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# Stratigraphy and Structure of the Ringebu-Vinstra District, Gudbrandsdalen; with a Short Analysis of the Western Part of the Sparagmite Region in Southern Norway

JENS-OLAF ENGLUND

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The Ringebu–Vinstra district, Gudbrandsdalen, is one in which several of the main structural units in Southern Norway come together. Essentially, the rocks belong to three main tectonic units: 1. Parautochthonous rocks of the Hedmark Group of latest Precambrian and Eocambrian age with overlying Cambro-Ordovician deposits. 2. Allochthonous sedimentary rocks, which can be correlated with parts of the Hedmark Group and the Cambro–Ordovician, corresponding to the Kvitvola nappe occurring in Østerdalen and in Engerdalen. 3. Crystalline rocks of the Caledonian overthrust massifs, which in places are overlain by sedimentary rocks – the Jotun nappe. At Feforkampen the crystalline rocks with their cover of sedimentary rocks most probably correspond to the Valdres nappe. The Espedalen massif and the outlier of crystalline rocks in Valsfjell could also belong to the Valdres nappe.

The sedimentary rocks from the present district are treated from a lithostratigraphical and petrographical point of view.

The structural evolution of the Ringebu–Vinstra district has been complex with four major phases of deformation ($D_1$–$D_4$). The first phase of deformation involved the thrusting of the Jotun nappe–Valdres nappe and the Kvitvola nappe with minor thrusting of the parautochthonous Vangsås Formation. Minor isoclinal, recumbent folds were produced. The structural pattern within the whole region is governed by $D_2$ folding on WNW axes, which affected all nappe units and underlying rocks. The third folding ($D_3$ phase) was developed on NE–SW axes. During the last movement phase in the district ($D_4$ phase) brittle structures including joints and faults were formed.

*J.-O. Englund, Department of Geology, Agricultural University of Norway, N-1432 Ås-NLH, Norway*

CONTENTS

## Introduction

The main results of geological investigations carried out in the Ringebu–Vinstra district, Gudbrandsdalen, in the summers 1965–1970 form the basis of the present paper. A brief analysis of the geology of neighbouring areas is also given. The work forms part of the regional mapping of the map-sheet Lillehammer (scale 1:250,000) undertaken by the Geological Survey of Norway under the leadership of Professor S. Skjeseth. The location of the mapped district is shown in Figs. 1 and 2.

### OUTLINE OF THE GEOLOGY

The Ringebu–Vinstra district is one in which several of the main structural units in Southern Norway come together. Essentially the rocks belong to three main tectonic units:

1. Parautochthonous rocks of the Hedmark Group (the 'sparagmites'), with overlying Cambro–Ordovician deposits.

2. Allochthonous sedimentary rocks, which can most probably be correlated with parts of the Hedmark Group and the Cambro–Ordovician, corresponding to the Kvitvola nappe occurring in Østerdalen and in Engerdalen.

3. Crystalline rocks of the Caledonian overthrust massifs, which in places are overlain by sedimentary rocks – the Jotun nappe. At Feforkampen the crystalline rocks with their cover of sedimentary rocks most probably correspond to the Valdres nappe of Kulling (1961). The Espedalen massif and the outlier of crystalline rocks in Valsfjell could also belong to the Valdres nappe.

Rocks of the Hedmark Group with overlying Cambro–Ordovician sediments occur in the southern half of the present district (Plate 1). The main litho-stratigraphical units are shown in Table 1.

The Kvitvola nappe occupies the northern half of the present district. The rocks of this nappe are regarded as being of latest Precambrian–Ordovician age, though this has not been proved by radiometric age determinations or by fossils. The main litho-stratigraphical units are, however, described together with their probable equivalent parautochthonous formations. The principal units are a 'light sparagmite' (corresponding to the Vangsås Formation)

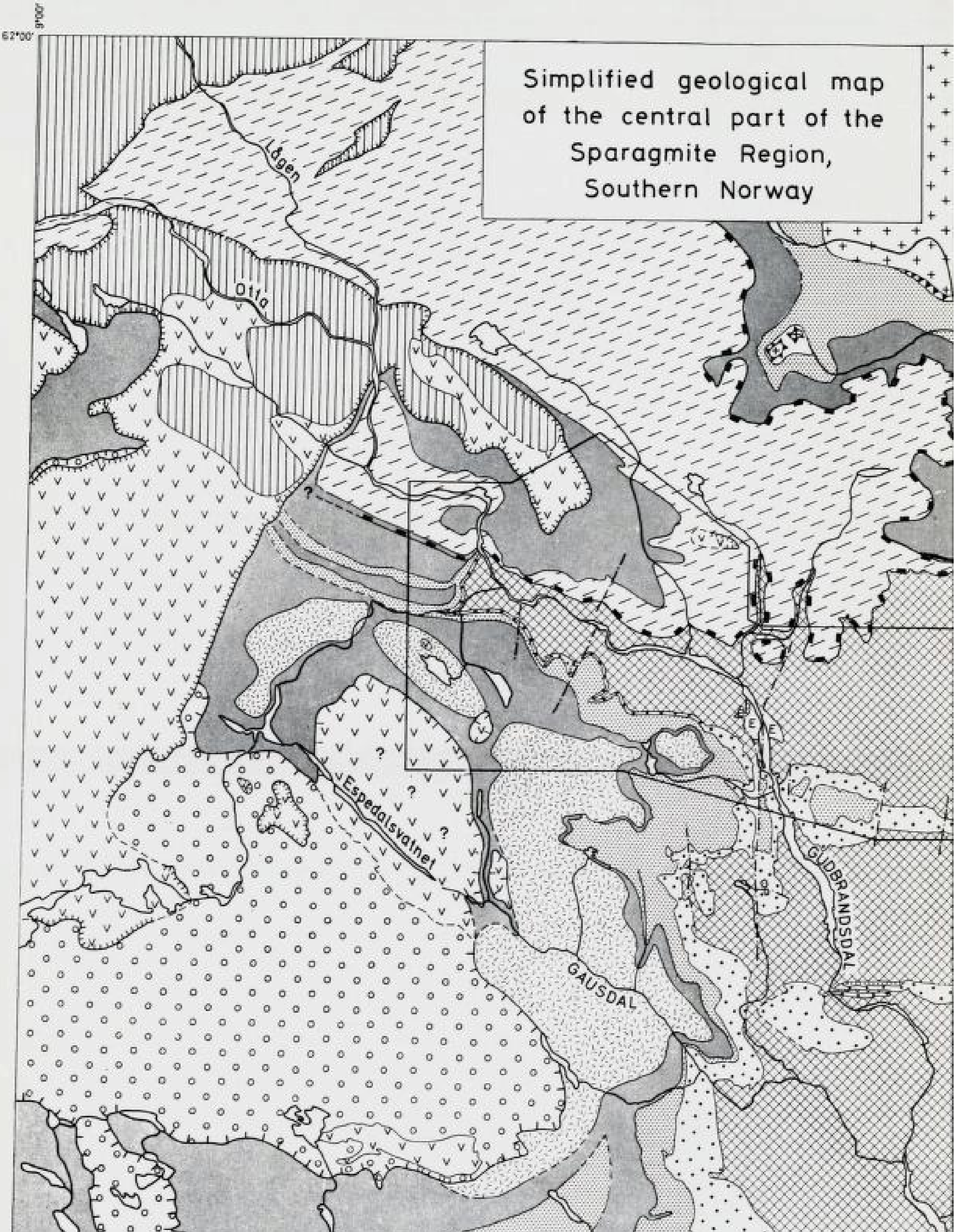
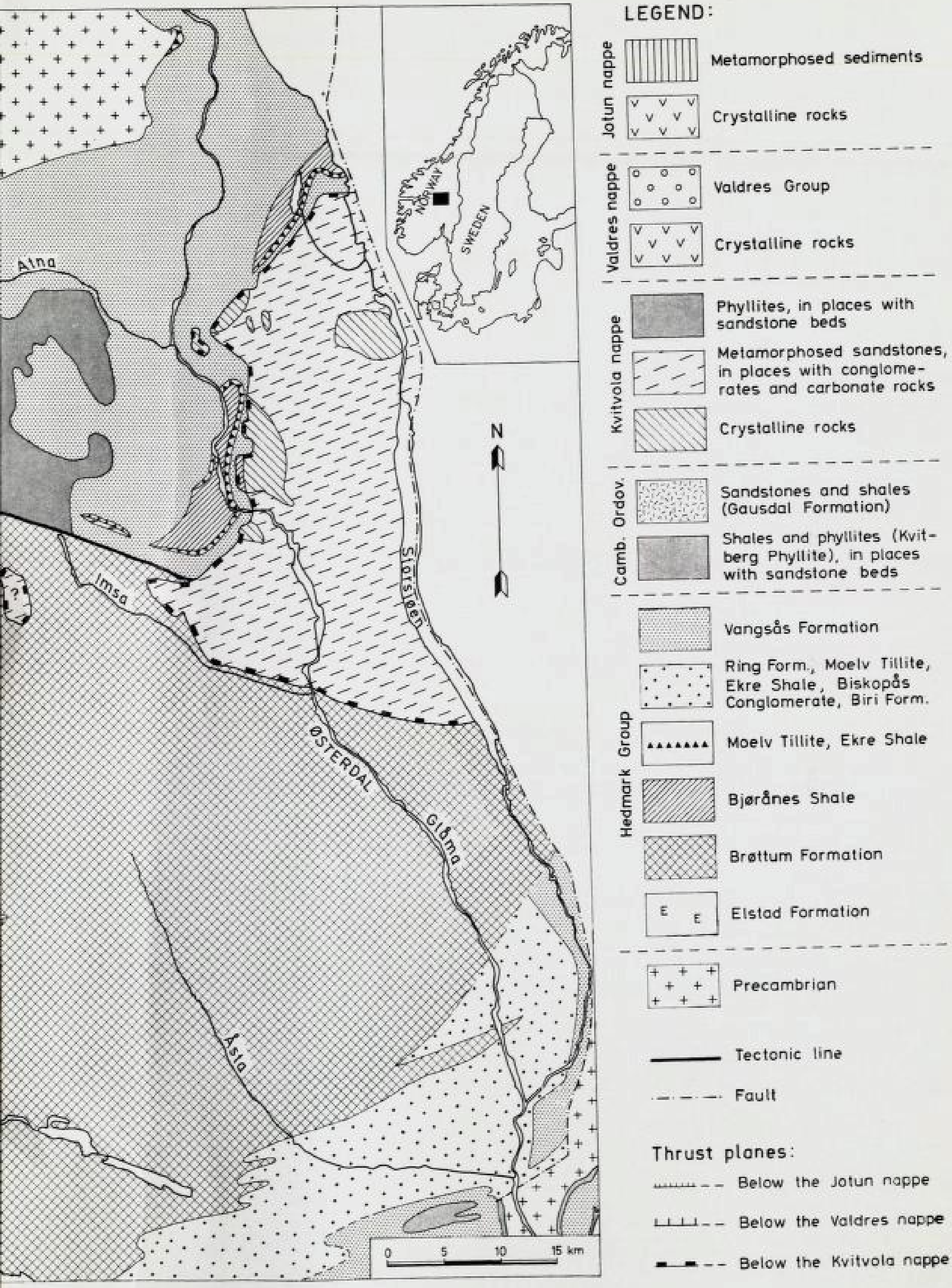



*Fig. 1.* Simplified geological map showing th




tation (framed) of the Ringebu–Vinstra district.

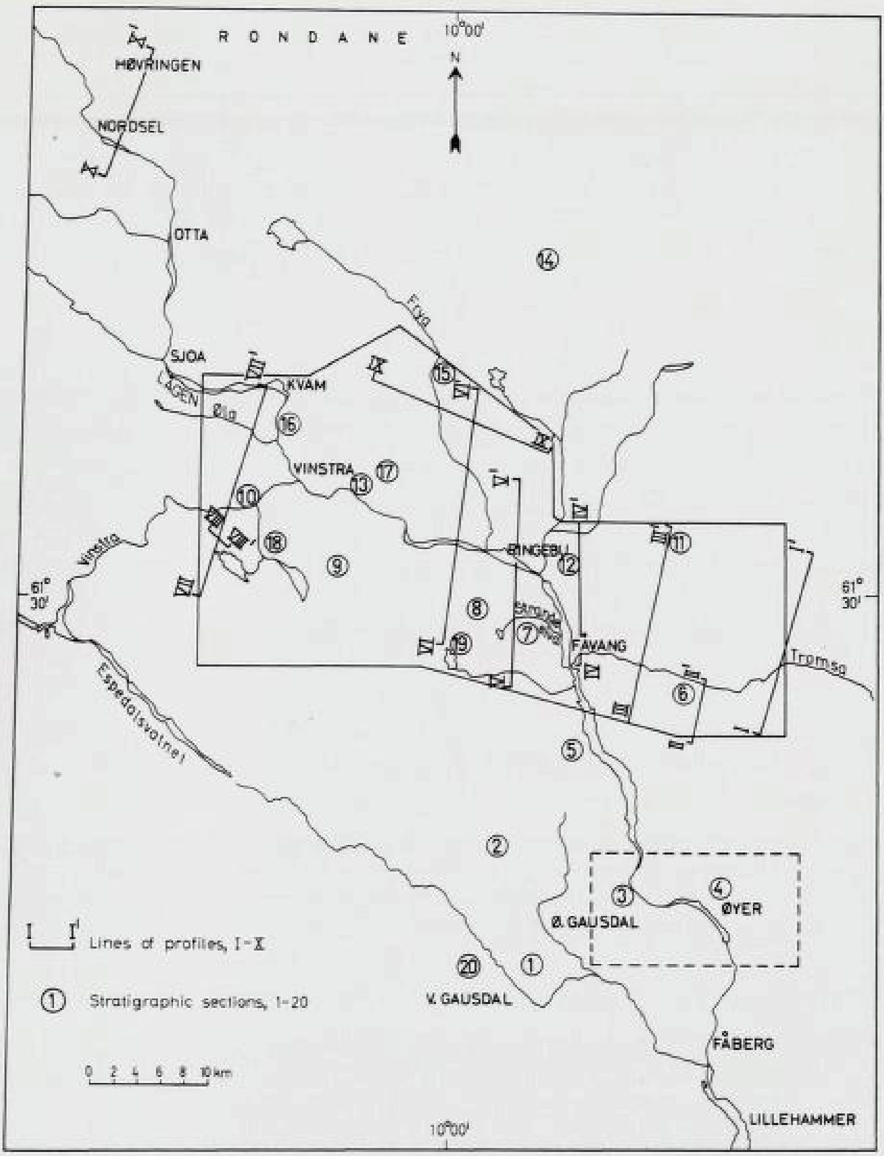



*Fig. 2.* Map showing the location (framed) of the mapped district (Plate 1), the stratigraphic sections, Figs. 5, 6, 10, 11 and 15 and the schematic profiles Figs. 16, 17 and 19. The dashed rectangular area has been mapped earlier by the author (Englund 1972).

overlain by phyllitic rocks (corresponding to the Kvitberg Phyllite). The most characteristic unit, however, is a conglomerate which probably corresponds to the Moelv Tillite.

Only outliers or smaller segments of the Jotun nappe – Valdres nappe are found in the western and northern parts of the present region. These units display a thrust boundary both to the underlying Kvitvola nappe and to the underlying parautochthonous rocks.

## PREVIOUS WORK

The Fåvang–Ringebu–Vinstra district and adjacent areas have been visited by numerous geologists, and the most detailed descriptions have been given by K. O. Bjørlykke (1893, 1905), Werenskiold (1911) and Dietrichson (1945a, 1950). The present region covers the northern part of the map-sheet Gausdal (scale 1:100,000) mapped by K. O. Bjørlykke (1893), the southern part of the map-sheet Søndre Fron (scale 1:100,000) mapped by Werenskiold (1911), and also parts of the areas mapped by Dietrichson (1945a, 1950) further west.

Some of the earliest profiles or brief descriptions from the region were presented by Kjerulf (1873, 1879) and Törnebohm (1896), and these were followed by more detailed descriptions by K. O. Bjørlykke (1905). Another paper dealing with the general geology of the region is that of C. Bugge (1954), who presented a profile from the Hundorp area. In a series of publications, Chr. Oftedahl discussed problems connected especially with the Elstad Formation, Biskopås Conglomerate and the Kvitvola nappe (Oftedahl 1945, 1949, 1954a, 1954b). The Fåvang area has been described by the present author (Englund 1966), and a gravimetric survey of the Ringebu–Vinstra district has been given by Ramberg & Englund (1969).

Publications of more general character dealing with the geology of the Sparagmite Region are those of Holtedahl (1953, 1960) and Skjeseth (1963). In addition, valuable information has been provided by Holmsen & Oftedahl (1956) from the eastern part of the Sparagmite Region, by K. Bjørlykke (1966b) from the Rena district, and by Strand (1967) from the Sjoa–Kvam district, just northwest of the present area. More specialized publications are those of Holtedahl (1922a), dealing with the petrography of carbonate rocks, Werenskiold (1932), on jointing, and Englund (1973), on the geochemistry and mineralogy of pelitic rocks.

## METHODS AND DEFINITIONS

*Mapping* was carried out on AMS 1:50,000 topographical maps, and on 1:40,000 aerial photographs. The positions of localities within the Ringebu–Vinstra district are indicated by coordinates on the main map, Plate 1.

Compass directions and angles of dip and plunge are based on the $400^g$ scale. The lower hemisphere is employed in all stereograms (Schmidt net), and the method of Strand (1944) has been adopted in the contouring of observations plotted on these diagrams.

*Grain-size measurements* have been carried out on some thin-sections. Coarse-grained sediments (Moelv Tillite with allochthonous equivalents) were also measured on acetate peel prints, and in outcrops by using regular nets. The acetate peel prints and thin-sections were made from slices cut normal to the bedding planes. Only the largest diameters of grains have been measured. Between 400 and 500 grains have been measured per thin-section. The acetate peel prints were made according to the method described by K. Bjørlykke (1966a).

*Table 1.* Stratigraphy of the Hedmark Group (nomenclature after K. Bjørlykke et al. 1967) with overlying Cambro–Ordovician sediments from the present district

| | |
|---|---|
| Cambro–Ordovician | Gausdal Formation |
| | Kvitberg Phyllite |
| Hedmark Group | Vangsås Formation |
| | Ekre Shale |
| | Moelv Tillite |
| | Ring Formation |
| | Biri Formation |
| | Biskopås Conglomerate |
| | Brøttum Formation |

*Modal analysis* by point counting has been carried out on sandstones and conglomerates. Ninety-four thin-sections from selected specimens have been examined. The analyses were made according to the method used by Englund (1972, p. 5).

## Stratigraphy

In the present paper, rocks of latest Precambrian and Eocambrian age are treated from a litho-stratigraphical and petrographical point of view together with overlying Cambro–Ordovician sediments.

The Hedmark Group is divided into two subgroups (K. Bjørlykke et al. 1967), the Lillehammer Subgroup and the Rena Subgroup. The base of the Ring Formation forms the boundary between these two subgroups, this boundary marking a conspicuous change in lithology within the Fåvang area.

The present district is situated in the western part of the 'main Sparagmite basin'. South of Ringebu–Hundorp, the western margin of this basin strikes about N–S, but in the Hundorp–Vinstra area it swings rather sharply to the west–northwest (Ramberg & Englund 1969).

The Elstad Formation has usually been regarded as the oldest formation of the Hedmark Group. The present investigation, however, seems to favour the view that it is younger than the Brøttum Formation and that the Elstad Sandstone corresponds to the Vangsås Formation and the Elstad Shale to Cambro–Ordovician or to the Biri Formation.

The term 'Valdres Sparagmite' (see Strand 1972, p. 32) is used here for those sedimentary rocks within the Valdres nappe which probably are of latest Precambrian and Eocambrian age. New formal names for formations within the Kvitvola nappe and within the Valdres nappe are not introduced here, because the type areas for such rocks must be Engerdalen and Valdres, respectively.

### BRØTTUM FORMATION

Outcrops of the Brøttum Formation are located in the central and eastern part of the mapped district (Plate 1). In the areas north of Ringebu–Vinstra the upper part of the Brøttum Formation is supposed to be represented by the Fron Member.

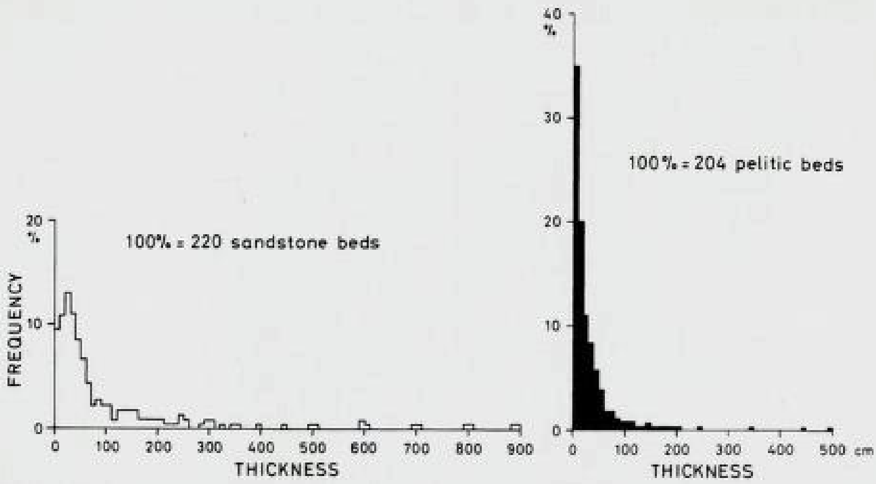



*Fig. 3.* Variation in thickness (in cm) of sandstone and pelitic beds in the Brøttum Formation at Harpefoss–Hundorp–Nårkampen.

The typical Brøttum Formation from the present region is weakly metamorphosed and consists of a monotonous alternation of pelitic beds and sandstones or, in part, siltstones. Variations in thickness of sandstones and pelitic beds from the Harpefoss–Hundorp–Nårkampen region (Fig. 3) are similar to the variations found at Øyer–Fåberg (Englund 1972, Fig. 3). The formation – the Fron Member excluded – is characterized by a predominance of sandstone (75%). The sandstone beds are usually $<$ 9 m and the pelitic beds $<$ 5 m in thickness.

The estimated thickness of the formation down to the river Lågen at Hundorp–Harpefoss is about 400–500 m. From gravimetric data, however, the calculated depth to the crystalline basement is about 1.5 to 3 km (Ramberg & Englund 1969).

In the stratigraphically lower parts of the formation at Hundorp–Harpefoss, sedimentary features resembling those described from the Øyer–Fåberg district (Englund 1972) are present. In the monotonous alternation of sandstone and pelitic beds, a sandstone together with its overlying pelite can be regarded as a rhythmic unit. The base of any one sandstone bed is usually sharp and erosional, but there is often a gradual transition into the overlying pelite. The presence of graded bedding and the absence of cross bedding are quite characteristic. In addition, fragments of shale have been observed in places in the sandstone beds.

The results of the grain-size measurements from one graded bed are shown in cumulative curves (Fig. 7) plotted on arithmetic probability paper. None of the curves show any marked break in slope. The results indicate that the investigated sandstone bed is moderately to poorly sorted (sorting scale after Folk & Ward 1957) and contains a low proportion of matrix. The grading is clearly demonstrated in the curves of Fig. 7.

The name 'Fron Sparagmite' was introduced by K. O. Bjørlykke (1905, p. 163) for what is here considered as the Fron Member of the Brøttum Formation. He regarded this unit as an equivalent of the Biskopås Conglomerate. The Fron Member is also characterized by an alternation of sandstone and pelitic beds, the sandstones being typically of grey to light grey colour, and in places appearing quartzitic. In the Brøttum Formation below this member, a dark grey coloration dominates in the sandstones and a dark grey to black colour in the pelites. The pelites of the Fron Member are light grey, sometimes with a slight greenish colour. Pyrite cubes are common within the typical Brøttum Formation but are seldom observed in the Fron Member, in which pelitic beds are rarely thicker than 10 cm and are, besides, more silty than lower down in the formation. Sandstone units up to 10 m thick are rather common, though the usual thickness is around 0.5–3 m. The Fron Member consists of about 85–90% sandstones and 10–15% pelites. Of primary sedimentary structures, a horizontal lamination is often present in the sandstone beds while in the uppermost parts of the Fron Member, cross bedding has been observed.

