Geology of the eastern part of the Meråker area

by Anna Siedlecka

Abstract

Within the mapped area slightly metamorphosed clastic sediments occur, probably of Upper Ordovician and Silurian age. The author describes a metagraywacke-slate association with metaconglomerates and gabbrodiorite sills, and a black-gray metasiltstone-slate association. Observations of preserved sedimentary structures, and microscopic investigations, indicate that these two association are different sedimentary facies. The first consists of beds representing a flysch facies formed by turbidity currents. The second is a black shale facies developed in euxinic environments. The beds are strongly folded and the folds overturned to the east. Silurian deposits form the centre of a syncline which runs from the Kjøllhaugene area south through the mapped area. Regional metamorphism altered the sediments to the greenschist facies, and in part to the epidote-albite-amphibolite facies.

Introduction

During the summer 1965 I was a member of the geological field party organized by Fr. Chr. Wolff of the Norges Geologiske Undersøkelse, and mapped an area (ca. 150 km^2) situated northeast from Meråker. The area is bounded on the south by the main road to Storlien (Sweden), on the west by the Kopperå river, on the north by the Fjergen lake, the Sørelva river and Halsjøen lake, and on the east by the border between Norway and Sweden. I have done least work east of the Kjerringfjellene mountains because of inaccessibility and inclement weather.

Previous investigations in the Meråker area have been discussed by Wolff (pp. 7-8 in this volume). Because of this, the results of these earlier investigations will not be cited here.

Acknowledgements

I am indebted to N.G.U., and especially to Fr. Chr Wolff for the very good organization of the field party and for the help he has given me.

Further, I wish to express my thanks to K. Birkenmajer for the helpful remarks about sedimentary markings, and to N. P. Lasca and R. P. Nickelsen who kindly corrected the English manuscript. The Institutt for Geologi, Universitetet i Oslo, was most generous in allowing me to use the Institutt's facilities.

Rock characteristics

Within the mapped area occur monotonous clastic sediments, slightly metamorphosed and folded in tight or isoclinal folds. During the mapping, the following strata have been distinguished:

1. The metagraywacke-slate association, which is subdivided on the geological map into, (a) the predominantly metagraywacke beds with the addition of slates; and (b) the predominantly slaty beds with the addition of metagraywackes. 2. The metaconglomerates.	Kjøllhaugene Group
3. The black-grey metasiltstone-slate association which on the geological map includes a separate subdivision for the metasiltstones and metasandstones. 4. The gabbro-diorite intrusions.	Slågån Group

KJØLLHAUGENE GROUP

Metagraywacke-slate association

The rocks were first described (Kjerulf, 1883; Reusch,1883, 1890) as grey and green «lersandstene», «lerstene», and occasionally as «skifre». Carstens (1920) described these rocks as sandstones interbedded with «lerglimmerskifer.» All writers emphasized the very monotonous character of the rocks occurring along the road to Storlien, between Meråker and the border between Norway and Sweden.

Most of the map area consists of the Kjøllhaugene Group. The group forms two zones called here: (1) the western or Bukhammer-Monsklumpene's zone, and (2) the eastern or Kjerringfjellene's zone. Altough the same sediments are found in both the eastern and western zones, there is some difference in sediment character between the zones. The dominantly slaty beds, found in the western part of the Bukhammer — Monsklumpene's zone grades eastward into a dominantly metagraywacke beds. The gradational zone between the slates and metagraywackes is used to mark the contact shown on the map (Pl. II). In the Kjerringfjellene's zone there is an interbedding of slates (which contain some metagraywackes) and metagraywackes (which contain some slates); metaconglomerates occur throughout the zone appearing in both the slate and metagraywacke beds.

Structural and textural features

Characteristic features of the metagraywacke-slate association are as follows:

1) Alternation of metagraywackes, slates, phyllites and metasiltstones. The metagraywacke beds range from 10 cm to 100 cm in thickness; in one case a 5 m thick bed was observed.
2) Rapid lateral variations in thickness and composition of beds are absent.
3) Most frequently the boundary between the metagraywacke and underlying slate is sharply defined. The boundary between the metagraywacke and the overlying bed is usually indistinct; there is often a transition from metagraywacke to slate, or metasiltstone. In such cases, the boundary is usually indicated by rock cleavage, which is distinct in the slates and absent in the metagraywackes.
4) On the surface forming the boundary between the slate and overlying metagraywacke, markings of sedimentary origin occur. These structures were observed only in cross-sections. As outcrops showing the bottom surface of the metagraywacke beds were not found, it was impossible to study the sedimentary markings in three dimensions. The most commonly observed markings are small round- or angular-backed crests, and long mud intrusions in the overlying metagraywacke. Crests and intrusions are generally asymmetric and point in the same direction (fig. 9, fig. 10, fig. 11, fig. 12, fig. 13). The structures seem to be flowage casts (Birkenmajer, 1958), or load casts (also called flow casts by Prentice, 1965; and torose-load casts by Crowell 1955),*) and they show great similarity to "flame-structures" (Walton, 1956; Kelling and Walton, 1957**), or "sawtooth-shaped contortions" (Mellen, 1956).

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*) The term "flow casts" for sedimentary structures was used first by Shrock (1948), and the term "load casts" by Kuenen (1953 a, 1953 b), but neither writer had differentiated directional and non-directional markings of such type.

**) Interpretated by these writers as "flute-load-casts".

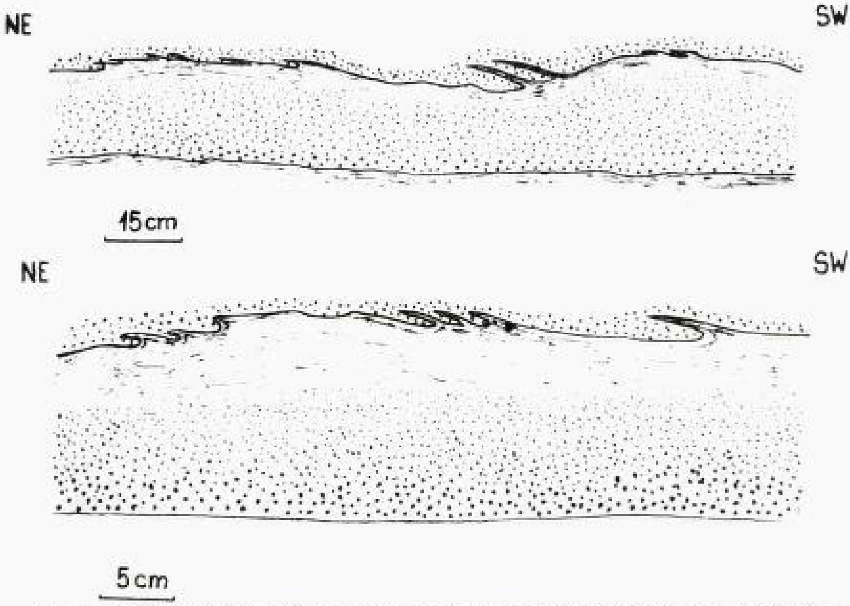

Fig. 9. Flame-structures (flowage casts or load casts). S shoreline of the Western Fjergen Lake.

Flammestrukturer (flomavstøpninger eller pålastningsavstøpninger), sørbredden av Vest-Fjergen.

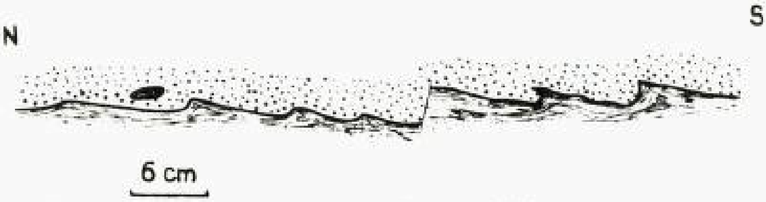

Fig. 10. Flowage casts (load casts). The Grønbekk stream, upper part.

Flomavstøpninger (pålastningsavstøpninger), øvre del av Grønbekken.

Similar, non-directional forms have been described by Kuenen (1957) as "load-casted flow marks." Since "flame-structures" in the metagraywacke-slate series show a distinct direction, they are probably formed in one of three ways: (1) by differential loading which accentuates the primary flute casts, or (2) by gravity creep of the overlying soft sandy sediment which incorporates the underyling mud, or (3) by a combination of the two methods. Dzułynski (1963) from work in the Carpathian flysch has described similar directional clay instrusions caused by sand flow.

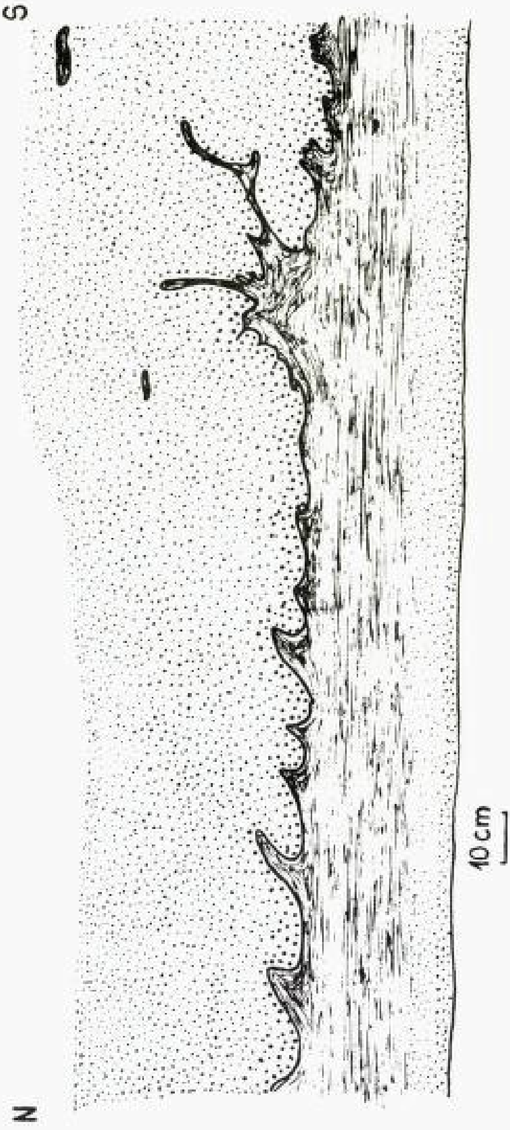

Fig. 11. Flame structures (flowage casts or load casts) and shale clasts floating in a metagraywacke. S shoreline of the Western Fjergen Lake.

Flammestrukturer (flomavstøpninger eller pålastningsavstøpninger) og skifer filler flytende i en metagråvakke. Sørbredden av Vest-Fjergen.

Fig. 12. Flame structures (flowage casts or load casts). Main road to Storlien, between Meråker and Grønberg.

