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The geology of the Komagfjord tectonic window of the Raipas suite Finmark, Norway

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CONTENTS

Abstract.

The report is based on four summers (1956-59) of field work in an area of approximately 860 km^2. The area is located in western Finnmark, northern Norway, between 70° 10′ and 70° 31′ N latitude and 12° 40′ and 13° 50′ E Oslo longitude (Oslo meridian is 10° 43′ 23″ E Greenwich meridian).

The purpose of the investigation was to study the rocks within a hitherto mainly unexamined area of Precambrian rocks surrounded by Caledonian rocks. Portions of the area near the sea had been visited by a few geologists prior to the initiation of this investigation. It was therefore quite certain that the rocks were Precambrian in age and constituted a window in the Caledonides, but the size of the window was unknown nor had most of the window been studied geologically.

This report establishes the Precambrian age of the rocks and delineates the boundaries of the window. The Precambrian rocks along the western coast of Finnmark were previously called the Raipas formation and known to outcrop in (at least) two windows. As this report differentiates seven formations which constitute two groups within the Komagfjord (the northermost) tectonic window, it is proposed that the Precambrian rocks of the two windows be known as the Raipas suite.

Evidence of at least two periods of deformation of the Precambrian rocks of the Komagfjord tectonic window is presented. The later deformation, in conjunction with the Caledonian orogeny, is most intense in the north-western part of the area. An earlier Precambrian (?) deformation is clearly demonstrable in the eastern part of the area. The latter is correlated with the Karelian deformation of the Precambrian rocks of the interior of Finnmark and northern Finland.

The metamorphic grade of most of the area is that of the greenschist facies. According to the classifications of Barth (1952) and Ram-

berg (1952) the high greenschist and low epidote amphibolite facies are represented. According to Turner (1958) the greenschist and almandine amphibolite facies are represented. The characteristic assemblages are of the 1) staurolite-quartz subfacies of the almandine amphibolite facies, and 2) the quartz-albite-epidote-biotite and 3) the quartz-albite-muscovite-chlorite subfacies of the greenschist facies. Intrusive rocks have mostly been retrograded to facies comparable to the surrounding rocks.

Copper-bearing sulphide mineralization within the area can be classified into two morphological and paragenetic types. Quite common are vein-type deposits, usually quite small, of the "pyritic paragenesis" (Vokes, 1957). The "copper paragenesis" (Vokes, 1957) is known only from one area of disseminated mineralization in arkosic sandstone at Ulveryggen. It is concluded that there is no available evidence which would lead one to predict that the vein-type deposits will support economically profitable exploitation now or in the forseeable future. Specifically, it is believed that the veins will not become larger, richer, or more frequent with depth – – – rather just the reverse. The disseminated mineralization of the "copper paragenesis" at Ulveryggen might be able to support small scale, selective mining at present. It is as yet unknown whether large scale mining would pay.

Limited geochemical prospecting suggests the possibility of as yet unknown mineralization(s) of the disseminated type and indicates that a relatively rapid, inexpensive "stream sediment method" is capable of detecting this sort of mineralization in this kind of largely barren terrian.

INTRODUCTION

Location of the area investigated.

The Komagfjord tectonic window is situated in the *fylke* (= county) of Finnmark, the northernmost *fylke* of Norway. It is between 70° 10′ and 70° 31′ N latitude and 12° 40′ and 13° 50′ E Oslo longitude (the Oslo meridian is 10° 43′ 23″ E Greenwich meridian). It covers parts of four map sheets: Hammerfest, U.3; Repparfjord, V.3; Komagfjord, U.4; and Stabbursdalen, V.4. The nearest city is Hammerfest on the island Kvaløya, to the northwest. The location of the area in relation to the Fenno-scandian peninsula is shown in Fig. 1.

Habitation and communications.

Permanent habitation is confined almost entirely to the coastline. Summer cabins are located along the excellent salmon fishing river Repparfjordelven. The largest village is Kvalsund which consists of about 75 houses.

The main occupations in the area are small-holding, with a few cattle and sheep, and fishing. The main crops grown on the small farms are potatoes and hay.

Fig. 1. Map showing location of the Komagfjord tectonic window.
Kart som viser beliggenheten av Komagfjord området.

During the summer months the nomadic Lapps (Same [pronounced sä'me], as they call themselves and prefer to be called) follow their reindeer to the coastal districts and live in summer encampments. There are three of these within or near the area; one is at Skaidi, one at Vuggenes-tjern, and one near Hulevann.

Communication in the area is by the main road in northern Norway (*Riksvei* 50) which follows very close to the whole southeastern boundary of the area, and by *Riksvei* (= highway) 910, which runs from the junction with *Riksvei* 50 at Skaidi to Hammerfest, following Repparfjordelven and Repparfjord to Kvalsund, and continuing on Kvaløya after a ferry across the sound Kvalsund. A small side road connects Kvalsund to Neverfjord. The remainder of the coastal district has no road connection (though this is planned for the future), but small coastal steamers call at Neverfjord, Porsa, l. Lerrisfjord, st. Lerrisfjord, Komagfjord, and Korsfjord, connecting these areas with Hammerfest, Alta, and the islands Seiland, Stjernøy, and Sørøy.

During the winter the roads are not all kept open, but then the coastal steamer also calls at Kvalsund and at Repparfjord quay.

The interior parts of the map area are accessible only on foot.

Physical features.

Most of the area lies above the timber line, thus exposures of the bedrock are generally very excellent. Close to the coast there is generally a fairly steep slope which is usually wooded until reaching the small farms along the coast. Above the characteristic coastal slope is hilly country—quite intricately dissected, young topography. The highest hills (maximum elevation is 718 m a.s.l.) are near the coast in the northern part of the area (explanation, see p. 11). Small bogs are common throughout the region, the largest occurring in the southern part where the relief is most gentle.

Small lakes, as can be seen from the map, Plate I, are extremely numerous. In these and in the streams connecting them excellent trout are abundant.

Wild animals, other than birds, are uncommon, only foxes and hares having been observed by me during four summers in the area. The bird life is, however, varied and abundant.

The average temperatures are: January, between —7°C and —1°C;

April, between —1°C and 5°C; July, between 10°C and 16°C; and October, between —1°C and 5°C. The yearly average is +1.5°C. During the months of July and August the temperature range is usually between 5°C and 30°C.

The precipitation averages are: January, 25–50 mm; April, 25–50 mm; July 35–60 mm; October, 50–100 mm; and the annual average is 676 mm. The amount of summer rainfall during the four field seasons has been highly variable.

Because of winter snow geological field work, except below about 200 m a.s.l., can hardly be begun before the middle of June. The photograph, Fig. 2, was taken July 9th, 1957, and shows that a considerable amount of snow still remains. The time of the first covering snowfall of the autumn is variable; in 1956 field work was stopped on September 20th because of new snow which covered the ground down to sea level.

There is a two month period during which the sun is above the horizon 24 hours a day. For this reason the crops which are grown mature very rapidly. However, only during very exceptional summers could grains be ripened.

Vegetation (by W. Stuart Watt).

The characteristic feature of the vegetation of the area is the absence of coniferous trees, though pine does occur a little further south (ca. 70°0′ N) near Alta. The most luxuriant vegetation in the region borders the coast. Here *Betula odorata* (birch) is the dominant tree with occasionally *Sorbus aucuparia* (rowan). There is a distinct lack of older trees in this belt, many of the trees being superficially even-aged. Below the tree cover there is a luxuriant vegetation dominated by *Vaccinium myrtillus* (bilberry or whortleberry) and *Empetrum hermaphroditum.*

Exposure is probably the greatest single factor limiting the vegetation. The trees form a narrow belt around the coast and up the valleys, but the affect of exposure was very clearly demonstrated at Båtdalselven where at about 200 m all the trees over about two meters high had their tops killed. The highest trees were found at 430 m, but they were single, apparently young specimens growing in the shelter of a cliff face.

Salix spp. (willow) are of wide distribution, occurring mainly along water courses on the sheltered sides of the lower valleys forming a low scrub layer. In westward draining valleys *Juniperus communis* has been observed as a frequent constituent of this low scrub layer.

Salix herbacea (dwarf willow) is locally particularly worthy of mention. It forms a mat over the ground where snow has lain quite late into the summer and is the only higher plant in this habitat.

Throughout many of the valleys *Vaccinium myrtillus* and *Empetrum hermaphroditum* are co-dominant with abundant *Vaccinium vitis-idaea* (red whortleberry, cowberry), *Phyllodoce coerulea*, and occasionally *Vaccinium uliginosum* (bog whortleberry). *Calluna vulgaris* (heather) has been seen in the valley above Porsa, associated with *Arctostaphylos alpina* (black bearberry), where ericaceous plants were particularly luxuriant.

Betula nana (dwarf birch) is relatively tolerant of exposure and occurs on the higher slopes whenever there is sufficient depth of soil, sometimes growing very densely.

Other plants that are locally important include *Viscaria alpina* which occurs on extensive areas of ultrabasic intrusives and is locally very abundant in the area of Ulveryggen where there is disseminated copper mineralization in the Steinfjell arkosic sandstone. *Dryas octopetala*, a calcicolous plant, has been found over areas of greenstone and greenschist, carbonate rocks, and quartzite. *Rubus chamaemorus* (cloudberry) is in some areas quite abundant and *Polygonum viviparum* was found on most of the flat ground of the higher valleys. Large silver-gray lichens (so-called reindeer-moss) are everywhere conspicuous.

The amount of vegetation cover varies enormously. When least, outcrops of bedrock are virtually continuous (see photo, Fig. 3). The largest continuously covered areas are in the boggy region near Vuggenestjern in the southeast. Even in the tree covered zone bordering the coast the outcrops are usually good. In general, the vegetation cover decreases with altitude.

General geology.

The Komagfjord tectonic window is an area of Precambrian rocks surrounded by overthrust Caledonides. These rocks are closely related to the rocks of the Alta–Kvænangen tectonic window to the south (see Holtedahl, 1918; Zenzen, 1915; Geukens and Moreau, 1958, 1960;

Reitan, 1960), the rocks of the two windows comprising the Raipas suite.* Within the Komagfjord window two groups have been differentiated, the Repparfjord group and the Saltvann group. The age relationship between the two groups is uncertain, though it is believed that the Saltvann group is either younger than or equivalent to the upper part of the Repparfjord group. Later intrusives have intruded both groups. These are probably also of Precambrian age; they are at any rate pre-Caledonian.

In brief, the Raipas suite in the Komagfjord tectonic window includes the following rocks. The lowest formation in the Repparfjord group is the Holmvann formation. The formation consists of a series of mostly rather dark greenish or grayish supracrustal rocks both of volcanic and ordinary sedimentary origin. Carbonate rocks and quartzite are interlayered with the greenstones and greenschists in the northern part of the area. There is probably an erosional unconformity between the Holmvann formation and the overlying formations. In the northeast, east, and southeast the Doggeelv formation, a mostly rather pure quartzite, overlies the Holmvann formation. Above the Doggeelv formation follows the Lomvann formation. It is a slate; in the northeast it is sandy with a gradational contact downwards while in the east and southeast it is finer-grained and has a sharp contact against the underlying quartzite. Along this contact a thin zone of conglomerate can sometimes be found. In the north near Kvalsund the Kvalsund formation, a very dark carbonaceous slate, directly overlies the Holmvann formation.

The Saltvann group consists of, lowermost, the Steinfjell formation, an arkosic sandstone with numerous intraformational conglomerates, which grades upward into the Djupelv formation, a strongly compressed conglomerate consisting mainly of greenstone and greenschist pebbles and cobbles with a little coarse sandy matrix. Uppermost is the Fiskevann formation, a conglomeratic arkosic sandstone in which pebbles of a purple microporphyry are especially characteristic.

* Previously referred to as the Raipas formation. As formations and groups are, on the basis of this paper, now differentiated within what has heretofore collectively been called Raipas formation, the name Raipas suite is proposed for all of the rocks of the two tectonic windows along the coast of northern Troms and western Finnmark. (See Anonymous, 1961, for code of stratigraphical nomenclature for Norway.)

The name Raipas is from the mountain called Unne (= Little) Raipas at Alta and was proposed by T. Dahll.

Fig. 2. Photograph taken towards southeast from atop Skinnfjell (718 m a. s. l.) showing general uniformity of maximum elevations throughout much of the area. (Photo, B. E. Borgen).

Mot sydøst fra Skinnfjell (718 m.o.h.). Viser like høyder på toppene over en stor del av området.

Fig. 3. Photograph across Bollevannene (F4) showing the exellence of outcrops at higher elevations (Photo, B. E. Borgen).

Bilde fra Bollevannene (F4) som viser snaufjell i de høyere delene av området. (Foto, B. E. Borgen).

The topography is very young. As is seen in Figs. 2 and 3, the elevations of the hilltops are mostly quite uniform. This is interpreted as representing nearly the Precambrian peneplain which has been intricately dissected though is as yet far from well-drained. The greatest elevations of the Precambrian are found in the north near the coast, at Skinnfjell (718 m) and Klakkeggen and Fisketind (both 695 m). It is believed that due to steep angle thrusting associated with the overriding of the Caledonides these parts of the Precambrian rocks have been elevated above the general level of the Precambrian peneplain. The boundaries of the tectonic window are lower on all sides than the interior parts of the window. This may be due to doming of the Precambrian surface in conjunction with the Caledonian orogeny or due to the pre-existence of an antiform which forced the Caledonian thrust plates to bend upwards. In either case the impediment which the part of the antiform to the northwest, i.e., direction from which the Caledonian thrusting came, would represent explains the fact that high angle thrusting in the Precambrian is most pronounced along the

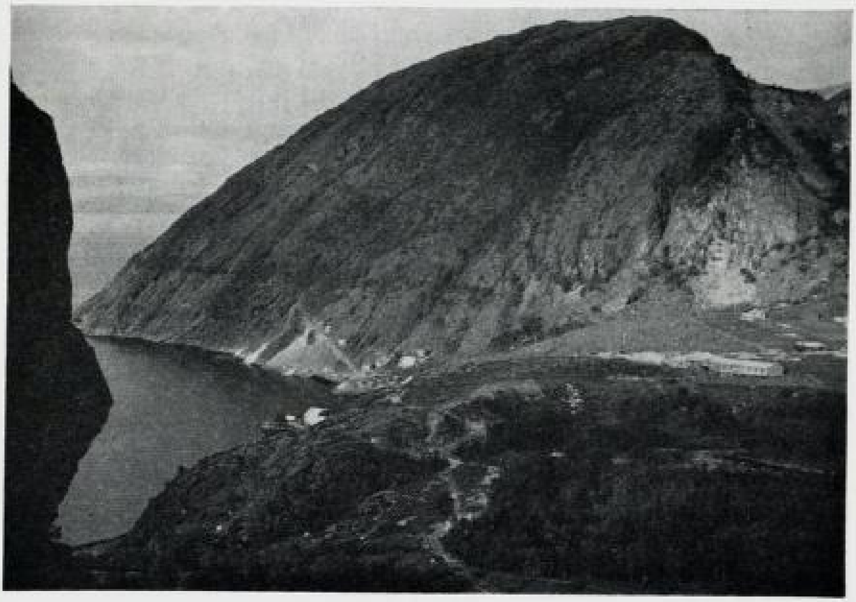


Fig. 4. Photograph at Porsa (D3) showing two clearly marked strand lines. The elevation of the hilltop is 267 m. a. s. l.
Bilde fra Porsa (D3) som viser to tydelige strandlinjer. Fjelltoppen er 267 m. o. h.

northwestern zone. This part served as a buttress which shielded the remainder of the window. In the process it was strongly deformed and, in a sense carried along by the over-riding masses, simultaneously over-riding the other Precambrian rocks to the southeast.

There is considerable evidence of ice activity during the most recent glaciation. "U" shaped valleys (e.g. Kvalsunddalen; Repparfjord-dalen), glacial striae primarily indicative of movement towards the northwest, and morains (very noticeable along the side of Repparfjord and between Nagjetvann and Vuggenestjern) have been observed. Glacial erratics also attest to ice movement towards the northwest. The reader interested in the Quaternary geology of the area is referred to Marthinussen (1961).

Relatively recent isostatic uplift is indicated by several strand lines, two of which are clearly evident in Fig. 4.

Previous work in the area.

Visits to parts of the Komagfjord tectonic window have been made by a few geologists, though no attempt has been made previously to establish with certainty the limits of the window or to make a systematic investigation of the types of rock represented and their distribution and structure throughout the entire window. Previous to this investigation most of the area had not been visited by a geologist.

Dahll's geological map of northern Norway dated 1866–1879 (in Reusch et al., 1891) shows an area of what he called the Raipas system near Kvalsund. Reusch (Reusch et al., 1891) reports having visited Kvalsund and gives a brief description of the rocks between Kvalsund and Beritsjord.

In 1916 Th. Vogt mapped a part of the area which lies on the Hammerfest, U.3, map sheet. A manuscript copy of his map is to be found in the map archives of Norges Geologiske Undersøkelse.

Holtedahl (1918, p. 110) published a map with geological observations along the coast from Korsfjord to st. Lerrisfjord and on his map of Finnmark (1918, Plate XXI) shows, quite correctly, the boundaries of the window along the coast.

During the years he directed the mining operations at Porsa mines, Kvalheim mapped parts of the area between Neverfjord, the Porsa mines at Grubevann, and Porsa.

In 1951 Strand (1952) began mapping on the Repparfjord, V.3, map sheet, and included most of the Raipas suite which occurs on that map sheet.

Vokes (1957) has studied the types of copper sulfide parageneses which occur within the Raipas suite.

