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CONTRIBUTIONS TO THE GEOLOGY OF THE MJØSA DISTRICTS AND THE CLASSICAL SPARAGMITE AREA IN SOUTHERN NORWAY

By

STEINAR SKJESETH

SAMMENDRAG:

Bidrag til geologien i Mjøstraktene med en kort foreløpig analyse av stratigrafi og tektonikk i det klassiske sparagmittområde

WITH 65 TEXT-FIGURES AND 2 PLATES

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Editor for
the Publications of the Geological Survey of Norway:

State Geologist
Fredrik Hagemann

A. W. BRØGGERS BOKTRYKKERI A/S - OSLO

Contents.

Abstract.

This publication gives a survey of the main results of geological investigations carried out in the Mjøsa Districts in central Southeast Norway by the author during recent years.

The transitional situation of the districts between the foreland and the miogeosynclinal zone of the Caledonian geosyncline, has influenced the Paleozoic sedimentation and the tectonics.

A short summary analysis of the Sparagmite Group is given. The Sparagmites were deposited in basins or faulted throughs. The sedimentary facies of the Sparagmite formations are explained by the extension and successive development of these basins. The marginal zones are characterized by conglomerates and pure oolitic limestones. The conglomerates were deposited in deltas in connection with the fault zones. Shales predominate in the central parts of the basins. There is a gradual transition from one formation to the next without any signs of folding.

The transition from the Sparagmite Group to the fossiliferous Lower Cambrian is marked by a thin conglomerate. There is no marked lithological contrast between the upper formation of the Sparagmite Group and the basal layers of the Lower Cambrian Holmia Series.

The upper beds in the so-called Ringsaker Quartzite yield *Scolithus* and *Monocraterion* down to a few meters below the Cambrian basal conglomerate. These findings may strengthen the view of a homotaxial deposition of the uppermost "Eocambrian" at Mjøsa and sandstones regarded as true Cambrian in Southern Sweden.

Holmia cf. mickwitzi was found in a zone below the Discinella holsti zone in Flagstad river, and *Callavia* n.sp. occur in the Volborthella zone in Lauselva, Hov i Land.

The Ordovician and Silurian stratigraphy is discussed in special chapters, which also contain descriptions of new localities. New sections through the Silurian are mentioned from the Toten District, near Hunselv, and along Brumundelv.

The tectonics in the districts are connected with the Caledonian movements in the miogeosyncline. The oldest sparagmites are regarded as autochthonous, whereas the upper formations were overthrust and form the Quartz-

sandstone nappe. Old structural lines are shown to have influenced the Caledonian tectonic picture.

The style and degree of folding of different formations in both the autochthonous and allochthonous position is determined by the thickness and stratigraphical distribution of competent and incompetent layers.

Most of the Mjøsa Districts naturally belong to the Permian Oslo Graben. The Permian faulting is mentioned in a final chapter.

Acknowledgements.

The author is grateful for this opportunity to express his heartiest thanks for all professional, technical and financial help received during the preparation and compilation of this paper.

The field investigations were begun in 1948 under the guidance of Professor L. Størmer. The author wishes to express his grateful thanks to Professor Størmer, as whose assistant he acted in the period 1950-52 and whose inspiring interest and personal kindness have been of the utmost importance during the later phases of the work.

From the beginning, the author has had the opportunity to present and discuss new results with Professor O. Holtedahl. Professor Holtedahl's encouraging interest in regional geology, together with his wealth of stimulating ideas, have been, and will continue to be in the future, an inspiration to greater efforts.

The author is indebted to State geologist P. Holmsen for his guidance during instructive field excursions in the Sparagmite area and for many fruitful discussions in the office.

Thank are also due to the author's colleagues in Norway and elsewhere in Scandinavia for discussions and suggestions.

Beginning in 1952 the author has been employed as State geologist with the Geological Survey of Norway (NGU), on behalf of which the mapping was carried out. NGU has also financied the preparation and printing of this publication, for which sincere thanks are due to its directors, Dr. H. Bjørlykke and Mr. K. Ingvaldsen.

Special thanks are given to the following, who collaborated in the preparation of the manuscript:

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Introduction.

This publication gives the major results of geological investigations carried out in the vicinity of Lake Mjøsa in Southern Norway during recent years. The geographical situation and extension of the mapped area is shown on the Key Map (Plate I).

It is impossible to give an exhaustive geological description of the district in question in one publication. In the following an attempt is made to give a rapid survey of geology and a regional geological interpretation, based on the investigations and publications by the author and by earlier workers. Particular stress is laid on descriptions of new localities and other observations which the writer finds are of greatest importance for an understanding of the geology of the district. Such a survey is in the writer's opinion necessary as a foundation for further, more detailed, stratigraphical, petrological and tectonic studies in this district.

The present (geological) investigations at Mjøsa were started in the summer of 1948. Results from the first year's work were presented for the degree examination at the University of Oslo in the spring of 1950. That work dealt especially with the geology of the Nes peninsula. Later on the area was extended to comprise the districts on both sides of lake Mjøsa. The investigations have mainly been concentrated on the "Cambro-Silurian" rocks, which are now almost completely mapped within the districts 9, 10, and 11 on Størmer's Key map of the Oslo Region (Størmer 1953, Fig. 1).

During the years 1950-52 the writer was engaged as assistant to Professor L. Størmer, who with the aid of grants from the Norwegian Research Council for Science and the Humanities commenced a more detailed study of the Middle Ordovician of the Oslo Region. In this period particular stress was laid upon investigations of the Middle

Ordovician of the Mjøsa district. An introductory survey of these investigations was given by Størmer in 1953.

The geological mapping has been carried out for and with financial aid from the Geological Survey of Norway. From 1952 the writer has been engaged as state geologist with the Survey. The mapping has been done with a view to revision and publication of the map sheets Hamar, Gjøvik, Lillehammer and Åmot.

The main part of the area dealt with in this publication is situated within the map sheets Hamar and Gjøvik and overlaps the adjoining map sheets Lillehammer and Åmot to the north. The scale of these maps is 1 : 100 000. The topographical maps, dating from 1882, are unfortunately faulty and out of date with regard to roads, railways, etc. A revised edition (scale 1 : 50 000) was published by the German Occupation Authorities in 1942. As these new maps were mainly founded on the earlier maps they have the same errors, but because of their more useful scale, they have been used as a basis for the geological mapping. For smaller areas aerial photographs have been of great help.

The bed-rock at Mjøsa is heavily covered by moraines and other Quaternary and Recent sediments. The Cambro-Silurian shales and limestones have given rise to rich agricultural land in the parishes around Mjøsa. The cover so formed hinders the mapping of the bedrock. However, thanks to some good tectonic and stratigraphical marker horizons, one can easily establish the main geological structure. The competent sandstones and thick limestones stand up as east-west trending escarpments, thus delineating the tectonic structures. The Cambrian alum shales abut mainly against quartzite and Precambrian rocks. These boundaries can easily be followed in the field because of the difference in topography and vegetation. Several lakes, lakelets and rivers are located in the district. The many exposures along the Mjøsa shoreline are of vital importance for the investigations of the geology of the district.

The best stratigraphical sections are met with in exposures in rivers and streams and along the roads and railways. Some of the rocks are utilized economically, especially the Ordovician limestones (Orthoceras and Mjøsa limestones). The many quarries are good starting points for detailed stratigraphical investigations.

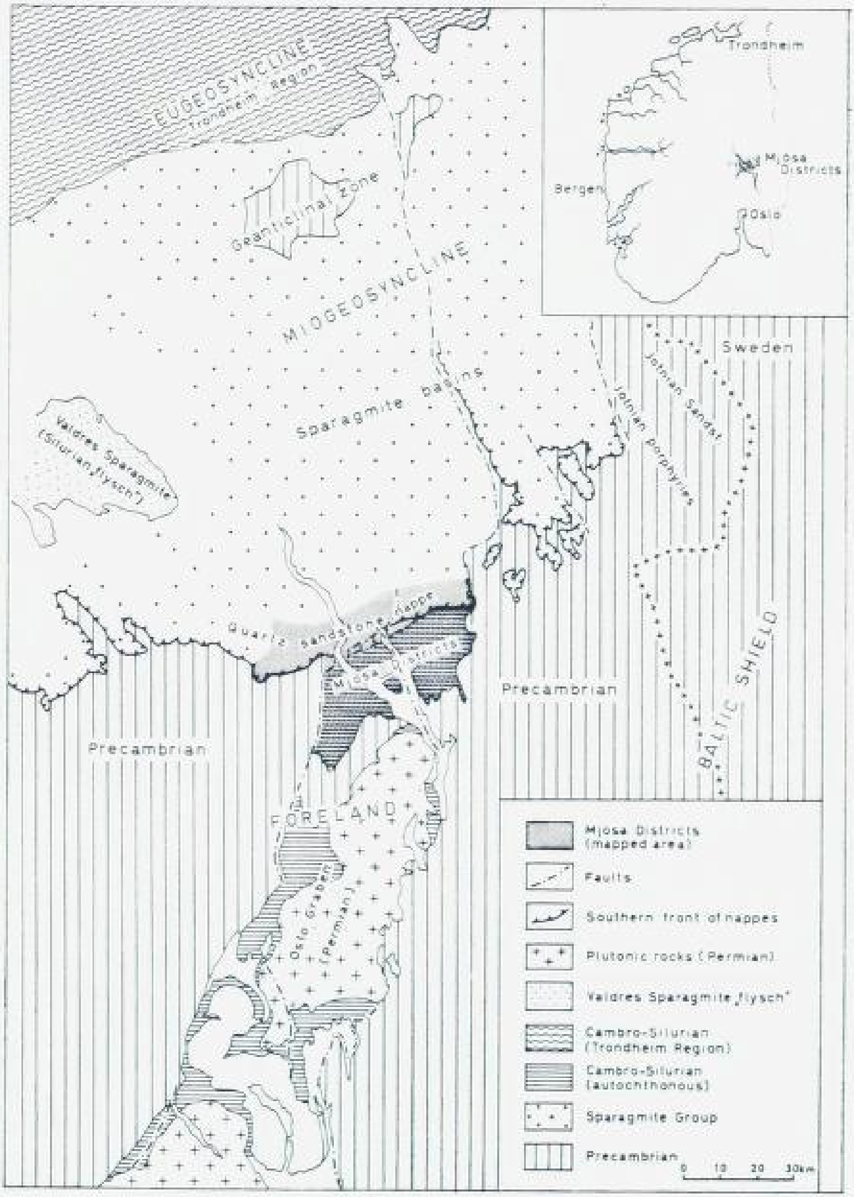

Fig. 1. *Key maps showing the situation and geological setting of the Mjøsa Districts.*
Nøkkelkart som viser den topografiske og geologiske beliggenhet av Mjøstraktene.

The geological setting of the Mjøsa Districts.

The Mjøsa Districts have a transitional situation between the foreland and the miogeosynclinal zone of the Caledonian geosyncline. This position has influenced the Paleozoic sedimentation and the tectonics of the districts (Fig. 1).

Prior to the Cambrian, faulting took place in this marginal zone of the Precambrian Baltic Shield. The faulting gave rise to basins in which the "Eocambrian" Sparagmite Group was deposited. The surroundings of northern Mjøsa are classical ground for the study of these formations. The Sparagmite basin had its southern limit in the mapped area, where the upper formations have a transgressive position on the peneplaned Precambrian.

The Lower Cambrian is represented only in the northern districts. The higher Cambro-Silurian sequence shows close affinities to the typical foreland development farther south in the Oslo Region. The noticeable differences in facies can be ascribed to the proximity of the Mountain chain, and several zones show increasing of terrigenous material towards the north.

Early Caledonian orogenic phases led to epirogenetic rise of the districts. A great hiatus is demonstrated between the Middle Ordovician and the Upper Llandovery. The break is followed by sedimentation of orthoquartzitic facies now commonly regarded as contemporaneous with the synorogenic Valdres Sparagmite formation.

Caledonian folding and thrusting took place in a late, post-Silurian phase. The movement resulted in a partition of the districts, with the front of the Quartz-sandstone nappe as the dividing line. The northern part belongs to this nappe unit, which has developed an imbricate structure of Highland type. South of the front of the nappe, the Cambro-Silurian is folded above undisturbed Precambrian basement (Jura-type folds).

Parts of the Mjøsa Districts belong to the Oslo Region and the Permian "Oslo Graben". It is a matter of opinion whether or not the Ringsaker District should be included in the Oslo Region. Permian faulting and extrusions of lavas may justify such an inclusion.

The downfaulting within the districts in Permian time protected the Paleozoic sediments from erosion in later geological periods.

Historical review.

The Mjøsa District is a classical one for the geology of Norway. Several geologists, foreign as well as Norwegian, have visited the area, and a rich geological literature has accumulated. The publications comprise tectonic, stratigraphical, paleontological and paleogeographical works.

A geological mention of the district was made by L. v. Buch (1810) in his "Reise durch Lappmarken und Norwegen". A year later (1811), H. Heyerdahl, local priest at that time, gave a geological description of the district. His interpretations of the geology were exceptionally advanced for that time. Heyerdahl was a good observer and understood the relative ages of the different rocks. He found that the rhomb porphyry and the overlying sandstone in Brumunddal were the youngest rocks in the district. Esmarck (1829) introduced the term Sparagmite for the feldspar-bearing sandstones occurring in the north of the district. "Sparagmite" later became a collective term for the whole sedimentary series underlying the fossiliferous Lower Cambrian. Keilhau mentioned the geology of Mjøsa (1826 and 1850) and concluded by stressing the importance of getting this part of Norway geologically mapped. Keilhau's successor at the University in Oslo, Th. Kjerulf, published a series of papers arising out of investigations carried out in the years 1857-84.

In 1862 he published "Beskrivelse af Jordbunden i Hedemarkens Sorenskriverier og Totens Thinglag", accompanied by the first geological map of the Mjøsa district. In this publication Kjerulf made the first stratigraphical division of the Cambro-Silurian at Mjøsa — a division founded on the stratigraphy near Oslo. Kjerulf's investigations and publications culminated in the publication of the geology of the map sheets Hamar and Gjövik (1884).

At this time Brøgger, who succeeded Kjerulf at the University, continued the stratigraphical investigations in the Oslo Region. In 1882 he published a description of a geological profile along the Mjøsa shore line, from Ringsaker to Saugstad. This publication contains the first mention of the Middle Cambrian Ölandicus zone (1 c α) at Ringsaker. The same year the Lower Ordovician beds at Mjøsa were briefly commented on in his classical work on "Die silurischen Etagen 2 und 3" (1882).

The map sheet Lillehammer was then worked out and geologically described by Ths. Münster (1900).

Schiötz introduced (1902) a new period in the geological understanding of the Mjøsa district. From detailed field work in the south-eastern parts of the Sparagmite area Schiötz arrived at the conclusion that the upper part of the Sparagmite (viz. the Quartz-sandstone) had been thrust a considerable distance (ca. 40 km) towards the south.

Bjørlykke (1905) did not accept Schiøtz's concept of thrusting, and tried to explain the profiles as the result of vertical displacements. In the same paper Bjørlykke gave a detailed description of the profile Hamar-Lillehammer, along the newly constructed railway.

Kiær treated the stratigraphy of the Cambro-Silurian in further publications. In 1897 he mentioned the Middle Ordovician beds and later introduced the term Mjøsa limestone for the limestone terminating the Ordovician at Mjøsa. In 1908 he gave a description of the Silurian at Mjøsa, accompanied by detailed descriptions of type localities. This work was followed by shorter comments on the Silurian by Kiær and Bjørlykke. In 1916 appeared Kiær's stratigraphical — paleontological description of the Lower Cambrian Holmia shale at Tømten, Ringsaker. In this work he also discussed the Cambrian-Eocambrian boundary and Lower Cambrian paleogeography. Holtedahl (1909) gave detailed description of the Middle Ordovician strata.

A regional description of the "Sparagmite formation" at Mjøsa was given by Goldschmidt (1908). This publication contained a description of the now classical profile Ringsaker-Brøttum and a geological map of the area. The work here was continued by Rothpletz (1910). He interpreted parts of the Sparagmites as equivalents of Cambrian and Ordovician layers farther south. This misinterpretation necessarily influenced his tectonic conclusions. Rothpletz supported Schiøtz's thrust theory and drew a profile across the south-eastern area based on Schiøtz's publication. The following year Holtedahl

(1915) described the geology of the northern part of lake Randsfjord. In this paper he advanced definite proof of the thrusting of the Quartz-sandstone. His description of this western part was parallel to that of Schiøtz, and indicated a general appreciation of the importance of thrusting in Norway.

The knowledge of the Lower Cambrian was then extended by Bråstad's (1915) and Vogt's (1924) stratigraphical investigations. Bråstad discovered the Lower Cambrian *Discinella* zone, and Vogt gave an exhaustive account of the Upper Eocambrian and the Lower Cambrian. Holtedahl (1921) pointed to the similarities between the so-called Moelv conglomerate and the tillites in Finnmark. In the same paper he gave a series of profiles near the front of the Quartz-sandstone nappe at Ringsaker and Furnes.

Cambrian and Lower Ordovician layers were dealt with in detail both stratigraphically and paleontologically by Strand (1929). The same year (1929) Rosendahl gave a description of the rhomb porphyries and the Brumunddal sandstone. Thus more or less detailed stratigraphical knowledge of the Paleozoic rocks at Mjøsa was at hand.

A guide to the geology of Southern Norway (Holtedahl, 1934) contains a rapid survey of the geology at Mjøsa, a summary of the Eocambrian-Paleozoic stratigraphy there.

A petrological work on the Lower Silurian sediments in the district was published by Major (1946). Bugge (1945) described some small areas in Ringsaker. Vogt (1953) described the geology on both sides of Mjøsa at Moelv-Biri, by means of geological maps and profiles. He introduced the terms Biri nappe and Moelv window for allochthonous and autochthonous series respectively.

The present author (1952) gave a stratigraphical description of the Lower Didymograptus zone at Ringsaker, including a geological map of the southern part of the parish. Størmer (1953) described the Middle Ordovician layers of the Mjøsa district. In addition, a geological map, showing boreholes for water in the central parts of Mjøsa was published by the present author (1953). A preliminary survey of the thrust tectonics at Mjøsa was presented in Uppsala in 1953 (Skjeseth 1954). The geology of the Mjøsa district is also dealt with briefly in Holtedahl's Norges Geologi (1953), the geological maps having been brought up to date after the last few years' mapping at Mjøsa.

Besides the above publications a series of popular geological descriptions are to be found in parish-books, tourist guide books, etc.;

Holtedahl (Hedemark, Land, Toten), Bråstad (Vardal), Rosendahl (Biri), Dam (Nes), Lundby (Furnes).

The limestones of the district were discussed by Holtedahl (1912) from an economic point of view, and an extremely carbonaceous alum shale at Bjørge, Vardal was described by Foslie (1919).

Among purely paleontological works may be mentioned the following: Angelin (1854) Trilobites, Linnarsson (1871) Trilobites, Holm (1900) Trilobites, Strand (1932) Cephalopods, Holtedahl (1926) Strophomenids, Monsen (1937) Graptolites, Kiær (1920) Algae, Hill (1953) Corals, Skjeseth (1955) Styginids, Henningsmoen (1953) Ostracods, Spjeldnæs (1957 a) Strophomenids and (1957 b) Porambonitids, Sweet (1958) Nautiloid cephalopods, Soot-Ryen (1960 a) Pelecypods and (1960) Notostracan and Conchostracan.

Stratigraphy.

The Sparagmite Group.

"Eocambrian".

The name "sparagmite" was introduced by J. Esmark in 1829 for feldspathic sandstones from the eastern part of Southern Norway. Th. Kjerulf used the name Sparagmite formation for the whole formational group underlying the fossiliferous Cambrian beds. The close connection between the Sparagmite Group and the Cambrian was clearly pointed out by Brøgger (1900) when he proposed the name "Eocambrian" for these rocks.

Since then the nomenclature and stratigraphical position of the "Eocambrian" rocks in the eastern part of Southern Norway has been much debated. Holtedahl has given a summary account of this subject as a contribution to the Cambrian Symposium of the Mexico Congress (1956, not yet printed). Short contributions concerning the "Eocambrian" in Sweden and Norway were made by B. Asklund (1958) and O. Holtedahl (1958) at a meeting in Paris in 1957 where the above problems were discussed.

Comments on the term Eocambrian and on the problem of the base of the Cambrian are given in a later chapter (p. 58).

Our knowledge of the Sparagmite Group was greatly advanced by Schiøtz's (1902) mapping and geological analysis of the south-eastern part of the area. Schiøtz showed that the sediments were deposited in basins bounded partly by faults and he outlined these basins on a sketch map (ibid. p. 99). He also demonstrated the folding and the thrusting of the formations and gave undoubted proof of the existence of Caledonian nappe(s) in this part of the country.

The now classical area for the Sparagmites at Mjøsa was dealt with by V. Goldschmidt (1908) and Ths. Münster (1900). K. O. Bjørlykke (1893) described the stratigraphy and development of the group in the Gausdal-Ringebu area.

G. Holmsen, P. Holmsen and Chr. Oftedahl have prepared geological maps, with accompanying descriptions, of the eastern part of the area. (G. Holmsen 1935, 1937, and 1950, P. Holmsen and Chr. Oftedahl 1956). The two last have also in other special publications made valuable contributions to the stratigraphy and tectonics of the Sparagmite group.

In a series of publications O. Holtedahl has widened our understanding of the geology within the Sparagmite area (1921, 1922). The glacial character of the Moelv Conglomerate was indicated by him.

During the last few years the Geological Survey of Norway has commenced detailed mapping and stratigraphical studies along the marginal zone of the Sparagmite area from Rena to Mjøsa and northwards via Gausdal to Ringebu. The students K. O. Bjørlykke, L. Kirkhusmo, B. Løberg, H. Chr. Seip and J. O. Englund are engaged in this team work under the leadership of the author. The work forms the basis for theses to be presented for the degree examination in geology at the University of Oslo. They have kindly placed the preliminary results of their investigations at the disposal of the author.

From a paleogeographical, stratigraphical and tectonic point of view the geology of the Mjøsa Districts is closely connected with the geology of the Sparagmite area.

The Sparagmite Group consists of the following formations in descending order:

Ringsaker Quartzite	Mjøsa Quartz-sandstone
Vardal Sparagmite	
Ekre Shale	
Moelv Conglomerate (= Moelv Tillite)	
Moelv Sparagmite	
Biri Shale and Limestone	
Biri Conglomerate	
Brøttum Shale and Limestone	
Brøttum Sparagmite	
Elstad Sparagmite.	

The formations are lithostratigraphical units and, as might be expected, the sediments show great regional variations in facies. There are no signs of folding during the cycles of sedimentation. The question as to whether the sparagmites are now in an allochthonous position is fundamental to the understanding of the group. The present investigations go to show that the upper formations down to the Ekre Shale form a nappe. The older formations evidently lay protected in their basins of deposition and were folded against the margins of the basin in a late phase of the orogeny. They must, in the writer's opinion, be regarded as autochthonous or parautochthonous.

Short comments are given below on the different formations, and on their distribution and development within their areas of deposition in Southeast Norway. The analysis is shown on a paleogeographical sketch map on which are drawn stratigraphical columns for type areas and localities.

The Sparagmite formations were deposited in basins or troughs limited by NW-SE trending faults or fault zones (Plate II). The main basin of sedimentation was divided in its southern area into a western and an eastern part by a horst between the Rendalen and the Osen fault zones. Fault zones also existed in the central Mjøsa Districts. The most important of these probably represented a northern continuation of the Hunselv fault. On the west, fault zones from Randsfjord to Snertingdal and Gausdal run parallel to the others. Most of the fault zones were rejuvenated in post-Caledonian time.

The southern limit of the basins is not quite clear. Fault zones or flexures seem to have existed in a zig-zag pattern. Towards the north the basin was partly closed by an island arc, or continuous land, which projected above sea level during most of the time of sedimentation. There the youngest formations were deposited directly on weathered Precambrian rocks. This geanticline, separating the eugeosyncline and miogeosyncline, of the Caledonian mountain chain in Southern Norway, is now visible as a series of windows exposing Precambrian rocks.

The transgressive character of the upper formations is clearly demonstrated in the currently mapped districts. The observations made may have consequences for the understanding of the whole Sparagmite Group.

Eocambrian rocks within the mapped area.
Description of localities.

In the area under consideration only the upper formations of the Sparagmite Group, the Tillite, Ekre Shale, Vardal Sparagmite, and Ringsaker Quartzite are represented. The last two units are commonly united in the so-called "Quartz-sandstone" formation. This lithologic

Fig. 2. *Vardal Conglomerate, a member of the Vardal Sparagmite, from Lauselva Hov i Land, consisting of quartz pebbles in grey sparagmite matrix.* (⅓ nat. size.)
Vardal-konglomerat fra Lauselva, Hov i Land, består av kvartsboller i grå, sparagmittisk grunnmasse. (⅓ nat. størr.)

Fig. 3. *Vardal Conglomerate from the northern side of Langodden south of Brumunddal.*
Vardal-konglomerat fra nordsiden av Langodden, syd for Brumunddal.

name is indefinite and may easily lead to confusion. The term Mjøsa Quartz-sandstone is to be preferred.

Autochthonous Series.

The investigations have shown that the Mjøsa Quartz-sandstone occupies relatively wide areas south of the front of the Quartz-sandstones nappe. In the writer's opinion this area must be regarded as autochthonous. The Mjøsa Quartz-sandstone in the areas in question belongs stratigraphically to the parautochthonous series to the south.

Locality Nes.

Just south of the horst on the Nes peninsula is a relatively wide area occupied by Mjøsa Quartz-sandstone, east of Stavsjø. This area is bounded on the east by Middle Ordovician shales along a north-south fault zone, the so-called Nes Fault (see p. 113). Towards the west and southwest the formation is overlain in normal succession by Lower Cambrian shales (see p. 39). The beds are moderately disturbed by Caledonian movements. The thrust movements have mainly affected the overlying strata, while the Quartz-sandstone tectonically belongs to the basement. The slight dip of strata towards the southwest may partly be ascribed to rotational movements of the block on the western side of the Nes fault (p. 114). Thus the oldest beds are exposed in the northeastern corner of the area. There is a gradual transition from the Ringsaker Quartzite down to the Vardal Sparagmite. In the northeastern corner of the area a conglomerate, the Vardal Conglomerate, with mainly quartz pebbles, occurs (cf. Fig. 2). The total thickness of the Eocambrian as Nes is estimated to be about 60 m.

Locality Furnes.

The southernmost Mjøsa Quartz-sandstone, occuring at Furnes, is also interpreted as autochthonous on account of its stratigraphical and tectonic behaviour. The moderate folding of the formation is most probably due to the thrusts in the Precambrian basement (see p. 101). The Mjøsa Quartz-sandstone is exposed at several localities from Langodden on Mjøsa and towards the east. Along this line it dips below Lower Cambrian beds of the Cambro-Silurian sequence to the south, as shown by Kjerulf (1862, p. 8, profile Hellerud).

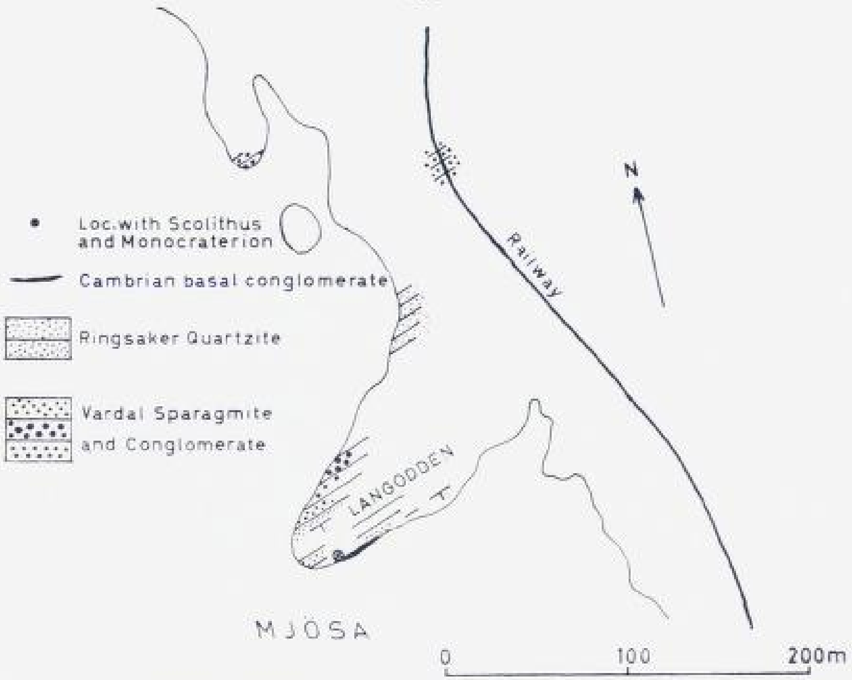

Fig. 4. *Sketch map showing the locality with Scolithus and Monocraterion at Langodden south of Brumunddal.*

Kartskisse som viser finnested for de vertikale ormerør (Scolithus og Monocraterion) på Langodden, syd for Brumunddal.

