Description of the geological maps "Tromsø" and "Målselv", Troms

I. The Precambrian window of Mauken-Andsfjell.

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Contents

Abstract

This paper is the first part of a description of the bedrock on the two 1 : 100,000 map sheets, "Målselv" and "Tromsø". The geological map, "Målselv", accompanies the paper. This part deals with the "window" of Precambrian rocks exposed beneath the Caledonian nappes in Målselv, just N of latitude 69° N. The basement consists of mountainous areas that rise far above the surrounding Precambrian peneplane. These Precambrian rocks are composed of two main units, the Mauken amphibolite and the Andsfjellet granodiorite. The amphibolite is thought to be a meta-basalt. Chemical analyses indicate a "normal", relatively acid, basaltic composition. The analyses are compared to analyses of meta-basalts from other parts of the North Scandinavian Precam-

Fig. 1. Location of the area described (arrow).

brian. The granodiorite is believed to be a product of a Precambrian granitisation. Chemical analyses of the granodiorite are given. It is shown to have an intrusive contact against the amphibolite. The junction between these two Precambrian units and the overlying schists is a pronounced thrust plane, which is a part of the Caledonian "major thrust". The question whether these basement outcrops formed actual mountains as early as in the Precambrian, or whether they result from a Caledonian uplift is discussed, and the latter hypothesis is thought most likely.

Preface

The geological mapping of the "Tromsø" and "Målselv" sheets began as early as 1947, but because of other duties the ultimate working up of the field material has had to be put off until recently. The geological map of the "Målselv" sheet was printed in 1959, the "Tromsø" sheet is still in manuscript. The author has made various supplementary observations within the relevant areas since the completion of the actual mapping. Since the topographic base of the "Målselv" sheet was printed, several new roads have been built, and attention is drawn to them in the text where they affect the area now under consideration.

These two sheets, stretching from Tromsø in the N to Øverbygd, Målselvdalen, in the S, provide a profile across the Caledonian mountain chain at this latitude - from the highest nappes in the NW to the Precambrian basement in the SE, described in this paper. The relatively highly metamorphosed rocks making up the greater portion of the bedrock within these two sheets, are traditionally thought of as thrust nappes of Caledonian age. No fossils have been found within these maps.

Research in the area treated in this first paper has, prior to the present work, been confined to the mapping carried out by the geologist, Karl Pettersen, who was also attached to Tromsø Museum (Pettersen 1887). He mentions the granodiorite ("granite") of Andsfjell and Mauken, but not the amphibolite. He comments on the discordance between the granodiorite and the overlying schists, and concludes that, because of it, the lower rock is of Precambrian age. It is also designated such on his map of "Tromsø Amt" (Tromsø county) published in 1890, shortly after his death.

The An-content of the plagioclases has been determined by refractive index measurements. Extinction angles for hornblende have been calculated using the universal stage. In order to aid the localisation of place names on the map, an individual co-ordinate system (in blue) is superimposed. The co-ordinates are given in the text as, e.g. (8.3, 2.6).

The chemical analyses have been carried out by Statens Råstofflaboratorium (State Raw Materials Laboratory) and Norges Geologiske Undersøkelse (Norwegian Geological Survey). Norges Geologiske Undersøkelse and Norges almenvitenskapelige forskningsråd (Norwegian Scientific Research Council) have financed the research, and the last-named body has covered the cost of printing the map. The manuscript has been translated by my assistant, Richard E. Binns, B.Sc., who has also given valuable help and good advice during the preparation of the manuscript.

Introduction

The morphology of the S part of the "Målselv" sheet is dominated by the Mauken-Andsfjell ridge. The Målselv river is flanked in its middle stretch by Mauken, but further N has cut through the ridge to leave Andsfjellet as an isolated remnant to the NW. The ridge continues eastwards to Skjold, a few kilometres off the map.

The bedrock of the Mauken-Andsfjell ridge is the structurally lowest unit within the two map-sheets, "Målselv-Tromsø". A marked thrust plane everywhere forms the junction between this unit and the overlying rocks. The rock clearly represents autochthonous Precambrian, and the thrust plane is the Caledonian "major thrust" separating the Precambrian from the overlying allochthonous and par-autochthonous Caledonian metamorphics. This nappe outcrops on the highest summits of the Mauken ridge. The basement consists of an older amphibolitic complex, and a younger, chiefly granodioritic, unit. The central part of the basement has a common foliation which strikes NW-SE, with a very steep, frequently vertical, dip. The contact between the amphibolite and the granodiorite is conformable to this foliation so that the granodiorite flanks the amphibolite in the SW, generally with a very steep dip. The basement foliation differs from this only near the thrust plane where it bends to parallel the latter (see Figs. 9-12). Other rock types occur in the basement, but these are genetically related to the two main types. Thus, in the amphibolite are conformable sheets or sills of very fine grained quartz dioritic rocks. "Transition rocks" of dioritic composition - clearly granitisation products of the amphibolite - outcrop in the border zone between the amphibolite and the granodiorite, especially in Andsfjell and near the SE edge of the map. Finally, at the junction between the amphibolite and the overlying nappe is a layer of green schists, which may be interpreted either as a border facies of the amphibolite or as an autochthonous basal greywacke.

The amphibolite group

The Mauken amphibolite is a steeply dipping layer trending NW-SE. In its northermost part, near Moen, it is about 1200 m thick. Around Myrefjell, some kilometers further S, the thickness reaches some 3000 m. Whether the thickness is primary or due to tectonic effects, is not easy to determine. This

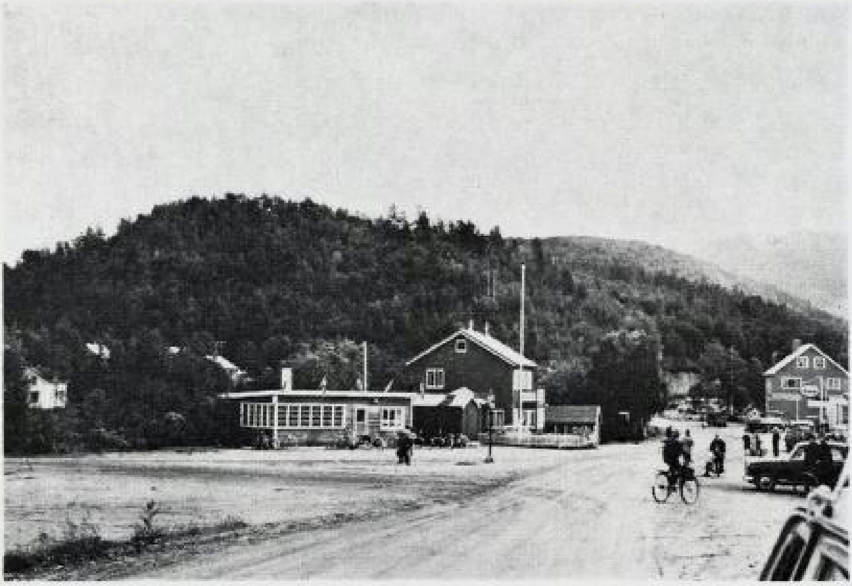

Fig. 2. Mauken seen from Olsborg (11.7, 8.6) towards SE.

matter will be discussed later. The unit has a uniform character, not varying particularly in composition or structure, either transversally, NE-SW, or longitudinally, NW-SE.

The amphibolite is very well exposed over the whole N part of Mauken. A particularly accessible profile is in the extreme N, eastwards from the bridge across Takelva, near Olsborg (11.5, 8.5) (Fig. 2). The amphibolite body shown on the map on Andsfjellet, consists, as we shall see, only to a lesser degree of amphibolite proper.

The foliation is primarily due to a parallel orientation of the hornblende (and biotite) crystals. Its strike is mostly 140 - 150°, but can range between 130 and 160°. This scatter is apparently due to local variations developed during the one deformation phase. Throughout the central area the foliation has a steep, often vertical, dip. Along the junction in the NE the amphibolite dips to NE. It dips to SW in the SW, near Maukdal (around 17, 2) in Målselvdalen, where it borders against the overlying schists and is not represented by the granodiorite.

The foliation also represents shear planes along which vertical movement has clearly taken place along the vertical lamination planes, not only during the recrystallisation phase of the hornblende and other minerals, but also continuing after that. Hence, the amphibolite minerals are frequently cataclastic. The shear planes are often coated with thin films of hydrothermally-formed quartz. Vertical shear planes are also frequently seen to trend in other directions - especially around 30°. Relatively minor slickensiding is occasionally developed.

Petrographically the amphibolite is rather heterogeneous. Thus, the amphibolite, itself, frequently has a streaky or banded structure. In addition, interlayered sheets, or sills, of quartz dioritic composition occur within the amphibolite. The quartz diorite bodies vary in thickness from about 20 cm to several metres. Such layers can, for example, be seen in the profile near Olsborg, or on the summit of Andsfjellet, as well as in the SE corner of the massif, outside the area covered by the map. The quartz diorite is a massive, grey rock with a very low content of mafic minerals. On weathered surfaces it appears very similar to the amphibolite, so that it is difficult to determine with accuracy the relative amounts of each. The quartz diorite, anyway, makes up a subordinate part. All the rocks of the amphibolite massif are completely recrystallized and highly cataclastic. The larger hornblende crystals are usually fractured, and often separated into isolated fragments. Feldspar and quartz often show mortar structure. Micro-shears are sometimes visible in thin sections.

The amphibolites are dark grey-green to nearly black. The dominant type is a homogeneous, massive rock, but it alternates with banded types. The banded amphibolites seem to occur subordinately in the massif, but the quantitative relationship between the two types is difficult to determine. Nor is it clear whether the banded types are fairly evenly distributed or mainly confined to certain zones. The homogeneous amphibolites frequently display only a weak NW-SE foliation parallel to the steeply dipping foliation of the massif as a whole, and show little tendency for splitting along that plane. The banded amphibolites are also massive rocks, without real schistosity, but with a greater tendency to split parallel to the banding. The banding results from an alternation of lighter grey, and darker layers. The individual bands have a breadth which varies from a few millimeters up to a couple of centimeters. The bands are often not very persistent, but wedge out, so that the structure becomes more streaky than banded (Fig. 3). In several places the amphibolites are cut by irregular networks of very fine quartz veins. The veins are usually only a few millimeters broad.

