STUDIES ON THE LATEST PRECAMBRIAN AND EOCAMBRIAN ROCKS IN NORWAY

No. 8.

STRATIGRAPHY AND STRUCTURE OF EOCAMBRIAN AND YOUNGER DEPOSITS IN A PART OF THE GUDBRANDSDAL VALLEY DISTRICT, SOUTH NORWAY

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Abstract.

A sequence of five separable formations of assumed Eocambrian to Cambrian and earliest Ordovician age are separated by a thrust-plane from the overlying Otta nappe. A lowermost formation of alternating schists and sandstones (often calcareous or dolomitic) and dolomites contains boulder-bearing schists, correlated with the Eocambrian glacial horizon of south Norway (Moelv tillite). It is succeeded by a light feldspathic sandstone ("light sparagmite") a formation of alternating schists and sandstones (often calcareous or dolomitic), a thick pelitic sequence (phyllites) and an uppermost sandstone. In the eastern part of the area described the rocks of this sequence are folded on NW—SE axes, two phases of folding have been ascertained, in the western part the structure is largely monoclinal with dips to NW or NNW.

The present paper gives the results of field work in 1961 on Eocambrian and later (Cambro-Ordovician?) deposits of eastern (miogeosynclinal) facies in an area in the Gudbrandsdalen valley district, shown on Fig.s 1 and 2. In this area the crystalline massif and the overlying eugeosynclinal deposits of the Otta nappe make out an upper tectonic unit, not dealt with in the present paper. The area is a part of the Sel map area described by the writer (Strand, 1951), but very little is contained in that paper on the rocks here in question. Other publications dealing with the same area and rocks are those of Bjørlykke (1905), Holtedahl (1922), Werenskiold (1932) and Dietrichson (1950).

The mapping was done on the available maps in scale 1 : 50 000, enlarged to 1 : 25 000. The work has not been detailed enough to determine an order of deposition within any of the formations separated, in parts of the area with good exposures this might be possible by more painstaking work on large scale maps. A report with maps submitted to the Geological Survey after the close of the investigations in 1961 contains data of local importance, not included in the present paper.

Stratigraphy and lithology.

A light-coloured feldspathic sandstone, the "light-sparagmite" of Norwegian geologists, is a conspicuous rock unit in the area. It corresponds to the "upper light sparagmite" mapped and described by Werenskiold (1911) in the Søndre Fron map area east of the present area. According to the interpretation of the stratigraphy and the tectonics of the present area shown in Fig.s 1 and 2, there is a sequence of five formations, one below and three above the "light sparagmite." No names will at present be introduced for these formations. Two other geologists, A. Prost and J. O. Englund, are engaged in mapping the areas to the east and south-east of the present area and it is thought better to delay the naming until larger areas have been investigated.

The sequence is, from top to bottom:

Formation 5. Light or somewhere dark sandstone.

Formation 4. "Phyllite formation" of grey or somewhere dark carbonaceous phyllites.

Formation 3. Alternating phyllites, siltstones and sandstones, the latter often calcareous or dolomitic.

Formation 2. The "light sparagmite."

Formation 1 has generally the same alternation of lithologies as formation 3, but has in addition dolomites and conglomerates of a special type.

The rocks are metamorphosed at a low grade (greenschist facies). The pelitic rocks are completely recrystallized to fine-grained chlorite-sericite phyllites, while the sandstones have partly retained the clastic structure.

The lower unit, formation 1, consists of pelitic and silty grey schists with interbedded sandstones and dolomites. The sandstones, of light to greyish colour, form benches of thickness up to several metres, and are very often carbonatic, either calcareous or dolomitic. Carbonatic sandstones of the formation are well exposed along the road north of the fork in the road at Sjoa railway station. The dolomites occur in relatively thick layers, about 10 metres at a maximum. There are white crystalline rather pure dolomites and dark grey and fine-grained, presumably less pure dolomites with shale lamellae. The dolomites, accompanied by light quartzitic sandstones seem to occur in the upper part of the formation. Holtedahl (1922, p. 20) gave a map showing some

