SVERIGES GEOLOGISKA UNDERSÖKNING

SER. Ca AVHANDLINGAR OCH UPPSATSER I A4 NR 64

JAN SVERRE SANDSTAD (Ed.)

PROTEROZOIC COPPER MINERALIZATIONS IN NORTHERNMOST NORWAY

7th IAGOD SYMPOSIUM
AND NORDKALOTT PROJECT MEETING

NORWEGIAN PART OF
EXCURSION GUIDE NO 6

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With contributions by R. Hagen, J.S. Sandstad and E. Vik

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Falu copper mine has been continuously mined for more than 900 years. Copper plate engraving from 1687 in Dahlberg's *Svecia Antiqua et Hodierna.*

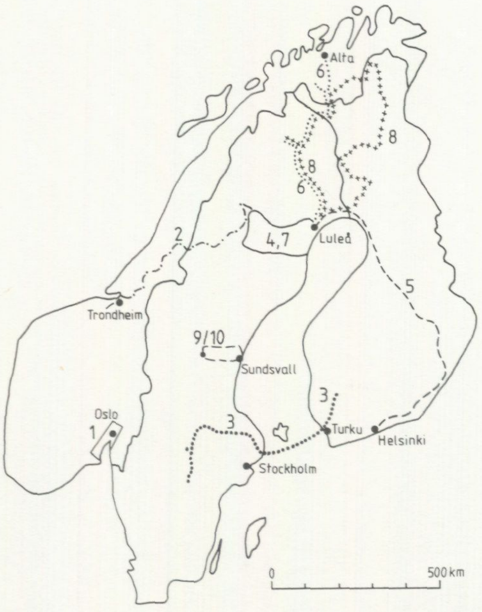
FOREWORD

Mining has ancient traditions in Scandinavia and Finland. In Bergslagen, Sweden, numerous mines produced Cu, Fe and Ag already during the medieval period. Some of them, e.g. Falun and Dannemora, are still active and are thus among the oldest operating mines in the world. Minerals like scheelite, gahnite and långbanite were first recognized in this region and the word skarn (originally having a pejorative connotation in Swedish meaning crap and whore) was used as a name for a certain mineral association for the first time by the old miners in Bergslagen. The most famous mining districts in Norway are Kongsberg, where silver was produced 1623–1957, and Røros, where copper was mined from 1644 until recently. The first mine in Finland was the Ojamo iron ore deposit, which was opened in 1540.

In addition to these ancient workings, ore bodies in several new mining districts have been exploited during the last century. Some of the most important of these occur in northern Sweden such as the Kiruna iron ores, the sulphide ores in the Skellefte district, the Laisvall Pb-mine and the Aitik Cu-Au mine. The sulphide ores in the Outokumpu district and in the Vihanti-Pyhäsalmi area are the most well-known Finnish deposits discovered during this century. In Norway, numerous deposits of pyrite and base metals were discovered round the turn of the century in the Sulitjelma and Grong districts and have been of major importance for the Norwegian mining industry. The discovery of extensive Mo-mineralization in the Oslo area, Norway and Pt-mineralization in the Kemi area, Finland have not led to any significant mining but have revealed new aspects of the metallogeny in the Nordic countries.

As a result of this long tradition in mining, the question of how ores are formed has been debated longer than any other geological problem in Scandinavia and Finland. It is therefore of special interest for the Nordic countries that the International Association on the Genesis of Ore Deposits (IAGOD) this year will arrange its 7th symposium in Scandinavia. The symposium, which is held in Luleå, Sweden, is arranged by the Geological Surveys of Sweden, Finland and Norway and the Luleå University of Technology. As an important part of the symposium programme, nine pre- and post-symposium excursions covering most of the important mining districts in Norway, Sweden and Finland are arranged (see overleaf). For these excursions, guide books have been written and are now available amongst the publications of the Geological Survey of Sweden (SGU Ca 59–67). The Swedish part of excursion no 6 was prepared in 1980 and was published by the Geological Survey of Finland. To all who have been involved in planning and organizing the excursions as well as writing the guide books I would like to express my sincere thanks.

Krister Sundblad, Geological Survey of Sweden
coordinator of the IAGOD-excursions 1986



1. Metallogeny associated with the Oslo Paleorift
Guide book: SGU Ca 59.
Excursion leader: S. Olerud.
Topic: Porphyry molybdenum mineralizations (Nordli, Hurdal and Bordvika, Drammen). Native silver-bearing veins at Kongsberg. Mineralizations associated with the Drammen granite; contact metasomatic Zn-Pb deposits (Konnerudkollen), intramagmatic Mo deposits.

2. Stratabound sulphide mineralizations in the central Scandinavian Caledonides
Guide book: SGU Ca 60.
Excursion leaders: M.B. Stephens and A. Reinsbakken.
Topic: Early Palaeozoic, massive Cu-Zn sulphide mineralizations in both volcanic (Gjersvik, Joma, Løkken and Stekenjokk) and sedimentary (Ankarvattnet) environments. The Laisvall sandstone-hosted, disseminated Pb-Zn deposit.

3. Mineral deposits of southwestern Finland and the Bergslagen province, Sweden
Guide book: SGU Ca 61.
Excursion leaders: H. Papunen and I. Lundström.
Topic: Proterozoic Zn-Cu-Pb deposits in volcanosedimentary environments including the mined-out Orijärvi and Aijala deposits in Finland, and the Garpenberg and Åmmeberg deposits in Sweden; the iron ore deposit of Dannemora in Sweden. Deposits associated with intrusive rocks include the Vammala Ni-Cu mine in Finland and the Wigström W deposit in Sweden.

4. Massive sulphide deposits in the Skellefte district
Guide book: SGU Ca 62.
Excursion leader: D. Rickard.
Topic: Proterozoic Cu-Zn-(Pb-As-Au) mineralizations in volcanosedimentary environments, including the Boliden, Långsele, Näsliden and Kristineberg deposits.

5. Proterozoic mineral deposits in central Finland
Guide book: SGU Ca 63.
Excursion leader: G. Gaál.
Topic: Early Proterozoic mineralizations including the Kemi Cr mine, PGE mineralization in the Penikat layered intrusion, Pyhäsalmi Cu-Zn deposit, Outukumpu Cu-Co-Zn mine and the Enonkoski Ni-Cu deposit.

6. Precambrian mineral deposits in northernmost Scandinavia
Guide books: SGU Ca 64 (Norwegian part)
Geol. Surv. Finland (1980), Guide 078 A+C, part 1 (Swedish part)
Excursion leaders: J.S. Sandstad and H. Lindroos.
Topic: Precambrian copper and iron ore deposits including visits to two of the largest mines in northern Europe: Kiirunavaara underground mine (Fe) and Aitik open pit operation (Cu, Au). In addition, the Raipas, Repparfjord, Bidjovagge and Viscaria Cu deposits and Au prospects in the Gällivare area will be shown.

7. Proterozoic mineralizations associated with granitoids
Guide book: SGU Ca 65.
Excursion leader: B. Öhlander.
Topic: Mineralizations associated with Proterozoic granitoid intrusions including the Pleutajokk, Rävaberget and Björklund U deposits, the Allebouda and Kåtaberget Mo deposits, the Storuman W mineralization and Tallberget Cu-Mo deposit.

8. Archaean and Proterozoic geology in northern Finland, Norway and Sweden
Guide book: SGU Ca 66
Excursion leaders: T. Sjöstrand, M. Often and V. Perttunen.
Topic: Archaean and Proterozoic geological environments in the ore-bearing Nordkalott area, including greenstone belts and granulites.

9/10. Enåsen Au deposit and Alnö alkaline complex
Guide book: SGU Ca 67.
Excursion leaders: T. Lundqvist, S. Sundberg and P. Kresten.
Topic: Geology at and around the Proterozoic Enåsen Au deposit and the Alnö alkaline complex.

PROTEROZOIC COPPER MINERALIZATIONS IN NORTHERNMOST NORWAY

CONTENTS

INTRODUCTION

Archaean to Early Proterozoic gneisses and volcano-sedimentary supracrustal rocks constitute the bedrock geology of the southern part of Finnmark. They are unconformably overlain by Late Proterozoic to Early Orodovician autochthon to parautochthon sediments. On top of these in the northwestern part of Finnmark rest Caledonian Nappes which are composed of Late Proterozoic and Early Palaeozoic metasediments, Precambrian basement rocks and Early Palaeozoic plutonic rocks (Fig. 1).

The Archaean gneisses consist mainly of felsic orthogneisses and paragneisses. They host the economically most important ore deposit in Finnmark, the Sydvaranger banded iron ore. The Archaean gneisses are in East Finnmark transected by shallow probable Early Proterozoic volcano-sedimentary belts where only minor Ni-prospects have been found (Boyd & Nixon 1985). In southwestern Finnmark the gneisses constitute a dome structure which are pierced by Early Proterozoic plutonic rocks.

The dome is flanked by two major metallogenic provinces, the Kautokeino Greenstone Belt in the west and the Karasjok Greenstone Belt in the east. They are probable of similar Early Proterozoic age (Krill *et al.* 1985) and consist of metavolcanites, mainly of tholeiitic basaltic composition, psammites and pelites. Komatiitic metavolcanites are found especially in the Karasjok Greenstone Belt (Henriksen 1983, Often 1985). Felsic volcanites are rare. The precise relationship between the volcano-sedimentary belts is however a subject under current discussion. They seem to have different depositional environments which also are reflected by their metallogenic development.

A complete 'Wilson orogenic cycle' is proposed for the Karasjok Greenstone Belt (Krill 1985, Often 1985). Massive and disseminated stratiform and stratabound copper sulphide deposits, banded iron formations and nickel mineralizations are found (Bjørlykke *et al.* 1985).