a

b

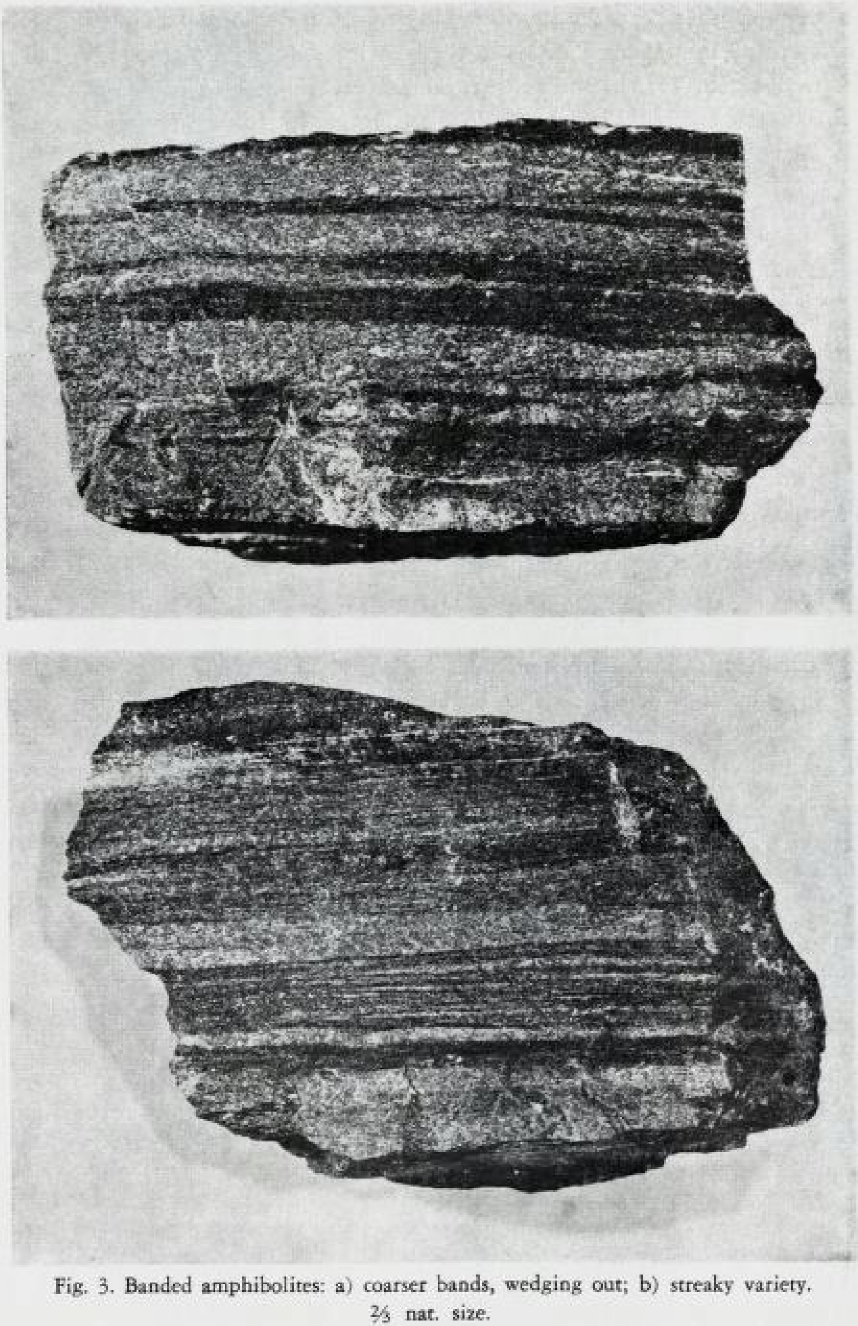

Fig. 3. Banded amphibolites: a) coarser bands, wedging out; b) streaky variety. ⅔ nat. size.

TABLE 1
Mineral assemblages of amphibolites from Mauken.

No.		Plag.	Hornbl.	γ/c	γ	Biot.	Musc.	Zois.
2287	Homogen. section	x	70-80 %	26°	1.670			
2248c	» »	x	40-50 »	28°	1.68			
2290	» »	x	30-50 »	24°	1.674			
617	» »	x	20-25 »	26°	—	20-25 %		
2288	» »	(x)				(x)	30 %	30 %
2261	Streaky section Dark band	x	70-80 »	25°	—	(x)		
	Light band	x	15 »	—	—			
2446b	» Dark band	x				50 %		
	Light band	x	20 »	26°	1.678			

On the basis of the mineral content of these rocks they can be divided into the following 4 types:

a) Amphibolites with hornblende as the sole dark mineral.
b) Amphibolites with hornblende and lesser amounts of biotite.
c) Bands with biotite, but without hornblende.
d) Bands with (clino-)zoisite, muscovite and biotite.

The pure amphibolite without biotite is the major variant. Table 1 summarizes the petrographic data on which this division is based.

These rocks contain phenocrysts of hornblende in an extremely fine grained groundmass of mainly light-coloured minerals. The hornblende forms relatively long-prismatic crystals, mostly 0.3 - 0.5 mm long, but occasionally up to 1 mm. The grain size of the groundmass is usually 0.02 - 0.04 mm. Where the hornblende content is especially large this mineral forms a more or less continuous mesh. The hornblende crystals are occasionally poikilitic and frequently have highly irregular outlines. Most of the hornblende individuals show sub-parallel orientation. Both the hornblende and the minerals of the groundmass display cataclastic effects. The crystals are often fractured, partly into separate pieces, and the quartz usually shows undulating extinction. (See Plate 7.)

The hornblende is an ordinary green hornblende, never actinolite. It is strongly pleochroitic, frequently in olive-green and pale yellow. Birefringence varies somewhat, between 0.020 and 0.025. The refractive index varies from 1.67 to 1.68. The extinction angle γ/c is high (25 - 28°). This is much higher than usually given for green hornblendes in metabasites from the mountain chain of N Norway (e.g. Vogt 1927, Bugge 1948, Vokes 1957). But Randall (1959) reports a similar value for hornblende in the Lyngen gabbro in Troms.

The biotite is brown and strongly pleochroitic. It occurs partly as independent flakes equal in size to the hornblende individuals, partly on the borders of the hornblende crystals where it is clearly recrystallized from that mineral. In the biotite-rich part of specimen 2446 b the biotite is less affected by cataclasis than are the other minerals.

The fine grained groundmass consists predominantly of feldspar and quartz. The feldspar is an acid plagioclase. Potash feldspar is not observed. The feldspar and quartz grains are of about equal size. Narrow twin lamellæ can be seen only in a few of the larger feldspars. The feldspar is often almost clear, and difficult then to distinguish from quartz, but it often contains small inclusions of sericite and rod-shaped zoisite. Large numbers of inclusions are never seen in the plagioclase. All the plagioclase seems to have the same degree of acidity, with an An content of 12 - 15 %.

Quartz occurs in all the specimens, though in varying amounts. The exact proportions of quartz and feldspar are difficult to determine, however. They seem to be about equal in specimen 2290, but otherwise quartz is considerably subordinate to feldspar. In specimen 2288, which chiefly consists of muscovite and zoisite, feldspar is insignificant in amount. The quartz almost always has undulating extinction.

Small grains of (clino-)zoisite and epidote occur in the groundmass of the majority of the specimens. In the zoisite-rich specimen, 2288, zoisite occurs as highly irregularly-shaped aggregates 0.3 - 1 mm in size. The zoisite gives anomalous, bluish, interference colours. The muscovite in this specimen consists chiefly of fine grained sericite (0.01 - 0.02 mm) in contact with the zoisite, but a few larger, scattered flakes are also seen.

Small amounts of sphene and iron-ore occur in all the specimens. A little apatite is found in specimen 617.

No pyroxene relicts have been observed, nor any alteration of hornblende to chlorite. The mineral combination muscovite-hornblende does not occur in any of the specimens. The small amounts of epidote and zoisite normally present, indicate that the original plagioclase has been calcium-poor.

According to the mineral assemblages outlined above the rocks in question must belong to the upper part of the epidote-amphibolite facies, in which a plagioclase with up to about 15 % An is stable.

TABLE 2

A comparison of the Mauken amphibolites with some other basaltic rocks

	Daly I	Mauken Amphibolites II	III	IV	Average V	Green sch. VI	Birtavarre VII	Finland VIII
SiO_2	48.8	50.0	49.0	49.4	49.3	48.8	48.5	49.4
TiO_2	2.2	1.8	1.2	1.8	1.6	1.2	1.2	1.7
Al_2O_3	14.0	14.2	14.4	13.3	14.0	14.6	17.3	14.1
Fe_2O_3	3.6	3.0	2.7	3.4	3.0	2.2	1.3	2.3
FeO	9.8	10.7	9.9	10.3	10.3	10.6	7.6	12.0
MnO	0.2	0.3	0.2	0.3	0.3	0.2	0.1	0.2
MgO	6.7	6.0	7.5	6.8	6.8	7.9	7.9	6.1
CaO	9.4	10.0	10.1	9.9	10.0	6.5	11.9	10.5
Na_2O	2.6	2.7	2.8	2.2	2.6	3.1	2.4	2.3
K_2O	0.7	0.4	0.2	0.3	0.3	0.2	0.3	0.6
H_2O	1.8	1.4	1.6	1.5	1.5	4.7	0.9	0.6
P_2O_5	0.3	0.1	0.1	0.2	0.1	0.1	0.3	tr.

I Daly 1933, p. 17, no. 60: Plateau Basalts, average of 43 analyses.
II Mauken, amphibolite no. 613.
III » » » 2447.
IV » » » 2287.
V Average of II, III, IV.
VI Mauken, green schist no. 850.
VII Birtavarre, Troms, metabasics, average of 5 analyses (Vokes 1957, p. 67).
VIII Sodankylä, Finland, amphibolite. (Mikkola 1941, p. 257).

The chemical composition of the amphibolite

Three chemical analyses of the "pure" (biotite-free) amphibolite have been carried out, and also one of the green schist which forms the junction zone between the amphibolite and the overlying meta-sedimentary schists. Chlorite is the chief mineral in the green schist, green hornblende only occurring as relicts. This rock will be treated in greater detail in another connestion (p. 197), so we shall only consider the three amphibolites here. Their analyses are given in Table 2 columns II, III and IV, the average of these being in column V.

There is a striking similarity between the three analyses. None of the components show any significant spread of values. These data should therefore provide a good foundation for a general consideration of the composition of the amphibolites.

The analyses fall well within the normal variation trend for gabbroid minor intrusives and extrusives. To aid comparison the table also contains "the average of 43 analyses of plateau basalts" given by Daly (1933, p. 17, no. 60). The similarity between this average analysis and the other three is quite striking. Only the potassium content differs noticeably, the Mauken analyses having 0.2 - 0.4 % K_2O against Daly's 0.7 %. The potassium content is, anyway, low compared with that normally given for basic magmatic rocks (e.g. Daly 1933, Johannsen 1932). (This is also a well-known feature of the *Caledonian* green schists of Norway.) The silica content of the new analyses is that of a basaltic magma of moderate acidity.

Without drawing any definite conclusions from the few analyses available, I will refer to some analyses from parts of the N Scandinavian Precambrian that are geographically close to the Mauken area.

From Vest-Finnmark, in Norway, all the analyses of "greenstones" (Holmsen, Padget and Pehkonen 1957) and of "diabase-like rocks" (Gjelsvik 1958) are too sodium-rich to bear comparison with the Mauken amphibolites. However, there are some analyses of non-spilitic meta-basites from Swedish and Finnish Lappland, that provide more suitable comparative material. Geijer (1931, p. 179, no. 1) gives an analysis of an "effusive diabase" from the Kiruna area. This contains the same amount of SiO_2 (49.1 %) as the Mauken specimens, but some more Al_2O_3 (15.7 %). None of the other components differs significantly from the Mauken amphibolites. The potassium values in several of Geijer's Precambrian meta-basites are rather low, similar in value to those of Mauken.

From Finland there is an analysis of an "amphibolite" from Sodankylä (Mikkola 1941, p. 257), which is the nearest of all in composition to the Mauken amphibolites. It is reproduced in Table 2. The only differences it shows from the amphibolites is in the F_2O_3/FeO relationship and in the somewhat higher potassium content.

Finally it should be mentioned that the *Caledonian* meta-basites from Birtavarre in Troms (Padget 1955, Vokes 1957) seem to differ markedly in chemical composition from the Precambrian amphibolites described above. Five analysed specimens from Birtavarre all contain significantly more aluminium and less iron. The average of these analyses is given in Table 2.

The quartz dioritic rock within the amphibolite

As described previously, this quartz diorite occurs as sheets or sills of light grey rock, concordantly interbedded here and there in the amphibolite. The rock is frequently translucent on fracture edges. It has no hornblende, and contains only small or completely insignificant amounts of biotite. Muscovite is absent. Plagioclase is the only feldspar (An 15-17 %). In the types poorest in biotite there is only a very faint foliation, but no schistosity.

Three specimens from different localities can be described in more detail.

Spec. 2503 a. From Andsfjell. Micro.: Plagioclase and quartz are the chief minerals, and have a fairly uniform grain size (0.05 - 0.07 mm). The quartz occurs as relatively equidimensional grains, without significantly undulating extinction. The feldspar forms the matrix between the quartz grains. Twin lamellæ are seldom. An = 15 %. Small slivers of dirty brown biotite and small lathes of zoisite, up to 0.02 mm long, occur in very insignificant amounts. The zoisite is always in the feldspar.

Spec. 2446 a. From Olsborg. Micro.: Mostly identical to the previous specimen. The quartz content is about 2/3 that of the plagioclase. The plagioclase is An 17 %.