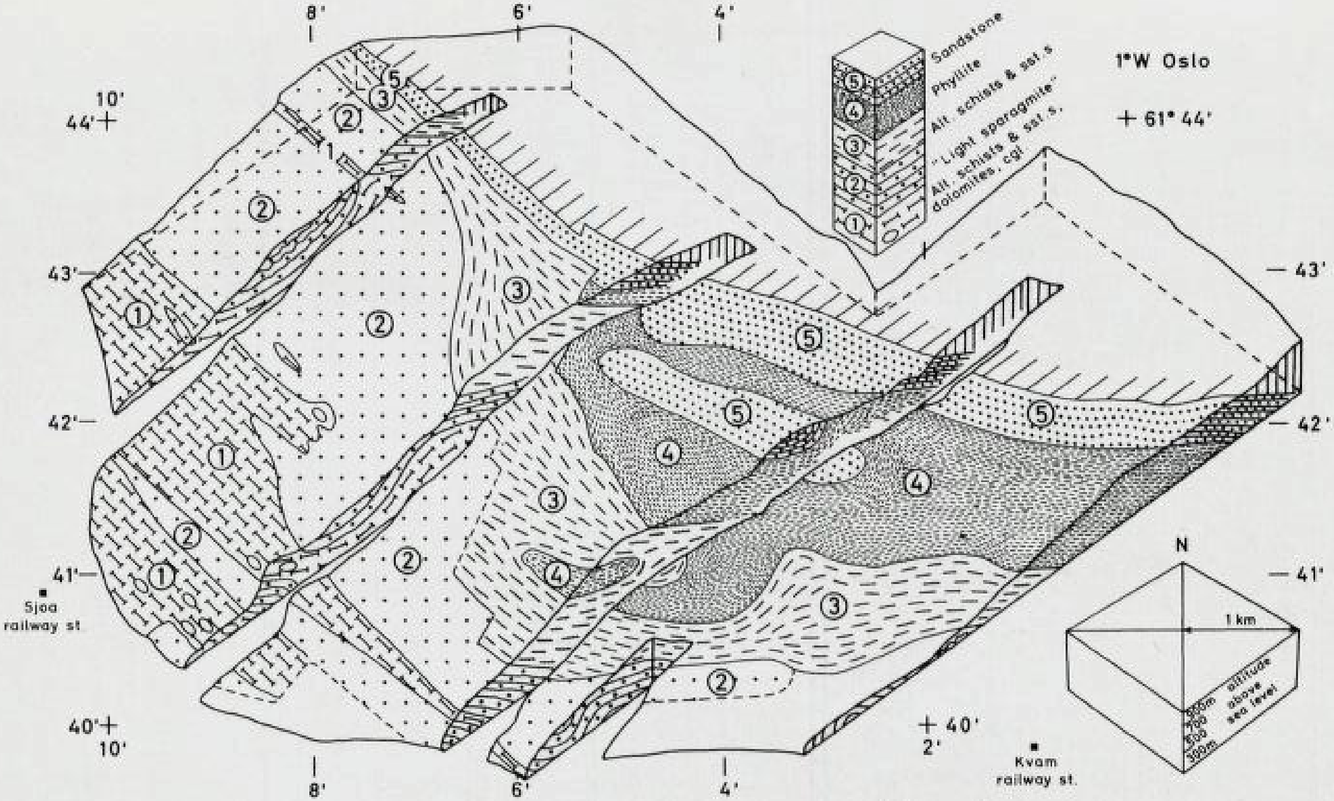


Fig. 1. Tectonogram of an area at the north side of the Gudbrandsdalen valley between Kvam and Sjoa railway stations, see Fig. 2 for location.

Fig. 1. Tektonogram av området på nordsiden av Gudbrandsdalen mellom Kvam og Sjoa jernbanestasjoner. Se fig. 2.

