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THE GEOLOGY OF PART OF THE HØLONDA-HORG DISTRICT, A TYPE AREA IN THE TRONDHEIM REGION

BY

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With 1 Geological Map, 8 Plates and 9 Figures in the Text.

ABSTRACT

This study was conducted primarily to clear up the stratigraphy in a low-grade metamorphosed and fossiliferous area in the Trondheim region, and to get a safe foundation for further investigations in more metamorphosed parts of the same region. As to facies development, the Hølonda—Horg area occupies about the same position in the Norwegian parts of the Caledonids as the Girvan area and vicinity in the Scotch parts. Three conglomerates, representing as many breaks, divide the Ordovician to lowermost Silurian series of strata into four parts, viz. the Støren, Lower Hovin, Upper Hovin and Horg Series. These conglomerates can be traced in various areas in the Trondheim region and in Western Norway. The break between the two Hovin Series, representing the Ekne Disturbance, close to the divide between the Caradocian and Ashgillian Series, seems to be of greatest general importance. Besides the well known effusive Støren Greenstones of Skiddavian age three younger divisions of volcanic rocks are established with more or less certainty, probably ranging from Llandeilian to Ashgillian. The volcanic series, comprising basalts, andesites and rhyolites, exhibits a decided prevalence of soda as compared to potash. The younger volcanic rocks accentuate the analogy between the British and Norwegian parts of the Caledonids.

CONTENTS

INTRODUCTION

The area extending from Horg in the valley of Gauldal (formerly Guldal) across Hølonda (formerly Høilandet or Hølandet) to Meldal in the valley of Orkdal represents a key area to the geology of the Trondheim region. It was from this area that Theodor Kjerulf and Knut Hauan (Kjerulf 1875, 1879) derived their stratigraphic terms the Støren Group, the Hovin Group and the Høiland Group, with the Gula Group just outside of it to the southeast. The area has, in a remarkable way, escaped metamorphism, a fact which also clearly emerges from the investigations of V. M. Goldschmidt (1915), while it is surrounded by more high-grade metamorphosed sediments. Probably, there is no other area in the Trondheim region, at any rate not in the southern and central part, which display so low-grade metamorphism. The occurrence of several fossil horizons through a greater part of the series of strata in the area is evidently conditioned by this low-grade metamorphism. Since the 'seventies and 'eighties four fossil horizons were known, viz. the Kalstad Limestone, the Hølonda Limestone, the Hovin Sandstone sens. lat. and the *Dicranograptus* Shale, and one more, the Langeland Slate, is added in more recent times. In addition there are two conglomerates with fossils in the rock fragments from lower beds, viz. the Lyngestein Conglomerate and the Volla Conglomerate.

The author was introduced to this area by his late friend professor Johan Kiær who, to such a high degree, has advanced our knowledge of the stratigraphy of this area and of the Trondheim region (1926, 1932 a). In his last years of life he invited me, then recently moved to Trondheim, to take part in excursions to this area for discussions of geological problems. The bright summer days of old which I spent in the Gauldal, in the Hølonda and in the Meldal with this eminent scientist, magnanimous man and beloved friend certainly belong to my best memories of life. The author had not at that time planned any closer investigation of the area. Later, however, it was felt that a detailed investigation of at least parts of the mentioned area would be highly desirable.

Besides obvious stratigraphic problems there was the possibility of finding volcanic rocks of younger age than the well known low Ordovician Støren or Bymark Greenstones which induced me to take up these investigations. A. E. Törnebohm (1896) had, in fact, assumed the existence of such effusives in Hølonda, viz. the Hølonda Porphyrites, even if these rocks, by more recent authors, were considered as intrusives. Moreover, farther to the northeast, I had detected beds of rhyolite tuffs above the Støren or Bymark Greenstones, the stratigraphic position of which was otherwise, however, not quite clear. These expectations were more than realised, as I believe, although at present with some reservations, to be able to assume four horizons with volcanic rocks in the area Hølonda

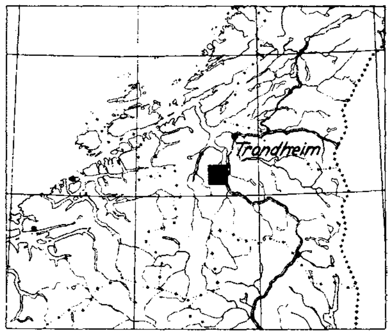


Fig. 1. The black square shows the position of the map area.

to Horg. They are: lowest, the well known Støren or Bymark Basaltic Greenstones, and, higher up, the andesitic Hølonda Porphyrites, the Hareklett and Esphaug Rhyolite Tuffs and the Grimsås Rhyolite or Quartz Porphyry, presumably ranging from the Skiddavian to the Ashgillian epoch.

The author worked for a short time in the field during the summers of 1940 and 1942, and a greater part of the summers of 1943 and 1944. In the field the sheet Melhus of the topographical maps to scale 1 : 100 000, enlarged to 1 : 25 000, was used. The geological mapping was performed for Norges Geologiske Undersøkelse, who also generously defrayed the expenses of 8 rock analyses. Some additional analyses of rocks from outside the mapped area were made possible by a grant from Norges Tekniske Høgskoles Fond, which also bestowed the funds to defray the expenses of the geological map accompanying this paper. I wish to express my thanks to director Carl Bugge and to the Trustees of Høgskolefondet, and to the former for the permission to publish the analyses and the present paper in this volume.

The investigations cover only a part of the area Horg—Hølonda—Meldal, but are intended to be continued in order to clear up some uncertain questions. It seems, however, expedient at this time to present a synopsis of the results so far achieved. In this paper a summary of the stratigraphic results will be given, and a description of the assumed volcanic rocks in the area. The geological map does not, by the way, cover all the surveyed area, which continues especially to the southeast on both sides of the valley of Gauldal.

PREVIOUS LITERATURE

The area Hølonda—Horg and vicinity has been one of the most intricate in norwegian geology, and for these reasons: First, the beds in the Horg syncline are steeply inclined and partly inverted, the chronological order of deposition not being immediately apparent. According to the dip of the beds the section might be interpreted as an anticline, or as a syncline, or, contingently, as a continuous series of beds. All these interpretations have been attempted.

Second, the series has different lithological development to the northwest and to the southeast. To the northwest occurs the Hølonda Beds, consisting of shales, sandstones, and partly quite thick limestones, while to the southeast appears the Hovin Series consisting of shales and sandstones, but without limestones. The area has never been to thoroughly studied that the relation of the Hølonda Limestone to the series of shales and sandstones to the southeast has been ascertained. The limestone, therefore, has been placed according to determinations of age on the basis of fossils.

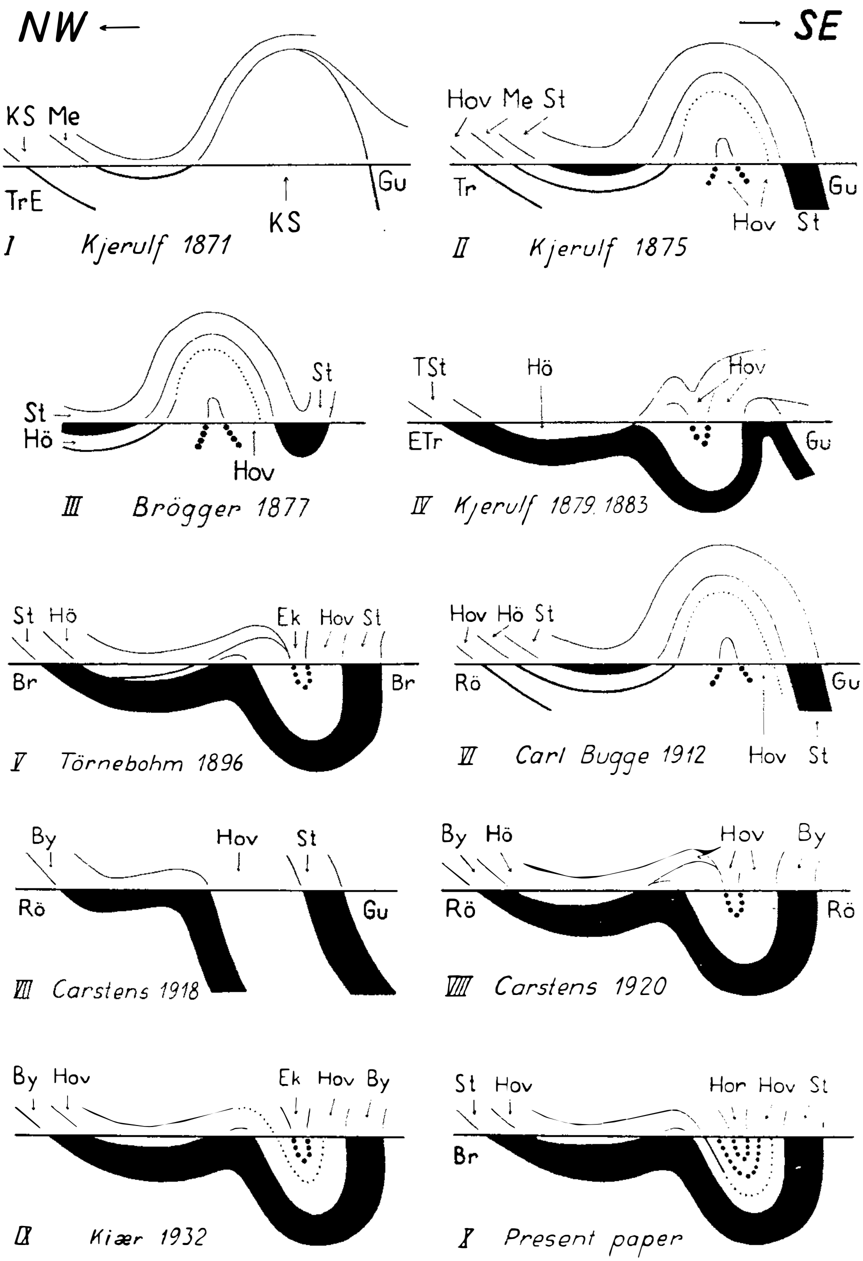
Third, the fossils from the Kalstad and the Hølonda Limestones in the Hølonda Beds were long ago referred, by Kjerulf (1871) and W. C. Brøgger (1877), in the main, to the Silurian system, while they, in fact, belong to comparatively low Ordovician, as stated by Johan Kiær (1926, 1932 a). Accordingly these limestones were, before the recent work of Kiær, considered younger than the Ordovician Trinucleus Sandstone Brøgger's in the Hovin Series, while, as a matter of fact, they are older. The fossils in the limestones were erroneously referred to the Silurian, partly owing to the fact that the fauna of the reference area, the Oslo region, was not sufficiently known in the 'seventies, and partly from the fact that the fauna of the Hølonda Beds, as assumed by Kiær, belong to another faunal province, corresponding to that of the Girvan area in Scotland.

In consequence of the complications mentioned above, the opinion of various authors as to the geology of this area has changed a great deal during the past. Furthermore, the authors have partly used different terms for one and the same series of beds, or the same term in deviating sense. I have, therefore, found it appropriate, and perhaps helpful to the readers, to make clear the conditions by a graphical synopsis (Fig. 2), which does not need extensive comments beyond the explanation to the figure.

Starting from a Silurian age of the Hølonda Beds, one arrives at a natural interpretation per se, when an anticline is assumed at Horg, as implied by Kjerulf (1875), Brøgger (1877) and Carl Bugge (1912). Brøgger mentions particularly that the limestones of the Hølonda Beds may be equivalent to that part of the Hovin Series which is situated farthest to the southeast in the section, close to the Støren Greenstones, so far in accordance with the present-day ideas. Actually no limestones were found there, but near Grut in Meldal limestone appeared in the same position. Today we may consider this as limestone or Hølonda facies, which extends as far as to the south side of the Horg syncline in the Orkdal valley.

Further geological investigations made it clear, however, that the folding at Horg could not be an anticline but a syncline. Kjerulf (1879, 1883) cannot be found to have made a direct statement to this effect as regards the area in question, but it was evidently his opinion. It was, however, the clue of Törnebohm (1896) to his interpretation of the western part of the Trondheim region, and the same applies to C. W. Carstens (1920). But since these authors had to start from the old conception of the age of the Hølonda Limestones in relation to that of the Hovin Sandstones, their solution of the problem was bound to be highly unnatural. It was the work of Kiær (1926, 1932 a) which provided the natural solution by the assumption that the Hølonda Beds were equivalent to the lower part of the Hovin Series.

Below follows a summary of the literature concerning the area covered by the map and nearest surroundings. Th. Kjerulf (1871, 1875, 1879), who started the systematic investigation of the Trondheim region, was particularly interested in the study of this area. His old geological map Melhus (1879) to scale 1 : 100 000, gives several informations and is even now of value. Kjerulf interpreted the Støren Greenstones partly as sediments (green mudstone and argillaceous sandstone, breccia etc.), and partly as intrusive greenstones. The Hølonda Porphyrites he evidently interpreted as intrusive rocks, they are, besides, not distinguished from the intrusive greenstones. Kjerulf (1871) placed the Kalstad Limestone at an age corresponding to the present-day Ordovician-Silurian étages 4—7 in the Oslo region. Kjerulf (1875, p. 27) indicates the following series of strata of the Hovin and Støren Groups from the section between Støren and Hovin, the terms used in the present paper being added in parenthesis:


NW ←
→ SE
KS Me
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KS
I Kjerulf 1871
Hov Me St
Tr
Gu
Hov St
II Kjerulf 1875
St
St
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III Brögger 1877
TSt
Hö
Hov
ETr
Gu
IV Kjerulf 1879. 1883
St Hö
Ek Hov St
Br
Br
V Törnebohm 1896
Hov Hö St
Rö
Gu
Hov St
VI Carl Bugge 1912
By
Hov
St
Rö
Gu
VII Carstens 1918
By Hö
Hov By
Rö
Rö
VIII Carstens 1920
By Hov
Ek Hov By
IX Kiær 1932
St Hov
Hor Hov St
Br
X Present paper

Fig. 2.

Fig. 2. Graphical synopsis of the interpretation of the various authors of the sequence of beds and of the foldings in the Hølonda—Horg area and surroundings. The terms used by the authors on series of beds (groups) are given. The low Ordovician Støren or Bymark Greenstones are marked out with black.

I. Kjerulf 1871: TrE = Trondhjemsfeltets eldre avdeling (Lower division of the Trondhjem region). KS = Konglomerat og sandstenrekken (Conglomerate and Sandstone Series); divided in 1875 in the Hovin Group and the Støren Group. Gu = Gulas skifre (Gula Schists). Me = Silurisk kalksten og lerskifer i Meldalen (Silurian limestone and shale in Meldal); in 1879 termed the Høiland Group.

II. Kjerulf 1875: Tr = Trondhjemsskifer = eldre avdeling (Trondhjem Schist = Lower division). Hov = Hovingruppen (Hovin Group). Me = Meldalens kalkstener (Meldal Limestones). St = Størengruppen (Støren Group). The three last mentioned groups constitute the Conglomerate and Sandstone Series = Middle division (Konglomerat og sandstensserien = midlere avdeling). Gu = Gulaskifer = yngre avdeling (Gula Schist = Upper division).

III. Brøgger 1877: Hov = Hovingruppen (Hovin Group). Hø = Høilandets kalkstener og skifre (Høiland Limestones and Shales). St = Størengruppen (Støren Group).

IV. Kjerulf 1879, 1883: ETr = Eldste Trondhjemslag (Lowest Trondhjem Beds). TSt = Trondhjem—Størengruppen (Trondhjem—Støren Group). Gu = Gulaskifrene (Gula Schists). Hov = Hovinsandstenens gruppe (Hovin Sandstone Group). Hø = Høilandets gruppe (Høiland Group).

V. Törnebohm 1896: Br = Brekskifergruppen (Brek Schist Group). St = Størengruppen (Støren Group). Hov = Hovingruppen (Hovin Group). Hø = Høilandets gruppe (Høiland Group). Ek = Eknegruppen (Ekne Group).

VI. Carl Bugge 1912: Rø = Rørosgruppen (Røros Group). Hov = Hovingruppen (Hovin Group). Hø = Høilandsgruppen (Høiland Group). St = Størengruppen (Støren Group). Gu = Gulagruppen (Gula Group).

VII. Carstens 1918: Rø = Glimmerskifer i den undre del av Rørosgruppen (Mica schist in the lower part of the Røros Group). By = Bymarkens grønnsten i den øvre del av Rørosgruppen (Bymark Greenstone in the upper part of the Røros Group). Hov = Hovingruppen (Hovin Group). St = Størengruppen (Støren Group). Gu = Gulagruppen (Gula Group). This sketched section is drawn through the same syncline as the others, but about 25—30 km farther to the NNE.

VIII. Carstens 1920: Rø = Rørosgruppen (Røros Group). By = Bymarkgruppen (Bymark Group). Hov = Hovingruppen (Hovin Group). Hø = Høilandets bergarter, regnet til Hovingruppen (Høiland rocks, classed with the Hovin Group).

IX. Kiær 1932: By = Bymark Greenstones. Hov = Hovin Group; the Høland division represents the lower part of the Hovin Group. Ek = Ekne Group.

X. Present Paper: Br. = Brek Series. St = Støren Series. Hov = Hovin Series, divided by a conglomerate in a lower and an upper part; the Hølonda Beds represent the lower part of the Lower Hovin Series. Hor = Horg Series.

a. Grey shales of the Gulfoss, lowermost (Gaulfoss Shales).
Lundemo Conglomerate (Lyngestein Conglomerate).
Hovin Sandstone (Id.).

b. Krokstad Sandstone (id.).
Green schist, chlorite schist, sandstone, breccia, argillaceous sandstone of the Støren narrowing, uppermost (Støren Greenstones and Krokstad Shales etc.).

W. C. Brøgger, in his exceedingly valuable paper (1877), offers the only more detailed description of a part of the Hølonda-Horg area existing so far, with geological sections and a geological map to scale 1 : 100 000. The Støren Greenstones and the Hølonda Porphyrites are interpreted as by Kjerulf. The Hølonda Porphyrites, termed porphyraceous diorite (porfyraktig diorit), are expressly regarded as intrusive rocks. He just mentions the Hareklett Rhyolite tuff from a single locality (the northern part of Harekletten), where it is termed a greenstonelike rock (grønstenlignende bergart), but elsewhere it is regarded as sandstone. Brøgger made admirable collections of fossils from the Hølonda Limestone at Stenset and Ven, and from a loose boulder of Hovin Sandstone near Esphaugen. He described (1877) the fossils from the Hølonda Limestone, termed the *Pentamerus* Limestone assuming an age corresponding to the present-day Silurian étages 5 b—7 in the Oslo region, considering the Kalstad Limestone to be contemporaneous. In a preliminary paper based on scant material, Brøgger (1875) referred the Esphaug fossils from his *Trinucleus* Sandstone to the Silurian étages 5 b—6 in the Oslo region, but in his final paper (1877) based on a larger amount of material he referred them to the uppermost part of étage 4 including 5 a in the Ordovician System, and perhaps to the lowermost part of étage 5 b, in the Silurian.

Alfred Getz (1887) described the graptolites from the *Dicranograptus* Shale, collected by M. Otto Herrmann (1884, 1885) and himself. The age of the horizon is supposed to correspond to Upper Llandeilian and Lower Caradocian in Wales and to transition beds between Glenkiln and Lower Hartfell of the Moffat Series in Scotland.

Hans Reusch (1891), a few years after he had published his pioneer work on the volcanic rocks of Western Norway, recognized the existence of lavas and pyroclastic material in the Trondheim region, viz. in the Støren Greenstones at the type locality of Støren. He also pointed to the connection with british vulcanism. The paper does not deal with the map area itself.

A. E. Tørnebohm (1896) presented a very short but excellent account of the geology of the Hølonda-Horg area, accompanied by a geological map to scale 1 : 800 000, which, in spite of the small scale, is still of great value. He clearly interpreted the Støren Group as a volcanic series consisting of basic lavas with pyroclastic material, distinguished it rather correctly from other rocks over large areas, and placed the series in the lower part of the Ordovician system. He also recognized the Hølonda Porphyrites as effusive rocks accompanied by pyroclastic material and pointed out their younger age in relation to the Støren Greenstones. In the same paper he interprets the Grimsås Quartz Porphyry as an intrusion of porphyry, but in a note in his preliminary communication (1892) it looks as if he entertains the idea that they may represent effusives.

Johan Kiær (1905) revised a part of Brøgger's fossils from the Kalstad and Hølonda Limestones and held that previous authors no doubt had ascribed them as of too young an age. They are assigned to horizons corresponding to the present-day lowest Silurian étage 5 b in the Oslo region. The *Trinucleus* Sandstone Brøgger's is referred to the uppermost Ordovician étage 5 a of the same region.

Per Schei (1909), who died young, and Carl Bugge (1910, 1912), who took up his work, found pillow lavas and beds of jasper (chert) in the Støren Greenstone, which they correlated with British pillow lavas and radiolarian cherts. According to a remark by Bugge (1910, p. 14) it looks as if Schei accepted Tørnebohm's interpretation of the geology of this area (see Fig. 2V), being of the opinion that the Røros Group had direct contact with the Støren Greenstones. Carl Bugge (1912) barely indicated intrusions of porphyrites, presumably belonging to the Hølonda Porphyrites, near Blokkum. None of these papers deal with the map area itself.

V. M. Goldschmidt (1916) comprises the volcanic greenstones of the mountain range, including the Støren Greenstones, and the accompanying basic intrusives to one group, viz. the stem of the green lavas and intrusive rocks. On his small scale map he marks the Hølonda Porphyrites as intrusive rocks belonging to the above mentioned stem. The rocks are not mentioned in the text.

C. W. Carstens (1920) assigns the Bymark (Støren) Greenstones to the lower part of the Ordovician, like Törnebohm, and emphasizes their submarine formation. In a later paper (1922 c), which does not deal with the map area, the series is correlated with british pillow lavas and radiolarian cherts of Arenig age. Structures in jasper from Løkken are interpreted as radiolaria. In his first and more comprehensive discussion of the Hølonda Porphyrites Carstens (1920), in agreement with Törnebohm's conception, interprets the rocks as probably being effusives and younger than the Bymark Greenstones. Some greenstones at Hølonda of the same petrological type as the Bymark Greenstones are moreover regarded as younger than the latter. In a subsequent paper Carstens (1922 b, vid. also 1922 a), however, interprets the porphyrites as intrusive rocks. He concludes that every reliable trace of younger ("Upper Ordovician") effusive rocks in Hølonda disappears. Carstens (1920, p. 92) advanced the following (with transitions connected) subdivision of the series of strata of the Hovin Group in the Gauldal valley, the Høiland Division being placed between b and c:

c. Thick conglomerates with shales, inter alia with the Lyngestein Conglomerate, which probably is younger than étage 5 b in the Oslo region; uppermost.
b. Thick sandstones beds, with the fossils from Grimsåsen, corresponding to étage 5 a.
a. Shales and thin sandstone beds, with graptolites in shale, corresponding to étage 5 a, lowermost, resting on the Bymark Greenstone.

