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## Innhold

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# Edel granat fra Otterøy ved Molde

Av
*Jens Hysingjord.*

**Abstract.**

A gem garnet from Otterøy by Molde, Western Norway, is described. The garnet displays an «alexandrite-like effect», i.e. the colour varies with the nature of the incident light.

The transmission curves shows absorbtion peaks at 5600 Å and at 4000 Å.

A chemical analysis shows that the garnet is a pyrope with the following composition:

$[Na_{0,008}, K_{0,006}, Fe''_{0,427}, Ca_{0,387}, Mn_{0,026}, Mg_{2,054}]$
$[V_{0,002}, Cr_{0,211}, Fe'''_{0,039}, Al_{1,785}]\ Si_{3,038}(OH)_{0,072}, O_{12,000}$

The refractive index is 1,747 ± 0,001. The cell size = 11,54 ± 0,01 Å.

A determination of the spesific gravity gave 3,715 ± 0,005.

**Innledning.**

Materialet som har vært undersøkt ble samlet inn sommeren 1963, under en befaring for gullsmed Johs. Forberg, Stjørdal.

Granatene er kjent av stedets befolkning og har sporadisk vært solgt til smykkesteinsformål.

Den edle granaten opptrer som bestanddel av granatførende peridotitt. Bergarten finnes ved Uglvik, ca. 3 km NØ for Misund på Otterøy (se fig. 2). Feltet er avmerket på Tore Gjelsviks kart (1951) over Sunnmøre og deler av Nordfjord.

Granaten opptrer i sterk vekslende mengde innen peridotittområdet. I enkelte soner har bergarten anslagsvis 10 % granat, i andre partier er peridotitten nærmest fri for granat. Granaten opptrer i en omvandlet peridotitt. Hovedmineralene er serpentin, olivin, pyroksen og granat. I mindre mengde opptrer hornblende. Aksessorisk opptrer kromitt.

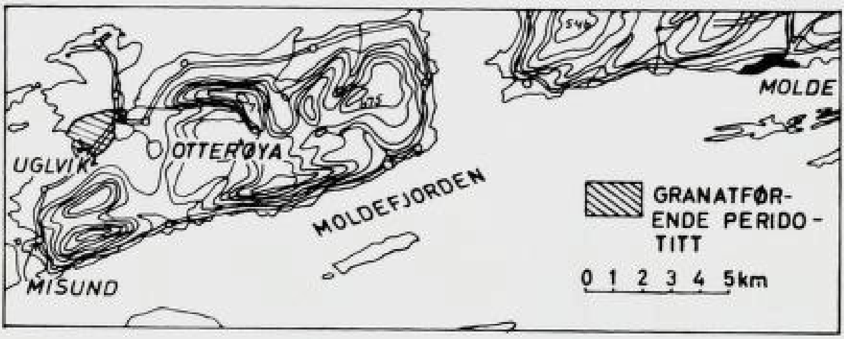



Fig. 2. Kartet viser beliggenheten av den granatførende peridotitt på Otterøy.

Pyroksenen er overveiende enstatitt. I mindre mengde opptrer kromdiopsid. En analysert kromdiopsid viste et $Cr_2O_3$ innhold på 1,9 %.

Granatene opptrer i mm store korn i en finkornet grunnmasse; sjeldnere i cm store aggregater.

**Kjemisk og fysiske bestemmelser.**

Kjemisk analyse av granaten viser:

| | | | |
|---|---|---|---|
| $SiO_2$ | 42,32 % | | |
| $TiO_2$ | 0,00 » | | |
| $Al_2O_3$ | 21,09 » | | |
| $Fe_2O_3$ | 0,73 » | | |
| FeO | 7,11 » | | |
| MnO | 0,42 » | | |
| MgO | 19,20 » | | |
| CaO | 5,03 » | | |
| $Na_2O$ | 0,06 » | | |
| $K_2O$ | 0,07 » | | |
| $H_2O$ | 0,15 » | Ni | x/1000 % |
| $P_2O_5$ | 0,00 » | Cu | x/1000 % |
| $Cr_2O_3$ | 3,72 » | | |
| $V_2O_5$ | ~ 0.05 » | | |
| Sum | 99,95 % | | |

Analytiker: Laboratorieingeniør Per-Reidar Graff, Geol. avd., NGU.

V, Ni og Cu er spektrografisk bestemt av laboratorieingeniør Magne Ødegård, Kjem. avd., NGU.

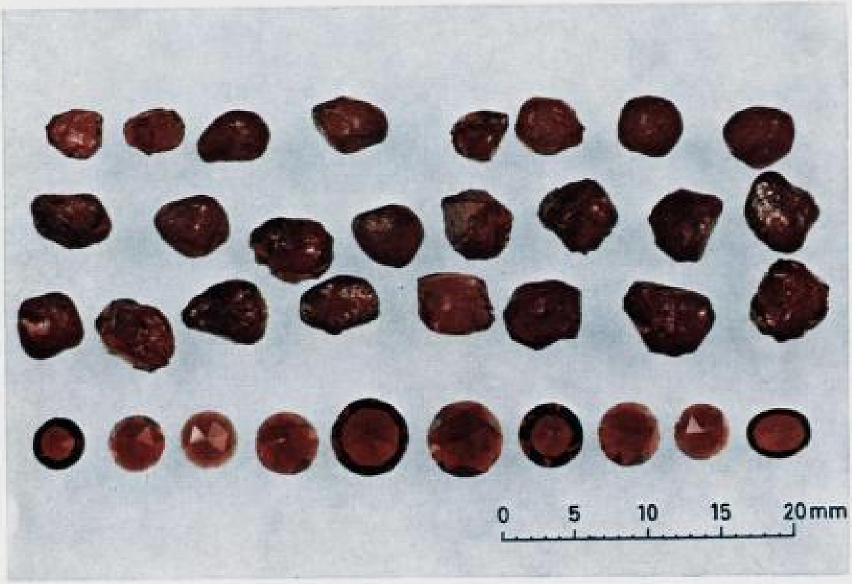



Fig. 1. Uslepne og slepne granater fra Otterøy ved Molde.

Beregningen av den kjemiske analyse viser at granaten er en pyrop med følgende atomforhold:

Antall atomer er basert på 12 O.

| | | | | | |
|---|---|---|---|---|---|
| Si | 3,038 | | Fe'' | 0,427 | 2,908 |
| (OH) | 0,072 | | Mg | 2,054 | |
| Al''' | 1,785 | 2,037 | Mn | 0,026 | |
| Fe''' | 0,039 | | Ca | 0,387 | |
| Cr''' | 0,211 | | Na | 0,008 | |
| V''' | 0,002 | | K | 0,006 | |

Molekyl % av rene endeledd:

| | | | |
|---|---|---|---|
| Almandin | 14,72 % | Pyrop | 70,81 % |
| Andraditt | 2,04 » | Spessartin | 0,88 » |
| Grossular | 0,64 » | Uvarovitt | 10,92 » |

Det ble tatt opp røntgendiagram av granaten. Det er benyttet Debye-Scherrer 11,8 cm kamera, Fe stråling, Mn filter.

Cellestørrelsen er beregnet til:

| | |
|---|---|
| $a_0$ = | 11,54 ± 0,01 Å |
| Brytningsindeks n = | 1,747 ± 0,001 |
| Sp. vekt. | 3,715 ± 0,005 |

*Spesielle undersøkelser.*

Granaten fra Otterøy har en helt særegen fargekvalitet. Den viser en fargeskifting som er betinget av endringer i kvaliteten på det innfallende lys; en egenskap som en kan kalle en «aleksandrittliknende effekt».

I gjennomfallende dagslys har den en fiolett farge, i lampelys er den vinrød.

Slepne fassetterte granater er blitt undersøkt med smykkestens-spektroskop. I spektroskopet iakttas to brede absorbsjonsbånd, et i den fiolette del av spektret og et som strekker seg fra den nedre del av rødt til øvre del av grønt.

For nøyere å undersøke kvaliteten av det gjennomfallende lys, ble det tatt opp en transmisjonskurve av granaten på et Beckman DB spektrofotometer.

En granat ble slipt til en jevntykk plate og limt på en glassplate med canadabalsam.

Granatens tykkelse var ca. 0,8 mm. Som nullreferanse ble brukt en glassplate med et skikt av canadabalsam.

Transmisjonskurven for granaten er vist på figur 3. Kurven viser absorbsjonsmaksima (eller minimum transmisjon) ved 5600 Å og ved 4000 Å.

Transmisjonskurven gir forklaring på den observerte fargeskifting hos granaten. Av kurven ser vi at det lys som trenger gjennom granaten hovedsakelig er røde og blå farger. Dagslyset har sitt energimaksimum i lysets kortbølgede del; lampelys har sitt energimaksimum i lysets langbølgede del. I gjennom-

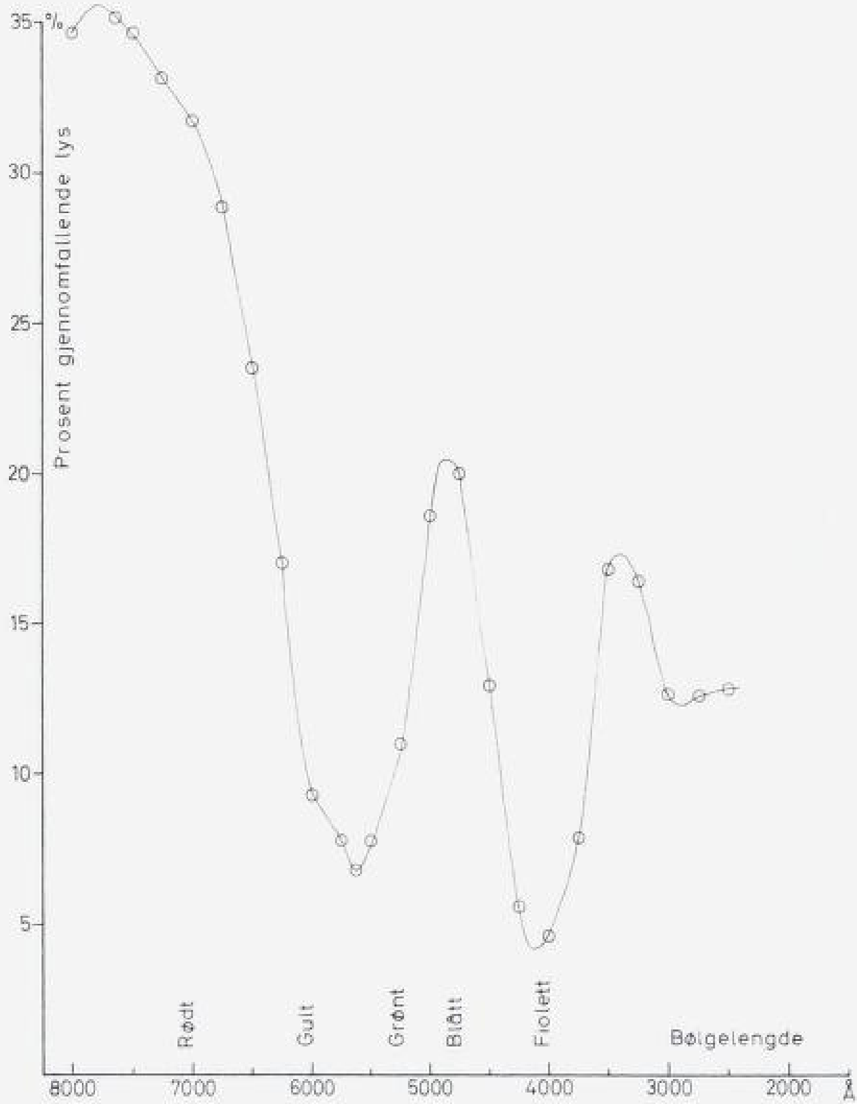



Fig. 3. Transmisjonskurve for edel granat, Otterøy, Molde. Kurven er opptatt på Beckman DB spektrofotometer av laboratorieingeniør Per-Reidar Graff, Geol. avd., NGU.

fallende dagslys vil derfor blå farge dominere over rødt, og granaten vil få en blålig til fiolett farge. I gjennomfallende lampelys vil rødt dominere over blått, og granaten vil her få en rødlig farge.

Naturlig aleksandritt er i dagslys grønn og i lampelys rød. «Syntetisk aleksandritt», som er syntetisk korund med tilblanding av $V_2O_5$ viser den samme fargeskifting. Denne aleksandritteffekt (White, Roy and Crichton, 1967), kan i naturlig aleksandritt tilbakeføres til innhold av $Cr_2O_3$. I «syntetisk aleksandritt» er det $V_2O_5$ som gir opphav til fargeeffekten.

En stor del av granatene fra Otterøy er hele, sprekkefrie og gjennomsiktige med en klar jevn farge som gjør at den egner seg til smykkesteinsformål.

Størrelsen på granatene plukket ut fra peridotitten er vanligvis 3—4 mm, sjelden 4—5 mm.

Gjennomsnittsvekten av 73 granater var 119 mg.

Granatene er vanskelig å få hele ut av bergarten. Ved å knuse peridotitten, brytes granatene istykker, og fragmentene blir vesentlig mindre enn det som ovenfor er angitt.

Gjennomsnittsvekten av 126 større granatfragmenter fra nedknust peridotitt var 34 mg.

Granatene fra Otterøy er vakre og særegne i farge, men vanskelighetene med å få dem hele ut av bergarten, kombinert med den noe lave gjennomsnittsstørrelsen vil vanskeliggjøre utnyttelsen av granatene til smykkesteinsformål.

## Takk

Jeg vil takke laboratorieingeniør Per-Reidar Graff for det utførte laboratoriearbeidet, og statsgeologene Harald Carstens og Thor L. Sverdrup for gjennomgåelse av manuskriptet.

## Litteratur.

*Gjelsvik, Tore.* 1951. Oversikt over bergartene i Sunnmøre og tilgrensende deler av Nordfjord. N.G.U. nr. 179.

*White, W. B.. Roy, R.,* and *Crichton, J. M.,* 1967. «The Alexandrite effect»: an optical study. Amer. Min., B 52, s. 867—871.

# Tectonic Features of an Area N.E. of Hegra, Nord-Trøndelag, and their regional Significance — Preliminary Notes

By

*David Roberts*

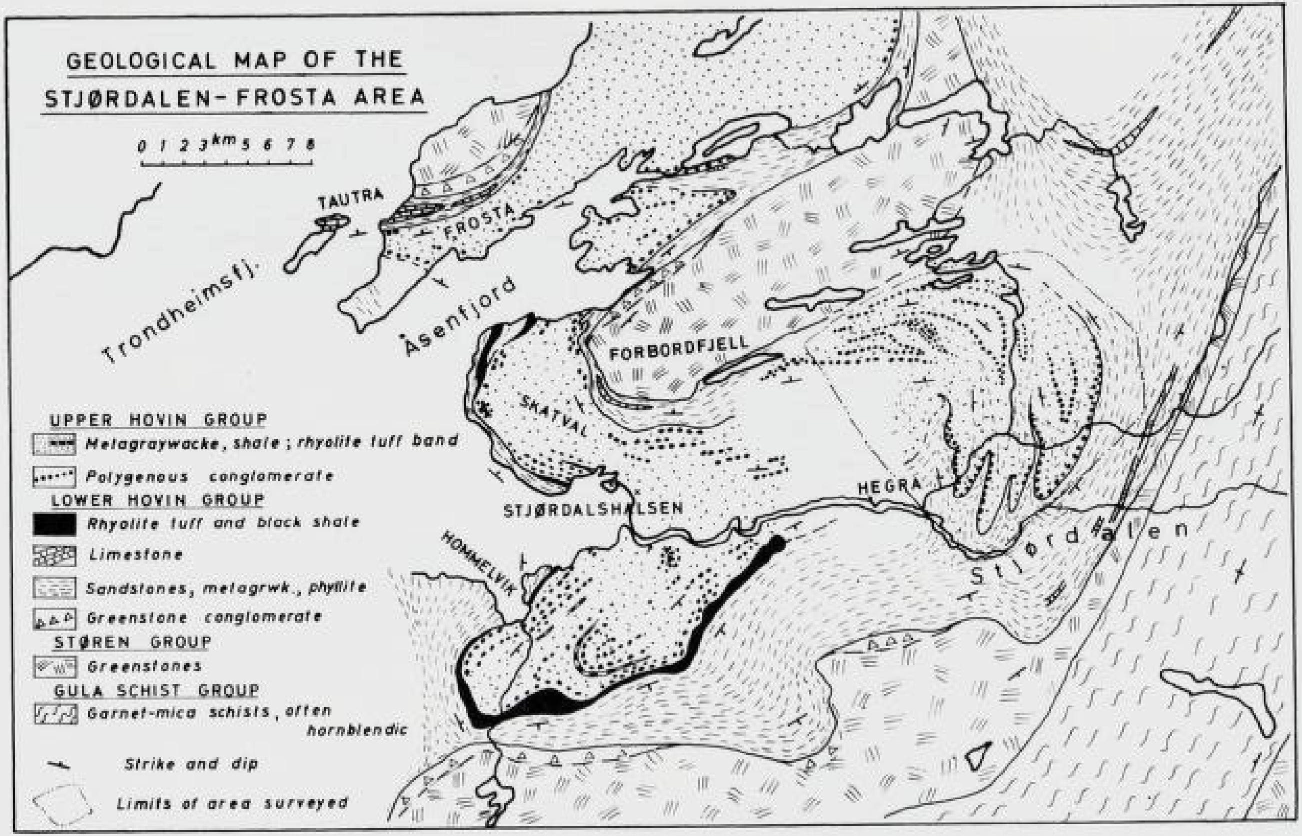
**Abstract**

Following brief notes on the low-grade metasediments occurring in an area near Hegra, 50 km east of Trondheim, the types of structures associated with three episodes of deformation of main Caledonian (Silurian) age are described. An outline of the suggested major structural picture is then presented. In this the principal structure is seen as a WNW-directed fold-nappe developed from the inverted western limb of the central Stjørdalen Anticline. A major eastward closing recumbent syncline underlies this nappe-like structure. These initial structures were then deformed by at least two further folding episodes. In conclusion, comparisons are noted between the ultimate fold pattern, the suggested evolution of these folds and H. Ramberg's experimentally produced orogenic structures.

**Introduction**

A survey of this particular area, situated north of the valley of Stjørdalen, east from Trondheim, was begun during the 1965 field-season and progressed during parts of the summers of 1966 and 1967 in conjunction with a mapping programme led by Statsgeolog Fr. Chr. Wolff further east in this same segment of the Central Norwegian Caledonides. Further geological mapping is contemplated, the aim being to eventually complete the 1 : 100,000 sheet 'Stjørdal' (rectangle 47 C). In view of the time factor involved in the completion of this work, and the renewed interest being devoted to the geological problems of the Trondheim region (Peacey 1964, Oftedahl 1964, Wolff 1964 and 1967, Torske 1965, Siedlecka 1967, Ramberg 1967), some notes on the tectonics of the Hegra area would seem appropriate at this stage. These comments also, in effect, constitute a supplement to the writer's recent article (Roberts 1967) on the tectonics of Stjørdalen and the NE Trondheim region.

Fig. 1. A geological map of the Stjørdalen - Frosta area. Western half of the map after Carstens (1960); E and SE tract after Wolff and, in part, Roberts.


GEOLOGICAL MAP OF THE
STJØRDALEN-FROSTA AREA
0 1 2 3 km 5 6 7 8
TAUTRA
FROSTA
Trondheimsfj.
Åsenfjord
FORBORDFJELL
SKATVAL
STJØRDALSHALSEN
HEGRA
HOMMELVIK
Stjørdalen
UPPER HOVIN GROUP
Metagraywacke, shale; rhyolite tuff band
Polygenous conglomerate
LOWER HOVIN GROUP
Rhyolite tuff and black shale
Limestone
Sandstones, metagrwk., phyllite
Greenstone conglomerate
STØREN GROUP
Greenstones
GULA SCHIST GROUP
Garnet-mica schists, often hornblendic
Strike and dip
Limits of area surveyed

Mapping (largely of a reconnaissance nature) in the western half of the 'Stjørdal' rectangle sheet has been done by H. Carstens; a version of this map appeared in the 1960 International Congress guide-book (Carstens 1960, map II). Before the present writer's investigations the eastern part of this rectangle sheet had been mapped only summarily by Fr. Chr. Wolff. The geology of this region is depicted in Fig. 1: the stratigraphical scheme shows the Gula Schist Group at the base, followed by the Støren Group and Lower and Upper Hovin Groups. Within the area considered here only the Hovin Groups are represented although the Støren Group occurs immediately to the NW and E.

Greenstone, greenschists and keratophyric rocks characterize the Støren Group: this is generally regarded as a volcanic sequence. A greenstone breccia or conglomerate locally marks the base of the Lower Hovin Group. In the Hegra area this is absent and the Lower Hovin Group comprises a lustrous grey phyllite followed by a mixed sequence of 'shale' or metasiltstone alternating fairly rapidly with metagraywacke bands. A dark grey pyritous shale occurs at the top of the group. Further west in Carstens' area a rhyolite tuff is present near the top of this group and a limestone occurs lower down. The base of the Upper Hovin Group is usually marked by a polygenous conglomerate; this may exceed 50 m in thickness with cobbles sometimes up to 40 cm across. Alternating metagraywackes, metasiltstones, shales, polygenous conglomerates and occasional quartzite conglomerates constitute the bulk of the Upper Hovin Group; thin limestones occur locally. In the SW of the 'Stjørdal' sheet a thin rhyolite tuff horizon is represented.

Primary structures are common throughout the Lower and Upper Hovin Groups and have proved an invaluable aid in the tectonic structural interpretation. Such structures include graded bedding, flame structures and load (? or flow) casts, ripple marks, shale clasts within metagraywacke beds, and sedimentary dykes. Complex slump structures, including primary folds, have been observed. Isolated pebbles (or cobbles) have also been noted in some pelitic units. Another notable feature is rapid lateral and vertical lithological variation in certain horizons, particularly of pebble content, size and distribution in some conglomerates. On the other hand some finely alternating pelite/psammite horizons are of such regular thickness as to have been quarried for roofing slate at many places within the area.

**Tectonic structures**

The deformational history of this Hegra area has followed a nearly identical pattern to that recognized from studies in other parts of the northern Trondheim region (Peacey 1964, Roberts 1967). Differences are apparent, however, not so much from the episodic aspect as in the state of preservation of major structures and their clearer relationship to the overall deformation picture. In this regard it is essential to consider the Hegra structures in a regional context, but since relatively little structural work has been done further to the west, the detailed regional structural pattern must await the results of future investigations. In the notes which follow, only the salient structural observations will therefore be commented upon.

Three generations of folds can be recognized within the Hovin Group metasediments NE of Hegra. Briefly, the earliest folds ($F_1$) are tight to isoclinal in style and can be observed on all scales; they deform the recognizable bedding, and the regional schistosity is axial planar to these folds. Fold axes, though locally of quite variable trend, generally plunge in a NE-E-direction: uncommon axial plunges towards N-NNW have also been recorded. Conglomerate pebbles are often elongated, a lineation which is ascribed to this first deformation episode. Second episode folds ($F_2$) are relatively uncommon and are best seen on a regional scale. They are less acute in style than the $F_1$ folds. Axial plunges are generally towards a north-easterly point.

Third generation structures ($F_3$) are found in virtually every outcrop, either as observable folds of variable open to tight style, or as a penetrative cleavage easily seen in the pelites but less readily apparent, and refracted, in the metagraywackes. This cleavage, moreover, is axial planar to the $F_3$ folds. Axes, for the most part. plunge towards a N-NNE point but locally the plunges are towards S-SW. Exceptions to the rule are indeed commonplace — west of this Hegra area $F_3$ axes tend to plunge more towards W or NW — and it is more than probable that the $F_3$ axial trend owes its variability to the fact that these small- to medium-sized folds have been superimposed on a variably dipping succession. The attitude of the $F_3$ axial surface cleavage is itself of interest. Although a detailed account cannot be given here, it is significant that the sense of overturning of these $F_3$ folds is invariably 'down-dip', the associated cleavage being of relatively gentle inclination, sometimes only a few degrees from the horizontal. Further west, in the SE Åsenfjord area, this prominent cleavage is locally deformed by an even later, but uncommon, set of minor structures (which could be termed $F_4$) trending NW-SE. Kink-bands and -folds deforming $F_3$ structures have also been observed in three localities in the Hegra area.

On a larger scale the Hegra area is dominated by a relatively open $F_2$ structure, here called the Hegra Antiform. This is seen to deform a series of tight or isoclinal major $F_1$ synforms and antiforms (Fig. 2).

**Regional structural considerations**

Two basic conditions must be satisfied in formulating, and in fitting the Hegra area into, an acceptable regional structural picture. These, to an extent, are mutually compatible and are briefly, (1) the inversion of the stratigraphical sequence over a large part of the 'Stjørdal' rectangle-sheet, and (2) the occurrence of a major $F_1$ fan-shaped anticline (the Stjørdalen Anticline) in the central part of the Trondheim region, with the higher grade rocks of the Gula Schist Group in its core (Roberts 1967).

With regard to the first point, several geologists have taken note of the situation for example on Forbordfjell (e.g., Bugge 1954, Carstens 1960). This mountain is capped by Støren Group greenstones which here structurally overlie

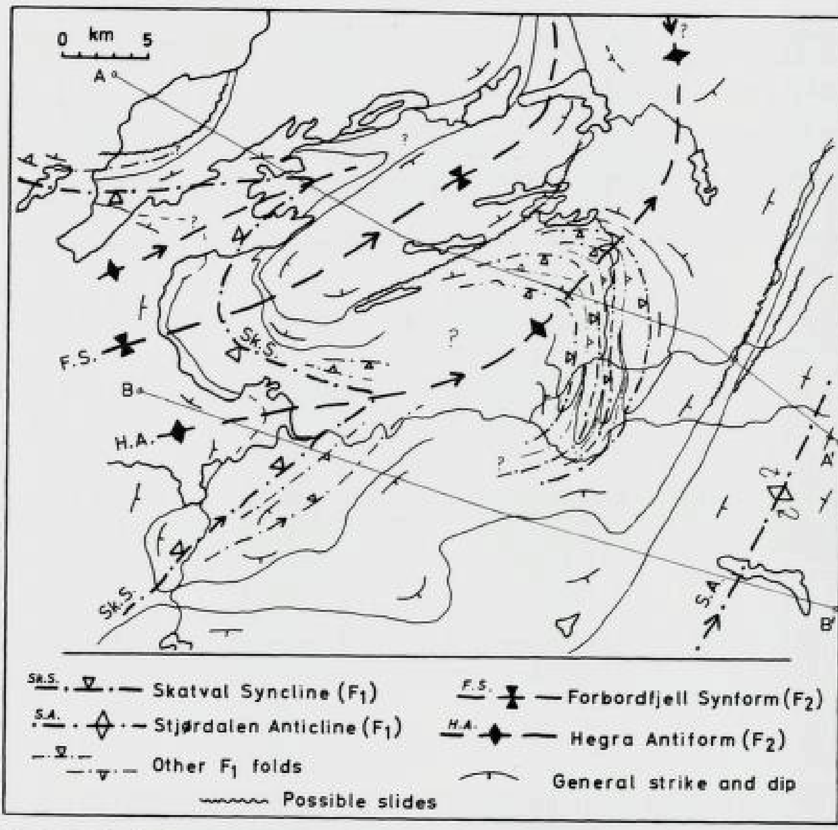



Fig. 2. Major fold axial plane traces. Main lithological boundaries as in figure 1. Fold axial plunges indicated by arrows. A-A', B-B', lines of section (see Fig. 3).

Hovin Group metasediments, the whole sequence moulded in a north-easterly plunging synform (or more properly a synformal anticline) hereafter referred to as the Forbordfjell Synform (Figs. 1 and 2).

The Stjørdalen Anticline further east is a curious structure in that both its limbs are inverted — on the eastern limb the sequence dips WNW while on the western limb dips are east-south-easterly (see e.g. Roberts 1967, Fig. 43). Considering the situation on this western limb north of the valley of Stjørdalen, the inverted sequence swings round through some 160° across the Hegra Antiform until a north-westerly dip is achieved (Fig. 1). The Støren Group greenstones then crop out again, structurally above the Hovin Groups, in the core of the Forbordfjell Synform (Fig. 2). The inference to be drawn from these observations is that the Stjørdalen Anticline is a much more complex structure than previously supposed, with its western limb of considerable dimensions and completely overturned, perhaps near-horizontal at one time in the manner of a recumbent structure. Moreover, this limb (or structure) has subsequently been deformed by the Hegra Antiform, Forbordfjell Synform and other $F_2$ folds in the Åsenfjord area, and then by the $F_3$ structures. Erosion has then helped in producing the present-day outcrop pattern. A cross-section is presented in Fig. 3a.

The question now arises as to what happens beneath the recumbent limb of this western nappe-like part of the Stjørdalen Anticline. A study of the sense of overturning of the medium- to large-scale $F_1$ folds in the area NE of Hegra suggests the possible presence of a major $F_1$ synclinal structure further to the west. On examining Carstens' map (the western part of Fig. 1), south of Hommelvik the Lower/Upper Hovin Group boundary displays a marked swing through almost 180°, the Upper Hovin rocks occurring in the core of a tight or near-isoclinal fold, the axial surface of which dips to the SE. As the axis of this fold plunges in a north-easterly direction the structure is synclinal. Following the axial plane trace north-eastwards (Fig. 2), it swings round to NW in the Stjørdalshalsen area becoming northerly around Skatval and again more NE-SW in trend on the south side of Åsenfjord. This sigmoidal curve is clearly due to the refolding of the syncline — here called the Skatval Syncline — by the major $F_2$ Hegra and Forbordfjell folds. The Skatval Syncline is therefore an $F_1$ fold of major proportions, and in the writer's opinion is to be regarded as the complementary structure to the Stjørdalen Anticline (Figs. 3b and 4).

In the Åsenfjord area an accurate tracing of this early syncline is rather difficult, but in all probability it swings westwards across yet another major

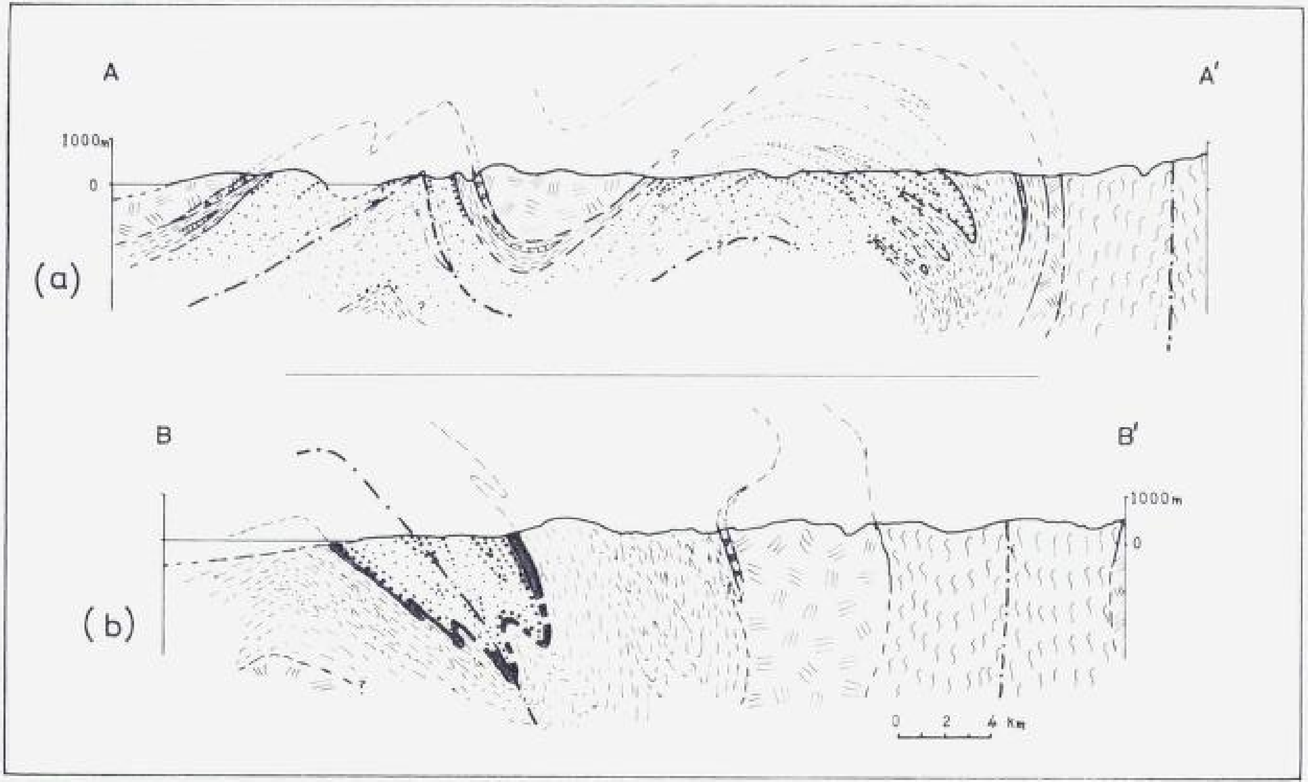



Fig. 3. Sections across the area. Lines A-A' and B-B' are indicated in figure 2. Symbols as in figures 1 and 2.

$F_2$ structure into the southern part of the Frosta peninsula, and then northwestwards beneath Trondheimsfjord. Further north one can but speculate at this stage, but it is quite possible that the tight synclinal fold present on the SE and S flanks of the Tømmerås Anticline (Wolff, 1960) and then disappearing beneath the fjord to the west is the same structure as the Skatval Syncline. This has been suggested quite independently by both Dr. J. S. Peacey and Professor John Rodgers (personal communications): at this point the writer wishes to express his gratitude to Dr. Peacey for providing much information and inspiration prior to and during the course of his studies in the Trondheim region.

**Concluding remarks**

Taking into consideration the results of the mapping near Hegra and the structural disposition of litho-stratigraphical groups in the eastern Trondheimsfjord region, the central major $F_1$ structure — the Stjørdalen Anticline — in this part of the Trondheim basin would seem to be far from simple. As well as being inverted in the present-day Stjørdalen profile, it is clear that the western limb was at one time more or less recumbent, rather complex, and of great magnitude forming part of a fold nappe or *Überfaltungsdecke* structure. The Skatval Syncline is essentially a complementary fold to this western substructure of the main central anticline. Fig. 4 depicts the generalized picture in the form of a schematic profile across the region contained by figure 1. Basically this shows the main overfolding in this western part of the northern Trondheim region to have been in a WNW-NW direction, the mirror image of that found further east in the Norwegian/Swedish Caledonides. The overall picture recalls C. Bugge's diagrammatic profile (1954, Fig. 11) across the mountain chain and also bears appreciable similarity to structures depicted in some of the illustrations of centrifuged model experiments carried out by Ramberg (1966).

In a more recent paper Ramberg (1967) has compared the structural evolution of these dynamic models with structures present in the Scandinavian Caledonides. Of particular interest here are Ramberg's remarks concerning small- and medium-scale folds in the eastern Trondheimsfjord area, these folds being the $F_3$ structures of the present study. Ramberg (1967, p. 49) states that, "It seems not unlikely, particularly in view of the apparent inversion of the Støren-Hovin groups at Forbordfjell and Foldsjø (Carstens, 1960), that these smaller folds are second-order folds on a huge recumbent nappe-like structure. The nearly horizontal axial plane schistosity signifies a compression in vertical direction such as would happen when a large recumbent fold spreads under

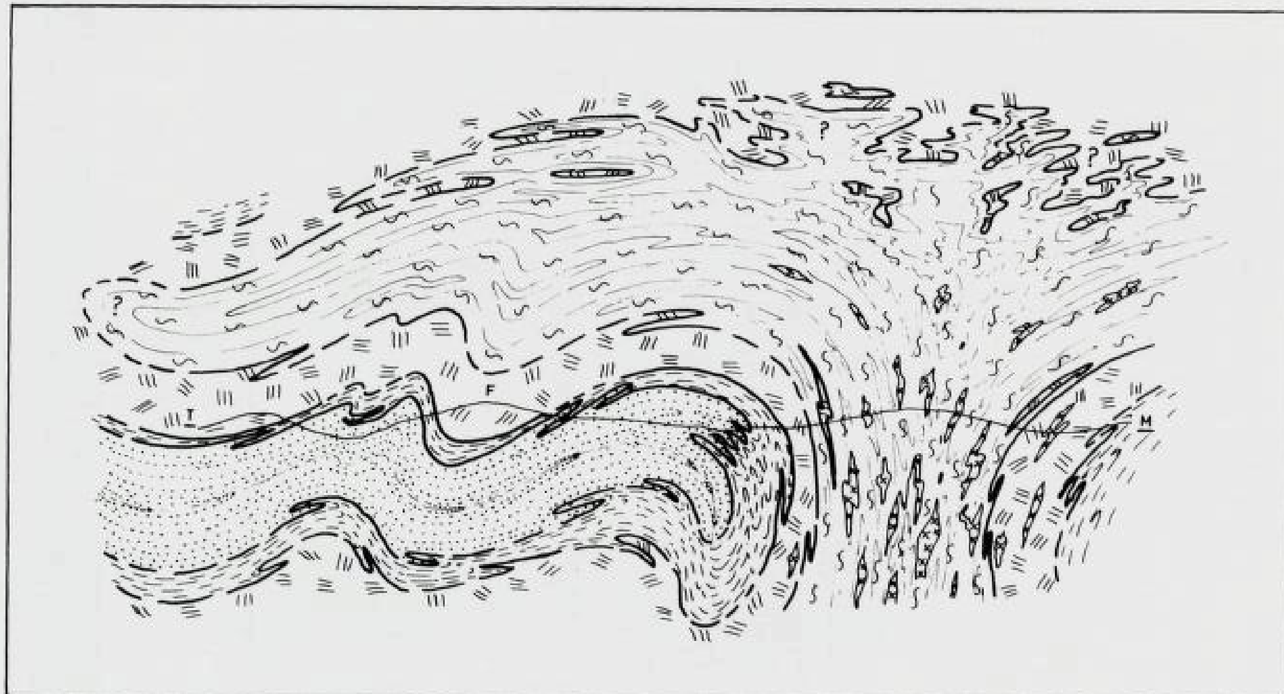



Fig. 4. Schematic reconstruction of the major structures occurring between Meråker (M) and Trondheimsfjord (T) — ca. ESE-WNW profile through Forbordfjell (F). Line TFM, present-day erosion surface. Symbols as in figure 1: xx - trondhjemite bodies. Profile not drawn to scale.

its own weight". This explanation for the development of these folds is essentially similar to that advocated by the present writer for an area further to the east (Roberts 1967, p. 105), and observations in the Hegra area have tended to support these views. With regard to the geometry and development of the principal (earliest) structures, it is tempting to go along with Ramberg's suggestion that these structures probably evolved along similar lines to those produced in his experiments, i.e., propelled by the body force of gravity. Gravitational gliding has almost certainly contributed towards lateral movement of these vast recumbent folds: the question of their actual *inception* is unfortunately too complex a topic to be discussed in these short notes, but Ramberg's experimentally-backed views are worthy of careful consideration by all concerned with Scandinavian Caledonian deformation.

