Metallogeny of Finnmark, North Norway

ARNE BJØRLYKKE, SVEIN OLERUD & JAN SVERRE SANDSTAD

Bjørlykke, A., Olerud, S. & Sandstad, J.S., 1985: Metallogeny of Finnmark, North Norway. *Nor.geol.unders. Bull. 403,* 183-196.

Metalliferous ore deposits and mineralisations in the county of Finnmark occur in rocks ascribed to three specific periods of geological time: 1) Archaean, 2) Early Proterozoic, 3) Caledonian. The only Archaean ore deposit is located at the largest iron mine in Norway, Sydvaranger; this was deposited in a shelf environment. The Early Proterozoic volcano-sedimentary belts can be divided into three major metallogenetic provinces. In the easternmost Pasvik area no significant deposits are known and only a few minor nickel mineralisations are present. The rocks of the Karasjok Greenstone Belt are thought to have accumulated during a complete 'Wilson orogenic cycle' and contain both stratiform and stratabound copper deposits, banded iron formations and nickel mineralisations. A continental rifting model is more likely for the rocks of the Kautokeino Greenstone Belt and for correlative units in the tectonic windows to the northwest. Stratabound copper deposits are dominant, occurring in both metavolcanites and metasediments, but gold, uranium and REE mineralisations are also found. This province includes the second operating ore mine in Finnmark at present, the Bidjovagge copper-gold mine. The Caledonian province contains lead deposits in both amphibolite-facies and very low grade metasandstones and Fe-Ti occurrences in mafic and ultramafic intrusive bodies in the Seiland magmatic province.

A. Bjørlykke, Institutt for geologi, Universitetet i Oslo, P.B. 1047, Blindern, N-0316 Oslo 3, Norway.

S.Olerud, Norges geologiske undersøkelse, P.B. 3006, N-7001 Trondheim, Norway

J.S. Sandstad, Norges geologiske undersøkelse, P.B. 3006, N-7001 Trondheim Norway

Introduction

The bedrock geology of the southern part of Finnmark is composed of Archaean to Early Proterozoic gneisses and volcano-sedimentary supracrustal rocks overlain unconformably by Late Proterozoic to Cambrian autochthonous and parautochthonous sediments. Above these, towards the northwest, are the Caledonian nappes which comprise Late Proterozoic to Early Ordovician metasediments, Precambrian basement rocks and Early Palaeozoic plutonic complexes (Plate 1).

The Archaean gneisses consist mainly of felsic orthogneisses and paragneisses. In East Finnmark these rocks are transected by shallow belts of probable Early Proterozoic volcano-sedimentary sequences. The Archaean gneisses in southwestern Finnmark constitute a dome structure, and this is pierced by Early Proterozoic plutonic rocks (Plate1). The dome is flanked by the Svecokarelian Kautokeino Greenstone Belt in the west and the Karasjok Greenstone Belt in the east. The precise relationship between these greenstone belts is a subject of current discussion, but they are probably of similar age, i.e. Early Proterozoic (Krill et al. 1985). The supracrustal rocks of the Alta-Kvænangen, Altenes and Repparfjord-Komagfjord tectonic windows are correlated with those in the Kautokeino Greenstone Belt (Pharaoh et al. 1983, Siedlecka et al. 1985). The volcano-sedimentary belts 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, but the greenstone belts are intruded by younger felsic intrusions mainly along their borders. The major types of ore deposits in these various units are listed in Table 1. The economically most important of these is the Sydvaranger iron ore deposit of Archaean age, which besides the Bidjovagge copper-gold mine is the only operating ore mine in Finnmark at present.

The present paper constitutes a review of the metalliferous ore deposits and mineralisations occurring in the county of Finnmark. The deposits are described broadly from oldest to youngest, and the description is followed by a discussion of the major metallogenetic provinces recognised in the different geological regions.

	Archaean	Early Proterozoic	Late Proterozoic	Palaeozoic
Deposits associated with basaltic volcanism		Bidjovagge (Cu-Au) Kåfjord (Cu) Porsa (Cu) Biggejavri (U-REE) Porsanger (Cu)		
Sedimentary sulphide deposits		Repparfjord (sandstone Cu) Raipas (dolomite -hosted Cu)	Geitvann (sandstone Pb-Zn) Daktegilva (dolo-mite-hosted Cu)	Dividalen Group (sandstone Pb)
Sedimentary iron deposits	Sydvaranger (Superior type BIF)	Karasjok (Algoma type BIF)		
Deposits in mafic igneous rocks	South Pasvik (Ni)	Anarjokka (Ni) Pasvik (Ni) Porsanger (Cu)		Seiland province (Fe-Ti)
Deposits asso-ciated with felsic igneous rocks		Gievdneguoika (Mo-W-F) Raitevarre (Cu)		

Table 1. The main ore deposit types of Finnmark.

Archaean deposits

Sydvaranger iron ore deposits

The Sydvaranger iron ore deposits occur in a strongly folded sequence of metavolcanites and metasediments of Late Archaean age (Bugge 1978, 1980). The iron formation can be traced for 100km from Kirkenes to the head of Varangerfjord (Plate 1). The stratigraphy is best known in the mining area of Bjørnevann (Fig. 1) (from top to bottom):

Biotite-hornblende gneiss (meta-andesite)
Quartz-banded iron ore
Bjørnevann gneiss (quartzite and arkosite with metarhyolitic interbeds)
Bjørnevann conglomerate

The iron formation, has a well developed banding of alternating quartz and magnetite. The content of clastic material is low, and carbonate and sulphide facies are practically absent. Primary slump structures have been reported (Bugge 1980). There is a marked petrographical difference between footwall and hanging wall. The footwall rocks consist of shallow-water sediments and felsic volcanites and the hanging wall rocks of mafic to intermediate volcanites. The ore consists of magnetite, quartz, hornblende, grünerite, epidote, biotite and sometimes hematite. Traces of pyrite and chalcopyrite are present and contain 0.8 and 2 ppm Au, respectively (Bugge 1978). The crude ore averages 30% magnetic iron and until now 130 mill. tonnes of ore have been mined. The reserves are in the order of 100 mill. tonnes, but the future of the mine is uncertain.