Spec. 1674 a. From Skjold, about 2 km SE of the SE corner of the "Målselv" sheet. Micro.: The minerals are mostly the same as in the previous specimens, but a little coarser. Quartz and feldspar measure about 0.15 mm, and the biotite is also correspondingly larger. Frequent twin lamellæ are seen in the feldspar. An = 17 %. Small sphene crystals are scattered throughout the section. A few tiny grains of apatite and calcite are seen.

A chemical analysis of specimen 1674 a is given in Table 3 (p. 186). The norm of the analysis, with Q = 30.6, Or = 4.0, Ab = 51.5 and An = 10.0, can be assumed to correspond very well with the mode of the rock. Calculated from the normative amounts of Ab and An the plagioclase has a composition of $\frac{10.0 \times 100}{61.5} = 16.3$ % anorthite.

The composition of the rock corresponds very closely to some of Goldschmidt's trondhjemites (Goldschmidt 1916) from the Norwegian mountain chain. Strand (1958, p. 126) refers to sheets in the green schists of Helgeland, Nordland, which seem, from their mineral content, to have a similar composition, too.

The rock is especially characterized by its pronounced leucocratic composition and its very low potassium content. It may best be called a very acid (meta-) leucodacite.

The granodiorite

The granodiorite is exposed in several isolated areas, namely in Andsfjellet, along the W side of Mauken from Moen and southwards for about 12 km*), at Storhaug near the confluence of Målselva and Barduelva, and along the W

*) As a revision of the printed map, this outcrop is connected to the tiny one in the N, just E of Moen, by a narrow zone, and does not stop at Fredriksberg, as the map shows. In addition the structure symbol at (11 - 6) on Andsfjell should show a dip of 25° to SE and not to NW.

slope of Mauken near the S edge of the map. The rock is particularly easily studied in Andsfjellet, itself, and beside nearby Andsvatn. Andsfjellet is almost dome-shaped, with the granodiorite standing out in the central part surrounded by the overlying mica schists in the NW, SE and SW. Tectonic movements have, however, also given the junction of the granodiorite an exceptionally irregular form, with correspondingly irregular branches (see map). The exposures in the S along the Målselv valley have more regular shapes dominated by the NW-SE strike of the rock.

It is possible to distinguish the following variations in this unit:

1. Medium grained, massive rock, with only a weakly developed foliation.
2. Pegmatitic type.
3. Aplitic dykes.
4. Migmatitic-like variants.
5. Coarse grained breccia.
6. Foliated mylonitic gneiss.

The massive granodiorite, type 1, is the most extensive of these variants. It occurs primarily in the central part of the unit, inside the narrow border zone which abuts against the amphibolite and the overlying rocks.

Mineralogically there is very little difference between the various structural types. All contain, though in somewhat varying amounts, quartz, acid plagioclase and microcline as the chief minerals, and only small numbers of dark minerals. The massive granodiorite will be described first.

This rock is generally megascopically rather homogeneous. It has a medium grained, white to light grey groundmass of quartz and feldspar, which is interspersed with very irregularly shaped aggregates of dark minerals. These are often drawn out to lengths of ½ - 1 cm and are about 2 mm in breadth. They are arranged more or less parallel and give the rock a mottled appearance, or one which is more or less streaky according to how far the foliation is developed. The total content of the mafic minerals is always low, but varies somewhat. Subordinate variants that are almost lacking in dark minerals also occur. The foliation is only defined by the parallel orientation of the dark aggregates. In the parts lacking these dark minerals no foliation can be discerned. Whilst the overall impression obtained from a study of these types is of a greyish-looking granodiorite, the microcline is sometimes slightly pinkish so that the colour of the rock is influenced by that. Under the microscope (examples are from thin sections of specimens 546, 794, 795, 797, 798, 2262, 2466 and 2480) the quartz, microcline and plagioclase show a granoblastic texture (Plate II, a). The grain size of these minerals is rather similar, varying usually between about ½ and 1 mm. The quartz is completely clear and shows no undulating extinction. The microcline is also wholly clear and displays beautifully developed lamellæ. It usually contains no perthitic inclusions. The plagioclase often has an almost rectangular shape, and then always has its long axis perpendicular to 010. The shape of the microcline is more irregular. It surrounds or includes numerous grains of plagioclase. The plagioclase shows very well developed albite twins with relatively broad lamellæ. It usually contains some inclusions, frequently in insignificant numbers and rarely in considerable amount. The numbers of inclusions vary from specimen to specimen. Plagioclase grains that are almost completely free of inclusions are seen. The inclusions mostly are small flakes of sericite, but also very small, mostly rod-shaped, crystals occur which are clearly mainly zoisite. The anorthite content of the plagioclase is the same in all specimens examined, namely only 3 - 5 %. It is hence a rather acid albite.

The proportions of microcline and albite vary a good deal from one specimen to another (as the analyses also indicate), and are not easy to determine with any exactitude, even under the microscope, as the distribution within any one thin section is rather uneven. The main type, however, contains a good deal more albite than microcline, though specimens occur where the two feldspars are more or less equal in amount. Quartz and feldspar usually lack all evidence of cataclasis.

The dark minerals consist of irregular intergrowths of biotite, hornblende, epidote and iron ore. The strongly birefringent epidote is the most common. Afterwards comes biotite, as dirty greenish-yellow, strongly pleochroic flakes. The hornblende is also deep green and strongly pleochroic. It occurs least, and is an unstable mineral.

Two analyses of the rock, both from Andsfjell, are given in Table 3, p. 186. The analyses indicate granodioritic or granitic rocks with a high percentage of silica and a relatively low aluminium content. The calcium content is low. The sodium/potassium relationship is very different in the two specimens. Specimen 546, with a greater proportion of Na_2O than K_2O, corresponds best to the main variant of the rocks and according to Johannsen (1932) this ought to be defined as a sodaclase-granodiorite.

To try to compare the analyses with some from other Precambrian granodiorites and granites from nearby regions, we may look at Ödman's reference to "7 Karelian migmatite granites" from Norrbotten county, Sweden (Ödman 1957, p. 126). None of these are like the Andsfjell granodiorite. They all

TABLE 3

Analyses of quartz diorite rock and granodiorites from the Mauken area

	Quartz diorite No. 1674a. Wt. %	Quartz diorite No. 1674a. Cation %	Granodiorites No. 546 Wt. %	Granodiorites No. 546 Cation %	Granodiorites No. 795 Wt. %	Granodiorites No. 795 Cation %
SiO_2	72.85	67.7	75.85	71.6	76.23	71.9
TiO_2	0.46	0.3	0.24	0.2	0.08	0.1
Al_2O_3	14.40	15.8	11.23	12.5	12.91	14.3
Fe_2O_3	0.32	0.2	2.73	1.9	0.58	0.4
FeO	1.56	1.1	1.24	1.0	0.75	0.6
MnO	0.01		0.04		0.01	
MgO	0.55	0.8	0.20	0.3	0.13	0.2
CaO	2.71	2.7	1.03	1.0	0.55	0.6
Na_2O	5.68	10.3	4.80	8.8	3.30	6.0
K_2O	0.66	0.8	2.40	2.9	5.00	6.0
H_2O-	0.04		0.04		0.05	
H_2O+	0.17		0.24		0.45	
CO_2	0.18	0.3	—		—	
P_2O_5	0.10		0.03		0.02	
	99.69	100.0	100.07	100.2	100.06	100.1
Q		30.6		35.2		34.8
Or		4.0		13.5		30.0
Ab		51.5		44.0		30.0
An		10.0		2.5		3.0
Σ fem		3.9		4.8		2.2
		100.0		100.0		100.0

contain less SiO_2, and with one exception, more Al_2O_3, and all contain considerably more K_2O than Na_2O. There is an especially large discrepancy between the Andsfjell specimens and the two analyses from the Vassijaure granite from close to the Norwegian border near Torneträsk. However, Strand's (Foslie and Strand 1956, p. 72, no. 1) analysis of a Precambrian "granitic gneiss" from Børgefjell, Nordland, Norway, corresponds fairly closely with specimen 795.

Some of the variants of the granodiorite that differ structurally or texturally from the main type, may now be treated.

Pegmatitic bodies occur at several localities within the basement, though in insignificant amounts. They consist of irregular dykes or lenses. Both pegmatites with pale pink microcline as the dominant feldspar (e.g. no. 798 b. from

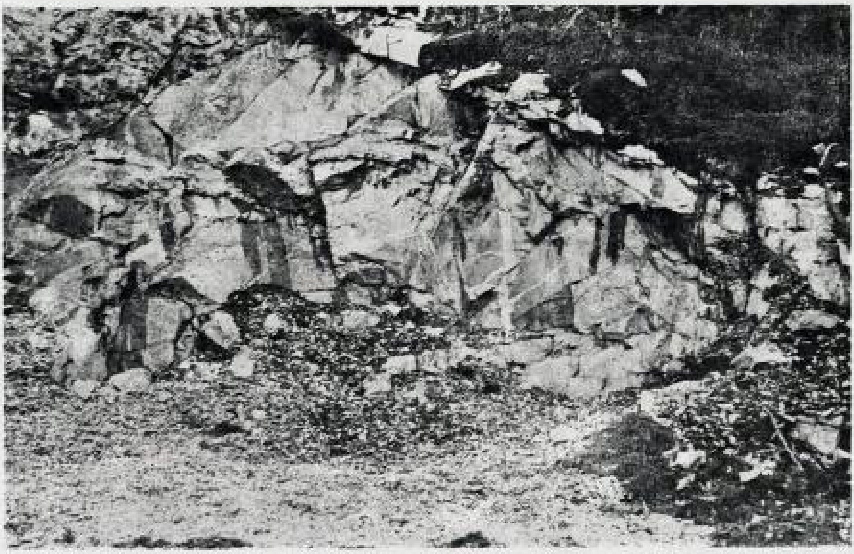

Fig. 4. Migmatitic structure within the granodiorite.

Andsvatn), and types with light grey albite as the main mineral (e.g. no. 2467 from the E side of Andsfjellet), occur. The feldspar crystals have dimensions of ½ - 2 cm. The albite, also in these, has only 3 - 5 % An. The mafic minerals again occur in extremely irregular "clumps", and only in very subordinate amounts. A pegmatite area of relatively large dimension is found on the E side of Andsfjellet. It forms a ridge-shaped area stretching from Bukteholmen (10.5, 8.5) more or less due W up the hillside. The pegmatite is a steeply dipping dyke-net with a strike parallel to the direction of the ridge. In these pegmatites are some beautiful quartz crystals up to several centimetres in size.

About due W of this pegmatite-net the map shows the granodiorite as having a worm-like branch within the otherwise overlying mica schists. This is a quartz segregation along a steep, brecciated fault line. This fault and the pegmatite ridge are probably tectonically associated.

Aplitic dykes, clearly cutting the granodiorite foliation, are found at several localities. Such dykes can, for example, be seen in the quarry near the bend of the main road WSW of the bridge over Målselva, near Buktemoen, Moen. They trend somewhat variously here, but generally with a 40° strike and about 60° dip to N. The dykes are often only about 10 - 20cm across, and are exposed for up to 20 m. The material is light grey to white, or light red, according to which type of feldspar dominates.

Fig. 5. Granodiorite intrusion in amphibolite (seen through water in the floor of a stream).

Migmatitic structures are seen in a few exposures. One is beside the road (13.5, 4.0) on the N side of Storhaugen (Fig. 4). Grey (black on the photograph) flake-shaped agmatitic inclusions are found in the granodioritic material here. These paleosome fragments have the same mineral content as the granodiorite, but have a larger proportion of biotite and hornblende, so that they achieve a definitely granodioritic composition. The agmatites are surrounded partly by light greyish granodioritic material, similar to the main type of the Andsfjell granodiorite, partly by irregular bodies of pegmatitic material, which are themselves cut by aplitic veins and dykes.

The clastic or mylonitic variants of the granodiorite will be described later.

