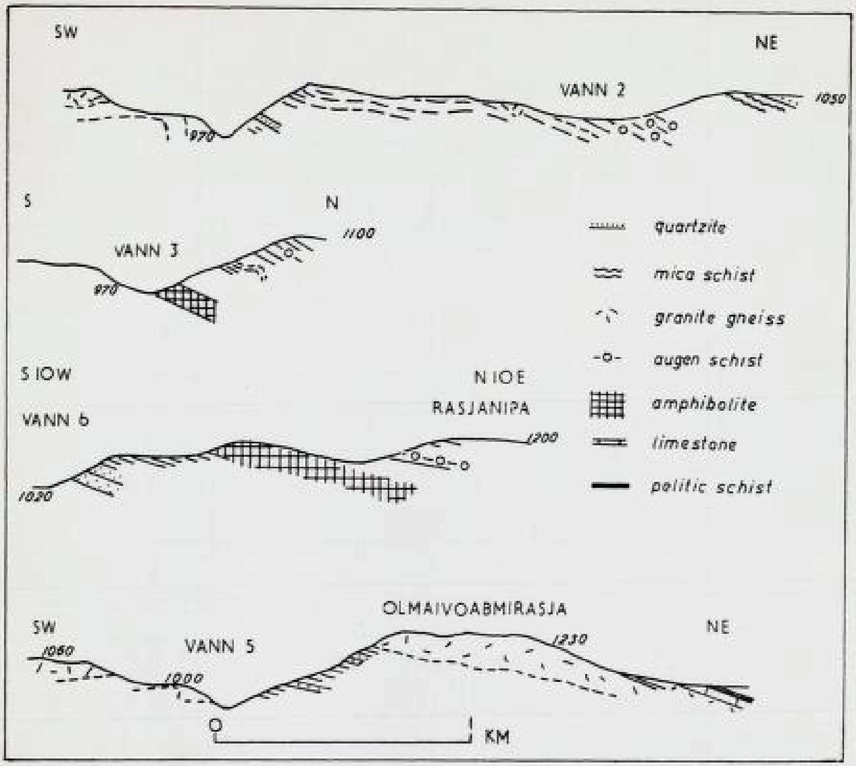

Fig. 14. Profiles through the granitized schists of the Birtavarre Series, Rasjanipa area.
Profiler gjennom de granittiserte skifrene i Birtavarre Series, Rasjanipa.

by more psammitic rocks to the south, and equivalent beds in the granitized schists contain only an occasional thin meta-limestone or calc-silicate layer.

Thus it is largely the lateral equivalents of the Big Limestone Series which are being granitized southwards to higher stratigraphic horizons.

iii. Guolas Javre.

The beds exposed on the south and southeastern sides of this large lake belong to the granitized schists. Close to the southwestern corner they are in the form of light-coloured granite-gneisses, feldspathized quartzites and mica-schists. Boudins of basic

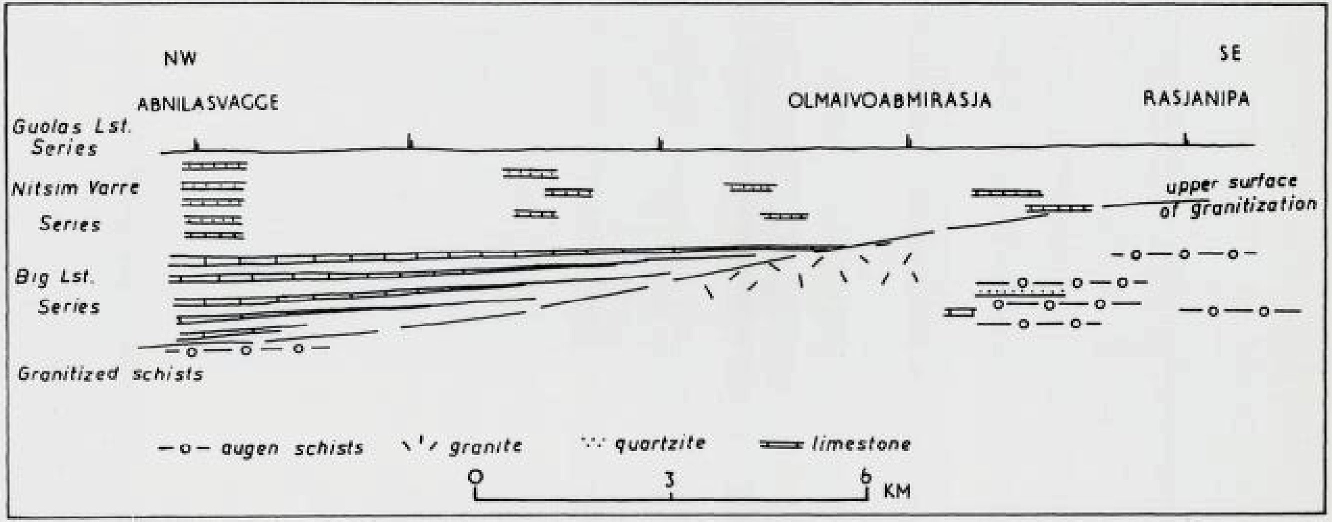

Fig. 15. Profile showing the relationship of granitization to the non-granitized schists of the Birtavarre Series.
Profiler som viser grenseforholdet mellom de granittiserte og de ugranittiserte skifrene i Birtavarre Series.

amphibolite are sometimes feldspathized marginally. The beds have strong lineation marked by grooving, striation, parallel orientation of prismatic minerals and the axes of small-scale folds.

SE of Guolas Javre further quartzitic, quartz-mica and biotite schists occur. These have not been systematically studied but clearly belong to the granitized part of the Birtavarre Series. Small amounts of quartzo-feldspathic material occur in thin layers, and augen of feldspar are present in others.

It is also convenient to mention here the occurrence of certain bodies of non-granitized basic igneous rock near Guolas Javre. First and foremost is the Haldit gabbro which has been treated in some detail petrographically by Hausen (1924 a). It is one of several laccolithic bodies present in the Caledonides of northern Norway. North of the Haldit gabbro occur numerous bodies of a dark, medium-grained basic rock lacking any sort of directive texture (see also under 'Basic intrusive rocks').

iv. Guolas Javre — Reisadalen.

No attempt has yet been made to survey the area systematically but scattered observations in the Gætke Jok, in the valley known as Bunta and in Reisadalen itself near Bilto indicate that similar granitized schists continue in this direction.

v. Reisadalen.

More detailed observations of the uppermost layers of the granitized schists were made in Reisadalen between Sappen and Hallern. Thus in the area of the Doris Jok the beds are largely psammitic and have a more thickly bedded and massive character. Feldspar augen are commonly developed as may be seen in typical exposures at the roadside, a little to the north of Bergbukt. Other exposures show a very intimate relationship between truly granitic material (quartz, feldspar, mica) and the schists (fig. 16).

Summary of granitization phenomena in the Birtavarre Series.

In the foregoing it has been shown that extensive granitization affects the lower part of the Birtavarre Series. This occurs in a

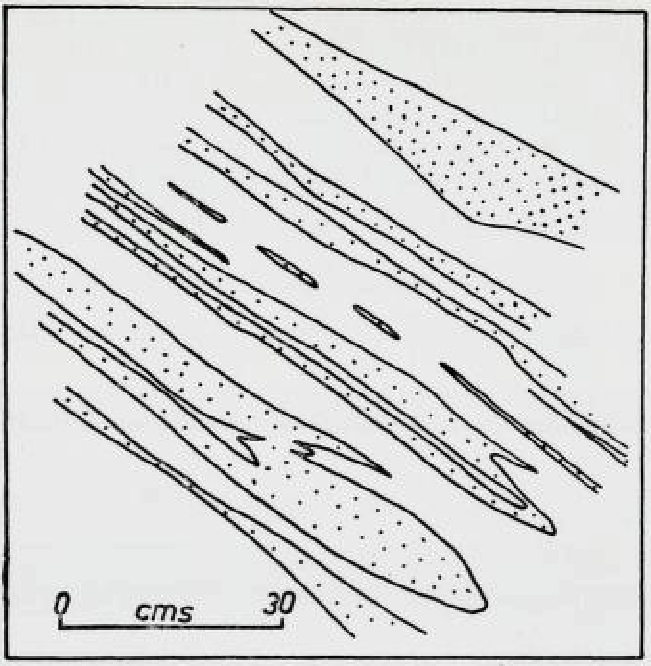

Fig. 16. Granitic material (dotted) associated with quartz-biotite schists, granitized Birtavarre Series, Linda Varre, Reisadalen.
Granittisk materiale (prikket) sammen med kvarts-biotitt-skifer i granittisert Birtavarre Series, Linda Varre, Reisadalen.

thick zone which has an extensive lateral distribution. Its upper limit is clearly somewhat discordant to the stratigraphy. The degree of granitization within the zone is variable; in some areas such as Olmaivoabmirasja, granite and granite-gneiss occur; in others, only weakly feldspathized schist and amphibolite are known. In all cases, however, there is abundant evidence of the later growth of the quartzo-feldspathic material (e. g. poikiloblastic augen, with a large number of tiny included minerals).

In thin-section there is a predominance of the alkali feldspars orthoclase, microcline and albite.

Several chemical analyses were made of representative samples in the laboratory of the Geological Survey of Norway by an experienced chemist. The results are set out in Tables 1—4 where the weight percentages are recalculated to the equivalent molecular percentages. Following the practice of Barth (1948) the modal minerals can then be fairly accurately determined. In the case of Table 4 further recalculation of the cations to a 'standard cell' of 160 anions has been carried out. This enables a comparison to be made of the cations lost and gained during granitization.

In Table 1 an analysis is presented of a composite sample of granitized schist from the Rasjanipa area. The beds usually contain much visible quartz and feldspar of secondary growth. Attention is drawn to the relatively high Na_2O and K_2O contents and the small proportion of iron and magnesia.

In Table 2 is given an analysis of a composite sample taken from one particular granitization unit, namely, the Lulle gneiss, Skibotndal. Very similar chemical proportions are found with slightly more soda and potash.

These two analyses, typical as they are of the granitized schists, fail to indicate precisely what amounts of material have been added and subtracted during metasomatism.

Two further analyses (Table 3) were therefore made to remedy this, one from a thickness of garnet-mica schist, the second from the same schist partly granitized. The schist lies near the upper surface of the granitization zone. It is evident from Table 4 that both silica and potash have increased while the iron and magnesia have decreased. With the latter has also disappeared a little soda. This must be regarded as an exception to the general rule since it is in an abnormally low amount in this rock (cf. Tables 1, 2).

The evidence, therefore, from field, optical and chemical studies suggests that the granitization is due to extensive K and Si and probably Na metasomatism. These elements probably travelled from depth southeastwards in a broad but restricted zone roughly parallel to the stratigraphy. The resultant alkali feldspar and free quartz occurs in a variety of ways but usually in layers of varying thickness, parallel to the schistosity. There is no evidence that it was magmatically injected though under stress conditions some of the more extensively granitized beds have yielded in a more plastic manner. When a number of closely spaced quartzo-feldspathic layers are present intricate folding has developed (fig. 13). This reflects their greater mobility and less competent character. It is thought by some (e. g. Ramberg, 1952, p. 242) to be due to greater power to undergo recrystallization under stress.

TABLE 1.

Granitized Schists, Rasjanipa, Birtavarre.

	Wt. %	Eq. mol. %
SiO_2	71.53	66.8
TiO_2	0.27	0.2
Al_2O_3	14.72	16.2
Fe_2O_3	1.25	0.9
FeO	1.36	1.1
MnO	0.07	0.1
MgO	0.59	0.8
CaO	2.30	2.3
Na_2O	4.18	7.6
K_2O	3.18	3.8
H_2O	0.55	(3.4)
P_2O_5	0.03	tr
Total	100.03	99.8

100.0	Modal Minerals
26.7	Quartz
36.0 3.5	Albite Anorthite } Plag. An_9
17.5	Orthoclase
2.3	Muscovite
3.8	Biotite
0.6	Titanite
6.7	Epidote
2.9	Clinozoisite

Analyst: E. Christensen, Laboratory, Geological Survey of Norway.

It may be noted that the Lulle gneiss, the granite-gneiss on and around Olmaivoabmirasja and that on the south side of Guolas Javre lie at about the same horizon. It is tentatively suggested that they represent the more extensive products in a former thrust zone, the latter having allowed a greater ease of access to metasomatic agencies and to subsequent crystal growth.

Finally it should be stated that there is no evidence from either petrological studies or structure that the granitized schists or any part of them belong to the Pre-Cambrian basement.

In addition to the granitization of regional dimensions discussed above, weaker and more local manifestations are known from the higher, non-granitized part of the Birtavarre Series. Brief mention of some of these has already been given in the appropriate stratigraphic sections.

TABLE 2.

Lulle Gneiss, Skibotndal.

	Wt. %	Eq. mol. %
SiO_2	68.72	63.6
TiO_2	0.21	0.1
Al_2O_3	16.49	18.2
Fe_2O_3	0.98	0.7
FeO	1.06	0.8
MnO	0.06	tr
MgO	0.37	0.5
CaO	1.76	1.8
Na_2O	4.27	7.7
K_2O	5.58	6.6
H_2O	0.40	(2.4)
Total	99.90	100.0

100.3	Modal Minerals
15.7	Quartz
36.5	Orthoclase
33.5 3.3	Albite Anorthite } Plag. An_9
3.2	Biotite
0.3	Titanite
7.8	Epidote

Analyst: E. Christensen, Laboratory, Geological Survey of Norway.

First, there is the narrow band present in the Schists-with-thin-Limestones. Here feldspathic augen were first noted through a few metres of schist on Store Moskogaissa. Northwards, on Lille Moskogaissa and down dip towards Kilen there is a visible thickening of the zone of feldspathization. Thus a little west of Lille Borsejok Vann the schists contain abundant schlieren and augen of feldspar in a zone 10 metres thick. Normal schistosity is absent and the massive bedded layers weather into rounded surfaces. Here and at Kilen it seems that this zone coincides with a zone of thrusting (the Cappis thrust, see later, Part 2). The zone is at a maximum at Kilen (20 m) where it contains boudins of amphibolite and irregular bodies of pegmatite. Contact with the underlying schist is very sharp. It is significant that the cores of the plagioclase of the zone have a slightly higher sodic content (An_{36}) than the containing schists. Rapid thinning of the zone takes place along its outcrop to the NE.

TABLE 3.

	wt. %	
	A mica-schist	B granitized mica-schist
SiO_2	54.72	70.85
TiO_2	1.60	0.61
Al_2O_3	19.55	15.73
Fe_2O_3	0.82	nil
FeO	7.54	2.96
MnO	0.16	0.08
MgO	3.83	1.01
CaO	4.07	1.01
Na_2O	2.66	2.04
K_2O	2.66	4.63
H_2O	2.55	1.30
P_2O_5	0.01	0.01
Total	100.17	100.23

TABLE 4.

	No. of cations Standard Cell (0 = 160)		Ions + and — to give granitized rock	
	A mica-schist	B granitized mica-schist	+	—
Si	49.3	61.1	11.8	
Ti	1.1	0.3		0.8
Al	20.9	16.1		4.8
$Fe^{\cdots}$	0.8	nil		0.8
$Fe^{\cdot\cdot}$	5.5	2.1		3.4
Mn	0.1	0.1	nil	nil
Mg	5.2	1.3		3.9
Ca	4.0	0.9		3.1
Na	4.6	3.4		1.2
K	3.0	5.1	2.1	
H	15.7	7.5		8.2
P	tr	tr	—	—
Total cations	110.2	97.9		
0	159.8	159.4		

A. Mica-schist Rasjanipa, Birtavarre. (R6/3114).

B. Granitized mica-schist, Olmaivoabmirasja, Birtavarre (R7/4135).

Analyst: B. Bruun, Laboratory, Geological Survey of Norway.

It should be noted, however, that it shows maximum thickness (20 + metres) at Kilen in the deepest part of the Kåfjorddalen syncline (see Part 2) and therefore lies nearer to the supposed source of the granitization agencies. This pre-supposes that the syncline was already developed before metasomatism took place.

Several small bodies of pegmatite are known from the Upper Ankerlia Schist as well as the thicker and more continuous sheet in the Schists-with-thin-Limestones. It seems likely that some but not all of these are localized on flat-lying fractures. They can hardly be included under the heading of regional metasomatism but the occasional relationship to structural breaks should be noted.

Of greater significance perhaps are granitization phenomena in the Store Borsejok Series. Here coarsely crystalline feldspathic material makes its appearance as lenses and schlieren in the more micaceous layers and is especially evident in the slopes of Kåfjorddalen a little north of the head of Kåfjord. The logical culmination appears to be in a large body of granite in Upper Trollvikdal. This is often slightly gneissic as revealed by the parallel planar orientation of the biotite. Other minerals include abundant microcline as well as orthoclase, oligoclase and smaller amounts of titanite and clinozoisite; the plagioclase frequently shows fine zonal structure and myrmekite is common. It has an attendant suite of pegmatite veins which are usually fairly flat-lying, have sharp margins, especially in the granitic rock and consist almost entirely of quartz, feldspar, mica with small amounts of tourmaline and apatite. The lateral (and stratigraphical) equivalents of the beds seem to be the extensively granitized schists in the direction of Kåfjord.