As will be shown later the Fron Member is quite strongly folded, often isoclinally, and the true thickness is thus difficult to estimate; however, it would seem to be less than 200–250 m.

The known regional distribution of the Fron Member is shown in Fig. 4.

*Discussion*

The Biskopås Conglomerate is missing west and north of the Fåvang area, and the Fron Member is therefore thought to be, in part, an equivalent of this conglomerate. The Fron Member seems to represent a relatively shallow water deposit.

The lower part of the Brøttum Formation at Hundorp–Harpefoss contains structures characteristic of turbidite facies, which is similar to the facies at Øyer–Fåberg (Englund 1972).

BISKOPÅS CONGLOMERATE

As already mentioned, the Biskopås Conglomerate is only developed in the southeastern part of the mapped district (Plate 1; Englund 1966, p. 66). Generally, this formation is found only in the marginal parts of the main Sparagmite basin (Fig. 4). In brief, the formation shows great variations in thickness (0–300 m), in the proportion of conglomeratic beds to sandstone beds, in the size of the pebbles and boulders (5–80 cm), and in the type of boulder material. Many of the pebbles and boulders are well sorted and well rounded (e.g. Fig. 28 A), and the matrix is of material similar to that found in the underlying Brøttum Formation. The contact with the Brøttum Formation is supposed to be erosional as shown in places by relatively large quantities of pebbles of sedimentary rocks in the basal parts of the formation. In the southern part of the Sparagmite basin the Biskopås Conglomerate is resting on different rock units; the Brøttum Formation or the Biri Formation.

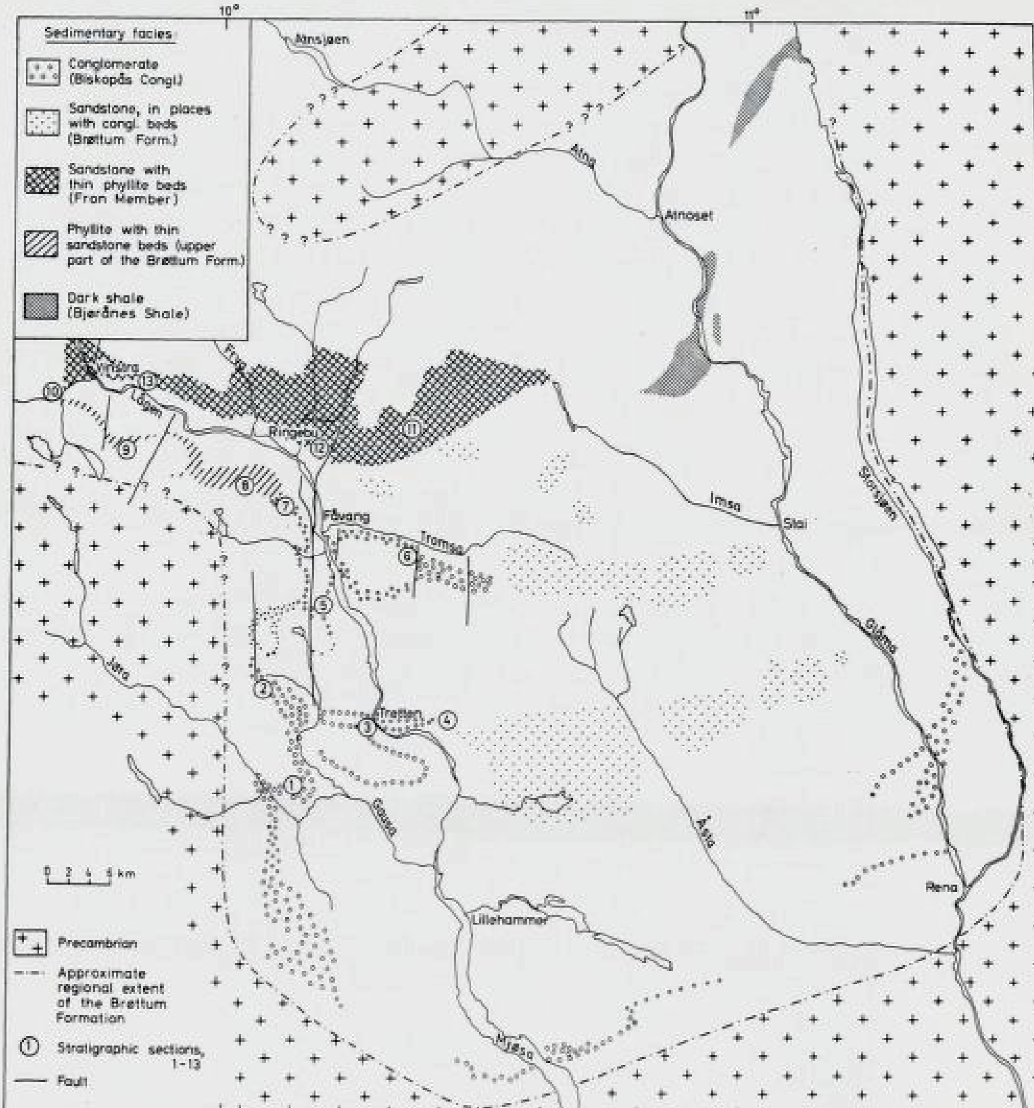



*Fig. 4.* Palaeogeographical map showing the regional distribution of the Biskopås Conglomerate in Southern Norway, and possibly equivalent deposits belonging to the Brøttum Formation.

The conglomerate is considered to represent a fluviatile–deltaic deposit (Skjeseth, 1963, p. 28).

The conglomeratic beds at Tretten–Øyer must be regarded as an eastern tongue of one of the deltas found at Gausdal further to the west (Figs. 4 and 5). This deltaic unit grades laterally eastwards into a thick (100–150 m) coarse-grained sandstone indistinguishable from the Brøttum Formation, but is thought to be partly equivalent to the Biskopås Conglomerate (Englund 1972, p. 29).

The Biskopås Conglomerate in the Fåvang area belongs to a different deltaic unit from that found in the Gausdal–Tretten area (Fig. 4). In conclusion, it is thought that the characteristic meta-anorthosite boulders (Fig. 30) found only near Fåvang were derived from a source situated to the west or southwest of the present region, at what was the margin of the depositional basin during the maximum extent of Brøttum Formation sedimentation (Ramberg & Englund 1969).

As noted above, the Fron Member is thought to be, in part, a chronostratigraphic equivalent of the Biskopås Conglomerate. This is also the case with some coarse-grained grey sandstones occurring east and northeast of the Fåvang area (Fig. 4). In, for instance, the mountain Veslefjell northeast of Fåvang, beds occur with grains up to 0.5 cm in diameter, and on Goppollfjellet and Høgfjell, to the east of Fåvang, grains up to 0.3 cm have been found. These sandstone units are up to 100–120 m in thickness.

*Discussion*

The Biskopås Conglomerate is regarded as a shallow-water deposit and K. Bjørlykke (1966b, p. 13) and Spjeldnæs (1967, p. 56) interpreted it as being related to regression due to an epeirogenic lowering of the sea level. Skjeseth (1963, p. 29) has explained the formation of this conglomerate by a tectonic subsidence of the basin. Of great interest to this discussion are the lateral variations observed within the mapped region from the Fåvang area towards the west-northwest. A rather rapid change in lithology occurs between Strandesætra (Fig. 6, section 7) and Nårkampen (Fig. 6, section 8): in the first locality the Biri Formation is underlain by 100 m of coarse-grained conglomerate, while in the second locality a grey phyllite with thin sandstone beds underlies this formation. The phyllite-rich upper part of the Brøttum Formation continues north-westwards into the region south of Vinstra–Harpefoss (Fig. 4). A chronostratigraphically equivalent pelitic unit is possibly found in Østerdalen within the Bjørånes Shale. This black shale with pyrite and carbonate layers occurs below the Moelv Tillite, but is regarded by K Bjørlykke (1969, p. 315) as being partly equivalent to the Brøttum Formation.

The rapid lateral variations noted at Strandesætra–Nårkampen indicate that tectonic movements with resulting erosion could have occurred in connection with the deposition of the Biskopås Conglomerate. A general regression of the sea, without tectonisation, would probably have caused more uniform facies variations within the sedimentation basin than those actually observed (Fig. 4). It is, however, clear that previously deposited sediments have been eroded by th Biskopås Conglomerate; most probably because they were exposed to erosion (e.g. limestone). A tectonic subsidence of the basin has, therefore, little plausibility, but tectonic movements (a general uplift) outside the basin of deposition would provide a probable explanation, as earlier indicated by the author (Englund 1966, p. 72) and by Løberg (1970, p. 174). It seems, however, probable that some regression of the sea must have occurred. The rivers bringing material to the basin could have followed zones of weakness, caused by faulting (Skjeseth 1963, p. 29).

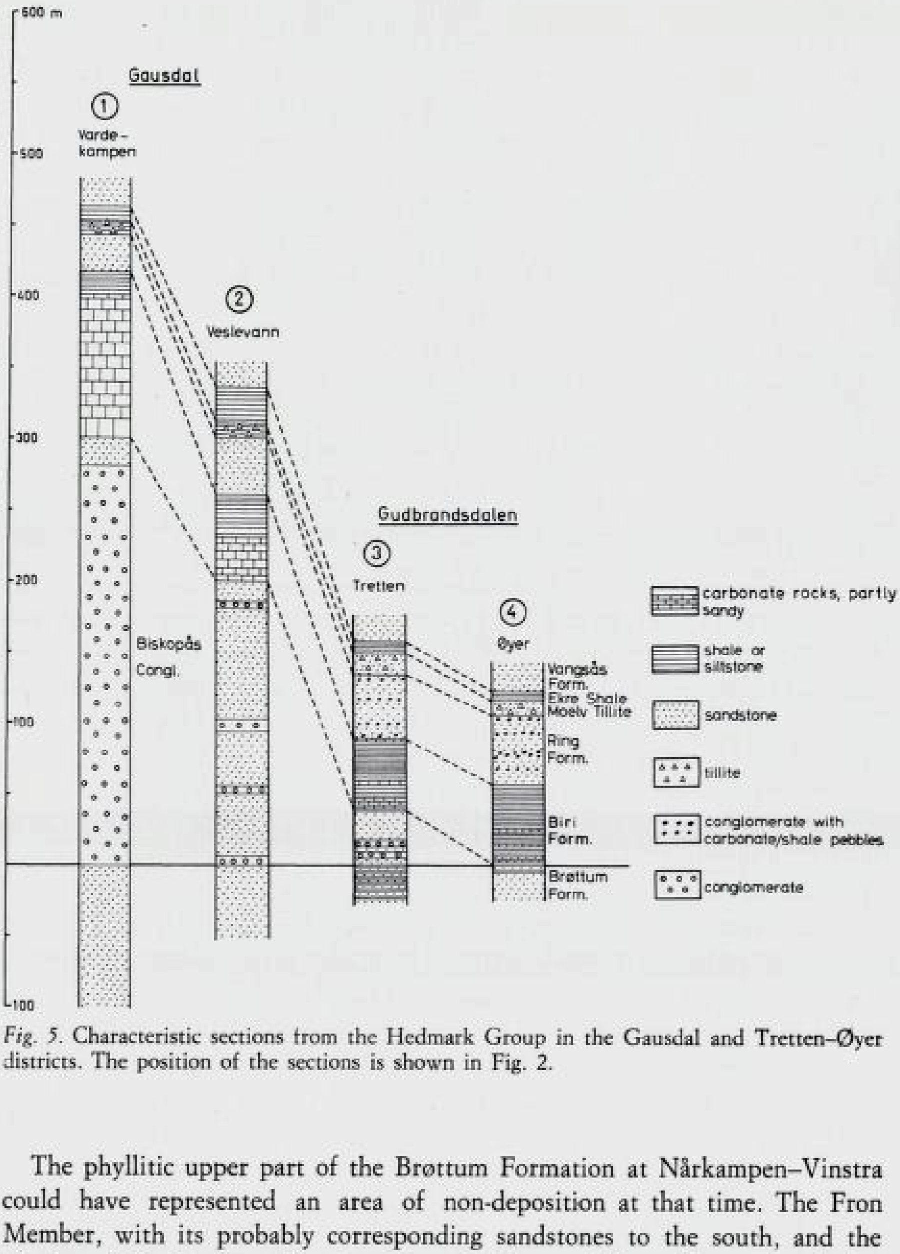



*Fig. 5.* Characteristic sections from the Hedmark Group in the Gausdal and Tretten–Øyer districts. The position of the sections is shown in Fig. 2.

The phyllitic upper part of the Brøttum Formation at Nårkampen–Vinstra could have represented an area of non-deposition at that time. The Fron Member, with its probably corresponding sandstones to the south, and the Bjørånes Shale, is situated in the more central parts of the sedimentation basin. It must, however, be remembered that Caledonian thrusting and folding may, to some degree, have altered the relative positions of the different rock units. Tectonic deformation and thrusting have possibly displaced the Biskopås Conglomerate somewhat to the south in relation to its source rocks, and erosion of the northern parts of the delta at Fåvang has also most probably occurred. Furthermore, it is probable that the Fron Member is displaced in relation to the Biskopås Conglomerate at Fåvang. Prost (1970, p. 757) regards this unit as allochthonous; being part of the Kvitvola nappe (see p. 32).

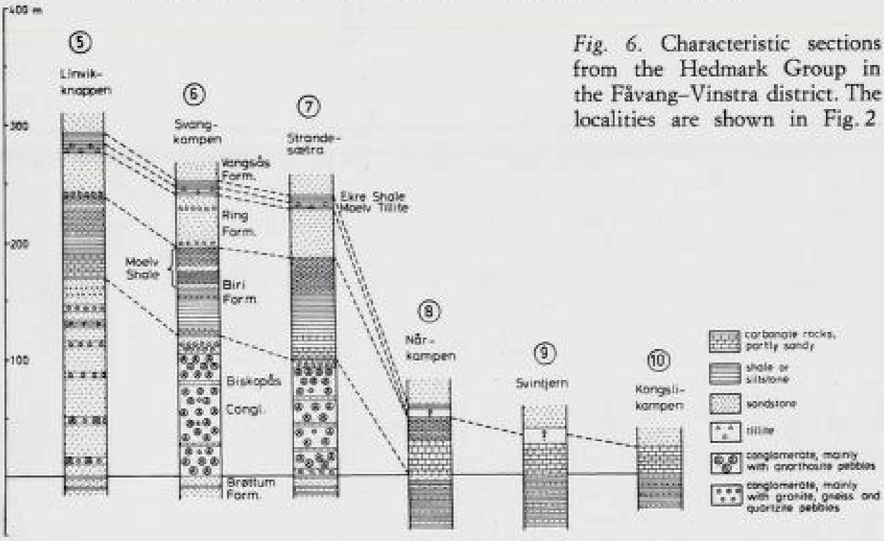



*Fig. 6.* Characteristic sections from the Hedmark Group in the Fåvang–Vinstra district. The localities are shown in Fig. 2

## BIRI FORMATION

This formation and its supposed allochthonous equivalents have a considerable regional distribution within the present district.

In the Fåvang area the formation is usually developed as a more or less impure carbonate rock in its lower part, overlain by a dark grey calcareous shale with limestone lenses (Fig. 28 D). The transition from the underlying formation is gradual. The upper part of the formation continues gradually into the overlying sandy Moelv Shale (Fig. 6, sections 5–7). A marked disconformity is present between the Moelv Shale and the overlying coarse-grained sandstone, which, in places, is conglomeratic. Remnants of a calcareous sandstone occur at the top of the Moelv Shale on Linvikknappen just south of the present area (Englund 1966, p. 75). In accordance with the author's observations from the Tretten–Øyer district (Fig. 5, sections 3 and 4; Englund 1972, p. 34), it seems correct to regard the Moelv Shale as a member of the Biri Formation, because a genetic relationship exists between the typical Biri Shale and the Moelv Shale.

From the Fåvang area, where the Biri Formation has its typical development, the shale members of the formation gradually disappear towards the west-northwest, and the carbonate member becomes more sandy (Fig. 6) and more dolomitic, as shown by a buff-weathered surface. In the area south and southwest of Vinstra the formation is bedded, more or less sandy carbonate rock (with 5–20 cm thick beds) with very subordinate pelitic beds. To the north, where the Biri Limestone is resting on the Fron Member, the formation is also developed as a fairly sandy carbonate. Only a few of the beds, ranging from 2 to 15 cm in thickness, are developed here as relatively pure limestone or dolomite.

Another characteristic feature is that the Vangsås Formation is partly resting directly on the Biri Formation west and northwest of Fåvang (Fig. 6, sections 8–10). The hiatus above the Biri Formation, and the sandy development of this formation, point to epeirogenic uplift of the sea bottom west and northwest of the present region.

Within the Kvitvola nappe the equivalents of the Biri Formation are developed either as buff-weathered dolomitic sandstone or as sandy dolomite with thin, grey phyllite beds (3–15 cm thick). The latter lithology predominates in the area of Abborsjøen–Frya, although the formation as a whole is quite rich in sandy material. Bedding is often visible, and the content of sandy material changes somewhat from layer to layer; individual beds are usually between 5 and 15 cm in thickness.

The character of the carbonate rocks has been checked on the X-ray diffractometer in six specimens south of Hundorp (K 4), in five specimens north of Harpefoss (H 9) and in seven specimens near Abborsjøen (P 8). Dolomite (2.88 Å) is the dominating mineral, besides quartz, albite and sericite. Only weak reflections of calcite (3.03 Å) were found. At Fåvang and at Kiliknappen, just south of Fåvang, calcite seems to be the prevailing carbonate mineral (Englund 1966, p. 73, 1973, p. 47).

RING FORMATION

Within the parautochthonous rocks of the present district this formation is restricted to the Fåvang area (Fig. 6, sections 5–7 and Plate 1) where it has earlier been described by the author (Englund 1966, p. 74). Here it is dominated by a coarse-grained sandstone with conglomerate beds. The contact with the underlying Moelv Shale is sharp and erosional.

Deposits possibly equivalent to the Ring Formation occur within the upper unit of the Kvitvola nappe (Fig. 10). The well-bedded gray sandstone with phyllite and siltstone beds is carbonate-deficient. The boundary to the underlying calcareous sandstone is, however, gradual and resembles the Biri Shale–Moelv Shale transition in the Fåvang area.

*Discussion*

A description and discussion of the Ring formation in Southern Norway have recently been given by K. Bjørlykke (1966b, p. 24) and Englund (1966, p. 76, 1972, p. 33). Of some interest is the observation from the present area, showing that the distribution of the conglomeratic facies of this formation is almost the same as that for the Biskopås Conglomerate. This tendency has been mentioned earlier by Skjeseth (1963, p. 31) as characteristic of great parts of the Sparagmite Region in Southern Norway. It seems reasonable to consider the deposition of the Ring Formation as being due to tectonic movements along the margins of the Sparagmite basin. The sedimentary character of the Ring Formation is somewhat different from that of the Biskopås Conglomerate. However, the same regional distribution of the conglomerate facies of these formations within some areas, and the erosional contact which both formations appear to have with underlying rocks, support the hypothesis that tectonic movements could have occurred in connection with the deposition of the Biskopås Conglomerate.

*Regional correlations*

The conglomerate known as the 'Rosten Conglomerate' at Nord Sel (see K. O. Bjørlykke 1905, Strand 1951), is overlain by a unit which, in the author's opinion, is possibly equivalent to the Moelv Tillite (Fig. 19). This tillite-like conglomerate has a sandy schistose matrix with scattered pebbles of quartz, quartzite, granite and some gneiss. Its thickness is around 5–10 m.

The character of the Rosten Conglomerate is partly that of a breccia, containing a high frequency of granitic and gneissic boulders (K. O. Bjørlykke 1905, p. 293, Strand 1951, p. 15) with diameters up to more than 1 m. This development is typical of the stratigraphically lower parts of the unit, where bedding seems to be lacking. Towards the overlying Moelv Tillite, where bedding can be observed, the size of the boulders gradually decreases and they become more spherical and rounded. Quartz and quartzite are quite common as boulders in the higher parts of the Rosten Conglomerate, in addition to gneiss. The monomictic character and the great size of boulders in this formation indicate a deposition very close to its source rock. A tectonic brecciation of the Precambrian gneisses along a fault scarp with subsequent short sedimentary transport could produce such a conglomerate or breccia. The formation seems to be pre-tillitic, and its character indicates a correlation with the Biskopås Conglomerate and/or the Ring Formation.

MOELV TILLITE

Within the Fåvang area, the formation is developed as a 'boulder clay', with scattered pebbles and boulders up to 1 m in diameter in a phyllitic matrix (Fig. 28 B; Englund 1966, p. 77). A weak stratification has been observed in places. The transitions to the underlying and overlying formations seem to be gradual and concordant.

Possible equivalents to the Moelv Tillite serve as a key horizon within the upper unit of the Kvitvola nappe (the conglomerate of Plate 1; the tillite of Fig. 10), with a thickness around 20–35 m. This formation was first observed by K. O. Bjørlykke (1905, p. 218) and Dietrichson (1960, p. 77) in the Kvam–Sjoa district. Recently, Strand (1967, p. 96) has presented a description of the conglomerate. Within the Kvitvola nappe occurrence, the pebbles are usually more scattered than in the Fåvang area. The matrix is sandy to silty, becoming finer grained towards the northwest. Stratification has been found within parts of the formation. The pebbles and boulders are usually angular to sub-angular (Strand 1967, p. 97), but the larger boulders are often rounded (maximum observed size 52 cm). The passage to the overlying formation is relatively sharp, and in places a primary interdigitation of conglomeratic and sandy beds has been observed (Fig. 10). The boundary to the underlying formation, on the other hand, is gradual and concordant.

The most common pebble material in the Kvitvola nappe occurrence is quartz, quartzites, and 'granitic rocks', though in places fragments of fine-grained dolomite are fairly abundant. Four thin-sections from the 'granitic rocks' showed these to be sodic quartz diorites with little microcline.

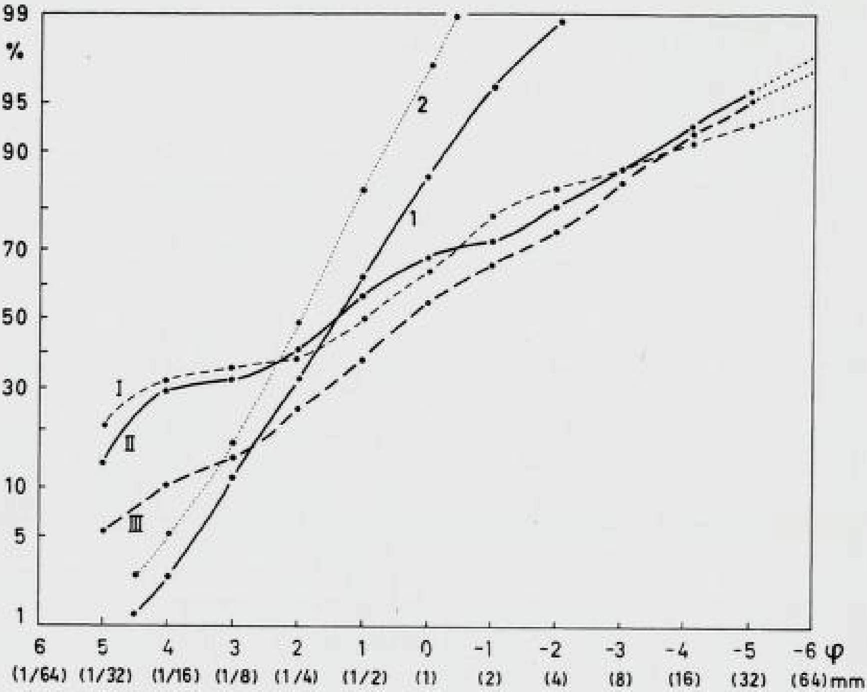



*Fig. 7.* Cumulative curves of grain-size distribution in the Moelv Tillite (I and II), in the supposed equivalent conglomerate in the Kvitvola nappe (III), and through one graded bed in the Brøttum Formation at Harpefoss (1 from the bottom, and 2 from the top of a bed 100 cm in thickness). I. Locality Oppsalåsen. II. Locality Svinåa (QI). III. Locality Veslefjell (L 14).