The relationship between the amphibolite and the granodiorite

The contact between the amphibolite and the granodiorite can be observed at many localities. This junction has, in a descriptive sense, a distinct "intrusive" character, with the amphibolite as the older unit and the granodiorite as a younger mobile component. The contact zone, however, has a somewhat different development in the various exposures.

Fig. 5 shows a section of the contact zone in an exposure in a stream about 0.5 km SE of Fredriksberg (12.5, 6.0). Granodioritic dykes are seen cutting the amphibolite. Their dominant trend is nearly perpendicular to the

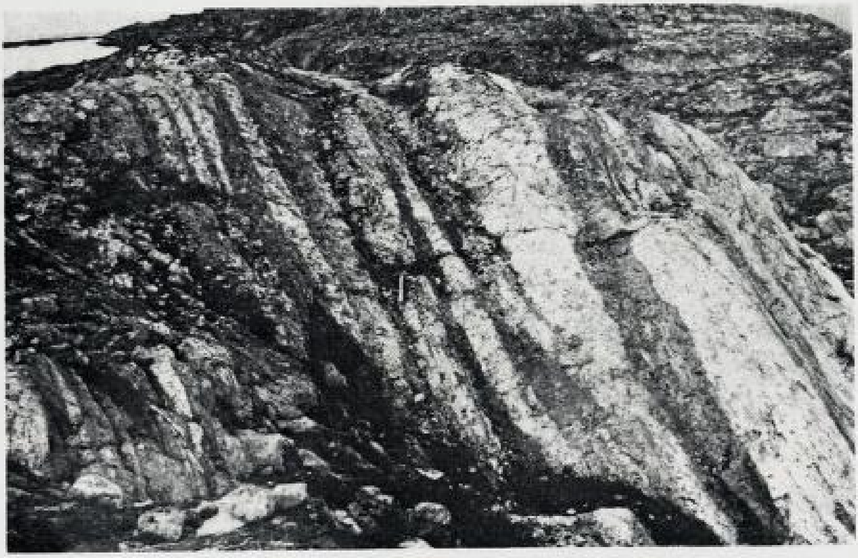

Fig. 6. Granodiorite intruding amphibolite, Andsfjell.

steep junction which itself trends NW-SE (the massive granodiorite, itself, is a few metres below the area shown in the photograph). Near the bottom of the photograph fragments of amphibolite can be seen in the granodioritic material. The surrounding fine grained amphibolite, here, displays no marked effects of metasomatism.

A characteristic granitization zone in the amphibolite is exposed over a large part of the summit plateau of Andsfjellet. The bedrock consists of a continuous layered alternation of the melanocratic host-rock and light granitic material. The layers have a regular strike of 155°, and a very steep dip. The thickness of both the melanocratic parts and the granitic horizons varies from about 10 cm up to several metres. The regular parallel structure can, at first glance, invite some uncertainty as to whether the process has been granitic intrusion of a basic rock, or the opposite. However, granitic apophyses can be observed crossing basic layers in several places, whilst the basic layers are never seen to cut granitic horizons. It can be observed, too, that the basic layers show a diffuse disintegration within the granitic material (Fig. 6, right-hand part).

The basic layers have been somewhat more deeply eroded than the granitic material has, and this tends to strengthen the false impression that there has been intrusion of basic material (Fig. 7).

Fig. 7. Dark bands of amphibolite in granodioritic material, Andsfjell.

The granitic material largely consists of white or pale pink aplite (e.g. specs. 2371 and 2504), but there is some coarser grained material, too. The quartz-diorite-aplite of the amphibolite occurs here, too, and can easily be mistaken for this, but it has a greyer, slightly glassy appearance.

The melanocratic layers are greyish rocks of dioritic appearance, and have only a faint foliation which parallels the strike of the layers. All the specimens are nearly equigranular, with the grain size varying in different layers from 1 - 2 mm and down to about 0.3 mm. Acid plagioclase is the main component, with varying amounts of hornblende and biotite as the dark minerals.

Microscopically, specimen 2503 from these beds, shows a pronounced granoblastic texture. About ⅔ of the thin section reveals plagioclase, with a grain size of around 0.3 mm and extremely irregular borders. It contains many inclusions, mostly of epidote and small muscovite flakes, but also of all the other minerals elsewhere in the thin section. Twin lamellæ cannot be seen, but cleavage cracks are visible in most grains. The refractive index, determined by immersion, indicates 5 % An, so it is a considerably more acid plagioclase than that of the amphibolites. Much quartz is present. Biotite is the major dark mineral, about 20 %, whilst hornblende is relatively rare. Both minerals are seen in thin section as sub-parallely orientated crystals, and are strongly pleochroic. The biotite is brown, with a slight greenish tinge which distinguishes it somewhat from the pure brown biotite of the amphibolites. The biotite and hornblende are often intergrown and the latter also occurs as inclusions in the former. The borders between the two minerals are often diffuse, and the hornblende gives the overall impression of being unstable. Scattered throughout the section are a few flakes of muscovite, up to 0.2 mm in size. Epidote occurs fairly commonly, and ore (magnetite?) in small amounts.

If we then pass on to the granodioritic area further up the Målselv valley, we find a type of granitization that has led chiefly to products with a somewhat different texture. This can easily be studied beside the main road, near Trongen (25.0, 0.5), and on the other side of the river, E of Alappmoen, or by the main road near Skjold, about 15 km further S along the valley (outside the area shown on the map). Coarse grained or pegmatitic intrusions of pinkish granite have, here, transformed the amphibolite to dark, granodioritic types in which the feldspar crystals are of considerably larger dimension than the other minerals, and often form definite porphyroblasts. This applies to the albite as well as the microcline. The microcline, especially, produces well-shaped rectangular cross sections, with dimensions up to ¾ x 1½ cm.

The granite intrusions E of Alappmoen, are primarily made up of sheets parallel to the steep foliation of the amphibolite. The sheets vary in thickness from about 20 cm to several metres. This metasomatically derived granodiorite forms a distinct zone some 10 m or more thick.

Three specimens from this area have been studied under the microscope: spec. 2450 from near the SE corner of the map, spec. 2449 b. from near Alappmoen, and spec. 541, from some kilometres E of the map. The samples are uniform with only slight variations in development. Acid plagioclase is always the chief mineral. Microcline occurs in varying amounts, which are difficult to determine exactly. The most microcline-rich sample is no. 541, in which this mineral seems to approach close to plagioclase in amount. The two other samples contain considerably less. Microcline forms definite phenocrysts only in the first of the specimens, otherwise the grain size of all the minerals varies between about 0.5 and 3 mm. The dark minerals vary between about 10 and about 25 % of the whole. Quartz is present in all the specimens. A few quite clear plagioclases with zonal structure are seen, the core having a somewhat higher extinction than the outer zone. In other cases the zoning is produced by a highly sericitic core surrounded by clearer material, or the sericite has developed along a definite zone with clearer plagioclase both in the core and in the outer zone. The refractive index, measured in comparison to quartz and canada balsam, indicates the plagioclase of the outer zones to be a rather pure albite.

Microcline occurs in various different habits. Plagioclase grains are seen in which the microcline occurs only as patchy antiperthitic inclusions. At other points the microcline forms bays in the plagioclase, and there are often only relicts left from the latter mineral. Furthermore, microcline phenocrysts containing inclusions of plagioclase (and of the dark minerals) are seen, though some microcline crystals show an almost complete lack of inclusions. Myrmekite is developed occasionally, but is not very typical.

The dark minerals of specimen 2450 consist of green hornblende and brownish-green biotite in more or less equal amounts. Both are strongly pleochroic and intergrown. Brownish speckled patches are often seen in the hornblende, clearly indicating an embryonic biotitization. No. 2449 b. has slivers of dirty brown biotite as the chief dark mineral. No hornblende is seen, but there is some epidote with a high interference colour. There are also a few allanite crystals, surrounded by borders of epidote. In No. 541 an iron-rich epidote forms about half of the dark minerals. There is also some dirty pale green hornblende with small inclusions of ore and epidote. Biotite is not present. The dark minerals are gathered into clumpy aggregates, like those in the "pure" granodiorite. Some sphene is seen in all the thin sections.

Whilst the contact between the amphibolite and the granodiorite is a very definite zone of granitization, it is also characterized by the tectonic tensions and movements that have taken place. The result of this shows itself to differing extent in different areas. On the summit plateau of Andsfjellet, with its characteristic "intrusive" structure, no conspicuous tectonization was observed. However, we are not at the actual contact of the granodiorite and the more easterly situated massive amphibolite of Mauken, as the amphibolite in Andsfjellet is an isolated patch "floating" in the granodiorite. At the eastern border of the Andsfjell massif, beside the main road to Finnsnes*), near Buktemoen (10.3, 8.8), a sharp contact between the Mauken amphibolite proper and the granodiorite can be observed. In the immediate few metres parallel to the contact, both the granodiorite and the amphibolite display a definite breccia structure, the rocks having been crushed somewhat, though no significant thrusting has taken place. The corresponding contact for the granodiorite of Mauken, SW of Myrefjell, has a decidedly tectonic character, even though the

*) A new road - not shown on the geological map.

intruded dykes (Fig. 5) show only slight signs of this. The contact is, here, accompanied by a zone where both the granodiorite and the amphibolite are brecciated. This zone has a width on the ground of some 10 m, through which the bedrock surface (mostly concealed) is often eroded into small elongated hollows. The contact has a marked brecciated character on either side of the river near Trongen and Alappmoen. Whilst the cataclastic textures connected with the Caledonian overthrusting follow the junction plane between the basement and the thrust cover, the breccia zone parallels the steep NW-SE foliation of the basement.

Concerning the time relationship between the brecciation and the granitization the following can be noted. As shown in Fig. 5, the granitic dykes reveal no sign of post-intrusive movements despite their location within that area of Mauken where the junction is so clearly tectonic. When we move further S, to the granitic dyke material in the Trongen/Alappmoen area, we see that this has a most distinct brecciose character (spec. 2449 a). On the other hand the tectonic effects are only weakly developed in the feldspathized types of this area, specs. 2450, 2449 b, and 541. Megascopically, these show no sign of brecciation, but the quartz is seen to have very marked undulating extinction, and mortar structure is developed at the borders of the feldspar crystals. On the whole, however, the newly formed phenocrysts of plagioclase and microcline show little evidence of crushing, though a few plagioclase grains have bent twin lamellae and some cracks, filled mostly with epidote. All this suggests that the granitization has continued after the major part of the brecciation took place.

The genesis of the granodiorite

Every aspect of the granodiorite and the granite make it natural to consider their formation by a process of granitization. It seems feasible, for all the areas described, to consider that the older, now granitized, rock, once consisted of parts of the neighbouring amphibolite. Paleosome relicts of obviously different rocks are not observed. It seems reasonable, furthermore, to attribute the granitization to a time after (or contemporaneous with) that when the amphibolite layers assumed their present vertical position. Such an interpretation finds support in the fact that the junction towards the amphibolite always runs parallel with the rather uniform NW-SE strike of the amphibolite, instead of having irregular bodies of massive granodiorite penetrating laterally into the amphibolite. The conditions along the junction can be attributed to a diapiric uplift of the granodiorite. The tendency to brecciation that can be observed along the junction zone can be attributed to such an uplift. This movement has affected the granodioritic rock along the contact, though the granitization has continued beyond the main period of uplift.

Granitic rocks also occur immediately beneath the post-Precambrian sediments in the nearby Dividalen district. It seems that this granite is somewhat different from the granites described here, though I can say nothing definite about this at present.

The relationships at the junction between the basement and the overlying metasediments

The contact between the granodiorite and the overlying metasediments

More or less metamorphosed sediments overlie the Mauken amphibolite complex and the Andsfjell granodiorite. These meta-sediments vary a good deal, including low metamorphic chlorite schists, muscovite-biotite schists, quartz-rich schists and quartzites. These will be dealt with in greater detail in a later paper - including a discussion on how far they represent par-autochthonous Cambrian, Eocambrian or Precambrian deposits or are parts of long-transported thrust nappes.