Flammestrukturer (flomavstøpninger eller pålastningsavstøpninger). Mellomriksveien til Storlien mellom Meråker og Grønberg.

Fig. 13. Flame-structures (flowage casts or load casts). Main road to Storlien, between Meråker and Grønberg.

Flammestruk'urer (flomavstøpninger eller pålastningsavstøpninger). Mellomriksveien til Storlien, mellom Meråker og Grønberg.

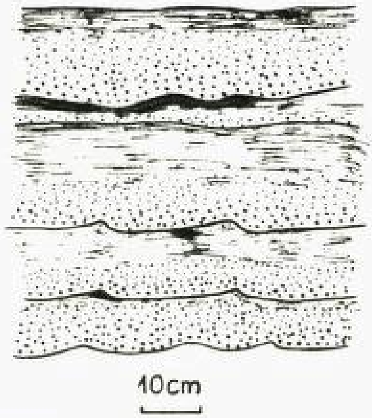

Fig. 14. Ripplemarks (?). The Lillekjerringelva river, upper part.
Bølgeslagsmerker (?). Øvre del av Lillekjerringelva.

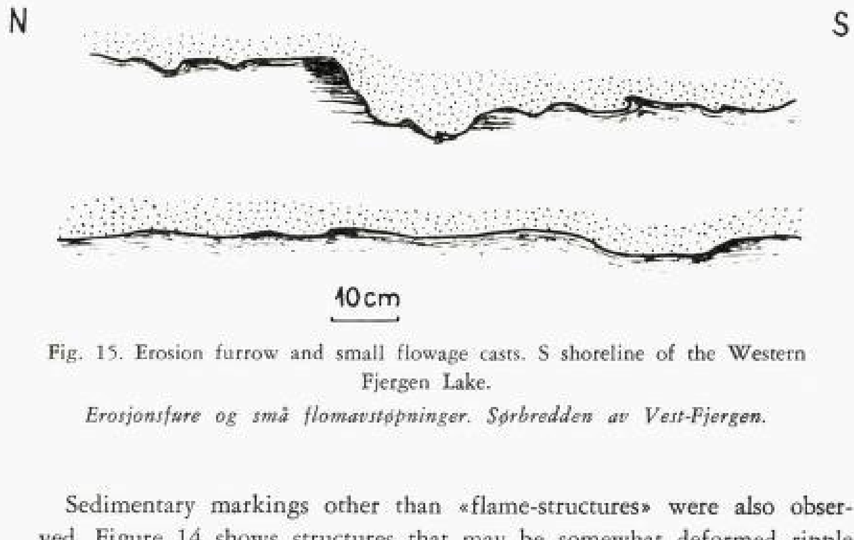

Fig. 15. Erosion furrow and small flowage casts. S shoreline of the Western Fjergen Lake.
Erosjonsfure og små flomavstøpninger. Sørbredden av Vest-Fjergen.

Sedimentary markings other than «flame-structures» were also observed. Figure 14 shows structures that may be somewhat deformed ripple marks. In fig. 15, the cross-section of an assymmetrical erosion furrow, and small later developed flowage casts are visible. Shale clasts, floating in the sandy sediment in the lower part of the metagraywacke layers (fig. 11, fig. 16), also indicate that subaqueous erosion of the sea bottom occurred.

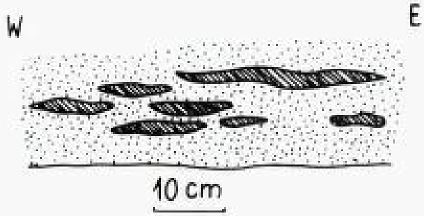

Fig. 16. Shale clasts floating in a metagraywacke. Meråker railway between the Grønbekk stream and Kopperå station.

Skiferfiller "flytende" i en metagråvakke. Meråkerbanen mellom Grønbekk og Kopperå stasjon.

5) Graded bedding is common. It is especially well developed in the thick metagraywacke layers. The most common type is asymmetric single normal graded-bedding (Fig. 17) but, more complicated graded bedding types were also observered, e. g., multiple grading in one layer, or asymmetric single inverted graded-bedding (terminology after Birkenmajer, 1959).

6) In the upper part of the fine-grained metagraywacke layers cross-bedding was sometimes noted. From the outcrops observed current direction could not be determined.

7) Metagraywackes are poorly sorted and consist of clayey, silty and sandy material; the clay and silt extend throughout the graded bedded layers. Prior to mechanical analysis the proportion of psammitic grains to the clay-silt matrix was determined. Three granulometric analyses were done following Krumbein's (1935) technique. The boundary between the sand and silt material was established at 0,06 mm (cf. Wentworth, 1922). The following grain size intervals > 0,06 mm were established:

0,06 —0,12 mm
0,12 — 0,18 mm
0,18 — 0,24 mm
0,24 — 0,30 mm
0,30 — 0,36 mm
0,36 — 0,42 mm etc.

Grains of quartz, feldspar, and rock fragments were measured; the biotite porphyroblasts were not. Sericite and chlorite flakes were generally under 0,06 mm in size. The results (see cumulative curves, fig. 18) show that the metagraywackes are poorly sorted and contain much clay and silt. These sediments were silty- and clayey sands prior to diagenesis and metamorphism.

Fig. 17. Graded bedding. Main road to Storlien, between Meråker and Grønberg.
Gradert lagning. Mellomriksveien til Storlien mellom Meråker og Grønberg.

The authigenic quartz recrystallization, and tectonic deformation of clastic grains, caused primary grains boundaries to be indistinct. Therefore, grain-size measurements could only be approximated. For the same reason roundness of grains could not be determined. In cases where the boundary between the clastic grain and the secondary quarts rim was distinct, a low roundness class was visible.

Petrology

As a result of microscopic investigations the following rock types has been subdivided:

A. Feldspathic metagraywackes. These rocks (Fig. 19—22) are fine grained, most commonly with grain-sizes up to 0,5 mm only. The texture is either massive or parallel. The parallel texture occurs only where the flaky

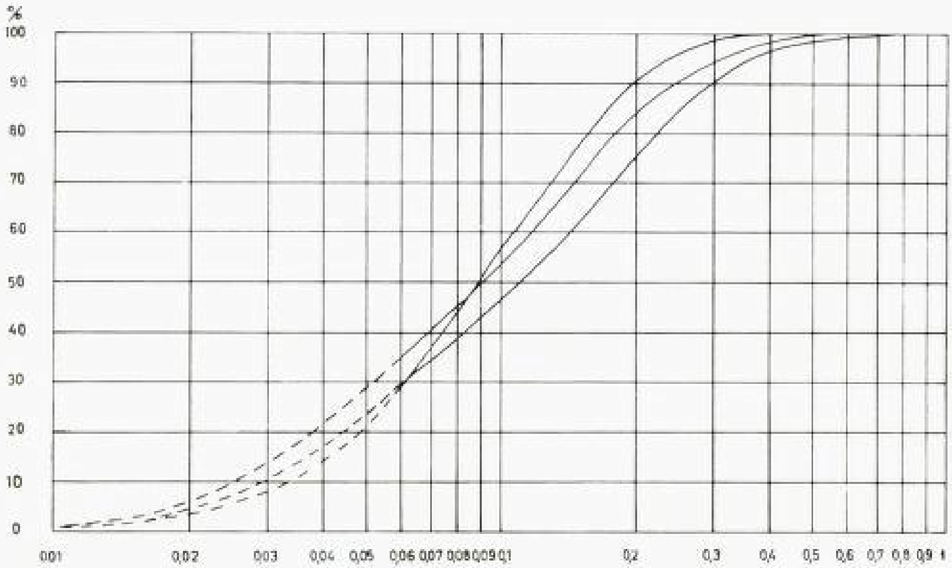

Fig. 18. Cumulative curves showing the granulometric composition of metagraywacke.
Kumulative kurver som viser den granulometriske sammensetning av metagråvakker.

minerals have a parallel orientation. Feldspathic metagraywackes consist mainly of quartz and feldspar, with occasional rock fragments. These components are evenly distributed throughout a matrix consisting of microcrystalline quartz, chlorite, sericite and plagioclase. The conventional boundary between coarser grains and matrix (ca. 0,6 mm) is used. Calcareous cement partly replaces the matrix. The secondary metamorphic epidote minerals and biotite occur in varying quantities; opaque minerals such as pyrite and iron oxide also appear.

The volumetric ratios between the constituents of the feldspathic metagraywackes were determined by statistical microscopic analyses*) and are summarized in Table 1 (p. 58).

A description of the constituents of the feldspathic metagraywackes follows:

Quartz. Detrital grains of quartz are either isometrical or somewhat elongate. Generally grain boundaries are very irregular due to overgrowths of authigenic quartz. In a few cases the boundary between the surface of

*) The point-count method of Chayes (1949) was used with the linear method as control.

Fig. 19

Fig. 20

a clastic grain and secondary quartz rim was observed. The recrystallization of authigenic silica caused individual grains to join forming larger grains. Some quartz grains show strain shadows when seen under crossed nicols. Most quartz grains contain inclusions, which were not studied in detail.

Feldspar. Detrital grains of feldspar are mostly plagioclase. The grains have the subangular shapes which are the result of little mechanical abrasion and cleavage. Plagioclases are relatively fresh and show albite twinning. Grains with both albite and pericline twinnings appear less frequently. Measurements of plagioclases taken on sections normal to 010 show that they contain ca. 10 % An (albite - oligoclase). Potassium feldspars, and perthites have been observed less frequently than plagioclases.

Rock fragments. 1) Fine-grained volcanic rocks with intersertal texture. These rocks consist of lath-shaped plagioclase (albite?), or of plagioclase and the allotriomorphic quartz, often with accessory chlorite. Scarcely any fragments of volcanic rocks with porphyric texture, in which the plagioclase phenocrysts are distributed through the fine-grained plagioclase background, were observed. 2) Quartzites. Quartzites are rare; they were visible only in coarser-grained metagraywackes. In fine-grained metagraywackes, quartzite fragments have probably been disintegrated. 3) Fragments of quartz-sericite and quartz-sericite-chlorite schists. These fragments are not common and are distinct only in the coarser-grained metagraywackes.

Matrix. The matrix is generally composed of ca. 30 % quartz, ca. 30 % chlorite, ca. 30 % sericite and ca. 10 % plagioclase. Quartz always shows strong regeneration. Chlorite occurs in very small flakes and has optical features similar to penninite.

Fig. 19. Metagraywacke. Main road to Storlien, ca. 4 km W of the border between Norway and Sweden. (Photomicrograph by O. Brynhildsrud, magnification X 24, crossed nicols.)

Metagråvakke. Mellomriksveien til Storlien, ca. 4 km vest for riksgrensen. (Mikrofoto ved O. Brynhildsrud, forstørrelse X 24, x-nicoler.)