Present investigation.

The present investigation began in the summer of 1956 at the suggestion of Sven Føyn, then director of Norges Geologiske Undersøkelse. It is a part of the Geological Survey's contribution to the Government's "North Norway Plan", which provides for the investigation and development of the economic potentialities of the northern part of the country. In this connection the purpose of this investigation was to acquire general geological knowledge of a heretofore essentially uninvestigated area and thereby provide the necessary basis for any possible future evaluation of resources and economic development within this area.

The summers of 1956, 1957, 1958, and 1959 have been devoted to the field work. The winter seasons have been used for the petrographic studies and map work, done primarily at the offices of Norges Geologiske Undersøkelse at the Geologisk-Mineralogisk Museum, Oslo, and completed at Stanford University, Stanford, California, U.S.A.

Much work remains to be done in this area and in related areas before a definite solution can be offered to the problems of the stratigraphy, especially of the Holmvann formation. Because of the size of the area and the limited time available it has been impossible to attempt to solve such a problem. The rocks are dark and mostly schistose and from even a short distance are of very uniform appearance and there have not been found good marker horizons. Therefore, very detailed studies would have to be made to arrive at a full understanding of the stratigraphy and structure of the Holmvann formation. The aim of this investigation has therefore been limited to solving the general stratigraphic and structural problems and to give some idea of the petrographical variations which occur within the various map units.

The mapping was done mostly on 1 : 50 000 enlargements of the four 1 : 100 000 map sheets previously mentioned. For the southern part of the area on the Hammerfest, U.3 map sheet, aerial photographs at ca. 1 : 20 000 of high quality were available. Aerial photographs of the entire area are now available but were not available at the time the mapping was done, with the exception noted above. The quality of the Hammerfest, U.3, map sheet is so poor that it could not be used as a base map. Large areas of that map bear no relation to reality. Therefore a drainage map has been made from a mosaic of aerial photographs. The other three map sheets are of variable quality but have been used as the basis for the geological map, Plate I.

Acknowledgements.

I would like to thank Mr. Sven Føyn, former director of Norges Geologiske Undersøkelse, for suggesting the investigation, for the facilities which have been made available to me, and for two valuable visits in the field during the summers of 1956 and 1957.

Special thanks are due to the men who have assisted me in the field. During the summer of 1956 Mr. Kåre Fagerlund of Porsa acted as my assistant and, with his first hand knowledge of the terrain and the people of the area, was invaluable in helping me to become acquainted in a new area. His active interest and zeal were also greatly appreciated. During the summer of 1957 Mr. W. Stuart Watt, of Durham University, and Mr. Bjørn Emil Borgen, Oslo, were my assistants. I wish to thank Mr. Watt especially for his botanical notes (p. 7–8) and for assisting with mapping. Mr. Borgen is due thanks for a number of excellent photographs (not all of which could be included in this report) and for his excellent maintenance of our numerous camps that summer. Mr. Lars Kirkhusmo, University of Oslo, was my helpful assistant during the summer of 1958; his cheerful assistance in all phases of the field work and field life greatly facilitated my work. In 1959 Mr. Richard Varne, Manchester University, and Mr. Tom Jacobsen, Oslo, assisted me in the field and were responsible for taking the stream sediment samples for the geochemical prospecting program which was begun in cooperation with Statens råstofflaboratorium, Trondheim.

Mr. Helge Øien and his family, of Repparfjord, deserve special thanks for the kind hospitality they showed me and my assistants on very numerous occasions during the four summers of field work.

Dr. Harald Bjørlykke, present director of Norges Geologiske Undersøkelse, has continued the interest shown by his predecessor in this investigation. The maps and drawings have been drafted by Mrs. Lajla

Nergaard and Mr. Perfecto Mary, the necessary thin sections have been made mostly by Mr. Knut Jacobsen, and the manuscript has been typed by Mrs. Eli Holmsen and Mrs. Walderhaug. The remainder of the staff of Norges Geologiske Undersøkelse have assisted me in numerous ways and to all of them I extend my thanks.

STRATIGRAPHY

The rocks of the Komagfjord tectonic window are Precambrian and in all probability of Karelian age (see e.g., Holtedahl, 1953; Reitan, 1960, in press). In part they are surprisingly little metamorphosed and tectonized and include types of rocks in which fossils could be expected to be well preserved. However, all search for fossils has been with negative results. Not even stromatolites, which can often be seen in the carbonate rocks of the Kvænangen window (Holtedahl, 1918; Geukens and Moreau, 1958, 1960; Reitan, 1960) have been observed.

The mapping of the Komagfjord tectonic window has been essentially of a reconnaissance nature and therefore the detailed problems of the stratigraphy within map units have been beyond the scope of the work. The broad features of the stratigraphy are, for the most part however, clear.

The legend of the map, Plate I, shows the presumed stratigraphic succession and the discussion which follows will be in the order from oldest to youngest, except where approximate equivalent age makes this impracticable.

Repparfjord group.

The dominant group of rocks within which a sequence of relative age can be determined has been called the Repparfjord group. Rocks quite typical of most of the formations belonging to this group and some relatively uncommon varieties can be seen along or near Repparfjord.

Holmvann formation.

The oldest formation within this group is the Holmvann formation. It is called a formation at this time as it constitutes a map unit in this report and accompanying map. It is clearly capable of being differentiated into numerous subdivisions but such differentiation could only be made for the whole unit after extensive detailed mapping. Schistosity generally parallel to the direction of the major fold axes (mainly NE–SW) is well developed. Original features, whether sedimentary or volcanic, are usually difficult to distinguish and individual layers cannot easily be recognized and cannot be followed. No characteristic marker horizons have been found. The impression has been obtained that individual lithologic units are not very persistent along the strike direction. To what extent this may be due to differences in response to tectonization or is a primary feature has not been determined. Very likely it is the result of a combination of the two.

The formation consists of a series of stratified rocks of supracrustal origin and is dominated by dark greenish and/or grayish to black fine-grained rocks of both volcanic and sedimentary origin. Although lithologically and petrographically quite variable they are of monotonously uniform appearance from even a few meters distance. The petrographic types will be discussed in more detail later (see p. 29–42). However, fine-grained matrix conglomerates of extremely variable thickness are not uncommon and quartzitic and carbonate rocks occur within the unit. The total thickness of the formation is probably variable as it appears that a number of the lithologically different types are individually of quite variable thickness and that the formation has been subjected to erosion before the deposition of the next overlying unit. There may also be erosional breaks within the formation but not any apparent deformation of the formation until after overlying formations had been deposited. At no place within the Komagfjord tectonic window has the base of the formation or any sign of an underlying formation been observed. This means that no more than approximate limits for the minimum thickness of the formation can be estimated.

Holtedahl (1918) measured 800 m of greenstone with interstratified shales in the vicinity of Alta, but this was a measure of what is exposed. The bottom is not exposed near Alta.

I estimate that the thickness of the Holmvann formation is at least 2000 m and very likely more. It cannot be appreciably less than this in the central part of the map area and there is no basis for a guess as to what maximum thickness the formation may reach.

Doggeelv formation.

The formation immediately overlying the Holmvann formation in the eastern and southeastern parts of the map area is the Doggeelv formation. There appears to be an erosional unconformity between the Holmvann formation and the Doggeelv formation. The Doggeelv formation is not present in the northern part of the area, near Kvalsund (F 1), where the Kvalsund formation (see p. 20) immediately overlies the Holmvann formation. The Doggeelv formation is partly gradational upwards into the Lomvann formation. This is especially the case north and east of Rødfjell (I 3). In this area the boundary between the formations as shown on the map (Plate I) is arbitrarily drawn to correspond to the line below which the rock is essentially a very pure quartzite of light color and without appreciable admixture of fine-grained dark material. Near the eastern and southeastern boundary of

Fig. 5. Shows cross-bedding in Doggeelv (quartzite) formation.
Viser kryss-skiktning i Doggeelv (kvartsitt) formasjonen.

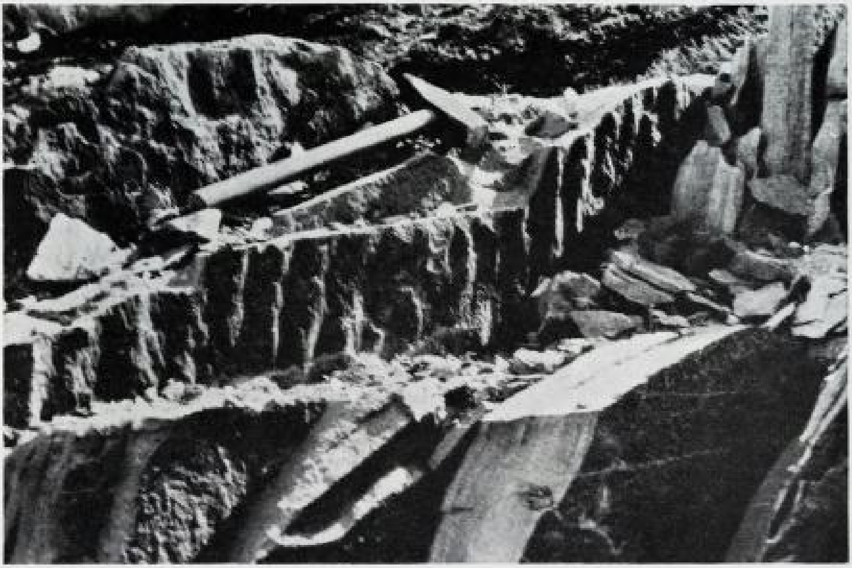


Fig. 6. Ripple marks in Doggeelv formation.
Bølgeslagsmerker i Doggeelv formasjonen.

the window the contact between the Doggeelv formation and the Lomvann formation is generally quite clearly marked where exposed, although exposures within the tectonic window are poorest east of the river Repparfjordelv and near the lakes Nagjetvann (F 6) and Vuggenestjern (G 6).

The Doggeelv formation is mostly a very pure, white orthoquartzite. In some places it is somewhat calcareous, it generally contains some micaceous minerals, and it is rarely conglomeratic. Ripple marks and cross-bedding can be found (see Fig. 5, 6,) making up-down determinations certain.

The thickness of the formation is not uniform, this being partly due to the mapping convention adopted where the boundary between it and the overlying formation is gradational. However, there is a real thinning of quartzose sedimentary rock towards the north. The maximum thickness of the formation is believed to be not less than 1500 m and may be as much as 2500 m; the uncertainty arises from the rapid changes of dip (generally towards the SE but sometimes towards the NW) and variability of strike. As mapped, the minimum stratigraphic thickness between the Holmvann formation and the Lomvann formation is ca. 100 m, however it is to be remembered that here the Lomvann formation is very quartzose—actually an impure quartzite—and the boundary is transitional and arbitrary as drawn.

Lomvann formation.

The Lomvann formation overlies the Doggeelv formation. In the vicinity of Fægfjord (H 1) the rock immediately overlying the Holmvann formation has been mapped as Lomvann formation. Here the Lomvann formation is an impure, rather dark grayish, medium fine-grained quartzite. North of Rødfjell and near Lomvann (I 3) the lower part of the formation as mapped is similar but it becomes more shaley higher in the section. East of Repparfjordelv there appears to be a sharp change of lithology marking the boundary between the Doggeelv formation and the Lomvann formation. The Lomvann formation is here a grayish-greenish rather light colored shale. Southwestwards along the strike the Lomvann formation continues to be a shale without appreciable admixture of sand-sized material. Where Repparfjordelv crosses the contact between the Doggeelv and Lomvann formations (H 6) a thin conglomerate was noted at the contact. Farther southwest near n. Vuggenesstein (G 6) the Lomvann formation is partly mottled with reddish shale, the reddish color being more common southwestwards.

The top of the Lomvann formation has not been observed nor has any indication of an overlying formation been found. It is found only along the boundary of the tectonic window. Therefore, only an estimate of the minimum thickness can be made. It appears that the minimum thickness must be on the order of 1000 m, perhaps approaching 1500 m, although the area in which the greatest apparent stratigraphic thickness of the formation is found is also the area in which exposures are worst. It is therefore difficult to determine whether or not folding has caused any repetition of strata or whether faulting or folding associated with the overthrusting of the Caledonides has resulted in an apparent increase in the thickness.

Kvalsund formation.

In the northern part of the area (F–G 1–2) the Kvalsund formation overlies the Holmvann formation. It is therefore, in the absence of any possible fossil evidence, correlated with the Doggeelv and Lomvann formation and on the map (Plate I.) is shown in the same color as the Lomvann formation. It is a very dark, usually black, carbonaceous slate. Cleavage is well developed and only very rarely it is possible to find a surface on which bedding can be observed. This has most often been possible on boulders which were not in place. Bedding has been observed to be at a large angle to the cleavage. The cleavage when observed in outcrop is very steeply dipping. The formation is not very resistant to weathering or erosion and is usually found forming gently undulating slopes or valley bottoms.

The thickness of the Kvalsund formation is difficult to estimate. Southwest of Kvalsund (F 1) it is wedged between thrust plates the behavior of which has been mainly controlled by the rocks of the Holmvann formation. Between Langørvann (G 1) and Kvalsund, where the greatest horizontal expanse of the formation is to be found, it appears to lie in a structural depression near the intersection of at least three thrust faults. In this area it appears to be mostly fairly flat-lying insofar as this can be determined from the small, ground level exposures of the rock with its well developed slaty cleavage. The whole area in which the formation is exposed has been complexly deformed and neither the top of the formation nor an overlying formation have been observed. The minimum thickness of the formation, however, must be at least 200 m and more likely approaches 500 m. There is no evidence upon which to base an estimate of the maximum thickness.

Summing the thicknesses of the formations constituting the Repparfjord group–Holmvann formation = 2000 + m, Doggeelv formation = 1500 to 2500 m, Lomvann formation = 1000 to 1500 + m and Kvalsund formation = 200 to 500 m, and noting that the Kvalsund formation does not overly the Holmvann formation where the Doggeelv and/or Lomvann formations do—yields an estimate of the thickness of the Repparfjord group of 4500 m or more. However, there is no necessary justification for the implicit assumption above that the Holmvann formation is equally thick where it is overlain by the Doggeelv and Lomvann formations as elsewhere. In fact, the indications that there were several basins into which the sediments overlying the Holmvann formation were deposited (see p. 64) and the probability that these basins were due to erosion and/or differences in the elevation of the top of the Holmvann formation, make such an assumption unjustified without positive supporting evidence. It is therefore difficult to determine a minimum thickness other than that of the Holmvann formation itself —i.e., 3000 + m.

Saltvann group.

Within the Saltvann group it has been possible to determine the relative ages of the three formations constituting it. However, the age relations between the rocks of the Saltvann group and those of the Repparfjord group have not been firmly established on the basis of the present study. Neither has correlation and comparison with other areas of Precambrian rocks in northern Fenno-Scandia made possible unquestionable designations of relative age.

Within the Komagfjord tectonic window the rocks of the Saltvann group are separated from those of the Repparfjord group by fault contacts. Towards the northwest the Repparfjord group is thrust upon the Saltvann group; towards the southeast there is a high angle fault (mostly very near vertical) with a mylonitized zone marking the contact between the groups. The sense of movement along this fault has not been determined. Both the thrust fault and the high angle fault disappear beneath the Caledonides near Hermanvann (D 4).

The only observations approaching direct evidence concerning the relative ages of the Repparfjord and Saltvann groups are those on the types of pebbles found in the conglomeratic Djupelv formation. These are predominantly greenstone and greenschist with some calcareous and quartzitic pebbles and some jasper pebbles. The Holmvann formation consists primarily of greenstone and greenschist, with layers of calcareous rocks (both limestone and dolomite) and quartzite, and within the carbonate rock immediately south of Neverfjordvannene (E 2–3) jasper veins have been found. It is therefore possible that pebbles in the Djupelv formation have been derived from erosion of the Holmvann formation.

There is some indication, beyond that found in the area covered by this report, that there were several basins of deposition underlain by the Holmvann formation and its equivalents into which sediments of differing character were deposited (see p. 64). It was indicated above that the Kvalsund formation is believed to be the equivalent of the Doggeelv and/or Lomvann formations. It may be that the Saltvann group is equivalent to or younger than the upper formations of the Repparfjord group. Though the evidence is not strong this is thought to be the case.