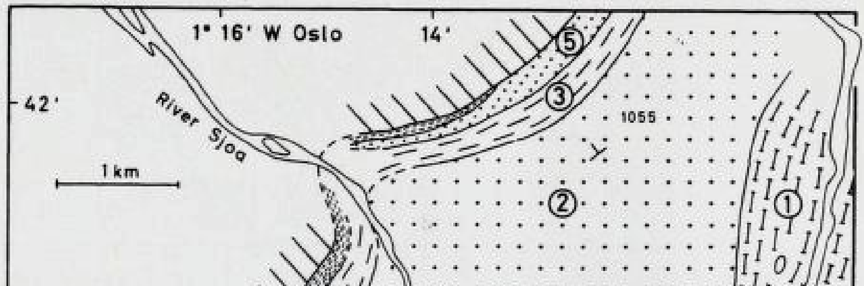


Fig. 2. Geologic map of an area at the lower part of the valley of River Sjoa, legend as in the tectonogram, Fig. 1. Map in corner shows location of the areas covered by the tectonogram, Fig. 1, and the present map.

Fig. 2. Geologisk kart over området ved den nedre del av Sjoas dalføre, tegnforklaring se fig. 1.

of the occurrences and published an analysis (showing 21.7 per cent of undissolved matter, the rest being carbonate very near to dolomite).

The formation contains conglomerates of an unusual type with boulders (maximum size observed is 47 cm.) and smaller fragments, occurring sparsely to wide apart in a matrix of pelitic or silty schist. At one locality, above (north of) the main road 2 km. south-east of the fork in the road at Sjoa railway station (40.3,9),[1] the boulders occur in a

[1] Minutes of latitude + 61°N and minutes of longitude + 1°W Oslo are used as coordinates.

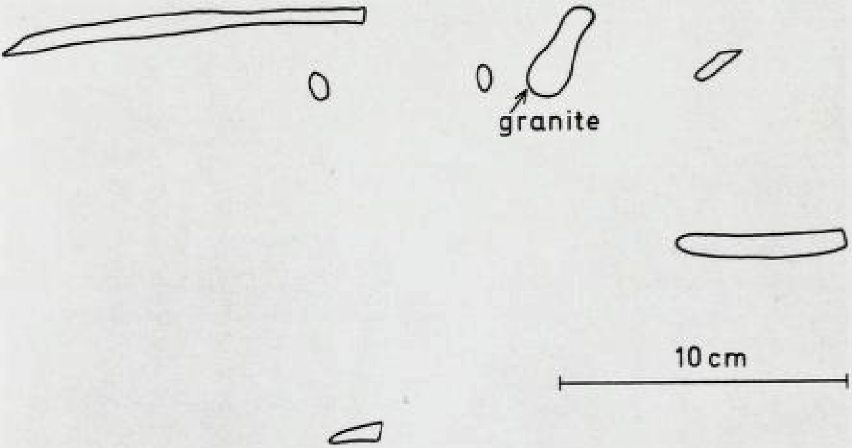


Fig. 3. Field sketch of a vertical section of "conglomerate schist" with fragments. Locality: north of the main road 2 km. south-east of the fork in the road at Sjoa railway station (40.3, 9).

Fig. 3. Skisse av en vertikal skjæring i «konglomeratskifer» med boller. Nord for riksveien 2 km sydøst for veiskillet ved Sjoa stasjon (40.3, 9).

frequency great enough to call the rock a real conglomerate, at the other localities marked on Fig.s 1 and 2 the boulders occur more sparsely. The conglomerate was first observed by Bjørlykke (1905, p. 218) and later by Dietrichson (1950, p. 77).

The boulders and fragments vary in form from rounded to angular and tabular, the latter form seems to be characteristic for fragments of sedimentary rocks (Fig. 3). Of sedimentary rocks among the fragments is a micaceous quartzite and fine-grained dolomites. Very common are greyish granitic rocks which under the microscope prove to be sodic quartz diorites with albite as the only or dominating feldspar, together with microcline. The albites in these rocks show a characteristic twinning pattern with truncate and tapering twin lamellae (Fig. 5). One of the rocks is a quartz porphyry. There are further strongly sheared gneissic rocks, a sampled specimen proved to be oligoclase gneiss.