If this interpretation is correct then it emphasizes again the layered character of the granitization in conformity with the stratigraphy and structure (fig. 3).

Remarks on the sedimentary facies.

In the fore-going, the layered, stratigraphical character of the schists comprising the Caledonides has been amply demonstrated. The several distinct units lie generally conformable to each other. The layering is apparently inherited from primary bedding and lamination. Taking also into consideration their character and distribution, it appears that they were originally of sedimentary origin for the most part though now much altered. Regional metamorphism, as well as metasomatism in some cases, have played a big part in effecting recrystallization, reconstitution of chemical elements and transference of material through the rocks. It is, however, still fairly easy to separate basic intrusive rocks such as amphibolite, dolerite and gabbro (see later, p. 58) from the layered, mainly sedimentary, rocks.

TABLE 5.

Sparagmitic Schist, Helligskogen, Skibotndal.

	wt. %	eq. mol. %	[1]) wt. %
SiO_2	77.25	74.7	76.26
TiO_2	0.33	0.3	0.49
Al_2O_3	9.42	10.7	11.76
Fe_2O_3	1.25	1.0	3.07
FeO	2.43	2.0	0.42
MnO	0.07	—	tr.
MgO	0.35	0.5	0.71
CaO	2.05	2.1	0.10
Na_2O	1.62	3.0	2.71
K_2O	3.28	4.1	3.55
H_2O	0.74	(4.8)	0.94
CO_2	0.96	(1.3)	nil
P_2O_5	0.08	0.1	0.02
S	0.24	0.4	nil
Total	100.07	98.9	100.03
—0 for S	0.09		
	99.98		

97.7	Modal Minerals	
54.9	Quartz	
13.5	Albite	Plag. An_8
1.0	Anorthite	
10.5	Orthoclase Microcline	
8.4	Muscovite	
3.5	Epidote	
0.6	Titanite	
1.6	Iron Pyrites	
0.3	Apatite	
2.9	Biotite	
0.5	Calcite	

Analysts: E. Christensen and B. Bruun. Laboratory, Geological Survey of Norway.

[1]) Granulitic sparagmite (average of three analyses). Barth, 1938, p. 64.

The chief rock types present include quartzites (Quartzite Series), meta-limestones (Guolas Limestone Series, Big Limestone Series) and mica-schists (Store Borsejok Series). These may conveniently be interpreted as originally sandstones, limestones and shales. The first two, being virtually monomineralic, have suffered recrystallization with some enlargement of the grain size. The mica-schists often grade into more quartzitic varieties representing sandy or silty shales. The graphitic schists are probably derived from more carbonaceous shales.

Throughout the succession few examples of coarse-grained conglomeratic or arkosic rocks were found. In fact conglomerate is limited to the narrow horizon at the base of the Lower Brown Schist near Akki Javre and to a horizon high in the sequence near

Agjeg mountain, Skibotndal. There is no evidence of any major stratigraphical unconformity.

The Sparagmitic Schists, forming the lower part of the succession, lack obvious megascopic features of granitization such as the presence of quartzo-feldspathic augen, veins etc. In the field they resemble metamorphosed sparagmites of other areas in Norway, e. g. Opdal, south of Trondheim. The similarity extends also to their appearance in hand specimens and in thin-sections as well as to their bulk chemical composition. The latter is set forth in Table 5 where the clear dominance of salic over femic constituents is demonstrated. The feldspar also constitutes a significant amount of the whole and suggests that the rock was once a slightly feldspathic (arkosic) sandstone. A small amount of epidote is commonly present as thin laminae in the rock.

In Table 5 a chemical analysis of metamorphosed sparagmites from Opdal is included and shows close similarity to the Sparagmite Schists of the present area. In both places the sparagmites occupy a position towards the base of the Caledonide sequence.

The extensive metasomatism which has affected the schists above has brought about considerable recrystallization. Only occasionally, as in the granite of Olmaivoabmirasja, is the layering lost or indistinct. Thus it is possible to appreciate that the beds were more variegated than the underlying Sparagmitic Schists. The commoner (sedimentary) rock types occur such as quartzite, mica-schist as well as thin, calc-silicate layers and meta-limestones.

In the higher, non-granitized part of the Birtavarre Series certain formations call for further comment. First and foremost is the Ankerlia Schist in which all the known ore bodies occur. Its sedimentary origin seems beyond doubt from the field relationships (e. g. gradational contacts with the enclosing Brown Schist) but the present mineral association is more akin to that of basic (?igneous) rock except in the presence of free quartz (20—25 %). It might therefore be interpreted as an impure muddy siltstone or sandstone.

A bulk chemical analysis (Table 6) shows much of interest in that it resembles a rock of the greywacke type (Table 7). When compared with proven greywackes from other parts of the world it is seen that the lime content is rather higher and the soda and potash correspondingly lower. This could easily be explained as a slightly higher primary lime content though the possibility of a lime metasomatism cannot be ruled out. Lime is however considered to be a constant component of all greywackes (Pettijohn, 1949, p. 247) and in poorly metamorphosed rocks is represented by calcite or ankerite. In metamorphic rocks it might be expected to enter calc-silicates.

In any event the proportions considered by Pettijohn to be significant are also found in the Ankerlia Schist, viz. $CaO > MgO$, $Fe^{\cdot\cdot} > Fe^{\cdot\cdot\cdot}$, $Na_2O > K_2O$. Again the total FeO, Fe_2O_3, MgO and MnO content is about the same in the 3 analyses listed, viz. 9.56 in 1, 8.2 in 2, 10.15 in 3. Such a rock is known to be very susceptible to alteration and even weakly metamorphosed greywackes often show extensive reaction between the primary detrital fragments and the matrix with the development of Fe, Mg silicates.

Optical determination has shown that some of the plagioclase is of high andesinic composition though some of the grains have an outer rim approaching An_{30}. The former may possibly be a reflection of the composition of the original detrital feldspar or of earlier metamorphism. The latter would then indicate a later metamorphism in the epidote-amphibolite facies.

It is also worth while recalling that greywackes are typical sediments of areas of geosynclinal deposition and bulk conspicuously in the sedimentary succession. A good example of this is in the Lower Palaeozoics of the south of Scotland. The metamorphic equivalents are not always easy to recognize but they might well be expected in comparable geological milieux.

The Ankerlia Schist also shows a marked thickening north and northwestwards as far as Ankerlia. In a distance of 3 kilometres it increases from about 40 to 800 metres (fig. 9). This is in the general direction of the presumed axis of the Caledonian geosyncline.

As pointed out earlier (p. 24), the Green Beds show a close resemblance to extrusive basaltic rocks. In Table 8 the chemical analysis is presented along with that of an olivine-basalt for comparison when the similarity is self-evident. The undersaturated character of the rock is clearly shown by the presence of olivine (8.34 %) in the norm. The modal minerals, however, differ considerably and emphasize the extensive reconstitution which has taken place. This is largely the result of the regional metamorphism. No primary lava structures now remain but it seems likely that the

TABLE 6.

Upper Ankerlia Schists, SE of Moskogaissa, Birtavarre.

	wt. %	eq. mol %
SiO_2	61.20	58.0
TiO_2	0.84	0.6
Al_2O_3	13.91	15.7
Fe_2O_3	1.54	1.1
FeO	4.05	3.2
MnO	0.09	0.1
MgO	4.47	6.3
CaO	9.78	9.9
Na_2O	1.88	3.5
K_2O	1.36	1.6
H_2O	0.79	(5.0)
P_2O_5	0.20	0.1
Total	100.11	100.1

Si	Ti	Al	$Fe^{\cdots}$	$Fe^{\cdot\cdot}$+Mn	Mg	Ca	Na	K	P			
58.0	0.6	15.7	1.1	3.3	6.3	9.9	3.5	1.6	0.1	98.9	Modal Minerals	
24.7										24.7	Quartz	
6.0		2.0					2.0			10.0	Albite	Plag. An_{43}
3.0		3.0				1.5				7.5	Anorthite	
12.6		4.2		5.7		2.8	1.4	0.7		27.4	Hornblende	
1.9		1.2		1.9				0.9		5.9	Biotite	
5.2		5.2				3.5				13.9	Clinozoisite	
4.0					1.4	2.0				7.4	Diopside	
						0.2			0.1	0.3	Apatite	
0.6	0.6					0.6				1.8	Sphene	

Analyst: B. Bruun, Laboratory, Geological Survey of Norway.

TABLE 7.

	Weight percentages		
	1	2	3
SiO_2	61.52	64.2	61.20
TiO_2	0.62	0.5	0.84
Al_2O_3	13.42	14.1	13.91
Fe_2O_3	1.73	1.0	1.54
FeO	4.45	4.2	4.05
MnO	nil	0.1	0.09
MgO	3.39	2.9	4.47
CaO	3.56	3.5	9.78
Na_2O	3.73	3.4	1.88
K_2O	2.17	2.0	1.36
H_2O	2.29	2.2a	0.79
P_2O_5	nil	0.1	0.20
CO_2	3.04	1.6	nil
Sum	99.92	100.0	100.11

1. Archean greywackes (average of three). After Todd E.W. 1928. Ont. Dept. of Mines, Ann Rpt., 37, (2), p. 20.
2. Average of 11 greywackes, compiled by Pettijohn, 1949, Sedimentary Rocks. Harper and Brothers. New York, p. 250.
3. Upper Ankerlia Schist, Birtavarre. Analyst: B. Bruun, Geological Survey of Norway.

a Probably in error: H_2O should be 2.4.

Green Beds represent an extrusive basaltic phase. They are quite conformable to the enclosing beds while their attenuated margins are sometimes interlayered with brown (quartz-mica) schist and for this reason are treated here along with the schists of sedimentary origin.

It may also be remembered that the structures resembling pillow lavas in size and shape were found in a greenstone in the Guolas Limestone Series near Akki Javre. If correctly interpreted, they indicate an earlier volcanic phase than that represented by the Green Beds.

The above discussion shows that the Caledonide succession is here one of (meta-) sediments with occasional volcanic horizons. The absence of much coarsely clastic material might suggest deposition at some distance from land or at least from land of no great

TABLE 8.

Green Beds, Moskogaissa, Birtavarre.

	[1]) wt. %	eq. mol %	[2]) wt. %
SiO_2	48.72	45.5	47.4
TiO_2	1.57	1.1	2.2
Al_2O_3	16.83	18.6	15.6
Fe_2O_3	1.86	1.3	3.7
FeO	7.54	5.9	9.2
MnO	0.17	0.1	0.3
MgO	7.91	11.1	8.5
CaO	11.05	11.1	10.2
Na_2O	2.56	4.8	2.1
K_2O	0.39	0.4	0.6
H_2O	1.33	(7.6)	c. a.
P_2O_5	0.14	0.1	0.2
Total	100.07	100.0	100.0

Si	Ti	Al	$Fe^{\cdots}$	$Fe^{\cdot\cdot}$+Mn	Mg	Ca	Na	K	P		
45.5	1.1	18.6	1.3	6.0	11.1	11.1	4.8	0.4	0.1	99.4	Modal Minerals
3.9		1.3					1.3			6.5	Albite } Plag. An_{48}
2.4		2.4				1.2				6.0	Anorthite }
34.6		11.5		15.6		7.7	3.5			72.9	Hornblende
1.2		0.8		0.8	0.8				0.4	4.0	Biotite
2.0		2.0				1.2				5.2	Clinozoisite
1.1	1.1					1.1				3.3	Titanite
						0.2			0.1	0.3	Apatite
				1.2						1.2	Ore

CIPW norm:

Or	2.24	57.08	Diop	16.76	42.71
Ab	21.48		Hyp	11.53	
An	33.36		Ol	8.34	
			Mt	2.70	
			Il	3.04	
			Ap	0.34	

[1]) Analyst: B. Bruun, Geologiâal Survey of Norway.

[2]) Hebridean olivine-basalt. Average of 7 analyses. Walker and Poldervaart (1949, p. 649).

c.a. — calculated anhydrous.

relief. It should be remembered, however, that the Caledonide rocks have been carried forward some distance SSE from their original place of deposition so that the present-day relationships to the foreland cannot be used to determine the sedimentary milieu.

The presence of volcanic horizons and abundant basic intrusives might well suggest approach to the axial part of the geosyncline rather then to any shore-line. The Ankerlia Schist certainly increases in thickness towards the supposed axial region but as will be seen later (p. 98) sedimentation was to some extent controlled locally by flexuring of the basement.

Basic intrusive rocks.

It is evident from Part 1 of this paper that basic rocks occur at all stratigraphic levels. They are variously referred to as amphibolite, greenstone, greenschist, dolerite and gabbro. A brief summary of each and their geological significance now seems necessary.

The amphibolites occur in nearly all formations though more abundantly in some (Nitsim Varre Series, Upper Ankerlia Schist) than others (Quartzite Series). For the most part they are interlayered conformably with the schists and only rarely can discordant relationships be seen. Mineralogically they show an abundance of green hornblende and andesinic plagioclase, sometimes with an outer margin of oligoclasic composition. Parallel orientation of the prismatic hornblende is common and gives the rock a marked directive texture. They are thought to be basaltic or doleritic rocks intruded into the Caledonide sediments *before* the main onset of the regional metamorphism.

A chemical analysis of a typical specimen of a suite in the Upper Ankerlia Schist near Magervannelv is given in Table 9.

The remarkable amount of basic rock in the Nitsim Varre Series includes some which is amphibolite of the type mentioned above, but also much which is less altered both mineralogically and texturally. The latter is particularly abundant on Nitsim Varre itself where both sill-like and discordant, dyke-like bodies are present.

Yet more remarkable is the occurrence of dolerite in the Schists-with-thin-Limestones. The large, wedge-like body forming the summit part of Store Moskogaissa shows clearly the intrusive nature of the dolerite: chilled margins are common, and the pre-

TABLE 9.

Amphibolite, Upper Ankerlia Schist, Magervannelv, Birtavarre.

	wt. %	eq. mol %
SiO_2	47.50	44.0
TiO_2	0.78	0.5
Al_2O_3	22.19	24.2
Fe_2O_3	1.50	1.1
FeO	4.60	3.6
MnO	0.09	0.7
MgO	6.57	9.1
CaO	13.56	13.5
Na_2O	1.94	3.5
K_2O	0.23	0.3
H_2O	0.86	(5.0)
P_2O_5	0.25	0.2
	100.07	100.7

Si	Ti	Al	$Fe^{\cdots}$	$Fe^{\cdot\cdot}$+Mn	Mg	Ca	Na	K	P		
44.0	0.5	24.2	1.1	4.3	9.1	13.5	3.5	0.3	0.2	102.8	Modal Minerals
7.2		2.4					2.4			12.0	Albite } Plag. An_{32}
10.0		10.0				5.0				25.0	Anorthite } Plag. An_{32}
23.8		8.3		10.5		5.3	1.1	0.3		49.3	Hornblende
3.8		3.8				2.4				10.0	Clinozoisite
0.5	0.5					0.5				1.5	Sphene
						0.3			0.2	0.5	Apatite
			0.5	4.0						4.5	Ore

CIPW norm:

Or	1.11	69.35	Diop	10.26	35.48
Ab	16.24		Hyp	9.84	
An	52.00		Ol	11.10	
			Mt	2.09	
			Il	1.52	
			Ap	0.67	

Analyst: B. Bruun, Laboratory, Geological Survey of Norway.

servation of sub-ophitic textures, original augite and lack of directice texture seem to indicate that the rocks were intruded after the main phase of regional metamorphism.

Other basic rocks apparently unaffected by the main phase of metamorphism include the Haldit gabbro massif and a series of dolerite bodies a little to the north. Both occur in the granitized part of the Birtavarre Series.

The Haldit gabbro has been treated elsewhere by Hausen (1942 a) who showed its layered character and general laccolithic form. Examination of the northern boundary during the present investigation shows that the schists turn over rather sharply to pass conformably beneath it. There also appears to be an apophysis of the main gabbro lying conformably in the schists. It is represented by a finger-like outcrop directed westwards and in direct line with an oval-shaped 'outlier' of the same rock capping a prominent hill to the south (fig. 17).

Mapping in the ground north of Haldit and east of Guolas Javre revealed the presence of numerous bodies of a dark, medium-grained holocrystalline dolerite (augite, often much altered to hornblende, andesinic plagioclase, clinozoisite, biotite). These apparently weather less easily than the schists and form distinct hills rising above the general level of the topography. The 'Hornasch' is one of the larger ones and forms a solid mass about 25 metres high (fig. 19). Smaller ones occur north of this but their precise limits are rarely visible due to the blanketing effect of scree, vegetation and the sand debris of an old lake flat. They are usually massive bedded and jointed and seem to be lens-like bodies conformable with the schists. The latter invariably show higher angles of dip than is normal for the granitized schists of this region.

Close to the contacts the schists seem to be welded together into a more rigid, less fissile rock, presumably a baking effect of intrusion. Some recrystallized quartzite as well as small transgressions of the dolerite were also noted. Narrow wedges of schist are occasionally enclosed within the dolerite.

Thus the clearly intrusive character of the dolerite is evident and its lack of textural reorientation suggests that it also came into place after the main phase of metamorphism. In the profile (fig. 18) the presumed form of these dolerite bodies is shown and an attempt is made to show their probable distribution in the granitized schists.