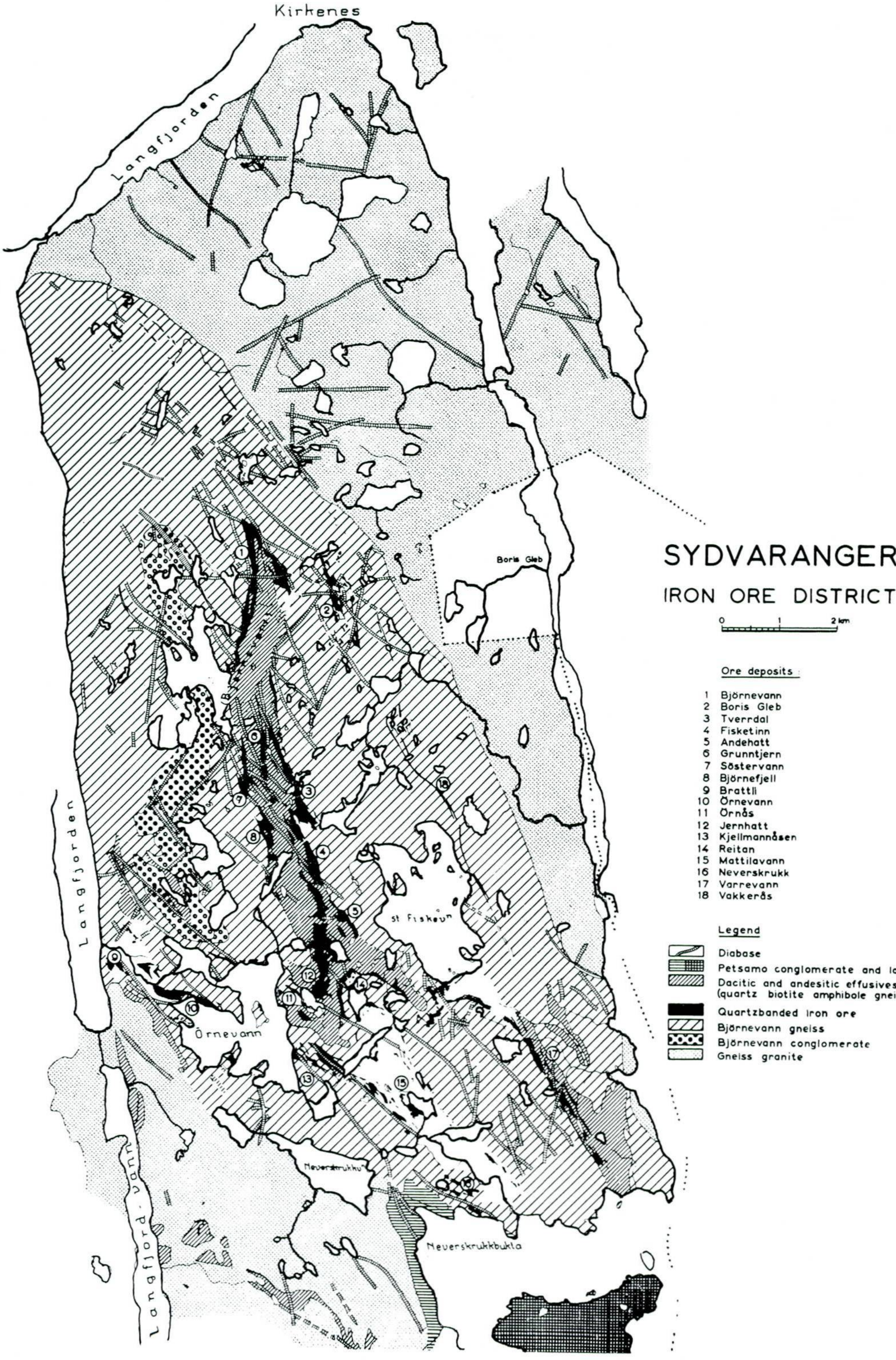


Fig. 1. Geology of the Sydvaranger iron ore deposit (from Bugge 1978).

Nickel mineralisation in South Pasvik

Prospecting for nickel has taken place in the Archaean rocks of South Pasvik. The area is a high-grade metamorphic terrain with granitic and biotite-hornblende gneisses, mica schists, amphibolites, ultramafites and olivine gabbro intrusions (Boyd & Nixon 1985). Both in Finland and in USSR ultramafic rocks of this complex have some associated nickel mineralisation (Likhachev 1978). Mineralisation of ore quality has been found only in harzburgitic boulders with grades up to 3.5% Ni, 0.5% Cu and 10.8% S (Boyd & Nixon 1985).

Early Proterozoic deposits

Nickel mineralisation in the Pasvik area

Exploration for nickel has taken place in the Early Proterozoic Petsamo Group (Råheim & Bugge unpubl. manus.) This volcano-sedimentary unit can be followed from Polmak in the west, through Finland, into Norway in Pasvik and eastward into USSR. In the Nikkeli area in USSR, near the Norwegian border, several large nickel deposits are known. In the Pasvik area the Petsamo Group rests unconformably upon the Archaean Bjørnevann Formation. A basal polymict conglomerate is followed by andesitic lavas and sediments, quartz keratophyres, a lower greenstone with sediments, a mixed phyllite unit consisting of sediments, greenstones, gabbros and serpentinites, and an upper greenstone unit with mixed sediments and volcanites (Boyd & Nixon 1985). The ultramafic bodies of the phyllite unit are strongly serpentinized. They are of limited size and the largest body has a strike length of 1km. They are practically sulphide-free, although pyrrhotite with pentlandite flames has been observed. The best nickel values have been obtained from a talc-chlorite schist with 0.3% Ni, but no significant deposits have yet been found in the Norwegian part of the Petsamo Group.

Annarjokka nickel mineralisation

A/S Sulfidmalm prospected for nickel in the southernmost part of the Karasjok greenstone belt in the 1960's and 1970's. Some enrichments of Ni and Cu were observed in ultramafic rocks, but according to Boyd & Nixon (1985) no significant mineralisations were found.

Karasjok banded iron deposits

The manganiferous banded iron formations in the southern part of the Karasjok Greenstone Belt have been described by Wennervirta (1969). The banded iron formations occur at two main stratigraphic levels (Often 1985); in the upper part of the lower pelite sequence and near the main komatiite level in the metavolcanites. According to Wennervirta (1969) the Njouvcokka deposit shows, stratigraphically from bottom to top, oxide, carbonate and sulphide facies of banded iron formations. Several occurrences are known in the area and there are lateral facies changes between the known deposits. The oxide facies is represented by a quartz-banded garnet-grünerite-biotite-plagioclase gneiss with magnetite and hematite. The carbonate facies rocks are quartz-banded marble with magnetite, hematite, manganiferous silicates and carbonates. These carbonate rocks gradually pass upwards into sulphide-bearing calc-silicate bearing rocks. The banded iron formations resemble the Algoma-type deposits of the Canadian Shield (Gross 1983) which are characteristic of Archaean volcanic suites, but which also occur in Proterozoic terrains, e.g. at Jerome, Arizona (Anderson & Creasey 1958). Comparable banded iron formations are found on the Baltic Shield. In Finland iron formations of both Archaean and Proterozoic age are known from greenstone belts (Laajoki 1983) and iron formations of Proterozoic age occur in Sweden (Frietsch 1982).

Raitevarre copper deposit

The Raitevarre copper deposit occurs near the top of the lower pelite unit of the Karasjok Greenstone Belt (Often 1985). A copper-enriched stratabound horizon can be traced more than 4km (Bugge 1978) and contains a 10-50m thick sequence with disseminations of chalcopyrite and pyrite in what Røsholt (1977) called a dioritic gneiss and Bugge (1978) called quartzites and micaceous gneisses. Often (1985) reinterpreted the copper-bearing lithologies to be intermediate volcaniclastic rocks. A stratigraphic column of the mineralized area based on the three above-mentioned papers are:

Metabasalts
Black schists, sulphide-bearing.
Intermediate volcaniclastic rocks with chalcopyrite and pyrite.

Various quartzitic, calcareous and volcaniclastic rocks.

No detailed study of the occurrence is available and a further classification is not possible at the present time. The described milieu broadly fits the volcanite-associated sulphide deposit type. However, the low grade disseminations of the sulphides and the composition of the host rock indicate that the possibility of the presence of a deformed porphyry copper type deposit cannot be disregarded.

Porsanger copper deposits

Several copper deposits are known in the Porsanger area in the northernmost exposed part of the Karasjok Greenstone Belt. Juve (1968) and Bugge (1978) described two main types of deposit in the area; a barren massive iron-sulphide type and a dissemination-vein type with copper-rich mineral assemblages. Both types are associated with basaltic volcanites and mafic intrusions.

The stratiform massive sulphide deposits consist mainly of pyrite and pyrrhotite with only a low copper content. They appear as up to 30 m thick beds with up to 1 m thick massive sulphide layers alternating with quartzitic and schistose layers which can be traced for 3.5km. Some of the deposits grade laterally into graphite schists. They were described as metamorphic 'vasskis' of Leksdalen type by Carstens (1931) and their exhalative-sedimentary origin seems indisputable. The dissemination-vein type is known as a mainly stratabound deposit of copper minerals. Chalcocite, bornite and hematite with accessory amounts of molybdenite and native copper is the main mineral paragenesis of this type. Both a synvolcanic origin and a later supergene enrichment during the formation of the Late Precambrian sandstones have been proposed for the genesis of these deposits (Juve 1968, Juve & Vokes 1980).

Bidjovagge copper-gold deposit

The Bidjovagge copper-gold deposit is located 40km northwest of Kautokeino in the Kautokeino Greenstone Belt. Mathiesen (1970a) has published a geological and geophysical map over the mining area, while the geology has been described in some detail by Hollander (1979). Hagen (1982) has discussed the occurrences of gold and tellurides. The mine was in production from 1970 to 1975, and was reopened in 1985. The latest published figures of proved reserves are about 2.8 mill.tonnes with 1.5-2.0% Cu and 2 mill.tonnes with 0.8% Cu. The average grade of gold is 1.2ppm (Hagen 1982).

