The Early Proterozoic Karasjok Greenstone Belt, Norway; a Preliminary description of Lithology, Stratigraphy and Mineralization

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The Karasjok Greenstone Belt of Finnmark, Norway, is a sequence of medium-grade metamorphic supracrustal rocks in the northernmost part of the Baltic Shield. Regional mapping has revealed a tectonostratigraphy with the greenstone belt resting on Archaean sialic basement, dipping away under the Tanaelv Migmatite Complex with the Levajok Granulite Complex on top. Major thrust zones separate the lowermost part of the greenstone belt, the clastic Skuvvanvarri Formation, from the mixed volcanic-sedimentary Iddjajav'ri Group. High grade thrust zones also separate the migmatite and granulite complexes from the greenstone belt. Pyroclastic komatiites constitute an important part of the Iddjajav'ri Group, suggesting volcanism in a shallow-water environment.

A plate-tectonic concept is applied to describe the evolution of the greenstone belt which is probably of Early to Middle Proterozoic age.

Mineralizations within the Karasjok Greenstone Belt are classified and briefly described. The two most important types are manganiferous banded iron-formations of Algoma type and large low-grade disseminated copper-gold mineralizations of uncertain origin.

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Introduction

The Karasjok Greenstone Belt is one of several prominent linear to arcuate structures in the northwestern part of the Precambrian Baltic Shield. It is situated in Finnmark, North Norway and underlies the eastern part of the generally flat plateau called Finnmarksvidda.

A major research project run by the Geological Survey of Norway (NGU), the Finnmark Programme, has now been going on for 4 years and much data has been obtained by extensive field mapping and by means of effective and powerful tools like helicopter-borne geophysical surveys covering large parts of the area. The use of helicopters in transport of geologists in the field has greatly improved the effectiveness of mapping in this area where outcrop is very scarce and very few roads exist. The potential for discovery of economic ore deposits, gold in particular, has triggered the interest of mining and prospecting companies in the Karasjok area. The Finnmark Programme is producing 8 maps in 1:50 000 scale covering the length of the Karasjok Greenstone Belt, partly in cooperation with A/S Prospektering. The present overview is based on this work.

It is the author's intention to discuss the Karasjok Greenstone Belt and its mineralizations on the basis of this new material and previous work from the greenstone belt and from adjacent and correlative rocks in Finland. The description relies heavily on fieldwork and to a lesser extent on laboratory work, since this is still in progress. The heavy till-cover of this part of the Baltic Shield also imposes severe problems on the compilation of maps and thus on the process of modelling the geological evolution of the Karasjok Greenstone Belt. This must be kept in mind when evaluating the proposed models.

Regional setting and main tectonostratigraphic units

The N-S trending Karasjok Greenstone Belt (Fig. 1) is 160 km long and up to 40 km wide. To the north the belt is overlain by autochthonous Vendian to Cambrian sediments of the Dividal Group and by the Caledonian nappes. The southern continuation into Finland, called the Kittilä Greenstone Complex by several workers

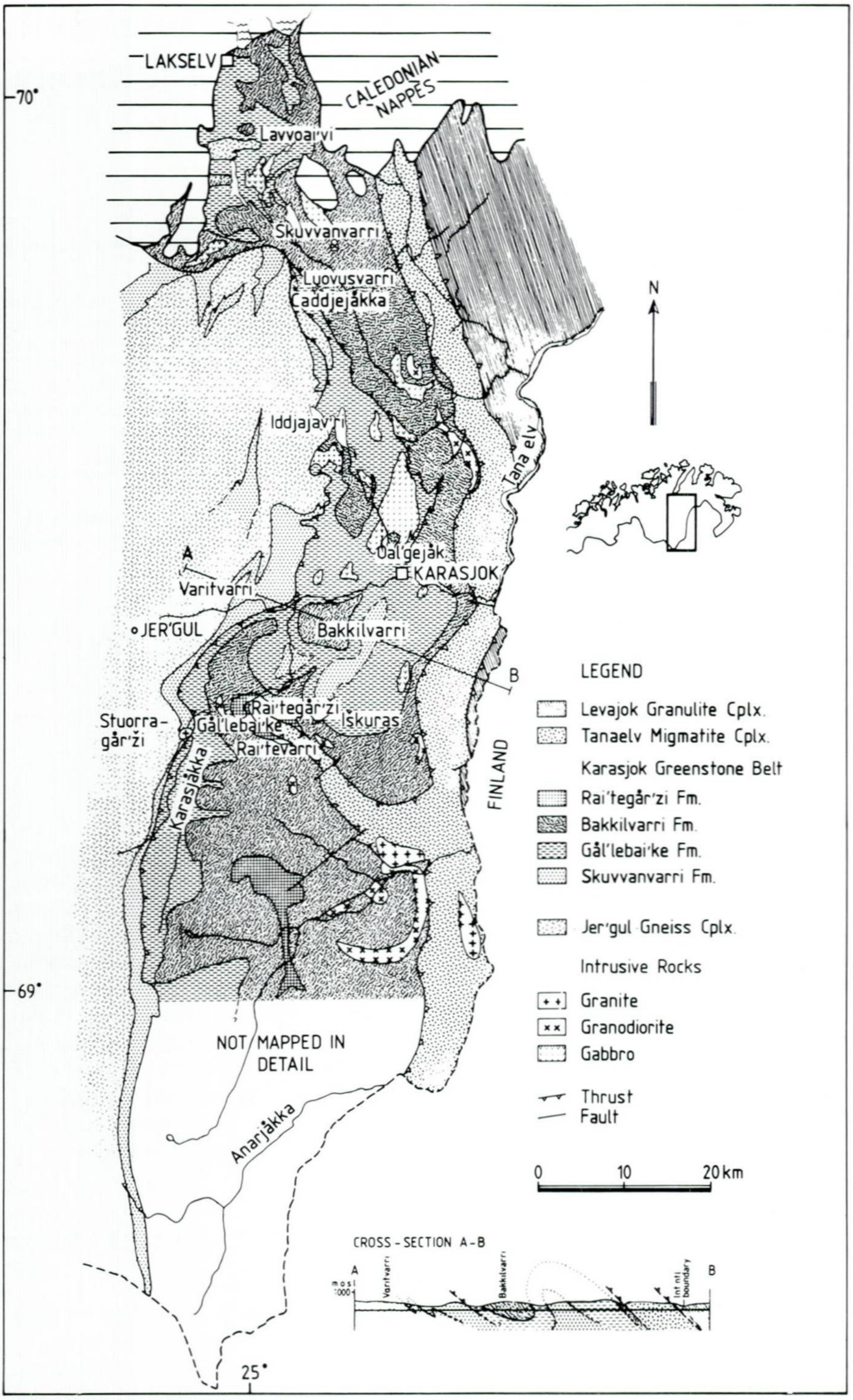

Fig. 1: Stratigraphic map of the Karasjok Greenstone Belt. Stratigraphic interpretation is based on published and unpublished work by D.F. Crowder, G. Elvebakk, H. Henriksen, S. Johnsen, A.G. Krill, K. Nilsen, L.P. Nilsson, M. Often, T. Pharaoh, A. Siedlecka and D. v.d. Wel.