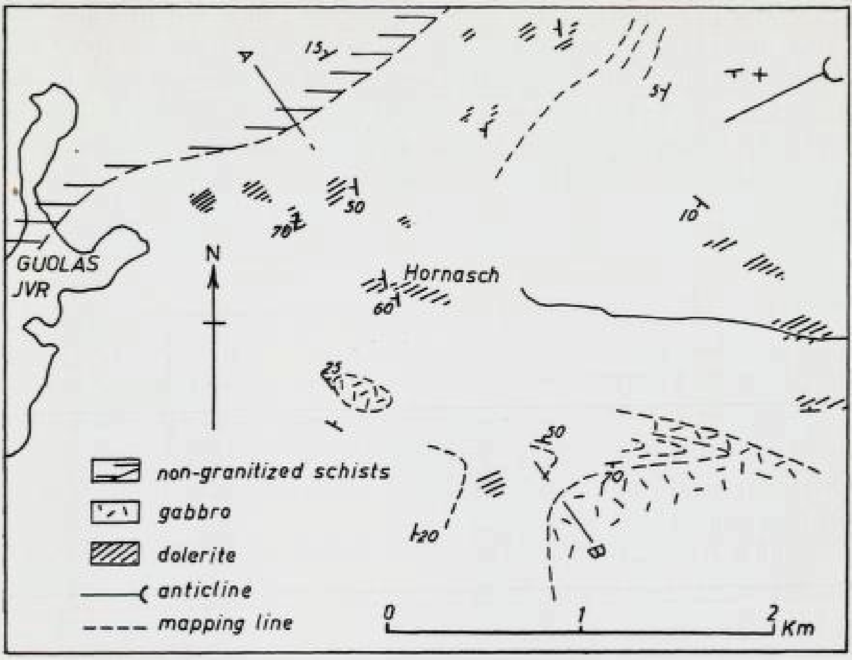

Fig. 17. Map showing distribution of dolerite and gabbro, Guolas Javre region.
Kart som viser utbredelsen av doleritt og gabbro, Guolas Javre-området.

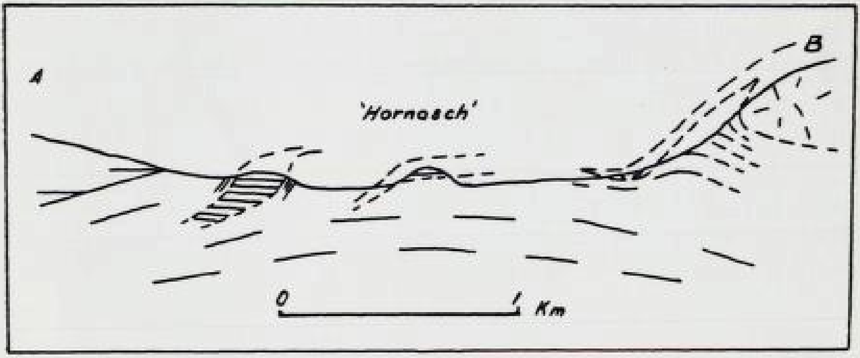

Fig. 18. Profile (see fig. 17) through dolerite and gabbro.
Profil (A—B på fig. 17) gjennom doleritt og gabbro.

The present-day outcrops are possibly connected in some way with the gabbro with which they are similar in petrography and in the lack of metamorphism. The most likely interpretation is that they form part of a 'feeder system' to the gabbro but the possibility of their being finer grained apophyses of the gabbro cannot be excluded.

Metamorphism.

The investigation has amply demonstrated the metamorphic character of most of the rocks of the area. Schistose types predominate and for the most part appear to be derived from a layered sequence of sediments with some contemporaneous extrusives. The present schistosity closely parallels the regional layering of the stratigraphical units and appears to be inherited from original bedding and lamination.

Other primary structures are generally lacking apart from some traces of cross-bedding in some of the quartzites and a possible pillow-lava structure. No fossils are known to occur.

Even a casual inspection shows that the rocks are in medium grades of metamorphism. The contrast in metamorphic grade shown by the Sparagmitic Schists and the shale of the Hyolithus zone is most marked in the Kilpisjärvi area where they are in close (tectonic) contact with each other.

In the estimation of the metamorphic facies most attention is given to the Green Beds, the amphibolites and the Ankerlia and Brown Schists. Lesser attention has been paid to the limestones and quartzites which are less sensitive indicators.

The Green Beds contain abundant green hornblende, andesinic feldspar (An_{45}) but with less calcic rims (An_{25}). (Clino-)zoisite, often myrmekitic, as well as a little titanite are commonly present.

The common association in the Ankerlia Schist is also an andesinic feldspar with less calcic rims (An_{25}), green hornblende, biotite, (clino-)zoisite, quartz and occasionally diopside. A little garnet was noted at a few places.

The Brown Schists contain quartz grains in association with an ankeritic carbonate, muscovitic, (clino-)zoisite, biotite and green porphyroblastic hornblende showing fine 'sieve' structure indicating its secondary growth.

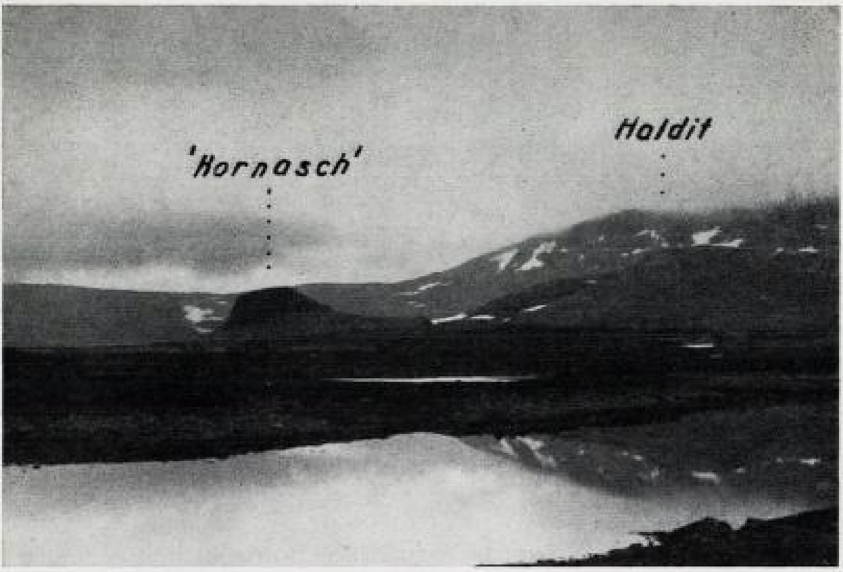

Fig. 19. The «Hornasch», Guolas Javre. Hill of unmetamorphosed dolerite. The Haldit gabbro forms high ground to the right.
«Hornasch», Guolas Javre, berg av umetamorfosert doleritt. Haldit gabbroen danner høyden til høyre.

The amphibolites of the Ankerlia Schist have a similar mineral assemblage with a little diopside in addition here and there.

In the estimation of the metamorphic facies the outer rims of the plagioclase are considered more reliable indicators than the cores. If one now accepts the view that plagioclases of composition An_{30} represent the border between the epidote-amphibolite facies on the one hand ($< An_{30}$) and the amphibolite facies ($> An_{30}$) on the other then the beds described lie fairly high in the former. (Clino-)zoisite is frequently present. It occurs *a.* in rocks known to be relatively lime-rich, e. g. Ankerlia Schist and *b.* possibly in part, as the result of saussuritization of a more calcic feldspar, e. g. Green Beds.

The more calcic cores to the plagioclase remain to be explained. In the first instance they may be considered as the result of an earlier phase of metamorphism with higher P,T conditions. There is little supporting evidence from the other minerals for this view.

On the other hand, an extrusive origin has been suggested for the Green Beds; the plagioclase may then have crystallized from a basic magma. The rims could then be interpreted as originally magmatic also. Similarly, the amphibolitic rocks whose intrusive origin seems beyond doubt in most cases. Even the Ankerlia Schist, whose sedimentary origin has been demonstrated, contains a similar plagioclase. This also may be original in the sense that the grains were derived from the weathering of basic (igneous) rocks. Such would not be unusual if the rock was of the greywacke type in its unmetamorphosed form.

The similarity of the feldspars in these three different rocks, however, suggests a common cause, namely, metamorphism. The rims are best interpreted as due to retrogressive metamorphism.

The epidote-amphibolite facies also seems to be indicated by the mica-schist and quartz-mica schist formations. Thus in the Store Borsejok Series the assemblages quartz-muscovite-kyanite and staurolite-mica schist are known to occur. By analogy with other areas (Ramberg, 1952, p. 147) such are probably only present in this and higher facies.

The granitized schists of the lower part of the Birtavarre Schists appear to belong to the same facies though accurate assessment is difficult owing to the extensive metasomatism and subsequent recrystallization. In some weakly granitized schists a few measurements on plagioclase apparently of pre-metasomatic age showed a higher lime content than the prevailing albite.

The Sparagmitic Schists are highly quartzitic (Table 5) and therefore less sensitive indicators of the metamorphism. The plagioclase is, however, albitic though no signs of granitization were seen. Such a feldspar would then indicate that these Schists are somewhat lower in the epidote-amphibolite facies.

Comparison with other areas.

Little work has so far been carried out on the Caledonides of northern Norway and therefore detailed stratigraphic correlations are impossible. Fossils are virtually non-existent so that comparisons can only be made on the basis of lithology and structure. Again little is known of the relative age and distribution of the volcanic episodes as represented by basic extrusive rocks so that comparisons on this basis are equally difficult. Finally it should be remembered that the stratigraphic succession in the vicinity of Birtavarre is rather more elaborate in that more units can be distinguished. Simplification in both north, south and westerly directions is known to occur.

Most of the existing information is conveniently summarized on the recently published geological map of Norway by O. Holtedahl and J. A. Dons (1953). Here the course of the big marginal overthrust (referred to provisionally as the 'Seve' thrust in this paper) is shown. An important division of the Caledonides has also been made into 'Bergarter sanns. vesentlig av Eokambrisk Alder' (Rocks probably mainly of Eocambrian age) and 'Kambro-Siluriske Sediment-Bergarter sterkt omvandlet' (Cambro-Silurian sedimentary rocks, much altered). The first includes gneissic rocks as well as quartzitic schists and phyllites. It outcrops extensively from 'Raisduoddar Haldde' (on the Finnish-Norwegian border) to North Cape. Nowhere are metallic ore deposits known to occur. Both the zone of regional granitization in the lower part of the Birtavarre Series as well as the Sparagmitic Schists clearly belong to it.

The second appears to include the higher beds which are generally speaking not granitized in the present area of consideration.

Such a division was subconsciously made by T. Vogt as a result of his researches in the Vaddas area (1927), some 40 kilometres NNE of Birtavarre. Here the Lilleelv Series is said to include quartzite and garnet-bearing gneiss and thus falls into the lower division while higher beds, including the Vaddas Series, the Vaddas Quartzite and Øksfjord Series belong to the upper. The junction between the two is shown accordingly on the map of Holtedahl and Dons (1953) and also its presumed continuation southwards along Reisadalen. Here it enters the present area of investigation and corresponds roughly to the upper limit of granitization. The present work shows that it should swing more westwards in the area north of Raisduoddar Haldde towards Skibotndal.

The contact between the two main divisions is therefore partly one of lithology and partly one of granitization. The latter seems to be more important in the Birtavarre — Skibotndal area.

Correlation of individual units within each of the two divisions is less straightforward. It is possible, however, to recognize similar granitized schists and augen schists in Skibotndal and around the Alta river, Finnmark. (Holtedahl collection, Geological Museum, Oslo.) Again, the Sparagmitic Schists of Skibotndal have their exact counterparts in the region of Gargia, Finnmark.

In the region of Lodiken, West Finnmark, light-coloured quartzo-feldspathic schists with visible pink and white feldspar are even more reminiscent of sparagmitic rocks from more southerly parts of Norway.

Correlations within the higher formations are no more easy to effect in the present state of investigations, though obvious similarities exist between the successions of the Birtavarre and Vaddas areas. Independent work, in each area has shown the importance of sedimentary facies variations thus making exact correlations even more difficult. Published descriptions of the Vaddas succession are not detailed enough to allow exact correlations with Birtavarre.

Part 2. Structure.

Introduction.

During the course of the investigation a great deal of structural information was collected. Particularly detailed observations were made in areas of known or suspected ore occurrence since it was early realized that the ore bodies show a definite elongation parallel to certain linear structures. Fairly detailed observations were also made on other members of the Caledonide succession and brief remarks on these have already been given in Part 1. It is now proposed to describe the more important features in more detail and attempt a synthesis of the information on a regional basis. From this the structural milieu of the rocks can be demonstrated and also the structural development of the region as a whole.

The 'Seve' thrust-plane.

Of first importance is the big plane of overthrust seen in the Kilpisjärvi region, Finland (fig. 20), and known since the days of Törnebohm to continue for a great distance both north-east and south-west. In more recent years (1942) Hausen has given a full and detailed description of that part of it which occurs in Enontekiö province, Finland.

In the present investigation attention was only paid to it in the Kilpisjärvi part of Enontekiö in connection with the construction of the geological profile northwestwards along Skibotndal (pl. 3).

It is here represented by a thick zone of mylonite which separates the allochthonous Sparagmitic Schists from underlying autochthonous Pre-Cambrian gneiss plus Hyolithus shale.

The mylonite rocks are dark-greyish and invariably have a very strong linear grooving on schistosity surfaces which is uniformly directed to the NNW. The Hyolithus shale becomes increasingly tectonized upwards towards the 'sole' of the mylonite and small-scale overthrusting to the SSE is evident (fig. 21). Dolomitic layers are thrown into sharp folds with nearly vertical limbs and have their axes aligned parallel to the lineation on the mylonite.

The thrust-plane extends ENE parallel to the strike of the Hyolithus shale. In most places it appears to dip NNW at a small angle according to Hausen but in the Kilpisjärvi region there are indications that it falls more steeply than the dip of the shale. If so, then the latter must be cut out to the NNW. Mylonitization of the basement gneiss might then be expected and this is in fact known to occur at one locality at the road-side a little north of Siilastupa (Kilpisjärvi). Exposures are not, however, complete enough to see the extent of the mylonitization.

There is as yet no accepted name for the overthrust in this area but it is proposed to adopt provisionally the term 'Seve'. The big disturbance with this name which occurs far to the south in Jämtland, Sweden, also separates contrasting rock-series. The overriding 'Seve' nappe there consists of garnet-bearing schists, quartz-rich granulite leptites and garnetiferous amphibolite (Asklund, 1938, p. 79). This association differs considerably from that of the allochthonous Caledonides of the present area of investigation. The 'Seve' thrust proper is only one of several in Jämtland. A similar state of affairs exists in an area south of Narvik described in detail by Kautsky (1953). Much more work is obviously necessary in intermediate ground before true identity of the tectonic units can be established.

Major or first-order folds.

Mapping has revealed the existence of several shallow folds in the area (see map, pl. 1). Most of these pitch at small angles (5—20°) to the NNW. A few, roughly at right angles to this direction, occur in Skibotndal and Abnalisvagge. The latter are usually weaker and less pronounced.

Kåfjorddalen Syncline. The dominant geological structure of of the Caledonides in the area investigated is a deep syncline whose axis coincides closely with the length of Kåfjorddalen. It is therefore, proposed to call it the Kåfjorddalen syncline. Its development is particularly clear in the non-granitized Birtavarre Series where

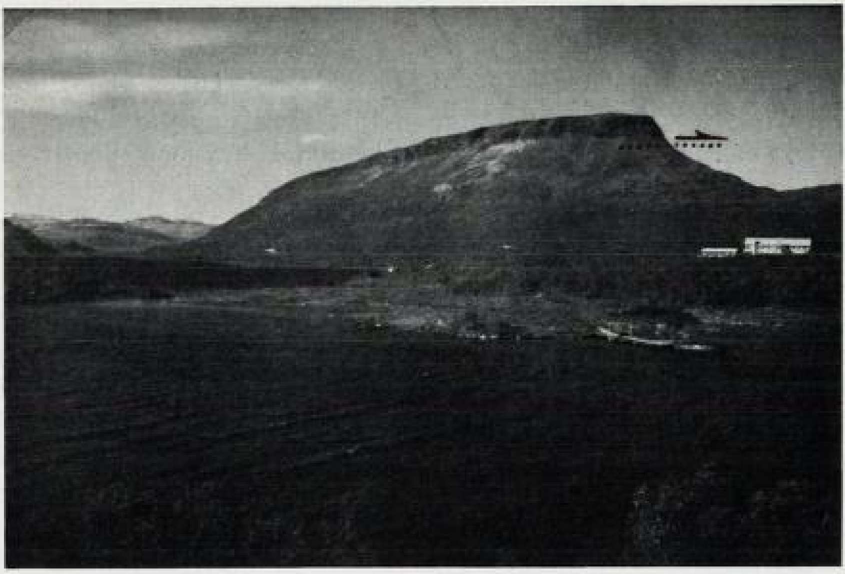

Fig. 20. View of Saana, Kilpisjärvi (Finland), from the south. The mylonite of the «Seve» thrust-plane forms the summit ridge; Hyolithus shale occurs below.
Utsikt over Saana, Kilpisjärvi (Finnland), fra sør. Mylonitten langs «Seve»-overskyvningsplanet danner selve fjellryggen; Hyolithusskifer forekommer under.