Fig. 5. *The upper beds of the Ringsaker Quartzite yielding Scolithus and Monocraterion, southern side of Langodden.*

De øvre lag av Ringsaker-kvartsitt på sydsiden av Langodden inneholder Scolithus og Monocraterion.

Fig. 6. *"Pipe rock" in Ringsaker Quartzite at Langodden, Furnes.*
Lagflate som viser "ormerør" i Ringsaker-kvartsitt, Langodden, Furnes.

Fig. 7. *Close up photo of the "pipe rock", Langodden, Furnes.*
Nærbilde av "ormerørene", Langodden, Furnes.

Fig. 8. *Scolithus in Ringsaker Quartzite from road section of Furnes Hospital. Nat. size.*
Scolithus i Ringsaker-kvartsitt fra vegskjæring ved Furnes Sykehus. Nat. størr.

The exposures at Langodden give the best information about the formations. Typical Vardal Sparagmite crops out at several places along the Mjøsa shoreline in the bay north of Langodden. On the northern side of the small peninsula the formation is conglomeratic (Fig. 3). The transition to the overlying Ringsaker Quartzite is gradual. The topmost bed of that formation and the basal conglomerate of the Holmia Series are encountered on the southern shoreline, the strata dipping gently southwards (Fig. 4).

About two meters below the basal conglomerate the beds are typical "pipe rocks", with vertical tubes of Scolithus type. Some of the tubes have funnel-shaped openings and should, according to the definitions given by Westergaard (1931, p. 12), be referred to the genus Monocraterion (Figs. 5, 6, 7). The overlying conglomerate resembles that described by Vogt (1924, p. 310) from Bråstadelva in Vardal.

Exposures of the upper beds also occur in a road-cut north of Helleberget along the old parish road Brumunddal-Jessnes. The Ringsaker Quartzite is cross-bedded, and Scolithus structures are common. The formation is overlain by Lower Cambrian shales (see p. 39). The Mjøsa Quartz-sandstone is well exposed in an open anticline at Toppen. On the northern flank of this anticline the highest beds of the quartzite are cut by the road just north of Furnes hospital. The beds here contain structures similar to those described as vertical worm burrows from Lower Cambrian Sandstones in Sweden. On the bedding surfaces they appear as minor crater-like hollows. In section they show *Scolithus*, *Monocraterion* and *Diplocraterion* structures (Figs. 8, 9). Towards the core of the above-named anticline, east of Toppen, there is a gradual transition to Vardal Sparagmite, which in its lower part is developed as a conglomerate of the same type as that described from Nes and Langodden. In the Flagstad river, where the anticline is overturned and partly broken up, the same conglomerate occurs near the bottom of the Eocambrian. Farther east the anticline is overridden by the Quartz-sandstone nappe.

Three borings for water have been of great help in estimation of thickness of the Mjøsa Quartz-sandstone at Furnes, which is of the order of 80 m. Mud from that depth carries fragments of gneiss, most probably derived from the Pre-Cambrian bedrock. The yield of water at this depth is also remarkably high.

Autochthonous? tillite at Landåsen.

Near Landåsen, situated in the northwestern corner of the mapped area, is a conglomerate which is interpreted as an equivalent of the Moelv Conglomerate. The formation occupies relatively wide areas on both sides of the road from Mustad to Oddnes a few hundred meters south of Landåsen Tourist Hotel. This tillite-like conglomerate is limited by the Randsfjord-Snertingdal fault zone to the west, and is overlain by Ekre Shale and Mjøsa Quartz-sandstone which forms the hillsides towards the southeast.

The conglomerate consists of angular fragments and boulders of

Precambrian gneiss in a fine-grained sparagmite matrix. The formation most probably lies in an autochthonous position near its primary area of deposition and was overridden by the Quartz-sandstone nappe. Detachment of the nappe has taken place in the Ekre Shale.

Allochthonous Series.
The area between Mjøsa and Randsfjord.

The Cambro-Silurian has a far wider extension in this area than appears from earlier geological maps. The best exposures through the Eocambrian series are found along the front of the nappe, where the series including the Ekre Shale is to be seen at several localities. Just south of the road Fluberg-Gjøvik is an instructive profile through these beds about 200 m east of the road to Granum farm. Near the bottom of the succession appears highly tectonized Ekre Shale followed upward by fine-grained Vardal Sparagmite and a conglomerate. The conglomerate consits mainly of quartz pebbles in a finer-grained sparagmite matrix. The name Vardal Conglomerate may be chosen for this member of the Vardal Sparagmite. The sparagmite above this conglomerate is followed by typical white to bluish Ringsaker Quartzite. The conglomerate crops out at several localities along the front of the nappe. The pebbles consist of white pegmatitic quartz (Fig. 2). The conglomerate is exposed on the western slope of the hillside at Laus-elva. Its thickness is there about 50 m. Elsewhere the conglomerate can be seen on the southern slope of Skonhovdhøgda and on the northern side of the road Vardal-Gjøvik, just south of Mæhlum farm. Ekre Shale here forms the oldest beds in the nappe. The conglomerate also crops out along the Mjøsa shoreline just north of Gjøvik (loc. described by Bråstad 1915). Near the base the conglomerate is closely packed, consisting of well rounded quartz pebbles. Above this basal bed larger pebbles occur scattered in a sparagmitic matrix. The thickness of the conglomerate is here about 30 m.

The thickness of the conglomerate as well as the size of the conglomerate pebbles seem to decrease towards the north. At the junction of the Bråstad and Sæter rivers is a thin conglomerate bench in the sparagmite (Vogt 1924, p. 308). A similar bench is exposed in the first road-cut north of Bråstad along the main road Gjøvik-Lillehammer.

On the Nes peninsula the same conglomerate is most probably represented at the locality of Vengshol just north of the horst (cfr. Bugge, C. 1945).

The stratigraphy of the Sparagmite Group.

Elstad Sparagmite.

The base of the Sparagmite Group is not known. Between Ringebu and Fåvang in Gudbrandsdalen the formations form an anticline (Bjørlykke 1893, p. 5). In this structure a pale arkosic formation apparently underlies the Brøttum Sparagmite. This formation has been called the Elstad Sparagmite (Bjørlykke 1905, p. 159), and was interpreted as the oldest known sparagmite formation. The present investigations by J. O. Englund confirm this view.

The Elstad Sparagmite consists of thick, rather homogeneous benches of pale sparagmites and orthoquartzites. The transition to the overlying Brøttum Sparagmite is marked by a thin conglomerate and by limestone beds. This assumed oldest formation may only have been deposited in the northernmost part of the main sparagmite basin.

Brøttum Sparagmite. ("The older dark sparagmite.")

This formation has its main distribution in the central part of the eastern basin. The thickness is estimated at 1000-1500 m. The sequence is well exposed in road sections along Mjøsa and Gudbrandsdalen from Biri and Brøttum to Fåvang.

Dark grey arkoses and greywackes alternate with black carbonaceous shales, often rich in pyrite. The sparagmite benches vary from a few centimeters to several meters in thickness. The sandstone beds show graded bedding and load casts. The formation has a monotonous development in the whole area, though shales dominate in the more central parts. The black shale indicates badly ventilated bottom conditions. This may be explained by the narrow inlet(s) to the basin. It is uncertain whether or not the formation is represented in the eastern basin. Similar rocks north of Jordet in Trysil are probable equivalents

Limestone horizons are reported from different localities, for example, from Reistad in Eastern Gausdal (Bjørlykke 1893, p. 9). These beds may initiate, and belong to, the next formation in the type area at Mjøsa.

Brøttum Shale and Limestone.

This formation has hitherto only been found on the eastern side of Mjøsa (Münster 1920, p. 12). It consists of alternating red arenaceous shales and limestones and seems to be restricted in extent. This may be partly due to erosion, as boulders of shale and limestone are common in the overlying Biri Conglomerate. The red formation is to be seen in contact with the conglomerate at Lake Næren. River sections along Åsta between Bjørnås bridge and Elvedalen give the best information about the formation in question. These localities were investigated by the author in the summer of 1962. Above light sparagmitic layers belonging to the Brøttum Sparagmite follow red arenaceous laminated shales. In its middle part the formation consists of thin bedded limestones. The formation is gently folded and the thickness is estimated at 50 m. At this place the Biri Conglomerate is lacking and the Brøttum Shale and Limestone show a gradual transition to Biri Shale.

Biri Conglomerate.

This conglomerate shows great variations in thickness and rests on both Brøttum Sparagmite and Brøttum Shale and Limestone. The conglomerate consists of large, mostly wellrounded boulders in a dark arkosic matrix. The thickness is about 150 m at Brøttum, where it appears as typical deltaic deposits showing cross-bedding. The conglomerate decreases in thickness from Biri westwards. Here the matrix is calcareous, as is clearly visible in outcrops along the new road from Torpa to Vingrom. At this locality the formation is only about 10 m thick. In Gausdal, near the river Roppa, the thickness of the conglomerate is estimated at 100 m.

Near Kirkestuen, south of the Fåvang Syncline, scattered boulders and layers of boulders occur in a dark sparagmite. On the northern flank of the same syncline a coarse conglomerate is to be seen in road sections at Fåvang.

The Biri Conglomerate also thins out and finally disappears eastwards. In the river section along Åsta (mentioned above) the formation is missing.

The conglomerate attains a great thickness north of Rena near the Rendalen fault zone (Oftedahl 1956). In an assumed parautochthonous sequence near Bjørånes farther north, the conglomeratic facies again disappears (Oftedahl 1956, p. 59). It is uncertain whether the formation in question is represented in the eastern basin. A conglomerate occuring north of Jordet may be an equivalent.

It seems logical to explain the formation of these coarse Biri Conglomerate by a subsidence of the basin. The subsidence most probably took place along the main fault zones already mentioned. The formation was deposited at the margins of the basin, near the faults. It is natural to assume that the rivers bringing the sediments to the basin followed the same zones of weakness from the surrounding land. The boulders in the conglomerate originate from east, south, and west respectively. To the east porphyries, sandstones and coarse granites are common. In the central part, near Mjøsa, quartzites and gneisses dominate. Anorthosites occur frequently in the Fåvang-Gausdal districts, indicating a west-to-east transport.

Biri Shale and Limestone.

At most places there is a gradual transition from the Biri Conglomerate to this formation. The basal layers show alternating shales and calcareous sparagmite benches. The formational boundary is well exposed in new sections along the main road at Roterud north of Biri.

The formation displays a great variation in facies from black shales, through shale with limestone lenses, to thick-bedded arenaceous limestone and pure limestone, often oolitic.

On both sides of Mjøsa the thickness is more than 200 m. Black shale, the so-called Biri Shale, dominates in the lower part while the Biri Limestone is found near the top. This limestone contains exceptionally well developed intraformational conglomerates or sedimentary breccias, indicating shallow water deposition. The sedimentary structures may be seen on the peninsulas of Kræmmerodden and Helgeberget on the western and eastern Mjøsa shore lines respectively.

In Gausdal, near Herfjell, an oolitic limestone underlies the Moelv Sparagmite, which in this area appears as a calcareous formation. At Fåvang the development is like that prevailing at Mjøsa.

At the bridge across the Åsta in Elvedalen the transition from Brøttum Shale and Limestone to Biri Shale is marked by beds showing slumping and truncation of the crumpled layers. These structures may easily be misinterpreted as an angular disconformity. Downstream from Elvedalen the Biri Shale has a varved appearance with alternating light and dark varves. The total thickness of the formation is about 200 m.

Biri Shale dominates near Arnestad in the northern part of the Rena district. Farther south, at Glomstad, the development is like that at Mjøsa. Closer to the Precambrian the oolitic facies is met with. In the vicinity of Jordet in Trysil the same members are found. There, also, the oolitic limestone seems to be distributed near the southern boundary of the basin.

The different members of the formation have a zonal distribution within the basin. The Biri Shale introduces the sedimentation and is mainly developed in the central part of the basin(s). Approaching the margins we have typical Biri Limestone, while the oolitic facies is associated with the littoral zone. At this time the basins were filled in and temporary transgression apparently took place. It is probable that the transgression resulted in a connection between the basins from Rena to Trysil.

One may say that the first main cycle of sedimentation was brought to an end. The formations mentioned above are called the "Old Sparagmite" and are regarded by several Scandinavian geologists as a unit distinct from the rest of the Sparagmite Group.

Moelv Sparagmite.

After the period of shallow water there followed renewed subsidience of the Sparagmite basins, evidently along the old zones of weakness. The movements are indicated by the formation of the Moelv Sparagmite and contemporaneous deposits. In the type area, Moelv, the sedimentation starts with shales and arkosic sandstones. This succession is a continuation of the Biri Shale but it would be better to regard it as a member of the Moelv Sparagmite and it is here given the name Moelv Shale. At Moelv the sparagmite is conglomeratic with white quartz and red feldspar giving the rock a red colour. For this the formation is also named the "Red Sparagmite". This formation is at Moelv assumed to be about 250 m thick. Towards the top the matrix has an increasing content of calcite (Münster 1900, p. 16). From Biri and westwards the formation decreases in thickness and changes character. Conglomerates with pebbles and largely angular boulders of Biri Limestone occur in the formation, e. g., at Svarken (Münster 1900, p. 13), and boulders of granite are also found.

At Herfjell-Nysæter in Western Gausdal is an alternation of thin beds of Limestone of Biri type and sparagmites near the base of the formation. Then follows a calcareous, crossbedded sparagmite about 50 m thick, extending from Herfjell to Nysæter. More or less continuous layers of conglomerates consisting of angular boulders of Biri Limestone occur at several horizons. The whole formation is regarded by Münster (ibid. p. 13) as Biri Limestone.

Farther north at Roppa a limestone occurs near the top of the formation. A dark coarse-grained sparagmite forms the transition to the overlying tillite. In the river Vigga the formation has a small thickness.

The Moelv Sparagmite shows its main development in the eastern basin, where it most probably has its greatest thickness along the Engerdal fault zone (Holtedahl 1921). The upper part is at several places a coarse polygenous conglomerate of Biri Conglomerate type. The stratigraphy in the vicinity of Jordet in Trysil is like that described from Nysæter and Herfjell in Gausdal. Arenaceous limestones and conglomerates with limestone boulders are common.

The Moelv Sparagmite is transgressive in parts of the basins and forms the basal layers above the Precambrian basement east of Lake Femund (G. Holmsen 1937, p. 19), and appears to have been deposited on the horst between Rendal and Slemdal.

The distribution of the conglomeratic facies of the formation is almost the same as for the Biri Conglomerate. The shale and limestone boulders in the conglomerate show that an erosion of the Biri Limestone took place in marginal areas of the basin.

Moelv Conglomerate (= tillite).

O. Holtedahl (1922 b) assumed a glacial origin for this "tillite-like" conglomerate in the type area south of Moelv. Most Scandinavian geologists now consider the conglomerate to be a tillite.

P. Holmsen gave a broad survey of the formation, its distribution and development in Southeast Norway (1954). He distinguished three main facies types: The Moelv Conglomerate with big boulders in red-brownish arkosic matrix, the boulder clay type, and the basal tillites resting directly on the Precambrian basement.

The Moelv Conglomerate has its main distribution along the Ringsaker inversion line (p. 109). The tillite reported from Landåsen (p. 25) contains boulders most likely derived from the neighbouring Precambrian. The shale conglomerate described by Münster and Bjørlykke from Gausdal must be regarded as contemporaneous with this, as already maintained by Münster. This conglomerate is exposed at Nysæter and Forsetsæter in Gausdal (Münster 1900, pp. 18-19) and also farther northeast at Roppa, in Vigga and Skeikampen (Bjørlykke 1893, p. 14).

The basal tillite is found at different places on the Precambrian bordering the Sparagmite basins. The formation often rests on strongly weathered Precambrian.

A basal conglomerate at Lauselva, Hov i Land, is a possible equivalent of the tillites. The basal tillite is distributed along the Rendalen and the Engerdalen fault lines (P. Holmsen 1954). The formation caps the Precambrian of the geanticlinal ridge north of the Sparagmite basin, in Tufsingdal (G. Holmsen 1937), Øversjødal, Brydal, and the Atnasjø-Snødøla area.

Ekre Shale.

This green-red, often laminated and varved, shale overlies the tillite formation and is about 40 m thick in the type locality Ekredalen south of Moelv. The formation has a wide geographical distribution. It seems to reach its maximum thickness in the eastern basin where it is transgressive in the area north and east of Osen-sjøen. The formation is tectonized and squeezed out at most places as it served as a detachment horizon and lubricating medium during the Caledonian movements of the Quartz-sandstone nappe.

Mjøsa Quartz-sandstone formation.
Vardal Sparagmite and Ringsaker Quartzite.

Sparagmite layers in the Ekre Shale mark the transition to this formation which is a grey sparagmite or greywacke at the base and a bluish-white orthoquartzite in its upper half. The formation is trans-

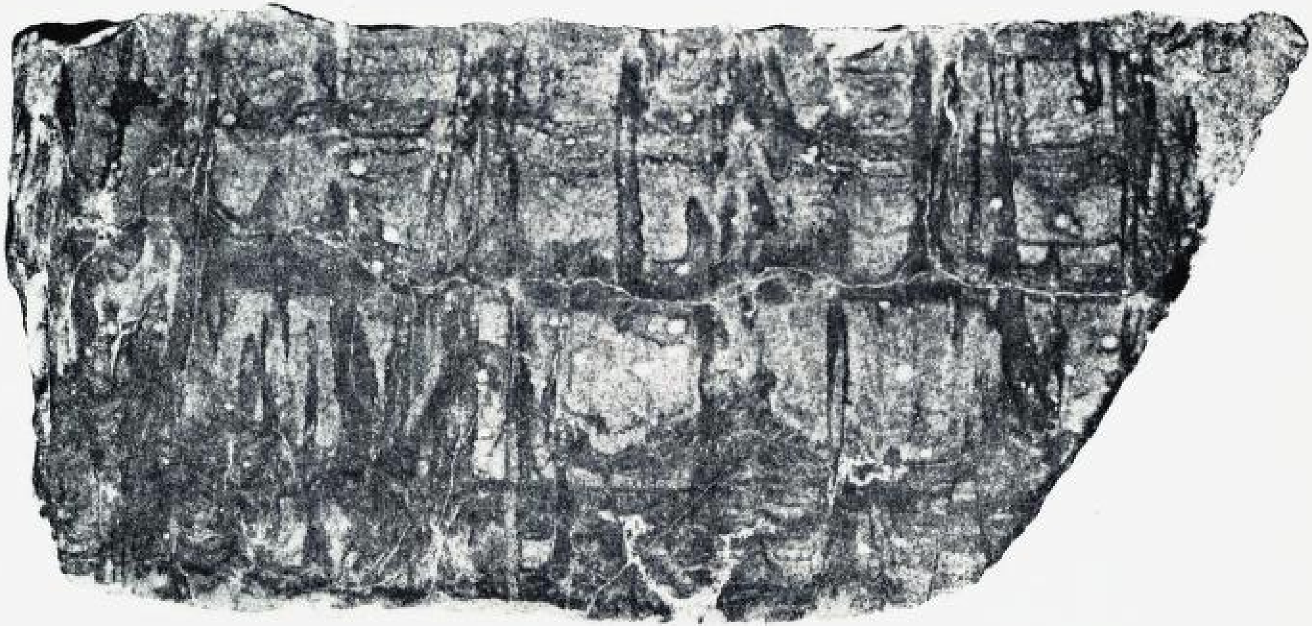

Fig. 9. *Vertical section showing the "pipe rock" at Furnes Hospital. The light spot contain fluorite. ⅔ nat. size.*
Vertikalsnitt gjennom ormerørene, Furnes Sykehus. De lyse flekkene inneholder flusspat. ⅔ nat. størr.

gressive. The "Eocambrian" sea reached its maximum extent at this time and invaded the Precambrian of the geanticlinal ridge as well as the marginal, partly peneplained Precambrian round the basin.

At this time the sparagmite basin was most likely continuous. The transgressive position of the sediments is clearly demonstrated in the southernmost part of the basin, where autochthonous quartz-sandstone overlies the Precambrian (p. 21). Along the southernmost marginal zone a conglomerate occurs in the middle part of the Vardal Sparagmite. The conglomerate consits typically of white quartz pebbles in a grey sparagmitic matrix. The same conglomerate is seen also in an autochthonous position in the southern part of the eastern basin, south of Jordet and along the road Rena-Jordet. East of the Rendalen fault zone (at Kvernbekken) a thin formation corresponding to the Quartz-sandstone overlies the Precambrian (P. Holmsen 1956,p. 35).

The same succession is met with in Engerdal at Nørgård. A closely corresponding formation of varied thickness occurs above basal tillite or Precambrian in the geanticlinal ridge. In Tufsingdal (G. Holmsen 1937) the tillite is overlain by a quartz conglomerate and quartzite. The same lithology is described from Øversjødal and Brydal-Spekedal where the formation is locally about 100 m thick (P. Holmsen 1950). The content of feldspar and the grain size decrease upwards and the whole sedimentation of the Sparagmite Group is brought to an end by deposition of the Ringsaker Quartzite.

The new information about this formation in autochthonous position at Nes-Furnes is of very great interest. The sedimentary structures and occurrence of Scolithus and Monocraterion indicate a near shore deposition, most probably in the tidal belt. These findings also justify the view of a contemporaneous deposition of these layers and of the sandstones in southern Sweden, hitherto commonly regarded as Lower Cambrian (Fig. 9). It may also throw more light on the stratigraphical position of the whole Sparagmite Group. The transition of the Lower Cambrian at Mjøsa is marked by a thin quartz conglomerate without any abrupt change in lithofacies. In the writer's opinion too much stress has been laid upon this nonangular unconformity.

The Cambrian system.

Description of localities.
Autochthonous series.

The basal beds of the Cambrian are exposed at several places along the front of the Quartz-sandstone nappe. In the vicinity at northern Randsfjord and from here to Gjøvik the Cambrian rests on Precambrian. In the more central parts, at Nes and Furnes, the Quartz-sandstone forms the basement, while in the east, from Hamar and eastwards, the Cambrian again rests on Precambrian. To the south, Cambrian alum shales overlap on to Precambrian. Here more continuous areas are overlain by Cambrian alum shales.

Northern part of Randsfjord. This area was the subject of detailed investigations and a publication by Holtedahl (1915). Holtedahl described a series of localities for the Cambrian basal beds, mainly stream-sections. On the Precambrian surface occurs a thin quartz-conglomerate and above this a grey shale of varying thickness (12-15 m). The basal beds in places fill small primary erosion pockets in the Precambrian basement. At one locality Holtedahl found fragments of *Torellella*, and considered the shale to be an equivalent of the Holmia shale (1 b α) at Ringsaker. The grey shale is succeeded by strongly tectonized black shales of Middle- and Upper Cambrian age. On these rests the Quartz-sandstone nappe. The Cambrian basal beds are covered by talus from the nappe at most localities except for the sections in the streams. In Lauselva, north-east of Hov railway station an exceptionally instructive section through the Cambrian basal beds occurs on the eastern side of the river. The locality, first discovered by H. Major 1944, (written communications) is situated about 150 m down stream from the locality with *Paradoxides* shale described and figured by Holtedahl (1915, p. 18). (See Figs. 10, 11.)

The basal beds at this new locality are exposed for a distance of 15 m. Above a strongly weathered and steeply inclined Precambrian gneiss follows with marked discordance a coarse, tillite-like conglomerate. In addition to small, well-rounded quartz pebbles, the conglomerate carries larger (20 cm) angular pieces of the Precambrian rocks (amphibolite, gneiss etc.). The matrix in the conglomerate consists mainly of mica from the Precambrian. Above the conglomerate follows a thin sandstone bench (5 cm), which on the surface is crowded with

System	Series	Zones and zone groups			Formations
Upper Cambrian	Olenid Series	Peltoura	Acerocare	$2d\delta$	Alum shales with stinkstone concretions (black shales)
			Peltoura scarabaeoides	$2d\gamma$	
			Peltoura minor	$2d\beta$	
			Protopeltoura preacursor	$2d\alpha$	
		Leptoplastus, Eurycare		2c	
		Parabolina spinulosa Orusia		2b	
		Olenus	Olenus Agnostus obesus	$2a\beta$	
			Agnostus pisiformis	$2a\alpha$	
Middle Cambrian	Paradoxides Series	Paradoxides forchhammeri	Lejopyge laevigata	$1d\beta$	
			Solenopleura brachymetopa	$1d\alpha$	
		Paradoxides paradoxissimus	Goniagnostus nathorsti	$1c\delta_2$	
			Ptychagnostus punctuosis	$1c\delta_1$	
			Hypagnostus parvifrons	$1c\gamma_2$	
			Tomagnostus fissus Ptychagnostus atavis	$1c\gamma_1$	
			Ptychagnostus gibbus	$1c\beta$	
		Paradoxides oelandicus		$1c\alpha$	Limestone, shale and phosphatic conglomerate
Lower Cambrian	Holmia Series	Strenuella linnarssoni Torellella		$1b\beta$	Strenuella Limestone (=Evjevik Limestone)
		Holmia kjerulfi Torellella		$1b\alpha$	Holmia Shale
		Volborthella tenuis Callavia sp. n.		$1a\beta$	Bråstad Shale
		Discinella holsti or Platysolenites		$1a\alpha_2$	Bråstad Sandstone
		Holmia cf. mickwitzi		$1a\alpha_1$	Brennsæter Limestone
	Eocambrian	Scolithus, Monocraterion Diplocraterion			Ringsaker Quartzite Vardal Sparagmite Ekre Shale Moelv Tillite

The Cambrian stratigraphy (cfr. Kiær 1916, Vogt 1924, Strand 1929, Henningsmoen 1956, 1957).

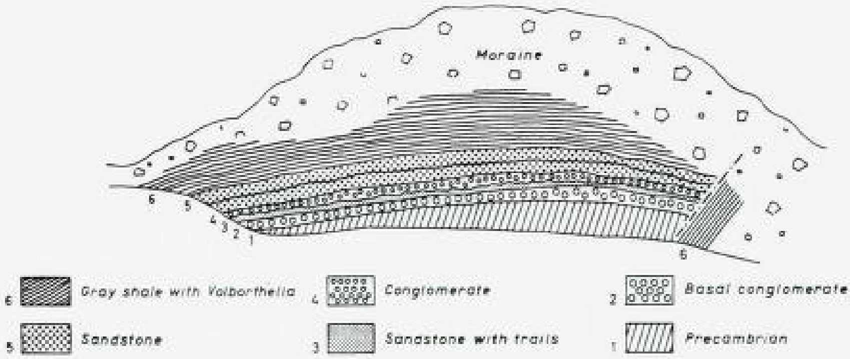

Fig. 10. *The autochthonous Cambrian basal layers along Lauselva, Hov i Land.*
Autoktone kambriske basallag langs Lauselva, Hov i Land.

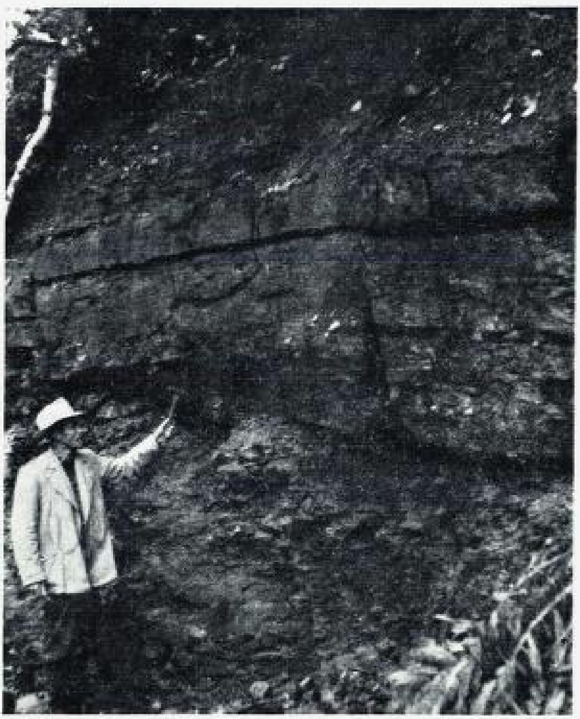

Fig. 11. *Flatlying Cambrian layers above weathered Precambrian gneisses at Lauselva, Hov i Land.*
Flatliggende kambriske lag over forvitret Prekambrium ved Lauselva, Hov i Land.