Fig. 20. Metagraywacke. Little unnamed lake, ca. 1,5 km NNE of the Bukhammer mountain. (Photomicrograph by O. Brynhildsrud, magnification X 24, crossed nicols.)

Metagråvakke, lite navnløst tjern ca. 1,5 km nord-nordøst for Bukhammeren. (Mikrofoto ved O. Brynhildsrud, forstørrelse X 24, x-nicoler.)

Fig. 21

Fig. 22

Calcareous cement. Calcareous cement is mostly calcite with subordinate amounts of other carbonates. It is present in distinct anhedral concentrations. Sometimes it also forms thin veins. Calcareous cement occurs in various quantities in the several of the thin sections examined (see Table 1).

Minerals from the epidote group. The minerals from the epidote group (epidote, clinozoisite) occur either as small isolated concentrations, or as well developed crystals ca. 0,05 mm in diameter.

Biotite. Biotite occurs as porphyroblasts, from 0,05 to 2 mm in size. The smaller porphyroblasts are mostly unoriented. The large ones (often with poikiloblastic texture) are parallel to the slate and phyllite foliation, which is not visible in the metagraywackes.

B. *Slates and phyllites.* These rocks (Fig. 23) are closely related to the metagraywackes. The top part of the graded layer of metagraywacke is often slaty and similar to the matrix in the lower part of the same layer. The mineral composition of slates and phyllites is as follows: quartz (ca. 30—60 %), sericite and muscovite (ca. 10—35 %), chlorite (ca. 5—40%). The minor constituents are plagioclases*), minerals of the epidote group (ca. 1—3 %), porphyroblasts of biotite (1—5 %) and of the opaque minerals (pyrite, magnetite?) (1—2 %). In slates lying near the calcareous metasiltstones, carbonates (ca. 15—20 %) were sometimes observed. These slates therefore form a transition from the slates and phyllites to the calcareous metasiltstones.

Slates and phyllites show parallel or lepidoblastic texture. Chlorite

*) Quantitative determination is difficult because the rock is very fine-grained.

Fig. 21. Metagraywacke. Ca. 1,5 km NNW of the Skillerfjell mountain. (Photomicrograph by O. Brynhildsrud, magnification X 24, crossed nicols.)

Metagråvakke. Ca. 1,5 km nord-nordvest for Skillerfjell. (Mikrofoto ved O. Brynhildsrud, forstørrelse X 24, --nicoler.)

Fig. 22. Metagraywacke. Main road to Storlien, ca. 2 km W of the border between Norway and Sweden. (Photomicrograph by O. Brynhildsrud, magnification X24, crossed nicols.)

Metagråvakke. Mellomriksveien til Storlien, ca. 2 km vest for riksgrensen (Mikrofoto ved O. Brynhildsrud, forstørrelse X 24, x-nicoler.)

Fig. 23

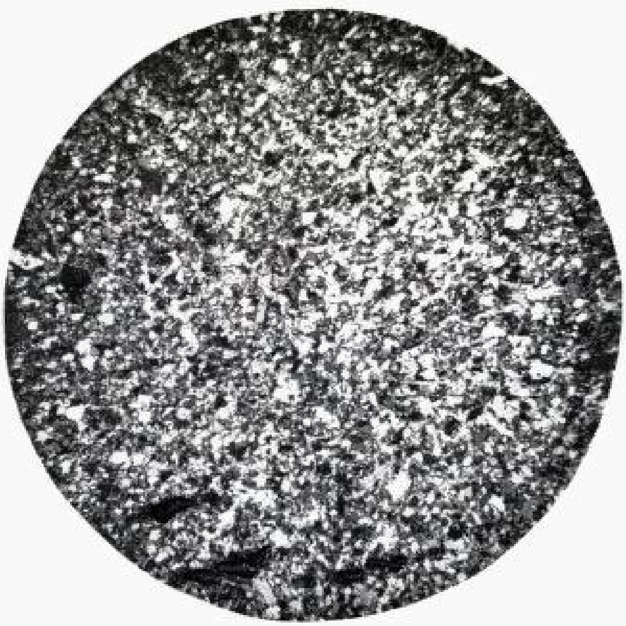

Fig. 24

and sericite flakes are very small but well defined. Quartz is partly regenerated, and some grains are slightly elongated parallel to the flaky minerals. A secondary cleavage crosses the original bedding and causes (1) a displacement and/or contortion of the bedding planes, (2) strain shadow and deformation of muscovite and sericite flakes, and (3) a complete destruction of bedding, if the cleavage planes occur close to one another.

Among the slates and phyllites, especially in the westernmost part of area schists were observed. They have the same mineral composition as the slates and phyllites, but are coarser-grained due to greater metamorphic recrystallization. Muscovite forms relatively large flakes and shows an exellent orientation. Quartz is completely regenerated, and its grains are more distinctly elongated parallely to the muscovite and chlorite flakes.

C. *Calcareous metasiltstones.* The calcareous metasiltstones (Fig 24) occur either as the thin independent layers within the metagraywacke-slate series, or as the upper parts of thick, graded layers of metagraywackes. Texturally they are an intermediate gradation between the metagraywackes, and slates or phyllites.

The calcareous metasiltstones occur more commonly in the Kjerringfjellene's zone. In the Bukhammer-Monsklumpene's zone, it was observed that metagraywackes grade directly into slate or phyllite. Metasiltstones have massive, or indistinct parallel texture caused by orientation of platy minerals. In some cases they show primary lamination, or graded bedding. The main constituents of calcareous metasiltstones are:

Quartz grains. Quartz grains (ca. 30—50 %), which reach a maximum of 0.1 mm in diameter, are generally $< 0{,}06$ mm. They are angular and often corroded by carbonates.

Fig. 23. Phyllite from the metagraywacke-slate series. The Grønbekk stream, upper part. (Photomicrograph by O. Brynhildsrud, magnification X 24, crossed nicols.)

Fyllitt fra metagråvakke-skiferserien, øvre del av Grønbekken. (Mikrofoto ved O. Brynhildsrud, forstørrelse X 24, x-nicoler.)

Fig. 24. Calcareous metasiltstone from the metagraywacke-slate series. Meråker railway, ca. 300 m W of Teveldal station. (Photomicrograph by O. Brynhildsrud, magnification X 24, crossed nicols.)

Kalkholdig metaleirstein fra gråvakke-skiferserien. Meråkerbanen, ca. 300 m vest for Teveldal stasjon. (Mikrofoto ved O. Brynhildsrud, forstørrelse X 24, x-nicoler.)

Plagioclases. Plagioclases (ca. 2—5 %) occur as small anhedral grains.
Matrix. Matrix (ca. 20—35 %) is composed principally of chlorite, sericite and quartz. The platy minerals are more abundant than quartz.
Carbonates. Carbonates (calcite and dolomite) occur either as anhedral grains (ca. 0,05—0,1 mm in diameter), which are sometimes twinned, or as simple rhombic crystals ca. 0,03—0,04 mm in size.

Minor constituents of the calcareous metasiltstones are biotite porphyroblasts and opaque minerals up to 1 mm in size. Many of the biotite porphyroblasts show poikiloblastic texture.

Metaconglomerates

Many layers of metaconglomerate occur in the Kjøllhaugene Group in the eastern zone. In the western zone they were observed in only one very poor outcrop on the south shore of West Fjergen lake.

Metaconglomerates from the Kjerringfjellene Mts. and similar sediments from the Kjøllhaugene and Halsjøfjell areas (north of the mapped area) were known to previous geologists. The metaconglomerates were reported by Kjerulf (1883), Törnebohm (1896), and Carstens (1920). Törnebohm (1896) mentioned the lateral disappearance to the south and north of the Kjøllhaugene conglomerates. Carstens (1920) first compared these conglomerates with the Lyngesten conglomerate from the Gauldalen valley.

In the mapped area metaconglomerate layers reach thickness of 3 m. Only i one profile, located between mountain tops 1067 m and 1018 m (Pl. II), were two layers greater than 10 m thick observed. Sparsely distributed pebbles were visible in some of the metagraywackes and metasiltstones lying above or below the metaconglomerate layer.

The metaconglomerates are poorly sorted and have white, grey and pink quartz and quartzite pebbles as the principal constituents. Accessory pebbles of limestone and of dark-grey and black volcanic (?) rocks occur. Pebble roundness varies greatly from subangular to well rounded fragments. The fine-grained material is less rounded than the coarse-grained material. Frequently the pebbles are scattered throughout an abundant matrix (conglomeratic mudstone), but in some layers they are closely packed. The coarser pebbles and cobbles, especially in metaconglomerates with a very abundant matrix, are elongated and oriented parallel to the bedding planes. This orientation seems to be in part a secondary, tectonic feature. The matrix of metaconglomerates is sandy and/or silty and is identical to the texture of the surrounding metagraywackes, metasiltstones, and slates.

An important characteristic of metaconglomerates is their lateral change. In the northeast part of the map area (Pl. II) the metaconglomerates are pebbly (material is up to ca. 5 cm in diameter) with a few cobbles as much as 20 cm in diameter. Southward the metaconglomerates gradually become finer-grained; those with closely-packed pebbles disappear, and only the conglomeratic mudstones occur. Further south conglomeratic mudstones grade into gravelites, gravelly metagraywackes or siltstones, and finally as the pebbles disappear, to the metagraywackes, metasiltstones, or slates of the metagraywacke-slate association. Because of the lateral change of the metaconglomerates, five to ten conglomeratic layers, not seen in the profile along the main road to Storlien, are seen in different profiles adjacent to Halsjøen lake. In the profile along the main road to Storlien, in two localities fine-grained conglomeratic mudstones were observed and in one locality a gravelly metagraywacke.

SLÅGÅN GROUP

Black-grey metasiltstone-slate association

The black-grey metasiltstones and slates occupy the central part of the mapped area, between zones of the metagraywacke-slate association (Pl. II), and extend from the northern boundary of the map to the Storlien road. It is a continuation of the black-grey shales of Silurian age occurring in the Kjøllhaugene area. The zone of black-grey shales is visible on the Törnebohm's (1896) map. The rocks of this zone were also described by Reusch (1890) from a profile along the Meråker railway: «*Omtrent 2½ kil. i Ø for vogterhuset Tovmodalen møder man en tyndskifrig, smaarynhet, graa lerglimmerskifer, der holder ved omtrend 800 m. I den derpaa følgende kvidlige sandstenagtige bergart træffes den første dioritiske masse . . .*» (Reusch, 1890, p. 14). Reusch did not compare these rocks with the Silurian deposits from the Kjøllhaugene area. Minor occurrences of the black-grey metasiltstones and slates were also observed by me in the eastern zone of the metagraywacke-slate series near the Storkjerring lake.