That the main Caledonian deformation sequence in this region can be dated to a Silurian age has been discussed elsewhere (e.g. Vogt 1945, Strand 1961). A division of the orogenic movement into fold episodes is justifiable in terms of fold superposition although it is questionable as to whether any marked time gap occurred between the development of the respective folds. The writer has previously remarked that the $F_1$ and $F_2$ sets may preferably be looked upon as "the product of a broadly continuous deformation" (Roberts 1967, p. 102) and it is indeed possible that some of the major $F_2$ structures were initiated during the closing stages of the emplacement of the vast $F_1$ recumbent folds. In this connection it seems not unlikely that large parts of the Støren/Lower Hovin boundary are tectonic with slides possibly present within the sequence: this appears to be the case, e.g. directly north of Hegra and again on the Frosta peninsula. With some isoclinal folds being affected by slides, Hovin Group strata directly adjacent to Støren greenstones may locally appear to young towards the latter. Sliding was most probably initiated during the $F_1$ deformaion and continued into the $F_2$ episode. Some minor thrusting occurred towards the end of this latter episode. On the SE side of the Forbordfjell Synform it is quite possible that Upper Hovin rocks may locally structurally underlie the Støren Group, the Lower Hovin having been completely excised during Caledonian movements. It is of interest here to note observations reported by other workers in the western Trondheim region, in whose areas the Støren-Hovin boundary has been regarded as a 'fault' (Chadwick et al. 1963, Torske 1965).

Another interesting point concerning the Hegra Antiform is whether or not this structure overlies a primary upwarp in the basement. Tracing this fold northwards it appears as if it might possibly connect with the small 'dome' of (?) basement rocks just SE of Levanger (Carstens 1960), and then link up with the Tømmerås Anticline which is considered to have developed upon a primary ridge in the basement (Peacey 1964, p. 63). Alternatively, this Hegra fold and other large $F_2$ anticlinal structures could be associated with basal culminations developed actually during the Caledonian orogeny. But as Ramberg's model experiments suggest, any primary bulges present in the basement were probably strongly activated, producing domal rises, during the main Caledonian orogeny (Ramberg 1967, p. 47).

Much more structural information is required from this western Trondheimsfjord region before a fully satisfactory tectonic picture can emerge, but the general pattern of events now appears somewhat more comprehensible than was the case a decade ago. An interesting exercise now would be to investigate the south-westward continuation of the major structures described above — $F_1$ recumbent folds or nappes deformed by tight or open $F_2$ folds — into the classical Hølonda-Horg district (Vogt 1945) and further west into the Surnadal region.

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# The Geology of the Løkken Area, Sør-Trøndelag

By

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**Abstract**

The paper describes the rock types and geological structure of the Løkken Area, near Trondheim. The area lies on the inverted limb of a nappe structure overturned to the north-west. This structure has been coaxially refolded. Chlorite grade basic metavolcanics of the Støren Group are perserved from erosion in the core of a synformal second fold, and are structurally underlain by sediments of the younger Hovin Group. Mica schists in the north, traditionally ascribed to the Cambrian Røros Group, are found to be, locally at last, equivalent to the Hovin Group sediments.

**Foreword**

This paper is the result of field investigations conducted in the Løkken Area in the summers of 1966 and 1967 by students from Imperial College, London, under the supervision of Dr. W. Skiba, who has contributed the following introduction.

**Introduction**

The Løkken Area is situated approximately 70 km south-west of Trondheim, and forms a westward continuation of the Fjeldheim-Gåsbakken Area, which was mapped by Chadwick, Blake, Rowling and Beswick in 1960 and 1961. Geologically the area is part of a broad structural depression in which metamorphosed Cambro-Silurian rocks have escaped erosion. The area is of considerable economic importance since it contains the Løkken concordant orebody of cupriferous pyrite, which is the largest of the many known occurrences in the Trondheim province.

The classical stratigraphic succession in this region was established through the work of numerous Norwegian geologists. Three main lithological groups are generally recognized:

| | | |
|---|---|---|
| Hovin Group | L. and M. Ordovician | Shales, sandstones and limestones. |
| Støren Group | U. Cambrian and L. Ord. | Metamorphosed Basic Volcanics. |
| Røros Group | Cambrian | Mica Schists. |

The distribution of these groups was shown on the geological map by C. W. Carstens (1952) at a scale of 1 : 50,000.

In 1966 a team of student geologists from Imperial College received an invitation from Mr. P. Sandvik, of Orkla Grube Aktiebolag, the company which operates the Løkken Mine, to initiate detailed geological investigations in the Løkken Area. After a broad reconnaissance, it appeared that there were two main geological problems:

(a) Determination of the structural geometry and history of the area in relation to metamorphism and the Caledonian Orogeny. A detailed knowledge of the origin, geological history and structural control of the orebody is essential in the systematic development of the area and in future prospecting.

(b) The spilitic volcanic rocks of the Støren Group exhibit an almost overwhelming variety which has defied attempts to establish a stratigraphic or other subdivision on a petrographic basis. A geochemical sampling was therefore devised to study:

( i) Variation of some major elements within individual lava pillows of different sizes.

( ii) Variation between cores of pillows taken from different levels of the same flow.

(iii) Variation between samples taken from comparable parts of different flows.

The opportunity is also being taken to establish any redistribution of major elements in pillow lavas in different states of strain. This study may contribute to the problem of the derivation of some of the chlorite schists in the area.

A geological map of the area has been made, a simplified version of which appears with this paper, and the general structure and range of rock types are described. The results of the geochemical investigations and the detailed study of deformation will form the subjects of further papers.

The field investigations were carried out in the summer months of 1966 by Messrs. E. H. Rutter, J. May and G. M. Kershaw, and in 1967 by E. H. Rutter, R. Chaplow and J. E. Matthews. The survey of the area considered is largely the work of E. H. Rutter, though the present synthesis drawn on the observations of all concerned.

The investigators are indebted to Messrs. Sandvik, Brøndbo, Nordstein and Sagvold of Orkla Grube Aktiebolag, who instigated the investigations, gave valuable advice on the area, and extended their hospitality which made the joint research possible. We also wish to gratefully thank Prof. T. Strand, Prof. J. Bugge, Prof. C. Oftedahl and Mr. F. C. Wolff for discussions of the Løkken problems.

*W. J. Skiba.*

**Lithological Succession**

Two distinct lithological groups are represented in the area:

(a) The Støren Group.

This group is predominantly composed of submarine basic lavas and tufface-ous sediments, with minor quantities of acid volcanic products and cherts. Rocks of this group are intruded by a number of gabbro masses.

(b) The Hovin Group.

This group is predominantly composed of sandstones and shales. Occasional intercalations of volcanic products occur near the base of the succession. Locally, a coarse polygenous breccia-conglomerate forms the basal unit of the Hovin Group. Because this conglomerate contains fragments of rocks typical of the Støren Group, it is inferred that the Hovin Group is stratigraphically younger than the Støren Group.

In the northern part of the area, structurally below the sandstones and shales of the Hovin Group, occurs part of a sequence of biotite mica schists and garnet mica schists which are traditionally regarded as comprising a third distinctive lithologic type in this area, the Røros Group. Because this group is structurally the lowest group of the area, it has in the past been assumed that it is also stratigraphically the oldest group of the area. Sedimentary structures in the Hovin Group sandstones and shales north of Løkken indicate that the rocks young consistently northwards, with no sign of any tectonic breaks in the succession. It thus appears that rocks previously attributed to the Røros Group in the Løkken Area are stratigraphically younger than the sandstones and shales of the Hovin Group.

The rocks of the Løkken Area were deformed and metamorphosed in the Greenschist Facies during the Caledonian Orogeny, but considerable variation in metamorphic grade and amount of deformation is observed across the area.

*The Støren Group*

The use of the term "Støren Group" to describe a thick sequence of basic volcanic products extensively developed in the Trondheim Region is now well established in the Norwegian Geological Literature, and will be followed here. Rocks of this group are widely developed in the Løkken Area, and are of particular economic importance and interest since the main Løkken pyrite orebody occurs within pillow lavas of this group. As may be seen from the map, these metavolcanic rocks form the core of a large synformal structure, here referred to as the Løkken Synform.

The greater part of the thickness of this sequence is made up of spilitic pillow lavas. There are also intercalations of basic pyroclastic materials, often showing primary sedimentary banding, pillow "agglomerates" and lenses of red jasper. Thin bands of pyritous black shale called "vasskis" are also quite common. Such bands are characteristically associated with the massive pyrite orebodies, though the converse is not always so.

Intercalations within the pillow lavas, and individual horizons within the pillow lavas themselves, are usually neither extensive nor very thick. This, coupled with poor exposure, has made it impossible so far to stratigraphically subdivide the Støren Group by the traditional techniques of geological mapping. A geochemical approach to this problem is currently being attempted, to determine whether zones of diagnostic chemical characteristics exist within the pillow lava series. It is hoped that this approach, coupled with further structural investigations, will lead to a useful stratigraphic subdivision of the Støren Group.

In the less deformed horizons of the Støren Group primary structures and textures are very well preserved, pseudomorphed by metamorphic minerals of the greenschist facies of regional metamorphism. In many cases the shapes of lava pillows can still be used to determine the local younging direction of the sequence. Within individual pillows concentric mineral zoning is generally well defined. The outer rims of the pillows consist of a thin zone, up to ½ cm in thickness, of chlorite. Then follows an epidote rich zone, up to about 2 cm thick, in which epidote filled vesicles can sometimes be distinguished. This zone passes into another made up of a fine grained intergrowth of actinolite and tremolite needles, albite, chlorite and epidote, which forms the entire core of the pillow. This region appears to be mineralogically homogeneous.

There is a restricted occurrence within the Støren Group of acid volcanic rocks. These rocks, as may be seen from the map, tend to form geographically separated areas of outcrop, but occur at about the same stratigraphic level. Two such outcrop areas appear in the area mapped, but it is also known that a similar outcrop occurs in the core of the Løkken Synform about 1 km west from the western extremity of the map.

Mineralogically, the acid rocks consist of a fine grained groundmass of quartz, albite, chlorite, muscovite and sometimes stilpnomelane. Set in this groundmass may be phenocrysts of fresh albite and quartz. Areas of non-porphyritic and porphyritic acid rocks can generally be mapped out on the ground. Following the nomenclature of spilites used for the basic rocks as a result of the omnipresence of albite as the main feldspar, the general richness in soda and the characteristic geological environment, the acid rocks are here referred to as quartz keratophyres.

The quartz keratophyres most commonly form lenticular intercalations within the basic metavolcanic rocks. They vary in thickness from one to twenty metres. Fine banding and fragmentary structures are quite commonly observed in the thinner members, which are generally of the non-porphyritic type. Such rocks are interpreted as acid pyroclastic rocks, whilst the more massive porphyritic rocks are tentatively interpreted as acid lavas or small, sill-like intrusions. Porphyritic acid rocks are also quite commonly observed to form small, cross cutting dykes.

Pillow lava breccias and small pockets of conglomerate are commonly observed within the Støren Group. However, only one such deposit can be truly compared with a volcanic agglomerate. This occurs about 2 km north-east of Storås. The rock is apparently undeformed, and consists of thoroughly angular fragments of basic lava. All the fragments make direct physical contact with their immediate neighbours. The outcrop is surrounded by a homogeneous mass of medium grained basic igneous rock, which is probably intrusive. This rock, which extends along the strike for some 10 km, is quite distinctive by virtue of rosette shaped clusters of actinolite set in a mass of euhedral epidote crystals, albite laths and interstitial chlorite. The rock is fresh and homogeneous in the east, passing through various stages of alteration until it is quite schistose in the west. It may represent a feeder dyke giving rise to the basic lavas, and has been described as albite dolerite on the map.

Finally, large bodies of massive cupriferous pyrite occur within the succession of pillow lavas of the Støren Group. A large, important deposit occurs at Løkken itself, and smaller deposits occur at Dragset and Høidal, etc. Pyrite is a universal accessory mineral in all rocks of this area.

*The Hovin Group*

Rocks of the Hovin Group which occur in the Løkken Area may be directly correlated with similar rocks in the neighbouring Fjeldheim Area to the east. The Hovin Group is comprised almost entirely of sedimentary rocks, although many of these are tuffaceous. In the Løkken Area the rocks are entirely unfossiliferous, but an Arenigian age is inferred for the group since Arenigian graptolites have been found in rocks at a stratigraphically equivalent level near Fjeldheim by Blake (1962).

The lowest member of the Hovin Group is a breccia conglomerate which immediately overlies the basic lavas of the Støren Group. The conglomerate is highly variable in lateral extent and thickness, and appears to have been derived from the rapid erosion of Støren Group lavas following a period of uplift. Petrographically, the conglomerate is entirely comparable to the laterally equivalent Fjeldheim Conglomerate which was described by Chadwick et. al. (1964).

In the Løkken Area the breccia-conglomerate is overlain by a series of sandstones and shales, which are often banded so that angular divergence between bedding and cleavage may be discerned. Occasionally, coarsening of grain size produces intercalations of conglomerate within this series. Most of the grains in the sandstones are lithic, and they are very poorly sorted. These rocks were clearly laid down in an unstable environment as evidenced by the common occurrence of graded bedding in the sandstone members.

The sandstone and shale series outcrops on both the northern and southern flanks of the Løkken Synform. In the south, these rocks are metamorphosed to chlorite grade and are almost undeformed, and primary sedimentary structures are very well preserved. In the south-west the highest part of the sequence becomes a hematite rich shale. On the northern flank of the Løkken Synform metamorphic grade is high chlorite, and deformation is much stronger. The shaly component of the sandstone and shale series are reconstituted to a chlorite schist. Metamorphic segregation of bands alternately rich in chlorite, calcite and epidote has taken place. The more massive sandstone bands, on the other hand, still exhibit well developed graded bedding. Northwards, the succession passes stratigraphically up into quartz-albite-mica schists via a transition group. Such primary structures as are preserved in the mica schists indicate that they were originally sediments poorer in basic volcanic material than the immediately subjacent sediments. Metamorphic grade reaches biotite subfacies in the outcrop of these schists, and in the extreme north-west of the area mapped almandine garnets begin to appear in the rocks. The way in which the metamorphic grade increases in the direction of stratigraphic younging suggests that the metamorphic isograds cut obliquely across the $f_1$ fold structures.

### Intrusive Rocks

In an early stage of the orogenic activity of the area, possibly at the same time as their formation, the basic lavas of the Støren Group were intruded by a number of gabbro masses. The gabbros were metamorphosed with the country rocks, but the primary gabbroic texture has been preserved in the larger masses, pseudomorphed by new minerals. The smaller gabbro masses have been deformed and have locally developed a schistosity, but the larger masses do not appear to have responded to tectonic forces by internal deformation.

The gabbros were clearly originally composed mainly of calcic feldspar and augite pyroxene. Traces of primary pyroxene remain in some parts of the gabbros, but in most cases it has been completely pseudomorphed by a mixture of tremolite and a pleochroic amphibole which may be hornblende. The calcic plagioclase is replaced by an intergrowth of albite and epidote.

It has been found that the metagabbro masses are heterogeneous. To a greater or lesser extent, primary banding, an alternation of felsic and mafic layers, has been found in all the masses, particularly near the margins. Unfortunately, the metagabbro masses are very poorly exposed, and it has not proved possible to map out these features in detail.

A further interesting aspect of the heterogeneity of the metagabbro masses is the occurrence of coarse granophyric zones around some parts of their margins. Areas where this feature has been found are shown on the map.

To a very limited extent there occurs in this area a very distinctive basic porphyritic rock, which is very similar to the Hølonda Porphyrite described by Chadwick et. al. (1964), and which occurs very extensively several km to the east of Løkken. There exists a controversy as to whether these rocks are intrusive or lava flows. In the Løkken Area small stock-like masses and cross cutting dykes occur together with lenticular bodies, and only in the metavolcanic rocks of the Støren Group. In the Gåsbakken Area the Hølonda Porphyrites are most extensively developed in the lower part of the Hovin Group. Hence, either the Hølonda Porphyrites are entirely intrusive, or their development spans a considerable range of time.

Basic dykes are very common in the Støren Group metavolcanics. Because they are usually thin and exposure is poor, such dykes cannot be traced over great distances. One exception to this generalization is a thick dyke of a dark, fine grained basic rock which occurs some 3 km north-west of Storås, and which can be traced laterally for a similar distance.

## Structural Geology

In this area it is possible to distinguish at least two phases of deformation, each of which is represented by a particular association of structures indicative of the particular dynamic conditions operative at that time.

### (a) The Earlier Folds, $f_1$

The most obvious indicator of the early deformation in this area is the presence of a penetrative schistosity. This schistosity is seen to be parallel to the axial surfaces of small folds in rocks which exhibit primary banding particularly well. Such folds can only be seen on the scale of a single exposure where the bedding is thin (10 cm or less), as in the sandstones and shales, or where they affect quartz veins. Small scale folds of $f_1$ age are never seen in the thick metavolcanic rocks of the Støren Group. However, $f_1$ folds in these rocks of the order of 100 m wavelength can be inferred from mapped bedding-cleavage and way-up criteria.

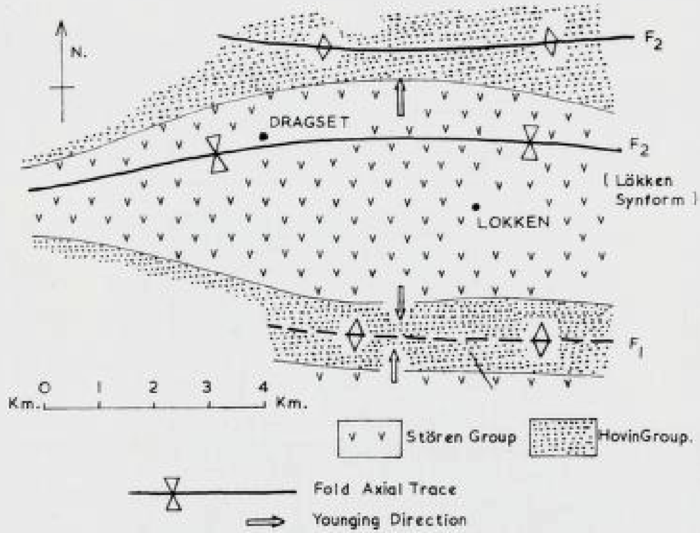


Fig. 1. Simplified sketch map showing the positions of the axial traces of the main $f_1$ and $f_2$ folds.

It is possible to map out a set of flat lying, nappe like $f_1$ overfolds which have been refolded by the $f_2$ movements. The axial traces of these major folds are indicated on a simplified map (Fig. 1). In the south of the area the form of a tight $f_1$ syncline in the Hovin Group sediments may be seen. This syncline is found to be antiformal, a fact which conflicts with the findings of Chadwick et al. (1964) along the eastward continuation of the same structure. Fig. 2 is a three dimensional representation of the structure of the Løkken Area. This is the interpretation found to be consistent with the structural data collected.

Only the $f_1$ phase of folding appears to have produced a significant amount of internal deformation of the rocks of the area, since deformed particles are flattened in the plane of the $f_1$ schistosity. Pillow structures, spherulites, gas vesicles and conglomerate pebbles are potential indicators of the amount of

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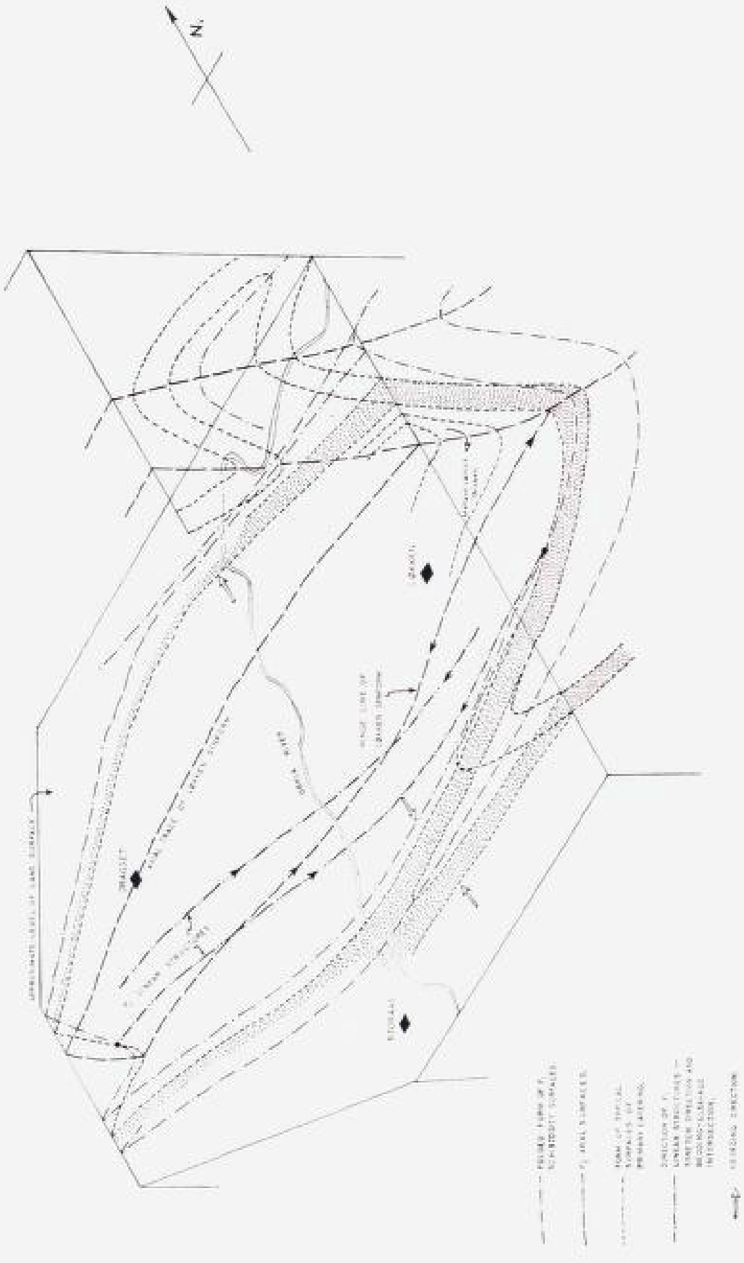
Fig. 2. Schematic block diagram to illustrate the geometry of the fold structure in the Løkken Area. In the top right hand corner the vertical plane of the front of the block is extended upwards to show the interpretation of the closure of the $f_1$ nappe structure. The stippled area is a hypothetical continuous horizon at the base of the Hovin Group to show more clearly the geometry of the $f_2$ Løkken Synform.



internal strain suffered by the rocks. Such structures are, unfortunately, highly unlikely to have originally been spherical particles, and the non-spherical forms may have possessed an original fabric. Where tectonic strain is very high,

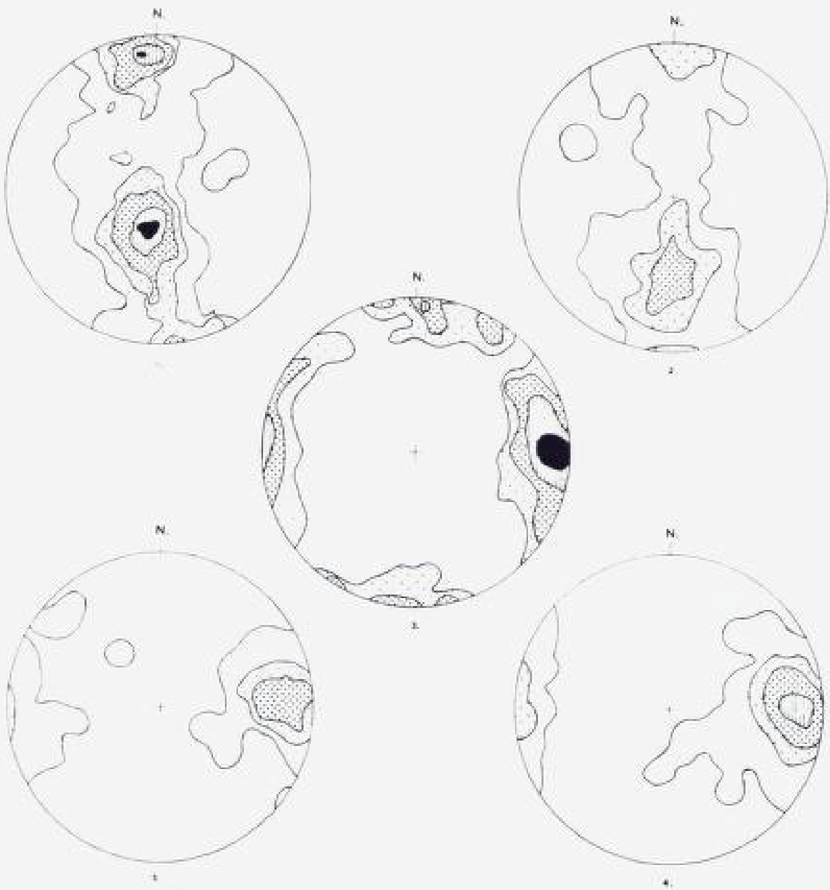


Fig. 3. Equal Area Projections, all lower hemisphere.

(1) Poles to $f_1$ schistosity surfaces west of the Orkla River. (328 readings)
(2) Poles to $f_1$ schistosity surfaces east of the Orkla River. (170 readings)
(3) Poles to barren joints over the whole area. (475 readings)
(4) Long axes of deformed lava pillows over the whole area. 174 readings)
(5) $f_2$ crenulation lineation over the whole area. (99 readings).

The scheme of shading used on all diagrams is: Black — over 30 points; Vertical ruling — between 20 and 30 points; Dense stipple — between 10 and 20 points; Light stipple — between 5 and 10 points; Blank — between 1 and 5 points, per 1 per cent of area of circle.

however, the long axes of the deformed objects may indicate the direction of maximum finite extension in the rocks. Measurements of the long axes of deformed objects, mainly lava pillows, are plotted in Fig. 3 (4). These are found to most frequently parallel the axial direction of the $f_1$ folds, as indicated by bedding-cleavage intersection lineations occurring in banded sedimentary rocks. Field measurements of the axial ratios of a number of approximately ellipsoidal lava pillows plot in the constriction field ($k>1$) of a deformation diagram of the type used by Flinn (1962). This gives rise to the pronounced linear fabric seen in strongly deformed pillow lavas.

A good mineral elongation lineation is conspicuously lacking in the rocks of this area. Although acicular crystals such as actinolite generally lie in the plane of the $f_1$ schistosity, they are, with few exceptions, randomly orientated, often producing a "Garben Skifer" texture.

When observations are made of the dip of a pillow lava flow or of a conglomerate outcrop, it is necessary to carefully distinguish primary layering from schistosity. Undeformed pillow lavas tend to be slightly flattened as a result of superincumbent load during cooling after eruption. This leads to a measurable "primary layering" of the flow. During deformation this is obscured and replaced by a flattening of the pillows in the plane of the schistosity, which may or may not coincide with the plane of the primary layering. Fig. 4 illustrates examples which are believed to represent successive stages in the deformation of pillow lavas. The earliest stage of deformation appears to be a rotation and interlocking of the pillows analogous to the packing of sand grains under pressure, and results in the formation of slickensides on the chloritic surfaces of the pillows. Further strain must be taken up by the internal deformation of the pillows. The whole pillow now begins to change shape, as also do internal structures such as vesicles. Eventually a penetrative schistosity is produced. All of these stages are observed in pillow lava flows in the Løkken Area. The pillow lavas are more often tectonically strained than not, and it is only in the south of the area, near Storås, that completely undeformed pillow lavas are found. The amount of deformation is observed to steadily increase northwards.

The basal conglomerate of the Hovin Group is always found to be deformed. It consists mainly of basic volcanic rock fragments and jasper fragments in a finer grained matrix of basic material. Because they are compositionally similar, the basic rock fragments appear to have deformed almost homogeneously with the matrix, producing good linear and planar fabrics. The jasper fragments, however, do not seem to have deformed at all, and the schistosity in the matrix is seen to be deflected around these rigid particles.

(b) The Later Folds, $f_2$

Unlike the $f_1$ folds, the $f_2$ folds do not appear to have produced strong internal deformation of the rocks. There was no associated metamorphism. The large scale flexure of the Løkken Synform (a synformal anticline) is the most important $f_2$ structure. In the north of the area lies a complementary antiform which is not so well defined as the Løkken Synform.

Angular relationships of the sufaces of the Løkken Synform are plotted in equal area projection in Figs. 3 (1) and 3 (2). These show the fold to be open, with an apical angle of about 85 degrees, essentially planar limbs, and a sharp hinge. The geographical distribution of dip values of the $f_1$ schistosity surfaces indicates that second order minor flexures of the order of 100 m wavelength occur on the more gently dipping parts of the $f_2$ major structures, for example on the hinge and southern flank areas of the Løkken Synform.

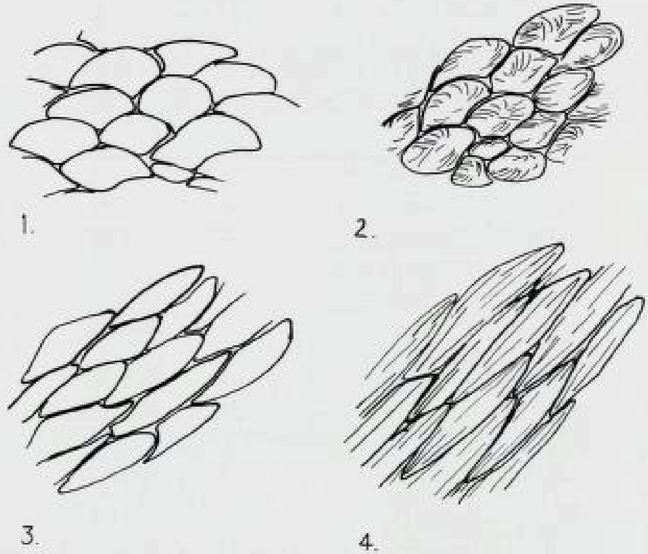



Fig. 4. Illustration of the proposed pattern of the progressive deformation of pillow lavas.
(1) Undeformed pillows slightly flattened in the plane of primary layering.
(2) Rotation and packing of pillows in the early stages of deformation. Slickensiding of chloritic rims.
(3) Internal deformation of pillows. Flattening produces a fabric which eventually overrides the primary fabric.
(4) Strong stretching and flattening of the pillows; imposition of a penetrative schistosity.

In the more schistose rocks a linear structure produced by crenulation of chlorite and mica flakes is consistently developed. This linear structure appears to be coaxial with the local plunge direction of the major $f_2$ folds, and measurements of this structure from over the whole area are plotted in equal area projection in Fig. 3 (5). It should be mentioned that other, less systematic, coarser crenulations have been observed in the schists. The significance of the latter structures is not yet understood.

In the flatter parts of the limbs of the complementary antiform north of the Løkken Synform is often observed a good crenulation cleavage which intersects the $f_1$ schistosity to form the $f_2$ lineation. This cleavage is almost vertical, striking east-west, and approximates to the axial surface of the $f_2$ folds. Small scale minor folds (wavelength less than one metre) of the $f_1$ schistosity are also quite common in the thinly laminated schists, in contrast to the absence of small scale folds in the more massive basic metavolcanics further south.

When crenulation lineation and schistosity measurements are analysed in subareas (defined by approximately north-south lines through Dragset, Storås and Løkken) it becomes clear that the plunge of the Løkken Synform varies from west to east. West of the Orkla River the fold plunges gently eastward. Between the Orkla River and Løkken the plunge is horizontal or gently westward, and east of Løkken the plunge is once more gently to the east. Similar variations are observed in the plunge of the $f_1$ structures.

The massive pyrite orebodies tend to occur along a line parallel to the $f_1$ linear structures, i.e. along a line connecting Dragset, Løkken and Høidal Mines. This line is slightly oblique to the hinge line of the $f_2$ Løkken Synform. The orebodies themselves are elongate in an east-west direction and tend to be flattened in the plane of the primary layering. It is probable that the marked east-west elongation of the Løkken Orebody is not a consequence of tectonic strain alone; it may reflect a surface feature present at the time of formation of the orebodies, for example, an east-west elongate trough.

It is clear from the asymmetry of the Løkken Synform that considerable variations in the thickness of the Støren Group volcanic pile exist within the area. The thickness of pillow lavas in the steeply dipping northern limb of the synform is considerably less than in the more gently dipping southern limb. It is concluded that the metavolcanics thin rapidly northwards and less rapidly westwards, and that this has led to a well defined axial surface trace of the synform very close to the contact between the metavolcanics and the structurally underlying Hovin Group metasediments.

(c) The Late $f_2$ Thrusts

The $f_2$ folds appear to have formed in a less ductile environment than the $f_1$ folds by a buckling process. A late stage in the formation of these was the development of thrust faults which allowed relief of material in their cores. Field evidence, in the form of drag folds, suggests that some of these thrusts have moved from south to north and others from north to south. It is possible that opposite senses of movement may exist on either side of some of the more extensive thrust planes. Fig. 5 illustrates diagrammatically the model proposed to describe the evolution of the $f_2$ folds and thrusts. The way in which thrusts cut across the $f_2$ fold structures is particularly well displayed in a quarry section near Svorkmo. The most extensive known thrust plane is the one which occurs in proximity to the Løkken orebody. This thrust, which dips gently westwards, intersects the mine workings at various levels. Low angle thrusts are observed at a number of exposures within the outcrop of the basic metavolcanics, but poor exposure makes it impossible to infer how these may be connected.

(d) Faulting and Jointing

The area is cut across by a number of north-south striking faults. These are relatively easily detected since they cross the strike of the rocks, often forming topographic depressions or fault line scarps. Where mappable lithologies meet such features, their contacts with surrounding rocks can often be shown to be displaced. Another well developed set of faults trends east-west, parallel to the local strike of the rocks. These are more difficult to detect, and are generally only shown on the map where they can actually be observed. Small faults are therefore probably a lot more common in this area than the map indicates.

Two systematic sets of joints are developed in the Løkken Area. The better developed set is the cross set, perpendicular to the local plunge direction of the $f_2$ structure (see Fig. 3 (3)). A systematic set of longitudinal joints is also developed, forming a significant concentration of poles in Fig. 3 (3). Other joints occurring in the area do not appear to be systematic.

Fig. 5. Illustration of the suggested progressive development of the late $f_2$ thrust faults as a response to the tightening of the $f_2$ buckle folds.

## Summary

Rocks of the Støren Group are the oldest rocks occurring in the Løkken Area. They are preserved from erosion in the core of a synformal structure which trends east-west. The predominant rock type is basic pillow lava with associated volcanic sediments. The volcanic pile is intruded by a number of metagabbro masses.

The Støren Group is stratigraphically succeeded by a series of shales and greywacke sandstones, with the local development of a breccia-conglomerate. Higher in the succession, these sediments, which form part of the Hovin Group, become progressively poorer in basic volcanic detritus.

The entire sequence was deformed and metamorphosed in the Greenschist Facies during the Caledonian Orogeny. The metamorphic grade increases from chlorite grade in the south of the area to the lower part of the garnet grade in the north.

The geological structure is most conveniently summarized in the following outline of the geological history of the area:

( i) Eruption of pillow lavas of the Støren Group. Intrusion of gabbros
( ii) Uplift and erosion leading to formation of the sediments of the Hovin Group.
( iii) Burial by superincumbent sediments.
( iv) Earliest folding, $f_1$, tight to isoclinal folding. Development of nappe-type recumbent folds with east-west axes, overturned toward the north-west.
( v) Regional metamorphism in the Greenschist Facies. Development of schistosity axial plane to the large overfolds.
( vi) Refolding of the $f_1$ schistosity locally coaxial with the $f_1$ folds. Formation of the $f_2$ Løkken Synform.
( vii) Development of thrust faults in the late stages of the tightening of the $f_2$ folds.
(viii) Uplift, faulting and jointing.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# The Geology of Skjervøy, North Troms, Norway

By

*R. P. Ash*

**Abstract**

A geological map and section of the island are presented. Despite the lack of sedimentary structures, the meta-sedimentary succession of limestones, overlain by pelite, overlain by a thick series of psammites is thought to be inverted on the basis of its similarity to the succession in the Loppen district and by the sense of vergence of the early minor folds.

Three periods of deformation are distinguished. $F_1$ predominates and forms a series of tight asymmetric minor folds, associated with a coarse lineation, which retain the same sense of vergence across the island.[1]) $F_2$ is represented by a single major fold exposed on the higher ground, minor folds, and a fine lineation on micaceous rurfaces. More brittle $F_3$ structures are also recorded. The tectonic setting of Skjervøy in relation to the major $F_1$ structures of West Finnmark is briefly discussed.

## 1. Introduction

Skjervøy, latitude 70° 02′ S and longitude 20° 58′ E, lies at the convergence of Reisafjord and Kvænangen Fjord on the coast of North Troms. It has a total area of about 25 km². The large natural harbour and village is a rapidly growing fishing centre. The topography is mild relative to most of the surrounding islands and divides the island into a southern and a northern half joined by an isthmus of land. The highest point on the island is the summit of Skattefjellet (347 m).

Drainage of most of the island is poor, the many glacial rock basins now holding areas of marshy ground or small lakes. Precipitation is high with considerable snow in winter and run off is rapid once all the natural basins are saturated. A number of the larger basins have been enlarged to form reservoirs providing the island with a self-sufficient water supply.

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[1]) See appendix at end of paper.

Rock exposure is generally good except on sheltered slopes where the arctic vegetation is characterised by the abundance of dwarf birch up to 300 m. Raised beaches lie at 2, 13, 33, and 57 m above present sea level.

The field mapping of the geology of Skjervøy was completed during the summer field season of 1966. The author is greatly indebted to Herr Johansen for his hospitality in Skjervøy and to Dr. P. R. Hooper of the Department of Geology, University College of Swansea, for generous assistance with the work and critical reading of proofs.

## 2. General geology

The island is composed of a meta-sedimentary succession dipping gently to the south-east as illustrated in Pl. V. The lithological units distinguished retain their essential identities over the whole island but more detailed correlation is hampered by rapid lateral changes in thickness and lithology. The thicknesses quoted are average figures based upon field observations and do not make allowance for complex intraformational folding present in most formations. No faunal evidence for the age of the meta-sediments is available. On the 1 : 1,000,000 Geological Map of Norway (Holtedahl and Dons, 1960) the whole Skjervøy succession is marked as Cambro-Silurian. In the Loppen district to the north, however, rocks which are correlated with those on Skjervøy (Hooper and Gronow, in press) are divided by Holtedahl and Dons into Eocambrian, predominantly quartzo-feldspathic rocks, and Cambro-Silurian which are predominantly limestones and pelites. All the lithological units are intruded by numerous basic sheets.

### *A. The Skattefjellet Psammites*

These form a thick series (700 m) of flaggy feldspathic sandstones, with a variable quantity of mica and small red garnets, which are probably derived from greywacke. Their foliation is defined by dark micaceous partings which carry lineations of the first and second generation folds. The typical mineral assemblage for the formation is (Plate II (i))

quartz + biotite + muscovite + plagioclase ($An_{30}$) + microcline + garnet. The plagioclase rarely shows good lamellar twinning and the microcline is most abundant in the highly deformed psammites, suggesting some degree of feldspathisation. The amunt of biotite is variable but it is usually the most abundant mica. Accessory sphene and iron ore are often present.