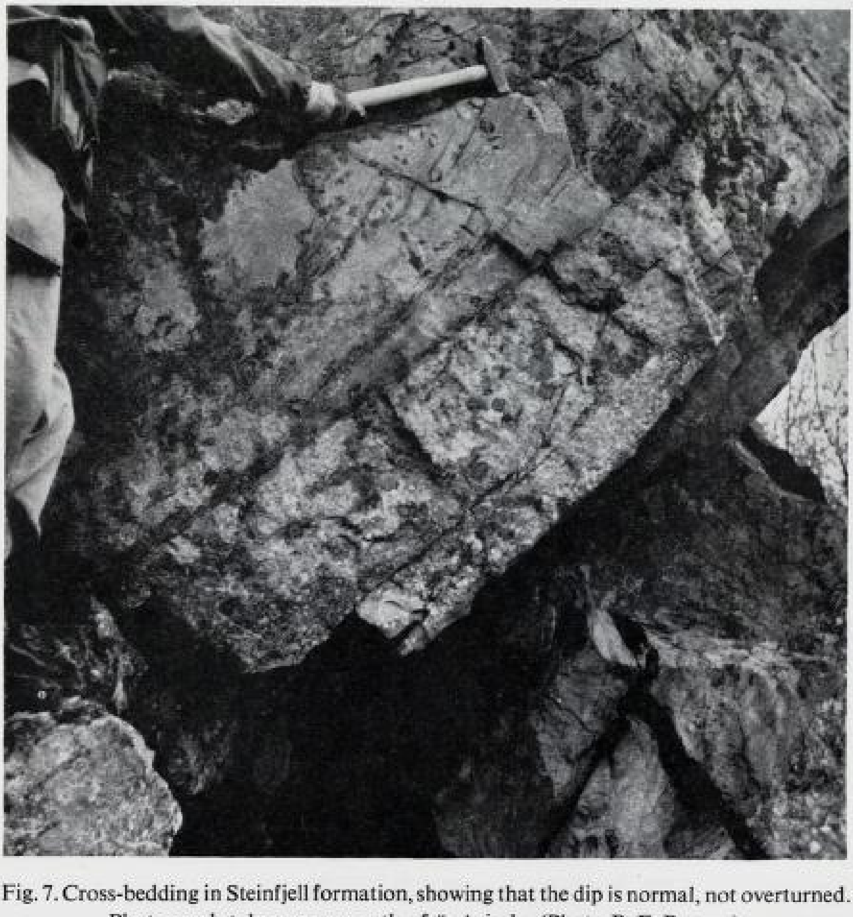


Fig. 7. Cross-bedding in Steinfjell formation, showing that the dip is normal, not overturned. Photograph taken near mouth of ö. Ariselv. (Photo B. E. Borgen).
Krysskiktning i Steinfjell formasjonen som viser at lagene ikke er invertert. Ovenfor veien på sydøst siden av ø. Ariselv.

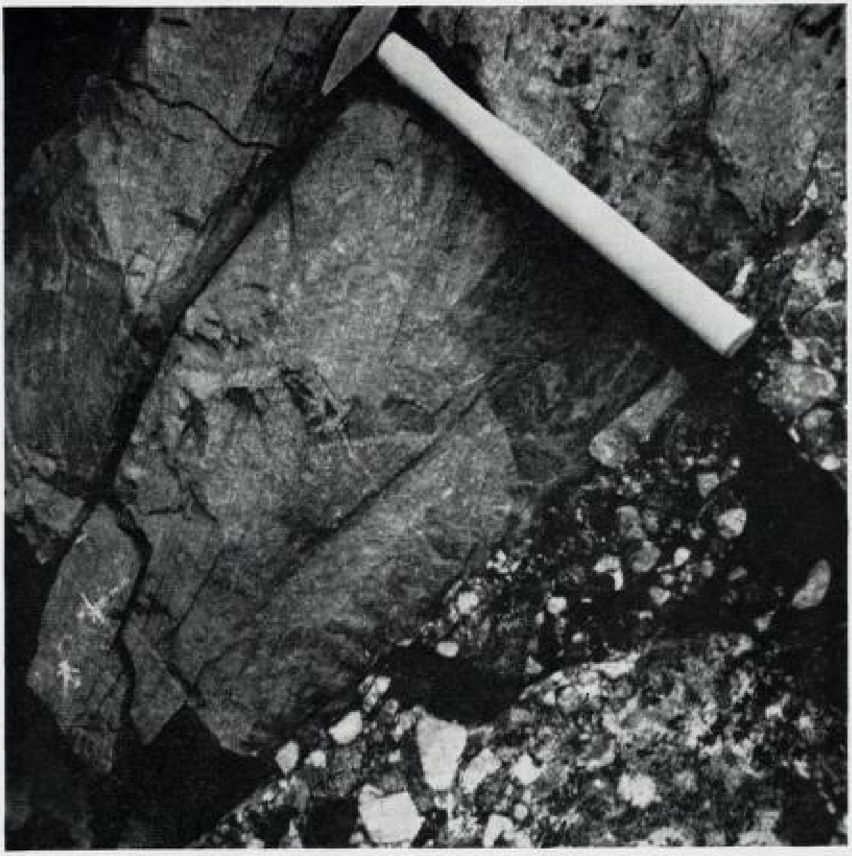
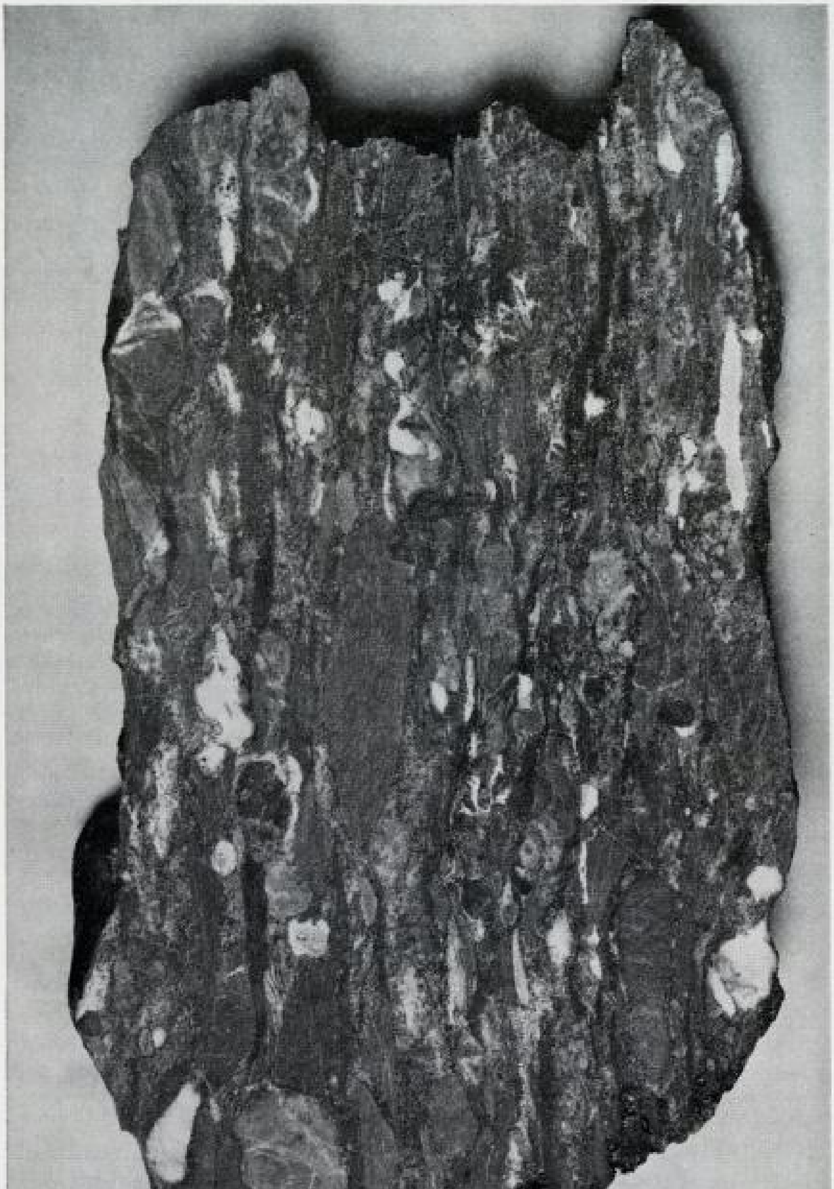


Fig. 8. A detail of the lower right hand portion of Fig. 7. (Photo, B. E. Borgen).
Detalj av nederste delen til høyre i Fig. 7.

Steinfjell formation.

The Steinfjell formation is the lowermost unit in the Saltvann group. It tends to form topographic highs with very little vegetative cover. Jointing is pronounced and the relief on the surface is rugged. The bottom of the formation is not exposed. It is generally a coarse-grained arkosic sandstone with frequent conglomeratic lenses. Cross-bedding can very often be found which gives reliable up-down determinations (Fig. 7, 8). The minimum thickness of the formation is 1000 m. The Steinfjell formation is transitional upwards into the overlying Djupelv formation.



Djupelv formation.

The Djupelv formation is a conglomerate containing a wide assortment of pebble and boulder sizes up to 20 cm in diameter. The boundary between the Steinfjell formation and the Djupelv formation is largely quite arbitrary. As drawn on the map (Plate I) it corresponds to a line stratigraphically above which conglomerate predominates over sandstone. For the most part the matrix of the conglomerate is very subordinate, consisting of a few coarse sand-sized grains separating pebbles. Extremely deformed greenstone and greenschist pebbles may easily be mistaken for a fine-grained groundmass (see Fig. 9). The maximum thickness of the formation is ca. 700 m.

Fiskevann formation.

Above the Djupelv formation lies the Fiskevann formation which is a conglomeratic arkosic sandstone. Only rarely does the amount of pebble material exceed the sandy groundmass. It is much better sorted than the Djupelv formation, pebbles exceeding 10 cm never having been observed. The matrix is a poorly rounded coarse-grained arkosic sandstone. The pebbles are remarkably uniformly of one characteristic type, a purple colored microporphyry. The source rock from which these porphyry pebbles were derived has not been observed within the Komagfjord tectonic window or in other areas of Precambriam rocks in northern Norway which have been visited.

Cross-bedding in the sandstone layers of the Fiskevann formation is common and up-down determinations are consequently certain (see Fig. 10).

The maximum thickness of the formation cannot be determined as it is everywhere cut off at its highest stratigraphic levels by the thrust fault between the Saltvann group and the Repparfjord group. Its maximum exposed thickness is about 700 m.

Fig. 9. Sawed surface of a sample of the Djupelv formation, showing the coarsely clastic groundmass and the varying degree of deformation of pebbles. The sample is ca. 45 cm. across, horizontally. (Photo, B. Mauritz).

Saget overflate på en prøve fra Djupelv formasjonen som viser grovkornet grunnmasse og varierende grad av deformasjon av rullesteinene. Prøven er ca. 45 cm. lang.

Fig. 10. Cross-bedding in Fiskevann formation.
Krysskiktning i Fiskevann formasjonen.

Summation of the maximum exposed thicknesses of the formations of the Saltvann group leads to an estimate of the thickness of the group in excess of 2000 m. Even though the Djupelv formation appears to thicken southwestwards at the expense of the Steinfjell formation by virtue of facies change this estimate of the thickness of the group is probably not too great. Neither the top nor the bottom of the group have been observed.

Intrusive rocks.

Numerous bodies of gabbroid basic rock and ultrabasic (mostly very completely serpentinized) rock and two bodies of trondhjemitic rock are found in the Precambrian rocks of the Komagfjord tectonic window. These appear to be intrusive into the low to moderately low-grade metamorphic supracrustal rocks. Their characteristics—grade of metamorphism, structural relationships, relict textures and mineralogy—are quite different from descriptions of the basic and ultrabasic rocks of the surrounding Caledonides.

Many of these bodies clearly cross-cut the supracrustal rocks surrounding them. However, many show contact fold relationships exactly parallel to deformation of bedding in the surrounding rocks indicating that they have been folded simultaneously. The affects of shearing and cataclasis which can be related to Caledonian deformation are especially clearly marked in the large Trondhjemitic intrusive (C–D 7), while near Doggeelv (J 3–4) folding of the contact between intrusive rock and sandstone is exactly parallel and believed to be the result of pre-Caledonian deformation (see discussion, p. 51). For these reasons and the fact of the great petrologic differences between these instrusives and those in the Caledonides, the date(s) of intrusion of these rocks into the Precambrian rocks is believed to be pre-Caledonian and probably Precambrian.

The relative ages between the intrusions—both intrusion of individual bodies and intrusion of different compositional types—has not been established.

It is worth noting that all of the formations of the Repparfjord group found to the southeast of the Saltvann group contain intrusive rocks while the rocks of the Repparfjord group found to the northwest include no intrusive rocks. The Steinfjell formation of the Saltvann group contains basic and ultrabasic intrusives. The amount of intrusive rock in the Holmvann formation (at least) appears to increase towards the south and southeast.

PETROLOGY AND METAMORPHISM

The Precambrian rocks of the Komagfjord tetonic window are of low metamorphic grade. Sometimes they are very thoroughly recrystallized such that the original nature of the rocks has been obscured, this being particularly true of the schistose units within the Holmvann formation. However, often original depositional features (e.g., cross bedding, ripple marks, pillow structure, Fig. 11) or textural features (e.g., amygdules, phenocrysts, conglomerate pebbles, Fig. 12) are well preserved and the original nature is evident. Original depositional

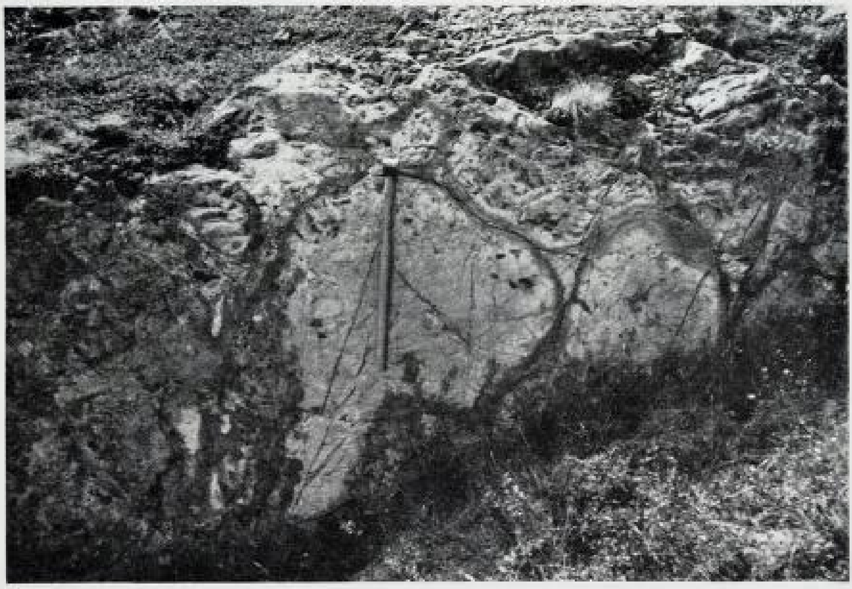


Fig. 11. Pillow structure in Holmvann formation. The hammer is ca. 48 cm long. Photograph taken near Hermanvann (D3).
Putestruktur i Holmvann formasjonen. Hammeren er ca. 48 cm. lang. Bilde tatt ved Hermanvann (D3).

features are frequently found in the Doggeelv formation, Lomvann formation, and the formations of the Saltvann group. The geologic relations of the intrusive bodies make their intrusive nature apparent even when they have suffered complete recrystallization obscuring all original textural features during low grade metamorphism. About half of the time field observations, with or without the aid of microscopic study, have made possible determination of the original nature of the rocks of the Holmvann formation. In about half of the remaining cases studied there appears to be fairly good evidence to substantiate a guess as to the original nature, and in the remaining cases there remains too little indication of the original nature to support a guess worthy of any degree of confidence. Within these limitations it appears that volumetrically a little over half of the Holmvann formation consists of volcanic rocks and the remainder of subaqueously deposited sedimentary rocks.

Fig. 12. Boulders of conglomerate in Holmvann formation, at head of Breidalselv (F4), showing variable deformation of pebbles. (Photo, B. E. Borgen).
Blokker fra konglomerat i Holmvann formasjonen, tatt ved øverste delen av Breidalselv (F4). Viser deformasjonen av rullesteinene.

Repparfjord group.

The petrology of the Repparfjord group will be discussed in the order of the stratigraphic succession of the formations comprising it. The Holmvann formation has the greatest areal extent and provides the greatest amount of information regarding to the metamorphism of the group.

The Holmvann formation is a thick supracrustal series of interbedded volcanic and sedimentary rocks. Superficially the rocks are quite uniformly of dark color, are mostly fine-grained (conglomerates usually have a predominantly very fine-grained matrix), and show a variably well developed schistosity.

The most common mineralogical assemblages are 1) oligoclase-andesine, hornblende, biotite, epidote, sphene, $\pm$ garnet, $\pm$ quartz,

± opaques, 2) albite, biotite, epidote, sphene, ± chlorite, ± quartz, ± ore, and 3) albite, chlorite, epidote, sphene, ± tremolite-actinolite, ± quartz, ± muscovite, ± opaques. In any one particular specimen even minerals not preceeded by the sign ± may be absent, but such cases are rare. Usually all of these phases are present, and sometimes all of those preceeded by the sign ± as well. Other assemblages which are found include 4) tremolite-actinolite, biotite, sphene, ± epidote, ± albite, ± opaques, 5) albite, chlorite, tremolite-actinolite, ± epidote, ± opaques, 6) tremolite-actinolite, talc, sphene, ± chlorite, ± quartz, ± opaques, 7) talc, chlorite, sphene, ± albite, ± serpentine, ± opaques, and 8) calcite, plagioclase, opaques, ± chlorite, ± sphene, ± quartz. Only assemblages numbered 1, 2, and 3 are common. Assemblage number 2 is most often found in samples taken from the Holmvann formation south of 70° 20′ north. In the northern part of the area samples most frequently contain assemblage number 3. Assemblage number 1 is found along a belt from the head of Båtdalselv (H 4) to the vicinity of the large gabbroic intrusive at Veifjell (E 7). In some cases disequilibrium assemblages are present; the assemblages above are beleived to represent assemblages which approach the equilibrium conditions. In particular, the coexistence of albite with hornblende or with hornblende and garnet is rare, as is also the coexistence of chlorite and hornblende. A few samples containing such combinations were partially analysed (cf. analysis numbers 5, 13, and 17, table 3) and were found to contain relatively low atomic rations of K to Na. This may have allowed hornblende and garnet to form with albite and chlorite at P-T conditions where some combination of the minerals albite, biotite, chlorite, and epidote, or albite, actinolite, chlorite, and epidote was ordinarily formed.