The Kautokeino Greenstone Belt is correlated with the supracrustal rocks of the Alta-Kvænangen, Altenes and Repparfjord-Komagfjord tectonic windows in the north (Fig. 1). Both a continental rifting (Torske 1978) and an ensialic back-arc basin (Pharaoh & Pearce 1984) are suggested as depositional environments for these sequences. Stratabound, often brecciated copper deposits associated with basaltic volcanism are the dominant ore types, but stratabound copper deposits are also found in sandstones

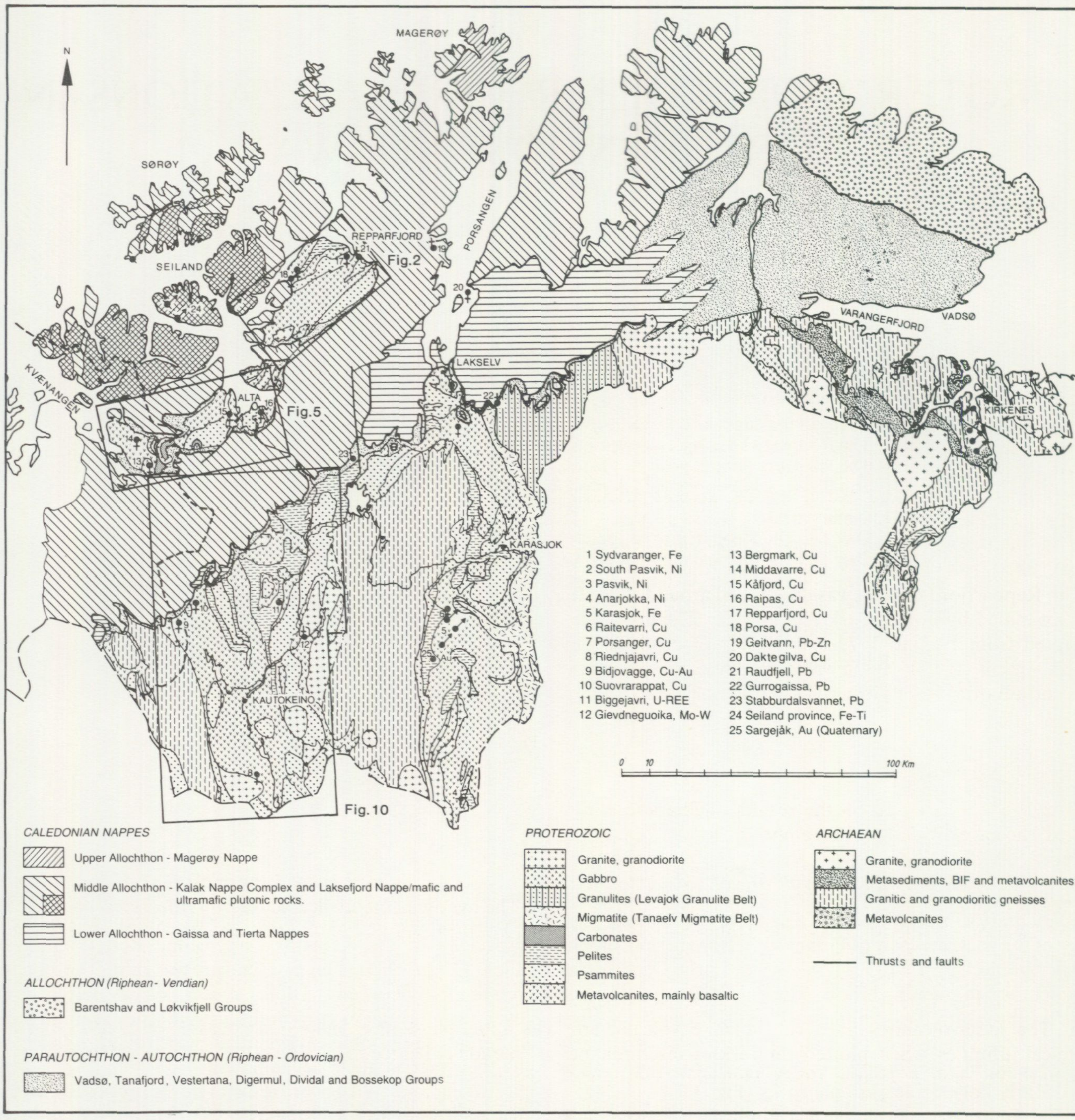


Fig. 1. Geological map over northernmost Norway. Reproduced from Bjørlykke *et al.* (1985).

and dolomites. Au, U and REE are also found in this province (Bjørlykke *et al.* 1985) which host the only other operating ore mine in Finnmark at present, the Bidjovagge Cu-Au deposit.

Minor lead mineralizations are found in the overlying autochthon and allochthon sedimentary rocks of Late Proterozoic to Early Palaeozoic age. Large but uneconomic magmatic enrichments of Fe-Ti-oxides are found within the Early Palaeozoic mafic plutonic rocks.

This excursion will concentrate on the different stratabound copper deposits in the Kautokeino Greenstone Belt and the correlative tectonic windows. The Repparfjord and Raipas copper deposits are located in sandstones and dolomites respectively while the Bidjovagge Cu-Au deposit is found in albite felsite associated basaltic volcanism.

GEOLOGY OF THE DEPOSITS

THE REPPARFJORD COPPER DEPOSIT

J.S. Sandstad

The Repparfjord copper deposit is located in sandstones on Ulveryggen in the Repparfjord–Komagfjord tectonic window (Fig. 2). The window is a large basement culmination which consists of Precambrian volcano-sedimentary rocks and minor basic and intermediate intrusions. These rocks are overlain by autochthonous Vendian to Cambrian sediments on to which Caledonian nappe complexes have been thrust. The geology of the Repparfjord-Komagfjord tectonic window has been described in some detail by Reitan (1963) and Pharaoh *et al.* (1983); the Repparfjord copper deposit by Vokes (1957), Fabricius (1979) and Stribrny (1980, 1985).

The Repparfjord deposit was discovered around 1900. It was examined by Foldal Verk A/S in 1970. The mine was operated from 1972 to 1979 and 3.1 Mt of ore with an average grade of 0.66 % Cu were produced. The copper concentrate of 51 000 t yielded 35.5 % Cu on average.

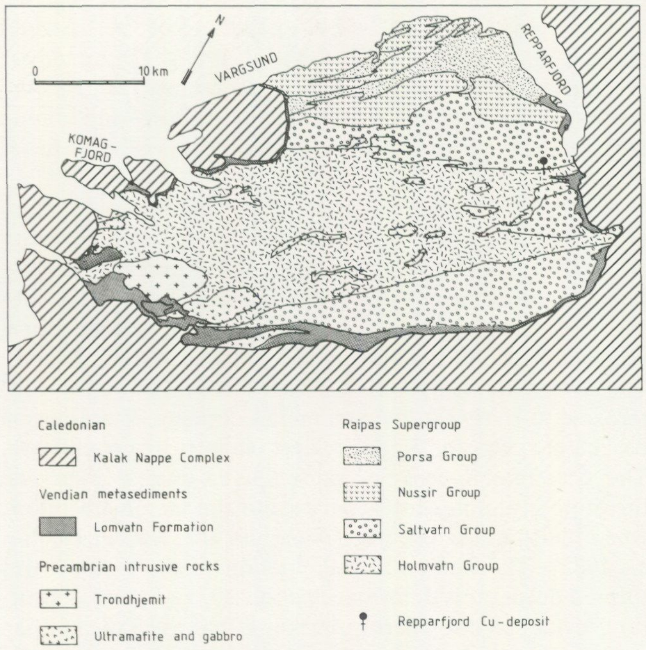


Fig. 2. Simplified geological map of the Repparfjord-Komagfjord tectonic window, modified from Pharaoh *et al.* (1983). The Repparfjord copper deposit is marked with the copper sign.

Geological setting

This description is based on the results of Pharaoh *et al.* (1983) who have divided the Precambrian supracrustal rocks of the Repparfjord-Komagfjord tectonic window into four groups with a total of twelve formations, collectively termed the Raipas Supergroup.

The base of the oldest rocks, the Holmvatn Group is nowhere exposed. The Holmvatn Group is at least 3 km thick and consists of highly immature sediments interbedded with metavolcanic rocks of basic and intermediate composition. The metavolcanites have calc-alkaline volcanic-arc chemical affinities when plotted on various discriminant diagrams (Pharaoh & Pearce 1984). However, the upper part of the group is dominated by metamorphosed tholeiitic pillow lavas which have whithin-plate basalt chemical characteristics. The group may in part represent debris flows while the lavas indicate a subaqueous environment.

The approximately 2.5 km thick sedimentary Saltvatn Group rests unconformably upon the Holmvatn Group although in places the contact is now tectonic. The lower part of the group consists of sandstones and polymict conglomerates. This formation is overlain by two conglomerate formations which are dominated by pebbles of greenstone and porphyritic dacite, respectively. The Saltvatn Group is considered to have been deposited under predominantly fluviatile conditions, partly by braided streams and in fanconglomerates (Pharaoh *et al.* 1983). The Repparfjord copper deposit is located in the lowermost part of this group.

The overlying metavolcanic Nussir Group is composed of a 2 km thick sequence of metamorphosed tholeiitic-basaltic pillow lavas, tuffs and tuffites deposited in a subaqueous environment. These rocks are believed to have been erupted on a strongly attenuated continental crust, associated with an initial phase of opening of an oceanic or back-arc basin (Pharaoh & Pearce 1984). Early this century, extensive mining was carried out on chalcopyrite- and pyrite-bearing quartz-carbonate veins within these metavolcanites. The relatively small mines are now exhausted. The mineralizations are assumed to represent fracture fillings of hydrothermal metamorphic origin, but a synvolcanic origin is also possible because of the shallow water depth during the deposition of the volcanites (Bjørlykke *et al.* 1985).

The greenstones are overlain with an erosional contact by shallow-marine sediments of the kilometre-thick Porsa Group which consists of dolomites and graphitic slates with subordinate beds of shales and sandstones.

The Precambrian volcanic and sedimentary supracrustal rocks described were subject to polyphase deformation during the Svecokarelian orogeny (Pharaoh *et al.* 1983). At the same time several peridotite-norite-gabbro and trondhjemite intrusions were emplaced, especially in the southern part of the window. The structure of the northwestern area is dominated by numerous Svecokarelian, NE–SW-trending, upright or slightly inclined, periclinal folds and a major overthrust towards the northwest (Pharaoh *et al.* 1983). Further south, more open folds of the second Svecokarelian phase predominate. More intense folding and faulting are prominent locally (Reitan 1963). The peak of the regional metamorphism was reached after the end of the first fold phase, c. 1840 Ma ago (Pharaoh *et al.* 1982). The metamorphic grade increases from lower greenschist facies in the northwest to upper greenschist and epidote-amphibolite facies in the mine area on Ulveryggen and amphibolite facies in the south.

The rocks showing evidence of Svecokarelian deformation are unconformably overlain by a thin sedimentary sequence (Lomvatn Formation) of probable Vendian to Cambrian age consisting of shallow-marine shales and sandstones with conglomerates at the base. Minor galena mineralizations are found in the basal conglomerates and sandstones. The overlying Caledonian nappes comprise Late Proterozoic to Early Ordovician metasediments, Precambrian basement rocks and Early Palaeozoic intrusive complexes. The Caledonian orogeny caused later intense imbricate thrusting in the northwestern part of the tectonic window, while the southeastern parts were less affected (Pharaoh *et al.* 1983). The dome-like culmination of the window was formed during this deformational phase, and there is structural evidence elsewhere suggesting that the Precambrian rocks in the window are parautochthonous (Roberts 1985).