The mineralised horizons occur at what is probably a low stratigraphic level of the volcano-sedimentary Čas'kejas Formation which is metamorphosed in upper low-grade facies around the deposit (Sandstad 1983, Siedlecka et al. 1985). The deposit occurs in the vicinity of a positive gravity Bouguer anomaly presumably caused by a thick pile of folded metavolcanites (Olesen & Solli 1985). This may indicate proximity to a volcanic centre. The mineralisations constitute four ore bodies on the eastern limb of a N-S trending, upright antiform. Only weak mineralisations are found on the western limb. A geological profile through the antiform and one of the ore bodies is shown in Fig. 2. Over a stratigraphic thickness of about 300m in the mining area the sequence is as follows (from top to bottom):

Massive amphibolite (metadiabase or metabasalt).
Banded amphibolite (metatuff and metatuffite).
Albite felsite, graphite felsite and graphitic schists, with Cu-mineralisations.
Massive amphibolite, magnetite-bearing.
Carbonates, interbedded with massive and banded amphibolites.

The albite felsites are very fine-grained, massive and partly layered consisting of albite with small amounts of quartz, carbonate, amphibole, biotite and muscovite. With an increasing content of carbon the rock grades into a graphite felsite. The transition to banded amphibolites is presumably continuous, with increasing amounts of mafic silicates. The massive amphibolites have either sub-ophitic or poikilitic textures and contain hornblende and plagioclase with subordinate amounts of biotite, chlorite and magnetite.

The main mineralisations occur as veins in brecciated and faulted zones in felsites and graphitic schists. Low-grade disseminations, in part defining a diffuse layering concordant to layering in the felsites, are found between the brecciated zones. This brecciation has probably both a primary and a later syntectonic origin. The ore minerals are chalcopyrite, py-

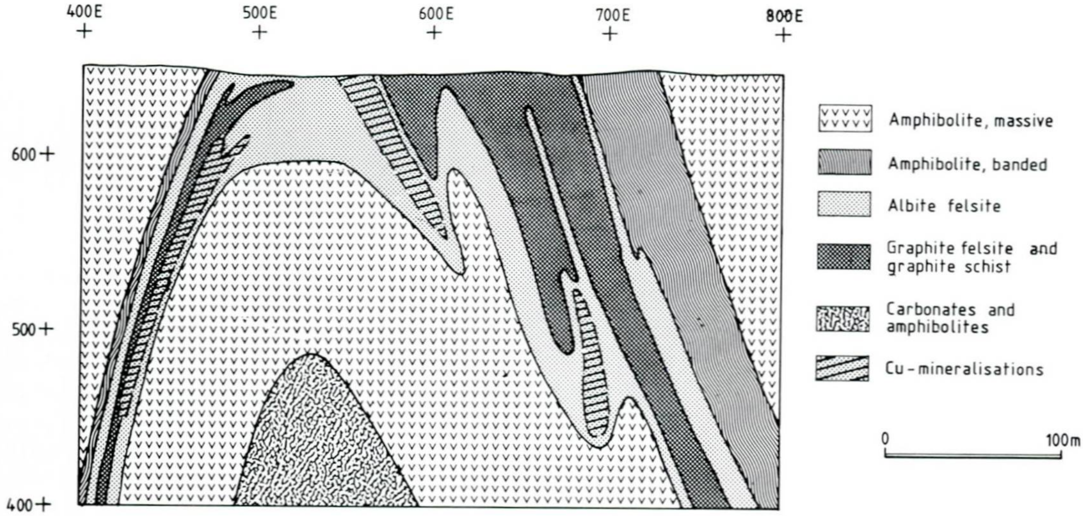


Fig. 2. Geologic section along profile 0 in the Bidjovagge copper mine, based on Mathiesen (1970a).The copper mineralisation shown on the eastern limb belongs to the 'A ore body'.

rite and minor pyrrhotite. Accessory minerals are magnetite, hematite and various tellurides (Hagen 1982). Gold accompanies both the sulphides and the tellurides. Gangue minerals are calcite, dolomite/ankerite, albite and quartz and minor amounts of amphiboles, muscovite, biotite and chlorite. The footwall rocks are transected by veins and veinlets containing gangue minerals and sulphides with associated carbonatisation and albitisation. A complex Ti-mineral was found in the albite felsite in a restricted area (Mathiesen 1970b). Later research has shown that it is a variety of davidite similar to the occurrence in Biggejavri.

Hollander (1979) proposed an exhalative-sedimentary origin for the mineralisations, with the albite felsite representing volcanic ashes settling in a reducing environment of organic black clay. Preliminary REE-analyses support the theory of the felsites representing siliceous extrusives; they are not consistent with patterns of chemical sediments. The albite felsites have also been considered to have a metasomatic origin (Padget 1959). Other theories point to some form of association between the mineralisations and the massive amphibolites. In this case the amphibolites are assumed to represent intrusions which were accompanied by hydrothermal copper-bearing solutions. They could have been intruded into unconsolidated sediments at shallow depths (Vik 1983) or at a late-orogenic stage (Gjelsvik 1958). A similar mineralisation has been found at *Suovrarappat,* 12km northeast of Bidjovagge, at possibly the same stratigraphic level (Sandstad 1983). Similar geological and geophysical patterns are found at *Riednjajav'ri,* 25km south of Kautokeino, but only negligible mineralisations have been found so far (Sandstad & Olesen 1984).

Biggejavri uranium and rare-earth element occurrence

A U-REE-bearing albite felsite was found at Biggejavri in 1983 (Olerud 1985) near the top of the amphibolite unit of the Suoluvuobmi Formation (Solli 1983). The amphibolites are succeeded by schists of the same formation. Field investigations in the form of regional and detailed mapping have shown that the main phase of albite felsite formation occurred prior to the Svecokarelian deformation and that the unit has a stratabound character. One phase of slightly radioactive albite felsite, however, occurs as post-tectonic dykes.

The amphibolites have both a massive lava character and pyroclastic textures, and are strongly carbonatised near the albite felsite. The radioactive albite felsite is medium- to fine-grained and according to Olerud (1985) consists of more than 90 % albite, a U-bearing, Cr- and V-rich variety of davidite, calcite, muscovite, chromite and rutile. Accessory minerals are calkinsite, monazite, orthite, coffinite, uranophane, brannerite, thortveitite and various sulphides. The chemical composition of this unusual rock is shown in Table 2. The origin of the rock is under discussion and an interpretation as a volcaniclastic sediment is proposed. The contents of uranium, scandium and rare-earth elements are of economic interest.

	average wt%		average ppm
SiO_2	63.19	U	978
Al_2O_3	18.42	Th	22
Fe_2O_3	1.33	Nb	< 5
TiO_2	1.62	Zr	93
MgO	0.64	Y	248
CaO	0.73	Sr	31
Na_2O	10.37	Rb	26
K_2O	0.25	Pb	206
MnO	0.03	Cu	< 5
P_2O_5	0.02	Zn	24
l.o.ign.	1.50	Co	24
		Ba	75
		Mo	16
		Ce	605
		La	1027
		Sn	< 5
		Sc	122
		Ga	33

Table 2. Average chemical analyses of 3 samples of the uraniferous rare-earth bearing albite felsite at Biggejavri, Kautokeino.

Gievdneguoika granite with Mo, W, F mineralisation

The Gievdneguoika granite is situated 40km northeast of Kautokeino village and has an outcrop area of less than 1km². It is a syn- to post-tectonic intrusion asssociated with the Svekokarelian orogeny and has been Rb-Sr-dated by Krill et al. (1985) to 1789 ± 64 m.y. B.P. The granite intrudes the contact between the amphibolites of the Gåldenvarri Formation and the granodiorites of the Jergul Gneiss Complex. The granite contains fragments derived from the amphibolitic country rock and metasediments from the overlying Masi Formation. Some of these fragments are massive skarn and consist of garnet, fluorite, quartz, diopside and small amounts of calcite and scheelite. Molybdenite- and scheelite-bearing quartz veins occur in the amphibolitic country rock.

The granite is extremely differentiated and selected elements show the following values (average of two samples): SiO_2 74.50%, Al_2O_3 14.61%, CaO 0.73%, Na_2O 4.75%, K_2O 4.30%, Rb 569ppm, Sr 7ppm, Nb 65ppm, Y 74ppm, Ba 10 ppm and U 22 ppm. The content of dark minerals is about 1% and these consist mainly of garnet, biotite, muscovite, idocrase, scheelite, molybdenite, pyrite and chalcopyrite. The chemistry of the granite is comperable to that of granites hosting Sn- and W- mineralisations (e.g. Haapala 1977 and Pearce & Gale 1977).