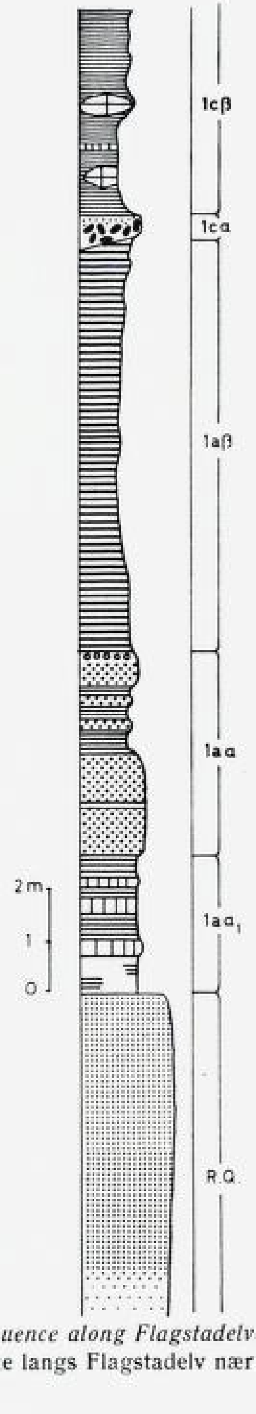

Fig. 12. *The Cambrian sequence along Flagstadelva near Brennsætersag, Vang.*
Den kambriske lagrekke langs Flagstadelv nær Brennsætersaga i Vang.

wormtracks and ripple marks. This bench is succeded by an upper conglomerate with well rounded quartz. Higher up in the succession follows a fine-grained sandstone bench (50 cm) and a grey shale. In the shale several specimens of *Volborthella tenuis* and *Callavia* sp.n. were found. Higher up the layers are covered till the above mentioned alum shales are met with along the western side of the river.

Hov-Gjøvik. Between Hov and Gjøvik the Cambrian layers are covered by talus and moraine. The present front of the nappe here coincides approximately with the Cambrian outcrops. Near Gåstjern *Volborthella tenuis* was found in a grey shale just above the Precambrian. On the hillside north of Gjøvik the Cambrian basal conglomerate is exposed. The conglomerate is met with on both sides of the road passing Øverby farm, at the drive entrance. The conglomerate is of the same type as the basal conglomerate described from Lauselva (p. 35). The layers immediately above the conglomerate are covered, but Cambrian alum shales are exposed in the fields just north of the farm. Somewhat higher up the Cambrian shales are to be seen in contact with and overridden by the Ekre shale of the Quartz-sandstone nappe. The Cambrian beds are exposed at several places below the main thrust plane, for example at the confluence of the Båstad river with lake Mjøsa. Along the shoreline to the north is one of the northernmost localities with autochthonous Cambrian in the Mjøsa district (loc. described by Bråstad 1915 and Vogt 1924). The shales contain Middle and Upper Cambrian fossils from zones 1 c γ — 2 a.

Locality Nes. At Nes Quartz-sandstone is overlain by Lower Cambrian grey shale. In a ditch traversing a pasture at the farm Tveter *Volborthella tenuis* was found in this shale.

Locality Furnes. Along the previously mentioned roadcut at Helleberget, Furnes (p. 25). The Eocambrian Ringsaker Quartzite is succeeded by basal Cambrian beds. The lowest layer is a thin conglomerate with quartz- and limestone pebbles. Next above is a grey shale with scattered, well-rounded quartz grains. This rock yields well preserved specimens of *Volborthella tenuis*. The profile is terminated by a grey calcareous shale containing *Holmia kjerulfi* and *Obolella rotundata*. East of this locality the Lower Cambrian is obscured (cfr. Kjerulf 1862, profile Hellerud).

Flagstad river. Flagstad river, which partly forms a natural boundary between the parishes of Furnes and Vang, has eroded a deep canyon through the Quartz-sandstone nappe down to the autochthon-

Fig. 13. *The Middle Cambrian basal conglomerate (Ölandicus conglomerate I c α) at Brennsætersag, Vang. (⅓ nat. size).*
Det Mellomkambriske basalkonglomerat (Ölandicus Konglomerat I c α) ved Brennsætersag i Vang. (⅓ nat. størr.)

ous series. From the Bjørge valley bridge and northwards the Orthoceras limestone and Lower Ordovician layers are isoclinically folded (cfr. Holtedahl 1909, p. 12). Upstream follow strongly folded alum shales. Just north of the ski jump at Gjørsliberget one meets with overturned Quartz-sandstone. This is an eastern continuation of the southern flank of the anticline described from Toppen, Furnes (p. 25). Lower Cambrian grey shales are exposed on both sides of the river, but as the anticline is partly fold-thrusted on these beds, they are stratigraphically disturbed. Northwards the Quartz-sandstone forms an anticline. On the northern limb of this fold the Lower Cambrian is exceptionally well preserved along the eastern side of the river about 200 m south of Brennsætersag (Fig. 12).

The strata immediately above the Ringsaker Quartzite are covered for about 1 m above the contact, where grey shales appear. These are succeeded by a series of dark calciferous sandstone benches interbedded with grey shales. The benches contain *Holmia* cf. *mickwitzi Hyolithus* sp. These beds are succeeded by a sandy quartzitic formation, consisting of alternating quartzitic benches and thin seams of grey shale. One of the quartzitic benches contains *Discinella holsti* and has developed the same peculiar rillmarks as described from corresponding beds in the Bråstad river (Bråstad 1915). The grey shales show the same type of worm tracks as the Lower Cambrian beds (1 a α) at Ringsaker. The sandy series is terminated upwards by a thick sandstone bench, consisting of quartz grains in a dark matrix. The upper part of the bench is conglomeratic and strongly pyritized; it also carries phosphoritic pebbles. This conglomerate bench forms the base of a 15 m thick grey shale, which consists of interbedded shale and sandstone benches. In the middle part *Volborthella tenuis* was found. The shale is overlain by an upper conglomerate with a markedly angular erosional disconformity. This conglomerate consists mainly of small quartz grains, phosphoritic pebbles, dark shale, and in addition pyrite and grains of galena (Fig. 13). The content of quartz grains decrease towards the top, where the bench has a sandy character. Sand fills fissures and erosional furrows in the conglomerate. The matrix is mainly calcite. Fragments of *Paradoxides* sp. occur frequently. The conglomerate is succeeded by Middle Cambrian alum shales with limestone nodules containing agnostids from sub-zones 1 c β and 1 c β_2. A thin sandy limestone bench (1 cm) near the top of this profile is cross-bedded. Towards the north the Cambrian beds are obscured. Opposite Brennsætersag the allochthonous Quartz-sandstone forms a syncline. North of this the autochthonous alum shales again occur in river cuts. East of this locality the autochthonous beds are strongly tectonized and obscured. They can, however, be followed at intervals to Nordby in Løten.

In the neighbourhood of Rena on the Glomma (described by Schiøtz 1902) one meets with the same conditions as those described from the western side of Mjøsa. The Cambrian alum shales with their basal beds rest on the Precambrian basement, and are overridden by the Quartz-sandstone nappe. The Precambrian-Cambrian contact within this area was reported from a single locality by Schiøtz (1902, p. 59).

The locality of Ulvåa, east of Elverum, was investigated by the author in 1953 in the company of P. Holmsen. As the profile in Ulvåa is exceptionally well exposed and is in addition of the utmost importance for the understanding of the Cambrian transgression in the Mjøsa District, a more detailed description of the profile will be given, even though it is situated outside the mapped area. The locality was first described by Schiøtz, 1902 (p. 59).

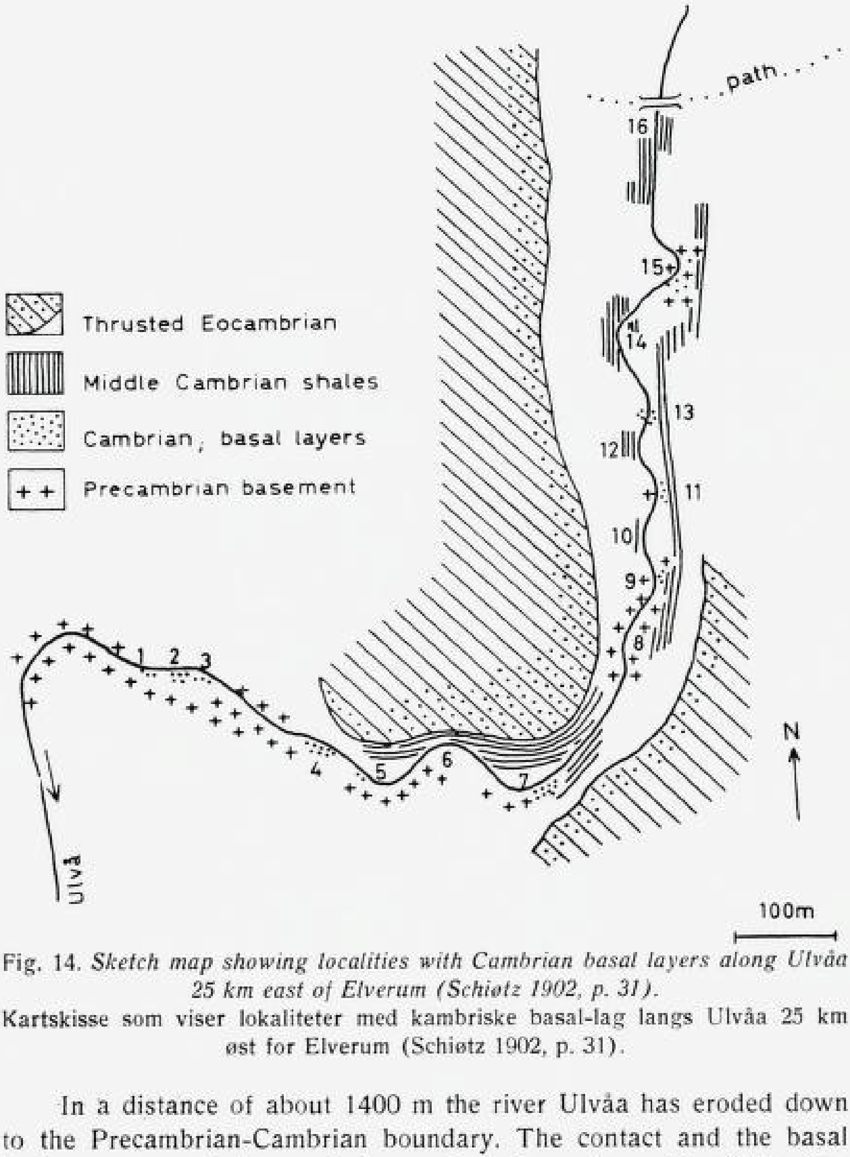

Fig. 14. *Sketch map showing localities with Cambrian basal layers along Ulvåa 25 km east of Elverum (Schiøtz 1902, p. 31).*
Kartskisse som viser lokaliteter med kambriske basal-lag langs Ulvåa 25 km øst for Elverum (Schiøtz 1902, p. 31).

In a distance of about 1400 m the river Ulvåa has eroded down to the Precambrian-Cambrian boundary. The contact and the basal beds are exposed at several places along the eastern side of the river (see sketch map Fig. 14). At the extreme south (loc. 1) the Precambrian surface is evidently weathered and in its upper part arkosic. At loc. 2 a basal conglomerate fills a pocket in the basement. The conglomerate at locs. 3 and 5 occurs in association with vertical quartz veins and partly fills fissures in the basement. Between these localities the arkosic basal conglomerate with quartz pebbles and pebbles from the Precambrian basement is overlain by a sandstone with worm-tracks and ripple marks (loc. 4). This sandstone is succeeded by an upper conglomerate containing limestone and phosphoritic pebbles.

At loc. 6 flat lying alum shales interbedded with calciferous sandstone layers form the steep western wall of the valley. In the lowest part *Paradoxides paradoxissimus, Hypagnostus gibbus,* and *Hyolithus* were found. Opposite this locality the sandstone containing worm trails is exposed in the bottom of the valley (loc. 7). Just above this locality water falls over a projecting Precambrian ridge. On the northern side of the waterfall occurs the basal conglomerate, here consisting of larger Precambrian boulders. At the northernmost locality (15) the basal beds are exposed continously for about 30 m. The Precambrian basement is here uneven, the lowest conglomerate filling hollows in the Precambrian to the south. Some meters to the north the sandstone and upper conglomerate overstep on to Precambrian. The upper conglomerate is a dark feldspar-bearing sandstone with quartz pebbles, dark pieces of limestone and phosphoric nodules, and forms the basal conglomerate of the Middle Cambrian shales lying above.

Løten-Stange area. The southern limit of the Cambro-Silurian on the eastern side of Mjøsa appears clearly in the topography. The Cambrian alum shales give rise to cultivated fields, while the Precambrian is wooded. Tongue-like Precambrian ridges project into the alum shales area to the north. The contact itself is mostly obscured, but at several localities boulders of the Cambrian basal beds are found.

Locality Busvold, Romedal. The Cambrian basal layers are exposed on a little hillock west of Busvold farm. Small quartz pebbles partly filling minor fissures occur on a Precambrian surface near an old outlying barn. In a ditch between the barn and the road is a basal arkose. From the fields large blocks of a dark conglomeratic sandstone bench has been taken out from the bedrock. The bench is similar to the upper conglomerate described from Ulvåa. Near Stange a grey sandstone and shale with worm tracks succeed the basal arkose. The conditions along the boundary are thus similar to those described from Ulvåa.

Alum shales within the Precambrian area. The investigations have shown that Cambrian alum shales occupy smaller areas far south within the Precambrian area. From Romedal to Tangen is a relatively broad valley. Alum shales are exposed at several localities on the eastern side of this valley, in Valset. Just south of the houses of Skårås farm the alum shales are worked for road material. The shale is unusually little disturbed tectonically, and contains, in contrast to the shales elsewhere in the district, well preserved fossils. At the same horizon alum shales are met with farther south.

Along a new road from Benningstad to Sæter north of Valset alum shales are again exposed in road cuts. The shales here are strongly deformed as they occur close to and in association with a fault zone. Alum shales are also met with near the same zone south of Klæpa, Løten.

Totenvika-Einavann. The Cambrian-Precambrian boundary is a westerly continuation of that described above. The conditions are nearly the same on both sides of Mjøsa. The Cambrian basal beds are exposed in Risbekken near Majer, Toten. (Loc. described by Strand 1929, pp. 324-25).

Locality Risbekken, E. Toten. The lowest part consists of a 50 cm thick basal conglomerate, which contains well rounded quartz pebbles and irregular fragments from the Precambrian in a greenishgrey calciferous sandstone. Thin seams of green shale occur in the middle part. The lower part is impregnated with pyrite and contains phosphoritic nodules. In this conglomerate fragments of *Torellella laevigata* were found. Above the conglomerate is a clear disconformity and an upper conglomerate (5-10 cm) consisting of small angular pieces of quartz in a carbonaceous matrix. This conglomerate forms the base of the alum shales. Near Einavann sills of Permian maenaite and camptonite occur in the Cambrian basal beds.

Allochthonous Series.

The Cambrian basal beds and the Lower Cambrian were the subject of a detailed description by Vogt (1924). In the following a rapid survey of the beds will be given mainly based on Vogt's description.

Locality Bråstadelva. This locality is the most representative as regards the development of the Cambrian basal beds in the southwestern part of the Quartz-sandstone nappe (Fig. 15).

Above the Ringsaker Quartzite is here a quartzitic basal bed containing angular fragments of a grey shale. These, as well as calcitic and pyritic parts of the quartzite, are weathered out, giving the bed a characteristic pitted appearance. The bed is also impregnated with galena. The top of the bed is a tectonic surface, overlain by thin seams

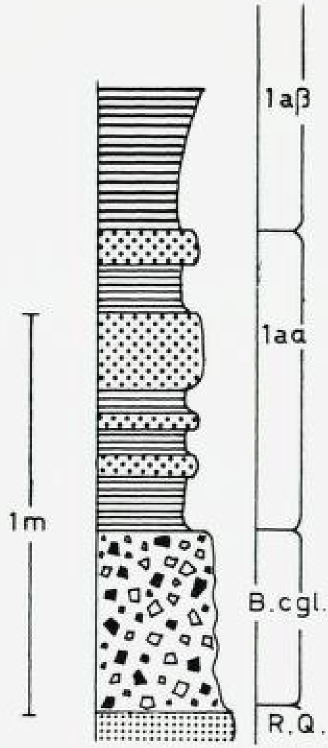

Fig. 15. *The Lower Cambrian sequence in Bråstadelv, Vardal, north of Gjøvik. (loc. Vogt 1924, p. 311).*
Underkambriske lag i Bråstadelva, Vardal, nord for Gjøvik.

of grey shale alternating with sandstone. Then follows a sandstone bed (15 cm) which in its upper, paler part contains *Discinella holsti.* The lower half of the bed is darker, with barite and fragments of horny brachiopods. The lower surface has developed peculiar flutings (Bråstad 1915, Pl. II). The *Medusina* sp. described from this surface is most probably a section through a pyrite nodule. The bed is succeeded by 10 cm of grey shale. The sandy-quartzitic beds terminate in a dark conglomeratic layer (5-7 cm) consisting of coarse sand, phosphorite together with large amounts of pyrite. The layer forms the base of the grey shales above, containing *Volborthella tenuis.*

As mentioned by Vogt (1924) the development described above is characteristic for the vicinity of Bråstadelv-Sæterelv. Towards the west the beds are obscured. The basal bed crops out at several places in Vardal and Fluberg, and is exposed in a brook between Mustad and Ålstad in Vardal.

Not far north of the last described localities, the Lower Cambrian has developed a quite different facies, called as the western facies by Vogt (1924).

The most instructive profiles are exposed along the shoreline on both sides of Mjøsa (Fig. 16). In this area is developed an imbricate structure caused by fold thrust, causing repetition of the Lower Cambrian strata. Besides the described localities, the Lower Cambrian is exceedingly well exposed in Stokke river south of Rendalen. At a waterfall east of Øvre Stokke farm well preserved specimens of *Holmia kjerulfi* were found in a grey-green calcareous shale.

The basal conglomerate at Ringstrand, Ringsaker (Vogt 1924, p. 303) contains, in addition to quartz-grains and larger blocks of Ringsaker Quartzite, angular fragments of a carbonaceous shale (Fig. 17).

The prevailing facies of Lower Cambrian at Ringsaker is also met with towards the east, in the Brumundelv just south of Brumundsaga, and in cuts in the Flagstadelv between Tørbustilen and Brennsæter timber works.

Cambrian system: Correlations in Norway.

Holmia series.

Lower Cambrian. In his publication on this subject, Vogt (1924) distinguished between an eastern, shaly and a western, more sandy, facies of the lowermost zones. The present investigations do not completely support this opinion. The "western" facies, according to Vogt's terms, seems to represent a littoral facies of the Lower Cambrian.

The Lower Cambrian shows a great and rapid change of facies regionally. This and the very scattered exposures, together with the lack of fossils of correlative value, make the interpretations difficult.

In the Flagstadelv (p. 39) fossiliferous beds were discovered below what had been regarded as the oldest Cambrian zone. These layers differ markedly from the overlying Discinella zone both petrographically and faunally and might be separated off as an independant zone, for which the designation 1 a α_1 is proposed.

Fig. 16. *The inverted boundary between Ringsaker Quartzite (left and north) and Lower Cambrian shale (right), at the classical locality of Steinsodden, Ringsaker.*
Den inverterte grense mellom Ringsakerkvarsitt (venstre og nord) og underkambriske sandsteinsskifre (høyre) ved den klassiske lokalitet Steinsodden, Ringsaker.

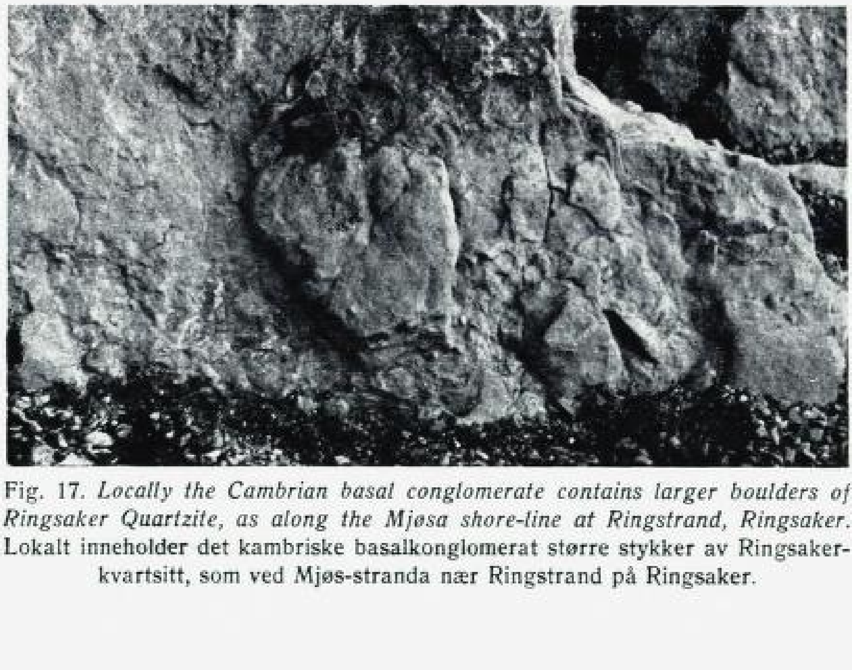

Fig. 17. *Locally the Cambrian basal conglomerate contains larger boulders of Ringsaker Quartzite, as along the Mjøsa shore-line at Ringstrand, Ringsaker.*
Lokalt inneholder det kambriske basalkonglomerat større stykker av Ringsakerkvartsitt, som ved Mjøs-stranda nær Ringstrand på Ringsaker.

Zone with Holmia cf. mickwitzi, Hyolithus sp. (1 a α_1).

This zone consists in its lower part of grey shale and in the upper part (The Brennsæter formation) mainly of dark limestone beds, alternating with thin layers of shale. In the limestone, *Holmia* cf. *mickwitzi, Hyolithus* sp. and *Obolella* sp. occur. Both the quartz-shale conglomerate at Vardal (type locality Bråstadelv) and the basal conglomerate in the section in Lauselv (Hov) might be regarded as contemporaneous deposits because of their stratigraphical positions. This zone is evidently missing at Ringsaker, where denudation has taken place before the deposition of the next zone.

Zone with Discinella holsti and Platysolenites antiquissimus (1 a α_2).

The type locality for this zone is Bråstadelva (see p. 44). Near the base of a sandy quartzitic series alternating with shales, *Discinella holsti* and fragments of brachiopods occur suddenly in a sandstone layer. The zone terminates in a coarse, sandy, conglomeratic layer containing phosphoritic grains. The zone has a similar development in Flagstadelva, where worm tracks of the same type as those characterizing the lower part of the Cambrian at Ringsaker (1 a α_2) are met with in the shales of the upper part. Parts of the sandstone at Ringsaker are most probably contemporaneous with this zone. The basal beds at Lauselva, Ulvå and Stange overlying the basal conglomerate might also be interpreted as possible equivalents of the zone (Fig. 18).

Zone with Volborthella tenuis, Callavia n.sp. (1 a β).

The type locality for the zone is Bråstadelv, Vardal (Bråstad 1915). This zone, consisting of arenaceous shales, has nearly the same development at Helleberget, Furnes, and Flagstadelv. In Lauselva a sandy bed represents the lowest part of the zone. At this locality *Callavia* n.sp. as well as *Volborthella tenuis* were found. Vogt correlated the beds yielding *Platysolenites antiquissimus* at Ringsaker with this zone mainly by correlation with corresponding strata in Esthonia. Misinterpretations have apparently arisen as a result of these correlations. Vogt (1924, p. 338) reported the two species *Volborthella tenuis* and *Platysolenites antiquissimus* from one and the same zone in Esthonia. Later Schindewolf, describing the Lower Cambrian in Esthonia, based his correlations on the misinterpretation that the two mentioned species occur together at Mjøsa.

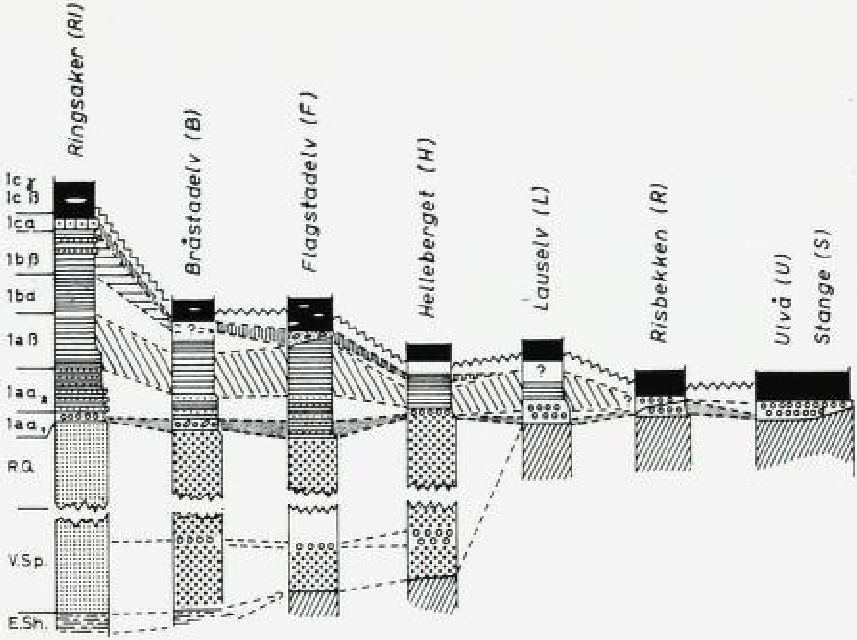

Fig. 18. *Correlation scheme showing the great difference in development of the Lower Cambrian in the Mjøsa Districts.*
Korrelasjonsskjema som viser den store variasjon i utvikling av Undre Kambrium i Mjøstraktene.

Zone with Holmia kjerulfi (1 b α).

The type locality for this zone is the classical one at Tømten, Ringsaker, where numerous specimens of the zone fossil *Holmia kjerulfi, Kjerulfi lata, Strenuella primæva* have been collected from the greenish shale. The zone is rather uniformly developed within the Quartz-sandstone nappe, but is only recognized at one locality in the autochthonous series (viz. Helleberget, Furnes). The absence of this zone is partly to be ascribed to denudation. In Flagstadelva parts of the Volborthella zone have also been subjected to denudation.

Zone with Strenuella linnarssoni and Torellella laevigata? (1 b β).

This zone, terminating the Lower Cambrian in the Mjøsa District, is known in the allochthonous series only. At the type locality Evjevika, Ringsaker, it consists mainly of limestone — the so-called Strenuella Limestone.

Fragments of *Torellella laevigata* are reported from the Cambrian basal beds at Risbekken, Toten (p. 44) and the two localities Hennungsfeltet and Bleiken, Hadeland. Because of the presence of these fragments the beds are interpreted as contemporaneous with the Strenuella zone at Ringsaker. *Torellella laevigata* and its vertical range are, however, too little known for it to be of any value as a zone fossil.

Middle Cambrian.
Zone with Paradoxides ölandicus (1 c α).

The Middle Cambrian in the Mjøsa District begins with a phosphorite-conglomerate named the "Ölandicus-conglomerate". The Lowest Middle Cambrian zone, the zone with *Paradoxides ölandicus* (1 c α) was first described from Saugstadvika, Ringsaker (Brögger, 1882). The zone was formerly assumed to be represented only in allochthonous layers (Henningsmoen, 1953). From the fossil assemblage, and the petrological nature of the conglomerate overlying the Volborthella zone i Flagstadelva, the conglomerate may be safely referred to the Ölandicus zone. An isolated occurrence of the Ölandicus zone far to the south, at Røykenvik, Hadeland, led to the assumption that it might possibly belong to an allochthonous nappe. (Strand, 1948). The development of this zone at Røykenvik might, in the writer's opinion, be ascribed to a local transgression southwards following a graben or trough in the Precambrian basement. This assumption is strengthened by its close proximity to the Randsfjord fault system, which, in the writer's opinion, originated in Precambrian time.

The Lower Cambrian — Middle Cambrian transition represents a hiatus in the stratigraphical succession, accompanied by denudation. This hiatus might coincide with the deposition of the beds containing a Protolenus fauna elsewhere, and explain the lack of this fauna in Southern Norway, as mentioned by several Norwegian geologists (Kiær 1916).

Zone with Paradoxides paradoxissimus (1 c β).

In the south of the Mjøsa District and further south in the Oslo Region, this zone forms the base of the Palaeozoic. At Mjøsa the zone is separated from the Precambrian by basal conglomerates. At Oslo the zone was deposited directly on the Precambrian (Spjeldnæs 1954).

In Ulvåa (p. 42) thin layers of sandstone are interbedded with black shale, and farther west the zone is developed as alum shale with calcareous concretions and limestones layers.

Middle and Upper Cambrian.

Conditions seem to have been stable from the deposition of the *Paradoxides paradoxissimus* zone and during the rest of the Cambrian, as the upper Middle Cambrian and Upper Cambrian have an apparently uniform development. These highly incompetent layers are tectonically disturbed. An understanding of the stratigraphical conditions must be founded on very detailed fossil and profile studies in the future.

In Fura, Løten, an intraformational breccia or conglomerate occurs in the sub-zone with *Orusia lenticularis*. The conglomerate was hitherto only met with in that area and may possibly be ascribed to a local break in the succession due to nearshore deposition (cfr. Asklund 1934).

Cambrian system: Correlations, outside Norway.

The Lower Cambrian fossiliferous beds in Scandinavia and The Baltic Region have been the subject of several publications and correlations. A number of paleogeographical maps showing land and sea distribution have been presented by the various authors.