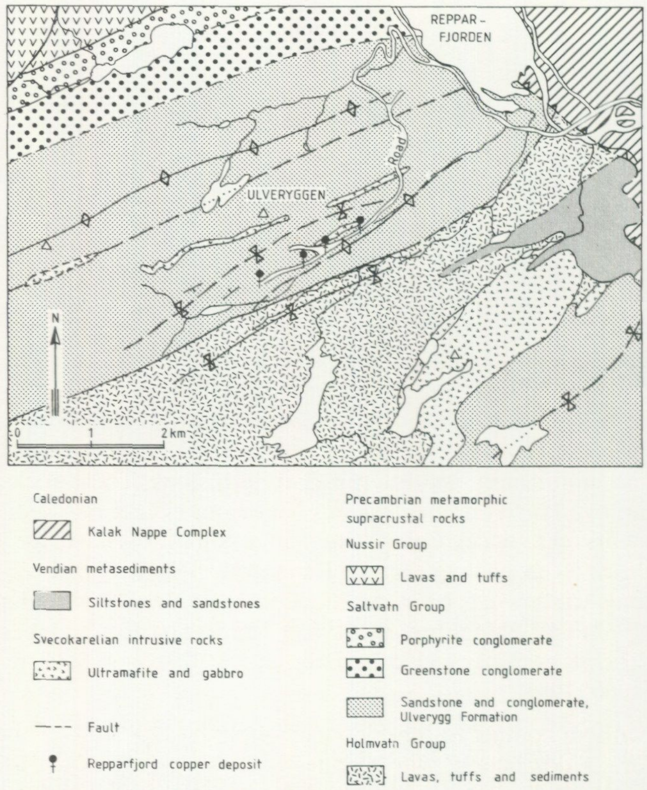


Fig. 3. Geological map of the Repparfjord area. The Repparfjord copper deposit is marked with the copper signs. Simplified from Pharaoh *et al.* (1983).

Ore geology

The Repparfjord copper deposit is located in the Ulverygg Formation, the lowermost formation of the Saltvatn Group (Fig. 3). The lithostratigraphy of the formation and the lithostratigraphic position of the mineralized sequence are shown in Fig. 4. The Ulverygg Formation is at least 1000 m thick (Reitan 1963) and consists of white or grey, lithic, feldspathic and quartzitic sandstones and polymict conglomerates. Pharaoh *et al.* (1983) considered that these moderately mature sediments were deposited in alluvial fans and on a coast-marginal braidplain by streams flowing from a fault-bounded source area to the west and northwest. Stribrny (1985) suggested deposition in a near-shore, submarine trench under constant current intensities. Fine-grained phyllite beds, up to one metre thick, occur sporadically within the sequence. They can be traced for several hundred metres and are assumed to represent metatuffs or metatuffites (Stribrny 1985). Minor mafic intrusions are found in the mining area. Two volcanic pipes occur within and to the south of the open pits. These are commonly brecciated with fragments consisting of quartz, chlorite-biotite and feldspar in a fine-grained matrix of chlorite and sericite. Porphyritic dykes with a dioritic composition are only a few metres thick but can be traced for several hundred metres. Their main minerals are plagioclase and hornblende. Both types of dykes are syn- or post-tectonic and weakly metamorphosed (Stribrny 1985).

The stratabound ore zones consist of diffuse lenticular bodies along a strike length of 1.8 km with maximum thickness of 60–80 m situated in a northwestly dipping (40–70°) limb of a NE–SW-trending, inclined fold. The mineralized area is transected by faults and minor shear zones with preferred orientations approximately N–S and WSW–ENE. Stribrny (1985) has concluded that the structures in the area of the ore deposit result from a single deformational event during the Svecokarelian orogeny. In the mine area, thin clast-supported, conglomerate beds occur at the base of thin (0.3–2.0 m) fining-upward cycles commonly with cross-bedding and in places with thin siltstone beds on top. The main constituent minerals of the sandstones are quartz (60–70 %), feldspar (10–15 %), light mica (5–10 %) and heavy minerals (5–10 %). Chlorite, biotite and epidote/zoisite occur in smaller amounts. The poorly sorted conglomerate beds consist of pebbles mainly of quartz with minor feldspar and rock fragments. Both opaque and non-opaque heavy minerals seem to be concentrated along laminae and bedding planes (Stribrny 1985). The translucent heavy minerals are, in order of decreasing abundance, zircon, sphene, rutile, apatite, tourmaline and monazite.

Stribrny (1985) has divided the ore mineralization into two paragenetic types. Chalcopyrite is the main ore mineral in 70–80 % of the ore. It generally occurs as single grains

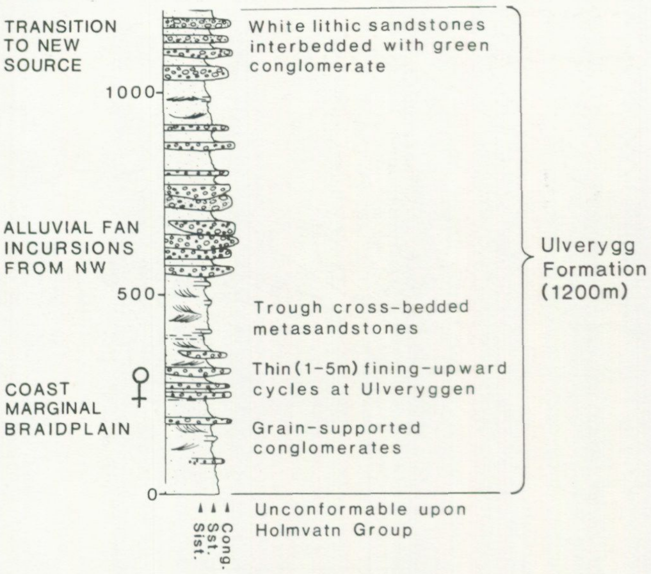


Fig. 4. Schematic lithostratigraphy for the Ulverygg Formation, from Pharaoh *et al.* (1983). Individual beds are not to scale thickness. The position of the Repparfjord copper deposit is marked with a copper sign.

without contact to other copper sulphides. 20–30 % of the ore is dominated by a bornite-chalcocite paragenesis; the latter predominates in more heavily tectonized areas but transitions exist between the two types. Minor copper sulphides are neodigenite, covellite and idaite. Malachite and azurite also occur in appreciable amounts. Other opaque minerals present to varying extent are hematite, magnetite, pyrite, chromian spinel and ilmenite. The copper sulphides occur mostly as scattered patches or grains interstitial to the clastic grains (Vokes 1957). They are most abundant in the conglomeratic beds at the base of graded cycles and in the fine-grained beds on the top (Stribrny 1985). Both chalcopyrite and bornite-chalcocite are most abundant in laminae rich in other heavy minerals. Minor copper mineralizations are found in randomly orientated quartz veinlets, in brecciated host rock and in mylonitic zones (Fabricius 1979).

Ore genesis

The composition of the ore minerals and the low grade of the Repparfjord copper deposit have made it difficult to study and delimit the ore bodies macroscopically. Extensive geochemical rock sampling and detailed microscopic studies have therefore been carried out. However, the genesis of the copper mineralizations is still in dispute.

In the earliest discussions concerning the genesis of the copper deposit, a clearly epigenetic origin was favoured by several authors in unpublished reports. The epigenetic term was used to imply hydrothermal solutions of magmatic origin, but an igneous source is not easy to detect. However, based on microscopic studies, Vokes (1957) concluded that the disseminated sulphides, in their present form, are of a later age than both the minerals of the enclosing sediments and the oxide minerals. Vokes also found that the quartz veinlets were accompanied by disseminated copper minerals in the sandstones and assumed an epigenetic model for the deposit. Fabricius (1979) modified these theories. Based on studies of fluid inclusions Fabricius proposed that 30–50 % of the ore was formed by hydrothermal solutions derived from gabbroic intrusions or lithostratigraphically lower sequences. This assumption is favoured by a slight zonal distribution of the ore minerals described in unpublished reports. The remaining parts of the mineralizations have been formed by detrital or diagenetic enrichment processes (Fabricius 1979). The discordant ore bodies located oblique to the transport directions of the sediments, the high energy level of the depositional environment and the brittle chalcopyrite do not, however, favour a synsedimentary, detrital model. Fabricius (1979) therefore concluded that the ore most probably formed as a result of a combination of sedimentary, diagenetic and epigenetic processes.

Stribrny (1985) rejected the epigenetic models, involving magmatic activities, and stated that the mineralizations have no association with the intrusions in the mine area. He argued for a synsedimentary detrital ore genesis with later alteration and mobilization during diagenesis and regional metamorphism, and interpreted the ore bodies to be concordant with the sedimentary layering (Stribrny 1985). Gravitional selection led to the stratiform enrichment of heavy minerals, and the distribution of the ore minerals and the non-precious minerals were thus controlled by depositional factors such as size, form and specific weight of individual grains. The only detrital sulphides are chalcopyrite and pyrite, while magnetite is the only iron oxide present. The formation of the other copper sulphides and hematite were ascribed to regional greenschist facies metamorphism (Stribrny 1985). This author thus regarded the Repparfjord copper deposit as a partly remobilized fossil, marine placer deposit.

Bjørlykke *et al.* (1985), in their review, pointed to the similarities between the Repparfjord copper deposit and the red-bed copper deposits, both in geological setting and in ore mineralogy. The association of fault-controlled cratonic basin and sediment-hosted red-bed copper deposit is well established (Bjørlykke & Sangster 1981, Brown 1984).

THE RAIPAS COPPER DEPOSIT

E. Vik

The Storviknes formation of the Early Proterozoic Raipas Group of the Alta-Kvænangen tectonic window contains a considerable number of small copper mineralizations, of which the abandoned Raipas deposit is the largest and best known. This deposit occurs in breccias of assumed karst-collapse origin within dolomites which formed in a tidal-flat environment. Several copper mineralizations are also found in the greenstones of the Kvenvik formation (Fig. 5).

The most extensive description of the geology of the Alta-Kvænangen tectonic window has been given by Zwaan & Gautier (1980). The underground workings of the Raipas

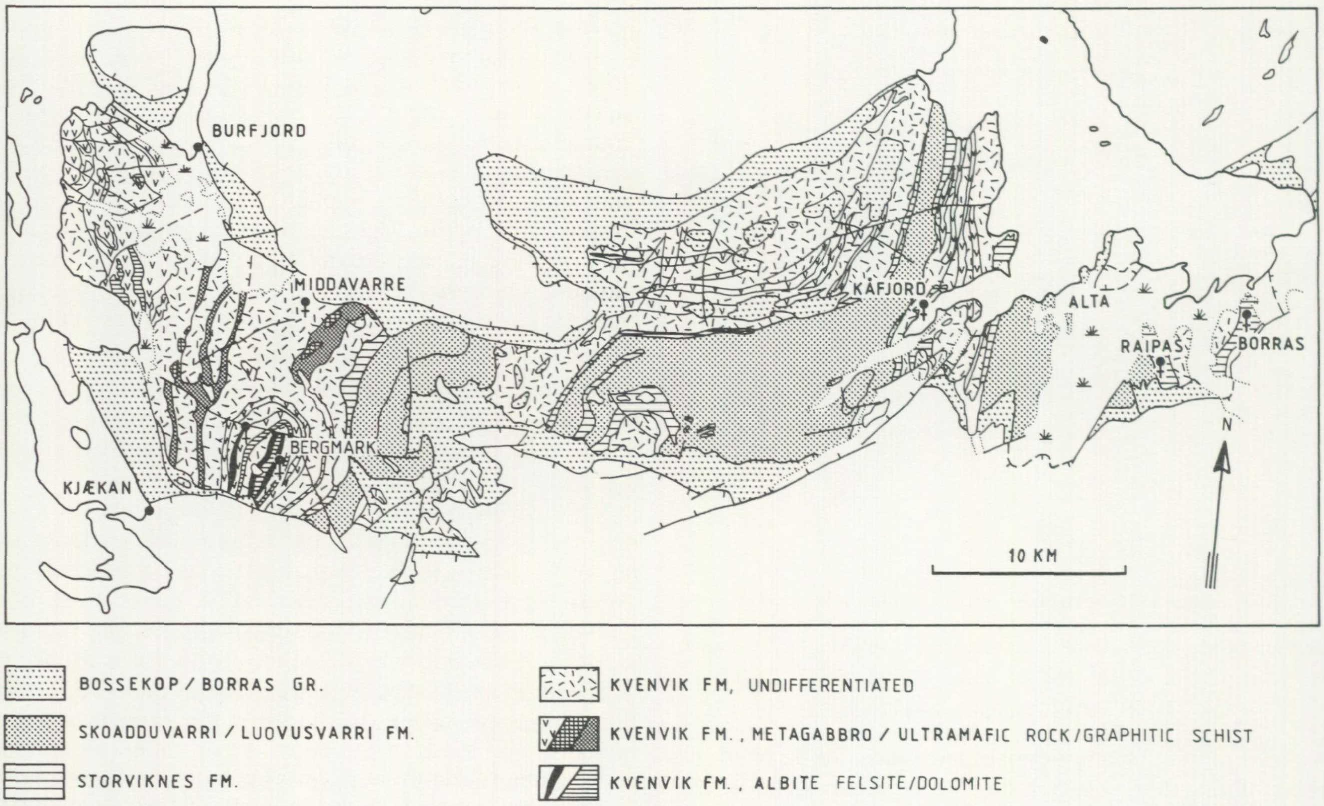


Fig. 5. Geological map of the Alta-Kvænangen tectonic window, modified from Zwaan (1986). Copper mineralizations of the Storviknes formation and the Kvenvik formation are marked.