(Rastas 1980, Silvennoinen et al. 1980) and Kittilä Greenstone Belt by Gaál et al. (1978), extends another 150 km towards south-southeast giving a total length of c. 300 km. Possible further continuations of this supracrustal sequence, towards the southeast in Finland and the Soviet Union and towards the west into Sweden, are currently under discussion. To the west the belt is unconformably overlying and partly thrust over the predominantly Archaean Jer'gul Gneiss Complex. To the east it is bounded by the overthrust Tanaelv Migmatite Complex which is in turn overthrust by the Levajok Granulite Complex (in Finland: Lapland Granulite Complex) described by Eskola (1952), Meriläinen (1976), Hörmann et al. (1980) and Krill (1985, this volume).

A brief description, formalization of unit names and an attempt at correlation within the Precambrian of Finnmark has been given by Siedlecka et al. (1985, this volume). Table 1 summarizes the tectonostratigraphy of the Karasjok area.

The Karasjok Greenstone Belt is asymmetric in the sense that it overlies the Jer'gul Gneiss Complex and dips away to the east beneath the Tanaelv Migmatite Complex, with gradually higher stratigraphic levels towards the east. Until recently the Tanaelv Migmatite Complex was not recognised as a separate unit, but was included as part of the Karasjok Greenstone Belt. It is now regarded by several workers as a separate tectonic unit (Meriläinen 1976, Hörmann et al. 1980, Barbey et al. 1980, Henriksen 1983, Krill 1985, this volume).

All the rocks in the area were metamorphosed and highly deformed during the Svecokarelian orogenic event, but the age of deposition or effusion has been debated strongly. The traditional concept of a Svecokarelian age of the Karasjok Greenstone Belt was challenged by Gaál et al. (1978) who suggested an Archaean age, and this has also been favoured by Finnish geologists for the Kittilä Greenstone Belt (Silvennoinen et al. 1980). Isotopic work by Kröner et al. (1981) also supported an Archaean age for the Kittilä Greenstone Belt. Recent work, however, by Krill et al. (1985, this volume) and Krill (1985, this volume) concludes that the Karasjok Greenstone Belt, Tanaelv Migmatite Complex and the Levajok Granulite Complex are probably all of Early Proterozoic age and that they were deposited and deformed in the same orogenic cycle, between about 2200 and 1700 Ma.

Jer'gul Gneiss Complex

The Jer'gul Gneiss Complex is the lowermost unit in the area and provides the basement for the Karasjok Greenstone Belt. It consists of tonalitic to granitic orthogneisses, and isotopic dating has suggested Archaean ages for the oldest rocks (Krill et al. 1985, this volume). Gravimetric measurements indicate a light sialic basement in the Iškuras overfolded dome structure (Fig. 1), a minimum of 30 km from the western margin of the Karasjok Greenstone Belt, suggesting that the Jer'gul Gneiss Complex extends beneath at least part of the greenstone belt. K. Nilsen (pers. comm. 1984) reports outcrops of possible basement gneisses in the Iškuras area. Svecokarelian intrusions dominate in the western and southern part of the complex, in Finland known as the Hätta Granite. Locally a primary angular unconformity is found marking the boundary with the Karasjok Greenstone Belt. Siedlecka (1985, this volume) describes the well preserved Čaddjejåkka unconformity. Krill et al. (1985, this volume) dated rocks below the unconformity to an age of 2110 ± 105 Ma (Rb-Sr), defining a maximum age for the overlying supracrustals.

Karasjok Greenstone Belt

Wennervirta (1969) gave a good description of the central part of the Karasjok Greenstone Belt and adjacent rocks and this is still the most comprehensive work on the Karasjok area. Crowder (1959) described the well exposed northernmost part of the belt and work by Pharaoh (1981, 1984a,b) added to the knowledge of this area. Skålvoll (1972) summarized the geology and compiled a map at the scale of 1:250 000 covering the main part of the greenstone belt and adjacent rocks. Henriksen (1983) focused on the mafic and ultramafic volcanic rocks of the central part of the belt.

The subdivision shown in Table 1 and in Fig. 2 separates the clastic *Skuvvanvarri Formation* from the volcanic-sedimentary *Vuomegielas Formation* and *Iddjajav'ri Group*. The Iddjajav'ri Group is subdivided into three formations; the *Gål'lebai'ke* mixed volcanic-sedimentary formation overlain by the *Bakkilvarri* mafic to ultramafic volcanic assemblage and the uppermost *Rai'tegår'ži* mixed volcanic-sedimentary unit.

The Vuomegielas Formation is described by Siedlecka (1985, this volume) and is found only in