With the exception of a very few samples which contain pyroxene and typically low temperature minerals such as chlorite or talc, or contain relict calcic plagioclase phenocrysts and a later generation of sodic plagioclase, a rather close approach to equilibrium assemblages has usually been achieved, occasional evidence of slight retrogressive metamorphism along small shear zones not being taken into account. This appears to be equally true both of rocks of sedimentary and volcanic origin.

Complete chemical analyses were made of four samples from the Holmvann formation; two of the samples were clearly originally argillaceous sediments (table 2) and two were originally amygdaloidal ba-

Table 1.

Amygdaloidal basalt: Collection nr. U3-1R193

Analysis No. 2	Wt. %	Cation %	Niggli parameters	Calculated	mode
SiO_2	47.40	47.0	si = 81.4	Minerals	%
TiO_2	1.26	1.0		Quartz	16.9
$AlO_{1\,1/2}$	16.19	18.9	al = 36.4	Biotite	–
$FeO_{1\,1/2}$	1.89	1.4		Chlorite (1)	20.6
FeO	15.85	13.1	fm = 47.6	Chlorite (2)	25.2
MnO	0.24	2.0		Zoisite	13.2
MgO	5.42	8.1		Albite (An_7)	14.5
CaO	4.55	4.8	c = 9.3	Orthoclase	4.0
$NaO_{1/2}$	1.39	2.7	alk = 6.7	Apatite	0.5
$KO_{1/2}$	0.63	0.8		Magnetite	2.1
H_2O —	0.07	–	k = 0.22	Sphene	3.0
H_2O +	5.01	–		Calcite	–
CO_2	–	–		–	–
$PO_{2\,1/2}$	0.29	0.2		–	–
Total	100.19	100.0			100.0

Analyst: Liv Bolkesjø.
Sp. wt. = 2.87.
Main minerals: albite (An_7), chlorite, epidote.
Accessories: sphene.
Amygdule fillings: quartz, epidote.

Amygdaloidal basalt: Collection no. U3-2R3.

Analysis No. 1	Wt. %	Cation %	Niggli parameters	Calculated	mode
SiO_2	49.59	46.8	si = 74.1	Minerals	%
TiO_2	1.67	1.2		Quartz	3.1
$AlO_{1\,1/2}$	14.68	16.3	al = 25.3	Biotite	5.6
$FeO_{1\,1/2}$	2.51	1.8		Chlorite (1)	19.0
FeO	10.56	8.3	fm = 29.3	Chlorite (2)	–
MnO	0.14	1.1		Epidote	28.9
MgO	5.15	7.3		Albite (An_7)	37.5
CaO	9.16	9.3	c = 14.7	Orthoclase	–
$NaO_{1/2}$	3.85	7.0	alk = 12.2	Apatite	0.5
$KO_{1/2}$	0.58	0.7		Hematite	1.8
H_2O —	0.02	–	k = 0.09	Sphene	3.6
H_2O +	2.24	–		Calcite	–
CO_2	–	–		–	–
$PO_{2\,1/2}$	0.21	0.2		–	–
Total	100.36	100.0			100.0

Analyst: Liv Bolkesjø.
Sp. wt. = 3.00.
Main minerals: albite (An_7), epidote, chlorite.
Accessories: biotite, hematite, sphene.
Amygdule fillings: epidote.

Table 2

Metamorphosed arenaceous argillite: Collection no. V3–2R11.

Analysis No. 3	Wt. %	Cation %	Niggli parameters	Calculated	mode
SiO_2	68.27	65.2	si = 194.8	Minerals	%
TiO_2	0.80	0.6		Quartz	32.2
$AlO_{1\,1/2}$	12.37	13.8	al = 41.4	Biotite	8.0
$FeO_{1\,1/2}$	1.23	0.9		Chlorite (1)	1.5
FeO	6.58	5.2	fm = 23.4	Chlorite (2)	6.7
MnO	0.09	0.1		Zoisite	–
MgO	1.18	1.7		Albite (An_{10})	37.0
CaO	2.00	2.1	c = 6.2	Orthoclase	10.0
$NaO_{1/2}$	3.59	6.7	alk = 28.9	Apatite	0.5
$KO_{1/2}$	2.50	3.0		Magnetite	1.3
H_2O —	0.04	–	k = 0.31	Sphene	1.8
H_2O +	1.20	–		Calcite	1.0
CO_2	0.38	0.5		–	–
$PO_{2\,1/2}$	0.25	0.2		–	–
Total	100.48	100.0			100.0

Analyst: Liv Bolkesjø.
Sp. wt. = 2.73.
Main minerals: albite (An_{5-10}), quartz, K-feldspar, biotite, chlorite.
Accessories: sphene, apatite, calcite.

Argilltie: Collection no. U3–1R190

Analysis No. 4	Wt. %	Cation %	Niggli parameters	Calculated	mode
SiO_2	55.23	52.9	si = 116.0	Minerals	%
TiO_2	1.92	1.4		Quartz	14.6
$AlO_{1\,1/2}$	14.51	16.3	al = 35.8	Biotite	–
$FeO_{1\,1/2}$	2.04	1.5		Chlorite (1)	18.7
FeO	9.79	7.8	fm = 35.2	Chlorite (2)	6.2
MnO	0.14	1.1		Zoisite	15.5
MgO	3.91	5.6		Albite (An_5)	36.5
CaO	5.87	6.0	c = 13.2	Orthoclase	1.5
$NaO_{1/2}$	3.71	6.9	alk = 15.8	Apatite	0.5
$KO_{1/2}$	0.25	0.3		Magnetite	2.3
H_2O —	0.03		k = 0.04	Sphene	4.2
H_2O +	2.76			Calcite	–
CO_2	–			–	–
$PO_{2\,1/2}$	0.31	0.2		–	–
Total	100.47	100.0			100.0

Analyst: Liv Bolkesjø.
Sp. wt. = 2.84.
Main minerals: albite (An_5), quartz, chlorite, epidote.
Accessories: opaques, sphene, (muscovite ?).

salts (table 1). From the analyses the modes were calculated following essentially the scheme of the epinorm calculation suggested by Barth (1955, 1959). Thin sections of the rocks were examined and the minerals constituting the rock were identified, after which the epinorm calculation was followed, attempting, however, to incorporate the elements present into those minerals which were known to be present. In the absence of an observed mode—which could not be determined accurately because of the extremely fine grain size of the minerals in these rocks—this gives the best possible indication of the relative abundances of the minerals in these rocks. Considering the sources of error inherent in the method, the accord between the calculated modes and thin section observations is very satisfactory. This subjective evaluation of the value of the calculated modes in these particular instances can be appreciated fully only by one who has examined the thin sections concerned. In these cases the calculated mode is the only method by which one can make a quantitative estimate of the minerals present which is not manifestly ridiculous.

The calculated mode of the argillite (analysis no. 4, table 2) might be objected to on the grounds that 1.5 % orthoclase appears in the mode but was not observed in thin section. To this can be answered the following: the mode may be adjusted to show 2.1 % muscovite, 19.6 % chlorite(1), and 4.7 % chlorite(2), in which case the mineralogy of the mode is in better agreement with that observed. Similarly, the presence of 4.0 % orthoclase in the basalt (analysis no. 2, table 1) might be found improper or excessive. To this one may answer that the calcic plagioclase which originally crystallized at high temperature could hold some potassium in solid solution as can also the albitic plagioclase stable at low temperatures. In addition to this, the saussuritization reaction of calcic plagioclase containing some K-feldspar in solid solution can produce muscovite (see Ramberg, 1952, p. 50) according to the reaction:

$$\underset{\text{anorthite}}{4\,CaAl_2Si_2O_8} + \underset{\text{orthoclase}}{KAlSi_3O_8} + 2H_2O = \underset{\text{zoisite}}{2\,Ca_2Al_3Si_3O_{12}(OH)} + \underset{\text{muscovite}}{KAl_3Si_3O_{10}(OH)_2} + \underset{\text{quartz}}{2\,SiO_2}$$

Table 3.

Analysis no.	Collection no.	Element	Wt. %*	Molecular proportion × 1000	*k*	M: Main minerals A: Accessories	Comments
5	U3-2R101	Na_2O	2.60	84	0.02	M: Hbl, Ab, Chl, Chert	Originally hornblende basaltic rock
		K_2O	0.09	2		A: Ep, Qtz	
6	U3-1R195	Na_2O	0.57	18	0.44	M: Chl, Ab, Ep	Originally basalt
		K_2O	0.65	14		A: Musc, Ore	
7	V3-1R201	Na_2O	3.09	100	0.15	M: Ab, Talc?, Ep	Originally amygdaloidal basaltic rock
		K_2O	0.82	17		A: Chl	
8	U4-2R109	Na_2O	3.78	122	0.35	M: Ab, Act	Originally amygdaloidal andesite (?basalt)
		K_2O	3.17	67		A: Ep, Chl, Qtz, Ore	
9	U3-2R17	Na_2O	3.40	110	0.31	M: Ab, Bi	Originally a basaltic rock
		K_2O	2.31	49		A: Ep, Sph, Ap	
10	V3-1R205	Na_2O	0.18	6	0.14	M: Chl, Talc	Originally basalt?
		K_2O	0.05	1		A: Sph, Zirc?, Hem	
11	U3-1R265	Na_2O	3.14	101	0.26	M: Chl, Ep, Chert, Ab	Metavolcanic
		K_2O	1.64	35		A: Qtz, Bi, Ore	
12	U3-1R283	Na_2O	2.15	69	0.16	M: Act, Chl, Ep, Ab	Metavolcanic
		K_2O	0.61	13		A: Sph, Qtz, Hem	
13	U4-2R13	Na_2O	1.20	39	0.11	M: Hbl, Ab, Qtz	Metavolcanic
		K_2O	0.25	5		A: Ep, Mt, Py	
14	U3-1R264	Na_2O	3.12	101	0.35	M: Chl, Ep, Ab	Stratified; perhaps tuffaceous
		K_2O	2.58	55		A: Bi, Hem	
15	U3-1R196	Na_2O	3.48	112	0.18	M: Qtz, Plag, K-feld	Originally impure fine-grained arenaceous sandstone
		K_2O	1.16	25		A: Musc, Ore	
16	U3-1R289	Na_2O	7.23	236	0.04	M: Qtz, Chl, Ab	Originally fine laminated shale
		K_2O	0.47	10		A: Sph, Ep	
17	U4-2R15	Na_2O	5.21	168	0.12	M: Hbl, Bi, Ab, Qtz	Metasediment?
		K_2O	1.07	23		A: Ep, Perthite, Garnet	

* Analyst: Liv Bolkesjø.

Saussuritization and sericitization of plagioclase feldspar are commonly observed in volcanic rocks which have undergone low grade metamorphism and this is also true of the volcanic rocks of the Komagfjord tectonic window. The above reaction may help to account for both the rather large amount of free quartz indicated in the mode from analysis no. 2 and observed filling amygdules seen in thin section, and the presence of a potassium rich phase in the mode which may in fact be represented both by K-feldspar in solid solution with the albite plagioclase and muscovite lamellae due to sericitization.

Analyses for Na_2O and K_2O in thirteen samples from the Holmvann formation were performed (see table 3). The *k* values (see, e.g. Niggli, 1954) were calculated for these and the four samples on which complete analyses had been performed. The *k* value is proportional to the ratio $K^+/Na^+ + K^+$, a low value indicating that a relatively high proportion of the alkalis in the rock is sodium. This was done in order to determine whether the rocks of the Holmvann formation which are predominantly greenstones and greenschists are of spilitic aspect. To be sure, the ratio of calcium to sodium is also characteristically below normal in spilites, but the *k* value is a much more easily obtained index because the analysis is simpler and more rapid.

Table 4.

Formulas used in calculated modes.

Quartz	SiO_2
Orthoclase	$KAlSi_3O_8$
Albite	$NaAlSi_3O_8$
Anorthite	$CaAl_2Si_2O_8$
Biotite	$KAl(Mg, Fe, Mn)_3Si_3O_{10}(OH)_2$*
Zoisite	$Ca_2Al_3Si_3O_{12}(OH)$*
Epidote	$Ca_2(Al, Fe)_3Si_3O_{12}(OH)$*
Chlorite (1)	$Mg_3Si_2O_5(OH)_4$*
Chlorite (2)	$Mg_2Al_2SiO_5(OH)_4$*
Sphene	$CaTiSiO_5$
Calcite	$CaCO_3$
Apatite	$Ca_5P_3O_{12}(F, Cl, OH)$*
Magnetite	Fe_3O_4
Hematite	Fe_2O_3

* F, Cl, and/or (OH) assumed to be available as required.

There are no systematic variations between the *k* value and the original rock type, whether extrusive or sedimentary, or between the *k* value and the sum of the molecular proportions of sodium and potassium, or between the *k* value and the molecular propartion of sodium or potassium taken individually. The average *k* value of eight samples from originally basaltic rocks is 0.21, ranging between 0.02 and 0.44. The average *k* value of twelve samples of originally extrusive origin including the basalts is 0.22, ranging between 0.02 and 0.44. The average *k* value of five originally sedimentary rocks is 0.14, ranging between 0.04 and 0.31. The average *k* value from the seventeen samples is 0.19.

These values are generally appreciably higher than the values reported by Gjelsvik (1958) from samples of the greenstones and greenschists of the Časkias group from the interior of Finnmark. Sixteen *k* values reported by him from samples in the vicinity of Časkias average 0.06, ranging between < 0.01 to 0.35. The highest values are from mica schists. These values and the above values can be compared with the *k* value of the average "greenstone magma" (Mikkola, 1941) which is 0.11, and the *k* value of the average composition of plateau basalts (Daly, 1933) which is 0.15.

As can be seen, the greenstones and greenschists from the Holmvann formation, though containing the minerals and having the textures typical of spilitic rocks, do not appear to be relatively enriched in sodium. Whatever the processes which give rise to spilites, they do not seem to have been operative generally upon the rocks of the Holmvann formation. These rocks have undergone low grade metamorphism but there is no indication of large scale sodium metasomatism.

Although the range of *k* values in the rocks of volcanic and sedimentary origin is essentially the same, the average value for the sediments is distinctly lower. Only one of the five, the arenaceous argillite (analysis no. 4) which is relatively high in biotite and K-feldspar, has a *k* value higher than the average for all the seventeen specimens. Ignoring it because of the abnormally high concentration of potassium minerals, the average *k* value for the remaining rocks of sedimentary origin is 0.9. The number of samples being considered is admittedly small and does not warrant conclusions to which great confidence should be attatched. However, keeping this limitation in mind, it is permissable to offer interpretations which might serve to explain the differences.

It is to be remembered that the Holmvann formation consists of interlayered supracrustal rocks of both volcanic and sedimentary origin. Among the volcanic rocks there appears to be only a very small percentage which are tuffaceous; for the most part they were extruded lavas. The rocks were predominantly formed sub-aqueously, both the volcanic and sedimentary rocks, and were, in all probability submarine. The entrapped water was saline.

During compaction and low grade metamorphism much of this water was pressed out of the rocks. The water, in moving out of the rocks, would tend to follow those avenues of easiest transport, i.e., into and trough the most permeable beds. Given a stratified pile of beds of variable permeability, the water would be pressed out of the relatively impermeable beds into those of greater permeability through which it could move most easily out of the pile. The liquid might be pressed out of the bed by compaction before equilibrium had been achieved. In no case could connate water from permeable beds be expected to penetrate into the relatively impermeable beds.

In the permeable beds the situation will be different. Again reaction between solid and liquid would be expected to take place tending towards a thermodynamically stable distribution of sodium between the phases present. However, in the case of the permeable bed during compaction, not only would the connate water originally contained within the bed be forced through the bed, but also water derived from adjacent less permeable beds. Thus, the sodium bearing liquid phase would constantly be renewed.

Given the present sequence of rocks, it appears evident that the sedimentary rocks, even though relatively fine-grained, would be more permeable than the fine-grained lava flows. The porosity of the basaltic lavas may have been higher (due to amygdules) but the permeability lower.

In addition to the above considerations it is also probable that the rocks derived from the lavas did not originally contain as high a percentage of as highly hydrated minerals as they now do. Relict pyroxene grains attest to this and it will be remembered that the saussuritization reaction requires water. On the other hand, sediments composed of detritus and weathering products derived from surface rocks and a certain admixture of clays formed by the flocculation of colloidal particles and other suspended material, would be expected to contain a high percentage of hydrated minerals.

The significance of this is the following. During compaction, diagenesis, and low grade metamorphism, the reaction between the connate water and the solid phases of the basalts would tend not only towards equilibrium distribution of sodium between the solids and the liquid, but also towards the incorporation of water into the hydrous minerals produced by the reaction between the original anhydrous phases and the liquid. Thus, the sodium concentration of the liquid pressed out of the relatively impereable beds into the permeable beds during compaction would probably not be greatly depleted by the reactions which had already occurred in the impermeable beds.

The reactions which would then occur in the permeable beds would be, as indicated, those leading to the equilibrium distribution of sodium between the minerals and the liquid. In this case, however, relatively less water from the liquid would be incorporated into the minerals (already presumably hydrous phases).

The net result of this process would be a relative enrichment of sodium in the most permeable beds. If the liquid expelled from the rocks during compaction were originally not rich in such constituents as potassium and calcium there might also be an absolute as well as a relative depletion of those elements in the rock.

In this way some strata of rocks of spilitic aspect within a sequence predominantly composed of non-spilitic rocks might be explained. A similar explanation has been offered by Dickinson (1962) to account for the conversion of zeolitic rhyodacite to albitic quartz keratophyre.