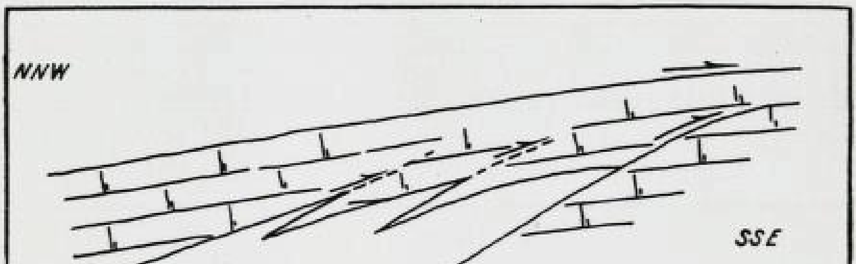

Fig. 21. Thrusting in a dolomite layer in the Hyolithus shale, Saana, Kilpisjärvi.
Overskyvninger i et dolomittlag i Hyolithusskifer, Saana, Kilpisjärvi.

its form is conveniently outlined by the outcrop of the Guolas Limestone Series. The axis passes through the middle of Guolas Javre. The plunge is about 15° to 20° to the NNW but becomes progressively less in this direction and is nearly absent along the length of Kåfjord proper. Full examination of the component beds of the syncline is greatly aided by the depth to which it is dissected along Kåfjord and Kåfjorddalen.

The western limb runs strongly northwards to the east of the Olmaivoabmirasja region and locally dips up to 70° are met with though they are usually much less. The dip lessens northwards and forms the eastern limb of a shallow, complementary anticline. The more easterly limb of the syncline, however, continues to Reisadalen. It dips gently westwards and merges with the regional strike of the Caledonides in this direction. Another shallow complementary anticline is developed in the vicinity of Hallern and Geira Jok with an axial trend to the NNW.

Other folds trending NNW. In the schists between Skardalen and Mandalen several shallow folds with axes trending NNW are present. They invariably have only gently dipping limbs.

Rasjanipa Syncline. The mountain of Rasjanipa is marked on aerial photographs by a series of concentric ridges arranged in horseshoe fashion. Most of the beds other than the very highest ones belong to the granitized schists of the Birtavarre Series. They are folded into a gentle syncline pitching at about 5° to the NNW. This direction is exactly parallel to the regional lineation and 'grain' of the rocks of the area and also to the axis of the Kåfjorddalen syncline.

Haldit Syncline. An examination of the map of Halditjokko (Hausen, 1942 a) shows that the gabbro massif is cradled in schists which have a gentle synclinal form pitching to the NNW. The fold axis is slightly out of line with that of the Kåfjorddalen syncline but has roughly the same axial direction.

Folds trending ENE. These are present in the Skardalen—Mandalen region also where they are at right angles to the folding described above. Their limbs are only gently dipping. Similar folds occur in Skibotndal (see profile, pl. 3) where they are almost exactly at right angles to the regional trend of the rocks.

Moskogaissi Anticline. A gentle anticline structure pitching about 10° to the west is present in the Moskogaissa area. Its

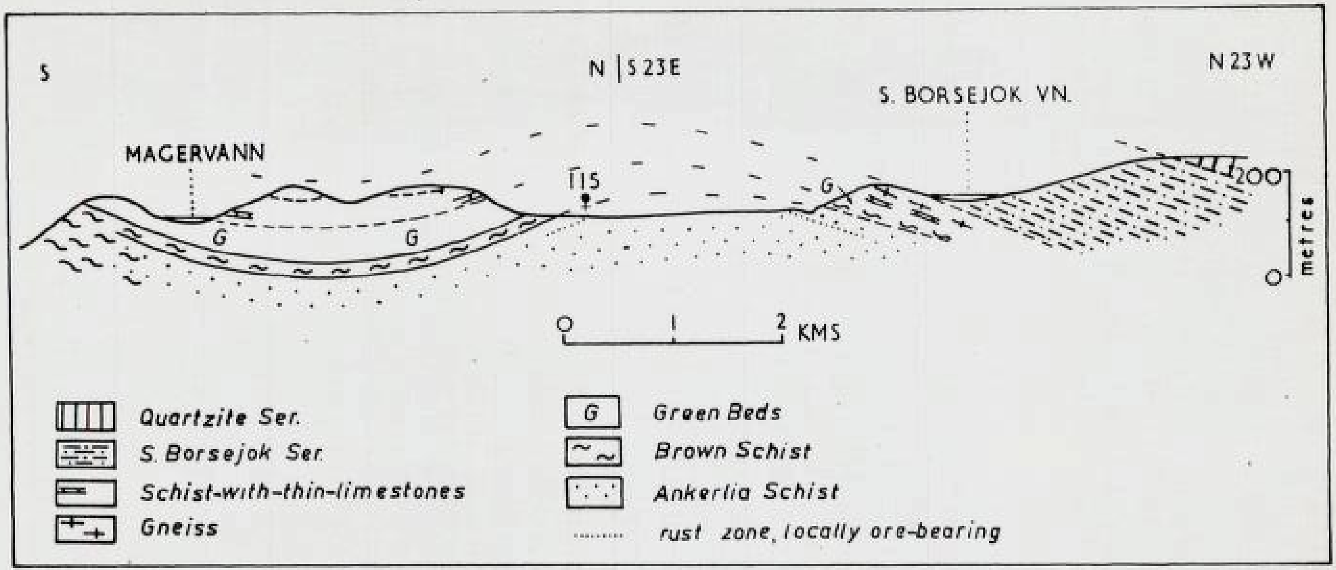

Fig. 22. Cross-section through the Moskogaissa anticline.
Profil gjennom Moskogaissa-antiklinalen.

form is outlined by the outcrop of the base of the Green Beds. The axis is parallel to the local lineation direction in this area (fig. 22) and to certain small-scale fold axes. The structure loses its strength on the NE side of Kåfjorddalen where the northerly limb merges with the general northeasterly strike of the beds.

The axial direction (westerly) is anomalous with respect to the other major folds of the region but as will be seen later this is due to rather special local conditions (see later under 'Dragfolding').

Lineation.

A variety of linear elements other than the first-order folds described above were studied and their directions carefully noted. The chief types include grooving and ribbing on bedding surfaces, parallel orientation of elongate minerals and small-scale folding. Near Guolas Javre the elongation of the constituent pebbles of a conglomerate and the pillow-like units of a greenstone were also measured.

The development of these elements on different rocks of the stratigraphic series is given in Part 1. Thus the Sparagmitic Schists and the granitized schists above show strong lineation on nearly all bedding and schistosity surfaces. Changes in direction are small and gradual. In the latter schists considerable folding of a plastic nature is common especially in Skibotndal (fig. 13). Here folds of two orders are evident. Those of the second order include asymmetrical, monoclinal folds up to 7 metres in height with steeper limbs facing SW or SSW. They never become truly recumbent. Superimposed on these are a variety of smaller, third-order folds whose axial planes are commonly inclined in the same direction but at varying angles. Their form indicates considerable plasticity of the layers during deformation and the complexity seems to vary inversely to their thickness. Thicker ones of quartzo-feldspathic material are more gently folded. Locally, failure by disruption of layers can be seen as well as small-scale thrusting and shearing of the fold limbs.

The nearly continuous exposures of these beds in roadside sections in Skibotndal enable a fairly complete profile to be drawn. That shown in the profile (pl. 3) is about 45° to the axis of folding and the folds are, therefore, rather more spread out than would actually be the case in a section at right angles. It should also be noted that the more complex folding occurs in a larger synclinal downwarp (pl. 3, B).

Minor fold structures are much less common in the Sparagmitic Schists though this is probably due to their more rigid character. Even so, strong grooving is usually present on most bedding surfaces.

Because of their linear structures and associated joint directions the Sparagmitic Schists and the granitized schists above give a well-marked 'grain' to the topography. This is particularly clear in aerial photographs where changes in direction are gradual. The regional lineation is clearly to the NW or NNW.

The non-granitized schists of the Birtavarre Series on the other hand have much weaker linear structures and trends are less regular. They give rise, therefore, to a correspondingly less marked 'grain' on aerial photographs. The map (pl. 1) shows nevertheless, a regional structural trend towards the NW or NNW but with significant deflections in 2 main areas:

a. Moskagaissa — Ankerlia — Skaide where linear structures trend more EW but become progressively NNW towards Skardalen; the main occurences of ore are found in this area.
b. Isa Varre — Nassa Varre — Mainarasja where lineation has an arcuate form, convex to the south-south-east.

While causes are given below for these local anomalies, it should be emphasized that there is general conformity and continuity in the directions of the lineation, thus providing further evidence that no significant tectonic break affects the regularity of the stratigraphic succession.

Finally it should be noted that in certain areas where exposures of rock surfaces are especially good it is sometimes possible to detect linear elements whose directions are other than the main ones shown on the map. Such features include, for example, crinkling of mica flakes into parallel ridges a few millimetres high on certain planes of schistosity. Fuller study of these has not yet been attempted. They are clearly subsidiary to the main trends discussed above.

Joints.

No systematic study of joints has been made since they appear to have little or no meaning for the control and distribution of ore bodies.

Some analysis has been made, however, of joints in relation to other structural elements, namely, lineation and fold axes. Thus in the granitized part of the Birtavarre Series strong, near-vertical jointing at high angles to the lineation is very marked. The larger and major joints are often marked by snow-filled hollows on aerial photographs. Those on Rasjanipa, for example, trend ENE and are almost at right angles to the axis of the synclinal structure. Another has a more northeasterly course. Smaller joints measured on the ground have similar directions. Good examples of both are common in the granitized schists and sparagmitic schists of Skibotndal.

Similar relationships to the lineation are known from the non-granitized Birtavarre Series but they only become marked and regularly developed when the linear structures are strong. Thus in the strongly deformed parts of the Quartzite Series strong joints at right angles to the fold axes and lineation are invariably present.

Study of some small folds (with irregular axial directions) in the Upper Ankerlia Schists has shown that joints are developed parallel to the fold axes and at right angles to the schistosity. They are clearly tension features.

Minor movements in the Birtavarre Series.

There is no evidence for any single, large-scale thrust comparable with the 'Seve' thrust nor of any large overfold structure. Small-scale movements are, however, many and varied. They include slipping on parallel schistosity planes, clear-cut thrusting with the development of angular relationships; less competent beds show much small-scale folding often markedly recumbent and distributed in a zonal or planar fashion slightly oblique to the layering of the rocks.

The main structures are described below with accompanying illustrations and photographs.

It is also of interest to note that certain of the separate rock formations are relatively undisturbed. These include the Store Borsejok Series (except the basal layers), Green Beds, Lower and Upper Brown Schists and Nitsim Varre Series.

The Cappis Thrust.

This thrust is the only one in the Caledonide succession which can be followed for any distance. It extends from a point a little north of Cappis Javre to Kilen, and northeastwards towards Njuorjo Javre and Goategaissa (see map, pl. 1). For most of its course it is represented by a zone, several metres thick, in which the schists are much sheared. Recrystallization phenomena with the development of large flakes of muscovitic and biotitic mica and granular quartz are also highly typical. Thin lenses of white vein-quartz also occur.

Linear grooving and ridging aligned parallel with the regional direction are commonly present on schistose surfaces as well as conspicuous slickensiding.

The thrust-zone occurs towards the base of the Store Borsejok Series and also affects the upper part of the Schists-with-thin-Limestones. Mapping has shown that it is somewhat discordant to the stratigraphy. Thus on Store Moskogaissa a nearly full succession of Schists-with-thin-Limestones is present, while north and northeastwards this Series gradually disappears. It is much reduced in thickness at Kilen and only the thicker and uppermost limestone seems to be present. This also disappears towards Njuorjo Javre. Some of the mica- and quartz-mica schists continue further but become increasingly sheared and recrystallized. In the region north of Njuorjo Javre sheared schists (partly reduced Schists-with-thin-Limestones and partly basal Store Borsejok Series) rest on Upper Ankerlia Schist. Thus the Schists-with-thin-Limestones becomes tectonically cut out to the north-east.

No Green Beds are known NE of Kilen but this seems to be a feature of original character and not due to later tectonic causes.

The thrust-zone from Njuorjo Javre Northwards. This part of the zone has been studied in fair detail by means of several profiles. A characteristic feature is the sharp junction with the underlying Upper Ankerlia Schist which has been mapped with some precision along the length of the zone till it disappears out of the area in

Reisadalen. The junction separates normal Ankerlia Schist from sheared and recrystallized schists of the basal Store Borsejok (? and Schists-with-thin-Limestones). The amount of shearing disappears gradually upwards into regularly bedded Store Borsejok Schists. Several typical profiles, somewhat simplified, are shown in fig. 6.

It should also be noted that the thrust zone separates rock-series with contrasting structures, the Store Borsejok being generally speaking little disturbed in contrast to the Ankerlia Schist which is locally buckled into shallow folds with variable axial directions immediately below the thrust zone. Cross-folding was clearly observed in several exposures.

A variety of petrographic types are found in the zone dependent on the nature of the original schists and the degree of tectonic movement. Thus it commonly happens that large mica flakes surround irregular lenses of white quartz and quartzo-feldspathic lenses studded with black tourmaline crystals. It is also common to find thicknesses of schist with feldspathic augen while in more extreme cases of mineral readjustment the schistosity becomes highly irregular and the rock tends towards a granitic gneiss. Such rock gives rise to patternless areas on aerial photographs and these are particularly characteristic for the northern part of the area, e. g. Goategaissa.

West and north-west of Njuorjo Javre. Here the thrust zone appears to lie in more variegated rocks including amphibolites and lime-schists besides the mica- and quartz-schists. Accordingly, calc-silicate schists and sheared amphibolites are also present.

Njuorjo Javre — Cappis. Here even greater original variegation of the layers occurs and therefore greater variety in the tectonized products. Thus a distinct layer of white meta-limestone is present. It is invariably much recrystallized and boudined. Again layers of graphitic schist belonging to the Store Borsejok Series ½—1 km east of Kilen shows much evidence of movement. They have undoubtedly provided a convenient gliding medium for the thrusting. Of further interest is the occurrence of a zone of gneiss. This varies considerably in thickness and character but has its maximum development at Kilen, where it is massively bedded and largely consists of mica, quartz and feldspar. It here rests abruptly on colour-banded Ankerlia Schist, and passes upwards into mica- and quartz-schists. Eastwards it is represented by layers only a few metres thick.

A similar gneiss zone occurs in the Schists-with-thin-Limestones north of the Moskogaissa area. Schists above are much sheared and the limestones much boudined. Southwards (and up dip) the zone rapidly becomes weaker, being limited to the occurrence of augen through a few metres on Store Moskogaissa.

There thus seems strong evidence that the gneiss represents a recrystallization phenomenon (localized granitization) in the thrust zone. The schists above are much sheared while several layers of limestone are boudined. At Mattisaksla the limestone shows very complicated relationships to dark, amphibolitic rock (fig. 7) and this is probably a tectonic effect aided by the well known mobility of limestone under directed pressure.

Cappis Javre. Here rather special features were noted. In the first place the thrust zone is marked by mechanical fracturing and brecciation and by the development of an angular discordance. Gouge is developed on several planes of movement. These features are well exposed in a small gorge a little NW of Cappis Javre. The observable features are shown in fig. 23. West of this, little or no trace of the zone was found.

Due east of Cappis Javre the beds are often standing vertical and in detail show evidence of severe tectonic deformation. Thus the mica-schists display small sharp-edged zig-zag folds and the quartzitic members are ridged and grooved. Sharp folds with minor folds on their flanks are also common. Both lineation and fold-axes are locally oriented N—S. Again, recognizable Banded Ankerlia Schist rests against Schists-with-thin-Limestones and a thrust-plane is postulated between the two. This has itself been thrown into a steep, monoclinal flexure in the manner shown in fig. 23 a. The latter appears, therefore, to be a feature developed after the formation of the thrust-plane. A 'klippe' of Schists-with-thin-Limestones occurs south of Cappis Javre.

In the foregoing it has been demonstrated that recrystallization with the development locally of granite-gneiss and augen schists occurs in a thrust zone. Other pegmatitic bodies outside but in the vicinity of the thrust-zone are known to occur including the gneissose pegmatite described in Part 1. (For relationship to the stratigraphy, see fig. 5.) It is here suggested that it may have been localized on an extensive planar fracture formed by forces also responsible for the Cappis thrust a short distance above. The other small pegmatitic bodies known from the Upper Ankerlia Schist between Kilen and Skaide cannot always be related to known thrust-planes.

Other thrust- and shear-planes.

Several smaller, local planes of thrusting and shearing were observed during the course of the survey. One of the clearest is in the Upper Ankerlia Schist, about ½ km N of Lille Moskogaissa. Here there is a marked angular discordance of the beds (fig. 24) and irregular-shaped bodies of quartzo-feldspathic rock are present in or close to the plane of discordance.