Johan Kiær (1926, 1932 a) assumed a Llandeilian age of the Kalstad and Hølonda Limestones, and correlated them proximate with the Stinchar Limestone in the Girvan area in Southern Uplands in Scotland. Hence these limestones had to represent the lower part of the Hovin Series in the Gauldal valley. While the Hølonda Beds is correlated with the limestone development of the Girvan area, the lower part of the Hovin Series is correlated with the shale and sandstone development in the Northern Belt of the same region, a double connection of general interest. New fossils were collected by Kiær, especially from the Kalstad Limestone, and by Trygve Strand from the Hølonda Limestone at Ven and Stenset. The old as well as the new material was described in contributions by August F. Foerste (1932), Assar Hadding (1932), Ove Arbo Høeg (1932), Johan Kiær (1932 b), F. R. Cowper Reed (1932), Trygve Strand (1932) and

Leif Størmer (1932). These papers form the basis for the determination of the age of the fossil horizons in this area. Kiær (1932 a, pp. 44—45) presented the following subdivisions of the series of beds from the section of the Gauldal valley between Støren and Hovin:

The Ekne Group:

6. Sandå Shale and Sandstone; uppermost.
5. Lyngestein Conglomerate.

The Hovin Group:

4. Hovin Sandstones, with the Grimsås fauna. In its lower portion a conglomerate of small thickness interchanging with sandstone occur.
3. *Dicranograptus* Shale with the *Dicranograptus* fauna.
2. Krokstad Slate and Shales with sandstone layers. In the lower part a roofing slate with *Trinucleus forosi* is found.
1. Bjørgen (Bjørkum) Shale, lowermost, resting on the Bymark Greenstones.

At Hølonda Kiær found the following series of strata:

2. A thick limestone horizon, uppermost.
1. A shale division, lowermost, resting on the Bymark Greenstones.

THE STØREN SERIES

For this principally volcanic series the author has retained the old term introduced into the literature by Kjerulf in 1875, and explicitly defined and applied by Törnebohm in 1896. The series consists primarily of exceedingly thick effusive grenstones with pyroclastic material, which may no doubt, in the main, be correlated with the Ballantrae Volcanic Rocks in Southern Uplands in Scotland, and with other British volcanic rocks of corresponding age. The thickness of the greenstones at Støren may be about 2500 m. Moreover, in the northwestern part of the area, thick sedimentary beds consisting of shales, slates, sandstones and limestones were, surprisingly, found, which to all appearance are intercalated in the greenstone series.

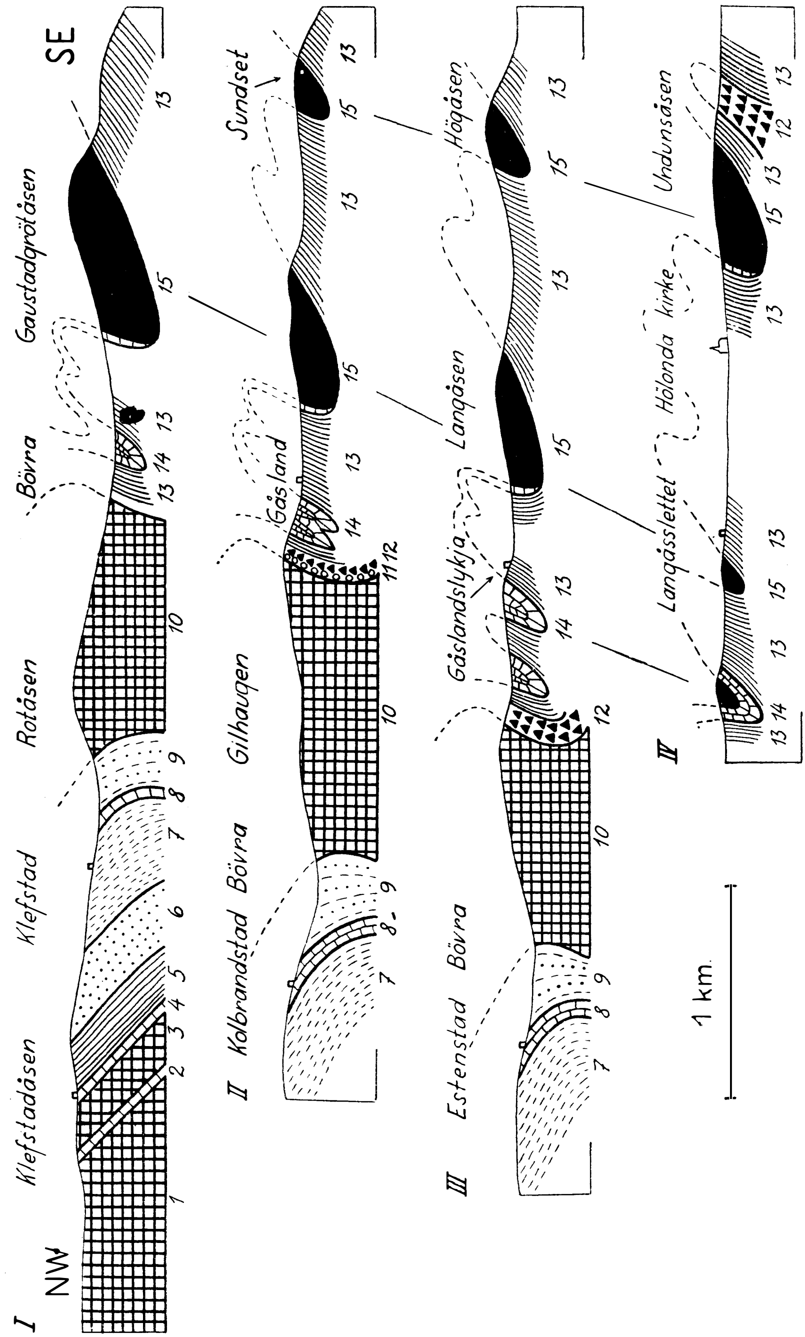
I
NW
SE
Klefstadåsen
Klefstad
Rotåsen
Bövra
Gaustadgrötåsen
II
Kolbrandstad Bövra
Gilhaugen
Gåsland
Sundset
III
Estenstad Bövra
Gåslandslykja
Langåsen
Högåsen
IV
Langåsslettet
Hölonda kirke
Undunsåsen
1 km.

Fig. 3.

The Intercalated Beds.

The thickest of the intercalated series of strata is the Jåren Beds, termed so from the district Jårengrenda, extending from Blokkum to Klefstad in the northwestern part of Hølonda. The numerous farms of the Jårengrenda are situated in line on limestone and easily disintegrated shales belonging to these beds, surrounded by harder rocks with woods on both sides. If large tectonic disturbances (overthrusts) do not exist, which can be definitely decided only by continued investigations to the north and south, the Jåren Beds may be normally intercalated in the greenstone series. The rocks of the Jåren Beds are somewhat more metamorphosed than the rocks of the Hølonda Beds. The Klefstadås and Blokkum Limestones, both belonging to the former beds, are metamorphosed to crystalline marbles, while the Hølonda Limestones generally is a fine-crystalline limestone. The shales belonging to the former beds are a little sericeous from fine scaly muscovite with chlorite, while the shales belonging to the latter beds are dull, only with the first traces of sericite.

To the east of the area of the Jåren Beds occur effusive greenstones, the upper of which is inverted to the southeast, see the sections Fig. 3 I—III. These greenstones undoubtedly belong to the Støren Greenstones. First, they are traced in the field in connection with indisputable Støren Greenstones farther to the north. Second, very characteristic beds, especially the Gaustadbakk Breccia, belonging to the lower part of the superimposed Hølonda Beds, appear along the inverted southeast side of the greenstones in question. It was these greenstones which, in the opinion of Carstens (1920), were younger than the Bymark (Støren) Greenstones, being assumed to rest in a syncline and to superimpose the Hølonda Beds.

The other series of strata intercalated in the Støren Greenstones is the Høve Slate, termed after the farm Høve at the norhern part of lake Ånøya, where the best known roofing slate quarries are situated.

Fig. 3. Geological sections from the northwestern part of Hølonda. 1 and 3: Lower Støren Greenstones. 2 and 4: Klefstadås Limestones. 5—9: Jåren Beds. 5: Vålåtjern Shales and Slates. 6: Restadgrøtås Sandstone and Schist. 7: Klefstad Shale. 8: Blokkum Limestone. 9: Klefstadmo Sandstones and Shales etc. 10: Upper Støren Greenstones. 11—14: Hølonda Beds. 11: Venna Conglomerate. 12: Gaustadbakk Breccia. 13: Hølonda Shales. 14: Hølonda Limestone. 15: Hølonda Porphyrite of the Almås type.

The Høve slate consists, at any rate in part, of fine-washed material of greenstone ash, and seems to have a more local extension.

These comparatively thick series of strata are found intercalated in the grenstones only to the northwest, whereas, to my knowledge, no other sediments than thin beds of red jasper occur farthest to the southeast, in the section of Støren. In the intermediate district, for instance around lake Grøtvatnet, a few thin beds of shales are found in he greenstones. They are, however, so thin that it has not been possible, at least not so far, to trace the beds in continuity in the highly covered country. Thus it looks as if the intercalated sedimentary beds, which are very thick to the northwest, are gradually thinning out and disappearing to the southeast. However, other possibilities may not as yet be repudiated.

Below follows a short description of the beds in the northwestern part of the area, the beds being listed from below:

1—4. The Lower Støren Greenstones with the Klefstadås Limestones.

1. The lower greenstones, lower part, basis not investigated. In the upper part, between the ridges Klefstadåsen—Røsliåsen and the farm Dalen, the greenstone is highly chloritized and frequently foliated.

2. The lower Klefstadås Limestones are usually snow-white, sometimes faintly pink calcite marbles. At the trail to the north of the farm Klefstadåsen two comparatively thin limestone beds appear, which join and increase much in thickness to the northeast.

3. The lower greenstones, upper part, with the Middle Klefstadås Limestones. The greenstones consist, inter alia, of greenstone breccia with abundant calcite, in part foliated, but sometimes well preserved. In this section some beds of white calcite marble appear to the northeast, but none to the southwest.

4. The Upper Klefstadås Limestones are greyish white calcite marbles, appearing together with thin beds of dark shales.

The Klefstadås Limestones, especially the lower, seem to correspond to the Estenstad Limestone a few km to the southeast of Trondheim. Here a white marble is encountered, which, in appearance, is very nearly identical with the Klefstadås limestones, also occurring in the same stratigraphical position. It is intercalated in greenstones, the superimposed part of these likewise containing greenstone breccia.

5—9. The Jåren Beds, thickness perhaps about 800 m.

5. The Vålåtjern Shales and Slates are commonly light greyish green to light grey shales and slates, with fine scaly muscovite and chlorite.

6. The Restadgrøtås Sandstones and Schists. The beds are massive and resistant to erosion, and form a range of ridges. Grey sandstones with much calcite and grains of quartz, quartzite and plagioclase appear, and greyish green massive schists with calcite, fine scaly muscovite, chlorite etc.

7. The Klefstad Shale, commonly dark grey, easily disintegrated shales with sericite.

8. The Blokkum Limestone, a greyish to lighter or darker bluish grey crystalline marble, comparatively thin in some places, but thick especially to the south, from Kolbrandstad to Blokkum, where it is also quite pure. Here it contains beds of sandstone and shale.

9. The Klefstadmo Sandstones, Shales and Schists, a rather varying series of beds.

10—12. The Upper Støren Greenstones with the Høve Slates.

10. The upper Greenstones, lower part.

11. The Høve Slates are greyish green to greenish slates, which have been quarried as roofing slate, and partly as flagstone, in many places, viz. at Myråsen, Stranda, Strandmoen, Høve, and Merket. Faint indications of ripplemarks are rarely seen. The slates consist of abundant albite and chlorite, frequently much epidote, and besides quartz, calcite and traces of sericite. Nearest above and below the slate, indistinctly bedded greenstone tuffs appear. They are more coarse-grained than the slates, and contain about the same minerals, whereof especially albite and chlorite abounds. The Høve Slates and the coarser tuffs are connected by transition beds, the boundaries, therefore, being estimated. It can hardly be doubted that the Høve Slates are containing a good deal of tuff material. They seem to disappear to the south, where they presumably pass into coarser greenstone tuffs not distinguished from the other greenstones.

12. The Upper Greenstone, upper part.

The Støren Greenstones and Associated Rocks.

Greenstones with fine pillow or ellipsoidal structures are exposed in road cuts and along the shore on the west side of lake Benna (Pl. III, Fig. 1). This bed, presumably, represents a single submarine lava flow. The structure resembles ellipsoidal pillows or woolbags of different size closely piled together. The size is from a few dm's to more than 1 m, rarely up to 1.5 × 2 m in diameter; most of them measures, perhaps, about 0.4 × 0.6 m. They have obviously been plastic, which is evident from the fact that they have partly made indentations into each other, a convex part of a pillow may lie up to a concave part of another, or both are flattened. One has the decided impression that this plasticity prevailed during the formation of the pillows. The outer margin is excessively chloritized, but frequently with an epidote rich border just inside. The interior of the pillows is comparatively well preserved, with hornblende, epidote, albite, chlorite, calcite, and titanite. The pillow structures are obviously identical with corresponding structures for instance in the Ballantrae Volcanic Rocks in Scotland, see Peach and Hornes memoir (1899). From Norway (Hordaland) the pillow structure was first figured and described by Hans Reusch (1888, p. 109—110, 402), as a cooling phenomenon in an old lava flow.

Beds of red jasper are rather common in the greenstone, and in this area without accompanying sediments of other nature. The thickness is mostly quite small, for instance 0.5—1 m, the beds being only exceptionally thicker. Along the strike the beds wedge out rapidly. The jaspers, in all probability, represent metamorphosed radiolarian cherts. The conditions for their appearance in the greenstones may be the absence or very scant supply of terrigenous sediments and a certain supply of siliceous water from volcanic action to the sea-water.

Some beds of shale, a few m thick, are found here and there, especially around lake Grøtvatnet. They generally consist of very fine clay material, and contain sericite and chlorite.

Greenstone breccias and agglomerates with more or less irregular fragments are very common (Pl. III, Fig. 2). Fragments of red jasper are also frequently found in the breccias. These fragments are often irregular in form, but may be somewhat rounded. Nevertheless, they do not seem to represent boulders in a genuine conglomerate. Thus, they are sometimes arranged in line, as if originating from a single bed of jasper broken into fragments. In addition to the somewhat different types of greenstone and fragments of red jasper, large fragments of tuff material of the Høve Slate type appear. The breccias evidently belong to the period of formation of the greenstone series. The author assumes that jasper fragments of at least one type are formed by laceration of somewhat consolidated jasper beds, through disturbances of the deposits on the sea bottom, either through volcanic eruptions, or by submarine slides on steep slopes. Breccias with fragments of jasper are often found in the upper part of the greenstone series, but also appear quite far down in the series. In the Trondheim region these breccias have, presumably, often been mistaken for the basement conglomerate (the Venna Conglomerate) superimposing the Støren Greenstones, at the base of the Hovin Series. Beyond this, very much of the greenstone series is so metamorphosed, that it is difficult to decide whether it is lavas or breccias and agglomerates or tuffs. The safest indication of the breccias is the appearance of fragments of red jasper, which will always be well preserved and easily visible.

The greater part of the greenstones are metamorphosed into rocks with abundant calcite and with chlorite, albite, quartz and titanite, with or without epidote. Elsewhere the rocks may contain actinolite or green hornblende, epidote, chlorite, albite, quartz, titanite, and more or less calcite (see Pl. VI, Fig. 1). Greenstones without hornblende minerals obviously occur in much greater quantities than greenstones with these minerals. Of mineral facies the following are represented: albite-chlorite facies, greenstone facies, actinolite greenstone facies and transitions to epidote amphibolite or saussurite gabbro facies, The whole series may be termed spilites.

From the Trondheim region, but outside the area in question, two analyses of rocks, apparently belonging to low-temperature stages, are published by V. M. Goldschmidt (1916 a), see analyses A—B p. 468. They contain 26.63 and 7.50 pct. calcite respectively, and may be representative of the most common greenstone types. The original chemical composition of the rocks is, however, considerably changed, especially as to the lime content.

Disregarding the different stages of metamorphism, several types of rocks existed originally. The all dominating type is without phenocrysts and with laths of albite, the original texture being more or less obliterated through the metamorphism. A rock of this type, belonging to the least metamorphosed part of the series, was selected for analysis from a large amount of material, see analysis 1 p. 466. The rock is rather light greenish coloured on account of the comparatively minor content of chlorite. The composition is typically basaltic. From the Trondheim region, but outside the area in question, C. W. Carstens

Analysis 1		Norm		Mineral composition	
SiO_2	48.16	Orthoclase	0.66	Quartz	10.90
TiO_2	0.92	Albite	22.23	Albite	11.99
ZrO_2	none	Anorthite	30.43	Hornblende	37.20
Cr_2O_3	0.06	Diopside	12.73	Epidote	22.43
Al_2O_3	15.60	Hedenbergite	5.60	Chlorite	14.82
Fe_2O_3	3.41	Enstatite	10.13	Titanite	2.25
FeO	7.41	Ferrosilite	5.11	Pyrite	0.04
MnO	0.16	Forsterite	1.94	Apatite	0.26
MgO	7 55	Fayalite	1.08	Calcite	0.48
CaO	11.12	Magnetite	4.95	H_2O	−0.42
BaO	none	Ilmenite	1.74		
Na_2O	2.63	Chromite	0.09		99.95
K_2O	0.11	Pyrite	0.04		
P_2O_5	0.11	Apatite	0 26		
S	0.02	Calcite	0.48		
F	none	H_2O	2.48		
CO_2	0 21				
$H_2O + 110°$	2.38		99.95		
$H_2O - 110°$	0.10	Colour index	43.67		
	99.95	Shand classification: Lime sub-basalt			
Gr.	3.010	CIPW classification: Auvergnose			

Analysis 1: Basaltic Støren Greenstone from lake Benna SW of Løberg seter, Horg. Analyst: Martha Klüver.

(1922 c) has published four analyses of comparatively well preserved rocks, see analyses C—F, p. 468. They generally show a somewhat unusual composition by the high percentages of magnesia in proportion to those of lime, and a checking of these analyses would, perhaps, be desirable. In order to get more information as to the chemical composition of these lavas, I have had analyzed two uncommonly well preserved rocks without phenocrysts from presumably corresponding greenstones of Western Norway, collected by the author during an excursion in 1931 under the guidance of C. F. Kolderup and N.-H. Kolderup, see the analyses 2 and 3, p. 467. Of these, analysis 2 exhibits a basaltic composition near to that of analysis 1, while analysis 3 shows a composition between basalt and andesite.

The analyses 1 and 2 display a striking accordance with the composition of plateau basalt, see the average of these two analyses, G, and the two averages of plateau basalts, H and I, on p. 468. This accordance indicates that these greenstones have preserved their chemical composition remarkably unchanged. In this connection the low percentages of carbon dioxide may be pointed out. A characteristic

	Analysis 2	Analysis 3
SiO_2	49.84	53.31
TiO_2	1.67	2.27
ZrO_2	none	none
Al_2O_3	12.85	14.84
Fe_2O_3	2.32	4.00
FeO	9.60	7.80
MnO	0.16	0.14
MgO	6.88	3.55
CaO	11.70	5.85
BaO	0.04	0.07
Na_2O	2.78	3.21
K_2O	0.19	2.65
P_2O_5	0.11	0.43
S	0.06	0.06
F	none	none
CO_2	0.06	none
$H_2O + 110°$	1.54	1.92
$H_2O - 110°$	0.06	0.10
	99.86	100.20
− O for S	0.01	0.01
	99.85	100.19
Gr.	2.988	2.859

Norm	2	3
Quartz	-	6.21
Orthoclase	1.11	15.64
Celsian	0.11	0.18
Albite	23.49	27.16
Anorthite	21.97	18.13
Diopside	17.17	3.86
Hedenbergite	11.46	2.81
Enstatite	8.51	7.05
Ferrosilite	6.53	5.91
Forsterite	0.46	-
Fayalite	0.39	-
Magnetite	3.36	5.80
Ilmenite	3.17	4.31
Pyrite	0.12	0.12
Apatite	0.26	0.99
Calcite	0.14	-
H_2O	1.60	2.02
	99.85	100.19
Colour index	51.43	30.85

Shand classification 2: Soda sub-basalt
3: Soda basalt, near soda andesite

CIPW classification 2: Auvergnose
3: Shoshonose

Analysis 2: Basaltic greenstone from Værøy in Askvoll, Sogn og Fjordane. Analyst: Martha Klüver.

Analysis 3: Andesito-basaltic greenstone from neolitic stonepit on Hesperøy, Nordøyane in Bømlo, Hordaland. Analyst: Martha Klüver.

feature of the Norwegian basaltic greenstones is the extremely low amount of potash, also appearing from the analyses B—F, and further the lower content of titanium dioxide. The low amount of potash is, in general, characteristic for many spilites, and has been regarded as due to leaching.

Of particular interest is the accordance between the amount of soda in the analyses 1 and 2 (G) and in the plateau basalts. In this instance it seems to be no question of addition of soda to the greenstones. It is not possible in this preliminary paper to discuss the fascinating spilite problem. It may only be mentioned, that even in submarine greenstones of the pillow lava type, it seems that production of albite may in some cases depend on regional metamorphism at low temperature, without addition of soda.

	A	B	C	D	E	F	G	H	I
SiO_2	38.07	47.78	46.66	46.78	49 06	54.50	49.00	47.14	48.80
TiO_2	0.66	1.40	1.70	1.36	1.04	2.00	1.30	2.44	2.19
Al_2O_3	13.71	14.95	16.38	15.51	17.28	15.32	14.25	14.91	13.98
Fe_2O_3	1.72	3.45	1.56	0.77	2.10	2.27	2.87	4.11	3.59
FeO	4.50	5.26	7.95	9.61	7.72	5.06	8.50	8.22	9.78
MnO	0.12	0.13	0.19	0.18	0.13	0.08	0.16	0.25	0.17
MgO	4.64	5.38	11.02	8.39	7.39	7.58	7.22	6.91	6.70
CaO	16.12	11.87	7.62	5.84	8.01	5.14	11.43	10.01	9.38
Na_2O	2.98	2.95	2.76	3.23	3.72	5.42	2.70	2.71	2.59
K_2O	2.43	0.21	0.14	0.15	0.08	0.19	0.15	0.84	0.69
P_2O_5	0.07	0.11	0.17	0.26	0.22	0.32	0.11	0.33	0.33
S	0.04	trace	-	0.12	0.06	-	0.04	-	-
CO_2	11.71	3.30	none	2.50	1.28	none	0 14	-	-
H_2O+	3.27	3.06	3.42	5.16	2.31	2.35	1.96	2.13	1.80
H_2O-	0.11	0.06	0.24	0.04	0.10	0.20	0.08		
	100.15	99.91	99.81	99.90	100.50	100.43	99.91	100.00	100.00

A. Pillow lava, Løkken mine, Meldal (V. M. Goldschmidt 1916 p. 15).
B. Pillow lava, Haga bridge, Støren (V. M. Goldschmidt 1916 p. 15).
C. Light greenstone, Frilsjøen, Meldal (C. W. Carstens 1922 c p. 195).
D. Schistose greenstone, Dragset, Meldal (C. W. Carstens 1922 c p. 202).
E. Greenstone schist, Skjødskift, Meldal (C. W. Carstens 1922 c p. 204).
F. Dark greenstone, Bjørnlivatn, Løkken, Meldal (C. W. Carstens 1922 c p. 198).
G. Average of analyses 1 and 2 in this paper.
H. Plateau basalt, average of 27 analyses (Tyrrell 1921).
I. Plateau basalt, average of 43 analyses (Daly 1933 No. 60).

Besides the dominating basaltic greenstone type without phenocrysts, other types are found, as mentioned, in minor quantities. One type contains abundantly phenocrysts of albite and somewhat less of dark minerals than the principal type. Another type contains, besides phenocrysts of albite, corroded phenocrysts of quartz. The latter type may contain rather a great deal of dark minerals, while it in part is considerably lighter green than the common greenstone. None of these rocks are analyzed as yet.