The thickness of formation 1 is at least 200 m. in the mountain between Rivers Lågen and Sjoa where it is exposed between altitudes 300 m. (in the valley floor) and 500 m.

Formation 2, the "light sparagmite" is of a monotonous lithology, consisting of light feldspathic sandstones with a parallel lamination,

Fig. 4. Boulder of quartzite in schist. Locality: west of Koloseter (41.6, 7.5).

Fig. 4. Kvartsittbolle i skifer. Vest for Koloseter (41.6, 7.5).

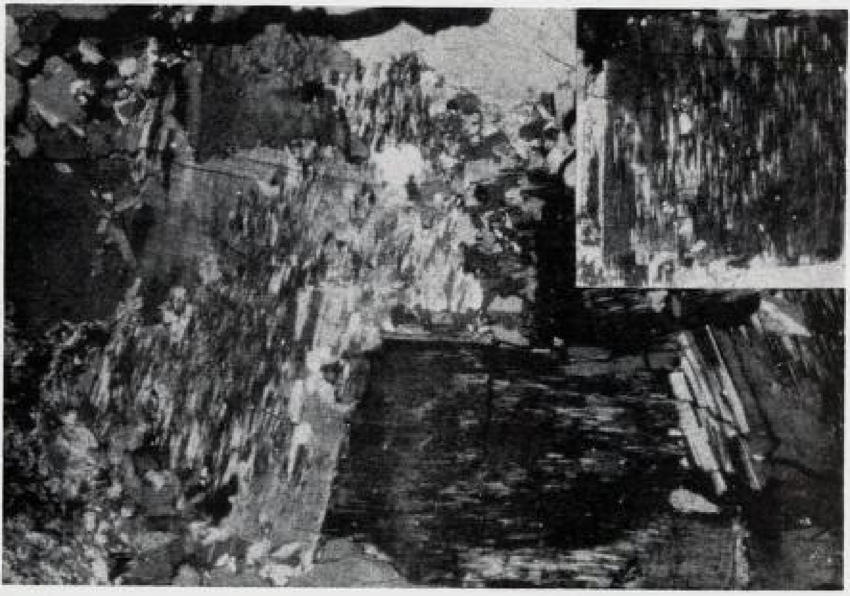


Fig. 5. Microphoto showing albites in granitic rocks occurring as boulders in "conglomerate schist." x 33. Locality as in Fig. 3.

Fig. 5. Mikrofoto av albitter i granitt som finnes som boller i «konglomeratskiferen». Lokalitet som fig. 3.

very often thin layers especially rich in mica form greenish streaks in the light or faintly yellowish rock. The parts of the sandstone especially rich in mica have greenish colour, while rocks with little or no mica have the appearance of quartzites. Dark or greyish sandstones occur as a subordinate part of the formation. The sandstone are parted in benches about 2 dm. thick, the thickness decreasing or increasing with the grain-size of the sandstone. Alternation of siltstones and sandstones, partly calcareous, is an especially fine-grained facies found in parts of the area. Cross-bedding is rare and mostly indistinct. Good cross-bedding was observed at one locality, at the bridge across the Sjoa at Åmot (40.8, 12), indicating that the sandstone is right side up. The formation has a maximum thickness within the area of 500 to 600 m., but thins to some 150 m. in the north-west part of the area.