In many cases movements are so closely parallel to the schistosity that they are often difficult to detect by a casual inspection. An exception to this is in the Lower Ankerlia Schist in the immediate neighbourhood of Ankerlia where rusting marks a plane of movement. Several exposures in the canyon-like walls fall into one structural horizon which shows better evidence of movement at same places than others. Thus thin gouge-planes are developed in one place, wrinkling and sharp folding of adjacent schists at another, slight discordance at a third. Irregular bodies of white quartz and sometimes a weak sulphide dissemination are found.

Other examples of movements are to be found in nearly all the small mines, e. g. Skaide, Borsejok, Sabetjok, and prospects of the area and it is in or close to these that the sulphide mineralization has taken place. Brecciation of the schists is common; also gouge-planes. In all cases it appears that movements closely parallel to the layering of the schists have been operative.

Quartz-veins *(Venites).*

Movements on an even lesser scale are possibly represented by quartz-veins. These are typical for the upper part of the Store Borsejok Series and the lower part of the Lower Ankerlia Schist. In the case of the former the containing beds are quartz-mica-garnet schists and the quartz veinlets occur as small, irregularly shaped lenses up to a metre or so in length along the bedding planes. The quartz sometimes has a faint purplish colour and in some lenses megascopic crystals of kyanite are conspicuous. Those of the Ankerlia Series are usually white and milky and commonly up to 2 cms in thickness but taper rapidly down to nothing. They

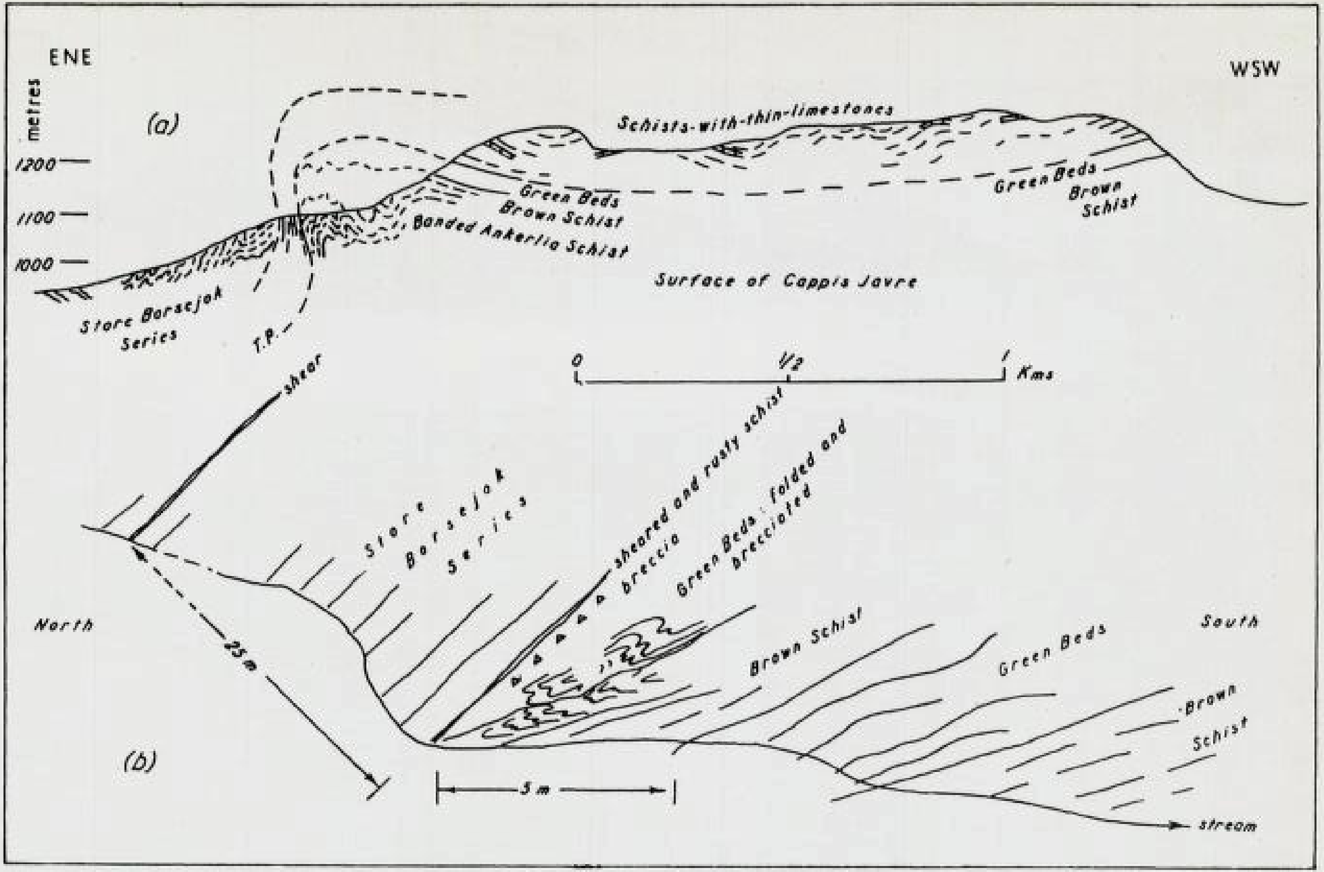

Fig. 23. (a) E—W profile just south of Cappis Javre: the Cappis Thrust (T. P.) is sharply folded; (b) profile through the Cappis Thrust, north of Cappis Javre, showing brecciation and angular discordance of beds. (F. M. Vokes' drawings.)

(a) Ø—V profil like sør for Cappis Javre: Cappis-overskyvningen (T. P.) er sterkt foldet; (b) profil gjennom Cappis-overskyvningen, nord for Cappis Javre, som viser breksje og vinkeldiskordans mellom lagene. (F. M. Vokes' tegninger.)

Fig. 24. Thrusting in the Upper Ankerlia Schist, Moskogaissa. The folded beds lie below the thrust-plane.
Overskyvning i Upper Ankerlia Schist, Moskogaissa. De foldete lagene ligger under skyveplanet.

are arranged parallel to the bedding and schistosity planes in the main (fig. 25) but a few cross-cutting veins are also known to occur. Occasionally large lenses up to 3 metres thick are present and were locally exploited as flux material for the smelter at Ankerlia. Some quartz is locally concentrated in small, irregular bodies on the limbs and crests of the smaller folds.

The quartz veinlets of both the Ankerlia and Store Borsejok schists are thought to represent local failures between successive layers during the operation of stress. The quartz itself is probably a segregation from the schists and as such is more correctly termed venite.

The differing shape of the quartz-bodies of the two series is probably due to differences in the nature of the containing schists and to their mode of failure under stress.

Drag-fold phenomena.

Two important deformations remain to be mentioned. The first concerns the Ankerlia Schist where rather spectacular folding,

Fig. 25. Quartz-veining (venites) in the Lower Ankerlia Schist, Ankerlia. *Kåfjorddalen.*
Kvarts-slirer (venites) i Lower Ankerlia Schist, Ankerlia, Kåfjorddalen.

interpreted as drag-folding, is developed towards the middle of the formation. The second concerns the Quartzite Series where drag-folding is combined with a limited amount of thrusting.

Both deformations are believed to be the result of shearing couples put on the rock succession. The differences in tectonic style may be ascribed to the differing competencies of the rocks concerned.

1. In the Ankerlia Schist.

The most important and accessible occurrences are seen on the ascent from Ankerlia to Moskogaissa, above the Monte Carlo mine towards Lille Borsejok Vann, and in the region south of Hanskijavre (about 2 km SE of Kilen). These are clearly part of the same fold zone. The schists affected are those of the Banded Ankerlia and those in the lower part of the Upper Ankerlia Schist. Similar disturbances occur, though on a lesser scale, between Sabetjok mine and Birtavarre Høyfjell mine.

The most spectacular folding is found on the ascent from

Fig. 26. Drag-fold in the Banded Ankerlia Schist, path, Ankerlia — Moskogaissa.
«Drag-fold» i Banded Ankerlia Schist, stien Ankerlia — Moskogaissa.

Ankerlia along the old mine track to Moskogaissa. Here the general lie of the beds is horizontal or with a gentle westerly dip not exceeding 5°. The beds are, however, folded through 120—150 metres and consist of quartz-hornblende-(clino-)zoisite schists and hornblende-biotite schists; the frequent thin bands of white quartz-rich rock in the Banded Ankerlia Schist conveniently display the form of the folds (fig. 26).

Strong linear grooving and ribs characteristic for the folded beds are often clearly the result of small shear-planes intersecting the schistosity planes. These are most marked on inclined fold limbs and at contacts between mica-rich and mica-poor layers (fig. 27).

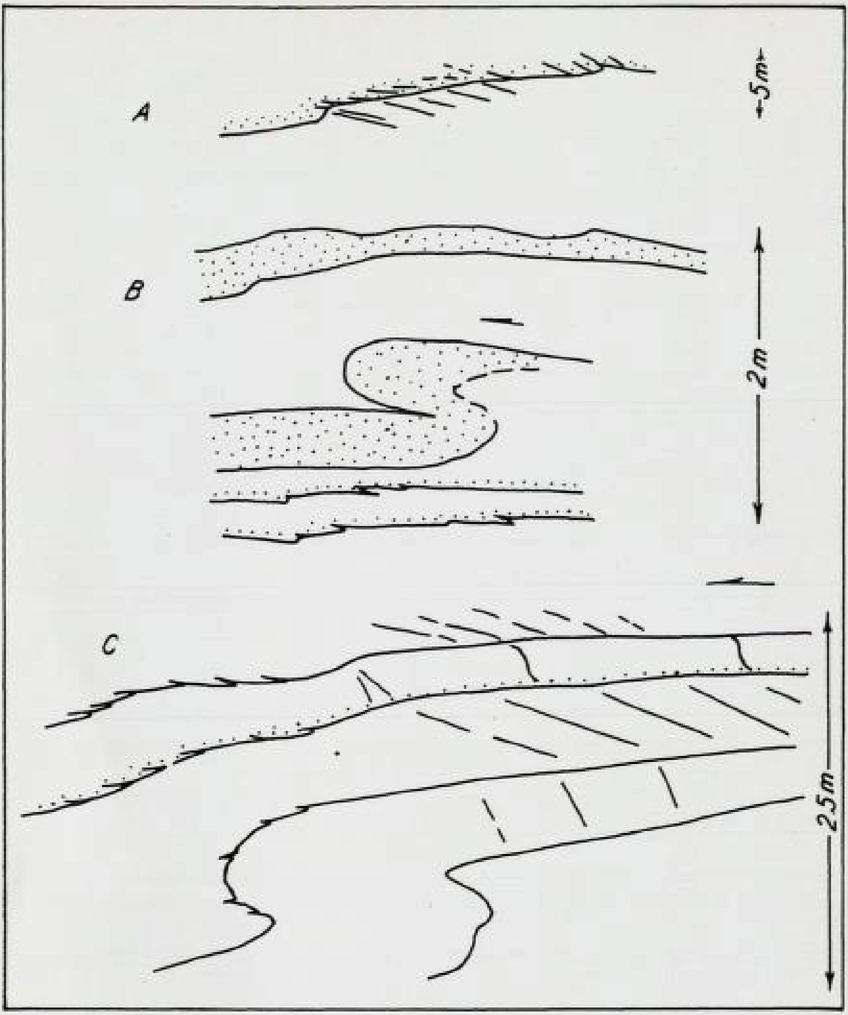

Fig. 27. Small-scale drag-folds with related shears and joints, Upper Ankerlia Schist, Moskogaissa.
Sprekker og skyvninger i forbindelse med «drag-folds» i Upper Ankerlia Schist, Moskogaissa.

An upward passage through the folding shows first a series of joints in the more rigid of the schists. These are parallel to each other but inclined at angles of 20°—35° to the bedding and downwards to the north. Above, several mica-rich layers are inter-

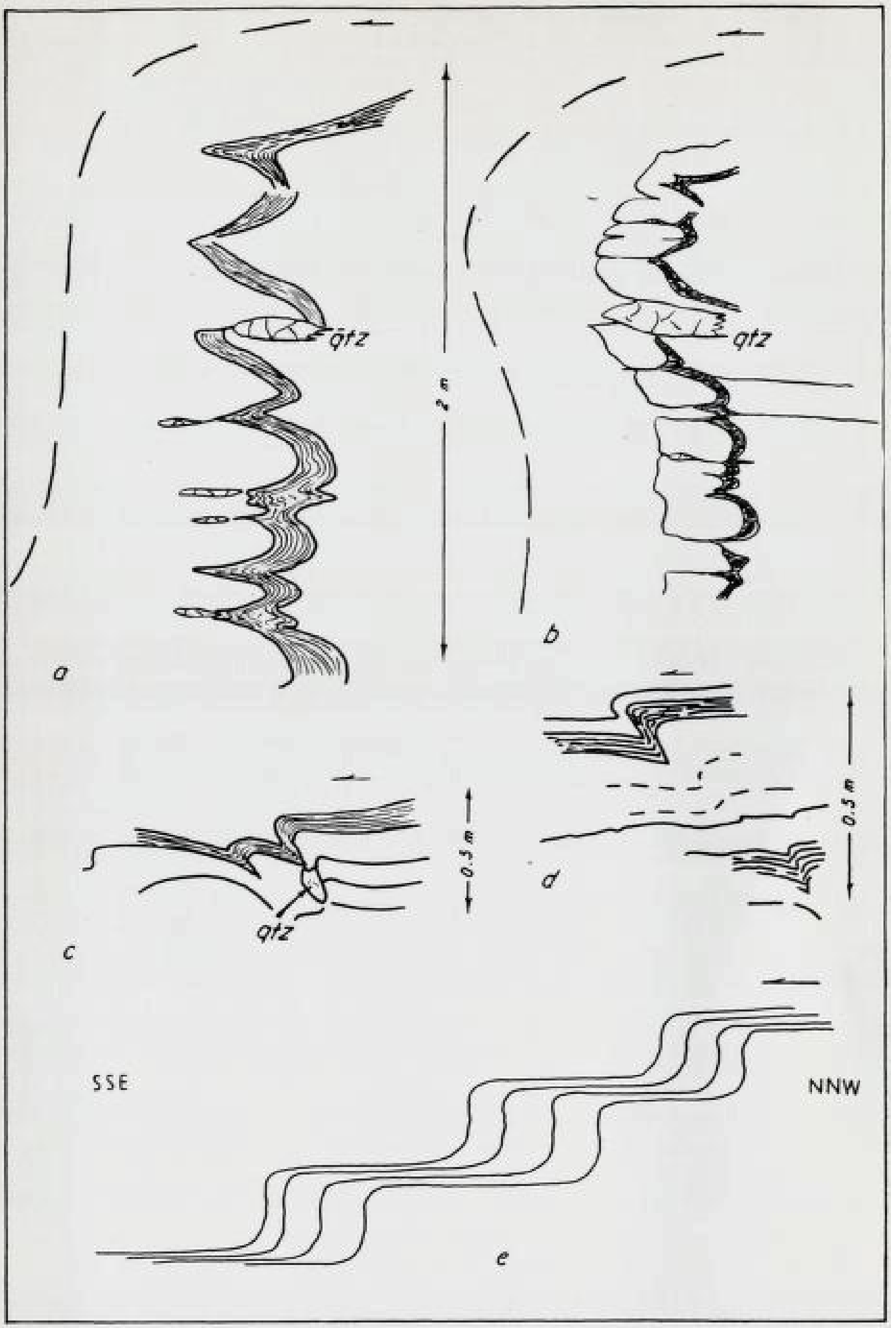

Fig. 28. Drag-folding in the Banded Ankerlia Schist, path Ankerlia to Moskogaissa. a, b. minor (third-order) folding on monoclinal limbs; c, d. incipient shearing in incompetent strata; e. generalized form of drag-folding.

«Drag-folding» i Banded Ankerlia Schist, langs stien fra Ankerlia til Moskogaissa; a, b. små folder (tredje orden) i «monoclinal» schenkel; c, d. begynnende skyvninger i incompetente lag; e. skjematisk fremstilling av «drag-folding».

Fig. 29. Shearing in the Upper Ankerlia Schist. Path Ankerlia — Moskogaissa. *«Drag-folds» med foldningsforkastninger i Upper Ankerlia Schist, stien Ankerlia — Moskogaissa.*

bedded and small-scale folding, overfolding (to the south) and shearing are developed (fig. 28). These structures sometimes occur on monoclinal flexures with a gently inclined limb. Higher still, deeper monoclines with steep or vertical limbs consistently facing south are found. The larger ones are 15 metres or more in height (fig. 28 e). Collectively they may be termed folds of the second-order in comparison with the larger first-order folds of the area.

Smaller, third-order folds and overfolds are commonly present on the monoclinal limbs. The latter are also cut by numerous tiny shear-planes which either lead to a slight discordance in the banding in more competent beds or to a fold (or shear-fold) in less competent beds (figs. 28 a—d). Commonly lenses of white or grey quartz are located on the planes of shear or incipient shear.

Many of these small structures seem to be the result of the differing competencies of adjacent beds and represent local adjustments of rock material, possibly during the development of the secondary folds. It is found that small movements, of the order of a few centimetres at the most, have taken place both to the south *and* north as judged by off-setting of the bands.