deposit have been mapped by Vokes (1955), who has also described the mineralogy of the deposit in a series of articles; e.g. Vokes (1957) and Vokes & Strand (1982). The following summary is based mainly on Vik (1979 and 1985).

The Raipas deposit was mined for 40 years in the middle of the nineteenth century. The total production was 12 500 metric tons of ore containing 7–8 % Cu.

Geological setting

The Raipas Group in the Alta-Kvænangen tectonic window is divided into four formations (Fig. 6): the Kvenvik, Storviknes, Skoadduvarri and Luovusvarri formations. Discordantly above lie the Vendian to Cambrian Bossekop and Borras Groups and the Kalak Nappe Complex (Zwaan & Gautier 1980). The Kvenvik formation consists of tholeiitic lavas and volcaniclastic rocks, some carbonate beds especially in the lower parts, and gabbroic sills. The Storviknes formation is a more than 600 m thick sequence of siltstones and dolomites. The Skoadduvarri and Luovusvarri formations consist mainly of feldspathic sandstones with thin beds of dolomite in the upper part of the succession.

The Early Proterozoic formations were deposited in shallow-marine environment. The lithostratigraphy suggests that sedimentation and volcanism occurred in a subsiding basin with limited supply of clastic material (Kvenvik and Storviknes formations) followed by sedimentation of more distal terrigenous material (Skoadduvarri and Luovusvarri formations). The geotectonic setting is debatable. Torske (1978) suggested deposition in an aulacogen while Pharaoh *et al.* (1984) assumed that the volcanites were erupted in an early stage of opening of an ocean or back-arc basin. The supracrustal rocks have been metamorphosed in greenschist facies during the Svecokarelian orogeny (Pharaoh *et al.* 1983) but they are little deformed.

The Storviknes formation

The Storviknes formation consists of a lower red siltstone, a dolomite unit and an upper grey siltstone with thin beds of dolomite (Fig. 7). In the Raipas area the lower siltstone is approximately 50 m thick and is overlain by 200 m of dolomite. The dolomite unit is divided into a lower interlaminated dolomite and slate and an upper massive dolomite. The upper siltstone can be several hundred metres thick and includes a few beds of dolomite, up to 4 m thick.

The interlaminated dolomite and slate is a reddish-brown rock with alternating one centimetre thick dolomite- and more resistant silica-rich laminae. Intraformational breccias with tabular fragments and cross-cutting channels occur loc-

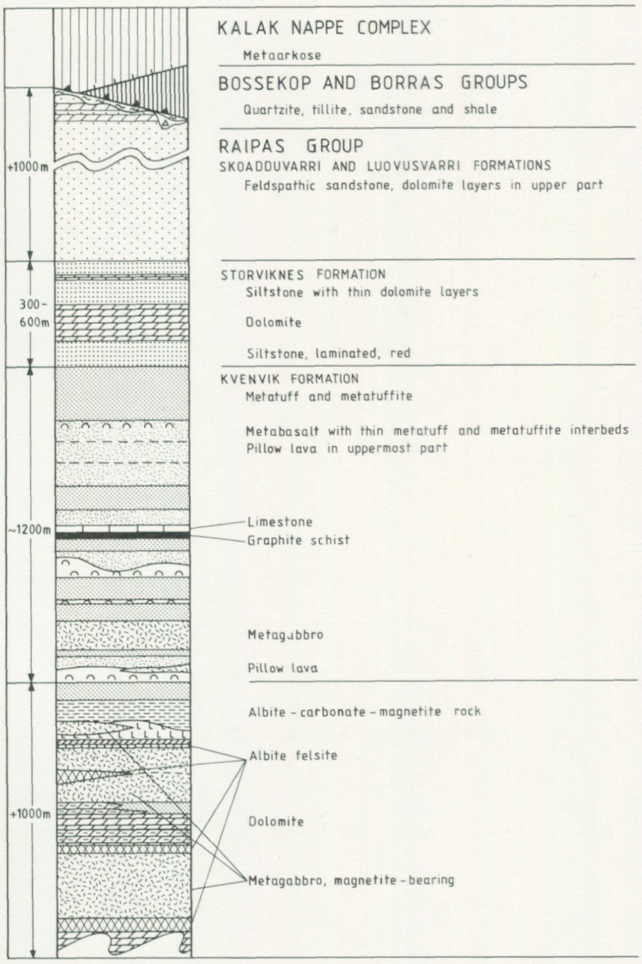


Fig. 6. Schematic lithostratigraphic column for the rocks of the Alta-Kvænangen tectonic window.

ally. The upper fifty metres of the dolomite unit is a massive dolomite, usually without lamination. Laminated parts may have a higher content of organic material and commonly show stromatolitic structures. Chert is found as replacement of the stromatolite laminations, as small angular 'lumps' and as layers. Locally, rocks with fragments of chert and slate in a matrix of red hematite-bearing claystone are present. Breccias with angular fragments of dolomite, chert and slate are found at the mine dumps near the Raipas deposit, and the copper mineralizations occur in breccias of this type. The old maps of the mine suggest that the breccia bodies themselves are mainly either tabular or equidimensional in form.

The primary structures of the dolomite indicate that the rocks were formed in a tidal-flat environment. Some of the occurrences of chert can be interpreted as pseudomorphs after anhydrite and suggest presence of a hypersaline solution, possibly in a sabkha-environment. The red claystones are assumed to have been deposited in karst depressions on the surface of the dolomite and as more extensive mud flows. The breccias of the Raipas mine probably originated as collapsed karst caves. The relationships between the different rock-types are shown in a simplified manner in Fig. 8.

The siltstone above the dolomite is mineralogically similar to the siltstone below. The thin interbeds of dolomite in the upper siltstone can be traced along strike over several hundred metres, and usually consist of a massive basal part and an upper laminated part. Immediately beneath the dolomite, the siltstone has a paler colour and locally carries disseminated pyrite. The siltstones were probably deposited in a shallow-marine environment, with the interbedded dolomites representing intertidal sediments. Pyrite-disseminated layers indicate reducing conditions in a predominantly oxidizing environment.

Copper mineralizations

The copper mineralizations are found in four different stratigraphic positions (Fig. 7):

1. In the basal layers of thin beds of dolomite in the upper siltstone.
2. In a thin conglomerate at the top of the massive dolomite.
3. In matrix of karst breccias in the massive dolomite.
4. In massive dolomite beds with a high content of organic material in the interlaminated dolomite and slate.

The mineralizations are almost completely dominated by copper, but cobalt is found in some of them, e.g. Borras (Fig. 5). Chalcopyrite, bornite, digenite and chalcocite are the main ore minerals and fahlore and minerals of the linneaite-series occur in varying amounts. The Raipas copper deposit is of type 3, while the occurrences of types 1, 2 and 4 are of minor importance.

The mineralized breccias of the Raipas deposit are found at the contact between the dolomite and the upper siltstone (Fig. 9). Several breccia bodies exist, both above and below a stratigraphic zone with several thin mudstone beds. The shape of the breccia bodies varies. The mineralized breccia bodies beneath the mudstone beds are tabular with their longest axes plunging down the dip of the sedimentary layering. The thickness of the bodies varies between 1 and 5 m with a maximum width of 20–25 m and maximum length of 60 m. The ore bodies are usually found in dolomite but they may continue into the mudstone. Above the mudstone beds the ore bodies are more irregular, but here they also occur mainly in dolomite. Some of the breccias may partly have extended to the surface and mapping has revealed the possibility of a surface depression above the mine.

The copper minerals are usually found in the matrix of the breccia together with coarse-grained dolomite and minor baryte. They occur in the light-coloured parts of the ordinary red-coloured breccia matrix and are unevenly distributed. Locally, the breccia matrix contains fine-grained disseminated sulphides, while in other parts the sulphide minerals constitute the entire matrix. Chalcopyrite and bornite are the main ore minerals. Varying amounts of fahlore are found, particularly in the bornite. Digenite occurs commonly as thin veneers between bornite and other sulphide minerals and along cracks in bornite, but is also intergrown