Kåfjord copper deposit

The Kåfjord copper deposit (Plate 1) occurs in the Kvenvik Formation in the lower part of the Lower Raipas Group (Zwaan and Gautier 1980). The copper-mineralisations have been known since the 18th century, and mining was carried out during the periods 1827-1878 and 1895-1906. About 5-6,000 tonnes of metallic copper has been produced from ore containing approximately 5-6% Cu (Moberg 1968). The description which follows is based mainly on the university theses of Mørk (1970) and Stache (1970).

The deposit consists of several veins located in brecciated greenstones and usually near the contact to metasediments comprising carbonates, mica schists and graphitic schists. The greenstones in the mining area have been assumed to represent intrusive rocks (Mørk 1970).

The rocks are folded into an anticline and metamorphosed in greenschist facies. A near flat-lying shear-zone, assumed to be a local thrust, has been recognised and this truncates the brecciated rocks (Mørk 1970). This shear-zone always occurs at less than 100 m above the mineralised veins and partly follows the boundary between the metasediments and greenstones. The veins are mainly subparallel to the strike of the greenstone although some branching occurs. The main veins have a strike length of up to 350m and are commonly 1-3m thick although they locally have a thickness of 8-10m. In the veins the sulphide minerals chalcopyrite and pyrite are found as clusters and disseminations, and hematite and magnetite are sometimes present. The gangue minerals are mainly calcite and quartz with minor amounts of ankerite, chlorite and actinolite.

Mørk (1970) proposed an epigenetic post- or syntectonic origin for the mineralisations. Alteration and leaching of the greenstones accompanying brecciation and folding led to the deposition of sulphides and gangue minerals in fissures. An alternative hypothesis regards the mineralisations as epithermal and synvolcanic. The brecciated greenstones then represent hydrothermal intrusive breccias in a shallow-marine environment. This theory still has to be developed. Similar deposits in the Alta-Kvænangen window occur on *Middavarre* and in *Bergmark* (Vik 1980, 1981). It is worth noting that at Bergmark there are also stratabound mineralisations of the Bidjovagge type (Vik 1983).

Raipas copper deposit

Several mineralisations of copper sulphides occur in the Storviknes Formation of the Lower Raipas Group in the Alta-Kvænangen tectonic window (Zwaan & Gautier 1980). The Raipas deposit is situated 5km southeast of Alta and is the largest and best known deposit in the Storviknes Formation. The deposit produced a total of 12,500 tonnes of ore between 1837 and 1870 with an average grade of 6.3% Cu (Vokes 1955).

The Storviknes Formation overlies greenstones of the Kvenvik Formation and comprises 600m of dolomites and grey and red siltstones with carbonate beds. Tidal channels, stromatolites and palaeokarsts are found in the upper part of the dolomite (Vik 1979). Above the dolomite there are deltaic and fluvial sandstones of the Skoadduvarri Formation (Zwaan & Gautier 1980).

The main copper mineralisations occur in the uppermost part of the dolomite sequence, mainly as cement in palaeokarst breccias together with dolomite and barite, but also partly disseminated in dolomite and in conglomerates at the top of the massive dolomite (Vik 1979). The major sulphides are chalcopyrite and bornite, with subordinate amounts of tennantite, digenite, linnaeite, siegenite and minerals of the cobaltite - gersdorffite series (Vokes 1957, Vokes & Strand 1982).

Repparfjord copper deposit

The Repparfjord copper deposit is situated in the lower part of the Ulverygg Formation, which is the lowermost part of the sedimentary Saltvatn Group in the Repparfjord-Komagfjord tectonic window. The geology of the window has recently been described by Pharaoh et al. (1983), while Fabricius (1979) and Stribrny (1979) have studied the mineralisations. The total amount of ore was about 10 mill. tonnes with a grade of 0.6 - 0.7 % Cu. The mine was operated from 1972 to 1978 and 3 mill. tonnes of ore were produced. The copper concentrate contained 35-40 % Cu and 50-70 g/tonne Ag (Stribrny 1979).

The Ulverygg Formation (Fig. 3) is at least 1,000m thick (Reitan 1963), and consists of white or grey, lithic, feldspathic and quartzitic sandstones and polymict conglomerates. The rocks are moderately folded and metamorphosed in greenschist facies (Pharaoh et al.1983). In the mine area thin, clast-supported, conglomerate beds occur at the base of thin fining-upward cycles commonly with cross-bedding and with siltstones at the top. These moderately mature sediments appear to have been deposited by braided streams flowing from a siliceous source area to the west and northwest. The ore zones consist of diffuse lenticular bodies along a strike length of up to 2km. The main ore minerals are chalcopyrite, bornite, digenite and chalcocite. The copper mineralisations occur as (Fabricius 1979, Stribrny 1979):

a) disseminations concentrated along bedding planes, and in the top or bottom beds of the fining-upward cycles;
b) disseminations and clusters in quartz veins and brecciated host rock;
c) fine-grained disseminations in mylonitic zones;

Type (a) constitutes 60% of the ore minerals. Chalcopyrite and bornite commonly occur together with hematite, magnetite, ilmenite and other heavy minerals. Type (b) consists of bornite with chalcocite, digenite and chalcopyrite. Both in geological setting and in ore mineralogy the Repparfjord deposit shows many similarities with 'red-bed' copper deposits (Brown 1981).

Porsa copper deposits

The Porsa copper deposits occur as a complex of veins in a wide area located in the Svartfjell Formation of the metavolcanic Nussir Group (Pharaoh et al. 1983) in the Repparfjord-Komagfjord tectonic window. Mining was carried out in the years 1890-1910 and 1929-1931. Total reserves are estimated to be less than 0.1 mill.tonnes of 1% Cu and a few thousand tonnes of 0.2-0.3% U (Krause 1981).

The veins generally occur on the top of metabasaltic lavas which are overlain by metasediments and metamorphosed in lower greenschist facies. The structure of the mining areas is dominated by NE-SW trending, upright Svecokarelian folds. One of the deposits is found in the vicinity of a major NW-SE trending thrust of similar age. The Svecokarelian basement was reactivated during the Caledonian orogeny, re-

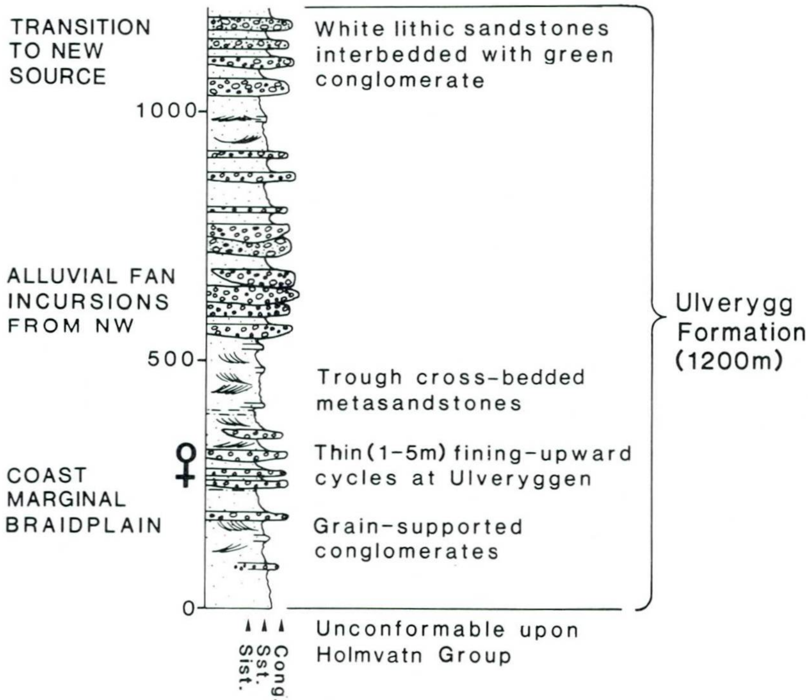


Fig. 3. Schematic lithostratigraphy for the Ulverygg formation, from Pharaoh et al. (1983). Individual beds shown are not to scale thickness. The position of the Ulveryggen copper mine is marked by a copper sign.

sulting in prominent break-thrusts on the Svecokarelian fold limbs (Pharaoh et al. 1983). The mineralised veins cut the regional NE-SW structures at an oblique angle; they are vertical and lens-shaped with a maximum thickness of 10m at the surface (Reitan 1963). The ore minerals are predominantly chalcopyrite, pyrite, magnetite and hematite, but brannerite, pitchblende and anatase have been found in two of the veins (Krause 1980). Gangue minerals are quartz and calcite with minor amounts of amphibole, chlorite, plagioclase and muscovite. The mineralisations are assumed to represent fracture fillings of hydrothermal, metamorphic origin, contemporaneous with either the Svecokarelian (Krause 1980) or the Caledonian orogeny (Reitan 1963). The greenstones and overlying black slates are looked upon as source rocks for the Cu and U, respectively. However, leaching of uranium from black shales is regarded as an ineffective mechanism (Lindahl 1983). A synvolcanic origin for both the copper and uranium mineralisations is also possible.