The unsorted character of the Moelv Tillite and its allochthonous equivalents is shown in Fig. 7. The tendency towards a bimodal distribution of the curves from the Fåvang region is remarkable. This could perhaps be explained by assuming that the coarser material (above about 1/8 mm) was mainly derived by dropping from floating ice, while the finer material (below about 1/16 mm) is the result of normal marine sedimentation. It has been widely accepted that the Moelv Tillite in Southern Norway was formed mainly by the dropping of material from floating ice (as shelf ice or icebergs) in a marine or brackish environment. The character of the Moelv Tillite at Fåvang–Gausdal and within the Kvitvola nappe must be interpreted as a facies deposited at greater distances from the land (or icefront) than the typical Moelv Tillite found further south (see also Englund 1972, p. 40).

The last occurrence of equivalents to the Moelv Tillite is that of a basal conglomerate in the Valdres Sparagmite sequence at Feforkampen. Just below the meta-gabbro/greenstone in Feforkampen (the sequence is inverted here), there occur well-sorted beds of conglomerate about 20–50 cm in thickness. The well-rounded pebbles, which are up to 5 cm in diameter, consist of quartz and quartzite. The rest of the formation, which has a total thickness up to 5–8 m, is unsorted and contains boulders up to approx. 1 m across (Dietrichson 1945a,

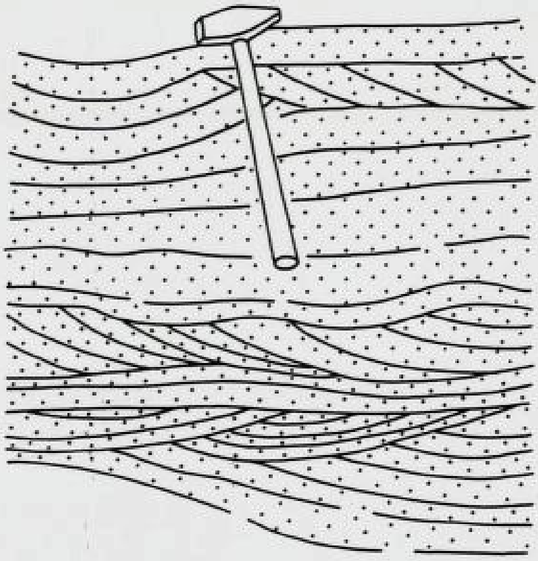


*Fig. 8.* Cross bedding in the Vangsås Formation south of Nårkampen (M 3).

p. 37). The boulder material at Feforkampen is dominated by quartz diorites, granites and some anorthosites; quartzite boulders are rather rare.

Interpretation of the conglomeratic unit at Feforkampen as an equivalent of the Moelv Tillite (Englund 1969), implies a derivation of this material by dropping from floating ice, and not as a moraine. The contact relations to the underlying basal rock support such a conclusion, since the thin quartzite conglomerate at the base of the formation has the character of a fluviatile or near shore deposit (transgression conglomerate?).

### EKRE SHALE

Good exposures of the Ekre Shale are found within the Fåvang area, where this formation has been described by the author (Englund 1966, p. 79, 1973). As with the underlying Moelv Tillite and Ring Formation, the Ekre Shale gradually disappears towards the northwest (Fig. 6).

Within the Valdres Sparagmite at Feforkampen, a green phyllite stratigraphically overlies the Moelv Tillite; it is thought to correspond to the Ekre Shale (Englund 1969). An equivalent phyllitic unit is lacking within the Kvitvola nappe (Fig. 10). This also seems to be a characteristic feature of the Kvitvola nappe along the Østerdalen valley and in Engerdalen (Oftedahl 1956, p. 98).

### VANGSÅS FORMATION (VEMDAL FORMATION)

This unit covers a great part of the mapped area south of the Kvitvola nappe (Plate 1). A short description of the formation in the Fåvang area has been given earlier by the author (Englund 1966, p. 79). Within the mapped region as a whole it displays a monotonous lithology, consisting of a grey to light grey sandstone, in some few places with conglomeratic beds. These coarse-grained

*Fig. 9 A.* Feldspathic sandstone ('light sparagmite') from the Kvitvola nappe. Conglomeratic beds in the lower part of the formation northwest of Veslefjell (K 14).

beds, with quartz and quartzite pebbles up to approx. 2 cm, occur only in the lower half of the formation. The formation ranges between 70 and 140 m in thickness, and has a fine-grained upper part which is partly quartzitic (Fig. 13). Generally, however, it is not possible to divide the Vangsås Formation within the present region into a lower feldspar-rich member (Vardal Sandstone) and an upper quartzitic member (Ringsaker Quartzite), as in the type-area at Mjøsa.

The boundary to the underlying Ekre Shale within the Fåvang area is usually sharp. Northwest from the Fåvang area, the Vangsås Formation is resting directly on the Biri Formation (Fig. 6). This boundary is sharp and erosional, and in one locality south of Kongslikampen (B 7) flute cast structures have been observed.

A parallel lamination is common within the Vangsås Formation. Cross bedding of the type shown in Fig. 8 is a characteristic feature of the middle and upper parts of the formation. It is not always possible to utilize the cross bedding in determining facing directions (Fig. 8, upper right), though in

*Fig. 9 B.* Feldspathic sandstone and quartzite ('light sparagmite') from the Kvitvola nappe. Typical development from the region north of Hundorp (L 8).

general the cross-stratification does have an erosional truncation facing up, and a tangential contact with the underlying bed. The character of the Vangsås Formation is that of a relatively shallow water deposit.

ALLOCHTHONOUS EQUIVALENTS TO THE VANGSÅS FORMATION

Within the Kvitvola nappe the 'light sparagmite' of Werenskiold (1911) is usually a monotonous lithology (Figs. 13 and 14). The lower part of the formation in the Frya–Dynjefjell–Veslefjell region (Fig. 9 A) is partly characterized by an alternation of sandstones and conglomeratic beds (with quartz and feldspar as pebbles). Further northwest, outside the mapped district, conglomeratic beds are more common and sometimes have a tillitic appearance.

The typical 'light sparagmite' is a light grey to yellowish feldspathic sandstone or quartzite with a characteristic bedding (Fig. 9 B). Units of thicknesses between 5 and 30 cm are commonly developed. As observed by Strand (1967, p. 99) in the Kvam–Sjoa area, thin layers rich in mica produce greenish streaks, while beds with little or no mica have the appearance of quartzites.

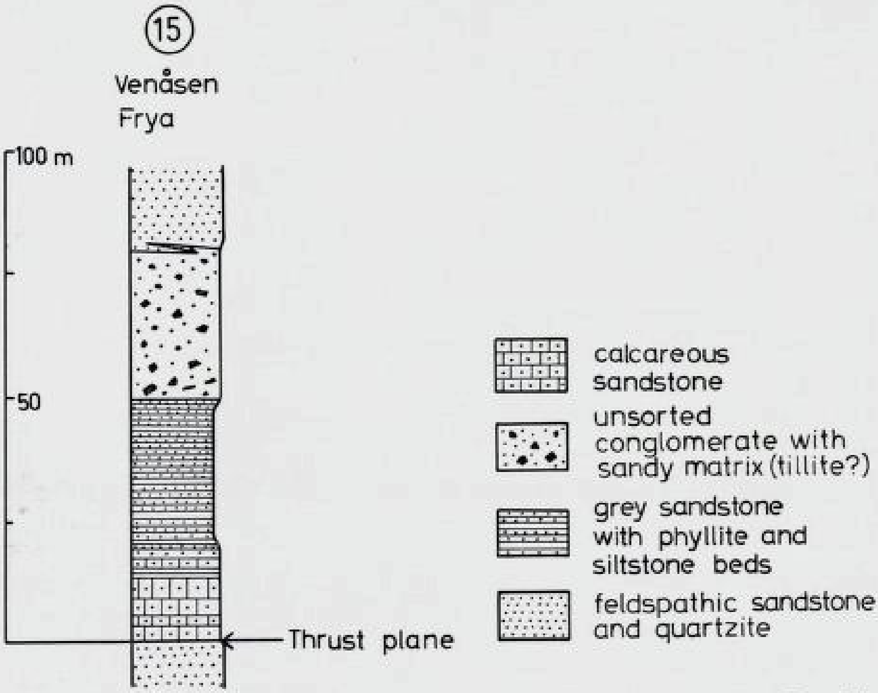



*Fig. 10.* Characteristic section in the upper unit of the Kvitvola nappe, river Frya. The locality is shown in Fig. 2.

This characteristic feature is also typical of the 'light sparagmite' within the mapped district. The formation has a maximum thickness around 400–600 m just north of Ringebu, but thins to some 200–300 m towards Dynjefjell–Veslefjell and towards Harpefoss–Vinstra. The imbricated slices at Kollberget and at Grønfjell–Krøkla have thicknesses around 50–150 m.

Cross bedding is seldom observed, but south of Teigkampen, just south of Raudhaugen, and in the region of Abborsjøen good examples of cross bedding indicate that the sandstone is right side up. The cross bedding is of a similar type to that observed in the parautochthonous Vangsås Formation.

The 'light sparagmite' of the lower and upper units of the Kvitvola nappe has similar lithologies, and the occurrence of an equivalent to the Moelv Tillite within the upper unit (Fig. 10) indicates that the 'light sparagmite' in this case corresponds to the Vangsås Formation. This is in accordance with the conclusion of K. Bjørlykke (1969, p. 317) from the Østerdalen valley.

The 'light sparagmite' of the lower unit is resting directly on the Biri Formation within the present district (Plate 1) and in areas further north towards Åstdalen (p. 31).

The second occurrence of an allochthonous Vangsås Formation is within the Valdres Sparagmite at Feforkampen (p. 30). A light grey quartzitic rock was first observed here by K. O. Bjørlykke (1905, p. 190). Later, Dietrichson (1950, p. 88) regarded it as a part of the Valdres Sparagmite. Equivalents of the Vangsås Formation have also been observed in the Valdres Sparagmite at Mellene, Valdres (Loeschke 1967, p. 60).

ELSTAD FORMATION

The Elstad Formation occurs only between Ringebu and Fåvang (Plate 1) where it is apparently underlying the Brøttum Formation (p. 36). This formation has been divided (Englund 1966, p. 62) into a lower sandstone member (Elstad Sandstone Member) and an upper pelitic member (Elstad Shale Member).

The lower member is a light grey sandstone with indistinct bedding. The feldspar content is usually high, but quartzitic beds have been observed (Fig. 13). The total thickness is up to 80–100 m. Angular fragments of grey to greenish phyllites up to 1 m across sometimes occur, usually in the structurally uppermost part of the sandstone, and in some places, scattered, rounded quartz and quartzite pebbles up to 10 cm in length are found. Because of a lack of primary sedimentary features showing sedimentary facing, it is impossible to decide whether the Elstad Formation is in a normal or an inverted position.

The Elstad Shale Member, on the contrary, shows a more varied development than the sandstone. Its thickness reaches up to about 40 m, and the unit is strongly tectonized with possible repetition of beds. Generally, this member seems to display two different developments.

The northern locality of this unit along the E 6 on the east side of the Lågen, and the third locality further south, show the following main lithologies: the boundary to the Elstad Sandstone Member is marked by a thin quartzite conglomerate with pebbles up to 4 cm. Then follows a zone (5–8 m) with coarse-grained sandstones, partly conglomeratic, and grey phyllites. Higher up grey to dark grey phyllites predominate, these containing thin brown sandstone beds. Pyrite cubes are present in the phyllites, which have a weak greenish coloration in their lower parts.

The other variety of Elstad Shale is found in the southern locality of this unit on the western side of the Lågen, in the westernmost locality north of Strandeelva, and in the second locality from the north along the main road, E 6. The boundary to the Elstad Sandstone Member is here usually sharp. The lower part of this type of Elstad Shale is a greenish calcareous phyllite grading into a grey to dark grey phyllite. Beds or lenses of nearly pure carbonate rocks are quite characteristic. Such calcareous beds occur up to 15–20 m from the Elstad Sandstone. Higher up, greenish grey to dark grey, somewhat calcareous phyllites predominate. The geochemistry and mineralogy of this variety of the Elstad Shale have recently been studied by the author (Englund 1973).

*Discussion*

As mentioned earlier (p. 5), it is possible that the Elstad Sandstone Member corresponds stratigraphically to the Vangsås Formation, having been overthrust by the overlying Brøttum Formation. Its petrographic development is

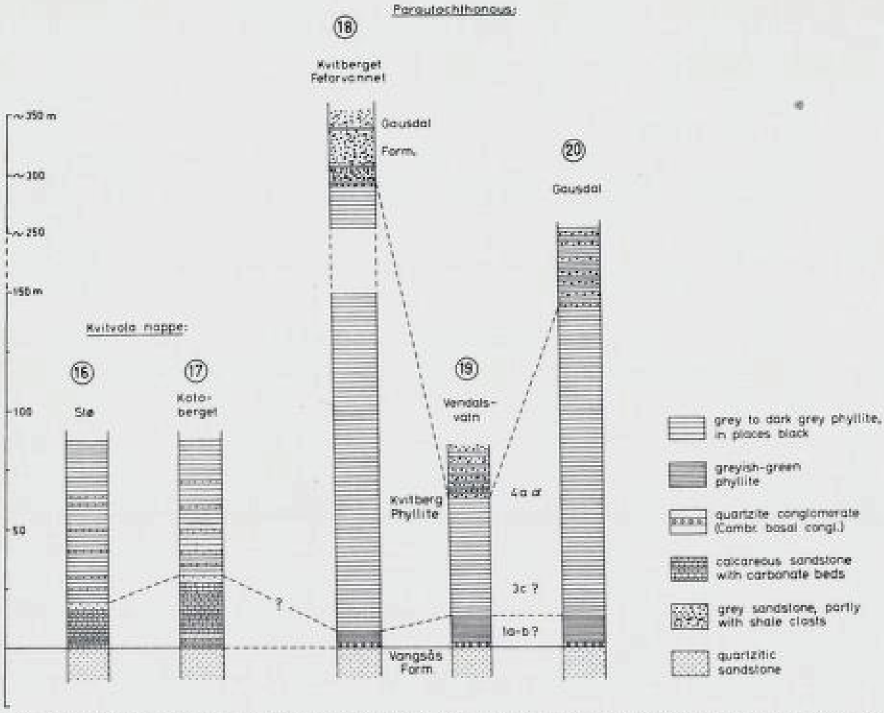



*Fig. 11.* Sections from the Cambro–Ordovician sequence along Gudbrandsdalen and the Gausdal valley. The localities are shown in Fig. 2.

reminiscent of that of the Vangsås Formation (p. 29). The author is inclined to regard the first variety of the Elstad Shale as corresponding to a (?) Cambrian–Ordovician succession. The above-mentioned quartzite conglomerate could then represent the Cambrian basal conglomerate.

The second type of Elstad Shale could be an equivalent to the Biri Formation. This possibility seems reasonable in the light of the observed hiatus within the Hedmark Group, whereby the Vangsås Formation overlies the Biri Formation northwest of the Fåvang area. Also quite likely, from a tectonic point of view (Fig. 16, sections IV and V; Plate 1; p. 38) is the notion that the Elstad Formation could be younger than the Brøttum Formation.

## KVITBERG PHYLLITE (CAMBRO–ORDOVICIAN)

This formation (up to 300–400 m) and its allochthonous equivalents cover a large part of the mapped district north and south of Gudbrandsdalen. Recently, a short description of the Kvitberg Phyllite was presented by the author (Englund 1973).

The name 'Kvitberg Phyllite' is introduced here as a litho-stratigrapical term of formational rank for phyllites overlying the Vangsås Formation in the present district. Its type area is in the vicinity of the mountain Kvitberget. The general development of the parautochthonous Kvitberg Phyllite is shown in Fig. 11.

The development of the corresponding phyllites within the Kvitvola nappe differs somewhat from that in the south. The upper boundary is unknown here. The transition between the 'light sparagmite' and the phyllite is in places characterized by a calcareous sandstone unit.

At some localities, black carbonaceous phyllite have been found within the Kvitvola nappe, but grey to dark grey types predominate. A characteristic feature is a number of grey to light grey sandstone beds in the lower part (Fig. 11, sections 16 and 17). The occurrence of sandy material in the Kvitvola nappe occurrence, and the usual lack or subordinate occurrence of this material to the south, are characteristic and general features of these rock units within the present region.

Stratigraphically equivalent deposits seem to occur above the Valdres Sparagmite in Feforkampen (p. 30). These phyllites have recently been described by the author (Englund 1973).

## THE EOCAMBRIAN–CAMBRIAN TRANSITION WITHIN THE KVITVOLA NAPPE

At many places within the upper unit of the Kvitvola nappe there occurs a calcareous sandstone suggestive of a Lower Cambrian or Upper Eocambrian age (Fig. 11). Dietrichson (1950, pp. 80–82), who has described this rock in the Vinstra region, regarded it as the uppermost part of the 'sparagmites' below possible equivalents of the Cambrian. This unit has also been described in some detail by K. O. Bjørlykke (1905, pp. 197–205) from the Vinstra–Kvam area. He regarded this rock as the uppermost part of the 'light sparagmite'. It corresponds to Strand's (1967) formation 3 from the Kvam–Sjoa district.

The thickness of this rock unit is up to ca. 40 m, and its boundaries to underlying and overlying rocks are transitional. In the upper part (0–9 m) of what is mapped here as an equivalent to the Vangsås Formation, thin calcareous sandstone beds are, in places, interbedded with quartzite layers.

This grey to light grey calcareous sandstone, partly showing brownish weathering due to contents of iron-bearing carbonate, is, in place, interbedded with phyllites or thin carbonate beds, often with a slight reddish colour. Bed thicknesses vary between 0.5 and 10 cm. The upper boundary of this unit is often marked by a light grey quartzite bed (Fig. 11, sections 16 and 17).

This calcareous sandstone is well developed in the western part of the mapped district, but seems to be lacking in places to the east. There the overlying phyllite is partly resting directly on the 'light sparagmite'.

### *Discussion*

Whether the calcareous rocks in question are partly detrital or are wholly micritic hat not been made clear. The Lower Cambrian rocks in the Mjøsa district show great and abrupt changes in lithology, indicating unstable sedimentary conditions (Skjeseth 1963); probably due to repeated transgressions and regressions with denudation and resedimentation. It seems, therefore,

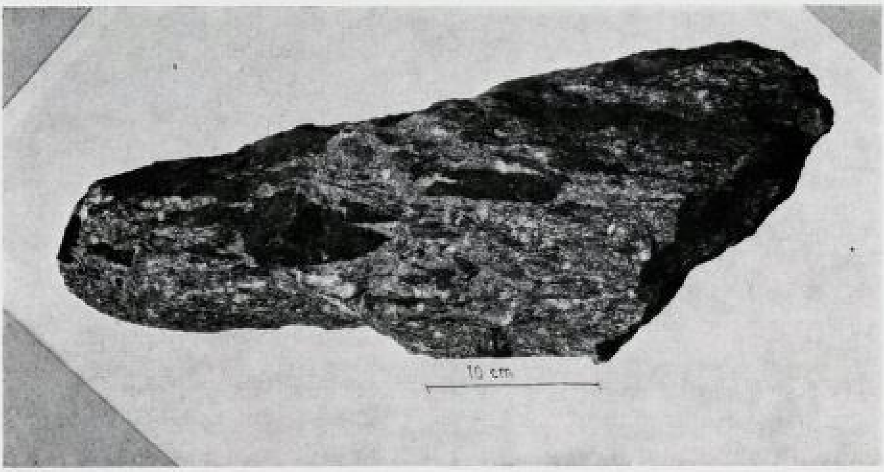



*Fig. 12.* Sedimentary breccia from the lower part of the Gausdal Formation just southeast of Feforvannet. Note the angular clasts of pelites (tectonically elongated) in a conglomeratic matrix with rounded quartz pebbles.

probable that the rocks from the present district indicate unstable sedimentary conditions; perhaps (?) epeirogenic movements could have taken place in parts of the sedimentation basin at the Eocambrian–Cambrian transition.

GAUSDAL FORMATION

This formation covers a large part of the mapped district in the south and southwest; Dietrichson (1950, p. 87) has earlier given it a short description. The formation can be followed further south into Gausdal (Fig. 1; Fig. 11, sections 18–20) where it has been described by K. O. Bjørlykke (1893, p. 19, 1905, p. 57) as an arenaceous shale. The formation there is overlying shales (Kvitberg Phyllite) with graptolites corresponding to 4 aα occurring in the upper part.

Within the present district the formation is at least 150 m in thickness, and lacks overlying younger deposits. The passage into the underlying Kvitberg Phyllite is relatively sharp and well defined, although, in places, there are thin (10–35 cm) sandstone beds just below this boundary. The formation is mostly developed as a grey, massive, coarse-grained sandstone interbedded with thin, grey, pelitic beds. Pyrite cubes (up to 4 mm) are commonly observed. In the Feforkampen–Feforvann area pelitic beds are quite subordinate (less than 5 per cent of the formation), but conglomeratic beds are very common. These beds contain quartz pebbles (often bluish) up to 4–5 cm across.

A characteristic feature of the formation within the whole mapped region is its high frequency of fragments of grey to dark grey phyllites (Fig. 12). This has earlier been mentioned by Törnebohm (1896, p. 145), who characterized the formation as a 'gneissic' grey sparagmite. Generally, these phyllite clasts seem to become less abundant and somewhat smaller (max. observed size, 30 cm), higher up in the formation.

Towards the southeast in the Toftesæterfjell–Storhaugen area the formation becomes more fine-grained. Conglomeratic beds are less frequent here, and the pelitic beds are thicker (up to 3–5 m) and constitute a larger part of the formation (about 10–15 per cent). Bedding is often difficult to detect within sandstone units, but a clear tendency towards graded bedding has been observed in some places. Cross bedding seems to be lacking.

South of the present region, a rhythmic alternation of sandstones, often showing graded bedding, and pelites predominates. The term 'flysch' is loosely applied to such deposits (Pettijohn et al. 1972, p. 499).

*Discussion*

This formation, which in places has the appearance of a sedimentary breccia, shows no positive evidence of shallow-water sedimentation, and indeed all the observed features are indicative of rapid deposition (? mudflows or turbidity currents) below wave base. Strong erosion of pelitic beds must have occurred, both from the underlying formation and from beds within the Gausdal Formation. The main sedimentary transport direction would appear to have been towards the southeast or south.

A strong invasion of sand from the north or northwest in Llandeilo time is known from many places along the Caledonian geosyncline (Størmer 1967, p. 202). In the Mjøsa district sandy and silty beds are common within the Hovinsholm Shale (= Robergia beds) and the Furuberg Formation (Skjeseth 1963), which possibly corresponds partly to the Gausdal Formation.

An interesting feature of this formation is that acid plagioclase is the dominating feldspar type (Fig. 14). Perthites of the 'Jotun-perthite' type have also been observed. These features, and the sedimentary development of the formation, indicate that rocks similar to those found in the Jotun nappe–Valdres nappe could have been affected by erosion at that time. Earlier, K. Bjørlykke (1965b) has indicated such a possibility based on a marked increase in the MgO content of shales near the boundary between the Lower and the Middle Ordovician near Oslo. No marked increase in the MgO content has been found within the Kvitberg Phyllite (Englund 1973, p. 42).