In addition to the effusive rocks mentioned above, minor intrusions of very light grey to almost white quartz-keratophyres occur in several places. The thickness is from a few up to about 15 meters, perhaps somewhat more. They are probably injected in the basic volcanic rocks near the existing surface. The rocks contain phenocrysts of albite and corroded quartz in a very fine-grained groundmass, with quartz, albite, muscovite, chlorite etc. (see Pl. VI, Fig. 2). They are partly silicified. Two analyses of these rocks are performed,

Analysis 4		Norm		Mineral composition	
SiO_2	72.96	Quartz	30.96	Quartz	31.55
TiO_2	0.18	Orthoclase	14.96	Albite	48.75
ZrO_2	none	Celsian	0.15	Clinozoisite	0.49
Al_2O_3	15.90	Albite	44.93	Biotite	0.45
Fe_2O_3	0.86	Anorthite	1.25	Muscovite	15.76
FeO	0 37	Corundum	3.92	Chlorite	1.97
MnO	0.01	Enstatite	1.40	Magnetite	0.51
MgO	0.56	Magnetite	1.16	Titanite	0.45
CaO	0.46	Hematite	0.06	Pyrite	0.04
BaO	0.06	Rutile	0.18	Apatite	0.07
Na_2O	5.31	Pyrite	0.04	Calcite	0 30
K_2O	2.53	Apatite	0.07	H_2O	− 0.24
P_2O_5	0.03	Calcite	0.30		
S	0.02	H_2O	0.72		100.10
F	none				
CO_2	0.13		100.10		
$H_2O + 110^\circ$	0.67	Colour index	6.83		
$H_2O - 110^\circ$	0.05				
	100.10				
Gr.	2.729				

Shand classification: Soda rhyolite

CIPW classification: Kallerudose

Analysis 4: Quartz-keratophyre from Sagelva between the lakes Skjegstadvatnet and Ånøya, Hølonda. Minor intrusion in the Støren Greenstone. Analyst: Martha Klüver.

Analysis 5		Norm		Mineral composition	
SiO_2	84.48	Quartz	67.05	Quartz	67.92
TiO_2	0.13	Orthoclase	7.68	Albite	15.21
ZrO_2	0.04	Albite	15.21	Muscovite	10.99
Al_2O_3	8.45	Anorthite	0.30	Chlorite	4.63
Fe_2O_3	0.51	Corundum	3.97	Magnetite	0.74
FeO	1.24	Enstatite	1.84	Titanite	0.21
MnO	0.03	Ferrosilite	1.67	Rutile	0.04
MgO	0.74	Magnetite	0.74	Zircon	0.06
CaO	0.31	Ilmenite	0.24	Pyrite	0.04
BaO	trace	Zircon	0.06	Apatite	0.03
Na_2O	1.80	Pyrite	0.04	Calcite	0.41
K_2O	1.30	Apatite	0.03	H_2O	−0.14
P_2O_5	0.01	Calcite	0.41		
S	0.02	H_2O	0.90		100.14
F	none				
CO_2	0.18		100.14		
$H_2O + 110^\circ$	0.86	Colour index	8.59		
$H_2O - 110^\circ$	0.04				
	100.14				
Gr.	2.688				

Analysis 5: Silicified quartz-keratophyre from lake Grøtvatnet, second promontory SE of Ven, Hølonda. Minor intrusion in the Støren Greenstone. Analyst: Martha Klüver.

see analysis 4 and 5, p. 469. Both rocks, no doubt, have lost a part of their original lime content. The establishment of quartz-keratophyres in genetical connection with the basic pillow lavas is interesting. It may, perhaps, be pointed out that Hans Reusch, as early as in 1888, found quartzporphyries and quartz-porphyry tuffs together with the greenstones of Bømmeløy in southwestern Norway.

THE HOVIN SERIES

It is suitable to divide the description of this sedimentary series with accompanying volcanic rocks into different parts, comprising the following areas:

1. The northwestern or Hølonda area. The Hølonda Limestone is partially developed in this area, but not in all places. Here the Hølonda Porphyrites appear, not being traced in the following two areas. In this area, only the lowest part of the Hovin series is preserved, as far as hitherto is known.

2. The intermediate area, representing the northwestern part of the Horg Syncline. The Hølonda Limestone appears locally in this area, but wedges out rapidly. Here the Hareklett and Esphaug Rhyolite Tuffs and the Grimsås Rhyolite or Quartz-porhpyry appear. The geology of this connecting area was formerly least known, the area being somewhat less accessible than the other two.

3. The southeastern area, representing the southeastern part of the Horg Syncline. Here no Hølonda Limestone appears, nor are volcanic rocks traced, except as pebbles in conglomerates. This is the classical Hovin area, which has previously been treated by several authors.

The Northwestern or Hølonda Area.

As to the tectonics, this area is built up of minor synclines and anticlines. The following synclines are apparent: in the eastern part of the area: 1. the Stenset Syncline; 2. the Berg Syncline; and 3. the Ramberg Syncline; in the western part of the area: 4. the Sundset Syncline; 5. the Almås Syncline; and 6. the Brennhokster Syncline. Syncline 4 may represent a continuation of syncline 2, and 5 of 3.

The hard rocks of the Hølonda Porphyrites, as the youngest member of the series, rest in the troughs of these synclines, and protrude as wooded ridges, often with very steep sides, see Pl. I, Fig. 2 and Pl. II, Figs. 1 and 2. The porphyrites in the eastern and in the western synclines belong to distinctly different types. As will be seen from sections I—IX on Figs. 3—5, the beds are frequently inverted to the southeast, indicating a general orogenic stress in this direction. Also within this area the lithological development varies considerably, almost every one of the mentioned synclines offering distinctive features as regards the development of the sediments. Below follows a description of the series of beds, listed from the bottom.

1. The Venna Conglomerate.

The Venna Conglomerate rests directly on the Støren Greenstones. It is best exposed on a promontory in the lake Grøtvatnet to the northeast of the farm Ven. The bulk of the material here consists of oblong, frequently irregular and twisted fragments of a very characteristic sandstone rich in calcite: the colour of the rock is light grey to light purplish-red, with weathered lines along the bedding, and consisting of fine-grained quartz with much fine-grained calcite, frequently so much that the rock is on the border of a quartz rich limestone. This type is not apparent in solid rock of the substratum. Frequently roundish boulders, up to some dm. in size, occur, consisting of a white or faintly pink calcite marble, which somewhat resembles the Klefstadås Limestones (see Pl. V, Fig. 1). Many larger boulders and smaller pebbles of red jasper also occur. A single large boulder of a rock with phenocrysts of albite and corroded quartz in a very fine-grained groundmass was found, much resembling the minor intrusions of quartz-keratophyre in the substratum. The common Støren Greenstone from the substratum I have hardly observed with certainty in this location; a few quite small pebbles may possibly pertain hereto.

A basal conglomerate of the same type, with, inter alia, the same characteristic calciferous sandstone, appear in two other places in the vicinity, both situated near the southern part of the lake Grøtvatnet. A basement conglomerate of another type, with pebbles of greenstone and red jesper etc. was found to the northwest of the farm Gåslandsgjerdet.

As generally observed, the pebbles in the Venna Conglomerate are inconsiderably rounded. One may, sometimes, use the term

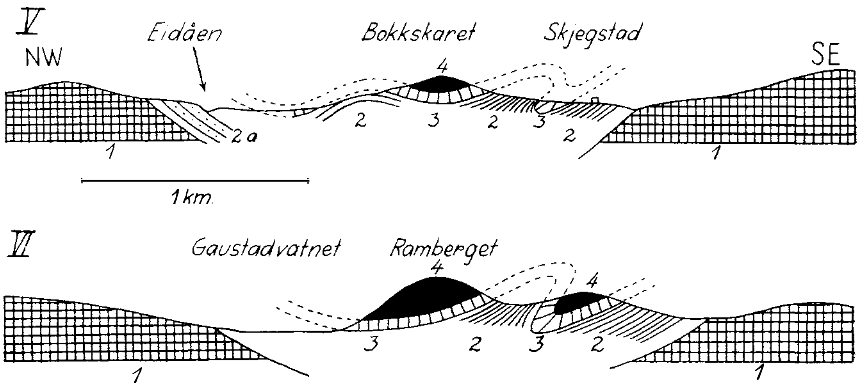

Fig. 4. Geological sections from the Skjegstad-Berg area. 1: Støren Greenstones. 2: Hølonda Shale (2) and Sandstone (2 a). 3: Hølonda Limestone. 4: Hølonda Porphyrite, Berg type.

breccia instead of conglomerate. The fragments consist at the same time of rocks which decompose more or less rapidly. The rock material, therefore, cannot have been transported very far.

This conglomerate is interpreted as the basal conglomerate of the Hovin Series. It is of interest to note that fragments of limestones and calciferous sandstones in the conglomerate are metamorphosed, the former into white marble, while the Hølonda Limestone, which appears not far up in the series above the conglomerate, is a bluish-grey unmetamorphosed limestone. Since the fragments of marble and calciferous sandstone seem to originate from the caledonian substratum, it looks as if this has been somewhat metamorphosed before the formation of the Venna Conglomerate.

2. The Gaustadbakk Breccia.

This characteristic breccia appears low down in the series, near the Støren Greenstones and below the Hølonda Shales. To the northwest of Gåslandsgjerdet the breccia occurs between the basal conglomerate (Venna Conglomerate) and the Hølonda Shales. Previous authors have interpreted this breccia as younger than the Hølonda Limestone. This is not surprising, because it really looks like it at the easily accessible road exposure near the farm Gaustadbakken. Here tectonic disturbances must, however, occur, probably a thrust, see fig. 6. For the conditions are otherwise clear enough in several

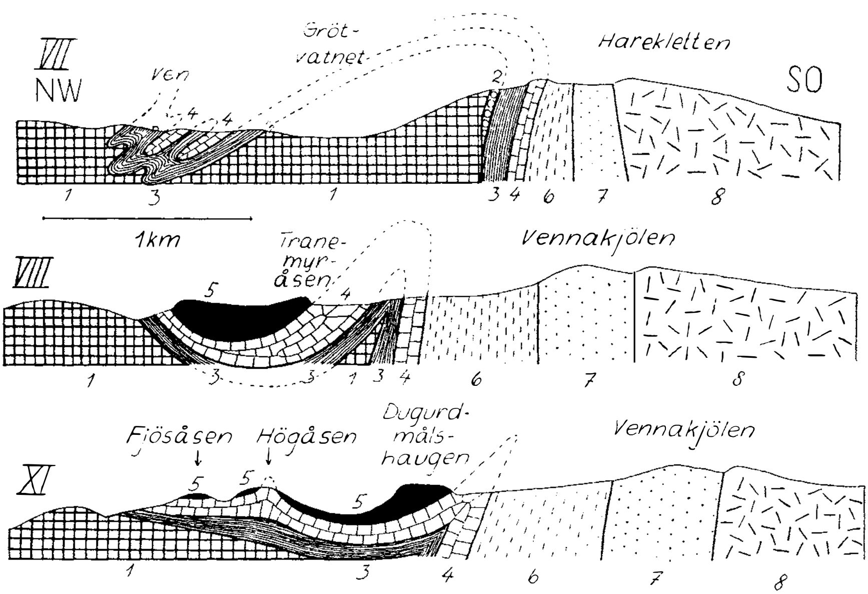

Fig. 5. Geological sections from the Ven-Stenset area. 1: Støren Greenstones. 2: Venna Conglomerate. 3: Hølonda Sandstone and Shale. 4: Hølonda Limestone. 5: Hølonda Porphyrite, Berg type. 6: Krokstad arenaceous Shale. 7: Krokstad Sandstone and Grit. 8: Hareklett massive Rhyolite Tuff.

places in the vicinity, for instance to the east of Gaustadbakken and around the lakelet Stensettjernet. The Gaustadbakk locality seems to have been of some consequence for the old interpretation, e. g. by W. C. Brøgger, as to the mutual relation between the Støren and Hovin Groups.

At Gaustadbakken and other places in the vicinity the breccia consists of thick beds with fragments of Støren Greenstones up to a few cm in size, further of fragments of red jasper, of several sediments etc., which are embedded in a reddish to reddish purple sandstone, with grains of quartz, quartzite, albite etc. Intercalated are thin beds of the same reddish sandstone, of green sandstone and chocolate-coloured shale. The thickness seems to vary abruptly, from a comparatively small thickness immediately above the Støren Greenstone in the woods to the east of Gaustadbakken, to a large thickness at the same farm and to the west of it.

This breccia is especially prominent in the area to the southwest and south of Hølonda church. Here mainly fragments of unmetamorphosed chocolate-coloured shale and mudstone appear, also pebbles or boulders of red jasper, crystalline limestone, etc. The chocolate-coloured shale and mudstone resemble the Almås Mudstone, which is superimposed on the breccia to the west of Gaustadbakken and in other places.

The red or reddish purple colour of the sandstones and mudstones in the Gaustadbakk Breccia is noteworthy. The colour of these sediments is a continental feature, which is in accordance with their appearance just above the basement conglomerate. It may be assumed that a regression has taken place at the time following the formation of the Støren Greenstones, rising land masses above the surface of the sea in these regions. The reddish beds may be attributed to the sedimentation of red soils from a land with semi-arid climate, indicating a hot and dry season each year; compare the conditions e. g. on the leeward side of the Hawaiian Islands (Twenhofel 1926).

3. The Hølonda Shales and Sandstones.

The different rocks of the series are well represented in the Almås section, see Fig. 6. Superimposing the Gaustadbakk Breccia occurs the chocolate-coloured mudstone, the Almås Mudstone, mentioned above. In future it should be distinguished on the map from the Hølonda Shales. The rock represents a typical mudstone without distinct foliation, with slightly varying shades of a reddish purple, everywhere of a comparatively dark shade. Under the microscope it proves exceedingly finegrained, with some calcite and trace of newformed sericite. Outside the Almås section this rock was found in the same geological position near the farm Bjørktjennåsen, where it is foliated, but otherwise of the same character. The assumption that this mudstone (red shale) is of a tuffaceous character, as assumed by Carstens (1920, pp. 88—91), it not confirmed. The colour of the mudstones and shales represents a remarkable feature displaying a definite continental type of these sediments.

Above the Almås Mudstone, in the Almås section, the normal rocks belonging to the Hølonda Shales and Sandstones appear. First, below the farm Almås, arenaceous greyish-green shales are exposed. Higher up, on the steep east side of the ridge Almåsåsen itself, a characteristic easily disintegrating shale appears, the Skjegstad Shale, which has a wide distribution at Hølonda. It is a dark grey to blackish grey coloured shale, with rusty stripes or dots after weathered grains of

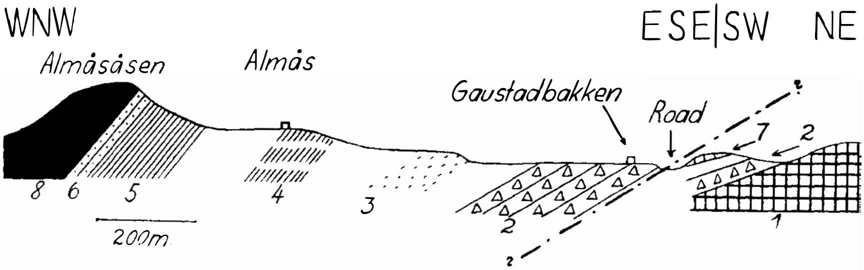

Fig. 6. Geological section from east of the farm Gaustadbakken to the ridge Almåsåsen. 1: Støren Greenstones. 2: Gaustadbakk Breccia. 3: Chocolate-coloured Almås Mudstone. 4: Greyish green arenaceous shale. 5: Dark, easily disintegrated shale. 6: Sandstone. 7: Hølonda Limestone. 8: Hølonda Porphyrite, Almås type.

pyrrhotite, elongated in the direction of the rock flowage (stretching). It disintegrates to small flakes not only on the surface, but at least 3—4 m downwards. At Hølonda it is extensively utilized as gravel for road-construction, and is said to produce an exceptionally good surface. Small gravel-pits of this shale are situated southwest of Skjegstad, southwest of Gaustadåsen, northwest of Sundset, on the southern side of lake Langåsvatnet, east of Hølonda church, where the largest pit is situated, and in other places. In these gravel-pits the shale is excavated without blasting. Since the shale disintegrates so easily, it is generally very much covered. Besides this shale other types of shale also appear at Hølonda, for instance harder grey shale, etc., sometimes alternating with sandstone beds.

Uppermost in the Almås section thin sandstone beds appear, underlying the Hølonda Porphyrite. In other places the Hølonda Shale and Sandstone chiefly consist of thin sandstone beds of comparatively small thickness. In the area around the farm Ven at lake Grøtvatnet, the series consists mainly of thin sandstone beds, with small amounts of shale. The lowermost sandstone beds in the vicinity are, sometimes, rather coarse clastic, with grains of the rocks from the substratum as greenstone and quartz-porphyry.

The thickness of the series is apparently exceedingly variable, from about 50 m or even less, e. g. to the south of Ven, and at the northern end of the lake Skjegstadvatnet, and up to several hundred meters, as, for instance, in the Almås section. However, this highly varying thickness is, at least in part, regarded as due to tectonic movements.

Traces of indeterminable fossils appear in the Hølonda Shales and Sandstones, for instance on the hillock about 100 m to the south and south-east of the buildings of Ven farm.

4. The Hølonda Limestone.

This limestone is fine-grained and almost everywhere of a darker or lighter bluish-grey colour, only occasionally light grey to yellowish grey. The thickness is very variable. Even if the apparently huge thickness, for instance near Ven, is, in part, produced by tectonic movements, there is no doubt that the thickness also primarily has varied a great deal. In a great central area, between Gaustadgrøtåsen and Hølonda church, the limestone is, moreover, wholly, or almost wholly, wedged out, while it reappears still farther to the northwest. This wedging-out may be traced, inter alia, on the south side of Middagsåsen, the porphyrite ridge farthest to the southwest in the vicinity of Stenset-Ven. In this central area sandsone or shale frequently occur in direct contact with the porphyrite. However, a thin bed of limestone, down to 3 m, is observed rather frequently just below or sometimes at the porphyrite contact.

Where the limestone is of greater thickness, a dark grey shale frequently appears intercalated in the upper part of the beds, which is thereby divided into a lower and an upper part. This shale may contain fossils. In some parts beds of calcareous nodules are common, and concretions rich in manganese are sometimes found in non-calcareous shale. This intercalated shale is known from several localities in the Ven-Stenset area, where it is, in part, accompanied by a light grey sandstone also containing fossils. On one of the last days of field work in the autumn 1944 a new fossil locality from a dark grey shale of the type mentioned above was found to the northeast of Trotland, outside and west of the map area. This horizon seems to belong to the intercalated shale bed in the limestone. If so, this shale is here much thicker than farther east. The other, less probable alternative is that the fossils belong to the upper part of the Hølonda Shale and Sandstone, below the Hølonda Limestone.

Traces of fossils are known from the Hølonda Limestone of many localities, but determinable fossils have previously been collected only in the vicinity of Ven and Stenset, mainly by W. C. Brøgger (1877) and Trygve Strand. The fossils are presumable derived as well from the lower and upper Hølonda Limestone as from the intercalated shale horizon. According to the descriptions by Ove Arbo Høeg (1932), Cowper Reed (1932), Trygve Strand (1932) and August F. Foerste (1932), the following fossils were known:

Rhabdoporella cf. *bacillum* Stoll.
Apidium rotundum Høeg
Halysis monoliformis Høeg

Orthis (Plesiomys) cf. *porcata* McCoy
» *(Dinorthis)* cf. *pectinella* (Emm.)?
» *(Dinorthis ?) subdecorata* Reed
» *(Plectorthis ?) hovinensis* Reed?
» *(Plectorthis)* cf. *subfissicosta* Reed
» *(Herbertella)* cf. *sinuata* Hall?
» *(Herbertella ?)* ? sp.
» *(Nicolella) angulata* Reed
» *(Horderleyella) bancrofti* Reed
» cf. *lyckholmiensis* Wysog.
Triplecia norvegica Reed
» sp.?
Oxoplecia dorsata (His.)
» *vagans* Reed
» ? ? sp.
Stropheodonta katuglåsensis Reed
Rafinesquina cf. *semiglobosina* (Dav.)?
Chonetoidea triangularis Reed
Leptelloidea cf. *delicatula* (Butts)
Holtedahlina ? hirundo Reed
Zygospira cf. *orbis* Reed?
Syntrophia cf. *affinis* Reed
Camarella cf. *thomsoni* (Dav.)
Camarella sp.
Parastrophina hemiplicata (Hall) var.
» cf. *angulosa* (Tørnq.)
Rhynchotrema sp.

Modiolopsis ? sp.

Hormotoma sp.
Lophospira
Euomphalid gastropod

Endoceras stensetense Foerste
» *vehnense* Foerste
» 2 sp.
Cyrtendoceras (?) sp.
Orthoceras katuglåsense Foerste
Geisonoceras strandi Foerste
Cycloceras kiæri Foerste
» *hoelandense* Foerste
» *trondhjemense* Foerste
Palaeonautilus (?) *broeggeri* Foerste

Gonotelus broeggeri Strand
Illænus sp.
Pliomera sp.

Crinoid stems

The present author has collected well preserved trilobites from the following horizons, the fossils being provisionally determined by Trygve Strand, who also furnished the information mentioned below.

1. Upper Hølonda Limestone, on the south side of the dam at the outlet of the pond Damtjernet near Ven:

Illænus sp., with a longitudinal furrow behind the rachis of the pygidium.

2. Shale intercalated in the Hølonda Limestone, at the winter-road at the pond Damtjernet near Ven:

Agnostus (Arthrorhachis) sp. ex. aff. *sidenbladhi* Linnarsson.

3. Shale probably intercalated in the Hølonda Limestone, to the northeast of Trotland, outside the map area:

Harpes sp.
Illænus sp.
Lichas (sens. lat.) sp.
Nileus sp.
Niobe? sp.

The cephalopods do not display, according to Foerste, any close affinities to known faunas in U. S. America or Canada. According to a more recent communication by professor Troedsson to dr. Trygve Strand it seems that the cephalopods are typically baltic. The affinities of the brachiopode fauna point, according to Cowper Reed, to an Upper Ordovician age. Strand (1932) is most inclined to assume a Chazyan age as probable. The trilobites may, perhaps, give the safest clue to the age. According to information from E. O. Ulrich to Strand (1932) the american genus *Gonotelus* points to an Upper Canadian age. Among the new finds it is *Arthrorhachis, Nileus* and *Niobe* which are of particular interest. This assemblage occur in the sections M—N in Newfoundland, in beds of middle and upper Chazyan, corresponding to the British Llandeilian Series; *Niobe* and *Nileus* occur in Glensaul, Ireland, in beds classed with the Llandeilian or lower. Conforming to Scandinavian—Baltic conditions, the horizon should, however, hardly be younger than the British Llanvirnian Series, but possibly older. Following the indications produced by the trilobites, the horizons may be placed in the Llanvirnian or in the Llandeilian Series, the former being, perhaps, at present the most eligible. Incidentally, it may be noted that the divide between the Canadian and the Chazyan is placed in the middle part of the Llanvirnian Series.

The new finds show that the fauna consists of a mixture of Scandinavian—Baltic and American forms, and that it belongs to the fauna province which comprises, inter alia, the Girvan area, Glensaul in Ireland, Newfoundland, and the eastern Appalachians in North America. This corroborates Johan Kiær's assumpfion of the close affinity between the Hølonda and Girvan areas. Dr. Trygve Strand has very kindly offered to describe the trilobites of the new collections.

5. The Hølonda Porphyrites.

Two distinctly different types of the Hølonda Porphyrites appear in the map area, viz. the Berg type, occurring in the eastern part of the Hølonda area, and the Almås type, appearing in the western part.