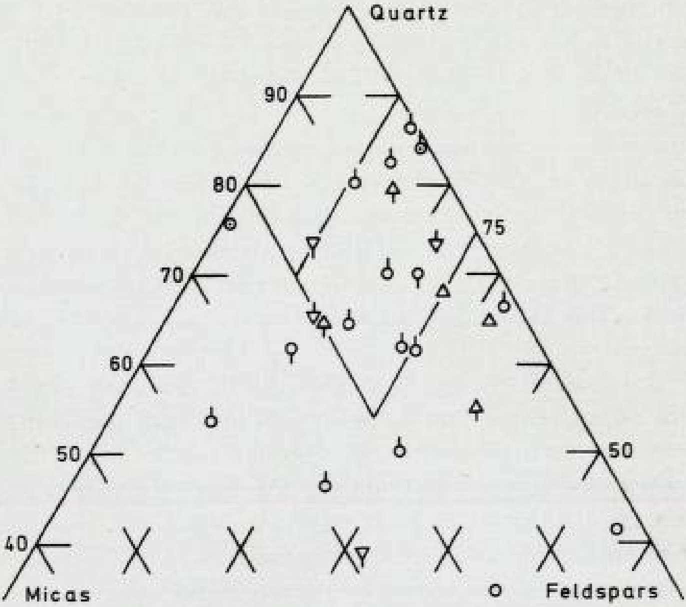
Formation 3 has lithologies similar to those of formation 1, especially the light calcareous sandstones of the two formations can not be distinguished. Characteristic of the formation is alternations of greenish chlorite-rich schists with thin bands of light sandstone with brownish weathering (probably due to contents of iron-bearing carbonate). Boulder-bearing schists have not been found within the formation, which also lacks the dolomites of formation 1, only locally there are thin layers of limestone. But the sediments very often contain carbonates (calcite or dolomite). As will appear from Fig.s 1 and 2 the formation has a large extension and thickness in the eastern part of the area, but is much reduced in thickness towards the north and west.

Dietrichson (1950, Fig. 4, p. 79) published a NE–SW section through the present area showing great inversions and overfoldings towards SW on the assumption that formations 1 and 3, here distinguished, were the same stratigraphic horizon. This interpretation can not be rejected as an impossible one, but it must imply that the "light sparagmite" is in the core of a very large recumbent fold throughout the whole of the present area.

Formation 4 consists exclusively of dark phyllites. Black carbonaceous phyllites apparently form an upper horizon in the formation near below the sandstones of formation 5. Like the underlying formation 3 and the overlying formation 5 the phyllites form a very thick pile in the south-east part of the area, but thin to very small thickness or disappearance in the north and west, a thinning that can probably be ascribed to tectonic processes. In the western part of the area (map. Fig. 2) the black schists commonly occur at the thrust-plane of the overlying Otta nappe. A sample from this part of the area was shown by radiation measurement to contain some 40 p.p. m. of uranium (with an estimated allowance for the radiation caused by the potash contents of the rock).

Formation 5 at the top of the sequence is a light sandstone, but the colour changes to dark grey in the northern and western parts of the area. Commonly the sandstones form thin benches separated by thin seams or layers of light or greenish schist with a rusty weathering. The more fine-grained types thus get a flaggy parting in layers of thickness down to one centimetre.

Some 26 thin-sections of sandstones have been examined and the mineral composition determined by point-counting, as shown in Fig. 6. As previously mentioned the sandstones have partly retained their clastic structure, especially the larger grains of feldspar have kept their characters of perthite structure and twinning pattern, while the quartz is more or less recrystallised. The phyllosilicates (commonly light mica, more seldom biotite and/or chlorite) occur in relatively large grains of nearly equal size, certainly formed by recrystallisation. The grain size commonly varies between 0.1 and 0.3 mm, larger grains are found in a few of the rocks.—More than half of the rocks fall by their mineral composition in the field between 10 and 25 per cent of feldspar and 0 and 20 per cent of phyllosilicates and are to be classed as feldspathic quartzites. As indicated in the diagram, Fig. 6, a majority of the rocks have a feldspar composition dominated either by potash feldspar (80 per cent or commonly more of the total feldspar) or by albite to an equal or a still higher degree. Among the different types of potash feldspar are string perthites (lenticular sections of the perthite inclusions). Feldspars of this type, characteristic of charnockitic rocks, were recorded from sandstones of the same sequence by Dietrichson (1950, p. 76). A number of the albite grains show the same twinning patterns as do the albites of the granitic rocks occurring as fragments in the conglomerate schists in formation 1. The difference between the two types of sandstone is certainly a significant one, showing that sediment must have been derived from two different source areas. Even if there are some exception to the rule, the sandstone rich in potash feldspar are dominating in formations 2 and 5, while the albite-rich sandstones are characteristic of formations 1 and 3 (most of these sandstones are calcareous or dolomitic). In a group of their own are two arkoses with about 50 per cent of feldspar from formation 2 in the northern part



Formations: ∇1, o2, Δ3, ⊖5,
Potash feldspar predominant: ∇ o ⊖
Albite —— " —— : ∇ ♀ Δ

Fig. 6. Diagram showing mineral composition of 26 sandstones.