RADIOMETRIC AGE	TECTONOSTRATIGRAPHIC UNIT			METAMORPHIC LITHOLOGY	INTERPRETATION
	LEVAJOK GRANULITE COMPLEX			Quartz-feldspar-garnet-gneiss, hypersthene-plagioclase-gneiss.	Greywacke-shale of a continental margin flysch deposit with syn-orogenic mafic intrusions and minor volcanites related to an inner arc.
	TANAELV MIGMATITE COMPLEX			Hornblende-plagioclase-gneiss; amphibolite; intruded by granite.	Island arc volcanites; basalts, dacites, andesites.
	KARASJOK GREENSTONE BELT	IDDJAJAV'RI GROUP	RAI'TEGÅR'ŽI FM.	Amphibolites; mica schists; partly migmatized towards overlying complex.	Mafic volcanites; aluminous terrigenous sediments.
2085 ± 85 Ma (Sm-Nd, komatiite)	KARASJOK GREENSTONE BELT	IDDJAJAV'RI GROUP	BAKKILVARRI FM.	Monotonous sequence of amphibolites, massive and banded; Chlorite-amphibole rocks commonly with fragmental textures. Minor metasediments; BIF; sulphidic horizons.	Tholeiitic volcanites, lavas and tuffs. Unknown amount of dykes. Komatiites, pyroclastics and lava deposited in shallow-water environment. Fe-Mn and S-bearing exhalites.
	KARASJOK GREENSTONE BELT	IDDJAJAV'RI GROUP	GÅL'LEBAI'KE FM.	Thin-bedded albitic metasandstones; quartz-mica schists; amphibolites/greenstone; chlorite-amphibole rocks, garnet-amphibole-gneiss; thin massive sulphide horizons; BIF; minor graphitic schists.	Shallow-marine feldspathic sandstones, Na-enrichment of uncertain origin. Mafic to felsic volcanites, lavas and tuffs deposited in shallow-water to subaerial environment; Pyroclastic komatiites; Fe-Mn and S-bearing exhalites.
	KARASJOK GREENSTONE BELT	SKUVVANVARRI FM.		Quartzite, partly feldspathic; minor quartz-mica schists; fuchsite-bearing conglomerates.	Mature quartz sandstone and alluvial fan conglomerates.
	KARASJOK GREENSTONE BELT	VOUMEGIELAS FM.		Amphibolites, hornblende schists, minor biotite schists, chlorite-amphibole rocks.	Mafic and ultramafic volcanites with minor metasediments.
2110 ± 105 Ma (Rb-Sr, Young intrusion)	JER'GUL GNEISS COMPLEX			Composite gneiss, migmatites and younger granodioritic/granitic intrusions; minor basic gneiss.	Mainly granitic to tonalitic intrusions with some metasediments.

Table 1: Tectonostratigraphic succession of the Karasjok area. Radiometric ages after Krill et al. (this volume).

in two minor areas, the type area to the north of the lake Iešjav'ri (which is to the west of the area shown in Fig. 1) and immediately to the west of Skuvvanvarri (Fig. 1, the area is too small to be shown on map). The formation consists of foliated amphibolites interpreted to represent mafic volcanites and minor metasediments interbedded with clastics of the overlying Skuvvanvarri Formation, suggesting a primary transitional relationship. The lower boundary is unknown. In the Skuvvanvarri area the amphibolites are Mg-rich with a komatiitic geochemical affinity.

The Skuvvanvarri Formation, described by Siedlecka (1985, this volume), is a sequence of terrigenous clastic rocks deposited on the Jer'gul Gneiss Complex. Mature quartzites and matrix-supported conglomerates are the principal rock types. Bright green fuchsite-bearing quartzite is a minor, but characteristic rock type and the conglomerates are commonly fuchsite-bearing. This occurrence of chromium-bearing mica has been taken as an indicator of the relative age of the Skuvvanvarri Formation vs. The Iddjajav'ri Group, pointing towards the chromium-rich komatiitic volcanites of the latter group as the chromium source for the fuchsite in the former. If so, the overlying Iddjajav'ri Group should be older than the Skuvvanvarri Formation and correlated with the Vuomegielas Formation. However, chromium-rich volcanites of komatiitic geochemical affinity also occur unconformably below the Skuvvanvarri Formation within the Voumegielas Formation (Siedlecka 1985, this volume) and could thus be the source for the chromium.

A primary depositional contact against the Jer'gul Gneiss Complex has been observed in only one area, apart from the Čadjejåkka locality. On the eastern slope of Varitvarri (Fig. 1, Map 2033 IV, UTM 199 049) slightly foliated, but fresh looking granite of the Jer'gul Gneiss Complex is overlain by mica schist with an upward increasing content of fragments, mainly composed of quartz, but also some of granite and gneiss, up to fist size. This matrix-supported conglomerate is about 20 m thick and grades over a few dm into pink to light grey quartzites, the thickness of which is uncertain owing to tectonic repetitions.

An undisturbed contact against the overlying Gål'lebai'ke Formation has not been observed.