Caledonian deposits

Geitvann lead-copper (-zinc) deposit

The Geitvann lead-copper (-zinc) deposit is situated on Porsangerhalvøya, 3 km southwest of Olderfjord. The mineralisation occurs in rocks of the Kolvik Nappe of the Kalak Nappe Complex. Lithologically the Kolvik Nappe consists mainly of metasandstones (Klubben Psammite Group) and pelitic to semi-pelitic schists (Gayer et al. 1985). The sedimentary thickness of the Klubben Psammite Group is difficult to estimate because of the strong polyphase folding and the complex thrusting both within and between the nappe units. However, the thickness of the group is estimated to be at least 2 km on Sørøy (Roberts 1974). A belt with metadolerite dykes and sills intruding the psammite occurs in the mineralised area. The dykes are mainly cross-cutting with respect to the banding in the psammites, but sills can be seen branching out from the steeply dipping dykes (Lindahl & Bjørlykke in prep.).

The mineralisation. which consists mainly of galena, chalcopyrite, pyrrhotite and sphalerite, is spatially bound to a bed enriched in calcite. In detail the richer part of the mineralisation occurs in breccias and veins. This could be due partly to regional metamorphism and partly to a primary stringer mineralisation. Comparison of the lead isotope composition of the Geitvann deposit with sulphide deposits in the Caledonide and Grenville orogens shows that it is most likely that the Geitvann deposit is hosted in metasediments of Late Riphean age (Lindahl & Bjørlykke in prep.).

Daktegilva copper mineralisation

A minor copper mineralisation is found in the Porsanger dolomite in the Gaissa Nappe. It is located on the small island Daktegilva in Porsangen. Quartz and copper minerals occur as matrix in brecciated dolomite.

Lead mineralisations in the Dividal Group

Several small occurrences of lead and minor zinc are known from the Dividal Group and correlative sedimentary formations. They occur in the lower part of the autochthonous sequence in sediments of Vendian to Early Cambrian age and can be classified as sandstone lead deposits of Laisvall type (Bjørlykke & Sangster 1981). At *Gurrogaissa,* 40km east of Lakselv, galena occurs both as fracture fillings in granulite-facies gneisses immediately beneath the Late Precambrian peneplain and as fracture fillings and disseminations in the lowermost blue-grey feldspathic sandstone of the Dividal Group. Lead isotope data from Gurrogaissa are less radiogenic than those from comparable Caledonian lead mineralisations further south, and this has been interpreted as relating to derivation from a uranium-poor source rock (Bjørlykke & Thorpe 1981).

At *Stabbursdalsvatna* (Bojobæsk) 40km southwest of Lakselv, disseminations of galena were found in 1974 in the lowermost quartzitic sandstone of the Dividal Group. The sandstone is only 1.5m thick and occurs just above the basal conglomerate. Disseminations and fracture fillings of galena are also reported from the basal sandstones of the Dividal Group at other localities in the Lakselv district (D. Roberts, pers.comm. 1983). A lead mineralisation has also been discovered at *Raudfjell* south of Repparfjord. Galena occurs as subeconomic veinlets and disseminations in coarse-grained sandstone and in the basal conglomerate of the Lomvann Formation (Pharaoh et al. 1983), a correlative of the Dividal Group.

Fe-Ti oxide occurrences in the Seiland magmatic province

Several large and low-grade deposits of Fe-Ti oxides are found within the synorogenic Finnmarkian intrusions of the Seiland province (Geis 1971). Recent work by Robins (1985) has revealed that the principal concentrations of Fe-Ti oxides are within layered mafic intrusions and alkaline ultrabasic rocks. He describes three main types of Fe-Ti oxide enrichments in the basic rock complex. 1) In the Hasvik subalkaline layered gabbro the Fe-Ti oxide enrichments occur in layers at a high level in the intrusion. 2) In the Rognsund layered intrusion of nepheline-normative olivine basalt composition the Fe-Ti oxides became cumulus minerals at an early stage. Thus, in this magma the Fe-Ti enrichment occurs in layers at a low level in the intrusion. 3) Robins (1985) also describes a swarm of apatite-ilmenite-titanomagnetite hornblende clinopyroxenite dykes. Geis (1971) has shown that the main oxide minerals in these occurrences are titanomagnetite, containing up to 0.59% V, and ilmenite.

Quaternary deposits

Alluvial gold deposits in the Karasjok area

In the southern part of the Karasjok Greenstone Belt several Quaternary alluvial gold deposits are known (H. Bjørlykke 1966). Sargejåk was the most important deposit and yielded approximately 20kg gold up to 1937. New investigations of the composition, transport directions and transport distances of the Quaternary superficial deposits by Often et al. (1984) have shown that the main gold-bearing gravel has been transported from the southeast. This indicates that the source rocks of the gold may be metakomatiites and metabasalts from the main komatiite stratigraphic level.

Discussion

The Archaean rocks in Finnmark occur in two provinces. In the eastern province the largest iron mine in Norway, Sydvaranger, is located in a thick sequence of intermediate to felsic metavolcanites and metasediments of Late Archaean age. Shallow-marine sediments in the sequence indicate a shelf environment (Bugge 1978) thus suggesting that the deposits belong to the Lake Superior type. In the western, Finnmarksvidda province, gneisses are the most common Archaean rocks, but a sequence of probable Archaean supracrustals which consist of a thin succession of mafic metavolcanites and metasediments is also known (Solli 1983). No significant mineralisation has been discovered in these

Archaean rocks in southwest Finnmark. The relationship between these two Archaean provinces is still uncertain.

The Early Proterozoic volcano-sedimentary belts constitute three major metallogenetic provinces. In the easternmost Pasvik area Ni is the most important ore element, but the occurrences are small. However, the potential of the area is indicated by the large Ni-deposit in USSR on the opposite side of the border in the Peschenga and Allarechka areas (Gorbunov et al. 1985). In the Karasjok Greenstone Belt both massive and disseminated stratiform and stratabound copper sulphide deposits, banded iron formations and nickel mineralisations are found. In addition, alluvial Au-deposits in Quaternary superficial material are known. In the Kautokeino Greenstone Belt and in the Alta-Kvænangen and Repparfjord-Komagfjord tectonic windows copper and partly gold are the most important ore elements. Copper deposits of stratabound type are generally brecciated and associated with basaltic volcanism, but stratabound Cu-deposits are also found in sandstones and in dolomites. Au, U and REE are also found in this province. A minor Mo-W occurrence located in a post-tectonic granite marks the end of this mineralising epoch.

Hietanen (1975) proposed a North American Cordilleran-type plate tectonic model for the Svecokarelian geosynclinal complex in southwestern Finland and northern Sweden. This model has been further developed by several authors (Berthelsen 1980, Gaál 1982), while Raith et al. (1982), Barbey et al. (1985) and Krill (1985) have presented plate tectonic models for the northernmost part of the Baltic Shield.