The present investigations of the Lower Cambrian at Mjøsa should be taken as a warning against too far-reaching correlations based on a single profile. Neighbouring localities show great and abrupt changes, especially in lithology. The many breaks marked by conglomerates indicate very unstable conditions leading to repeated transgressions and regressions with denudation and resedimentation. The absence of one of the zone fossils at one locality does not necessarily mean that the zone in question was not deposited in that area. The fossils occuring in the lowermost part of the Lower Cambrian and their vertical ranges are too little known and the correlative values of some of them are questionable.

			Mjøsa (M) Kiær 1916 Vogt 1924 Henningsmoen 1956		Västerbotten (V) Kulling 1942, 1960		Öster- and Väster-Götland Närke Visingsö (Vi) Thorslund 1960 Magnusson 1960		
Lower Cambrian	Holmia Series	1bβ	Strenuella (= Evjevik) Lst.	Strenuella linnarssoni		Strenuella linnarssoni	HIATUS		
Lower Cambrian	Holmia Series	1bα	Holmia Shale	Holmia kjerulfi		Holmia kjerulfi	Lingulid Sandstone	Monocraterion	
Lower Cambrian	Holmia Series	1aβ	Bråstad Shale	Volborthella tenuis Callavia sp.n.		Volborthella tenuis	Mickwitzia Sandstone	Diplocraterion	
Lower Cambrian	Holmia Series	1aα₂	Bråstad Sandstone	Platysolenites and (or) Discinella holsti		Platysolenites	PRE-CAMBRIAN		
Lower Cambrian	Holmia Series	1aα₁	Brennsæter Limestone	Holmia cf. mickwitzi		?			
Lower Cambrian	Eocambrian		Ringsaker Quartzite	Scolithus, Monocraterion Diplocraterion	Laisberg Sandstone			Visingsö Formations (?)	?
Lower Cambrian	Eocambrian		Vardal Sparagmite	PRE-CAMBRIAN		PRE-CAMBRIAN			
Lower Cambrian	Eocambrian		Ekre Shale						
Lower Cambrian	Eocambrian		Moelv Tillite		Sito Tillite				

Öland – Gotland (Ö, G) Wærn 1949–53 Hessland 1953–55			Esthonia (E) Öpik 1956			Scania (S) Regnell 1960			Bornholm (B) Hansen 1937
HIATUS			HIATUS			Arenaceous lst. shale, dark sandstone	Strenuella aff. linnarssoni		Rispebjerg Sandstone
HIATUS			Tiseri sandst. / Kakumägi beds	Diplocraterion Scolithus Scenella discinoides		Grey shale (grey-wacke)	Holmia kjerulfi		Rispebjerg Sandstone
Shale and sandstone	Volborthella tenuis		Lükati beds	Volborthella tenuis		„Rispebjerg sandstone" / Calcareous phosphatic glauconitic sandst.	Holmia torelli and Kjerulfia lundegreni		Lower-, middle- and upper green shales
Light sandstone	Discinella holsti		Lontova beds = Blue clay	Platysolenites					
Basal sandstone	Scolithus linearis Monocraterion Diplocraterion		Lower sandstone			Hardeberga Sandstone	Scolithus Diplocraterion		Nexö Sandstone
			Basal conglomerate arkose			Arkose Conglomerate			Red arkose
		?			?			?	
PRE-CAMBRIAN			PRE-CAMBRIAN			PRE-CAMBRIAN			PRE-CAMBRIAN

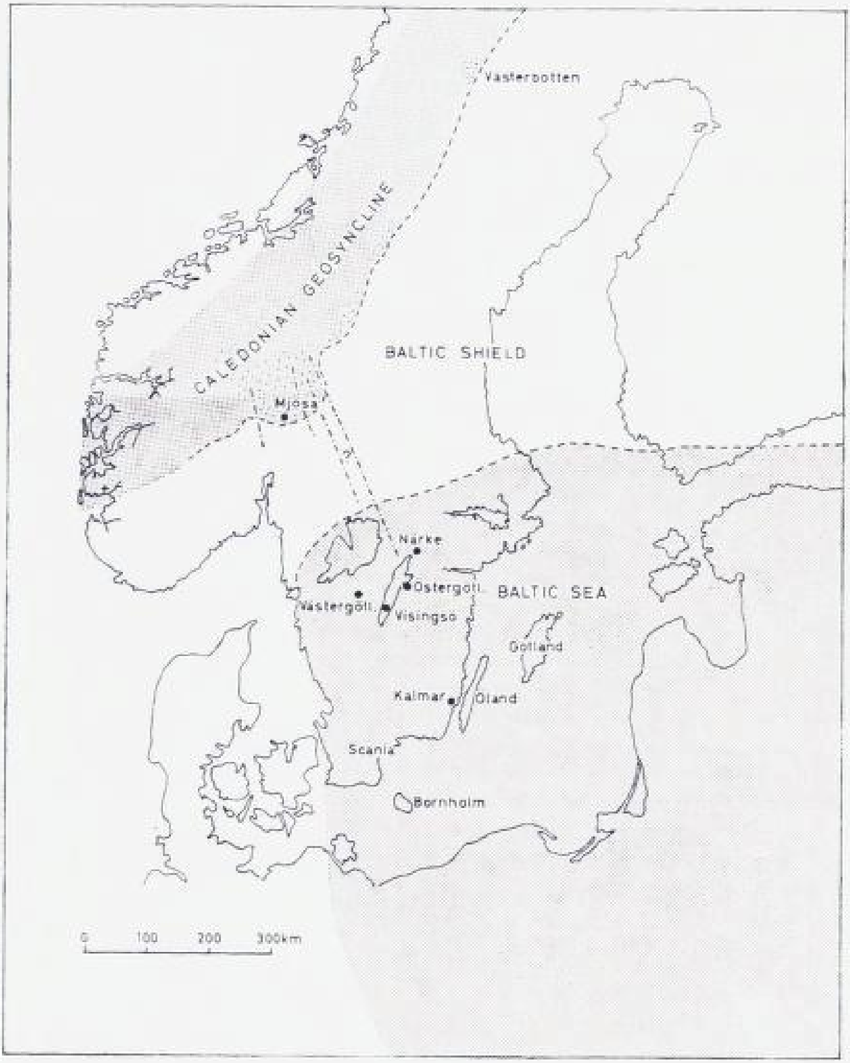

Fig. 19. *Paleogeographical map showing the distribution of the sea in Lower Cambrian Time.*
Fordeling av land og hav i Undre Kambrium.

Most of the geologists involved in the Cambrian stratigraphical problems are in agreement as to the main paleogeographical lines and correlations of the Lower Cambrian zones within the Baltic Shield. The Lower Cambrian is found in two separate areas. Along the southeastern margin of the Caledonian Mountain Chain the lowest fossiliferous Cambrian has a distribution in common with the Eocambrian. A slight transgression took place onto the foreland. An inundation of the Baltic Shield took place from the southeast onto southern Sweden, to form a Cambrian "Baltic Sea".

The strata show increasing thickness and fewer stratigraphical breaks from southern Sweden via Öland-Gotland to Esthonia and from Scania via Bornholm to Poland.

The basal formations in this Baltic basin of sedimentation, which are commonly regarded as Cambrian, are in the writer's opinion contemporaneous with the Upper Eocambrian layers at Mjøsa and elsewhere in this northern area.

The Lower Cambrian biozones reported from the Mjøsa district are described from several areas along the Caledonian mountain chain in Norway and Sweden. As could be expected local breaks in sedimentation and differing lithological development are reported.

Västerbotten.

The stratigraphy in this shelf area in Sweden is strikingly like that at Mjøsa, as emphasized by Kulling (1960). Above a peneplaned Precambrian basement comes a tillite formation, the "Sito tillite", locally separated from the basement by a sandy-arkosic bed. Varved shales are reported in connection with the tillite. Next follows a sandstone, the Laisberg-sandstone, which in some areas also rests directly on the Precambrian basement. The lower part of this formation is often an arkose or a real basal conglomerate. The zones with *Platysolenites antiquissimus* and *Volborthella tenuis, Holmia kjerulfi* and *Strenuella linnarssoni* are recognized by their zone fossils. The *Discinella holsti* zone may, according Kulling, be represented in the Laisberg sandstone. The last formation is an stratigraphical equivalent of the Ringsaker Quartzite and the Hardeberga sandstone in Scania (Kulling 1942, p. 33) and was interpreted by Kulling as the basal Cambrian beds.

Esthonia.

The Cambrian in this area is treated by A. A. Öpik in a series of papers. A review of these papers was given in 1956 (Öpik 1956, p. 97). The Cambrian in Esthonia consists of a basal conglomerate overlain by sandstone which in turn passes upwards into Blue Clay. (Lontova beds.) Then follow interbedded sandstones and clays (Lükati beds) and at the top Tiskri sandstone. The total thickness is 150—160 m. The *Platysolenites* and *Volborthella* zones are represented as well as zones with *Scenella discinoides* and *Diplocraterion*.

The series are characterized by unconsolidated sandstones and clay. These rock types may be traced in the Cambrian layers at Gotland in Sweden. The lack of *Discinella holsti* has been taken as an indication of a post-Discinella age of the strata. Correlation with the Cambrian in Sweden indicates that the Blue Clay is older than assumed by Öpik.

Gotland.

The Lower Cambrian series may be correlated with that of Esthonia and consists of sandstones with clay dominating in the basal part (Blue Clay) (Thorslund 1960, p. 95). *Scolithus* and *Diplocraterion* characterize the sandy formations.

Öland.

The Lower Cambrian rests directly on the Precambrian and has been located by diamond drilling (Hessland 1953-55 and Wærn 1949-53). The Lower Cambrian is 78.04 m thick. Its main component is sandstone. The lower part is devoid of fossils. Then follow strata with Scolithus. *Discinella holsti* was found some 40 m above the base and at a somewhat higher level, *Volborthella conica* appears. The upper part, which contains grey shales in addition to sandstone has yielded many specimens of *Volborthella tenuis*. The Middle Cambrian was deposited directly on a worn surface of the Volborthella zone.

The so called Kalmarsund sandstone on the mainland opposite Öland is interpreted as contemporaneous with the beds described above (Thorslund 1960, p. 94).

Östergötland, Närke and Västergötland.

The Cambrian sea reached these areas somewhat later. The lowest zones are missing. The formations in Västergötland are separated in two zones, the Mickwitzia sandstone and the Lingulid sandstone. *Scolithus, Monocraterion* and *Diplocraterion* are common. The same lithological formations with their zone fossils occur in Östergötland and Närke. These areas, however, show greater lithological affinities with the Baltic sequence (Thorslund 1960).

Scania.

The Lower Cambrian strata occupy relatively wide areas in Scania (I. Regnell 1960). Above the Precambrian basement are thin layers of arkoses at the base of the Hardeberga Sandstone, which is more than 100 m thick.

Above this follows more calcareous sandstone with *Diplocraterion* and *Scolithus*. The formation is referred by Regnell to the Discinella zone. In the succeeding formations three tribolite zones are separated. The lowest contains *Holmia torelli* and *Kjerulfia lundegreni,* the next *Holmia kjerulfi* and the topmost zone *Strenuella linnarssoni.*

Bornholm.

The Lower Cambrian shows almost the same lithological divisions as in Scania (Hansen 1937). The sequence commences with arkose, the so called Nexø sandstone.

Poland.

The Lower Cambrian beds are more than 800 m thick (Samsonowicz 1956) and were most probably deposited near the southern "slope" of the Baltic Shield. The fossils listed show great affinity with Scandinavian types, and the different biozones seem to be represented.

A summary correlation table for the different areas and a paleogeographical map are presented in Fig. 19. The basal formations deposited in the Baltic basin are most likely contemporaneous with the upper Eocambrian at Mjøsa. This view is strengthened by the discovery of *Scolithus* and *Diplocraterion* in the Ringsaker Quartzite (p. 33).

The marginal areas of the Baltic Shield were unstable at the beginning of the Cambrian. Marked subsidence in certain areas led to deposition of thick sedimentary Lower Cambrian formations while the same sequence on the craton is diminutive.

The so called Visingsö Series in Southern Sweden attracts great interest (Magnusson 1960, p. 65). This group of formations, now considered to be of late Eocambrian age, is more than 1000 m thick.

The "Visingsö Series" is divided into three formations, a lower sandstone, a middle arkosic sandstone and upper, an often dark-coloured shale. The formations were deposited in a north-south downfaulted through. On both sides Lower Cambrian beds rest on crystalline Precambrian rocks.

From the extension of the Visigsö Series and the trend of fault lines limiting the formations, it is tempting to connect the downfaulting with the faults at the eastern sparagmite basin in Southern Norway.

Comments on the term Eocambrian and the base of the Cambrian system.

The position of the base of the Cambrian system has been much debated during recent years. A great number of different propositions are now at hand. Essentially the question has been: should the lower boundary be determined by fossil content or by lithological criteria? Some geologists have proposed to use the base of the "biozone of Olenellids" as the base of the system. But this leads to the exclusion of the lowermost fossiliferous zones now commonly regarded as Lower Cambrian. A base of the system founded on lithological characters also leads to difficulties. In Britain the base of the Cambrian is nowadays taken at the conglomerate next below any formation yielding Lower Cambrian fossils (Stubblefield 1956, p. 30), a practice which can be of local value only.

The present knowledge of the Cambrian system and underlying sediments seems to be too deficient to fix a generally acceptable lower boundary of the system. For the time being, the classification of the unfossiliferous rocks underlying the true Cambrian should be local as proposed by R. B. Neuman and A. R. Palmer (1956, p. 247). However, in their conclusions (p. 433) these authors introduce the terms "Cambrian and Cambrian?" or "Cambrian and Precambrian" for formations or larger units of related sediments that contain Cambrian fossils only in their upper parts.

The stratigraphical position of the sediments underlying the fossiliferous Cambrian in Scandinavia, the Sparagmite Group in the Mjøsa Districts, has been the subject of much discussion. The problems were debated at the Scandinavian winter-meeting in Oslo in 1956. Many of the participants were of the opinion that the term "Eocambrian" should be restricted to the upper sparagmite formations down to and including the tillites. The lower tillite horizon was regarded as a suitable base for the Cambrian system and for regional chronostratigraphical correlations. (Cfr. Holtedahl 1956, p. 84.)

The term Sparagmitian was formerly used by Th. Vogt (1924, p. 345) for the whole series underlying the fossiliferous Lower Cambrian.

In the type area Varanger in Finnmark occur two separate tillite horizons. The Moelv Conglomerate and contemporaneous deposits in Southern Norway may be regarded as an equivalent to the upper tillite (cfr. Holtedahl 1960, p. 124). Chr. Oftedahl (1945) has pointed to a possible glacial origin of the Biri Conglomerate. This formation may correspond to the lower tillite in Finnmark. Kulling (1942) introduced the name Varanger Glaciation for this early period of glaciation.

Asklund (1956, p. 87) used the names Varegium and Sparagmitium as formational names. He regards the whole sequence as Precambrian. Asklund reports unconformities between the two "formations" and between the Varegian and the Lower Cambrian.

In the writer's opinion the term "Sparagmite" should be used for the whole Sparagmite Group in the sense of a lithostratigraphical unit.

The sequence at Mjøsa demonstrates gradual transitions from one formation to the next, indicating a close time relation. The whole sedimentation of the Sparagmite formations most probably represents a short span of time, not long enough to represent a full geological system comparable with the Cambrian. As mentioned in the foregoing at least the upper part of the Eocambrian may be regarded as a series belonging to the Cambrian. In so far as the correlation questions are not yet settled, the base of the Eocambrian at Mjøsa remains an open question. To avoid confusion and misunderstanding the writer recommends for the time being the use of the term "Eocambrian" for the whole series. When considered necessary a further division into "Pre-tillite" — and "Post-tillite" — Eocambrian may be made.

The Ordovician system.

The Ordovician of the Mjøsa area has been the subject of several stratigraphical studies. Strand (1929) briefly mentioned the Lower Ordovician in connection with his investigations of the Cambrian in the district. The stratigraphy and paleontology of the Lower Didymograptus Zones (3 b) were described by the author (1952). The Middle Ordovician has been dealt with by several geologists. Holtedahl (1909) gave a survey of this part of the stratigraphical succession, based on regional investigations and descriptions of representative profiles. The age of the "Mjøsa Limestone" has been much discussed in the past. This limestone, terminating the Ordovician System at Mjøsa, was long interpreted as Upper Ordovician (Kiær 1908, Holtedahl 1909). In connection with stratigraphical studies in the Baltic, Raymond paid a visit to the Oslo Region. He pointed out a hiatus in the Middle Ordovician, between the zones 4 b and 4 c, and he regarded the Mjøsa Limestone as contemporaneous with the Upper Chasmops Limestone (Raymond 1916). His opinion as to the age has been supported by Norwegian geologists (Kiær 1920, 1926, Størmer 1945, 1953).

An introduction to the Middle Ordovician Stratigraphy of the Oslo Region was given by Størmer (1953). This publication contains, in addition to regional descriptions and stratigraphical correlations, references to earlier works. The chapters dealing with the Mjøsa District are to a great extent founded on the investigations carried out by the author during recent years.

Autochthonous strata.

Ceratopyge Series. (2 e-3 a). Dictyonema Shale (2 e), Ceratopyge Shale and Limestone (3 a β-γ).

These zones apparently have a uniform development in the district. Asklund (1934) mentioned a possible non deposition of the Dictyonema Shale at Løten in the southeast part of the Mjøsa District. The present investigations, however, show that the three zones of the series are present in this area also, and from Løten church and up the Fura river fine sections through them are exposed. *Dictyonema flabelliforme,* the zone fossil, was also found in Starelva just south of Romedal church.

System			Series	Stage	Oslo (Zones and Zone groups)	Toten - Nes - Hamar Mjøsa south	Ringsaker Mjøsa north
Ordovician	Upper Ordovician	Ashgillian	Tretaspis Series (4cα–5b)	5b 5a 4dα–γ 4cβ–γ 4cα	Calcareous sandstone formation Gastropod limestone Isotelus shales and limestones Upper Tretaspis shales and limestones Lower Tretaspis shale	HIATUS	HIATUS
	Middle Ordovician	Caradocian	Chasmosp Series (4aβ–4bδ)	$4b\delta_2$ $4b\delta_1$ 4bγ 4bβ 4bα 4aβ	HIATUS Upper Chasmops limestone Upper Chasmops shale Lower Chasmops limestone Lower Chasmops shale Ampyx limestone	Mjøsa Limestone (reef and algal limestone Furuberg formation { Cyclocrinus beds Coelosphaeridium beds } Hovinsholm Shale	Mjøsa Limestone (red and shaly in upper part) Furuberg formation { Cyclocrinus beds Coelosphaeridium beds } Hovinsholm Shale (= Robergia beds)
		Llandeilian Llanvirnian	Ogygiocaris Series (4aα)	$4a\alpha_{3-4}$ $4a\alpha_{1-2}$	Ogygiocaris shale Upper Didymograptus shale	Cephalopod shale Ogygiocaris shale Upper Didymograptus shale	Ogygiocaris shale Upper Didymograptus shale
	Lower Ordovician	Arenigian	Asaphus Series (3b–3cγ)	3cγ 3cβ 3cα 3bα–ε	Endoceratid limest. Asaphus shale Megistaspis limest. } Orthoceras limestone Lower Didymograptus shale (= Phyllograptus shale)	Helskjær shale and limestone Endoceratid limestone Asaphus shale Megistaspis limestone Lower Didymograptus shale	Stein Limestone (= Orthoceras limestone Heramb Shale and limestone Lower Didymograptus Shale Stein Shale and limestone
		Tremadocian	Ceratopyge Series (2e–3aγ)	3aγ 3aβ 3aα 2eα–δ	Ceratopyge limestone Ceratopyge shales Dictyonema shale	Ceratopyge limestone Ceratopyge shales Dictyonema shale	Ceratopyge limestone Ceratopyge shales Dictyonema shale

Fig. 20. *The boundary between the zones 3 c β and 3 c γ is marked by a corrosion surface with overlying iron oolites. Helskjær, Helgøy. ½ nat size.*
Grensen mellom sonene 3 c β og 3 c γ er markert ved en korrosjonsflate med overliggende jernoolitter. Helskjær, Helgøy. ½ nat. størr.

In the river Ulvåa, east of Elverum, the zones are well preserved in a section along the eastern bank some hundred meters upstream from the main Elverum-Trysil road. The series is here overridden by the Quartz-sandstone nappe.

Asaphus series. (3 b-c). Lower Didymograptus Shale (3 b) and Orthoceras Limestone (3 c).

The incompetent Lower Didymograptus Shale is tectonically disturbed at most localities, and no complete sections through the zones were detected. The development seems to be like that of the district around Oslo (Skjeseth 1952).

At Ottestad, south of Hamar, a specimen of *Megistaspis planilimbata* was found in a small, well-rounded limestone lens of the type occurring in the upper part of the shale (Skjeseth 1952, p. 159).

The Orthoceras Limestone (3 c) occupies relatively wide areas, and can be followed as east-west trending escarpments in the terrain.

The best section in the limestone is displayed along the Mjøsa shoreline at Helskjær, Helgøya, where the Lower Didymograptus Shale forms the core of an overturned anticline (Fig. 43). The lowest part of the Orthoceras Limestone consists of a light grey, massive limestone, corresponding to the Megistaspis Limestone (3 c α) near Oslo. Then follows upwards a nodular limestone, most probably corresponding to the Asaphus Shale (3 c β) near Oslo. This zone is separated from an upper limestone by a marked corrosion surface (Fig. 20). The upper limestone, yielding *Cycloendoceras* sp., has a basal bed rich in oolites. This limestone may be regarded as an equivalent of the Endoceratid Limestone (3 c γ). Upwards there is a gradual lithological transition to the more carbonaceous rocks of the Ogygiocaris Series (4 a α).

Helskjær Shale and Limestone is here introduced as a new name for the transitional beds, which collectively may be regarded as a member of the Orthoceras Limestone formation. Type area for the member is Helskjær, Helgøya (not Nydal, Furnes, Størmer 1956).

The succession upwards from the Endoceratid Limestone is: nodular limestone, limestones with interbedded shales, shale with limestone beds, and finally shale with limestone lenses. The increasing content of carbon upwards is noticeable. Immediately above the nodular limestone occurs *Asaphus striatus* and, somewhat higher, *Megistaspis* cf. *centaurus*.

The Helskjær Shale and Limestone is exposed in two cuts along the road from Nydal to Furnes church, where the beds yield an exceptionally rich fauna. *Megistaspis* cfr. *centaurus, Telephus mobergi, Ogygiocaris* cf. *dilatata, Niobe frontalis, Trinucleus* sp., *Bronteopsis holtedahli, Asaphus striatus, Ptychopyge* sp. were collected from one bed. The fauna is a mixed one, representing both the Asaphus and the Ogygiocaris Series. The layer thus have a transitional character both faunally and lithologically.

The Orthoceras Limestone (3 c) has a similar development at Domkirkeodden, Hamar, and in the roadcut at Ottestad, described later in the chapter on folding (Fig. 41). At both localities a corrosion surface, overlain by oolites, separates the zones 3 c β-γ.

To the east and the west, at Løten and near Raufoss, the Orthoceras Limestone has a somewhat different development. In a roadcut at Greveløs near Raufoss, a 14 m thick, nearly uniform, thin-bedded arenaceous limestone is succeeded by the Helskjær Shale and Limestone. The limestone has an irregularly reticulate weathered surface, and is like the Stein Limestone (= Orthoceras Limestone) at Ringsaker. A similar development is met with at Fura, Løten. The beds are mostly obscured and strongly tectonized. *Megistaspis gigas* was found below the main road bridge at Løten church, about 4 m above the limestone.

Ogygiocaris Series (4 a α). Upper Didymograptus Shale, Ogygiocaris Shale and Cephalopod Shale.

These "zones" constitute a natural formation consisting of carbonaceous black shales with limestone lenses. The three stratigraphical units are members of this formation, and their names are most naturally selected from one of the localities near Oslo. The Cephalopod Shale is restricted to the northern districts of the Oslo Region, and may be regarded as a biostratigraphic formation.

Upper Didymograptus Shale-Ogygiocaris Shale. (4 a α_{1-2}-4 a α_3.)

A subdivision of these zones at Mjøsa is difficult with our present knowledge of the fauna. The Ogygiocaris Shale is a black shale with flat limestone lenses containing the characteristic fauna with *Ogygiocaris sarsi regina, Ogygiocaris sarsi delicata, Pseudomegistaspis patagiata, Trinucleus faveolatus, Telephus bicuspis, Ampyx mammilatus, Obolella.* A nodular limestone terminates the shale upwards. This limestone is exposed at Helskjær, Helgøya (Holtedahl 1909, p. 8), and in Flagstadelva, Bjørgedal.

Cephalopod Shale (4 a α_4?) (name Holtedahl 1909).

The Cephalopod Shale is a black shale which may be differentiated from the typical Ogygiocaris Shale by the shape of its limestone lenses. The lenses are rounded and contain barytes and characteristic cephalopods which often weather out of the limestone lenses. The cephalopod fauna has been described by Sweet (1958, p. 20) who listed 28 species.

The Hovinsholm Shale is a characteristic formation in the Mjøsa District. It consists of grey shale alternating with sandy limestone. As no fossils were detected from the formation it was termed the "fossil-barren beds" by Holtedahl (1909). Later, several specimens of *Robergia microphthalma* were sampled in the same formation at Ringsaker. The name Robergia Beds was then proposed as a name for this formation (Størmer 1953, p. 109). The new name "Hovinsholm Shale" is chosen from the farm Hovinsholm in the southernmost part of Helgøy (type locality), where the formation is exposed along the Mjøsa shoreline and on the small island, Holmen, south of the farm.

The beds are isoclinally folded and are thus repeated in the profile. This makes an estimation of the thickness of the formation difficult. It also explains the wide regional distribution of this formation around the many synclinoria formed by the Mjøsa Limestone in the district. The beds have been resistant to ice erosion and weathering, and thus usually have a thin cover of soil. The formation is mostly wooded, due to its physical character, in contrast to the incompetent Ordovician shales. Upwards the formation shows a gradual transition to the Furuberg Formation, with thick arenaceous limestones in the transition beds. The formational boundary is thus difficult to fix. Apart from a few scattered finds of fossils in the transitional beds, no fossils have hitherto been detected in the formation.

Furuberg Formation.

The formation comprises the Coelosphaeridium Beds and Cyclocrinus Beds. The formational name is taken from Furuberget, north of Hamar, where the beds are well exposed in a railroad section and along the Mjøsa shoreline.

The Coelosphaeridium Shale.

This member consists in its lowest part of arenaceous limestone beds alternating with shale. Upwards in the succession the limestones are thinner and less arenaceous. This part is rich in fossils among which *Coelosphaeridium cyclocrinophilum, Mastopora* sp., *Platystrophia lynx, Orthis* sp. and *Diplotrypa* sp. are common.

The Cyclocrinus Shale and Limestone. Holtedahl (1909) subdivided these beds into a lower Cyclocrinus Shale and an upper Cyclocrinus Limestone. He did not include the beds transitional to the overlying Mjøsa Limestone in the Cyclocrinus zone, but pointed out a closer affinity to the latter than to the Mjøsa Limestone. The beds in question naturally belong to the Cyclocrinus Shale and Limestone, both lithologically and faunally (Størmer 1953, p. 104).

The Mjøsa Limestone plays a dominating role in the geology of the Mjøsa District. The name was introduced by Kiær in 1908.

The thickness of the limestone is about 100 m. The limestone is pure and has a $CaCO_3$ content of about 90 %, exceptionally up to 95 %. A series of quarries is situated along the limestone "streaks" in the district. These quarries are good starting points for detailed stratigraphical studies. The exposures at Helgøya and the sections at Furuberget north of Hamar are type localities.

In the Toten District the quarry at the farm Ånerud gives the best information as to the limestone (Størmer 1953, p. 99). Here it is exposed almost continuously for about 100 m along the road in the quarry east of the farm. Thin beds of red to grey impure limestone form the lower half of the formation. Higher up in the succession numerous stylolites occur in the pale limestone beds. About 15 m downwards from the top is a marked erosional surface (Figs. 22, 23). The surface is overlain by a cross-bedded sandy limestone with Solenopora. The topmost beds are again characterized by stylolites. Here scattered specimens of Stromatoporids are met with.

In a roadcut near Holter, W. Toten, the limestone contains Stromatoporids and corals which form reefs elsewhere in the districts. The most common fossil regionally in this limestone is Solenopora. Beds rich in this fossil occur especially near the base of the limestone throughout the whole district. At Eriksrudtjern, the Mjøsa Limestone is developed as a reef limestone. The soil cover is a hindrance to detailed studies of the reef at this locality.

At Bergvika on Helgøy, fine sections may be seen through true reefs in the Mjøsa Limestone. The reef development here was first mentioned by Kiær (1898, p. 40).

The steep wall on the southern limb of the syncline forming Bergvika gives the best section through the limestone. The basal beds consist almost solely of Solenopora, thus giving the limestone a conglomeratic appearance. The surface of these show ripple marks. The core of a genuine reef is situated near the shore of lake Mjøsa, partly below water level, and is most accessible for studies at low water early in the springtime. The core consists of a massive framework of Stromatoporids (Fig. 21). On the western flank of the reef is a coarse conglomerate with Stromatoporids and tabulate corals of which *Eofletcheria subparallela, Liopora favosa* and *Nyctopora aff. parvotubulata* are the commonest (Hill 1953).