The formation has suffered considerable deformation both by $F_1$ and $F_2$. A number of $F_1$ axial planes have been traced on the western flank of Skattefjellet and large $F_2$ fold closures are found on the summits of Stusnesfjell.

Lailafjell and Trollfjell. Minor folds of both $F_1$ and $F_2$ deformations are common and are distinguished by style and axial trend. $F_1$ drag folds have an axial planar cleavage which is not easily recognized in the quartzo-feldspathic bands but is noted in the preferred orientation of mica plates in the foliation partings. $F_2$ drag folds have typically monoclinal profiles with a considerable thickening of the short limbs of the folds.

*B The Sandøra Augen Gneiss*

This formation forms a wedge of gneissic rocks cropping out within the psammites in the south of Skjervøy. To the west the group dips beneath the shallow Skattørsund and is apparently continuous with similar rocks on the island of Kågen. On Skjervøy the wedge passes without any sharp structural or lithological break into highly deformed Skattefjellet psammites. The wedge may represent an intermediate sized $F_1$ fold closure.[1])

A variety of mineral assemblages are exhibited in this formation but the following are typical (Plate II (ii)):

quartz + microcline + muscovite ± biotite ± garnet

and in feldspathic bands:

microcline + quartz + muscovite.

Microcline is a very prominent mineral in the formation and the numerous feldspathic bands in the psammites suggests the possibility of a progressive feldspathisation of the psammites, reaching a maximum development in the wedge of Sandøra augen gneiss.

The basic intrusions within the gneiss have suffered intense deformation and are only traced with difficulty as schistose bands carrying pink feldspar augen. Their schistosity is defined by the abundance of dark biotite present in greater abundance than hornblende.

*C. The Pelites*

There are three principal outcrops of pelitic rocks. Those occurring around Trollfjell and those forming a belt around the bottom slopes of Skattefjellet are clearly in the same stratigraphic positions separated only by faulting through the centre of the island. The third outcrop, the Vågen pelite, forms a narrow wedge within the Skattefjellet psammites which is widest at the southern shore of Skjervøy harbour, narrowing south-westwards.

The maximum thickness of the Vågen pelite wedge is in excess of 50 m. Both the lower and the upper contacts with psammitic rocks are abrupt litho-

[1]) See appendix at end of paper.

logical changes and are at least in part tectonic. The rocks are massive in character forming a prominent shoulder on the northern flank of Skattefjellet. Intraformational folding is suspected but can seldom be demonstrated. An exception to this is illustrated in Fig. 2. The typical mineral assemblage is:

muscovite + garnet + quartz ± plagioclase ($An_{30}$)

Mica is represented almost exclusively by muscovite. Small red garnets are numerous in all specimens of the group with diameters of one to two millimetres only.

The northern edge of the wedge is occupied by an impersistent semipelitic unit which has a maximum development of 20m. It is distinguished from the pelite by the presence of quartzo-feldspathic ribs about 1.5 cm thick which exhibit numerous $F_1$ folds intruded by basic sheets. It appears probable that Vågen pelite is of tectonic origin, forming the core to a large $F_1$ drag fold.

The two main outcrops of pelite form a massive formation with only limited jointing and steep brown-weathering outcrops. The maximum thickness seen is in the south where over 70m occurs on the lower slopes of Skattefjellet. Mineralogically these pelites are very similar to the Vågen pelite although the latter is slightly more quartz rich. The garnets are usually small, pink and idioblastic except where the formation passes into the large $F_2$ fold closure around the summit of Trollfjell. Garnets from this locality are larger and poorly formed, indicating extended or renewed metamorphism related to the $F_2$ deformation.

The junction of the pelites with the Skattefjellet psammites is very abrupt and usually intruded by basic sheets. The original relation between the supposed Eo-cambrian and Cambro-Silurian members of the succession is therefore obscure. Approaching the other side of the pelites the junction is marked by a passage into semi-pelitic rocks and a great increase in the number of basic sheets.

Along the summit of Trollfjell a persistent slice of psammitic rocks is found in the pelites. These psammites are not represented along the west coast of the island, for example in the area around Isakeidet, where the pelitic succession is uninterrupted. The band is therefore regarded as a tectonic feature resulting from the severe $F_1$ deformation and recorded as Skattefjellet psammite on the map. (Plate V.)

*D. The Lysthus Semi-pelites*

This is a large and variable formation separating the true pelites from the more calcareous formations. The junctions with the pelites on the one side and the calcareous formation on the other are transitional. The maximum thickness of the unit is seen in a broad outcrop to the south of Finneidet where it is in excess of 100m.

The typical semi-pelitic mineral assemblage is:

biotite + quartz + muscovite + plagioclase ($An_{30}$) ± garnet

The quartz content of some bands may exceed that of mica, but several pelitic bands of a light rusty appearance also occur within the group. These more schistose divisions are composed of:

muscovite + biotite + small garnets + a little quartz.

In contrast to the pelites the abundant mica in the Lysthus semi-pelites is biotite. This stands out even in the hand specimens by the very dark coloration of the micaceous partings.

Within the quartzo-feldspathic bands micas are also abundant but muscovite and biotite are in approximately equal proportions. The muscovite micas form much larger plates than do the biotites and from the textural relation of the muscovite plates to other minerals it appears that muscovite continued to crystallise later than the other minerals.

$F_1$ drag fold structures are very well developed in parts of the Lysthus semi-pelites and the axial plane cleavage is again best represented by the preferred orientation of the mica plates. Another distinctive feature of this formation is the abundance of basic sheets.

An important horizon within the formation is the Eyrie Limestone. This is a pure meta-limestone with associated calc-silicate and calcareous-pelitic rocks which may be traced from just north of the summit of Trollfjell to the coast 200 m south-west of Ramneset. Near Isakeidet on the west coast of the island the 10 m of Eyrie Limestone appears to be represented only by a band of green and purple calc-silicate slates with a maximum development of 3 m. To the south of Finneidet there is no trace of a calcareous band within the semi-pelites. The transition to the Prestberget formation begins with the appearance of zoisite in the biotite-rich partings of the semi-pelite assemblage.

*E. The Prestberget Formation*

Defining the boundary betweet the Lysthus semi-pelites and the Prestberget formation is difficult as it depends on the first appearance of a distinctly calcareous lithology. The boundary drawn on the map (Plate V) may therefore be diachronous in part.

The complete formation is exposed on the coast west of Trollfjell where it has an average thickness of 80—100 m. On the eastern slopes of Trollfjell the formation is highly deformed and considerably increased in thickness by the $F_2$ fold. In contrast, where the formation crops out on the western side of the island and around the northern part of Skjervøy harbour the foliation is almost flat and $F_1$ folds are never developed. The thin, often slaty foliation of the formation is the axial plane cleavage of the $F_1$ deformation and the abundant basic sheets which intrude this plane carry the same cleavage.

Mineral assemblages within the formation show considerable variation but a number of generalisations can be made. Biotite is the most abundant mica and is present in almost all the assemblages examined. (Plate III (ii)). Amphiboles are common, usually in the form of hornblende but occasionally in the form of tremolite-actinolite with a much weaker pleochroism. Plagioclase feldspars are represented by andesine in the range $An_{30-40}$. The mineral assemblage of the green calcareous schists is:

tremolite-actinolite + biotite + carbonate + quartz + zoisite + andesine

In the purple calcareous schists it is:

biotite + hornblende + carbonate + quartz + andesine + zoisite

and in the metamorphosed marls:

clinopyroxene + biotite + andesine + quartz ± hornblende

In some more quartz-rich bands the typical calcareous schist lithology is developed as partings between quartzo-feldspathic bands:

biotite + quartz + zoisite + andesine + hornblende

Thus the Prestberget formation is the metamorphosed derivative of a series of impure calcareous sediments with occasional more magnesia-rich members in the form of marls.

As the next formation, the Engnes Limestone, is approached along the track to Engnes, several lenses of pure meta-limestone are developed which reflect an increasing proportion of carbonate leading eventually to a passage into almost pure meta-limestone. The junction between the Prestberget formation and the Engnes Limestone is poorly exposed along the entire outcrop from Mortevågen to Ramneset and it is necessarily defined only by an arbitrary line (Plate V) which places all the calcareous schists within the Prestberget formation.

*F. The Engnes Limestone*

The limestone occurs in three separate outcrops, in two of which the complete formation appears to be exposed. In the third, near the playing field north of the village only the lower part is exposed in the form of impure limestone.

In the north of the island a continuous coastal section from Engnes west to Mortevågen and south to Ramneset exposes a total thickness of about 140 m of pure limestone considerably deformed by folding. The numerous $F_1$ minor folds indicate the probability of a number of intraformational $F_1$ folds. In contrast to this thick development, the limestones at Finneidet have a total thickness of only 20 m. No $F_1$ folds are developed at this locality and it would appear that the limestones are here attenuated on the limb of an $F_1$ fold.

The basic intrusions within the limestones have suffered considerable boudinage as a result of the $F_1$ deformation. At Finneidet the intrusions are small and often completely pinched out by the boudins. Boudinage in the Engnes area is no less severe but many of the intrusions reach considerable dimensions. Boudins exceeding 5 m in thickness which can be traced for less than 20 m along the strike are indicative of the serverity of this effect.

The original limestone has been completely recrystallised during the metamorphism to a white granular or saccharoidal marble composed of a mosaic of carbonate crystals. Close to the junction with the Bratteidet formation at Mortevågen a number of pelitic and calc-silicate bands appear. Similar lithologies occur again on the southern side of Engnesbukta but none of these bands persist for more than a limited distance owing to the $F_1$ deformation.

*G. The Bratteidet Formation.*

This formation is represented by isolated outcrops. The larger is at Bratteidet where 20 m is exposed beneath the Engnes Limestone. It is limited to the north by a large fault which runs through Bratteidet. This fault has a downthrow to the north which brings the topmost Skattefjellet psammite against the Bratteidet Formation. To the south where the Bratteidet Formation succeeds the Engnes Limestone there is an abrupt tectonic contact at which pure limestone is succeeded by biotite schist.

At Bratteidet the lower half of the formation is largely composed of pelitic rocks with varied lithologies including such minerals as zoisite, hornblende and garnet (Plate III (i) ). The purest pelitic rocks of the Skjervøy succession are developed here. The upper half of the formation is mainly composed of massive quartzites. Shear zones between quartzite bands have a more foliated quartz + muscovite + microcline lithology. Much of the formation has an appreciable calcium content which is represented by the occurrence of zoisite in the biotite schists and in impure pelitic bands associated with the quartzites.

Impure pelitic bands exposed at Mortevågen and south of Engnesbukta are somewhat similar in appearance to the pelites at Bratteidet, but are succeeded by the topmost Engnes Limestone and are included within the latter formation. While it is possible that these pelites have been intimately folded into the Engnes Limestone by the $F_1$ deformation no conclusive evidence is available.

At Engnes only the quartzite members of the formation are represented. In the small bay immediately to the east of Engnes they appear in a single small outcrop in which the massive foliation is dissected by numerous joints. About 20 m south of the Engnes light a single lens of quartzite 5 m in length has been sheared into the limestones and subsequently cut by a basic intrusion.

Substanial $F_1$ deformation also occured at Bratteidet resulting in the cleavage and attenuation of basic intrusions within the formation, and a tendency towards the rodding of quartzitic members in the $F_1$ axial direction. In addition the pelitic members exhibit the strain-slip cleavage of the $F_2$ deformation.

*H. The Basic Sheets*

Numerous basic sheets varying in width from 20 cm to 5 m cut all the meta-sedimentary formations on the island. All those examined are amphibolites with an essential hornblende-andesine ($An_{30}$-$An_{40}$) assemblage and are of igneous origin (Plate IV (i) ). Some have finer grained margins which might be due in part to chilling during intrusion.

Variations in the mineralogy of the sheets appear to be a result of metamorphism. Zoisite frequently develops in sheets intruded into the calcareous formations (with the exeption of the pure limestones) while the biotite content increases with the degree of shear to which they have been subjected. Pink garnets may be numerous or absent within different parts of the same sheet tending to occur in the finer phases of the sheets or where cleavage and shearing are most intense. They frequently develop rhombdodecahedral form.

The mineral assemblage from a massive amphibolite with relict ophitic texture is.

hornblende + andesine + biotite + iron ore.

From sheets in the calcareous formation it is:

hornblende + andesine + zoisite + almandine or

hornblende + andesine + zoisite + biotite + almandine.

From severly sheared sheets it is:

hornblende + biotite + andesine + epidote + almandine (Plate IV (ii) )

while "ghost" amphibolites from the Sandøre augen gneiss have the assemblage:

biotite + hornblende + microcline + andesine.

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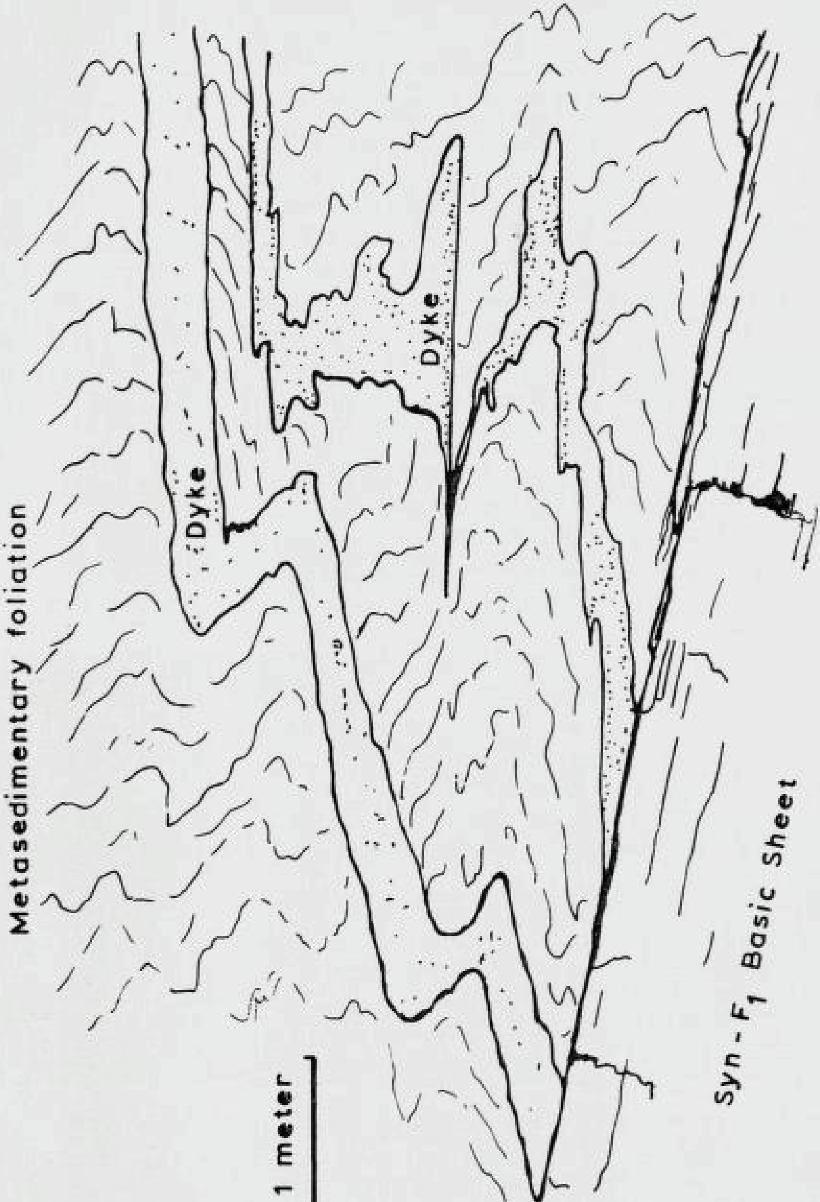
Fig. 1. $F_1$ structures in the Lysthus Formation south of Sjøburdneset. The two smaller amphibolites are deformed by the typical $F_1$ "drag" folds. The larger later amphibolite is parallel to the axial planes of the $F_1$ folds, but contains the $F_1$ axial plane cleavage ($S_2$).


Metasedimentary foliation
Dyke
Dyke
1 meter
Syn-$F_1$ Basic Sheet

Two generations of intrusions are demonstrated. The earlier are few in number and do not exceed about 50 cm in width. They are fine grained with abundant biotite and may also be rich in almandine. South of Sjøburdneset sheets of this earlier suite are deformed by an $F_1$ drag fold and cut by a larger dyke of the later suite (Fig. 1). Clearly the earlier suite was emplaced prior to the $F_1$ deformation.

Amphibolites of the second and main suite were intruded with remarkable concordance to the axial plane of $F_1$ (Plate I (i) ). They often lie in the limbs of the $F_1$ minor folds parallel to but not along the axial planes of the folds. They carry the axial plane cleavage of $F_1$ and must therefore be regarded as syn-$F_1$ intrusions. Similar basic sheets with a similar relation to the $F_1$ folds have been described from all parts of the Loppen district north of Kvænangen Fjord (Mr. D. Lewis, personal communication, Hooper and Gronow, in press). They constitute an important piece of evidence in the correlation of the $F_1$ folds of the two areas. In the Loppen district Hooper and Gronow have shown that they were intruded after the formation of the $F_1$ folds but prior to late $F_1$ axial plane shear which was concentrated in the $F_1$ fold limbs.

In nearly all the metasedimentary formations on Skjervøy the sheets have suffered some bouodinage during the $F_1$ deformation although the phenome-

Fig. 2. Small $F_1$ "ghost" fold in the Vågen pelite (Photo P.R.H.).

non is most fully developed in the meta-limestones. In the areas of $F_2$ folding all the sheets become folded and may ultimately be deformed into large rods with the trend and plunge of the $F_2$ axes. Several small sheets south of Tennskjerneset are not deformed by the $F_1$ shear.

*I. Discussion*

No sedimentary structures have been found on Skjervøy, due perhaps to the intense late $F_1$ shearing. The succession does show very marked similarities to that established for the Loppen district (Hooper and Gronow, in press) and indeed with that established on Sørøy (Sturt and Ramsay 1965). In both these areas sedimentary structures have shown the quartzo-feldspathic formations to lie at the bottom, overlain successively by a pelitic group and then a limestone group. If the obvious correlation of these successions with that of Skjervøy is accepted, then the Skjervøy succession is inverted. This conclusion is convincingly supported by the structural evidence recorded below.

The mineral assemblages indicate that the Skjervøy succession has been regionally metamorphosed to the almandine-amphibolite facies of the Barrovian type facies series. The presence of zoisite in stable paragenesis with oligoclase-andesine ($An_{30}$) implies that the sillimanite-almandine-orthoclase sub-facies has not been reached. As neither staurolite nor kyanite has yet been identified a further sub-division between the staurolite-almandine sub-facies and the kyanite-almandine-muscovite sub-facies is not possible.

The schistosity of the meta-sediments is produced by the preferred orientation of mica plates while the cleavage of the amphibolite sheets and of the Prestberget formation is similarly produced by the preferred orientation of biotite and hornblende. There is no reason to suppose that the foliation of the psammites results from any process other than the accentuation of the original bedding ($S_1$) by metamorphic differentiation and shearing. While this may also be true for the semi-pelites it is doubtful whether the foliation of the pelitic and calcareous formations bears any relation to the original bedding. In the Vågen pelite isolated quartzite stringers may be observed making an angle of up to 40° with the foliation, but it cannot be proved that these represent the original bedding.

Zoisite prisms developed in the sheared amphibolites to the north of Finneidet have a preferred orientation of their long (b-crystallographic) axes in the direction of the $F_1$ fold axes.

Inclusions in the idioblastic garnets do not indicate rotation during the $F_1$ deformation even in the highly cleaved margins of the basic sheets. It is therefore believed that the main genesis of garnet was of post-$F_1$ age. Where the garnet-mica schists have been folded by $F_2$, the garnets become xenoblastic and larger, indicating continued or renewed crystallisation during the $F_2$ deformation. Here also zoisite aggregates have a preferred orientation parallel to the $F_2$ fold axes. There does not, therefore, appear to have been any lowering of the metamorphic grade until after the $F_2$ deformation.

An anomalous assemblage is found in a small outcrop at Isakeidet. It is a chlorite-almandine-biotite schist well developed adjacent to the calc-silicate band representing the Eyrie limestone at this locality.

## 3. Structure

Two major generations of folds, $F_1$ and $F_2$, are recognised on Skjervøy and a third deformation, $F_3$, is represented by joint sets and locally developed strain-slip cleavage. $F_1$ predominates in the south-west of the island from Sjøburdneset to Sandøra where it is beautifully developed and, to a lesser extent, in the Mortevågen, Engnes, Engnesbukta area in the north. $F_2$ structures predominate on the summits Lailafjell and Stusnesfjell and even more strongly the Trollfjell-Ramneset area where a large $F_2$ fold closure can be seen.

### *A. The $F_1$ Deformation*

The earliest folds are small, tight asymmetric drag folds, reclined with their axes approximating to the angle and direction of dip of the foliation. When plotted on a stereogram those from the south-west coast form a single maximum plunging 20° in the direction 145° (Fig. 3a). They are associated with a characteristic coarse lineation and basic sheets which lie parallel to their axial planes, dipping south-south-east at approximately 25° (Fig. 3b), virtually parallel to the foliation plane (Fig. 3c).

The predominant sense of vergence implied by the asymmetry of the $F_1$ minor folds indicates that the whole Skjervøy succession lies on a single major $F_1$ fold limb. If the succession is inverted, as lithological correlation with the Loppen and Sørøy districts suggests, then Skjervøy lies on the inverted limb of an $F_1$ anticline facing west. This is the same direction of facing as the $F_1$ folds in the Loppen district. If it is assumed, on the other hand, that the succession is not inverted, not only are the lithological units in the opposite order to that established over a wide area to the north, but the $F_1$ folds must be supposed to face eastwards in a direction opposite to that of the Loppen district. While the second possibility cannot be ruled out entirely in the absence of sedimentary structures, it may be considered most unlikely.

A strong cleavage is developed parallel to the $F_1$ axial plane ($S_2$) which also affects the axial planar basic sheets and forms the schistosity in the pelitic and calcareous formations. The implication is that after the development of the $F_1$ folds and the intrusion of the basic sheets parallel to their axial planes, the same stress field produced further shearing which developed more especially along the limbs of the $F_1$ folds and within the basic sheets. The degree of movement in the $S_2$ cleavage plane is demonstrated by the non-affine deformation of quartz stringers in amphibolite sheets (Plate 1 (ii)).

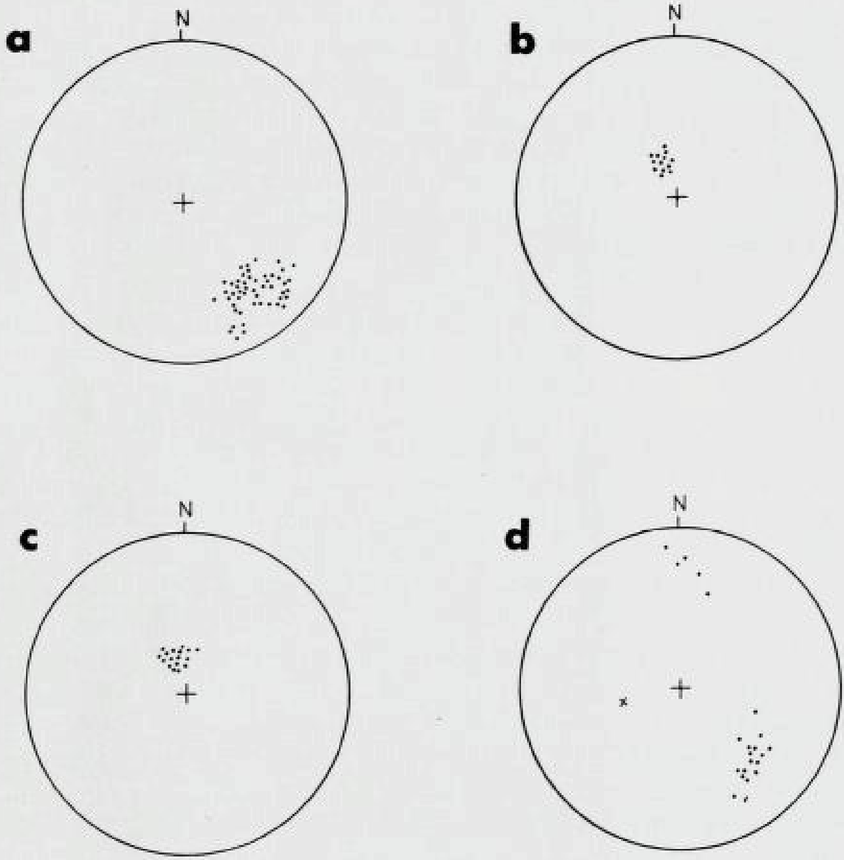



Fig. 3. Stereograms illustrating the principal features of the $F_1$ and $F_2$ deformations. (a) $F_1$ fold axes from the Finneidet - Stusneset - Sandøra area, southern Skjervøy. (b) Poles to the axial planes of the $F_1$ "drag" folds in the Skattefjellet and Finneidet-Sjøburdneset areas. (c) Poles to the foliation planes in the psammitic rocks of the Tennskjerneset - Skattøra area. (d) $F_2$ lineations forming a great circle distribution around $F_1$ folds. The cross indicates the derived pole to the $F_2$ axial plane, Stusneset.

The $F_1$ minor folds have a similar fold profile with thickened hinge zones and attenuated limbs. The interlimb angle varies up to 30° but subsequent shearing has frequently caused the folds to become isoclinal so that in areas of very intense deformation, the poles to the foliation planes form a single maximum, despite the presence of some quite large $F_1$ drag folds.

*B. The $F_2$ Deformation.*

On the summit of Trollfjell a major $F_2$ fold causes the foliation to swing from its normal gentle south-easterly dip through a synformal closure with an axis plunging 10° in direction 142° and an axial plane dipping 15° in direction 110° - into a vertical easterly limb. This vertical limb, with associated minor $F_2$ folds, may be traced parallel to the $F_2$ axis from the summit of Trollfjell to the coast near Ramnneset. The $F_1$ axial plane present as the $S_2$ cleavage in the basic sheets and in the minor $F_1$ folds, is folded around the $F_2$ synform, but the $F_1$ lineation has been obliterated in the axial region and the pattern of deformation of the $F_1$ linear structures cannot therefore be used to demonstrate the mechanism of the $F_2$ folding.

Little of the overturned limb of the $F_2$ fold can be seen as the land surface has been lowered by erosion to expose only the fold closure over most of the area. $F_2$ drag folds indicate that, like $F_1$, the $F_2$ deformation has a similar style and monoclinic symmetry. In contrast with $F_1$, however, these folds are more open and there is no great development of cleavage and shearing parallel to the axial planes. None of the amphibolite sheets can be shown to post-date $F_2$.

Over much of the island an $F_2$ strain-slip cleavage is developed within the pelitic partings of the psammitic and semi-pelitic formations. It forms a microfold lineation in those mica plates orientated parallel to the axial planes of the $F_1$ structures. Its orientation is remarkably constant over much of the island. At Stusneset it is found superimposed upon a number of minor $F_1$ folds to form a great circle on a stereographic projection (Fig. 3d). In the pelitic rocks exposed between Finneidet and Bratteidet a typical $F_2$ strain-slip cleavage is developed with a south-westerly dipping axial plane. North of Isakeidet, however, an $F_2$ drag fold has an axial plane similar in attitude to that of the major fold on Trollfjell.

If a correction is made for the major faulting which crosses the island of Skjervøy on the northern side of the village, it is apparent that the three areas of $F_2$ folding lie on a single axial plane. As they also have the same axial plunge they are regarded as the now isolated fragments of a single fold, the Trollfjell synform.

*C. The $F_3$ Deformation.*

At Engnes and Mortevågen small horizontal crenulations and pinches in limestone and pelitic bands have a trend of 060°. In pelites at Bratteidet a very inconsistent strain-slip cleavage is developed at a small angle to the foliation and apparently post-dating the prominent $F_2$ strain-slip cleavage. Further evidence for an $F_3$ deformation is presented by a conjugate joint set which is occasionally developed in the meta-limestones and pelites at Mortevågen. These are approximately vertical with trends of 315° and 345°.

*D. Faults.*

The major faults appear to be developed along two principal directions of 055° and 080° and are either vertical or have a steep hade to the north. All the major jointing in the north end of the island is also in these planes. Within the Trollfjell synform faults with these trends have horizontal displacements and it is possible that this set is associated with the $F_2$ deformation.

The majority of faults have downthrows towards the north but do not normally show drag features, even when the movement has been substantial. The largest single fault trends at about 080° through Bratteidet and has an estimated downthrow to the north of 350 m. This is sufficient to bring the Skattefjellet psammites of Lailafjell against the quartzites of the Bratteidet formation. Eastwards this large throw is dispersed among a series of faults which cross the island to reach the sea less than half a mile south-west of Ramnneset. Here a fault throws $F_2$ folded psammites, pelites and semi-pelites on the north against the Prestberget formation to the south which is undisturbed by $F_2$. The faults which reach the sea immediately north of Ramnneset have downthrows to the south which may total 30 to 40 m.

Numerous small strike faults trending 060° to 070° with hades to the north of about 10° cut the psammites of Stusnesfjell and are well exposed at Stusneset. Many of these faults have small downthrows to the south but the trend is representative of the major joint set in the south of the island.

## 4. Discussion

A detailed correlation of stratigraphic units is hampered by rapid lateral changes in lithology and thickness, due mainly to the severe deformation suffered by these rocks. It follows that a detailed correlation with successions from other areas is unlikely to prove fruitful. On the larger scale, however, the broad divisions with a pelite group lying between a thick series of feldspathic sandstones on the one side and a calcareous group on the other corresponds with the successions established in the Loppen district (Hooper and Gronow, in press) and Sørøy (Sturt and Ramsay, 1965). In both these more northerly areas sedimentary structures prove the limestones to be the youngest of the three groups, and if correlation of the Skjervøy succession with these successions is accepted, then the former must be inverted. Unfortunately sedimentary structures are not available to confirm or disprove this.

The structures, too, bear a close comparison with those of the Loppen district. The earliest ($F_1$) is a set of tight asymmetric folds with axial planar basic sheets bearing the late-$F_1$ axial plane cleavage. These are the specific and rather unusual features of the $F_1$ in the Loppen district (Hooper and Gronow, in press). In both areas $F_2$ is a more open folding associated with a faint lineation caused by a crenulation of mica surfaces, while $F_3$ is mainly represented by faults and joint sets.

In the Loppen district the $F_1$ minor asymmetric folds are strictly congruous to the major $F_1$ closures. With this in mind the sense of vergence of the minor folds on Skjervøy implies that the whole island is on the inverted limb of a large overturned $F_1$ anticline facing west. Thus the $F_1$ structures provide strong independent support for believing the Skjervøy succession to be inverted and for its correlation with the successions of the Loppen district and Sørøy. The significance of Skjervøy in the regional pattern of the $F_1$ deformation has been discussed by Hooper and Gronow (in press).

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*Holtedahl, O.* and *Dons, J. A.* (1960). The Geology of Norway. Norges Geol. Unders., Nr. 208.

*Hooper, P. R.* and *Gronow, C. W.* (in press). The regional significance of the Caledonian structures of the Sandland Peninsula, West Finnmark, Northern Norway. Quart. Journ. Geol. Soc. London.

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## Appendix

### Recent observations on the southern shore of Skjervøy and the opposite coast of Kågen

*P. R. Hooper, D. E. Pearson and D. Lewis.*

In the summer of 1967 brief visits were made to the shores of the low lying peninsula extending eastwards from the main mass of Kågen by P.R.H. and D.E.P., while D.L. independently spent a day on the good exposures on the southern shore of Skjervøy in a search for primary sedimentary structures.

Sedimentary structures were not found owing to the severe $F_1$ tectonism. However, while confirming the persistent sense of vergence of the $F_1$ minor folds over the greater part of the island as recorded by Ash, D.L. noted many clear and persistent examples of these folds verging in the opposite sense south of a line running through the centre of the lens of augen gneiss. He was thus able to confirm Ash's suggestion that the augen gneiss represents an $F_1$ fold closure.

On Kågen, to the south, the foliation is similar to that on Skjervøy (dipping gently south-east) with psammites in the north overlain to the south by a thin band of pelite and then limestone. Strongly developed minor $F_1$ folds have a sense of vergence similar to that recorded by D.L. south of the augen gneiss on Skjervøy. On the basis of the correlation suggested by Ash (above) and by Hooper and Gronow (in press) the major isoclinal $F_1$ fold thus identified crossing the southern end of Skjervøy is an anticline facing and closing westwards with an axial plane trace trending ENE-WSW and with a southerly overlying limb in the correct stratigraphic position. The apparent closure east-

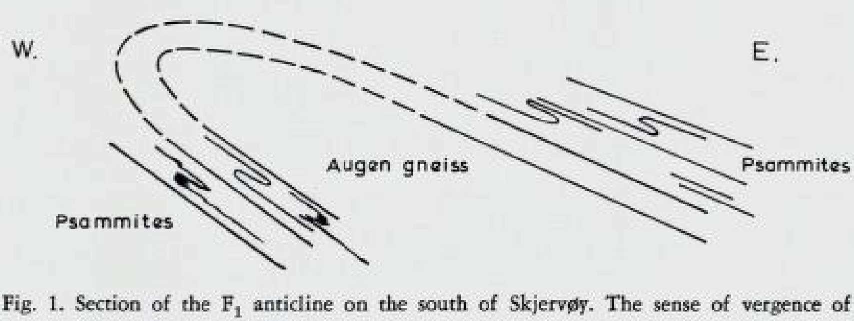



Fig. 1. Section of the $F_1$ anticline on the south of Skjervøy. The sense of vergence of the minor folds indicates that the anticline closes and faces west. The axis plunges gently to the south-east.

wards of the augen gneiss on Ash's map appears to be fortuitous. Augen gneiss typically develops as impersistent lenses in the Loppen District. The drag folds in fact indicate a closure westwards as indicated in Fig. 1. The apparent incongruous nature of the minor folds on Plate V of Ash's paper is not real. It is a consequence of recording "drag sense" as if the observer were looking north, when in fact the folds are plunging gently south. The "drag sense" should always be recorded on a map looking down plunge.

It is of particular importance to note that this major fold is not accompanied by a significant change in the foliation on a regional scale and can only be identified by repetition of lithological units and the sense of vergence of the minor $F_1$ folds. It would be surprising if other examples of major isoclinal $F_1$ folds, capable of repeating the succession on a regional scale, were not present in North Troms.

# En „flyttblokk" av finsand

Av
*J. Låg*

**Abstract**

*An "erratic boulder" of fine sand*

A special, isolated deposit of fine sand in a coarse sand deposit of fluvio-glacial character at Brusletten, Dovre, in central Norway has been described. The fine sand has probably been incorporated in the coarse sand deposit as a frozen mass. In order to gain a better understanding of the mode of formation of Norwegian fluvio-glacial deposits, it would seem necessary to lay greater weight in the study of the structures within the soil material itself.

I forbindelse med undersøkelse av skogjorda i Oppland fylke (Låg [1968]) kom jeg sommeren 1967 over en interessant detalj i et grustak ved Brusletten, sør for Brennhaug, i Dovre. Grustaket ligger i furuskogen på vestsida av Lågen, like vest for riksvegen. I nordveggen i grustaket var det i dagene 24.—28. juli 1967 synlig en avsetning som ved overfladisk betraktning kunne bli tatt for å være en stor blokk. Men ved nærmere undersøkelse viste det seg at dette var en avleiring med en spesiell geologisk forhistorie.

Det er store glacifluviale lausavleiringer langs hoveddalføret i Dovre. Grustaket ved Brusletten ligger i et slikt sediment.

Det øverste 1—2 m tykke laget i grustaket var et steinrikt grussjikt. I dette gruslaget var det utviklet et regulært jernpodsolprofil med tynt bleikjordsjikt. Videre nedover i jordmassen var det lagdelt grovsand med spredte gruskorn og små steiner. I det steinrike, øverste sjiktet lå det også endel blokker, særlig på overgangen mot underlaget. Den største høyden på veggen i grustaket var ca. 10 m.

Den blokklignende avsetningen var plassert aller øverst i grovsandavsetningen, på overgangen mot det steinrike gruslaget. Fargen var brunaktig, mens grovsandsedimentet hadde lys grålig farge. Lengden var ca. 1,7 m og bredden ca. 1,2 m. Ved nøyaktige studier viste det seg at det bare var alminnelig vannsortert finsand også i denne spesielle avsetningen. Sjiktningen i finsandlagene var omtrent horisontale. Lagene av grovsand hadde derimot helling nedover mot dalbunnen. Finsanden var ikke fullt så godt konsolidert som den omkringliggende grovsanden. Overflaten av finsandavsetningen lå derfor 10—15 cm innenfor veggen i grustaket. Det var over alt skarp grense mellom den særegne avsetningen av finsand og det omgivende materialet. Størsteparten av finsanden tilhørte den groveste fraksjonen, altså partikkelstørrelse 0,2—0,06 mm.

Det kunne ha ligget nær å tenke seg at denne spesielle finsandforekomsten var resultat av gjennomforvitring av en blokk av en sandsteinbergart. Men en slik forklaringsmåte måtte forkastes. Jordmasse fra en forvitret blokk ville bl. a. vise variasjon i strukturforhold avhengig av svakhetssoner i bergarten. I dette tilfelle var jorda svært homogen. Endel tynne røtter var trengt ned fra overflatelaget, og rottrevlene var jevnt fordelt gjennom jordmassen.

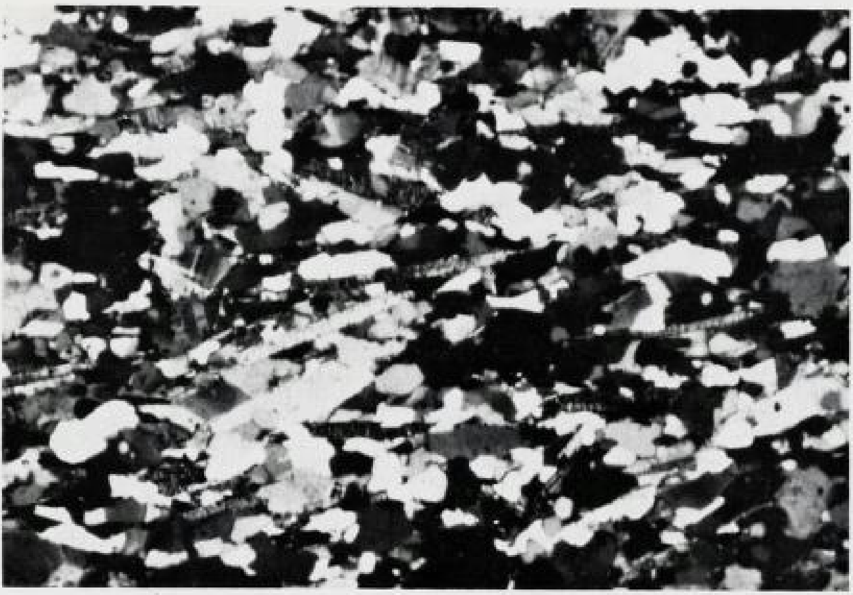
En annen forklaringsmåte kunne ha vært at finsand var sedimentert på regulær måte i en grop etter en isblokk som hadde vært innleiret i den grove sanden. Den horisontale lagdelingen kunne peke i retning av en slik dannelsesmåte. Men grensa mellom sandavleiringene skulle da ha vært preget av rekke-

Fig. 1. Nærbilde av «finsandblokken» (midt på bildet). Det skimtes merker etter små setninger som har foregått i sandmassen. 28.7.67.