The mineral assemblages characterizing the rocks of the Holmvann formation, besides reflecting compositional variations, are indicative of different degrees of metamorphism. They are characteristic of the high greenschist facies and lower epidote amphibolite facies as these are defined by Barth (1952) and by Ramberg (1952). According to the classification proposed by Turner (*in* Fyfe, Turner, and Verhoogen, 1958) the greenschist facies and the almandine amphibolite facies are represented. Both the quartz-albite-muscovite-chlorite subfacies and the quartz-albite-epidote-biotite subfacies of the greenschist facies can be recognized by assemblages 3, 5, 7, and 8 and 2, 4, and 6 respectively (see p. 30). The staurolite-quartz subfacies of the almandine amphibolite facies is represented by assemblage 1. The mineral assemblages are characteristic of pelitic, basic, and magnesian compositional types.

The highest metamorphic grade, represented by assemblage 1, is found to outcrop along a belt extending southwestwards from Breidalselv (H 4) past the upper reaches of Båtdalselv, Mikkeldalselv, Breidalselv (G 5), Markfjell, and to Småhaugene. The assemblages characteristic of the lowest metamorphic grade, assemblages 3, 5, 7, and 8, are found only in the northern part of the area. Thus there is a rough zoning of metamorphic facies, a slight general increase occurring from the north to the south. Although not completely clearly established there appears to be a slight increase of grade from west to east. A line perpendicular to isograds would be approximately a NNW –SSE line with metamorphism increasing towards the south-southeast; the isograd separating the quartz-albite-muscovite-chlorite subfacies (to the north) from the quartz-albite-epidote-biotite subfacies (to the south) would be approximately that connecting Klakkeggen (D 4) and Gænočokjavre (I 3).

The highest metamorphic grade is represented by the rocks in the belt (H 4 to E 7) mentioned above. This belt coincides with the area of greatest density of gabbroic and ultrabasic intrusives. There appear to be three possible explanations for this coincidence. They are:

1. Both are related to a single cause without a direct causal relationship between them. There is an anticline extending southwestwards close to the boundary between the Holmvann formation and the overlying Doggeelv formation (see the structural map, plate II). The axis of the anticline approximately coincides with the belt within which the rocks of highest metamorphic grade and the closely spaced intrusives occur. The anticlinal axis may be a zone of relative weakness through which intrusion was easiest and may bring to the surface the deepest and therefore highest grade rocks of the Holmvann formation. If this is the case the geographic coincidence between the intrusives and the metamorphic grade, though having a common cause, are not directly causally related. However, although the details of the structure in the southern part of the area have not been as clearly worked out as in the northern part, it does not seem likely that the rocks in this zone are stratigraphically lower than *all* other parts of the Holmvann formation.

2. The zone in which the higher grade rocks occur is one in which the temperature was raised above that attained in the majority of the area, reactions leading to mineral assemblages characteristic of higher grade being induced by the increase in temperature which was itself caused by the intrusion of the hot gabbroic and ultrabasic magmas. Several factors militate against immediate adoption of this explana-

tion. First, zones of thermal contact metamorphism are not observed along the boundaries of the intrusive bodies in this zone of higher grade metamorphism of the surrounding rocks, nor have contact metamorphic aureols been observed around intrusives in other parts of the Holmvann formation, or the Doggeelv, Lomvann, or Steinfjell formations. Second, the metamorphic grade of the intrusive bodies is, with the exception of some relics in the larger bodies, quite comparable to that of the surrounding rocks. It would therefore appear that the period of intrusion antedates the time of the metamorphism.

3. The zone of highest metamorphic grade may not necessarily represent a zone in which the temperature was appreciably elevated. As has been shown very clearly by Fyfe and Turner (*in* Fyfe, Turner, and Verhoogen, 1958) and by Yoder (1952), a given metamorphic assemblage is dependent on the temperature, fluid pressure, and load pressure. A relatively small change of the fluid pressure (mainly H_2O) at constant load pressure and temperature, can cause a change in the assemblage of minerals which is stable. Given the proper original conditions, a change of fluid pressure might induce reactions which would result in a mineral assemblage characteristic of a facies different from that of the original.

The assemblage of the zone of highest metamorphic grade, the staurolite—quartz subfacies, is characteristic of the lowest part of the almandine amphibolite facies, while the surrounding quartz-albite-epidote-biotite subfacies assemblage is characteristic of the upper part of the greenschist facies (Turner's terminology; by the terminology of Ramberg they would be lower epidote amphibolite facies assemblages). Thus, only a small change in fluid pressure would be necessary to accomplish the transformation from one assemblage to the other.

The change in fluid pressure could be caused by a relative dehydration of the rocks surrounding the intrusive bodies while the intrusive rocks were being hydrated (see Thompson, 1956). Water could be withdrawn from the rocks of the Holmvann formation and incorporated into hydrated phases in the basic and ultrabasic intrusives in accord with the reactions leading to saussuritization, sericitization, chloritization, and serpentinitization. The facts that the same relative grade of metamorphism is exhibited by the intrusive bodies and the surrounding rocks and that there is no apparent contact metamorphism around the many small intrusions in any of the formations, support these proposals.

The conclusion of the above discussion is that there is a slight increase in the grade of regional metamorphism when proceeding south-southeasterly, the grade increasing to the high greenschist facies (Turner's classification) or the low epidote amphibolite facies (Barth's and Ramberg's classifications) with an apparent local increase in metamorphic grade in the southeastern part of the area (H 4 to E 7) caused by the lowering of the fluid pressure in the area of greatest density of intrusive rocks following the hydration reactions accompanying the low temperature metamorphism of the intrusives.

The formations overlying the Holmvann formation are not ideally suited to studies of metamorphic reactions. The Doggeelv formation is generally a fairly pure quartzite though some muscovite or biotite is commonly present. Partial analyses of four samples were performed (table 5), these suggest that the proportions of quartz to other minerals vary but quartz dominates. The variations in the relative proportions of potassium and sodium and the variation in the absolute amounts of these elements indicates that the proportions and absolute amounts of detrital feldspars incorporated into the rock varied. This confirms the impression obtained by examination of thin sections. Little can be said of the variation of the metamorphic grade of the quartzite although metamorphism has been sufficient throughout the formation to allow the detrital grains to be cemented by quartz. However, as quartz is known to form as an authigenic mineral and remembering that these are Precambrian rocks (hence, much time for solution and re-precipitation even if the rate of the process was very slow) this fact cannot be considered very significant. As biotite and muscovite are stable from very low grades of metamorphism (greenschist facies) up to very high grades, their presence is not significant. In the bed of Breidalselv (G 6)

Table 5.

Analyses of quartzite: Doggeelev formation.

Analysis no.	18	19	20	21
Collection no.	V3-1R4	V3-1R37	U4-1R115	V3-1R230
Wt. % SiO_2	85.01	98.79	93.88	92.58
Wt. % Na_2O	0.82	0.06	1.71	0.69
Wt. % K_2O	3.41	0.04	0.06	1.63
k-value	0.73	0.33	0.02	0.61

Analyst: Kjersti Haugen.

not far from the Holmvann formation there was found a small pegmatite which measured 15 × 10 × 8 cm. It consisted of quartz pods up to about 6 cm in largest dimension, potassium feldspar crystals up to about 4 cm, and biotite. This is probably indicative of a metamorphic grade comparable to that attained by the nearby Holmvann formation, i.e., epidote amphibolite facies.

Thin section examinations have revealed certain variations. When the quartzite is very pure the quartz grains are interlocking, having sutured boundaries. When the percentage of the groundmass increases the degree of rounding of grains can be determined; it varies from subangular to well rounded. The groundmass may consist of very fine-grained muscovite, quartz, sometimes chlorite, and sometimes some calcite. Detrital grains are very predominantly quartz but microline, plagioclase, perthite, hornblende, quartzite, and sericite schist have been identified. The percerentage of opaques is consistently low. The sorting is generally good and may be excellent.

The Lomvann formation is variable from an impure quartzite in the north to a very fine-grained shale in the south. In the south where it could possibly yield most petrologic information it is poorly exposed. Metamorphism has not been sufficient to cause the growth of grains of appreciable size by recrystallization. Petrographic examination of a few specimens has revealed that the dominant minerals are either very fine-grained quartz and chlorite or quartz and muscovite (sericite). Other minerals which are present include plagioclase, sphene, opaques and (rarely) carbonates.

The Kvalsund formation is a very fine-grained carbonaceous slate. Slaty cleavage is well developed. The proportion of carbon and the fine grain size have made petrographic study difficult. The metamorphic grade exhibited by the surrounding rocks of the Holmvann formation is that of the greenschist facies. No information obtained from the Kvalsund formation controverts this.

Saltvann group.

The Saltvann group comprises three formations of sedimentary rocks. The lowest formation is the Steinfjell arkosic sandstone which is generally a poorly sorted sometimes conglomeratic impure arkosic sandstone. The middle formation is the Djupelv conglomerate which is a heterogeneous, poorly sorted conglomerate containing little matrix. The highest formation is the Fiskevann formation which is a conglomeratic arkosic sandstone characterized by pebbles, cobbles, and small boulders almost exclusively of one rock type.

The deposition of the three formations appears to have occurred without any major hiatus; the boundaries between formations are essentially arbitrary in detail. The boundary between the Steinfjell formation and the Djupelv formation does not follow a single stratigraphic or time line; due to lateral sedimentary facies change the formational boundary cuts across time lines. The Djupelv formation thickens towards the southwest at the expense of the Steinfjell formation.

The Steinfjell formation is quite variable. At times it is conglomeratic but even discounting this the grain size varies from course to medium fine. The sorting, rounding, and sphericity of the grains is consistently poor. At times there is a tendency for the longest axes of grains to be roughly parallel. The detrital fragments include quartz, plagioclase, microcline, potassium feldspar devoid of twinning, perthite, zircon, and quartzite. At times secondarily overgrown quartz on detrital quartz grains or quartzite grains is recognizable. Quartz grains generally show undulatory extinction. The groundmass is variable in quantity and somewhat variable in mineralogy. Very fine-grained muscovite, i.e., sericite, is always present. Chlorite is generally present and biotite, characteristically olive-drab in color, is frequently present. It appears from thin section study that biotite, when present, is just beginning to crystallize. Thus, the Steinfjell formation has largely just reached the biotite isograd. The Steinfjell formation has undergone metamorphism of the same grade as the adjacent rocks of the Holmvann formation. Depending on the scheme of classification used, this represents the boundary between the greenschist and epidote amphibolite facies (Barth, 1952, p. 337), the upper part of the greenschist facies (Ramberg, 1952, p. 144), or the mid-portion of the greenschist facies (Turner *in* Fyfe, Turner, and Verhoogen, p. 223). In this case it is probably most informative simply to note that the biotite isograd was just reached by large portions of the formation while the remainder must have been just below this grade of metamorphism. The samples were not taken with the aim of pin-pointing the position of the isograd, but it appears to correlate with the stratigraphic level. However, without good stratigraphic marker beds or detailed studies of this problem this suggestion can not be verified.

The Djupelv conglomerate overlies the Steinfjell formation. It is a heterogeneous polymict conglomerate containing a large range of pebble, cobble, and boulder sizes. It consits predominantly of pebbles, most of which are greenstones and greenschists, and of only a minor amount of a coarse, sandy matrix. This can usually be seen as interstitial filling between the fragments and an often discontinuous line of sand-sized grains separating fragments. The rock has suffered sufficient compression and shearing to have very significantly deformed the less competent fragments. These may even be streched out to (in cross-section) appear as elongate folded streaks. In addition there are more competent fragments which may be essentially round, slightly elongate, cracked, slightly folded, etc. All gradations between the extremes are represented. Study of the photograph (fig. 10) of a sawed surface should provide the best appreciation of the character of the conglomerate. The percentage of incompetent fragments which have suffered extreme deformation is so high that except on a sawed surface or very favorable, slightly weathered, clean surfaces, it appears to be a conglomerate with a fine-grained dark matrix. In the field this can best be seen not to be the case by examining overhanging, slightly weathered surfaces.

The variety of types of rock fragments is considerable. Included are a variety of greenstones and greenschists, microporphyry, vein quartz, quartzite, jasper (in fact all gradations from white to deep brownish-red cryptocrystalline silica), limestone, and dolomite. There has also been some recrystallization of quartz, it appearing in pressure shadows of competent fragments and as small veins filling cracks in competent fragments, and of the carbonates which fill interstices and small veins along with quartz.

Examination of thin sections shows the mineral assemblages of the majority of fine-grained rock fragments to consist of some combination of chlorite, muscovite, quartz, sericitized and saussuritized plagioclase, sphene, and opaques. The groundmass consists of fragments of quartzite, quartz grains, sericitized and saussuritized plagioclase, chlorite, muscovite, and carbonate(s). The assemblages would correspond to the quartz-albite-muscovite-chlorite subfacies of the greenschist facies (Turner's terminology). Biotite does not appear to have begun to form; the biotite isograd does not appear to have been reached.

The Fiskevann conglomerate, which is the highest formation of the Saltvann group, is characterized by containing, in almost all exposures, only one type of pebble. The groundmass is a fairly well-sorted medium sand-sized arkosic sandstone containing poorly rounded grains of low sphericity of quartz, microcline, perthite, myrmikite, plagioclase (sericitized and saussuritized and apparently now albitic), quartzite, opaque grains, and zircon (?). A small amount of sericite matrix is present.

The rock type of the purple colored pebbles which are abundant in the conglomerate is fine-grained porphyry. In it are stubby lath-shaped plagioclase crystals set in an extremely fine-grained groundmass. The groundmass consists of plagioclase, quartz, and opaque minerals. The rock is evidently a volcanic rock; no counterpart to it has been observed in the Holmvann formation.

No information indicative of the exact grade of metamorphism of the Fiskevann formation has been obtained, though it is evident that the metamorphic grade is low.

Intrusive rocks.

The intrusive bodies consists of three subdivisions, gabbroic (including doleritic), ultrabasic, and trondhjemitic. Gradations between the first two are possible and the boundary lines drawn between them on the map are then approximate. Most commonly in the field the ultrabasic bodies can be recognized by a rusty reddish weathering surface. Fresh surfaces are very dark. The gabbroic intrusives have dark weathering surfaces and may be impossible to distinguish from surrounding greenstones and greenschists from any appreciable distance in the field. The trondhjemite intrusives have very light colored weathered surfaces. All of the intrusives tend to form topographic highs, but there are exceptions.

All of the intrusive bodies have suffered metamorphism at low grade corresponding to that of the surrounding rocks. The degree of recrystallization accompanying the metamorphism has not always been complete, although unaltered relics are never found. Alteration of original constituents has always been so extensive as to make positive identification of the original mineral difficult, and precise pin-pointing of position in a solid solution series (i.e., plagioclases, ortho- and clinopyroxenes) impossible. The alteration products are always fine-grained.

Identifiable original constituents of the gabbroic intrusives are plagioclase and pyroxene or hornblende. The plagioclase is always severely altered due to saussuritization and sericitization. The pyroxene is also severely altered. Both ortho-pyroxene and clinopyroxene have been identified as original constituents though never have both been recognized in the same specimen. At times only a relict shape remains and in these cases hornblende as the original constituent cannot be ruled out, but the presence of primary hornblende has not been verified. The common alteration products are tremolite, serpentine, chlorite, epidote, sericite, and talc (?). Opaque minerals are always present. Late quartz veins are sometimes present. In one doubtful case—a schistose rock which may have been part of a gabbroic intrusive or may have been part of the supracrustal Holmvann formation—the minerals garnet, biotite, and chlorite were identified as metamorphic products along with quartz and plagioclase.

The ultrabasics have a characteristic reddish surficial alteration from which they can readily be recognized from great distances in the field. Some stand as ridges and one, Rødfjell (= Red Mountain), has been named for its color. Other characteristic field features are blocky jointing, slightly rounded smooth-lined outcrops, a ringing almost metallic sound when struck by a hammer, and great toughness making sample collection strenuous and requiring a heavy hammer and shortening the life-time of wooden handles. Relics of orthopyroxene and clinopyroxene have been recognized. Clot-like clusters of serpentine have suggested the previous presence of olivine. However, for the most part, these rocks consist of fine-grained "matty" serpentine with tremolite, tremolite-actinolite, chlorite, talc, and magnetite as frequent products of metamorphism. Some assemblages, such as talc, serpentine, and magnetite, have suggested originally extremely mafic—especially magnesium-rich—original rocks. Chrysotile veinlets are not uncommon.

The trondhjemitic intrusives are very white in outcrop appearance. In that they occur only in the vicinity of gabbroic intrusives and the Holmvann formation they are easily recognized from considerable distance. Mineralogically they are identical with that commonly displayed by trondhjemite or quartz-rich ferromagnesian mineral-poor tonalite. However, because trondhjemite has previously in Norway been applied only to rocks in the Caledonides, these rocks are termed trondhjemitic intrusives on the map because they are believed to have been intruded prior to the Caledonian orogeny. The essential constituents are plagioclase (oligoclase $\sim An_{25}$), quartz, and biotite; accessories are apatite, zircon, and magnetite. In all samples there is evidence of brecciation and granulation with secondary development of chlorite. Interstitial muscovite may or may not be primary. The plagioclase is somewhat sericitized and saussuritized. Quartz, at least, has been partly recrystallized during or after the brecciation and granulation. The tectonic deformation of the rock is beleived to be associated with the overthrusting of the Caledonides.

The Caledonides.

The surrounding Caledonides closest to the tetonic window include quartzose mica schists, mica schists and chlorite-rich schists. To the west, as observed on the peninsulas between St. Lerrisfjord and Korsfjord and between Korsfjord and Skillefjord, the metamorphic grade apparently increases and the rocks are gneissose. Study of the surrounding Caledonides has not been a part of this investigation.