In the two nearby basement windows, at Bardu in the S and Dividalen in the SE, the relationships near the contact of the Precambrian gneisses are more simple than is the case here, as we there have relatively unmetamorphosed sediments - shales and sandstones - resting on the basement surfaces. In the Mauken-Andsfjell region all the immediately overlying sediments are more strongly tectonized and recrystallized.

In addition, the granodioritic and amphibolitic rocks which abut against the meta-sediments display special tectonic and metamorphic characteristics. The granodiorite is transformed into streaky and banded gneisses. Instead of amphibolites we get green schists in which hornblende is unstable and chlorite is the prevailing mineral. The junction, thus also symbolizes a sharp break in the metamorphic facies.

The following can be said regarding the structural relationships at the junction. Neglecting an area extremely close to the junction plane, there is a distinct angular disconformity between the foliation in the basement and that in the overlying schists. Whilst the former has a NW-SE strike with a steep dip, the schists have an E-W or WSW-ENE strike with a moderate northerly dip. The foliation in the schists coincides with the sedimentary layering. A special feature with this discordance is that the foliation of the schists also abuts against the *junction plane* at an acute angle. A schematic picture of this is shown in Fig. 8.

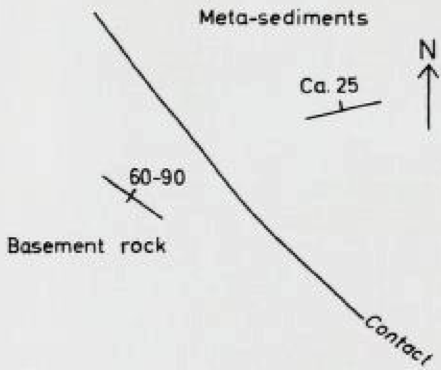

Fig. 8. Schematic sketch of relations at the junction between the basement and the overlying meta-sediments.

This feature is shown in a general way on the 1 : 100,000 map, in the divergent directions of the foliation in the Mauken amphibolite and the meta-sediments along the N side of Takelvdalen (around 15, 19.). In the immediate vicinity of the junction plane, however, the foliations of both the basement and of the schists are parallel to the plane. These relationships will be further explained by reference to some more detailed observations.

The contact between the granodiorite and the overlying meta-sediments

The junction is exposed in a road cutting by the N side of Andsvatn, about midway along the lake (5.5, 4.3). The plane of contact here trends northwards at about 160° with about 40° W dip. Within the immediate 5 m or so of the contact the foliation of both the biotite schists and the granodiorite is in full conformity with the junction plane. West of the contact the mica schist gradually modifies its trend across about 50 m, until it has a stable strike of about 20°, with a dip of about 25° towards the NW. In this transition belt the schist has many small folds with nearly horizontal axes trending at 160°. Eastwards from the contact the trend of the granodiorite foliation changes gradually through some 10 m to a strike of 170°, and a dip of 70° W. The sketch map and profile in Fig. 9 shows this. The granodiorite near the junction is strongly foliated.

The junction near the eastern outlet of Andsvatn (7.0, 4.1) is seen in the road cutting, here, in a 10-15 m high exposure of granodiorite overlain by a couple of metres of biotite schist (Fig. 10).

No discordance can be observed at this point because the exposure only embraces the concordant beds in the vicinity of the contact. The junction plane, near the top of the cutting, has a moderate dip. The granodiorite exposed here reveals a very fine picture of the tectonization suffered by this rock near the contact. Here, the granodiorite as a whole has a banded character conformable to the junction plane, but from the bottom of this gneiss layer to the top, adjacent to the schist, several textural variants reveal the gradual evolution of the mylonitization of the rock. At the foot of the exposure is a type of

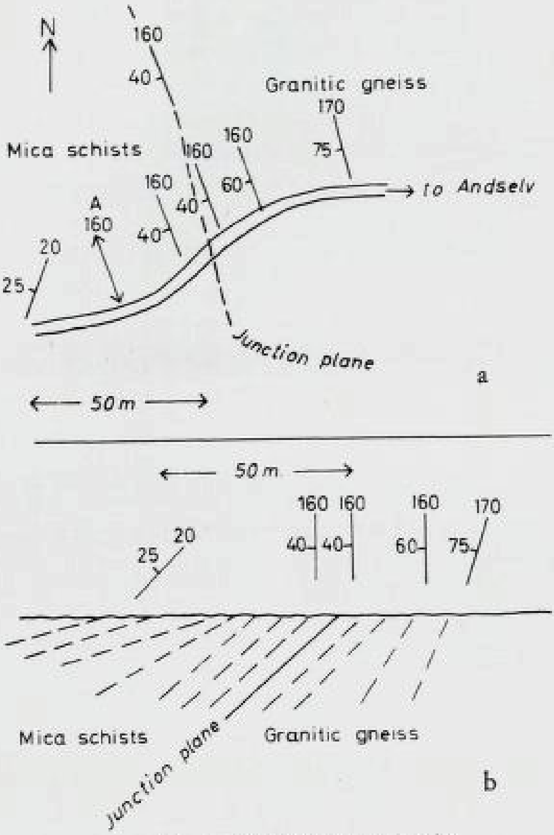

Fig. 9. Plan a) and profile b) of the contact near Andsvatn.

granodiorite not differing particularly from the massive types described previously, in which the dark minerals produce a foliation whilst no real cataclasis is developed. Above this is a distinctly cataclastic, foliated rock, in the lower part with a coarse streaky texture in which the foliation is picked out by mica-covered shear planes that do not occur more tightly than to produce a brecciose texture in the rock. Higher up, the shear planes are closer together and become more parallel to each other. The rock splits easily along these planes. At the top is a megascopically homogeneous, fine grained, light grey, strongly foliated gneiss. Under the microscope this is seen to have the mineral assemblage of the massive granodiorites. Acid plagioclase is the dominant feldspar, with microcline less common, and only very small amounts of dark minerals. The minerals show a very well defined mortar structure. The feldspars, with a grain size of 0.2 - 0.5 mm, are scattered in a fine grained groundmass. The vast majority of these phenocrysts display cataclastic effects. They are broken up, often into separate pieces, and the twin lamellae are often bent (Pl. II b). The biotite schist overlying the gneiss is a highly crushed, compact rock, rich in quartz lenses (specs. 547, 812 and 2263).

Storhaug, near the confluence of Målselva and Barduelva (13.5, 3.5), is an isolated hill, with a smooth slope in the S, but ending towards the N in a steep, terraced cliff going down to the drift covered valley floor about 200 m below. The junction plane lies in a nearly horizontal position in the summit of this hill. Immediately above the plane is a dark, heavily tectonized phyllitic

Fig. 10. Mylonitic gneiss and overlying mica schists near Andsvatn.

schist, cut throughout by numerous glide planes and crumbling easily when hammered. Below this are horizontal layers of mylonitized granodioritic gneisses identical with those at the last locality described. At the foot of the cliff is the exposure of migmatitic granodiorite mentioned earlier (p. 188), apparently showing no trace of the thrusting movements near the summit.

The contact between the amphibolite and the overlying meta-sediments - and their relationships to the green schist

Between the amphibolite complex, as we have termed it previously, and the overlying meta-sediments, we find some specially characteristic features along the border in the NE from Olsborg up through Takelvdalen.

In this stretch a rather extensive belt of green schists forms the junction zone for the amphibolite. Their thickness is only some few metres, but because of the coincidence of the topographical surface and their layering they have a relatively large outcrop. Chlorite is the chief mineral and green hornblende is unstable or is completely destroyed. Selvages of greenish biotite can be seen intergrown with the chlorite in a few specimens. Albite is rather common, and epidotic minerals are ubiquitous. All samples, too, contain significant amounts of sphene, and some ore occurs in a few. Above this schist is a thickness of a few metres of a quartz-bearing, chloritic biotite schist which goes over to a quartz-rich schist, which after a few metres is replaced by a purely quartzitic rock. The lowermost meta-sedimentary layers do not differ greatly in composition from the hornblende-free green schists, and as the colour of the biotite is fairly similar to that of the chlorite and hornblende it is very easy to confuse these green rocks in the field.

We shall consider this feature in more detail at an exposure of the junction that is relatively well suited for that study. This is beside Takelva, about 3 km above Olsborg (13.5, 8.0). There is quite a good exposure beside, and in the river. Along the short NW-SE trending stretch of river the junction zone is crossed over about 15 m. SW of here the amphibolite has a strike of 130 - 140° and a dip to NE of 60 - 70°. To the NE of the junction the quartz schists outcrop with a strike of about 80° and a dip of 25° to N, which is a constant attitude for the Takelva meta-sediments as a whole.

It should be mentioned here that immediately W of this locality there is a strip of limestone within the pure (chlorite-free) amphibolite. Beside the river this layer is only a few metres thick and it wedges out and disappears towards the SE, just beyond the S bank of the river. The limestone is distorted, partly by boudinage, and it must be assumed to represent a tectonic inclusion of a limestone that occurs somewhat higher up in the sedimentary succession.

The circumstances beside the junction are shown in the sketch (Fig. 11). Furthest to the S is a relatively massive, only slightly schistose "greenstone" which reveals under the microscope a tightly intertwined assemblage of green hornblende and green chlorite (spec. 2292). The hornblende is the remains of crystals of 0.2 - 0.3 mm, which are now in process of disintegration and chloritization. The hornblende has a somewhat lighter colour than is normal in the chlorite-free amphibolites. The chlorite is quite deep green, and strongly pleochroic. It has brownish-violet, anomalous interference colours. The crystals often form rosette-shaped aggregates. Feldspar and quartz form an extremely fine grained groundmass of crystals of 0.02 mm size, all of which show strongly undulating extinction.

About 5 m NE of this sample (i.e. 3 m higher in the profile) the green schist has a strike of 100° with a dip of about 50° to N (spec. 2293). This sample contains the same assemblage as the previous one. A few plagioclase

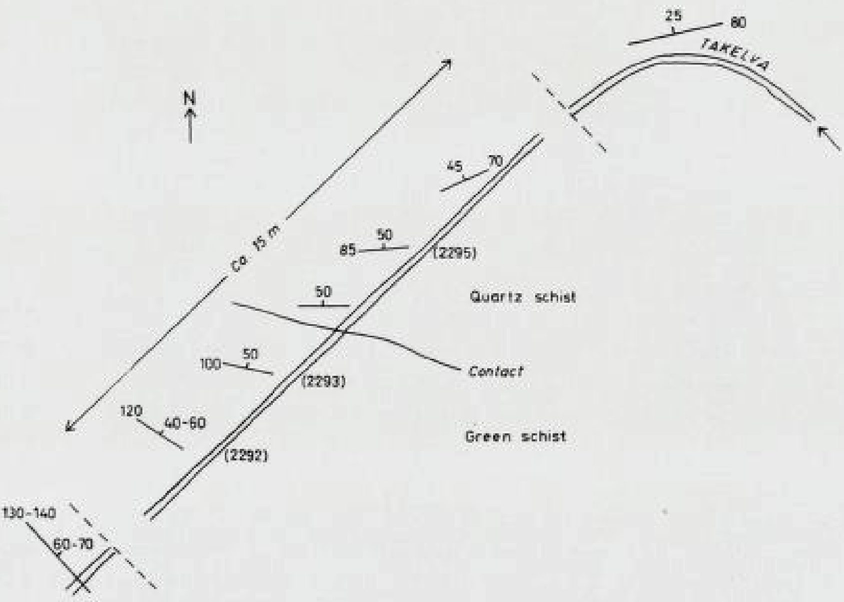

Fig. 11. Plan of the contact at the river, Takelv.

grains of dimensions 0.2 - 0.3 mm are preserved among the fine-grained groundmass, though frequently in a very fractured state.

A couple of metres above this specimen is a small exposure in the river, consisting of a platy, chlorite-bearing schist, which crumbles very easily and it was impossible to obtain a specimen of it. This strikes at 90°, with a dip of about 50° N. The schist resembles the next specimen rather than the one described earlier.