Plate I.

( i) Amphibolite lying parallel to the axial plane of an $F_1$ fold. Sjøburdneset.

(ii) Non-affine deformation of a quartz stringer in an amphibolite, due to movement parallel to $S_2$, Bratteidet.



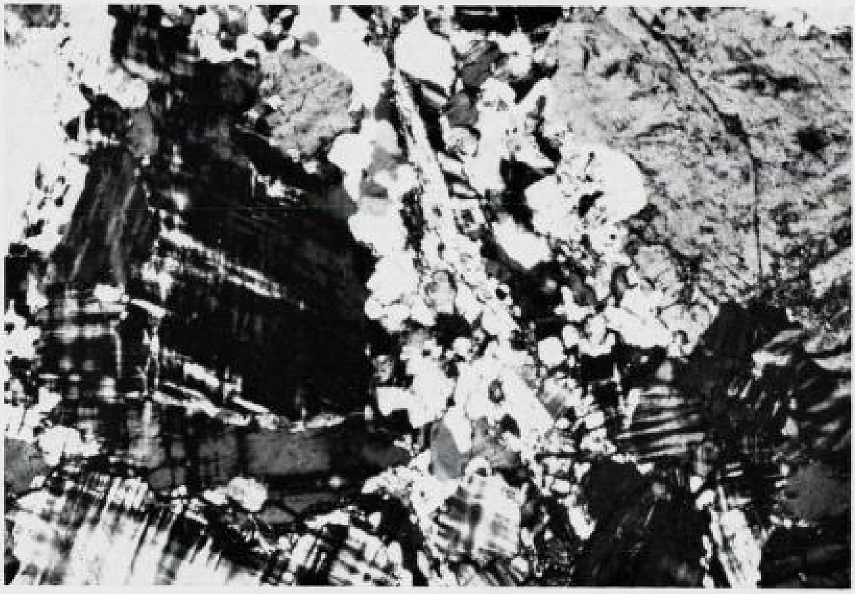


Plate II.

( i) Skattefjellet psammite (quartz-biotite-muscovite-microcline-oligoclase-garnet). Nor 2761, x-nicols, X. 38.

(ii) Sandøra augen gneiss (microcline-quartz-muscovite) Nor 3763, x-nicols, X. 38.

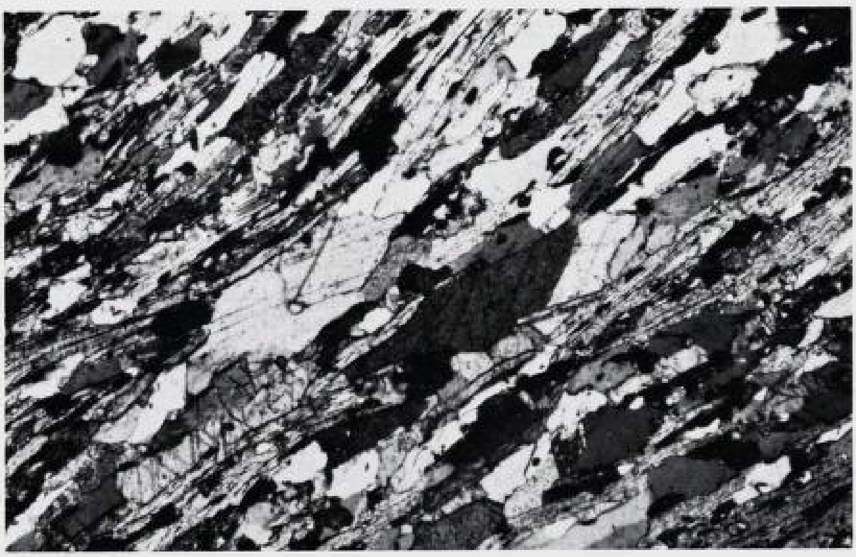


Plate III.

(i) Bratteidet pelite (biotite-zoisite-quartz-garnet), Nor 3778 P.P.L. X. 38.

(ii) Prestberget Formation (actinolite-biotite-calcite-quartz-zoisite). Nor 3770, x-nicols, X. 38.

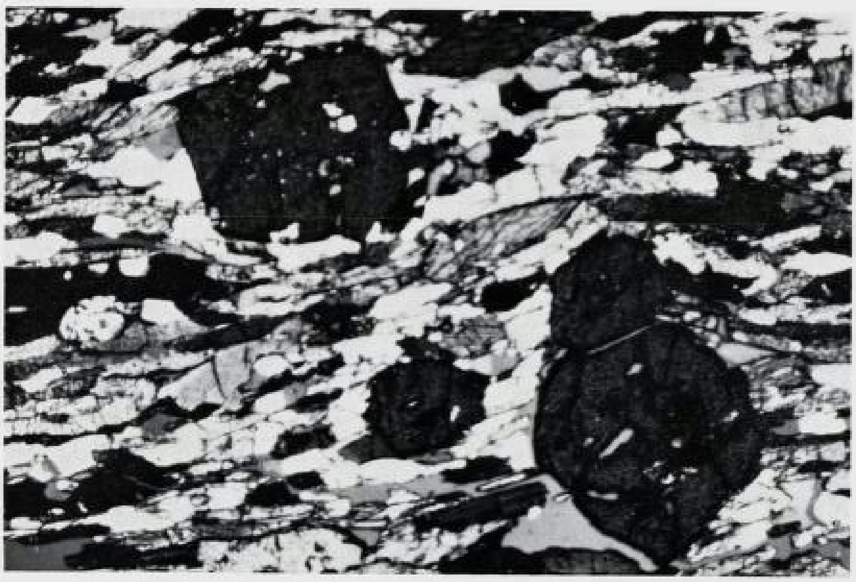


Plate IV

( i) Coarse amphibolite (hornblende-andesine-biotite), Nor 3781 P.P.L. X. 38.

(ii) Sheared margin of amphibolite dyke (hornblende-andesine-zoisite-garnet). Foliation parallel to $S_2$. Nor 3780, x-nicols, X. 38.

Plate V. Geological map and section of Skjervøy.

Fig. 2. Oversiktsbilde over nordveggen i grustaket ved Brusletten, Dovre. «Flyttblokken» av finsand sees omtrent midt på bildet. 24.7.67.

følgen for sedimentasjonen. Etter detaljstudium av avgrensinga av finsand-sedimentet ble det klart at heller ikke denne forklaringsmåten kunne opprettholdes.

Den eneste holdbare forklaringen synes å være at finsandsedimentet er brakt på plass som en gjennomfrosset blokk mens sedimentasjonen av det grove materialet foregikk. Avsetningsmåten for den brunlige finsandavleiringen skulle altså være tilsvarende som for steinblokker i glacifluvialsedimentet. Det var ikke synlig alminnelige blokker i grovsandsedimentet under besøkene 24. og 28. juli 1967. Men i det steinrike gruslaget fantes det blokker på flere steder. I bunnen av grustaket, som rest etter den utgravete massen, lå det igjen noen store blokker. Det kan selvfølgelig tenkes å ligge steinblokker i grovsandavleiringen selv om ingen var synlige i veggene i grustaket på dette tidspunkt.

Det er alminnelig å forklare forekomst av blokker i mer finkornete sedimenter ved at disse store bergartsbruddstykkene er fraktet fram av drivende isflak. Hvis sedimentasjonen har foregått i åpninger inne i breisen, kan steiner og blokker være falt ned fra selve breen.

I forbindelse med nedsmeltinga av isbreen i nordre Gudbrandsdalen har det vært muligheter for dannelse av finsandsedimenter oppe på eller inne i åpninger i isen. Ved senking av vann-nivået kunne det bli vilkår for gjennomfrysing av tykke sedimentlag. En sammenfrosset jordmasse kan flyttes og avsettes på nytt på tilsvarende måte som en steinblokk. Volumvekten for en slik teleklump vil være noe mindre enn for bergartene, og den vil ha lettere for å smuldre ved mekaniske påkjenninger under transporten. Ellers vil likheten med en alminnelig steinblokk være stor.

Finsandavsetningen var orientert med den største utstrekningen noenlunde horisontalt og parallelt med lagdelingen. Blokker av sedimentbergarter vil også ha en viss tendens til å være plassert på tilsvarende måte i våre kvartære glacifluvialsedimenter.

Det har i tidens løp vært mye diskusjon om dannelsesmåter for glacifluvialsedimenter i de sentrale deler av Norge (se f.eks. Holtedahl 1960, og litteratur referert i dette verket). I de fleste tilfellene er det lagt hovedvekt på overflateformer ved forsøk på utredning av dannelsen av avleiringene. Det synes å være grunn til å legge større vekt enn tidligere på studier av indre strukturer av jordmassene når dannelsesmåten skal klarlegges.

**Referert litteratur:**

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*Låg, J.* (1968): Undersøkelse av skogjorda i Oppland ved Landsskogtakseringens markarbeid somrene 1962 og 1963. (Manuskript til trykning i Medd. fra Det norske Skogforsøksvesen.)

# The Porsanger Sandstone Formation and subjacent Rocks in the Lakselv District, Finnmark, Northern Norway

By

*Brian White* [1])

**Contents**



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**Abstract**

The Porsanger Sandstone Formation forms an imbricated thrust mass lying between the Precambrian Basement Complex to the south-east and an allochthonous nappe of "Caledonian" metamorphic rocks to the north-west. The Porsanger Sandstone Formation is separated from the basement by a thin sequence of autochthonous "Hyolithes Zone" sediments.

The feldspathic sandstones and shales of the "Hyolithes Zone" rest unconformably upon a weathered surface of Precambrian gneisses. The "Hyolithes Zone" lies in the north-west limb of a north-easterly striking anticline which developed during post-Lower Cambrian time, folding the Basement Complex and the "Hyolithes Zone" as a single unit. The Porsanger Sandstone Formation was thrust over this structure during the Caledonian orogeny. In addition, the Porsanger Sandstone Formation was folded asymmetrically about northerly axes and the sequence is repeated by a number of thrust faults which dip to the west at a low angle.

The Porsanger Sandstone Formation is subdivided into four lithostratigraphical units: 1. Skallenes Sandstone, 2. Bjørnnes Sandstone, 3. Valddak Sandstone, 4. Gorssavatn Shales. Lithologically the formation begins with the feldspathic sandstones of the Skallenes Sandstone, these grade into protoquartzites in the upper part of this member. The Bjørnnes Sandstone is characterised by limonitic sandstones and quartzose shales. The limonite is believed to have been derived from an original siderite cement. Orthoquartzites make up virtually the whole of the Valddak Sandstone and the formation ends with the green and grey quartzose shales of the Gorssavatn Shales.

Transverse ripple marks, cross-stratified units and dessication cracks indicate a shallow-water environment of deposition. Chert micropebbles found in small numbers throughout the sandstones show that part of the provenance was composed of sedimentary rocks. Thus there is indirect evidence of an even earlier cycle of sedimentation, uplift and erosion.

The age of the Porsanger Sandstone Formation is uncertain but is most probably Precambrian. No fossils were found in the formation, although horizontal worm burrows occur at a few restricted horizons. Precise correlation of the Porsanger Sandstone Formation with other formations in Finnmark awaits further work in, as yet, unstudied areas.

## 1. Introduction

The writer spent the summers of 1962-65 investigating the sedimentary rocks immediately west and south of the Inner Porsangerfjord. The area studied may be conveniently subdivided, on both a geographical and geological basis, by the Stabburselv river (Fig. 1). This paper is concerned with the area south of Stabburselva. It is bounded to the west by Dilljaelva and its main right bank tributary Njuoidosnjoaskeelva, to the east by Porsangerfjord. The southern limit of detailed observations is indicated in Fig. 9, although some work was carried out south of this line, particularly in the area west of Kjøkenes.

High ground is a feature of almost the whole area, with elevations in the Njæidan Mountain area exceeding 600 m. A major topographic feature is the

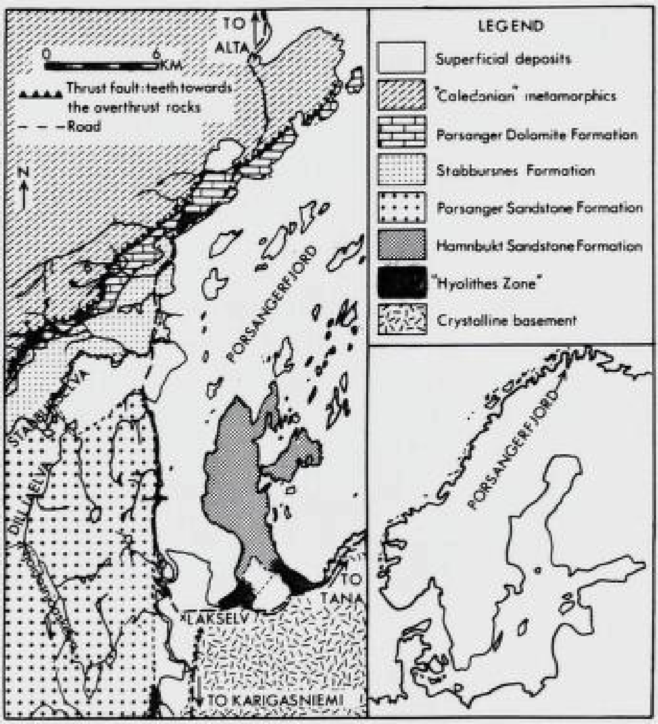


Fig. 1. Simplified geology of the Lakselv District.

steep scarp which extends along the entire eastern edge of the area investigated. The general outlines of the topography are shown in Fig. 8.

Good exposures are found in the scarp and in a number of streams which drain the northern and western flanks of the mountains. In other parts exposure is generally poor, with large areas covered by boulder fields and exotic glacial deposits.

The Porsanger Sandstone Formation forms part of a wedge of sedimentary rocks lying at the eastern margin of the Caledonian Fold Belt. The Porsanger Sandstone Formation is thrust over a thin sequence of autochthonous "Hyolithes Zone" sediments which, in turn, lie unconformably on gneisses of the Fennoscandian Basement Complex. To the north-west the sediments are overlain by an exotic nappe of "Caledonian" metamorphic rocks (Fig. 2).

Mapping was carried out using 1 : 50 000 U.S. Army Map Series maps enlarged to 1 : 20 000. The area described in this paper is covered by AMS Series M711 Sheet 2035 III (Lakselv). Aerial photographs were used in the final field season.

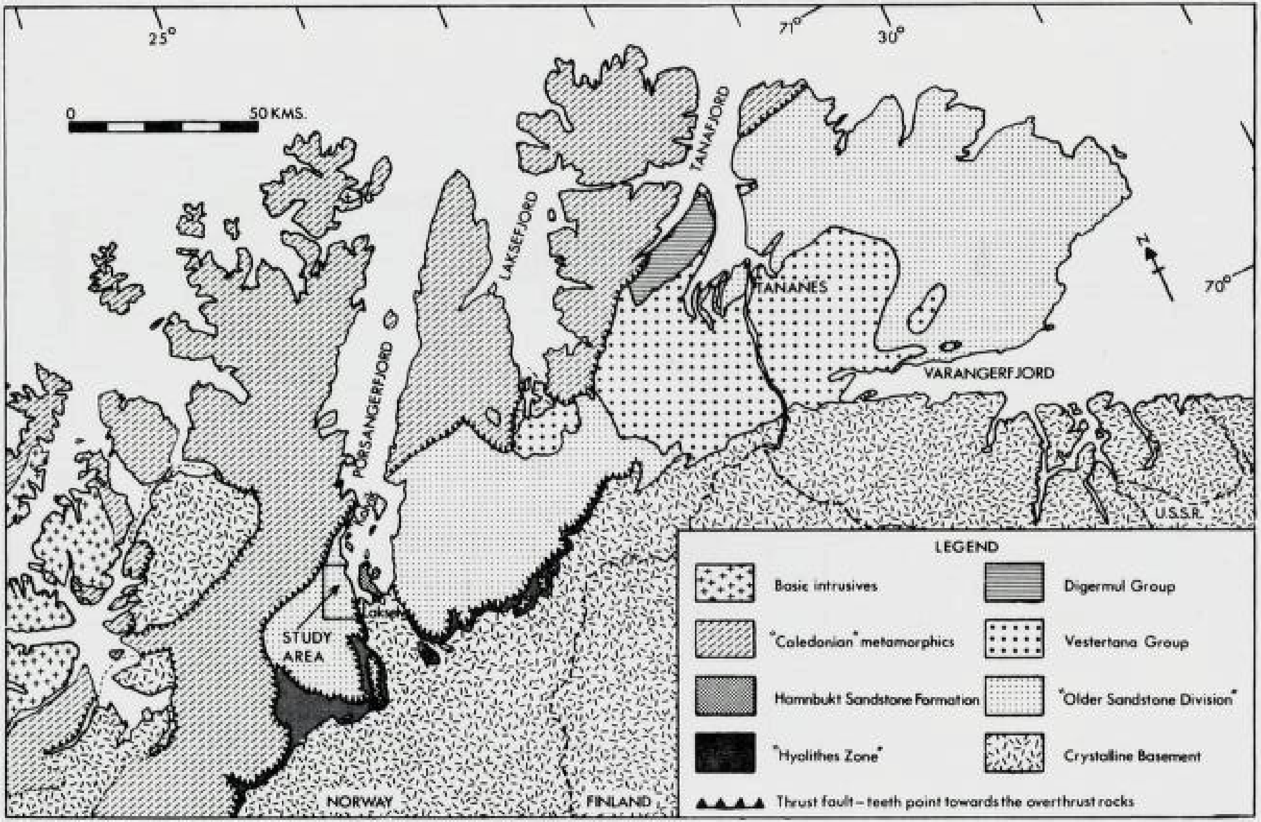


Fig. 2. Geological map of Finnmark. (Largely after Holtedahl and Dons 1960, and Reading 1965).

## 2. History of Research

Early observations on the geology of Finnmark were made by Dahll (1867, 1891) and Reusch (1891). A more comprehensive account was given by Holtedahl (1918), including a review of earlier work. He subdivided the rocks of Finnmark as follows:

Thrust Caledonian metamorphic rocks
Younger Tillite-bearing Sandstone Division
Older Dolomite-bearing Sandstone Division
Hyolithus Zone[1])
Crystalline Precambrian Basement.

The discovery of *Platysolenites antiquissimus* in the Hyolithus Zone gave its age as Lower Cambrian. The overlying sediments were thought to be conformable upon the Hyolithus Zone and younger than Lower Cambrian. The sedimentary rocks in the Inner Porsangerfjord area were assigned to the Older Dolomite-bearing Sandstone Division and the following succession was established:

| | |
|---|---|
| Thrust Caledonian metamorphic rocks | |
| Porsanger Dolomite .......... | 100-200 m. |
| Shales ...................... | 50-100 m. |
| Porsanger Sandstone .......... | 500 m. |
| Hyolithus Zone ............. | 240 m. |
| Precambrian metamorphic rocks. | |

Later investigations by Holtedahl (1931) showed that there is a thrust separating the Hyolithus Zone and the Porsanger Sandstone. The sedimentary rocks overlying the Hyolithus Zone were thus regarded as being older than Lower Cambrian and, therefore, of Precambrian age.

The results of investigations on the metamorphic rocks of the Lakselv valley were given by Crowder (1959). He describes, very briefly, the relationships between the Precambrian Basement Complex and the overlying sediments in the western part of the Lakselv valley.

## 3. Stratigraphy and Field Descriptions

(a) General Statement

Almost the whole of the area is made up of rocks belonging to the Porsanger Sandstone Formation. In the extreme south there are small outcrops of

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[1]) Hyolithus Zone was used by earlier workers for what is now generally known as the "Hyolithes Zone".

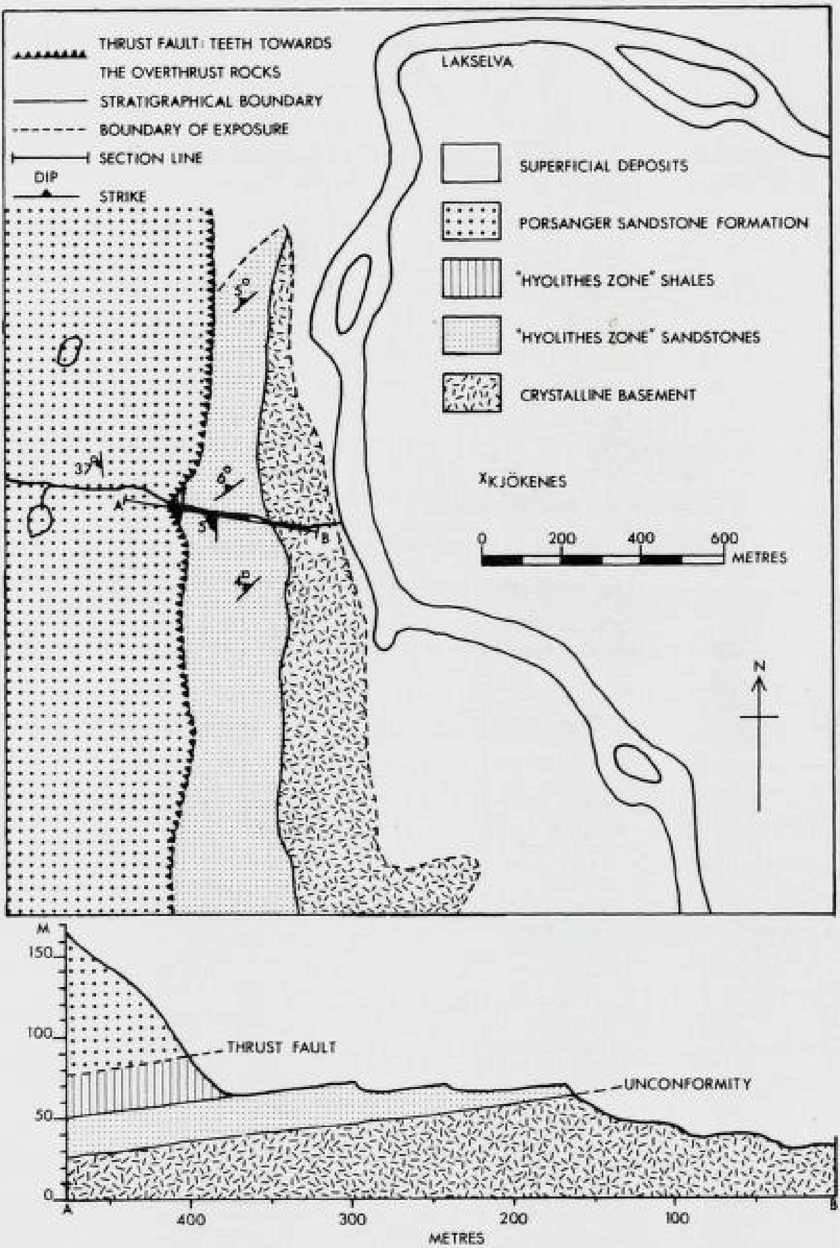


Fig. 3. Geology in the vicinity of the stream section west of Kjøkenes.

"Hyolithes Zone" sandstones and shales lying unconformably upon gneisses of the Precambrian Basement Complex. These sediments are separated from the overlying Porsanger Sandstone Formation by a low angle thrust fault.

(b) Relationships Between the Basement Complex, the "Hyolithes Zone" and the Porsanger Sandstone Formation

Southwards from Valddak for a distance of 15 km. the base of the Porsanger Sandstone Formation is obscured by screes and fluvio-glacial deposits. The relationship between the Porsanger Sandstone Formation and the underlying rocks is revealed in a stream section less than 1 km. west of Kjøkenes. This locality is 2 km. north of the exposure described by Crowder (1959) and represents a further northward extension of the known outcrop of the "Hyolithes Zone". The geology in the vicinity of the stream section is illustrated by Figs. 3 and 4.

The "Hyolithes Zone" sediments lie unconformably on a weathered surface of gneisses belonging to the Precambrian Basement Complex (Plate 1 Fig. 1). The plane of unconformity dips towards the north-west at a low angle. At the base of the "Hyolithes Zone" there is a thin conglomerate with well-rounded pebbles up to 10 cm. in diameter. Although the conglomerate is made up mainly of quartz pebbles, it does contain some fragments of gneiss similar to that found in the underlying basement.

Above the basal conglomerate there are 5 m. of coarse-grained, feldspathic sandstones with pebbly horizons up to 5 cm. thick. There follows 15 m. of medium to fine-grained feldspathic sandstones, with an overall upward decrease in grain size. The upper 4 m. are made up of very hard, fine-grained feldspathic sandstones with a characteristic blue-grey colour.

Occasional cross-stratified units occur, particularly in the medium-grained rocks and these indicate current movement from east to west. The sandstones dip uniformly towards the north-west at around 5°, with no sign of minor folding or faulting.

The sandstones are overlain by 21 m. of grey and green shales. This horizon is usually covered by scree and the only exposures found were where the stream cuts through the scarp. The shales are homogeneous with no indication of bedding planes. An exhaustive search failed to yield any fossils.

The shales are overlain by sandstones belonging to the Porsanger Sandstone Formation. The two are separated by a low angle thrust. The sandstones are cut by numerous small faults and they are strongly folded about northerly axes (Plate 1 Fig. 2). Immediately above the shales the sandstones are considerably shattered and the bedding is obliterated. Higher in the scarp the distinctive Bjørnnes Sandstone outcrops. This horizon may be traced in the upper part of the scarp, northward into the area where detailed mapping was carried out.

The strong folding and minor faulting in the Porsanger Sandstone Formation rocks is in sharp contrast with the uniformly dipping sandstones of the "Hyolithes Zone".

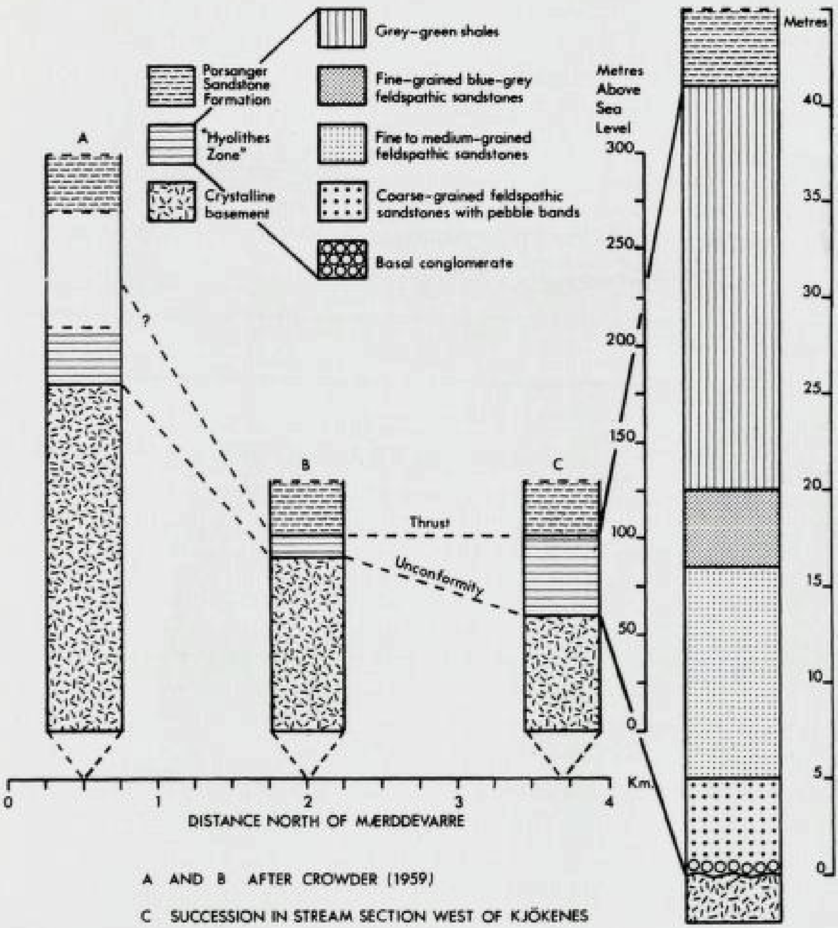


Fig. 4. "Hyolithes Zone" sections at localities north of Mærddevarre and an expanded succession for the "Hyolithes Zone" from the stream section west of Kjøkenes.

(c) The Porsanger Sandstone Formation

The succession for the Porsanger Sandstone Formation is shown in Fig. 5. The entire succession is not fully exposed in any one section and the succession shown in Fig. 5 was built up from the cross sections shown in Fig. 6. The formation name is derived from the usage of Holtedahl (1918, p. 134). Members are named after localities where they are well-displayed. Lithostratigraphical units are used throughout, in accordance with the recommendations of Anon. (1961).

(i) *Skallenes Sandstone.* This lowest member of the Porsanger Sandstone Formation is well-displayed in a stream section north-west of Skallenes and the name has been derived from this locality. The lower 38 m. are feldspathic sandstones, with variable amounts of interbedded green and black shales. The sandstones are light coloured and evenly bedded, with beds reaching a maximum thickness of 40 cm. Shales are generally subordinate to sandstones and occcur as intercalations up to 3 cm. thick. There are one or two horizons where shales predominate, but these are less than 4 m. thick.

The upper 70 m. of the Skallenes Sandstone consists of light coloured, well-bedded sandstones. These show a progressive upward change from feldspathic sandstones to protoquartzites. The rocks also become more massively bedded in the upper part of the member.

Transverse ripple marks are common at some horizons (Plate 2 Fig. 1) and cross-stratified units are found occasionally. In the more shaly horizons mud cracks are common, frequently occurring as casts on the soles of sandstone beds where these overlie thin shales. In the lower part of the Skallenes Sandstone horizontal worm burrows are found at a few horizons (Plate 2 Fig. 2).

The Skallenes Sandstone has a measured thickness of 108 m. As the base is formed by a thrust the original sedimentary thickness probably exceeded this figure.

(ii) *Bjørnnes Sandstone.* This member is well-exposed along the highway near Bjørnnes and it has been named after that locality. There is an abrupt boundary between the massive protoquartzites of the upper part of the Skallenes Sandstone and the rocks in the lower part of the Bjørnnes Sandstone. There is a marked difference in the relative resistance to erosion and streams frequently follow this junction.

Brown-weathering, grey sandstones alternating with black shales form the lowest 3 m. of this member. The sandstone beds are usually less than 3 cm. thick, laterally persistent and of uniform thickness. This horizon is overlain by 3 m of massive-bedded, brown-weathering sandstones, with individual beds

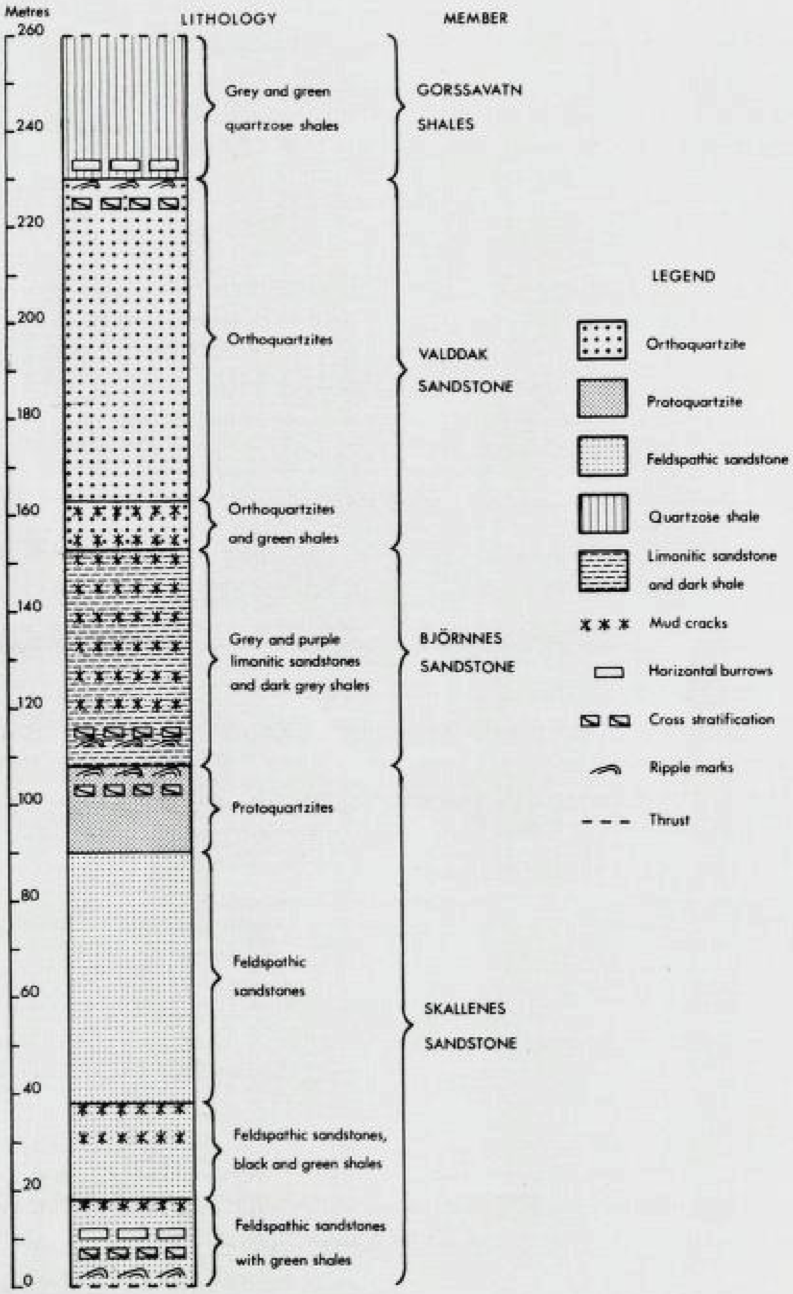


Fig. 5. The Porsanger Sandstone Formation succession.

reaching a thickness of 50 cm. The sandstones extend continuously along the strike but their thickness is rather variable. This horizon contains some transverse ripple marks and cross-stratified units.

The remainder of the Bjørnnes Sandstone is made up of limonitic sandstones with shale intercalations. Sandstone beds vary in thickness from 5 to 25 cm. in the lower part, up to a maximum of 40 cm. in the upper part of the member. Although the thickness of individual beds varies, they can be followed continuously along the strike. The sandstones vary in colour from pale to dark grey, with occasional purple horizons.

Lenses of purple sandstone occur within some of the grey sandstone beds, these have their long axes parallel to the bedding of the grey sandstones. Two sets of joints have developed within the purple sandstone lenses, and these intersect the bedding planes to produce triangular shaped blocks (Plate 2 Fig. 3). Concretions also occur and where these lie within a triangular block a quite spectacular feature is produced. The concretions are made up of alternating concentric shells of light coloured, friable sandstone and iron oxide. The combination of concretions, jointing and bedding produces a characteristic feature which is confined to the Bjørnnes Sandstone. It is particularly evident on weathered surfaces.

The interbedded shales vary in colour from pale grey to black and range in thickness from less than 1 cm. to 8 cm. At the shale-sandstone interface mud crack casts and mud flake impressions are common.

The Bjørnnes Sandstone has a total thickness of 45 m. and is notable for its dark, yellow-brown weathering colour. This coloration readily distinguishes the Bjørnnes Sandstone from any other member of the Porsanger Sandstone Formation.

(iii) *Valddak Sandstone*. The most readily accessible and complete exposure of this member is found near a small lake in the upper part of the scarp 1 km. south of Valddak. Here the junctions with both the underlying and overlying members are exposed, as well as the complete succession for this member. The small lake mentioned above is unnamed on the available topographic maps, so it has been named "Valddakvatn" for convenience of location.

There is a transition from the upper part of the Bjørnnes Sandstone to this member. The brown-weathering, grey sandstones and dark shales of the lower member give way to light coloured orthoquartzites and intercalated green shales. This change is taken as the boundary between the Bjørnnes Sandstone and the Valddak Sandstone.

In the lower 10 m. of this member, well-bedded, very pale grey orthoquartzites up to 30 cm. thick, alternate with green shaly bands usually less than

3 cm. thick. Occasional transverse ripple marks and cross-stratified units occur in the orthoquartzites. Mud cracks are a common feature of the shaly bands.

Above this horizon the shale bands die out and there follows a sequence of massive, very light coloured orthoquartzites. The bedding is uniform and extends along the strike with little change in thickness of individual beds, which reach a maximum of 150 cm. thick. In the upper part of the member prominent transverse ripple marks occur. The total thickness of the Valddak Sandstone is 67 m.

(iv) *Gorssavatn Shales*. This member is best displayed in the vicinity of the stream which drains into Gorssavatn from the northern end of the scarp. The lake is the nearest named locality and provides the name for this member.

There is an abrupt change from the massive orthoquartzites of the Valddak Sandstone to the pale grey and green shales which make up the Gorssavatn Shales. This member is susceptible to erosion and exposures are uncommon. In a few instances streams cut their way along the junction between the soft shales and the much more resistant underlying sandstones. The presence of the Gorssavatn Shales is often only indicated by small, drift-filled valleys extending along the strike.

The shales lack distinctive features other than their colour, uniformity and general lack of discernible bedding planes. The maximum observed thickness of the Gorssavatn Shales is 30 m. In all cases where it is exposed, the upper part of this member is overlain by thrust masses of sandstone and the original sedimentary thickness is unknown.

### 4. Structures of the Porsanger Sandstone Formation

The broad outlines of the structures in the area were determined to enable the stratigraphical succession of the Porsanger Sandstone Formation to be established.

The Porsanger Sandstone Formation is a thrust mass lying above the sole thrust which separates it from the underlying autochthonous "Hyolithes Zone" sediments. Within the main thrust mass smaller thrust faults occur. These dip towards the west closely parallel to the dip of the strata involved, so producing an imbricate structure. These small thrusts are most readily recognized in sequences where beds dip generally to the west, but with repetition of characteristic horizons. The distinctive Bjørnnes Sandstone is particularly useful in this respect.