STRUCTURE

The structure of the Komagfjord tectonic window can be most easily reviewed by describing three structurally coherent areas and considering the relationships between these areas. The three rather distinct areas are 1) the northwestern area in which the Repparfjord group is found, 2) the eastern and southern area of the Repparfjord group, and 3) the area separating the above two, in which the Saltvann group is found. The relationships between the Precambrian rocks and the surrounding Caledonides will be considered.

Study of the structural map (Plate II) and the cross-section diagrams (Fig. 13) will make most of the major structural features within the area apparent.

Repparfjord group, NW.

The northwestern area in which the Repparfjord group is found is particularly characterized by overthrust faults with curving fault planes which are convex downwards and dip towards the northwest. The surface trace of the faults is generally concave towards the northwest. In

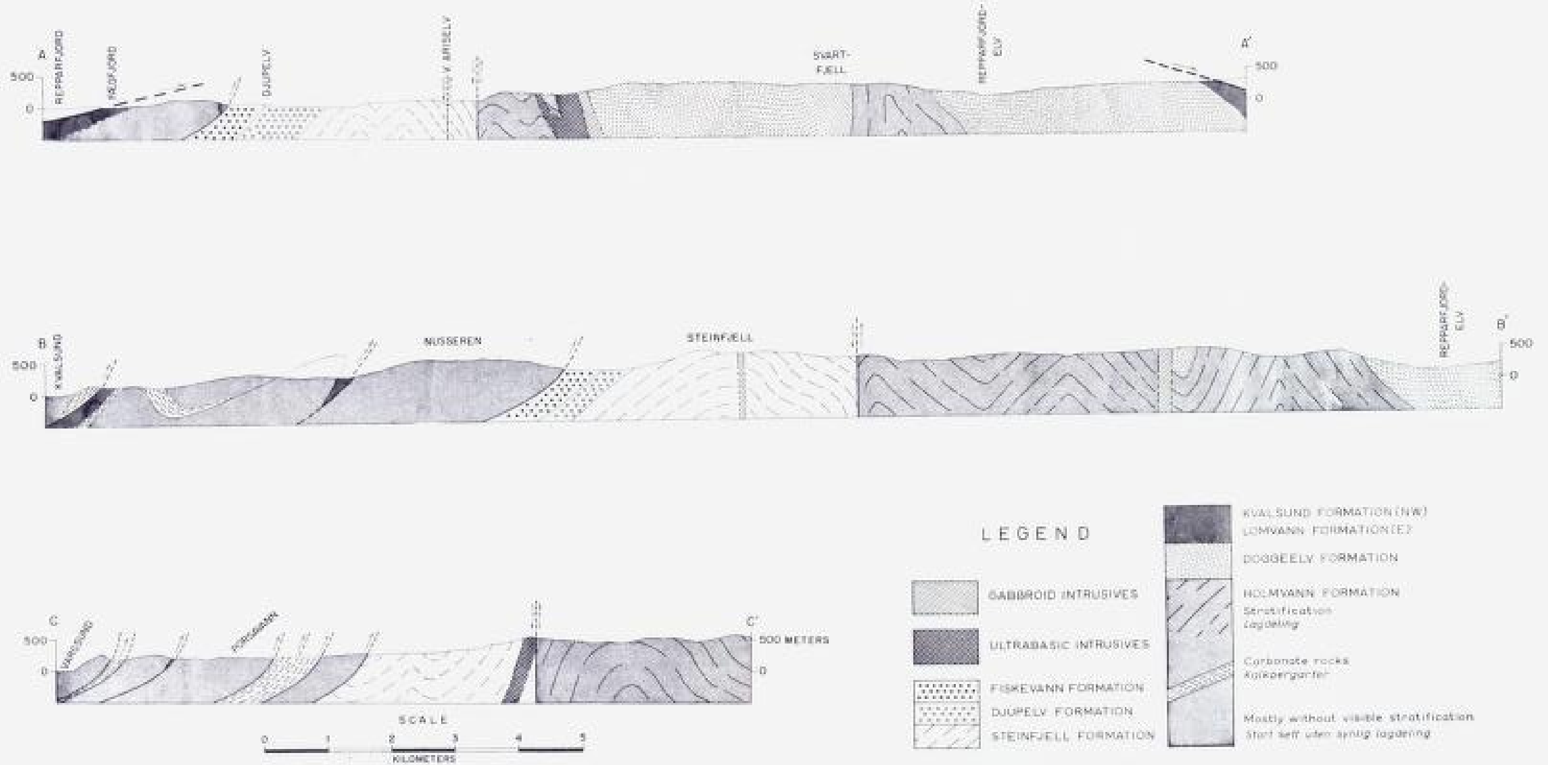


Fig. 13. Cross-section diagrams. See Plate II for locations of sections.
Tverr-profiler. Beliggenhet se plansje II.

the area between Kvalsund (G 1) and Nusseren (G–H 1) there is asymmetrical folding with axial planes dipping towards the northwest.

The movement involved in the thrusting has most often occurred in or adjacent to carbonate strata or talc-rich layers, apparently because these least competent rocks provided planes of relatively easy movement. The result has been to repeat the strata in outcrop several times; the greater the number of bifurcations of the overthrusts the more frequent the repetition. In part the bifurcations were so numerous and closely spaced that it has been impossible on the structural map to show the traces of the individual planes of movement. Instead a zone of closely spaced thrust faults has been shown.

The topography and drainage of this area is very strongly controlled by the structure and affords evidence upon which the structural interpretation has been based. The valleys and streams tend to follow the traces of faults or fault zones. The topographic highs tend to have steeper slopes on their southeastern sides than on their northwestern sides. The carbonate rocks, which, largely coincide with the fault planes, tend to occur most frequently in valleys. Conversely, massive green-

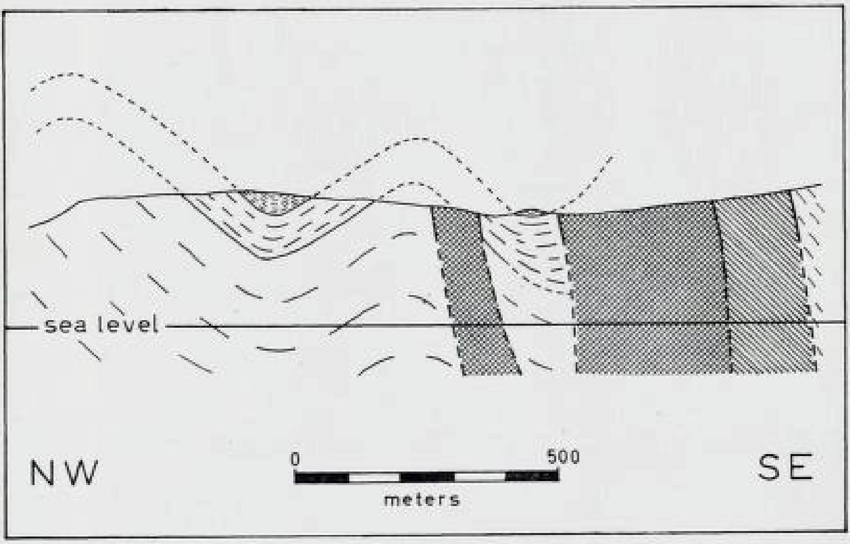


Fig. 14. Cross-sestion illustrating structures near northermost end of intrusives at head of Boriselv (I3).

Profil som viser strukturer nær nordenden av intrusiver ved Boriselv (I3) stones mostly undisected by thrust faults form elongate topographic highs such as Segelnesfjell (D–E 2–3), Middagstind (E 2–3), Høgfjell (E–F 1–2), and Skinnfjell (E–F 2–3). The highest mountain within the area, Skinnfjell at 718 m, has apparently resulted from the elevation of a massive block of greenstone of the Holmvann formation above the predominant level of the Precambrian peneplain in conjunction with the thrusting (see also p. 6 and p. 11).

Movement along the faults was towards the southeast. This is substantiated by the shapes of the fault planes and the evidence of radial fracturing of the massive, competent greenstone blocks (see p. 57). There appears to be some indication of the sense of the movement in the rocks of the Saltvann group, especially near the lake Hermanvann (D 4) as can be seen from cross-section C–C′ (Fig. 13). The asymmetry of the folds southeast of Kvalsund (F 1) as seen in section B–B′ (Fig. 13) and the regional interpretation of the movement of the Caledonides (see Strand, 1960 and references cited therein, and Geukens and Moreau, 1960) are consistent with this interpretation. The regional movement of the Caledonides is important as it is beleived that the overthrusting within the rocks of the Repparfjord group in the area being considered was caused by and was contemporaneous with the over-riding of the Caledonides. The general antiform of the Precambrian rocks constituted an obstruction to the over-riding Caledonides with the result that the foremost (most northwesterly) portions of the Precambrian rocks were dragged along by the Caledonides, be-

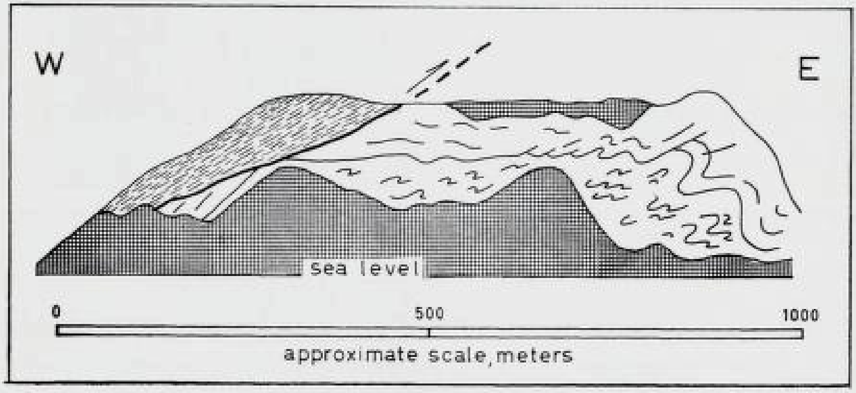


Fig. 15. Sketch of north wall of Skillefjord (A–B 8) at head of fjord.
Skisse fra nordveggen av Skillefjord (A–B 8).

ing pulled up the curving thrust planes along which rupture occurred. The consequent elevation of the Precambrian rocks and warping of the Caledonide-Precambrian contact resulted in a shielding of the remainder of the Precambrian rocks. The structures within the Precambrian rocks in other areas within the tectonic window are therefore only to a minor degree (see Fig. 14) influenced by the Caledonides.

Repparfjord group, SE.

The structures within the remainder of the Repparfjord group are in strong contrast to those just described from the northwestern area. Thrust faults are uncommon except for minor thrust faults seen in the southwestern part, from St. Lerrisfjord (C 5) and southward, as illustrated by the sketch (Fig. 15) of the north side of Skillefjord (A–B 8).

The cross-section diagrams (Fig. 13) show the differences quite

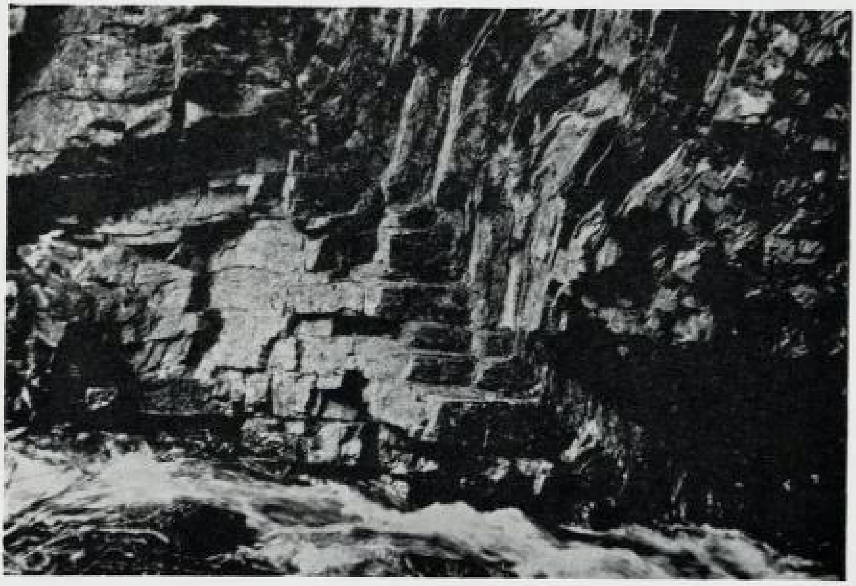


Fig. 16. Step-like folding of Doggeelv formation. Photograph taken towards southwestern valley wall of Doggeelv (J4).

Trappetrinn foldning av Doggeelv formasjonen. Bilde tatt mot den sydvestlige dalsiden av Doggeelv (J4).

clearly. The folds are rather open and frequently slightly asymmetrical with axial planes dipping towards the southeast. Small folds on the flanks of larger folds may have long southeastern flanks and short, shallow-dipping northwestern flanks, making a kind of step-wise ascent of individual strata up the southeastern flanks of the major folds (Fig. 16). Both of these observations are consistent with deformation resulting from a shear couple in which the upper shear vector is directed towards the northwest and the lower towards the southeast. This is, of course, exactly opposite to that which would result from deformation in conjunction with the over-riding of the Caledonides. However, it is the same kind of deformation as is seen in other Precambrian rocks in Finnmark (see p. 64 and Reitan, 1960).

The intrusive rocks in this area cross-cut the stratified supracrustal rocks (Fig. 14) but on numerous occasions—although on a scale too small to be evident from the map—small folds of the contacts between the intrusives and supracrustals may be seen to be parallel to the deformation of the supracrustals. The intrusives therefore at least partly pre-date the deformation in which they were involved.

The trondhjemitic intrusives (C–D 7–8) are brecciated and have been partially recrystallized during the shearing and brecciation. The deformation which caused the brecciation and initiated the recrystallization may in this case have been that associated with the over-riding of the Caledonides.

These structural features help to date the intrusives relative to the surrounding supracrustals. The gabbroid and ultrabasic intrusives are apparently partly prior to and/or contemporaneous with deformation which pre-dates the Caledonian deformation. The trondhjemitic intrusives pre-date the Caledonian deformation which presumably caused the apparently late brecciation.

It therefore appears that the supracrustal rocks and the intrusive rocks have been involved in a pre-Caledonian and probably Precambrian period of deformation as well as the Caledonian deformation.

Saltvann group.

The Saltvann group occurs as a belt stretching from Repparfjord towards Gufsvikklumpen (C 4). It is bounded on the northwest by overthrust rocks of the Repparfjord group and appears to have been somewhat deformed in response to the overthrusting near this boundary. To the southwest the rocks of this group disappear under the Caledonides and to the northeast are bounded by Repparfjord and, as they do not reappear on the opposite side of the fjord, presumably disappear under the Caledonides here, too, although the contact is submerged. To the southeast they are separated from the rocks of the Repparfjord group by a high angle fault (essentially vertical though the dip varies slightly on both sides of the vertical). This fault is a fairly complex tear fault. The trace of the fault on the map would apparently allow for little strike-slip movement. The sense of the movement along the fault cannot be determined in the field. For the most part the fault is not exposed, covered valleys coinciding with it. However, wherever the fault can be approached closely it is possible to collect mylonitized (and later partly recrystallized) samples. Therefore, the sense of movement indicated on the map (Plate I) and in the cross-sections (Fig. 13) is conjectural, based on lithologic grounds and regional correlations (see p. 21 and p. 64).

There seems to be no positive evidence which would support the affirmation that this fault occured in response to the Caledonian deformation. There is equally little indisputable evidence confirming a pre-Caledonian age. However, it seems unlikely that this fault would have developed in response to the Caledonian deformation, which would more likely have produced a thrust fault. It is therefore presumed to be pre-Caledonian, possibly the result of a tensional phase associated with relaxation following the compressional phase which caused the pre-Caledonian folding of the Precambrian rocks.

There are several anticlines and synclines which trend diagonally across the belt of rocks of the Saltvann group. These do not deviate significantly from the trends of the folds in the Repparfjord group and are very likely the product of the same pre-Caledonian stresses which caused the folding in the Repparfjord group. The fact that several of these folds are cut off by one or more of the bounding fault lines indicates that they pre-dated the faults, which is, of course, consistent with the interpretations proposed above.

In the vicinity of Ulveryggen (H–I 2) there are several faults (Fig. 17; Reitan 1960). These branch from each other and the "stem" is cut off by the major high angle fault. On this basis they are presumed to be older than the major fault though it is possible that these faults are minor bifurcations of the major fault and contemporaneous with it.