Analysis 6		Norm		Mineral composition	
SiO_2	53.46	Quartz	2.66	Quartz	12.00
TiO_2	0 90	Orthoclase	10.24	Albite	28.59
ZrO_2	0.03	Celsian	0.11	Muscovite[1]	1.00
Al_2O_3	17.00	Albite	26.74	Biotite	2.00
Fe_2O_3	2.04	Anorthite	27.01	Hornblende	22.48
FeO	6.11	Diopside	7.25	Epidote	20.08
MnO	0.13	Hedenbergite	4 31	Chlorite	11 66
MgO	4.87	Enstatite	8.76	Titanite	2.22
CaO	8.71	Ferrosilite	5.97	Zircon	0.04
BaO	0.04	Magnetite	2.96	Pyrite	0.02
Na_2O	3.16	Ilmenite	1.71	Apatite	0,72
K_2O	1.73	Zircon	0.04	H_2O	−0.81
P_2O_5	0.31	Apatite	0 72		
S	0.01	Pyrite	0.02		100.00
CO_2	nil	H_2O	1.50		
$H_2O+110°$	1.42				
$H_2O-110°$	0.08		100 00		
		Colour Index	31.74		
	100.00	Shand classification: Lime basalt, near Lime andesite			
Gr.	2.954	CIPW classification: Hessose			

Analysis 6: Andesito-basaltic Hølonda Porphyrite (Almås type), from the southwestern side of Almåsåsen, Hølonda. Analyst: Martha Klüver.

[1] In albite phenocrysts.

Outside the map area to the west still another type occurs, which display considerable resemblance to the first type.

The Berg type is a rather normal andesite, see analyses 7 and 8, pp. 480—481, see also Pl. VII, Fig. 1. Thickly tabular phenocrysts of a formerly more basic plagioclase abound; these are now altered into albite with small scales of muscovite and small grains of clinozoisite. Further the rock contains more sporadic phenocrysts formerly consisting of a pyroxene, probably of pigeonite, which is now altered into hornblende and chlorite. These different phenocrysts are embedded in a very fine-grained groundmass consisting of extremely small laths of albite with epidote, hornblende, chlorite, titanite, etc. Sometimes small amygdalae are filled with chlorite and epidote.

The Almås type differs considerably from the former type, see analysis 6, p. 479, and also Pl. VII, Fig. 2. According to the chemical composition the rock is transitional between basalt and andesite. Examined under the microscope it differs from the Berg type inter alia in the much more crowded phenocrysts of albite and altered pyroxene. The minerals present are albite, hornblende, epidote and clinozoisite, chlorite, titanite etc.

Analysis 7		Norm		Mineral composition	
SiO_2	53.90	Quartz	2.06	Quartz	8.67
TiO_2	1.10	Orthoclase	7.46	Albite	44.36
ZrO_2	0.03	Celsian	0 10	Muscovite[1]	1.00
Al_2O_3	19.14	Albite	39.59	Biotite	2.00
Fe_2O_3	2.02	Anorthite	27.42	Hornblende	2.89
FeO	4.74	Diopside	0.85	Epidote	18.68
MnO	0.14	Hedenbergite	0.40	Chlorite	18.34
MgO	3.58	Enstatite	8.52	Titanite	3.09
CaO	6.71	Ferrosilite	4.72	Zircon	0.04
BaO	0.04	Magnetite	2.93	Pyrite	0.08
Na_2O	4.68	Ilmenite	2.33	Apatite	1.14
K_2O	1.26	Zircon	0.04	Calcite	0.39
P_2O_5	0.49	Apatite	1.14	H_2O	– 0.45
S	0.04	Pyrite	0.08		
CO_2	0.17	Calcite	0.39		100.23
$H_2O+110°$	2.13	H_2O	2.20		
$H_2O-110°$	0.07				
			100.23		
	100.24	Colour index	21.01		
– O for S	0.01	Shand classification: Soda-andesite			
	100.23	CIPW classification: Andose.			
Gr.	2.865				

Analysis 7: Andesitic Hølonda Porphyrite (Berg type) from the road to the north-east of Berg, Hølonda. Analyst: Martha Klüver.

[1] In albite phenocrysts.

The question as to whether these porphyrites are of intrusive or extrusive character is not easy to decide. Where the immediate contact with the Hølonda Limestone is exposed, for instance on the east side of the ridge Tranemyråsen, the limestone is a little foliated but only just bleached and hardly visibly recrystallized even close to, i. e. 10 cm off, the contact. Some small enclosures of limestone in porphyrite directly above, or almost at the contact, at the northwestern end of the pond Damtjernet near Ven, are also just a little bleached, but very little recrystallized. It is, on the whole, striking how little metamorphosing influence the porphyrite exercises on its substratum. However, one single exception from this rule is observed. Evidently, near the summit of Høgåsen at Stenset, the eastern of the three ridges named Katugleåsen on the ordnance map, extraordinary conditions prevail. Here it appears, in the Hølonda Limestone, a finegrained lime silicate hornfels with abundant epidote, in not inconsiderable distance, perhaps 50 m or more, from the porphyrite contact. Carstens (1922 b)

Analysis 8		Norm		Mineral composition	
SiO_2	54.58	Orthoclase	6.28	Quartz	5.49
TiO_2	1.14	Albite	47.13	Albite	48.46
Al_2O_3	18.23	Anorthite	21.58	Muscovite[1]	1.00
Fe_2O_3	2.43	Diopside	4.95	Biotite	2.00
FeO	4.89	Hedenbergite	3.12	Hornblende	10.64
MnO	0.11	Enstatite	4.80	Epidote	17.66
MgO	2.92	Ferrosilite	3.47	Chlorite	11.12
CaO	7.03	Forsterite	0.13	Titanite	2.80
BaO	trace	Fayalite	0.10	Pyrite	0.04
Na_2O	5.57	Magnetite	3.52	Apatite	0.99
K_2O	1.06	Ilmenite	2.17	Calcite	0.23
P_2O_5	0.43	Pyrite	0 04	H_2O	−0.26
S	0.02	Apatite	0.99		
CO_2	0.10	Calcite	0.23		100.17
$H_2O+110°$	1.56	H_2O	1.66		
$H_2O-110°$	0.10				
			100.17		
	100.17	Colour index	23.29		
Gr.	2.810	Shand classification: Soda-andesite			
		CIPW classification: Andose			

Analysis 8: Andesitic Hølonda Porphyrite (Berg type) from the east side of Tranemyråsen, to the south of Ven, Hølonda. Analyst: Martha Klüver.

[1] In albite phenocrysts.

obviously refers to this locality when he assumes a contact metamorphism of beds superimposing the porphyrites of Katugleåsen, and herein finds proof of the intrusive character of these rocks. Actually, the metamorphosed beds are not superimposed on but underlying the porphyrite, but otherwise the conclusion seems natural, considering this locality only. However, at other localities, no such metamorphism has been traced. On the contrary, wholly unmetamorphosed calcareous shales with fossils are found near the porphyrite, for instance at Damtjernet, Ven, and at other places. It may also be noted that strong tectonic disturbances exist at Høgåsen, with steep to vertical beds. Considering these facts, the metamorphism at Høgåsen may be ascribed to other circumstances, perhaps an underlying injection, the vicinity of a volcanic vent, etc.

Interesting is the abundant occurrence of fragments of porphyrite in the Hølonda Limestone below the porphyrites, more or less close to the contact. The fragments vary greatly in size, from a few mm and less to ½ m and even more. Two examples are shown on Pl. IV, Figs. 1 and 2. In addition to the larger fragment, about 10 cm in diameter, Fig. 1 shows some smaller fragments, about 4—6 mm in diameter, situated above and to the left of the upper end of the greater fragment. In both cases the limestone is brecciated, this being most evident on the weathered surface of the rock of Fig. 2. The matches giving the dimensions, are 5 cm long. All fragments observed consist of porphyrite of the Berg type, or a rock very close to this. These fragments occur in the area of the porphyrite of the Berg type in many localities, e. g. near the farm Skjegstad, at the dam of Damtjernet near Ven (Pl. IV, Fig. 2); between Damtjernet, near Ven, and Tranemyren (Pl. IV, Fig. 1); on the south side of the ridge Tranemyråsen; near the summit of Høgåsen, Stenset; and at the south side of Fjøsåsen, Stenset. However, fragments of porphyrite of the Berg type occur also in the area of the porphyrite of the Almås type, near the contact with this rock, e. g. at Sundset, to the southeast of Gåslandsvatnet and between Krokstad, Hølonda, and Gåsbakken. In the latter locality, fragments are found in calcareous shale. Here a portion of porphyrite of the Berg type, about 2 m thick, also occur, seemingly representing a minor intrusion. Fragments of porphyrite of the Almås type are never observed.

The limestone breccia sometimes occurring together with the porphyrite fragments does not indicate a tectonic breccia, but a breccia formed as a sediment soon after the induration of the rock. Sometimes, as at the dam of Damtjernet near Ven, apparently undistorted fossils (*Illœnus* sp.) are also found in the limestone together with porphyrite fragments. Generally, the limestone itself is, as mentioned above, entirely unmetamorphosed. In the author's opinion, the porphyrite fragments may, most naturally, be interpreted as pyroclastic material. This interpretation, especially applying to the Berg type, does not exclude the occurrence of minor intrusions or dikes of porphyrite in the substratum. Within the map area, the porphyrites of both types seem to be placed in one and the same horizon, even if this cannot always be proved because of the partial wedging-out of the Hølonda Limestone. Beds superimposing the Hølonda Porphyrites are not observed in the map area. Whereas the texture of the Berg type is entirely congruent with an effusive origin, this cannot right away be said of the texture of the Almås type. Notwithstanding the near chemical connection between the two rocks, and the similar geological occurrence, the mode of formation of the Almås type seems at present somewhat doubtful. It is hoped, that the question of the nature of the porphyrites will be further elucidated by continued investigation.

The Intermediate Area.

This area represents the northwestern part of the Horg Syncline. Most of the beds can be identified as well with beds of the Hølonda area as with beds of the southeastern area. A correlation of the beds in the whole map area can consequently be accomplished. The beds of the intermediate area are steeply inclined to vertical and, in the northwestern part, generally inverted to the southeast. See sections VII—XI on Figs. 5 and 7.

1. The Venna Conglomerate.

This conglomerate is exposed to the south of the Våttan seter, resting on the Støren Greenstones. The fragments consist of the same calcite rich sandstone found in the conglomerate near Ven, of red jasper and also of some greenstone material.

2. The Hølonda Shales and Sandstones = the Krokstad arenaceous Shale, lower part.

Where the Hølonda Limestone is developed, these beds can be correlated with the Hølonda Shales and Sandstones, but where the limestone is wedged out, they can only be parallelized with the lower part of the Krokstad arenaceous Shale. The rocks consist rather uniformly of grey arenaceous shales, sometimes with thin beds of fine-grained sandstone. The easily disintegrating dark shale of the Skjegstad type is lacking.

3. The Hølonda Limestone.

This limestone was traced from the Hølonda area into the Horg syncline in the region to the south of Ven. Apparently it soon wedges out, preserving, however, a large thickness towards Våttan seter. To the west of the pond Damtjønna, between the Tømme farms and Grøtan, the limestone reappears in a small quarry as a bed only about 5 m thick. The limestone occurring in the Horg syncline is metamorphosed into a bluish grey marble with white calcite veins, or partly into grey or white crystalline marble. Fossils are not observed here.

4. The Krokstad arenaceous Shale, middle and upper part.

Above the Hølonda Limestone follows, mostly in inverted position, a thick series of arenaceous shale, similar to the lower part of the same beds. It is a rather uniform, grey to greenish grey, somewhat

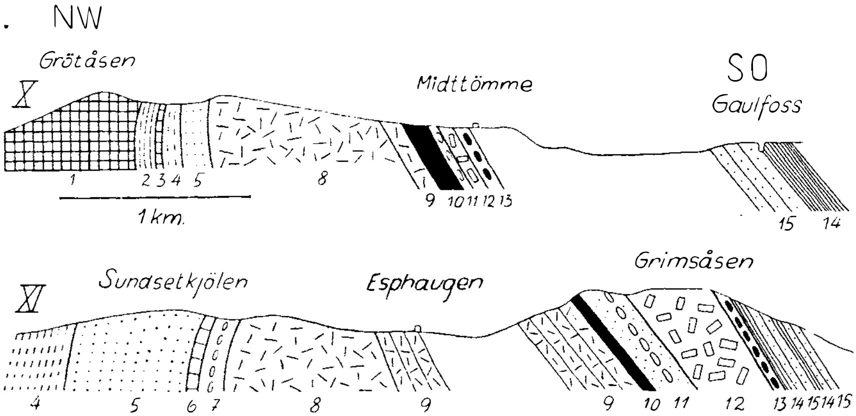

Fig. 7. Geological sections from the northwestern part of the Horg Syncline. 1: Støren Greenstones. 2: Hølonda Shale. 3: Hølonda Limestone. 4: Krokstad arenaceous Shale, upper part. 5: Krokstad Sandstone and Grit. 6: Svarttjern Limestone. 7: Granite boulder conglomerate of Sundsetkjølen. 8: Hareklett massive Rhyolite Tuff. 9: Esphaug bedded Rhyolite Tuff. 10: Tømme black Shale. 11: Volla Conglomerate and Sandstone. 12: Grimsås Rhyolite. 13—15: Horg Series. 13: Lyngestein Conglomerate. 14: Dark shale and 15: grey sandstone, No. 14 and 15 belonging to the Sandå Beds.

sericeous, arenaceous shale, at times with thin beds of grey sandstone. The thickness is large to the southwest, decreasing, however, to a comparatively small thickness towards the northeast.

5. The Krokstad Sandstone and Grit.

The above mentioned arenaceous shale graduates into a sandstone divison, occupying parts of the elevated region at the watershed between Hølonda and the valley Gauldal, see Pl. II, Fig. 2, the foreground of the picture. The demarkation between this and the preceding division is transitional, the boundary being placed below the first beds of coarse sandstone. In its typical development the division consists of thick beds of coarse greyish green to almost green sandstone. Frequently thinner beds of fine-grained sandstone also occur, with intercalated arenaceous shale. In the lower and middle part, e. g. on the summit of the ridge Kjølåsen (on the ordnance map named Høgåsen), thick beds of greyish green grit appear, with well worn pebbles up to a size of 0.5—1 cm. The sand grains and pebbles of the coarse sandstone and grit consist of quartz and quartzite, fine-grained sediments, and sometimes of red jasper and greenstone in subordinate quantity. The grit obviously represents the breccia marked down on Brøgger's map (1877) on Sundsetkjølen. The thickness of this division is also large to the southwest, decreasing in thickness, however, towards the northeast, the size of the grains simultaneously diminishing.

6. The Svarttjern Limestone.

In the uppermost part of the Krokstad Sandstone and Grit a partially not inconsiderable bed of limestone appears. Northwest of the farm Esphaugen, a bed of quite pure limestone 26 m thick, including 1 m shale, was measured, both the lower and the upper boundary of the limestone being covered. To the southwest the thickness diminishes, being only a few m thick, e. g. at Giltjernet. The limestone is metamorphosed to a somewhat crystalline greyish blue marble with white veins of calcite. No fossils were found.

Ad. 3 and 6. The Position of the Kalstad Limestone.

The Kalstad Limestone, situated about 15 km outside the map area and to the southwest, has been identified with the Hølonda Limestone by all previous authors, see Kiær (1932 a). This is due to the fairly similar, stratigraphical position of the two limestones. However, after the establishment of the Svarttjern Limestone, this bed, as far as we know at present, corresponds equally well to the Kalstad Limestone. The identity of the Kalstad and Hølonda Limestones is not ascertained by the fossils. Only two calcareous algae, described by Arbo Høeg (1932), are identical or nearly so, viz, *Rhabdoporella* cf. *bacillum* Stolley and *Halysis* (cf.) *monoliformis* Høeg, and the algae may have a rather wide vertical distribution. Certainly, the limestones represent two different facies developments; the Kalstad Limestone is principally a coral reef limestone with calcareous algae in profusion, brachiopods, etc., whereas the Hølonda Limestone lacks corals but contains brachiopods, cephalopods, trilobits, etc. However, althoug both contain brachiopods, they have no species in common.

If the Kalstad Limestone, as here assumed, is correlated with either the Hølonda Limestone or the Svarttjern Limestone or a horizon close to these, the outside limits of the age should, from stratigraphical relations, be the Lower Llanvirnian (Langeland Slate) and Middle to Upper Caradocian (Tømme Beds and *Dicranograptus* Shale). The age determinations of the Kalstad Limestone on the basis of fossils do not, as yet, tell us very much. The brachiopods, according to Cowper Reed (1932), point to an Upper Ordovician age (Ashgillian Series). According to Arbo Høeg (1932) the algae indicate an age contemporaneous with the Mjøs Limestone, between the étages 4 bδ and 4 cα in the Oslo region, or a younger Ordovician age, corresponding to the upper part of the Caradocian Series or the Ashgillian. Johan Kiær (1932 a) presumes that there is a general resemblance of the algae and particularly of the corals in the Kalstad Limestone and in the Llandeilian Stinchar Limestone of the Girvan area in Scotland. As material of comparison, Kiær used collections from the Craighead Limestone, which was regarded as contemporaneous with the genuine Stinchar Limestone. However, E. O. Ulrich (1930) considers the two limestones mentioned to be of different age, the Craighead Limestone being placed in the Balclatchie Stage (Lower Caradocian) or with the Drummock Beds (Upper Caradocian to Ashgillian). If the Kalstad Limestone is correlated with the Svarttjern Limestone, a proximate Lower Caradocian age should be possible; but the age relations may as yet be regarded as rather uncertain.

7. The Conglomerate of Sundsetkjølen.

Somewhat above the limestone horizon a quartz-diorite boulder conglomerate or breccia of inconsiderable thickness and limited distribution appears. The boulders consist of a coarse-grained grey quartz-diorite or granodiorite, with abundant quartz and acid plagioclase, some chessboard-albite and small quantities of dark minerals, i. e. chlorite, representing altered biotite; further laths of secondary muscovite, crystals of titanite and traces of zircon. The rock is very different from the trondheimites, and has a rather precambrian appearance. The boulders are 1.5 dm and even more in diameter, and are, at least in part, angular. The conglomerate or breccia is situated very near to the basis of a large division of volcanic tuffs, perhaps nearer than is shown on the geological map, and it may be possible that the boulders represent detached stones from the substratum brought to the existing surface by volcanic action.

8. The Hareklett massive Rhyolite Tuff.

This division occupies parts of the elevated region at the watershed between Hølonda and the valley Gauldal, including the highest ridge Harekletten. The northwestern boundary is marked in the topography over a long distances through a small escarpment, the massive tuff division being more resistant to erosion than the underlying sandstone division. The tuffs are wholly massive, generally without trace of bedding. The colour of the fresh rock is grey to olivaceous grey. In the field the fragmental structure is only visible on particularly well weathered surfaces, and hardly in fresh rock. The rock consists uniformly of small fragments of rhyolite, from 1 mm and less in diameter up to 4 $\times$ 6 mm in size, rarely larger. These fragments are extremely fine-grained, with traces of fluidal texture. Of minerals are seen very fine flakes of muscovite in great quantities, small grains of clinozoisite or epidote and traces of titanite and magnetite etc. Phenocrysts of quartz and altered plagioclase rarely occur. Besides these rhyolite fragments quartz grains in small quantities of two types are found: one is glassy and, obviously, represents phenocrysts from the rhyolite, whereas the other has a wavy extinction; to the latter type also belong grains of quartzite. Reference may be made to analysis 9, p. 488 and to the microphotograph Pl. VIII, Fig. 1. This remarkable tuff division attains its greatest thickness within the map area, and is thinning out both to the northeast and to the southwest. It is also observed near the outlet of the lake Selbusjøen, 17 to 18 kms farther to the northeast.

9. The Esphaug bedded Rhyolite Tuff, etc.

The massive tuff described above graduates upwards into a bedded division, very much like a common sandstone in appearance, the material consisting, however, predominantly of fragments of the same rhyolite which occurs in the preceding division. Under the microscope the rocks from the two divisions are extremely similar. Besides the dominating fragments of rhyolite the same two types of quartz as in the massive rock are found. However, in this division other sediments in minor quantities occur, viz. beds of common fine-grained sandstone with thin intercalated layers of greenish grey shale, e. g. at the farm Esphaugen, and alternating layers of grey and black shale, e. g. at the road to the west of Kvennabakken. This division wedges out to the northeast.

Analysis 9		Norm		Mineral composition	
SiO_2	71.46	Quartz	41.80	Quartz	43.67
TiO_2	0.36	Orthoclase	17.91	Albite	25.21
ZrO_2	0.02	Celsian	0.18	Muscovite	14.89
Al_2O_3	13.97	Albite	17.51	Epidote	5.91
Fe_2O_3	1.16	Anorthite	8.41	Chlorite	6.37
FeO	1.78	Corundum	4.15	Magnetite	1.16
MnO	0.03	Enstatite	2.79	Titanite	0.88
MgO	1.12	Ferrosilite	1.44	Zircon	0.03
CaO	2.63	Magnetite	1.69	Pyrite	0.30
BaO	0.07	Ilmenite	0.68	Apatite	0.09
Na_2O	2.07	Zircon	0.03	Calcite	1.57
K_2O	3.03	Pyrite	0.30	H_2O	−0.15
P_2O_5	0.04	Apatite	0.09		
S	0.16	Calcite	1.57		99.93
CO_2	0.69	H_2O	1.38		
$H_2O+110°$	1.27				
$H_2O-110°$	0.11		99.93		
		Colour index	11.17		
	99.97				
−O for S	0.04	Shand classification: Potash-rhyolite, near to Soda-rhyolite			
	99.93	CIPW classification: Toscanose			
Gr.	2.809				

Analysis 9: Hareklett Rhyolite Tuff from the mountain side to the west-northwest of the farms Midttømme, Horg. Analyst: Martha Klüver.

10. The Tømme black Shale and Mudstone.

This shale is developed rather differently in the northeastern and southwestern part of the map area, the rivulet Kolo approximately forming the divide. To the northeast appears a relatively thick division of black foliated shale, with a grey streak, disintegrating into small slabs. In the topography this quite easily disintegrating shale appears in a longitudinal depression in the woods behind the farms from Moum to Nordtømme, being particularly well exposed in a glen named Tjuedalen.

To the southwest the thickness diminishes, and at the same time the shale passes into a mostly massive, black mudstone with a light grey streak. This mudstone alternates with thin layers and thicker beds of grey tuffaceous sandstone, principally consisting of rhyolite fragments, similar to the Hareklett and Esphaug tuffs. These beds appear, inter alia, in the uppermost steep part of the northwestern slope of the ridge named Grimsåsen on the ordnance map.

Ad 10. The Esphaug fossiliferous boulder.

In the early 'seventies Th. Kjerulf discovered a large fossiliferous boulder measuring about 2 $\times$ 2 $\times$ 4 m, near the farm Esphaugen. The first fossils, collected by Kjerulf and his collaborators, were described by W. C. Brøgger (1875). Later on the latter visited the locality and cut the boulder practically to pieces, collecting a larger amount of material (Brøgger 1877). Tales of this fossil hunting are still told in the vicinity, even if attributed to professor Amund Helland, and the owner of the farm Esphaugen, Peder Esphaug, has shown me the spot, which is situated immediately to the south of the road nearly 1 km east of the farm, measured along the main road. Only the base of the boulder, measuring about 2 $\times$ 2 m, and some débris, heavily overgrown with moss, remain, the greater part of the rock fragments being used in road-work. The rock consists of tuffaceous sandstone with single pebbles of rhyolite, a few cm in diameter, and traces of fossils. It is identical with the Esphaug bedded tuff and with the tuff beds in the Tømme Mudstone, excepting the size of the single pebbles. Pieces of the fine clastic material mentioned by Brøgger were kindly lent to me by the Palæontological Museum of the University in Oslo. They display the great similarity or identity of this rock with the black Tømme Mudstone, cropping out on the hillside at a distance of less than 1 km to the south or southeast of the boulder. The general glacial movement of the region was about northwestern, glacial striae towards the north in a single locality, in the bed of the stream Kolo, supposedly being deflected. In the opinion of the author, it is, therefore, extremely probably that the boulder may be ascribed to the horizon of the Tømme Mudstone. This coincides so far with the opinion of Brøgger, who decidedly fixed the origin of the boulder to the northwestern side of the ridge Grimsåsen. Brøgger also mentions fossils in outcroups on this hillside. I have crossed the horizon in question several times without observing fossils, the hillside, however, being very heavily covered and overgrown.