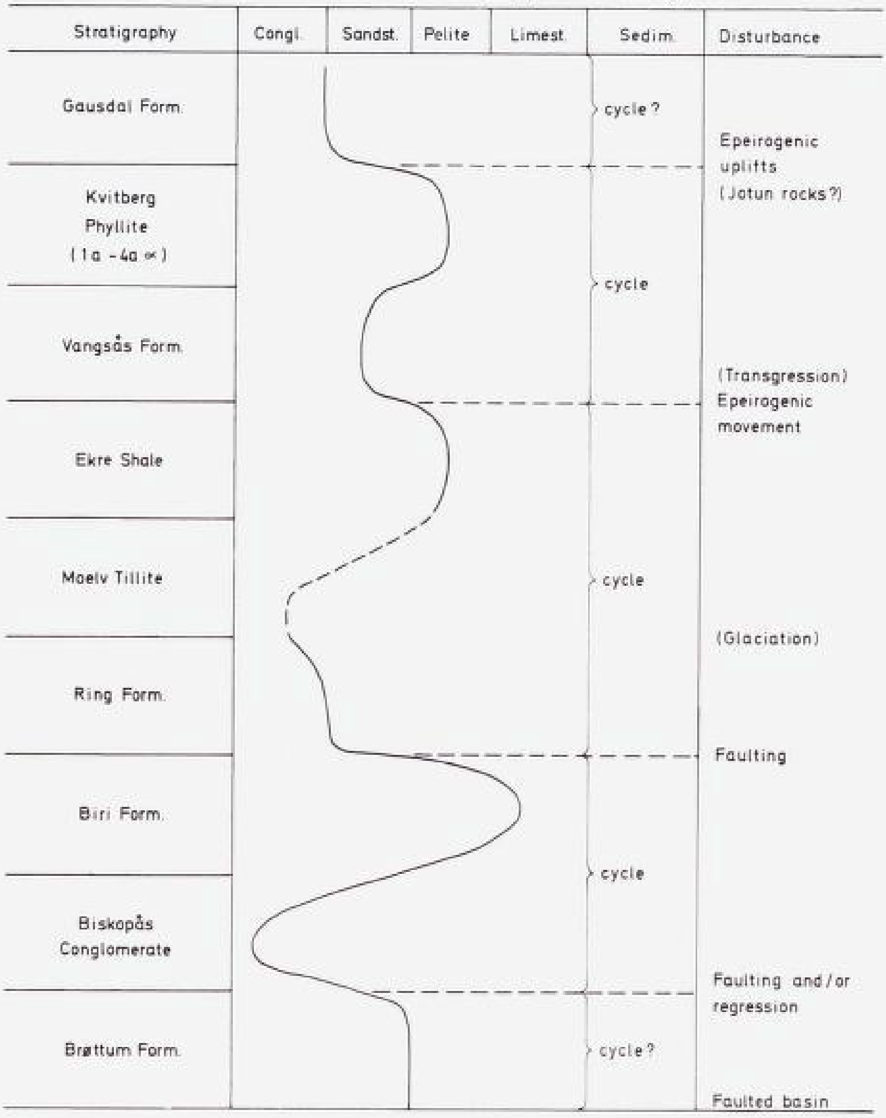
## CRYSTALLINE ROCKS OF THE JOTUN NAPPE–VALDRES NAPPE

The petrography of these rocks has been described in a series of papers: K. O. Bjørlykke (1905, p. 191), Werenskiold (1911, pp. 62–64), Oftedahl (1944), and Dietrichson (1945a, p. 16, 1950, p. 92, 1960).

## SOME GENERAL CONCLUSIONS

Rocks of the Hedmark Group have been deposited in basins or faulted troughs in the Precambrian Shield (Skjeseth 1963, p. 5, Strand 1972, p. 17). The sedimentary facies of these rocks are explained by the extension and successive development of the sedimentary basins. The major sedimentary successions within the Hedmark Group and within the overlying Cambro-Ordovician along Gudbrandsdalen are indicated in Table 2. These sedimentary cycles start with

*Table 2.* Possible main sedimentary cycles and main disturbances in the Hedmark Group and the Cambro–Ordovician of the Lillehammer–Ringebu–Vinstra region




coarse-grained clastic sediments and terminate with pelites or carbonate rocks.

An initial sedimentary cycle is perhaps represented by the Brøttum Formation, which has a total thickness of at least 1500 m. The transition to the overlying Biskopås Conglomerate reflects great disturbances in the sedimentation and a new cycle would appear to commence. The Biri Formation is considered to represent the end of a sedimentary cycle. Another possible cycle starts with the Ring Formation and terminates with the Ekre Shale. The glacial Moelv Tillite belongs to this cycle, although it is perhaps possible that the Moelv Tillite and the Ekre Shale should be regarded as one separate cycle.

The transgressive Vangsås Formation at the end of the Eocambrian marks the beginning of a cycle that embraces the Kvitberg Phyllite. Further south, at Mjøsa–Oslo, the transition Lower Cambrian–Middle Cambrian possibly represents the end of one cycle (Størmer 1967, p. 208). Within the present region the greenish lower part of the Kvitberg Phyllite shows no visible sedimentary break with the rest of the formation. The next sedimentary cycle would therefore appear to start with the coarse-grained Gausdal Formation. Rocks similar to those found in the Jotun nappe–Valdres nappe were possibly exposed and affected by erosion at that time – the (?)Pre-Caradocian disturbance in Britain – although alternatively, the 'Jotun perthites' found in the Gausdal Formation could have been derived from older sediments, as e. g. the Vangsås Formation.

## Petrography

Ninety-four thin-sections have been examined from sandstone formations (Figs. 13 and 14). The clastic character is evident in most cases except near the thrust planes of the Kvitvola nappe, where recrystallization appears to be related to tectonization features.

### THE MINERALS

*Quartz* has been observed in all thin-sections. It occurs both as clastic and as recrystallized grains, and is the principal mineral in numerous veins. The longest dimension of grains is usually parallel to the $D_2$ lineation (see p. 29 for explanation of structural notation; also p. 49).

*Feldspars* have been observed in most samples. Both clastic and recrystallized grains have been observed. Larger grains have retained their perthitic structure and twinning pattern, and are usually elongated parallel to the $D_2$ lineation. Sometimes the elongated feldspars are broken by open tension cracks perpendicular to the elongation lineation.

Plagioclase of a composition between pure albite and albite-oligoclase (An 10), as determined by the extinction angles, is the dominating feldspar type in the Brøttum and Gausdal Formations (Fig. 14). Some of the albite grains within these formations are chess-board albites. The other formations (including the Fron Member) show a more mixed feldspar content, often with potash feldspar as the dominating type. Some few grains of chess-board albite have been observed in the feldspathic sandstones and quartzites just south of Teigkampen.

Potash feldspar is mostly a cross-hatched microcline, but may also be untwinned. Larger grains are sometimes perthitic, and the type 'Jotun-perthite' has been found in very subordinate amounts in the Brøttum and Gausdal Formations. This perthite type is, however, more common within the Vangsås Formation, and in the feldspathic sandstones and quartzites of the Kvitvola nappe.

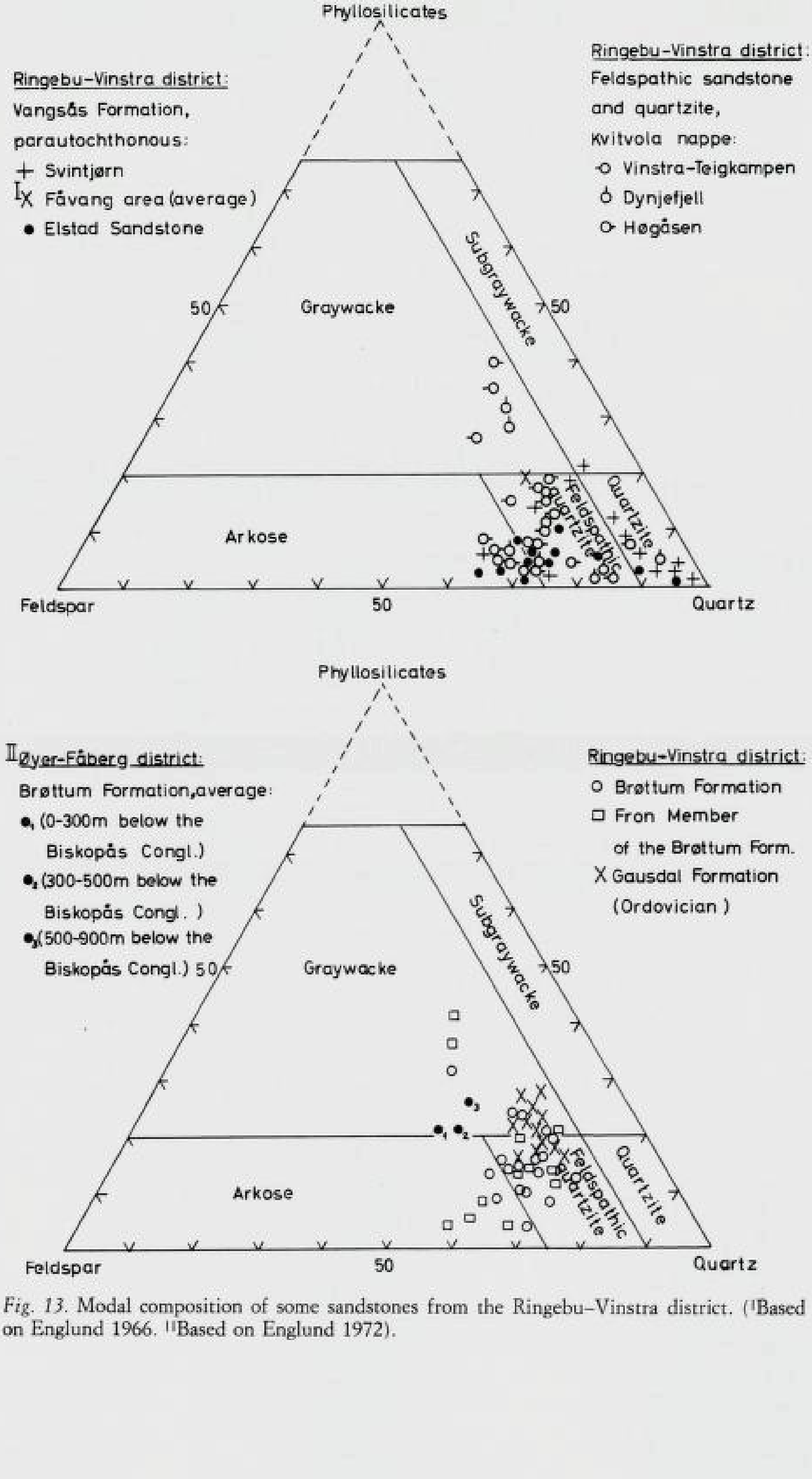



*Fig. 13.* Modal composition of some sandstones from the Ringebu–Vinstra district. ([I]Based on Englund 1966. [II]Based on Englund 1972).

*White mica* is, quantitatively, the dominating phyllosilicate. In the Brøttum and Gausdal Formations it usually occurs as the minutely crystalline variety, sericite. The flakes are commonly oriented parallel to the main slaty cleavage of $D_2$ age. In the feldspathic sandstones and quartzites of the Kvitvola nappe, white mica often occurs in relatively large flakes, certainly formed by recrystallization. The grain-size commonly varies between 0.1 and 0.3 mm. Larger grains (up to 0.5 mm across) of white mica within the Vangsås Formation are of supposed detrital origin.

*Biotite* occurs as a subordinate phyllosilicate within the Kvitvola nappe. It is partly intergrown with white mica, and is frequently a greenish variety.

*Chlorite* is present as a very subordinate mineral within both the parautochthonous rocks and within the Kvitvola nappe. It is most common within the Gausdal Formation, where it constitutes between 1% and 7% of the mode.

*Epidote* is a subordinate mineral within the whole region, but is most common within the Kvitvola nappe. It is probably of metamorphic origin.

*Carbonate* minerals are often present as a minor constituent in many thin-sections. Textural relations suggest that the carbonate minerals are the result of recrystallization.

LITHOSTRATIGRAPHICAL UNITS

The slightly metamorphosed sandstones from the present region have been classified in the scheme of Fig. 13, which has earlier been used by Stålhøs (1956), Bjørlykke (1966b) and Englund (1966, 1972) for corresponding rocks in Sweden and Norway. As a supplement, the relations between sodic plagioclase, potash feldspar and phyllosilicates are shown in Fig. 14.

*Brøttum Formation.* This formation has been investigated in the Harpefoss–Svintjørn area, and the Fron Member in the area north of Ringebu. The formation is mostly a feldspathic quartzite, but quite a few samples fall in the graywacke and arkose fields. Compared with the Brøttum Formation in the Øyer–Fåberg district, high contents of quartz and low contents of phyllosilicates are typical of the Harpefoss region.

Sodic plagioclase is the predominant feldspar within the typical Brøttum Formation, while the Fron Member is partly dominated by potash feldspars.

*Gausdal Formation.* All samples have been taken from the Feforvannet–Feforkampen area. Petrographically this formation resembles the Brøttum Formation. It is classified as a feldspathic quartzite or graywacke, and sodic plagioclase is the dominating feldspar type.

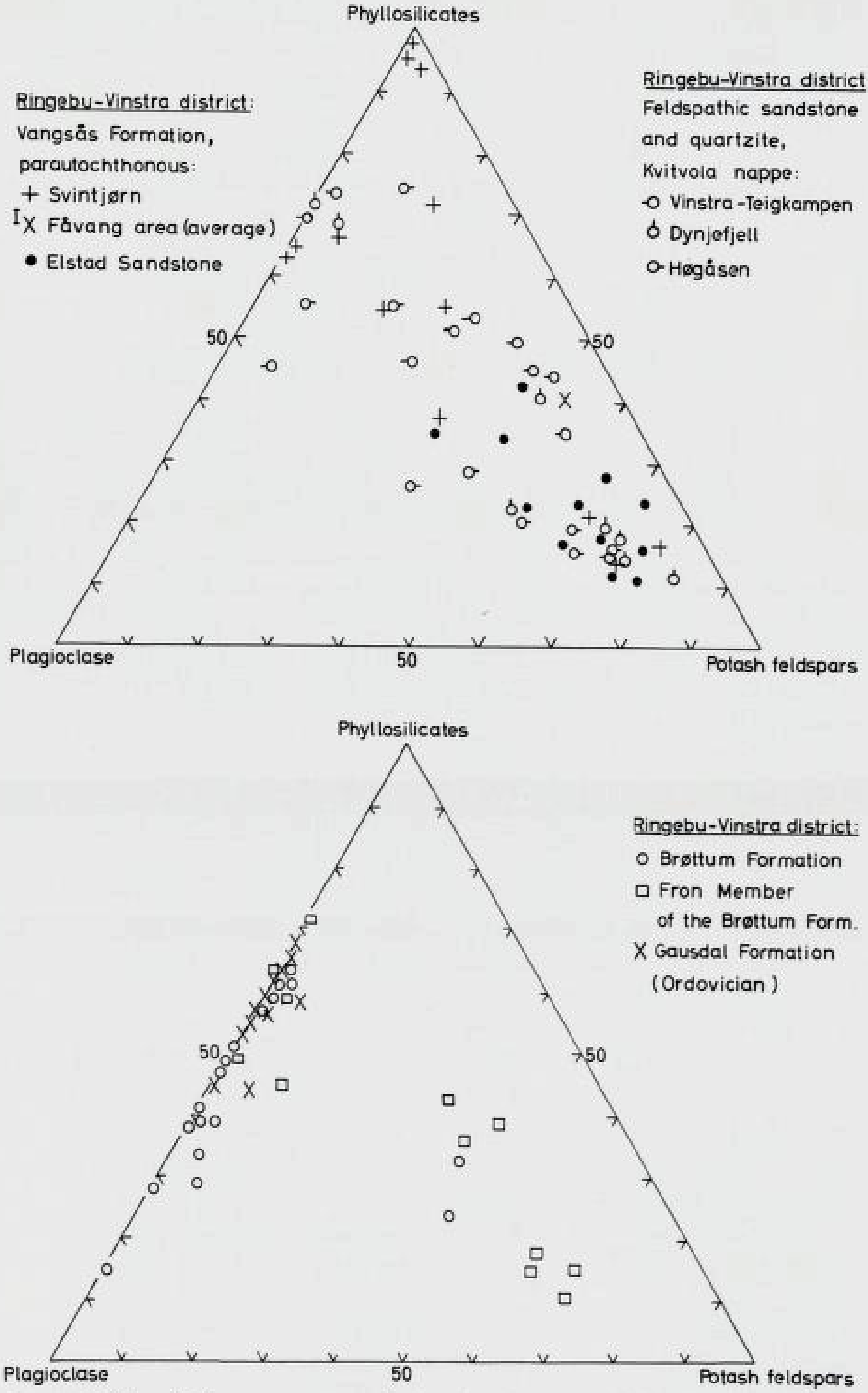



*Fig. 14.* Relationship between content of sodic plagioclase, potash feldspar and phyllosilicates in some sandstones from the Ringebu–Vinstra district. ([1]Based on Englund 1966).

*Vangsås Formation.* As shown in Fig. 13 this formation is mostly a quartzite or feldspathic quartzite. The feldspar-deficient variety always comes from the upper part of the formation. The typical lithology of this formation in the Fåvang area is relatively poor in quartz, but the quartzitic unit earlier mapped in this area as an Ordovician rock (Kvitfjell Quartzite) by the author (Englund 1966, p. 81) is now regarded as being equivalent to the Vangsås Formation.

The relative amounts of sodic plagioclase and potash feldspars vary within this formation, though it seems that potash feldspar is somewhat more dominant within the Fåvang area than further west.

*Elstad Sandstone Member.* This member of the Elstad Formation has earlier been described as an arkose (Englund 1966, p. 60), based on samples taken from the eastern side of the river Lågen. Twelve new samples from the western side of the Lågen show a composition ranging from arkose through feldspathic quartzite to quartzite (Fig. 14). Potash feldspar is always the principal feldspar type. The mineralogical composition of this formation is similar to that of the Vangsås Formation.

*Feldspathic sandstones and quartzites in the Kvitvola nappe.* This formation, which corresponds to the Vangsås Formation, has been investigated at three different localities (Fig. 13). Most samples occupy the field of feldspathic quartzite. The upper part of the formation is always the most quartzitic, while in the lower parts the lithology in places is a graywacke or an arkose. The relative proportions of sodic plagioclase and potash feldspar show large variations, apparently without any regional trend.

## Structural geology

The structural evolution of the Ringebu–Vinstra district has been complex. Four major phases of deformation have been recognized ($D_1$–$D_4$). In addition, earlier tectonic movements have influenced the sedimentation of the 'Sparagmite rocks' and the Ordovician Gausdal Formation.

Structures belonging to different sets or phases have been separated by their interference relationships, such as, e.g., refolding of earlier folds and lineations.

### MAJOR STRUCTURES

The most important megascopic structures recognized within the present region are associated with thrusting ($D_1$ and $D_2$ phases) and folding ($D_2$ and $D_3$ phases). In addition, there is a later phase of faulting ($D_4$).

#### *Thrusting*

Following Strand (1972, p. 30), the term nappe is used here in a broad sense for rock complexes of great extent moved for considerable distances above a substratum, and thus includes both thrust sheets and fold nappes.

*Jotun nappe–Valdres nappe.* These nappes are the highest tectonic units within the present district, thrust above rocks of the Kvitvola nappe in the north and above parautochthonous rocks in the south. Only outliers of these nappes are found within the present region, but just to the northwest and west the Jotun nappe occurs as a continuous unit (Figs. 18 and 20). In this paper the term Jotun nappe includes both the basement complex of crystalline rocks and its overlying sequence of sediments.

In the northern part of the mapped district, outliers of Strand's (1951) 'Otta nappe' are found, but, as pointed out recently (Strand 1972, p. 37), this nappe must be part of the large Jotun nappe together with its cover of sediments. Within the present district, this cover of sediments most probably corresponds to the Heidal Group of Gjelsvik (1946). Mica schists, partly with plagioclase porphyroblasts, and flagstones are met with at Trabelifjell and just south of Vaglfjell.

The outlier of the Valdres nappe at Feforkampen is composed of a series of imbricated wedges (Fig. 17, VIII), which strike northeast and dip towards the northwest. The structural sequence, going down from the metagabbro in the southeastern hillside of Feforkampen is:

1. Conglomerate with primary sedimentary contact to the metagabbro – most probably corresponds to the Moelv Tillite (Englund 1969).
2. Greenish phyllite – Ekre Shale.
3. Light quartzitic sandstone (6–8 m) – Vangsås Formation.
4. Greenish phyllite (6–10 m) – Lower Cambrian (?).
5. Dark grey to black phyllite (> 10 m) – Alum Shale.
6. Thrust plane above the Gausdal Formation.

The conglomerate was first observed by K. O. Bjørlykke (1905, p. 190) and has been described as the Gabbro Conglomerate of the Valdres Sparagmite by Dietrichson (1945a, 1950). This conglomerate is known from many places in Southern Norway, but is restricted towards the east-northeast to the areas of Dokkvatn–Espedalsvatn–Feforkampen–Hindseter, Sjodalen. It is further interesting to note that remnants of Alum Shale have been found at different places within the same region as that in which the Gabbro Conglomerate has been observed (Dietrichson 1945a, p. 85) as, for example, at Neset farm in Svatsum. at Feforkampen, on Olasfjell in Kvikne, and just southeast of Heidalsmuen. In the author's opinion the Gabbro Conglomerate corresponds to the Eocambrian Moelv Tillite, and this unit, together with equivalents of the Ekre Shale and the Vangsås Formation, belongs to the Valdres Sparagmite.

The relationships at Feforkampen show that the Valdres Sparagmite here was thrust (fold-thrust?) into its present position along with crystalline rocks upon which it was initially deposited. The sequence here could belong to the lower limb of a great recumbent fold.

The author has not mapped within the Espedalen massif which lies to the southwest of the present region, but older data (Dietrichson 1945a, 1945b) and air-photo studies suggest that this unit is composed of imbricated wedges striking northeast and dipping towards the northwest (Plate 1). It is possible that large recumbent folds also exist in this area. The Espedalen massif consists of crystalline rocks overlain in places by deformed sediments which are probably equivalent to the sedimentary rocks in Feforkampen (Dietrichson 1950). Consequently the Espedalen massif and the outlier in Valsfjell seem to be parts of the Valdres nappe (Fig. 1), in accordance with Strand (1972, p. 34).

At present it is difficult to make any correlation between the Heidal Group and the Valdres Sparagmite, but both these units occupy the same stratigraphic position above crystalline rocks. Observations from the present region show that there are marked similarities between the quartzitic sandstone of the Heidal Group and the Eocambrian Vangsås Formation – as has been earlier mentioned by Strand (1964, p. 290).

The term 'Valdres nappe' was introduced by Kulling (1961) for the great tectonic unit composed of the Valdres Sparagmite and younger rocks in Southern Norway (Strand 1972, p. 33). In the vicinity of Bygdin this tectonic unit displays a clear thrust boundary to the crystalline Jotun rocks (Strand 1945, Hossack 1967). On Grønsennknipa in Valdres, however, a primary sedimentary contact is found between the Valdres Sparagmite and crystalline rocks (Nickelsen 1967 p. 118, Hossack 1972, p. 6), just as on the mountain Feforkampen.

The Jotun nappe–Valdres nappe was emplaced in the $D_1$ phase. The main thrust plane, upon which the nappes rest, has been truncated by minor thrusting. This is seen at Feforkampen (Fig. 17, VIII), and on a larger scale north of Gudbrandsdalen (Fig. 17, IX). Such imbrication of the Jotun nappe has been described earlier by Strand (1951, p. 29) from the Sel and Vågå map areas. Within the present region this imbrication is affected by the later $D_2$ folding and the imbrication is therefore regarded as a late $D_1$ episode.