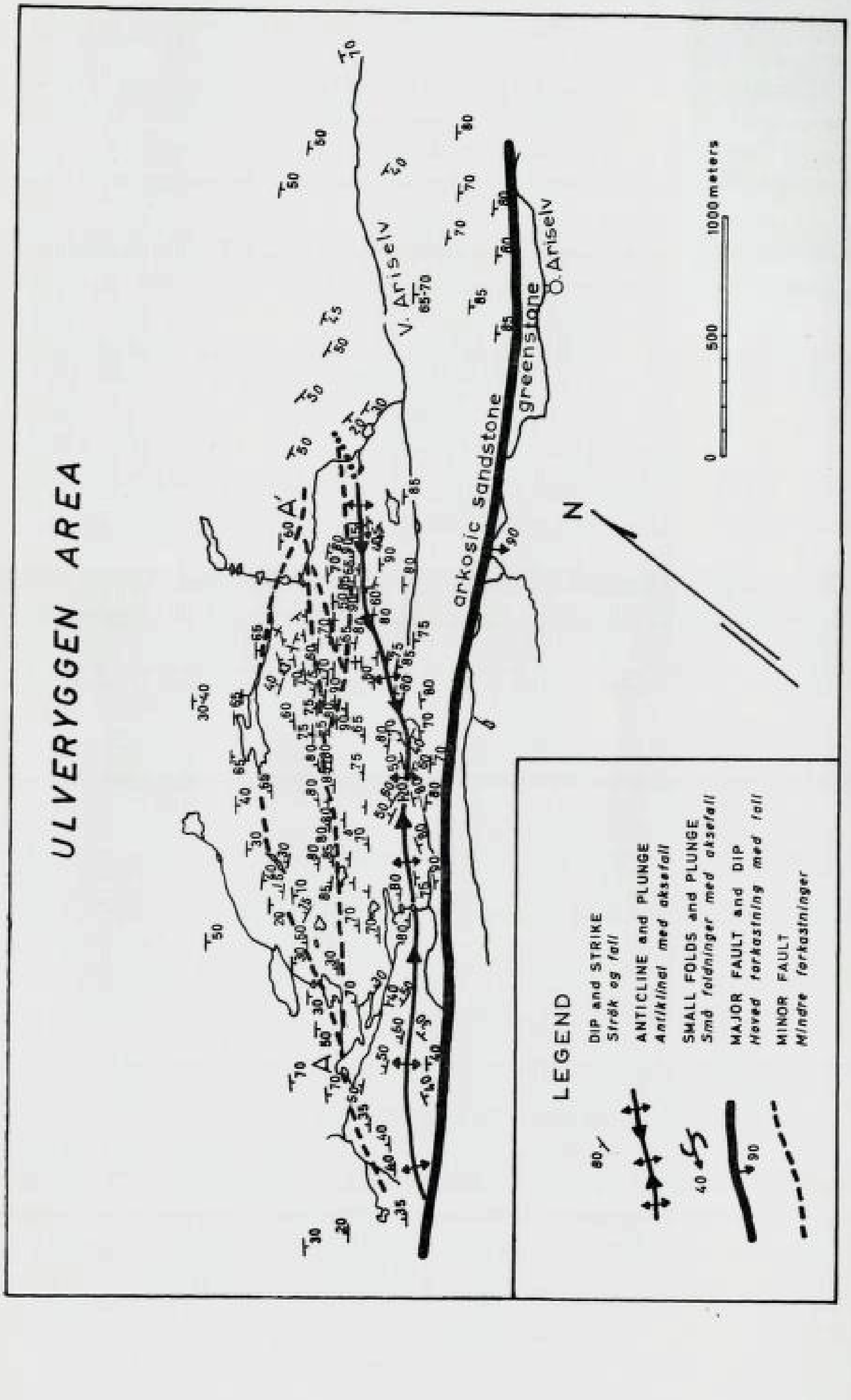

ULVERYGGEN AREA
V. Ariselv
Ö. Ariselv
greenstone
arkosic sandstone
N
0
500
1000 meters
LEGEND
DIP and STRIKE
Strøk og fall
ANTICLINE and PLUNGE
Antiklinal med aksefall
SMALL FOLDS and PLUNGE
Små foldninger med aksefall
MAJOR FAULT and DIP
Hoved forkastning med fall
MINOR FAULT
Mindre forkastninger

Fig. 17.

In either case the faults are beleived to be pre-Caledonian and, in all probability, Precambrian. This supports conclusions reached (p. 59) concerning the age of the mineralization at Ulveryggen.

Summary.

The structural observations allow the following conclusions to be drawn.

The Repparfjord group of rocks in the northwestern part of the area have been thrust towards the southeast moving along fault planes concave upwards and towards the northwest and dipping towards the northwest. This thrusting was caused by and was contemporaneous with the over-riding of the Caledonides. Therefore, the pre-Caledonian distance between the Repparfjord group rocks in this area and in the southern and eastern arean, where the same group outcrops, was greater than it is at present. Stratigraphic correlations must be considered bearing this in mind. Although the distance of movement is unknown, what may appear to be rather extreme depositional facies changes from the present proximity (i.e., Kvalsund formation and Doggeelv–Lomvann formations), were, at the time of deposition, appreciably less extreme.

In addition, the structural observations account for the sites of veins bearing Cu–Fe sulfides and indicate that this type of vein deposit cannot be expected to become more frequent or the veins larger with increased depth (see p. 57).

The type of deformation of the southern and eastern portion of the rocks of the Repparfjord group cannot be explained as a consequence of the Caledonian orogeny. As the surrounding Caledonides have not suffered the same deformation the conclusion is inescapable that the Precambrian rocks were involved in a pre-Caledonian period of deformation which is consistent with that found in the Precambrian rocks of Finnmarksvidda (see p. 64 and Reitan, 1960) and is believed to be Karelian.

The structural observations around Ulveryggen in rocks of the Saltvann group indicate that the deformation was pre-Caledonian and that the disseminated mineralization spacially associated with it is more likely also pre-Caledonian than contemporaneous with or after the Caledonian orogeny (see p. 59).

ECONOMIC GEOLOGY

No special emphasis has been placed on the metallic or non-metallic deposits of economically valuable types during the course of this investigation, although their presence and geological environment have been noted and samples have been collected. Some of the samples were given to Vokes who made a mineralogical study of the types of mineralization represented (Vokes, 1957).

Metallic deposits.

The metallic deposits are of copper-iron sulphides. Vokes (1957) has distinguished two different parageneses which he called "the copper paragenesis" and "the pyritic paragenesis". Within the Komagfjord window the former is represented by the disseminated mineralization known to be present at Ulveryggen, near Repparfjord, in the Steinfjell formation. The pyritic paragenesis is represented by innumerable small vein fillings especially common in the Holmvann formation but also known from the Doggeelv formation and the gabbroid intrusives. Typical of this type of deposit, but of larger dimensions than are common, are the deposits at Bratthammer mine, the Porsa mines, and Bachkes mine.

Morphologically the deposits of the pyritic paragenesis are distinct veins of clearly limited extent and very commonly of lens-like form. The sulphide minerals are pyrite and chalcopyrite; the gangue is calcite and quartz; magnetite may be present in small amounts. The sequence of crystallization of the ore minerals is pyrite and magnetite, followed by chalcopyrite (Vokes, 1957).

The deposits in the vicinity of the Porsa mines at Grubevann, including Bachkes mine, are in veins which are essentially perpendicular to the main structures in the area. The general strike of the rocks is NE–SW with dip. ca. 50° NW and the veins strike essentially E–W at the Porsa mines and about NW–SE at Bachkes mine. They are about vertical and lens shaped on the surface; mine maps and reports indicate that they become thinner with depth. They appear to be crack-filling deposits.

The Holmevann formation between Grubevann and Kvalsund is characterized by high angle thrust faults or reverse faults which occurred in the domed-up Precambrian rocks as the Caledonides overrode (see p. 50). The mountains Segelnesfjell, Middagstind, Midtfjell, Skinnfjell, Høgfjell, and Langvassfjell, consist of massive greenstone. The mountains are separated by valleys in which occur the carbonate rocks, quartzites, and some talc-rich schists and greenschists. These valleys represent the zones of major reverse faulting, especially the carbonate rocks being good lubricants along planes of movement. The fault-lines are characteristically arc-formed with the center of curvature to the northwest. The massive, volcanic greenstones forming the mountains were also slightly bent along the same kind of arcs during the movement upward and forward and were therefore subjected to tension about parallel to the strike throughout the outer portions of the arc. In relatively competent rocks such as the greenstones, this resulted in cracks essentially perpendicular to the strike which were filled with constituents of the fluid phase, thus forming the mineralized veins.

As the main reverse faults are curving faults which become flatter with depth one cannot expect the tensional openings to become wider with depth—rather just the opposite—nor can one expect them to continue to great depths. (The veins in the Porsa mines had thinned from 10 meters broad at the thickest at a depth of 12 meters below the surface to 3 meters broad at 75 meters below the surface for "Grennville" vein, and from 11 meters broad near the surface to ca 2 meters at 96 meters below the surface for "Paralell" vein. The length of the veins also diminished with depth.) As tensional cracks would form wherever the tension exceeded the strength of the rocks, one cannot expect to find a principal vein—a "mother lode"—from which the known deposits are mere off-shots. The deformation was of a type which would lead to the formation of numerous relatively small deposits; a dispersion of the metals of the ore forming fluids rather than a concentration at any one or a few sites.

The above evaluation based on knowledge gleaned from the reports in the archives of Norges Geologiske Undersøkelse and from the interpretation of the structures in the area which developed from the regional geological mapping does not offer any hope that the known deposits could be profitably re-opened for mining or that any unknown deposits of significance remain to be found.

The formation of the deposits was undoubtedly contemporaneous with the Caledonian orogeny.

The mineralization of the copper paragenesis occurring in the Komagfjord window is located at Ulveryggen. The dominant texture of the mineralization is one where the sulphides occur as scattered patches or grains interstitial to the clastic grains of the country rock. The sizes of the patches varies considerably, from about 5 mm and down. The grain size of the sulphides is generally less than 1 mm. Veins and veinlets generally less than 1 cm wide and generally filled by sulphides cut in all directions through the sandstone. At times the mineralization is so finely disseminated that even with the help of a 10 power magnifying lens it is impossible to identify mineral types or make any estimate of the grade of the ore. Such samples may, however, when assayed prove to be among the richest in Cu which can be found (personal communication, C. W. Archibald, Invex Corporation).

The area of known mineralization on Ulveryggen is located about roughly in the center of the map, Fig. 17. It is roughly eliptical in shape, about 1700 meters long and 400 meters broad. Within this area are zones of low-grade mineralization which are separated by barren or virtually barren sandstone.

The mineralization appears to be related to an area of particularly intense faulting and shearing (see Fig. 17; Reitan, 1958). This spacial relation may be fortuitous (see discussion later, p. 61, on the results of preliminary geochemical prospecting in the area). If, however, the mineralization is contemporaneous with the faulting spacially associated with it, one has some basis for dating the period of impregnation. The folding and faulting is cut off by the fault along the boundary between the Steinfjell formation and the Holmvann formation. This means that the faulting within the Steinfjell formation in the vicinity of the known mineralization is probably older than the fault between the Steinfjell and Holmvann formations. The fault between the formations can, in turn, be followed to the contact between the Precambrian rocks and the surrounding Caledonides (near Hermannvann), where it disappears under the overthrust Caledonides. As this fault is an essentially vertical fault it does not appear to be related to the faulting which occurred in the Precambrian rocks at the time of the Caledonian orogeny (cfr. the faulting along Vargsund). This means that this fault in all probability antedates the Caledonian overthrusting. (See p. 53 for a more complete discussion.) Therefore, the tectonic activity associated with the mineralization appears to antedate the steep fault between the two formations which itself antedates the Caledonian orogeny. It is therefore pre-Caledonian and in all probability Precambrian. If the spacial relationship between the mineralization and the tectonism is not simply fortuitous, then the mineralization must be regarded as pre-Caledonian, probably Precambrian. According to Vokes' (1957) description of the textures of the mineralization and its relations to the detrital grains of the surrounding sandstone, it does not appear to be a syngenetic deposit, though it must be kept in mind that this criterion is not decisive as the sulphides may have been mobilized since their deposition and the textures accordingly modified.

The mineralization at Ulveryggen is not easily seen on the weathered surfaces—especially as there usually is some lichen growth on the rocks—and does not draw the attention of a geologist engaged in regional mapping. For this reason it was decided to begin a program of geochemical prospecting over the Steinfjell formation. The first step in the plan to cover all of the exposure of the sandstone was taken during the summer of 1959 in co-operation with Statens råstofflaboratorium (State Raw Materials Laboratory), Trondheim. In that summer 441 samples of stream sediments were taken by two men during 12 working days between July 15th and August 25th within an area of about 10 km^2. The samples were analysed using Holman's method, a semi-quatitative analysis by which the easily soluble Cu is determined (Holman, 1956). The analyses were made by Statens råstofflaboratorium under the supervision of Mr. Bjørn Bølviken. The map, Fig. 18, shows the results of the analyses.

In the area near the mines the results show very high quantities of Cu in the stream sediments, indicating that the technique is effective in the terrain. Part of the reason for the very high concentrations near the mine is that much of the water in the streams comes out of the mines, and the surface area of rock exposed to weathering—because of the mine dumps—is extraordinarily high. However, in the northwestern part of the area sampled most of the analyses show anomolously high Cu in the stream sediments. The drainage system involved has no connection with that below the mines so there can be no question of contamination from the mines.

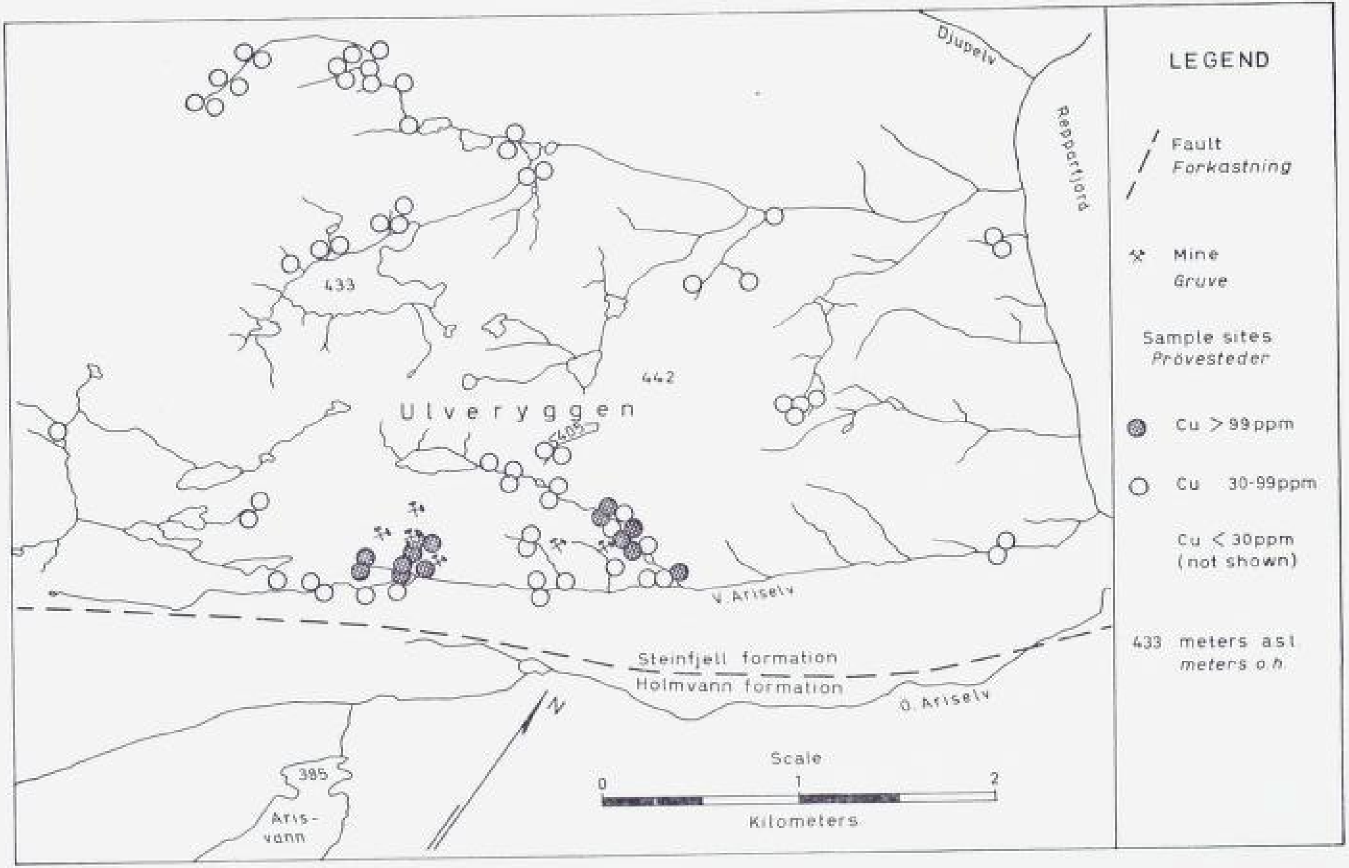

LEGEND
Fault
Forkastning
Mine
Gruve
Sample sites
Prövesteder
Cu > 99ppm
Cu 30-99ppm
Cu < 30ppm
(not shown)
433 meters asl
meters o.h.
Djupelv
Repparfjord
433
442
Ulveryggen
405
V. Ariselv
Steinfjell formation
Holmvann formation
Ö. Ariselv
N
Scale
0
1
2
Kilometers
385
Aris-
vann

Fig. 18.

Unfortunately, at the time of writing, there has been no opportunity to make a detailed examination of the rocks in this area since the analyses were made. The program of geochemical prospecting of the Steinfjell formation has also been interrupted, but it is planned that it will be resumed along with detailed geological examination of the rock in the areas of anomolously Cu-rich stream sediments. Until such time, no reliable and complete evaluation of the geochemical prospecting done thus far can be made.

The anomolously high values of the northwestern part of the area sampled come from streams which do not drain the zone of unusually great tectonization shown in Fig. 17 and spacially associated with the area of known mineralization. This may mean that the mineralization has no genetic relationship to the tectonism. However, supplementary and more detailed investigations will have to be made before this question can be decided.

Non-metallic deposits.

No non-metallic deposits have been commercially exploited within the area of the Komagfjord window. It has been beyond the scope of this report to attempt to study non-metallic deposits in sufficient detail to determine whether they could be of economic interest. It is also a type of investigation which is outside of my field of competence.