Where sandstones of either the Skallenes Sandstone or Valddak Sandstone members lie immediately above a thrust plane their lithology is modified. All

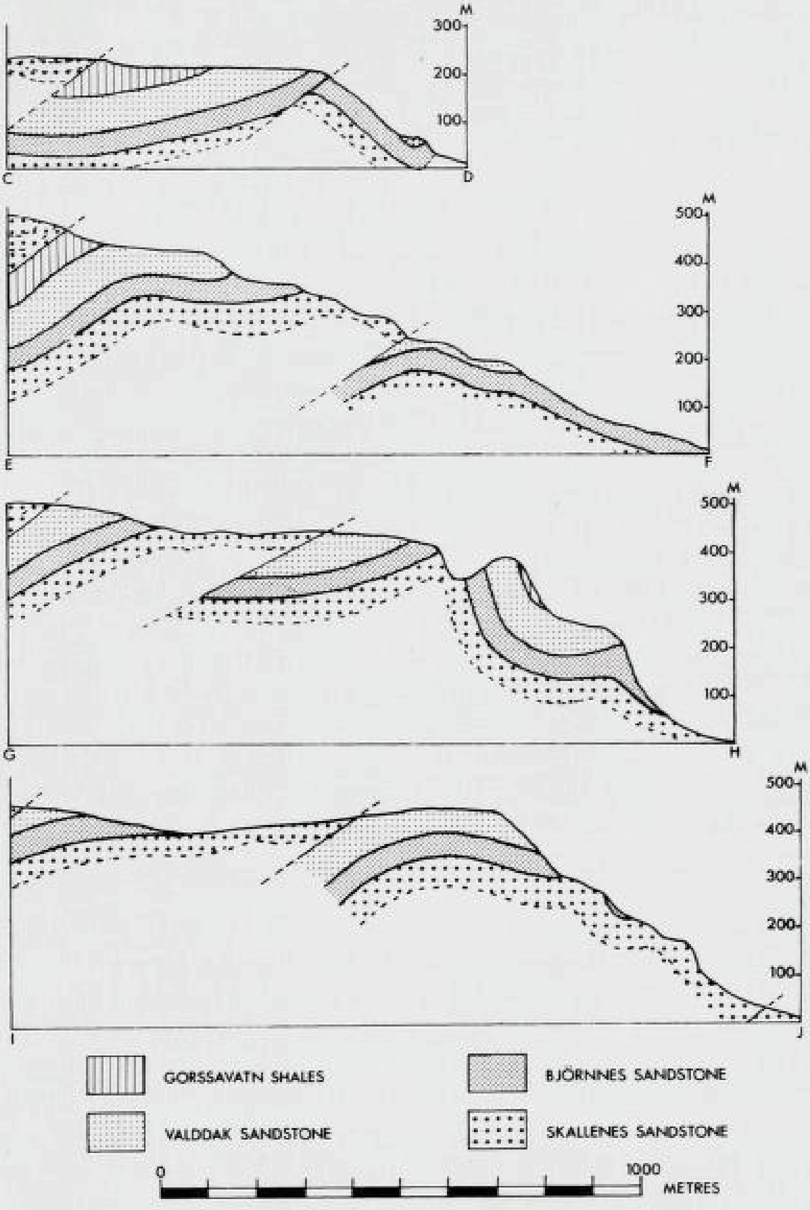


Fig. 6. Cross sections through the scarp west of Porsangerfjord.

traces of individual clastic grains are lost, bedding is to a large extent destroyed and the rock becomes hard and splintery. Where other evidence is lacking these features sometimes allow the presence of a thrust to be detected.

The Porsanger Sandstone Formation is folded into a series of asymmetrical folds, with axial planes striking north to north-north-east and dipping towards the west. The eastern limbs have dips up to 80°, but the dips in western limbs rarely exceed 40° and are frequently much less. The Bjørnnes Sandstone forms a relatively incompetent horizon compared to the massive sandstones both beneath and above it. Thus drag folds are frequently developed where this member lies in the limbs of folds. Structures in the scarp are illustrated in Fig. 6.

## 5. **Petrology**

(a) Metamorphic Rocks of the Basement Complex

The metamorphic rocks of this area were described by Crowder (1959) and the present author only examined the gneisses immediately below the unconformity near Kjøkenes. The variation in mineralogical composition of the gneisses related to depth below the unconformity is shown by Fig. 7. Plagioclase generally shows a fairly high degree of alteration, whereas microcline remains unaltered. There is an upward increase in the microcline to plagioclase ratio. Green pleochroic mica occurs at lower levels but decreases in importance towards the unconformity, while at the same time there is an upward increase in colourless mica. In order to illustrate the change in mica content, a distinction has been made between "coloured mica" and "colourless mica". The percentage of quartz increases towards the unconformity.

(b) "Hyolithes Zone"

The sandstones of the "Hyolithes Zone" contain 85 to 93 % quartz, 7 to 14 % feldspar, including microcline and albite-oligoclase. They are, therefore, classified as feldspathic sandstones. Accessory minerals include muscovite and green tourmaline.

The quartz forms a sutured mosaic, produced by secondary quartz overgrowths and later pressure solution. The intensity of pressure solution is greatest where the sandstones have a relatively high clay mineral content. Where distinguishable the original quartz and feldspar grains have well-rounded outlines (Plate 3 Fig. 1). In parts of the sandstones the mosaic is incomplete and the remaining pore space has been infilled by carbonate cement. The carbonate pore-filling is usually a single crystal. Staining, using the method described by Dickson (1965), shows that the carbonate is calcite, with ferroan calcite sometimes occurring at the margin of the crystal. Where euhedral quartz overgrowths project into the carbonate-filled pores they frequently show corrosion (Plate 3 Fig. 2).

Rounded feldspar grains sometimes penetrate adjacent quartz grains without losing their rounded outline (Plate 3 Fig. 3). This suggests that the feldspars are less susceptible to pressure solution than quartz. An example of physical compaction is illustrated by Plate 3 Fig. 4. Here mica is caught between two rounded feldspar grains without any pressure solution effects, but with some disruption of the mica.

(c) Porsanger Sandstone Formation

(i) *Skallenes Sandstone*. The feldspathic sandstones in the lower part of this member contain 75 to 85 % quartz, 10 to 16 % feldspar, up to 5 % lithic fragments and up to 5 % matrix. Both microcline and plagioclase feldspar

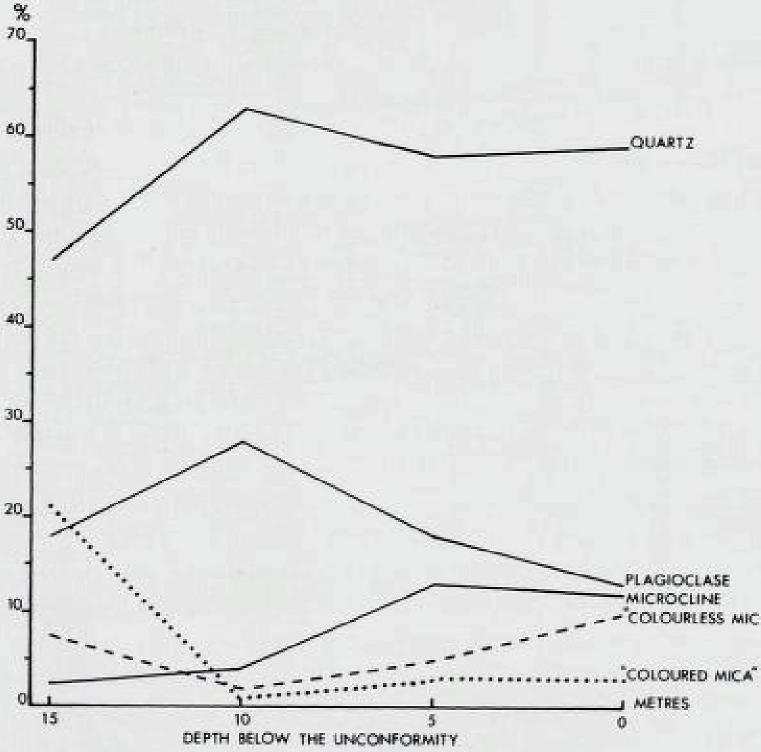


Fig. 7. Variation in the composition of gneisses below the Basement Complex-"Hyolithes Zone" unconformity.

occurs, with an approximately equal number of chert and quartzite grains forming the lithic fragments. The matrix is mainly composed of sericite, probably derived from feldspars. The quartz occurs as a mosaic produced by secondary quartz overgrowths and pressure solution. The feldspar grains are well-rounded, as are the quartz grains where their original outlines can still be seen. Zircon occurs as an accessory mineral.

The quartzose shales from the lower part of the Skallenes Sandstone are made up of angular quartz grains, with minor microcline and plagioclase. The grains are of coarse silt size and they are set in a matrix of clay minerals, biotite and muscovite. Silt size particles make up 20 to 45 % of the total composition of the shales.

The upper part of the Skallenes Sandstone is free of shales and the sandstones show a progressive decrease in both feldspar and matrix. They consist essentially of quartz with up to 5 % lithic fragments, with both chert and quartzite micropebbles being present. Thus there is an overall change from feldspathic sandstones in the lower part of the Skallenes Sandstone, to protoquartzites in the upper. This change is associated with an absence of shales in the upper part of the member.

(ii) *Bjørnnes Sandstone.* The detrital grains in the sandstones of this member are mainly quartz, with feldspar always less than 4 % and usually absent. Well-rounded grains of microcline form the most common feldspar, although plagioclase grains also occur. Up to 6 % of the detrital grains are lithic fragments, with both chert and quartzite present. Green tourmaline occurs as an accessory mineral.

The sandstones differ from others found in the Porsanger Sandstone Formation in their content of iron minerals, mainly limonite but with some associated hæmatite. These minerals occur as pore filling and form 5 to 30 % of the total composition of the sandstones. The contact between the quartz grains and the limonite is frequently jagged and irregular, suggesting corrosion of one by the other. The limonite occasionally appears to corrode secondary quartz which has grown around an original rounded quartz grain (Plate 3 Fig. 5).

In exceptional cases a carbonate mineral occurs in the central part of a limonite-filled pore space (Plate 3 Fig. 6). This carbonate failed to respond to staining using the method of Dickson (1965). However, a deep blue coloration was produced using an acid solution of potassium ferricyanide. This shows that the carbonate is siderite.

In parts of this member the sandstones pass into quartzose shales, with an increase in the matrix and a decrease in the detrital quartz grains. The matrix is composed of clay minerals, chlorite, sericite and limonite. The detrital grains are mostly quartz, with microcline and plagioclase together accounting for less than 1 % of the total composition of the shales. Up to 5 % of the detrital grains are lithic fragments, including both chert and quartzite. The detrital grains are angular to subrounded in outline and lie within the size range coarse silt to fine sand.

(iii) *Valddak Sandstone.* Apart from minor quartzose shales in the lower part, the Valddak Sandstone is made up of orthoquarzites. The rocks contain 95 % or more of quartz, the remainder being chert and quartzite micropebbles. The quartz forms a sutured mosaic with the original grain shapes destroyed by pressure solution.

(iv) *Gorssavatn Shales.* The quartzose shales of this member contain 10 to 40 % quartz grains, with minor amounts of microcline and plagioclase. The detrital grains are angular and range in size from medium to coarse silt. The matrix consists largely of clay minerals and chlorite, with minor amounts of muscovite.

Occasionally concentrations of silt size grains occur which are almost circular in outline. These truncate adjacent seams of clay minerals, indicating that they post-date the deposition of the sediment. It is possible that these structures are cross sections of the horizontal burrows of sediment-eating organisms.

## 6. Discussion

(a) Metamorphic Rocks of the Basement Complex

The changes in the mineralogical composition of the gneisses below the unconformity are probably due to weathering. Goldich (1938) has studied the weathering of gneiss, including the relative stability of minerals. Quartz is among the most stable of minerals and ought to become relatively more abundant as less stable minerals are removed. He also concluded that among the feldspars, microcline is more stable than plagioclase. On weathering, biotite passes through an intermediate green stage and finally becomes colourless. The mineralogical changes shown in Fig. 7 are consistent with the changes which Goldich indicated should take place on weathering.

The Kjøkenes section occurs in the side of a glaciated valley and the rocks are only likely to have been exposed to weathering since the retreat of the last Pleistocene glacier. Glacial erosion would expose the rocks to weathering virtually simultaneously once the ice withdrew. This suggests that the differential weathering is not a post-glacial feature. The only other period of time available for the weathering of the basement is prior to the deposition of the "Hyolithes Zone" sediments.

Gustavson (1962) in describing the very similar geological circumstances in Dividalen, mentions that the basement rocks show a weathered surface beneath the overlying "Hyolithes Zone" sediments.

(b) The Unconformity Between the Basement Complex and the "Hyolithes Zone"

In Fig. 4 the section west of Kjøkenes is compared with those of Crowder (1959 p. 22, Fig. 2). This diagram shows that the height above sea-level of the unconformity falls from 180 m. just north of Mærddevarre, to 60 m. west of Kjøkenes. These two localities are separated by a distance of 3.2 km. The plane of unconformity dips towards the north-west and the overall dip can be calculated, giving a value of 5° 30'. Thus the dip of the unconformity is the same as the observed dip of the "Hyolithes Zone" sandstones. Holtedahl (1931) put forward the view that the Basement Complex and the "Hyolithes Zone" rocks have been folded as a single unit, to produce a north-east striking anticline. The parallelism of the dip of the plane of unconformity and the "Hyolithes Zone" strata supports this view.

(c) The "Hyolithes Zone"

The sandstones and basal conglomerates represent an advancing shore-line associated with a marine transgression. After deposition of sub-rounded to rounded clastic grains, increasing depth of burial eventually caused pressure solution along grain boundaries. The intensity of pressure solution was greatest where the clay mineral content was highest, a relationship also described by Heald (1956). Silica released during pressure solution migrated to parts of the sediment unaffected by pressure solution, where it was deposited as secondary overgrowths around original quartz grains. This dual process of cementation in sandstones has been described by Heald (1955) and Thomson (1959).

Pressure solution and associated secondary overgrowths did not produce complete loss of porosity and the remaining pore spaces were subsequently filled by calcite cement. In some carbonate-filled pores euhedral quartz overgrowths project into the calcite, showing that the calcite cementation took place later than the formation of the secondary quartz overgrowths. Most of the quartz grains marginal to the carbonate-filled pores show some corrosion by calcite. Siever (1959) noted that carbonate precipitation is the latest stage in the cementation of sandstones and that it is often accompanied by replacement of quartz by calcite. The carbonate filling any one pore is usually a single crystal of calcite. This feature is described by Siever (1959), who also notes that dolomite usually forms a number of small rhombohedra under similar circumstances.

The occurrence of rounded feldspar grains penetrating adjacent quartz grains and the physical squeezing of mica by two feldspar grains suggests variable response of these three minerals to pressure solution. Heald (1955) has discussed the relative stability of minerals under stress and gives the following order of decreasing stability: mica, feldspar, quartz. This sequence is in agreement with the relationships found in the "Hyolithes Zone" sandstones.

The sharp change from fine-grained sandstones to homogeneous shales indicates that a rapid deepening of the sea took place soon after sedimentation began in the area. The uniform grey-green colour of the shales suggests a quiet, non-oxidizing environment of sedimentation.

(d) The Thrust Between the "Hyolithes Zone" and the Porsanger Sandstone Formation

The tectonic break between the "Hyolithes Zone" shales and the overlying sandstones of the Porsanger Sandstone Formation corresponds to the thrust described by Holtedahl (1931). He suggested that the Basement Complex-"Hyolithes Zone" anticline had protected the sediments to the south-east from cutting out by the thrust. He describes an increase in the thickness of the "Hyolithes Zone" below the thrust plane in a south-easterly direction away from the anticlinal axis. Fig. 4 shows that there is a similar, although less marked, increase in a north-westerly direction.

The folding of the Basement Complex-"Hyolithes Zone" unit must have taken place after the deposition of the "Hyolithes Zone" sediments, but prior to the overthrusting of the Porsanger Sandstone Formation. This is in agreement with the conclusions of Holtedahl (1931), which were based on his observations some distance south of the localities discussed here. Gustavson (1962) describes a similar up-doming of the Basement Complex and "Hyolithes Zone" in Dividalen, some 250 km. to the south-west along the margin of the Caledonian Fold Belt. He assigns the age of the folding to post-"Hyolithes Zone" deposition but pre-overthrusting.

(e) The Porsanger Sandstone Formation

(i) *Skallenes Sandstone*. The progressive change from feldspathic sandstones and thin shales to protoquartzites shows that conditions became steadily more stable during the deposition of this member. The presence of transverse ripple marks, cross-stratified units and dessication cracks points to a shallow-water environment of deposition. Of particular interest are the horizontal worm burrows found in parts of the Skallenes Sandstone. These represent the only signs of organic activity found in this member.

(ii) *Bjørnnes Sandstone.* The presence of appreciable limonite in this member distinguishes it from the remainder of the Porsanger Sandstone Formation. The clue to the origin of the limonite probably lies in the presence of siderite in the centre of some limonite-filled pores. Pettijohn (1957) suggests that siderite cementation of sandstones may be more common than has been generally recognised. The ready change of siderite to limonite or hæmatite in outcrop, may destroy all evidence of a pre-existing siderite cement.

If siderite once occupied the whole of the pore space it could explain the present anomalous relationship between the quartz grains and the limonite pore filling. These appear to have corroded contacts, but corrosion of either of these two chemically stable minerals by the other is unlikely. Hallimond (1925) says that siderite may corrode or even totally replace quartz. It seems likely, then, that the pore filling in these sandstones was originally siderite.

This raises the question of the origin and time of formation of the siderite. Secondary quartz overgrowths project into some of the pores, indicating that the pore filling took place later than the development of the quartz overgrowths. Hallimond (1925) suggests that siderite may completely replace an earlier calcite cement. Pettijohn (1957) discusses this replacement and attributes it to an early stage in the diagenesis of sediments. No trace of calcite was found in the Bjørnnes Sandstone rocks, but this does not rule out the possibility of complete replacement of an earlier calcite cement by siderite.

The lack of iron-rich minerals in the members below and above the Björnnes Sandstone, particularly in the otherwise very similar rocks in the lower part of the Valddak Sandstone, gives some indication of the time of origin of the siderite. If the formation of siderite had taken place later than the deposition of the Valddak Sandstone, it would surely have affected the lower part of that member. Thus it seems likely that the siderite was formed either at the time of deposition of the Bjørnnes Sandstone, or very soon afterwards.

The stability fields of hæmatite, siderite and pyrite were investigated by Krumbein and Garrels (1952). Conditions favouring the formation of siderite are a negative redox potential and relatively low pH. These conditions do not apply in normal marine conditions, where the redox potential is positive. James (1954) suggests that conditions of negative redox potential may exist at moderate depths in a restricted marine basin, so allowing the formation of siderite. The ripple marks, cross-stratified units and dessication cracks found in the Bjørnnes Sandstone indicate deposition in shallow, agitated waters, which must have had a positive redox potential. Emery and Rittenberg (1952) show that there will be a change to lower pH and from positive to negative redox potential, on passing from sea-water to unconsolidated sediments on the sea-floor.

James (1954) suggests that iron in the form of a ferric hydrosol, may be carried into a marine basin by rivers. Under normal marine conditions it would be deposited as colloidal ferric oxide. If reducing conditions later develop below the sediment-water interface, this colloid could be converted to siderite.

Thus the siderite in the Bjørnnes Sandstone seems most likely to have formed in an early diagenetic stage, from material carried into the depositional basin at the same time as the detrital grains. As the siderite is restricted to this member there must have been some difference in either the source, the transporting medium or the site of deposition. One possible explanation is that a large river was entering the basin and depositing its load of iron close to the area where the Bjørnnes Sandstone was being deposited.

(iii) *Valddak Sandstone*. This member represents deposition under very stable shelf conditions, with an adequate supply of detrital material. Prolonged wave and current activity winnowed away all the finer detritus and unstable components, so producing a mature orthoquartzite. The chert grains found in this member, as well as in the two underlying members, show that part of the provenance was made up of sedimentary rocks, probably including cherty carbonates. Thus there must have been at least one earlier cycle of sedimentation, uplift and erosion prior to the deposition of the Porsanger Sandstone Formation.

(iv) *Gorssavatn Shales*. The quartzose shales which make up this member indicate a relatively sudden decrease in the energy of the environment of deposition. This was probably due to a deepening of the sea at this time. There are some indications of the activity of sediment-eating organisms in the shales.

## 7. Age of the Sediments

(a) "Hyolithes Zone"

The limited exposures of "Hyolithes Zone" sediments discussed in this paper are a northward extension of those described by Holtedahl (1918). He reported the discovery of *Platysolenites antiquissimus* from these sediments, so confirming that they belonged to the "Hyolithes Zone". No direct evidence of the age of the rocks was found in the area described, but they are assumed to be the same age as the contiguous rocks to the south.

(b) Porsanger Sandstone Formation

Since the recognition by Holtedahl (1931) of the thrust plane separating the "Hyolithes Zone" and the Porsanger Sandstone Formation, the latter has been considered of Precambrian age. The thrusting took place during the

Caledonian orogeny and the tectonic relationships do not prove a Precambrian age for the Porsanger Sandstone Formation. On purely tectonic grounds the formation could belong to the Lower Palaeozoic just as easily as it could be Precambrian.

Considering the sediments themselves, one of the most striking features is the almost total lack of signs of organisms or organic activity. The nature of the sediments suggests that some signs, at least, of any original fauna should have been preserved. While not being absolutely conclusive, this very absence of fossils is, in itself, a strong indication that the sediments are of Precambrian age.

The Porsanger Sandstone was included in the Older Dolomite-bearing Sandstone Division by Holtedahl (1918). Partially equivalent to this is the Older Sandstone Series of Føyn (1937), the succession for which was established in the Tananes area. Both Føyn (1937) and Rosendahl (1945) commented on the similarity between the Porsanger Sandstone and the Older Sandstone Series of East Finnmark. Lithological similarities, however, are no guarantee of age equivalence. The Older Sandstone Series in East Finnmark is unconformably overlain by the Tillite-bearing Series, which in turn passes conformably upwards into fossiliferous Cambrian rocks (Føyn (1937); Reading (1965)).

If the Porsanger Sandstone Formation could be shown to be equivalent to part of the Older Sandstone Series of East Finnmark, then its age would be confirmed as Precambrian. The present author (White unpublished Ph. D. thesis 1966) attempted to correlate the entire sequence of rocks found west of Porsangerfjord with the Older Sandstone Series of East Finnmark. The weaknesses in this correlation are the dangers of equating lithological similarity with time equivalence: the 140 km. separating the two areas and the lack of geological information about the intervening area. It remains true that there are lithological similarities between the two areas and, perhaps more significantly, there are fairly close similarities between the sequence of lithologies.

The evidence currently available thus points to a Precambrian age for the Porsanger Sandstone Formation. This evidence is, however, negative in the case of the absence of a fauna and suspect in the case of lithological similarity.

## 8. Appendix 1. Notes on Fig. 8.

Geological Localities West and South of Porsangerfjord

This map is designed for the use of any geologist who is able to spend only a few hours in this area, but who would like to see something of the geology. The main road, Riksveg 50, passes through the area, between the

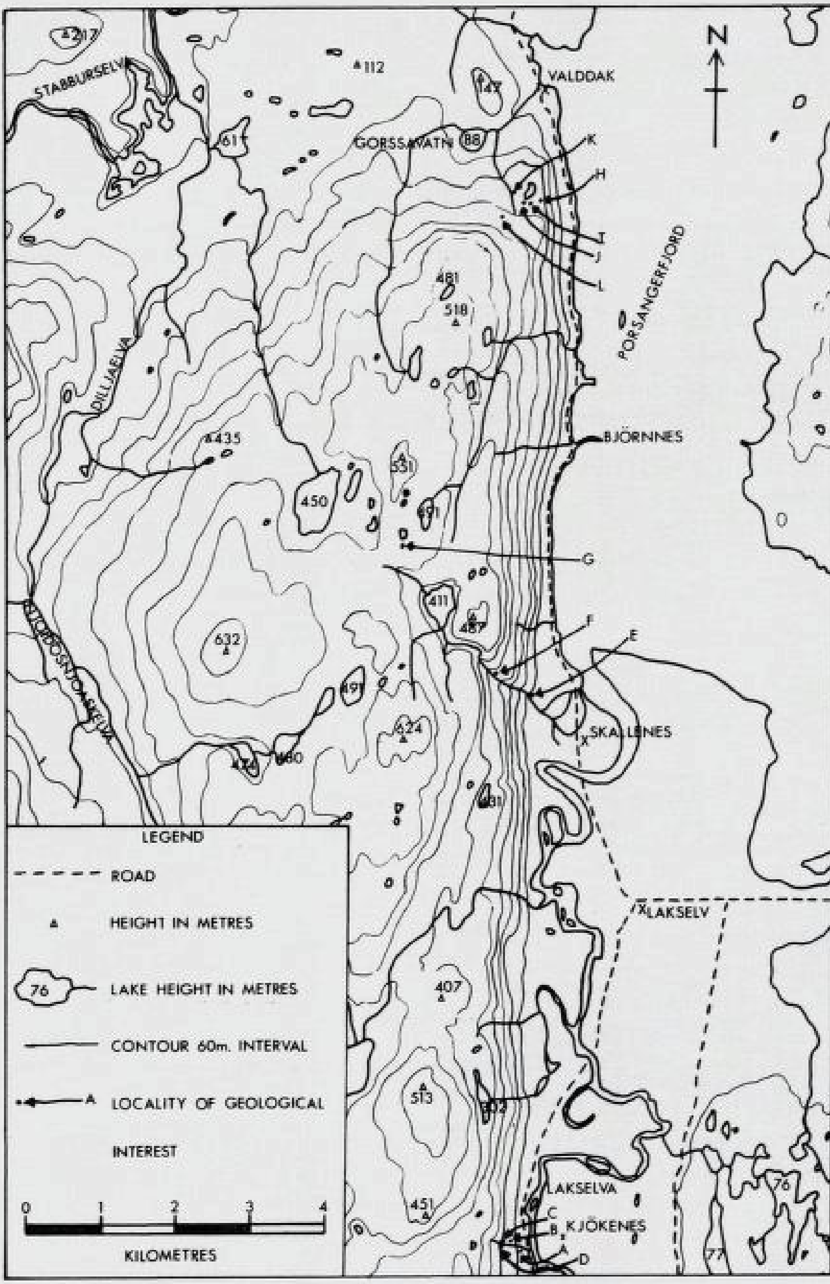


Fig. 8. Geological Localities West and South of Porsangerfjord.

scarp and Porsangerfjord. In addition a minor road leaves Lakselv in a south-westerly direction, crosses Lakselva and passes by the important section west of Kjøkenes. This road is not shown on the AMS Lakselv map, but its approximate path has been drawn on Fig. 8.

Places where particular geological features are well-exposed are indicated as localities of geological interest on the map. Some account has also been taken of proximity to roads in selecting these localities. The localities fall into three main clusters and each of these will be described in turn.

(a) The Stream Section West of Kjøkenes

This area is readily accessible by taking the road south-west from Lakselv. The stream section lies very close to this road.

*Locality A.* Here the gneisses of the Precambrian Basement Complex are unconformably overlain by almost flat-lying sandstones and thin conglomerates of the "Hyolithes Zone" (see Plate 1 Fig. 1).

*Locality B.* "Hyolithes Zone" sandstones are well-exposed along the stream.

*Locality C.* Small exposures of "Hyolithes Zone" shales are exposed where the stream cuts through the lower part of the scarp.

*Locality D.* A little higher up in the stream section the strongly folded sandstones of the Porsanger Sandstone Formation are thrust over the "Hyolithes Zone" shales. Plate 1 Fig. 2 shows the strong minor folding in the Porsanger Sandstone Formation of this locality.

(b) The Stream Section North-west of Skallenes.

The stream which drains Lake 411 passes through an area which is notable for its interesting geological features and spectacular scenery.

*Locality E.* Here the stream reaches the foot of the scarp and spreads out to lose itself over the drift deposits which fill the valley. This part of the scarp consists of rocks belonging to the Skallenes Sandstone. Here may be seen ripple marks, dessication cracks in the thin shaly bands, horizontal worm burrows and cross-stratified units.

Upstream there are several waterfalls, some of which must be by-passed either to the north or south.

*Locality F* lies at the top of the highest and most spectacular of these waterfalls (see Plate 1 Fig. 3). Here the stream follows the junction between the Skallenes Sandstone and the Bjørnnes Sandstone. Hill 487 is an anticline with the topography closely following the structure. The side of the hill consists of rocks belonging to the Bjørnnes Sandstone and these show numerous drag-folds due to their relative incompetency. The transition to the Valddak

Sandstone is well-displayed and the massive orthoquartzites of this member form a protective cap at the summit of hill 487. Plate 1 Fig. 3 is a view of hill 487 showing the structural and topographic conformity.

*Locality G.* Here purple sandstone lenses of the Bjørnnes Sandstone are well-exposed. The triangular blocks formed by intersection of joints and bedding planes and iron-rich concretions occur near a tributary of the small stream which flows into the north-west corner of Lake 411.

(c) The Northern End of the Scarp

The northern end of the scarp is readily accessible from the main highway.

*Locality H.* The Bjørnnes Sandstone - Valddak Sandstone junction is well-displayed in the upper part of the cliff.

*Locality I.* A complete succession of the massive orthoquartzites of the Valddak Sandstone is exposed here. Prominent ripple marks occur in the upper part of the member.

*Locality J.* The junction of the Valddak Sandstone with the overlying Gorssavatn Shales is exposed in this vicinity.

*Locality K.* A small stream drains the northern end of the scarp. In and near this stream the Gorssavatn Shales are well-exposed.

*Locality L.* Here sandstones of the Skallenes Sandstone are thrust over the Gorssavatn Shales.

## 9. Appendix 2. Notes on Fig. 9
## The Geology of the Njæidan Mountain Area

It will be noted that there is an east to west decline in the geological information presented by this map. This is a reflection of the decrease in the degree of exposure. In the scarp face which extends along the eastern edge of the area, exposure is very good. It is in this area that the Porsanger Sandstone Formation succession was established and where the structures are best displayed.

To the west of the top of the scarp, exposures become fewer and less continuous. Nevertheless, by utilizing topographic features such as lines of lakes and valleys which parallel the strike of softer members, as well as exposures of the more resistant members, a reasonably reliable map can be drawn.

West of a line drawn south from Nasteelva exposures become scattered and limited in extent. It was not found possible to draw any sort of reliable map in this part of the area. Exposures are frequently limited to hard, massive sandstones which could belong to either the Skallenes Sandstone or the Valddak Sandstone, as far as their field appearance is concerned. Such exposures have been mapped as undifferentiated sandstone.

Some exposures of the more characteristic Bjørnnes Sandstone and Gorssavatn Shales occur, but their relationships to the other members, in such a structurally complex area, are not clear.

### 10. Acknowledgements

All of the field-work and much of the preparation for this paper was carried out while I was a member of the Department of Geology, University College, Cardiff, Wales. The help and advice of the staff of that department, in particular Professor J. G. C. Anderson, is gratefully acknowledged. During 1963-64 I was supported by a D.S.I.R. Research Studentship. The field work was completed in the summer of 1965 with the aid of a travel grant from University College, Cardiff. Direktor H. Bjørlykke and the staff of Norges geologiske undersøkelse are thanked for their hospitality and help during my visits to Trondheim and for the loan of aerial photographs. To the many Norwegians, too numerous to mention individually, who made my journeys through Norway so memorable, my heartfelt thanks. For their many kindnesses I would particularly like to thank Rektor S. Føyn, Dr. G. Henningsmoen and Cand. real. K. Bjørlykke.

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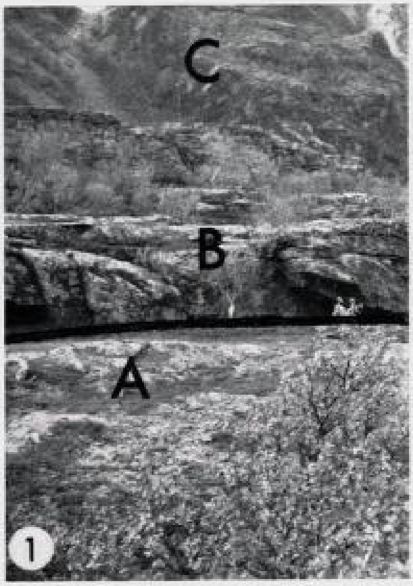




Plate 1 Fig. 1. Sandstones of the "Hyolithes Zone" (B) lying unconformably upon gneisses of the Precambrian Basement Complex (A). The scarp in the background is made up of a thrust mass of sandstones belonging to the Porsanger Sandstone Formation (C). West of Kjøkenes.

Plate 1 Fig. 2. Strongly folded sandstones of the Porsanger Sandstone Formation. Upper part of the section west of Kjøkenes.

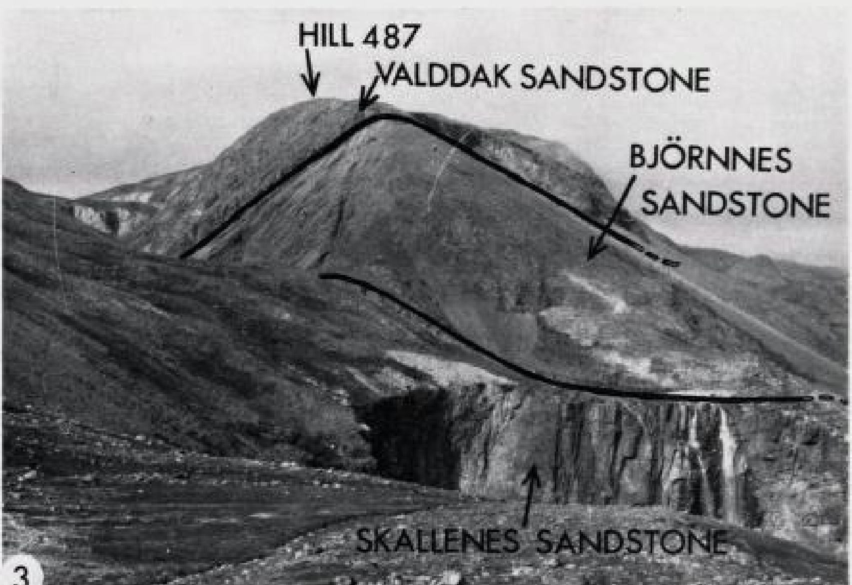
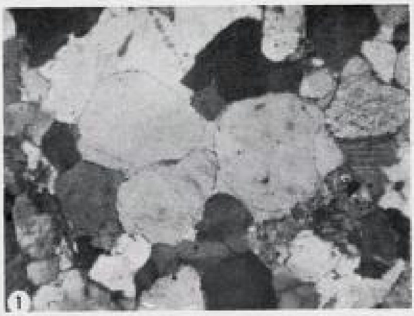



Plate 1 Fig. 3. View of the upper part of the stream section north-west of Skallenes and of Hill 487. The stream falls over a 60 m. high cliff of sandstones belonging to the Skallenes Sandstone. The side of Hill 487 is formed by the less resistant Bjørnnes Sandstone. The harder rocks of the Valddak Sandstone form a protective cap over the top of the hill. The whole of Hill 487 is an anticline and there is a strong relationship between the structure and the topography.

Plate 2 Fig. 1. Ripple marks in the Skallenes Sandstone. Upper part of Nasteelva.

Plate 2 Fig. 2. Rippled sandstones with horizontal worm burrows, in the Skallenes Sandstone. Stream north-west of Skallenes.

Plate 2 Fig. 3. Purple sandstone lens in the Bjørnnes Sandstone, with triangular shaped blocks produced by the intersection of joints and bedding planes. North-west of Lake 411.



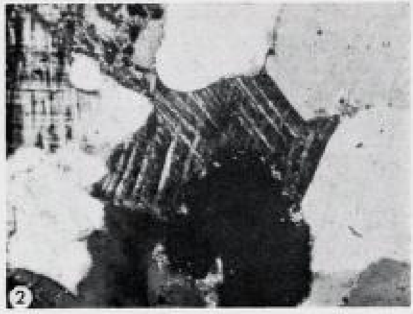
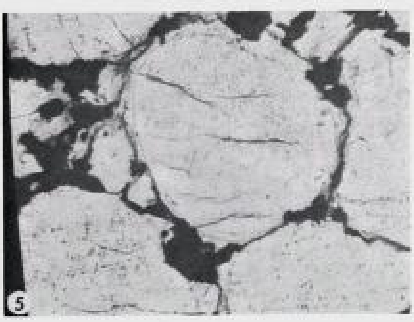


Plate 3 Fig. 1. Rounded quartz grains with secondary overgrowths. "Hyolithes Zone" feldspathic sandstone. Crossed polarisers. X33.

Plate 3 Fig. 2. Calcite pore filling in feldspathic sandstone of the "Hyolithes Zone". Euhedral quartz projects into the carbonate but most of the marginal quartz shows some corrosion. Crossed polarisers. X94.

Plate 3 Fig. 3. Rounded feldspar grain projecting into adjacent quartz grains. Feldspathic sandstone of the "Hyolithes Zone". Crossed polarisers. X94.

Plate 3 Fig. 4. A mica flake squeezed between two rounded feldspar grains. "Hyolithes Zone" feldspathic sandstone. Crossed polarisers. X94.



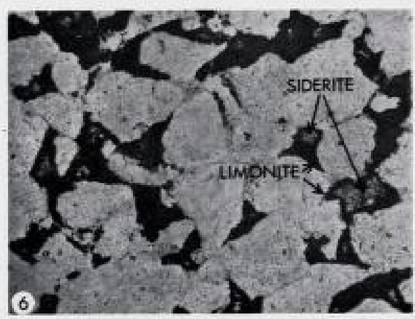



Plate 3 Fig. 5. Rounded quartz grain with secondary overgrowth, apparently corroded by limonite. Limonitic sandstone of the Bjørnnes Sandstone. Plane polarised light. X94.

Plate 3 Fig. 6. Limonitic sandstone of the Bjørnnes Sandstone, with siderite at the centre of a limonite-filled pore. Plane polarised light. X33.

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NGU = Norges Geologiske Undersøkelse
NGT = Norsk Geologisk Tidsskrift

# Rhombeporfyr-stratigrafi vest for Holmestrand

*Stratigraphy of Permian rhomb porphyries west of Holmestrand, Southern Oslo Region*

Av
*Henrik Heyer.*

**Abstract**

Results from field work 1967 within an area of 4.5 × 6 km² in the Vestfold lava plateau, Southern Oslo Region, show that the lower half of the lava series is much richer in flows than earlier realized, and consists of at least 23 rhomb porphyry flows and two trachyte flows below what was earlier termed rhomb porphyry No. 13.

**Innledning**

Jeg vil først rette en hjertelig takk til professor Chr. Oftedahl for hans gode råd og veiledning under feltarbeidet og for tilleggsopplysninger og forberedelser som har gjort denne publikasjon mulig. Kartlegningen ble utført for Norges Geologiske Undersøkelse.

De beskrevne lavaer er bestemt på grunnlag av feltspat-strøkornenes form, størrelse og i hvilken mengde de forekommer. Som nøkkel til beskrivelsene er det derfor nødvendig med forklaring av en del betegnelser:

"Tett pakket" vil her si at strøkornene (XX) dekker rundt 25 % eller mer av total overflate ($RP_{13}$).

| | |
|---|---|
| Middels pakket: | Ca. 15 — 20 % ($RP_{2a}$). |
| Åpent pakket: | Ca. 10 % ($RP_4$). |

Strøkornenes størrelse:

| | |
|---|---|
| Store XX: | 2 — 4 cm. |
| Middels store XX: | 0.75 — 2 cm. |
| Små XX: | 0.1 — 0.75 cm. |
| Ørsmå XX: | Under 0.1 cm. |

Det har vært vanskelig å finne samsvar mellom de fleste lavaene i dette felt og de som er behandlet av Chr. Oftedahl (1952). Jeg har derfor funnet det hensiktsmessig å innføre en del helt nye betegnelser. Det er da stort sett lokalitetsbetegnelser fra lokaliteter der de respektive lavaer lot seg stratigrafisk bestemme. Det er således ikke samsvar mellom Hegg- eller Ende type her og typer med samme navn f. eks. hos W. C. Brøgger (Oftedahl, 1952, p. 21).

**Rhombeporfyrenes geologi**

Det kartlagte område fremgår av fig. 1. Beskrivelsen av de enkelte porfyrtyper er sammenstillet i tabell 1, og som eksempel på to karakteristiske typer er typene Rykås og Greåker D vist i fig. 2. De utskilte strømmer gis så en summarisk beskrivelse i stratigrafisk rekkefølge.