The boundary between the black-grey metasiltstone-slate association and the metagraywacke-slate association of the western zone is distinct, but not sharp. The boundary between the black-grey metasiltstone-slate association and eastern zone of the metagraywacke-slate association is not distinct. There is a transition between both associations.

Within the mapped area the black-grey metasiltstone-slate association consisst of dark-grey calcareous metasiltstones, fine-grained metasandstones, and dark-grey and black slates and phyllites. Metasiltstones, slates and phyllites when seen in the field usually show a characteristic type of disintegration. They turn rusty-grey in colour, and weather extensively leaving abundant tabular and prolate fragments.

Metasiltstones and fine-grained sandstones commonly occur near the west boundary of the Kjerringfjellene's metagraywacke-slate zone (Pl. II), where they are observed as thin to medium thick, sometimes laminated beds intercalated between phyllites and slates. The sandy or silty laminae were also observed between slaty rocks.

Under the microscope the metasiltstones and fine-grained metasandstones show a massive or indistinct parallel texture, and consist of quartz grains, abundant matrix, many carbonates and accessory feldspars, biotite and opaque minerals. These minerals are described below.

Quartz. Quartz grains are commonly equidimensional; grain size reaches a maximum of 0,1 mm, but is most commonly $< 0,05$ mm. Primary boundaries of clastic grains are usually not recognisable due to overgrowth of secondary quartz and corrosion by carbonates.

Feldspar. Clastic grains of feldspar are usually poorly-rounded and in most cases are acid plagioclases.

Carbonates. Carbonates form two kinds of concentrations: (1) anhedral grains often twinned, up to 0,25 mm in size (calcite) and (2) rhombic crystals 0,025 — 0,05 mm in size, single or in aggregates, many of them with iron-oxide rims (dolomite).

Matrix. The matrix is a massive, very fine-grained mixture of quartz, chlorite and sericite.

Biotite. Biotite forms porphyroblasts.

Opaque minerals. Opaque minerals occur throughout the matrix in anhedral concentrations which reach a maximum of 0,25 mm in size.

Statistical microscopic analysis of metasiltstone shows the following composition:

quartz	21,3 %		
feldspar	3,6 %	quartz	ca. 45 %
matrix	33,8 %	sericite	ca. 35 %
carbonates	33,0 %	chlorite	ca. 20 %
biotite	7,5 %		
opaque min.	0,8 %		

Slates and phyllites usually have lepidoblastic texture parallel to the primary bedding. Relict structures, such as fine-graded bedding and lamination (interbedding of flaky minerals and quartz laminae) have been observed. The lepidoblastic texture is crossed by cleavage-planes. Because of the cleavage, bedding planes are displaced and contorted (Fig. 25, Fig 26). Cleavage is not visible in metasiltstones (Fig. 26) and metasandstones.

The major constituents of the slates and phyllites are either quartz, sericite and chlorite, or just quartz and chlorite. A few plagioclase fragments have also been observed. Many porphyroblasts are also present; most of them are biotite porphyroblasts, or poikiloblasts, up to 1mm in size, and porphyroblasts of opaque minerals (mostly pyrite) 0,5 mm in size.

Pyrite crystals lying parallel to bedding and deformed by cleavage were observed. Therefore, we know that the pyrite is older than the cleavage. In only one case have carbonate porphyroblasts and none of biotite been observed. Minor amounts of epidote minerals, zircon and tournalines are also present. The slates and phyllites described probably contain graphite (?) which accounts for the dark-gray and black colours.

Gabbro-diorite intrusions

Within the western zone of the Kjøllhaugene Group there occur many gabbro-diorite intrusions. These were known to previous geologists. Kjerulf (1883) was the first to mention numerous masses of diorite and saussurite gabbro from this area. He called the rocks on Midsundstøtten syenite-like rocks following O. Schiötz's usage. Reusch (1890) described the intrusions as diorite masses. Later, Carstens (1929) described these rocks as gabbro intrusions and gabbro-like pegmatite-veins.

The intrusions form sills which are injected into the metagraywackes and slates. The sills range in thickness from a few metres to ca. 100 m. Gabbro-diorite sills on Midtsundstøtten, and in the western part of Grønbæklien (Pl. II), are the largest which I have observed in the area. The gabbrodiorite sills show variations in colour and texture. They are (1) finegrained grey-green (e.g. near Kopperå station) and dark-grey (e.g. at the stream west of the Lillekjerringelva river), or (2) coarse-grained with feldspars and amphiboles up to ca. 2 cm in size (e.g. at Midtsundstøtten, and Grønbæklien, a part of the intrusions visible along the main road to Storlien). The largest coarse-grained sills show gradually finer grained texture towards the contact with the country rock. Contact-metamorphic zones are usually narrow, and represented by hornfelses with carbonate porphyroblasts.

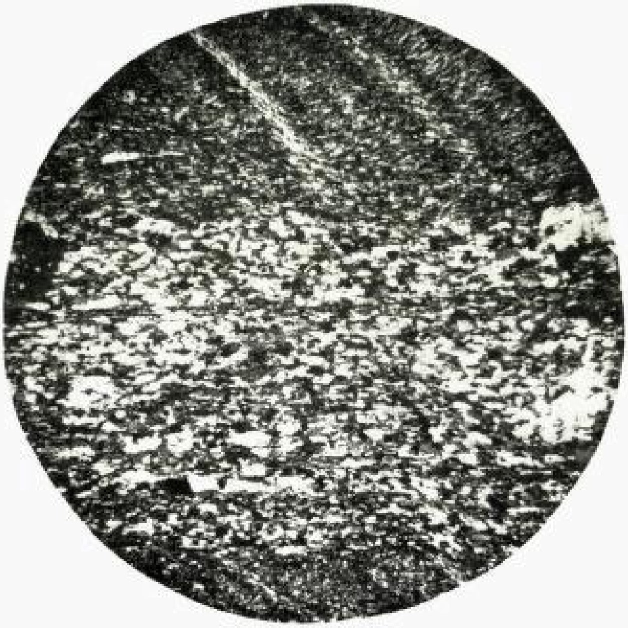

Fig. 25

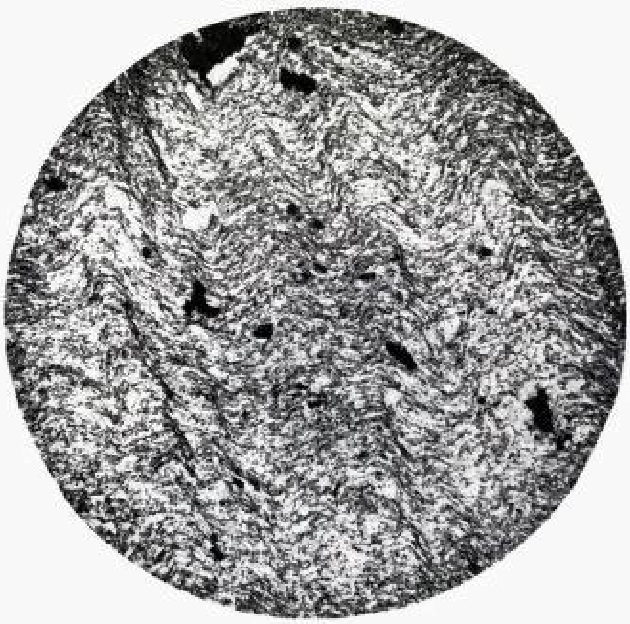

Fig. 26

The principal components of the gabbro-diorites are amphiboles (ca. 30—45 %) and plagioclases (ca. 30—60 %). Minor constituents are: biotite, chlorite, sericite, epidote minerals, quartz, carbonates, titanite and opaque minerals.

The plagioclases (ca. 35 % An) are either allotriomorphic or hypidiomorphic. Many are partly altered to saussurite. Amphiboles are idiomorphic or hypidiomorphic, and many are converted to biotite, or altered to aggregates of chlorite, carbonates, epidote and quartz.

Petrographic descriptions of gabbro-diorite instrusions will be made by F. Fediuk, who has my field samples.

Development of sediments

As has been mentioned, the metagraywacke-slate association oocupies most of the map area. Characteristics of the rocks have been described in detail (see p. 23 f.). Many preserved primary features are important indicators for the determination of (1) the sedimentary environment, (2) the mechanism of deposition, and (3) the geology of the source area.

The metagraywacke-slate association consists mostly of interbedded metagraywackes and slates. On the bedding surfaces between the metagraywackes and slates, sedimentary markings occur. Graded bedding is common, but sorting is so poor that in the lowermost parts of graded layers fine and coarse material occur together. Matrix is usually very abundant and has the same composition as slate. The sand-size material consists of quartz, feldspar and occasionally rock fragments. The term graywacke facies is applied to the sediments (whether weakly metamorphosed or not) which contain

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Fig. 25. Slate with a silty lamina from the black-grey metasiltstone-slate association. Main road to Storlien, ca. 0,5 km E of the last gabbro-diorite sill. (Photomicrograph by O. Brynhildsrud, magnification X 24, crossed nicols.)

Skifer med et leirlag fra den gråsvarte metaleirstein-skiferserien. Mellomriksveien til Storlien. Ca. 0,5 km øst for den siste gabbro-diorittgangen. (Mikrofoto ved O. Brynhildsrud, forstørrelse X 24, x-nicoler.)

Fig. 26. Slate from the black-grey metasiltstone-slate association. Ca. 1,2 km NNE of Monsklumpen. (Photomicrograph by O. Brynhildsrud, magnification X 24, plane polarised light.)

Skifer fra den gråsvarte metaleirstein-skiferserien, ca. 1,2 km nord-nordøst for Monsklumpen. (Mikrofoto ved O. Brynhildsrud, forstørrelse X 24, planpolarisert lys.)

the characteristic features mentioned above. The dominance of feldspar over rock fragments in the metagraywackes, seems to indicate a plutonic provenance for the clastic material. It is possible that feldspar was present in greather amounts prior to induration, and that its very fine grains have quickly disintegrated so contributing to the quartz-sericite matrix. The composition of metagraywackes also indicates the predominance of mechanical weathering in the source area. The low sorting index seems to be caused by quick, not selective transportation.

The next important problem to be considered is the environment of sedimentation of the graywacke facies, and its relation to flysch. The term flysch is used by some geologists exclusively as a facies term (e.g., Vassoevič, 1948, 1951: Sujkowski, 1957) by others as a facies and genetic term. In the second case, the term indicates both facies and a definite stage in the development of a geosyncline (e.g. Vassoevič, 1958; Bouma, 1962; Contescu, 1963.) In recent years flysch facies has been defined as a sequense of marine clastic sediments, characterized by an assemblage of positive and negative diagnostic features (e.g. Dzułynski, 1963; Dzułynski and Smith, 1964; Dzułynski and Walton, 1965). A comparison of these features with the characteristics of the metagraywacke-slate association shows that it conforms to the facies definition of flysch.