Based on recent age determinations and structural and metamorphic studies Krill (1985) has proposed a plate tectonic model and described a complete 'Wilson orogenic cycle' for the Early to Middle Proterozoic rocks in the eastern part of Finnmarksvidda. Gaál (1982) suggested that sea-floor spreading (Norrland Ocean) took place around 2.1 Ma B.P. and that island arcs formed at 1.9 Ma. Sm/Nd ages for komatiites from the Karasjok area (Mearns & Krill 1984) also give a date around 2.1 Ma. This indicates that sea-floor spreading took place in northern Finland, Norrland and in central Finnmark at the same time. Mäkelä (1980) suggested that the Outokumpu Cu-Co deposit is of Cyprus-type deposited in a marginal basin and Gaál (1982) related the formation of the Outokumpu deposit to the sea-floor spreading at 2.1 Ma. On geochemical grounds Park (1983) proposed that the Outokumpu assemblages were deposited in an island-arc or back-arc basin tectonic settings rather than on the deep ocean floor. These tectonic settings are consistent with the current assumptions for the tectonic settings of the Karasjok Greenstone Belt (Krill 1985, Often 1985). Cu-Co deposits like Outokumpu have not been found in the Karasjok Greenstone Belt but low-grade copper deposits associated with quartzites (meta-exhalites?) and black schists in the Porsanger area may represent similar deposit types. Several nickel deposits are also found in the Karelian zone of the Svecokarelian orogen (Papunen & Vorma 1985), and the minor occurrences of nickel known in the Karasjok Greenstone Belt resemble those of the Kotalahti-type. According to Gaál (1982) the oceanic plate was subducted in an east-northeasterly direction beneath the Archaean craton at 1.9 Ma B.P. and an island arc with stratiform lead-zinc and porphyry-type copper-molybdenum deposits was formed. Acidic metavolcanites with stratiform zinc mineralisations are also known from the Karasjok area (J. Heim, pers. comm. 1984). The banded iron formation in Karasjok of probable Algoma-type may be related to the island arc environment of the central Finnmark orogenic belt.

Both a continental rifting (Torske 1978, Witschard 1980) and an ensialic back-arc basin environment (Pharaoh & Pearce 1984) have been suggested as depositional environments for the supracrustals in the Kautokeino Greenstone Belt and tectonic windows further to the north. The best preserved example of rift sediments is exposed in the Repparfjord-Komagfjord window where the 3km-thick Saltvann Group was deposited in a horst-and-graben tectonic environment. The association of fault-controlled cratonic basins and sediment-hosted 'red bed' copper deposits is well established (Bjørlykke & Sangster 1981). On a global scale the largest deposits of this type were formed in the Middle and Upper Proterozoic of Africa and Australia. Repparfjord would thus seem to be one of the oldest examples of this type of deposition. The greenstones from the Nussir Group in the Repparfjord-Komagfjord window, the Kvenvik Greenstone in the Alta-Kvænangen window, the Čas'kejas Formation in the Kautokeino Greenstone Belt and the Kiruna and Vittangi Groups in northern Sweden can be correlated (Pharaoh & Pearce 1984). The greenstones occur in sequences with shallow-marine sediments, tuffites and diabases. The brecciated character of the volcanite-hosted deposits and the association with shallow-marine sediments indicate that boiling of the ore-forming solutions played an important role in the sulphide precipitation. These volcano-sedimentary belts are characterised by an enrichment of uranium in association with the Cu-Au deposits and by the albite felsites. This must presumably reflect a high degree of involvment of continental crust in the ore-forming process. The Bidjovagge deposit has been correlated with the Viscaria Cu-deposit in Kiruna, the Kopperåsen Cu-U deposit near the Norwegian border in northern Sweden and the Pahtavuoma Cu-Zn-U deposit in Kittilä (Inkinen 1979). Most convincing is the correlation between Viscaria and Bidjovagge. The more stratiform appearance of the Viscaria deposit can be explained by a lower temperature of the ore-forming solutions or a somewhat greater water depth during the sulphide precipitation in the Kiruna area. The youngest sulphide occurrences in the Svecokarelian in Finnmark are those of the Raipas-type deposits. They show many similarities with Phanerozoic karst-related lead-zinc deposits (Bernard 1973), but the copper dominance of this province is also reflected in the metal composition of the Raipas-type.

The Caledonian nappe complexes in Finnmark lack the Lower Ordovician metavolcanites and later granitic intrusions found in the Norwegian Caledonides further south and are thus comparatively barren metallogenically. However, the Late Precambrian to Cambrian clastic sediments within the nappes were deposited along the Baltoscandian continental margin or in intercratonic basins, a situation which should have favoured the formation of lead-zinc deposits. At the present time the only known deposit of this type is that of Geitvann.

The occurrences of galena in the thin autochthonous Late Precambrian to Cambrian sediments are related to the main Cambrian trangression and the formation of orthoquartzites. The lead was derived either directly from the Precambrian basement due to weathering or by local leaching of arkoses (Bjørlykke & Sangster 1981, Bjørlykke & Thorpe 1982). An important argument for a local source of the lead is the non-radiogenic lead isotope composition of the galena in the Gurrogaissa area.

Several examples of large magmatic enrichment of Fe-Ti-oxides are known from the Seiland province but the grade reported from these deposits is too low to be of economic interest.

Acknowledgements

Thanks are due to colleagues in the Finnmark programme for valuable information, and especially to M. Often for discussions of the metallogeny of the Karasjok Greenstone Belt. The authors also thank G. Juve and F.M. Vokes for their comments and D. Roberts for improving the English text.

References

Anderson, C.A. & Creasey, S.C. 1958: Geology and ore deposits of the Jerome area. Yavapai Count, Arizona. *U.S. Geol. Survey. Prof Paper 308,* 185pp.

Bernard, A.J. 1973: Metallogenic processes of intra-karstic sedimentation. *In* Amstutz, G.C. & Bernard, A.J. (eds.): *Ores in sediments.* Berlin, Springer-Verlag, 43-57.

Berthelsen, A. 1980: Towards a palinspastic tectonic analysis of the Baltic Shield. *26e Cong.Gòeol.Int., Abs. 3,* Paris, 1405.

Bjørlykke, A. & Sangster, D.F. 1981: An overview of sandstone lead deposits and their relation to red-bed copper and carbonate-hosted lead-zinc deposits. *Econ. Geol., 75th Anniversary vol.* 179-213.

Bjørlykke, A & Thorpe, R.I. 1982: The source of lead in the Osen sandstone lead deposit on the Baltic Shield, Norway. *Econ. Geol. 77,* 430-440.

Bjørlykke, H. 1966: De alluviale gullforekomster i indre Finnmark. *Nor. geol. unders. 236,* 66pp.

Boyd, R. & Nixon, F. 1985: Norwegian nickel deposits: a review. *Geol. Surv. Finland Bull. 333,* 363-394.

Brown, A.C. 1981: The timing of mineralization in stratiform copper deposits. *In* Wolf, K.H. (ed.): *Handbook of strata-bound and strati form ore deposits. v. 9,* Elsevier, Amsterdam, 1-23.

Bugge, J.A.W. 1978: Norway. *In* Bowie, S.H.U., Kvalheim, A. & Haslam, H.W. (eds.), *Mineral deposits of Europe. Vol.1:North West Europe. Inst. Mining and Metall. and the Min. Soc. London,* 199-249.

Bugge, J.A.W. 1980: The Sydvaranger type of quartz banded iron ore, with a synopsis of Precambrian geology and ore deposits of Finnmark. *Geol. Surv. Finland, Bull. 307,* 15-24.

Carstens, C.W. 1931: Die Kiesvorkommen im Porsangergebiet. *Nor.geol. Tidsskr. 12,* 171-177.

Fabricius, J. 1979: Ulveryggen kobberforekomst, Finnmark, Norge. *Dansk geol. Foren., Årsskrift 1979,* 107-110.

Frietsch, R. 1982: A model for the formation of the non-apatitic iron ores, manganese ores and suphide ores of Central Sweden. *Sver.geol. unders. C 795,* 43 pp.

Gaál, 1982: Proterozoic tectonic evolution and late Svecokarelian plate deformation of the central Baltic Shield. *Geol. Rundsch., 71,* 158-170.

Gayer, R.A., Hayes, S.J. & Rice, A.H.N. 1985: The structural develop ment of the Kalak Nappe Complex of eastern and central Porsanger halvøya, Finnmark, Norway. *Nor.geol.unders. Bull. 400,* 67-87.

Geis, H.-P. 1971: A short desciption of the iron-titanium provinces in Norway with special reference to those in production. *Minerals Sci. Engng. 3,* 13-24.

Gjelsvik, T. 1958: Epigenetiske koppermineraliseringer på Finnmarks vidda. *Nor. geol. unders. 203,* 49-59.

Gorbunov, G.I., Yakovlev, Yu, N., Goncharov, Yu, V., Gorelov, V.A. & Tel'nov, V.A. 1985: The nickel areas of the Kola Peninsula. *In* Papunen, H. & Gorbunov, G.I. (eds.): *Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geol.Surv.Finland, Bull. 333,* 41-109.