Fig. 6. Diagram som viser mineralsammensetning av 26 sandstener.

of the area with potash feldspar and plagioclase in roughly equal amounts. They also contain epidote.

Pelitic or silty schists with boulders, the "Conglomerate schists," of exactly the same type as in the present area are known from the Østerdalen district in the east part of the south Norwegian Sparagmite region (Bjørlykke, 1905, p. 61 f.; Holtedahl, 1921, p. 38 f.; Holmsen 1954; Holmsen & Oftedahl, 1956, p. 88 f.). The "conglomerate schist" horizon has been correlated with the Moelv tillite in the south Norwegian Sparagmite basin and considered as a glacial marine sediment deposited at some distance from the glaciated areas in the east.[1]

[1] It may be thought improbable that tabulate fragments like those shown in Fig. 3 could have been transported and worn by a glacier. But rafting by ice formed in fjords and bays is a possible way of transporting material. According to Johansen (1955) large quantities of flint have been brought into the Oslofjord area by ice drifting in

The "light sparagmite" of formation 2 can be correlated with the Vemdal sandstone, which is separated from the Moelv tillite by the intervening Ekre shale formation. The Vemdal is a widely transgressive formation of latest Eocambrian age. The overlying deposits of formations 3 to 5 should thus be Cambrian or younger. The black carbonaceous schist in the upper part of formation 4 can tentatively be correlated with the widely distributed alum shales mainly of Upper Cambrian and earliest Ordovician age, in accordance with Dietrichson (1950). In support of this correlation is the concentration of uranium found in the rock. This should give an early Ordovician age to the sandstone of formation 5.

The "conglomerate schists" of Østerdalen, previously referred to, belong to a sequence containing sandstones of "light sparagmite" types and dolomites, very similar to the sequence in the present area. The Østerdalen rocks in question belong to the Kvitvola nappe, overthrust above Eocambrian and Cambro-Ordovician sediments. The sediments of the Kvitvola nappe display a characteristic facies of deposits of about Eocambrian age, distinct from the parautochthonous sequence of the same age in the Sparagmite basins in central south Norway. Deposits of the latter facies occur in the Fåvang area, 40 km. south-east of the present area (Englund, 1966). According to personal communications from A. Prost and J. O. Englund there seems to be a tectonic boundary between the sequence of "Sparagmite basin facies" and an overlying sequence of "Kvitvola facies," extending into the present area. These rocks should thus be a western equivalent of the Kvitvola nappe, stratigraphically as well as tectonically, as was indicated by Oftedahl (1954).

Structures.

In the area at the north side of the main valley of Gudbrandsdalen, shown in the tectonogram, Fig. 1, the structural pattern is wholly governed by folding on WNW axes, by which the Otta nappe north of the area was folded down in a broad synformal structure. The mega-

during late-Glacial and post-Glacial times. Boulders of flint measuring 3 $dm.^3$ in volume have been found. Also at present material is being transported in the Oslofjord by drifting ice in cold winters. According to a personal communication from Mr. Johansen rock fragments much larger than the above-mentioned flint boulders can be moved in this way.