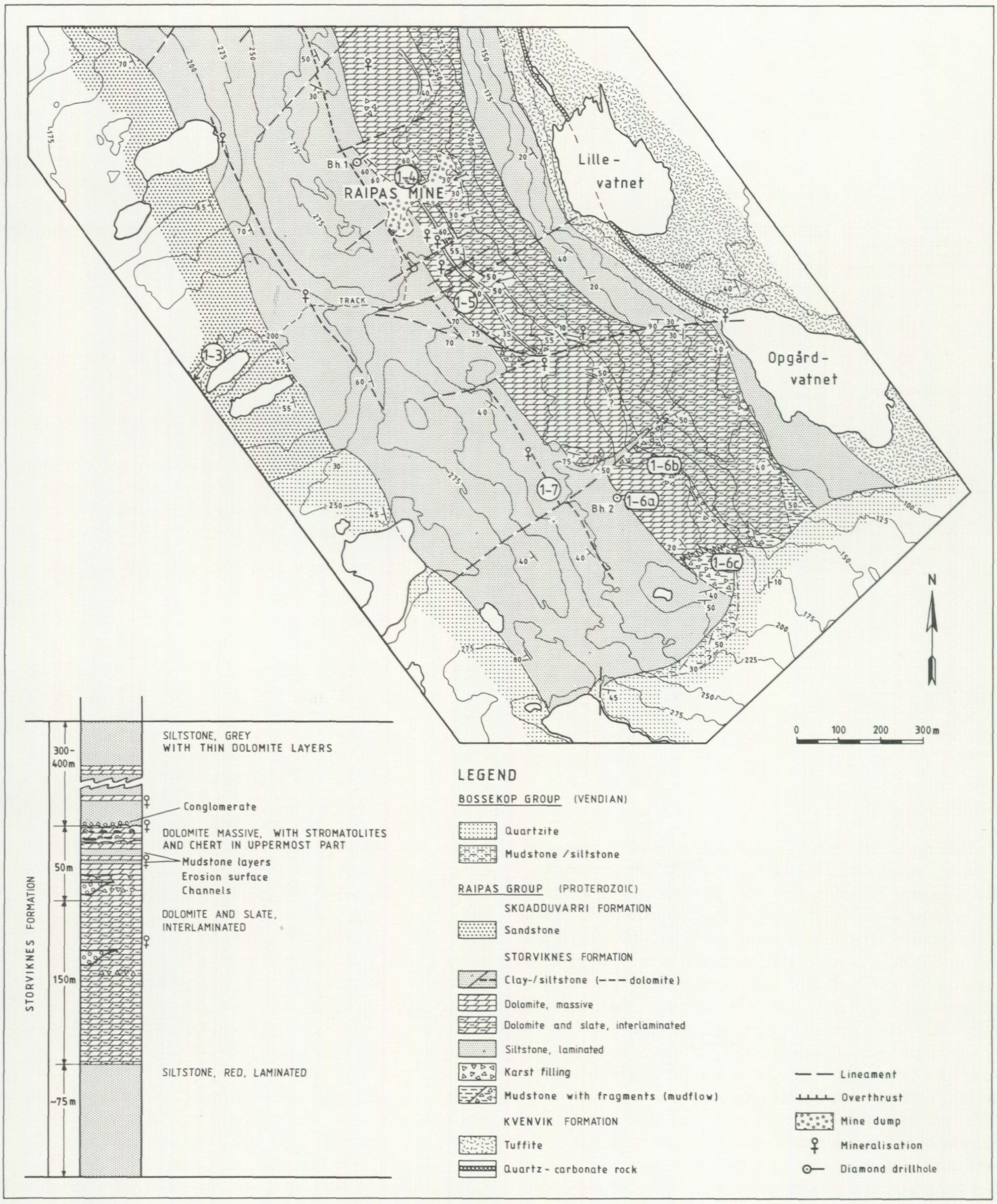


Fig. 7. Geological map of the Raipas area and schematic lithostratigraphic column for the Storviknes formation with the lithostratigraphic positions of the four different types of copper mineralizations marked. Excursion stops 1–3 to 1–7 are indicated.

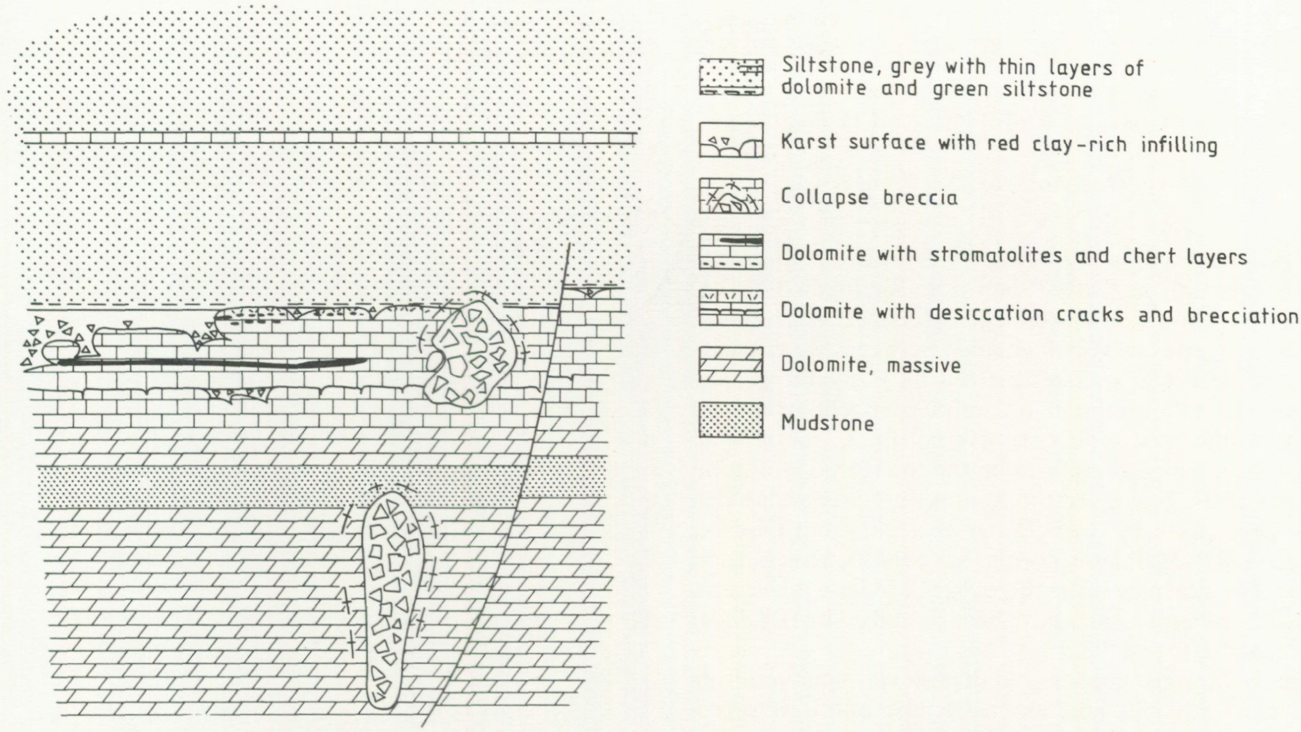


Fig. 8. Simplified sketch of the relationships between the rock types in the upper part of the Storviknes formation.

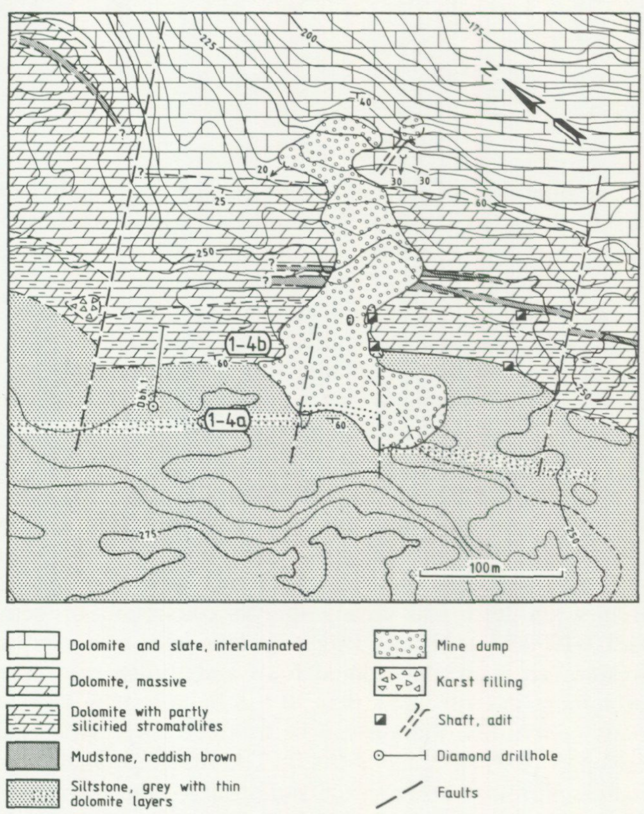


Fig. 9. Geological map of the Raipas copper deposit with excursion localities 1–4a and 1–4b marked.

with bornite. Smaller amounts of the linneaite-series mineral siegenite and minerals of the cobaltite-gersdorffite series are also found. Baryte occurs in coarse-grained, tabular crystals and in fine-grained disseminations or dense masses in the breccia matrix. Both white and red baryte has been found. The mineral occurs only at the mine dumps, and very little is known about the primary distribution of baryte in the deposit.

Ore genesis

The copper in the Raipas deposit is probably derived from the mafic components of the siltstones by decomposition and was transported in chloride-complexes under oxidizing conditions. Rose (1976) has shown that up to 50 ppm copper can be transported in saline waters together with sulphate when hematite is stable. During compaction, perhaps as a result of the relatively rapid deposition of the overlying sediments of the Skoadduvarri formation, the pore-waters may have been expelled and entered a more reducing environment in the permeable karst-collapse cavities. The sulphides will then have been precipitated. The Raipas copper deposit shows similarities to better known copper deposits of the red-bed copper type, as recently summarized by Gustafson & Williams (1981).

THE BIDJOVAGGE COPPER-GOLD DEPOSIT

R. Hagen & J.S. Sandstad

The Bidjovagge copper-gold deposit is located in the north-western part of the Early Proterozoic Kautokeino Greenstone Belt. This volcano-sedimentary sequence constitutes a 40–50 kilometres wide belt situated between two culminations of Archaean gneisses pierced by Early Proterozoic plutons. Late Precambrian to Cambrian autochthonous and parautochthonous sediments overlie these rocks, with Caledonian nappe complexes on the top (Fig. 10). Recent reviews of the geology of the Kautokeino Greenstone Belt have been given by Siedlecka *et al.* (1985) and Olsen & Nilsen (1985). Mathiesen (1970a) has published a geological and geophysical map of the Bidjovagge copper-gold deposit, while the mineralizations have been described by Hollander (1979) and Hagen (1982).

The Bidjovagge copper-gold deposit was operated from 1971 to 1975, and 0.4 million metric tons of ore were produced. In 1983 the Outokumpu Oy of Finland obtained an option agreement with the Norwegian owner, A/S Sydvaranger. The mine was reopened in June 1985 and 0.8 million metric tons of crude ore with 1.1 % Cu and 1–2 g/t Au are planned to be produced in the next three years.

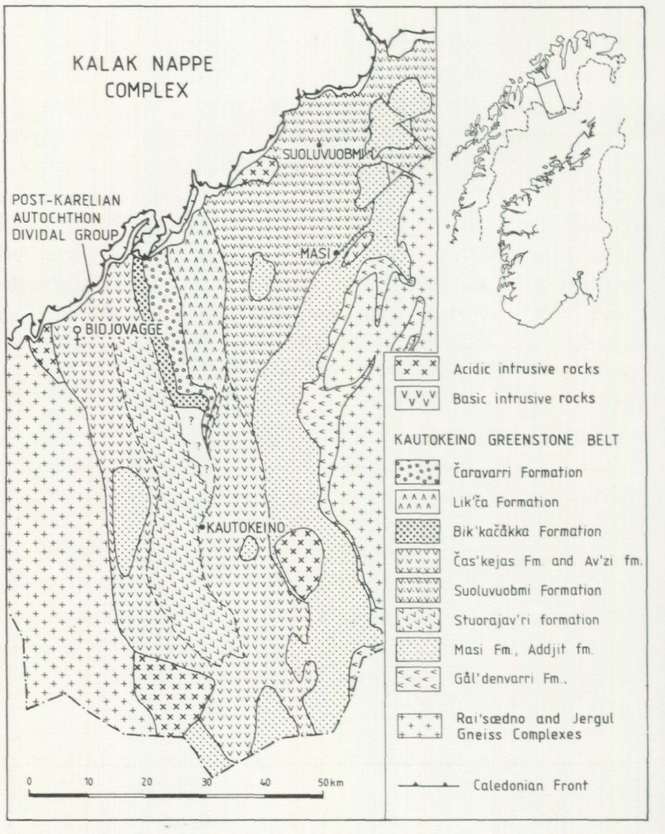


Fig. 10. Lithostratigraphic map of the Kautokeino Greenstone Belt, modified from Siedlecka *et al.* (1985).