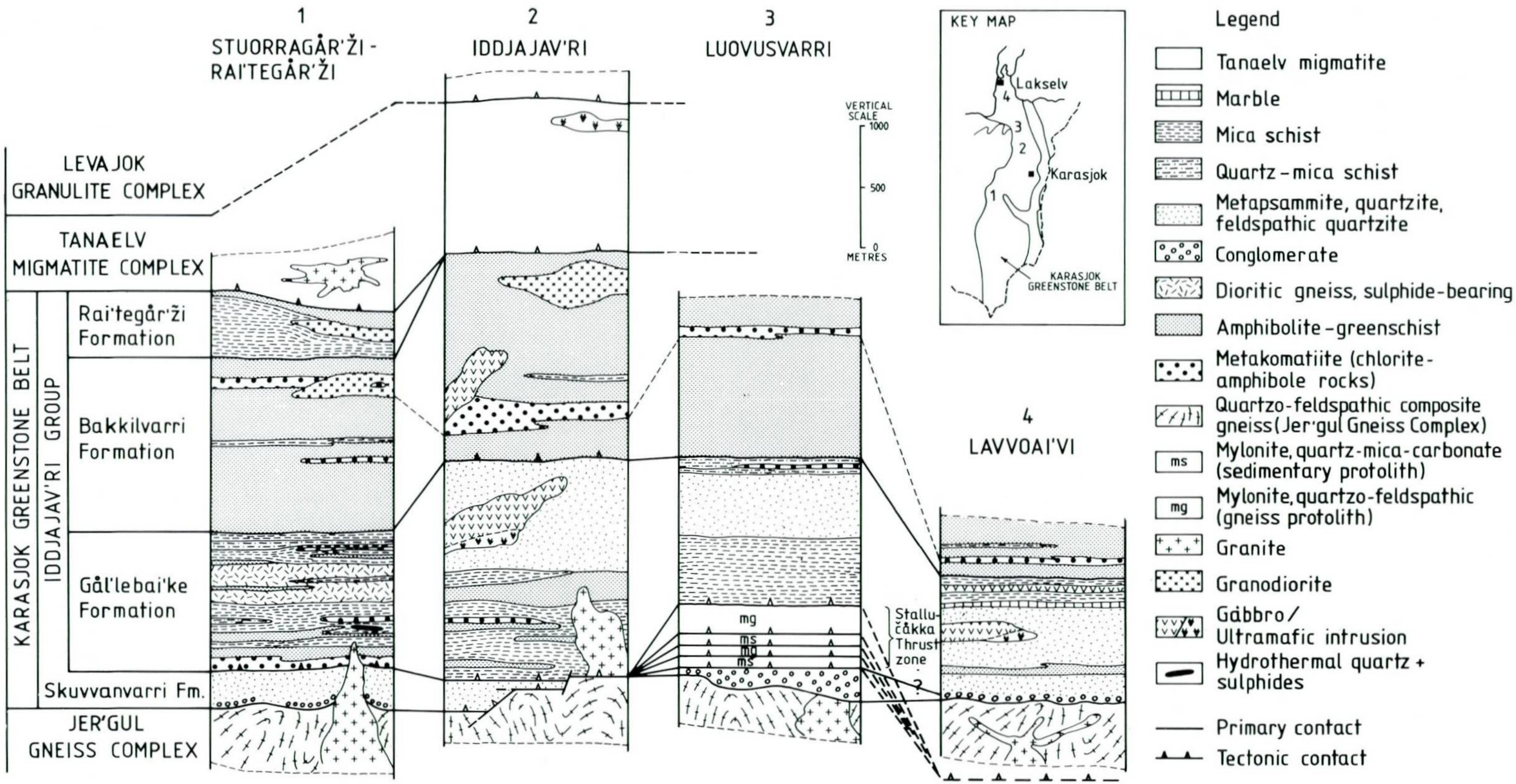

Fig. 2: Schematic stratigraphic relationships in representative domains in the Karasjok Greenstone Belt. Stratigraphic thicknesses are approximate and very uncertain due to isoclinal folding and local thrusting. (1) River profile along Karasjåkka, UTM 140900 to 230900. (2) Composite section from Iddjajav'ri to Valljåkka, UTM 310230 to 540300 (modified after Henriksen, 1984). (3) Across the top of Luovusvarri, c. UTM 280400 to 320440 (modified after Pharaoh 1984b). (4) Southern slope of Lavvoai'vi, c. UTM 240615 to 240635 (modified after Pharaoh 1984a).

In the northern part of the greenstone belt, a major mylonite zone, the Stallučåkka Thrust (Pharaoh 1984 b, Siedlecka 1985, this volume), separates the two formations and is thought to continue towards the south. In the Iddjajav'ri (Fig. 1) area the Skuvvanvarri Formation is completely obliterated by the Stallučåkka Thrust and late intrusions.

The Gål'lebai'ke Formation, the lowermost unit of the Iddjajav'ri Group, is characterized by a variation of volcanic and sedimentary layers, with rapid lateral facies changes (Fig. 2).

The type-section at Gål'lebai'ke (see Fig. 2, section 1) starts with strongly foliated amphibolites and chlorite-amphibole rocks with several horizons of sulphide-bearing quartzite, locally massive sulphide, and only minor metasediments. This sequence is interpreted as a pile of mafic to ultramafic volcanic rocks (komatiites) with volcanic exhalative chert horizons. The central part of the formation in the type section is dominated by mica schists.

Sulphide-bearing gneiss of dioritic to quartzdioritic composition, locally with chalcopyrite, is an important member in the central to upper part of the formation because of the Cu-Au potential of the Rai'tevarri mineralization (Røsholt 1977, Bugge 1978). The origin of this rock is uncertain, but the slightly banded appearance with varying amount of amphibole and the occurrence of metasedimentary layers, e.g. carbonate horizons is indicative of a supracrustal origin. The rock is seemingly stratabound, being traceable for at least 10 km, and this suggests a volcanic origin, possibly a combination of volcaniclastics and lava. H. Henriksen (pers. comm. 1984, internal A/S Sydvaranger report) reported possible igneous textures and suggested an intrusive origin for the dioritic gneiss concluding that the seemingly stratabound and banded nature resulted from strong flattening deformation, alteration and isoclinal folding.

The upper part of the formation consists mainly of psammitic metasediments with only minor volcanites. The psammites of the Gål'lebai'ke Formation are mostly feldspathic with albite as a major mineral. A high Na_2O/K_2O ratio is characteristic of the psammites of the Gål'lebai'ke Formation even though exceptions are found. Elvebakk et al. (1985, this volume) describes a remarkably well preserved locality at Oal'gejåkka where the psammites have an exceptionally high albite content of up to 70 % and a sodium content up to 8 %. The sedimentary structures define a near-shore to tidal marine environment for the sand deposits. The high Na-content is puzzling but a volcaniclastic origin will account for the high feldspar content and diagenetic Na-metasomatism is a possible explanation for the high albite content (Surdam & Boles 1979). Other models are possible.

The Gål'lebai'ke Formation shows a marked facies change from mafic volcanites and greywackes in the south to psammites and minor mafic volcanites in the north as shown in Fig. 2.

Primary textures are normally obliterated, but a few exceptions exist. An intertidal environment is demonstrated by sedimentary structures preserved in the Oal'gejåkka locality (Elvebakk et al. 1985, this volume). Amygdules in mafic volcanic rocks and volcaniclastic textures in ultramafic volcanites give additional indications of shallow-water to subaerial conditions.

A very limited number of way-up determinations indicate that the formation is in an upright position, but recumbent folding has inverted the strata locally. The control on total thickness is thus poor, but the impression from the best profiles indicate a total thickness of 1000 - 1500 m, being remarkably consistent throughout the length of the belt.

The upper boundary is transitional into the volcanic Bakkilvarri Formation, but is commonly found to be disturbed by local thrusting. In the Lakselv area the predominantly psammitic Gål'lebai'ke Formation terminates with a marble and mica schist unit that constitutes an excellent marker horizon (Crowder 1959, Pharaoh 1981, 1984 a).

The Iškuras dome structure (Fig. 1) represents an upfolding of the Gål'lebai'ke Formation and underlying strata, exposing mainly feldspathic psammites and minor mafic volcanites. It is probable that also the underlying Skuvvanvarri Formation and the Jer'gul Gneiss Complex is exposed, but the extent is uncertain.

The Bakkilvarri Formation is a monotonous sequence of mafic volcanic rocks with an ultramafic volcanic unit (komatiite) in the central to upper part. Sediments constitute only minor parts of the formation (Fig. 2).

The principal rock types are foliated to schistose amphibolites, mostly garnet-bearing, sometimes banded with felsic or graphitic material, and sometimes massive with grain size from fine to coarse. These rocks are interpreted as tholeiitic basaltic lavas, tuffs and tuffites with an unknown amount of dykes and sills. Primary structures are very scarce, but Henriksen (1983) reported pillows in a few localities.