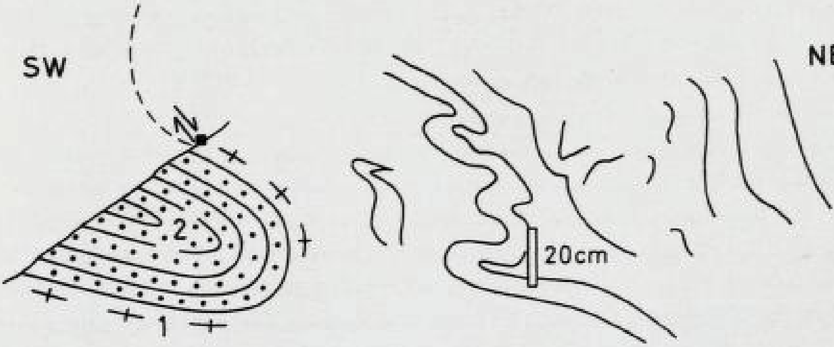


Fig. 7. Parasitic folds or "drag-folds" in a thin quartzite layer in dolomitic schist, formation 1. Locality: At brook north-east of Bjørkerusten farm (40.3, 7.5). The section to the left shows the situation of the locality. The sense of movement of the "drag-folds" indicate an anticline to the right and up and a syncline to the left and down, in accordance with the writer's interpretation.

Fig. 7. Parasittiske folder eller «drag-folds» i et tynt kvartsittlag i dolomittførende skifer, formasjon 1. Ved bekk nordøst for Bjørkerusten (40.3, 7.5). Foldene tyder på en antiklinal opp til høyre og en synklinal ned til venstre (se profilet til venstre).

scopic structures will appear from the tectonogram. Strong folding on a megascopic scale is found in the south-west part where the sandstone of formation 2 forms an overfolded syncline followed to the north-east by an anticline with rocks of formation 1 in the core, inverted above the sandstones of formation 2. Towards north-west the folding structures seem to smoothen out, towards south-east they disappear beneath the cover in the valley floor. As shown in the south-westernmost part of the tectonogram, the rocks of formation 1 are underlain by sandstones not to be distinguished from the sandstones of formation 2, possibly forming a second overfolded syncline, most of which is concealed in the valley floor. Large folds overfolded to the south-west are known south-east of the present area, in Teigkampen and at the north side of the Vinstra valley (Bjørlykke, 1905, p. 197; Dietrichson, 1950, p. 77 f.).

In the area at the west side of the Gudbrandsdalen valley, shown on the map, Fig 2, the megascopic structure is simply a monocline dipping SE or ESE. The trend of the large synformal structure with the Otta nappe has here turned from a WNW to a NNE direction.

The folded complex is transsected by a number of major joints directed NNE. They can clearly be seen on air-photos and some of them can be followed in the field as clefts and depressions. A number of smaller rivers and brooks following the same direction have eroded deep ravines. The joints were earlier mentioned by Bjørlykke (1905, p. 205), and Werenskiold (1932).

In parts of the area faulting has taken place along the joints, as shown on the tectonogram, Fig. 1. Apparently the faulting does not affect the whole complex of rocks transsected, it has not been possible to detect any offsets in the syncline of sandstone of formation 2 in the south-west part of the area. This can be understood on the assumption that the movements along the joints took place during the folding, the different parts of the complex separated by the joints could thus be folded independently of the others, resulting in a number of transcurrent faults by which the rocks east of the joints were moved more strongly to south-west than were those at the west side.

Mesoscopic structures are folds of dimensions between some 10 metres and a few centimetres, minute crenulations in the incompetent schists and a lineation structure by parallel arrangement of grains in the sandstones. The latter structure must have had its origin during the recrystallisation of the rocks. It may here be remarked that no observations indicate the presence of structures of an order of size intermediate between the megascopic structures shown in Fig. 1 and the mesoscopic structures mentioned in the preceding.

The mesoscopic folds are of different styles. Folds of concentric type, some metres wide, are exposed along the road along the Veikla river north of Kvam railway station (40.5, 2) in sandstones of formation 2. At other localities the rocks of the same formation show small folds of a similar type with greatly thickened hinges. A number of observations show structures in two different directions, indicating two (or more) phases of deformation. The clearest evidence was given by an exposure at the road 1 km. north-west of Kvam railway station (40.1, 2) where a micaceous quartz-schist (formation 2) shows folding with the axis parallel to a lineation pitching faintly 320 g, the lineation is folded by a younger fold with axial direction 360 g. An observation made in a phyllite in Tjørnseterfjell east of Haugseter (61° 44.5'N, 0° 58'W Oslo, north-east of the area here described) shows small scale folds pitching about 40 g in direction 280 g, and overturned to the north. These folds are bent and twisted, apparently by a deformation that made minute crenulations directed 370 g. Whether the east-west folding here observed represents the same phase as the folding and lineation

