A preliminary note on the geology of the area between Altevatn and Målselva, Indre Troms, N. Norway

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Abstract

An area of approx. 1,600 square kilometres in Indre Troms, N. Norway, has been geologically mapped. The area is built up of 1) granites and migmatites of the basement, overlain by 2) non-metamorphic sediments of the Hyolithus zone, on which, in overthrust position, rest 3) metamorphic Caledonian rocks. The overthrust Caledonian rocks have been divided into three 'sequences', which may represent different thrust sheets. The most common rocks and structures found in the three sequences are given in table I, and illustrated in the profiles of figures 2 and 3. Fig. 1 shows a sketch map of the area.

Introduction

During the summers of 1965 and 1966 an area of approx. 1,600 square kilometres in Indre Troms, N. Norway, was geologically mapped by students of the Geological Institute of Aarhus University. This mapping formed part of an exploration program of A.S. Sydvaranger, mining company[2]). Although the mapping is not yet completed (we reckon to be able to finish the map in 1967, while local detail problems probably will require prolonged fieldwork) it seems worth-while to report some of the results, arrived at during the first two summers, in this note.

The investigated area, which lies in northern Norway, is located between latitudes 68°30′ and 69° and between longitudes 19° and 20°15′, approx. 120 km SSE of Tromsø and 80 km ENE of Narvik. The area mapped until

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[2]) Our sincere thanks are due to A.S. Sydvaranger for the opportunity it gave us to investigate this interesting area. Although, of course, the company was mainly interested in the economical aspects of the investigations, we had complete freedom to pursue our own scientific interests. Especially we appreciate the cooperation of Hr. bergingeniør Andreas Eriksen of A.S. Sydvaranger and his kind help in many matters of technical importance.

now is limited to the south by Altevatn, to the east by the Norwegian-Swedish boundary, to the north by Rostaelva and Målselva, and to the west by a line through Kirkesdalen to the northwestern tip of Altevatn.

Geologically speaking, the area mapped is situated in the marginal zone of the Caledonian mountain chain, where the rocks of the Caledonian chain overlie the granites and migmatites of the Precambrian basement.

As a topographical base for the mapping the maps on a 1 : 50,000 scale of Norges Geografiske Oppmåling and aerial photograps on a scale of approx. 1 : 20,000 of Widerøe's Flyveselskab were used.

The mapping was done at a rate of approx. 200 km^2 per man per summer lasting 2½ months. At this rate, a fairly good covering of most of the area is possible because, in general the stratigraphy of the area is relatively simple and because rather large parts of the area are almost completely covered by Quaternary deposits.

Apart from the two authors of this report, the following students of the Geological Department of the Aarhus University took part in the mapping: Holger L. Andersen and Peter B. Sørensen in 1965, Arvid H. Mortensen and Niels F. Schrøder in 1966. All of these contributed essentially to the results reported here.

Mainlines of tectonics and stratigraphy in the investigated area

Fig. 1 gives a very simplified geological sketch of the area mapped. The most southeastern part of the area is mainly built up of Precambrian granites and migmatites (in the following shortly called the 'basement'). On top of these granites etc., non-metamorphic sediments (arkoses, conglomerates, quartzites and shales) of the Hyolithus zone, up to approx. 150 m thick, occur. On top of these non-metamorphic sediments and separated from them by a clearly tectonic contact, a thick sequence of metamorphic rocks (a.o. mica-schists, amphibolites and metagabbros, marbles, quartzites) is found. This sequence attains an estimated thickness of approx. 2,500 m in the central part of the area.

The fact that these schists (often containing kyanite and staurolite), and other fairly high-grade metamorphic rocks, lie on top of non-metamorphic sediments, proves that the former have been thrusted on top of the latter.

In the southern part of the area the top of the basement, with its cover of Hyolithus zone sediments, dips gently (estimated average dip approx. 2°) towards NW, and disappears under the surface. In Dividalen, the basement and Hyolithus zone sediments appear on the surface again in an approx. 9 km