*$RP_1$*. Mangler i kartfeltet, men finnes ved Fegstadgårdene 2.5 km SSØ for kartets SØ-hjørne. Der kiler den ut mot nord, og kommer igjen etter vel 7 km, i Vollsåsen 200 m nordenfor kartgrensa.

*$RP_2$* (2a) er en karakteristisk lava med uregelmessige krystaller, og en mektighet rundt 30 m i profilet Solumsås—Gunnestad 1 km syd for kartets sydøstre hjørne. Inne på den østlige del av kartet er mektigheten usikker på grunn av overdekning og en mulig forkastning. F. eks. kan lokalitetene Haug og Østre Gudum tyde på ca. 5 m mektighet (dersom det ikke er noen forkastning). $RP_{2b}$ synes å mangle i dette området, men ser ut til å komme inn like nordenfor kartet.

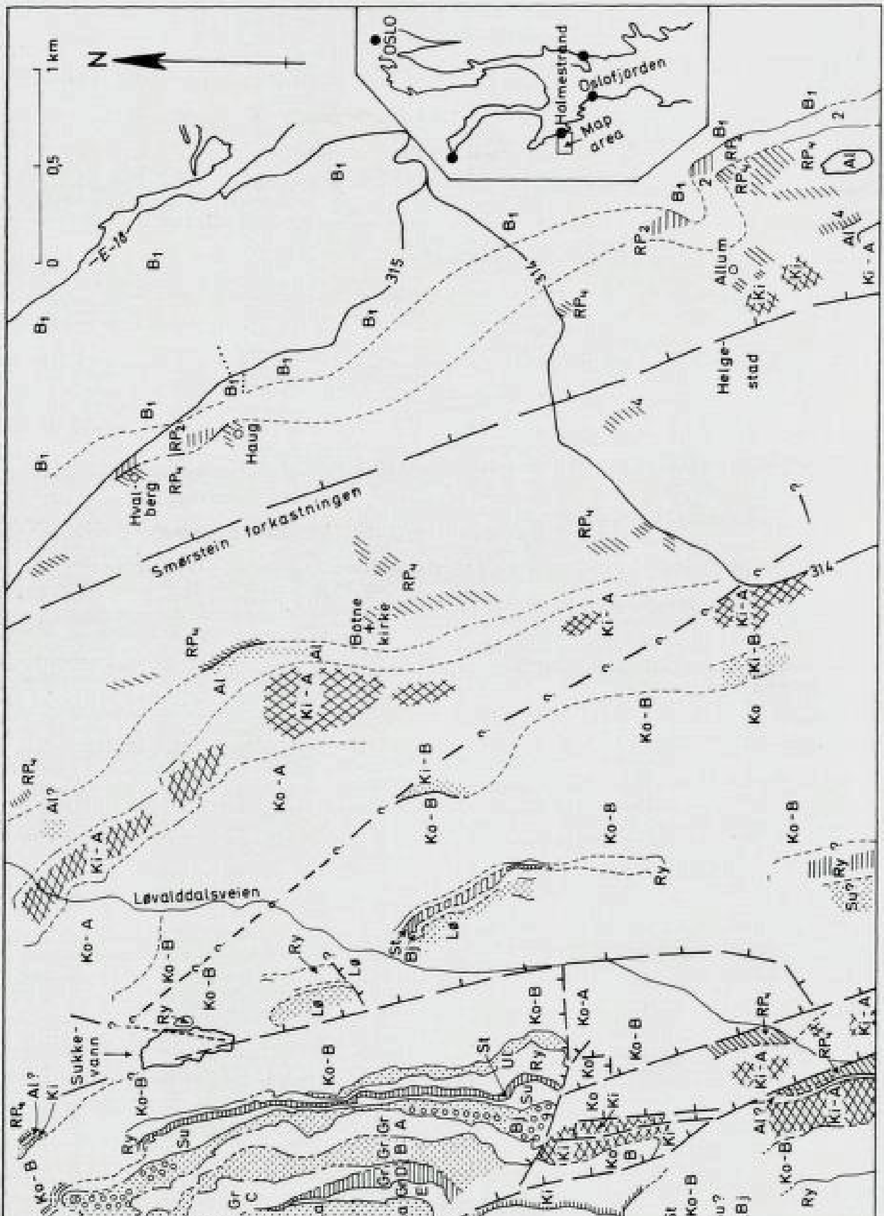
*$RP_4$*. I lokaliteten ved Hvalberg viser den seg å være en lava med rhomber og mange båtformete krystaller, mens den noen meter høyere er åpnere pakket og har flere rundete og tungete krystaller. Det kan derfor synes mulig at det dreier seg om to strømmer.

*Allum type*. Lokaliteter ved gårdene Allum og Kiste viser at $RP_4$ følges av en lava som er åpnere enn $RP_4$. Den er her 3 m mektig. Den synes også å være til stede ved Myhre-gårdene nord for Botne kirke, men fortsatt tynn. Allum type kan være identisk med 4b.

*Kiste A*. Lokalitetene Solumsåsen, Allum, Kiste og Grønnmarkåsen viser en vakker båtlava oppå Allum typen. Den finnes fortsatt på østsida av Øiebukta i Hillstadvannets sydende og øst for Svinevoll i Våle.

*Kiste B*. Nærmest en forminsket utgave av Kiste A. Den opptrer tydelig i bunnen av Knattenåsen vest for Botne kirke (i Våle f. eks. i bunnen av Rykåsen).

*Korsgård A*. Denne er ikke noe sted med sikkerhet funnet som lava. Den opptrer over Kiste B som en grøt av fragmenter og bruddstykker og synes å kunne representere en autobreksje. Den finnes ved Berggårdene øst for Sukkevann, men mangler i Knattenåsen og i kartets sydvestre hjørne, og synes å mangle i Stuåsen vest for Sukkevann.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*Korsgård B.* Særpreget lava med relativt stor mektighet, anslagsvis 60—70 m, og den dominerer i et belte fra Sukkevann i nord og i alle fall ned til Våle kirke i syd. Dette kan være $RP_5$.

Oppe i åsen vest for gården Sukke, finner en direkte kontakt mellom Korsgård B og Rykås type. Mot syd kommer en ny lava inn mellom disse to. Den vokser raskt mot syd, men blir neppe over 15 m. Finnes også inne ved kartets vest-grense, men ser ut til å mangle øst for Sukke. Denne lava fikk betegnelsen Uleåstype og ligner meget på øverste del av $RP_4$. Det er mulig dette kan være $RP_{5bV}$.

*Rykås type.* (Se fig. 2). Overleirer Uleås type, og er en rektangelporfyr som stedvis kan minne om $RP_{13}$. Opptrer på en rekke lokaliteter og er hele tiden ca. 5 m mektig.

*Stuås type,* ligner Rykås type som den overleirer.

*Sukke type* overleirer Stuås type. Mangler øst for forkastningen fra Sukkevann, opptrer i åsen opp for gården Sukke, men er forsvunnet igjen i kartets sydvestre hjørne. Denne uregelmessighet kan vel kanskje skyldes lavalandskapets daværende relieff.

*Bjørnås type* overleirer Sukke type og ligner Rykås type.

*Løvald type* overleirer Bjørnås type og ligner svært på Sukke type. Den finnes øst for forkastningen ved Sukkevann, men mangler vestenfor ved Sukke. Den kommer igjen i kartets sydvestre hjørne. Lenger vest, i Heggsåsen ved Kronlia i Hillestad, ser det ut til at det over Løvald type kommer tre nye, tynne lavaer som mangler østover og sydover. Den nederste ligner en storvokst Korsgård B (ganske uregelmessige rektangler). Den neste ligner Bjørnås type, er tett pakket og har rektangulære-ovale krystaller. Den øverste har to generasjoner krystaller. (Åpen, med rektangler og listeformete krystaller).

*Greaker A, B og C* er tre nesten identiske lavaer som overleirer hverandre. De minner svært om Uleås type og øverste del av $RP_{4a}$. Greaker C synes lokal. Den forsvinner mot syd.

*Greaker D.* To-generasjonslava (se fig. 2), og er meget forskjellig fra de øvrige Greaker lavaer.

*Greaker E.* Nesten identisk med Greaker A, B og C. Den forsvinner mot syd.

*Lakjeld type* er meget lik $RP_1$. Den ble også funnet lenger vest, ca. 200 m øst for gården Ende ved Revåvannet hvor den overleirer en Greaker type.

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Fig. 1. Rhombeporfyrer etc. vest for Holmestrand, med forkastninger. Symboler på lavastrømmene etter tabell 1.

*Rhomb porphyries etc. west of Holmestrand, with faults. Symbols of lava flows from Table 1.*

*Hegg type.* I åsen mellom gårdene Ende og Lakjeld viste den seg å bestå av minst 4 identiske strømmer (hver ca. 5 m mektig) med konglomerater mellom. Også Hegg type ble observert ved Revåvannet. Den vokser trolig mot vest.

*Ende type.* Overleirer Hegg type øst for Ende ved vestgrensa av kartet. Ca. 300 m lenger syd er den forsvunnet. Det ser ut til at den kiler ut både mot syd og øst. Minner noe om $RP_{13}$, men ikke noen egentlig rektangelporfyr.

*$T_1a$.* Betegnelsen $T_1$ fordi denne lava synes å være identisk med Oftedahls $T_1$ ved Hillestad landhandel (riksvei 315, ca. 1 km øst for krysset Kronlia), som etter analyse (Chr. Oftedahl, personlig meddelelse) viser trakyttisk kjemi.

*$T_1b$* minner meget av Krokskogens $RP_{12a}$ med hensyn til krystaller. (Se Oftedahl, 1952, fig. 4, s. 13).

*$RP_{13}$.* Lavaen synes identisk, også stratigrafisk, med $RP_{13}$ ved Revåvannet. Noen basalt under $T_1$ synes ikke å opptre innenfor det kartlagte felt.

## Konglomerater

$RP_1$ og $RP_2$ ligger over et basaltkonglomerat som i mitt område har ca. 5 m mektighet. Konglomeratet fører godt rundet materiale av mandelbasalter, basalter med vesentlig plagioklaskrystaller, samt afyrisk basalt. Skarpkantede stykker finnes i blant. Bollenes gjennomsnittsstørrelse er ca. 5 cm. De største bollene har diameter på 20 cm.

Mellom $RP_1$ og $RP_2$ i Vollsåsen, forekommer et ca. 10 m mektig konglomerat med boller opptil hodestore. Materialet er godt rundet og fører boller av $RP_1$.

Mellom $RP_2$ og 4a i Solumsås finnes et ca. 3 m mektig konglomerat. Det er sandig i bunnen, men fører mindre sand mot toppen. Godt rundet materiale med gjennomsnittsstørrelse ca. 10 m. Konglomeratet synes også å være tilstede ved gården Haug, men ved Hvalberg ca. 400 m lenger nord er det forsvunnet.

Mellom $RP_4$ og Allum type i Solumsås er et minst 2 m mektig lag av sandig konglomerat-agglomerat. Rundet-kantet materiale. Ved Botne kirke og ned til riksvei 314 har $RP_4$ karakter av agglomerat, minst 3 m mektig, med skarpkantet, ikke særlig grovt (ca. 5 cm) materiale. Nord for Botne kirke ser det ut til å være et tynt konglomerat.

Mellom Allum og Kiste A lavaene i toppen av Solumsås og ved Kiste ligger et konglomerat, 3 m ved Kiste, noe tykkere i Solumsås. Solumsås: Rundete boller, ofte porøse, fulle av gassblærer. Bollene er 5—10 cm, noen større, iblandet kantete småfragmenter (1—3 cm) som flesteparten er røde lik bruddstykker av slaggskorpe. Renere konglomerat finnes ved Kiste.

Ved Kårfjord har Kiste A konglomerat i toppen. Også lenger syd, i Våle, er dette konglomeratet observert.

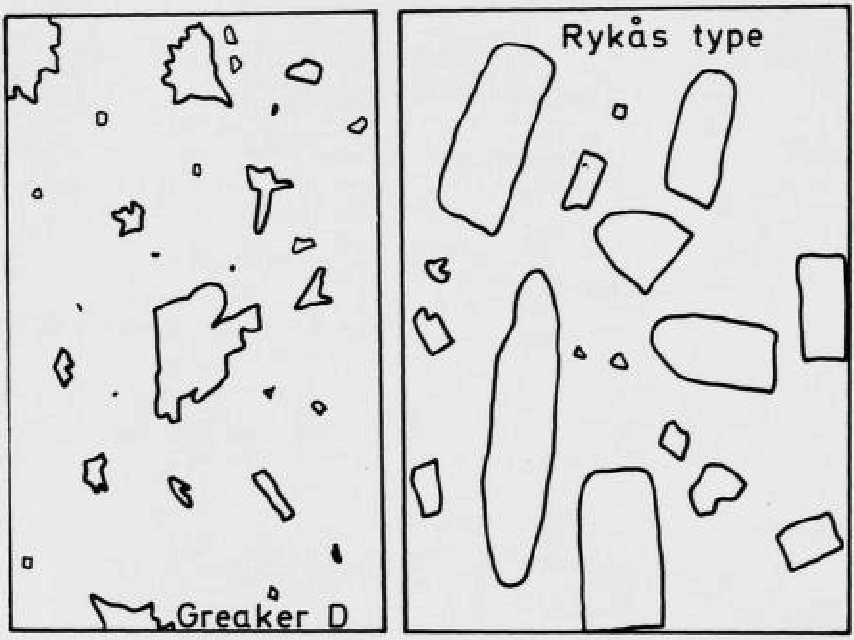


Fig. 2. Rhombeporfyrtyper Greaker D og Rykås. Naturlig størrelse.
*Rhomb porphyry types Greaker D and Rykås. Natural size.*

Mellom Kiste B og Korsgård type ligger et konglomerat ved Gullhaug syd for Øde Bringaker som har dårlig rundet-kantet materiale. Ca. 4 m mektig.

Mellom Korsgård B og Rykås type ligger et tynt, fint konglomerat ved Korsgården. I Rykåsen danner toppen av Korsgård B en ujevn, slaggig flate med sandlommer nedover. Rykås type ligger direkte over uten konglomerat. Ovenfor Sukke har også Korsgård B sandlommer og sandskorpe, uten konglomerat. 100 m lenger syd, der Uleås type kiler ut, ligger et lokalt konglomerat over Uleås type. Konglomerat mellom Uleås og Rykås type er ellers bare funnet i Uleåsen i kartets sydvestre hjørne, og kontakten er ellers uten sedimenter.

Mellom Rykås og Stuås type er 10 lokaliteter undersøkt fordelt over 12 km$^2$ og konglomerat er over alt vært tilstede. Ovenfor Sukke : 3—5 m konglomerat med dårlig rundet materiale. Bollenes størrelse varierer fra 2 cm til hodestørrelse, gjennomsnitt 10 cm.

Også Stuås type synes å være avsluttet med et konglomerat de fleste steder, noen steder nærmest et agglomerat.

Mellom Bjørnås og Greaker type, ca. 500 m vestenfor Sukkevann, ligger et ca. 15 m mektig konglomerat med dårlig rundet materiale med 10 cm til hodestore boller nederst. Høyere opp varierer bollene fra 5—10 cm. Konglomeratet har samme karakter 2 km lenger syd, med boller på 10—20 cm, ofte over hodestore. Etter 1 km, både mot vest og øst, er konglomeratet under 5 m mektig.

Mellom Greaker lavaene ligger tynne konglomerater og agglomerater. Greaker B er i syd full av fragmenter (1—3 cm), sand og noen få små boller, mens det lenger nord er konglomerat og agglomerat.

Over Lakjeld type finnes i syd et agglomerat, og 500 m lenger nord er i stedet et konglomerat, ca. 5 m mektig.

Hegg type, som består av flere strømmer, har 5 m konglomerat mellom hver strøm, og konglomerat i toppen.

Mellom $T_1$a og $T_1$b ser det ut til å ligge et 2—3 m agglomerat med 2—3 cm store fragmenter.

Det synes å være karakteristisk at det nesten uten unntak finnes erosjonsmateriale mellom de forskjellige lavaer, og vesentlig i form av konglomerat. Sandsteinslag synes ikke representert.

Typisk er at det i disse sedimenter, enten det er konglomerater eller agglomerater, bare forekommer lavamateriale, og det ser ut til at det vesentlig er materiale fra den lava sedimentet overleirer. Lagdeling eller kornsortering er ikke observert.

Disse fakta, samt at materialet ofte er dårlig rundet, skulle tyde på relativt kort transport, kanskje i tallrike småelver, at det har vært en markert pause mellom hver erupsjon av de innbyrdes nesten identiske lavaer av Greaker type og Hegg type.

## Forkastninger

På østlige del av kartet går en NNV-forkastning som følger Mofjellbekken sydover på kartet, betegnet Smørsteinforkastningen, fordi den synes å gå ut i fjorden ved Bogen på Smørstein. Den synes videre å passere ned mellom gårdene Allum og Helgestad. Derfra bøyer den noe av og fortsetter omtrent rett syd og ser ut til å kunne følges minst 9 km videre.

Fra Sukkevann går en forkastning som synes å ende ved Viskjold, 3 km lenger syd, idet den sammen med et system av småforkastninger munner ut i en større som kommer fra Hillestadvannets østside og fortsetter videre mot syd. Denne avgrenser $RP_{13}$ mot vest. På vestsida repeteres Korsgård-typen.

Mens den østlige forkastningen ser ut til å gå relativt rettlinjet, viser de vestlige mer ujevn kurs og står dessuten i forbindelse med et kompleks av småforkastninger (stedvis øst-vest gående). At et lignende kompleks av mer eller mindre tversgående småforkastninger synes å mangle i øst, kan bero på at de er skjult av den sterkere overdekningen. I alle fall ser det ut til at de dominerende nordvest-nordgående forkastninger i en viss grad også har blitt fulgt av mindre forkastninger i de mellomliggende blokker.

## Konklusjoner

Den nederste del av RP-serien (under $RP_{13}$) viser seg nå å være bygget opp av et større antall lokale strømmer enn tidligere antatt, og en del av disse er også nye typer med hensyn til utseende. For noen av disse typer gjelder at de har bygget opp tynne dekker ved gjentatte erupsjoner av identiske, eller nesten identiske strømmer (Greaker- og Hegg-lavaene).

Videre synes det å være karakteristisk at det nesten uten unntak finnes erosjonsmateriale mellom de forskjellige lavaer, og vesentlig i form av konglomerater. Sandstein synes ikke representert.

Typisk er at det i disse sedimenter, enten det er konglomerater eller agglomerater, bare forekommer lavamateriale, og det ser ut til at det vesentlig er materiale fra den lava sedimentet overleirer. Noen lagdeling eller sortering i varv er ikke observert.

Disse fakta, samt at materialet ofte er dårlig rundet, skulle tyde på relativt kort transport, kanskje i tallrike småelver, at det har vært markerte pauser mellom hver erupsjon og at det også har vært slike pauser mellom hver erupsjon av de nesten identiske lavaer av Greaker type og Hegg type.

Angående forkastningene ser det i alle fall ut til at de dominerende nordvest-nord-gående forkastningene i en viss grad også har blitt fulgt av mindre forkastninger i de mellomliggende blokker.

## Litteratur

*Oftedahl, Chr.*: Studies on the Igneous Rock Complex of the Oslo Region. XII The Lavas. Skr. utg. av Det Norske Vidensk.-Akad. i Oslo. I Mat.-Naturv. Klasse. 1952. No. 3.

*Tabell 1.*

Rhombeporfyrbeskrivelse fra $RP_1$ til $RP_{13}$.
*Description of rhomb porphyries from $RP_1$ to $RP_{13}$.*

| Betegnelse | Beskrivelse | Mektighet i m |
|---|---|---|
| Rektangel-porfyr, $RP_{13}$ | Middelstore feltspat-strøkorn (= XX), stedvis opptil 3—4 cm. XX er rektangulære, de fleste rundet i hjørnene. Noen små XX, få ørsmå XX. | Min. 30 |
| $T_1b$ | 1 cm ørsmå XX. Ujevne XX, få lister, middels pakket. | Min. 5 |
| $T_1a$ | 2 generasjoner XX: 0.1 — 0.3 cm, og 1—1½ cm XX. De små er hovedsakelig rektangler. De større er rektangler og uregelmessige XX som ligger spredt. | Min. 5 |
| Ende type E | Middelsstore XX. Gjennomsnitt 1½—2 cm. Middels åpent pakket, de fleste XX noe rundete. Få rektangler, noen rundete rektangler. Tendens til båtform. Noen ovale. Minner noe om $RP_{13}$. | 0 — 10 |
| Hegg type He | 2 generasjoner XX. Store XX ligger spredt — meget spredt (åpent — meget åpent pakket). Noen Karlsbadere, noen rhomber, noen båter (2—3 cm XX). Smågenerasjonen: Vesentlig lister 0.1—0.5 cm lange. | Min. 15 |
| Lakjeld type La | Middels store XX, gjennomsnitt ca. 2 cm. Noen XX opp til 3 cm, mange mindre, ned til 0.5 cm, noen 0.5—0.2 cm. Få små, meget få ørsmå. Mange båter, få gode rhomber, få nesten rekt. Noen lange, tynne båter. De fleste XX noe rundete. Middelstett pakket. $RP_1$ type. | Min. 2 |
| Greaker E Gr E | Rundete, tungete XX. Meget åpent pakket. Nesten lik Greaker C. Ligner $RP_4$ (øverste del), men uttynnet i forhold. | 0 — ca. 5 |
| Greaker D Gr D | 2 generasjoner XX: 1—1½ cm, uregelmessige XX, og ørsmå til 0.5 cm, uregelmessige XX. Noen lister og rektangler. De større XX meget spredt. | 0 — min. 5 |
| Greaker C Gr C | Åpent — til meget åpent pakket. Middels store XX. Oftest rundete — tungete XX. Gjennomsnitt XX: ca. 2 cm, få små. $RP_{4a}$ type, uttynnet. | 0 — 5 |
| Greaker B Gr B | Åpent — meget åpent pakket. Middels — over m. XX (1—2½ cm). Meget få små/ørsmå XX, meget få svært uregelmessige XX, de fleste er rundete, noen ovale. $RP_{4a}$ type, uttynnet. | Ca. 10 |

| Betegnelse | Beskrivelse | Mektighet i m |
|---|---|---|
| Greaker A<br>Gr. A | Åpent — meget åpent pakket. 1½—2½ cm XX. Noen båter og Karlsbadere, noen tannete, tungete, rundete, XX. Få små, meget få ørsmå. $RP_{4a}$ type, uttynnet. | Ca. 10 — 15 |
| | — 3 lokale lavaer lenger vest. | |
| Løvald type<br>Lø | Åpent pakket. Lange middelsstore, mange små XX. Mange rektangler, noen båter, noen rhomber og uregelmessige. Ligner Sukke type. | 5 — 10 |
| Bjørnås<br>type<br>Bj | Middels store XX. Middels tett pakket. Gj.snitt: 1½ cm, noen ca. 3 cm. Mange ned til 0.3 cm. Noen små, få ørsmå. De fleste noe rundete. Noen rekt. — rundete rekt. De store XX er gjerne rundete båter og ovaler. | 10 — 20 |
| Sukke<br>type<br>Su | Middels store XX, noen 2—2½ cm, gjennomsnitt: 1 cm. Åpent — middels pakket. Mange uregelmessige XX, noen rekt., noen små, få ørsmå. | 0 — 15 |
| Stuås<br>type<br>St | Tett pakket. Middels store XX. Gj.snitt: 1½ cm. Mange rekt.: 1—1½ cm. Noen 2 cm, få 3—4 cm. Noen rundete — ovale, noen ujevne, få båter. Mange små, noen ørsmå. Ligner Rykås type. | Ca. 5 |
| Rykås<br>type<br>Ry | Middels tett pakket (tett i bunnen, åpnere øverst). Middelsstore XX. Gj.snitt: 2 cm. Få 3—4 cm. Ikke typiske rhomber, mange rekt., rundete rekt., båter og ovaler. Meget få halve ovaler. Noen små, få ørsmå. | 4 — 5 |
| Uleås type<br>Ul | Lik $RP_{4a}$ (øvre del). Kanskje noe tettere pakket. | 0 — 10 |
| Korsgård B<br>Ko-B | Middels pakket. Middels store XX. Uregelmessige XX, men med tendens til rektangler. Meget få XX over 1.5 cm. Få rektangler, få ovale, noen rundete båter. Mange små, noen ørsmå. Ingen takkete eller innskårne som hos $RP_{2a}$. Jevn variasjon fra middels til små XX. | Min. 60 |
| Korsgård A<br>Ko-A | Åpent pakket ? Middels store XX, noen rundete. Minner om en grov 2a type, men åpnere pakket. | 0 — ca. 20 |
| Kiste B<br>Ki-B | Middels tett pakket. Middels små XX. Vesentlig båter og rundete båter. Få rekt., mange små XX, få ørsmå. | 5 — 20 |
| Kiste A<br>Ki-A | Tett — middels pakket. Middels store XX. Vesentlig båter. Noen rundete, noen uregelmessige båter. Få små, meget få ørsmå XX. $RP_1$ type. | 15 — 20 |

| Betegnelse | Beskrivelse | Mektighet i m |
|---|---|---|
| Allum type Al | Åpent pakket. Middels store XX, uregelm. innskårne og takkete. Noen båter, noen jevne båter, noen Karlsbadere, noen små og noen ørsmå XX. | Lava, 3 Kongl., 3 |
| $RP_{4a}$ | Åpent pakket. Middels til noe over middels store XX. Meget få små, nesten ingen ørsmå XX. Uregelmessige — rundete, noen tungete XX. Mange båter og noen tungete XX i bunnen. | Ca. 20 |
| $RP_{2a}$ | Middels til åpent pakket. Middels små XX. De større XX ligger spredt. Bare uregelmessige takkete og innskårne XX, en del Karlsbader-tvillinger. | Ca. 30 |
| $RP_1$ | Ren båtlava. Tett til middels pakket, middels store XX. | Ca. 30 |
| | | 232 — 348 m |
| | Serien mellom $B_1$ og $RP_{13}$ er neppe over 400 m. | |

# Bredemte sjøer eller subglaciale avsetninger?

Av

*Per Holmsen.*

**Abstract**

The present paper is a criticism and a contradiction of J. Gjessing's theory (Gjessing, 1960, 1966) of a subglacial formation of deposits that are actually terraces and bottom sediments of former glacial (ice-dammed) lakes in East-Central Norway. Gjessing's primary objection against the existence of these lakes led to awkward misinterpretations, the most unreasonable consequences and exaggerations of which are stressed critically, in particular his views concerning the following four principal themes: 1. The flat-lying beds in terraces. 2. The shore-lines of former glacial lakes. 3. The "sheet-like drainage". 4. The "ground water level" within, and below, the dead ice body.

## Innledning

I et foredrag utarbeidet for INQUA-kongressen 1965 i Boulder, Colorado, senere trykt (Gjessing, 1966), fastholder Gjessing sitt tidligere syn på subglacial terrassedannelse og «den flatemessige drenering» innen de bredemte sjøers område på Østlandet, et syn som bygger på teorier som ble fremsatt i hans doktoravhandling (Gjessing, 1960). Hans teorier og formuleringer fører til åpenbare urimeligheter og bør derfor analyseres kritisk og imøtegåes i særskilt oppsats. Dette er hensikten med denne artikkel.

Bortsett fra 1. opponents innlegg under doktordisputasen (Hoppe, 1960) er den eneste trykte imøtegåelse inntil nylig gitt av O. Holtedahl og gjelder subglacial terrassedannelse (Holtedahl, 1960, side 398-99). Holtedahl tar der klart avstand fra tanken om at Grimsmoen er dannet subglacialt under et istak, og fastholder at det ikke er noen forhold som skulle motsi eksistensen av isfrie partier i de bredemte sjøer. Også en del andre av Gjessings synsmåter er gjengitt av Holtedahl på en måte som røper misbilligelse av Gjessings teorier.

I et nylig utkommet arbeid (Lundqvist, 1967, side 17-18) har Jan Lundqvist kritisert Gjessings overdrivelse av det subglaciale prinsipp, idet han sier at dersom de sedimenter Gjessing beskriver (bresjøsedimenter og terrasser) var dannet subglacialt, måtte man vente at de hadde et topplag av morenemateriale «i betydelig utstrekning». Lundqvist påviser at de akkumulasjoner Gjessing sikter til er slike som ellers tolkes som sandurdannelser, bresjøsedimenter og lateraldannelser, og at det skal sterkere kriterier (enn de som Gjessing anfører) for å forkaste den eldre tankegang.

Min kritikk av de nevnte Gjessings arbeider gjelder vesentlig teorier og formuleringer som angår de bredemte sjøer på Østlandet under avsmeltningstiden. Den er konsentrert omkring følgende fire begreper: 1. Den flattliggende lagstilling i terrassene. 2. Setenes (strandlinjenes) natur. 3. «Den flatemessige drenering». 4. «Grunnvannspeilet» inne i, og under, isen.

### Kommentar til de fire punkter

1. Det er tydeligvis den flattliggende lagstilling i terrasser, og særlig observasjonene ved Grimsmoen i Folldal, som har vært Gjessings utgangspunkt for de tanker som har ført til et så avvikende syn på de spørsmål som er sammenfattet i ovenstående fire punkter. Gjessing mener åpenbart at dersom lagene var avsatt i en (bredemt) sjø, måtte man vente at de var skråttstillet, slik som lagene av «foreset beds» i et vanlig delta. Han sier (Gjessing, 1960, side 296 og følgende sider) at lagene må være avsatt under et istak. Han forutsetter nemlig at materialet i terrassen ikke kan være ført ut på dypere vann uten at tverrsnittet av vannstrømmen var begrenset av is, slik at strømhastigheten og dermed transportevnen kunne bibeholdes. Det fremgår at han mener at sandpartiklene ellers ikke kunne transporteres lenger enn til deltaskråningen. Av dette resonnement fremgår at hverken Grimsmoen eller andre lignende terrasser kan være avsatt i bredemte sjøer, men at avsetningen fant sted subglacialt i tunneler og kamre med lavt istak. Han beskriver prosessen slik at avsetningene i disse subglaciale rom vokste og derved tvang vannstrømmene til å smelte istaket oppover slik at nye lag kunne få plass. På grunn av at strømhastigheten på denne måte ble bibeholdt (ved at istaket hele tiden var lavt), ble lagene avsatt *flattliggende, som på bunnen av en elv*. De mange grytehull i den store terrasse tenker han seg å være merker etter ispillarer som har nådd «fra overflaten ned til massenes bunn... Den eneste måte hvorpå de store ispartier kunne isoleres, var ved at smeltende elveløp fjernet den mellomliggende is, hvor flater og rygger nå finnes, og akkumulerte løsmateriale i stedet. Ettersom akkumulasjonen av løsmateriale foregikk, nedenfra og oppover, må isen være smeltet slik at taket i tunneler og store kamre hevet seg tilsvarende». Sitatet hentet fra doktoravhandlingen side 297).

I sin senere publikasjon (Gjessing, 1966, side 144, fig. 6) fremstiller Gjessing i et skjematisert blokkdiagram hvorledes en subglacial vifte («subglacial fan») tenkes avsatt på en dalbunn ved utløpet av en sideelv. Figuren viser et for-

Gjessing generaliserer de forhold han beskriver fra Nordre Atnedal til å gjelde også for de andre bresperrede daler på Østlandet.

Hvor langt en bredemt sjø nådde i sin utvikling måtte bero på hvor snart vannet klarte å finne et avløp forbi eller under isdemningen (den gjenliggende isrest som dannet vannskillet inntil da). Meget tyder på at Nordre Atnedalen, som Gjessing har studert særlig inngående, kan oppfattes som et grensetilfelle, og at vannet allerede under et tidlig stadium (av å være en bredemt sjø) fant et utløp mot syd, subglacialt eller englacialt, langs det nåværende vassdrag. Det ble derfor ikke dannet noen sammenhengende sete.

4. «Grunnvann og grunnvannspeilet». Gjessing anvender disse termer (1960, side 313, 326, 428 etc.) på vannansamlinger i isen. Disse termer anvendes ellers bare på vann i porøse *og* permeable masser. Da en fast ismasse som materiale betraktet ikke er permeabel, kan disse termer ikke uten ny definisjon anvendes på vannansamlinger i en ismasse. I stedet burde termen *kommuniserende* vann ha vært benyttet. Dette ville ha hjulpet forfatteren meget til å forstå de hydrodynamiske forhold som hersket i et isdemt basseng. Gjessing har nemlig den merkelige oppfatning at grunnvannspeilet til å begynne med lå ved isens bunn (Gjessing, 1960, side 307, 328): «Vannet rant vekk... i grunnvannspeilet på det grunnvann som fylte akkumulasjonssystemenes løsmasser, og som var dannet sammen med disse (?) ... Vannet fortsatte subaerilt ... Unntatt ... hvor det dukket ned ... under isen for å renne vekk i grunnvannspeilet på massenes overflater i dypet». Og (side 328): «Løsmassene ble bygd opp på sitt nåværende underlag, fra isens bunn og oppover. Etter hvert som materialet ble akkumulert, smeltet elven de anlagte kamres og tunnelers tak, slik at akkumulasjonsflaten, *grunnvannspeilet* (understreket her) og elven stadig hevet seg rett oppover gjennom isen». Hvorledes grunnvannspeilet skulle kunne ligge ved isens bunn (eller nær denne) under et tidlig stadium gjennom Nordre Atnedalen (som avsnittet gjelder), og så senere stige til nivå med passområdet i nord, er ufattelig, og det lar seg ikke gjøre å følge Gjessings tankegang her. Det skyldes at Gjessings resonnement rommer flere store inkonsekvenser.

Det man først og fremst savner i Gjessings fremstilling av isavsmeltningstidens drenering i området mellom hovedvannskillet og restene av innlandsisen er en dyperegående analyse av de hovedfaktorer som kontrollerte dreneringen, både de glacialgeologiske og de hydrodynamiske, og naturligvis også de rent sedimentologiske forhold.

Det ville ha vært ønskelig med en analyse av spørsmålet om hvorledes en subglacial tunnel kan oppstå i en dynamisk død ismasse, siden den subglaciale drenering er Gjessings hovedtema. Det har vært benektet at det er mulig, og flere forskere har vært inne på spørsmålet. Enkelte har ment at subglaciale tunneler var en arv fra den tid isen var dynamisk levende, da sprekker kunne oppstå. Gjessing går bare ut fra at isen ble opptint langs bunnen (Gjessing, 1960, side 318, 1966, side 141) på grunn av smeltevann som trengte ned ovenfra langs sidene av den døde ismasse. Det forutsetter at der allerede har vært åpne kanaler, eller som Gjessing sannsynligvis regner med, at bunnmorenen allerede var opptint på forhånd. Det kunne vært nyttig for resonnementet om hvorledes dreneringen til slutt ble snudd om, hvis der var diskutert muligheten for at isen slo sprekker på grunn av oppdriften i alt det smeltevann som forutsettes å gjennomtrenge og omgi isen.

Den viktigste mangel angår de sedimentologiske forhold, spesielt de flattliggende lag i terrassene. Det finnes mange lagvis flattliggende subakvatiske sedimenter i verden hvor der aldri har ligget is. Man savner også en videreføring av resonnementet i innledningen, om at der var årstider da som nå, men manglende vegetasjonsdekke. Hvilke konsekvenser måtte dette ha for elvenes materialføring fra de blottlagte morenemasser inn mot isen? Hva med isgang i elvene, som i nåtiden er ansvarlig for en stor del av transporten av grus og stein? Hva med temperaturfordelingen i de bredemte bassenger som nødvendigvis måtte oppstå der hvor elvene fra nord og vest, altså fra de allerede blottlagte områder, rant inn mot innlandsisen? Man må vel vente at de førte en betydelig større varmesum (om sommeren) inn mot disse steder fordi de drenerte områder som allerede var (delvis) isfri? — større varmesum til å smelte isen enn hva ablasjonen kunne utrette alene på et begrenset område av isen? Det måtte vel bevirke dannelsen av åpne vannflater, med den følge at ytterligere varme ble absorbert (en vannflate reflekterer meget mindre av solstrålingen enn rene sne- og isflater). En slik betraktning kunne kanskje også ført til en forklaring på hvorfor der lå is igjen på vannskillene ved utløpene av noen store bredemte sjøer, f. eks. ved Rugldalen og over Kvikneskogen: disse steder kom det nemlig ingen betydelige vassdrag ned mot isen fra de allerede isfri områder, og derfor heller ingen ekstraordinær lokal varmesum. Det vannet som rant ut måtte vel da forutsettes å ha en temperatur nær 0° etter å ha rent langt i kontakt med isen?

Det er her bare pekt på noen av de momenter man savner i Gjessings betraktninger. Var de blitt behandlet, ville de trolig ha ført til et annet resultat. Ved å fortolke terrassene og bresjøsedimentene som subglaciale dannelser, avsatt under et istak, får det billede som fremkommer en påfallende likhet med et vanlig subaerilt eller subakvatisk landskap. Dette burde ha advart Gjessing mot overdrivelse, på denne måte blir isen nemlig bare en fiksjon. Det svekker tilliten til, kanskje også interessen for, den meget omfattende grenet subglacialt tunnelsystem hvor avsetningen har funnet sted («... contiguous esker accumulations in braided tunnels»). Siden der ikke henvises til noen bestemt lokalitet, må denne fig. 6 oppfattes som en prinsippskisse, slik forfatteren tenker seg at mange glacifluviale terrasser er dannet. Den er sannsynligvis inspirert, likesom teksten på en foregående side (141), av de iakttagelser ved Grimsmoen som ble publisert i doktoravhandlingen av 1960.

Det synes som om de flattliggende lag i Grimsmoen og andre lignende terrasser (innen bresjøområdene) har vært et tankekors for Gjessing, et spørsmål som har opptatt ham i den grad at det har dominert alle hans tankebilleder vedrørende bredemte sjøer. Det synes merkelig at han ikke har villet diskutere andre muligheter hvorved flattliggende lag kan være avsatt. Det mangler fremfor alt en betraktning av hvorledes et delta bygges ut, og særlig et delta i en sjø med trinnvis synkende vannstand.

Det synes naturlig å betrakte de flattliggende lag i Grimsmoen, bestående av (fin) sand og silt (Gjessing, 1960, fig. 84 og 85, side 296-97) som bunnlagene *utenfor* et delta. Lokaliteten heter forøvrig Oddmelan. Ifølge Ivar K. Streitlien er toppflaten i Oddmelan 732-734 m.o.h., og den refereres til Mjovatnets bresjø, hvis utløp nord for Mjovatnet oppgis til 734 m.o.h. (Streitlien, 1935, side 43-45). Imidlertid har der vært mange bresjønivåer i Folldal, og det er sannsynlig at de finkornige lagene i Oddmelan (Gjessings Grimsmoen) ble avsatt i en tidligere bresjø da vannstanden var høyere enn toppflaten i Oddmelan. Denne er planert senere under Mjovatnets bresjø-stadium, da den fikk et grovere topplag. På den tid da bunnlagene i Oddmelan ble avsatt lå sannsynligvis deltaskråningen med de forventede skråttstillede lag vesentlig lenger tilbake og høyere (nærmere de daværende elveutløp).