In many recent papers flysch deposits are considered as deep water sediments, deposited in a geosynclinal trough flanket by tectonically active source lands. The most important agents contributing to flysch sedimentation are thought to be gravity mass movements such as submarine slumps and slides, and turbidity currents (see Kuenen, 1958; Ksiazkiewicz, 1958). Many flysch formations can be called turbidite formations (Kuenen, 1964) if their characteristic features show that they are formed by turbidity currents. Most positive and negative features of turbidite formation (see Kuenen, 1964, p. 16) have been found in the metagraywacke-slate association in the Meråker area, and it is therefore concluded that this association is a graywacke and flysch facies (partly shaly flysch, partly sandy flysch), and a turbidite formation. An abundance of sedimentary markings, which is usually present in flysch and turbidite formations, has not been observed, but future detailed sedimentological studies may provide additional data.

It was not possible to study the directions of sediment transportation in the metagraywackes and slates in detail. The alinement of mud intrusions («flame-structures») indicates transport from the north or northeast, sometimes from the south, along the longitudinal axis of the sedimentary basin.

Metaconglomerates which occur within the Kjerringfjellene's zone of metagraywacke-slate association consists mostly of quartz and quartzite pebbles, and often have a similar character to conglomeratic mudstones. It does not seem possible that the quartz and quartzite pebbles, and the sandy or silty graywacke material, have the same provenance. If the source area was the same the conglomerates should have a polymictic character. A more probable hypothesis is that pebbly material was transported from another direction (e. g. from the E side of the trough), across and subordinate to the principal longitudinal direction. It is possible that pebbles and cobbles were transported from the shallow-water zone along shelf channels, and then along a submarine canyon crossing a continental slope, either by currents and/or by slump movements, to the deep-water zone of the basin. The occurrence of the metaconglomerates within the deep-water flysch sediments, the quick lateral disappearence of the metaconglomerates, and the commonly observed dominance of graywacke matrix over pebbles leads one to conclude that the conglomerates were deltaic sediments deposited at the mouth of a submarine canyon. Although there are several explanations for conglomeratic mudstones (called also tilloid conglomerates), in the Meråker area the most important fact, both as to genesis and stratigraphic interpretation, is that conglomerates occur within geosynclinal flysch sediments. The discussed tilloid conglomerates in the Meråker area are therefore thought to be deep water sediments.

In the eastern zone of the metagraywacke-slate association, the calcareous character of sediments is more common than in the Bukhammer-Monsklumpene's zone. This characteristic of the eastern zone seems to be related to a somewhat shallower water environment lying nearer the continental slope. Most pebbles of the metaconglomerates were transported and deposited in the shallower zone, but some were transported to the deeper western zone.

The similarity between the Meråker metagraywacke-slate association, and both the Silurian deposits of Wales and the Upper Ordovician deposits of Scotland, should be emphasized. The similarities occur in (1) the structural characteristic and mineral composition (see Wood and Smith, 1958), (2) the presence of «flame-structures» (see Walton, 1956; Kelling and Walton, 1957), (3) the common occurrence of graded bedding, and (4) the predominance of longitudinal directions of transportation (see Kuenen, 1957; Knill, 1954, 1960; Kelling, 1964).

The metagraywacke-slate association grades vertically into dark-grey and black slates and phyllites interbedded with meatsiltstones and fine-grained sandstones. The boundary between both associations is relatively distinct, but not sharp. The slaty-silty dark-grey and black rocks show the following features, important to determination of sedimentary environments: (1) a dominance of shales, (2) a dark-grey and black colour, (3) the presence of pyrite*), (4) usually an abundance of carbonates, and (5) the presence of planktonic and/or epiplanktonic fauna (*Monograptidae* and *Rastrites* from Kjøllhaugene). Sediments with such features are developed in euxinic environments at varying depths and are called black shale facies or euxinic facies.

Stratigraphy

Establishment of the stratigraphic position of the described beds is difficult because fossils are lacking, and lithology is very monotonous. The first stratigraphy was based on lithologic similarities between the Meråker area sediments and those of the western part of the Trondheim region. Later the stratigraphy was revised to include the Silurian graptolite fauna found by Getz (1890) in the dark shales of Kjøllhaugene .The graptolites from Kjøllhaugene were verified later by Elles (Kiær, 1932), who established that Getz's descriptions were correct, and that this fauna indicates sediments corresponding in age to the upper part of Middle, and Upper Birkhill time in England and Scotland.

Törnebohm (1896) described the rocks of the eastern part of the Meråker profile as the Meraker Group *(Meraker-gruppen),* and on the basis of the lithologic similarities compared it with the Hovin Group from the western part of the Trondheim region. The Meraker Group on Törnebohm's (1896) map is bounded on the west by the Sul Schists Group *(Sul skiffres gruppen),* which Törnebohm compared with the Høiland Group**). Törnebohm has included in the Sul Schists Group the dark shales in which the Silurian graptolites were found. Therefore, both the Sul Schists Group and the Høiland Group were considered Silurian in age by Törnebohm.

Carstens (1920) suggested that the so-called Lyngesten conglomerate from the Hovin district was similar to conglomerates from Kjøllhaugene; further that conglomerates from both areas, and shales with Silurian graptolites from Kjøllhaugene, together with the subjacent sandstones are younger than the Høilanda division (equal to the lower part of the Lower Hovin Series of

*) Pyrite can be partly secondary and not indicative of conditions of deposition.

**) This view, accepted by Carstens (1920), was later discarded because it was based on an incorrect interpretation of the tectonics in the western part of the Trondheim region.

Kiær, 1932; and Vogt, 1945). Later writers (Kiær, 1932; Vogt, 1945; Strand, 1960: Wolff, 1964) accepted Carstens' correlation and assign the conglomerates from Kjøllhaugene and Lyngesten to the Silurian. The series of subjacent sandstones and shales has been included in the Upper Hovin Group. The age of this group is thought to be Ashgillian because, in the western part of the Trondheim region, shales with graptolite fauna of Caradocian age occur below a similar sandy series and below the Volla conglomerate.

From field observations of the author it has been established that:

1. The black-grey metasiltstone-slate association is a continuation of the Silurian dark shales from the Kjøllhaugene area. No fossils were found in the map area. To the south, the rocks show higher grade metamorphism which may have caused complete destruction of the fauna.
2. The sedimentary structures occurring in the metagraywacke-slate association show that both the eastern and western zones of this series are older than the black shale facies containing the graptolite fauna.
3. There is a continuity of sedimentation between the graywacke facies and black shale facies.
4. Layers of metaconglomerates occurring within the metagraywacke-slate association do not delineate any stratigraphic boundaries.

Since other areas in the Trondheim region were not visited by the author, it is difficult to compare rocks from other parts of the Trondheim region with those found in the mapped area (Pl. II). Some similarities can be drawn between the metaconglomerates of the mapped area and the Lyngesten conglomerate, which has been described in detail by Vogt (1945). The principal similarity between the conglomerates is the dominance of the quartz and quartzite pebbles. However, differences exist indicating different sedimentary environments. The Lyngesten conglomerate (Vogt, 1945) is a basal conglomerate and is an index layer for the stratigraphy. Moreover, « . . *Details previously mentioned by Brøgger display unconformable relations to the substratum, and the conglomerate apparently also overlaps older beds*» (Vogt, 1945, 523). Vogt (1945) regarded the Lyngesten conglomerate as an effect of the Horg disturbance which occurred between Ordovician and Silurian. The Horg disturbance caused the elevation above sea level and the denudation of land masses in the Horg area. Vogt suggested that, in his area, it was a regresion and denudiation that caused a stratigraphic hiatus.

A comparison of features characteristic of both the Lyngesten conglomerate and the metaconglomerates from Kjerringfjellene (see p. 38; 45) show that both have (1) similar composition and (2) different genetic features. These two conglomerates were deposited under different conditions. While the Lyngesten conglomerate is probably a littoral sediment, the metaconglomerates from Kjerringfjellene are deep marine conglomeratic mudstones interbedded with flysch and cannot be used as direct evidence for orogenic disturbance.

The differences between the conglomerates do not negate possibility of contemporaneous deposition, but indicate that stratigraphic correlation cannot be based here solely on the lithologic character of pebbles.

As mentioned earlier, the boundary between the metagraywacke-slate association with metaconglomerates, and the black-gray metasiltstone-slate association of Silurian age is not sharp. Therefore, the stratigraphic boundary between the Ordovician and Silurian may only be shown by a facies change in the Meråker area. The difference in depositional environment, between the northern and western part of the Trondheim region, is probably caused by the greather distance of the Meråker area from the former sea-shore. There was continuous deposition in the Meråker area, first, the rapid, deep-marine sedimentation of flysch, and later the slower deposition of the black shale facies.

From the present work, it is concluded that the stratigraphy of the Meråker area is as follows:

Black-grey slates, phyllites, metasiltstones and finegrained metasandstones	Slågån Group = Horg Group = Lower Silurian
Metagraywacke-slate association with metaconglomerates	Kjøllhaugene Group = Upper (?) Hovin Group = Upper (?) Ordovician

The gabbro-diorite sills occurring in the western zone of the metagraywacke-slate association are younger than the surrounding sediments and older than the main phase of Caledonian orogeny. A more exact dating of the sills is very difficult.

Rocks showing similarities to the metagraywacke-slate association have recently been described from the Verdalen valley north of Kjøllhaugene, and from the Blåsjö lake area in Jämtland (Sweden). These rocks may be an extension of the metagraywacke-slate series from the Meråker area. From the eastern part of the Verdalen valley area, Wolff (1960) described the Vera schists as consisting mainly of chlorite schists with biotite porphyroblasts and including horizons of quartzite conglomerates. He correlates the conglomerates with those from Kjøllhaugene and concludes that the Vera schists are Silurian in age. The black-grey Silurian shales known from Kjøllhaugene are not found in the Verdalen valley area; they disappear probably in the northern part of the Kjøllhaugene area (see Törnebohm's map, 1896).

Nilsson (1964) has described the Blåsjö phyllite, which is a calc-phyllite with gabbro intrusions, from the Blåsjö area. "*This calc-phyllite has been deposited fairly rapidly in shallow well-areated sea-water as marls- calciferous sandstones and muds*" (Nilsson, 1964, p. 66). Nilsson regards the Blåsjö phyllite as the lowermost unit in the succession (older than Lower Ordovician). Descriptions of the sedimentary structures are lacking, however, petrographic characteristics seem to indicate that the Blåsjö phyllite could be an equivalent of the metagraywacke-slate association. If future comparative studies indicate that the same rocks occur in the Meråker, Kjøllhaugene, Verdal and Blåsjö areas, as seen by gradually shallower facies northward, the stratigraphy in the Blåsjö area should be revised.