Gross, G.A. 1983: Tectonic systems and the deposition of iron formation. *Precamb. Res. 20,* 171-187.

Haapala, I. 1977: Petrography and geochemistry of the Eurajoki stock, a rapakivi-granite complex with greisen-type mineralisation in southwestern Finland. *Geol. Surv. Finland, Bull. 286,* 128pp.

Hagen, R. 1982: The Bidjovagge copper-gold deposits of western Finn mark, Norway. *Geol. Rundschau 71,* 94-103.

Henriksen, H. 1983: Komatiitic chlorite-amphibole rocks and mafic metavolcanics from the Karasjok Greenstone Belt, Finnmark, Northern Norway: a preliminary report. *Nor.geol.unders. 382,* 17-43.

Hietanen, A. 1975: Generation of potassium-poor magmas in the northern Sierra Nevada and the Svecofennian of Finnland. *Jour. Res. U.S. Geol.Surv. 30, 6,* 631-645.

Hollander, N.B. 1979: The geology of the Bidjovagge mining field, western Finnmark, Norway. *Nor. geol. Tidsskr. 59,* 327-336.

Inkinen, O. 1979: Copper, zinc and uranium occurrences at Pahtavuoma in the Kittilä Greenstone Complex, Northern Finland. *Econ.Geol. 74,* 1153-1165.

Juve, G. 1968: Porsanger kobber- og kisforekomster, Finmark, Norge. *Geol. Før. Stockh. Førh., 90,* 461-462.

Juve, G. and Vokes, F.M. 1980: Copper ores in Scandinavia. *In* S. Jankovic (Ed.): *Proc. Int. Symposium The European Copper Deposits,* Bor.Yugoslavia, Sept. 1979, 147-159.

Krause, M. 1980: Some uranium mineralisations in the Raipas Suite of the Komagfjord tectonic window, Finnmark, Norway. *Nor. geol. unders. 355,* 49-52.

Krause, M. 1981: *Eine Schwermetallprospektion im alten Porsa Neverfjord Gruben Bezirk von Nord-Norwegen.* Unpubl. thesis Johannes Gutenberg-Universitat, 155pp.

Krill, A.G. 1985: Svecokarelian thrusting with thermal inversion in the Karasjok area of the of the Baltic Shield. *Nor. geol. unders. Bull. 403, (this volume).*

Krill, A.G., Bergh, S., Lindahl, I., Mearns, E., Often, M., Olerud, S., Olesen, O., Sandstad, J.S. & Siedlecka, A. 1985: Rb-Sr, U-Pb and Sm-Nd dates from the Precambrian rocks of Finnmark, Norway. *Nor. geol. unders.Bull. 403 (this volume).*

Laajoki, K. 1983: Outlines of the Precambrian exogenic geologi of Finland. *Res. Terrea, Ser. C, 3,* 46pp.

Likhachev, A.P. 1978: Genesis of copper-nickel ores in the Pechenga and Allarechensk areas. *Int. Geol. Rev. 18,* 663-674.

Lindahl, I. 1983: Classification of uranium mineralisations. *Nor. geol. unders. 380,* 125-142.

Mathiesen C.O. 1970a: A geological-geophysical map over the Bidjovagge area. 1:10,000. *Nor. geol. unders.*

Mathiesen, C.O. 1970b: An occurrence of unusual minerals at Bidjovagge, northern Norway. *Nor.geol.unders. 266,* 86-104.

Mäkelä, K. 1980: Geochemistry and origin of Haveri and Kiipu, Protero zoic strata-bound volcanogenic gold-copper and zinc mineralization from southwestern Finland. *Geol.Surv.Finland, Bull. 310,* 79 pp.

Mearns, E.W. & Krill, A.G. 1984: Sm-Nd age for komatiites from the the Karasjok greenstone belt, Northern Norway. *Abstr. Geolognytt 20,* 38.

Moberg, A. 1968: Kopparverket i Kåfjord - Ett bidrag til Nordkalottens historia. *Norrbottens museum.* 144pp.

Mørk, K. 1970: *En geologisk undersøkelse av området omkring Kåfjord Kobbergruve. Kåfjord i Alta, Finnmark.* Unpubl. Cand.real. thesis Univ. Oslo, 105pp.

Often, M. 1985: The Early Proterozoic Karasjok greenstone belt, Norway; a preliminary description of lithology, stratigraphy and mineralization. *Nor.geol.unders. Bull. 403 (this volume).*

Often, M., Olsen, L. & Hamborg, M. 1984: Gullet i Sargejåk, Karasjok; Hvor kommer det fra. *In* Often, M. (1984): Et informasjonsmøte om Finn marks geologi. *Unpubl. NGU report 84.095,* 37-42.

Olerud, S. 1985: Mikrosondeundersøkelse av radioaktiv albittfels fra Biggejavri, Kautokeino. *Unpubl. NGU report 85.159.*

Olesen, O. & Solli, A. 1985: Geophysical and geological interpretations of regional structures within the Precambrian Kautokeino Greenstone Belt, Finnmark, North Norway. *Nor.geol.unders.Bull. 403 (this volume).*

Padget, P. 1959: Leucodiabase and associated rocks in the Karelidic Zone of Fennoscandia. *Geol. Før. Forh. Stockholm 81,* 316-332.

Papunen, H. & Vorma, A. 1985: *Nickel deposits in Finland, a review. In* Papunen, H. & Gorbunov, G.I. (eds.): *Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides.* Geol.Surv.Finland Bull. 333, 123-143.

Park, A.F. 1983: Nature, affinities and significance of metavolcanic rocks in the Outokumpu assemblages, eastern Finland. *Bull.Geol.Soc. Finland 56, Part 1-2,* 25-52.

Pearce, J.A. & Gale, G.H. 1977: Identification of ore-deposition environment from trace-element geochemistry of associated igneous host rocks. *IMM spec. publ. no. 7,* 14-24.

Pharaoh, T.C. & Pearce, J.A. 1984: Geochemical evidence for the tec tonic setting of Early Proterozoic metavolcanic sequences in Lapland. *Precamb. Res. 25,* 283-308.

Pharaoh, T.C., Ramsay, D. & Jansen, Ø. 1983: Stratigraphy and struc ture of the northern part of the Repparfjord-Komagfjord window, Finnmark, northern Norway. *Nor. geol. unders. 377,* 45pp.

Raith, M., Raase, P. & Hóormann, P.K. 1982: The Precambrian of Finnish Lapland: evolution and regime of metamorphism. *Geol.Rundschau 71,* 230-244.

Reitan, P.H. 1963: The geology of the Komagfjord tectonic window of the Raipas Suite, Finnmark, Norway. *Nor. geol. unders. 221,* 71pp.

Roberts, D. 1974: Hammerfest. Beskrivelse til det 1:250 000 berggrunnsgeologiske kart. *Nor.geol.unders. 301,* 66 pp.

Robins, B. 1985: Disseminated Fe-Ti oxides in the Seiland magmatic province of North Norway. Nor. geol. unders. Bull. 402, (in press).

Røsholt, B. 1977: Case history of copper mineralization with naturally copper-poisened areas at Raitevarre, Karasjok, Finnmark County, Nor way. *IMM. Prospecting in glaciated terrain 1976,* 138-139.

Sandstad, J.S. 1983: Bergrunnsgeologisk kartlegging av prekambrisk grunnfjell innen kartbladet Målljus, Kvænangen/Kautokeino, Troms/Finnmark. *Unpubl. NGU report 1886/5,* 28pp.

Sandstad, J.S. & Olesen, O. 1984: Kobber- gullmineraliseringer med Riednjajavri, Kautokeino. *In* Often, M. (ed.): *Et informasjonsmøte om Finnmarks geologi. Unpubl. NGU-report 84.095,* 73-76.

Siedlecka, A., Iversen, E., Krill, A.G., Lieungh, B., Often, M., Sandstad, J.S. & Solli, A. 1985: Lithostratigraphy and correlation of the Archaean and Early Proterozoic rocks of Finnmarksvidda and Sørvaranger district. *Nor. geol. unders.Bull. 403 (this volume).*

Solli, A. 1983: Precambrian stratigraphy in the Masi area, south western Finnmark, Norway. *Nor. geol. unders. 380,* 97-105.

Stache, G-A. 1970: *Die Geologie Des Kupferbezirkes Kaafjord in des unteren Raipas-Formation von Nord-Norwegen.* Unpubl. thesis Univ. Clausthal-Zellerfeld, 108pp.