Tongues from the reef core partly interfinger with the flanking beds. In a westerly direction from the reef, a large number of Stromatoporids and corals occur in the limestone. In a quarry about 100 m west of the core, large bodies of Stromatoporids and corals are found. Here a carbonaceous mudstone fills up interstices between the boulders. This mudstone contains dendroid graptolites.

Fig. 21. *The main coral reef in the Mjøsa Limestone at Lodvika, Heløy.*
Koralrevet i Mjøskalken ved Lodvika, Helgøy.

Fig. 22. *Near the top (to the right) of the Mjøsa Limestone erosion phenomena — crossbedding etc. — are met with, indicating uplift and shallow water. Aanerud Limestone quarry, W. Toten.*

Nær toppen av Mjøskalken finnes erosjonsfenomener, kryss-skiktning m. v. som indikerer landheving og grunt vann. Aanerud kalkbrudd, Vestre Toten.

Fig. 23. *Detail showing erosion furrow and crossbedding in Mjøsa Limestone (loc. Fig. 22).*

Detalj som viser erosjonsfure og kryss-skiktning i Mjøskalkens øvre del, (samme lok. som fig. 22).

Fig. 24. *Weathered surface of reticulate Mjøsa Limestone — southern flank of the syncline — at Bergvika, Helgøy.*
Forvitret overflate av Mjøskalk ved sydflanken av synklinalen i Bergvika, Helgøy.

Above the reef is a sandy conglomeratic limestone bed. The conglomerate most probably contains detritus eroded from the reef. It is succeeded by dark limestone with Solenopora and fragments of Cephalopods as typical fossils. Then follows a thin-bedded fossiliferous limestone with seams of shale between the limestone beds. From beds on the northern flank of the main syncline, a rich and varied collection of fossils was collected. The following species are common: *Chasmops* sp., *Bumastoides* sp., *Encrinurus* sp., *Illaenus* sp., *Isotelus* sp., *Cybele* sp. Amongst the brachiopods *Mjoesina mjoesensis* dominates.

The uppermost part of the Mjøsa Limestone in these sections is a "reticulate" limestone (Fig. 24).

Variations in facies and in the thickness of the layers are demonstrated in the sections on either side of the syncline. Elsewhere in the Nes-Hamar District, ripplemarks are developed in the basal beds of the Mjøsa Limestone. In the classical section at Furuberget subaqueous sliding has taken place in these sediments. About 20 m from the base in this section a fragmental (conglomeratic) layer, 20 cm thick and containing Stromatoporids and corals, probably corresponds to the conglomeratic layer just above the reef at Helgøya. The upper half of the limestone has been quarried. The limestone in the quarry (Fig. 47) is mainly dark and unfossiliferous.

Allochthonous strata.
Ceratopyge Series (2 e-3 a).

Dictyonema Shale (2 e). The most complete section through this zone is exposed along the northern shoreline at Steinsodden, Ringsaker, and in a road-cut on the main road just north of Stein farm. At these localities the black shales yield well preserved graptolites representing different sub-zones. The large limestone lenses occuring in the shale contain in addition a trilobite fauna.

Ceratopyge Shale and Limestone (3 a β-γ). The Ceratopyge Shale is recognized at Snartum elv in Snertingdal valley. Limestone lenses in a black shale contain, in addition to the zone fossil *Ceratopyge forficula,* a great number of *Triarthrus angelini.*

The Ceratopyge Limestone (3 a γ) is a light grey limestone, rich in fossils. At Steinsodden, Ringsaker, this formation also comprises, lithologically, the lowermost part of the Lower Didymograptus Zones (3 b α).

Asaphus Series (3 b-c).

Lower Didymograptus Zones (3 b α-δ). At Ringsaker these zones have a somewhat different development from that prevailing in the Oslo Region. The lowermost and uppermost parts have developed a limestone-trilobite facies. Locally the characteristic Lower Didymograptus Shale (graptolite-black-shale) formation comprises lithologically only the two middle zones 3 b β-γ. There is a gradual transition from the Ceratopyge Limestone to the graptolite shale above. To these transitional layers, consisting of grey shale with limestone lenses, the name *Steinsodden Shale and Limestone* is given. They may be interpreted as a member of the Ceratopyge Limestone, and are described by Strand (1929, p. 326). Besides numbers of *Ceratopyge* sp. (Skjeseth 1953), *Megistaspis stenorachis* is found in the beds.

The Lower Didymograptus Shale.

This black shale formation, the stratigraphical range of which varies within the district, is exposed in a profile at Heramb, Ringsaker, (Skjeseth 1952). Here it has a gradual upward transition to the Stein Limestone. Near the base of the transition beds, for which the author introduces the name *Heramb Shale and Limestone,* limestone lenses occur scattered in a grey shale. Above the latter, the lenses are arranged in continuous beds interlayered with grey shale. Near the bottom of the Stein Limestone is a nodular limestone terminating the transitional beds. This member yields a mixed fauna of graptolites and trilobites. The following fossils were collected at the type locality: *Megistaspis planilimbata, Megistaspis herambensis, Ptychopyge minor, Raymondaspis limbatus, Niobe insignis, Tetragraptus serra, Dichograptus octobranchialis, Didymograptus extensus.*

In the nodular limestone *Megistaspis limbata* occurs.

Stein Limestone (= Orthoceras Limestone.)

A northern facies of the Orthoceras Limestone, at Ringsaker and adjacent districts in the allochtonous area, has been pointed out by earlier writers (Strand 1929, Størmer 1953). As type locality for this formation, to which the name Stein Limestone is given here, the farm Stein at Ringsaker has been chosen. The limestone is exposed at this locality on Steinsodden and on the small island Steinsholmen west of the farm. Good exposures through the limestone are to be seen in the shore-section along lake Mjøsa and westwards, north of Redalen, opposite Stein (Fig. 25).

The Stein Limestone is well bedded, with a characteristic weathered surface. The Limestone are often separed by thin seams of sandy shale or mudstone (Fig. 26). The formation is distributed throughout the allochthonous area, where the competent limestone plays the same dominating tectonic role, as does the Mjøsa Limestone in the autochthonous area. The limestone forms marked east-west trending heights, on which the houses of the farms are often placed, while the soft shales on both sides of the limestone give rich cultivated fields. The bedded limestone has been utilized to a great extent as building stone. The anticline are eroded and the synclines project in the terrain mainly at the inner arc around the anticlinorium formed by the Eocambrian Mjøsa Quartz-sandstone in the southern Ringsaker area.

At all localities where the contact with the overlying black shales is observed, there is an abrupt change of facies. Most probably the Stein Limestone comprises the transitional Helskjær Shale and Limestone, developed in the autochthonous areas.

Ogygiocaris Series. (4 a α.)
Upper Didymograptus Shale. (4 a α_{1-2}.)
Ogygiocaris Shale. (4 a α_{3-4}.)

The presence of the Upper Didymograptus Shale in the allochthonous area is indicated by the occurrence of *Didymograptus geminus*, which is found in a railroad-cut at Tande, north of Ringsaker Railway station. The Ogygiocaris Shale has the same lithological appearance and fossils as in south.

The Cephalopod Shale.

This formation is most probably not developed at Ringsaker. Apart from a few scattered findings of rounded limestone lenses with barite characterizing the shale in the Nes-Hamar District, this formation is not found in this district. To a great extent it seems to have been replaced by the overlying Hovinsholm Shale. This assumption is also strengthened by the fossils hitherto found.

Robergia Beds.

The Hovinsholm Shale. As mentioned above this formation seems to have a greater vertical stratigraphical range than in the autochthonous areas. The finding of fossils in these beds at Ringsaker has contributed to a better knowledge of the formation.

Locality Heramb. In a road-cut just south of the farm Heramb the following fossils were collected in the grey shale: *Robergia microphthalma, Pseudomegistaspis* cf. *patagiata, Lituites* sp., *Ostracods, Corynoides* cf. *curtus, Glyptograptus teretiusculus euglypthus?, Amplexograptus* aff. *vasae* and *Diplograptus* sp. (graptolites determined by Bulman). The locality Heramb is surrounded by cultivated fields where the bedrock is covered by soil, and thus gives little information as to the exact stratigraphical position of the fossil-bearing horizon. The distance to the Stein Limestone, exposed at farm Heramb, is about 150 m.

Fig. 25. *The Orthoceras Limestone of the Quartz-sandstone nappe is about 40 m thick and consists of thin impure benches separated by silt-sandstone layers. Redalen. Ringsaker in the background.*
Orthocerkalken i Kvartssandsteinsdekket er ca. 40 m tykk og består av tynne urene kalksteinsbenker med mellomliggende sandige skiferlag, Redalen. Ringsaker i bakgrunnen.

Fig. 26. *Detail from the Orthoceras Limestone, showing reticulate surface and siltstone separating the beds. Heramb, Ringsaker.*
Detalj fra Orthocerkalken. Heramb, Ringsaker.

Locality Holmen, Brumunddal.

The stratigraphical succession and development of the formation can be best seen in a steep river bank, on the eastern side of the Brumundelv, near Holmen. The layers here belong to the northern flank of the main Silurian syncline, south of the locality. Above a mostly obscured, carbonaceous shale (Ogygiocaris series) follow grey shales interlayered with sandy beds (28 m), containing *Ampyx costatus* and *Nileus armadillo*. Grey shales with limestone-lenses and sandy limestone layers compose the next 20 m. Here *Robergia microphthalma, Megistaspis* sp. and *Dionide* sp. were found. The uppermost 30 m in this profile consist of cross-bedded sandstone beds, separated by seams of grey shale.

The uppermost beds are transitional to the next formation, which is obscured here.

Furuberg formation.

This formation crops out at several places within the Veldre, Brumunddal synclinorium, and along the northern side of the horst on the Nes peninsula. The transition to this formation from the Hovindsholm Shale is gradual as in south.

Coelosphaeridum beds. These layers were described in detail from the railroad section at Fangberget, Veldre, by Holtedahl (1909, pp. 23—26). Here the lowest part consists of grey shale with thick, sandy layers.

North of the horst the beds are exposed at several localities. A more complete section is exposed between the farms Tørud and Bratberg, where the beds are exposed along the roadcuts and in two quarries where the shale is taken out and used as road material. This profile represents the northern flank of the synclinorium at Bratberg. The beds are repeated by drag-folding. The layers yield an exceptionally rich and varied fauna. Brachiopods and algae predominate. The most common fossils are: *Platystrophia lynx, Orthis, Mastopora, Coelosphaeridum, Chasmops, Asaphids.*

Cyclocrinus beds.

Holtedahl mentioned these beds from the section at Fangberget. He pointed to their diminutive development.

In the section at Tørud sandy limestone benches, intraformational breccias, cross-bedding, wormtracks on the bedding surfaces, and ripple marks point to shallow water deposition. A bench rich in fossil fragments, mainly crinoid stems, marks the boundary with the Mjøsa Limestone.

The Mjøsa Limestone.

This formation has apparently a quite different development from that prevailling farther south in the district. The lower part consists of limestone with Solenopora. The upper part is impure and shaly with some nodular limestone benches.

The sediments have a red colour. The beds may be studied in sections along the Brumundelv, upstream from Torsæter bridge. At the northernmost locality shown in Fig. 33 on the eastern side of the river, cephalopods (*Ormoceras kiæri*) and horny brachiopods are common. The formation in question does not play the same dominating role as the Mjøsa Limestone in south.

The Silurian system.

The only comprehensive work on the Silurian in the Mjøsa Districts is that of Kiær (1908). In a chapter on "Das obersilurische Gebiet beim Mjösen" (p. 395) he gives a historical review and a survey of the geological relationships. He also deals with the occurrence and regional distribution of the different zones. Further he gives a stratigraphical survey founded on representative areas and profiles. In later works Kiær revised his first stratigraphical interpretations on some points. In 1946 Major gave a sedimentary-petrological analysis of the oldest Silurian sandstones in the northern part of the Oslo Region, and in this connection he described those in the Toten District.

As no further systematic sampling or determination of fossils from the Silurian in the Oslo Region has been done, the zonal divisions proposed by Kiær are used below. The treatment of the Silurian is limited to a regional description, mention of new sections and some stratigraphical details of importance for the understanding of the regional geology of the Mjøsa Districts.

The Silurian in the Mjøsa Districts occurs in the cores of many synclines and synclinoria involving the Mjøsa Limestone. The Silurian has its main distribution within the wide synclinoria in Vestre Toten and in the area west of the Brumunddal fault-zone.

New Silurian areas were found just south and north of the horst at Dæhli, Nes, and at Tørud-Bratberg, Ringsaker, respectively.

Autochthonous strata.

Profile Eina-Reinsvold. From tectonic considerations the youngest Silurian strata were to be expected near the Hunselv fault zone. As the succession there reaches higher in the Silurian than elsewhere in the Mjøsa District, a preliminary profile is given from the railway- and roadcuts between Bruflat and Reinsvoll (Fig. 30). The rocks in this area were formerly interpreted as being mainly of Ordovician age.

Striclandia Series.

Stage 6 c. Special interest attaches to the Ordovician-Silurian boundary, because of the great hiatus revealed between the Mjøsa Limestone and the Silurian strata above.

Toten.

At all places where the contact is accessible at Toten, erosion has taken place in the top part of the limestone, which thus demonstrates fine karst phenomena. Overlying Silurian sandstone has filled in the cavities and erosional furrows in the limestone. The contact can be seen in the Eina limestone quarry, at the Hole quarries near Bøverbru and in the first roadcut south of Bruflat (Fig. 28). However, it can, be best studied in Kyset limestone quarry, situated at the western closure of one of the main anticlines. Here the upper part of the Mjøsa Limestone is quarried along the north and south flanks of the anticline. The above-mentioned contact is most clearly exposed in the northernmost quarry, where the sandstone fills out the erosional channels, hollows and cavities down to 2,80 m below the surface of the limestone (Fig. 27). Above the basal beds comes a sandy-quartzitic formation of varying thickness.

In the more central parts of the Mjøsa Districts the contact limestone-sandstone is obscured at most localities. The conditions at the

System		Series		Stage	Oslo Zones and zone groups	Toten–Nes–Hamar (Mjøsa south)	Ringsaker (Mjøsa north)
Silurian	Upper silurian	Ringerike series	Down-tonian	10	Ringerike Sandstone		
		Uppe Spirifer series	Ludlowian	9g	Shale with Leperditia norvegica	Not preserved	Not preserved
				9f	Favosites limestone		
				9e	Chonetes limestone		
				9d	Limestone with Howellella sp.		
				9c, 9b	Shale and Limestone with Leperditia phaseolus		
				9a	Lst. and sh. with Camarotoechia nucula	Bruflat Sandstone	
		Lower Spirifer series	Wen-lockian	8d	Malmøy limestone		Bruflat Sandstone
				8c	Limestone with Rhynchotreta cuneata		
				8b, 8a	Monograptus shale		
	Lower Silurian	Pentamerus series	Llandoverian	7c	Crinoid sh. + Stricklandia lirata lst.	Ek Shale (=Monograptus shale)	Ek Shale (=Monograptus shale)
				7b, 7a	Pentamerus limestone	Pentamerus limestone	Pentamerus limestone Borealis limestone
		Stricklandia series		6c	Sh. and calc. sst. with Stricklandia lens	Helgøya Quartzite	Helgøya Quartzite
				6b	Calc. sst. with Plectatrypa	HIATUS	HIATUS
				6a	Sh. and lst. with Climacograptus normalis		

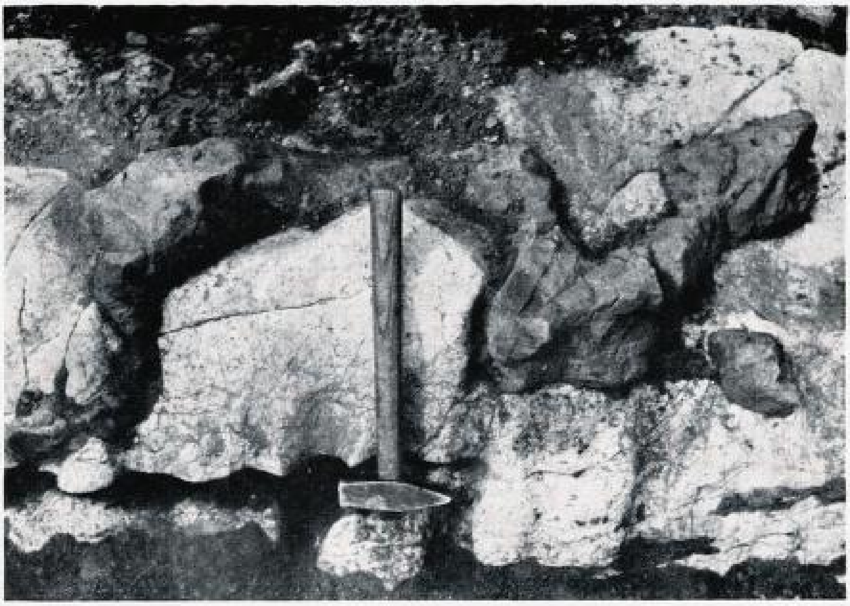

Fig. 27. *Prior to the deposition of the Silurian Helgøya Quartzite a karst surface was formed in the Mjøsa Limestone. The Silurian sand filled in caves and channels to a depth of at least 3 m in the Mjøsa Limestone. Kyset Limestone quarry, W. Toten.*

Før avsetning av den siluriske Helgøy-kvartsitt ble det dannet en karstoverflate. Den siluriske sand fylte huler og kanaler til minst 3 m ned i Mjøskalken. Kyset Kalkbrudd, V. Toten.

Ordovician-Silurian boundary are somewhat different on Helgøya. On Eksberget, at the "new road" (Kiær 1908, p. 423) the contact was uncovered. A thin conglomerate overlies the limestone concordantly. A block with the same conglomerate is to be seen at the road just west of Presterud. The limestone is overlain by a thin conglomerate layer consisting of small quartz pebbles. This diminutive thickness of the basal beds, representing so great a span of time, was unexpected. The unconformity may easily be overlooked (Fig. 29).

The formation is a well defined lithostratigraphical unit for which the writer propose the name Helgøya Quartzite. Type locality is Eksberget on Helgøya. The formation lies between the Middle Ordovician Mjøsa Limestone and the Pentamerus Limestone. The average thickness varies from 6-10 m. Quartzitic sandstones and shales predominate.

Fig. 28. *Erosion channel in Mjøsa Limestone filled in with Silurian sand. First road section south of Bruflat, W. Toten.*
Erosjonskanal fylt med silurisk sandstein. Første vegskjæring syd for Bruflat, V. Toten.

Fig. 29. *Silurian basal conglomerate at Presterud, near Bergvika, Helgøy.*
Silurisk basalkonglomerat ved Presterud nær Bergvika, Helgøy.

Calcareous beds in the uppermost part are relatively rich in fossils. The formation most probably corresponds to the sub-Stage 6 c in the Oslo Region.

Pentamerus Series.

Stage 7 a-b. As mentioned by Kiær a differentiation into two separate zones is difficult as no typical Borealis Limestone (Stage 7 a) had been found in the Mjøsa Districts. Kiær assumed that this stage was involved in the Pentamerus Limestone. The present investigations indicate a hiatus between the Striclandia Series and the Pentamerus Series (p. 86).

Stage 7 c.

This stage is developed as grey-black and reddish-brown shales. Some layers are exceptionally rich in graptolites. The term "Monograptus Shale" is commonly used for the formation. At the same time the name is a collective one for shales yielding monograptids. (Størmer 1956, p. 45.) The writer introduces the name Ek Shale for the formation. Type locality is Eksberget on Helgøya where the shales are well exposed (Kiær 1908, p. 415). Kiær determined four zones (7 c α-δ) based on the graptolite fauna. The formation thickness is estimated at 80-100 m.

The Ek Shale represents a northern facies within the Oslo Region. It shows a gradual transition to the overlying Spirifer Series. Lithologically the formation comprises the lowermost part of this series.

Graptolite shales of the same formation are also met with at different places on Toten, for example in the first railroad section north of the boundary between the parishes Eina and V. Toten.

Spirifer Series.
Stage 8-9.

The lower part is shaly and rich in graptolites. The content of sand increases upwards. These sandy layers have developed beautiful ripple marks in the second railway-cut north of Bruflat (Figs. 31, 32). In the railway-cut north of this the Silurian is folded into an anticline; here thin limestone benches alternating with sandstones occur in north-

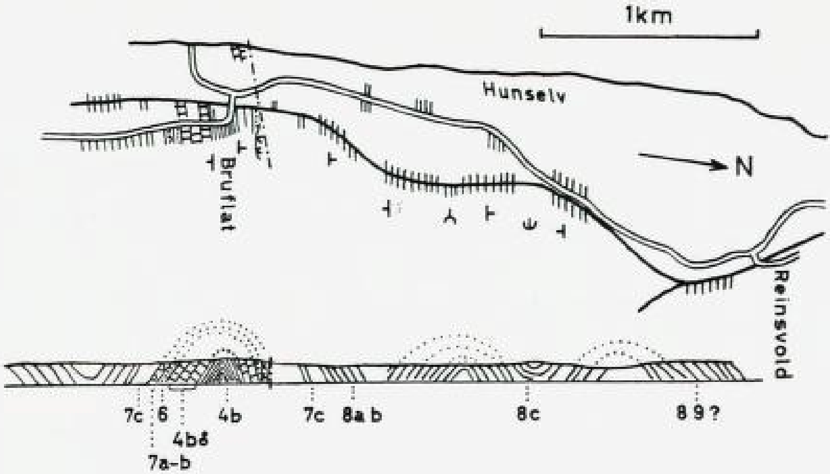

Fig. 30. *Schematic sketch map and section, showing the Silurian layers between Bruflat and Reinsvold, W. Toten.*
Skjematisk kartskisse og profil som viser de siluriske lag mellom Bruflat og Reinsvold, Vestre Toten.

Fig. 31. *Ripple marks in the Silurian sandstones (8 a-b) in the first railway section north of Bruflat, W. Toten.*
Bølgeslagsmerker i den siluriske sandstein (8 a-b) i første jernbaneskjæring nord for Bruflat, V. Toten.

Fig. 32. *Detail from the locality Bruflat (Fig. 31).*
Detalj fra lokaliteten ved Bruflat (fig. 31).

ern flank. Here *Chonetes, Strophomenids, Porpites porpita,* were found. In the next cut beds higher in the succession, yielding *Chonetes* sp. and *Glassia oborata,* are met with. These occur in the calcareous sandstones containing shale laminae. Just south of Reinsvold a dark sandy limestone the youngest bed in this district, occurs. At Breiskallen the same formation occupies the area north and west of the railway station.

The name Bruflat Sandstone is here proposed for the grey sandstone with layers of shale and calcareous sandstones in its upper part. Type locality is the railroad section between Bruflat and Reinsvold in Toten District. The formation terminates the known Silurian sequence in the Mjøsa Districts. Lithologically the formation is an early parallel to the later Ringerike Sandstone (Downtonian) farther south in the

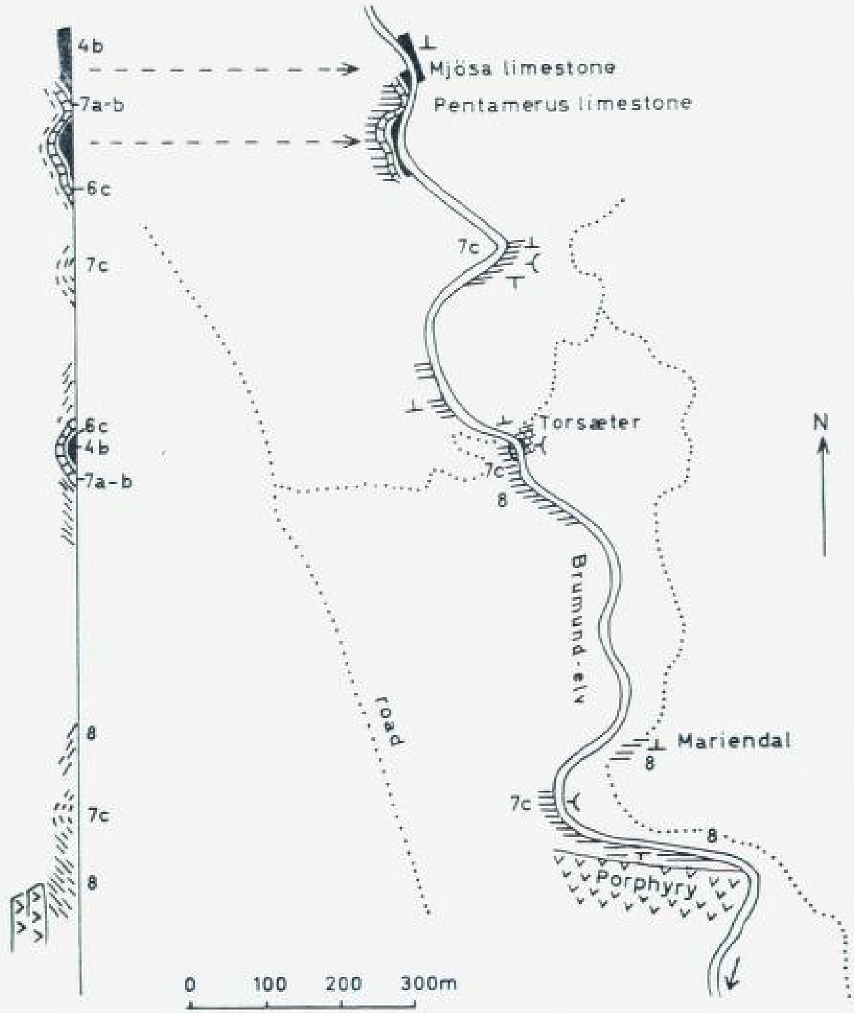

Fig. 33. *Sketch map and section along Brumundelv showing outcrops of Silurian strata.*
Kartskisse og profil langs Brumundelv som viser lokaliteter for siluriske lag.

Oslo Region. The high content of sand in the Silurian in the northern part of the Oslo Region may be ascribed to uplift and erosion in the Caledonian Mountains.

Fig. 34. *The sequence on the eastern bank of Brumundelv at Torsæter bridge. At the lower right hand corner is seen the contact between Mjøsa Limestone and Silurian. Below the bridge Pentamerus Limestone.*
Lagrekken langs østre bredd av Brumundelv ved Torsæter bro. I det nedre høyre hjørne kontakt mellom Mjøskalk og silur. Under broen Pentameruskalk.

Allochthonous strata.

Stage 6 c. At Tørud-Bratberg the Mjøsa Limestone is overlain by typical Helgøya Quartzite. The best profiles through the Silurian strata, however, are found in sections along the Brumundelv (see Fig. 33) (Bjørlykke 1903, 1904 and Kiær 1904, 1908, p. 423).

At Torsæter bridge the Silurian strata form an anticline exposed on the east side of the river (Fig. 34). A weathered surface of the Mjøsa Limestone is succeded by sandstone alternating with shales. The shales are crowded by worm trails. The upper layers towards the Pentamerus Limestone are calcareous and relatively rich in fossils. The same formation is also well exposed some one hundrer meters upstream. At the northern flank of a marked syncline a 2 m thick sandstone bench projects into the stream. The bench demonstrates load cast structures. The load casts only affect the lower half of the bench (Fig. 35, 36). The

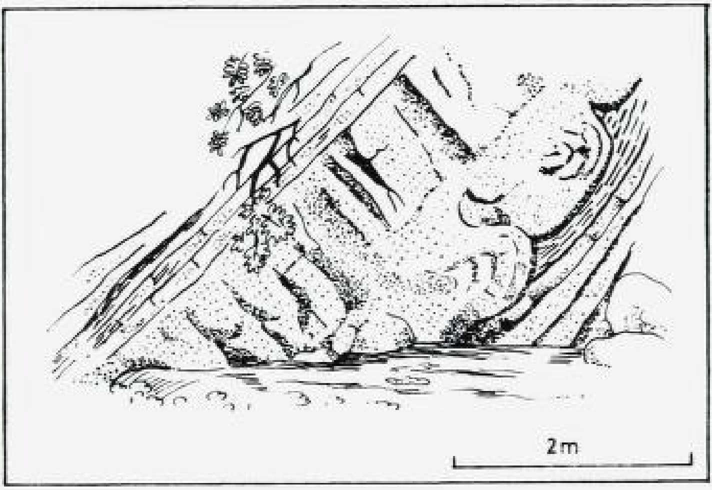

Fig. 35. *Sandstone bench with load casts at Brumundelv, northernmost part of the section Fig. 33 (after photo).*
Sandsteinsbenk med "loadcast" ved Brumundelv, lengst nord i profil fig. 33 (etter fotografi).

Fig. 36. *Detail from one of the load casts shown in Fig. 35.*
Detalj fra sedimentstrukturene vist på fig. 35.

Fig. 37. *Weathered out layer of bentonite in the Ek Shale (= Monograptus Shale). — East bank of Brumundelv, first exposure north of Torsæter bridge.* Utvitret lag av bentonitt i Ek skifer (= Monograptus-skifer) på østre elvebredd — første blotning nord for Torsæter bro.

structures may also be studied in the next anticline towards the south. The stage 6 c shows great variation in development and thickness in the area.