Fibrous serpentine (clinochrysotile) has been identified from the serpentinite body at Rødfjell. At least in cracks there occurs sufficiently long-fiber serpentine that, if the quantity is sufficient, it could be of economic interest. There are numerous thoroughly serpentinized ultrabasic bodies within the area, however none is thought to be any more promising than that at Rødfjell.

In Vesterdalen, the valley between Segelnesfjell and Middagstind, and near Beritsjord very talc-rich schist has been observed. It is undoubtedly connected with the reverse faults common in the valleys in this area. Whether the quality of the talc or the sizes of the schist lenses would allow profitable exploitation has not been determined.

The purpose of these comments is not to stimulate hopes but only to indicate that there are deposits which warrant investigation by a qualified and competent geologist.

Historical.

The main mining in the area has been carried out in the coastal area between Beritsjord and Grubevann. There are numerous small prospects from which a few tons of hand-sorted ore have been shipped, mainly to the Kåfjord Mines near Alta.

The largest individual mine was the Porsa mine at Grubevann, driven on two parallel veins, the so-called "Grenville" vein and "Paralell" vein. These were exploited from 1890 to 1910 and from 1924 to 1931 (reports on the Porsa area in the NGU archives). During the last working period the grade was not higher than about 1 % Cu and the reserves were estimated to be only a few thousand tons. The latter few years of operation were unfortunate—fires caused much equipment to be destroyed in February, 1926—and the fall of copper prices in 1929 finally forced the mines to close down. Since then there has been no mining activity in the area.

Bachkes Mine was worked from 1900 to 1906. The calculated production (derived from very incomplete records) was about 10,000 tons of ore which varied from about 20 % to about 2 % Cu. The calculated average was about 5 % Cu. This is after the product from the mine had been hand-sorted. Kvalheim (1928, NGU archives) says that the proved reserves are about 400 tons with probable additional reserves of about 300 tons. The Cu content is quite uncertain; one bore hole indicates that it may be about 3 to 6 % Cu.

The area of mineralization at Ulveryggen was the object of considerable exploratory work from 1903 to 1909. In 1907 there were 200 tons of ore carted to the sea where 80 tons of 10–15 % Cu concentrate was obtained and shipped. In 1912 there was again some exploration by an English syndicate (no more specific information in the NGU archives). In 1956, 1957, and 1958 some exploratory work including diamond drilling was done by Invex Corporation, Toronto, Canada, but no results of their investigations have been made public. At no time has regular mining been carried on for an extended period of time.

Conclusions.

The vein-type of deposits in the greenstones of the Holmvann formation, deposits of the "pyritic paragenesis", do not appear to offer any hope of profitable exploitation. They are characteristically quite small and are not extremely rich deposits. Even the largest and best known deposits appear to be of no economic value.

There is little hope that new deposits of any size will be found in the future. The area is very little covered by vegetation and alluvium and this type of deposit is very easily seen in the field. It was my experience that virtually every small sulphide-bearing vein in the Holmvann formation has been noted and investigated, at least to the extent of there having been expended a few blasts of dynamite.

The deposit at Ulveryggen, of the "copper paragenesis", is more difficult to evaluate. It is quite possible that selective mining on a small scale could be profitably conducted. Whether large-scale mining would pay or not is unknown. Insufficient evidence is available, at least to me, to be able to solve the problem. The difficulty lies in the presence of barren or virtually barren rock between the mineralized lenses.

It is conceivable that as yet undiscovered deposits of this type, disseminated mineralization in sandstone, exist in the Steinfjell formation. It is a type of deposit which is not readily noted by a casual observer. It is therefore my opinion that the entire area where the formation crops out should be systematically prospected geochemically. The preliminary work done so far indicates that the "stream sediment method" works in this area. If any anomalously high Cu values are obtained from the stream sediments in any area then a competent geologist should make a detailed study of the area concerned. Such a program could be rapidly and inexpesnively completed. The main difficulty which may be encountered is in getting suitable samples of proper grain size from a number of the streams. At present it is the intention of Norges Geologiske Undersøkelse in co-operation with Statens råstofflaboratorium to conduct such an investigation.

CORRELATIONS WITH OTHER AREAS

The Precambrian of northern Norway has been described and correlations between areas have been attempted elsewhere, the most recent being by Reitan (1960; in press; see also the references cited in these).

In the absence of fossil evidence and radiometric age determinations, attempted correlations between areas can be based only on lithologic-stratigraphic and structural similarities. Were the mapping continous and in greater detail—and there are some probably critical areas as yet unmapped at any scale—greater confidence could be placed in correlations. Given the existing circumstances the correlations which are proposed must be regarded as tentative.

A general stratigraphic sequence of the Karelian formations has been worked out in Finland. In eastern Finland, according to Väyrynen (1933), it is as follows:

Kalevian phyllites and mica schists

Jatulian	marine Jatulian; phyllites and dolomites
	Kainuan quartzite
	Sariolian arkoses and conglomerates

——————— great unconformity ———————

Granite gneiss basement

According to the studies carried out by Härme (1949) in northern Finland the general sequence of the Karelian formations begins with quartzites which are overlain by greenstones and slates with some dolomites. The quartzites are correlated with the Kainuan quartzites of eastern Finland and the greenstones and slates are beleived to be equivalent to the uralite diabase sills in the Jatulian formations and the Kalevian phyllites and schists.

Mikkola (1941) has called the Karelian rocks in Finnish Lapland, which consist mainly of quartzites, mica schists, and basic volcanics, the Lapponian formations. The overlying clastic sedimentary rocks he has called the Kumpu-Oraniemi formation.

In eastern Finland two phases of movement of the Karelidic belt have been distinguished (Väyrynen, 1939). The first, resulting in rather moderate folding, acted from west to east. Characteristic of later movements was overthrusting from the northwest.

The characteristics of the Karelidic belt in Finland have recently been summarized by Simonen (1960).

In northern Norway a general stratigraphic sequence can be recognized which is very comparable to that reported in Finland. Gneisses are overlain by quartzose clastic sediments (rarely local basal conglomerate, arkosite frequent near the base though K-metasomatism is beleived to account for some of the feldspar, and quartzite which is sometimes micaceous is common) which are in turn overlain by a thick sequence of greenstones with greenschists and intercalated carbonates. These would correlate with the Lapponian formations overlying basal gneiss in northern Finland. The same general sequence has been observed in northern Sweden (Padget, 1960, personal communication).

It is quite possible that the greenstone-greenschist formations are of variable thickness with the result that separated basins existed into which quite variable though predominantly clastic sediments were deposited with at least local unconformities between the Lapponian and overlying formations. In northern Finland Mikkola (1941) called these sediments the Kumpu-Oraniemi formation and described them as coarse-grained arkosic quartzites and conglomerates.

In northern Norway the equivalents would be: in the western interior of Finnmark the argillite and overlying sandstones, grit, and quartzite of the Čaravarre group (Holmsen, Padget, and Pehkonen, 1957); in the vicinity of Alta and Talvik Geukens and Moreau (1960) have distinguished two basins of sedimentation, the western containing, from below, alternating quartzites, dark violet schists and stromatolite limestone, and grayish schists, and the eastern (described by Holtedahl, 1918, near Alta) containing calcareous schists, carbonate rocks, and partly schistose graywackes underlying mostly violet colored quartzitic schists, graywacke, sandstone, and quartzite. In the Komagfjord window two basins of deposition are distinguished. In the northwestern basins only the Kvalsund formation is found while in the eastern and southern basin the Doggeelv and Lomvann formations are found. The rocks of the Saltvann group may represent still another basin of deposition, though the stratigraphic position of these rocks remains uncertain (see p. 21).

Thus it appears that the Holmvann formation can be correlated with the upper portions of the Lapponian formations of northern Norway, Finland, and Sweden and that the Kvalsund, Doggeelv, and Lomvann formations, and probably the Saltvann group, are the stratigraphic equivalents of a variety of lithologic types which were deposited in separate basins upon the Lapponian formations and are now present only in a few places in northern Norway.

No attempt will be made here to correlate with the rocks overlying the gneisses in eastern Finnmark, as such attempts are very uncertain (see Bugge, 1960; Reitan, 1960, in press).

The Precambrian folding in the Komagfjord window is in complete accord with the Karelian structures found by Väyrynen (1933) and by Holmsen, Padget, and Pehkonen (1957) (see Reitan, 1960, in press) and serves to strengthen the degree of confidence which can be placed in the correlations which have been suggested.

SAMMENDRAG

Komagfjord-området ligger i Vest-Finnmark mellom 70° 10′ og 70° 31′ nord og 12° 40′ og 13° 50′ øst Oslo meridian. Det omfatter deler av fire forskjellige kartblad: Hammerfest, U.3, Repparfjord, V.3, Komagfjord, U.4, og Stabbursdalen, V.4 (se også fig. 1). Områdets grense mot syd og sydøst følger meget nær Riksvei 50. I nord-nordvest og vest følger den kysten. De indre deler er tilgjengelige bare til fots.

Området er et tektonisk vindu. På kartet ser man at prekambriske bergarter er omgitt av overskjøvne kaledonske bergarter. De førstnevnte er nær beslektet med de prekambriske bergartene sønnenfor i Alta-Kvænangen-vinduet (Holtedahl, 1918, 1953, Zenzen, 1915, Geukens og Moreau, 1958, 1960, Reitan 1960). De prekambriske bergartene i begge vinduene har tidligere vært kjent som Raipas-formasjonen (navnet gitt av T. Dahll etter Unne Raipas ved Alta), men p.g.a. de nye formasjoner og grupper som oppstilles i nærværende arbeide, foreslås det å bruke betegnelsen Raipas-*suiten* (se Anonymous, 1961). Innenfor Komagfjord-området er det to grupper, Repparfjord-gruppen og Saltvann-gruppen. Aldersforholdet mellom disse er usikkert, men det antas at Saltvann-gruppen er enten yngre enn eller ekvivalent med den øverste delen av Repparfjord-gruppen. I begge grupper, som utvilsomt er pre-kaledonske og sannsynligvis prekambriske, finnes yngre intrusiver.

I Raipas-suiten innenfor Komagfjord-området finnes følgende formasjoner og bergarter: Den nederste formasjon i Repparfjord-gruppen er Holmvann-formasjonen, en serie mørkt grønn-grå suprakrustale vulkanske og sedimentære lag i den nordlige delen av området, med noen karbonat- og kvartsittlag. I nordøst, øst og sydøst har en Doggeelv formasjonen, stort sett en ganske ren kvartsitt, som overligger Holmvann-formasjonen. Øverst kommer Lomvann-formasjonen, en leirskifer som i nordøst er sandrik med overgangskontakt mot Doggeelv-formasjonen. I øst og sydøst er leirskiferen mere finkornet med skarp kontakt (og med konglomerat enkelte steder) mot den underliggende kvartsitten. I nord, i nærheten av Kvalsund, har en Kvalsund-formasjonen, en svart, kullstoffrik leirskifer som hviler på Holmvann-formasjonen uten mellomliggende kvartsitt.

Saltvann-gruppen består nederst av Steinfjell-formasjonen, en feltspatrik sandstein med intraformasjonale konglomeratlag. Den viser overgang oppover til Djupelv-formasjonen, et sterkpresset konglomerat som hovedsakelig består av grønnstein- og grønnskifer-boller med litt grovkornet, sandig grunnmasse. Øverst er Fiskevannformasjonen, en konglomeratisk feltspatrik sandstein som inneholder mange, meget karakteristiske, mørke mikroporfyr-boller.

To deformasjonsperioder kan ettervises. Den første er pre-kaledonsk og sannsynligvis prekambrisk. Den sees best i de østligere delene av området (fig. 14 og 16) hvor foldene tyder på trykk fra sydøst. Den yngre deformasjonen står i forbindelse med kaledonske bevegelser. Den iakttas best i den nordvestlige delen av området som er karakterisert ved flere overskyvninger mot sydøst. De prekambriske bergarter i nordvest ble skjøvet opp og mot sydøst langs buete skyveflater. Resultatet er at prekambrium står høyere over havet i nordvest (f.eks. Skinnfjell, 718 m o.h.) enn noe annet sted innenfor området (se fig. 2). Saltvann-gruppen viser merker etter kaledonsk deformasjon langs nordøst grensen (Fig. 13) og etter tidligere deformasjon omkring Ulveryggen (fig. 17, Reitan, 1960).

Metamorfosegraden innenfor området varierer fra høy grønnskiferfacies til lav epidot-amfibolitt-facies (etter Barth, 1952, og Ramberg, 1952) eller grønnskifer-facies til almandin-amfibolitt-facies (etter Turner, 1958). Der finnes mineralselskaper som er typiske for kvarts-albit-muskovit-klorit-subfacies og kvarts-albit-epidot-biotit-subfacies av grønnskifer-facies og for staurolit-kvarts-subfacies av almandin-amfibolitt-facies (Turner, 1958). Den høyeste metamorfosegrad finnes langs et belte som strekker seg fra Breidalselv (H 4) forbi den øverste delen av Båtdalselv, Mikkeldalselv, Breidalselv (G 5), Markfjell og til Småhaugene. Den laveste metamorfosegrad finnes bare i den nordlige delen av området. Grovt sett har man en sone-ordning med stigende metamorfosegrad mot syd og sydøst. Isograden som skiller kvarts-albit-muscovit-klorit-subfacies (i nord) fra kvarts-albit-epidot-biotit-subfacies (i syd) går omtrent gjennom Klakkeggen (D 4) og Gænočokjavre (I 3).

Kopper-jernsulfid mineralisering er meget alminnelig innenfor Komagfjord-området. Der forekommer to assosiasjonstyper, «Kopperparagenesen» og «kisparagenesen» (Vokes, 1957). Den første sees på Ulveryggen ved Repparfjord, og den andre finnes i mange små ganger gjennom hele området, særlig i Holmvann-formasjonen. Kisparagenese finnes ved Bratthammer, Porsa og Bachkes gruver. Disse forekomster er større enn vanlig for denne type. «Kisparagenesen» forekommer i vel avgrensete ganger, vanligvis linseformete. Mineralene er svovelkis og kopperkis med kalkspat, kvarts og muligens litt magnetitt.

Forekomstene ved Porsa står loddrett på strøket. Strøket i nærheten er ca. NØ-SV med fall ca. 50° mot NV. Gruvekartene viser at gangene blir tynnere mot dypet. De ser ut til å være sprekkefyllinger. Som sagt før er Holmvann-formasjonen omkring gruvene karakterisert ved forholdsvis steile skyvninger med buete skyveflater, som i dagen er konvekse mot SV. Under skyvningen ble de ganske kompetente grønnsteinene bøyet, hvorved oppsto tensjonssprekker. Disse ble fylt med metallførende løsninger, hvorav kismineralene krystalliserte. Skyveflatene blir planere mot dypet og derfor kan man ikke vente at de gjenfylte sprekkene vider seg ut nedover — tvert imot, de blir tynnere og må antas å forsvinne på ikke særlig stort dyp. Siden deformasjonen var fordelt over flere blokker og disse grønnsteinsblokkene sprakk alle steder hvor tensjonen ble stor nok, må man videre regne med at mineraliseringen er fordelt over mange små ganger. Man kan således ikke vente å finne flere store gang-forekomster innenfor området og det kan ikke ansees økonomisk forsvarlig å sette igang drift på de nedlagte gruvene.

«Kopperparagenesen» er kjent som spredt mineralisering av Steinfjell-formasjonen på Ulveryggen (fig. 17), innenfor et område ca. 1700 m langt og 400 m bredt. Mineraliserte soner er adskilt ved umineralisert sandstein. Det ser ut som om mineraliseringen muligens er forbundet med forkastninger og forholdsvis sterke skjærbevegelser (Reitan, 1958). I så fall er det, siden denne deformasjonen er pre-kaledonsk, mest sannsynlig at mineraliseringen er pre-kaledonsk og muligens prekambrisk.

I samarbeid med Statens råstofflaboratorium ble geokjemisk prospektering påbegynt sommeren 1959. For å prøve den valgte metoden ble et lite område omkring Ulveryggen undersøkt. Resultatene tyder på at metoden godt kan brukes selv i snaufjellsområder (lite vegetasjon). Da mineraliseringsproduktene i sandsteinen delvis er uhyre finkornete og vanskelige å se, anbefales det at større deler, særlig av Steinfjell-formasjonen blir undersøkt ved geokjemiske prospektering.

Så vidt man kan dømme av undersøkelsene hittil er det meget mulig at gruvedrift på Ulveryggen i liten skala kunne lønne seg. Den umineraliserte sandsteinen som adskiller de mineraliserte soner utgjør en vanskelighet.

Det er mulig at det finnes flere mineraliserte områder i Steinfjellformasjonen enn de som er kjent på Ulveryggen. For å undersøke dette burde det foretas systematisk geokjemisk prospektering sammen med mere detaljert geologisk kartlegging i enkelte områder.

Arbeider i Finnland (Väyrynen 1933, 1939, Mikkola 1941, Härme 1949, Simonen 1960) og Finnmark (Holtedahl 1918, Holmsen, Padget og Pehkonen 1957, Reitan 1960), tyder på at stratigrafien og strukturen i Komagfjordområdet kan korreleres med karelsk stratigrafi og struktur i de indre delene av Finnmark, i Nord-Finnland og i Sverige (Padget 1960, personlig opplysning) og Syd-Finnland.

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Geologic Map of the Komagfjord Tectonic W

Paul H. Reitan

Geologisk kart over Komagfjord om

STRUCTURAL MAP
(NORTHERN PART)

KOMAGFJORD TECTONIC WINDOW

Strukturkart (nordlige del) Komagfjord området