Geological setting

The Kautokeino Greenstone Belt is dominated by basic metavolcanites, but also includes two thick psammitic formations (Siedlecka *et al.* 1985). The lowermost rock unit in the northern part of the greenstone belt is the Gåldenvarri Formation, which has been found only at the eastern margin. The sequence is at least 1.5 km thick and is composed of basic and ultrabasic metavolcanites (Solli 1983) which are assumed to represent metamorphic lavas and tuffs. The metavolcanites are unconformably overlain by the 500–1000 m thick Masi Formation. This metasedimentary formation includes quartzite, feldspathic quartzite and conglomerate of both alluvial and coastal-marine origin (Siedlecka *et al.* 1985).

Stratigraphically above these formations lies a new series of volcanic rocks which has been divided into several formations. The metavolcanites around the Bidjovagge copper deposit belong to the Cas'kejas Formation (Siedlecka *et al.* 1985). This is estimated to be about 4 km thick and consists mainly of metamorphosed tuffs and tuffites and minor pillow lavas accumulated in a subaqueous environment. These rocks are intruded by synvolcanic diabase sills and carry thin interbeds of carbonate, albite felsite, graphite felsite and graphitic schists. The mafic rocks have a tholeiitic-basaltic chemistry with ocean-floor and within-plate chemical affinities in trace element diagrams. The upper part of the formation is dominated by pelitic rocks.

The boundary to the fine-grained slates and argillites of the overlying Bik'kacåkka Formation is transitional. Subordinate beds of sandstone and dolomite are found in the lower part of this 1000–1500 metres thick formation.

The Caravarri Formation is more than 4 km thick and lies with a sharp stratigraphic contact in the west and fault contact in the east on top of the Precambrian supracrustal sequence. A medium- to coarse-grained feldspathic sandstone is the predominant rock type. Beds of conglomerate, pebbly sandstone and siltstone also occur. The sequence is interpreted to be alluvial, consisting mainly of braided stream deposits with subordinate debris-flow accumulations (Torske & Bergh 1984).

The supracrustal rocks of the Kautokeino Greenstone Belt were deformed during the Svecokarelian orogeny (1800–1900 Ma). Open to tight upright folds occur in the western areas, while inclined folds and thrusts are more prominent in eastern districts. It has been concluded that most of the deformation can be ascribed to gravitational tectonics (Olesen & Solli 1985). The metamorphic grade increases from the low-grade sandstone of the Carravarri Formation in the central part of the belt towards medium-grade along the margin to the Archaean gneisses.

Ore geology

The Bidjovagge copper-gold deposit is located in albite felsite and graphite felsite in the lower part of the Cas'kejas Formation. A generalized geological map of the Bidjovagge area is shown in Fig. 11. The mineralized units are found in two N–S trending anticlines. The stratigraphy of the mining area is shown in Fig. 12 which is a simplified cross-section through the southern parts of the A ore body. The footwall rocks consist of interbedded banded amphibolites, assumed to represent metatuffs and metatuffites, and carbonate rocks. The overlying massive amphibolite, which is a metadiabase, is followed by the mineralized albite felsite and graphite felsite. These rocks are in turn overlain by alternating massive and banded amphibolites. The ore deposit occurs in the vicinity of a positive gravity anomaly presumably caused by a thick pile of folded metavolcanites (Olesen & Solli 1985). This may indicate proximity to a volcanic centre.

The metadiabases of the mining area have either subophitic or poikilitic textures and are assumed to have intruded as synvolcanic sills. They have a tholeiitic basalt composition similar to that of the banded amphibolites. The albite felsite

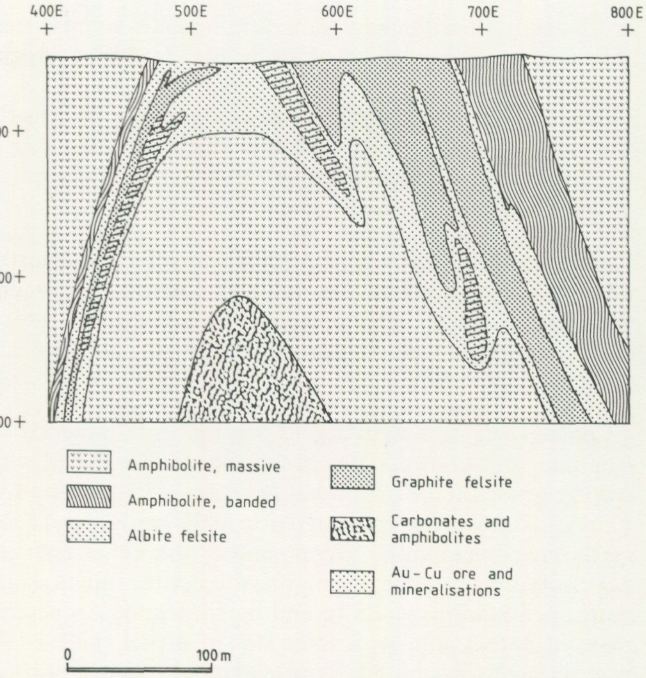


Fig. 12. Geological cross section along profile 0 in the Bidjovagge copper-gold deposit, based on Mathiesen (1970a). The copper-gold mineralizations shown in the eastern limb of the anticline belong to the A ore body.

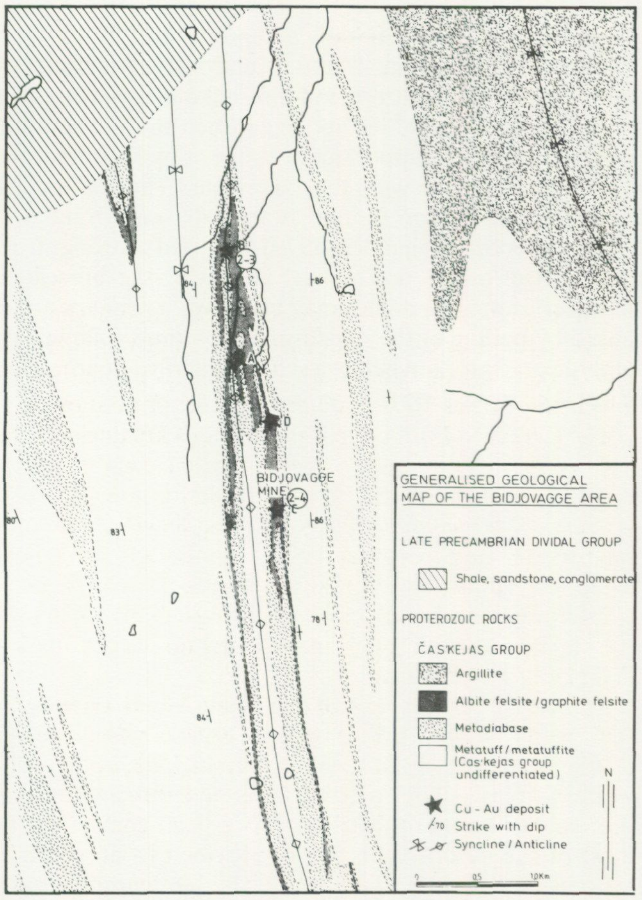


Fig. 11. Simplified geological map of the Bidjovagge area. With the copper-gold ore bodies A, B, C and D. Excursion stops 2–3 and 2–4 are indicated at ore bodies B and C, respectively.

is a very fine-grained rock which consists of 80–90 % albite and minor amounts of carbonates, quartz and mafic silicates. Ilmenite, rutile and pyrite are accessory minerals. The rock is usually massive, but a fine banding is commonly observed. The transition to the banded amphibolites is presumably continuous. The graphite felsite is an albite felsite with up to 40 % carbon. The carbon is present as graphite with a grain size usually less than 0.005 mm. The origin of the felsites is uncertain and will be discussed below.

Four ore bodies over a strike length of 2.4 km have been discovered in the eastern limb of the major anticline (Fig. 11), and have been named A, B, C and D in order of their discovery. Although they occur in brecciated and faulted zones of the felsites, the mineralizations must be classified as stratabound. The ore bodies are very irregular and lenticular in form. Low-grade mineralizations, in part defining a diffuse layering in the felsites, are commonly present between the ore bodies.

Different types of copper and gold mineralizations are found at Bidjovagge:

1. The main mineralization occurs in veins and veinlets composed of coarse-grained ankerite and chalcopyrite with minor amounts of pyrite and pyrrhotite. The veins are usually cross-cutting, forming a breccia texture in the fine-grained albite felsite. Concordant veins up to several metres thick are also present along the contact between the albite felsite and the graphite felsite.

2. Chalcopyrite with minor gangue minerals is found in thin cross-cutting veinlets in albite felsite, forming a stockwork texture.
3. Disseminated chalcopyrite in albite felsite is usually observed in association with the vein mineralizations.
4. Chalcopyrite in graphite felsite forms very irregular veins and veinlets with minor gangue minerals.
5. In close association with the copper ore bodies, gold mineralizations with minor sulphides have been recognized. Gold assays of more than 10 ppm are not unusual in these zones. An assemblage of native gold and tellurides occurs in veinlets composed of quartz and carbonate.

Chalcopyrite and native gold are the only minerals of economic importance. They are unevenly distributed with average grades in the ore bodies between 1–2 % Cu and 1–2 ppm Au. The average grade of pyrite in the ore is about 7 %. Pyrrhotite commonly accompanies the chalcopyrite. Accessory minerals are magnetite, sphalerite, galena, marcasite, pentlandite, violarite and molybdenite. An assemblage of native gold with tellurides of nickel (melonite), bismuth (tellurobismuthite) and lead (altaite) are important constituents of the gold ores, but are also found in the copper ores (Hagen 1982). Mathiesen (1970b) has described davidite and associated Ti, V, U and REE minerals close to the A ore body. The most important non-opaque gangue minerals are ankerite, albite, quartz and hornblende.

The footwall rocks are transected by numerous carbonate-bearing veins and veinlets with associated carbonatization and albitization. Sulphide minerals, hematite, magnetite, albite and quartz also occur in these veins and veinlets. Locally, biotite-enriched zones have been observed. Scapolitization is very common in the footwall rocks, but scapolite is also found in a regional scale and may not be related to the copper-gold mineralization. Secondary chlorite can be observed along fractures (Hollander 1979). Hematite derived from a supergene oxidation is very extensive close to the A ore body.

Ore genesis

The Bidjovagge copper-gold deposit is a stratabound volcanogenic sulphide deposit. The stratabound character is substantiated by the occurrences of several smaller sulphide deposits in albite felsite and graphite felsite in the Kautokeino Greenstone Belt. It has similarities to volcanite-associated massive sulphide deposits as defined by Franklin *et al.* (1981), while the most important discrepancies are the lack of massive ore and occurrences of albite felsite and graphite felsite at Bidjovagge.