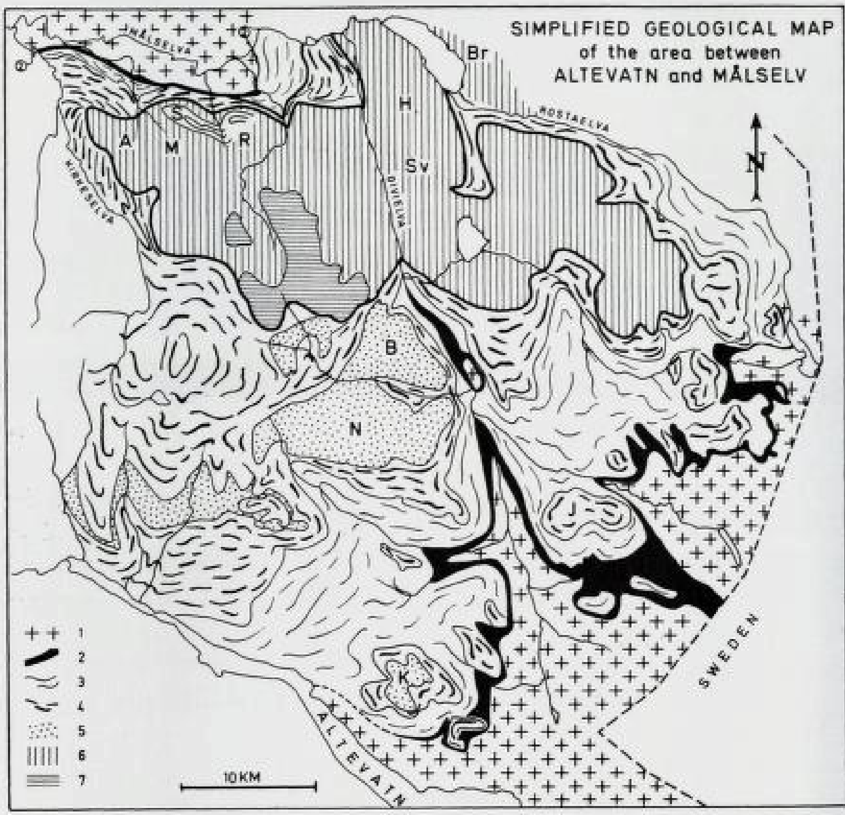

Fig. 1. Geological sketch map of the investigated area.

1. Basement. Mainly granitic rocks and migmatites.
2. Hyolithus zone sediments.

3-5. Rocks of the lower sequence. 3. Low grade rocks (without visible biotite), mainly kakirites, phyllonites and mylonites: probably normal low grade sediments are also present. 4. Rocks of higher metamorphic grade (with biotite). 5. Main outcrops of amphibolite and meta-gabbro.

6. Rocks of the middle sequence.
7. Rocks of the upper sequence.

The signatures for the rocks of the lower sequence roughly indicate the outcrop pattern of the formations mapped. It should be noted that this outcrop pattern is mainly determined by the topography of the area, the bedding mostly being subhorizontal.

Topographical abbreviations: A: Alappen. B: Bangfjellet. Br.: Brattlifjellet. H: Habafjellet. J: Jerta/Litle Jerta. K: Kistefjell. M: Middagsfjell. N: Njunis. R: Ruten. S: Storfjell. Sv.: Svortberget.

long window[1]), then, towards N, they disappear under the valley bottom for a distance of some 20 km, reappearing again in a large window on both sides of Målselva. This window has been described by Berthelsen (this issue) and has been called the Mauken window. Also along Målselva Hyolithus zone sediments have been found on top of the basement rocks, but here they are much thinner (approx. 20 m), and generally also more strongly tectonized than in the southern part of the area. We have good reasons to assume that the Hyolithus zone sediments in the Mauken window and those in the southern part of the area form a continuous horizon, and this would mean that the overlying metamorphic rocks form a continuous sheet, thrust over the underlying sediments for a distance of at least 50 km.

Apart from the main thrust plane between the Hyolithus zone sediments and the overlying rocks, the existence of several other important thrust planes has been proved, and it is probable that many thrust planes of minor importance are present.

During our mapping we have subdivided the rocks in the area into a number of formations which can be arranged into three sequences, each of which locally shows clear tectonic contacts with the underlying rocks. It is possible that we are dealing with three different thrust sheets or nappes. Locally, there is a clear discordance at the bottom of these 'nappes', but elsewhere the contacts with the underlying formations are concordant, and then it is difficult to verify whether one has to do with a normal or a tectonic contact. For the time being, it seems best to call these units neutrally the lower, the middle and the upper sequence. Table I gives an insight into the lithological character and the tectonic style of these three 'sequences'.

In the following pages a more detailed discussion of the stratigraphy and structures within the lower two sequences will be given.

The lower sequence

On Jerta and Litle Jerta mountains in the SE part of the area (indicated with J on the map of Fig. 1) a good section through the lower part of the lower sequence is found.

The following units (formations) can be mapped.