The following forms from the Esphaug boulder are described or mentioned by Brøgger (1877), Kiær (1932 a), Cowper Reed (1932) and Størmer (1932):

Nidulites sp.

Cup corals

Orthis (Schizophorella) fallax McCoy
» *(Plectorthis)* cf. *plicata* Sow.
» *(Plectorthis ?) hovinensis* Reed
» *(Austinella)* cf. *whitfieldi* Winch.
» *(Pionodema)* aff. *subaequata* Conr.
» *(Dinorthis ?)* sp.
» *(Platystrophia)* cf. *elegantula* McEw. var. *triplicata* McEw.
» cf. *tricenaria* Conr.
Ptychoglyptus pauciradiatus Reed
Strophomena cf. *planodorsata* Winch. and Schuch.?
Raphinesquina cf. *alternata* (Emm.)?
Sowerbyella (Eochonetes) cf. *advena* (Reed)
Plectatrypa marginalis (Dalm.) var.
Catazyga cf. *anticostiensis* (Bill.)
Zygospira cf. *recurvirostris* (Bill.)
Rhynchotrema cf. *capax* (Conr.)?
» cf. *subtrigonale* (Hall)?

Ctenodonta ? sp.

aff. *Holopea* sp.
aff. *Hormotoma* sp.
Euomphalid gastropod?
Bellerophontid gastropod?
Hyolithid

Cephalopods

Illænus sp.
Calymmene sp.
Cryptolithus sp. aff. *concentricus* Eaton and Reed

Crinoid stems

According to Cowper Reed the brachiopods point to an Upper Ordovician age. The most reliable guide may, however, be the trilobites, and of these the *Cryptolithus* sp., which resembles *C. concentricus,* according to Størmer decidedly points to a Caradocian age. This determination of age agrees extremely well with the stratigraphical facts, as will be commented on in a subsequent chapter.

Incidentally it may be mentioned that a few badly preserved fossils are collected by Kjerulf from another boulder near Esphaugen, consisting, however, of the Lyngestein Conglomerate. The source of these fossils is, presumably, a huge boulder of this conglomerate, measuring no less than 6 × 9 × 5 m. It is situated on the north side of the road at the divide between the two Esphaugen farms.

11. The Volla Conglomerate and Sandstone.

Above the black shale and mudstone appears a division distinguished by a conglomerate and by weathered fragments of rhyolite. The most conspicuous rock is a dark, and, when fine-grained, almost black sandstone, mottled by light coloured to nearly white grains of feldspars. This rock consists of heavily weathered effusive fragments, apparently of rhyolite, with grains of strongly decomposed feldspars and glassy quartz and quartzite. The rock has considerable resemblance to the Esphaug bedded tuff, which, however, consists of less weathered fragments; thus the feldspars in the latter rocks are not separable as to colour from the groundmass, the colour of the rock also being different. Other rocks also appear, as massive coarse sandstone beds, lighter in colour, consisting principally of rhyolite fragments, and exhibiting greater resemblance to the Esphaug beds; further of fine-grained grey sandstone in thinner beds. The latter rock appears between the black Tømme shale and the conglomerate beds to the northwest of the Tømme farms. The cobbles in the conglomerate may be up to the size of a fist and more, and well rounded. They frequently occur rather scattered in the tuffaceous sandstone, sometimes, however, in thick beds of normal conglomeratic character. The rocks of the cobbles consist principally of an olivaceous grey rhyolite, profuse in phenocrysts of plagioclase, more or less decomposed, and with more dissipated phenocrysts of quartz in an extremely fine-grained groundmass with trace of fluidal texture. In addition, cobbles of whitish quartzite and of greyish blue unmetamorphosed limestone are observed. These beds form an extremely characteristic division, traced also outside the map area 5 to 6 km to the southwest, viz. to the northwest of the pond Altbjørvatnet.

12. The Grimsås Rhyolite.

The colour of this rock is light grey, or light greenish yellow from epidote, or, rarely, nearly black from finely distributed magnetite dust in almost imperceptible quantities, as near the farms Nordtømme. The microscopic appearance is, however, quite uniform. The rock consists of abundant phenocrysts of generally clear albite, representing in the main the orignal composition of the plagioclase, and more scattered phenocrysts of quartz in a fine-grained groundmass. The latter is in part extremely fine-grained, with trace of fluidal texture, and, even in the same thin section, somewhat recrystallized. The rock also contains fine scaly muscovite, small grains of clinozoisite or epidote, etc. Frequently the rock is somewhat silicified. The rock is somewhat similar to the rhyolite from the rhyolite tuffs described above, except for the generally clear albite phenocrysts. See the analysis 10 on p. 492 and Pl. VIII, Fig. 2. All observations at hand indicate that the rock occupies everywhere one and the same horizon. At present an effusive origin appears most probable.

Analysis 10		Norm		Mineral composition	
SiO_2	73.17	Quartz	30.64	Quartz	31.84
TiO_2	0.15	Orthoclase	19.54	Albite	50.82
ZrO_2	hardly present	Celsian	0.07	Muscovite	10.01
Al_2O_3	15.77	Albite	38.22	Clinozoisite	3.48
Fe_2O_3	0.14	Anorthite	4.78	Chlorite	3.98
FeO	1.22	Corundum	2.99	Magnetite	0.20
MnO	0.04	Enstatite	1.07	Titanite	0.37
MgO	0.43	Ferrosilite	1.93	Pyrite	0.02
CaO	0.98	Magnetite	0.20	Apatite	0.03
BaO	0.03	Ilmenite	0.29	H_2O	−0.72
Na_2O	4.52	Apatite	0.03		
K_2O	3.31	Pyrite	0.02		100.03
P_2O_5	0.01	H_2O	0.25		
S	0.01				
CO_2	nil		100.03		
$H_2O + 110°$	0.20	Colour index	6.53		
$H_2O - 110°$	0.05				
	100.03				
Gr.	2.703				

Shand classification: Albite—rhyolite

CIPW classification: Liparose

Analysis 10: Grimsås Rhyolite from quarry at the farms Nordtømme, Horg. Analyst: Martha Klüver.

The Southeastern Area.

Between the Støren and Hovin railway stations the narrow transverse valley of Gauldal intersects the beds, affording favourable sections in the steep sides of the valley, and at times in road and railway cuts. The beds are steeply inclined and inverted to the northeast, see section XII, Fig. 8. Only the upper beds are included on the geological map, but the entire Hovin Series will be cursory mentioned. The terms used by Johan Kiær (1932 a) for the beds in this area are adapted for geological mapping and employed with some modifications.

As the beds close above the Støren Greenstones in the examined part of the area are covered, no conglomerate corresponding to the Venna Conglomerate has, so far, been observed.

1. The Krokstad arenaceous Shale, lower part = The Bjørgen Shale.

The lowest observed member of the series is a greyish green to almost green arenaceous shale, best exposed on the eastern side of the valley. The rocks seem to be rather similar to the middle and

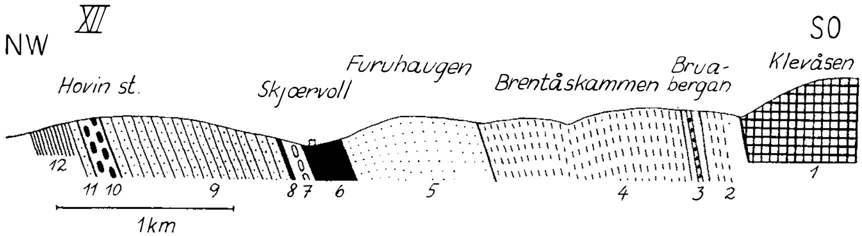

Fig. 8. Geological section from Støren to Hovin. 1: Støren Greenstones. 2: Krokstad arenaceous Shale, lower part. 3: Flagstone horizon with fragments of greenstones etc. 4: Krokstad arenaceous Shale, upper part. 5: Krokstad Sandstone and Grit. 6: Dicranograptus Shale. 7: Volla Conglomerate. 8. Horizon with black shale. 9: Hovin Sandstone s.str. 10—12: Horg Series. 10: Lyngestein Conglomerate. 11: Sandstone and 12: dark shale, No. 11 and 12 belonging to the Sandå Beds.

upper part of the Krokstad arenaceous Shale. The term Bjørgen (Bjørkum) Shale is applied to all shale below the Langeland Slate and Flagstone horizon. As the latter is not developed in the intermediate area, Kiær's term the Krokstad Shale, etc. is extended to comprise also the Bjørgen Shale. In the southeastern area, too, the slate horizon may frequently be difficult to distinguish.

2. The Langeland Slate and Flagstone, and the Bruaberg Conglomerate.

In the railway cuts below the Bruabergan a greyish green to almost green flagstone is well exposed. The rock consists of very thin layers of slate and very fine-grained sandstone alternating, the latter frequently being less than 1 cm thick. It splits easily into large flags with plane surfaces up to a few m in diameter.

This flagstone horizon, apparently, is identical with the slate horizon outside the map area nearly 20 km to the northeast, where there are roofing slate quarries of dark grey slates at the farms Langeland and Bjørgen. According to Kiær (1922 a) this horizon occupies just the same geological position as the flagstone at the Bruabergan. He also maintains the correlation mentioned above. In 1920 a complete specimen of *Trinucleus forosi,* described by Størmer (1932), see also Kiær (1922, 1926, 1932 a), was found on an old slab of roofing slate on the Singsås church in Gauldal. The slate quarries in Flå were disclosed as the origin of this slab, i. e. the quarries at Langeland or

Bjørgen, see P. A. Øyen (1922). According to Størmer this specimen is closely related to the british species *Trinucleus murchisoni* Salter and especially *T. etheridgei* Hicks, which occur in the Arenig Series of Great Britain. The closest resemblance to *T. etheridgei* indicates, according to Størmer, an Upper Arenig age. H. Hicks (1875) and Hopkinson and Lapworth (1875), mention that the latter species is found at the Llanvirn slate quarry in Pembrokeshire, Wales, in the *Didymograptus bifidus*-zone in Upper Arenig, corresponding to the present-day Lower Llanvirnian.

At the railway cut below Bruabergan beds of conglomerate or breccia 0.35 to 2.0 m thick, alternating with beds of finer and coarser green sandstones, appear in the flagstone, the total thickness of the beds of conglomerate and sandstone put together being 8.1 m. The fragments in the conglomerate consist prinsipally of different types of Støren Greenstones; and of red jasper, a single fragment as large as 15 × 70 cm in size; yellowish white fine-grained calcite marble up to 5 × 25 cm; a rock very similar to quartz-keratophyr; coarse-grained white quartzite; sandstones; etc. Reference may be made to the paper by Kiær (1932 a, p. 41), which also includes short descriptions of some of the fragments by the present author.

The appearance of mud cracks in the shale filled with sandstone from the superimposed conglomerate is interesting. This feature at once demonstrates the up-down of the beds, and indicates that the sediments occasionally were elevated above the sea level.

The thin conglomerate or breccia appears to be widespread, as it is observed, in the same geological position, rather far outside the map area, viz. to the south of Krokettjernet, more than 10 km from this locality.

3. The Krokstad arenaceous Shale, middle and upper Part.

The rocks of this division are rather similar to the flagstone mentioned above, being greyish green shales intercalated with numerous extremely thin layers of fine-grained sandstone, measuring generally only 0.1 to 1 cm. These sandstone layers are, however, more irregular, whereby the plane parting is lost, the rock assuming a massive character. Intercalated thin beds of fine-grained greenish grey sandstone appear. The thickness of the Krokstad arenaceous Shale, including the flagstone horizon, may be about 1300 m.

These beds are lithologically similar to the corresponding beds of the intermediate area. The latter are, however, more tectonically affected and frequently a little crumpled or folded on a small scale, the external appearance, therefore, being somewhat deviating.

4. The Krokstad Sandstone and Grit.

This division consists principally of beds of greenish sandstones, fine-grained and coarse-grained, with thick beds of grit. The grains of the latter are well rounded and reaches a size of up to 0.5—1 cm. They consist of quartz and conspicuous white quartzite; greenstones in abundance, apparently belonging to the Støren Greenstones; fine-grained sediments; etc. Interbedded in the sandstone, arenaceous shale similar to the rocks of the underlying division also occur. The boundary between the shale and sandstone division of the Krokstad beds is transitional, the divide being placed below the first beds of coarse sandstone. This division corresponds to the upper part of the Krokstad Shale, etc. of Kiær. The thickness may be about 600 m. The beds of sandstone and grit of the present division are almost identical with the corresponding beds of the intermediate area.

5. The *Dicranograptus* Shale.

This division consists principally of very fine-clastic black shales with a grey streak, accompanied by beds of dark sandstone. The shale frequently contains small pyrrhotite grains in abundance, or sometimes extremely thin veins of pyrite, the exposed rock is, therefore, generally covered with rust. The thickness may be about 200 m. This division is entirely similar to the northern part of the Tømme Shale in the intermediate area, except that the latter is not so rich in iron sulphides. They no doubt in the main represent the same horizon.

In the 'eighties (see Getz 1887) graptolites were collected in this black shale on several localities situated between the farm Kvernmoen within the map area, and the farm Ringveåsen outside of it and about 7 km to the northeast. Assar Hadding (1932) determined the following graptolites from these old collections:

Dicranograptus ramosus Hall
— — var. *longicaulis* Lapw.
— — var.
Dicellograptus forchhammeri Geinitz
Leptograptus flaccidus Hall var. *macer* Elles and Wood

Diplograptus truncatus Lapw. aff. var. *pauperatus* Elles and Wood
— *calcaratus* Lapw. cf. var. *basilicus* Lapw.
— cf. *foliaceus* Murch.
Climacograptus bicornis Hall var.
— cf. *caudatus* Lapw.
— sp. aff. *pulchellus* Hadding.
— *brevis* Elles and Wood

According to Hadding this assemblage appears in the zones of *Dicranograptus clingani* and *Pleurograptus linearis* in the Middle and Upper Caradocian Series. It is probable, but not certain, that both zones are represented.

6. The Volla Conglomerate and Sandstone.

The conglomerate belonging to this division is rather poorly exposed, at least much overgrown, near the road on the west side of the valley. For that reason, probably, it has largely been overlooked by previous authors, but pebbles in sandstone from this locality are mentioned by Brøgger (1877), and quoted from him by Kiær (1932 a). However, the conglomerate is well exposed on the east side of the valley, particularly on the bank of the river Gaula, and in a quarry at the farm Vollagjerdet near Vollan. It proved to be persistent within, and also outside, the present area; thus it was located to the southeast of Altbjørvatnet, about 7 km outside the map, to the southwest. This division is separated from the lower par of Kiær's Hovin Sandstone.

The conglomerate may consist of densely packed cobbles in thick beds, or of more scattered cobbles in coarse sandstone or grit. The cobbles are well rounded and frequently of the size of a fist or greater, measured up to 10 $\times$ 20 cm. The conglomerate is distinctly polygenous, with various rocks in abundance. Fragments of light grey to white quartzite and of quartz-porphyry are, perhaps, the most common. The latter rock consists of resorbed quartz phenocrysts, sometimes dihexaëders, in profusion, and more scattered plagioclase phenocrysts in a fine-grained groundmass. This presumably effusive rock differs both from the Hareklett and from the Grimsås Rhyolite. Cobbles of different types of more basic effusives with laths of plagioclase further occur, differing, however, from the Støren Greenstones; and of grey coarse-grained granite; of grey and greyish blue unmetamorphosed limestone, partly with crinoid stems; etc. The sandstones of this division are coarse-grained, grey or greenish grey, and consist of quartz, quartzite, plagioclase and minor quantities of the acid and more basic effusives mentioned above. The thicknes of this division may be about 150 m, the bulk consisting of sandstone.

7. Black Shale near Nylendet.

On the west side of the Gauldal valley, near the small farms Nylendet, an outcrop of black shale occurs. The visible thickness is only about 5 m, the ground, however, being covered on both sides. This thin shale forms the divide between the preceding and following division.

8. The Hovin Sandstone sens. str.

This characteristic division consists mostly of thick beds of a generally dark grey medium-grained sandstone with level surfaces, typically separated by thin layers or beds of dark shale. The thickness of the sandstone beds frequently measures about 1 to 3 m, but may be up to 5 m. To the south of Hovin railway station there is a large quarry of this sandstone. Just north of the quarry cross-bedding in thin sandstone beds display the up-down of the series. The sandstone is calcite bearing, and consists of angular grains of quartz and plagioclase, etc., with scattered sedimented flakes of muscovite and altered biotite. In the Gauldal valley the thickness of this division may be about 500 m.

THE HORG SERIES

The basal conglomerate of this series, the magnificient Lyngestein Conglomerate, is known from the days of Theodor Kjerulf. As long as this conglomerate was the only one known from the upper part of the beds in the Gauldal valley, it was natural to correlate it with the large Hopla Conglomerate in the Ekne area, in the inner part of the Trondheimsfjord, as done by A. E. Törnebohm (1896), the present author (Vogt 1926) and Kiær (1932 a). A consequence of this correlation was that the Lyngestein Conglomerate and superimposed beds should belong to the Ekne Series (Group) of A. E. Törnebohm (1896). However, after the establishment of the Volla Conglomerate, the author has good reason to believe that it is the latter which corresponds to the Hopla Conglomerate, and not the Lyngestein Conglomerate. Thence, the Ekne beds should correspond to the upper part of the Hovin Series. Accordingly, a new notation must be procured for the uppermost beds in the present area, and the author suggests the term Horg Series.

1. The Lyngestein Conglomerate.

This conglomerate is distinctly different from the polygenous Volla Conglomerate, being prominently a quartzite conglomerate, other rocks occurring only in minor quantity. The fragments are extremely well worn, frequently forming regular ellipsoids or ovaloids, even if the boulders are quite large. Generally, they are closely packed together and touching each other, with minor pebbles and sandstone in the interspaces. The entirely predominating rock is an uniform light grey to white quartzite. Besides, an almost black, very fine-grained quartzite is commonly appearing. A dark blue unmetamorphic limestone frequently occurs, often in more angular pieces; fragments of fossils, particularly crinoid stems, are common in this rock; lighter coloured varieties of unmetamorphic limestones are also found. Quartz-porphyry, with corroded quartz phenocrysts in abundance and more scattered phenocrysts of decomposed feldspar also occur. To the southeast, cobbles of an intersertal quartz-gabbro (quartz-hyperite) appear, with rather large laths of plagioclase and with quartz in minor quantities in the interspaces. A single small pebble of a medium-grained somewhat trondheimite-like rock was found to the southeast, consisting of quartz, acid plagioclase, chessboard-albite and chlorite, altered from biotite. However, it cannot be maintained that this rock actually represents a caledonian trondheimite. Coarse grey sandstone beds in the conglomerate are calciferous and contain grains of quartz, quartzite, a little plagioclase, flakes of muscovite, etc.

Certain differences exist between the conglomerate on the northwestern and on the southeastern side of the Horg syncline. This is ascribed to unequal distances from the source of the rock material, especially of the quartzite. This applies to the thickness, the size of the fragments and the amount of sandstone. The thickness is greater, and the size of the fragments larger to the southeast, whereas the amount of sandstone is larger to the northwest. Again, in the southeastern outcrop, the thickness decreases and the quantity of sandstone increases towards the southwest. For instance, the largest fragments measured at one location at Gaua river, in the southeast, was 22 × 35 cm, but 8 × 12 cm at Midttømme, in the northwest, see Pl. V,

Fig. 2. At Gaua the thickness was somewhat more than 39 m, whereof 13 per cent are sandstone beds, and above Hovin railway station, farther to the northeast, somewhat more than 65 m, only with some quite insignificant beds of sandstone. The largest thickness evidently appears still farther to the northeast, presumably in the neighbourhood of the hill Lyngesteinen. The evidence points to a supply of rock fragments in an easterly direction. The quartzite fragments may possibly come from Algonkian quartzites belonging to the Quartzite-Shale Series of Bror Asklund (1938) to the east, corresponding to the Ringsaker Quartzite of the Mjøsa area.

2. The Sandå Beds.

The division, the youngest known in the district, may be arranged in subdivisions of dark shale and sandstone. The beds are best exposed on the southeastern side of the Horg syncline. Above the Lyngestein Conglomerate first follows a relatively thin sandstone division, consisting of thin and thick beds of grey sandstone. These beds are underlying a large division of dark shales, extremely well exposed in the Gaulfoss gorge and surroundings. Lowest appear, on the river bank east of the inlet to the gorge, an extremely characteristic rock, consisting of a banded dark grey shale. Thin layers of grey silt measuring 1 mm to a few cm, alternate with almost black shale. The boundary between the silt layers and the shale is sometimes sharp on one side and diffuse on the other. This "varve"-like structure indicates a seasonal deposition. A single very irregular bed of rhyolite tuff also appears, measuring about 30 cm. The disarrangement of this bed is obviously caused by a small slip on the sea bottom. In the gorge itself alternating beds of almost black shale and thin beds of dark fine-grained sandstone follow. All these beds, termed the Gaulfoss Shales, split after a false cleavage and not after the bedding. Crystals of pyrite are distributed in the rocks.

To the northwest of the gorge follows a sandstone division, presumably superimposed on these shales, and consisting of dark grey sandstone beds. This sandstone frequently contains irregular fragments of black shale, indicating that beds in the neighbourhood at times were elevated above the sea level. The rocks of the Sandå Beds give, on the whole the impression of having been formed in shallow water.

CORRELATIONS WITHIN THE MAP AREA

As to the stratigraphical correlations within the map area, reference may be made to the table p. 501. Tentatively are added the British subdivisions, being the most convenient for this part of the Caledonids. Underlying the Langeland Slate of probably Lower Llanvirnian age, the Støren Greenstone Series may belong to the Skiddavian and possibly also lower. The break between the Støren Series and the Venna Conglomerate is evident. The rocks belonging to the former series were probably also somewhat metamorphosed before the deposition of the conglomerate.

The Hølonda Limestone to the northwest and the Langeland Slate to the southeast are both occurring far down in the Krokstad Shale, but do not appear together within the map area. However, it seems that a part of the Gaustadbak Breccia may be correlated with the thin Bruaberg Breccia, which is intercalated in the Langeland Slate and Flagstone horizon. Both breccias contain fragments from the Støren Greenstones, both display indications of an elevation above the sea level, and both appear in approximately the same stratigraphical position. The Bruaberg Breccia may particularly be correlated with some horizon in the upper part of the Gaustadbakk Breccia. The Hølonda Limestone may thence be somewhat younger than the Langeland Slate. So far, this is in accordance with the evidence obtained from the fossils, which is, however, not quite definite.

The approximate identity of the Krokstad Shale and Sandstone on both sides of the Horg syncline, is supported by stratigraphical and lithological evidences. It is remarkable that fragments from the Støren Series appear so high up in the series as in the Krokstad Sandstone and Grit. Incidentally it may be observed that the boundary between the Krokstad Shale and the Krokstad Sandstone is indicated on Kjerulf's old geological map (1879); the Hovin Sandstone Group of Kjerulf includes the Krokstad Sandstone and superimposed beds, whereas the Krokstad Shale is incorporated in the Støren Group to the southeast and in the Hølonda Group to the northwest.

The Tømme Beds, with the fossils of the Esphaug boulder, may principally be correlated with the *Dicranograptus* Shale. In both cases the fossils indicate a Caradocian age; the beds are similar, and occur in the same stratigraphical position. Previous authors have placed this fossiliferous boulder with the Hovin Sandstone; but Brøgger

Correlation between the Beds in the Hølonda-Horg Area.