Apple green chlorite-amphibole rocks in the Karasjok Greenstone Belt have earlier been denoted as chloritization zones within the amphibolites (Crowder 1959), but it is now clear that they constitute an important group of rocks with komatiitic affinity that both petrologically and genetically must be distinguished from the amphibolites (Henriksen 1983). They consist mainly of magnesian chlorite and actinolite, an entirely metamorphic assemblage. The geochemistry and extrusive character of these rocks are diagnostic of komatiites as proposed by Arndt & Nisbet (1982). The composition is in the range 35-46 % SiO_2, 18-37 % MgO, 3-8 % Al_2O_3 and 1-12 % CaO. Primary structures are surprisingly common (Figs. 3-6), showing a dominance of pyroclastics with grain size from fine tuff to breccia/conglomerate (Fisher & Schmincke 1984). Vesicular blocks are quite common. Coarse pyroclastics and probable agglomerates are found showing proximity to the vent (Figs. 5 and 6). Beautifully preserved pillows in some localities give evidence of a subaqueous environment (Fig. 3), whereas vesicles in the same pillows (Fig. 4) and the abundance of pyroclastic material indicate relatively shallow water (Often 1984). Undoubted spinifex-textures have not been reported, but Henriksen (1983) describes microscopic textures that might represent microspinifex. Massive flows are uncommon. Wennervirta (1969) recognised the effusive character of these ultramafic volcanic rocks, but used the term agglomerate in a broad sense for all coarse volcanic breccias/conglomerates. Chlorite-amphibole rocks of very similar chemistry and textures have been described from Finnish Lapland by several workers, e.g. Saverikko (1983), Kröner (1981) and Mikkola (1941). Volcaniclastic ultramafic rocks are very rare and few descriptions exist from other parts of the world. Where known, such rocks constitute only minor parts of the ultramafic volcanic pile (Gélinas et al. 1977, Nisbet et al. 1977, Nisbet & Chinner 1981). Following the geochemical classification of Viljoen et al. (1982), the chlorite-amphibole rocks of the Karasjok area can be characterized as of the Geluk-type komatiites.

Terrigenous sedimentation was very limited during accumulation of the Bakkilvarri Formation, but some greywacke-type metasediments occur. Manganese-bearing banded iron-formations of Algoma type (Gross 1983) are associated with the komatiites. Sulphidic chemical precipitates are found as lateral extensions of the iron-formations and as layers within the pile of mafic volcanites.

A good Sm-Nd whole-rock errorchron has been obtained from the komatiites (Krill et al. 1985, this volume) giving an Early Proterozoic age, 2085 ± 85 Ma.

The upper boundary is clearly defined only in a few well exposed profiles, e.g. Storfossen - Rai'tegår'ži (Fig. 1 and 2) where the overlying Rai'tegår'ži Formation starts with a several hundred metres thick aluminous mica schist. In other areas the boundary is marked only by a gradational higher influx of terrigenous sediments.

The Rai'tegår'ži Formation conformably overlies the Bakkilvarri Formation and consists of mixed terrigenous metasediments and mafic volcanic rocks, i.e. mica schists and amphibolites. The volcanites are indistinguishable from those of the Bakkilvarri Formation. It is the marked influx of sediments that necessitates the distinction towards the Bakkilvarri Formation. Due to the limited exposure, however, these formations are not separately mappable in most parts of the Karasjok Greenstone Belt.

This tectonostratigraphically uppermost part of the Karasjok Greenstone Belt is strongly deformed and metamorphosed in upper amphibolite facies, and partly migmatised towards the Tanaelv Migmatite Complex. No primary textures have been recognised so there is no control on possible overfolding within this unit. It is, however, probable that recumbent folding has repeated the sequence which in places shows an apparent thickness of several kilometres.

The upper boundary is thought to be tectonic. Field evidence is not unambiguous, but airborne geophysical mapping indicates a slight angular discordance between the Iddjajav'ri Group and the Tanaelv Migmatite Complex.

Tanaelv Migmatite Complex

This narrow belt of high-grade metamorphic gneisses overlies the Karasjok Greenstone Belt to the east. The composition of the belt varies from amphibolites to hornblende gneisses and more felsic varieties. In the central and southern part (in Norway) magnetite-bearing granite occurs as veins and larger masses and migmatization is common. Detrital rocks are uncom-

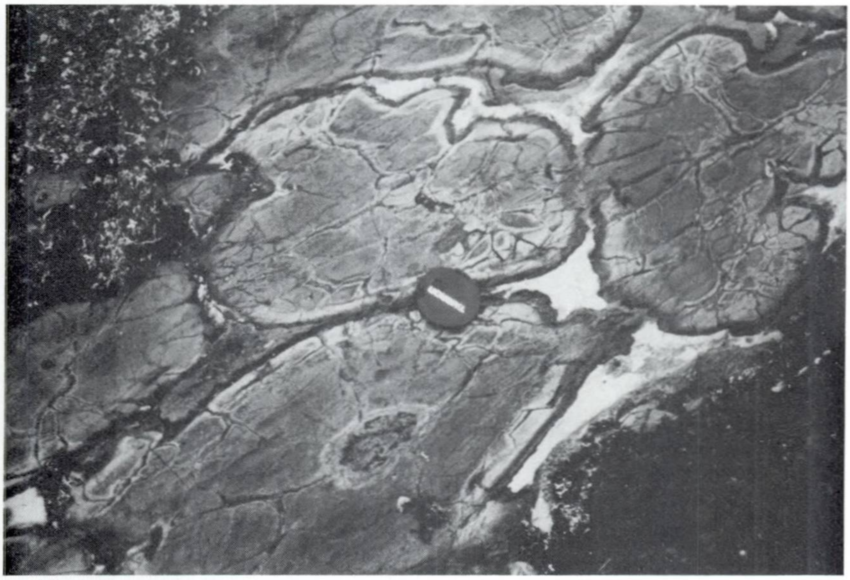

Fig. 3: Pillowed metakomatiite (chlorite-actinolite rock). Note radial cracking and light-coloured rims along the cracks and outer pillow margins indicating either finer grain size or alteration. The structure in the centre of the lowermost pillow probably represents later infilling of a drainage tube. This feature is common. (UTM 3810 3385, map-sheet 2034 II).