The mode of origin of the copper-gold deposit is closely related to the formation of the albite felsite and graphite felsite, which is a subject of debate. Hollander (1979) proposed that the felsites represent volcanic ashes settling in a reducing environment of organic black clays. The felsites have also been assumed to be the result of substantial hydrothermal alteration of the basic metavolcanites. The present authors suggest that the felsites originated as chemical sediments precipitated from hydrothermal solutions with associated alteration of the basic volcanic rocks. However, preliminary REE-analyses are not consistent with published patterns of chemical sediments, but rather support the theory of the felsites representing siliceous extrusive rocks (Bjørlykke *et al.* 1985). The origin of the graphite as a result of organic activity is generally accepted.

Unpublished sulphur-isotope analyses give sulphur-isotope ratios close to zero and indicate a magmatic source for the sulphur. These results, in addition to the alteration patterns observed, support an ore genesis by hydrothermal solutions associated with the volcanism. The felsites are assumed to have been formed at an early stage in the ore-forming process. Hollander (1979) favoured a strong structural control of the ore bodies. However, the brecciated character of the ore bodies may also have a primary origin caused by boiling of the ore-forming solutions followed by sulphide precipitation below a shallow-marine environment (Bjørlykke *et al.* 1985).

EXCURSION ROUTE

DAY 1A. THE REPPARFJORD COPPER DEPOSIT

J.S. Sandstad

INTRODUCTION

The Repparfjord copper deposit is located within the Repparfjord-Komagfjord tectonic window (Fig. 2). This forms a large basement culmination of Precambrian volcano-sedimentary rocks and minor intrusions within the nappe complexes of the Norwegian Caledonian fold belt. The copper deposit is found in the Ulverygg Formation in the lower part of a 2.5 km thick sedimentary group, which rests unconformably on a 3 km thick sequence of immature metasediments and basic and intermediate metavolcanites. Minor syn- or post-tectonic and weakly metamorphosed mafic intrusions occur in the mining area.

The Ulverygg Formation consists of sandstones and conglomerates deposited either in alluvial fans and coast-marginal braidplains (Pharaoh *et al.* 1983) or in a near-shore submarine trench (Stribrny 1985). Chalcopyrite and bornite-chalcocite are most abundant in laminae rich in other heavy minerals, in the conglomeratic beds at the bottom of graded cycles and in fine-grained beds at the tops of these cycles. Minor parts of the mineralizations are found in randomly orientated quartz veinlets, in brecciated host rock and in mylonitic zones. Detrital, diagenetic and epigenetic enrichment processes have been proposed for the copper mineralizations. A comparison with red-bed copper deposits seems also reasonable.

The main road (no. 94) between Skaidi and the head of Repparfjorden lies upon Quaternary fluvial deposits which cover the bedrock of the Caledonian nappe complexes. The mining plants by the fjord and the mine road are located in the ore-bearing Ulverygg Formation (Fig. 3). Copper production of the mine ceased in 1979.

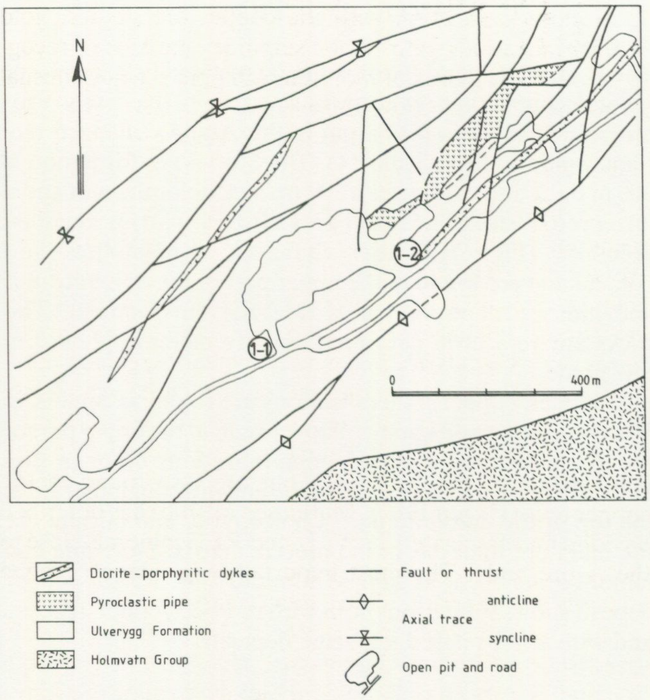


Fig. 13. Geological map of the Repparfjord copper deposit, simplified from Stribrny (1980). Excursion stops 1–1 and 1–2 are marked.

STOP DESCRIPTIONS

Stop 1–1. – General overview and the Ulverygg Formation. Locality: Ulveryggen, southern end of Main open pit. Map-sheet M711/1935 I Repparfjorden (973 165)

The metasediments of the Caledonian nappe complexes are situated on the opposite, northeastern side of the main valley. A major fault, located along the small river in the valley to the southeast, forms the contact between the metavolcanites and the overlying metasediments (Fig. 13). The metavolcanites are intruded by serpentinite and gabbro which are comparatively resistant and form mountain peaks.

The copper mineralizations extend for 600–700 m southwestwards and 1000–1100 m northeastwards along the strike. Sandstones and conglomerates are seen in the entrance to the open pit. Fining-upward cycles and cross-bedding are common.

Stop 1–2. – The Ulverygg Formation and mafic intrusions. Locality: Ulveryggen, northern end of Main open pit and southern end of John open pit. Map-sheet M711/1935 I Repparfjorden (976 167).

The copper-bearing sandstones and conglomerates can be most readily studied in the northern part of the open pit (Fig. 13). The low-grade copper mineralizations are hard to see, but copper sulphides occur along laminae and bedding planes and in quartz veinlets.

On the northern side of the entrance to the Main open pit, there is an approximately 10 m thick porphyritic diorite dyke with chilled margins, plagioclase laths and alteration haloes. Walking 200–300 m northwards to the southern end of the John open pit, a volcanic pipe can be studied.

The main road between Skaidi and Alta is mostly located on Precambrian metasediments correlative with the Ulverygg Formation and on metasediments of the Caledonian Kalak Nappe Complex. Downhill towards Altafjord the road follows the Vendian to Cambrian sediments which unconformably overlie the Proterozoic supracrustal rocks. The Alta-Kvænangen tectonic window is situated at the head of Altafjord and westwards.

DAY 1B. THE RAIPAS COPPER DEPOSIT

E. Vik & J.S. Sandstad

INTRODUCTION

The Raipas copper deposit is the largest and best known of several copper mineralizations located in the Early Proterozoic Storviknes formation in the Alta-Kvænangen tectonic window (Figs. 5 and 14). The Storviknes formation is 600 m thick and comprises a 200 m thick dolomite unit and a lower red siltstone and upper grey siltstone with interbedded dolomite (Fig. 7). Tidal channels, stromatolites and palaeokarst are found in the upper part of the dolomite unit and indicate deposition in a tidal-flat environment. The rocks are very little deformed and are metamorphosed in low grade.

The main copper mineralizations are found as cement in breccias of assumed karst-collapse origin in the upper part of the dolomite. Minor copper mineralizations occur in thin dolomite beds in the upper siltstone and in a conglomerate at the top of the dolomite unit. Chalcopyrite and bornite are the main ore minerals in the breccia matrix. Dolomite and minor baryte occur as gangue minerals. The Raipas copper deposit shows similarities both with red-bed copper deposits and with karst-related lead-zinc deposits.

STOP DESCRIPTIONS

The excursion stops are all located within the area of mapsheet M711/1834 I Alta. In total, the excursion will involve about 5 km of walking both along a track and in the hilly terrain. Solid waterproof boots are recommended.

Stop 1–3. – Skoadduvarri formation.
Locality: Along the track to the Raipas mine (893 901 to 598 600).

The sandstone of the Skoadduvarri formation is well exposed along the track to the abandoned Raipas mine. The sandstone is grey and fine-grained. Sedimentary structures are hard to see.

Stop 1–4. – Storviknes formation and copper mineralizations in karst breccias.
Locality: The Raipas mine (906 605), Fig. 9.

The underground mine workings are not accessible. Different types of breccias originating from the workings are seen on the mine dumps. The copper-mineralized breccias are of type 3 as outlined in the description of the deposit (p. 11). Stratigraphic sections of the upper part of the dolomite unit are found exposed in slopes both to the north and to the south of the mine.

1–4a: Dolomite with partly silicified stromatolites.
1–4b: Thin dolomite beds in the upper siltstone.

Stop 1–5. – Conglomerate of the Storviknes formation.
Locality: 250 m south of Raipas mine (908 603).

A 50 cm thick conglomerate bed is present at the top of the massive dolomite. Fragments consisting of chert and dolomite occur in a matrix of dolomite. The conglomerate has no copper mineralizations here.

Stop 1–6. – Upper part of the dolomite unit of the Storviknes formation.
Locality: About 1 km southeast of Raipas mine (913 599).

The upper part of the dolomite unit is seen in several exposures in this area.

1–6a: Conglomerate bed at the top of the massive dolomite with disseminated copper sulphides; copper mineralizations of type 2. In the dolomite, which in places contains stromatolites, there are disc- and mushroom-shaped structures and thin layers of chert.
1–6b: Massive chert layers and 'chert-pipes' are seen. Karst breccia, with infilling of red claystone around fragments of chert and slate, is also present.
1–6c: Mud flows with fragments consisting of chert and slate in red hematite-bearing mudstone.

Stop 1–7. – Upper siltstone of Storviknes formation.
Locality: 750 m south of Raipas mine (911 599).

Here, there is a thin dolomite bed in the upper grey siltstone of the Storviknes formation. Minor, low-grade copper mineralizations of type 1 are found in the basal layers of this dolomite.

DAY 2A. THE RAIPAS GROUP

J.S. Sandstad

INTRODUCTION

The rocks of the Raipas Group within the Alta-Kvænangen tectonic window (Fig. 5) have briefly been described on pp. 10–11. A more complete description of the formations that will be visited is here presented.

The Kvenvik formation is the lowermost formation of the Raipas Group and is at least 2000 m thick (Zwaan & Gautier 1980). The main rock types are massive coarse-grained metadiabases or metagabbros, fine-grained metabasalts and very fine-grained metamorphic tuffs and tuffites. The lavas are both subaerial and subaqueous and locally contain well-preserved primary structures including pillow lava, pillow breccia, columnar jointing, amygdules and pipe vesicles. Bedding, graded bedding, cross-bedding and accretionary lapilli are found in the volcaniclastic rocks. The low-grade metamorphic volcanites have a tholeiitic basalt composition and are believed to have formed as ocean islands surrounded by shallow-marine deposits. Minor copper deposits of different types are found within this formation (Bjørlykke *et al.* 1985).