Higher up, the steepness of the monoclinal flexures lessens, and folds become less numerous till more regularly bedded schists, disturbed only by an occasional shear, are met with (fig. 29).

It should be emphasized that the folds impart a strong lineation to the rocks. There is also much ribbing and grooving on bedding surfaces arranged strictly parallel to the fold axes and trending east-west.

Careful studies of the Upper Ankerlia Schist exposed in the central part of the Moskogaissa anticline around Moskogaissa show that the E—W lineation and some folding are present. The situation is however complicated by another set of local folds and flexures trending more N—S to give cross-folding.

The fold structures described above clearly continue across Kåfjorddalen to the area 2 km S of Kilen. Here the strike, fold-axes and lineation trend northeasterly and become weaker in that direction. Similar schists are involved.

The folding can be followed high up on the mountain side above Monte Carlo mine in the direction of Lille Borsejok Vann, but it is not known to continue with the same intensity northwards in the Ankerlia Schist. Southwards, equivalent schists are fairly regularly bedded. There are a few sharp overfolds ⅓—⅔ metres high in the top of some Banded Ankerlia Schist below Sabetjok mine. Near Magervannelv, on the opposite side of the valley from Sabetjok and on the same general strike, some highly plastic folding was observed (fig. 30). This also lies above the attenuated Banded Ankerlia Schist. Similarly, a local amount of drag-folding is present in the ground between Sabetjok mine and Birtavarre Høyfjell where a body of sulphide ore is currently being studied. Here the 'dimensions' of the folding can be more completely studied. It is evident that a small 'pocket' of folding is developed with a limited extent both at right angles to the fold axes, laterally parallel to the fold axes, as well as vertically in the schist succession. Relationship are expressed somewhat diagrammatically but based

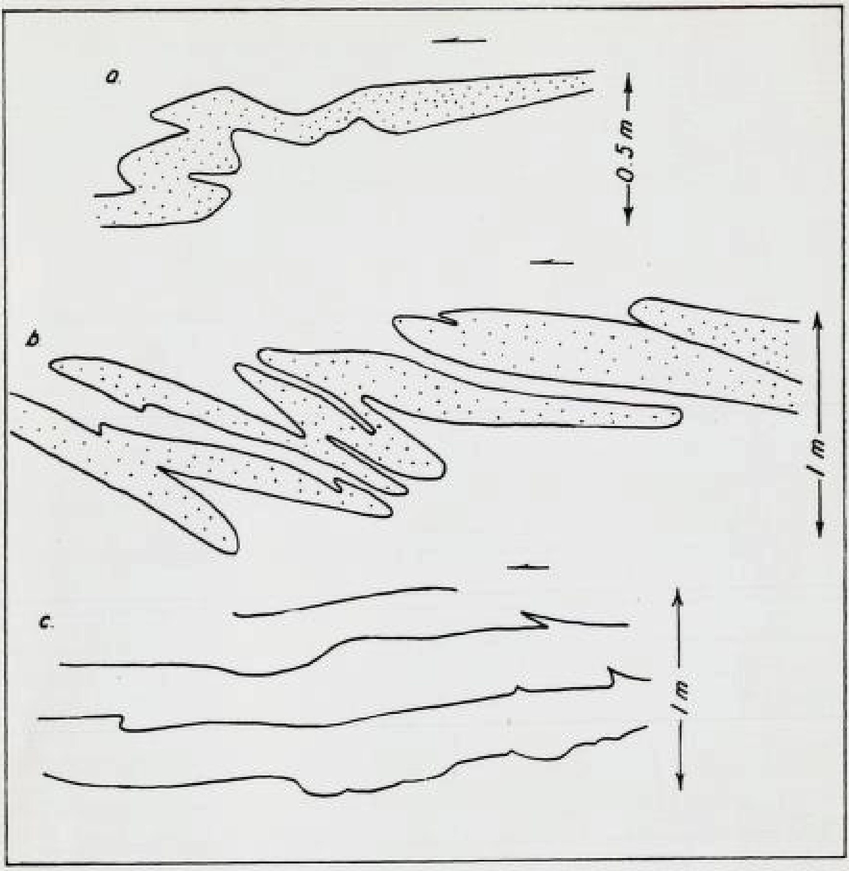

Fig. 30. Plastic folding of incompetent strata, Ankerlia Schist, Magervannelv.
Plastisk foldning av incompetente lag, Ankerlia Schist, Magervannelv.

on certain field observations, in fig. 31. Thus gently inclined monoclinal flexures (here leading to local reversal of the regional dip) face south and third-order overfolds are also found (fig. 32) as well as compressed folds with near-vertical limbs locally. At the other extreme occur beds crossed by inclined fractures (incipient shears) and weak, asymmetrical folds. Fold axes and lineation here trend ESE.

Attention may now be turned to the anomalous axial direction of the Moskogaissa anticline. Thus in the Moskogaissa region it

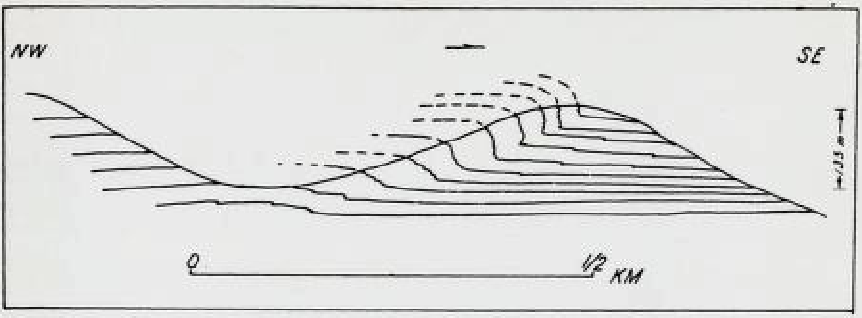

Fig. 31. Profile a little east of Sabetjok showing drag-folding in the Ankerlia Schist.
Profil litt sør for Sabetjok, viser drag-folding i Ankerlia Schist.

plunges westerly at 10° but curves into a northerly direction towards Cappis Javre. The plunge is locally reserved.

This trend is clearly anomalous with respect to the other major folds of the region and to the regional lineation. It is, however, concordant with the local lineation and fold axes both of the Ankerlia Schist and higher formations.

Furthermore the deepest drag folds known from the Banded Ankerlia Schist occur beneath the axis of the Moskogaissa anticline. It may be that the latter is an upwarping brought about as a consequence of the local development of these drag-folds.

It should be noted that all the folds described above show their maximum development along or near to Kåfjorddalen. This coincides with:

i. the axial part of the Kåfjorddalen syncline;
ii. a marked deflection in the regional lineation trend;
iii. the greatest known thickness of the Ankerlia Schist.

2. In the Quartzite Series.

The Quartzite Series occurs in two main outcrops, high up on each side of Kåfjorddalen (see map, pl. 1). These have been studied most fully on their southerly and easterly borders since exposures there are more accessible and continuous. Here tectonic disturbances were first noted and after further work were seen to fall into a broad but distinct zone in the Series.

Fig. 32. Drag-folds in the Ankerlia Schist, a little east of Sabetjok (movement from left to rigth).
«Drag-folds» i Ankerlia Schist, litt øst for Sabetjok.

Fig. 33. Overfold in the Quartzite Series, a little SSE of Isa Varre (movement from right to left). (F. M. Vokes photo.)
Overfolding i Quartzite Series, litt SSØ for Isa Varre. (F. M. Vokes foto.)

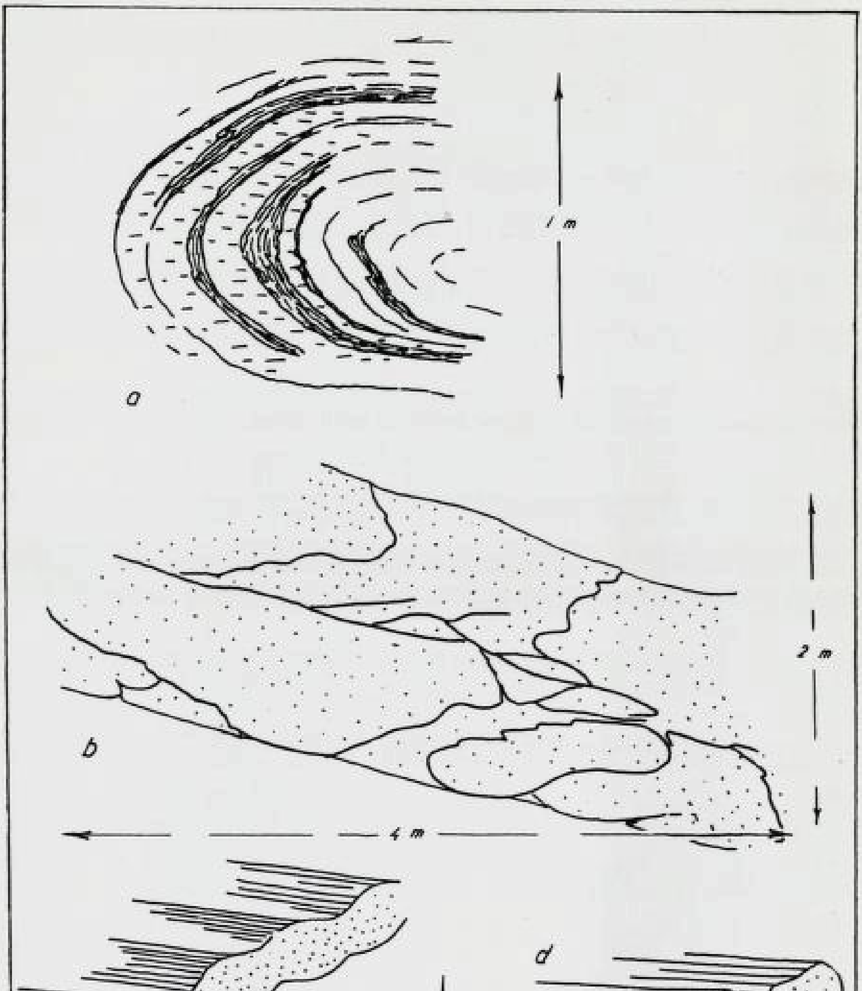

Fig. 34. Structures in the Quartzite Series, Isa Varre. a. overfold, mica flakes orientated parallel to axial plane; b. fracture system in a quartzite; c, d. boudined quartzite.

Strukturer i Quartzite Series, Isa Varre. a. overfold, glimmerskjell orientert parallelt med akseplanet; b. sprekkesystem i en kvartsitt; c, d. tektonisk, utklemte kvartsittlag.

In the ground south of Isa Varre a convenient upward passage through the zone can be studied. Its base occurs about 50 metres above the base of the Quartzite Series and is marked by flexuring and folding of restricted layers of the succession within undisturbed schists. In some cases overfolding occurs, locally towards the south-west (figs. 33—34). Such folding becomes more severe and frequent upwards with the frequent development of minor (third-order) folds on the fold limbs. They usually occur in more micaceous layers and have the style of drag-folds. Typical examples are shown in fig. 35. The thicker quartzitic layers develop a large number of fracture surfaces, frequently intersecting with each other but roughly parallel with the fold axes and with each other. They are conveniently displayed on vertical joint planes at right angles to the latter (fig. 34 b). Grooving and striation are invariably present on bedding surfaces to give a strong lineation which is aligned parallel with the fold axes.

The structures become weaker and less numerous upwards: fairly flat-lying schists form the higher parts of IsaVarre.

Rather similar structures are found a little to the east, along the edge of the steep valley of Kåfjorddalen. Here the base of the zone occurs a little lower in the Quartzite Series and the folds appear to be more compressed. Vertical beds are crossed for several metres and appear to represent close-packed, isoclinal folds, some of which are locally recumbent. At one place, the small detached core of such an overfold was seen. In general, however, it is impossible to see here the full amplitude of the folds and the style can only be guessed. Overfolding is locally directed to the south and south-south-east.

Transverse profiles across the more eastern outcrop, north-east of Kåfjorddalen in the Mainarasja region, show the 'zonal' character of the tectonism (fig. 36). Failure has taken place at certain horizons only. Intervening beds lie generally undisturbed. Overfolding to the east, with the shearing out of several of the fold limbs, is fairly common. Where the beds are more severely disturbed very complicated fold and shear structures are revealed by the study of quartzite/mica-schist contacts.

A further profile shows that tectonic complications become more severe locally to the west. Thus the prevailing westerly dip becomes reversed and a series of folds are developed overturned to the east.

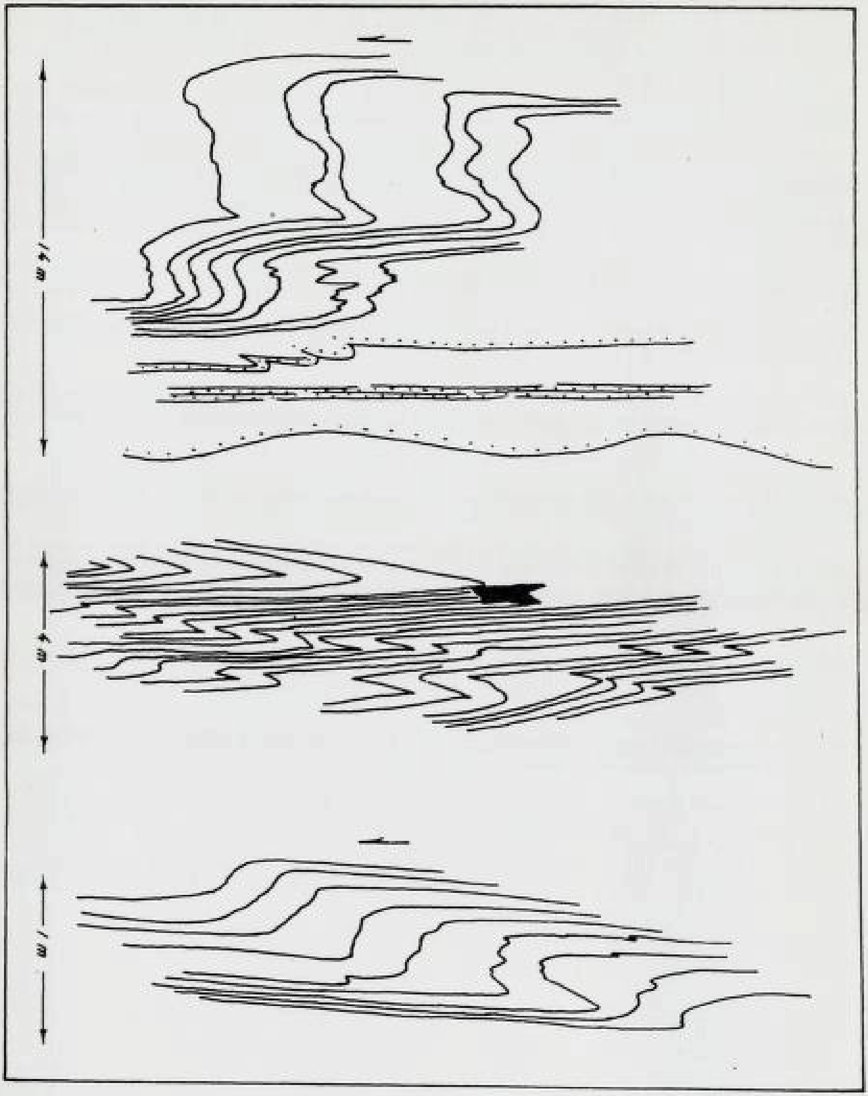

Fig. 35. Drag-folding in the Quartzite Series, Isa Varre.
«Drag-folding» i Quartzite Series, Isa Varre.

At one place their constituent layers are pinched, boudined and often disharmonically folded (fig. 37).

The area south of Mainarasja and particularly around Nassa Varre shows further features of interest. In the first place, the zone of disturbance now begins only a few metres above the base of the Quartzite Series and is quite severe. Thus some of the quartzites are broken by parallel joint planes inclined down to the north-west. Slight movements have taken place on some and accentuate the imbricate structure (fig. 38).