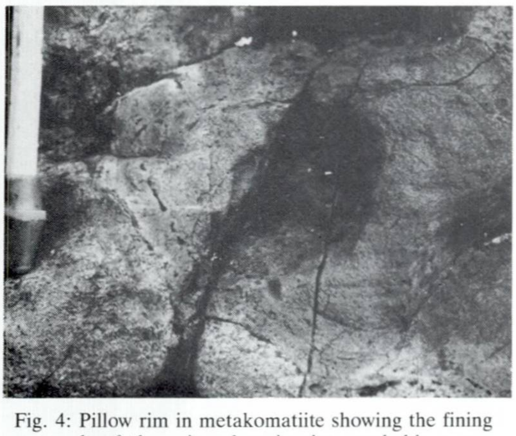

Fig. 4: Pillow rim in metakomatiite showing the fining outwards of the mineral grain size, probably representing relict chilling. Note concentric vesicles. See pencil for scale. (UTM 2995 0180, map-sheet 2033 IV).

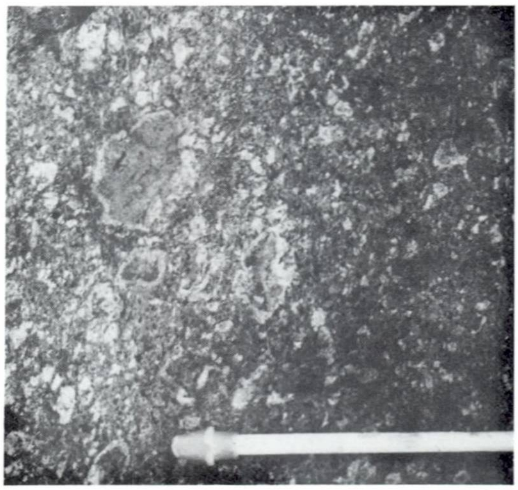

Fig. 5: Pyroclastic metakomatiite breccia showing lapilli size irregular fragments with light-coloured rims representing chilled margins or alteration. Matrix consists of coarse tuff to lapilli size fragments often rounded (UTM 3015 0200, map-sheet 2033 IV).

mon. Descriptions of the Tanaelv Migmatite Complex have been given by Meriläinen (1976), Hörmann et al. (1980) (West Inari Schist Zone) and Barbey et al. (1980) (Tana River Belt), based mainly on work from the extension of the belt into Finland, and by Krill (1985, this volume) from work in Norway. Krill summarizes the work from the area and, partly on geochemical evidence, interprets the Tanaelv Migmatite Complex as a magmatic arc sequence of Early Proterozoic age.

Levajok Granulite Complex

The well exposed Norwegian part of the 50 km-wide granulite complex is described by Krill (1985, this volume) and the entire Lapland Granulite Belt is discussed by him in the context of work from Finland (Eskola 1952, Meriläinen 1976, Hörmann et al. 1980, Raith et al. 1982, Bernard-Griffiths 1984).

The granulites were probably produced from monotonous Al-rich metasediments and synorogenic calc-alkaline intrusions with minor possible volcanites. Recent isotopic datings (Bernard-Griffiths 1984) indicate an age of 2060

Fig. 6: Metakomatiite showing conglomeratic texture with well rounded fragments of different colour and texture. The chemical composition, however, is similar both in the fragments and in the matrix. The rounding process is not known (UTM 1520 7980, map-sheet 2033 III).

± 200 Ma (Sm-Nd) and emplacement of the synorogenic intrusions at 2000 - 1800 Ma, during the granulite-facies metamorphism.

The Levajok Granulite Complex has been thrust towards the west over the Tanaelv Migmatite Complex and the eastern margin is in turn overthrust by the Baisvarri Gneiss Complex (Krill 1985, this volume). The contacts on both sides are formed under high-grade metamorphic conditions.

Intrusive rocks

Most of the radiometric datings that have been carried out within the Karasjok Greenstone Belt are related to the intrusive rocks, and they play a major role in the outlining of the belt's history.

A mafic dyke swarm with a preferred NNE-SSW trend cuts the Jer'gul Gneiss Complex near the western margin of the Karasjok Greenstone Belt. K-contaminated dykes of komatiitic composition and the same orientation are also observed. The dykes are thought to represent feeders for the magmatic activity during the tensional phase recorded in the Gål'lebai'ke Formation. Similar dykes are seen cutting the Skuvvanvarri Formation. Only a few mafic dykes are recognised in the Iddjajav'ri Group, but the extent of their existence is difficult to assess due to the pervasive obliteration of primary features in the amphibolites.

A number of larger mafic bodies, gabbros and associated minor ultramafic rocks, intrude the greenstone belt and some are also found in the Jer'gul Gneiss Complex. They normally have metamorphic textures and mineral assemblages, are strongly deformed towards the margins, and sometimes show well preserved primary mineralogy and textures in the central parts.

Relict primary structures observed in the supracrustals of the Iddjajav'ri Group appear to be spatially associated with gabbro intrusions, suggesting that such structures have survived in the strainshadow of the gabbro. The gabbroic intrusions might represent synvolcanic magma chambers feeding the tholeiitic basaltic volcanism in the greenstone belt.

A large mafic intrusive complex in the eastern part of the Kittilä Greenstone Belt, the Koitelainen Gabbro, has yielded a zircon concordia age for pegmatitic segregations of 2435 Ma (Puustinen 1977) and Kröner et al. (1971) have concluded that the age of the Kittilä Greenstone Belt is c. 2600 Ma. This age is in clear contrast with the younger age of the komatiites from the Bakkilvarri Formation (Krill et al. 1985, this volume).

Granodioritic sill-like intrusions are common in the upper and eastern part of the Iddjajav'ri Group. They have undergone the same strong deformation as the sourrounding rocks and are dated by Krill et al. (1985, this volume) giving an uncertain zircon age of 1890 Ma.

Granitic intrusions are found mainly within the Tanaelv Migmatite Complex where they appear as veins, sills and larger bodies. They are weakly foliated and typically contain magnetite. The Rb-Sr whole-rock isochrons give intrusion ages of ca 1750 Ma and they are thought to represent syntectonic anatectic melts (Krill et al. 1985, this volume). A few granites are also found along the western margin of the greenstone belt and a Rb-Sr errorchron obtained from the Stuorragår'ži granite gives 1730 Ma. The granite is unfoliated and probably represents post-tectonic remelting of the Jer'gul Gneiss Complex (Krill et al. 1985, this volume).

The youngest rock in the Karasjok area is a post-tectonic mafic dolerite which is subparallel to a late system of faults with a NE-SW trend.