Pentamerus Series.

Stage 7 a-b. The Pentamerus Series is exposed in the described sections. Above the sandstone of stage 6 (Fig. 35) follows a 30 cm thick, well-defined arenaceous limestone bench yielding *Pentamerus borealis* and *Favosites* sp. The thin bench no doubt represents the Borealis limestone (7 a) not found elsewhere in the districts. The formation is succeeded by a typical, rather pure, thick nodular Pentamerus limestone (7 b).

Stage 7 c. Graptolite shales belonging to the Ek Shale have been previously described from sections at Torsæter and downstream to Mariendal (Kiær 1908, p. 423). In addition the formation is found for a long distance along the Brumund elv at the first river bend north of Torsæter bridge (Fig. 37). The layers form a shear-folded anticline with axes almost parallel to the river. Near the core of this anticline occure four thin (2-10 cm) blue-greyish bentonite layers. The bentonite layers are surprisingly little disturbed by tectonic movements and are found in the zone with *Monograptus turriculatus* (7 c α). Bentonites are found in corresponding beds in Jämtland in Sweden (Thorslund 1948, p. 6). The bentonites may be useful for stratigraphical correlations and for dating of volcanicity in the more central part of the Caledonian Mountain Chain. An analysis of the bentonite was carried out for comparison with the Jämtlandian bentonites and also with Middle Ordovician bentonites in the Oslo Region (Hagemann & Spjeldnæs 1955, p. 38).

	Mjøsa 7c	Jämtland 7c	Oslo Region (Middle Ordovician)
SiO_2	49.23	57.24	49.49
TiO_2	1.14	0.56	0.94
Al_2O_3	27.40	22.44	25.92
Fe_2O_3	1.40	0.36	2.25
FeO	0.58	1.76	1.39
MnO	trace	0.01	trace
CaO	1.33	0.34	0.45
MgO	2.38	3.14	3.44
K_2O	7.92	6.50	7.54
Na_2O	0.30	1.41	0.54
H_2O-	3.10	1.23	2.52
H_2O+	4.76	4.37	4.80
P_2O_5	0.18	0.21	0.03
CO_2	—	0.02	—
F	0.22	0.24	0.25
SO_3	0.18	0.13	0.11
	100.12	99.93	99.67

Stage 8. Downstream from Torsæter the upper Silurian beds crop out. The best exposures are met with at Mariendal where the strata yield graptolites from stage 8 a-b.

At the steep southern river bank the Silurian strata are seen to be overlain with angular disconformity by Permian porphyries. The Silurian shows an increasing content of sand upwards.

Tectonics.

Regional Survey.

The Mjøsa Districts form the transition from the foreland to the miogeosynclinal zone of the Caledonian Mountain Chain. The folding and thrusting of the sediments in the districts took place in a late orogenetic phase in post Silurian time. Earlier phases in the more central part of the Caledonian chain have influenced the sedimentation in this transitional area and led to epirogenic movements.

The tectonic problems at Mjøsa necessarily have to be seen in relation to the development of the Caledonides in central Southeast Norway. The main structural lines of this area given in the map Fig. 38. and in the profile Fig. 39.

The different orogenic phases during the evolution of the Caledonian mountain chain are given by Th. Vogt (1928) who separates the following:

Svalbardian phase Erian phase Ardennian phase	Silurian-Devonian
Horg (Taconian) phase	Ordovician-Silurian
Ekne phase	Middle Ordovician
Trondheim phase (Trysil disturbance.)	Cambrian-Ordovician.

The orogeny was initiated in the central part of the geosynclinal belt and moved successively on to the foreland.

The Trondheim phase resulted in epirogenic uplifts in the miogeosynclinal belt with denudation of older sediments (Skjeseth 1962). The Ekne phase, which may be regarded as a subphase of the Horg phase, is marked by a hiatus in the Ordovician layers in the Oslo Region (Størmer 1953). During the Horg phase most probably the emplacement of the crystalline Lower Jotun nappe took place (Strand 1960). There are no signs indicating a folding of the sediments near Mjøsa at this time.

The Mjøsa Districts were subjected to regional epirogenic uplift resulting in a hiatus between Middle Ordovician and Lower Silurian. Farther south in the Oslo Region a slight angular disconformity is presumed to exist between the Ordovician and the Silurian (Spjeldnæs 1957 c). Erosion of the Lower Jotun nappe resulted in the deposition of the Valdres Sparagmite formation, commonly interpreted as a synorogenic sediment. At Mjøsa the Middle Ordovician Mjøsa Limestone is overlain by a Silurian orthoquartzite. This formation most probably corresponds to the Valdres Sparagmite or part of it. The mineral composition points to a common parent rock for both these formations. The sediments in question have their parallel in Sweden in the Offerdalsconglomerate and the Silurian Phacopsquartzite (Asklund 1960).

In post-Silurian time, during the Ardennian-Erian? phases, the folding and thrusting reached the marginal zone of the geosyncline.

At this time the Upper Jotun nappe was thrust over the Valdres Sparagmite. Metamorphic sparagmitian rocks were thrust as a nappe over the geanticlinal ridge into the Sparagmite area. This Kvitvola nappe which occurs in the northern part of the area has a dolomite as detachment horizon and lubricating medium. As assumed by P. Holmsen (1956, p. 19), the Lower Jotun nappe, or erosional remnants of it, on "the back" of the Kvitvola nappe most probably was brought from its more central position to the sparagmite area. These thrust movements resulted in detachment of the Mjøsa Quartz-sandstone with the Ekre Shale as gliding horizon and shearing plane. The Quartz-sandstone nappe moved on to the foreland out of the sparagmite basin. Ordovician and Silurian strata were separated from the Cambrian alum shales and folded in front of the nappe. Folding of the Jura type took place. The Cambrian alum shale itself served as a lubricating medium. The distance of movement is estimated to be about 30 km.

Finally the movements also affected the rest of the Sparagmite Group. The tectonic style was determined by the distribution of competent and incompetent layers and by the old structural lines in the Precambrian basement.

The sparagmites were folded against the southern margin of the basin and inverted along this line in the so-called Ringsaker inversion. A composite anticline, the Moelv anticline, can be traced along the line. The incompetent Biri formation caused a more complicated structure behind this anticline. Locally, on both sides of Mjøsa, the limestone forms a recumbent fold, folded and thrust above younger sparagmites for more than 3 km. This nappe has been called both the Biri nappe (Vogt 1953) and the Sparagmite nappe (Skjeseth 1954). The first name must be preferred as the nappe has a purely local extension. The sparagmites form an anticlinorium which may be followed from Biri-Gausdal to Fåvang. The beds are flat lying with numerous drag-

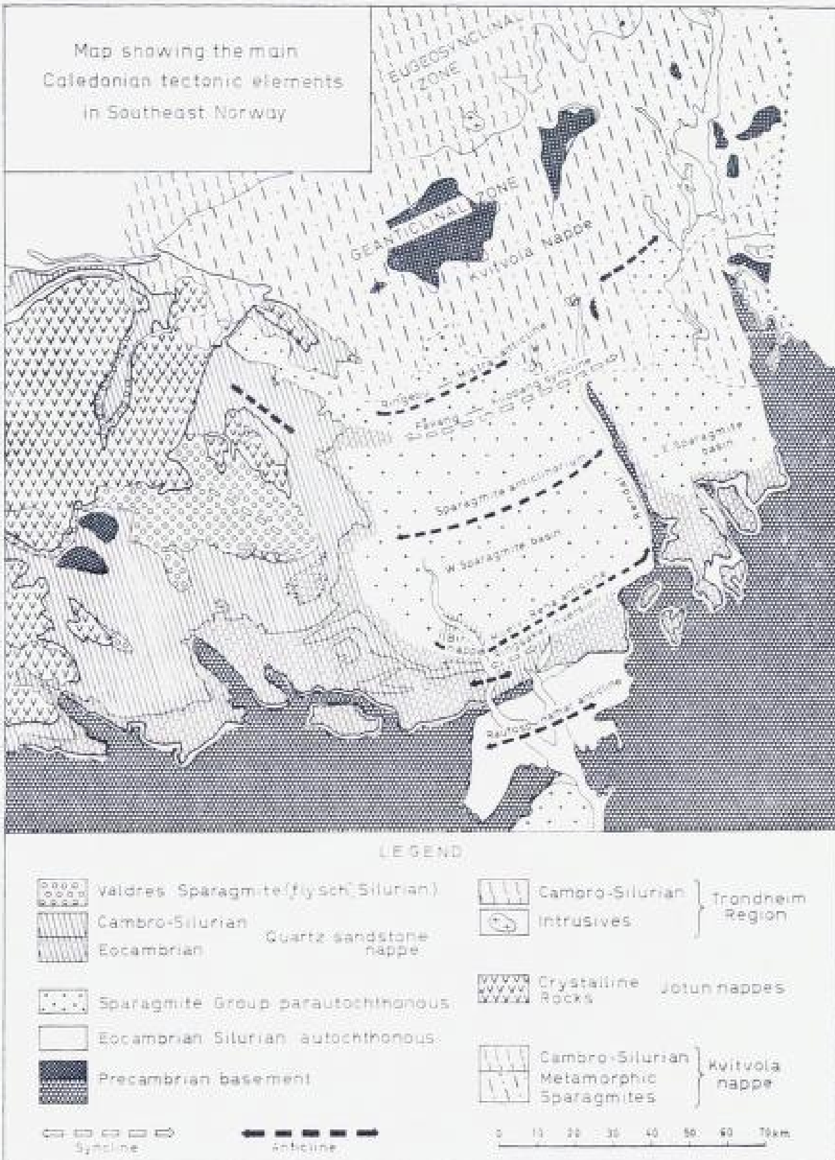

Fig. 38. *Map showing main elements of the Caledonian tectonics in Southeast Norway.*
Kart som viser viktige hovedelementer i Kaledonisk tektonikk i Sydøst-Norge.

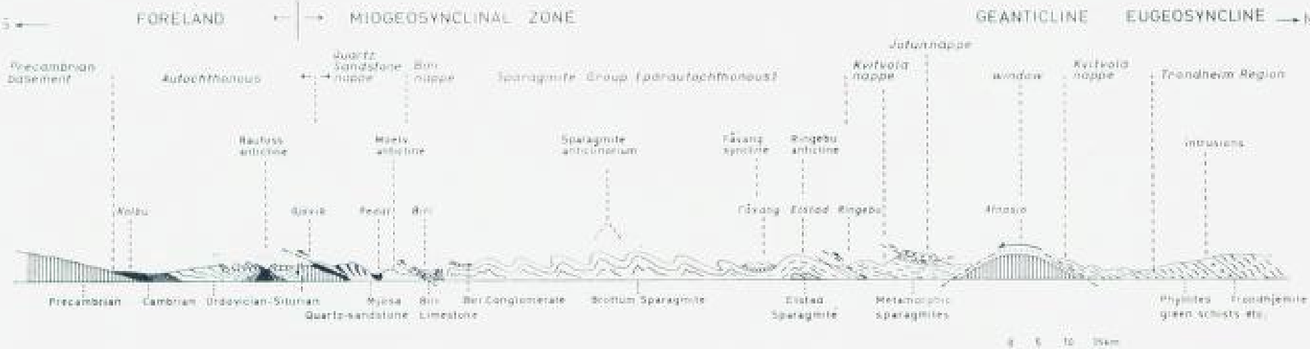

Fig. 39. ***Simplified composite section showing the main tectonic elements from the foreland across the miogeosyncline to the eugeosyncline.***

Forenklet og sammensatt profil som viser tektoniske hovedelement fra forland over miogeosynklinal til eugeosynklinal sone.

folds, mostly shear-folds, in the Brøttum Sparagmite. This style of folding is due to the shale-sparagmite alternation with detachments along the many shale horizons.

Between Fåvang and Koppang lies an east-west syncline. Beyond this again is a composite anticline which may be traced across the whole sparagmite area as an anticlinical zone. Near Ringebu the Elstad Sparagmite (p. 27) evidently forms the core of the anticline.

North of Mistra mainly pale sparagmites form the Rendalsølen anticline. At Mistra the layers have been folded into an inversed position against a Precambrian wall to the south. Here slices of Precambrian are thrust above sparagmitic rocks (P. Holmsen 1956, p. 24). In the strike direction east of Femund blocks of Precambrian are thrusted above Cambro-Silurian along low angle thrust planes (G. Holmsen 1937). The Precambrian of the geanticlinal ridge is also affected by the movements which here evidently only resulted in minor high angle faults. Corresponding rocks in Sweden have been thrusted a long distance as a genuine nappe, the Olden nappe (Asklund 1961). In the same paper (1961, p. 20). Asklund assumes that also the Precambrian of the geanticlinal ridge in Norway is also allochthonous.

The parautochthonous position of the older sparagmites can be demonstrated along the Rendalen fault zone (P. Holmsen 1956, p. 55). On the eastern side of the fault zone the Quartz-sandstone nappe overlies thin autochthonous Eocambrian and Cambrian beds above the Precambrian basement. On the western side there are folded sparagmites. The fault was rejuvenated in post-Caledonian (most probably Permian) time when the western block was downfaulted. The folding of the sparagmites resulted in a detachment along the vertical plane of the fault zone, sinistral wrench faulting taking place. This movement resulted in a tectonic structure similar to the diagrammatic explanation of the Brenta fault (Trevisian in de Sitter 1956, p. 168). The last phase of folding led to an imbrication of beds belonging to the different tectonic nappe units (Strand 1951. P. Holmsen 1956). (Fig. 40.)

In the whole area it can be clearly shown how old structural lines have determined the situation of new folds and structures. This is pointed out by Holtedahl who has explained the change in strike direction near the margins of the old sparagmite basin as a drag effect.

The main strike direction is WSW-ENE. Cross-folding is common especially in the northernmost districts. The Jotun nappes and the Valdres Sparagmite are preserved in synclines with axes perpendicular to

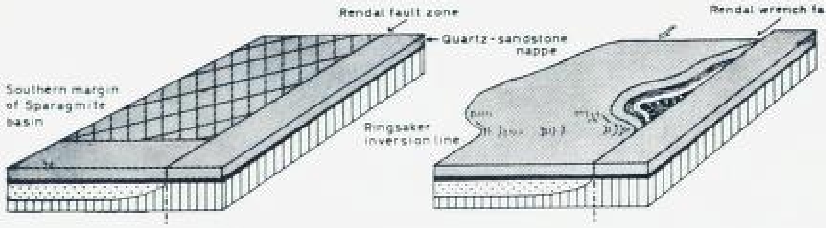

Fig. 40. *Schematic representation of the Caledonian thrusting and folding in the Sparagmite area. The Mjøsa Quartz-sandstone was detached in the Ekre Shale from the older sparagmites and thrust (30—40 km) towards the south with the autochthonous Cambrian alum shales as lubricating medium. The extension of the Sparagmite basin is indicated by cross-hatching. Later the movements also affected the older sparagmites. Wrench faulting evidently took place along the Rendal fault zone. The sparagmites were folded into inversion against the southern margin of the Sparagmite basin. (Autochthonous Mjøsa Quartz-sandstone dotted.)*

Skjematisk fremstilling av den kaledonske skyvning og folding i Sparagmittområdet. Mjøs-kvartssandsteinen løsnet i Ekreskiferen fra de eldre sparagmitter og ble skjøvet (30—40 km) mot syd med de autoktone kambriske alunskifre som "smøremiddel". Utstrekningen av sparagmittbekkenet er antydet med kryssskravering. Senere (til høyre) berørte skyvningen også de eldre sparagmitter. Horisontalforkastning fant øyensynlig sted langs Rendalens forkastningssone. Sparagmittene ble foldet til inversjon mot sydkanten av sparagmittbekkenet. (Autokton Mjøs-kvartssandstein prikket.)

the main Caledonian strike direction. The main crossfolds are bounded on the sides by Precambrian rocks. It is therefore reasonable to explain the cross-folding as a result of pressure between the more resistant blocks.

A. *Folding and thrusting.*

The mapped area belongs to two different tectonic units. The district south of a line Hov i Land-Skonhovd-Gjøvik-Høsbjør-Elverum belongs tectonically to the Oslo Region and must be regarded as autochthonous. Within this unit Paleozoic sediments are folded on a Precambrian crystalline basement. The occurrence of nappe-like structure farther south in the Oslo Region has been pointed out by earlier writers. In Stubdal, Åsa, Ogygiocaris-shale is thrust over Downtonian sandstone (Størmer 1942). A nappe was assumed to exist at Hadeland due to an abrupt change in facies in the Middle Ordovician beds (Størmer 1945). The occurrence of *Paradoxides ölandicus* at Røykenvik, Hadeland, as well as the different development of the Cambrian strata at Hennungsbygda has also been explained by thrusting (Strand 1948).

The overfolding of incompetent Ogygiocaris-shale above Downtonian sandstone may be interpreted as a local tectonic phenomenon, caused by the different nature of the sediments. Later investigations at Hadeland (Størmer 1953) imply that the abrupt change in facies of the Middle Ordovician there is primary. On tectonic grounds the existence of a nappe there is difficult to explain since the Silurian does not seem to have been tectonically influenced at the assumed line of break (see map, Kiær 1908). The local occurrence of the Ölandicus-zone at Røykenvik may, according to the view of the present author, be explained most naturally as a result of a Cambrian transgression along a north-south depression (p. 50). This zone occurs in a stratigraphical succession at the Røykenvik locality. The sequence stratigraphically and tectonically belongs to the Cambro-Silurian of Hadeland to the south.

The first genuine nappe, the so-called Quartz-sandstone nappe, is encountered along the line mentioned above.

1. *Parautochthonous-autochthonous series.*

This series has developed a type of folding which in most features resembles that of the Jura Mountains. Above the Precambrian basement occurs a thick formation consisting of soft, incompetent Cambrian alum shales, which is succeeded by a series of competent and incompetent beds of sandstones, limestones, and shales. During the thrust movements the alum shales behaved as a lubricant and thus played the same role as the anhydrite in the Alps.

Fig. 41. *Intricately folded Cambrian-Ordovician beds along the main road north of Ottestad church (length of section 25 m).*
Komplisert foldete kambrisk-ordoviciske lag langs riksvegen nord for Ottestad kirke (lengde av profilet ca. 25 m).

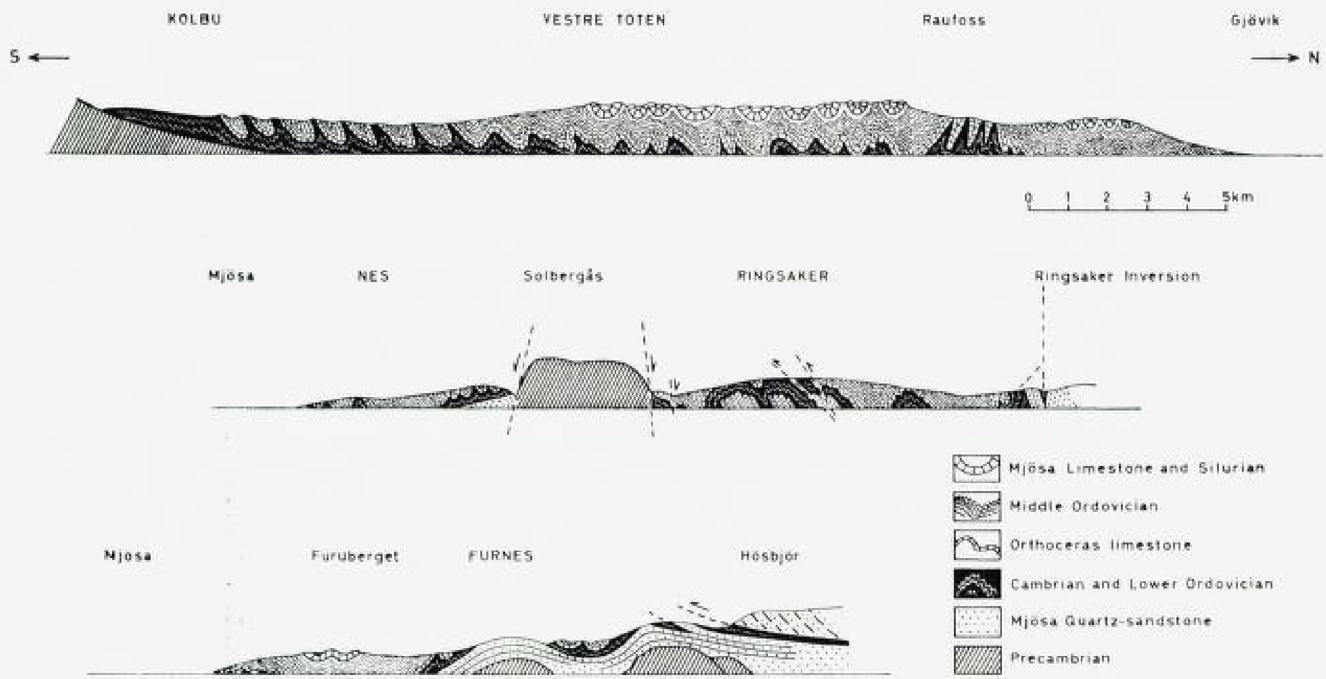

Fig. 42. *N-S sections showing the tectonics on the western side, in the central part and on the eastern side of lake Mjøsa. (Vertical scale somewhat exaggerated.)*

N-S profiler som viser tektonikken på vestsiden, i det sentrale området og på østsiden av Mjøsa (høyden overdrevet).

The main detachment has taken place in the alum shales, though detachment is also clearly demonstrated at stratigraphically higher incompetent zones. The size of the folds is determined by the thickness of the competent layers. The folds are mostly concentric.

A profile along the main road at Ottestad gives good information concerning the degree and style of folding in the lowest part of the Cambro-Silurian (profile Fig. 41). The folding in the Toten Districts is apparent in the profile from Kolbu to Gjøvik (Fig. 42). The thick component Mjøsa limestone and overlying Silurian strata have behaved as a single tectonic unit which has controlled the folding. The limestones in this area can be followed nearly continuously from the vicinity of Eina northwards to Gjøvik. The continuity is broken where a steep anticlinorium runs from Raufoss in the direction of the narrow channel between Nes and Helgøy. In this anticlinorium, consisting of Cambrian and Lower Ordovician beds, a flowage of shale material towards the core of the anticlinorium seems to have taken place. The Orthoceras limestone is isoclinally folded and affected by numerous thrust causing it to be repeated 20 times within 400 m along an east-west road east of Raufoss. This anticlinorium coincides with the assumed southern boundary line of the Eocambrian basin at Mjøsa.

The dips of east-west trending flanks of the main folds in the Mjøsa Limestone are as a rule steep. They flatten out, however, near the closure of the syncline to the east, where lakelets occur (Skjeseth 1956, p. 27). The folds in the Mjøsa Limestone most commonly seem to be of the fan-fold type.

Helgøy is a key area for the tectonics of the sediments under discussion. A tectonic sketch map with a profile section of the island is given in Fig. 43.

On the southernmost part of the island the Orthoceras Limestone is isoclinally folded. The Mjøsa Limestone composing the central parts of the island, forms a syncline which plunges gently to the east. In this direction the syncline is responsible for the bay Bergvika. The main syncline is a typical fan-fold, with its flanks converging upwards. In the core of the syncline a minor anticline or pucker has arisen caused by compression in this part of the syncline. This irregularity in the fold led Kiær to assume the existence of a fault running inside the southern limb of the main syncline (Kiær 1908, p. 411).

The tectonics of the sediments just below the Mjøsa limestone, viz. Cyclorinus beds, follow for the most part the tectonics of the limestone

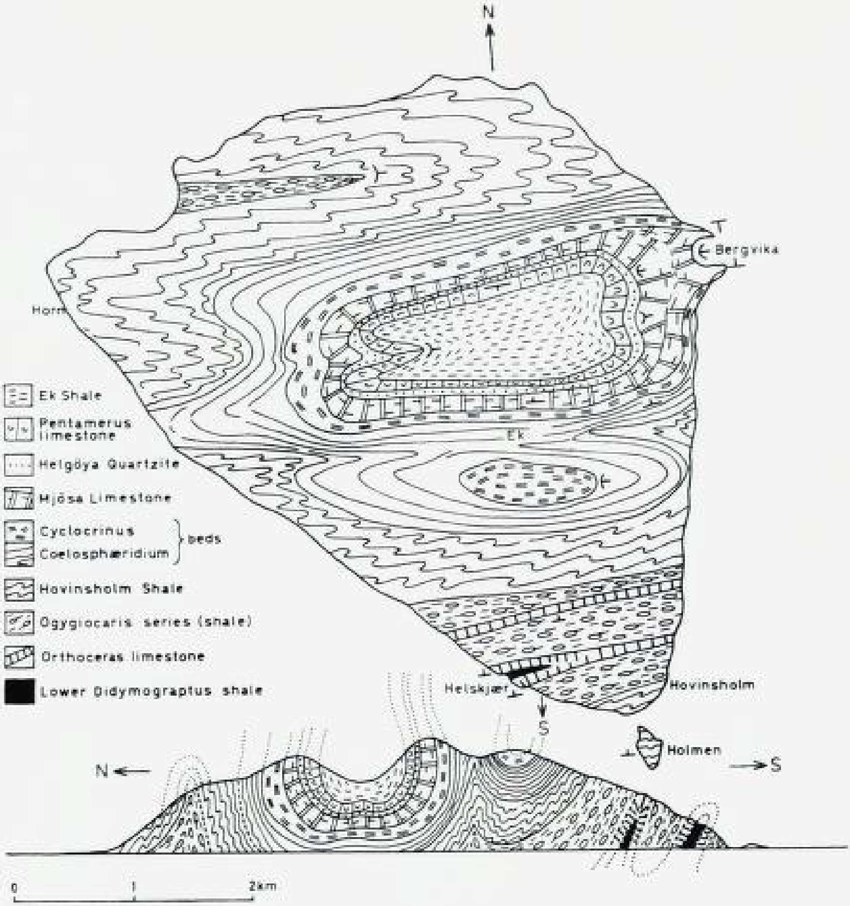

Fig. 43. *Helgøya is a key area for the stratigraphy and tectonics in the Mjøsa Districts. The main stratigraphic and tectonic elements are shown in map and cross-section.*
Helgøya er et nøkkelområde for tektonikk og stratigrafi i Mjøstraktene. De stratigrafiske og tektoniske trekk vist på kart og profil.

as interpreted by Holtedahl (1908, p. 38). Along the eastern shore line minor folding is to be seen in the Robergia beds (Fig. 44). These folds must be interpreted as drag-folds related to the main folds. The dimensions of the folds depend on the thickness of the sandstone layers and the distance between them. Drag folds due to disharmonic folding are developed in the Mjøsa limestone (Fig. 45). At several

Fig. 44. *"Drag folds" in the Hovinsholm Shale at Hov on Helgøy.*
Slepefolder i Hovinsholmskifer ved Hov på Helgøya.

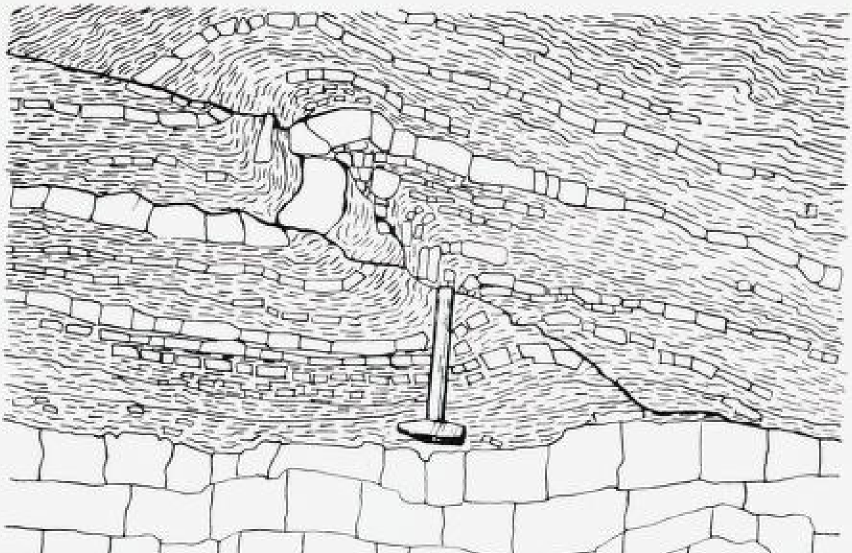

Fig. 45. *Disharmonic folding and small scale thrusting in Cyclocrinus layers just below the Mjøsa Limestone. Lodvik, eastern side of Helgøy.*
Disharmonisk foldning og små overskyvninger i Cyclocrinuslag like under Mjøskalk. Lodvika øst på Helgøya.