About 2 m above is a greyish biotite schist with a strike of 85 - 90° and a dip of about 60° to N (spec. 2295). This schist has a brownish-green biotite as the chief dark mineral. Intergrown with this biotite, but in much inferior amounts, is a green chlorite similar in appearance to that in the previous specimens. Hornblende is not found. The schist contains considerably more quartz than the previous specimens. Plagioclase is present in considerable quantity, chiefly a crystals of dimensions 0.2 - 0.5 mm. These crystals are often very cataclastic. A few calcite aggregates occur. There is a little ore, but sphene is only present in insignificant amounts. Higher up in the profile this schist clearly goes over gradually, through a few metres, to a feldspathic quartzite, which I named the "lower quartzite zone" on the geological map. Whilst specimen 2293 belongs to the amphibolite complex, specimen 2295, about 4 m higher in the profile, without any doubt belongs to the overlying meta-sediments.

I shall also refer to a couple of other specimens from the green schist of Takelvdalen.

No. 850 is an excellently foliated, phyllonitic schist, chiefly of fine grain (0.05 mm), but with a few larger relict feldspar crystals (0.2 - 0.3 mm). Over half of the thin section is taken up by a light green mesh, mostly of chlorite, but with some (10 - 15 %?) slivers of hornblende. The hornblende has the same pale colour as the chlorite and therefore is not easily distinguishable from it until they are seen under crossed nicols.

No. 623 reveals, under the microscope, highly elongated foliated aggregates of biotite and chlorite. The biotite shows a brownish-green colour parallel to its base, the chlorite is pale grass green. Some rod-like hornblendes occur. In cross section these prove to lie parallel to the micas. Some calcite is seen in the thin section.

No. 614 is also a platy, fine grained green schist. Sphene crystals are for the most part arranged in "stringy" parallel rows about 0.3 - 0.6 mm apart. Green chlorite, as in the previous specimen, occurs in intergrown habit with slivers of brownish-green biotite, and makes up a continuous mesh in the thin section. Hornblende does not seem to be present. One or two grains of calcite are seen.

Some more data on the minerals from these schists may be added.

Plagioclase in specimens 850 and 614 gave, by the immersion method, an anorthite content of 5 % or less. The anorthite content is thus considerably lower than that in the feldspar of the amphibolite which had 12 - 15 % An. The plagioclase in the schists (2295) also has an anorthite content of less than 5 %.

The hornblende rods of specimen 623 gave the following data $\gamma \sim 1.67$ and $\gamma/c = 22 - 23°. \gamma - \alpha = 0.02 - 0.025$. It is highly pleochroic. Despite it shape it therefore proves to be a green hornblende and not actinolite.

The refractive index of the chlorite was determined in the green schists (specimens 614, 623 and 850) to 1.625, in specimen 2292 to 1.63. The chlorite is distinctly birefringent, but the optical characters are difficult to determine in the very small flakes. The refractive index places it midway between iron-free and iron-bearing chlorite components.

Concerning the biotite that occurs in the green schists and in the overlying schist (spec. 2295) it may be said that the brownish-green colour distinguishes it from the pure brown biotite which, among elsewhere, occurs in the amphibolite.

However, there is no significant difference in the refractive indexes of the two types of biotite. Both the greenish biotite (spec. 2295) and the brown biotite in the amphibolite specimen 2446b (p. 179) have $\gamma \sim 1.64$.

The meta-sediments (2295) immediately overlying the green schists in this profile, contain significant amounts of albite, as well as biotite and chlorite, of the same types as in the green schists. The quartzites of the "lower quartzite zone", which follow, are also frequently feldspathic and in my opinion represent original arkosic rocks. It is natural to assume that specimen 2295 represents a basal greywacke overlying the amphibolite. This will best explain its transitional character between the green schists and the overlying meta-sediments. It may be thought, too, that the green schists, proper, contain some very little altered debris from the amphibolite surface, but, otherwise it seems very feasible to assume that the green schists represent a part of the amphibolite that has been made schistose by Caledonian tectonism. A chemical analysis of one of the green schists, specimen 850, is given in Table 2, p. 181, no. VI. Its composition differs very little from that of the massive amphibolite, though the content of Al_2O_3 proves to be somewhat higher than in the latter, and K_2O somewhat lower. It is significant that the calcium content is considerably lower, but otherwise the differences from the amphibolites are so small that the analysis indicates that no weathering of the amphibolite has taken place - as would be expected if it referred to a clastic sediment. On the contrary, the analysis supports the theory that the green schists represent a lower metamorphic facies of the amphibolite, perhaps where a certain degree of metasomatism has been effective (the H_2O content of the schist is so much higher than in the amphibolites that this must be taken into account in a more detailed consideration of the values of the analyses).

A profile NE-SW from Takelvdalen up towards Humpen (15.0, 6.4). somewhat further S than the last observations, shows the following features. Beside the farm, Skogvang, furthest in the NE is green schist with a strike of 90° and a dip of 25° N. In the slope above, the green schist has a strike of 110° with 20-25° N dip. At a height over the valley floor of 200 m the green schist strike has swung to 130°, with a dip to N of about 30°. Further up the slope the dip increases gradually through 40 to 60° and finally becomes vertical. Then at about 300 m over the valley floor comes the amphibolite, with a strike of 140° and a vertical dip. At the contact the amphibolite is a dark mylonitic rock some metres thick.

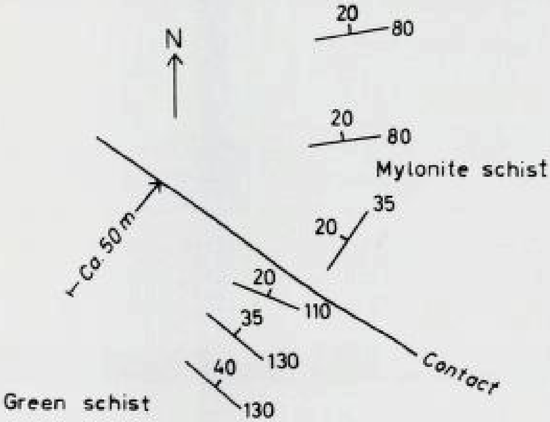

Fig. 12. Plan of the contact at Rundhaug.

A profile from the slope above Rundhaug in Målselvdalen (20.5, 1.2) shows the following features. Up to the junction, at about 150 m over the valley floor, are compact, massive green schists. The schistosity is not always easy to identify, but where it is conspicuous it has a strike of 120 - 130°, and a dip of 20 - 40° to N. The schists are frequently cut by millimetre-broad quartz veins. These mainly are parallel to the foliation but also branch into a network of veins.

The green schists, 5 - 10 m below the contact, have a strike of 110° and a dip of 20° N. Immediately above the contact the meta-sedimentary schists are distorted with strikes varying from 20 to 35 and 40° and with a dip of 20° to N. A few metres above this, the schists are more constant with strike 80° and dip 20° N. Fig. 12 shows all this.

The sedimentary rocks immediately above the green schists are very tectonized sericite-chlorite schists (phyllite). It seems very likely that these could represent a metamorphosed variant of the shales from the Hyolithus zone, as it is seen in Dividalen.

Discussion and Conclusions

The term amphibolite group is used to describe the pure amphibolites, their streaky horizons of varying composition, and the somewhat thicker layers of quartz diorite or leucodacite.

The pure amphibolite consists mostly of green hornblende. It has no pyroxene or chlorite. The plagioclase has about 15 % An. Epidote and zoisite occur only in small amounts. Both the petrography and the chemical composition suggest that the rock is an altered effusive of basaltic character. Its composition is particularly close to certain average analyses of plateau basalts indicated in the literature. Assumed relict variolitic structures are observed, but the rock is otherwise so completely recrystallized that traces of primary structures are mostly destroyed. No examples of pillow structures have been observed.

Even though everything points to the rock being an effusive, the possibility of its representing a highly metamorphosed and tectonised plutonic rock cannot be rejected. The shape of the outcrop, for example, allows this possibility. I shall, however, discuss this rock in the basis of its being an effusive.

The light, streaky horizons in the amphibolite are distinguished from this by having little or no hornblende. In some of them biotite is the chief mineral, in others muscovite and zoisite are most important. Muscovite and hornblende do not occur together.

A similar streaky banding in amphibolites is not an unusual occurrence, and several examples are described from the Caledonian nappes. Foslie (1941, p. 64) refers to rocks from Tysfjord, Nordland, which, according to the mineral assemblages he reports, seem identical with the ones here. Kulling (1955, p. 168) gives a comprehensive account of banded amphibolites with similar mineralogical compositions, from Västerbotten in Sweden, and has a photograph which could easily be from Mauken. I have observed a similar structure in an amphibolite at Mosjøen, Nordland. The three interpretations for this banding that seem particularly appropriate are that they derive from:

1. an alternation of tuffitic material and lava flows,
2. detrial sedimentary material deposited in alternation with lava or tuff,
3. metamorphic differentiation.

Kulling, somewhat tentatively, considered the last to be most likely. Foslie also reached no definite conclusion, allowing the possibilities of tuffitic or detrital sedimentation to remain open. Strand (Foslie and Strand, 1956) describes banded greenstones from the Namsen area, in Trøndelag, in which he believes the banding to be due to metamorphic differentiation, whilst from Helgeland, Nordland (1958), he describes banded green schists which he ascribes to an alternating development of volcanic and sedimentary material.

In the present case I find it most probable that the bands derive from tuffitic deposits alternating with lava flows. The homogeneous composition of the amphibolites, indicated by the chemical analyses, suggests the improbability of any significant metamorphic differentiation. Nor does the composition of the light streaks point directly to a sedimentary origin.

I also find it reasonable to interpret the very fine grained quartz dioritic layers in the amphibolite as tuffites, even though the texture of the rock gives no real cause for this. They bear a certain megascopic similarity to the Andsfjell aplites, but differ mineralogically.

Three analyses of pure amphibolite, taken from a transverse profile, are available. The analyses agree closely with each other. They are used for comparing the amphibolites with metamorphosed basic effusives from the Precambrian of Norwegian, Swedish and Finnish Lappland. The few analyses available from the Lappland Precambrian show a noticeable - in one case striking - similarity to the Mauken amphibolites. The Mauken amphibolites seem to have a clearly different composition from the *Caledonian* metabasalts in Birtavarre, N Norway.

Green schists — Near their junction against the overlying meta-sediments, the amphibolites go over into a relatively thin zone of chlorite-bearing schists containing only a little hornblende, if any. An analysis of these green schists shows that they have a very similar composition to the amphibolites. I believe it most reasonable to consider these green schists as a border facies of the amphibolites, which have undergone retrograde metamorphism during the Caledonian thrust movements. On the other hand the green schists seem to be connected, by a degree of transition, to the overlying meta-sediments of assumed Eocambrian-Silurian age. The reason for this is not fully clear. It is also possible that the green schists partly represent a thin bed of altered debris (a basal greywacke) that has overlain the Precambrian amphibolite surface.

The granodiorite forms the next largest unit in the area. According to its feldspar content it varies from granodioritic to granitic. Most of it seems to have a granodioritic composition, and it is that collective term that is used on the map and in the text. The chief variant of these rocks is medium to fine grained, but aplites and pegmatites also occur. I believe the granodiorite has been formed by a granitization process, for which - in the present area - the Mauken amphibolites apparently represent the host rock. The granitisation seems to have taken place during a diapiric uplift movement.

The granodiorite is distinctly intrusive in its relation to the amphibolites. Breccia structure is, however, also seen at several points along the junctions, thus showing that movements must have taken place at a relatively late stage in the granitisation. However, a few of the bodies, intrusive into the amphibolite, are little affected by cataclasis, thus indicating that these are of somewhat younger date.