*Kvitvola nappe.* There appears to be a tectonic boundary within the present region between the 'Sparagmite basin facies' of the Hedmark Group and an overlying nappe sequence of 'Kvitvola facies' to the north (Fig. 1 and Plate 1). This nappe unit should therefore be a western equivalent of the Kvitvola nappe found in Engerdalen and in Østerdalen, as was indicated by Oftedahl (1954a). Earlier, Törnebohm (1896) had regarded the rocks north of Hundorp–Ringebu as belonging to a nappe unit.

Within the present region the Kvitvola nappe can be divided into two imbricated main units. The dominating rock-type within these units is Werenskiold's (1911) 'upper light sparagmite' (corresponding to the Vangsås Formation) from the map-sheet Søndre Fron. The feldspathic sandstones and quartzites of the lower unit are resting on different rock-types. Within the mapped region they are resting on probable equivalents to the Biri Formation found from the Vinstra area and eastwards towards Ringebu, and then northwards to the mountains Rundfjell–Remdalshøgdene just south of Åstdalen, about 18 km northeast of Ringebu (Fig. 15; Werenskiold 1911, map). The boundary between the 'light sparagmite' and the underlying Biri Formation

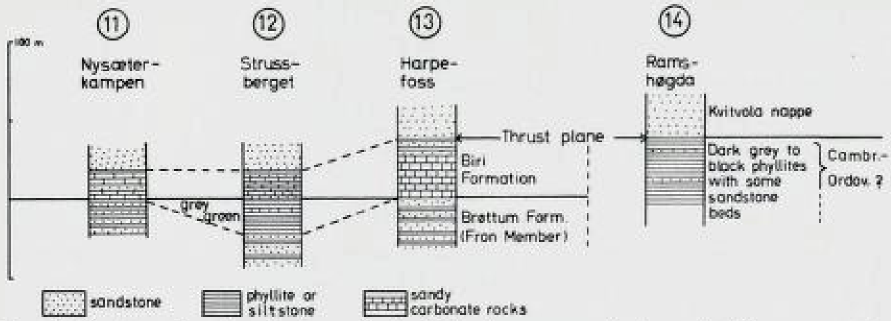



*Fig. 15.* Sections showing the base of the Kvitvola nappe and the underlying parautochthonous rocks in the Ringebu–Vinstra–Ramshøgda area. The localities are shown in Fig. 2.

is usually sharp and well-defined. In places, slices of carbonate rocks have been found within the Fron Member of the Brøttum Formation (Fig. 16, IV and V), which suggests either that it has been infolded in this unit or that it is overthrust by parts of the unit.

From Åstdalen and further north (Fig. 32; Werenskiold 1911, map) towards the mountain Snuskletten and then westwards towards Ramshøgda and Atnasjøen, the 'light sparagmite' is resting either on Vangsås Formation or on supposed Cambro–Ordovician phyllites. This is well demonstrated in the area around the Precambrian gneisses of the Snødøla window. There the Precambrian rocks (Prost 1963) are overlain by Moelv Tillite (basal tillite), Ekre Shale, Vangsås Formation (Werenskiold's (1911) 'lower light sparagmite') and dark grey to black phyllites of supposed Cambro–Ordovician age.

According to K. Bjørlykke (1965a) the Kvitvola nappe in Southern Norway occurs in two different tectonic positions:

1. Resting on Vangsås Formation and Cambro–Ordovician sediments,
2. With carbonate beds and conglomerate schists in the lower parts, overlying the autochthonous Brøttum Formation.

The Kvitvola nappe north and west of Åstdalen belongs to case 1, but south of this valley, Prost (1970, p. 756) regards the Fron Member as belonging to the Kvitvola nappe. It seems, however, difficult to accept this view mainly because of the lack of the Fron Member and the Biri Formation below the 'light sparagmite' north and northwest of Åstdalen. In addition these units can be followed to Kongslikampen near Vinstra, below supposed parautochthonous rocks.

The upper imbricated unit of the Kvitvola nappe has a position different from cases 1 and 2. It is resting on feldspathic sandstones and quartzites of the lower Kvitvola unit, but its stratigraphy and lithology (Fig. 10) correspond well with those described from the Koppang area and from Engerdalen. Along the southwestern margin of the nappe, the whole unit is overfolded towards the southwest (Fig. 16, VI and VII). A characteristic rock-type of this upper unit is a conglomerate which is probably equivalent to the Moelv

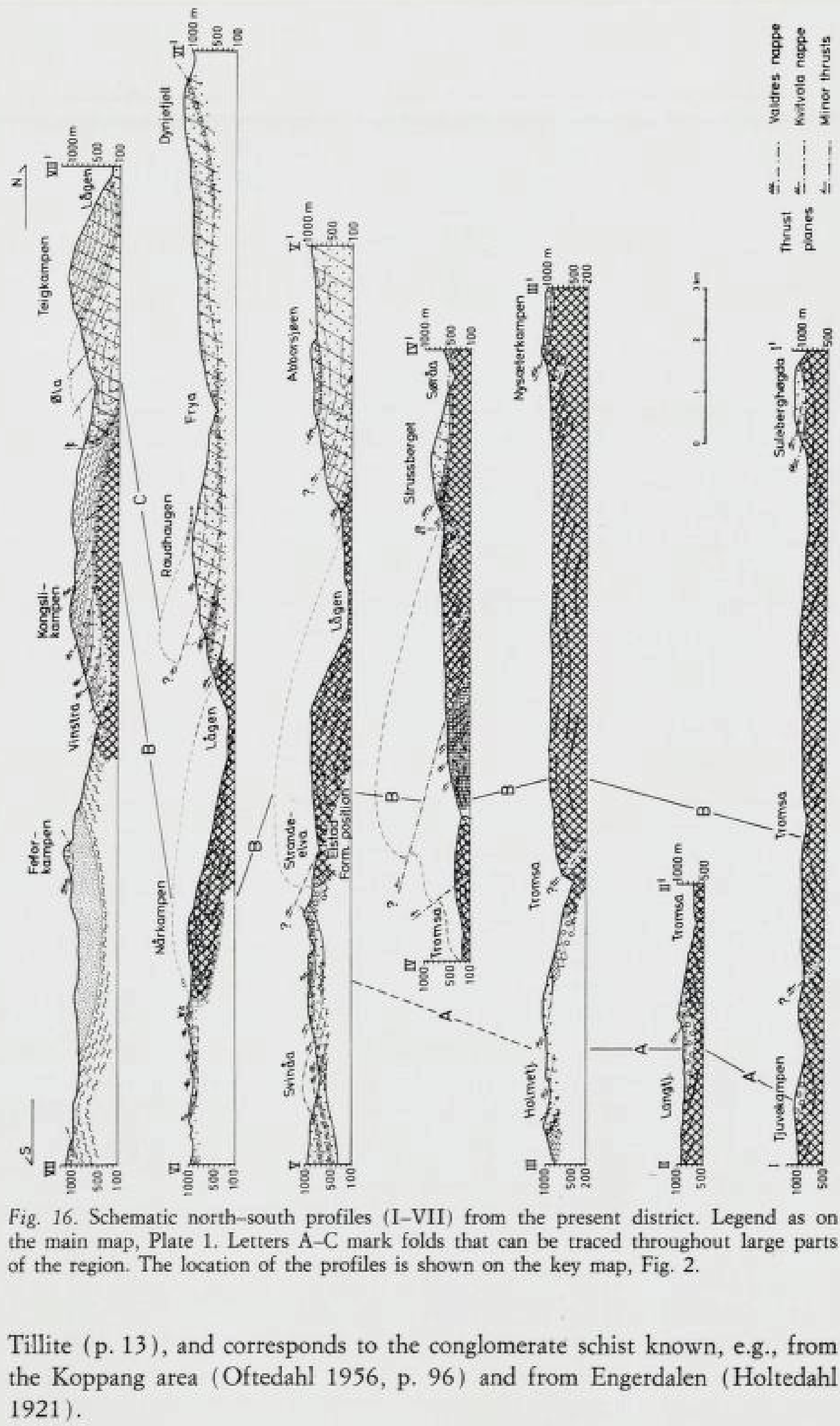



*Fig. 16.* Schematic north–south profiles (I–VII) from the present district. Legend as on the main map, Plate 1. Letters A–C mark folds that can be traced throughout large parts of the region. The location of the profiles is shown on the key map, Fig. 2.

Tillite (p. 13), and corresponds to the conglomerate schist known, e.g., from the Koppang area (Oftedahl 1956, p. 96) and from Engerdalen (Holtedahl 1921).

In the area just west of Vinstra it is impossible to distinguish between a lower and an upper nappe unit, and this region must therefore represent part of the root-zone for the upper unit. To the north the upper unit can be followed towards the lake Furusjøen (Fig. 18).

From the region just east of Kvam and eastwards towards Kollberget–Grønfjell–Krøkla, minor imbricated slices of the 'light sparagmite' can be followed within the Cambro–Ordovician phyllites. All these slices are part of the upper unit of the Kvitvola nappe.

A characteristic and interesting feature of the Kvitvola nappe is that thrust-planes often follow one and the same stratigraphic horizon for many kilometres. When thrusting has once started along a zone of weakness (shaly or calcareous formation), this zone then serves as a lubricating medium.

*Imbricate structures in the Vangsås Formation.* Within the present region, a strong imbrication of the Vangsås Formation has been found. The author has described this earlier from the Fåvang area (Englund 1966, p. 85), and later mapping towards the Vinstra area (Plate 1) has shown this to be a general feature within the whole region.

The imbricated units of the Vangsås Formation are usually separated by Cambro–Ordovician phyllites, but in the Oppsalåsen–Svangkampen area the Moelv Tillite and Ekre Shale have also been found between these units. Four of the profiles in Fig. 16 demonstrate the general development of this imbrication structure. It will be seen that the thrust-planes are mostly of the low-angle type and are often folded ($D_2$ folding, see p. 35). This folding is especially well demonstrated in the areas south of Strandeelva–Nårkampen, and just north of Gompen the thrust-plane has been brought up to a vertical or partly inverted position.

It seems possible that the total imbrication of the Vangsås Formation is of two different origins. One type could belong to the $D_1$ phase because the imbricated units and their thrust-planes are folded by the later $D_2$ folds. This type is by far the more important and dominates in the area between Segalstadsæterkampen and Svintjern. The other type of imbrication appears to be connected with $D_2$ folds and is developed as typical thrust-faults. This type has more or less affected the whole region, but is best demonstrated just north of Gompen, and is possibly the main type on the eastern side of the river Lågen.

Primary structures (cross bedding) in the imbricated units always show a normal way-up sequence, except those connected with the minor inversion just north of Gompen. This means that large recumbent folds have not been recognized within the thrust Vangsås Formation.

The direction of transport is unknown, but is most likely towards the south-east or in the direction of overfolding of the $D_2$ folds, towards the south. In the first case, the minimum transport distance of some of the imbricated units is around 7–8 km, and in the second case about 4–5 km. These data suggest that the Vangsås Formation has been subjected to rather strong compression within the present region.

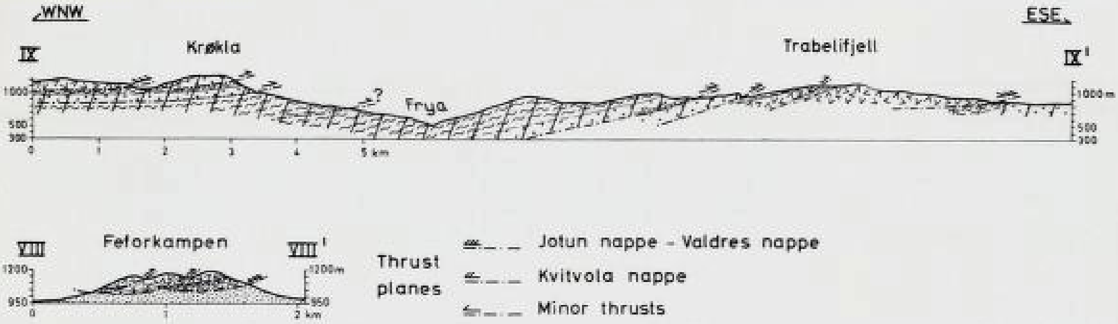



*Fig. 17.* Schematic east–west profiles (VIII–IX) from the present district. Legend as on the main map, Plate 1. The location of the profiles is shown on the key map, Fig. 2.

*Folding*

*$D_1$ folds.* The oldest folds in the Ringebu–Vinstra district are small recumbent folds (Fig. 22) which were later refolded ($D_2$). Major recumbent $D_1$ fold-nappes have not been recognized within the present region, but the author is of the opinion that the inverted sequence at Feforkampen could be part of the lower limb of a great recumbent fold.

Isoclinal and recumbent folds usually associated with large scale thrusting have been reported in recent years from different parts of the southern Caledonian mountain chain (see Strand 1969, p. 356, 1972, Smithson & Ramberg 1970).

*$D_2$ folds.* The structural pattern within the whole region is governed by $D_2$ folding on WNW axes. This deformation affects all nappe units. As can be seen from the maps (Figs. 18, 20 and Plate 1), and profiles (Fig. 16) several major folds can be traced throughout the area. Some of these structures have been followed outside the mapped district.

In the area north of Gudbrandsdalen, a large synformal structure with Jotun nappe rocks in its core can be followed from Trabelifjell–Kirkegårdsfjell towards Krøkla–Gråhø and to the region south of Otta. This is a well known structure mentioned by many authors, e.g., Strand (1967, p. 102). The map pattern on the northeast side of Gudbrandsdalen (see Werenskiold's (1911) map) is dominated by this fold direction which has often been referred to as a Caledonian cross-folding (Strand 1960, p. 192). The next important structure to the southwest is the Øla–Raudhaugen overturned anticline (Fig. 16 C). Large folds similarly overfolded to the southwest have previously been described from the area of Øla–Teigkampen (Bjørlykke 1905, p. 197, Dietrichson 1950, p. 77). This fold structure follows the southwestern margin of the Kvitvola nappe.

The largest and regionally most important fold is referred to here as the Vinstra–Ringebu Anticline (Fig. 18), which continues towards Stai, Østerdalen. The axial trend changes somewhat from about 140$^g$ in the Vinstra area to about 110$^g$ in the area east of Ringebu. Skjeseth (1963, p. 90)

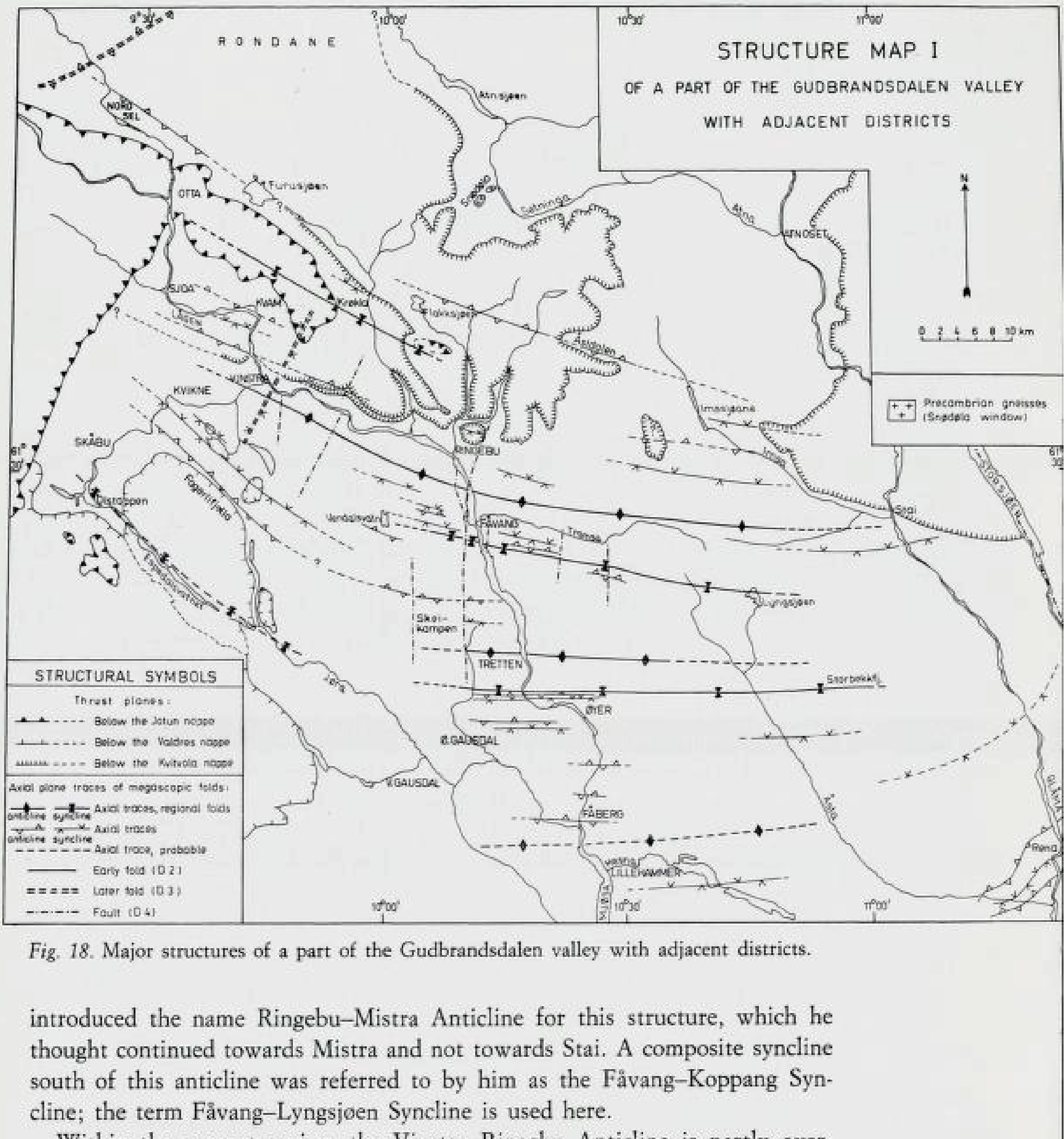



*Fig. 18.* Major structures of a part of the Gudbrandsdalen valley with adjacent districts.

introduced the name Ringebu–Mistra Anticline for this structure, which he thought continued towards Mistra and not towards Stai. A composite syncline south of this anticline was referred to by him as the Fåvang–Koppang Syncline; the term Fåvang–Lyngsjøen Syncline is used here.

Within the present region, the Vinstra–Ringebu Anticline is partly overturned towards the southwest (Fig. 16 B). This can be demonstrated along Steinåa (L 4, L 5), where the Brøttum Formation overlies the Biri Formation over a distance of at least 2 km (Fig. 16, VI). The Vangsås Formation is here also partly overlain by the Brøttum Formation. The existence of great overfolds in this region was earlier postulated by C. Bugge (1954, p. 35), but his interpretation differs somewhat from that of the present author. To the northwest of Steinåa it has not been possible to follow this overfolding, but to the southeast it is partly visible. In the areas south of the Elstad Formation, which is situated in the central parts of this anticline (Fig. 16, IV and V), vertical and partly inverted strata of the Brøttum Formation may be observed. Many authors have discussed the stratigraphic and tectonic position of the Elstad Formation (see Englund 1966, p. 92), and the discovery of a large recumbent fold in the Brøttum Formation to the west is possibly of considerable importance to this discussion (see p. 38). Further east along the southern limb of the Vinstra–Ringebu Anticline, vertical or steeply dipping beds occur along the main E 6 road, along the river Breia (Y 1) and on the northern hillside of Rognvola southwest of Stai (Oftedahl 1956, p. 68).

Earlier, the Fåvang–Lyngsjøen Syncline has been briefly described by the author (Englund 1966, p. 84). It is most symmetrical on the eastern side of the Lågen (Fig. 16 A). Because of the syncline's western plunge profile V of Fig. 16 is structurally higher than sections I, II and III, and the actual synclinal character is lost in section VI. The term Fåvang Synclinorium has been used by the author in an earlier paper (Englund 1972) in referring to the general downfolding of this region. All minor $D_2$ folds within the Fåvang area are large-scale parasitic folds (terminology of de Sitter 1958) on the limbs of the main Fåvang–Lyngsjøen Syncline.

The structural pattern further south in Gudbrandsdalen is governed entirely by $D_2$ folds on E–W axes. Broad synclinal structures occur at Tretten–Øyer and south of Lillehammer, with corresponding anticlines just north of these structures (Fig. 18).

The rocks of the Espedalen massif are elongated to the northwest and are greatly influenced by $D_2$ folding in that direction. A major synclinal structure can be followed from Olstappen and southeast along Espedalsvatnet (Fig. 18). Another large syncline can be traced from the area southeast of Valsfjellet and towards the northwest along Feforvannet. The Valdres nappe at Feforkampen forms a minor syncline within this larger structure (Fig. 16, VII). Between this main syncline and the Espedalen massif there is a major anticline.

Other $D_2$ folds that can be mentioned are: a syncline in the Teigkampen area with a corresponding anticline to the north, minor synclines at Strussberget and Skottåsen, a syncline from west of Rognvola eastwards to Tronkberget on the eastern side of the Glåma, south of Stai. Other prominent structures occur in the area of the river Imsa with a marked syncline through Bølhøgda and the southern part of Skarven.

In the north of the mapped district an important antiformal structure can be traced from Rosten, Nord-Sel, to Furusjøen in the southeast (Fig. 18). The conglomeratic unit known as the Rosten Conglomerate (Strand 1951, p. 15) occupies the central parts of this anticline (Fig. 19). Further to the southeast a major anticline, partly overturned towards the southwest, is traceable from Flakksjøen towards Åstdalen and to the area north of Imssjøane. In the author's opinion these two anticlines are situated along a very important major structure which demonstrates the presence of large-scale thrusting. Northeast of the anticline at Rosten, a thrust unit of the Vardhø Schists and Gneisses (Strand 1951, p. 29) now occurs above feldspathic sandstones and quartzites probably

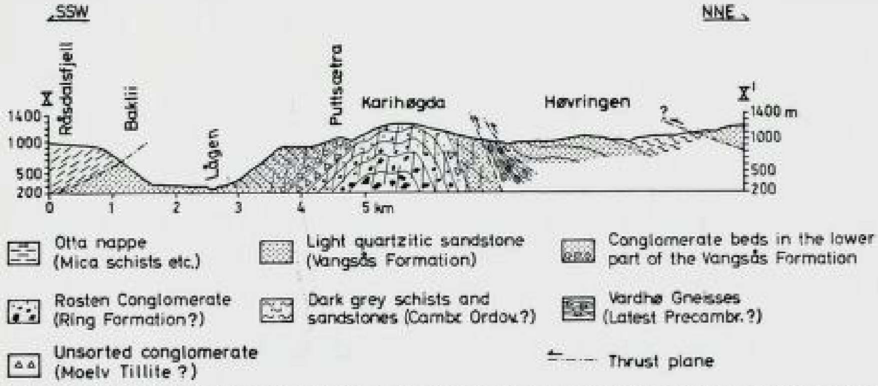



*Fig. 19.* Schematic profile from the Nord Sel–Høvringen district showing the structural position of the Rosten Conglomerate. The location of the profile is shown on the key map, Fig. 2.

corresponding to the Vangsås Formation (Fig. 19). In the area just east of Imssjøane, imbricated nappe structures contain Precambrian basement rocks overlain by Moelv Tillite and younger sediments. These units may have their roots in the Precambrian windows about 50 km to the northwest (K. Bjørlykke 1969).

Viewed in a regional perspective, the megascopic $D_2$ folds along Gudbrandsdalen and in adjacent districts show some general trends (Fig. 18). Where overfolding occurs this is always towards the southwest or south; none have been observed in the opposite direction by the author. The axial traces are arcuate in plan, striking NW–SE in the western part and E–W in the central part of the region. Along the Østerdalen valley the fold axial trend is partly NE–SW, a trend which is common in the southern part of the Sparagmite basin in the Rena district (K. Bjørlykke 1966b). On a regional scale, the axial traces shown in Fig. 18 can thus be regarded as minor folds on a large salient that has been influenced by old structural lines in the Precambrian basement. This salient must occupy great parts of the Sparagmite basin and continue outside the present region.