(8) quartzitic schists).
7) 2nd amphibolite, with bands and inclusions of schists and marble.
6) (garnet-) micaschists, fairly coarse grained.

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[1]) This window has been described by Gustavson (1963), but Gustavsons accompanying sketch map, in some respects, does not agree with our findings.

Table I. Main lithological and structural features of the rocks in the three 'sequences' of Caledonian overthrust rocks.

III Rocks of the Upper sequence Folding, on a minor scale, rarely observed.	At the base approx. 100 m micaschists, marbles and amphibolites. Thereover mainly garnet-micaschists, in the lower few hundred metres without marble, higher up with marble bands. Amphibolites rare. Max. exposed thickness approx. 800 m.
— — Thrustplane locally evident — — — — — — — —	
II Rocks of the Middle sequence Large scale isoclinal recumbent folds with axes trending WNW-ESE. Lineation, with WNW-ESE trend, common. Refolding on N-S, NW-SE and NE-SW trending axes.	Garnet-micaschists (with local occurrence of staurolite and kyanite), marbles and quartzites. Amphibolites rare. Max. thickness approx. 900 m.
— — Thrustplane locally evident — — — — — — — —	
I Rocks of the Lower sequence Minor thrusts common. Large scale thrusts possibly present. Isoclinal and open folds, on a minor scale, with axes trending in varying directions. Large scale open folds mostly with N-S and WNW-ESE trending axes. Lineation common in WNW-ESE direction.	Granite kakirites, phyllonites and mylonites common in the lower part, together with low-grade schists of probable sedimentary origin in which locally lenses and bands of dolomite occur. Higher up predominantly micaschists and amphibolites. Marbles subordinate. Max. thickness approx. 1,000 m.
— — MAIN THRUSTPLANE — — — — — — — —	
	Hyolithus zone sediments and basement rocks.

5) 1st amphibolite, strongly foliated and lineated, often containing 'augen' of feldspar and hornblende.
4) augen-schists and -gneisses.
3) (garnet-) micaschists.
2) low-grade schists, partly 'Hartschiefer'.
1) (granite-) kakirites and -mylonites.
0) Hyolithus zone and basement rocks.

In the southwestern part of the area the higher part of the lower sequence is well represented. A formation consisting of schists, marble and amphibolites, which can be correlated with formation 7 in the Jerta area, is here overlain by

10 etc) Several formations mainly consisting of micaschists.
9) 3rd amphibolite.
8) fine-grained micaschists.

The rock types in the different formations have not yet been investigated in detail and the origin of some of them is as yet unclear. The low-grade schists (2) are at least partly of mylonitic origin (Hartschiefer being common), but some seem to be normal low-grade metamorphic sedimentary rocks[1]). The (garnet-) micaschists of the formation 3 locally still have phyllonitic characteristics but those of the formation 6 and higher schist formations are certainly normal metasediments. The augen-schists and gneisses (4) have strongly mylonitic textures, but contrary to the rocks in the formations 1 and 2 they are completely recrystallized. The rocks may contain large amounts of alkali feldspar, and some of them might be orthogneisses. The origin of the 1st amphibolite is not evident but in the amphibolites of the formation 7, and locally in those of formation 9, remnant igneous textures have been found.

In the Jerta area the formations dip towards NW, with a dip steeper than that of the underlying Hyolithus zone sediments and the top of the basement. Towards NW the high-grade formations thin out and disappear above (or into) the formation of the low-grade rocks (see Fig. 2). The latter attain a thickness of approx. 1,000 m in the area N and NW of Jerta.

At many other places in the area the same stratigraphical succession as on Jerta and Litle Jerta has been found. The amphibolite sheet which forms the top of Kistefjell (K on the map of Fig. 1), for example, is underlain by augen-schists and -gneisses and must, therefore, probably be correlated with the 1st amphibolite of Jerta.

In Sandelvdalen, between Njunis and Bangfjell (indicated with N and B resp. in Fig. 1) the whole succession of Jerta is again found. Here, however, the '2nd amphibolite' attains a thickness of up to 500 m, or more, and builds up most of Bangfjell and the Njunis massif. In the amphibolites of Njunis and Bangfjell the igneous (gabbroic) textures are locally well preserved, and it is clear that one is dealing with rocks of intrusive origin.

Also in the northern part of the area, both in Dividalen and south of the Mauken window along Målselva, the Jerta stratigraphy is locally found back. Especially the characteristic association of augen-gneisses with (augen-) amphibolites often serves as a stratigraphic marker. Often the Jerta stratigraphy is not complete, one or several formations being very thin or absent.