2. At der har eksistert et stort antall bredemte sjøer i Nordre Østerdalen, Folldalen (delvis også i Øvre Gudbrandsdalen) må kunne ansees bevist gjennom Gunnar Holmsens grunnleggende undersøkelser (G. Holmsen, 1915) av gamle strandlinjer eller *seter* (dialekt: såtå). Selv om billedet av store isfrie sjøer senere ble modifisert (Reusch, 1917) slik at der må ha ligget meget is igjen i sjøene, står det allikevel fast at der har eksistert store kommuniserende vannflater i dalsystemene mellom restene av innlandsisen og hovedvannskillet. Det forhold at setene var horisontale over meget lange avstander beviser dette. At gjenliggende ispartier har kunnet hindre setedannelsen på en rekke steder og strekninger, bl. a. nær utløpene, kan ikke forstyrre det faktum at setene er nøyaktig horisontale (korrigert for den senere skrå landhevning).

Gjessing antar (Gjessing, 1960, side 428) at setene er dannet som laterale spylerenner (av «fluvial aktivitet») og at de representerer «nær horisontale stabile dreneringsnivåer, som dreneringsbasis eller akkumulasjonsbasis, ... samtidig som de utgjorde den nedre grense for fluvial erosjon og utjevning». Dette gjelder endog for seten etter Nedre Glåmsjø, som kan følges horisontalt fra nær Rugldalens vannskille i nord til Atneglopen i syd, en distanse på mere enn 100 kilometer. Over lange distanser er seten dessuten sammenhengende uten avbrudd, i Glåmdalen ved Tynset mere enn 10 kilometer flere steder, i Rendalen mere enn 15 kilometer i Fonnåsfjellets østside. Disse korte anførsler skulle være tilstrekkelig til å utelukke muligheten for at seten er dannet av rennende vann. Hvorvidt *solifluksjon* (Gjessing: «setninger») kan ha vært årsak, eller medvirkende årsak, til setens utforming i morenemateriale, er en interessant, men lite studert tanke.

For i noen grad å bøte på inkonsekvensen i å oppfatte setene som smeltevannløp, har Gjessing innført et nytt begrep i læren om de døde ismasser, nemlig grunnvannstanden i ismassene. Se nedenstående kommentar under punkt 4.

Siden Gjessing nevner Gunnar Holmsens avhandling av 1915 både i teksten og litteraturfortegenlsen, kan han ikke være ubekjent med den. Det er uforståelig at han da kan ignorere hovedresultatene av et så grunnleggende og nøyaktig arbeid.

3. «Den flatemessige drenering». Denne term, som Gjessing innfører i kvartærgeologien, er mere egnet til å villede og distrahere enn til å opplyse. Det er ved hjelp av denne term at han forsøker å forklare bresjøsedimentene som subglacialt avsatt (idet han ikke kan akseptere tanken om bredemte sjøer i de områder han beskriver). Betingelsene for at denne type drenering skal opptre er ifølge hans egen tekst (Gjessing, 1960, side 320-21, 328) at isen er smeltet så meget ned at «vannets trykk i et punkt ved isens bunn oppveier isens trykk samme sted». At dette betyr det samme som at isen begynner å flyte opp på grunn av oppdriften er ikke nevnt. Uttrykt med andre og mere konservative ord betyr det det samme som at der oppstår en (bredemt) sjø. Hvorfor så ikke benytte dette uttrykk som allerede har fått hevd i litteraturen? Hvis så var gjort, ville sedimentene ikke lenger ha vært noe problem, og samtidig ville en del andre glaciologiske konsekvenser ha gått opp for forfatteren, bl. a. at isen begynte å kalve. Det fremgår klart at Gjessing (1960, side 325) betrakter den døde is som en monolittisk masse også etter at den er begynt å flyte: «Da ingen vannsirkulasjon i sluttfasen gikk ned under grunnvannspeilet, som da antagelig var nær horisontalt..., ble vannet i dypet ikke lenger utskiftet og isen derfor ikke påvirket til å smelte. Isen ble således under sluttfasen konservert under passhøyden» (utløpet. Sitatet gjelder omtalen av Nordre Atnedal og passhøyden betegner nivået svarende til avløpet i nord).

detaljbeskrivelse av viktige morfologiske formelementer, særlig i Nordre Atnedal og ved Jutulhugget hvor Gjessing har nedlagt mest arbeid i marken. Det er beklagelig, for den store rikdom på former disse steder, mange av dem så utmerket illustrert ved gode fotografier i avhandlingen av 1960, fortjener den største interesse.

Det som Gjessing mente å legge hovedvekten på (uttrykkelig sagt i innledningen til doktoravhandlingen), nemlig den subglaciale drenering, hadde fortjent en bedre skjebne. Forfatteren hadde lykkes bedre i sitt forehavende herom dersom beskrivelsen av subglaciale akkumulasjoner var blitt kritisk begrenset til steder der slike virkelig forekommer.

Denne kritikk kommer kanskje sent, dersom den ansees utelukkende som en imøtegåelse av doktoravhandlingen av 1960. Imidlertid var det ventet at Gjessing etter hvert ville fragå de mest ekstreme synsmåter som den gang ble fremlagt, og en kritikk som denne kunne derfor ansees overflødig. Når Gjessing derimot gjentar sine mest ekstreme påstander, til og med beregnet for et internasjonalt forum og i egenskap av leder for den norske delegasjon til INQUA-kongressen i 1965 (Gjessing, 1966), får spørsmålene en mere alvorlig karakter. Det synes derfor nødvendig å presisere hvilke punkter i Gjessings synsmåter som er mest uakseptable sett fra et kvartærgeologisk standpunkt.

Oslo i januar 1968.

*Per Holmsen.*

(Manuskriptet utarbeidet i desember 1967).

**Litteratur**

*Gjessing, J.*, 1960. Isavsmeltningstidens drenering. Ad Novas No. 3, Universitetsforlaget, Oslo.

— 1966. Deglaciation of Southeast and Eas-Central South Normay. Norsk Geografisk Tidsskrift 20.

*Holmsen, G.*, 1915. Brædæmte sjøer i Nordre Østerdalen. Norges geologiske undersøkelse Nr. 73.

*Holtedahl, O.*, 1960. Geology of Norway. Norges geologiske undersøkelse Nr. 208.

*Hoppe, G.*, 1960. Just Gjessing: Isavsmeltingstidens drenering o.s.v. Hoppes innlegg som første opponent. Norsk Geografisk Tidsskrift 17, side 373-381.

*Lundqvist, Jan, 1967.* Submoräna sediment i Jämtlands Län. Sveriges Geologiska Undersökning Serie C. Nr. 618.

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*Streitlien, I. K.*, 1935. De løse avleringer (i Wolmer Marlow:) Folldal. Norges geologiske undersøkelse Nr. 145, side 26-64.

NORGES GEOLOGISKE
UNDERSØKELSE

# ÅRSBERETNING FOR 1967

VED
STYRET FOR N.G.U.

# Innhold.

# Årsberetning for 1967

## NGU's administrasjon.

Styret for Norges geologiske undersøkelse hadde i 1967 følgende medlemmer:

Professor Jens A. W. Bugge, Universitetet i Oslo, formann,
Direktør Olav Øverlie, Christiania Spigerverk, varaformann,
Professor Niels-Henrik Kolderup, Universitetet i Bergen,
Professor Steinar Skjeseth, NLH, Ås,
Administrerende direktør Karl Ingvaldsen, NGU.

Varamenn:
Direktør Leiv Løvold, Folldal Verk A/S, Folldal,
Professor Rolf Selmer-Olsen, NTH, Trondheim.

I 1967 ble det holdt 5 ordinære styremøter.

Forslag til nytt ansettelsesreglement ved NGU ble oversendt Industridepartementet i desember. Forslag til omorganisering ved institusjonen var under arbeid i 1967.

Den daglige ledelse ved NGU har i 1967 foruten adm. direktør siv.ing. Karl Ingvaldsen, bestått av direktør c.r. Inge Aalstad ved Geofysisk avdeling og direktør, siv.ing. Aslak Kvalheim ved Kjemisk avdeling. Direktør dr. philos. Harald Bjørlykke ved Geologisk avdeling var sykepermittert i 1967 og statsgeolog Thor L. Sverdrup har delvis dekket førstnevntes funksjoner. Kontorsjef ved institusjonen har vært c.j. Per Kr. Gundersen.

## Personale.

### Ansettelser i 1967.

*Administrasjonskontoret:*
Odde, Lise, kontorassistent I, 19. juni

*Geologisk avdeling:*

Berg, Tor, laboratorieassistent II, 16. januar
*Kollung, Sigbjørn, statsgeolog II, 1. april
*Aarsland, Edvard P., laborant i særklasse, 1. april

*Geofysisk avdeling:*

Eidsvig, Per, geofysiker II, 1. januar
*Haugen, Torbjørn, tegner I, 1. april
*Haugan, Arne, avdelingsingeniør II, 1. april
*Uddu, Odd, avdelingsingeniør II, 1. april
*Grønli, Gunnar, tegner i særklasse, 1. april
*Kirkeby, Kåre, instrumentmaker i særklasse, 1. april
*Tetli, Alf, snekker, 1. april
*Sagflaat, Hans, tegner II, 1. april
*Opsahl, Henrik, konstruktør II, 1. april
*Dalsegg, Einar, teknisk assistent I, 1. april
*Melleby, Petter, teknisk assistent I, 1. april, midl.
*Hove, Erling, tegner, 1. november, midl.
*Olsen, Karin, tegner, 1. november, midl.

*Kjemisk avdeling:*

Rossing, Rolf, laborant I, 16. januar
Ryghaug, Per, laboratorieassistent II, 9. januar
Berg, Unni, kontorassistent I, 23. januar
*Storvik, Arne, 1. laborant, 1. april
Øyen, Sissel, kontorassistent I, 1. november

## Avskjed i 1967.

*Administrasjonskontoret:*

Møystad, Torill, kontorassistent I, 30. juni

*Geologisk avdeling:*

Møller, Laura, sekretær I, 30. november

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* Disse personer er gått over fra annen stilling eller engasjement ved institusjonen.

*Geofysisk avdeling:*

Dalsaune, Einar, konstruktør II, 14. januar
Brattli, Johannes, borformann, døde 22. mars
Andreassen, Tore, tegner I, 31. mars
Skauge, Ole, mekanikerformann, 30. september
Hillesund, Tove, bud/betjent, vikar, 26. august

*Kjemisk avdeling:*

Grennes, Johannes, laboratorieingeniør I, 1. juni
Berg, Unni, kontorassistent I, 20. september

Ved utgangen av 1967 hadde NGU følgende personale i heldagsstilling. Den oppførte ansettelsesdato angir tidspunktet da vedkommende ble knyttet til NGU.

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*Administrasjonskontoret:*

Adm. direktør:
Ingvaldsen, Karl, siv.ing., a. 1. januar 1958

Bergingeniør:
Welde, Harald, siv.ing., a. 1. januar 1965

Kontorsjef:
Gundersen, Per Kristian, c. j., a. 1. oktober 1960

Forvalter:
Thorvaldsen, Arvid, a. 1. juli 1956

Bibliotekar:
Ryssdal, Marit, a. 1. oktober 1963

Fotograf:
Aamo, Ingemar, a. 1. august 1962

Regnskapsfører:
Hanssen, Alf, a. 1. august 1955

Kasserer:
Nygård, Hjørdis, a. 17. juli 1961

Kontorfullmektig I:
Ristan, Anne Margrethe, a. 1. mai 1961

Kontorassistent/fullmektig II:
Aursand, Marit, a. 1. august 1965
Widerøe, Grethe, a. 20. juni 1966, midl.
Bakken, Solveig, a. 12. mai 1966
Odde, Lise, a. 19. juni 1967

Vakt- og varmemester:
Wold, Jostein, a. 15. august 1961

*Geologisk avdeling:*

Direktør:
Bjørlykke, Harald, dr. philos., a. 1. august 1958

Statsgeolog I:
Broch, Olaf Anton, c. r., a. 1. juli 1930
Holmsen, Per, c. r., a. 1. juli 1939
Hagemann, Fredrik, c. r., a. 1. mars 1957, midl. tjenestefri til 1. desember
Sverdrup, Thor Lorck, c. r., a. 16. november 1958
Bryn, Knut Ørn, c. r., a. 1. januar 1959
Carstens, Harald, dr. philos., a. 1. desember 1963
Wolff, Christian Fredrik, c. r., a. 16. februar 1960

Statsgeolog II:
Skålvoll, Harald, c. r., a. 1. juli 1957
Thorkildsen, Christian Dick, c. r., a. 1. februar 1960
Gustavson, Magne, c. r., a. 1. januar 1961
Hysingjord, Jens, c. r., a. 15. august 1961
Kollung, Sigbjørn, c.r., a. 1. april 1961
Gvein, Øyvind, c. r., a. 11. desember 1963
Roberts, David, Ph.D., a. 1. juni 1965, midl.

Midlertidig statsgeolog:
Poulsen, Arthur O., cand. min.
Holmsen, Gunnar, dr. philos.

Vitenskapelig assistent:
Nissen, August, c. r., a. 1. januar 1964

Englund, Jens Olaf, c. r., a. 3. oktober 1964
Hovland, Roar, siv.ing., a. 1. april 1965, midl. tjenestefri fra 4/7
Reite, Arne, c. r., a. 5. april 1965
Rye, Noralf, c. r., a. 1. juli 1965
Kildal, Ellen Sigmond, c. r., a. 1. oktober 1965, midl.
Juve, Gunnar, c. r., a. 1. januar 1966
Hultin, Ivar, c. r., a. 1. august 1966

Laboratorieingeniør I:
Graff, Per-Reidar, c. r., a. 1. april 1964

Konstruktør II:
Klemetsrud, Harald Tidemann, a. 1. juli 1957
Sørensen, Erling, a. 1. mai 1963

Teknisk assistent I:
Hatling, Harald, a. 1. februar 1961
Gust, Johan, a. 1. oktober 1962
Røste, Johannes Rye, a. 9. desember 1963

Preparant I:
Jacobsen, Tom, a. 1. mai 1962
Iversen, Egil, a. 1. august 1965

Laborant i særklasse:
Aarsland, Edvard P., a. 1. januar 1959

Laborant I:
Holiløkk, Lars, a. 1. juni 1959
Forbordsaune, Johan, a. 1. januar 1961

Tegner I:
Vikholt, Hallfrid, a. 1. mars 1955
Nergaard, Lajla, a. 1. januar 1962

Tegner II:
Lund, Astri, a. 1. januar 1962
Hemming, Beret, a. 1. august 1964
Evensen, Bina, a. 17. januar 1966

Sekretær I:
Møller, Laura, a. 1. april 1961

Kontorassistent/fullmektig II:
Anderssen, Gunhild, a. 1. januar 1962
Teige, Astri, a. 18. februar 1964, midl.
Iversen, Bjørn Sverre, a. 1. september 1966, midl.

En del geologer ved andre institusjoner og viderekomne studenter har vært knyttet til avdelingen som vitenskapelige medarbeidere under sommerens markarbeid. Videre har diverse personell vært ansatt i korttidsengasjementer.

*Geofysisk avdeling:*
Direktør:
Aalstad, Inge, c.r., a. 1. oktober 1962 (15. juli 1952)

Geofysiker I:
Sakshaug, Gunnar, siv.ing., a. 1. juli 1936
Singsaas, Per, a. 1. september 1937
Hillestad, Gustav, siv.ing., a. 20. januar 1953

Fysiker I:
Breen, Arne, siv.ing., a. 1. desember 1940

Geolog I:
Svinndal, Sverre, c.r., a. 1. juli 1961

Geofysiker II:
Moxnes, Hans Petter, c.r., a. 6. juli 1959
Håbrekke, Henrik, siv.ing., a. 17. august 1959
Sindre, Atle, c.r., a. 24. mai 1961
Eidvig, Per, siv.ing., a. 1. januar 1967

Geolog II:
Tan, Tek Hong, c.r. (nederl. eks.), a. 23. april 1959
Barkey, Henri, c.r. (nederl. eks.), a. 1. desember 1963, midl.

Avdelingsingeniør II:
Uddu, Odd, a. 1. oktober 1952
Haugan, Arne, a. 1. juni 1961

Konstruktør I:
Brandhaug, Kolbjørn, a. 1. september 1958

Konstruktør II:
Opsahl, Henrik, a. 21. april 1953, vikar
Gausdal, Odd, a. 20. september 1957

Borformann:
Vassbotn, Sven, a. 1. september 1963

Teknisk assistent I:
Dalsegg, Einar, a. 1. mai 1966
Melleby, Peter, a. 14. november 1955, midl.

Tekniker I:
Blokkum, Oddvar, a. 17. januar 1961

Tekniker II:
Staw, Jomar, a. 18. juni 1956

Laborant II:
Opdahl, Ragnar, a. 23. oktober 1957

Laboratorieassistent II:
Johansen, Hermann, a. 1. april 1963, midl.

Tegner i særklasse:
Grønli, Gunnar, a. 12. januar 1956

Tegner I:
Haugen, Torbjørn, a. 3. juni 1959
Solvang, Terje, a. 1. januar 1961
Godø, Rolf, a. 1. januar 1966

Tegner II:
Østby, Solveig, a. 14. august 1961
Sagflaat, Hans, a. 1. februar 1966, midl.

Tegner:
Danielsen, Birgith, a. 1. februar 1966, midl.
Olsen, Karin, a. 1. november 1967, midl.
Hove, Erling, a. 1. november 1967, midl.

Mekanikerformann:
Brevik, Bjørn, a. 1. mai 1939, vikar

Mekaniker:
Pettersen, Reidar, a. 25. mars 1952
Gravseth, Odd, a. 10. november 1953

Instrumentmaker i særklasse:
Kirkeby, Kåre, a. 15. september 1951

Snekker:
Pettersen, Norman, a. 18. februar 1946
Tetli, Alf, a. 1. oktober 1958

Sekretær I:
Singsaas, Cathrine, a. 1. oktober 1953

Kontorassistent/fullmektig II:
Wettavik, Vigdis, a. 1. mars 1964

*Kjemisk avdeling:*
Direktør:
Kvalheim, Aslak, siv.ing., a. 1. oktober 1947 (1. oktober 1937)

Laboratorieingeniør I:
Aarvik, Jon, siv.ing., a. 25. august 1950
Faye, Gjert Chr., siv.ing., a. 10. desember 1958
Andreassen, Birger Th., siv.ing., a. 15. februar 1961
Nilsen, Rolf, siv.ing., a. 1. april 1963

Geokjemiker I:
Bølviken, Bjørn, siv.ing., a. 1. mars 1954

Laboratorieingeniør II:,
Ødegård, Magne, siv.ing., a. 1. mai 1961
Krog, Jan Reidar, siv.ing., a. 1. mai 1964
Stige, Leif, c. r., a. 4. januar 1965

Geokjemiker II:
Hvatum, Ole Ø., siv.agr., a. 1. april 1961

Konstruktør I:
Berner, Beate, a. 4. januar 1955
Næss, Gunnar, a. 16. januar 1960
Solem, Knut, a. 1. januar 1961
Flårønning, Asbjørn, a. 1. juni 1964

Konstruktør II:
Bremseth, Asbjørn, a. 9. november 1959

Konstruktør III:
Sivertsen, Tove, a. 9. januar 1958

Teknisk assistent I:
Wik, John M., a. 23. november 1953

Tegner I:
Holmberget, Edna, a. 1. september 1960

Førstelaborant:
Storvik, Arne, a. 1. mars 1964

Laborant I:
Horgmo, Birger, a. 1. mars 1953
Ekremsæter, Jørgen, a. 1. september 1960
Wolden, Odd, a. 1. mars 1963
Kalvøy, Henry, a. 24. mai 1965
Rossing, Rolf, a. 16. januar 1967

Laboratorieassistent I:
Skarholt, Siri, a. 1. januar 1961
Tan, Brith, a. 1. juni 1963
Taftøy, Inger, a. 1. februar 1966

Laboratorieassistent II:
Ryghaug, Per, a. 9. januar 1967

Sekretær I:
Bersvendsen, Jørgen H., a. 1. juni 1957

Kontorassistent/fullmektig II:
Øyen, Sissel, a. 1. november 1967

Ved utgangen av 1967 hadde NGU 143 stillinger, hvorav 125 fast organiserte stillinger og 18 helårsengasjementer. Ved budsjettbehandlingen for 1967 fikk NGU innvilget nye faste organiserte stillinger som statsgeolog II og laboratorieassistent II ved Geologisk avdeling, en stilling som teknisk assistent I i helårsengasjement ved Geofysisk avdeling og en fast organisert laboratorieassistent I-stilling ved Kjemisk avdeling.

I forbindelse med Justerings- og normeringsforhandlingene 1967 fikk NGU lønnsklassehevning for i alt 13 stillinger.

Bidjovaggeundersøkelsene hadde ved utgangen av 1967 3 medarbeidere i helaårsengasjement: Geolog C. O. Mathiesen, bergingeniør P. J. Paulsen og sekretær M. Sandvold.

Geokjemiker B. Bølviken kom tilbake til NGU 14/4 1967 etter permisjon 1½ år for medvirkning i FN-oppdrag i Equador.

Statsgeolog F. Hagemann har hatt permisjon i 1 år i forbindelse med et stipendium fra Industridepartementet for en oljegeolog, og kom tilbake i sin stilling ved NGU 1/12 1967. Statsgeolog K. Ø. Bryn har under permisjonen virket som daglig leder av institusjonens Oslokontor.

## Budsjett og regnskap.

| Statsbudsjettets kap. 3943 | | Budsjett | | Regnskap |
|---|---|---|---|---|
| *Inntekter:* | | | | |
| 1. Oppdragsinntekter | kr. | 755.000,— | kr. | 759.453,19 |
| 2. Salg av karter og publikasjoner | » | 15.000,— | » | 108.602,52 |
| 3. Salg av instrumenter | » | 20.000,— | » | 122.877,10 |
| 4. Andre inntekter | » | 10.000,— | » | 16.091,70 |
| | kr. | 800.000,— | kr. | 1.007.024,51 |

| Statsbudsjettets kap. 943 | | | | |
|---|---|---|---|---|
| *Utgifter:* | | | | |
| 01. Lønninger | kr. | 4.915.600,— | kr. | 5.194.257,25 |
| 10. Kjøp av kontorutstyr | » | 37.000,— | » | 37.475,05 |
| 11. Kjøp av feltutstyr | » | 112.000,— | » | 110.380,46 |
| 12. Kjøp av instrumenter | » | 157.600,— | » | 157.877,16 |
| 13. Kjøp av maskiner og transportutstyr | » | 58.000,— | » | 55.743,23 |
| 15. Vedlikehold | » | 100.000,— | » | 106.526,55 |
| 29. Andre driftsutgifter | | | | |
| 291. Kontorutgifter | » | 159.000,— | » | 176.359,15 |
| 292. Trykningsutgifter | » | 120.000,— | » | 129.761,05 |
| 293. Bygningers drift | » | 170.000,— | » | 196.044,68 |
| 294. Reise- og forpleiningsutgifter | » | 705.000,— | » | 705.326,14 |
| 295. Forbruksvarer | » | 389.000,— | » | 424.044,71 |
| 296. Ymse driftsutgifter | » | 595.000,— | » | 554.024,45 |
| | kr. | 7.518.200,— | kr. | 7.847.819,88 |

| Statsbudsjettets kap. 945 | | | | |
|---|---|---|---|---|
| 20. Undersøkelser | kr. | 439.469,86 | kr. | 260.011,73 |
| Hydrologisk dekade | kr. | 447.252,79 | kr. | 198.257,18 |

Overskridelsen på utgiftsregnskapet skyldes i det vesentligste lønnsreguleringer som er kommet til i perioden. Salg av instrumenter og magnetiske kart over kontinentalsokkelområdene utgjorde forholdsvis store beløp i 1967.

Bidjovaggeundersøkelsene hadde til disposisjon kr. 439.469,85 overført fra 1966.

## Fra virksomheten i 1967.

### Bidjovaggeundersøkelsene.

Feltarbeidet 1967 i Bidjovagge foregikk i forholdsvis liten skala og omfattet utfyllende geologisk kartlegging i feltet, supplerende prøvetaking for analyse av borkjerner og vedlikeholdsarbeid i leiren. Gjennom året har NGU i stor utstrekning bistått Industridepartementet under de pågående forhandlinger om drift i Bidjovagge og som ved årets slutt konsentrerte seg om en avtale mellom staten og A/S Bleikvassli Gruber.

### Repparfjordfeltet.

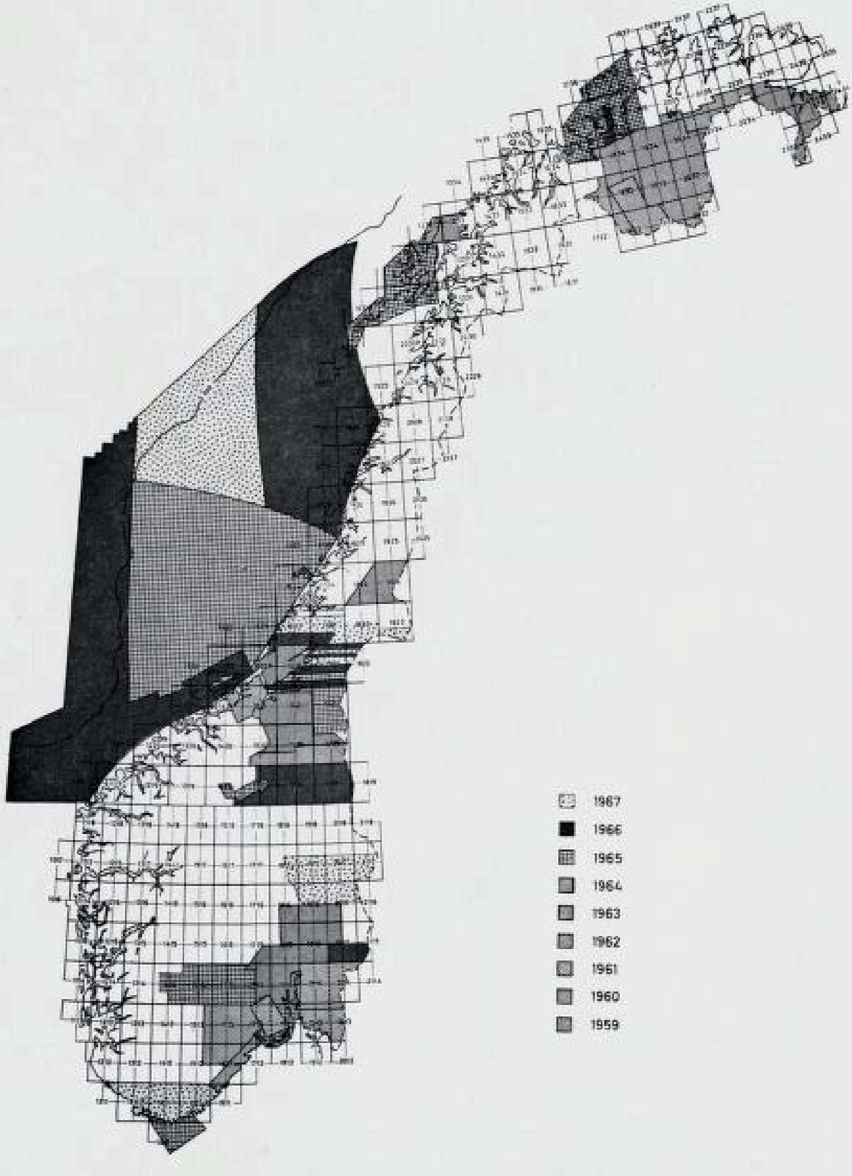
I 1967 gjennomførte NGU som oppdrag for A/S Repparfjord Kobberfelter (A/S National Industri) det fjerde og avsluttende års undersøkelsesprogram. Ved siden av geofysiske og geokjemiske undersøkelser ble det diamantboret 3 600 m i feltet. Den endelige rapport, som ble ferdig redigert på nyåret 1968, viser en malmreserve tilstrekkelig for bergverksdrift. Resultatet av NGU's undersøkelser gir et vesentlig større malmareal enn tidligere antatt, men også en langt lavere kobbergehalt. En stor del av malmen kan avbygges i dagbrudd. Malmberegningen viser henimot 10 mill. tonn malm med gjennomsnittlig 0,7 % kobber, alternativt en mindre tonnasje med noe høyere kobbergehalt.

### Undersøkelser på kontinentalsokkelen.

NGU fortsatte i 1967 flymålingene på kontinentalsokkelen, som nå er dekket fra 62. breddegrad (Stad) og opp til Lofoten. Utover sokkelen dekker det målte område til og med 500 m havdyp. Styrets formann, professor J. A. W. Bugge, ble i 1967 oppnevnt som medlem av NTNF's sokkelkomité hvor professor H. Mosby, Universitetet i Bergen, er formann. I den foregående kontinentalsikkelkomité under NAVF hvor professor Chr. Oftedahl var formann, deltok fra NGU direktørene H. Bjørlykke og I. Aalstad.

I forståelse med Industridepartementet som administrerer prospekteringen etter hydrokarboner på den norske kontinentalsokkel, har NGU i sitt budsjettforslag for 1969 foreslått en kontinentalsokkelgruppe ved institusjonen foreløpig omfattende et personale på 5, hvorav 3 med høyere utdannelse. For budsjettåret 1968 fikk institusjonen bevilget kr. 50,000 til anskaffelser under dette prosjekt.

Under en ekstraordinær bevilgning til NTNF ifølge St.prp. nr. 125 (1966/67) fikk NGU i 1967 kr. 150.000 til fortsatt aeromagnetisk kartlegging over norske kontinentalsokkelområder.




*Utførte geofysiske flymålinger ved NGU til og med 1967.*

### Disposisjonsfond.

Ved budsjettforslaget 1969 har NGU fornyet sin anmodning til myndighetene om opprettelse av et disposisjonsfond ved institusjonen. Utviklingen det siste år har i høy grad bekreftet berettigelsen av at NGU disponerer slike midler. Det vil mellom annet gjøre det langt lettere å bearbeide aktuelle oppgaver som erfaringsmessig melder seg i løpet av et budsjettår.

### Forslag om reisning av laboratoriebygg m.v. ved NGU.

Samtidig med budsjettforberedelsen for 1969 har NGU fremmet et forslag om utvidelse av institusjonens laboratorier og et nytt anlegg for prøvebehandling, dertil innredning av et mindre auditorium ved NGU. Denne sak har vært forberedt i flere år, og etter styrets oppfatning vil det få meget uheldige konsekvenser om denne saken ikke nå blir realisert. De foreløpige planer går ut på noe over 2 500 m² bruttoareal og tar sikte på mer kontor- og laboratorieplass for nye aktiviteter, som for eksempel geokjemisk prospektering. Byggeprosjektet er også nødvendig for at NGU kan utnytte moderne utstyr for anorganiske bestemmelser og få øket kapasitet i analytisk arbeide. Den foreslåtte utvidelse av lokalene ved NGU har også en umiddelbar betydning for utbygningen av universitetet i Trondheim. Utvidelsen ved NGU må primært sees som et ledd i arbeidet i og utenfor institusjonen ved å ta rede på norske mineralske råstoffreserver. Disse får på flere måter en stadig økende betydning for det industrielle næringsliv.

### Samarbeidsutvalg.

Samarbeidsutvalget ved NGU har i 1967 bestått av følgende representanter:

For administrasjonen:

| | |
|---|---|
| Adm. direktør K. Ingvaldsen | Varamann kontorsjef P. Kr. Gundersen |
| Direktør A. Kvalheim | » lab.ing. G. Faye |
| Direktør H. Bjørlykke | » statsgeolog T. L. Sverdrup |
| Direktør I. Aalstad | » geofysiker G .Hillestad |

For de ansatte:

| | |
|---|---|
| Regnskapsfører A. Hanssen<br>Statstjenestemannsforbundet | Varamann sekretær J. Bersvendsen |
| Konstruktør K. Solem<br>Statstjenestemennenes Ingeniørforening | » avd.ing. O. Uddu |

| | |
|---|---|
| Statsgeolog M. Gustavson<br>Embetsmennenes Landsforbund | Varamann geolog S. Svinndal |
| Mekaniker R. Pettersen<br>Norsk Tjenestemannslag | » tegner T. Solvang |

Adm. direktør K. Ingvaldsen har fungert som formann med regnskapsfører A. Hanssen som nestformann.

Det har vært avholdt 4 møter i Samarbeidsutvalget ved NGU.

Av viktige saker som har vært drøftet kan nevnes bl. a. regulering av felttillegget for personale som har feltarbeid. Krav til myndighetene er fremsatt gjennom de respektive organisasjoner. Videre har det vært behandlet instruks for verneutvalg ved NGU og ansettelsesreglement ved NGU. Legekontroll ved Oslokontoret ble etablert i 1967 i samarbeid med Norges vassdrags- og elektrisitetsvesen. Fra 2. halvår 1967 ble det etterbevilget midler til andre velferdsformål for NGU-ansatte.

«NGU-nytt» utkom med 3 nummer i 1967.

## Biblioteket.

Tilveksten av periodisk litteratur var 1468 bind og samlet antall pr. 31/12 1967 er 33 747 bind.

Boktilveksten var på 385 bind og samlet bestand ved utgangen av året er 4398 bind.

I løpet av året er katalogisert 705 titler med 6219 bind, herav periodika 363 titler med 5834 bind, bøker 337 titler med 380 bind og separater 5 titler med 5 bind. I alt pr. 31/12 1967 katalogisert 3392 titler med 11 886 bind.

Det er sluttet 10 nye bytteforbindelser og NGU har nå i alt 293 slike avtaler.

Den endelige katalogisering av periodika har fortsatt, og i alt er nå ca. ⅓ av tidsskriftsamlingen katalogisert. NGU's publikasjonsrekke er katalogisert og grundig analysert. Dette arbeid skal danne grunnlaget for et trykt forfatter- og emneregister.

## Utenlandsreiser og møter i utlandet.

Geolog Tan deltok i en kongress som Organisasjonen for naturvitenskapelige og teknologiske fakulteter i Nederland (ONTFN) avholdt i Leiden 29.—31. mars.

Geolog Barkey deltok i et kurs i ingeniørgeologi som ble avholdt ved University of Wales, Swansea, i tiden 3.—7. april.

Statsgeolog Hysingjord og vit. ass. Hultin deltok i et mikrosonde-symposium som ble avholdt i Gøteborg 18. april.

Fysiker Breen og geofysikerne Eidsvig, Sakshaug og Sindre deltok i den kongress som European Association of Exploration Geophysicists avholdt i Stockholm i dagene 7.—9. juni.

Statsgeologene Gustavson og Wolff deltok i tiden 11.—28. juni i en ekskursjon til De britiske øyer, arrangert av Instiutt for geologi, Universitetet i Oslo. Wolff tilbrakte samtidig et par dager i London for å konferere med dr. Wells ved University College, London, om utgivelse av geologiske kart fra Glomfjord.

Direktør Kvalheim oppholdt seg i tiden 13. juni—14. juli i Canada og USA og deltok bl. a. i 13. Internasjonale spektroskopiske kollokvium i Ottawa, studerte olivinsandproduksjon i staten Washington, geokjemisk prospektering m. m. i Vancouver, Denver og Boston.

Laboratorieingeniørene Faye og Ødegård deltok i 14. Internasjonale spektroskopiske kollokvium i Debrecen, Ungarn, i tiden 5.—15. august.

Adm. direktør deltok i det årlige nordiske direktørmøte som denne gang fant sted i Nord-Jylland i dagene 28.—31. august.

Direktør Kvalheim deltok i tiden 28. august—2. september som komitémedlem i IUPAC-konferansen i Prag.

Vit. ass. Juve deltok i tiden 28. august—4. september som student ved «Second International Summerschool on Quantitative Methods in Reflected-Light Microscopy», Bendheim, Tyskland. I tiden 4.—8. september besøkte han universitetene: Institut de Géologie Appliquée, Sorbonne, Paris, og Université de Caen, Normandie, og i tiden 9.—17. september deltok han i symposium over malmdannende prosesser ved universitetet i St. Andrews, Fife, Skottland.

Direktør Aalstad foretok en reise til Canada og USA i tiden 12. okober—5. november. Hovedformålet med reisen var å delta i Canadian Centennial Conference on Mining and Groundwater Geophysics som ble avholdt i Niagara Falls i tiden 22.—26. okober. I Ottawa besøkte han Geological Survey of Canada, Dominion Observatory, Geoterrex og Canadian Aero Service. Videre var han i Toronto på besøk hos Sharpe Instruments og McPhar Geophysics Ltd. for å se på det geofysiske måleutstyr som disse firmaer produserer. I USA besøkte han Geological Survey i Washington og i New York Lamont Geological Observatory.

Geofysikerne Eidsvig og Sindre foretok en reise til Sverige i tiden 20.—23. november. De besøkte SGU's stasjon i Malåträsk og Boliden Aktiebolag i Boliden for å diskutere problemer i forbindelse med IP-målinger og bygging av IP-utstyr.

## Publikasjoner.

*Carstens, H.*: Exsolutions in ternary feldspars. I. On the formation of antiperthites. Contr. Mineral & Petrol. *14*, 27—35 (1967).
— Exsolutions in ternary feldspars. II. Intergranular precipitation in alkali feldspars containing calcium in solid .solutions. Contr. Mineral & Petrol. *14*, 316—370 (1967).
*Gvein, Ø.*: Kongsvingerfeltets geologi. NGU nr. 246 B.
*Gustavson, M.*: The Caledonian Mountain Chain of the Southern Troms and Ofoten areas. Part I. Basement Rocks and Caledonian Meta-Sediments. NGU nr. 239.
— Petrography and metamorphism in the Precambrian rocks of the Magnor Area, S. Norway. NGU nr. 246 A.
*Kollung, S.*: Geologiske undersøkelser i sørlige Helgeland og nordlige Namdal. NGU nr. 254.
*Roberts, D.*: Structural observations from the Kopperå Riksgrense area and discussion of the tectonics of Stjørdal and the N.E. of Trondheim region. NGU nr. 245.
— Geological investigations in the Snåsa—Lurudal area, Nord-Trøndelag. NGU (Årbok 1966) nr. 255.
*Siedlecka, A.*: Geology of the eastern part of the Meråker area. NGU nr. 245.
*Siedlecka, A.* & *Siedlecki, S.*: Geology of the northernmost part of the Meråker area. NGU nr. 245.
*Sverdrup, Thor L.*: Oversikt over den norske mineral- og stenindustri i perioden 1950—1966. NGU's småskrifter nr. 8, 1967.
— Litt om norsk stenindustri. Tidsskriftet Sten, nr. 1, 1967.
*Sverdrup, Thor L.* og *Sørensen, E.*: Orienterende undersøkelser vedrørende sprøhet og flisighet av bergarter. NGU's Årbok 1966.
*Wolff, F. Chr.*: Studies in the Trondheim Region, Central Norwegian Caledonides. II.
I. Geology of the Meråker area. Introduction.
II. Geology of the Trondheim region. NGU nr. 245.

## Geologisk avdeling.

Statsgeolog T. L. Sverdrup har, bortsett fra 1 måned i 1967, vært bemyndiget som ansvarshavende ved Geologisk avdeling under direktør H. Bjørlykkes sykdom.