*Comments on the tectonic relations in and around the Elstad Formation.* As already mentioned, the Elstad Formation is situated in the central parts of the Vinstra–Ringebu Anticline. This formation is strongly imbricated (Fig. 16, IV; also Englund 1966, p. 90), though in the tectonically overlying Brøttum Formation the degree of imbrication seems to be less marked. On the eastern side of the river Lågen slices of the Elstad Forrmation, dipping steeply to the north, appear to be overlain by partly flat-lying beds of the Brøttum Formation. On the western side of the river, however, a unit of the Elstad Sandstone is resting on the Brøttum Formation and to the north is partly overthrust by this formation (Plate 1).

Within a zone on the southern limb of the Vinstra–Ringebu Anticline, steeply dipping or inverted strata are present in the Brøttum Formation, and brecciated beds can be seen in places. This zone most probably represents thrust-faulting on a large scale (Fig. 16, I, III, IV and V).

Another interesting feature of the region is the gravimetric model (Ramberg & Englund 1969). This model shows a distinct and broad gravity low running along Gudbrandsdalen within the Elstad Formation and further to the northwest. This means that a thick sedimentary cover (1.5–3 km) separates the Elstad Formation from the crystalline basement; a possible interpretation of this could be that the Elstad Formation is 'floating' in the Brøttum Formation.

*$D_3$ folds.* Within the present region there are two main trends of fold axes, one NW–SE or E–W ($D_2$ folds) and the other NE–SW ($D_3$ folds). The latter parallels the main Caledonian strike and has been found only on a broad megascopic scale within the Vinstra area (Fig. 18). In this deformation phase a large open syncline was produced which refolds the older $D_2$ structures. Possible equivalent structures have been described by Strand (1951, 1964) from the Sel and Vågå map areas, and a young fold-phase which governs the map pattern in the Bjørånes window in Østerdalen (K. Bjørlykke, 1969, p. 317) could be of similar age.

*Faulting*

The faults occurring in parts of the present district (Figs. 18, 20 and Plate 1) are usually parallel to master joints found in nearby areas. These joints are clearly visible on air-photos. All the observed faults have affected the entire complex of sediments.

This late Caledonian (?) or Permian faulting phase ($D_4$) is, for the greater part, probably controlled by the latest Precambrian and Eocambrian fault-system. This has been demonstrated for the Rendal fault (Skjeseth 1963) and the Engerdal fault (Holtedahl 1921). The great fault transecting the Fåvang area (Englund 1966, p. 95) is probably parallel to the western margin of the sedimentation basin for the Hedmark Group (Ramberg & Englund 1969). The fault is probably a northern continuation of the Hov–Snertingdal fault zone mapped by Skjeseth (1963, p. 114) in the Mjøsa district. In the Fåvang area, the eastern block shows a relative downthrow of approximately 450–480 m along this fault, which continues towards the north along the western border of the Elstad Formation with a minor branch appearing to follow the course of the Lågen. In the discussion of the tectonic position of the Elstad Formation it is important to remember that this unit has been downfaulted perhaps 300–500 m in relation to the Brøttum Formation.

A minor fault has been found east of Svangkampen with a western downthrow of ca. 80–120 m, and another occurs just west of Tjuvekampen and continues southwards along Vålsjøen (Fig. 18 and Plate 1). Here, too, it is the western side of the fault which has been downthrown. In the Hundorp–Vinstra area only few minor faults are present, some of which have been mentioned earlier by Bjørlykke (1905). The area around Harpefoss–Svintjern forms a minor horst-like structure bounded by N–S and NNE–SSW trending faults.


*Fig. 20.* Structural observations from a part of the Gudbrandsdalen valley.

All faults mentioned here seem to be later than the folding and no features have been observed which could indicate movement along the faults during the folding. Such faults have been described, however, from the Kvam–Sjoa district by Strand (1967, p. 104).

## MINOR STRUCTURES

Various mesoscopic structures have been recorded and these provide proof of three or possibly four phases of folding. Mesoscopic structures are folds of

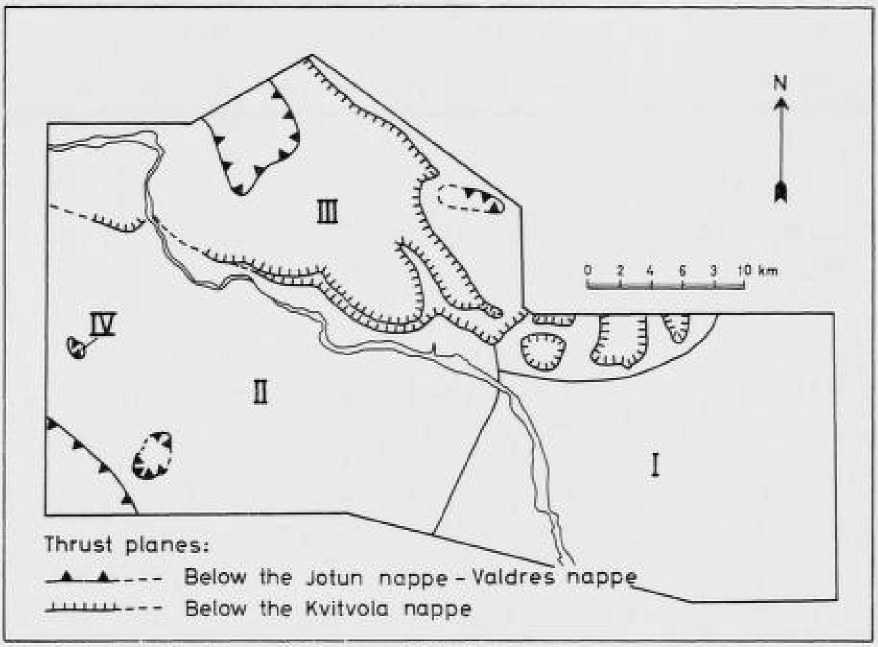



*Fig. 21.* Structural sub-areas of the mapped district.

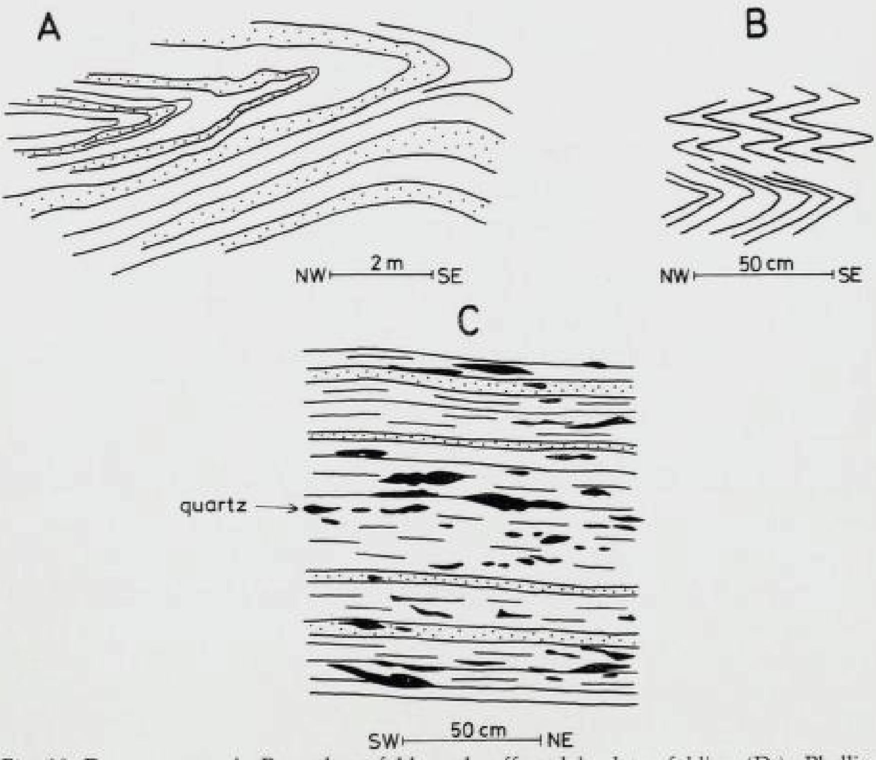



*Fig. 22.* $D_1$ structures. A. Recumbent fold partly affected by later folding ($D_3$). Phyllite with sandstone beds in the Brøttum Formation at Harpefoss (I 8). B. Minor folds in Cambro–Ordovician phyllite south of Vinstra (E 7). C. Phyllite and sandstone beds with numerous quartz segregations of supposed $D_1$ origin. Cambro–Ordovician, just below the upper unit of the Kvitvola nappe north of Hundorp (M 7).

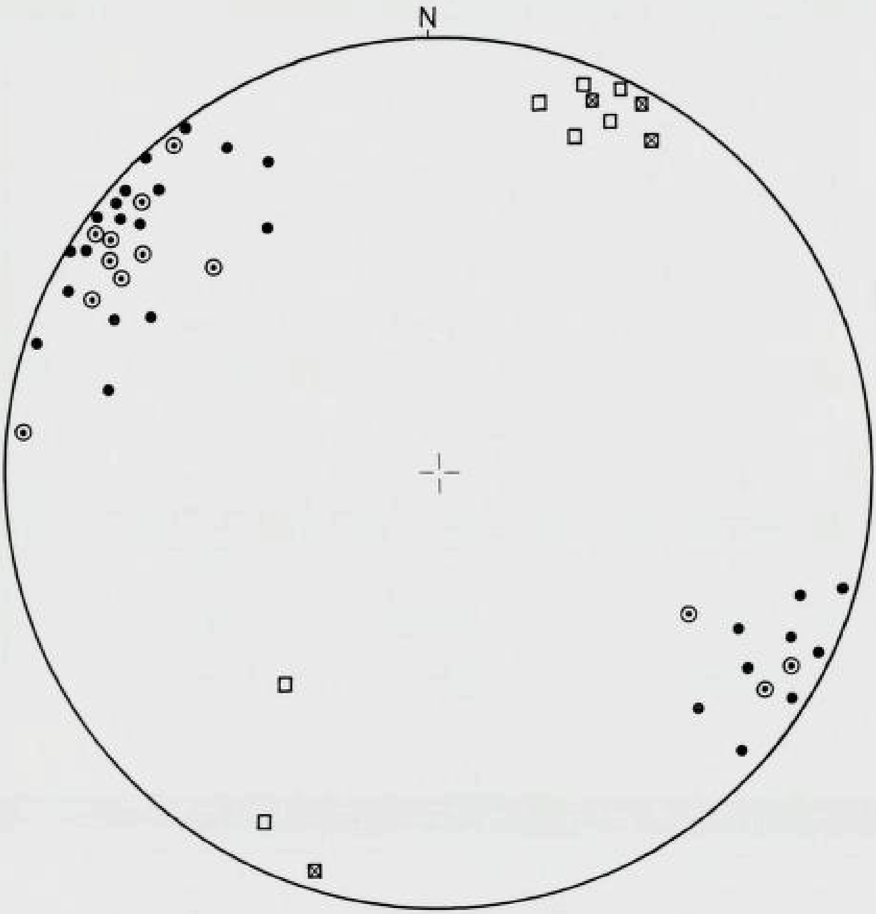



*Fig. 23.* Orientation of supposed $D_1$ structures from the sub-areas I and II.

dimensions observable on outcrop scale, minute crenulations in the incompetent phyllites, a lineation structure marked by parallel arrangement of elongate grains in the sandstones, and orientation of pebbles and boulders in the conglomerates. Because of variations in fold style, and because of lithological and tectonic differences, descriptions of minor structures are, in this paper, divided conveniently and geographically into four sub-areas (Fig. 21).

*First deformation phase ($D_1$)*

The folds of this deformation are tight to isoclinal, often with sharp hinges and with thinning of the limbs (Fig. 22 A and B). Such folds have been found within all tectonic units. Their axes trend approx. NNE–SSW (Fig. 23) with

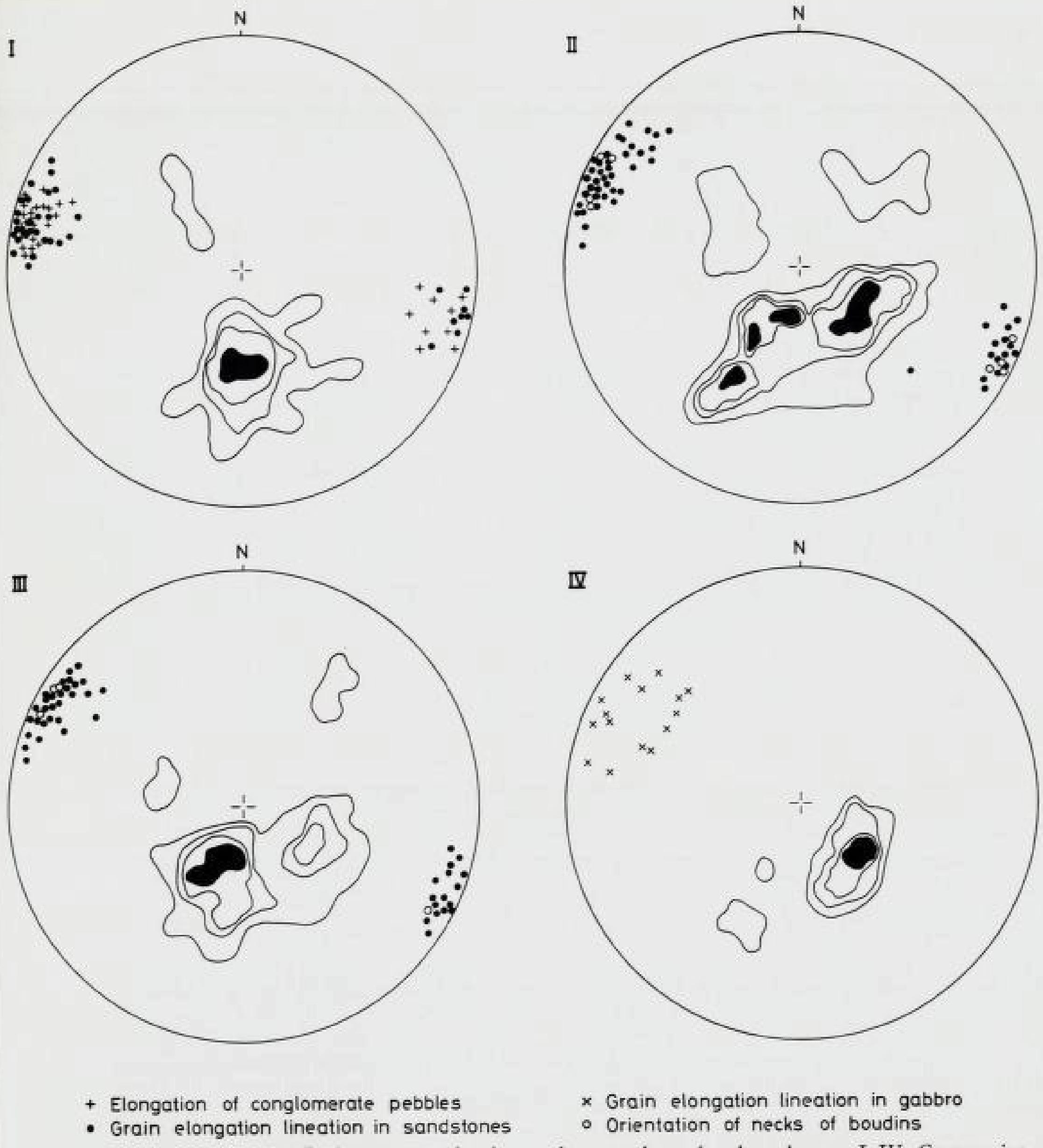



*Fig. 24.* $D_2$ lineations and poles to cleavage planes for the sub-areas I–IV. Contour intervals 2, 7, 15 and 25 per cent.

axial planes dipping gently to the west-northwest. The sense of overturning of $D_1$ folds is usually unknown since it is impossible to differentiate between long and short limbs in these structures.

An axial plane cleavage of $D_1$ age has been observed. This early cleavage is often more or less erased by later recrystallization and mineral growth. The strongly concentrated cleavage poles seen in Fig. 24, IV, from the rocks at Feforkampen are of supposed $D_1$ origin. A corresponding concentration is

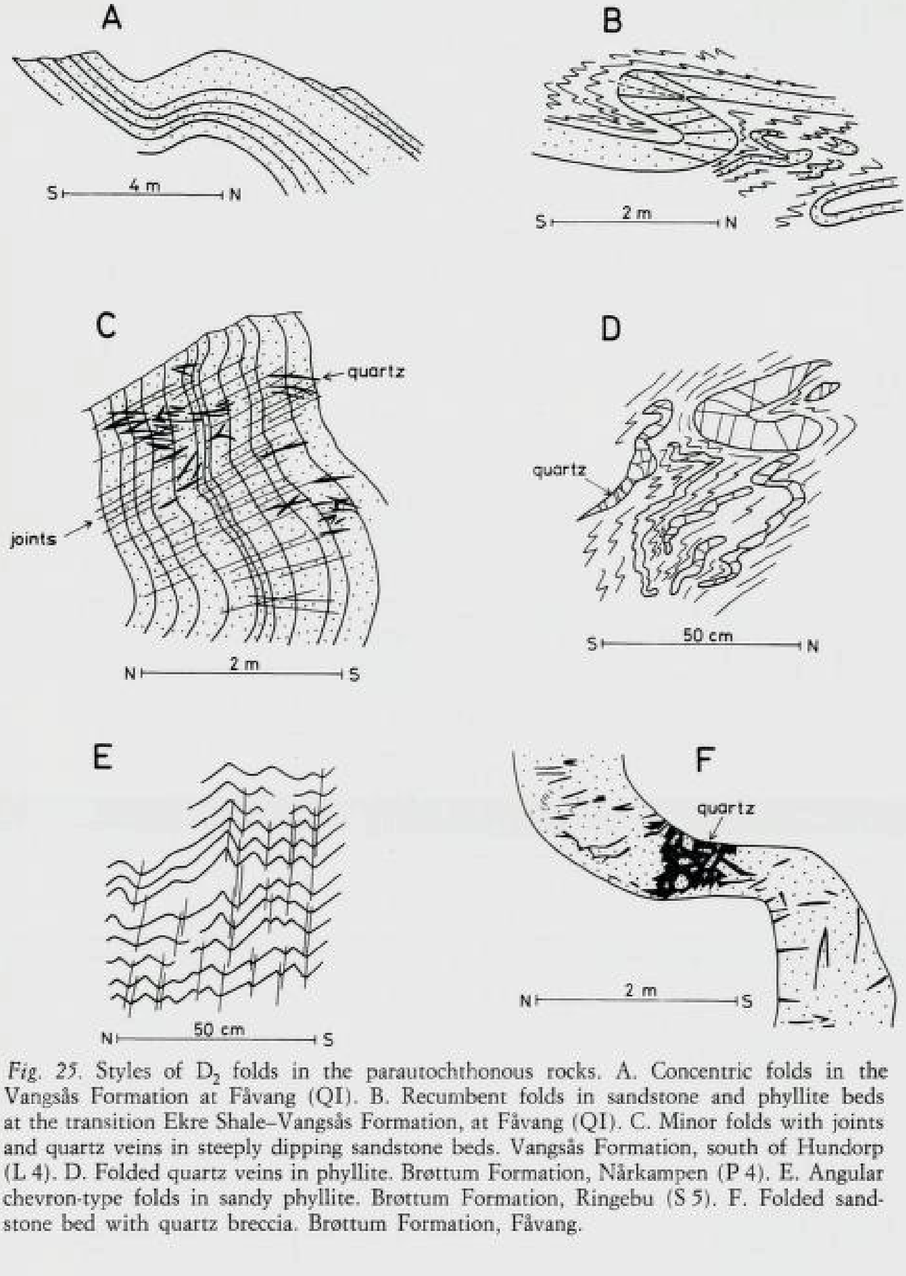



*Fig. 25.* Styles of $D_2$ folds in the parautochthonous rocks. A. Concentric folds in the Vangsås Formation at Fåvang (QI). B. Recumbent folds in sandstone and phyllite beds at the transition Ekre Shale–Vangsås Formation, at Fåvang (QI). C. Minor folds with joints and quartz veins in steeply dipping sandstone beds. Vangsås Formation, south of Hundorp (L 4). D. Folded quartz veins in phyllite. Brøttum Formation, Nårkampen (P 4). E. Angular chevron-type folds in sandy phyllite. Brøttum Formation, Ringebu (S 5). F. Folded sandstone bed with quartz breccia. Brøttum Formation, Fåvang.

found in the underlying parautochthonous rocks (Fig. 24 II) and in the Kvitvola nappe (Fig. 24 III). Generally, the thrusting of the Jotun nappe–Valdres nappe and of the Kvitvola nappe induced cataclastic textures both in the underlying sediments and in the thrust units, and formed the first schistosity or cleavage of the region lying approximately parallel to the thrust planes.

Veins of quartz and feldspar, partly also with hematite, are found in many places near the thrust planes for the Jotun–Valdres and Kvitvola nappes, and

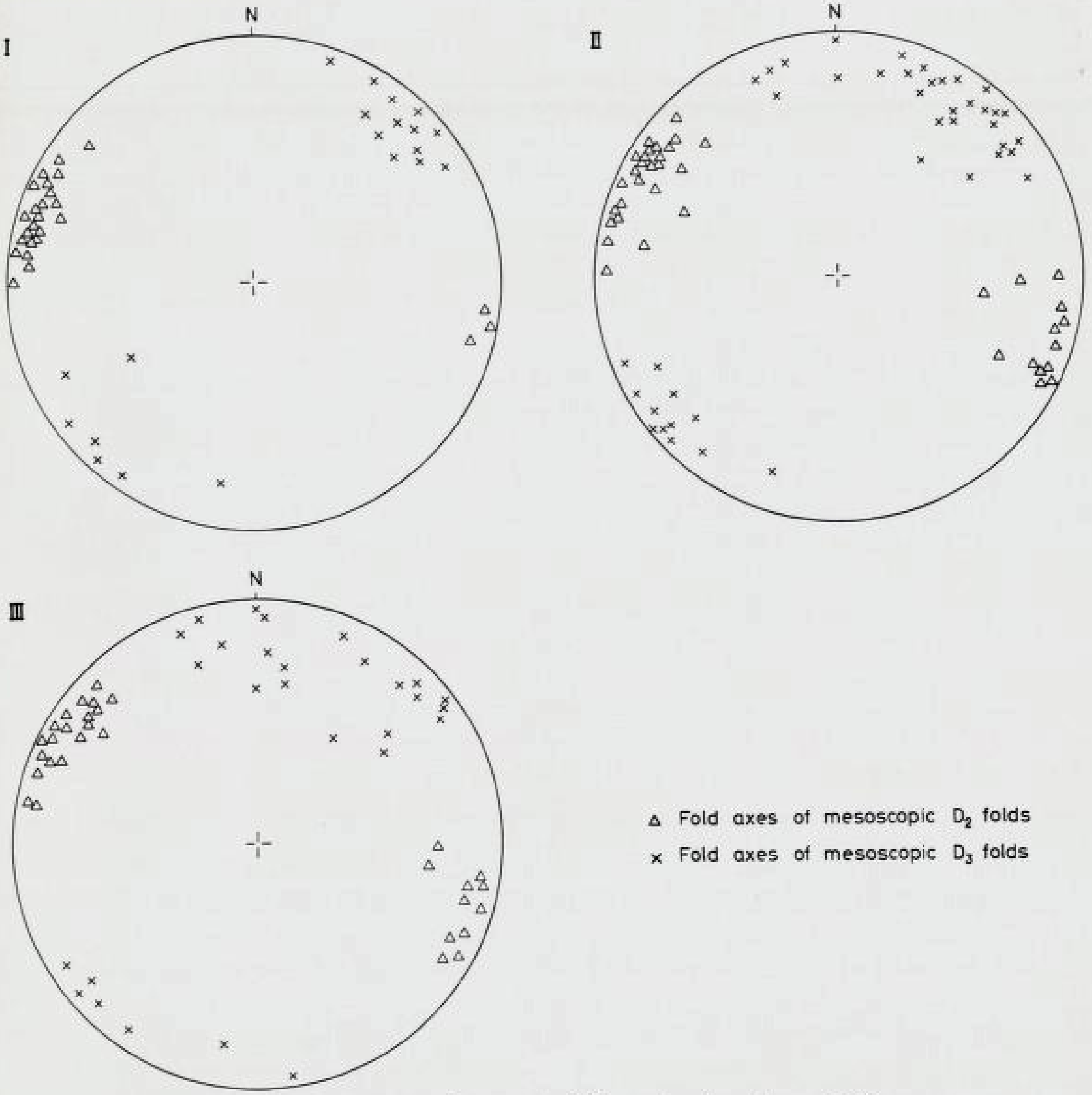



*Fig. 26.* Orientation of mesoscopic fold axes for the sub-areas I–III.

within the Kvitberg Phyllite (Fig. 22 C). These veins are sometimes boudinaged and are often affected by later $D_2$ folding (Fig. 27 D). This phase of vein-formation (low-temperature veins) seems to be connected with the thrusting of the Jotun–Valdres and Kvitvola nappes.