As said before, the high-grade metamorphic formations of Jerta and Litle Jerta disappear to the northwest, but some 10 km to the north, on the eastern side of Dividalen, they reappear again at an altitude of approx. 900 m, with fairly steep NW dips (approx. 40°). This repetition of the stratigraphy - and a few analogous cases - are possibly due to thrusting of the high-grade forma-

[1]) Even in thin section it is often difficult to see whether one is dealing with normal phyllites or with rocks of mylonitic origin.

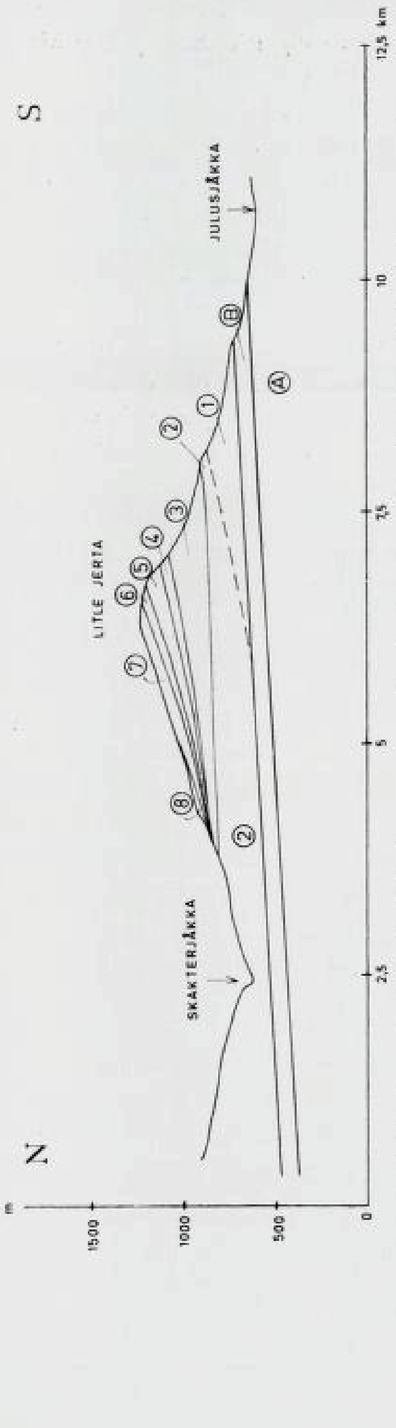

Fig. 2. Profile through the rocks of the lower sequence in the Jerta area. Note that the vertical scale is exaggerated two times.
A: Basement rocks. B: Hyolithus zone sediments.
1-8 overthrust Caledonian rocks, subdivided into the different formations described on p. 255-257.

tions over the low-grade rocks. The wedging out of the high-grade metamorphic formations on Jerta and Litle Jerta (Fig. 2) is also possibly caused by thrust movements. There are several indications that intensive thrusting has taken place at many places in the lower sequence, such as the common occurrence of tectonic discordances and mylonite zones, and the local occurrence of granite kakirites (thrust) on top of meta-sedimentary rocks (marbles and normal mica-schists).

Furthermore, if normal low-grade sediments do occur in the formation 2 of the Jerta stratigraphical section, this might indicate the overthrusted position of the more high-grade rocks which overlie them (comp. Kulling's thrust between his Abisko and Seve-Køli nappes (e.g. Kulling, 1964) and Gustavson's thrust between his Storfjell and Rombak groups (Gustavson, 1966)). In the field the presence of a thrust plane between the low-grade schists and the more high-grade schists is only rarely evident. Generally there seems to exist a gradual transition between the two rock types.

The pattern of folding in the rocks of the lower sequence is complicated. Large scale folds occur locally, but generally the different formations lie subhorizontal, or slightly inclined, over large distances, and do not show signs of large scale folding. On a minor scale both isoclinal folds and more open folds are commonly present. The axes of these folds have low plunges in almost any direction. It has been observed in many instances that the foliation of the schists etc. is an axial plane foliation belonging to some of the isoclinal folds. In other cases, however, the foliation itself is folded, both in isoclinal and in more open folds.

Several large folds with amplitudes of up to several km have been mapped. These have subhorizontal axes with WNW-ESE or N-S trends. In both cases it is the foliation of the schists etc. that has been folded - only locally a new foliation starts to develop in relation to the folds.