Highly characteristic for this aera also is the occurrence of a large number of elongated log-like rock units, arranged parallel to each other and having marked striation along their length. They appear to be fine examples of mullion structure recently described from Scotland (Wilson, 1953). The rocks concerned are usually the more micaceous quartz-schists which are here clearly thrown into closely packed folds and overfolds. Fractures parallel with the fold axes but oblique to the bedding have

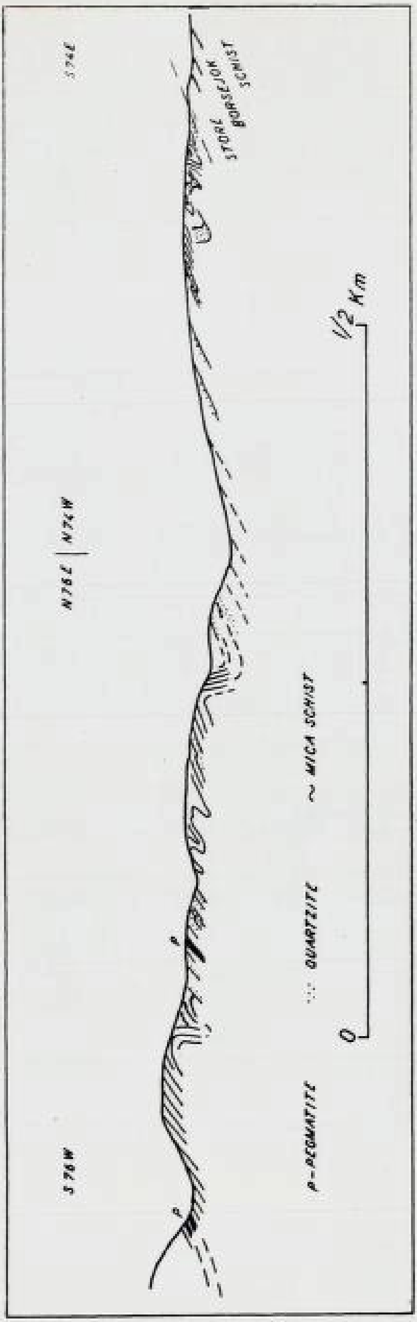

Fig. 36. Folding in the Quartzite Series, Mainarasja. *Foldning i Quartzite Series, Mainarasja.*

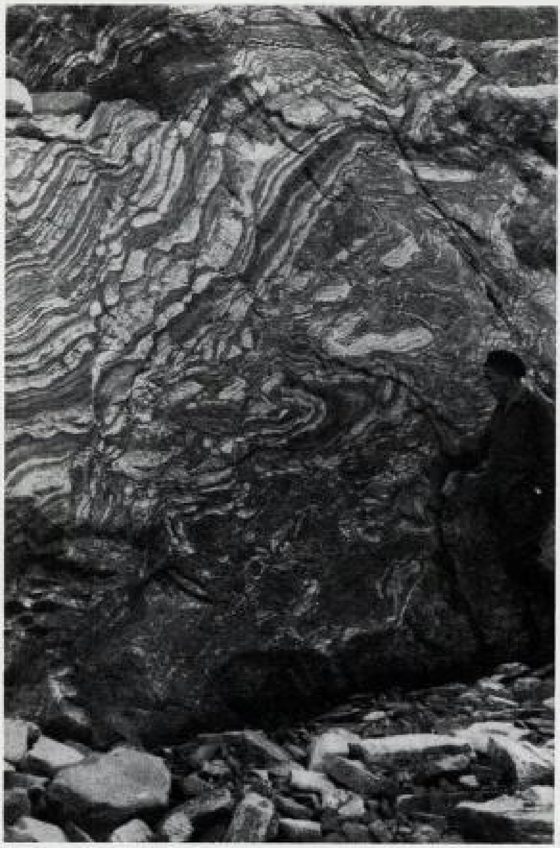

Fig. 37. Disharmonic folding, Quartzite Series, Mainarasja.
Uregelmessig foldning, Quartzite Series, Mainarasja.

apparently developed in the disturbed beds and the rock units have then rotated slightly under continuing tectonic pressure to give the log-like or mullion form (fig. 34 d).

These structures, the lineation along their length and the fold axes are clearly, therefore, homoaxial.

When sections and profiles of sufficient depth can be examined as on the steep mountain side a little east of Nassa Varre and overlooking Kåfjorddalen, a series of deeper folds can be discerned. At this particular locality, the situation is further complicated by a thickness of lime-schist with numerous mica-rich layers. It appears to belong stratigraphically to the basal part of the Quartzite Series. The mobility of the rock, however, is great under directed pressure and it has been thrown into spectacular folds (fig. 39) with accom-

Fig. 38. Imbricated quartzite, Quartzite Series, Nassa Varre.
Sprekkestruktur i kvartsitt, Quartzite Series, Nassa Varre.

panying shears. The quartzitic schists above are probably even more disturbed than usual by the extreme mobility of these lime-rich layers. Relationships are shown in fig. 40. A similar white-weathering rock on the opposite side of Kåfjorddalen appears to be folded also (when seen through binoculars), though less severely. It is generally inaccessible for direct observation but could well be the same lime-schist. The beds examined along the shoulder of the valley side, several metres above it, are much folded in a similar way to those on Nassa Varre.

Finally, it must be emphasized that the often severe deformations described above are reflected in the petropraphic character of the constituent minerals. Thus strain quartz and bent mica flakes are especially common along with recrystallization quartz-veins. Some quartzo-feldspathic replacement bodies also occur. The tendency for micas to aggregate into small ovoid dots or speckles provides an easily measurable linear element.

Folding therefore in the Quartzite Series occurs in a broad zone whose base is clearly somewhat oblique to the stratigraphy, being higher to the west on Isavarre and lower in the region of Nassa Varre.

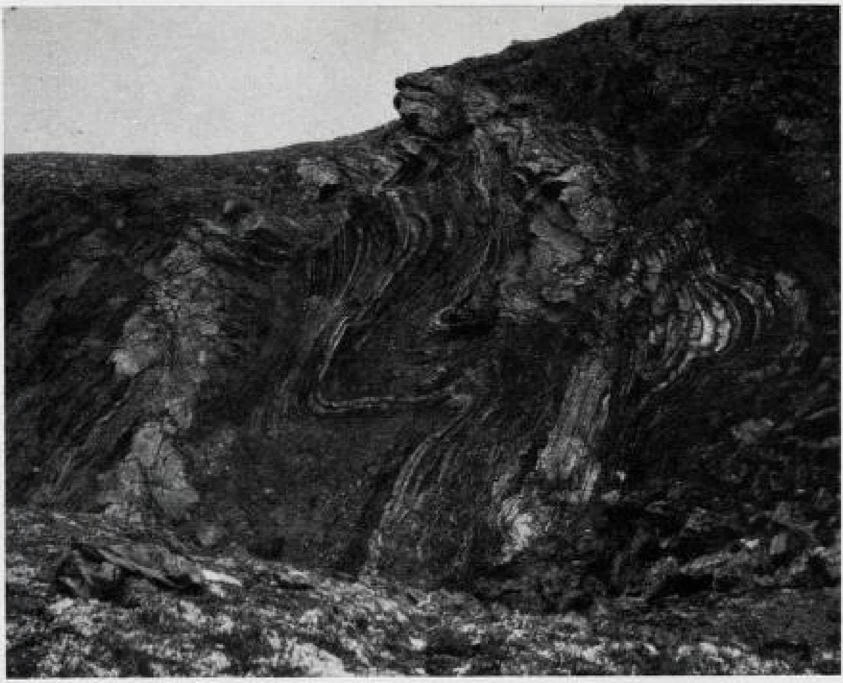

Fig. 39. Folding in the lime-schists of the Quartzite Series on the SW side of Nassa Varre.
Foldning i kalkskifer i Quartzite Series, Nassa Varre, på SV siden av Nassa Varre.

The folds and other linear elements within the zone describe an arc convex to the SSE (see map, pl. 1). Overfolding and thrusting occur at right angles to this arc and outwards from its centre.

To account for such a structure it is necessary to assume that movement was at a maximum down the 'axis' of the arcuation to the SSE but hindered along its flanks. Such may be due to the existence of two resistant areas. That to the south-east is the normal foreland block upon which the marginal Caledonides as a whole are riding: the other an area at depth to the south-west below the present day Olmaivoabmirasja and Nitsim Varre.

The style of so many of the folds, especially those in the more micaceous beds, strongly suggests that they are drag phenomena developed as a result of shear-couples put on the stratigraphic column. Since such folds occur at several distinct horizons, several planes of movement are necessary. These seem to fall into 2 main

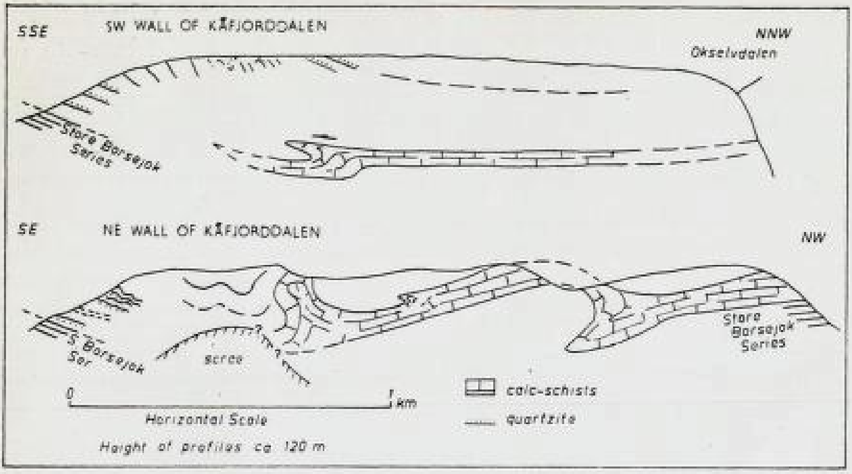

Fig. 40. Profiles along both sides of Kåfjorddalen showing folding of the lime-schist of the Quartzite Series.
Profiler langs begge sidene av Kåfjorddalen, viser foldningen av kalkskifrene i Quartzite Series.

groups, each of which is somewhat oblique to the stratigraphy (i. e. in the Ankerlia Schist and Quartzite Series).

Another pertinent feature is the coincidence between the presumed direction of movement which formed the structural arcuation and the axis of the Kåfjorddalen syncline. The calc-schist and lime-phyllite known from Nassa Varre and possibly occurring in the SW side of Kåfjorddalen, are also apparently limited to the axial part of the syncline.

Summary of structural data.

The folds and shear structures described above from the Ankerlia Schist and Quartzite Series have some features in common. Both appear to be drag phenomena, the result of shearing couples. The linear trends are concordant to each other though arcuation is more complete in the case of the Quartzite Series. Both appear to be explainable as a result of a greater amount of movement from the NNW down Kåfjorddalen between more resistant areas (at depth). The Moskogaissa anticlinal axis, which is concordant to these linear elements, is clearly the result of the same movement.

As suggested earlier (p. 88) its development may have been aided by the deeper drag-folds in the Banded Ankerlia Schist beneath its axial crest.

The differences in tectonic style shown by the drag-folds appear to be largely due to the varying rock types involved. No ore is known from the Quartzite Series but several small pockets occur in the Ankerlia Schist where they are closely connected to local folding, shearing and brecciation. Ore is absent from the Cappis thrust, a structure also due to movement to the SSE.

Attention is drawn to the stratigraphical anomalies along the length of the Kåfjorddalen syncline where certain formations such as the Ankerlia Schist are notably thicker and where the calc-schists in the Quartzite Series only occur.

Such features indicate that greater deposition was possible along the present axial part of the Kåfjorddalen syncline than to the east, south or west. Thus a local downwarp of basement rocks was in progress *during* sedimentary deposition giving rise to a tectonically negative area. This has been further emphasized by synclinal folding of the sediments at a later date to give the present Kåfjorddalen syncline. The latter has therefore a more ancient origin than would be appreciated at first sight.

Again, several of the stratigraphic formations (e. g. Ankerlia Schist, Brown Schist) are thinner in the Olmaivoabmirasja — Nitsim Varre area. This is thought to be a feature of original deposition controlled by the more rigid block, the area being a tectonically positive one during sedimentation. The fact that some formations appear to cross it uniformily (e. g. Nitsim Varre Series) shows that it was not at all times operative.

Regional considerations.

A glance at the structural map of the area shows the dominance of linear structures whose alignment is NNW—SSE. This includes the major folds as well as the regional lineation. A limited amount of movement at right angles has presumably taken place.

Now the long supposed direction of overthrust is also to the SSE and therefore parallel to the alignment. The present work seems to support this traditonal view though the exact way in which folds develop parallel to this direction cannot be conclusively demonstrated. Possible influence from structures in the basement cannot be overlooked. It is, however, a fact of observation in the present area that these folds have usually only gently dipping limbs and no large recumbents are known.

Again there is a fairly conclusive evidence from the drag-folding in the Ankerlia Schist and Quartzite Series that movement to the SSE has taken place. The trends of this folding are at all angles to the main direction of movement and are locally at right angles.

The megascopic linear structures on the mylonite of the 'Seve' thrust-plane, in the Hyolithus Shale immediately below and on the schists above are clearly homoaxial and would suggest that the movements in each were similarly uniform in direction.

Accepting, therefore, that movement has in fact been mainly to the SSE then the regional lineation is in *a* (with regard to this movement direction) and the associated joints are then in the *ac* and *bc* planes. Symmetrologically, however, the same lineation is in *b* and at right angles to the main trend of the Caledonides. Such a relationship is common experience in the geology of the Caledonides of Scandinavia, (e. g. Bygdin conglomerate, T. Strand 1944), especially where the rocks belong to a comparable geological milieu (i. e. marginal, overthrusted Caledonides). Systematic studies are however rare but a valuable summary of the known facts and their relevance in relation to direction of movement and transport have recently been given (Kvale, 1953). The present work supports accepted views of Scandinavian geologists on nearly all points.

Summary and conclusions.

A complete stratigraphic succession is established for the first time through the Caledonides of this little known part of northern Norway. The rocks are mainly layered schists in medium grades of metamorphism. They are believed to be largely of sedimentary origin but with some contemporaneous extrusives. Towards the base, quartzitic rocks, somewhat feldspar-bearing, are referred to as 'Sparagmitic Schists': more variegated beds above are collectively termed the 'Birtavarre Series'. Within the latter several formational units are distinguished and these show their greatest variety and thickness in and around Kåfjorddalen. The lower part of the Series is extensively granitized and this is believed to be the result of a metasomatic process involving enrichment in soda, potash and to some extent silica. Granite-gneiss, augen-gneiss and granite are locally developed. The upper surface of granitization is shown to be slightly discordant to the stratigraphy. Weaker and more localized granitization occurs at higher levels. In one case (Schists-with-thin-Limestones) it is clearly related to a thrust zone (The Cappis Thrust). Basic rocks are common at most levels — — — mainly as amphibolite but with some non-metamorphosed dolerite. Contact relations with the Haldit gabbro along its northern boundary show the schists to pass conformably beneath it. Isolated dolerite bodies a little to the north are possibly parts of a former 'feeder system' to the gabbro.

In the realm of structure, brief description is given of the all-important marginal overthrust in the Kilpisjärvi region which separates metamorphosed Caledonide schists (allochthonous) from Hyolithus Shale (autochthonous). The name 'Seve' is provisionally adopted. Regional lineation in the Caledonide schists is shown to trend mainly NW at right angles to the 'Seve' thrust front: important deflections in the Moskogaissa—Ankerlia region coincide with the occurrence of the main ore bodies. Several major folds, the deepest being the Kåfjorddalen synclinal, also trend NW. Joints both parallel and at right angles to these linear elements are also treated. Abundant quartz-veining (venite) is described from the Lower Ankerlia Schist and Store Borsejok Series. Also some small-scale thrusts. These and the more extensive Cappis Thrust are all thought to be the result of movements roughly parallel to the layering of the rocks. Likewise drag-fold phenomena in the Ankerlia Schist (ore-bearing formation) and the Quartzite Series. The relationship of the latter to deflections in the regional lineation is very close. Thus the arcuate arrangement of the fold-axes is interpreted as the result of movements from the NNW or NW with maximum translation down the length of Kåfjorddalen. Two rigid blocks at either side, one the foreland to the SE, the other at depth beneath Nitsim Varre and Olmaivoabmirasja, are postulated. The axis of arcuation coincides with the axis of the Kåfjorddalen syncline where lithological variations and thicknesses are greatest. It is suggested that the syncline has a more ancient origin than other NW trending fold axes being a tectonically negative area during sedimentation. The flanking rigid blocks were correspondingly tectonically positive.

Thus the inter-relationship of stratigraphy and structure is amply demonstrated, the former providing a convenient frame-work to which later metamorphism, granitization, intrusive activity and structural features can be related.

The *geological history* clearly begins with sedimentary deposition interrupted by volcanic phases. Some basic rocks were also intruded. The rocks as a whole belong to the Caledonian geosynclinal milieu and are most probably of Lower Palæozoic age though no fossils were found. A local down-flexuring of the basement (along Kåfjorddalen) possibly took place during sedimentation.

The next major phase is one of regional metamorphism. It was apparently closely followed or even accompanied in the later stages by metasomatism with the development of granitic rocks. During the same period tectonic movements of small magnitude and at different levels took place to the SE or SSE. In some cases granitization is localized along thrust-planes though often such relationships cannot always be seen. The last and major movement is represented by the 'Seve' thrust.

The rough parallelism of the planes of fracture and the zones of granitization with the regional layering of the rocks is a direct reflection of the overthrusting on to the autochthonous rocks of the foreland. In this sense the rocks belong to the marginal zone of the Caledonides.

A later phase of igneous intrusion is represented by the unmetamorphosed dolerite (Store Moskogaissa, 'Hornasch') and gabbro (Raisduoddar Haldde).

Acknowledgements.

It is great pleasure to be able to record my thanks to the many people who have helped and assisted in the progress of the work. Dr. T. Gjelsvik who acted as administrative leader and general councellor to the survey group, Frank M. Vokes who did much valuable work in the Cappis-Abnilasvagge region, (1953), Johannes A. Dons who made a preliminary map of the Guolas Javre—Skaide area (1952) and Fredrik Hagemann, field assistant to the author

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Sammendrag.

Birtavarre-områdets geologi.