### Berggrunnskartlegging.

Seksjonsleder er statsgeolog F. C. Wolff.

Ved seksjonen har i 1967 arbeidet: Statsgeologene H. Carstens, F. C. Wolff, M. Gustavson, S. Kollung, H. Skålvoll samt de vitenskapelige assistentene E. Kildal (Bergen) og A. Nissen. Dessuten har seksjonen hatt følgende engasjerte medarbeidere: Dr. David Roberts„ dr. Anna Siedlecka og professor Stanislaw Siedlecki.

Seksjonen har i tillegg hatt en rekke innen- og utenlandske medarbeidere i sommerhalvåret. Flere av de øvrige geologer ved institusjonen har også utført berggrunnsgeologisk kartlegging.

Statsgeolog H. Carstens har foretatt innsamling av kvartsprøver i Vest-Agder og Trøndelag til bruk for pågående undersøkelser.

Statsgeolog F. C. Wolff har bearbeidet og beskrevet materiale i Trondheimsfeltet fra rektangelbladene på strekningen mellom Snåsa og Vågå. Videre har han ført tilsyn med Kartarkivet og med utgivelsen av den årlige katalog over geologiske feltarbeider. I feltsesongen har han ledet det pågående feltarbeidet innen rektangelbladene Meråker og Essand.

Statsgeolog M. Gustavson har kartlagt på AMS M 711-bladene Øye 1517 II og Vang 1617 III som et ledd i kartleggingen av AMS M 515-bladet NP 31, 32-11 Årdal.

Statsgeolog S. Kollung har foretatt kartlegging på rektangelbladene Trollhetta og Rennebu og bearbeidet det innsamlede materiale. Videre har han fullført bearbeidelsen og beskrivelsen fra Søndre Helgeland og Nordre Namdal.

Statsgeolog H. Skålvoll kartla på gradteigbladene Lappoluobbal og Lavvoaive i Indre Finnmark samt på AMS M 711-blad Våler og Odalen. Sammen med dr. Priem og dr. Verschure fra Amsterdam har han foretatt innsamling av prøver for aldersbestemmelse fra de prekambriske formasjoner i Finnmark.

Vit. ass. E. S. Kildal har gjennomført kartlegging på AMS M 711 Bergen: Bergsdalen, Masfjord, Modal, Fensfjord, Årdal: Larvik og Kyrkjebø samt Sauda: Sand i Ryfylke.

Fru Kildal har administrert og ledet NGU's Vestlandskontor hvor 37 medarbeidere fra Universitetet i Bergen deltar i kartleggingsarbeidet. Hennes hovedoppgave har vært å kompilere kartbladene Måløy (NP 31, 32-10) som snart er ferdig til trykking, og Bergen (NP 31, 32-14) som er påbegynt.

Vit. ass A. Nissen har drevet kartlegging på AMS M 711-kartbladene 1927 IV Sjona, 1927 I Nord-Rana, 1927 II Nesna og 1927 III Elsfjord.

Engasjert statsgeolog D. Roberts har kartlagt på gradteigbladet Rolfsøy i Finnmark og på rektangelbladet Stjørdal i Trøndelag.

Engasjert statsgeolog S. Siedlecki og engasjert vit. ass. A. Siedlecka har fortsatt sine kartleggingsarbeider innen AMS M 515, kartbladet NR 35, 36-5 Vadsø.

Statsgeolog P. Holmsen har foretatt en kompletterende undersøkelse av Oppdal berggrunn med henblikk på å utgi rektangelbladet Oppdal.

Vit. ass. J. O. Englund har foretatt kartlegging på kartblad Lillehammer (1 : 250 000), NP 31, 32-12 (Tretten—Øyerområdet).

### Kvartærgeologisk kartlegging.

Ved den kvartærgeologiske seksjon har følgende arbeidet i 1967: Statsgeolog P. Holmsen, vitenskapelige assistenter A. Reite og N. Rye. Videre har pensjonert statsgeolog dr. philos. G. Holmsen arbeidet på deltid.

Seksjonen har i tillegg hatt en rekke innenlandske medarbeidere i sommersesongen.

Statsgeolog P. Holmsen har foretatt kvartærgeologisk kartlegging på landgeneralkart Jotunheimen. For å få et sikkert bilde av de kvartærgeologiske forhold har en også foretatt en undersøkelse av den vestlige del av Sygnefjell og tilstøtende deler av Mørkedalen.

Vit. ass. A. Reite har foretatt den kvartærgeologiske kartlegging av AMS-bladet NP 31, 32-4, Trondheim.

Vit. ass. N. Rye begynte kvartærgeologisk kartlegging innen AMS-bladet NP 31, 32-15, Odda.

Vit. ass. S. R. Østmo, som er tilknyttet den hydrologiske dekade, har drevet kvartærgeologisk kartlegging på kartblad 1915 I-IV (1 : 50 000) Romerike. Videre har han arbeidet på kartblad Stavanger (1 : 250 000) NO 31-6.

Vit. ass. G. Goffeng som også er tilknyttet den hydrologiske dekade har kartlagt på kartblad Hamar (1 : 250 000) NP 31, 32-16.

Pensjonert statsgeolog G. Holmsen har også fortsatt arbeidet med å systematisere norske grusforekomster.

Vit. ass. N. Rye fortsatte arbeidet med undersøkelse av økonomisk viktige sand- og grusforekomster i Vest-Norge i samarbbeide med dr. G. Holmsen. Feltarbeidet har foregått vesentlig i Hordaland og Sogn og Fjordane.

For utarbeidelse av et grus/sandarkiv for Trøndelagfylkene har vit. ass. A. Reite foretatt befaring og prøvetaking av et stort antall forekomster innen 1 : 250 000 — kartbladene Trondheim, Østersund, Grong og Mosjøen.

### Hydrogeologi.

Seksjonsleder er statsgeolog F. Hagemann. Under hans permisjon i tidsrommet 1/12-66 — 12/12-67 ble seksjonen ledet av statsgeolog K. Ø. Bryn. Ved seksjonen har følgende arbeidet: Statsgeologene F. Hagemann og K. Ø. Bryn, vitenskapelig assistent J. O. Englund og engasjert vitenskapelige assistent L. A. Kirkhusmo.

Samtlige har vært beskjeftiget med oppdrag i forbindelse med grunnvannsforsyning ved boring i fast fjell og løsavleiringer, og det er utført en rekke befaringer i forbindelse med planleggingen av enkelt- og felles vannforsyningsanlegg.

På grunn av liten bemanning ved seksjonen har en ikke fått utført alle oppdrag, og det er også blitt liten tid til bearbeiding av det innsamlede materialet.

Konstruktør T. Klemetsrud har undersøkt mulighetene for grunnvannsforsyning fra sand- og grusavsetninger. I løpet av året er det bygget en rekke rørbrønner forskjellige steder i landet på grunnlag av disse forundersøkelser. Som eksempel kan nevnes at den første prøvebrønnen til Kongsvinger har gitt ca. 7000 l/min. over lengere tid ved kontinuerlig prøvepumping.

Arbeidet med å overføre vannboringsarkivets data til hullkort fortsatte i 1967 og ventes å være fullført i 1968. Det skjer i samarbeid med Forsvarets Forskningsinstitutt på Kjeller.

Arbeidet i forbindelse med den Internasjonale Hydrologiske Dekade fortsatte i 1967. Vit.ass. G. Goffeng og vit. ass. S. R. Østmo er ansatt i forbindelse med dette prosjekt med arbeidssted h.h.v. ved NLH, Ås, og ved NGU's Oslokontor.

Det er etablert regelmessing målinger i en rekke brønner på Romerike. Den kvartærgeologiske kartleggingen på Romerike i forbindelse med Dekaden er påbegynt, og seismiske målinger er utført ved geofysiker G. Hillestad.

## Mineralske råstoffer og bygningssten.

Seksjonens leder er statsgeolog T. L. Sverdrup.

Ved seksjonen har i 1967 følgende vært ansatt: Statsgeologene T. L. Sverdrup, J. Hysingjord, C. D. Thorkildsen og Ø. Gvein. Vit. ass. I. Hultin har delvis arbeidet ved denne seksjon og delvis ved malmseksjonen.

Statsgeolog T. L. Sverdrup har sammen med statsgeolog J. Hysingjord foretatt diverse undersøkelser vedrørende feltspat: I Evje for A/S Norsk Feltspat Co.„ i Østfold for Tiltaksrådet i Rakkestad og videre i Våler.

Som oppdrag for Forskingsgruppe for Sjeldne Jordarter har Sverdrup i samarbeid med Hysingjord foretatt diverse innsamlingsarbeider i Sør-Norge. Videre er det foretatt innsamling av prøver for aldersbestemmelser i det sydøstnorfske prekambrium. Aldersbestemmelsene utføres ved Laboratorium voor Isotopen Geologie, Amsterdam.

Som oppdrag for Elektrokemisk A/S, Fiskaa Verk, har statsgeolog J. Hysingjord foretatt befaringer av Hidra og Trevatn kvartsforekomst, og for S. Lunøe gruvedrift er foreatt befaring av Snekkevik kvartsittforekomst.

Statsgeolog Thorkildsen har som et ledd i arbeidet med oppfølging av flyanomalier, foretatt innsamling av prøver for radiometriske undersøkelser i Oslofeltet og i Dombåsområdet.

Statsgeolog Ø. Gvein har hatt ansvaret for diamantboringer på skifer utført følgende steder: Østre Slidre, Valdres, oppdrag for A/S Valdres Skiferbrudd, Engan i Oppdal, oppdrag for Stenkontoret og Opdalsten A/S, og Imsdal i Snåsa, oppdrag for Stenkontoret. Han har videre foretatt diverse marmorundersøkelser i Verran og ved Deråsbrenne, Namdalseid, og befaringer i Lierne, Høylandet og Årsetfjorden i Nord-Trøndelag.

Vit. ass. I. Hultin har hatt ansvaret for diamantboring på kleberstensforekomst ved Klungen i Leinstrand, oppdrag for Nidaros Domkirkes restaureringsarbeider, og videre har han hatt ansvaret for diamantboring på kalkforekomst ved Tromsdalen i Verdal, oppdrag for Nicolay Buch, Trondheim. Videre har han foretatt kleberstensundersøkelser i Lom som oppdrag for Lom kommune.

## Malm.

Seksjonen har i 1967 hatt følgende ansatt: Vit. assistenter G. Juve og R. Hovland og tekn. ass. J. Gust. Videre har vit. ass. I. Hultin delvis arbeidet for seksjonen.

En er nå godt i gang med registreringsarbeid, beskrivelse og ordning av malmsamlingen, men mangelen på arbeidskraft har sinket arbeidet.

Vit. ass. G. Juve har fortsatt kartleggingen av Lakselvdalens kobber- og kisforekomster, delvis som oppdrag for A/S Sydvaranger. Videre har han gjort endel detaljarbeider innen «Ofotenbassenget».

Vit. ass. R. Hovland har arbeidet med undersøkelse av norske ilmenitt-magnetittforekomster. Følgende forekomster er befart: Seljeseth, Beverfjord, Vågseter og Strømme, alle i Møre og Romsdal, samt forekomstene ved det tidligere Eikeland Verk i Aust-Agder og Tingstad kobbergrube i Frol.

Vit. ass. I. Hultin har som oppdrag for A/S Eidefoss Kraftanlegg undersøkt diverse sulfidforekomster i Vågå og Lom. Videre har han foretatt magnetometriske målinger over og kartlegging av kromittforekomster i Røros.

Tekn. ass. J. Gust har foretatt befaringer av sulfidforekomster i Nord-Østerdal og utført diverse undersøkelser i Bindalen gullfelter. Videre har han foretatt plottingsarbeider av malmforekomster på kartblad 1 : 50 000.

## Laboratorier og preparantverksted.

Kjemisk laboratoriums leder er laboratorieingeniør P. R. Graff.

I løpet av året er det utført 133 silikatanalyser og 343 andre analyser, vesentlig for institusjonens eget behov. Laboratoriet har fortsatt arbeidet med kartotekføring av alle fullstendige analyser av norske bergarter.

Radiometrisk laboratorium var ledet av statsgeolog C. D. Thorkildsen. Det er i 1967 anskaffet et nytt portabelt scintillometer, og det er foretatt radiometriske målinger av såvel prøver innsamlet av NGU's geologer som av innsendte prøver.

Også mineralseparasjonslaboratoriet er forestått av C. D. Thorkildsen. I samarbeide med Laboratorium voor Isotopen Geologie, Amsterdam, er det foretatt innsamling av bergarter med henblikk på aldersbestemmelser som er separert med tunge væsker og på høyintensitetsmagnetseparator.

Ved røntgenlaboratoriet, ledet av statsgeolog J. Hysingjord, er det i løpet av året gjort 317 pulveropptak av egne og innsendte prøver.

Jordartslaboratoriet har utført 62 sprøhets- og flisighetsanalyser for å undersøke bergarters brukbarhet som vegtilslagsmateriale. Videre er det utført 116 kornfordelingsanalyser og sikting og måling av 119 bergartsprøver for analyse av sjeldne jordarter ved IFA. Det er preparert ca. 70 torv- og gytjeprøver for pollenanalyse.

Preparantverkstedet har i løpet av året fremstilt 1609 tynnslip, 652 polerslip og 104 kombinasjonsslip.

### Bergarkivet.

Ansvarshavende for Bergarkivet er sekretær G. Anderssen.

Arbeidet med nyregistrering og nummerering av kartsamlingen ble på det nærmeste avsluttet i 1967, antall kart pr. 31/12 1967 er kommet opp i 1533 nummer.

Arkivet har i 1967 hatt en tilvekst på 66 rapporter: 36 rapporter vedrørende «Industrielle mineraler og bygningssten» og 30 rapporter vedrørende «Malmer». Rapportsamlingen utgjør pr. 31/12 1967 4837 rapporter, hvorav 3843 omhandler «Malmer» og 944 «Industrielle mineraler og bygningssten».

Pensjonert statsgeolog A. O. Poulsen har fortsatt arbeidet i Oslo med å samle inn data og rapporter fra Øst- og Vestlandske bergdistrikter.

## Geofysisk avdeling.

### Feltarbeider.

Geofysisk avdeling har i 1967 utført 46 oppdrag med i alt 1173 feltgruppedager. Av disse ble 15 oppdrag med 329 feltgruppedager utført for egne midler, mens 31 oppdrag med tilsammen 844 feltgruppedager ble uført for oppdragsgivere utenfor institusjonen.

*Geofysiske bakkemålinger og borhullsmålinger.*

For A/S Røros Kobberverk ble det utført omfattende elektromagnetiske målinger i Nordgrubefeltet under ledelse av geofysikerne Sakshaug og Singsaas og i Storwartzområdet under ledelse av geofysiker Singsaas.

For samme oppdragsgiver ble også utført elektromagnetiske målinger med kabelutlegg av i alt 11 diamantborhull på tilsammen ca. 3 000 meter av geofysiker Singsaas.

For A/S Sulitjelma Gruber ble det under ledelse av geofysiker Sakshaug utført elektromagnetiske målinger av to områder, det ene ved Ingeborgvann og det andre ved Baldoaivve.

På Ytterøya utførte geofysiker Singsaas en elektromagnetisk undersøkelse for H. & F. Bachke.

Forsøksmålinger med indusert polarisasjon (IP) ble utført ved en forekomst av kobberkis og molybdenglans ved Langvann i Setesdalsheiene og ved Pustbakken på Røros. I Repparfjord ble IP-målinger utført for A/S National Industri som en fortsettelse av tidligere års målinger, mens et oppdrag ved Storhusmannsberget i Meråker ble utført for Elektrokemisk A/S, Skorovas Gruber. IP-målingene ble utført av geofysikerne Sindre og Eidsvig.

*Flymålinger.*

Til de geofysiske målinger fra fly ble det også i 1967 benyttet et 4-motors fly av type Heron som ble leiet fra Nor-Fly A/S, Hønefoss. Målingene ble ledet av geofysiker Håbrekke.

Det ble fløyet i alt 367 timer og målt en samlet profillengde på ca. 54 000 km.

Den systematiske dekning av landet med magnetiske målinger med profilavstand 500 meter ble fortsatt, og det ble målt områder på Sørlandet, på Østlandet og i Trøndelag på i alt vel 20 000 km$^2$. Elektromagnetisk og radiometrisk måling ble også utført samtidig.

Et ca. 25 000 km$^2$ stort område av kontinentalsokkelen sydvest for Lofoten ble målt magnetisk med ca. 4 km profilavstand og Loran-navigasjon. Denne måling ble finansiert av en ekstra bevilgning til kontinentalsokkelundersøkelser som vi mottok gjennom NTNF, og med dette er hele sokkelområdet fra 62°N til Lofoten dekket med magnetiske målinger.

I løpet av 1967 ble 62 aeromagnetiske kartblad i skala 1 : 50 000 offentliggjort, og antallet slike kart er dermed kommet opp i 142. Det ble solgt 3 kart for de magnetiske målingene over kontinentalsokkelen.

*Seismiske målinger.*

Det ble utført 5 oppdrag med tilsammen 75 feltdager.

For Trondheim biologiske stasjon ble det utført undervannsmålinger på 3 lokaliteter ved Trondheimsfjorden med sikte på å finne egnet sted for nytt havnebasseng. I Vesterålen ble det også gjort målinger under vann på aktuelle steder for 4 bruer som prosjekteres for å knytte de største øyene sammen.

I samarbeid med prof. Olaf Holtedahl ble det lagt opp et måleprogram ved Monaryggen i Østfold for å belyse spørsmålet vedrørende ryggens dannelse og et eventuelt gammelt elveløp fra Øyeren.

På oppfordring fra prof. Holtedahl ble det også målt et profil ved Berger—Frogner på Romerike for å skaffe opplysninger om løsmassene.

Lenger nord på Romerike ble de siste års målinger i forbindelse med den Hydrologiske Dekade fortsatt med et profil sydover fra Hurdalssjøen.

Leder for målingene har vært geofysiker G. Hillestad.

*Geologiske og ingeniørgeologiske undersøkelser i forbindelse med vannkraftutbygging.*

Som oppdrag for Statskraftverkene har det under ledelse av geolog S. Svinndal vært utført geologisk tunnelkartlegging ved Tokke kraftanletgg, Noreanleggene og Trollheim kraftanlegg. Det er ved disse anlegg kartlagt ca. 27 km tunnel. For statskraftverkene har geolog H. Barkey utført ingeniørgeologiske undersøkelser i Jotunheimen. Videre er det ved Rana-anleggene utført geologiske undersøkelser i tilsammen 20 km tunnel. Sammen med geofysikerne Sindre og Eidsvig har geolog Barkey også utført endel forsøk med bruk av IP måleutstyr som hjelp ved ingeniørgeologiske undersøkelser ved registrering av leirslepper etc.

*Malmgeologiske undersøkelser.*

De regionale malmundersøkelsene i Indre Finnmark har fortsatt under ledelse av geolog T. H. Tan. Arbeidet har bestått i slingrammålinger, prøvetaking av morene som et ledd i geokjemiske undersøkelser og geologisk kartlegging.

Geologene Svinndal og Barkey har arbeidet en del i Femundtraktene med oppfølging av flyanomalier, og Svinndal har videre utført undersøkelser i Fensfeltet i forbindelse med oppdrag for «Forskningsgruppe for Sjeldne Jordarter».

I forbindelse med diamantboroppdrag på Ytterøya har geolog Svinndal gjort en del befaringer og utført den geologiske bearbeidelse av kjernematerialet.

*Diamantboringer.*

I løpet av året er det diamantboret 8114 m fordelt på 12 forskjellige oppdrag. Det største oppdraget har vært ved Repparfjord Kobberfelter hvor det for A/S National Industri ble boret 3619 m. På Ytterøya er det for H. & F. Bachke boret i to omganger med tilsammen 1408 m, og for A/S Røros Kobberverk er det i Rødalen boret tilsammen 1680 m. Videre er det boret for kvartsundersøkelser ved Boen ved Kjevik og for feltspatundersøkelser ved Lid i Evje. Diamantboring for skiferundersøkelser er utført ved Valdres skiferbrudd, ved Engan i Oppdal og ved Imsdal i Snåsa. Ved Hylla Kalkverk og i Tromsdalen er det boret for kalkundersøkelser, og i Leinstrand er det utført et lite boroppdrag for undersøkelse av klebersten for Nidaros Domkirke.

Oppdragene har vært ledet av borformennene Gausdal og Vassbotn.

## Verksted- og laboratoriearbeid.

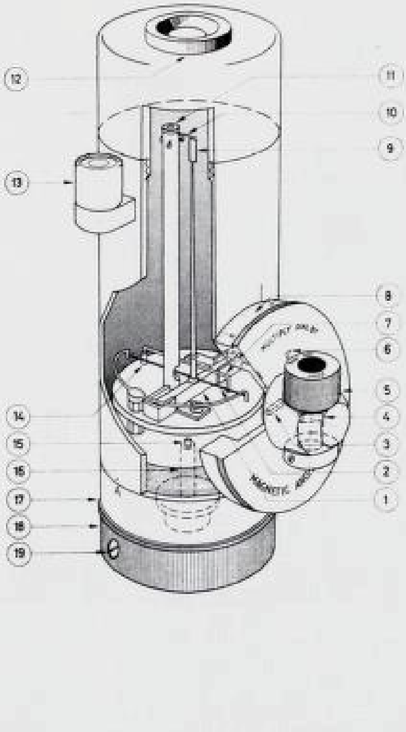
Verkstedet har som vanlig besørget vedlikehold av instrumenter og utstyr, herunder 10 biler, 3 Muskeg beltebiler og diamantboreutstyr.

For salg ble fremstilt 3 stk. måleapparater for slingrammålinger, og 1 stk. susceptibilitetsmåler.

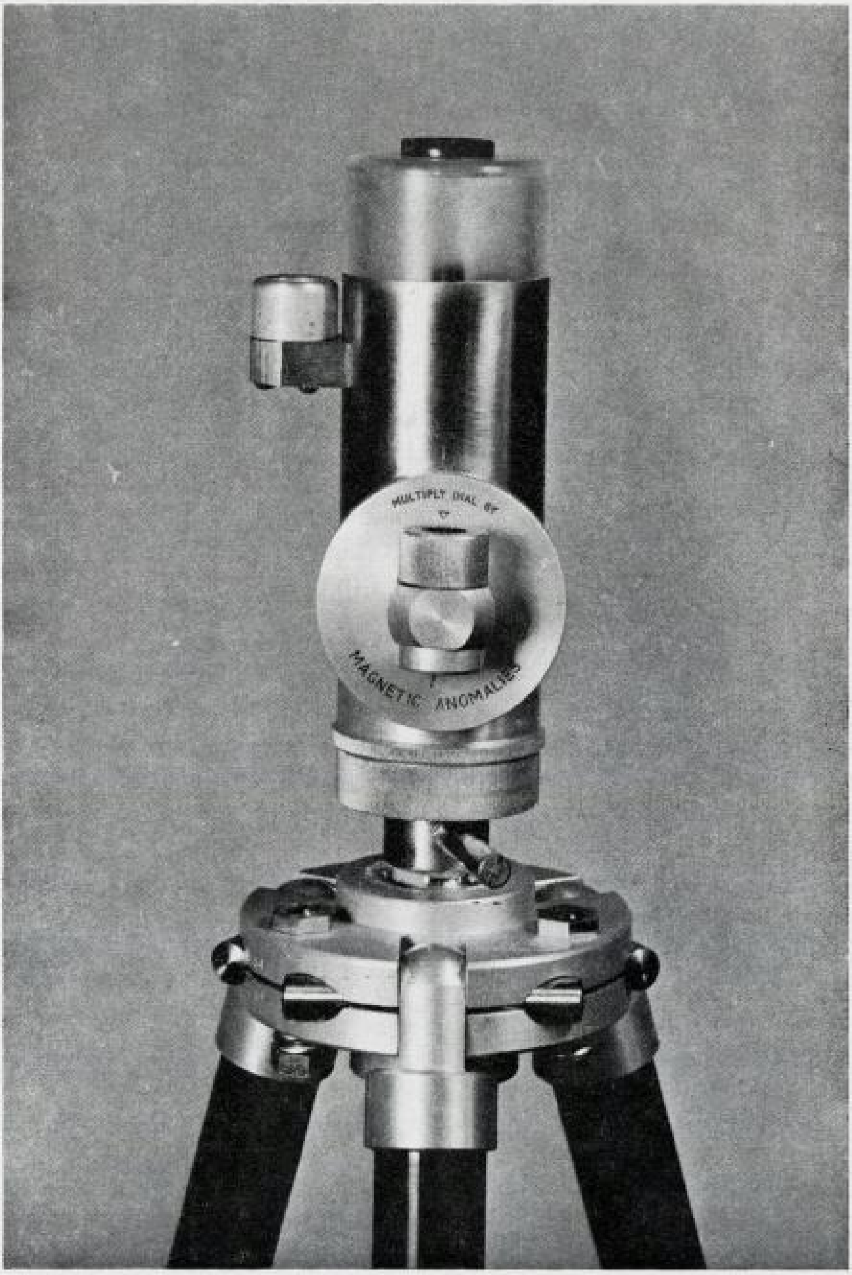
Av magnetometre ble det solgt 58 stk., hvorav 56 stk. utenlands gjennom det svenske firma Craelius i henhold til inngått avtale. Produksjon av en ny serie på 100 stk. magnetometre er påbegynt.

*NGU magnetometer for måling av vertikal og horisontal feltstyrke.*

1. Magnetnål
2. Opphengningstråd
3. Kompensasjonsmagnet
4. Innstillbar kompensasjonsmagnet for valg av måleområde
5. Områdevelger
6. Anviser for måleområde
7. Arreteringsbøyle
8. Skala for avlesing av anomalier
9. Viser festet til magnetnål
10. Merke for innstilling av viser
11. Innvendig libelle
12. Lupe
13. Utvendig libelle
14. Trykknapp for arreteringsbøyle
15. Fast kompensasjonsmagnet
16. Holdeskrue for fast kompensasjonsmagnet
17. Arreteringsring
18. Fot
19. Skrue for nulljustering



Vekt: 0,37 kg
Høyde: 119 m/m
Største bredde: 57 m/m




*NGU magnetometer på stativ.*

## Kjemisk avdeling.

### Spektrografisk og kjemisk analytisk arbeid.

Ledere: Laboratorieingeniør G. Faye (spektrografi) og
laboratorieingeniør B. Andreassen (kjemisk analyse).

Fordelingen av det spektrokjemiske analysearbeidet er utviklet videre i retning av at mer og mer rutineanalyser utføres ved kvantometret og røntgeninstrumentet, mens de vanlige spektrografene brukes til de mange oppgaver som faller utenfor gjennomarbeidede rutiner. Storparten av analysene gjelder mineraler, bergarter og malmer, bl. a. store serier av borkjerneprøver og oppredningsprøver.

Ved de kjemiske analyselaboratoriene har det som tidligere vesentlig vært utført silikatanalyser, malmanalyser, herav til dels omfattende totalanalyser og til dels spesialanalyser i praktisk talt fast bestilling.

Anskaffelsen av atomabsorbsjonsinstrument, som dog vesentlig må benyttes for geokjemisk prospektering, har gjort det mulig å få overført det siste ledd i visse typer kjemiske rutineanalyser til dette instrument. Dette har vist seg å være en stor vinning.

Analysevirksomheten fordeler seg slik med antall bestemmelser:

| Utført av | | Utført for | | | |
|---|---|---|---|---|---|
| Kjemisk lab. | Spektr. lab. | Kjemisk avd. | Geof. avd. | Geolog. avd. | **Kunder** |
| 3 275 | 3 932 | 220 | 23 | 674 | 6 290 |

Kunder er for en vesentlig del bergverksselskap.

I tillegg til tallene i tabellen kommer ca. 30 000 bestemmelser utført ved de geokjemiske laboratorier i forbindelse med geokjemisk prospektering.

### Laboratorium for keramiske og ildfaste materaler.

Leder: Laboratorieingeniør J. Grenness.

For Sjøfartsdirektoratet har en fortsatt arbeidet med å bestemme fuktighetsgrenser for malmkonsentrater som transporteres med skip, et arbeid som kommer til å gå nesten kontinuerlig, da slike konsentrater skal innsendes til prøvning hvert år.

Serier av ildfast stein (forsteritt-blandinger) er undersøkt på fysikalske egenskaper så som: Spesifikk vekt, varmekapasitet, varmeledningsevne, utvidelseskoeffisient, elektrisk ledningsevne m. m.

Forøvrig har laboratoriet som vanlig utført sikte- og slemmeanalyser, spesifikk vektbestemmelser, smeltepunktbestemmelser o. l., bl. a. som delløsning av institusjonens forskjellige oppgaver.

## Geokjemisk prospektering.

Leder: Geokjemiker B. Bølviken.

*Oppdrag:*

Geokjemisk prospektering med bekkesedimentmetoden er utført for 4 oppdragsgivere i følgende områder:

1. I et ca. 300 km² stort område ved Karasjok.
2. I et ca. 200 km² stort område ved Repparfjord.
3. I et ca. 450 km² stort område rundt Folldal.
4. I et ca. 75 km² stort område i Meråker. Her har bergverksselskapet selv gjort feltarbeidet, mens den videre bearbeidelse inkl. bl. a. analysering og kartrapportering er gitt Kjemisk avdeling som oppdrag.

*Egne undersøkelser:*

Metodestudiene nær blymineralisering langs fjellranden i det sydlige Norge har fortsatt. I tillegg til geokjemiker Ø. Hvatums jordprøveprosjekt ved Gjøvik er studiene utvidet til å omfatte bekkesedimentundersøkelser, både i detalj (nær kjent mineralisering) og regionalt.

*Atomabsorpsjon.*

Anskaffelsen av instrument for atomabsorpsjon ble mulig ved et bidrag fra Folldal Verk A/S. Instrumentet kunne tas i bruk sommeren 1967 og har i høy grad innfridd forventningene. Meget stor analysekapasitet og stor nøyaktighet gjør instrumentet meget velegnet for analysering av geokjemiske prøver, og geokjemisk prospektering kan dermed gå lettere og på sikrere grunn enn før.

## Metallurgisk laboratorium.

Ledere: Laboratorieingeniørene J. Aarvik og R. Nilsen.

Ingeniør Aarvik har fortsatt katalysatorforsøk og arbeidet med patentsaker.

Ingeniør Nilsen har studert mineralers evne til å absorbere metallioner fra vandige oppløsninger. Arbeidet er av betydning for geokjemisk prospektering og for forskjellige problemer i forbindelse med gruvevann.


GEOLOGICAL MAP
OF THE
LØKKEN AREA
LEGEND
RIVER GRAVELS AND LARGER PEAT BOG AREAS
GARNET BEARING MICA SCHIST
BIOTITE BEARING MICA SCHIST
HEMATITIC SHALE
SHALES AND SANDSTONES
BRECCIA + CONGLOMERATE
HOVIN GROUP
BASIC PILLOW LAVAS AND TUFFS
ACID LAVAS, TUFFS AND MINOR INTRUSIVES
AGGLOMERATE
ALBITE DOLERITE
STÖREN GROUP
METAGABBRO
GRANOPHYRE
HØLONDA PORPHYRITE
BASIC DYKE
DIP OF $F_1$ SCHISTOSITY
$F_1$ PILLOW ELONGATION DIRECTION
$F_2$ CRENULATION LINEATION
FAULT
OBSERVED THRUST PLANE
LITHOLOGICAL BOUNDARY
MINE WORKINGS
SVORKMO
LAKSØYEN
DRAGSET
RIVER ORKLA
BJØRNLI
LØKKEN
HØIDAL
STORÅS
N.
SCALE
km.

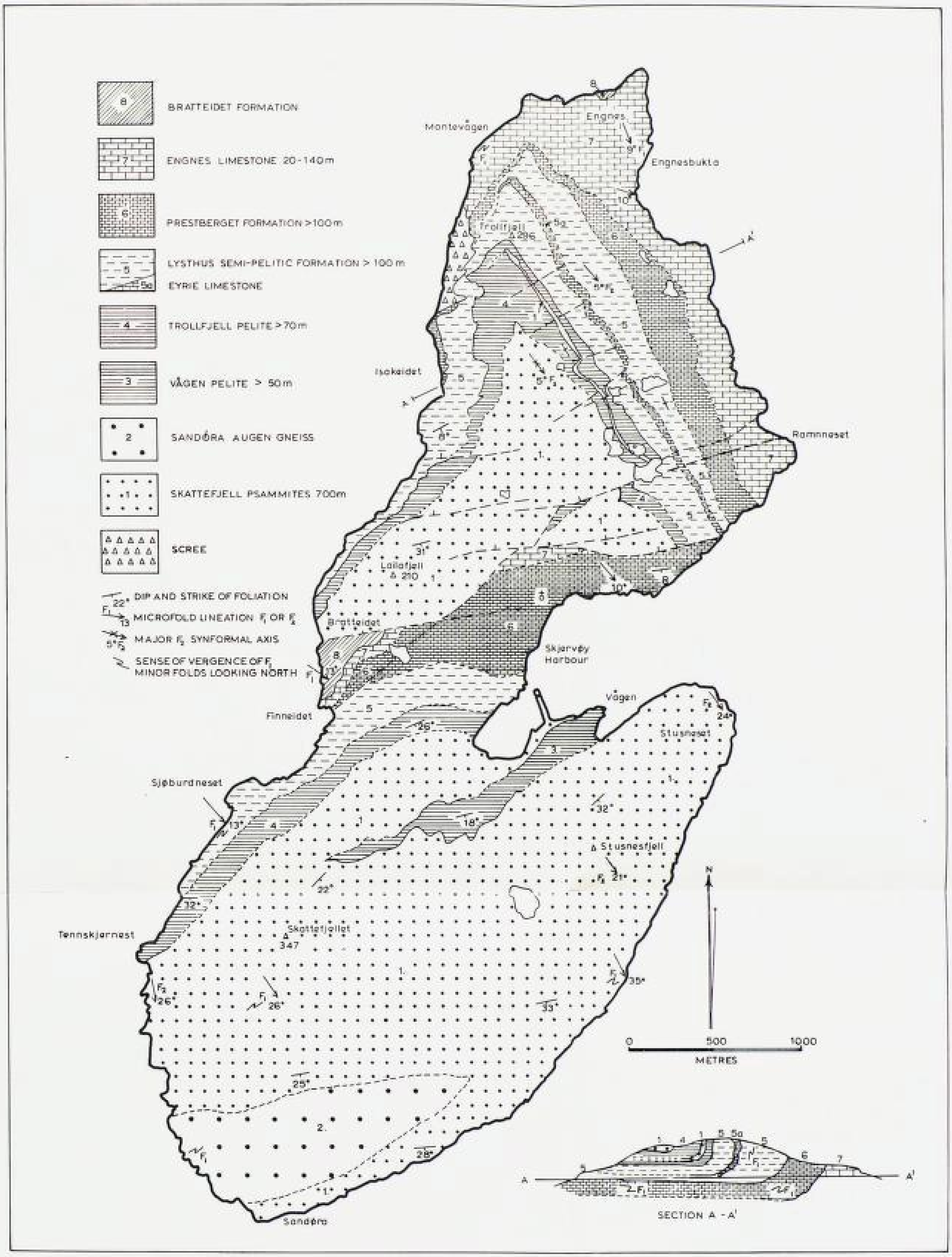



Plate V. Geological map of Skjervøy.

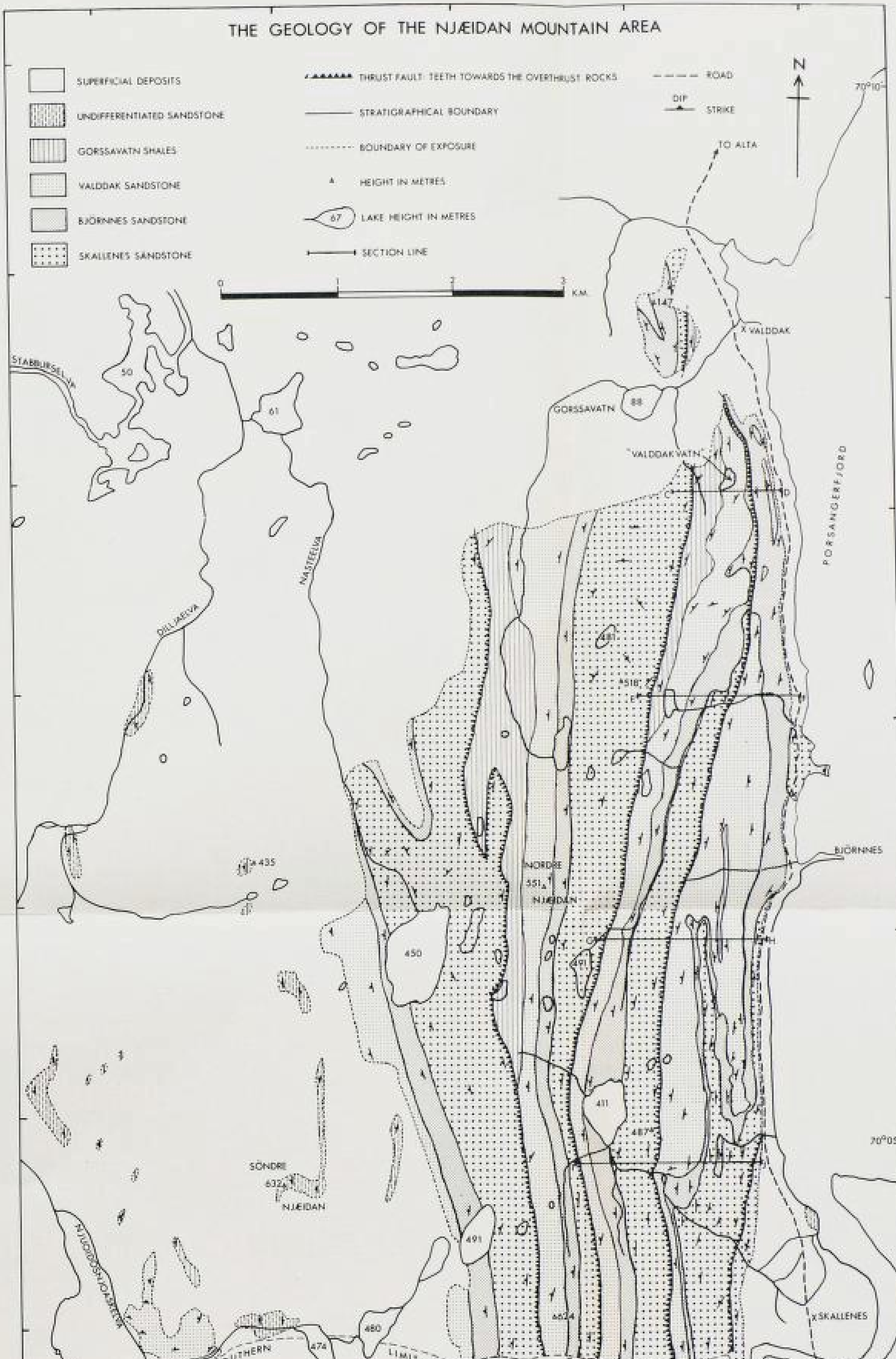



Fig. 9. The Geology of the Njæidan Mountain Area.