Unlike the measured fold axes in the lower sequence, the measured lineations trend WNW-ESE with few exceptions. Commonly there is a clear connection between this lineation and local folds with WNW-ESE axes. Often the lineation is a distinct mineral lineation. In the amphibolites of the formation 5 of the Jerta section, for example, a distinct hornblende lineation in WNW-ESE direction is common. In view of these facts we do not believe that the lineation in this direction is due to the thrusting of the metamorphic rocks over the basement and Hyolithus zone rocks, (comp. Kvale, 1953). It is evident that the metamorphism of the rocks must have taken place before they were thrust on top of the non-metamorphic Hyolithus zone sediments, and a lineation due to the orientation of metamorphic minerals must therefore be older than these thrust movements. The common occurrence of the lineation in rocks folded on WNW-ESE axes indicates a relation between the folding and the lineation.

The middle sequence

The middle sequence consists of metamorphic rocks whose sedimentary origin is evident. Micaschists, marbles and quartzites are the most common rock types. It has been possible to divide the sequence in a number of formations, which can be mapped through parts of the area. Due to the complex structures and to the fact that several of the formations are lithologically more or less identical, however, mapping of the formations is difficult and correlations between different parts of the area sometimes hazardous. The best defined formation in the middle sequence consists of homogeneous, thick-bedded, approx. 200 m thick quartzites, having fairly sharp contacts with the underlying and overlying formations. This quartzite formation can be mapped over long distances, and it is largely due to these quartzites that we have come to a fairly good understanding of the structures in the middle sequence.

The middle sequence seems to be built up of a pile of large scale isoclinal recumbent folds with subhorizontal WNW-ESE trending axes. The quartzite formation very clearly marks one of these folds (see Fig. 3). The hinge of this fold runs through Ruten mountain (indicated with R in Fig. 1), and toward ESE. N of Rostadalen thick-bedded quartzites occur at two levels, separated by some 700 m of schists and marbles. We think that these quartzites form the limbs of a large recumbent fold (see Fig. 3).

Since the rocks of the middle sequence are completely recrystallized, original sedimentary structures are only seldom recognizable. In the schists relict graded bedding has been locally recognized, and in the quartzites structures have been found which possibly may be interpreted as remnants of original cross bedding. Both phenomena indicate that the quartzites in the upper limb of the isoclinal fold lie in their normal position, whereas those in the lower limb are overturned. This conclusion is based on only a few observations in strongly folded rocks and should therefore be treated with caution.

Also on Alappen and Storfjell (indicated with A and S in Fig. 1) large isoclinal folds with the same axial trends are found. Minor isoclinal folds and parasitic folds with axial trends between W-E and NW-SE, but generally in WNW-ESE direction, are common.

The large recumbent folds generally fold a preexisting schistosity of the schists, but a new schistosity, parallel with the axial planes of the isoclinal recumbent folds is often more or less clearly present. A distinct WNW-ESE trending mineral lineation in the different rocks is parallel with the axes of the isoclinal folds, and is obviously related with the isoclinal folding. In a few outcrops a strongly tectonized conglomerate has been found in which the pebbles are clearly stretched (to 5-10 times their original length) in the same direction in which also the mineral lineations are found.

In the middle sequence rather small isoclinal folds locally occur which are older[1]) than the large scale recumbent folds. The folds give rise to an axial plane schistosity in the rocks. The axes of these folds have variable trends.

Folds younger[1]) than the large recumbent folds are of common occurrence. These folds cause a crenulation of the earlier formed schistosity. They range in size from a few metres to several tens of metres. In most cases they are too small to show on a 1 : 50,000 map.

At first sight the axes of these late folds seem to scatter in all directions, but a more detailed investigation seems to justify their subdivision into three groups, with axes trending roughly in N-S, NW-SE, and NE-SW directions

[1]) Arguments for these age relationships will be given in a later paper.

There are indications that the folds with N-S trending axes are the oldest, and those with NE-SW trending axes the youngest of these later folds. The folds have in most cases much the same style, they generally consist of a subhorizontal and a subvertical flank.

There is a good correspondence between the structures in the middle and the lower sequences. In both folding on WNW-ESE axes gives rise to a strong lineation in the rocks, but large scale recumbent folds on WNW-ESE axes have as yet only been found with certainty in the middle sequence. In both sequences folds have been found that are older than the folding on WNW-ESE axes. Younger folds with different axial trends are ubiquitous in both sequences. These folds may become quite large (up to several km) in the lower sequence, whereas in the middle sequence they are generally much smaller. Also the subdivision of the younger folds into several groups with different axial trends seems to be much the same in the two sequences.

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