Within the parautochthonous rocks and within the Kvitvola nappe, a lineation of supposed $D_1$ origin has occasionally been observed. This lineation, which is clearly affected by later $D_2$ folds, is defined by elongate feldspars, quartz and micas and always shows a NW–SE trend (Fig. 23). This, however, is approximately parallel to the strong $D_2$ lineation found throughout the present region and can only be definitely distinguished where $D_2$ folds occur.

Of considerable interest in this connection are the observations of Hossack (1967) from the Bygdin area. He regarded the northwesterly pebble elongation of the Bygdin Conglomerate and a corresponding lineation in the sandstones as being connected with the thrusting of the Jotun nappe ('Upper Jotun nappe'). A later deformation phase in this area produced folds and lineations in the same direction, and these could correspond to the $D_2$ structures of the present region.

*Second deformation phase ($D_2$)*

Linear structures of five decriptive classes have been recorded:

1. Axes of mesoscopic folds in sandstones and sandy phyllites.
2. Elongation of pebbles and boulders in conglomerates.
3. Elongation of quartz, feldspars and other minerals in sandstones.
4. Orientation of necks of boudins.
5. Intersection of bedding and slaty or flow cleavage.

The orientations of these structures have been measured within the relatively most competent units; few observations are from the typical incompetent units.

*Folds.* $D_2$ folds are developed nearly everywhere within the present region and have also been recognized in adjacent districts (Fig. 20). The folds vary in style, and some typical profiles of $D_2$ folds from the parautochthonous rocks are shown in Fig. 25. Generally, the style within this rock-unit appears to be controlled by the grain-size of the rock, with folds of parallel (concentric) type dominating in coarse-grained rocks and of similar type (terminology of Hills 1963) in the fine-grained phyllitic rocks.

Folds of recumbent type, several metres in amplitude, are exposed along the railway-line in the Brøttum Formation just south of Ringebu, and are also quite common in many places within the Fron Member. It would seem, however, that fold styles like those in Fig. 25 A and F are more common in competent units than the recumbent type (Fig. 25 B). Disharmonic folding is not infrequent (Fig. 25 B and D) where competent and incompetent beds are closely interlayered.

The orientations of mesoscopic $D_2$ folds in the parautochthonous rocks are shown in Figs. 20, 26 I and II. Most of these folds trend between E–W and SE–NW and show a variable plunge. The $D_2$ fold axes are parallel to a strong lineation in the rocks in the form of a dimensional elongation of quartz, feldspars and other minerals. At some localities (Nårkampen, Steinåa and Svintjern), however, the $D_2$ lineation is deformed by a younger fold with an axial trend some 20° clockwise to that of the former. In the Kvitvola rocks such relations seem to be more common and have been described by Strand (1967, p. 104) from the Kvam–Sjoa district. Also within the Kvitvola nappe, mesoscopic $D_2$ folds of different style have been observed (Fig. 27). Generally, however, their styles are usually more 'plastic' than those within the parautochthonous rocks, and isoclinal and recumbent folds of the types shown in

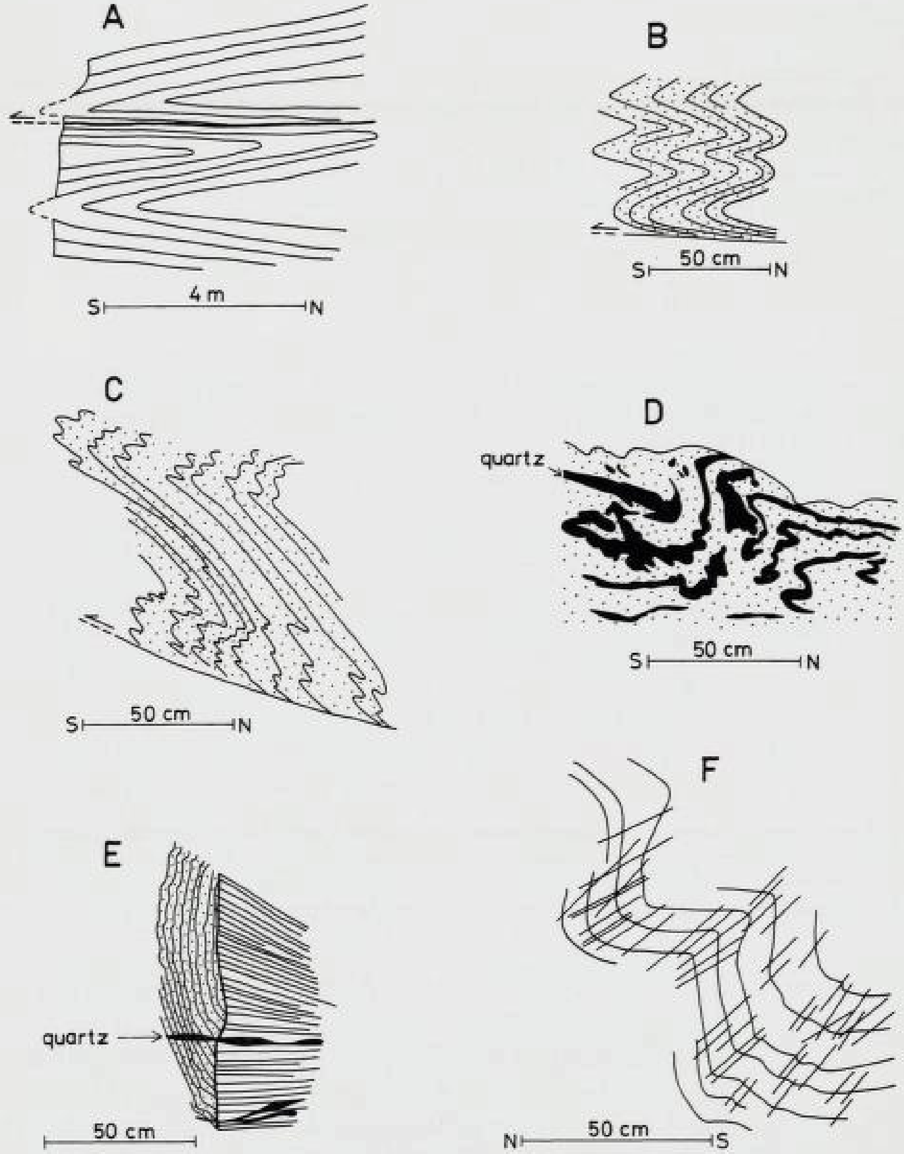



*Fig. 27.* $D_2$ structures from the Kvitvola nappe in the Ringebu–Vinstra district. A, B. Recumbent folds in sandstone and phyllite beds. Cambro–Ordovician, just below the upper unit of the Kvitvola nappe at Harpefoss (H 9). C, D. Folds near the base of the feldspathic sandstone ('light sparagmite') at Vinstra. E. Typical lineation in the feldspathic sandstone north of Hundorp (L 8). F. Concentric folding combined with some shear in sandstone and phyllite beds. Cambro–Ordovician, north of Hundorp (L 10).

Fig. 27 A, B and C are much more common. Such folds are always overturned towards the SW or SSW.

Examples of both concentric and similar-type folds are found in this nappe unit (Fig. 27 F). Generally, the styles of folds within the Kvitvola nappe are less dependent on grain-size than those within the parautochthonous unit.

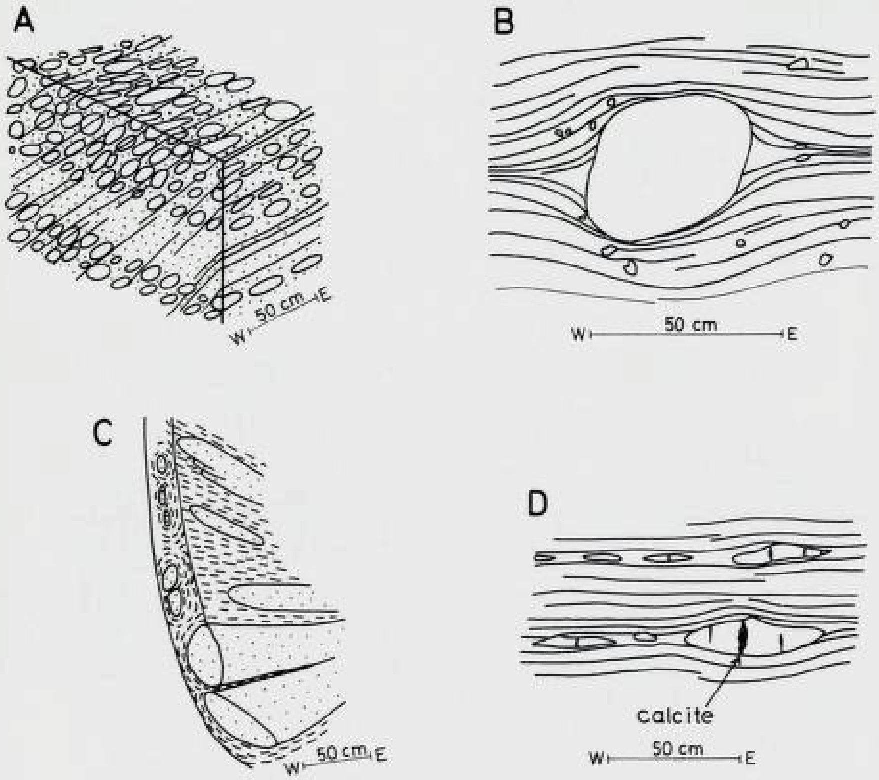



*Fig. 28.* $D_2$ structures from the parautochthonous rocks. A. Relationship between cleavage, bedding and stretched conglomerate pebbles in the Biskopås Conglomerate at Fåvang (Q 3). B. Symmetrical deviation of cleavage around a boulder in the Moelv Tillite at Oppsalåsen, Fåvang. C. Boudinage of a sandstone bed on the southern limb of an anticline. Crushed sandstone between the boudins. Vangsås Formation at Hundorp (L 4). D. Boudinage of limestone lenses in a phyllitic rock. Biri Formation, south of Strandeelva (P 2).

The orientation of mesoscopic $D_2$ folds in the Kvitvola nappe is parallel to that of $D_2$ folds in the parautochthonous rocks (Fig. 26). Typical of these folds is a strong grain elongation lineation parallel to their axes (Fig. 27 E).

The plastic character of most of the minor $D_2$ folds within the Kvitvola nappe suggests that they were formed in a different environment to that of corresponding structures in the parautochthonous rocks, perhaps in a more central part of the mountain chain. This necessitates a great deal of thrusting of the Kvitvola nappe after the formation of these structures, which are contemporaneous with the metamorphism of the Kvitvola rocks. It is therefore possible that the mesoscopic $D_2$ structures in the Kvitvola nappe were formed at a relatively early stage in the $D_2$ deformation.

As mentioned above, minor $D_2$ structures trending in two different directions have been observed locally. At present it is impossible to judge whether or not these observations indicate separate tectonic phases of regional importance. The author is inclined to regard both directions as belonging to the same deformation, the $D_2$ phase.

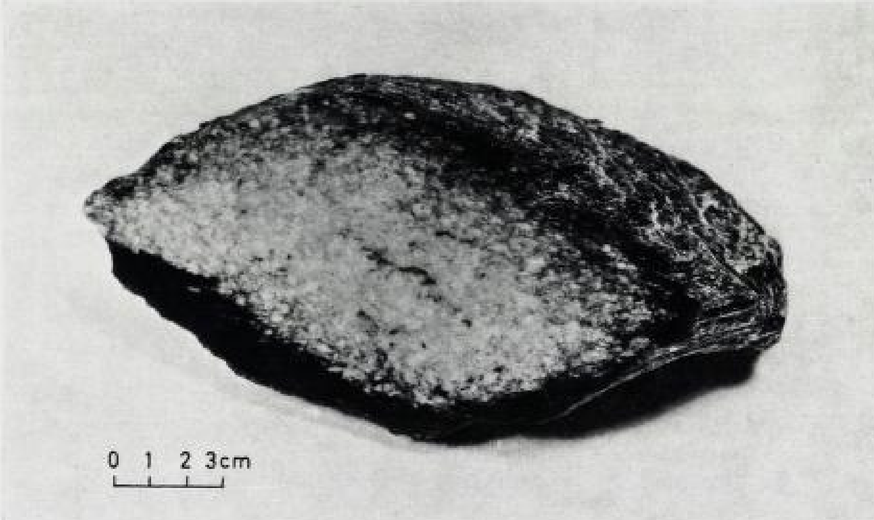



*Fig. 29.* Anorthosite boulder with dark mylonitic outer zone. Biskopås Conglomerate at Fåvang.

*Elongation of pebbles and boulders.* Deformed pebbles and boulders in the Biskopås Conglomerate within the Fåvang area (Fig. 28 A) are oriented with their shortest dimension normal to the $D_2$ cleavage and with their long axes paralleling the axes of $D_2$ folds (Figs. 24 I and 26 I). In the sandstones, dimensional orientation of quartz and feldspars can be seen as being always parallel to the pebble elongation, as well as to the $D_2$ fold axes (Figs. 24 and 26).

Fig. 20 shows observed directions of elongation lineations in conglomerates and sandstones from the present district and some adjacent areas. A constant alignment can be seen following the main $D_2$ folding trend. Within the allochthonous crystalline rocks, at, e.g., Feforkampen (Fig. 24 IV), a dimensional grain elongation lineation can also be found parallel to the $D_2$ fold axes.

The distortion of the meta-anorthosite boulders in the Biskopås Conglomerate within the Fåvang area has been measured earlier by the author (Englund 1966, p. 88). At four localities these boulders show ratios of the three principal axes of approximately 3.28–3.86 : 1.44–1.60 : 1. Some new observations (22) from Tjuvekampen have given the average ratio 3.3 : 1.5 : 1. The elongated boulders are never broken by open tension cracks perpendicular to their length, but this is sometimes the case with the feldspar in the sandstones. The meta-anorthosite boulders from the Fåvang area, in places, display a thin, green, fine-grained outer zone (Fig. 29); this is thought to have been derived by a type of 'mylonitization' resulting from a rotation of the boulders during their deformation.

Deformed pebbles have been described from the Norwegian Caledonides by several authors (e.g. Strand 1945, Oftedahl 1948). The discussion usually centres around the problem as to whether the elongation of the pebbles is so-called 'a-lineation' associated with thrusting and formed parallel to the postulated movement direction (Kvale 1953), or a 'b-lineation' formed perpendicular to the movement direction. The deformation of the Bygdin Conglomerate, which belongs to the Valdres nappe, is an example of the so-called 'a-lineation' (Strand 1945). All observations from the present area and from the Tretten–Øyer district (Englund 1972, p. 53) indicate that the pebble deformation is here of the 'b-lineation' type.

The orientation of the long axes of some of the pebbles and boulders in the Rosten Conglomerate, Nord-Sel, have been measured by the author (Fig. 20). On average, these axes are parallel to those of the strong $D_2$ folding of this area. Considerable variation in the shape of the pebbles has been observed, from near rod shapes to pancake types (see e.g. Bjørlykke 1905, p. 294), a variation which is much greater than that occurring within the Biskopås Conglomerate at Fåvang. It would therefore seem that the Rosten Conglomerate has suffered a more complicated tectonic deformation than the Biskopås Conglomerate. The possibility that some of this pebble deformation may have occurred parallel to the so-called 'a-lineation' of the $D_1$ phase seems plausible.

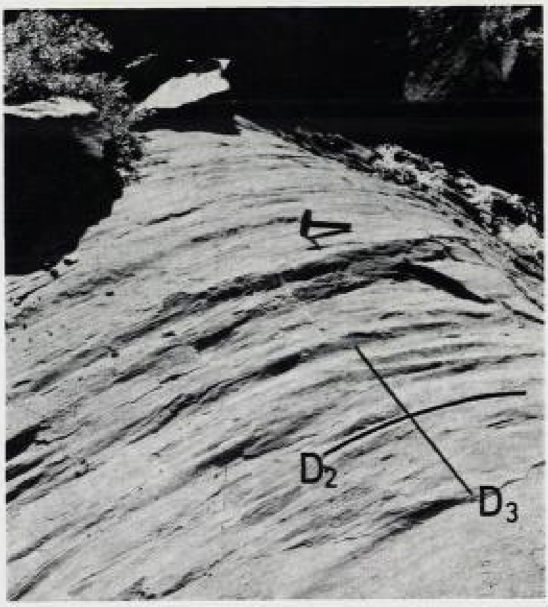
*Boudinage* of different types has been observed (Fig. 28 C and D). It usually appears to have been formed from squeezing and stretching in the fold limbs, in which case the boudins are elongated parallel to the trend of the $D_2$ fold axes (Figs. 20, 24 II and III).

*Intersection of bedding and cleavage.* This lineation is often parallel to other linear structures, such as the preferred orientation of quartz, feldspars and other minerals or the elongation of pebbles (Fig. 28 A). Intersection lineations of this type are inferred to be parallel to major $D_2$ fold axes. This is clearly seen within the parautochthonous rocks of the Ringebu–Vinstra district and has also been observed further south in Gudbrandsdalen (Englund 1972, p. 53). Within the Kvitvola nappe this lineation type is well developed, and in the allochthonous rocks at Feforkampen it has been observed locally.

*Cleavage.* The parautochthonous rocks generally show a relict bedding and prominent secondary $D_2$ cleavage both in the argillaceous rocks and in the sandstones and conglomerates (Fig. 28 A). The pelites are sufficiently recrystallized to show a true slaty or flow cleavage that grades into schistosity at Hundorp–Vinstra (Englund 1973).

The $D_2$ cleavage within the Ringebu–Fåvang (Fig. 24 I) and Hundorp–Vinstra areas (Fig. 24 II) strikes about east-west and dips towards the north (Fig. 20). In mesoscopic $D_2$ folds, the cleavage is often seen to be parallel to the axial planes (Fig. 25 E). A symmetrical deviation of the cleavage about pebbles (Fig. 28 B) or limestone lenses (Fig. 28 D) and quartz veins has often been observed. Such a relationship provides reasonably good evidence of flattening within the cleavage and normal to the maximum compressive stress (Hills 1963, p. 302).

*Fig. 30.* Second lineation deformed around a third fold. Vangsås Formation south of Hundorp (L 3).




The same type of $D_2$ cleavage (Fig. 27 F) is found in the Kvitvola nappe, and as shown by the strong concentration of cleavage poles in Fig. 24 III, the strike and dip of this S-plane conform with that in the parautochthonous rocks.

*Joints.* Sets of steep to vertical parallel or nearly parallel joints are present in most outcrops. The master joints are clearly visible on air-photos and some can be followed in the field as clefts and depressions. Although an analysis of the joint pattern has not been carried out, it can be noted that joints trending NNE and partly towards NNW are particularly prominent. These joints were mentioned by Werenskiold (1932), and are also dominant further south in Gudbrandsdalen (Englund 1972, p. 51). Locally, a relationship between jointing and $D_2$ folds can be observed (Fig. 25 C and F).

*Third deformation phase ($D_3$)*

Folds of this phase are recognized by their deformation of $D_2$ lineations (Fig. 30) and folds, and are generally of concentric type. Some profiles of $D_3$ folds from the parautochthonous rocks and from the Kvitvola nappe are illustrated in Fig. 31.

The $D_3$ folds show a relatively large variation in fold axial orientation (Figs. 20 and 26). This variation is explained as being due to the imposition of $D_3$ folding on the previously folded bedding surfaces. Within the Fåvang area this phase of deformation is very weak, but it increases in importance towards the Vinstra area.

*Fourth deformation phase ($D_4$)*

Minor structures of a fourth deformation phase in this district are associated

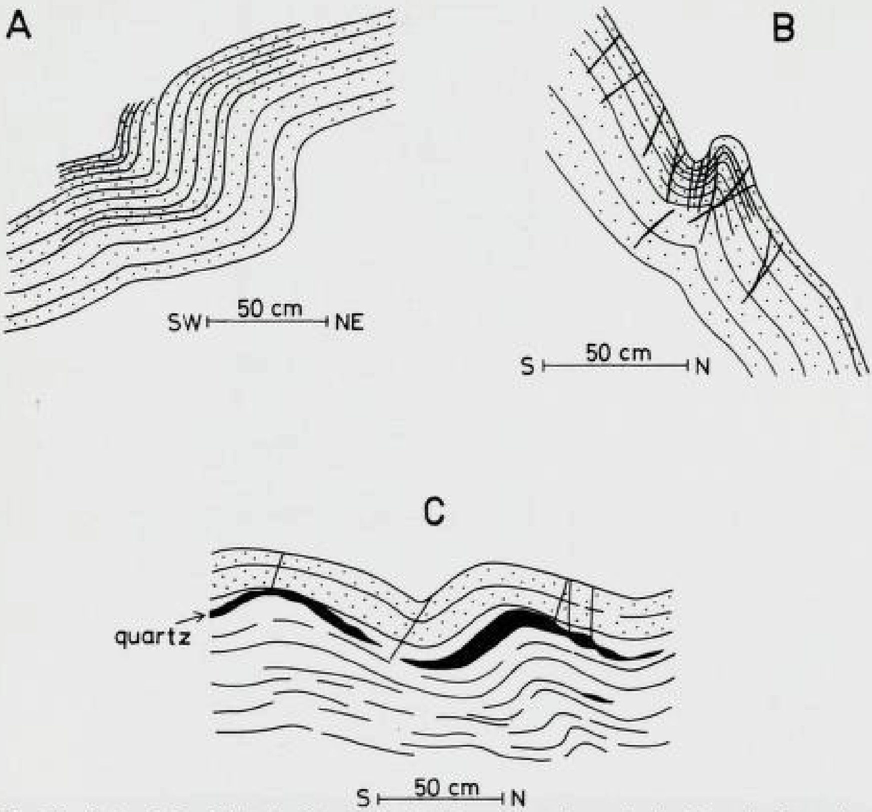



*Fig. 31.* Style of $D_3$ folds. A. Concentric folding of sandstone beds. Vangsås Formation, near Svintjern (I 5). B. Drag-fold, with small thrust faults, on the limb of a larger fold. Sandstone beds in the Cambro–Ordovician north of Vinstra (F 10). C. Concentric folding of sandstone and phyllite beds with quartz veins. Cambro–Ordovician, north of Vinstra, (F 10).

with the late Caledonian (?) or Permian faulting. Several joints paralleling these faults are possibly of the same age, since they transect structures of the first three deformation phases.