The greenstones are overlain by the Storviknes formation

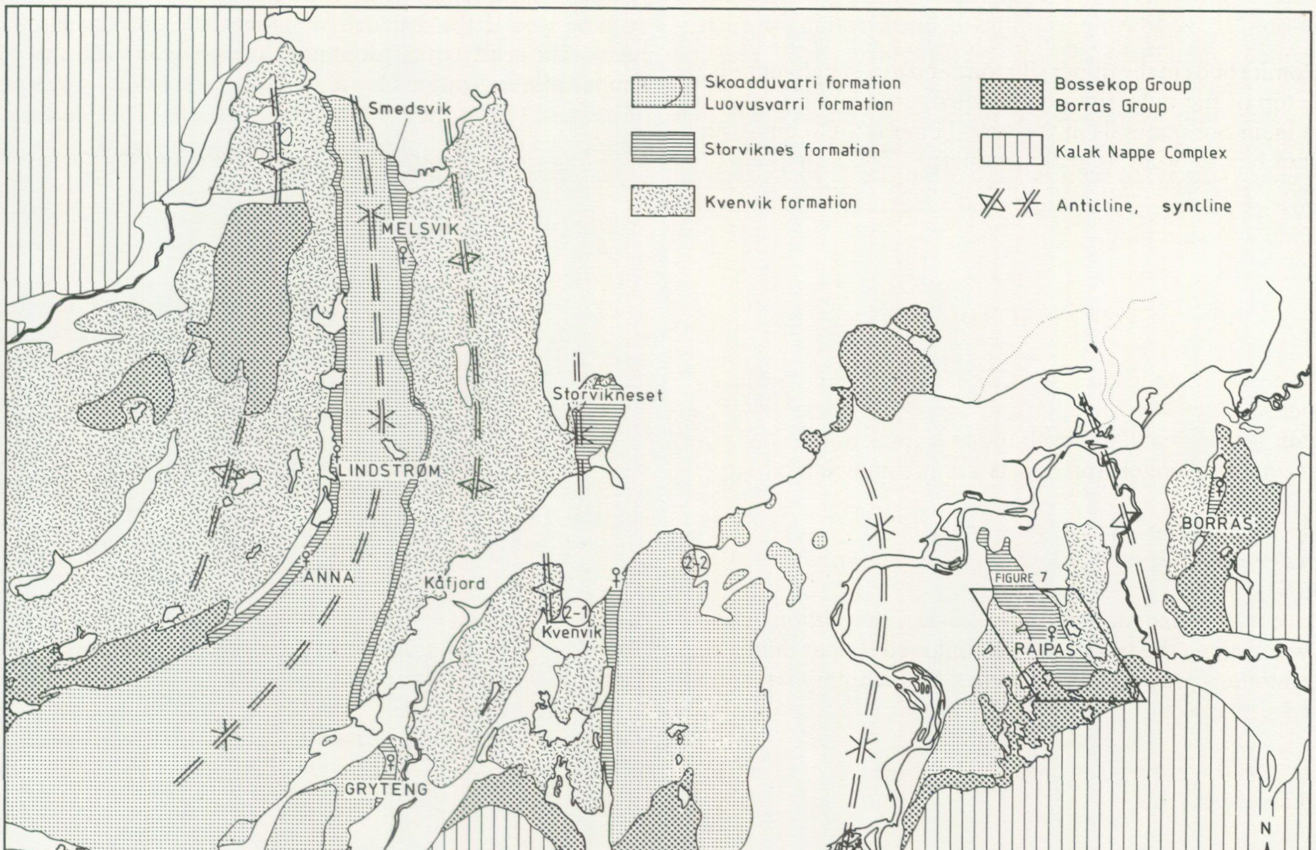


Fig. 14. Geological map of the Alta area, simplified from Zwaan & Gautier (1980). Copper mineralizations of the Storviknes formation are marked. Excursion stops 2–1 and 2–2 are indicated.

with siltstones and dolomite that includes the Raipas copper deposit. Conformably above this lies the Skoadduvarri formation. The relatively homogeneous fine-grained sandstone is classified as a lithic wacke and has minor thin slaty and conglomeratic interbeds (Zwaan & Gautier 1980). Cross-bedding, graded bedding and ripple marks are present. The formation is at least 1000 m thick and is considered to have been deposited in a near-shore, fan-delta environment. No economic prospects are known in this formation.

A thin dolomite interbedded with sandstone, termed the Luovusvarri formation, forms the uppermost unit of the Raipas Group.

STOP DESCRIPTIONS

Stop 2–1. – Kvenvik formation.
Locality: Kvenvika, Alta. Map-sheet M711/1834 I Alta (805 605).

A cross-section along the shore (Fig. 14), provides a traverse upwards in the stratigraphy of the greenstone formation. In the lower part of the inclined section are coarse-grained metadiabases or metagabbros and massive metabasalts with amygdules. Pillow lavas follow, passing upwards into volcaniclastic rocks with interbedded thin metabasalts with hyaloclastic breccias and dark grey schists. Primary structures seen in the volcaniclastic rocks include cross-bedding, intraformational breccias, accretionary lapilli and slumping.

Stop 2–2. – Skoadduvarri formation.
Locality: Hjemmeluft, Alta. Map-sheet M711/1834 I Alta (823 619).

The sandstones with interbedded slates are well exposed in road-cuts (Fig. 14). Cross-bedding, intraformational breccias, ripple marks and other sedimentary structures can be seen.

Please do not take a hammer to the second part of this locality. It is one of the largest areas of rock carvings in Norway. Both the rock carvings and the primary structures in the sandstone can be studied here. 2500 to 3000 carvings are found in four different places in Alta. The Hjemmeluft area is the largest of these. Carvings to different style and content occur at different altitudes above the present sea level. They are thought to have been made from 6200 to 2500 years ago in the shore area while the land was rising following the Quaternary glaciation. The carvings depict people, animals, boats and weapons as well as undefineable patterns and figures.

The road just south of Alta lies upon extensive Quaternary marine and fluvial deposits. The relationships between the Precambrian basement with the overlying Vendian to Cambrian autochthonous sediments and Caledonian nappes can be seen in the distance in mountain cliffs 5 km south of Alta. The road thereafter passes through a canyon located in meta-arkoses of the Caledonian nappes before it reaches Finnmarksvidda (the Finnmark plateau). The plateau is underlain by Precambrian basement extensively covered by Quaternary glacial deposits.

DAY 2B. THE BIDJOVAGGE COPPER-GOLD DEPOSIT

R. Hagen & J.S. Sandstad

INTRODUCTION

The Bidjovagge copper-gold deposit is located in the northwestern part of the Early Proterozoic Kautokeino Greenstone Belt on Finnmarksvidda (Fig. 10). The deposit is found in the lower part of the metavolcanic Cas'kejas Formation. This formation consists of metamorphosed tuffs and tuffites and minor pillow lavas interlayered with thin beds of carbonate rocks, albite felsites, graphite felsite and schists. The rocks have probably been deposited in a shallow-marine environment and are intruded by synvolcanic diabase sills. The mafic rocks have a tholeiitic basalt chemistry and have in the mining area been metamorphosed in the upper part of low grade.

The main mineralization occurs in veins and veinlets in brecciated zones in albite felsite and graphite felsite and define four ore bodies in the eastern limb of an anticline (Fig. 11). Extensive low-grade sulphide disseminations are found in the felsites between the ore bodies. The main ore minerals are chalcopyrite, pyrite and minor pyrrhotite. Gold is generally accompanied by various tellurides. The albite felsite is very fine-grained, homogeneous and partly banded and consists of 80–90 % albite with minor amounts carbonate, quartz and mafic silicates. With an increasing content of carbon the rock is termed graphite felsite.

An exhalative-sedimentary mode of origin has been proposed for the mineralizations (Hollander 1979). They are stratabound and their brecciated character may be due to boiling of the ore-forming solutions accompanied by precipitation of sulphide minerals in a shallow-marine environment (Bjørlykke *et al.* 1985).

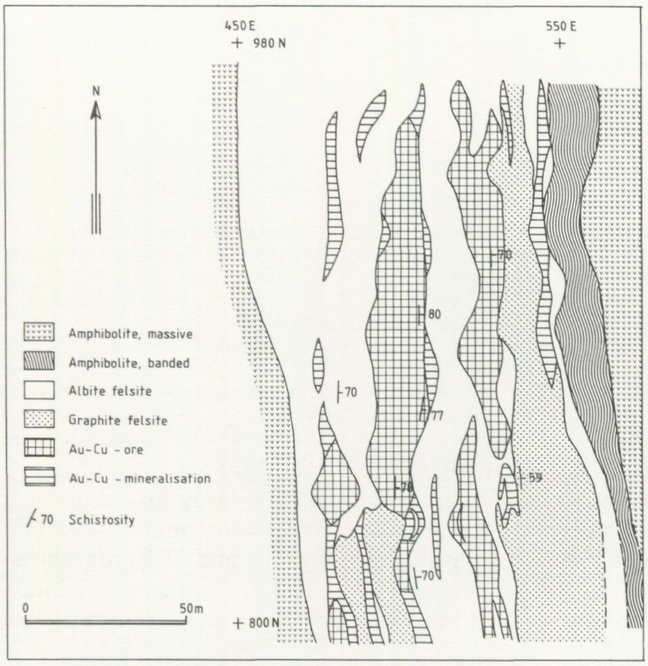


Fig. 15. Geological map of the B ore body, based on mapping by K. Söderholm (unpubl. results 1985).

STOP DESCRIPTIONS

Stop 2–3. – General overview and copper-gold mineralizations in albite felsite and graphite felsite.
Locality: Bidjovagge, B ore body, open pit in the northernmost part of the mining area (Fig. 15). Map sheet M711/1833 IV Mållejus (586 885).

2–3 km north of the open pit we can see the escarpment of Late Precambrian to Cambrian, autochthonous to parautochthonous sediments which overlie the Early Proterozoic volcano-sedimentary rocks. Further north there are meta-arkoses of the Caledonian nappe complexes.

Since the mine reopened as late as June 1985, the area of the open pit had just been stripped off its Quaternary cover at the time of the planning of this excursion. Hopefully, the copper-gold mineralizations will be well exposed in August 1986. In the eastern wall of the pit a fine-grained, banded amphibolite is exposed. It is a metamorphic tuff or tuffite stratigraphically above the mineralizations. Chalcopyrite is seen in ankerite-quartz-albite veins and veinlets mostly in albite felsite, but also in graphite felsite. Both sharp and transitional contacts exist between the rock units. The estimated reserves in this B ore body are 0.44 million metric tons of 1.1 % copper and 2.4 ppm gold.

Stop 2–4. – Wall rocks of the copper-gold mineralizations and gold mineralization in albite felsite.
Locality: Bidjovagge, C ore body, in the southernmost part of the mining area. Map sheet M711/1833 Mållejus (600 864).

Here we can see the massive amphibolite in the footwall, assumed to represent a metadiabase, and the massive and banded amphibolites of the hanging wall. We can also study the albite felsite and graphite felsite and the gradual transition from banded amphibolite to albite felsite. The banded amphibolite carries evidence of scapolitization.

Gold mineralization accompanied by negligible amounts of copper is found in an albite felsite close to the main C ore body. Native gold and various tellurides occur in quartz-carbonate-bearing veinlets. The estimated reserves here are 30 000 metric tons with an average grade of 6 ppm gold.

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