Remarks concerning the structural geology

Recognition of structures is very difficult because: (1) only two lithostratigraphical units occur in the area; (2) the metagraywacke-slate association probably changes laterally and vertically from shaly flysch to sandy flysch; (3) guide horizons are lacking; and (4) the beds are very strongly contorted and folded. The multiplication of the small folds does not permit measurements of thickness of particular series.

Generally, the beds strike NNE with some local variations to N or NE. In the western part of the area the beds dip 30—100°*) W (27—90°). In the eastern part of the area they dip to the east, the angles of dip are gradually smaller to the east, and some of the beds lie horizontally (E part of Kjerringfjellene Mts.). The relations are expressed in cross-sections (Pl. II).

Two fold structures within the western zone of the metagraywacke-slate association have been observed: the Midtsundstøtten syncline and Grønbæklien syncline (Pl. II). The Midtsundstøtten syncline is very well exposed (Fig. 27); it is asymmetrical with a ca. 90° (81°) steep western limb and gentle, ca. 25° (22,5°), eastern limb. The axial plane of the syncline dips to the west. Moreover, a gabbro-diorite sill which can be traced in both limbs clearly marks the syncline's form. The Grønbæklien syncline is poorly

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*) A Swedish compass with 400° was used. The measurements in parenthesis are recounted to 360°. All measurements of strike and dip shown on the geological map are those of the 400° compass.

Fig. 27. Western limb of the Midtsundstøtten syncline, looking south.
Vestsiden av Midtsundstøttens synklinal sett mot syd.

exposed. However, it was possible to trace this syncline because a gabbro-diorite sill, folded conformably to the sedimentary layers, is very distinctly reflected in the surface morphology. A second, nearly completely eroded, gabbro-diorite sill gives a characteristic hill in the central part of the syncline. Many small folds were observed in addition to those of the Midtsundstøtten and Grønbæklien synclines, especially in the slaty incompetent complexes. Such folds (fig. 28, 29, 30, and 31) are mostly tight or isoclinal cleavage folds, disharmonic folds, and tectonic contortions.

Metagraywackes interbedded with some slates occur to the east of the Midtsundstøtten and Grønbæklien synclines (Pl. II). These beds are inverted (as indicated by sedimentary structures) and lie in contact with the metasiltstones and slates of Silurian age to the east. It seems probable that the metagraywacke complex forms an anticline with a tectonically reduced western limb. A second possibility is that the anticline is a folded group of sediments in which a facies change occurred; i.e., the western limb (eastern limb of the Midtsundstøtten syncline) consists of the slates and metagraywackes, while the eastern limb consists of only metagraywackes (see Pl. II). In this case, the anticline

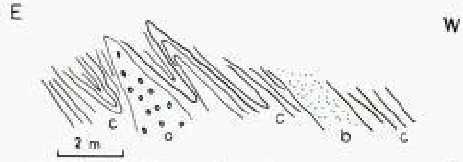

Fig. 28. Tight or isoclinal folds observed in the eastern zone of the metagraywacke-slate association. a — conglomeratic mudstone, b — metagraywacke, c — slate.
Bratte, tette folder observert i den østre sonen av metagråvakke-skiferserien. a. Konglomeratisk slamstein, b. metagråvakke, c. skifer.

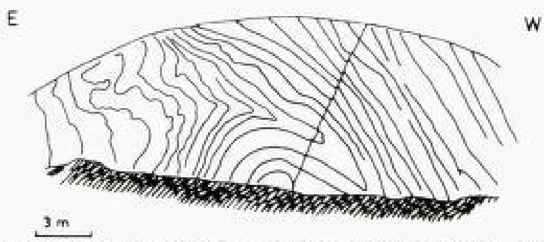

Fig. 29. Folded and contorted beds in the western zone of the metagraywacke-slate association (above S shoreline of the Fjergen lake).
Foldede og vridde lag i den vestre sonen av metagråvakke-skiferserien (over sørbredden av Fjergen).

Fig. 30. Folds and joints in the western zone of the metagraywacke-slate association. a - quartz. Meråker railway.
Folder og sprekker i den vestre sonen av metagråvakke-skiferserien. a - kvarts. Meråkerbanen.

Fig. 31. Folds in the eastern zone of the metagraywacke-slate association. Cross-section along a fissure cutting the Skillerfjell mountain.
Folder i den østre sonen av metagråvakke-skiferserien. Snitt langs en sprekk som skjærer Skillerfjell.

need not have been tectonically reduced. To the east is a relatively large syncline having the younger, Silurian rocks in the trough.

Further eastward tectonic interpretation is based on stratigraphy and on small folds. The Silurian rocks also crop out in the southeastern part of the area and have been interpretated as synclinal folds. In the northeastern part of the area only rocks of the Kjøllhaugene Group crops out, dipping first west and then east. The style of folding seen in the cross-sections (Pl. II, C-D; E-F) is diagrammatic and shows only the general type of folds in the area. Although faults were not observed, many vertical fissures occur and trend east or eastsoutheast. They can be traced for several kilometers. Cleavage is very common, but no measurements were taken as a detailed study of the tectonics in the south of the area has been done by D. Roberts.

Generally, the structure of the mapped area can be interpreted as a fold-compressive type, with the direction of the deformative stress from west to east.

Traces of tectonic phases earlier than the main Caledonian orogeny have not been found.

Metamorphism

The textures and mineral composition of the rocks indicate that the deposits have undergone a low grade of metamorphism. Cleavage crossing the bedding is well-developed only in the pelitic rocks. The elongation of quartz grains is distinct, especially in the slates and phyllites. In the coarser-grained sediments quartz grains are relatively undeformed; in some parts of the meta-conglomerates however, and in a few coarse-grained metagraywackes, the pebbles and quartz grains are elongated. Chlorite and sericite usually show an excellent orientation parallel either to the bedding, or to the cleavage. Chlorite and sericite are probably altered clay minerals, which primarily formed the shale and the graywacke matrix. The new metamorphic constituents of the rocks are biotite and the epidote minerals. Biotite forms the relatively large porphyroblasts and poikiloblastic metacrysts; both are generally parallel to the cleavage.

Carbonates and authigenic quartz are also secondary constituents of the rocks, but their presence could have been caused by diagenesis, not necessarily by metamorphic phenomena. A replacement of silicates by the carbonates could take place during both diagenesis and metamorphism. It is not possible to distinguish between the generations of carbonates. Some of the carbonates have probably originated during the formation of epidote.

The quantities of biotite and epidote seem to increase towards the west, but this increase is not very distinct. This phenomenon could indicate the increasing intensity of metamorphism to the west. The minerals and textures indicate that the rocks belong to the greenschists facies, and perhaps in part to the albite-epidote-amphibolite facies. It is not possible to drawn a boundary-line between the two facies.

The gradual increase of metamorphism toward the west is in agreement with the metamorphic zones described by Goldschmidt (1915) in the area south of Stjørdalen (southern part of the Trondheim region).

Conclusions

The most important conclusions are as follows:

1) The Upper Ordovician deposits in the map area are developed as the metagraywacke-slate association which represents a flysch facies and turbidite formation;
2) The metaconglomerates occurring within the flysch facies are also deep marine deposits and show no stratigraphic boundary;
3) The Silurian deposits from the Kjøllhaugene area continue southward through the map area and are a black shale facies.

In the paper sedimentological problems are emphasized. Because the sedimentological observations in the mapped area are of a preliminary character, and because the area is relatively small, no regional conclusions are possible. The continuation and development of sedimentological investigations in the Trondheim region would help to explain in more detail the history of this part of the Caledonian geosyncline, and could also be an useful method in stratigraphic correlation.

Oslo, February 1966.

Sammendrag

Sommeren 1965 kartla jeg et ca. 150 km^2 stort område ved Meråker (se Fig. 1). I området forekommer følgende grupper og ledd:

Kjøllhaugene Gruppen.

1) Metagråvake-skifer-serien, bestående av vekslende metagråvaker, skifre og i mindre antall også karbonatholdige metaleirstener (metasiltstones). Metagråvakene består hovedsakelig av kvarts, feldspat, noen få bergartfragmenter, matrix og karbonater. Matrix er en kvarts-kloritt-serisitt-plagioklas blanding. Metagråvakenes sammensetning fremgår av Tab. I. Skifrenes sammensetning

er svært lik metagråvakenes matrix. De karbonatholdige metaleirstener består av kvarts (30—50 %), plagioklaser (2—5 %) og relativt mye karbonater (opp til 30 %). Matrix er som i metagråvakene. Meget karakteristisk for alle disse bergartene er ca. 1—2 mm store biotitt-porfyroblaster. I matrix finnes også epidot og opake mineraler.

Serien viser en del primære strukturer som karakteriserer dannelsesforholdene. Metagråvakene er dårlig sorterte (fig. 7), og graded bedding forekommer ofte. På grensen mellom de graderte lagene finnes sedimentære strukturer (fig. 9, 10, 11, 12, 13) som sannsynligvis er *flowage casts* eller *load casts* og ligner meget på *flame structures* beskrevet fra Skottland (Walton 1956, Kelling og Walton 1957). Strukturer som ligner på deformerte ripple marks og spor av undervannserosjon ble også observert (fig. 11, 14, 15, 16).

2) Metakonglomerater, som forekommer i flere, noen få meter tykke lag i den østlige del av metagråvake-skifer-serien (Pl. II). I konglomeratene dominerer kvarts og kvartsittboller som oftest er opptil 5 cm i diameter, sjelden så store som 20 cm. Bollene blir mindre mot syd, dessuten blir det færre av dem, slik at matrix (som er identisk med metagråvakenes) dominerer mer og mer, og metakonglomeratene avløses ofte gradvis av metagråvaker.

Slågån Gruppen.

3) Svartgrå metaleirsten-skifer-serien. Metaleirstenene består hovedsakelig av kvarts, feltspat, matrix og karbonater, blant hvilke er mye dolomitt (statistisk analyse — se s. 40). Skifrenes hovedkomponenter er kvarts, serisitt og kloritt. De gir sort strek og er trolig grafittholdige. I serien forekommer også finkornete, mørk-grå sandstener (se Pl. II).

Serien er en fortsettelse av skifrene ved Kjøllhaugene hvor de siluriske graptoliter er funnet av Getz (1890). Man kan følge denne serien fra Fjergens sørstrand sørover til riksveien til Storlien (se Pl. II).

Intrusive bergarter.

4) Konkordante ganger (sills) av gabbro-dioritt. Gangene ble observert bare i den vestlige metagråvake-skifer-serien. De er fra noen få meter til omtrent 100 m tykke. Hovedkomponenter i gabbro-diorittene er amfiboler og plagioklaser. I mindre antall forekommer biotitt, kloritt, serisitt, epidot-mineraler, kvarts, karbonater, titanitt og opake mineraler.