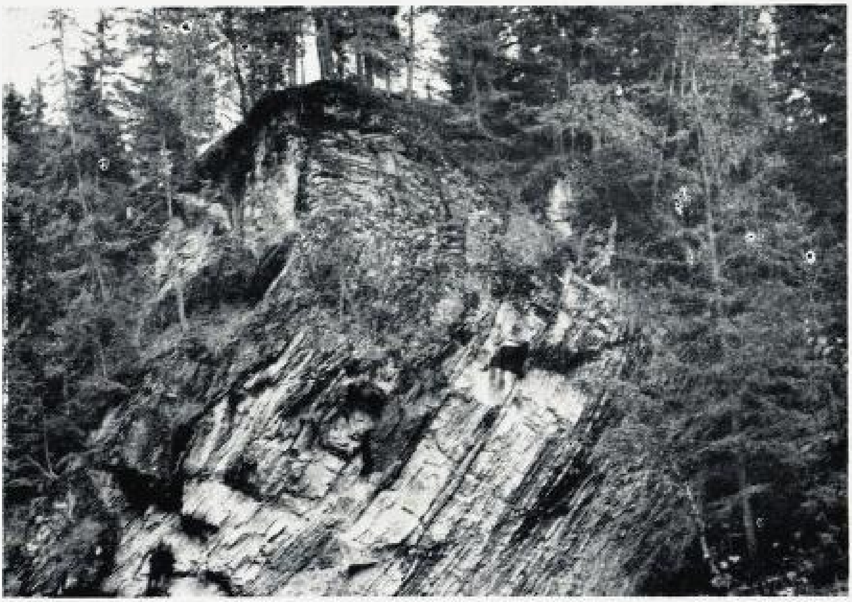

Fig. 46. *Overturned anticline in Orthoceras Limestone just north of Bjørge at Flagstad river. Inverted Helskjær shale and limestone to the right.*
Overfoldet antiklinal i Orthocerkalk like nord for broen i Bjørgedalen, Flagstad-elv. Invertert Helskjær-skifer og kalk til høyre.

places folds which die out downwards can be seen above an undisturbed flat surface which has served as a detachment horizon.

At Nes the Mjøsa limestone forms a synclinorium, preserved in the east and the west of the peninsula. It is broken in the central parts of Nes by the Nes fault zone, and continues eastwards to the classical Furuberg, where a fine syncline may be seen in the limestone on the site of a quarry (Fig. 47). Compression in the syncline has caused minor thrusts.

2. *The tectonics along the front of the Quartz-sandstone nappe.*

The geology along the front of the Quartz-sandstone nappe is rather complicated as the Precambrian basement here is also partly thrust by the movements. Permian faults also add to the complication.

The present front of the nappe mainly follows the assumed southern margin of the Sparagmite basin. It appears therefore reasonable

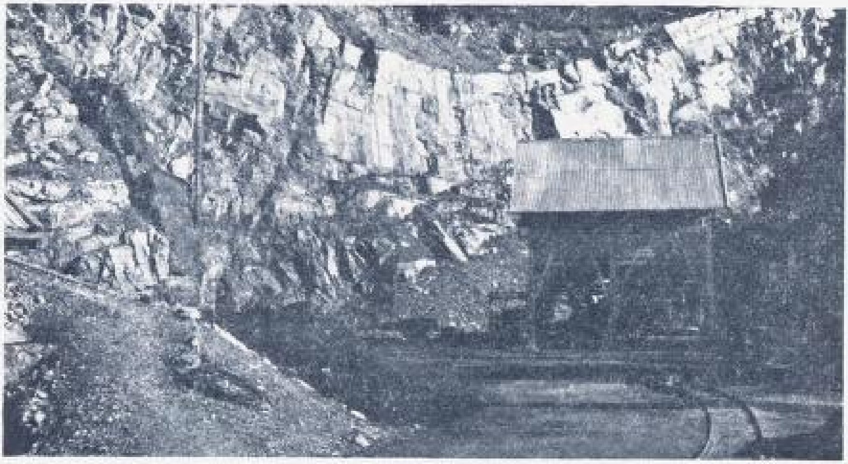

Fig. 47. *The Mjøsa Limestone and Silurian layers played a dominating role in the tectonics of the autochthonous series in Mjøsa Districts. Syncline in Mjøsa Limestone at Furuberget (Steens Limestone quarry) north of Hamar. Permian basic dike to the left.*

Mjøskalken og overliggende siluriske lag spilte en dominerende rolle for tektonikken i den autoktone serien i Mjøstraktene. Synklinal i Mjøskalk i Furuberget (Steens kalkbrenneri) nord for Hamar. Permisk basisk eruptivgang til venstre.

to ascribe the Caledonian movements visible in the Precambrian to rejuvenation of old fault lines or flexures limiting the basin.

A series of profiles (N-S) is given to illustrate the conditions at the front of the nappe (Fig. 48). The first profile runs just west of Gjøvik. From Gjøvik northwards, the Precambrian rises to its maximum height at Øverby farm and neighbourhood where the basal Cambrian conglomerate rests on the Precambrian. In the Berg heights the Quartz-sandstone is met with. In the next profile the front of the nappe lies farther south. West of the Precambrian rise at Øverby is an anticline in the nappe, the crest of which runs along the upper road in Vardal. A thrusted block of Precambrian most probably occupies the core of this anticline, which has its closure in Byelva just south-west of Mustad farm. Between these two profiles is a flexure dipping westwards. In the third profile, across Skonhovdhøgda, the nappe reaches farthest south. Here the continuation of the Precambrian (southernmost in the second profile) seems to form the core of the anticline in Skonhovdhøgda.

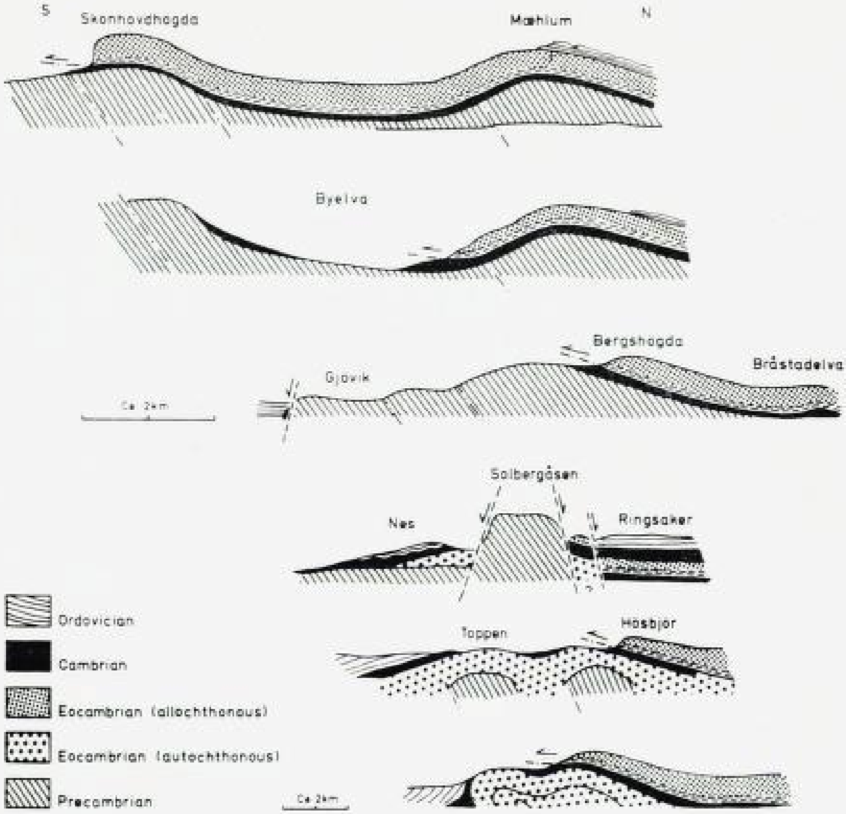

Fig. 48. *Schematic sections across the front of the Quartz-sandstone nappe. The Precambrian basement most probably was affected by the Caledonian movements along the line of the front. Lowermost section is along the Flagstad river.* Skjematiske profiler over fronten av Kvarts-sandsteinsdekket. Grunnfjellet ble sannsynligvis oppskjøvet ved de kaledonske bevegelser, langs denne linjen. Det underste profilet er fra Flagstadelv.

Similar conditions are seen in the vicinity of Fluberg, where the Precambrian has apparently taken part in the thrusting. Holtedahl (1915, p. 21) assumed that the Precambrian there was partly affected in the Caledonian orogeny.

On the Nes peninsula the conditions are more complicated as the front of the nappe here is interrupted by a horst, which undoubtedly underwent its latest development in Permian time. There is much to show that the Precambrian here was thrusted during the orogeny and

Fig. 49. *The Quartz sandstone nappe above the autochthonous lubricating Cambrian alum shale. Løken farm, Hov i Land.*
Kvartssandsteinsdekket over autokton kambrisk alunskifer. Løken, Hov i Land.

Fig. 50. *The thrust plane and the contact between Ringsaker Quartzite and Cambrian alum shale. Løken, Hov i Land.*
Overskyvningsplanet og kontakten mellom Ringsakerkvartsitt og kambrisk alunskifer. Løken, Hov i Land.

that the Caledonian thrust lines were rejuvenated in Permian time. The gentle folding of the Quartz-sandstone at Nes south of the horst may be ascribed to movements in the Precambrian below as demonstrated at Gjøvik. The folding may be due to a primary wedging out of the Eocambrian rocks in this area.

The autochthonous Quartz-sandstone at Furnes forms open folds, quite different from those usually developed in the Eocambrian rocks. Judging from the conditions near Gjøvik it appears reasonable to assume a core of Precambrian in the anticlinorium. This assumption is strengthened by the results from the borings carried out (see p. 25). Above the Precambrian the Quartz-sandstone cover seems to have been folded. This is shown in the profile Furnes-Høsbjør (Fig. 48). The gradual compression of the anticlinorium towards the west may be ascribed to resistance of the Precambrian wall limiting the Sparagmite basin and the wedging out of the sediment cover.

The Quartz-sandstone nappe.

The existence of the so-called Quartz-sandstone nappe was first pointed to by Schiøtz (1902) from the south-eastern Eocambrian area. Holtedahl (1915) described the same tectonic unit from the vicinity of northern Randsfjord. Both estimated the transport of the Quartz-sandstone to be from 15-40 km towards the south.

The main movement has taken place along a low angle thrust. The nappe has developed typical imbricate structures of "Highland type". The oldest known formation in the nappe is the Ekre Shale, which together with the autochthonous Cambrian alum shales served as a lubricating medium.

The thrusting is particularly clear at Løken farm, Hov i Land, where the contact between the thrust quartzite and the alum shale is beautifully exposed in a roadcut about 100 m long (Figs. 49, 50).

From Bergshøgda north of Gjøvik, where the Ekre shale forms the base of the nappe, the thrust plane can be followed nearly continuously down to the outlet of Bråstadelva and from there along the Mjøsa shore line, where Vogt (1924) described the nappe-like overthrusting. At the extreeme northern end in Vogt's profile comes autochthonous Cambrian alum shale. North of this locality the Ringsaker Quartzite is repeated by thrusting.

At Ringsaker the Cambro-Silurian of the nappe is preserved from erosion in a graben. Immediately north of the horst, and in close proximity to it, is a series of small areas where the Quartz-sandstone is thrust above alum shale. At the easternmost locality, Stenseng, described by Bugge (1945), the Vardal Sparagmite overlies the Ringsaker Quartzite with a well-developed breccia separating the two. The Quartzite in turn overlies Cambrian alum shale. The Quartz sandstone is probably overturned at this locality.

The thrusting is clearly demonstrated at Vengshol farm, where deformed Vardal Conglomerate overlies Cambrian alum shale (Fig. 64). East of Mjøsa the front of the nappe is well marked in Høsbjørkampen (Fig. 42) at the classical locality Høsbjør. Along the western side of Flagstadelva from Brennsæter sag and upstream, the gently undulating thrust-plane can be followed for several hundred meters.

Tectonic details of the nappe.

The Quartz-sandstone nappe is known to be typical thrust nappe, with imbricate structures of the "Highland type". The conditions are especially suitable for detailed tectonic studies, as the nappe is eroded to different levels in the west, east and in the more central parts. To the west the Quartz-sandstone and the lower part of the overlying Cambro-Silurian are mainly preserved. The area on the east side of the Brumund fault zone is occupied by Quartz-sandstone, while in the Ringsaker Graben the Cambro-Silurian is also preserved. The differing plunge directions of the main fold-axes contribute to a better understanding of the tectonics.

In the southernmost part of Ringsaker the beds form an anticlinorium with flat, easterly-plunging axes. The anticlinorium is well marked by the competent Stein Limestone (Orthoceras Limestone). The anticlines are often eroded, as tensional joints are developed along their crests (Fig. 59), while the synclines now form the heights and the east-west runnings ridges (Fig. 60).

The Quartz-sandstone occupies the cores of the anticlinorium with tongue-like extensions towards the east. The two more northerly tongues are clearly thrust. The southernmost, however, has developed a type of imbricate structure. The Quartz-sandstone has determined the whole tectonic style. A series of profiles across the two northerly tongues illustrates the tectonics within this part of the anticlinorium

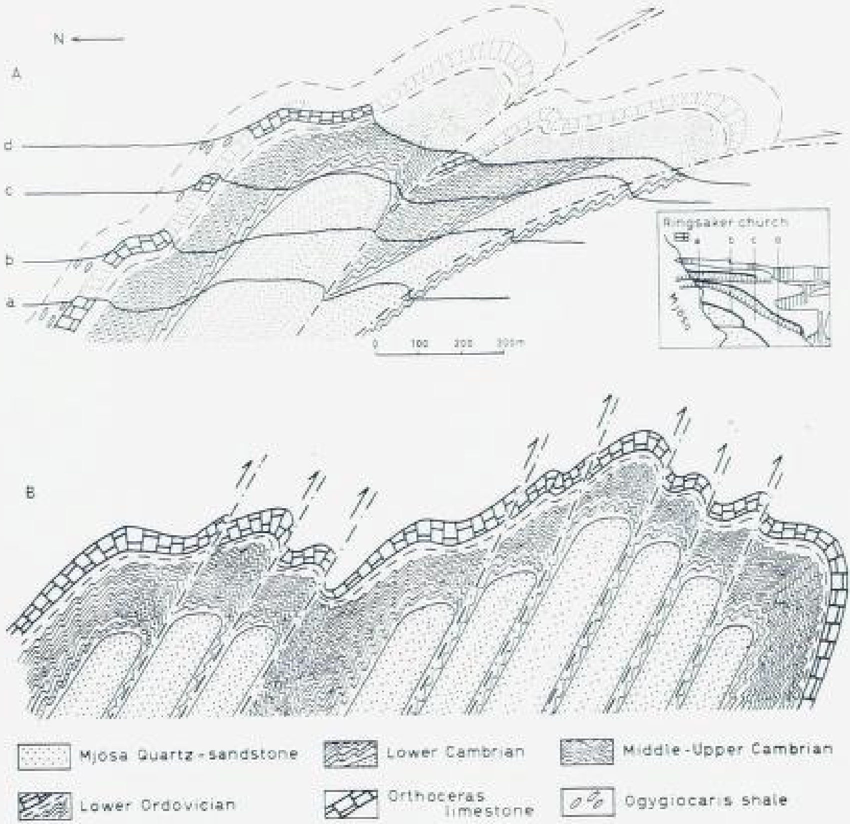

Fig. 51. A. *Composite section (a-d) to show the character of the imbricate structure in the Quartz-sandstone nappe. Ringsaker.* B. *"Shear folds" in Ringsaker Quartzite in the southern part of Ringsaker.*

A. Sammensatt profil (a-d) som viser karakteren av taksteinstrukturen i Kvartssandsteinsdekket. Ringsaker. B. "Skjærfolder" i Ringsakerkvartsitt i Søndre Ringsaker.

(profiles a-d, Fig. 51). The thrusts are fold thrusts, and the narrow anticlines appear as folds recumbent to the east.

The two southerly anticlines may be interpreted as types of shear-folds and are composed of a series of highly compressed minor anticlines separated by thin layers of Lower Cambrian in alternating normal and inverted position (Fig. 51 B).

The shear-folds have their continuation on the western side of Mjøsa in Glæstadhøgda and Bjørgehøgda, and they close towards

Fig. 52. *The core of the northernmost anticline in profile a Fig. 49. Folded Ringsaker Quartzite along the Mjøsa shore-line west of Vinju.*
Kjernen i den nordligste antiklinal i profil a fig. 49. Foldet Ringsaker-kvartsitt langs Mjøsa vest for Vinju.

Fig. 53. *Disharmonically folded Ringsaker Quartzite along the road from Mustad to Landåsen north of Seval in Vardal.*
Disharmonisk foldet Ringsaker-kvartsitt langs vegen fra Mustad til Landåsen nord for Seval i Vardal.

Fig. 54. *The Lower Cambrian layers dragfolded above the Ringsaker Quartzite. Mjøsa shore-line at Kråkvik, Ringsaker.*
De under-kambriske lagene er "slepefoldet" over Ringsaker-kvartsitten. Mjøsstranda ved Kråkvik, Ringsaker.

Fig. 55. *Zig-zag folding in incompetent Cambrian alum shale in road section between Vold and Kråkvik farm, Ringsaker.*
Småfoldet kambrisk alunskifer i vegskjæring mellom gardene Vold og Kråkvik på Ringsaker.

Fig. 56. *Syncline in Orthoceras Limestone (= Stein Limestone) at Heramb, Ringsaker.*
Synklinal i Orthocerkalk (= Stein-kalk) ved Heramb, Ringsaker.

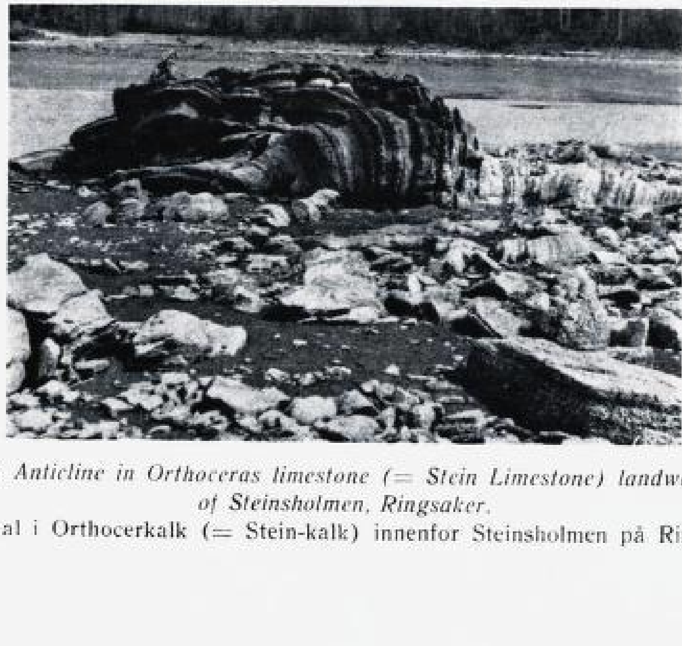

Fig. 57. *Anticline in Orthoceras limestone (= Stein Limestone) landward side of Steinsholmen, Ringsaker.*
Antiklinal i Orthocerkalk (= Stein-kalk) innenfor Steinsholmen på Ringsaker.

Fig. 58. *The bay between Steinsholmen and the mainland is determined by a syncline in the Orthoceras limestone (= Stein Limestone).*
Bukten mellom Steinsholmen og land er betinget av en synklinal i Orthocer-kalken (= Stein-kalk).

Ringsjø. The intense folding of the sediments can best be seen along the main road Gjøvik-Lillehammer, where most of the synclines are completely squeezed out and have detached cores. The enrichment of carbon in one of those, at Bjørge, Vardal, is of interest in this connection and must be ascribed to the tectonic movements. This carbonaceous alum shale contains about 50 % C, 16—17 % being the usual content in the Oslo Region. The locality was described by Foslie (1919).

The two northerly thrusts described from Ringsaker (Fig. 51) can be followed up Snertingdal.

North of the anticlinorium at Ringsaker is a synclinorium in the Brumunddal-Veldre area. The Ringsaker inversion-line forms the southern flank of the next anticlinorium, viz. the composite Moelv anticline.

South of Tørbustilen a recumbent fold cut by a high angle thrust plane can be seen along the Flagstad river. The main direction of strike within the Quartz sandstone nappe is E-W and the axial planes of the folds dip at a high angle towards the north. On the western side

Fig. 59. *Anticline in Orthoceras limestone (= Stein Limestone) on the outer side of Steinsholmen, Ringsaker. The core consists of Lower Didymograptus shale.* Antiklinal i Orthocerkalk på utsiden av Steinsholmen, Ringsaker. Kjernen består Undre Didymograptus-skifer.

Fig. 60. *The competent Orthoceras Limestone has played a dominating role in the tectonics and topography at Ringsaker. The heights in the background are determined by open synclines in the limestone, while the anticlines are eroded.* Den kompetente Orthocerkalken har spilt en dominerende rolle for tektonikk og topografi på Ringsaker. Høydene i bakgrunnen er betinget av åpne synklinaler i kalken, mens antiklinalene er erodert.

of the lake Mjøsa, in the area between Hov and Fluberg, there is in addition to the main E-W strike direction a N-S trend of the fold-axes. Some of these structures may be ascribed to movements in the Precambrian basement.

Faults.

The Mjøsa Districts are traversed by a series of fault zones, some of which are continuations of fault zones in the Oslo Region farther south (Figs. 61, 62).

Hunselv fault zone.

The Cambro-Silurian of the Hadeland Districts is bounded on the west by a fault zone along Randsfjord. A minor fault most probably branches from this fault and follows the Jaren-Grua valley.

The continuation of the Randsfjord fault zone northwards is not yet cleared up. There is much evidence to show that a continuous fault zone runs from Røykenvik to Einavann southernmost in the Toten District. This fault limits the small area of Cambrian rocks at Hennung.

Southwest of Einavann the fault zone is marked by a deep valley. From Einavann the fault zone is followed by the Hunselv. Hence the name Hunselv fault is given to this part of the fault zone.

A minor fault, the Eina fault, branches from the main fault, runs along the Einavann and most likely is responsible for the valley south of Einavann. The two faults unite just north of Bruflat and thus limit a wedge-like Cambro-Silurian block tilted down to the northeast. This tilting, in the writer's opinion, may be a drag effect related to the downsinking of the main Cambro-Silurian block on the eastern side of the Hunselv fault zone. North of Eina the folds between the above mentioned fault zones have an easterly axial plunge as distinct from the westerly plunge elsewhere in the W. Toten District. Northwards the river runs along the fault to Raufoss whence it turns into the Precambrian and unites with the fault again at Breiskallen. The fault zone is here marked by a waterfall below the road bridge.

From Raufoss to Breiskallen the fault zone forms a valley utilized by the railroad. Along the road one may see how alum shale is interspersed through the fault breccia. Fault drag is present at Breiskall-

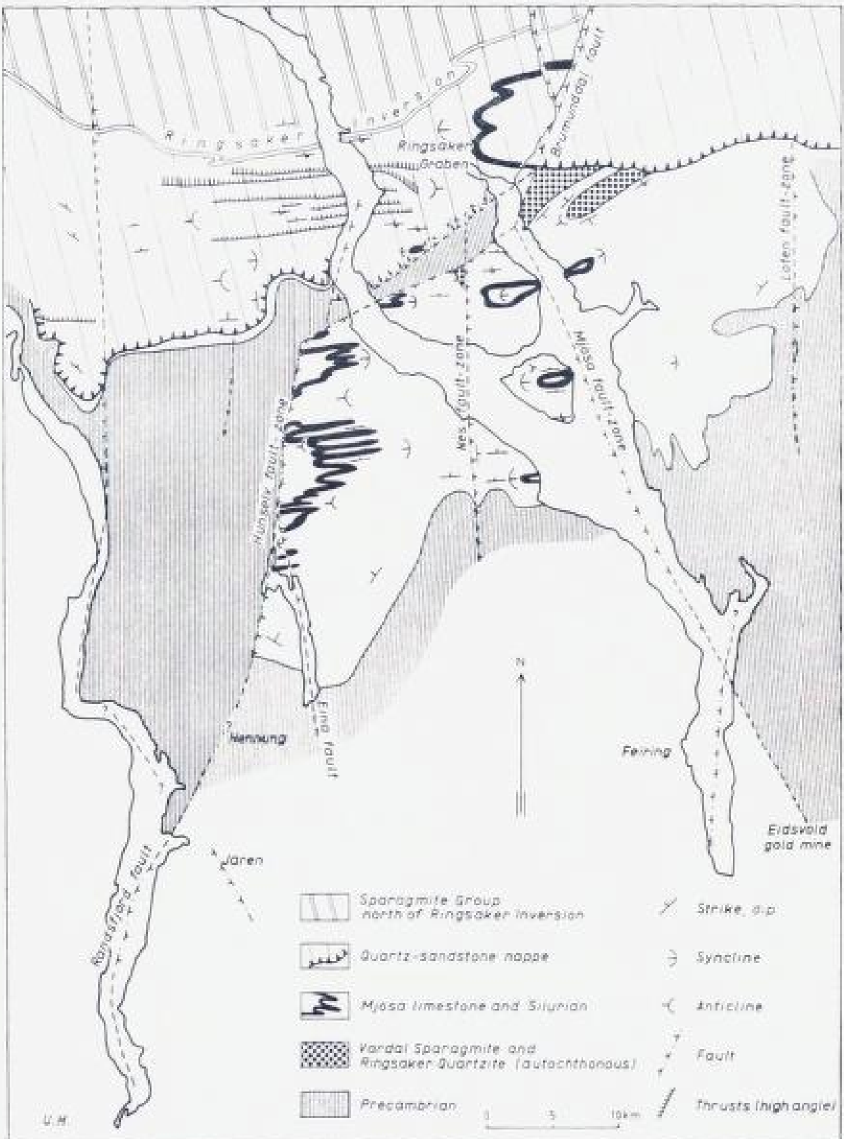

Fig. 61. *Map showing the trend of main Permian fault zones in the Mjøsa Districts.*
Kart som viser forløpet av permiske forkastningssoner i Mjøstraktene.

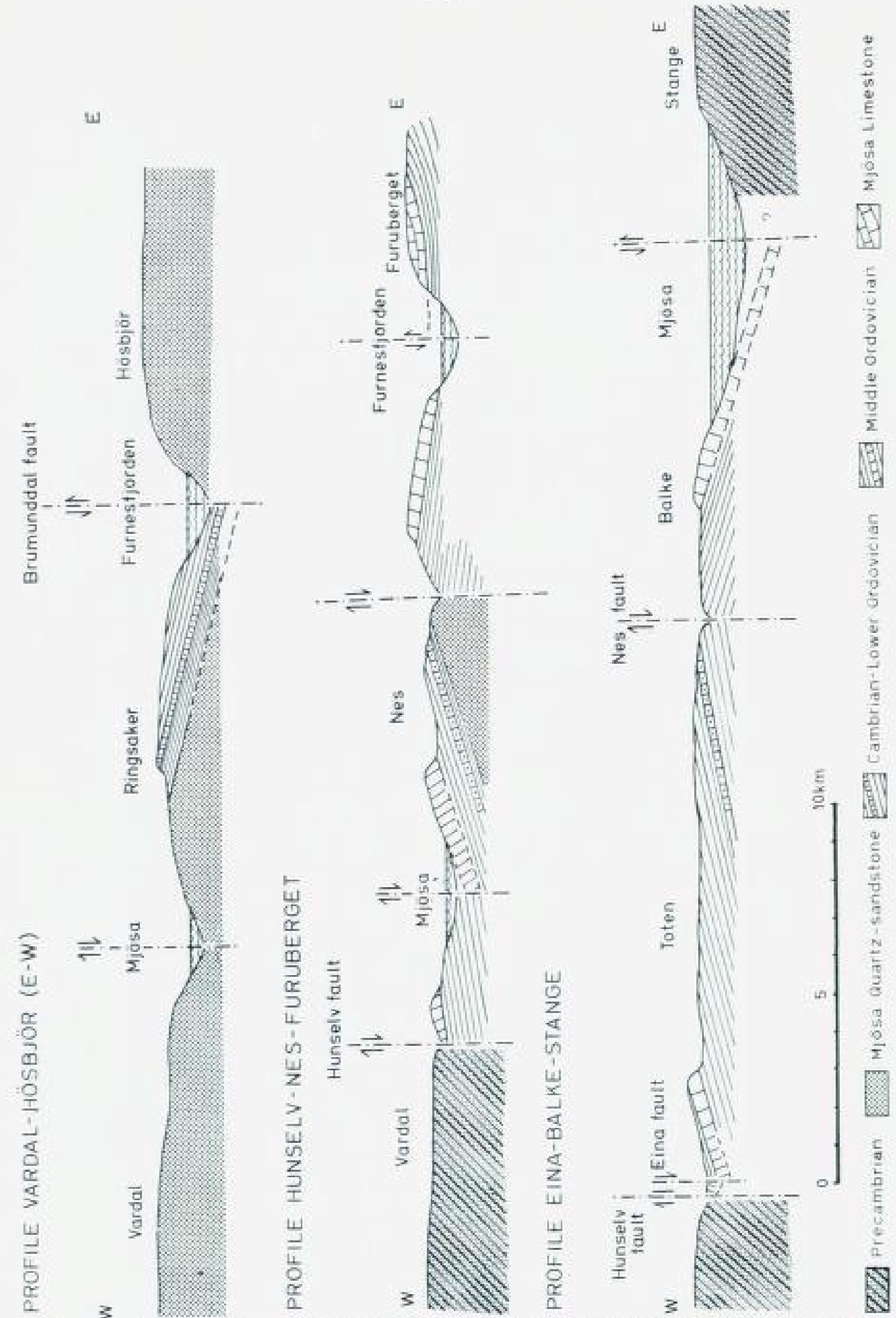

Fig. 62. *Cross-sections W-E to demonstrate the Permian faulting in the Mjøsa Districts.*

Tverrprofil som viser de permiske forkastningene i Mjøs-distriktene.

bakken, where strongly tectonized alum shales dip at a high angle along the fault plane.