Tectonic and metamorphic evolution

Krill (1985, this volume) presents the detailed evidence for a Middle Proterozoic thrusting event with thermal inversion in the Karasjok area. Combined metamorphic, structural and field mapping evidence shows that the Levajok Granulite Complex and the Tanaelv Migmatite Complex were thrust on top of the Karasjok Greenstone Belt with the granulite complex still under granulite facies conditions. This thermal inversion resulted in the asymmetric metamorphic pattern seen today with greenschist facies along the western margin and a gradual increase going east and tectonostratigraphically upwards, through upper amphibolite facies in the Rai'tegår'ži Formation and the Tanaelv Migmatite Complex into granulite facies in the Levajok Granulite Complex.

Hörmann et al. (1980) and Barbey et al. (1980) suggested that plate tectonic activity was responsible for the formation of the Tanaelv Migmatite Complex and the Levajok Granulite Complex. Krill (1985, this volume) provides further support for the plate tectonic interpretation, incorporating also structural and metamorphic evidence from the greenstone belt. The present tectonic model is the same as presented by Krill (1985, this volume), with some additional stratigraphic and structural observations incorporated.

The clastic sedimentation represented in the Skuvvanvarri Formation initiated around 2100 Ma ago with the beginning of intraplate subsidence and rifting along a N-S spreading axis. This tensional phase might also have been responsible for the rifting further west initiating the formation of the Kautokeino Greenstone Belt, but these rocks are not necessarily coeval with those of the Karasjok Greenstone Belt. Pharaoh & Pearce (1984) present a model in which the Kautokeino Greenstone Belt is formed in a back-arc spreading situation related to a cordilleran-type plate margin in the Skellefte area during Early Proterozoic time.

The Gål'lebai'ke Formation was deposited along the margin of the western plate as the Jer'gul and Baisvarri plates moved apart. The ensialic nature of the present Karasjok Greenstone Belt is indicated by the Iškuras dome structure where a gravity low suggests a light sialic crust. The deposition rate kept pace with subsidence as shown by the tidal-flat sediments at Oal'gejåkka, near the boundary against the overlying Bakkilvarri Formation. The decreasing amount of terrigenous sediments and synchronous increasing amount of volcanic rocks to the south suggests the location of a tensional regime towards the south with greater effusion of volcanic products during this period (Fig. 2).

Around 2085 Ma. ago a period of extensive mafic volcanism led to the accumulation of the Bakkilvarri Formation at least partly upon the Gål'lebai'ke Formation, bringing up large quantities of komatiites from a mantle source. The explosive nature of the komatiitic volcanism is shown by the predominance of pyroclastics which also indicates relatively shallow-water conditions. The presence of mafic and ultramafic dykes in the Jer'gul Gneiss Complex presumably indicates the ensialic character of the volcanism, and this must have covered large parts of what is now the central gneiss dome on Finnmarksvidda.

Thick flysch deposits of the Levajok Granulite Complex developed towards the east simultanously with the Karasjok volcanism in the west, probably indicating a passive plate margin along the Baisvarri Gneiss Complex.

East-dipping subduction of mafic oceanic crust resulted in the formation of magmatic arcs, i.e. the Tanaelv Migmatite Complex and parts of Levajok Granulite Complex. Heat from subduction-generated intrusions contributed to the high-grade metamorphism of the preserved parts of the Tanaelv Migmatite Complex and the Levajok Granulite Complex. Oceanic crust was apparently totally consumed in the subduction and in the later closing of the Svecokarelian ocean that occurred around 1800 Ma. ago. The collision resulted in the development of extensive thrust-faulting subparallel to the subduction zone where the eastern units were thrust above the western. The metamorphism reached medium to high grade in the eastern parts of the greenstone belt during the overthrusting of the hot granulites.

The Karasjok Greenstone Belt thus developed from a full 'Wilson cycle', starting around 2100 Ma and terminating about 1750 - 1800 Ma ago. This is in contrast with the Kautokeino Greenstone Belt which exhibits features of the more common granite-greenstone terrain (Olesen & Solli 1985, this volume) suggesting that it never developed past the rift-stage.

Metallogenesis

Since the early 18th century the Karasjok area has been known to contain deposits of alluvial gold. They have never proved economic, but a large number of findings have been reported from the greenstone belt area, particularly in the central and southern parts, and they are still given consideration by prospectors searching for gold deposits (Bjørlykke 1966). Sources for the alluvial gold, however, have not yet been established.

No mine has been in regular operation within the greenstone belt, but extensive prospecting investigations were carried out in the first years of this century on several minor sulphide deposits in the 'Porsanger Field', the northernmost part of Karasjok Greenstone Belt (Nordenskjöld 1909, Carstens 1931). Juve (1968) described the Porsanger mineralizations and Bugge (1978) presented an overview of the known deposits in the Karasjok area. The following is a short presentation of the types of occurrences in the context of the tectonostratigraphic framework described. Table 2 summarize the known types of mineralizations.

Stratiform mineralizations

Sulphidic horizons, generally with massive pyrrhotite/pyrite layers (normally ca 50 % sulphides + quartz + carbonate) with minor base metal sulphides, are common in the volcanic successions of the Iddjajav'ri Group. The massive sulphide layers are usually up to 1 m thick and associated with and laterally grade into sulphide impregnations in surrounding volcano-sedimentary rocks. These rust zones are 10-30 m thick, can extend for several kilometres and are often graphitic. In the south-central part of the greenstone belt the sulphide horizons occur as lateral extensions of banded iron-formations (BIF). There is a common spatial relationship with komatiite horizons suggesting a genetic link. Carstens (1931) pointed to the similarities between the massive iron-sulphide horizons of the Porsanger area and 'vass-kis' in the Caledonides, now regarded as sulphide facies iron-formations.

Banded iron-formations (BIF) are common in the south-central part of Karasjok Greenstone Belt (Wennervirta 1969, Bugge 1978). Magnetite and/or hematite with minor base-metal sul-