The conditions along the junctions between the basement and the overlying meta-sediments — The schists above the basement lie with a distinct angular disconformity on both the granodiorite and the amphibolite. They show, furthermore, not only disconformity towards the foliation of the amphibolite and granodiorite, but also towards the intermediate junction plane. Only beside the contact, itself, have both the basement and the schists a foliation that is expected within the overlying sediments, but these do not seem to occur;

It seems possible that the massif has been uplifted in Caledonian times, after the overlying meta-sediments had assumed their present position, or simultaneous with that. A fairly gentle bulging-up of the surface is a preferable mechanism to an uplift "en bloc". Gustavson (1963) assumes such a possibility for the basement windows in Dividalen. The many vertical minor faults, and not least the very steep shear planes of the amphibolite, make such an interpretation probable. Cataclastic phenomena are a normal occurrence in the otherwise massive amphibolite, and indicate that shearing took place not only during the formation of the hornblende, but also continued afterwards. The existing parallelism between the structural trends of the basement and the overlying schists, just beside the contact, must be interpreted as being derived from thrust movements across an extremely uneven surface. But this conformity may also be due to a pressure from below, brought about by an uplifting massif, after the schists had been emplaced above. However, in this case we should expect to find extensive chloritisation of the hornblende in the central part of the massif, something which does not in fact occur. I will, therefore, refrain from taking up any definite standpoint in this question.

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conformable to the junction plane. All the surrounding rocks near the junction are more or less cataclastic, mylonitised and schistose. The junction must therefore be considered as a tectonic thrust plane. The overlying meta-sediments clearly consist of Caledonian nappes, though remains of par-autochthonous Cambrian (and Eocambrian?) sediments are also present. The rocks in the immediate vicinity of the junction have been imprinted with a coincidental foliation.

It should, however, be noted that, whilst the NW-SE structural trend of the basement is discordant to the WSW-ENE strike of the overlying schists, this first direction is nevertheless a well-known structural feature within the Caledonian nappes (the "cross-folding"). This is especially apparent in the nappes which make up the greater part of the map-sheets "Målselv" and "Tromsø", where there are synform and antiform systems of very similar scale to what we have in the Mauken area. Any possible connection between these will not be discussed in the present paper.

The structure of the basement — The Mauken amphibolite complex has a steep NW-SE foliation in its central part, and has a dip to NE in its eastern limb and one to SW in its western limb. It is therefore natural to consider the structure as an isoclinal antiform with a very steep axial plane. On the other hand, the uniformity in petrography and structure that the rock shows along a transverse profile, gives no direct support for such an assumption. As an alternative the amphibolite complex could perhaps represent one very steep limb of a large fold whose original shape it is impossible to reconstruct. In the latter case the basaltic layer has had a thickness of a least 3000 m, in the former, at least half that. The research carried out has not produced any more information supporting or contradicting either of these alternatives.

The amphibolite complex forms a ridge-shaped area, the granodiorite of Andsfjell, with its rather dome-like appearance, terminating this ridge in the NW. The Precambrian surface, here, reaches at least 500 m higher than it does in the surrounding region. The sides of this Precambrian massif mostly slope quite steeply (30-50°). The question then arises whether these Precambrian outcrops have been monadnocks on the Precambrian peneplane, or whether they have assumed their present position during later movements. Against the monadnock theory may be noted, among others, the following points:

1. the mountain sides have been relatively steep and the mountains rather high to have belonged to a peneplane;

2. with such steep mountain slopes, traces of coarse debris (talus) could be

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Plate I. Amphibolite, specimen 2448 c. Plane polarised light. Green hornblende in a fine grained groundmass of plagioclase and quartz. Diam. of photo = 2 mm.

Plate II a). Granodiorite, specimen 2262. Crossed nicols. Microcline, with plagioclase and quartz. Diam. of photo = 2 mm.

Plate II b). Mylonitic gneiss, specimen 547. Crossed nicols. Crushed, fine grained groundmass of quartz and feldspar. A few large, highly cataclastic plagioclase grains. Diam. of photo = 2 mm.

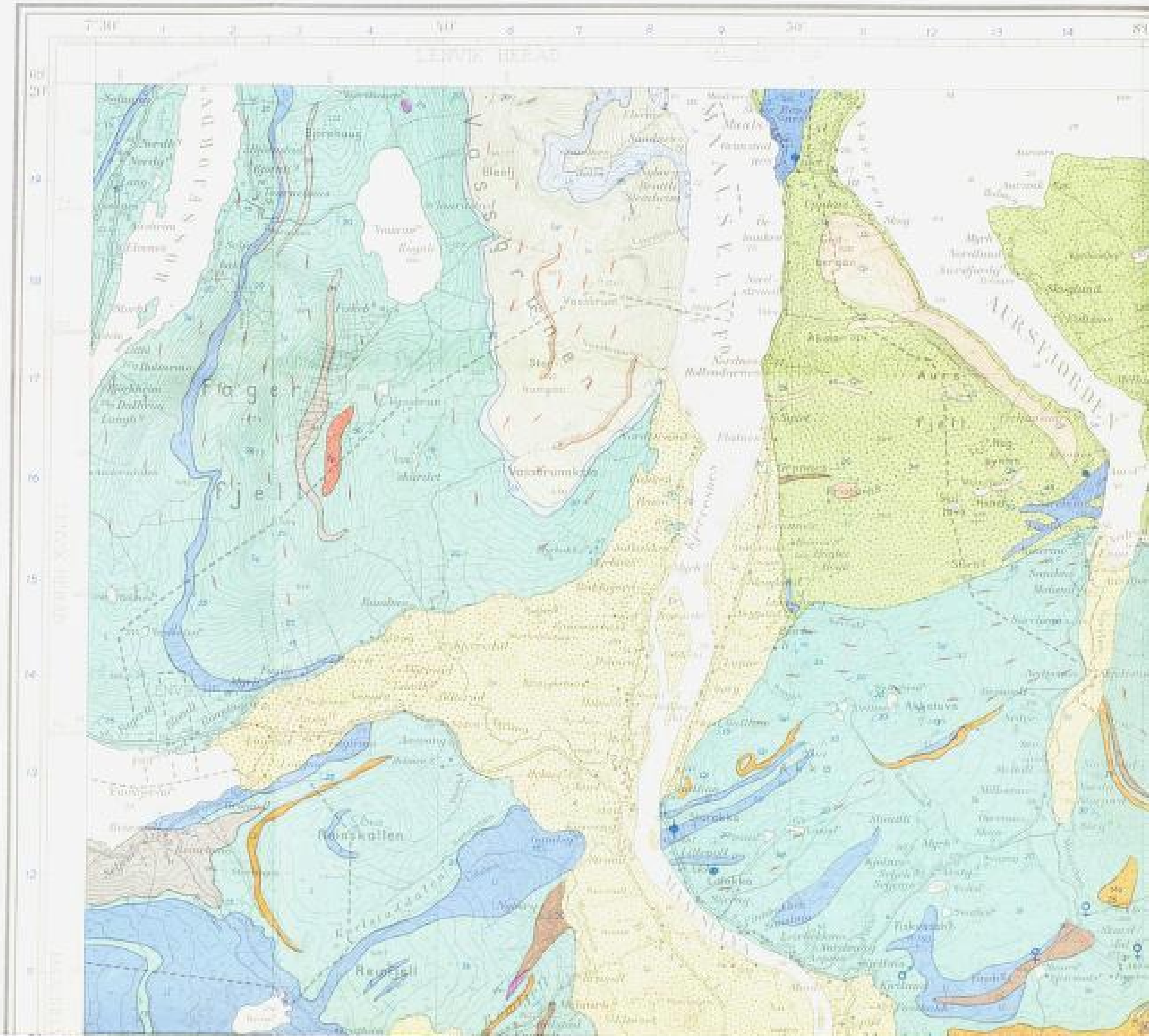
TROMSØ

Geologis

MÅLS

Tromsø

MÅLSELV



Rekkefølgen av de lagdelte bergarter
Stratigraphy

Øvre avdeling
Upper division

- Øvre gneissone — *Upper gneiss zone*
- Øvre kalksone — *Upper limestone division*
- Øvre biotittskifer — *Upper biotite-schist*
- Øvre kvartsittsone — *Upper quartzite zone*

Klorittskiferavdelingen
Chlorite-schist division

- Muskovitt-granatskifer — *Muscovite-garnet-schist*
- Undre kalksone — *Lower limestone zone*
- Konglomerater — *Conglomerates*
- Klorittskifer — *Chlorite schist*

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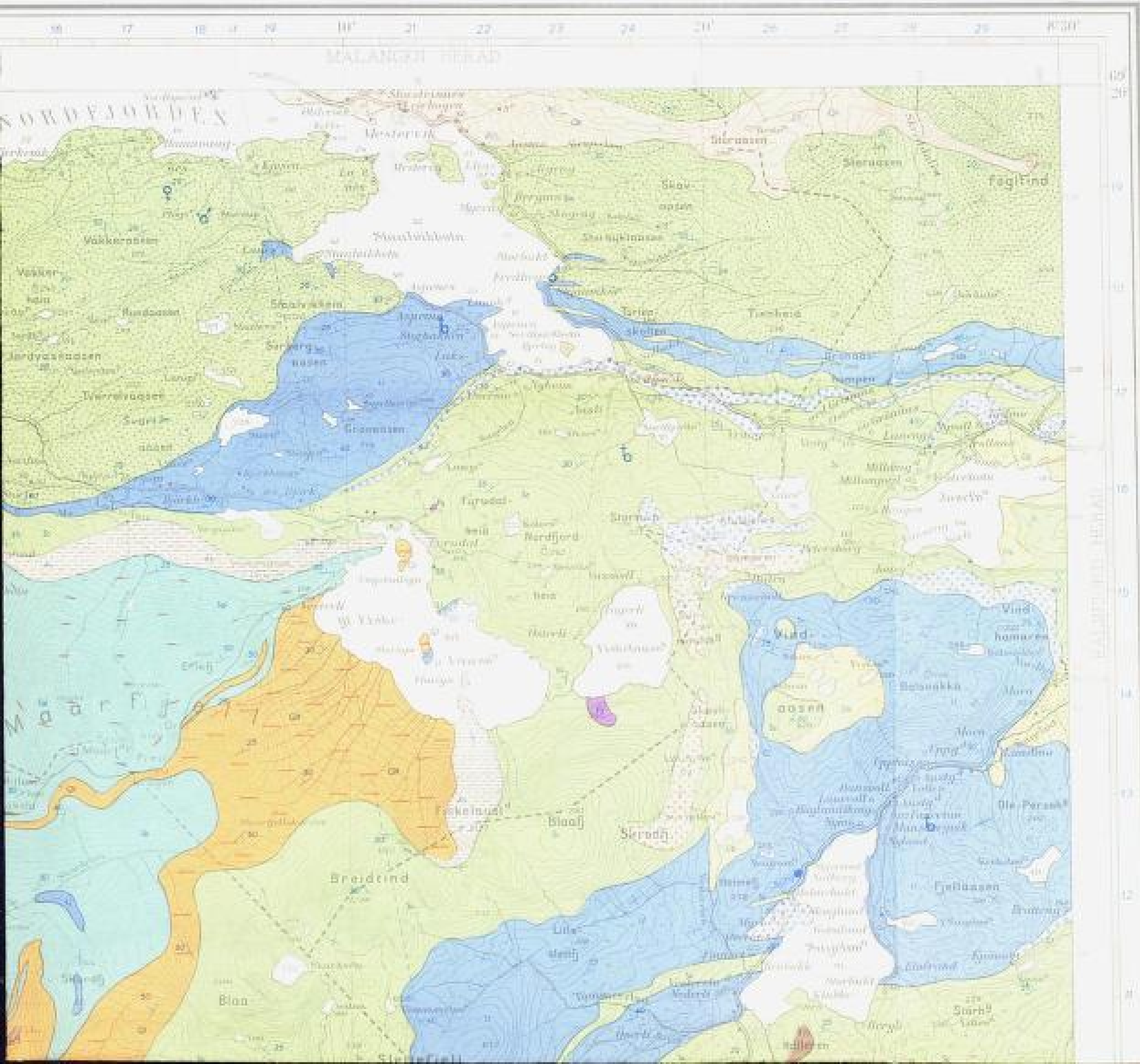