I den undersøkte lagserie ble det ikke observert noen hiatus eller diskordans. Strøket er overveiende mot NNE med fall mot W, i den østlige delen av området delvis mot E.

Følgende hovedkonklusjoner kan trekkes:

A) Metagråvake-skifer-serien representerer dypmarin *flysch facies* og såkalt *turbidite formation*. Konglomerater som forekommer i serien er sannsynligvis avsetninger av deltaer av submarine kanaler. Metagråvake-skifer-serien ligner svært meget på de siluriske avsetninger i Wales og overordoviciske avsetninger i Skottland. Svartgrå metaleirsten-skifer-serien representerer såkalt svart skifer-facies (*euxinic facies, black shale facies*).

B) Metagråvake-skifer-serien med konglomerater svarer sannsynligvis til Øvre Hovin-Gruppe (Øvre Ordovicium). Svartgrå metaleirsten-skifer-serien svarer til Horg-Gruppen (Under Silur). Det er overgang mellom de to seriene. Konglomeratene viser ikke noen stratigrafisk grense.

C) Alle bergarter er sterk overfoldet og danner assymetriske synklinaler og antiklinaler skjøvet østover. Den største synklinalen har siluriske avleiringer i kjernen og den overordoviciske metagråvake-skifer-serien på begge sider (se Pl. II).

D) Sekundære forandringer av struktur og forekomster av epidot og biotitt porfyroblaster tyder på at metamorfosen i området svarer til grønnskifer-facies. Metamorfosen forsterkes vestover og svarer i den vestlige del av området muligens til albitt-epidot-amfibolit-facies.

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Table 1. **Mineral composition of metagraywackes**

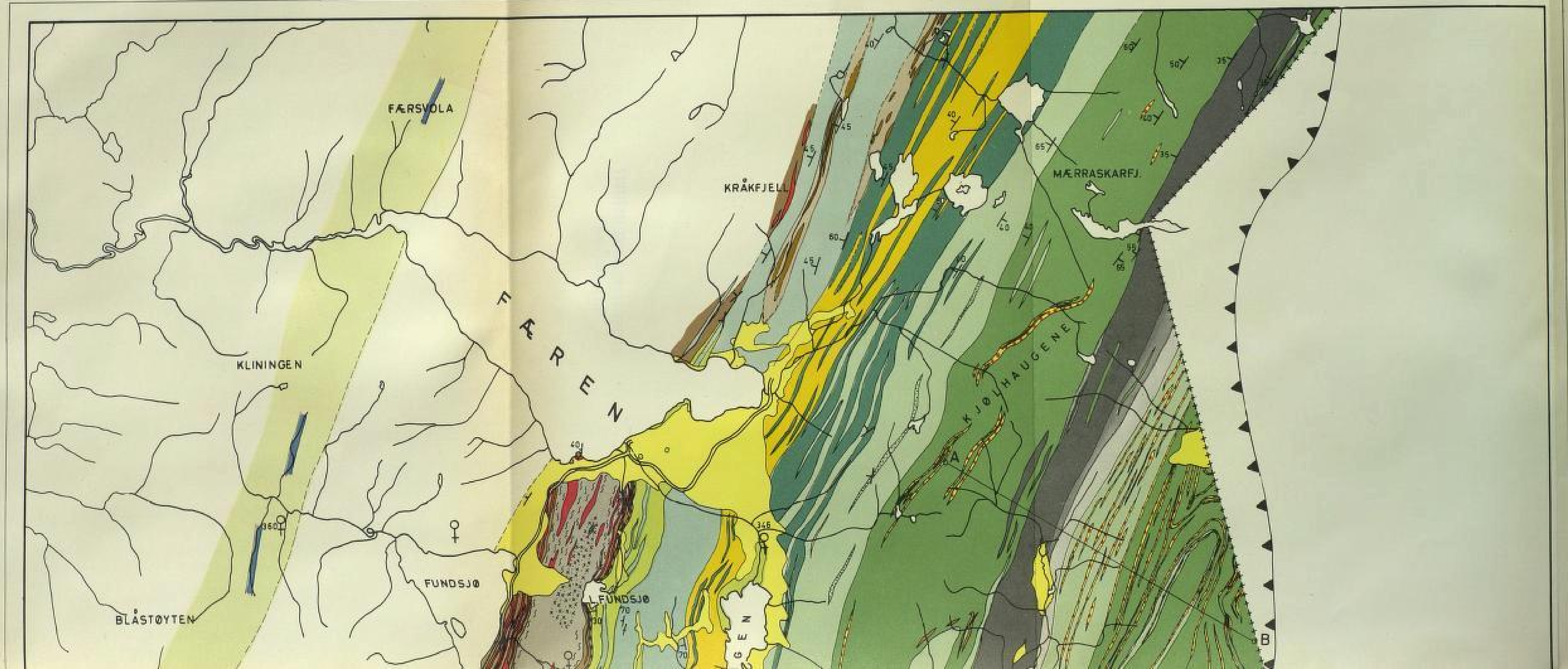
	quartz	feldspar	fragments of volcanic rocks	fragments of schists and quartzites	Matrix (< 0,06 mm)					carbonates	porphyroblasts of biotite	epidote	opaque minerals
					total	quartz	chlorite	sericite	feldspar				
Main road to Storlien, S of Teveldal station	31,4	11,2	2,0	2,8	36,3	30	30	30	10	11,0	5,2	—	0,1
Little unnamed lake, ca. 1,5 km NNE of Bokhammer	36,5	9,6	—	—	42,3	25	30	35	?	—	8,4	1,7	1,5
Lillekjerringelva river, upper part	13,8	4,2	0,6	—	59,5	30	30	30	10	10,3	10,7	—	0,9
Main road to Storlien, ca. 700 m from the border between Norway and Sweden ..	34,7	6,5	5,0	8,7	32,5	35	30	30	5	9,2	2,2	—	0,2
Unnamed stream W of the Lillekjerring-elva river	40,6	8,4	0,7	—	40,2	25	30	40	5	8,7	0,6	—	0,8
S shoreline of East Fjergen Lake, near Storfloa	37,1	3,4	+	+	50,0	35	25	30	5	0,8	7,9	3,0	0.2
Main road to Storlien near first (from E side) gabbro-diorite sill	35,4	8,4	—	0,3	37,3					3,6	15,0	—	—
Valley W of Skillerfjell	34,6	6,6	0,9	9,0	29,5	50	40	5	5	12,3	6,0	0,4	0,8
Hill ca. 1,5 km SE of Midtsundstøtten	38,0	10,2	—	—	38,6	35	20	30	15	9,4	3,2	—	0,6


KJØLHAUGENE

GEOLOGICAL MAP OF THE MERÅKER AREA

GEOLOGISK KART OVER MERÅKER

Scale 1:100 000



LEGEND

Quaternary.

Slågån Group (Silurian).

Grey to grey-black phyllite, slate and metasiltstone.

Grey slates with intercalations of metasandstone.

Grey metasandstone with intercalations of slate.

Kjølhaugen Group (Upper Ordovician).

Grey-green slates and phyllites with intercalations of metagraywacke.

The Kjølhaugene quartzite conglomerate.

Grey-green metagraywackes with intercalations of slate (dotted: thicker beds of subgraywacke).

Grey phyllite.

Sulåmo Group (Middle Ordovician).

Metabasite with banded structure.

Metabasite of massive structure.

Grey phyllite.

Grey calcareous metasandstone.

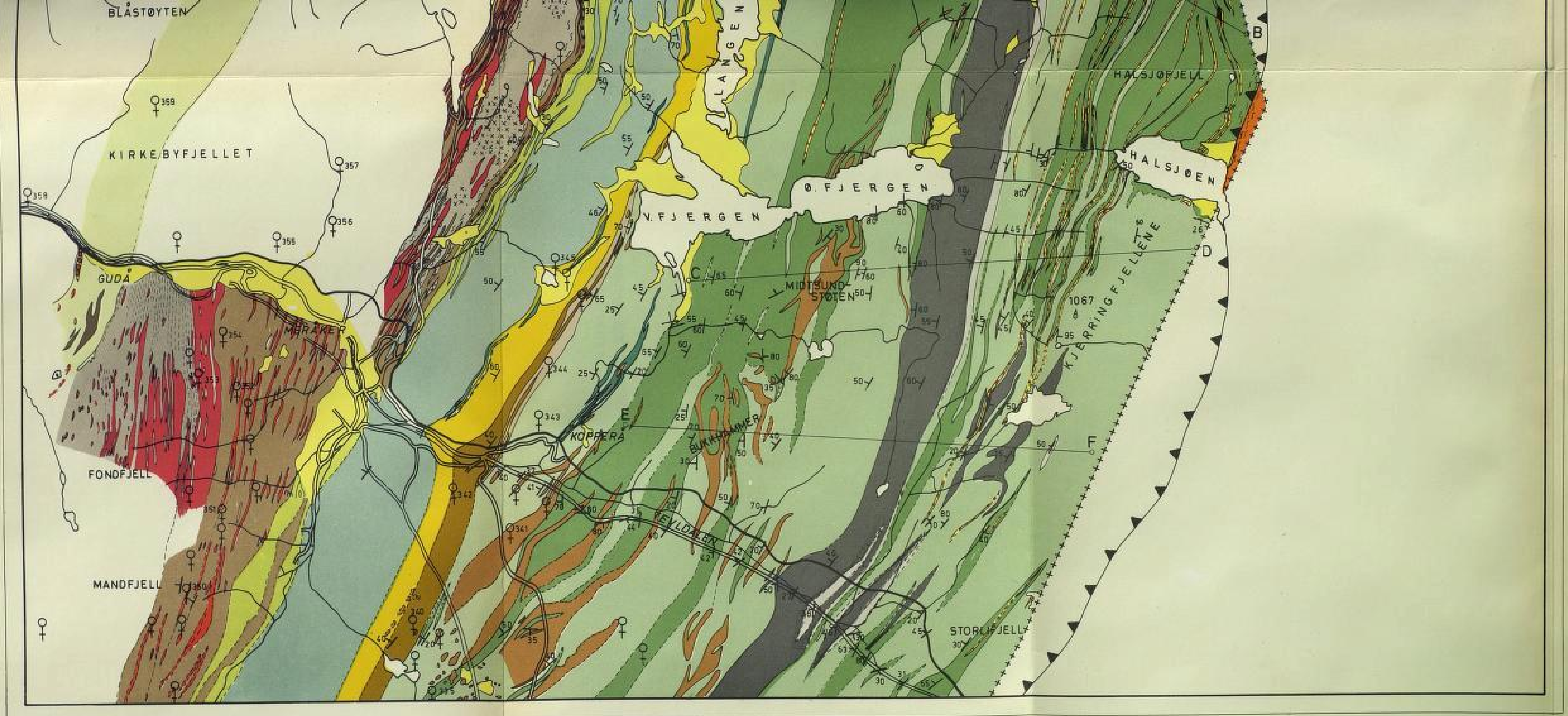
The Brenna conglomerate.