		Northwestern Area	Intermediate Area	Southeastern Area
Llandoverian	Horg Series	Absent	2. Sandå Beds 1. Lyngestein Conglomerate	2. Sandå Beds 1. Lyngestein Conglomerate
Llandoverian			Break	Break
Ashgillian	Upper Hovin Series			2. Hovin Sandstone
Ashgillian	Upper Hovin Series		2. Grimsås Rhyolite	
Ashgillian	Upper Hovin Series		1. Volla Conglomerate	1. Volla Conglomerate
Caradocian	Lower Hovin Series		Break?	Break
Caradocian	Lower Hovin Series		9. Tømme black Beds with *Cryptolithus* and Rhyolite Tuff 8. Esphaug bedded Rhyolite Tuff 7. Hareklett massive Rhyolite Tuff	5. *Dicranograptus* Shale
Caradocian	Lower Hovin Series		6. Svarttjern Limestone 5. Krokstad Sandstone	4. Krokstad Sandstone
Llandeilian	Lower Hovin Series		4. Krokstad Shale, middle and upper Part	3. Krokstad Shale, middle and upper Part
Llandeilian	Lower Hovin Series	5. Hølonda Andesite		
Llandeilian	Lower Hovin Series	4. Hølonda Limestone, fossiliferous	3. Hølonda Limestone	
Llanvirnian	Lower Hovin Series	3. Hølonda Shale	2. Hølonda Shale, or Krokstad Shale, lower Part	
Llanvirnian	Lower Hovin Series	2. Gaustadbakk Breccia and Almås Mudstone		2. Langeland Slate with *Trinucleus*, and the Bruaberg Breccia 1. Bjørgen Shale, or Krokstad Shale, lower Part
Llanvirnian	Lower Hovin Series	1. Venna Conglomerate	1. Venna Conglomerate	(Venna Conglomerate)
Skiddavian		Break	Break	Break
Skiddavian	Støren Series	3. Upper Støren Greenstones with Høve Slate 2. Jåren Beds 1. Lower Støren Greenstones	Støren Greenstones	Støren Greenstones

(1877) may, perhaps, have used the term in an extended sense, covering a greater part of the Hovin Series, and subsequently the district has not been closely studied. This classification does not, however, agree very well with the stratigraphical evidence, particularly not after the establishment of the Volla Conglomerate. However, this discrepancy has vanished, as the geological conditions in the intermediate area have proved to be quite different from those previously supposed. The correlation with the Hovin Sandstone can no longer be contended. In the Tømme Beds and in the *Dicranograptus* Shale obviously two contemporary Caradocian faunas are preserved: To the northwest a shelly facies, and to the southeast a graptolite facies.

In the black Tømme mudstone, beds of rhyolite tuff of the same type as in the Esphaug and Hareklett Rhyolite Tuffs are intercalated. The latter tuffs, presumably being rather quickly deposited, may well be contemporaneous with the lower part of the *Dicranograptus* Shale. This assumption is supported by the occasional appearance of partially dark shales in the Esphaug bedded Tuff, and by a thin bed of black carbonaceous shale at Giltjernet, just below the Hareklett massive Tuff, not previously mentioned. On the other hand, grains of quartzite, etc. appear in small quantities in the tuffs, adverting to an association with the Krokstad Sandstone. However, the close connection with the Tømme Beds rather decidely indicates a Caradocian age.

The Volla Conglomerate and Sandstone are rather differently developed on both sides of the Horg syncline. This applies to the sandstone material, which appears in great quantities in both places. To the northwest it consists almost exclusively of rhyolite tuff, for the most part heavily weathered, whereas, to the southeast, it is chiefly made up of quartz and quartzite grains and only subordinately of grains of effusives. However, this difference is consistent with the great volcanic activity in the intermediate area, which is lacking in the southeastern. In the latter, the boundary below the Volla Beds seems to be very marked, which can hardly be said of the one in the former area. To the southeast a break is assumed. To the northwest, however, a break seems more doubtful; the interval is, perhaps, bridged by volcanic tuffs. The stones in the conglomerates on both sides of the Horg syncline are, indeed, more similar, except that the acid volcanic rocks on both sides are slightly different. Obviously they are derived from different sources.

In the intermediate area the Lyngestein Conglomerate rests on the Grimsås Rhyolite, which is lacking in the southeastern area, and in the latter on the Hovin Sandstone, which is not found in the intermediate area of the map. However, outside the map, farther to be southwest, rocks appear which probably are equivalent to the Hovin Sandstone. The deficiency of these beds in the district mentioned may tentatively be ascribed to an erosion before the deposition of the Lyngestein Conglomerate. The lower boundary of the latter is sharp, with indications of unevennesses in the substratum formed by erosion. Accordingly, a break below the Lyngestein Conglomerate is maintained.

SOME STRATIGRAPHICAL CORRELATIONS

The Trondheim Region.

A few typical areas in the Trondheim region should be mentioned, see correlation table p. 504. To the north of the lake Foldsjøen, about 5 to 7 km south of Hommelvik railway station, the lower part of the Lower Hovin Series is disclosed. Above typical Støren Greenstones with pillow structures and breccias follow, in inverted position, sandstones and shales with a bed of conglomerate. Next occurs the Nyhus crinoid-bearing Limestone, mentioned by Kjerulf already in 1871. It proved to be a thin bed of dark bluish grey limestone with very indistinct traces of crinoid stems, the visible thickness being only only about 2 m. This bed may approximately be correlated with the Hølonda Limestone. Further to the north sandstones and shales follow, but are not closely examined.

In the vicinity of Hommelvik, on the north side of the syncline, thick beds of sandstone with beds of conglomerate, superimposed on a dark shale, appear. The conglomerate is polygenous, with cobbles of different types of light grey granites, quartzites and acid effusive rocks. This conglomerate exhibits a very great similarity to the Volla Conglomerate. It is underlying thick beds of sandstones, with thin layers of shale between the beds, resembling very much the Hovin Sandstone.

An important geological section is located at Åsen to the south of the Ekne area. It is mentioned by A. E. Törnebohm (1896) and was visited cursorily by the present author in 1924 (Vogt 1926). During the last few years, however, it was unfortunately considered

Correlations between Beds in the Trondheim Region.

	Horg	Hommelvik	Ekne-Åsen	Kjølahaugene
Horg Series	Gaulfoss Shale } Sandå Beds Lower Sandstone } Sandå Beds Lyngestein Conglomerate			*Rastrites* Shale Sandstone Quartzite Conglomerate
	Break			
Upper Hovin Series	Hovin Sandstone Volla Conglomerate	Hovin Sandstone Polygenous Conglomerate	Hovin Sandstone } Ekne Series Hopla Conglomerate } Ekne Series	
	Break	Break	Break	
Lower Hovin Series	*Dicranograptus* Shale Krokstad Sandstone } Krokstad Beds Krokstad Shale p. p. } Krokstad Beds Hølonda Limestone } Krokstad Beds Krokstad Shale p. p. } Krokstad Beds Langeland Slate } Krokstad Beds Bjørgen Shale } Krokstad Beds Venna Conglomerate	Dark Shale ? Nyhus Limestone Sandstone and Shale Covered	Shales, etc. Thick Limestone? Shale Roofing Slate Shales, with thin Limest.? Stokvola Breccia?	
	Break	Break	Break	
Støren Series	Støren Greenstones	Støren Greenstones	Støren Greenstones	

inadvisable to revisit this very interesting area. Superimposed on the Støren Greenstones, in the mountain Stokvola, the Stokvola Greenstone Breccia of Törnebohm occurs. After the investigations at Hølonda it is not quite clear if this breccia may be correlated with the Venna Conglomerate or if it belongs to the greenstone breccias in the Støren Greenstone proper. The former correlation may, however, be probable; if so, the term of Törnebohm should be retained for this conglomerate in the Trondheim region.

Above the Stokvola Breccia or Conglomerate follows a division of shales and some sandstone with a normal and steep dip to the north. These beds obviously correspond, in the main, to the Krokstad Beds at Horg. To the south of Åsen church a roofing slate horizon with trails probably of trilobites, etc. appear in these beds. About 1 km to the east, viz. to the south of Åsen railway station, an upper thick, partially brecciated bed, and a lower thin bed of limestone occur. The relation between the slate horizon and the limestones is not examined. However, the beds appear rather close together, and it seems that the slate horizon may be placed between the two limestones. The slate may preferably be correlated with the Langeland Slate, and the upper thick limestone with the Hølonda Limestone.

On the south side of the lake Hammervatnet follows the Hopla Conglomerate, resting farther to the west, at Hellem, on a limestone. This thick conglomerate is well exposed in the road cuts between the western end of Hammervatnet and the farm Hopla. Beds of coarse-grained and more fine-grained sandstone alternate with thick beds of conglomerate with well rounded ellipsoidal stones up to 3 dm in size. The conglomerate is polygenous, with fragments of various types of granite, partially very similar to Precambrian granites e. g. in the Ørlandet area; further, of quartzite, an effusive porphyrite rock of intermediate composition, etc. Angular fragments of shales, particularly black shale, also occur. In the opinion of the author it is extremely probably that this conglomerate corresponds to the Volla Conglomerate. In this location sandstones, so far not closely examined, is superimposed on the conglomerate.

Another section in the Ekne area was studied in 1937, viz. at the south side of the Trondheimsfjord between the Skogn (Alstadhaug) and Ekne churches. On the Fiborg peninsula the Støren Greenstones appear, and in the upper part, i. e. to the southwest, with a greenstone conglomerate. Close above the latter follow thick conglomerate beds alternating with sandstone beds in two small promontories. The fragments consist of granite, quartzite, etc., cemented by ordinary sandstone. Törnebohm (1896) seems to have traced this conglomerate in connection with the Hopla Conglomerate, which it certainly resembles. Upwards follows a large division of thick and thin sandstone beds, with intercalated thin layers of shale. The sandstone is calciferous and somewhat metamorphosed, with newformed sericite and clinozoisite, and is correlated with the Hovin Sandstone, which it resembles. Incidentally, it may be noted that the areas mentioned (at Hommelvik and at Åsen-Ekne) belong to the same northwestern synclinorium in the Trondheim region as the Hølonda—Horg area.

On the low mountain Malbuheia, on the ordnance map Steinkjer, a sandstone and conglomerate division appear in a small syncline. On the summit the cobbles are well rounded, of size up to a cocoa-nut or head, and more, and consist chiefly of grey granites. After a cursory examination in 1924 the author had the impression that this division rests on the Precambrian substratum with a great unconformity. It is tentatively correlated with the Volla Conglomerate. The author has studied the base of the Cambro-Silurian series on several localities in the northwestern part of the Trondheim region, but nowhere encountered similar conditions. A conglomerate on the hill Geværsteinen, on the ordnance map Skjørn, not visited by the author, may, perhaps, occupy the same position as the Malbuhei Conglomerate.

Törnebohm (1896) further distinguishes the following areas with rocks belonging to the Ekne Group: 1. Conglomerates in the Stjørdal valley, which must be more closely studied before it is appropriate to discuss them. A thick division of sandstone, probably corresponding to the Hovin Sandstone, occurs in this valley. This calciferous sandstone is metamorphosed and contains new-formed acicular hornblende, representing the needle-sandstone of Kjerulf (1883). 2. A small area to the northeast of the Mosviken church, which is probably made up of Støren Greenstones. 3. A large are to the northwest of Steinkjer. The author has not seen very much of this area, but so far no rocks to be correlated with the Upper Hovin Series have been detected. 4. A large area to the north of the great lake Snåsavatnet, which is actually made up of Støren Greenstones, see a note by the present author (1926).

The only discovery so far of Silurian fossils in the Trondheim region is that by Alfred Getz (1887) from the mountains Kjølahaugene close to the Swedish-Norwegian border, on the ordnance map Meraker. The fossiliferous shales apparently represent the youngest beds in a small syncline. According to Getz, the following beds appear: 1. Sandstone beds, lowermost. 2. Conglomerate beds with cobbles of quartzite and marble, by Törnebohm expressly termed a quartzite conglomerate. 3. Sandstone beds. 4. Black and grey shale, uppermost. This shale contains graptolite species belonging to the genera *Monograptus* and *Rastrites.* According to information from Miss Gertrude E. Elles to Johan Kiær (1932 a), the zones of *Monograptus convolutus* and *Monograptus sedgwicki* are probably both represented. They belong to the upper part of the Middle Llandoverian and lowermost part of the Upper Llandoverian Series of Great Britain.

The Otta Serpentine Conglomerate from the Otta valley in Gudbrandsdalen (se Vogt, 1916) is also traced into the proper Trondheim region, on the southeastern side of the Trondheim synclinorium. Recently it was discovered as far to the northeast as the Røros area by Leiv Gjessing, my geological assistant in that area. The fossils found in this conglomerate in the Otta valley and described by Herman Hedstrøm (1930) display an age corresponding to the *Expansus* Shale (3 cβ) and the *Orthoceras* Limestone (3 cγ) in the Oslo region. These horizons correspond broadly to the lower part of the Llanvirnian Series in Great Britain. The Langeland Slate in Gauldalen is ascribed to about the same age, and it seems, therefore, natural to correlate the Otta Conglomerate with the Bruaberg Conglomerate, which is contemporaneous with the Langeland Slate horizon. However, the difference in age between the Bruaberg and the Venna (Stokvola) Conglomerates may be insignificant, and the Otta Conglomerate may, perhaps, as well be contemporaneous with the latter. This is, more or less, in accordance with previous correlations (see V. M. Goldschmidt 1916, C. W. Carstens 1920, p. 136 and Th. Vogt 1928, p. 102), which is extensively corroborated by more recent data based on fossils.

The lowermost series of the Cambro-Ordovician strata of the Trondheim region is not encountered within the map area, but may conveniently be mentioned here, particularly as to the question of denomination. The term Røros Group is at present applied to Cambro-Ordovician sediments below the Støren Series. However, this term is felt to be extremely unsatisfactory for the northwestern part of the Trondheim region. During the last years, the author, assisted by various geological collaborators, has made detailed investigations in the Røros area. The latter is situated in the southeastern part of the Trondheim synclinorium, and about 100 km from the northwestern part. Despite the fairly detailed investigations, it has not, as yet, been possible to correlate, even broadly, the beds on both sides of the synclinorium. This is particularly due to the fact that effusive rocks corresponding to the Støren Greenstones either are lacking, or their presence in the Røros area are, at least, very questionable. Furthermore, the stratigraphy and tectonics in the Røros area are rather difficult to unravel, as guide zones mostly are lacking. The only indication is that both series appear low down in the series of strata. Therefore, in the opinion of the author the term Røros Series cannot be applied in the remote northwestern part of the Trondheim region, at least not at present. Th. Kjerulf (1875), who introduced the term, did not use it for beds situated to the northwest. On his geological map he marked, with the same colour, the lowest beds to the southeast as Røros Schist, and the lowest to the northwest as Trondhjem Schist. Neither can Kjerulf's term Trondhjem Schist be applied, as the beds in question do not actually appear at Trondheim. The term Brek Schist Group of Törnebohm (1896) may, however, be useful. On the type locality the group includes, in fact, a greater part of the sediments below the Støren Greenstones, which are clearly defined in this area. However, the lowermost division, a hornblende porphyroblast schist, is excepted, and is, for petrological reasons, included in the Røros Group. Meanwhile, Törnebohm himself discusses the possibility that this lowermost schist may represent a more high-grade metamorphosed part of the Brek Schist Group. To avoid the introduction of a new term, it is proposed to include this lowest schist in the latter group. The Brek Series comprise, then, the beds above the Sparagmitian Beds or other Precambrian rocks and the beds below the Støren Greenstones in the northwestern part of the Trondheim region. The term Røros Series is reserved for more or less contemporary divisions, as yet not closely defined, in the southeastern part of the same region.

Western Norway.

Reference may be made to previous correlations between beds in the Trondheim region and in western Norwegian areas by C. W. Carstens (1920, pp. 139—143), Thorolf Vogt (1928, pp. 101—108)

Correlation between Beds in the Trondheim Region and the Western Norway.

	Trondheim Region		Os	Stord	Karmøy
Horg Series	Sandå Beds	*Rastrites* Shale	*Rastrites* Shale		
			Stricklandinia Shale and Limestone of Ulven-Vaktdal (6 c)		
	Lyngestein Quartsite Conglomerate		Quartzite and Quartzite Conglomerate of Skarpefjell	Quartzitic Sandstone?	Quartzite Conglomerate of Ryvingen?
	Break		Break?		
Upper Hovin Series [Ekne Series]	Hovin Sandstone		Schist?	*Orthograptus* Shale	
			Coral Limestone of Kuven-Valle (5 a)	Coral Limestone of Limbu-viken (5 a)	Sandstone, etc. of Tjøst-heim (4 d or 5 a)
			Schist	Shale	
	Volla (Hopla) polygenous Conglomerate		Moberg polygenous Conglo-merate	Polygenous Conglomerate	Polygenous Conglome-rate of Skudeneset
Lover Hovin Series	Break		Large break	Large break	Large break?
	Dicranograptus Shale				
	Krokstad Beds				
	Venna (Stokvola) Conglomerate				
	Break				
Støren Series	Støren Greenstones		Greenstones	Greenstones	
Brek Series	Schists and Limestone		Schist	Schists and Limestone	

and Johan Kiær (1929, pp. 41—46), particularly to the latter. After the present investigation of a type area in the Trondheim region, a reconsideration may, perhaps, be in order, see the table p. 509. The author had the privilege to visit the Os and Stord areas under the versed guidance of the professors C. F. Kolderup and N.-H. Kolderup.

The most complete succession of beds with fossil horizons is found in the Os area to the south of Bergen. This area was described by Hans Reusch (1882), who made his remarkable discovery of three different fossil horizons in the more or less metamorphosed rocks. Recently C. F. and N.-H. Kolderup (1940) have published an excellent geological map of the area with short descriptions of the rocks. Descriptions and determinations of the fossils are contained in a paper by Kiær (1929). The beds are vertical, or nearly so, and the order of succession is difficult to decide. Apparently there exist two synclines divided by a large intrusion of gabbro: one in the district of Os proper, including Ordovician beds, and another, in the district of Ulven, with Silurian beds. From below, and principally from the south, the following beds are disclosed.

1. Lower mica schists. 2. Green schists and greenstones, correlated with the Støren Greenstones. 3. The polygenous Moberg Conglomerate, with cobbles of green schists and greenstones, amphibolites, trondheimites, quartzites and limestones, supposedly corresponding to the polygenous Volla (Hopla) Conglomerate in the Trondheim region. According to C. F. and N.-H. Kolderup, the "chloritic sparagmite" of Reusch, on the north side of the syncline, containing also a polygenous conglomerate, may represent this and, perhaps, the preceding division. 4. Mica schists. 5. Coral-bearing limestone or marble at Kuven—Valle—Heglandsdalen. According to Kiær this corresponds to the Gastropod Limestone (étage 5 a) in the Oslo region, i.e. to the upper part of the Ashgillian Series. The limestone bed is intercalated in schist, but occupies principally the central part of the presumed syncline.

On the north side of the large gabbro intrusion follows: 6. Quartzite and quartzite conglomerate, inter alia on the hill Skarpefjell. The stratigraphical position of these beds corresponds to that of the Lyngestein Quartzite Conglomerate and particularly the quartzite conglomerate at Kjølahaugene. The agreement as to the rock in the cobbles of these conglomerates is remarkable. 7. Mica schist and calcareous nodules with *Stricklandinia lens,* etc., according to Kiær corresponding to the *Stricklandinia* Shale and Limestone (étage 6 c), with abundant occurrence of this species, in the Oslo region, i.e. to the Middle Llandoverian Series. 8. *Rastrites* Shale at Ulven. According to information submitted by Gertrude Elles to Kiær (1929) *Rastrites peregrinus* Barr. is present, belonging to the zone of *Monograptus convolutus,* uppermost in the Middle Llandoverian Series. This zone is also represented at Kjølahaugene in the Trondheim region. According to Astrid Monsen (C. F. and N.-H. Kolderup 1940), *Rastrites maximus* is discovered in another locality at Ulven. This indicates the zone of *Monograptus turriculatus,* far down in Upper Llandoverian. The zone of *Monograptus sedgwicki,* between these two horizons, is not established at Ulven, where it may be anticipated, but probably occurs at Kjølahaugene.

The area in the neighbourhood of Limbuviken at Stord was described by Hans Reusch (1888), who discovered the fossil horizons on this locality, and by Johan Kiær (1929), who also examined the fossils collected by Reusch, C. F. Kolderup and others. Petrological descriptions of some rocks by the present author (1929) accompanies the paper of Kiær. The original order of succession is difficult to decide, not least because of strong tectonic disturbances. The following tentative sequence seems probable and conforms to that advanced by Kiær: 1. Mica schists e. g. at Lervik, with limestone, lowermost. 2. Effusive greenstones, corresponding to the Støren Greenstones. 3. A very thick polygenous conglomerate, with cobbles consisting of various types of effusive greenstones; rhyolites with phenocrysts of corroded quartz and plagioclase, similar to quartz porphyries in the Volla Conglomerate; granites of various types; saussurite gabbro; quartzites and sandstones; red jasper; limestones; etc. The author (1929) designated some granitic rocks with abundant plagioclase in this conglomerate as trondheimites. They differ, however, somewhat from the genuine Caledonian trondheimites, and are not necessarily identical with them. I should prefer to term them trondheimite-like rocks. This conglomerate probably corresponds to the Volla (Hopla) Conglomerate. 4. Shales with fragments of effusive rocks. 5. Limestone beds with corals and other fossils, e.g. at Limbuviken. According to Kiær they correspond to the Gastropod Limestone (étage 5 a) in the Oslo region, and also to the fossiliferous limestone at Kuven—Valle in the Os area. 6. Shales. 7. Black *Orthograptus* Shale. According to Gertrude Elles (Kiær 1929) it belongs to the zone of

Orthograptus vesiculosus in the lower part of the Lower Llandoverian Series. As pointed out by Kiær it is noteworthy that this shale follows conformably, and without interposed coarse-grained sediments, the shales and limestones No. 6 and 5. 8. The "diabase" of Reusch. It is not decided whether this rock is of effusive or intrusive origin. It is very fine-grained and with minute laths of plagioclase, but the effusive character must be checked by field studies. The stratigraphical position of this rock is also questionable. 9. Thin shale? 10. Quartzitic sandstone, which possibly may be correlated with the quartzite and quartzite conglomerate at Skarpefjell, etc. in the Os area. Farther to the north the beds are cut by a large intrusion of granite.

The recent remarkable discovery of fossils by Fridtjov Isachsen (Broch, Isachsen, Isberg, Strand 1940), on the southern part of the large island Karmøy is of great interest. The lowest sedimentary division known in this area may, probably, be the large polygenous conglomerate at Skudeneset, etc., with cobbles consisting of effusive greenstones, effusive quartz porphyrites, granites (trondheimites), etc. This conglomerate, most naturally, corresponds to the polygenous conglomerate at Stord and Os, as presumed by Isachsen. A fossiliferous division, probably superimposed on this conglomerate, follows at Tjøstheim, etc., consisting chiefly of sandstones with intercalated thin beds of shales, and conglomerate. The fossiliferous beds may correspond to the étage 4d or 5a in the Oslo region, both zones belonging to the Ashgillian Series. The Tjøstheim beds may correspond to the Coral Limestones at Stord and Os or, perhaps, to a somewhat lower horizon. The latter alternative seems justifiable from a stratigraphical point of view. It is of interest to note that the sandstone division at Tjøstheim, etc. may, broadly, be contemporaneous with the Hovin Sandstone in the Trondheim area.

THE VOLCANIC ROCKS

A synopsis of the volcanic rocks in the Hølonda—Horg area is given in the table on p. 513. The Støren Greenstones underlie beds of probably Lower Llanvirnian age, indicating a Skiddavian age of the volcanic rocks. Investigations on the island Smøla in Møre has previously yielded a similar age. On this island Hans Reusch (1914) discovered basic lavas and traces of fossils in an intercalated cherty

Volcanic Rocks in the Hølonda-Horg Area.