Stribrny, B. 1979: *Zur Geologie und Lagerstättenbildung des Kupfer vorkommens der Grube Repparfjord, Ulverygen am Repparfjord, Finnmark, Norwegen.* Unpul.thesis, J.W. Goethe-Univ. Frankfurt am Main, 183 pp.

Torske, T. 1978: En proterozoisk aulakogen i Nord-Norges grunnfjell. *Abstr. XIII Nord. Geol. Vintermøte,* Copenhagen, 72-73.

Vik, E. 1979 Geologiske undersøkelser av Raipas kobbergruver, Alta, Finnmark. *Unpubl. NGU report 1625/10a,* 20pp.

Vik, E. 1980: Middavarre kobberforekomst, Kvænangen, Troms. *Unpubl. NGU-report 1650/46a,* 30pp.

Vik, E. 1981: Bergmark gruvefelt, Kvænangen, Troms. Foreløpig rapport fra geologiske og geofysiske undersøkelser 1979-1980. *Unpubl. NGU report 1800/46C,* 50pp.

Vik, E. 1983: Cedars gruve - en "Bidjovagge- type" mineralisering i Kvænangen, Troms. *In "Malm 82" Malmgeologisk symposium 24-26 oct. 1982,* 38-50.

Vokes, F.M. 1955: Observations at the Raipas mine, Alta, Finnmark. *Nor. geol. unders. 191,* 103-114.

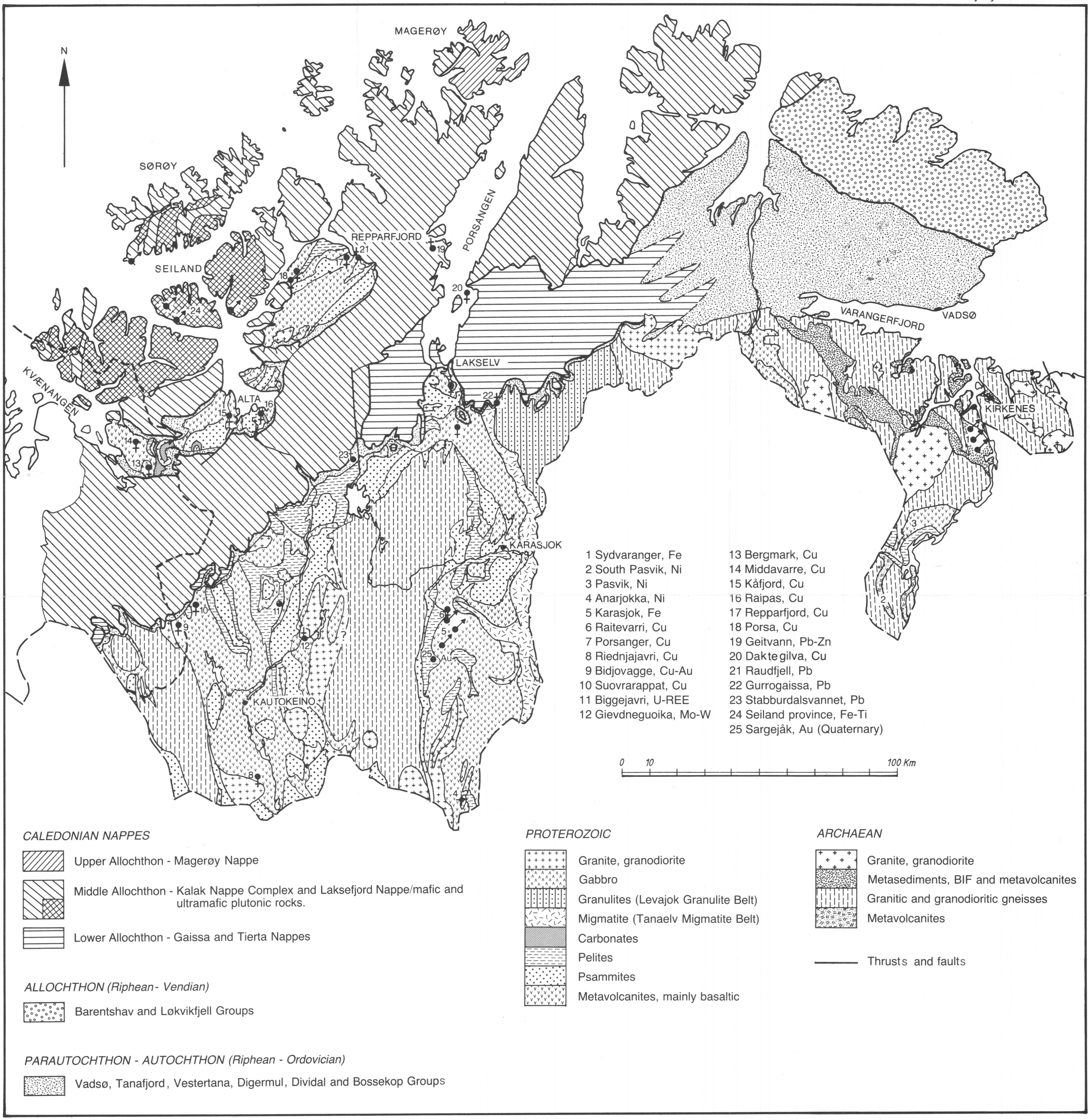
Vokes, F.M. 1957: Some copper sulphide parageneses from the Raipas formation of Northern Norway. *Nor. geol. unders. 200,* 74-113.

Vokes, F.M. & Strand, G.S. 1982: Atoll texture in minerals of cobaltite-gersdorfite series from the Raipas mine, Finnmark, Norway. *In* Amstutz, G.D. et al. (eds.): *Ore genesis - The state of art.* Springer-Verlag, 118-130.

Wennervirta, H. 1969: Karasjokområdets geologi. *Nor. geol. unders. 258,* 131-184.

Witschard, F. 1980: Stratigraphy and geotectonic evolution of the northern Norrbotten. *Abstr. Geol. Før. Stockh. Førh. 102,* 188-190.

Zwaan, K.B. & Gautier, A.M. 1980: Alta and Gargia. Description of the geological maps (AMS-M711) 1834 I and 1934 IV - 1:50 000. *Nor. geol. unders. 357,* 1-47.


N
MAGERØY
SØRØY
SEILAND
KVÆNANGEN
ALTA
REPPARFJORD
PORSANGEN
LAKSELV
VARANGERFJORD
VADSØ
KIRKENES
KARASJOK
KAUTOKEINO
1 Sydvaranger, Fe
2 South Pasvik, Ni
3 Pasvik, Ni
4 Anarjokka, Ni
5 Karasjok, Fe
6 Raitevarri, Cu
7 Porsanger, Cu
8 Riednjajavri, Cu
9 Bidjovagge, Cu-Au
10 Suovrarappat, Cu
11 Biggejavri, U-REE
12 Gievdneguoika, Mo-W
13 Bergmark, Cu
14 Middavarre, Cu
15 Kåfjord, Cu
16 Raipas, Cu
17 Repparfjord, Cu
18 Porsa, Cu
19 Geitvann, Pb-Zn
20 Daktegilva, Cu
21 Raudfjell, Pb
22 Gurrogaissa, Pb
23 Stabburdalsvannet, Pb
24 Seiland province, Fe-Ti
25 Sargejåk, Au (Quaternary)
0 10 100 Km
CALEDONIAN NAPPES
Upper Allochthon - Magerøy Nappe
Middle Allochthon - Kalak Nappe Complex and Laksefjord Nappe/mafic and ultramafic plutonic rocks.
Lower Allochthon - Gaissa and Tierta Nappes
ALLOCHTHON (Riphean - Vendian)
Barentshav and Løkvikfjell Groups
PARAUTOCHTHON - AUTOCHTHON (Riphean - Ordovician)
Vadsø, Tanafjord, Vestertana, Digermul, Dividal and Bossekop Groups
PROTEROZOIC
Granite, granodiorite
Gabbro
Granulites (Levajok Granulite Belt)
Migmatite (Tanaelv Migmatite Belt)
Carbonates
Pelites
Psammites
Metavolcanites, mainly basaltic
ARCHAEAN
Granite, granodiorite
Metasediments, BIF and metavolcanites
Granitic and granodioritic gneisses
Metavolcanites
Thrusts and faults