Kvartære løsavleiringer
Quaternary deposits

- Dr — Marine avsetninger / *Marine deposits*
- Db — [illegible] / *Morainic drift*

Fjellkjedens bergarter
Rocks of the Caledonian range

- Sø — Biotittskifer i Øvre avdeling / *Biotite-schist in the Upper division*
- S — Biotittskifer, nivå ikke angitt / *Biotite-schist, level not stated*
- Su — Biotittskifer i Undre avdeling / *Biotite-schist in the Lower division*
- Skl — Biotittskifer, kalk- og hornblendeholdig / *Biotite-schist, calcite- and hornblende-bearing*
- Sc — Klorittskifer i Klorittskiferavdelingen / *Chlorite-schist in the Chlorite-schist division*
- Sm — Muskovitt-granat-(biotitt-)skifer i Klorittskiferavdelingen / *Muscovite-garnet-(biotite-)schist in the Chlorite-schist division*
- Sg — Plagioklasrik skifer og glimmerskifergneis, nivå ikke angitt / *Plagioclase-schist and mica-schist-gneiss, level not stated*
- Sgø — Plagioklasrik skifer og glimmerskifergneis, Øvre gneissone / *Plagioclase-schist and mica-schist-gneiss, Upper gneiss zone*
- Sgu — Plagioklasrik skifer og glimmerskifergneis, Undre gneissone / *Plagioclase-schist and mica-schist-gneiss, Lower gneiss zone*

- Lø — Kalkstein (marmor), Øvre kalksone / *Limestone (marble), Upper limestone zone*
- Lu — Kalkstein (marmor), Undre kalksone / *Limestone (marble), Lower limestone zone*
- L — Kalkstein (marmor), nivå ikke angitt / *Limestone (marble), level not stated*

- Hornblendeskifer

Undre gneissone
Lower gneiss zone

Undre kvartsitter (mikroklinkvartsitt)
Lower quartzites (microcline-quartzite)

Undre biotittskifer, grønnskifer
Lower biotite-schist, greenschist

Mylonitter
Mylonites

Granodior., amfib. i Andsfjell og Manken
Granodior., amphib. in Andsfjell and Manken

Undre avdeling
Lower division

Strøk og fall
Strike and dip

Profil-linje
Section line

Malmforekomster
Ore deposits

Svovelkis
Pyrite

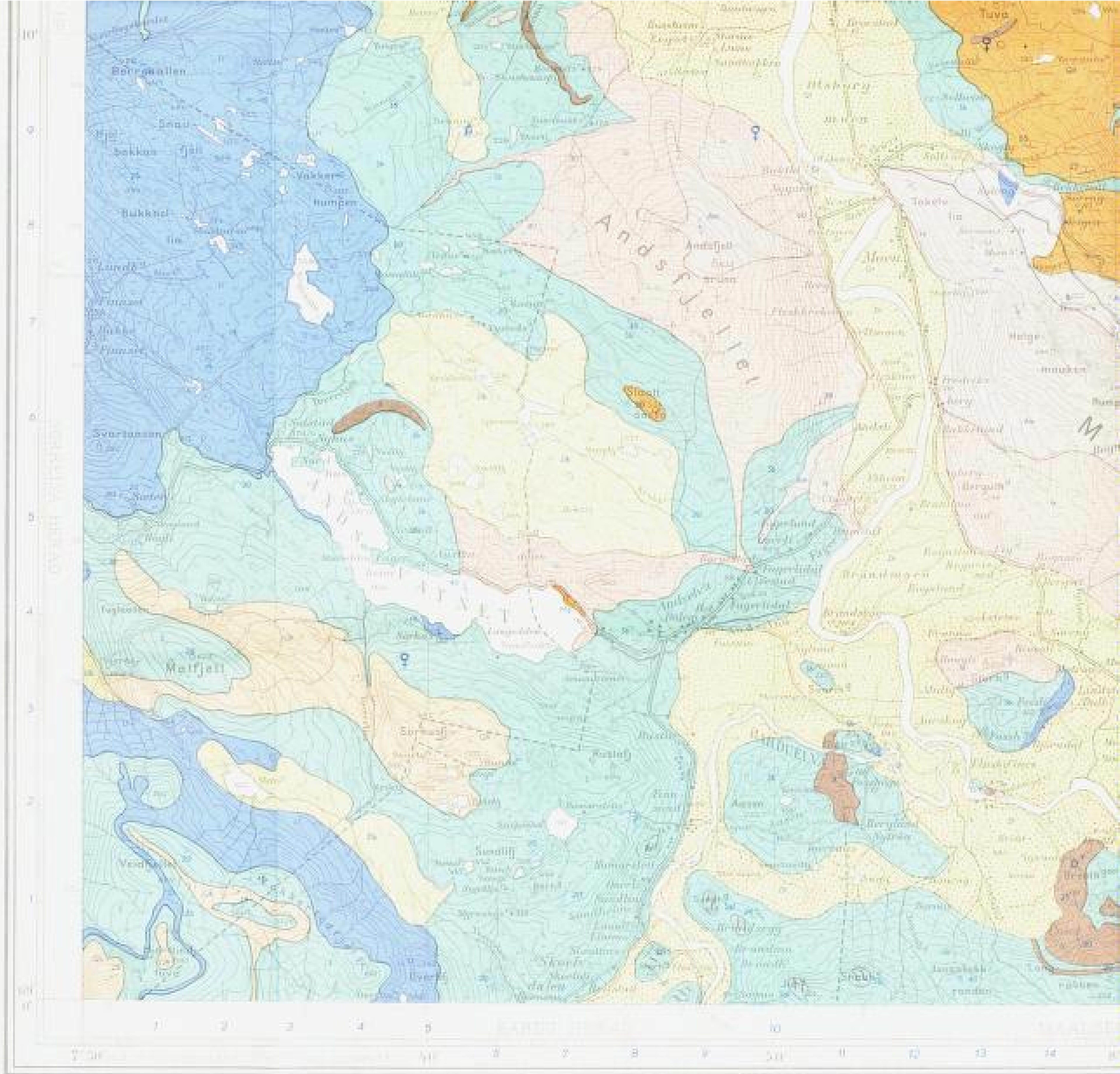
Jern
Iron

Titan-jern
Titaniferous

Sink og bly
Zink and Lead

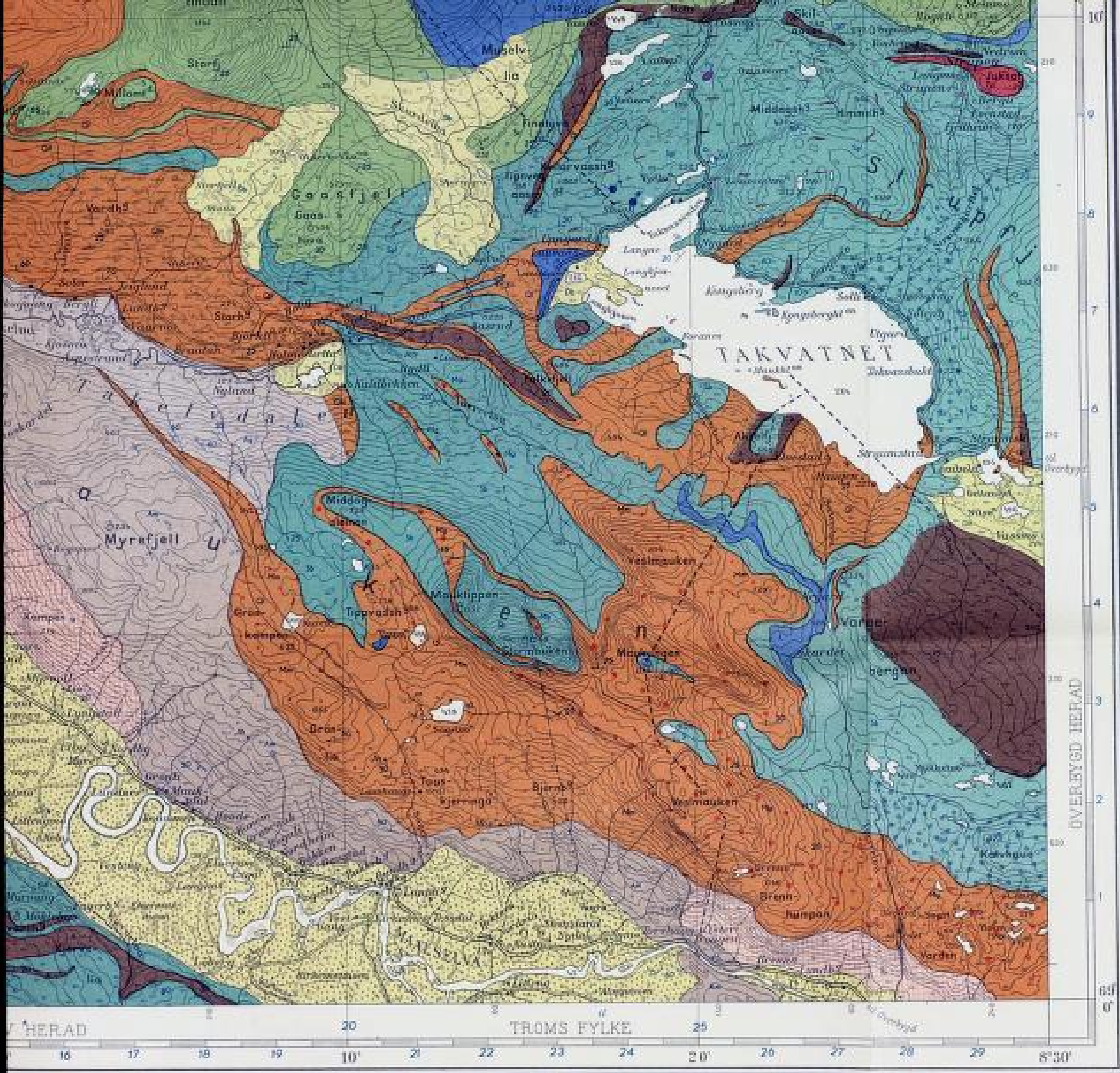
Grafitt
Graphite

Kalk
Limestone



Utarbeidet på grunnlag av geologiske Målebl.
Litografert og trykt hos A.s John Griegs Boktrykkeri, Bergen

Målestokk



Geologisk kartlagt 1948—54 av Kåre Landmark, med støtte fra Norges Geologiske Undersøkelse. Trykt med bidrag fra Norges almenvitenskapelige forskningsråd.

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- Qh — Kvartsitt, Øvre kvartsittsone — *Quartzite, Upper quartzite zone*

Undre kvartsittsone — *Lower quartzite zone*:

- Qs — Serisittkvartsitt — *Sericite-quartzite*
- Ql — Kvartsitt med små mengder mikroklin — *Quartzite, containing small amounts of microcline*
- Qll — Mikrolinkvartsitt, kvartsittgneis — *Microline-quartzite, quartzite-gneiss*
- Mg — Mylonittgneis — *Mylonite-gneiss*
- Mm — Mylonitt — *Mylonite*

(Qll, Mg, Mm:) Arkose, dels også kataklastisk granodioritt Ia — *Arkose, in part also cataclastic granodiorite Ia*

- Cl — Kalk-konglomerat — *Limestone conglomerate*
- Cq — Kvartsitt-konglomerat — *Quartzite conglomerate*

- A — Amfibolitt — *Amphibolite*
- Am — Amfibolitt i Mauken og Andsfjell — *Amphibolite in Mauken and Andsfjell*
- As — Skifrig saussurittgabbro — *Schistose saussurite gabbro*
- Ag — Grønnskifer — *Green-schist*

- Ps — Serpentin — *Serpentine*
- Pg — Sagvanditt — *Sagvandite*

- Tp — Trondhjemitt, pegmatittisk eller grovkornet — *Trondhjemite, pegmatitic or coarse-grained*
- Il — Granodiorittisk gneis, vesentlig finkornet — *Granodioritic gneiss, mainly fine-grained*
- Ia — Granodioritt i Andsfjell og Mauken — *Granodiorite in Andsfjell and Mauken.*