## THE TECTONIC DEVELOPMENT OF THE DISTRICT AND SOME REGIONAL CORRELATIONS

The main conclusions arising from the present work may be summarized as follows:

1. The earliest tectonic deformation of the Ringebu–Vinstra district is represented by small recumbent folds which were subsequently refolded ($D_1$ and $D_2$ phases). It seems plausible that the Valdres nappe rocks at Feforkampen and in the (?) Espedalen massif constitute the inverted limbs of regional recumbent folds, and although detailed knowledge of the $D_1$ deformation is lacking, the emplacement of the Jotun nappe–Valdres nappe is considered to belong to this phase.

Observations of great interest are those from Grønsennknipa (Nickelsen

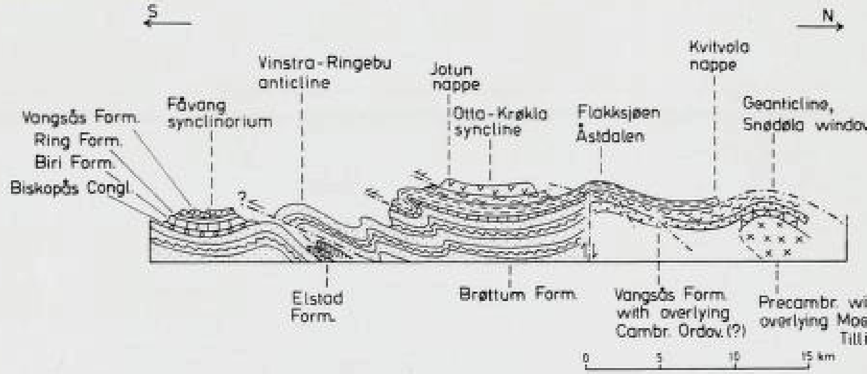



*Fig. 32.* Simplified composite section showing the main tectonic elements from the Fåvang synclinorium to the Snødøla window.

1967) and Feforkampen, which show that the crystalline rocks there represent the basement rocks to the Valdres Sparagmite. This means that rocks of latest Precambrian and Eocambrian age, together with some of their crystalline basement, constitute parts of the Valdres nappe. A plausible root zone for this nappe unit cannot as yet be demonstrated, as the nappe always seems to be resting on younger rocks.

2. As pointed out by Skjeseth (1963, p. 89), the Kvitvola nappe in Southern Norway has been partly thrust over the Snødøla–Brydal Precambrian geanticline from a more central position in the geosyncline into the southern Sparagmite Region.

The relationship of the lower nappe unit of the Kvitvola nappe resting on different rock-types (Fig. 32) can be explained as follows:

A. The Kvitvola nappe was emplaced on a folded or otherwise tectonically disturbed underlying complex during the $D_1$ phase.

B. The Kvitvola nappe was emplaced during at least two of the main phases ($D_1$ and $D_2$).

The emplacement of the Kvitvola nappe must belong partly to the $D_1$ phase, because a strong megascopic folding of this nappe occurred during the $D_2$ phase. Case A thus implies that the present region must have been tectonically disturbed before the $D_1$ fold-phase.

In case B, part of the emplacement of the Kvitvola nappe is inferred to have occurred during the $D_2$ phase. The direction of this transport is unknown, though it was most likely towards the south-southwest or south. This emplacement could then have brought the Kvitvola nappe to rest on the Biri Formation and on the Fron Member of the Brøttum Formation. This conclusion is supported by the plastic character of many mesoscopic $D_2$ folds, which indicates that they were formed in a different environment from that of corresponding structures in the parautochthonous rocks to the south.

In the Østerdalen valley crystalline rocks occur within the Kvitvola nappe, and most probably represent parts of this nappe (K. Bjørlykke 1965a, p. 13). This indicates that the Valdres nappe and the Kvitvola nappe have been thrust together with parts of their crystalline basement.

3. The Kvitvola nappe to the north of the present district and the Valdres nappe to the south form large salients with a similar geological and structural position (Figs. 1 and 18). The author has tried to follow these units along the sole of the crystalline Jotun rocks in the region north and south of Heidalsmuen, but without success.

The possibility of regarding the Kvitvola nappe and the Valdres nappe as equivalent nappe units seems plausible, but more data from areas west of the present region are necessary to solve this problem.

4. Another problem is the relationship between the Valdres Sparagmite and the Heidal Group, both of which occupy the same stratigraphic position above crystalline rocks. It seems reasonable to regard the Heidal Group as a metamorphic equivalent of the Vangsås Formation with overlying Cambro–Ordovician.

5. The thrusting and imbrication of the Vangsås Formation are most probably both a $D_1$ and a $D_2$ structure.

6. The Gausdal Formation seems to be a somewhat thrust unit in relation to the underlying phyllite. It partly occupies the same stratigraphic–tectonic position above the Kvitberg Phyllite as the crystalline rocks of the Jotun nappe–Valdres nappe have in other regions. The thrusting of these nappes could have separated the already deposited Gausdal Formation from the Kvitberg Phyllite in front of these nappes. The complex tectonic relationships around the outlier on Valsfjell can probably be explained as a type of 'imbrication' between thrust units of the Valdres nappe and the Gausdal Formation.

7. The dominant trend of megascopic and mesoscopic $D_2$ structures is NW–SE in the western part, about E–W in the central parts of the Sparagmite basin, and partly towards NE–SW along the Østerdalen valley. Viewed in greater perspective the axial traces shown in Fig. 18 can be regarded as those of minor folds on a large salient. As pointed out by Skjeseth (1963, p. 92) the occurrence of Caledonian folds and structures within the Sparagmite basin is determined by old structural lines. This has also been suggested by Holtedahl (1922b, p. 43), who explained the change in strike near the margin of the old sedimentation basin as a drag effect. The Vinstra–Ringebu Anticline is located just north of the western margin of the sedimentation basin of the Brøttum Formation; this swings rather sharply to the west-northwest in the Ringebu–Vinstra region (Fig. 4; Ramberg & Englund 1969, p. 321). This anticline can therefore be explained as a result of folding against a Precambrian wall to the south: a composite syncline, or synclinorium, occurs at Vendalsvatn–Fåvang–Lyngsjøen.

It seems possible that structures further south in Gudbrandsdalen could be explained in a similar manner. Aeromagnetic data (K. Åm, pers. comm.) have shown that, north of an east-west line between Fåberg and Lillehammer, there is a marked deepening of the sedimentation basin to the Brøttum Formation. This means that the large anticline between Lillehammer and Øyer could be partly the result of folding against a Precambrian wall which formed the southern margin of the sedimentation basin.

*Table 3.* Attempt at a regional correlation of the main tectonic phases observed at different places along the Gudbrandsdalen valley

| | Mjøsa district<br>Skjeseth (1963)<br>A. Bjørlykke<br>(pers. comm.) | Tretten–Øyer<br>Englund (1972) | Fåvang<br>Present paper | Hundorp–Vinstra<br>Present paper | Kvam–Sjoa (part of the Sel and Vågå area, Strand 1967) | Prestberget (part of the Sel and Vågå area, Strand 1964) |
|---|---|---|---|---|---|---|
| Deformation phases | Thrusting:<br>Vangsås Form.<br>(Osen nappe) | | D 1<br>Thrusting:<br>Vangsås Form. | D 1<br>Thrusting:<br>Jotun nappe–<br>Valdres nappe<br>Kvitvola nappe<br>Vangsås form.<br>Minor folding | | F 1<br>Thrusting:<br>Jotun nappe<br><br>Minor folding |
| | Regional folding | Regional folding<br><br>Minor thrusting | D 2<br>Regional folding with strong lineation.<br>Minor thrusting. | D 2<br>Regional folding with strong lineation.<br>Minor thrusting | Regional folding with strong lineation | F 2<br>Regional folding with strong lineation |
| | | | D 3<br><br>Minor folding | D 3<br>Regional folding and minor folding | Regional folding | F 3<br>Regional folding |
| | Faults | Faults | D 4<br>Faults | D 4<br>Faults | | |

The Tretten–Øyer–Storbekkfjell syncline is located in a region where all formations of the Hedmark Group are particularly thin and where pelitic units are relatively dominant. The presence of this syncline could therefore possibly be due to the thinning out of beds towards this region.

8. The problem concerning the stratigraphic and tectonic position of the Elstad Formation has not yet been satisfactorily solved. It has been shown that this unit is situated near the central parts of the Vinstra–Ringebu Anticline, and that this anticline forms a large recumbent fold west of the Elstad Formation. The Elstad Sandstone could be a downfolded and overthrust unit corresponding to the Vangsås Formation. The idea of regarding the Elstad Formation as a unit younger than the Brøttum Formation has earlier been postulated by, e.g., Oftedahl (1949, p. 167 and 1954b, pp. 157–158). This idea invokes a great deal of thrusting of the Brøttum Formation. The alternative explanation is that the Elstad Formation is older than the Brøttum Formation, and has been thrust up into the central parts of the Vinstra–Ringebu Anticline. To the present author the first alternative seems more plausible (Fig. 32).

9. Folding of the $D_3$ deformation phase is of both large and small amplitude.

During this phase the rocks were much less ductile than in the earlier deformation phases.

10. Large-scale faulting ( ? Permian ) and possibly a great deal of jointing occurred during the $D_4$ phase.

11. Polyphase deformation has now been demonstrated in different parts of the Caledonian mountain chain in Southern Norway. An attempt at correlating some of these phases along the Gudbrandsdalen valley is shown in Table 3.

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REFERENCES

Bjørlykke, K. O. 1893: Gausdal. Fjeldbygningen inden rektangelkartet Gausdals omraade. *Norges geol. Unders. 13*, 36. pp. (Geol. map. 1891).

Bjørlykke, K. O. 1905: Det centrale Norges fjeldbygning. *Norges geol. Unders. 39*, 595 pp.

Bjørlykke, K. 1965a: The Eocambrian stratigraphy of the Bjørånes window and the thrusting of the Kvitvola nappe. *Norges geol. Unders. 234, Årb. 1964*, 5–14.

Bjørlykke, K. 1965b: The Middle Ordovician of the Oslo Region, Norway. 20. The geochemistry and mineralogy of some shales from the Oslo Region. *Norsk geol. Tidsskr. 45*, 435–456.

Bjørlykke, K. 1966a: The study of arenaceous sediments by means of acetate replicas. *Sedimentology 6*, 343–345.

Bjørlykke, K. 1966b: Studies on the latest Precambrian and Eocambrian Rocks in Norway. No. 1. Sedimentary petrology of the Sparagmites of the Rena district, S. Norway. *Norges geol. Unders. 238*, 1–53.

Bjørlykke, K. 1969: Geologien i sentrale deler av Østerdalen. *Norsk geol. Tidsskr. 49*, 313–318.

Bjørlykke, K., Englund, J. O. & Kirkhusmo, L. A. 1967: Studies on the latest Precambrian and Eocambrian Rocks in Norway. No. 3. Latest Precambrian and Eocambrian Stratigraphy of Norway. *Norges geol. Unders. 251*, 5–17.

Bugge, C. 1954: Den kaledonske fjellkjede i Norge. *Norges geol. Unders. 189*, 79 pp.

de Sitter, L. U. 1958: Boudins and parasitic folds in relation to cleavage and folding. *Geologie Mijnb. 20*, 277–286.

Dietrichson, B. 1945a: Geologiske undersøkelser i Espedalen. *Norges geol. Unders. 163*, 45 pp.

Dietrichson, B. 1945b: Sedimentene på det undre skyvedekke i Gudbrandsdalen. *Norsk geol. Tidsskr. 25*, 53–69.

Dietrichson, B. 1950: Det kaledonske knuteområde i Gudbrandsdalen. *Norsk geol. Tidsskr. 28*, 65–143.

Dietrichson, B. 1960: Intact recrystallized rocks of ultrabasic to intermediate composition along the movement-zone of the Jotun – norite nappe in the East–Jotunheimen, Central Norway. *Int. geol. Congr., 21 Session, Norden 1960. Part 19*, 64–88.

Englund, J.-O. 1966: Studies on the latest Precambrian and Eocambrian Rocks in Norway. No. 2. Sparagmittgruppens bergarter ved Fåvang, Gudbrandsdalen. En sedimentologisk og tektonisk undersøkelse. *Norges geol. Unders. 238*, 55–103.

Englund, J.-O. 1969: Geologien i Gudbrandsdalen fra Lillehammer til Vinstra. *Norsk geol. Tidsskr. 49*, 319–322.

Englund, J.-O. 1972: Studies on the latest Precambrian and Eocambrian Rocks in Norway. No. 11. Sedimentological and structural investigations of the Hedmark Group in the Tretten–Øyer–Fåberg district, Gudbrandsdalen. *Norges geol. Unders. 276*, 59 pp.

Englund, J.-O. 1973: Studies on the latest Precambrian and Eocambrian Rocks in Norway. No. 12. Geochemistry and mineralogy of pelitic rocks from the Hedmark Group and the Cambro-Ordovician sequence, Southern Norway. *Norges geol. Unders. 286*, 60 pp.

Folk, R. L. & Ward, W. C. 1957: Brazos River bar, a study in the significance of grain-size parameters. *J. Sediment. Petrology 27*, 3–27.

Gjelsvik, T. 1946: Anorthosittkomplekset i Heidal. *Norsk geol. Tidsskr. 26*, 1–58.

Hills, E. S. 1963: *Elements of Structural Geology*. 483 pp. Methuen & Co. Ltd. London.

Holmsen, P. & Oftedahl, Chr. 1956: Ytre Rendal og Stor-Elvdal. *Norges geol. Unders. 194*, 173 pp. map.

Holtedahl, O. 1921: Engerdalen. *Norges geol. Unders. 89*, 74 pp. map.

Holtedahl, O. 1922a: Kalksten og dolomit i de østlandske dalfører. *Norges geol. Unders. 87, I*. 32 pp.

Holtedahl, O. 1922b: Om Trysilsandstenen og sparagmitavdelingen. *Norsk geol. Tidsskr. 6*, 17–48.

Holtedahl, O. 1953: Norges geologi. I. *Norges geol. Unders. 164*, 583 pp. Maps.

Holtedahl, O. 1960: Geology of Norway. *Norges geol. Unders. 208*, 540 pp.

Hossack, J. R. 1967: Structural history of the Bygdin area, Oppland. *Norges geol. Unders. 247, Årb. 1966*, 78–107.

Hossack, J. R. 1972: The geological history of the Grønsennknipa Nappe, Valdres. *Norges geol. Unders. 281*, 26 pp.

Kjerulf, Th. 1873: Om Grundfjeldets og Sparagmitfjeldets Mægtighed i Norge. 2. Sparagmitfjeldet. *Univ. Program 2. Halvaar 1872*. Christiania (Oslo). 85 pp.

Kjerulf, Th. 1879: *Udsigt over det sydlige Norges geologi.* 262 pp. W. C. Fabritius, Christiania (Oslo).

Kulling, O. 1961: On the age and tectonic position of the Valdres sparagmite. *Geol. För. Stockholm Förh. 83*, 210–214.

Kvale, A. 1953: Linear structures and their relation to movement in the Caledonides of Scandinavia and Scotland. *Q. J. geol. Soc. Lond. 109*, 51–74.

Løberg, B. E. 1970: Investigations at the south-western border of the Sparagmite basin (Gausdal Vestfjell and Fåberg Vestfjell), Southern Norway. *Norges geol. Unders. 266, Årb. 1968*, 160–205.

Loeschke, J. 1967: Zur Petrographie des Valdres – Sparagmites zwischen Bitihorn und Langsuen/Valdres (Süd-Norwegen). *Norges geol. Unders. 243 A*, 5–66.

Nickelsen, R. 1967: The structure of Mellene and Heggeberg, Valdres. *Norges geol. Unders. 243 C*, 99–121.

Oftedahl, Chr. 1944: En presset norit ved Sulseter, N. Fron. *Norsk geol. Tidsskr. 23*, p. 193.

Oftedahl, Chr. 1945: Om tillitene i det central-norske sparagmitområde. *Norsk geol. Tidsskr. 25*, 285–294.

Oftedahl, Chr. 1948: Deformation of quartz conglomerates in Central Norway. *J. Geol. 56*, 476–487.

Oftedahl, Chr. 1949: Skyvedekker i det centrale Norges sparagmittformasjon. *Norsk geol. Tidsskr. 27*, 164–170.

Oftedahl, Chr. 1954a: Dekketektonikken i den nordlige del av det østlandske sparagmittområde. *Norges geol. Unders. 188, Årb. 1953*, 5–20.

Oftedahl, Chr. 1954b: Skyvedekkene i det sydnorske sparagmittområde. *Geol. För. Stockholm Förh. 76*, 156–161.

Pettijohn, F. J., Potter, P. E. & Siever, R. 1972: *Sand and Sandstone*. 618 pp. Springer-Verlag, Berlin. Heidelberg. New York.

Prost, A. 1963: Observations sur la fenêtre antécambrienne de la Snødøla et sur la région septentrionale de 'Fjell' de Ringebu (Norvège). *Bull. Soc. Géol. France. 7e série 5*, 351–357.

Prost, A. 1970: Sur la nature et la délimitation des nappes de charriage dans la partie nord de la 'région sparagmitique' de Norvège méridionale (Calédonides externes). *Bull. Soc. Géol. France. 7e série 12*, 755–764.

Ramberg, I. B. & Englund. J.-O. 1969: Studies on the latest Precambrian and Eocambrian Rocks in Norway. No. 10. The source rock of the Biskopås Conglomerate at Fåvang, and the western margin of the sedimentation basin of the Brøttum Formation at Fåvang–Vinstra, Southern Norway. *Norges geol. Unders. 258, Årb. 1968*, 302–324.

Skjeseth, S. 1963: Contribution to the geology of the Mjøsa district and the classical sparagmite area in Southern Norway. *Norges geol. Unders. 220*, 126 pp.

Smithson, S. B. & Ramberg, I. B. 1970: Geophysical profile bearing on the origin of the Jotun Nappe in the Norwegian Caledonides. *Geol. Soc. Am. Bull. 81*, 1571–1576.

Spjeldnæs, N. 1967: Studies on the latest Precambrian and Eocambrian Rocks in Norway. No. 6. Fossils from pebbles in the Biskopåsen Formation in Southern Norway. *Norges geol. Unders. 251*, 53–82.

Stålhøs, G. 1956: The sparagmite series and the Vemdal quartzite of the Hede region, Härjedalen. *Bull. geol. Inst. Uppsala 36*, 297–368.

Størmer, L. 1967: Some aspects of the Caledonian geosyncline and foreland west of the Baltic Shield. *Q. Jl. geol. Soc. Lond. 123*, 183–214.

Strand, T. 1944: A method of counting out petrofabric diagrams. *Norsk geol. Tidsskr. 24*, 294–298.

Strand, T. 1945: Structural petrology of the Bygdin Conglomerate. *Norsk geol. Tidsskr. 24*, 14–51.

Strand, T. 1951: The Sel and Vågå map areas. *Norges geol. Unders. 178*, 116 pp.

Strand, T. 1960: The pre-Devonian rocks and structures in the region of Caledonian deformation. *Norges geol. Unders. 208*, 170–284.

Strand, T. 1964: Geology and structure of the Prestberget area. *Norges geol. Unders. 228*, 289–310.

Strand, T. 1967: 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 Gudbrandsdalen valley district, South Norway. *Norges geol. Unders. 251*, 93–106.

Strand, T. 1969: Geology of the Grotli area. *Norsk geol. Tidsskr. 49*, 341–360.

Strand, T. 1972: The Norwegian Caledonides. *In* Strand & Kulling: *Scandinavian Caledonides*, 302 pp. John Wiley and Sons, London.

Törnebohm,, A. E. 1896: Grunddragen af det centrala Skandinaviens bergbygnad. *Kgl. Sv. Vet. Akad. Förh. 28, 5*, 210 pp. Stockholm.

Werenskiold, W. 1911: Søndre Fron. Fjeldbygningen inden rektangelkartet Søndre Frons område. *Norges geol. Unders. 60*, 107 pp.

Werenskiold, W. 1932: Et sprekkesystem i Gudbrandsdalen. *Norsk geol. Tidsskr. 12*, 575–576.


GEOLOGICAL MAP OF THE RINGEBU–VINSTRA DISTRICT,
GUDBRANDSDALEN, SOUTHERN NORWAY
JENS-OLAF ENGLUND 1970
D E F G H I J K L M N O P Q R S T U V W X Y Z Æ Ø Å
10°00'
N
Gråhø
Veslefjell
Vaglfjell
Krøkla
Avsl
Dynjefjell
Bosen
Grønfjell
Trabelifjell
Sula
Kollberget
Augla
Frya
Forbundsfjellet
VINSTRA
Vinstra
HARPEFOSS
Raudhaugen
Abborsjøen
0–5⁹ 5–50⁹ 50–95⁹ 95–100⁹ Strike and dip of bedding
Inverted bed
Fault
down
Stratigraphical boundary
Minor thrusts
NAPPE UNITS
(Valdres nappe)
Feforkampen:
Feldspathic sandstone and quartzite with phyllite
Conglomerate and phyllite
Crystalline rocks
(Jotun nappe)
Schist and sandstone
Crystalline rocks
Thrust plane
Ring Formation (Moelv Shale included)
Biri Formation
Biskopås Conglomerate
Fron Member
Brøttum Formation
Shale
Sandstone
Elstad Formation
Hedmark Group
Cambr. Ordov.
Gausdal Formation
Kvitberg Phyllite
Cambrian basal cgl. (outcrop)
Vangsås Formation
Ekre Shale
Moelv Tillite
Hedmark Group
(Kvitvola nappe)
Phyllite with sandstone beds in the lower part
Calcareous sandstone
Feldspathic sandstone and quartzite, in places with phyllite beds
Conglomerate
Carbonate rocks and phyllite, in places with sandstone beds in the upper part
Thrust plane

GEOLOGICAL MAP OF THE RINGEBU-VINSTRA DISTRICT,
GUDBRANDSDALEN, SOUTHERN NORWAY
JENS-OLAF ENGLUND 1970
N
0 1 2 3 Km
10°00'
Strike and dip of bedding
0-5° 5-50° 50-95° 95-100°
Inverted bed
Stratigraphical boundary
Fault
down
Minor thrusts
Ring Formation (Moelv Shale included)
Biri Formation
Biskopås Conglomerate
Fron Member
Brøttum Formation
Shale
Sandstone
Elstad Formation
Hedmark Group
Cambr. Ordov.
Gausdal Forma
Kvitberg Phylli
Cambrian basa (outcrop)
Vangsås Form
Ekre Shale
Moelv Tillite
Feforka
KVAM
Teigkampen
Gråhø
Vaglfjell
Krøkla
Avsj.
Veslefjell
Dynjefjell
Trabelifjell
Bosen
Grønfjell
Kollberget
Sula
Øla
Augla
Frya
Forbundsfjellet
VINSTRA
Vinstra
Kongslikampen
HARPEFOSS
Raudhaugen
Abborsjøen
Jora


Kvitberget
HUNDORP
LÅGEN
Nysæterkampen
Strussberget
Høgåsen
RINGEBU
Vesletjellet
Steinåa
Gååvannet
Svintj.
Nårkampen
61°
30'
Skottåsen
Høgåsen
Valsfjell
Valsvann
Store
Jetningen
Kampen
Toftesæter-
fjell
Storhaugen
Segalstad-
sæterkampen
FAVANG
Tramsa
Vendals-
vann
Svinåa
Oppsal-
åsen
Holmetj.
Svang-
kampen
Langtj.
Tjuvekampen

Plate 1.


6
5
4
3
2
1
kampen
Kvitberget
Feforvannet
Gålåvannet
Svintj.
Valsfjell
Valsvann
Fagerlivann
Fagerlifjella
Store Jetningen
Toftesæter-fjell
Storhaugen
Vendals-vann
Svinåa
Segalstad-sæterkampen
HUNDORP
LÅGEN
Steinåa
Nårkampen
Kampen
RINGEBU
Strussberget
Høgåsen
Nysæterkampen
Skottåsen
FAVANG
Tromsa
Oppsal-åsen
Holmetj.
Svang-kampen

Plate 1.