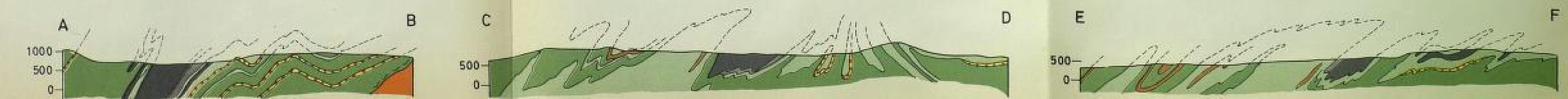
The Brenna limestone.

Grey and black phyllite.

Grey phyllites and graywackes.

The Lille Fundsjø conglomerate.





Grey phyllites and graywackes.

The Lille Fundsjø conglomerate.

Fundsjø Group (Lower Ordovician).

Metabasites.

Quartz-keratophyre.

Sonvatn Group (Cambrian)

Mica schists, often with garnet.

Alternating amphibolites and schists.

The Gudå quartzite conglomerate.

Limestone.

?Eocambrian.

Schists and gneisses.

Caledonian intrusives.

Granitic rocks.

Fine- to medium-grained gabbro.

Fine- to medium-grained gabbro, without preferred orientation.

Fine- to medium-grained gabbro, strongly schistose.

Hornblende gabbro.

Structures.

Strike and dip.

Lines of section.

Foliation, lineation.

Mylonite zone.

Thrust plane.

Occurrences of pyritic and chalcopyritic ore.

GEOLOGICAL MAP OF THE TRONDHEIM REGION

GEOLOGISK KART OVER TRONDHEIMSFELTET

1: 500000

COMPILED BY FR.CHR.WOLFF AFTER:
SAMMENTEGNET AV FR.CHR.WOLFF ETTER:

T.BIRKELAND, C.W.CARSTENS, H.CARSTENS, J.CHALOUPSKY, G.GRAMMELTVEDT, F.FEDIUK, M.FIŠERA, S.FOSLIE, J.FÆRDEN, A.HAUGEN, H.HEIM, P.HOLMSEN, H.J.KISCH, GHR.OFTEDAHL, J.PEACEY, Z.PELC, D.ROBERTS, I.J.RUI, G.SCHAAR, A.SIEDLECKA, S.SIEDLECKI, T.STRAND, TH.VOGT, FR.CHR.WOLFF.

LEGEND
TEGNFORKLARING

RÖRAGEN BEDS (DEVONIAN)
RÖRAGENFELTET (DEVON)

CONGLOMERATE AND SHALE
KONGLOMERAT OG SKIFER

SLÅGÅN GROUP – HORG GROUP (SILURIAN)
SLÅGÅNGRUPPEN – HORGGRUPPEN (SILUR)

DARK SHALE AND SANDSTONE
MÖRK SKIFER OG SANDSTEIN

KJÖLHAUGEN GROUP – RÖROS GROUP – UPPER HOVIN GROUP (UPPER ORDOVICIAN)
KJÖLHAUGGRUPPEN RÖROSGRUPPEN ÖVRE HOVINGRUPPEN (ÖVRE ORDOVICIUM)

PHYLLITE, METAGRAYWACKES, WITH INCREASING AMOUNTS OF BIOTITE, HORNBLEND AND GARNET TOWARDS THE SOUTHEAST, PARTLY CONGLOMERATIC
FYLLITT, METAGRÅVAKKER MED ÖKENDE MENGDER AV BIOTITT, HORNBLENDE OG GRANAT MOT SYDÖST, DELVIS KONGLOMERATISK

POLYGENOUS CONGLOMERATE
POLYMIKT KONGLOMERAT

SULÅMO GROUP – LOWER HOVIN GROUP (MIDDLE ORDOVICIAN)
SULÅMOGRUPPEN UNDRE HOVINGRUPPEN (MIDTRE ORDOVICIUM)

DARK SHALE AND RHYOLITE TUFF IN WEST, GREENSTONE IN EAST
MÖRK SKIFER OG RHYOLITT TUFF I VEST, GRÖNNSTEN I ÖST

GREY CALCAROUS SANDSTONE AND GREY TO DARK PHYLLITE
GRÅ KALKHOLDIG SANDSTEIN OG GRÅ TIL MÖRK FYLLITT

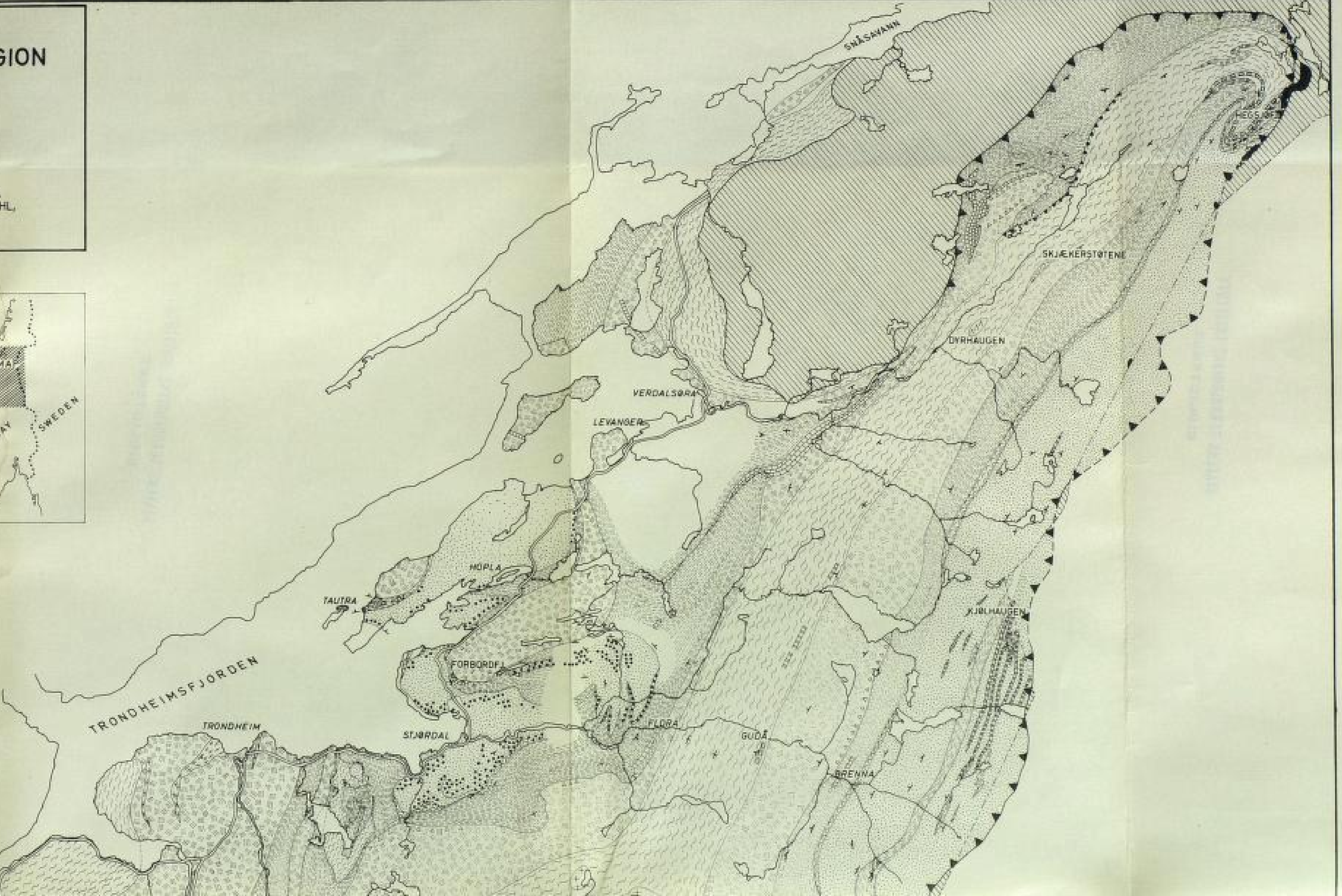
HÖLONDA, TROMSDALEN, BRENNA AND SIMILAR LIMESTONES
HÖLONDA, TROMSDALEN, BRENNA OG LIGNENDE KALKSTEINER

VENNA, STOKKVOLA, LILLE FUNDSJÖ AND SIMILAR CONGLOMERATES
VENNA, STOKKVOLA, LILLE FUNDSJÖ OG LIGNENDE KONGLOMERATER

FUNDSJÖ GROUP – STÖREN GROUP (LOWER ORDOVICIAN)
FUNDSJÖGRUPPEN – STÖRENGRUPPEN (UNDRE ORDOVICIUM)

GREENSTONES AND QUARTZKERATOPHYRES
GRÖNNSTENER OG KVARTSKERATOFYRER

GRANODIORITIC GNEISS
GRANODIORITTISK GNEISS



GRANODIORITIC GNEISS
GRANODIORITTISK GNEISS
SONVATN GROUP – GULA SCHIST GROUP (CAMBRIAN)
SONVATNGRUPPEN – GULASKIFERGRUPPEN (KAMBRIUM)
MICA SCHISTS, OFTEN WITH GARNET
GLIMMERSKIFER, OFTE MED GRANAT
CONGLOMERATES OF THE GUDÅ CONGLOMERATE ZONE
KONGLOMERATER TILHÖRENDE GUDÅKONGLOMERATSONEN
LIMESTONE
KALKSTEIN
CALEDONIAN INTRUSIVES
KALEDONSKE INTRUSIVER
LARGER BODIES OF TRONDHJEMITE
STÖRRE LEGEMER AV TRONDHJEMITT
LARGER BODIES OF GABBRO
STÖRRE LEGEMER AV GABBRO
NORITE
NORITT (DYRHAUGEN)
SERPENTINITES
SERPENTINER
UNDIFFERENTIATED ROCKS BELOW THE TRONDHEIM NAPPE
UDIFFERENSIERTE BERGARTER UNDER TRONDHEIMSDEKKET
STRIKE AND DIP
STRÖK OG FALL
TRONDHEIM NAPPE THRUST PLANE
TRONDHEIMSDEKKETS SKYVEPLAN
MINOR THRUST PLANES
MINDRE SKYVEPLAN
SUPPOSED THRUST PLANE
ANTATT SKYVEPLAN
SELBUSJØEN
SVORKMO
LUNDAMO
BUKKHAMMER
USMADAM
HYLLINGEN
GAULA
VOLL FJELL
HALTDALEN
STUESJØ
ARGEN
AURSUNDEN
RØRAGEN
RØROS
SÅTERSJ
FERAGEN
VISET
FOLLDAL
GRIMSDALEN