Upper and Middle Llandoverian	Horg Series	Thin layer of rhyolite tuff in Gaulfoss Shale. Thickness 0.3 m
Lower Llandoverian	Upper Hovin Series	Grimsås Rhyolite. Thickness about 50 to 500 m
Ashgillian		
Caradocian	Lower Hovin Series	Esphaug bedded Rhyolite Tuff. Thickness from 0 to about 700 m. Hareklett massive Rhyolite Tuff. Thickness about 200 to 1000 m
Llandeilian		Hølonda andesitic Porphyrites. Hanging wall not exposed. Thickness perhaps a few hundred meters.
Llanvirnian		
Skiddavian	Støren Series	Støren Greenstones. Principally metamorphosed basalts and pyroclastic material of basaltic composition, with small amounts of intermediate and more acid effusives, and insignificant injections of quartz-keratophyre. With pillow structures and thin layers of jasper. Thickness about 2500 m at Støren.

limestone. Olaf Holtedahl, on several occasions (1915, 1918, 1919, 1924), described and discussed the fossils from Smøla, which proved to belong to the american-arctic faunal province and to be of Canadian age. These important attainments were subsequently corroborated by Trygve Strand (1932 b). The basic lavas from Smøla were described by C. W. Carstens (1924) and classed with the Støren (Bymark) Grenstones. Undoubtedly, the Støren basaltic Greenstones are generally contemporaneous with basaltic volcanic rocks of early Ordovician age in Great Britain. At that time the centre of volcanism there was in the southern part of Scotland, viz. in Souhern Uplands and in Highland Border areas, and the Ballantrae Volcanic Rocks, of Lower Skiddavian age, may be distinguished as close counterparts of our rocks. But volcanic rocks of a similar age also occur in other parts, especially in various Welsh areas.

The Hølonda andesitic Porphyrites may probably be of Llandeilian age. Volcanic rocks of a similar age are known in various areas of Great Britain, but the centre of volcanism was in Northern England. The closest counterpart to our rocks may be the Borrowdale Volcanic Series in the Lake District, where andesites seem to be the most prominent rocks.

The Hareklett and Esphaug Rhyolite Tuffs are situated below the fossiliferous Tømme Shale Horizon, and may be of Caradocian age. In Great Britain the rhyolites are the most prominent volcanic rocks of that age. These rocks are represented especially by the Snowdon Volcanic Series in Northern Wales, and by the Jarlside Volcanic Rocks in the Lake District and Cross Fell in Northern England.

The Grimsås Rhyolite or Quartz-porphyry, probably representing an effusive rock, appear above the Volla Conglomerate and may apparently be of Ashgillian age. The volcanism in Great Britain is diminishing at this epoch, but rhyolites are known inter alia in the Peebles-Broughton area in the Central and Southern Belt of the Southern Uplands in Scotland.

As far as known, the volcanism in the Hølonda—Horg area practically expired at the close of the Ordovician period. Intercalated in the Gaulfoss Shales, which tentatively is placed in the Middle or Upper Llandoverian, only a quite insignificant bed of rhyolite tuff appear.

Outside the Hølonda—Horg area volcanic rocks younger than the Støren Greenstones are not as yet known in the Trondheim region, except the Hareklett Rhyolite Tuff which is found close to the western end of the lake Selbusjøen. C. W. Carstens (1920) has assumed the existence of younger volcanic rocks in various areas in the Trondheim region. However, the greenstones to the north of the lake Jonsvatnet near Trondheim probably belong to the Støren Series. The extended area from Skatval to the Levanger district consists, in the southern part, of Støren Greenstones, and in the northern part of intrusive amphibolites in the Brek Series. The origin of the rocks in the area to the west of Røros is not as yet quite clear; probably they consist of intrusive amphibolites, but if they should happen to be effusive origin, they may belong to the Støren Greenstones.

Among the volcanic rocks mentioned, the Støren Greenstones are beyond comparison the most extensive. Indeed, the basic volcanic rocks in areas of Great Britain, in Western Norway, in the Trondheim region and in Southern Lapland in Sweden form an extended and, at least partially, connected basalt belt with contemporaneous volcanism in early Ordovician time. The general trend of this belt coincides with the later Caledonian folding zone. The basalt eruptions of this belt may decidedly be considered as the first great revelation of the forces which in much later time produced the Caledonian orogeny proper.

The establishment in the Hølonda—Horg area of volcanic rocks younger than the Støren Greenstones indicates, perhaps, a greater correspondance between the British and the Norwegian part of the Caledonids than previously evident. It is remarkable that the general trend of the magmatic differentiation seems to proceed on parallel lines which are also co-ordinated as to time. In the Trondheim region the series including basalt, andesite and rhyolite seems to be extruded at the Skiddavian, Llandeilian and Caradocian-Ashgillian epochs respectively. In Great Britain the younger effusive rocks are far more extensive and also much more varying. But a general tendency in the same direction is certainly perceptible also here.

The series of volcanic and intrusive rocks in the Hølonda—Horg area is metamorphosed to such an extent that the original minerals have disappeared. The present minerals are quartz, albite, hornblende, epidote, chlorite, muscovite, etc., and the differentiation series can no more be characterized by its minerals. One is dependent on the chemical composition, which is not always quite reliable because of the extraction particularly of lime in rocks with abundant chlorite and small quantities of hornblende. Anyway, in order to obtain, as closely as possible, the original composition, the rock specimens were selected among the less metamorphosed types.

The volcanic series, comprising the Støren Greenstones, the Hølonda Andesites and the Grimsås Rhyolite, exhibits a decided prevalence of soda in proportion to potash. This appears from the following table, where the figures affixed indicate the number of the analyses in the present paper and the average composition of Daly (1933), respectively.

Hølonda—Horg etc.		$K_2O : Na_2O$
Støren Greenstones	1.2	1 : 180
Hølonda Andesites	6.7.8	1 : 3.3
Grimsås Rhyolite	10	1 : 1.4

Average Compositions Daly.

Plateau basalt	60	1 : 3.8
All andesite	49	1 : 1.8
All rhyolite	5	1 : 0.76

The appearance of plagioclase (albite) phenocrysts also in the rhyolites is in accordance with the prevalence of soda; and likewise the differentiation of the intrusions of quartz-keratophyre, rich in soda, from the Støren basalt magma. In the Hareklett Rhyolite tuff, potash is excessive in proportion to soda; but the rock fragments in this tuff may have been weathered before sedimentation, and the tuffs are also somewhat blended with foreign material. The predominance of soda in the rocks mentioned is considered a primary feature, indicating that the rocks constitute a series of common origin. In this connection the intrusive trondheimites may also be kept in mind. The proportion $K_2O : Na_2O$ is 1 : 3.2 as an average of 12 analyses published by V. M. Goldschmidt (1916). They are probably formed at a later juncture, but of a kindred magma.

According to the method of A. M. Peacock (1931), the alkali-lime index of the rock series is procured, see Fig. 9. From the figures of the analyses the index is about 55.0 and about 55.8 when the analyses are calculated as water free. The typical Hølonda Porphyrite of the Berg type No. 8 is a rather basic andesite, with less silica and more lime and alkalis than the averages of andesites of Daly (1933). It corresponds fairly well to basic andesites, e.g. to the aleutites. The andesito-basalt No. 6 agrees with transition rocks between andesites and basalts, e.g. with the granulitic basalt of H. H. Thomas (1911) from the Skomer Island. The latter rock may, perhaps, be approximately contemporaneous with our Støren Greenstones. The andesite rock No. 7, with much epidote and chlorite and only small amounts of hornblende, may have lost some lime and perhaps also silica. The quartz-keratophyre No. 4 may also have lost some lime, whereas the rhyolite No. 10 has normal percentages of lime and alkalis. The rhyolite tuff No. 9 falls beyond the general trend. An alkali-lime index of 55 to 56 represents a rather alkalic character of the rock series. It should belong to the alkali-calcic series, although very close to the calc-alkalic. C. W. Carstens (1922 c) has also mentioned the somewhat alkalic character of the effusives in the Trondheim region on the

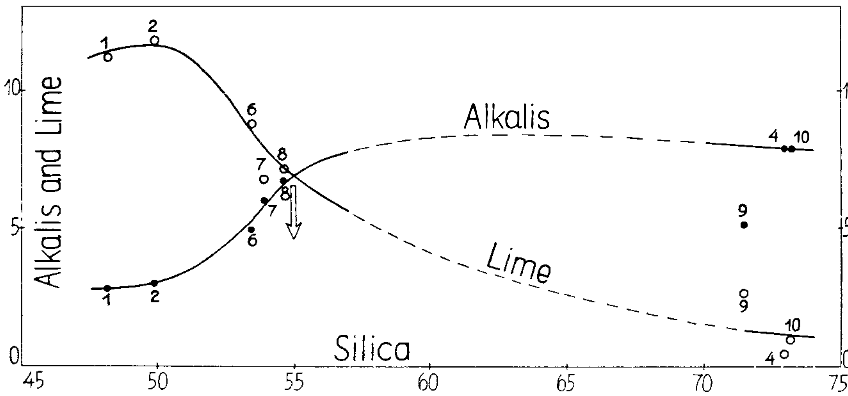

Fig. 9. Curves for $Na_2O + K_2O$ and CaO of the volcanic series in the Hølonda—Horg area. The figures refer to the number of the analyses in the text.

basis of an andesitic greenstone belonging to the Støren Greenstones (analysis F).

The question is whether the chemical composition of these rocks is altered to a discernible degree through the metamorphism. As previously mentioned, the basaltic greenstones exhibite a close resemblance to the plateau basalts, only, in our rocks, the percentages of lime are slightly higher and of alkalis slightly lower. A perceptible change in the chemical composition seems hardly probable here. So far, this seems to be the case with the best preserved andesitic rocks. However, this should be corroborated through additional analyses.

DIASTROPHISM

The correlations over considerable distances as mentioned in previous chapters, are based upon the co-ordination of two principles: First the paleontological evidence, and second the diastrophic evidence. The latter refers to displacements of the shore-line, which may be contemporaneous over large regions. In this chapter the elevation of land masses above the sea level is considered, presumptively indicating smaller or greater orogenic disturbances. A priori it is not considered unconditionally necessary that these elevations of land masses in an orogenic zone are syncronal with the world-wide regressions of the sea outside this zone. The elevation of the land is manifested by synorogenic conglomerates. According to the terminology of Twenhofel (1926, p. 155), they may chiefly be designated as cobble and boulder conglomerates. Not only are the rock fragments in the conglomerates derived from a land mass above the sea level; but at least the well rounded larger cobbles and boulders, consisting of rocks from obviously remote sources, may have been transported long distances in rapidly flowing rivers.

Three important and coarse conglomerates are encountered in the Hølonda—Horg area, each forming the basal conglomerate of a stratigraphical unity. To these are added granule conglomerates, and also a cobble conglmerate of quite restricted extension, in the middle part of one of the series. These conglomerates are all very different and each of them reveals a different story of origin. Below follows a synopsis of relations pertaining to this connection, particularly in the Trondheim and Bergen regions; see the table on p. 519, in which is tentatively added the classification in étages of the Oslo region.

THE TRONDHEIM DISTURBANCE

In the Hølonda—Horg area the Venna Conglomerate as far as I have seen, consists exclusively of rock fragments which undoubtedly or probably belong to the substratum, i. e. the Støren Series. The fragments, frequently being angular and reaching the size of boulders, may have been transported only a short distance. The conglomerate or breccia was presumptively formed of the existing débris as the sea transgressed the land surface. Moreover, the whole character of the conglomerate indicates that the transgression at the locations studied by the author has been a rapid one. The conglomerate may be interpreted as a basal conglomerate proper, so far, in a restricted sense, the only in our area. The Gaustadbakk Breccia and the Bruaberg Conglomerate or Breccia, are closely connected with the Venna Conglomerate. They bear evidence of continental conditions and indicate minor displacements of the shore-line shortly after the greater transgression had taken place.

Already Törnebohm (1896) presumed an elevation above the sea level, and denudation of the Støren Greenstones after their formation, interpreting the Stokvola Greenstone Breccia in accordance with this. The same interpretation was maintained by V. M. Goldschmidt (1916), C. W. Carstens (1918, 1920) and particularly by Olaf Holtedahl (1920 a) who called attention to the orogenic character of the un-

Diastrophism in the Trondheim and Bergen Regions.

Upper Llandoverian	7 a—c	Horg Series	
Middle Llandoverian	6 a—c?		Lyngestein Conglomerate
Lower Llandoverian	5 b?	Break	Horg Disturbance
	Break		
Ashgillian	4 c β—5 a	Upper Hovin Series [Ekne Series]	Volla (Hopla) Conglomerate
Caradocian	4 c α	Break	Ekne Disturbance
	Break		
	4 b β—4 b δ	Lower Hovin Series / Great break	Krokstad Granule Congl.
Llandeilian	4 a α_2—4 b α		
Llanvirnian	3 c—4 a α_1		Gaustadbakk Breccia. Venna (Stokvola?) Congl.
Skiddavian	Break?	Break	Trondheim Disturbance
	3 b	Støren Series	
Tremadocian	2 e—3 a		
Cambrian	1—2 d	Brek Series	

conformity and introduced the term Trondheim disturbance for the orogeny implied.

This orogenic disturbance seems to have been of considerable consequence. First, the substratum might have been somewhat metamorphosed before the transgression took place. This seems probable from a comparison, in the Hølonda area, between the metamorphosed rock fragments in the basal conglomerate (e. g. calcite marble) and the almost unmetamorphosed rocks above the latter (e. g. fine-grained limestone). Second, a break corresponding to the Trondheim disturbance may be traced over wide-spread regions. A break in Southeastern Norway, previously termed the Trysil elevation by the present author (1928, 1936) is probably identical with the Trondheim disturbance. As a matter of fact, the Trondheim disturbance in the type region was formerly referred to a younger age than at present, viz. to the Llandeilian epoch (Holtedahl), and to a presumed break above the *Orthoceras* Limestone (between 3 cγ and 4 aα) in the Oslo region (Th. Vogt). An unconformity demonstrated by Holtedahl (1920 b) in the Trysil area, below the *Orthoceras* Limestone, should accordingly represent an older phase than the Trondheim disturbance. However, the paleontological evidence now known displays approximately the same age for the two breaks, compare also the table by Olaf Holtedahl in the general view of the Caledonides by Bailey and Holtedahl (1938). Breaks corresponding to the Trondheim disturbance are accordingly known from most of Southern Norway. Conglomerates below (not above) the Fauske and Evenes Limestones in Northern Norway may belong to the same phase (Th. Vogt, 1926).

CONGLOMERATES IN THE LOWER HOVIN SERIES

In the Krokstad Sandstone several beds of granule conglomerates with well rounded granules and small pebbles partially of rocks from the Støren Series occur. These occurrences display a minor elevation of some more distant land masses, presumably in the Llandeilian epoch. The conglomerates may, perhaps, be contemporaneous with e. g. the Benan Conglomerate in the Girvan area.

A quartz-diorite cobble conglomerate or breccia at Sundsetkjølen has a quite limited distribution. As it appears at the base of a volcanic tuff, it might possibly have been formed in connection with volcanic action.

THE EKNE DISTURBANCE

The Volla Conglomerate consists of cobbles and pebbles which are derived partly from nearby sources, viz. quartz-porphyries and fossil bearing limestones, and partly from more remote sources, viz. quartzites and granites. Especially the latter group is well rounded. The Hopla Conglomerate is probably contemporaneous; it has a similar composition and contains inter alia boulders of practically unweathered coarse-grained granite. These granites are, to all appearance, of Precambrian age. Their occurrence demonstrates the remarkable fact that the Precambrian basement complex was probably uncovered even in those times. Observations by Törnebohm (1896) seems to indicate an uneven and denuded substratum below the Hopla Conglomerate, which also seems to overlap the underlying beds. In the opinion of the author the conglomerate was transported by rapidly flowing rivers and deposited on more or less even plains.

The orogeny manifested by these conglomerates (the author's "Ekne disturbance" 1928, 1936) seems to have been of importance in the Caledonides of Norway, and the denudation at this time considerable. The underlying Lower Hovin Series is probably most completely preserved in the Horg area. Even in the southern part of the Ekne area, at Åsen, the upper part of the series may perhaps be missing, and in the northeastern part of the same area, at Fiborg, the Ekne Conglomerate in all probability rests directly on the Stokvola Greenstone Conglomerate. This feature also supports the presumption that the whole Lower Hovin Series is lacking in Western Norway, at Os and at Stord.

The correlation by Carstens (1920) of the Støren (Bymark) Greenstones in the Trondheim region with the extensive volcanic greenstones in Western Norway, vaguely suggested by Hans Reusch (1891) and definitely by Schei (1909), appears to me to be valid. A contemporary age is also maintained by Kiær (1929) and in the recent memoir by C. F. Kolderup and N.-H. Kolderup (1940). Incidentally it may be mentioned that the existence of younger Ordovician volcanic rocks in Western Norway is not admitted at present. At the time when Carstens advanced the correlation mentioned above, it was apparently supported by paleontological evidence, the greenstones in both regions underlying beds classed by him (p. 136, 141) with the Oslo étages 5 a and 5. However, Kiær's revision of the fossils proved the beds in the two regions to be of very different age. Kiær, maintaining the synchronal age of the greenstones, found himself obliged to accept a great break between the greenstones and the fossiliferous beds in Western Norway.

The existence of such a break now appears to be very natural, as it is likely to represent the denudation, below the Volla Conglomerate, of land masses elevated during the Ekne disturbance. A non-deposition of the lacking beds is, of course, possible, but does not seem probable. This great denudation may, perhaps, be the clue to the comprehension of the remarkably small thicknesses of the Cambro-silurian sediments in Western Norway as compared with those in the Trondheim region and in Northern Norway. Further, these small thicknesses make it comprehensible why the Precambrian substratum at present is uncovered to such a high degree in Western Norway, contrary to the conditions in the Trondheim region. This feature contributes very much to the particular style of the Western Norwegian Caledonides. As mentioned above, the Precambrian substratum was probably uncovered, in certain parts of the Caledonides, as early as in the time of the Ekne disturbance. The question arises if younger ordovician sediments in some places were not deposited directly on Precambrian rocks. This possibility has been suggested concerning the conglomerates and sandstones of Malbuheia, etc. in the Trondheim region, and I should like to mention that the same potentially may be present with regard to the Skudenes Conglomerate at Karmøy.

The lost interval of the Ekne disturbance may be placed between the *Dicranograptus* Shale in Horg, in Middle or Upper Caradocian. and the coral limestones in Upper Ashgillian in the Os and Stord areas. Broadly, it may be placed between the Caradocian and Ashgillian epochs, so far in accordance with previous suppositions by the author. The break in the Oslo region between the Upper *Chasmops* Limestone (4 bδ) and the Lower *Trinucleus* Shale (4 cα) may be not far from contemporaneous. This applies also to a break between the zones of *Dicranograptus clingani* and *Pleurograptus linearis* mentioned from Jemtland by Per Thorslund (1940). These correlations depend on the occurrence or absence of the zone of *Pleurograptus linearis* in Horg, as Thorslund has referred the horizon 4cα at Oslo to this zone.

Consequently, the Ekne disturbance is nearly contemporaneous with the Taconic revolution in North America, which is placed between the American Ordovician and Silurian periods, i. e. approximately between the British Caradocian and Ashgillian epochs. Apparently the Ekne disturbance is the most important of the early Caledonian orogenies in Norway. The land masses were elevated above the sea level over large regions, the beds were tilted and perhaps gently folded, and the denudation was radical. The unconformity is generally very marked, but no non-conformity has been observed.

THE HORG DISTURBANCE

The Lyngestein Conglomerate, so far the most conspicuous conglomerate in the Hølonda—Horg area, is composed of two elements, one far transported and one of local origin. The former consists almost exclusively of cobbles and boulders of quartzites, very well rounded, and the latter especially of quartz-porphyries or rhyolites and fossiliferous limestones. The limestone fragments may be angular and sometimes extremely irregular in shape, as if weathered after the transportation. The conglomerate is wholly dominated by the quartzites. Details previously mentioned by Brøgger display unconformable relations to the substratum, and the conglomerate apparently also overlaps older beds.

Very much the same may be said of this conglomerate as of the Volla (Hopla) Conglomerate; but the former is principally a quartzite conglomerate while the latter is typically polygenous. It is a remarkable fact that the conglomerates corresponding to the Lyngestein Conglomerate are all quartzite conglomerates, whereas those being correlated with the Volla Conglomerate are all polygenous. This might of course be a question only of different sources of the rock fragments. But to this is to be said that the same rule involves so remote districts as the Trondheim region and Western Norway. It may, perhaps, be more natural to assume a difference in weathering of the rock material before the transportation in rivers. The land mass supplying the rock fragments to the Venna Conglomerate, etc. may have been inconsiderably weathered, whereas the land which is the source of the Lyngestein Conglomerate, etc. may have been weathered for a long time. The granites, etc. were then largely decomposed, whereas the quartzites survived. This difference in weathering accords so far with the ages of the conglomerates if a land mass is supposed to have persisted in the time between the two disturbances. A consequence of the Horg disturbance (new term) may have been a rejuvenation of such a land mass. A possible alternative may be that, at the time of the Ekne disturbance, only eminences of quartzite were formed; this would be very acceptable for the Trondheim and Jemtland regions, but hardly for Western Norway.

The hiatus corresponding to the Horg disturbance may be placed between the *Orthograptus* Shale at Stord, in the lowermost part of the lower Llandoverian Series, and the *Stricklandinia* Shale (6 c) at Os, belonging to Middle Llandoverian. It should approximately be placed between Lower and Middle Llandoverian, so far corresponding to a break established by O. T. Jones (1925) in the Llandovery district of Wales. The break in the Oslo region between the uppermost Ordovician beds (5 a) and the lowermost Silurian (5 b), demonstrated by Johan Kiær many years ago (1901), may, however, be not far from contemporaneous. The fact is that the beds 5 b in the Oslo region, according to St. Joseph (1938), probably belong to the uppermost part of Lower Llandoverian, whereas the greater part of this series are lacking, the Gastropod Limestone (5 a) being of distinct Ordovician age. The hiatus mentioned by Bror Asklund (1938) from Jemtland, below the well known quartzite with *Phacops elliptifrons,* appears to be approximately contemporaneous to our Ekne disturbance, the mentioned quartzite being correlated with our Lyngestein Quartzite Conglomerate.

The Horg disturbance is apparently distinguished by an elevation of land masses and a marked unconformity, by tilting of the beds and overlapping. A denudation below the beds of the Horg Series is perceptible in the Horg area.

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Fig. 1. View of the Gauldal Valley looking southeast. The Støren Greenstones (G) cross the valley in the background. On this side follow the Lower and Upper Hovin Series in southeastern development. Th. Vogt phot.

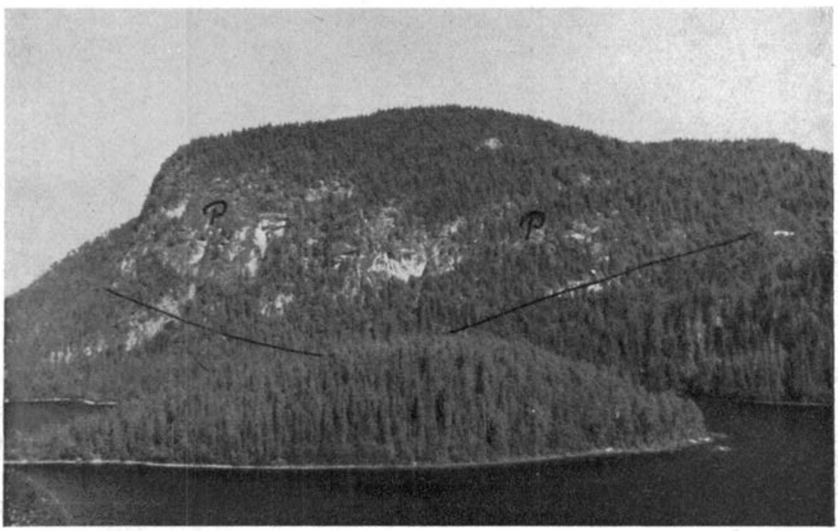

Fig. 2. Hølonda Porphyrite, Berg type (P) in the hill Ramberget, resting on Hølonda Limestone. The lake Gaustadvatnet in the foreground. Th.Vogt phot.