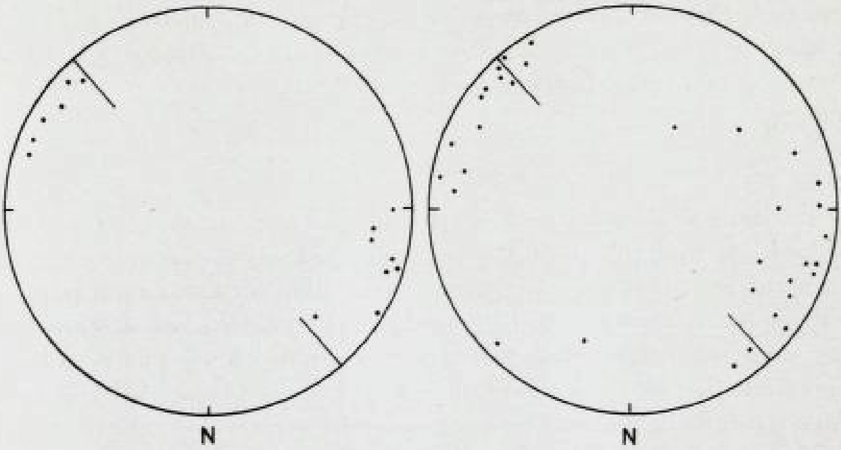


Fig. 8. L structures mainly from the area of the tectonogram, Fig. 1. Equal area projection, lower hemisphere.

Right diagram: Fold axes of mesoscopic folds. Left diagram: Directions of parallel arrangement of mineral grains.

Fig. 8. Linjestrukturer vesentlig fra området for tektonogrammet fig. 1. Flatetro projeksjon, under halvkule.

Til høyre: foldningsakser til mesoskopiske folder. Til venstre: retninger for parallellordning av mineralkorn.

directed 320 g can not be decided. The diagrams, Fig. 8, show observed directions of fold axes and of lineations by parallel arrangement of mineral grains. It is seen that a number of observations of fold axes are in the interval of directions 350—370 g, not occupied by lineations. This seems a confirmation of the direct observation recorded in the preceding, indicating the presence of a folding and lineation with direction about 330 g, followed by a younger folding at an angle of trend some 30 g clockwise to the direction of the former one.

In Prestberget, some 40 km. north-west of the present area, Strand (1964) described the structures in the Otta nappe and underlying sediments, corresponding to those in the present area. Here a folding on west-north-west axes (F_2) with a strong lineation structure has affected the Otta nappe and the underlying sediments subsequently to the emplacement of the nappe, and was followed by a fainter folding (F_3) with axial direction nearer to the north. The two phases of folding in evidence in the present area can thus be correlated with the two later phases in Prestberget. Structures corresponding to the phase F_1 in Prestberget, probably connected with the emplacement of the nappe, have not been ascertained in the present area.

Sammendrag.

En lagrekke av antatt eokambrisk til kambrisk og eldste ordovicisk alder ligger under Otta-dekket i området omkring Kvam og Sjoa jernbanestasjoner. Den underste formasjon i lagrekken består av vekslende skifrer og sandstener (ofte kalkholdige eller dolomitiske) og dolomitter. Den inneholder «konglomeratskifrer» med opptil halvmeterstore spredte boller, som blir oppfattet som et ishavssediment samtidig med Moelv-tilliten. Den overleires av lys feltspatførende sandsten («lys sparagmitt»), en formasjon av vekslende skifrer og sandstener (ofte kalkholdige eller dolomitiske), en formasjon av fylliter og øverst av en sandsten. I den østlige del av området (Fig. 1) er lagene sterkt foldet med akseretning nordvest—sydøst, i den vestlige del (Fig. 2) ligger hele lagpakken stort sett med ensartet nordvestlig til nord-nordvestlige fall.

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