From the last locality the fault turns in an easterly direction, and probably has its continuation in the southern fault limiting the horst on the Nes peninsula.

Skumsjø fault. A minor fault at Skumsjø runs into the Quartz-sandstone nappe, just west of Skonhovd farm, Vardal.

Hov-Snertingdal fault zone. A more or less continuous fault zone passes through the eastern part of the mapped area. The exact course of this zone has not been mapped in detail. To the south the zone is traceable in the Precambrian. Just north of the N. Berg farm, uphill from Hov railway station, an interesting breccia occurs in a shallow well. The breccia consists mainly of calcite and pyrite in a carbonaceous matrix (Fig. 63). The carbon has most probably come from the alum shale above and has followed the fault plane downwards. Northwards the fault zone is followed by Lauselva and runs to Landåsen, where the area occupied by the basal tillite is limited by the fault plane. To the north the fault may be seen along the river east of Nykirke, Snertingdal, where a relative sinking of the eastern block has taken place.

The fault zone is also clearly demonstrated in Gausdal and Fåvang where it has recently been mapped by Seip and Englund.

The horst traversing the Nes peninsula in an east-west direction is an upstanding block of Precambrian rocks, limited by steep fault planes (Fig. 65). On the northern side small faults branch from the main fault and limit areas with alum shales and Eocambrian rocks. At Vengshol the Eocambrian abuts against Middle Ordovician Coelosphaeridium Shale.

A Bordal the Ringsaker Quartzite lies close to the Precambrian of the horst and is strongly brecciated (Fig. 64).

The conditions at the fault plane may be studied in a little brook following the fault zone near the road from Ringsaker to Stavjø at Ulvhilrud. The alum shales on the steep fault plane are polished and have developed beautiful slickensides. The limestone lenses in the shale are partly orientated parallel to the direction of the movements. The southern fault zone limiting the horst is obscured at most. A change in the direction of this faults occurs at its intersection with the Nes fault-zone.

Nes fault zone. The Nes peninsula is divided into a eastern and

Fig. 63. *Permian? breccia with calcite and alum shale, from the Precambrian at Berg, Hov i Land. ⅔ nat. size.*
Permisk? breksje med kalkspat og alunskifer, fra grunnfjellet ved Berg, Hov i Land. ⅔ nat. størr.

western block by a north-south fault, the so-called Nes fault, which downthrows to the east. The fault zone also affects the horst in which it appears as a mylonite breccia zone. The movements along the fault zone have resulted in the fold-axes in the Cambrian-Silurian plunging away from the fault zone. The displacements are greatest at Nes, where the Eocambrian abuts against Middle Ordovician beds. The fault zone may be followed from Kapp to Lena in the Toten District. In a beck south of Kapp dragging of the Ordovician beds has resulted in a flexure dipping eastwards.

Brumunddal fault zone. The southernmost fault zone of the horst has no traceable continuation at Furnes. The horst fault zones unite in the so-called Brumunddal fault zone. From this a minor fault branches off in a northwesterly direction, passing east of the Brumundsag. The downthrow of the western side is considerable, as Permian rhomb porphyries and sandstones are brought against Eocambrian rocks on the eastern side.

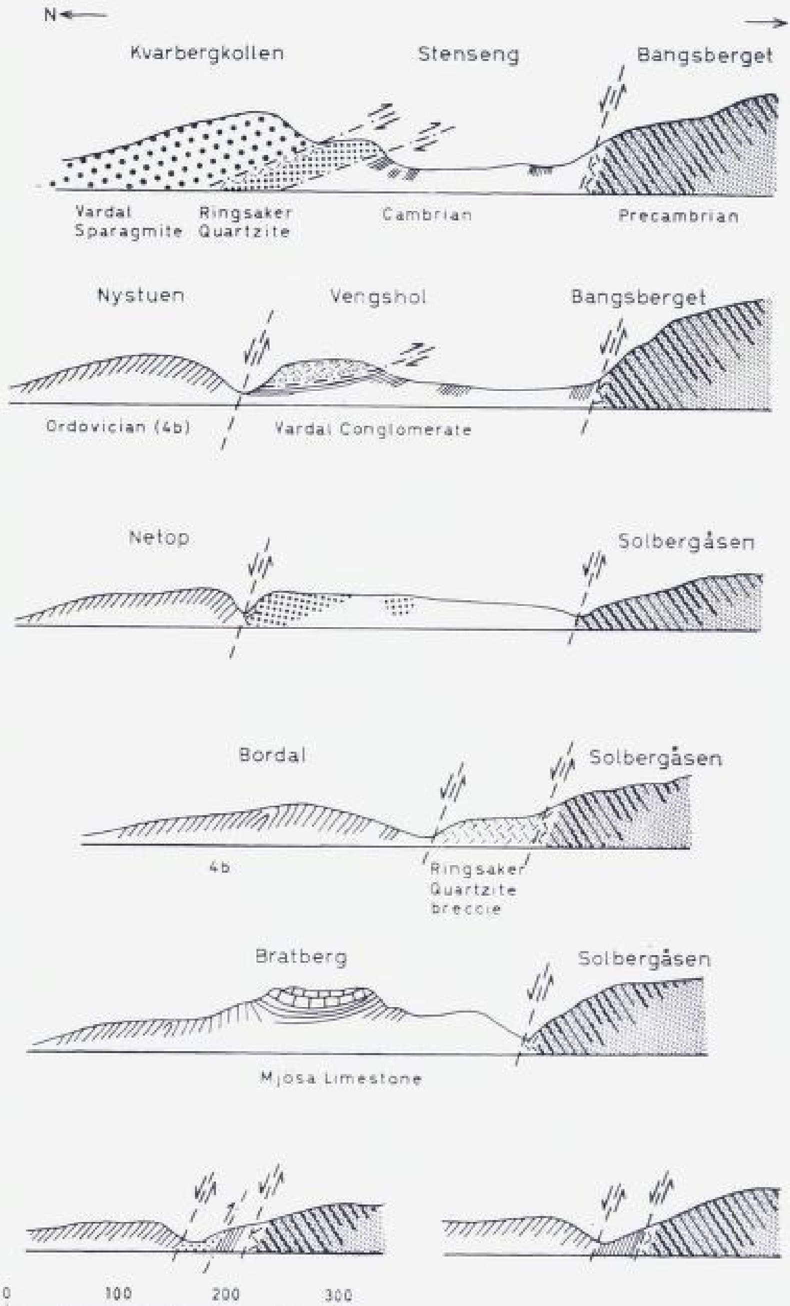

Fig. 64. *N-S sections showing the tectonics along the northern fault zone of the horst with Precambrian rocks on the Nes peninsula. The two lowermost sections are east and west of the road from Ringsaker to Stavsjo at farm Ulvildrud.* N-S profiler som viser tektonikken langs forkastningssonen på nordsiden av grunnfjellshorsten på Neshalvøya. De to nedre profiler er fra øst- og vestsiden av vegen fra Ringsaker til Stavsjo ved Ulvildrud.

Fig. 65. *The horst with Precambrian rocks on the Nes peninsula in the background, seen from Veldre railway station.*
Grunnfjells-horsten på Neshalvøya i bakgrunnen, sett fra Veldre jernbanestasjon.

Ringsaker graben. Southern Ringsaker thus forms a graben which is limited by steep fault zones to the east, west, and the south.

The down-faulted block within the graben has tilted down to the east, where the greatest displacements have taken place, viz. along the Brumunddal fault zone. A series of minor faults parallel to this fault zone cut the Ringsaker graben. The displacements are too small to be drawn on the present geological map.

Mjøsa fault zone. A continuous fault zone is drawn on the map in the eastern part of lake Mjøsa, from Furnesfjord to Minnesund in the south. The vertical displacements along this fault zone cannot be great. Along Furnesfjord they have resulted in a change of axial plunge as shown by the synclines of Mjøsa Limestone on the opposite sides of the fjord. At Balke (Toten District) a syncline with Mjøsa Limestone has an easterly plunging axis. On the opposite shoreline at Stange, the bedrock consists of Precambrian gneisses. The former Eidsvold gold mine is situated along the continuation of the fault zone to the south, where the breccia zone is mineralized.

A fault zone is also drawn along the southern extension of lake Mjøsa, where Cambro-Silurian occupies the western side, at Feiring, and Precambrian the eastern side.

Romedal-Løten fault zone. The last mentioned fault may possible have a continuation northwards in the Romedal-Løten fault zone. The latter is exposed in new cuts along the road from Benningstad to Sæter in Løten, where alum shales occur along the fault plane. It is possible that the areas with alum shale in the southern part of Valset owe their existence to this zone. — The displacements there were in many cases considerable in post-Cambrian time. A breccia zone in the Precambrian is exposed at Gata, Valset, along the road to Haresjøen.

Sammendrag.

Bidrag til geologien i Mjøstraktene med en kort foreløbig analyse av stratigrafi og tektonikk i det klassiske sparagmittområde.

Avhandlingen gir resultater av undersøkelser utført av forfatteren i de siste årene i Mjøstraktene. Arbeidet ble påbegynt 1948 og var på det nærmeste fullført 1954. Praktiske oppdrag og annen virksomhet ved Norges geologiske undersøkelse gjorde det nødvendig å legge arbeidet til side. Siste sommer (1962) ble det gitt anledning til å utføre avsluttende feltarbeid og til bearbeidelse av materialet.

Mjøstraktene er et nøkkelområde for Sør-Norges geologi (fig. 1). Her avsluttes det klassiske sparagmittområdet mot syd, samtidig som traktene danner overgang fra forland til den miogeosynklinale sone av den kaledonske fjellkjede. Denne beliggenhet har satt sitt preg på stratigrafien og tektonikken. Oslofeltet har sin nordlige begrensning ved Mjøsa.

Avhandlingen er delt i en stratigrafisk og tektonisk del.

Stratigrafi.

I det stratigrafiske avsnittet blir det først gitt en oversikt over Sparagmittgruppens bergarter. De ble avsatt i to mer eller mindre adskilte bekkener. Forskjellig faciesutvikling forklares ut fra bekkenets gradvise utforming. Dette er sammenfattet i en paleogeografisk skisse (plate II). De yngste ledd av Sparagmittgruppen, Mjøskvartssandsteinen, finnes autokton på Nes og Furnes. I de øvre benker ble det der funnet vertikale ormerør etter *Scolithus*, *Monocraterion* og *Diplocraterion*. Disse "fossilene" er kjent fra underkambriske sandsteiner bl. a. i Syd-Sverige. Funnene kan tyde på at i hvert fall øvre del av Sparagmittgruppen bør regnes til Kambrium.

Kambrium.

Undersøkelsen bragte nye opplysninger om Undre Kambrium i distriktene. I Lauselva, Hov i Land (fig. 10, 11) ble det funnet *Callavia* n.sp. sammen med *Volborthella tenuis*. I Flagstadelva er det et nesten sammenhengende profil gjennom de underkambriske lagene (fig. 12, 13). Der ble det funnet en kalksandsteinsformasjon med *Holmia* cfr. *mickwitzi* under sandsteinslag med *Discinella holsti*. Over sonen med *Volborthella tenuis* er det et erosjonsdiskordans og et overliggende fosforittkonglomerat som parallelliseres med Ölandicus-sonen, 1 c α. Utviklingen av Undre Kambrium viser at det har vært ustabile forhold på den tiden med stadige trans- og regresjoner. Forfatteren anbefaler å bruke betegnelsen Eokambrium for den tiden da Sparagmittgruppens bergarter ble avsatt.

Ordovicium.

Utviklingen av de forskjellige formasjoner blir ganske kort kommentert. På grunn av lithostratigrafisk forskjell fra andre områder blir det foreslått innført lithostratigrafiske navn fra typeområder og lokaliteter i traktene. Dette gjelder også kambriske og siluriske lag.

Silur.

De siluriske lag har en langt større utbredelse enn det som går fram av tidligere geologiske kart. Sandsteinen som følger bruddet over den ordoviciske Mjøskalken viser interessante trekk i autoktone og alloktone lagserier. I nye skjæringer i Brumunddal (fig. 33) er sonen med *Pentamerus borealis* utviklet som en tynn kalksandsteinsbenk. I første skjæring nord for Torsæter bru ble det funnet fire bentonittlag i den siluriske monograptusskifer, 7 c.

Tektonikk.

Tektonikken i distriktene sees først i relasjon til utviklingen i sparagmittbekkenet og i den miogeosynklinale sone av den kaledonske fjellkjede. Tidligere foldingsfaser førte bare til epirogenetiske hevninger.

Ekne og Horg fasene forårsaket det store brudd i avsetning mellom Mellom-ordovicium og Silur.

Foldningene og skyvningene i området fant sted i en post-silurisk fase. Da antar en at øvre Jotundekke ble skjøvet fram. Metamorfe sparagmittbergarter med erosjonsrester av undre Jotundekke ble skjøvet over den geantiklinale sone inn i sparagmittområdet. Mjøs-kvartssandsteinen løsnet fra resten av sparagmittgruppen og skled fram på Ekreskifer 30-40 km. Ordoviciske og siluriske lag ble skjøvet over alunskifer og foldet over en uforstyrret grunnfjellsflate. Videre sammenskyvning førte til imbrikasjon og folding av sparagmittene. Dette forhold er skjematisk demonstrert fra Rendalen (fig. 40). Sparagmittbergartene ble foldet til inversjon mot sydveggen av bekkenet.

Det er vist hvordan gamle tektoniske linjer bl. a. begrensningen for sparagmittbekkenet har vært bestemmende for den kaledonske tektonikk.

Mjøstraktene ble naturlig delt i en sydlig autokton del og en nordlig allokton.

De autoktone lag er foldet over grunnfjell og har utviklet Juratype folder. Størrelse av foldene er bestemt av tykkelse og avstand mellom kompetente lag. Langs fronten av Kvartssandsteinsdekket er grunnfjellet delvis oppskjøvet i kaledonsk tid.

Kvartssandsteinsdekket viser taksteinstruktur av en spesiell type. Sterkt sammenpressede folder danner skjærfolder. Den kompetente Mjøs-kvartssandsteinen har dominert det tektoniske bilde. Orthocerkalken i allokton serie har med sine 40 m mektighet satt sitt preg på tektonikken.

Permiske forkastninger delte feltet opp i nord-syd gående blokker (fig. 61). De relative bevegelser er vist på tverrprofilene (fig. 62).

List of Literature.

Abbreviations:

G.F.F.: Geologiska Föreningen i Stockholms Förhandlingar. Stockholm.
K.N.V. Forh.: Det Kongelige Norske Videnskabers Selskabs forhandlinger. Trondheim.
N.G.T.: Norsk Geologisk Tidsskrift. (Kristiania) Oslo.
N.G.U.: Norges Geologiske Undersøkelse. (Christiania) (Kristiania) Oslo.
S.G.U.: Sveriges Geologiska Undersökning. Stockholm.
Vid.Selsk.: Videnskapsselskapet i Kristiania. Matematisk-naturvidenskapelig klasse. Kristiania (Oslo).

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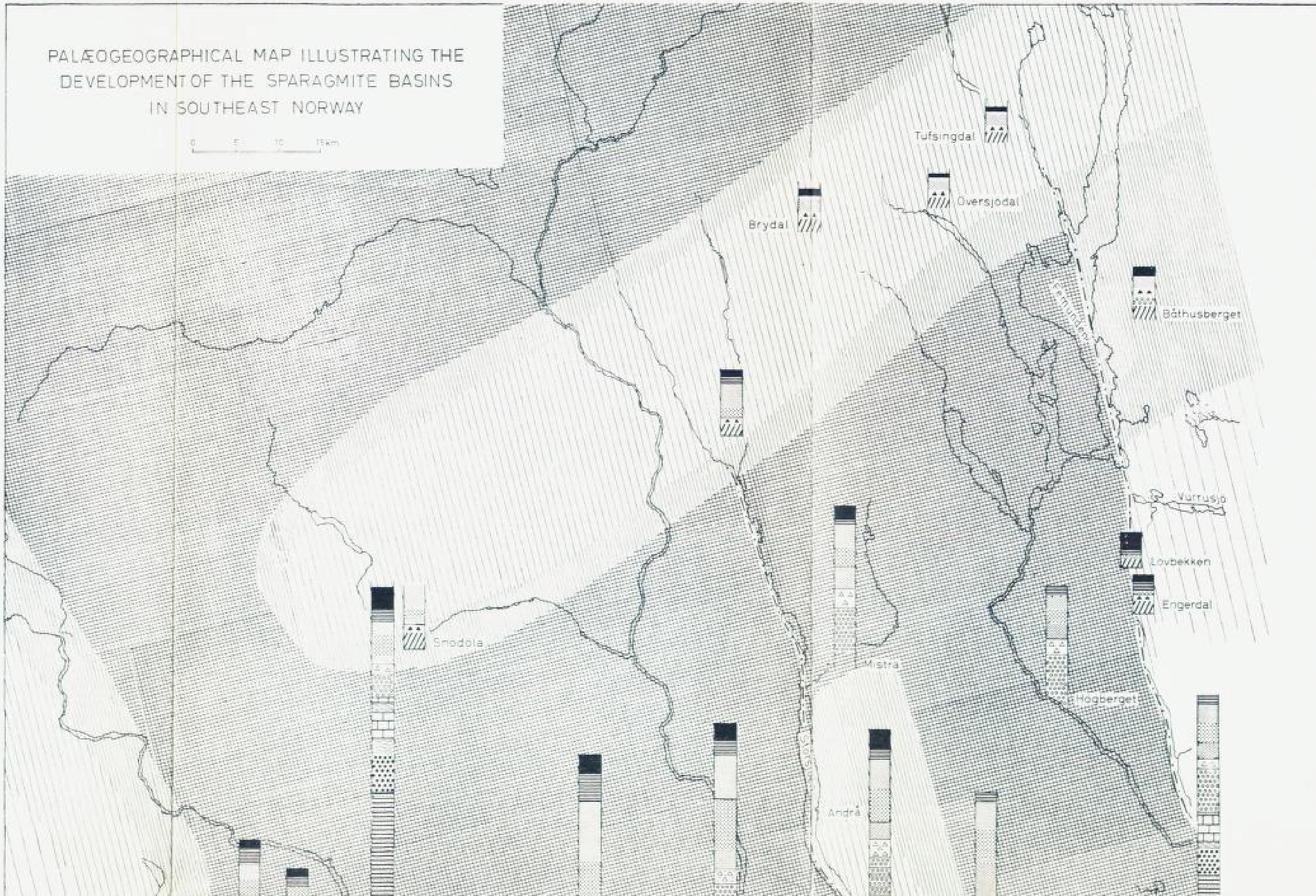
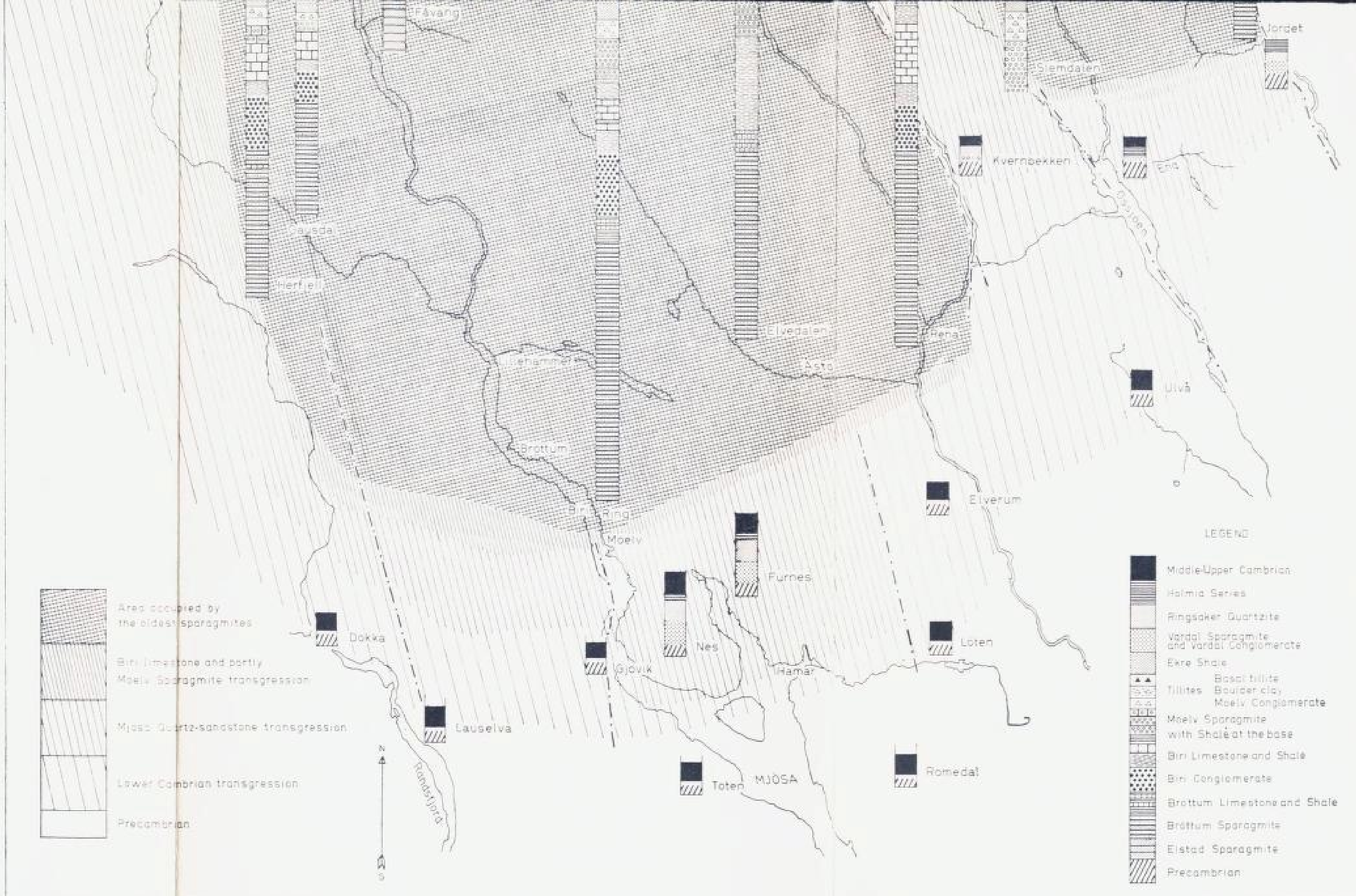

PALÆOGEOGRAPHICAL MAP ILLUSTRATING THE DEVELOPMENT OF THE SPARAGMITE BASINS IN SOUTHEAST NORWAY
0 5 10 15km
Tufsingdal
Oversjødal
Brydal
Femunden
Båthusberget
Vurrusjø
Løvbekken
Engerdal
Snødola
Mistra
Høgberget
Andrå

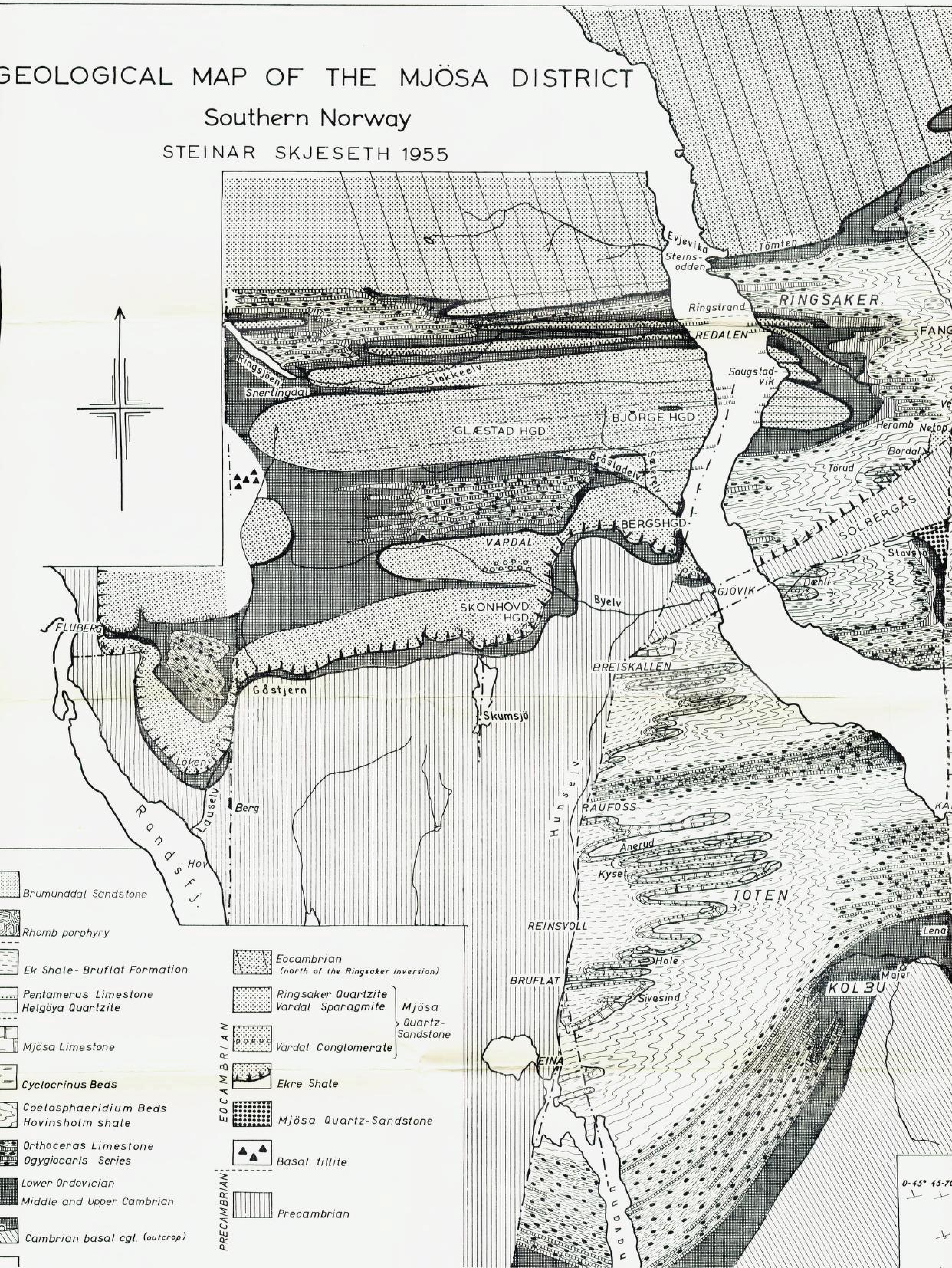


Fåvang
Jorget
Sjemdalen
Kvernbekken
Ena
Osen
Gausdal
Herfjell
Elvedalen
Hena
Åsta
Lillehammer
Ulvå
Brottum
Elverum
Biri
Ring
Moelv
Furnes
Nes
Gjøvik
Hamar
Dokka
Loten
Lauselva
Randsfjord
Toten
MJØSA
Romedal
N
S
Area occupied by the oldest sparagmites
Biri Limestone and partly Moelv Sparagmite transgression
Mjøsa Quartz-sandstone transgression
Lower Cambrian transgression
Precambrian
LEGEND
Middle-Upper Cambrian
Holmia Series
Ringsaker Quartzite
Vardal Sparagmite and Vardal Conglomerate
Ekre Shale
Tillites
Bosal tillite
Boulder clay
Moelv Conglomerate
Moelv Sparagmite with Shale at the base
Biri Limestone and Shale
Biri Conglomerate
Brottum Limestone and Shale
Brottum Sparagmite
Elstad Sparagmite
Precambrian

GEOLOGICAL MAP OF THE MJÖSA DISTRICT

Southern Norway

STEINAR SKJESETH 1955



Brumundsag
Holmen
Thor-
sæter
BØRGEBERGET
Brumundelv
VELDRE
HÖSBJÖRKAMPEN
Törbustilen
Brennsætersag
Nordby
ELVERUM
BRUMUNDDAL
Hellerud
Helleberget
Toppen
BANGS-
BERGET
Furnesfj.
VANG
LÖTEN
Flagstadelv
FURNES
JESSNES
Furu-
berg
Gålås
Domkirke-
odden
HAMAR
NES
Fura
Bokosjöen
Benningstad
OTTESTAD
Sæter
ROMEDAL
Busvold
Bergevika
HELGÖYA
Ek
Helskjær
STANGE
Skårås
Mjösa
Balke
Totenvika
Trondheim
Oslo
Strike and dip
Inverted beds
Minor thrust
Major thrust
(Quartz-sandstone nappe)