I årene 1899—1919 var det en del mindre koppergruver i drift i Birtavarre-området, Kåfjord i Lyngen, Troms. De viktigste av gruvene var «Moskogaissa 115» sørøst for Kåfjorddalen, «Skaide»-gruven nordøst for Kåfjorddalen, og «Sabetjok»-gruven som ligger i den bratte skrenten øst for Kåfjorddalen. Gruvene ble drevet på forskjellige «malmlinser». Malmen består av magnetkis, kopperkis og en del sinkblende. Kopperet ble utvunnet ved smelteverket i Ankerlia i Kåfjorddalen.

Norges Geologiske Undersøkelse begynte sommeren 1952 en systematisk undersøkelse av Birtavarre-området. Hensikten var å undersøke de kjente malmforekomstene, samt å oppspore nye forekomster med henblikk på mulig gjenopptagelse av driften i området. Arbeidet inngikk som et ledd i en større plan for geologisk utforsking av Nord-Norge, med bakgrunn i regjeringens utbyggingsprogram for Nord-Norge.

Den første sommeren ble det utarbeidet et geologisk kart rundt det tidligere gruveområdet for om mulig å skaffe rede på form, utbredelse og forbindelse mellom de kjente malmkroppene. Neste sommer (1953) ble den geologiske kartlegging utvidet til å om-

fatte et større område, og dessuten ble det gjort spesielt detaljerte undersøkelser i nærheten av og i de tilgjengelige deler av gruvene. Samme år utførte Geofysisk Malmleting, Trondheim, elektromagnetiske undersøkelser på anmodning av NGU. Sommeren 1954 ble det gjort supplerende geologisk kartlegging, de elektromagnetiske undersøkelser ble fortsatt og diamantboringer ble satt i gang.

Det ble klart allerede under første års feltarbeid at malmforekomstene i området er begrenset til en bestemt bergartsformasjon (Ankerlia skifer) som derfor ble gjort til gjenstand for særlig inngående undersøkelser. Også mellom strukturene i berget og malmens opptreden er det et lovmessig forhold. Det er derfor lagt stor vekt på å få oppklart områdets stratigrafi (laginndelingen) og på undersøkelse av strukturene.

Foruten forfatteren har følgende deltatt i de geologiske undersøkelser av Birtavarre-området: Statsgeolog dr. T. Gjelsvik (leder), geolog F. M. Vokes og konservator J. A. Dons. I denne avhandling fremlegges resultatene av den geologiske kartleggingen. Malmene og deres opptreden vil bli behandlet i en senere publikasjon av F. M. Vokes.

Stratigrafi. Et oversiktskart over Birtavarre-området er gitt i pl. 1. Den geologiske kartleggingen har vist at det er flere atskilte bergartsavdelinger i Birtavarre-området. De fleste av bergartene var opprinnelig sedimenter (sand, leire, kalkslam osv.) som ble avsatt i hav i eokambrisk og kambro-silurisk tid. En del av lagene er av vulkansk opprinnelse. Under den kaledonske fjellkjededannelse ble bergartene presset, foldet, omkrystallisert og til dels skjøvet. De er derfor nå for det meste temmelig skifrige (glimmerskifer, grønnskifer, kalkskifer og kvartsitt). P. g. a. foldning og skyvning har lagene mer eller mindre skråstilling, fallet er for det meste moderat (under 35°). Formasjonene omkring gruveområdet i Birtavarre fortsetter mot nordøst over Reisadalen i retning av Vaddas-området. Mot sørvest er kartleggingen utstrakt til å omfatte Skibotndal.

Lagrekken i Birtavarre-området består av to store hovedledd, nemlig underst *sparagmittiske skifre* (i kartforklaringen pl. 1 betegnet som *Sparagmitic Schists)* og derover *Birtavarre-serien.* Hele dette kompleks er under fjellkjededannelsen blitt skjøvet mot sør. Ved Kilpisjärvi i Finnland kan man se at sparagmitten ligger med en oppknusingssone *(mylonite)* ovenpå kambrisk skifer *(Hyolithus Zone),* som igjen ligger på normal plass *(autochthonous)* på grunnfjellsgneis. *(Pre-Cambrian gneiss.)*

Birtavarre-serien er igjen inndelt i en rekke formasjoner etter bergartens karakter (de engelske navn i parentes er de samme som i tegnforklaringen til oversiktskartet pl. 1 og spesialkartet pl. 2):

Kvartsitt-serien	*(Quartzite Series)*
Store Borsejok-serien	*(Store Borsejok Series)*
Skifer med tynne kalklag	*(Schists-with-thin-limestones)*
Grønne lag	*(Green beds)*
Øvre brune skifer	*(Upper Brown Schist)*
Ankerlia skifer	*(Ankerlia Schist)*
Nedre brune skifer	*(Lower Brown Schist)*
Guolas kalkstein-serien	*(Guolas Limestone Series)*
Nitsim Varre-serien	*(Nitsim Varre Series)*
Store kalkstein-serien	*(Big Limestone Series)*
Skifergruppe, delvis gneis og øyegneis	*(Schists, gneiss, augen-gneiss).*

Lagrekken er gjengitt ovenfor i den rekkefølge formasjonene forekommer i naturen, med Kvartsitt-serien øverst og «Skifergruppe, delvis gneis og øyegneis» nederst.

En del av formasjonsnavnene sier uten videre hva hovedbergartene i formasjonene er (f. eks. «Store kalkstein-serien», «Guolas kalkstein-serien», «Skifer med tynne kalklag», «Kvartsitt-serien»). Av de øvrige formasjonene består «Nitsim Varre-serien» vesentlig av kvartsitt og mørk skifer, og «Store Borsejok-serien» av skifer. De «grønne lag» har utpreget grønn farge og er svært skifrige. De inneholder materiale av vulkansk opprinnelse.

Ankerlia skifer — den malmførende formasjon — er stort sett mørkegrå eller blågrå. Formasjonen har en midtre sone med hvite bånd. *(Banded Ankerlia Schist.)*

Noen av formasjonene, som f. eks. Guolas kalksteinen, har samme tykkelse og utseende i hele området, mens andre formasjoner som «Nedre brune skifer» og «Ankerlia skifer» har størst tykkelse langs Kåfjorddalen. De tynnes fort ut mot nordnordøst, sør og vest.

Opløsninger med kalium, natrium og kiselsyre har under fjellkjededannelsen enkelte steder omdannet skifrene slik at de har fått granittisk sammensetning (gneis og øyegneis) vesentlig i underste skifergruppe.

Andre bergartstyper. Birtavarre-seriens lagdelte bergarter er i mange tilfelle gjennomsatt av mørke, basiske bergarter (amfibolitt, doleritt, gabbro). En del av disse fremtrengte (eruptive) bergarter ligger som flate ganger eller linser mellom de sedimentære lagene. De har deltatt i omvandlingsprosessen som er knyttet til fjellkjededannelsen og må derfor ha trengt fram før foldningen var avsluttet. Andre av de eruptive bergartene ser ut til å være dannet senere. Eksempler på sistnevnte er gabbroen i Haldit og doleritten i Hornasch (se fig. 17, 18 og 19).

Struktur. Som nevnt under omtalen av lagrekken ble bergartene under fjellkjededannelsen utsatt for trykk slik at sparagmittskifrene og Birtavarre-serien ble skjøvet som en enhet i sørøstlig retning mot og delvis over de mer stabile grunnfjellsgneisene med overliggende kambrisk Hyolithus-skifer *('Seve' Thrust,* se pl. 1).

Undersøkelsene i Birtavarre har vist at det også har foregått en rekke forskjellige forskyvninger av mindre format innen lagrekken. Den mest fremtredende av disse skyvninger er den såkalte Cappis-overskyvningen *(Cappis Thrust,* se pl. 1). Ved denne overskyvning er Store Borsejok-serien og Kvartsitt-serien skjøvet fram over de underliggende formasjoner, særlig i den østlige delen av området. Mindre skyvninger, helt ned til rene detaljer i de enkelte lagene, er konstatert.

Trykket førte også til at bergartene ble foldet. Foldene kan ha en bredde på opptil flere km, f. eks. i Rasjanipa. De store foldenes akser *(major folds,* se pl. 1) stuper 5—15° mot NV eller NNV. Mindre folder *(minor folds,* se pl. 1) er også meget alminnelige, men aksene har skiftende retninger. Noen av foldningsaksene er parallelle med glidestriper *(lineation,* se pl. 1) på lagflatene til bergartene. Småfoldene er svært ofte skjeve, altså med en bratt og en flat side, og den øvre delen av folden kan være skjøvet litt henover den undre delen *(drag-folds).* Eksempler på dette er vist i fig. 26, 27, 28, 32, 35.

Malm-«platene» eller -«linsene» har stort sett sin lengde-akse parallelt med lineasjonsretningen. Hovedsakelig er denne SSØ—NNV, men ved Kåfjorddalen, hvor flere av de viktigste gruvene finnes (Moskogaissa, Skaide, Sabetjok), er lineasjonens (og malmlinsenes) strøkretning mer Ø—V.

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Explanation of the plates.

Forklaring til plansjene.

Pl. 1. Generalized geological map of the Birtavarre and neighbouring areas. The main structural features are shown in red and blue. Inset map shows location of the area surveyed (in black).

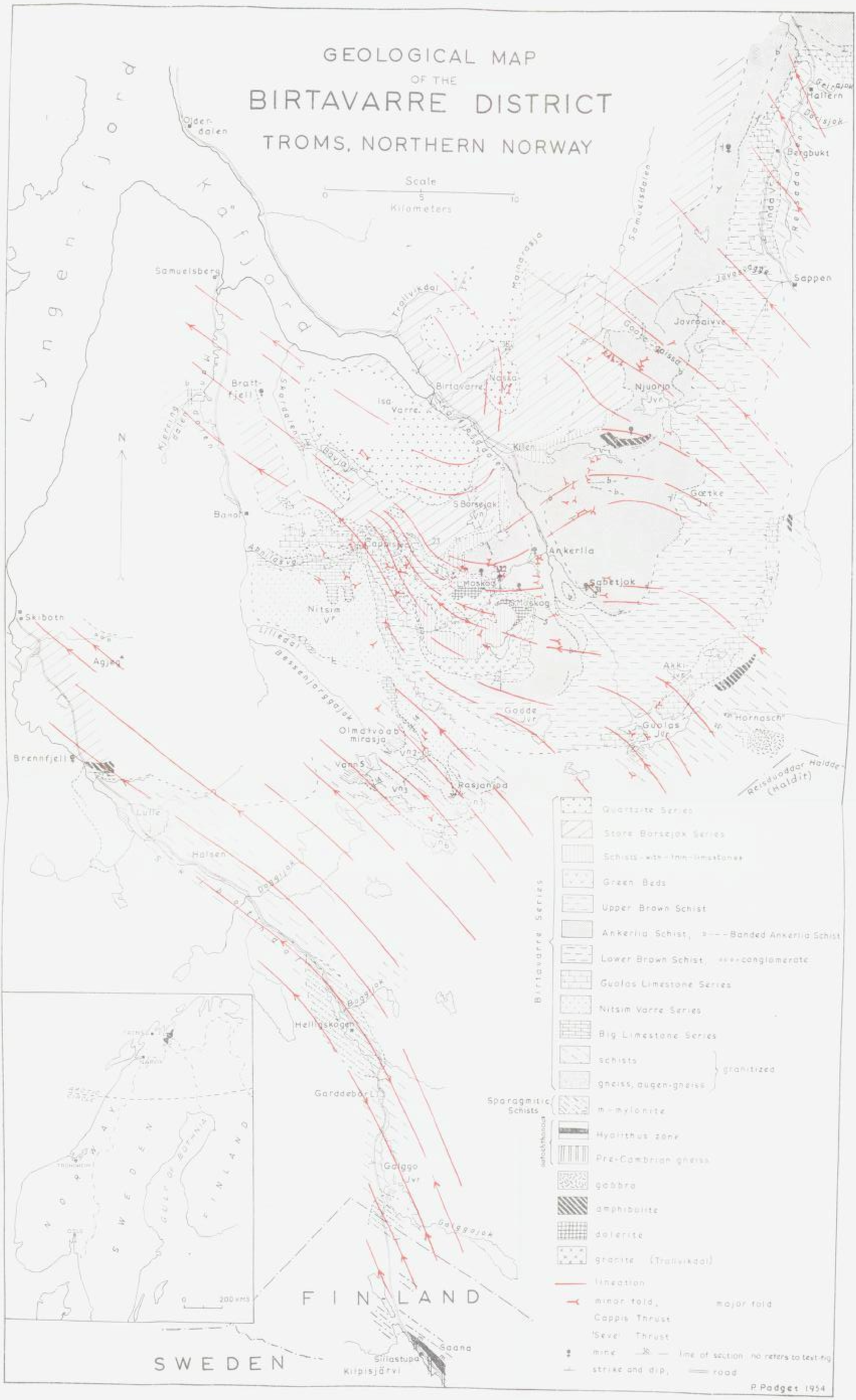
Geologisk oversiktskart over Birtavarre og omliggende områder. Hovedstrukturene er tegnet med rødt og blått. Nøkkelkartet viser beliggenheten av det undersøkte området (svart).

Pl. 2. Detailed geological map of Kåfjorddalen, Birtavarre.

Detaljert geologisk kart over Kåfjorddalen, Birtavarre.

Pl. 3. Profile through the Caledonides in Skibotndal. Profile B, and enlarged part of profile A, shows folding in granitized schists.

Profiler gjennom Kaledonidene i Skibotndal. Profil B, en forstørret del av profil A, viser foldning i granittiserte skifre.


GEOLOGICAL MAP
OF THE
BIRTAVARRE DISTRICT
TROMS, NORTHERN NORWAY
Scale
0
5
10
Kilometers
Lyngen fjord
Kåfjord
N
Olderdalen
Samuelsberg
Brattfjell
Kjerringdalen
Skardalen
Bavjak
Isa Varre
Birtavarre
Naska Vr
Kilen
Trollvikdal
Mainarasja
Samuelsdalen
Sappen
Bergbukt
Hallern
Reisadalen
Javreoaivve
Njuorjo Jvr
Gætke Jvr
S Borsejok
Ankerlia
Sabetjok
Moskog
Cappis
Appilasvg
Bahol
Skiboth
Agjek
Nitsim Vr
Lilledal
Bassenjarggajok
Godde Jvr
Guolas Jvr
Akki Jvr
"Hornasch"
Reisduoddar Halde (Haldit)
Olmatvoabmi mirasja
Vann 5
Vn 2
Vn 3
Rasjanjad
Brennfjell
Lulle
Holsen
Doggijok
Helligskogen
Garddebori
Gaiggo Jvr
Gaiggajok
Saana
Siilastupa
Kilpisjärvi
FINLAND
SWEDEN
NORWAY
SWEDEN
FINLAND
GULF OF BOTHNIA
TROMSØ
NARVIK
TRONDHEIM
OSLO
0
200 KMS
Birtavarre Series
Quartzite Series
Store Borsejok Series
Schists-with-thin-limestones
Green Beds
Upper Brown Schist
Ankerlia Schist, b---Banded Ankerlia Schist
Lower Brown Schist, ooo conglomerate
Guolas Limestone Series
Nitsim Varre Series
Big Limestone Series
schists
gneiss, augen-gneiss
granitized
Sparagmitic Schists
m-mylonite
autochthonous
Hyolithus zone
Pre-Cambrian gneiss
gabbro
amphibolite
dolerite
granite (Trollvikdal)
lineation
minor fold, major fold
Cappis Thrust
'Seve' Thrust
mine
line of section, no refers to text-fig
strike and dip,
road
P Padget 1954


NW
Aajeg
PROFILE A
congl
augen gneiss
Bridge
Lulle
Holsen
Doggi Jok
Ovre Vatn
Brennfjell
a
road
Store
Borsejok
Series
Brown Schist
Gualas Limestone
Granitised
Schists
0
2
a – amphibolite
N10W
S10E N20E
Garddebor Luobal
PROFILE B
a
a- amphibolite
0

Norges Geologiske Undersøkelse. Nr. 192 — 1955.


DETAILED GEOLOGICAL MAP
of the
KÅFJORDDALEN AREA
BIRTAVARRE
Quartzite Series
Store Borsejok Series
Schists with thin limestones
granitized schists
Green Beds
Upper Brown Schist
Ankerlia Schist
b---- Banded Ankerlia Schist
Lower Brown Schist
oooo conglomerate
Guolas Limestone Series
amphibolite, greenstone
Nitsim Varre Series
Big Limestone Series
schists
gneiss, augen-gneiss
granitized
gabbro
amphibolite
dolerite
B Borsejok
M Monte Carlo
BH Birtavarre Høyfjell
111
115
117
Moskogaissa
strike dip
road
Scale
0
Kilometers
5
N
Birtavarre
Nassa varre
Isa varre
Kåfjorddalen
Njuorjo jvr
Ovrovagge
Skaide
Kilen
Mattisaksla
Store Borsejok vann
Lille Borsejokvann
Ankerlia
Birtavarre
Rosejavre
Sabetjok
Guolle jok
Moskogaissa
Store Moskogaissa
Mager vann
Gælke javre
Akkijavre
Guolas javre
Godde javre
'Harnasch'
Olmaivoab mirasja
Vann 5
Vann 2-1
P Padget 1954