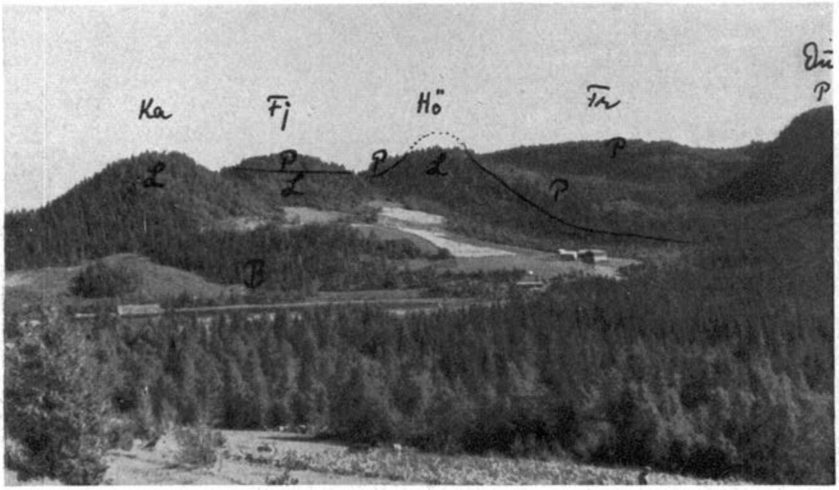

Fig. 1. Hølonda Porphyrite, Berg type (P) in the hills around the farm Stenset, resting on Hølonda Limestone (L). B = Gaustadbakk Breccia. Ka = Katugleåsen. Fj = Fjøsåsen. Hø = Høgåsen at Stenset. Tr = Tranemyråsen. Du = Dugurmålshaugen. Stenset to the right. Th. Vogt phot.

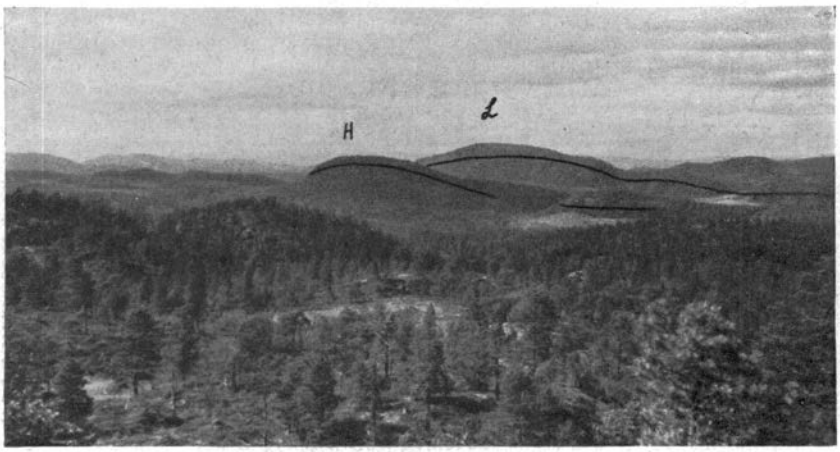

Fig. 2. Hølonda Porphyrite, Almås type at the summits of Høgåsen at Sundset (H) and Langåsåsen (L), looking from Knuthammeren at Vennakjølen. Th. Vogt phot.

Fig. 1. Pillow structures in Støren Greenstone. Road cut at the western side of the lake Benna. $^1/_{25}$ nat. size. Th. Vogt phot.

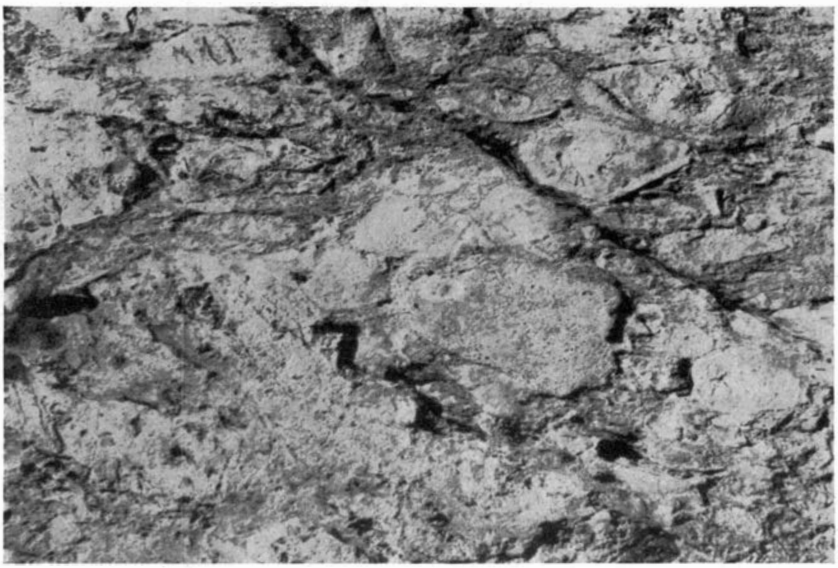

Fig. 2. Greenstone breccia (agglomerate) in Støren Greenstone. On the east side of the lake Benna. $^1/_6$ nat. size. Th. Vogt phot.

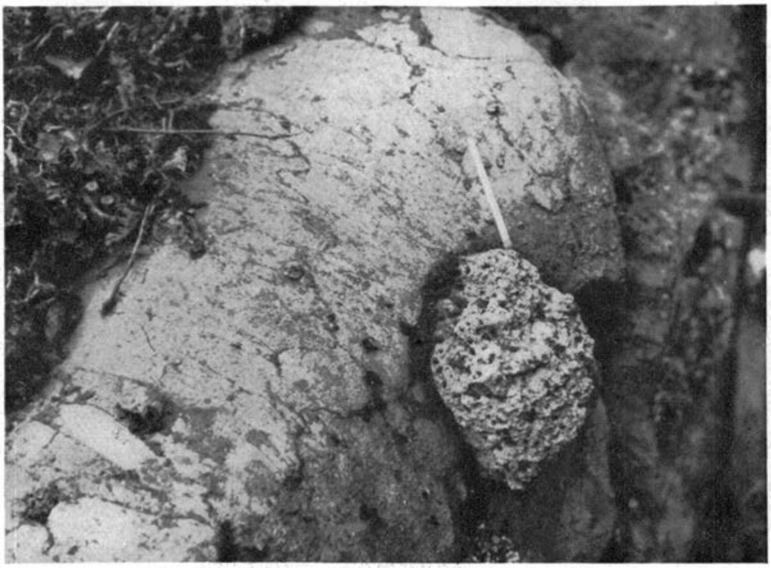

Fig. 1. Fragments of Hølonda Porphyrite, Berg type, in somewhat brecciated Hølonda Limestone. Note the diminutive fragments to the right close above the upper end of the match, and to the left of the upper end of the greater fragment. To the northeast of Tranemyrtjernene between Stenset and Ven. 1/3 nat. size. Th. Vogt phot.

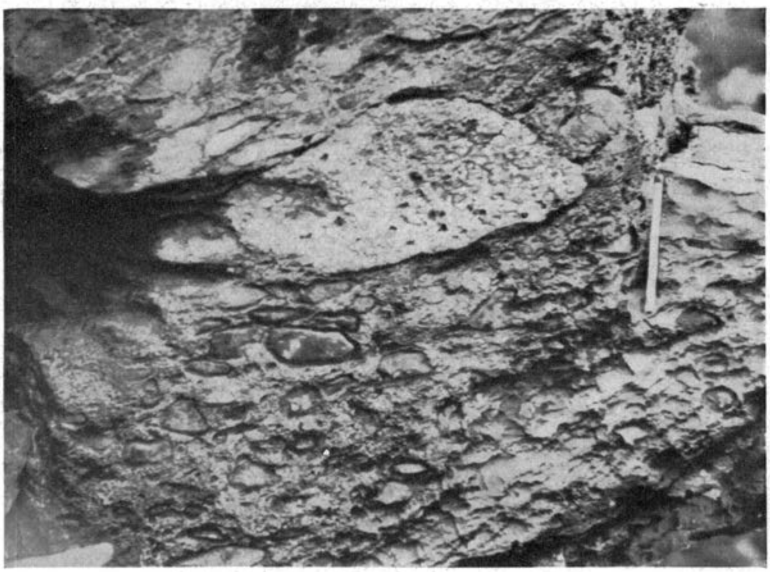

Fig. 2. Fragment of Hølonda Porphyrite, Berg type, in brecciated and weathered Hølonda Limestone. At the dam at the outlet of Damtjernet, Ven. 1/3 nat. size. Th. Vogt phot.

Fig. 1. Venna Conglomerate with a boulder of calcite marble in the centre to the right. From the promontory to the northeast of the farm Ven. Th. Vogt phot.

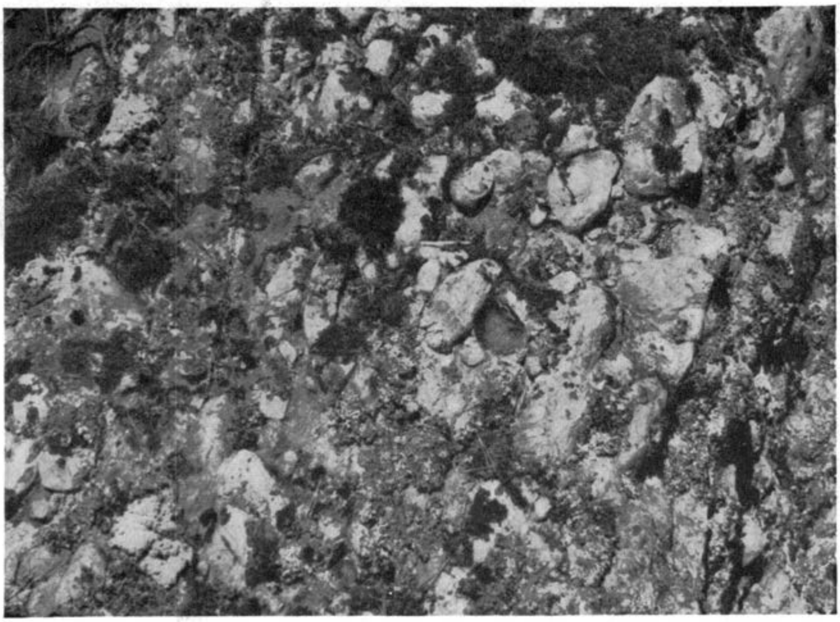

Fig. 2. Lyngestein Conglomerate with pebbles and cobbles chiefly of quartzite. Close to the farm Midttømme. $^1/_7$ nat. size. Th. Vogt phot.

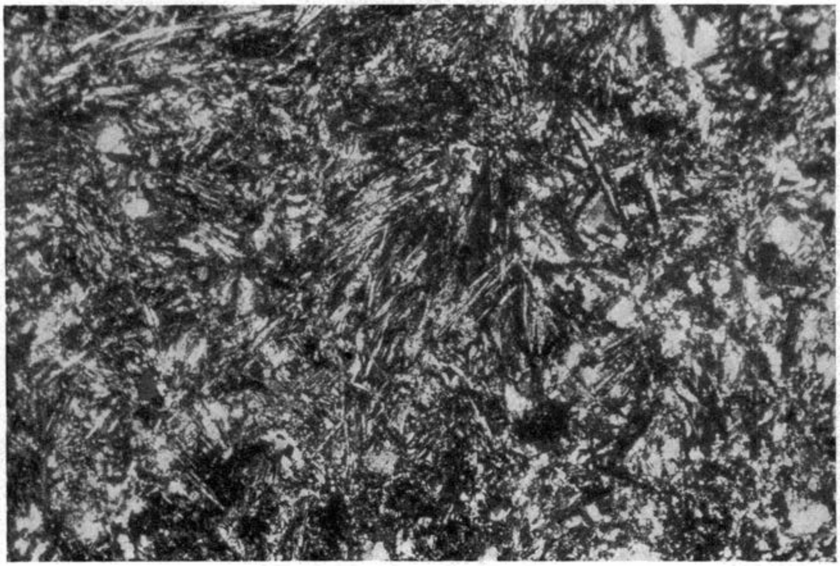

Fig. 1. Støren Greenstone, from the inner part of a pillow, consisting of acicular hornblende, epidote, chlorite, albite, etc. From the western side of Benna. Crossed nicols. 25 × nat. size. Anker Iversen phot.

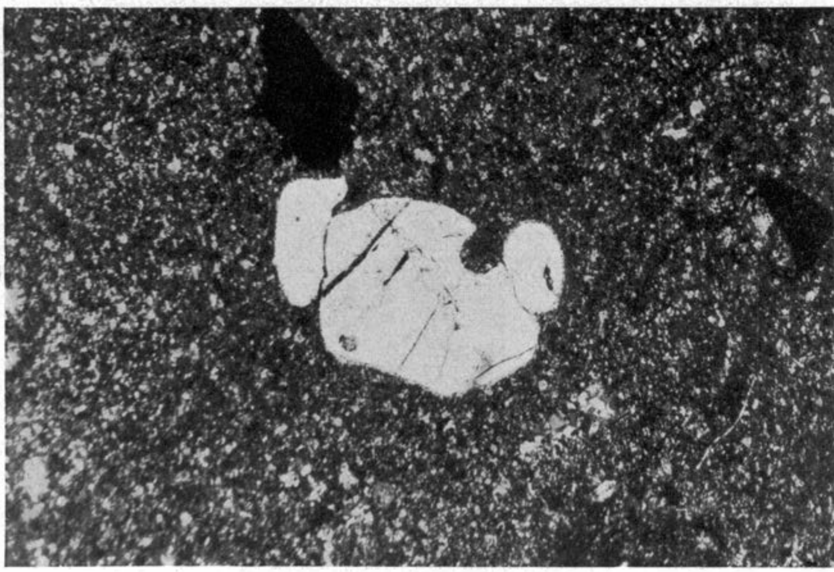

Fig. 2. Quartz-keratophyre in Støren Greenstone, with a corroded phenocryst of quartz. Promontory to the southeast of the farm Ven. Crossed nicols. 25 × nat. size. Anker Iversen phot.

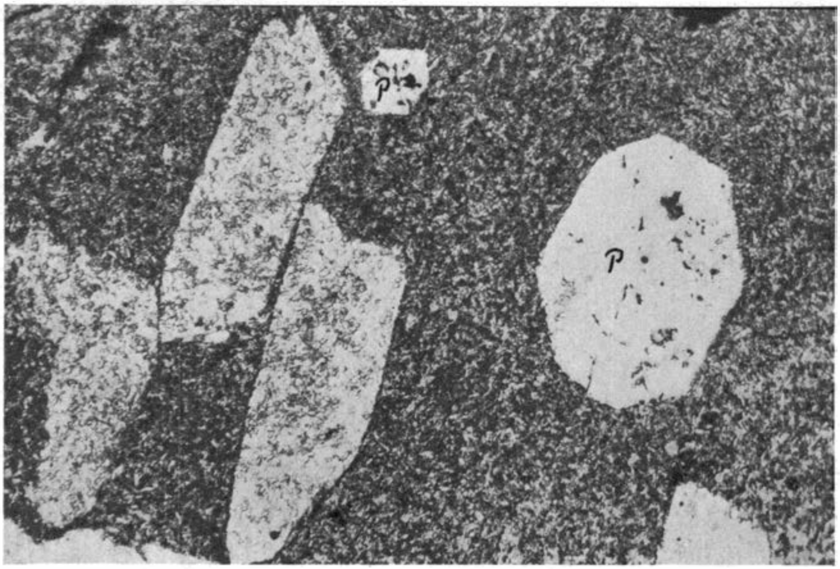

Fig. 1. Hølonda Porphyrite, Berg type, with phenocrysts of altered plagioclase, profuse in small grains of epidote, and altered pyroxene (P), consisting of chlorite and hornblende. To the northeast of the farm Berg. 25 × nat. size. Anker Iversen phot.

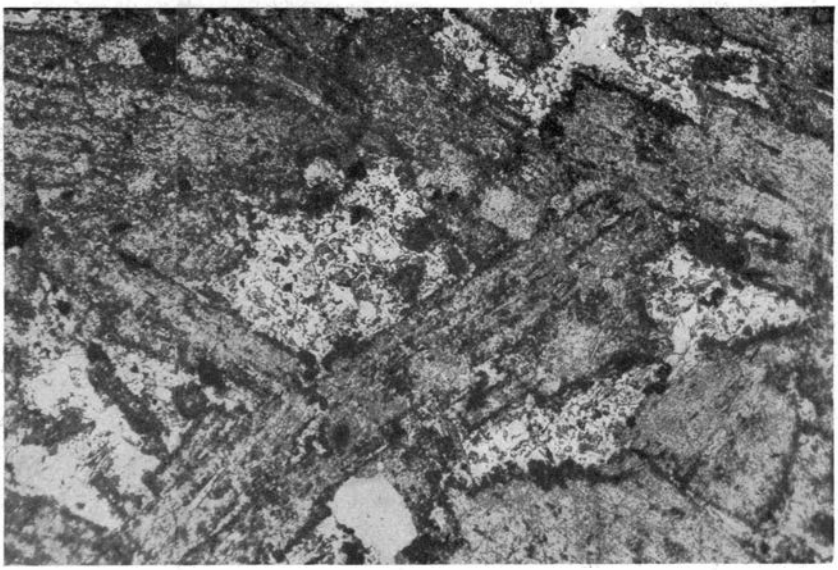

Fig. 2. Hølonda Porphyrite, Almås type, profuse in phenocrysts of altered plagioclase and with some hornblende. From the ridge Almåsåsen close to the lower boundary. 25 × nat. size. Anker Iversen phot.

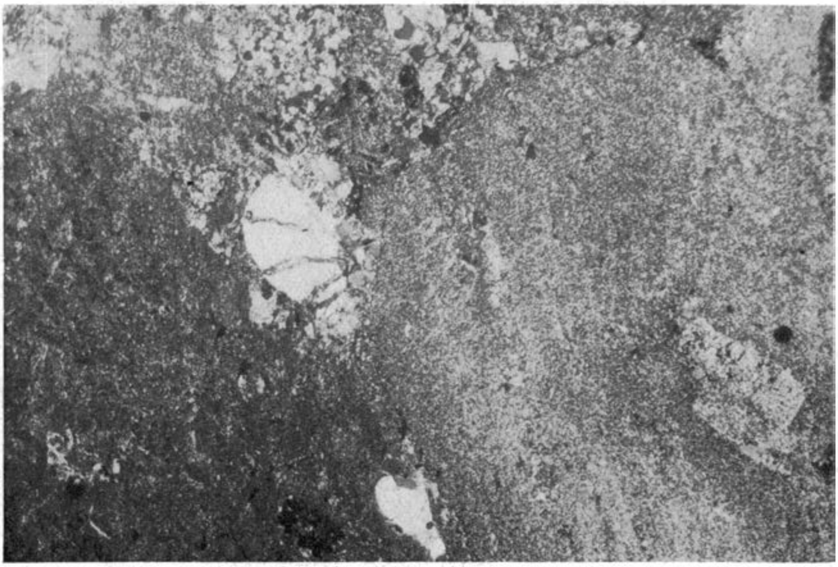

Fig. 1. Hareklett Rhyolite Tuff, with parts of two greater fragments of rhyolite, the one with an altered phenocryst of feldspar. Otherwise with grains of quartz, quartzite and smaller grains of rhyolite. To the westnorthwest of the farm Midttømme. Crossed nicols. 25 × nat. size. Anker Iversen phot.

Fig. 2. Grimsås Rhyolite with phenocrysts of albite. From a quarry at the farm Nordtømme. Crossed nicols. 25 × nat. size. Anker Iversen phot.

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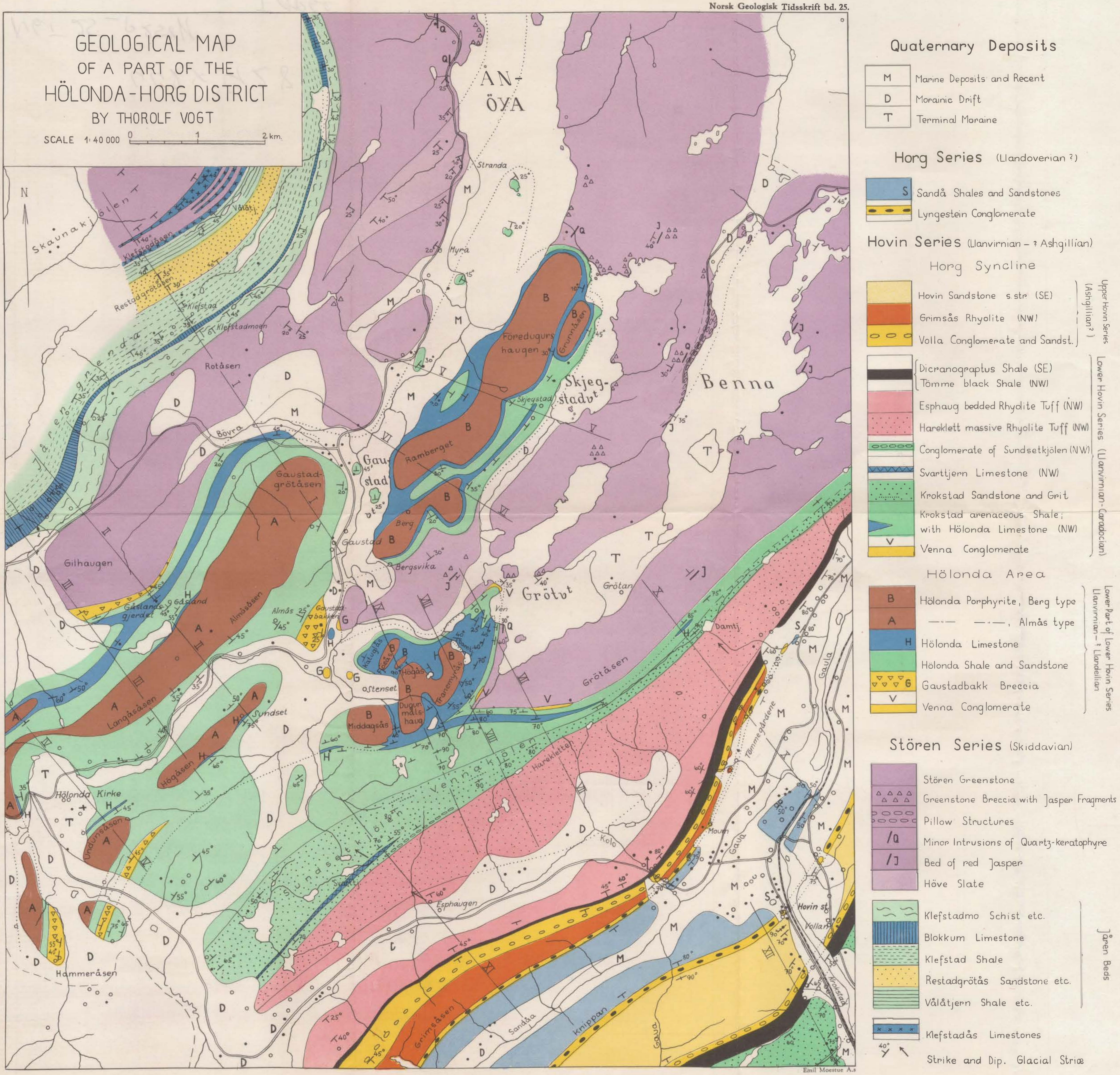

Emil Moestue A.s