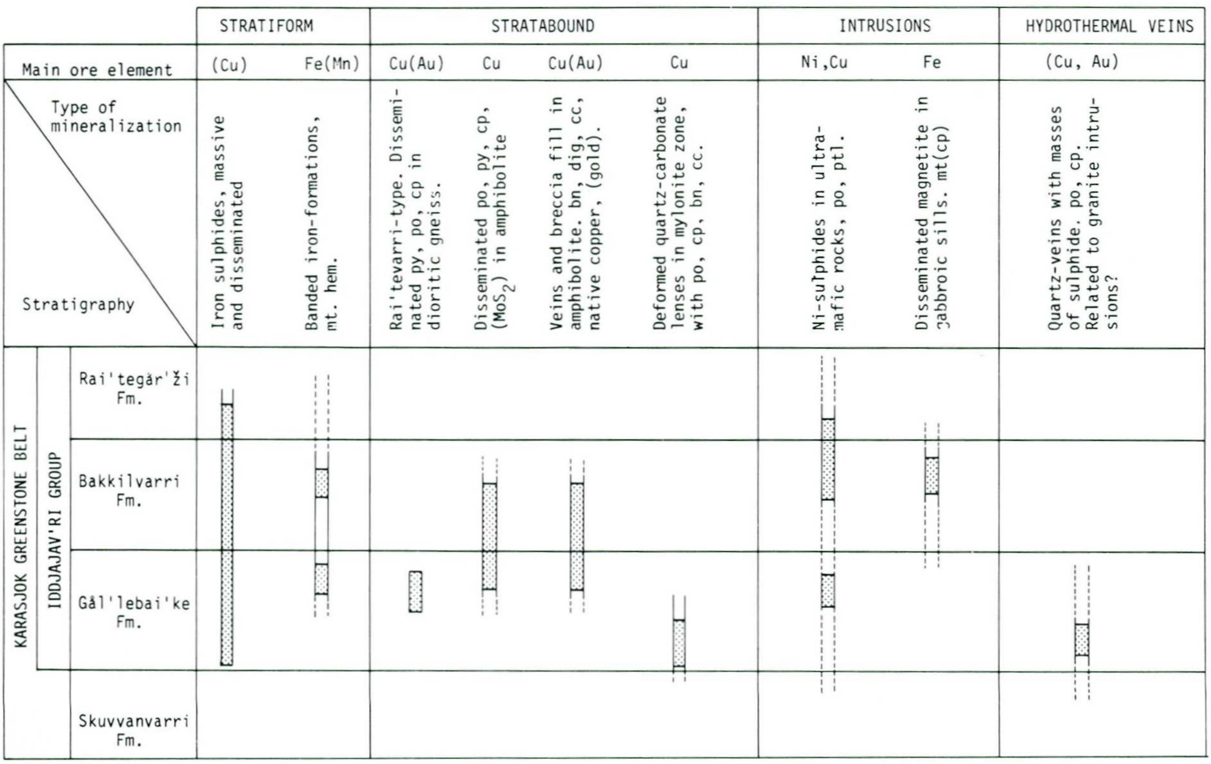

Table 2. Stratigraphic position of mineralization in the Karasjok Greenstone Belt.

phides interbanded with quartzite is the main facies, but a mixture of alternating thin layers of iron-oxides, iron-silicates, iron-carbonates and iron-sulphides is characteristic. Graphite is commonly associated with the iron-formations. The iron content is low, up to 30 %. Manganese is a major constituent grading up to 10 %, fixed in carbonate and silicates. The thickness is up to 40 m and total tonnage is considerable, but the grade is too low to be of any economic significance. The iron-formations are in some localitites seen to grade laterally into sulphidic horizons, establishing the genetic relationship between these types of mineralizations.

There seems to be one main horizon of oxide-facies iron-formation in the central parts of the Bakkilvarri Formation. This level is clearly seen on the aeromagnetic maps. In addition, several minor horizons with lower iron-oxide content are found both in the upper part of Gål'lebai'ke Formation and in the Bakkilvarri Formation. The main horizon and several of the minor ones are closely associated with komatiite horizons, normally with the iron formation on top. The hightemperature komatiitic magmatism (1400 - 1700°C, Green et al. 1975, Nisbet 1982) might have provided the heat energy needed to establish the convective hydrothermal systems that produced the exhalative ironformations and the stratiform sulphide deposits.

Stratabound mineralizations

The Raitevarri Cu-Au deposit is a disseminated pyrite/pyrrhotite and chalcopyrite mineralization of considerable potential in a dioritic gneiss of variable composition in the Gål'lebai'ke Formation (Røsholt 1977). The origin of the mineralization is not satisfactorily understood as only limited work has been done. The mineralized rock unit is about 250 m thick and is found over a distance of 10 km along strike, and observations further south indicate that the same rock type is found in equivalent stratigraphic position another 15 km away. As discussed earlier, the gneiss is considered to be of volcanic origin. Iron sulphide impregnation is characteristic for the entire unit, but copper sulphides are present only in limited zones 10-50 m thick which might suggest a possible syngenetic origin for the iron-sulphides and an epigenetic origin for the copper. The behaviour of the gold is not known. Average grade (Bugge 1978) is less than 0.4 % Cu with a few ppm Au in the copper concentrate. H. Henriksen (pers. comm. 1985, internal A/S Sydvaranger reports) regards the host rock as intrusive and proposes a porphyry copper model for the strongly deformed and metamorphosed Raitevarri mineralization.

Other disseminated Cu mineralizations occur in the Porsanger area (Bugge 1978). Disseminated copper-sulphides, mainly chalcocite, in amphibolites of both volcanic and intrusive origin are found in zones following strike and up to 100 m thick. Juve (1968, pers.comm. 1985) suggested a syngenetic or subvolcanic origin for these low-grade mineralizations, having an average copper content of less than 0.2 %. They seem to occur both in the Gål'lebai'ke and in the Bakkilvarri Formations.

Stratabound vein-type Cu-mineralizations are found in association with the disseminated Cu-mineralizations in the Porsanger area. They are small, high-grade vein deposits with chalcopyrite, bornite, digenite and chalcocite. Small amounts of gold have been reported. Juve (1968, pers.comm. 1985) considers these mineralizations to be products of two different processes: 1) Late Precambrian supergene processes with weathering of the disseminated mineralizations. 2) Subvolcanic hydrothermal activity possibly related to the formation of the disseminated mineralizations.

Other stratabound deposits. Within a zone of deformation/mylonitization along the river Karasjåkka, considered to be the southward extension of the Stallučåkka Thrust (Siedlecka, 1985 this volume), a number of small, very low-grade occurrencies of copper sulphides are found. The sulphides occur in deformed quartz-carbonate lenses and mainly in mafic rocks within the lower parts of the Gål'lebai'ke Formation. They are probably related to the Middle Proterozoic thrusting and coeval with the prograde metamorphism (Krill 1985, this volume).

Mineralization related to intrusions

Disseminated Ni-Cu-mineralizations in differentiated mafic to ultramafic intrusive rocks have been investigated, but economic grades have not been found. Very little information is available on these occurrencies.

Sulphide-bearing quartz veins are common adjacent to the Stuorragår'ži granite in the lower part of the Gål'lebai'ke Formation. They carry pyrrhotite, small quantities of chalcopyrite and minute amounts of gold. A genetic relation to the granite is suggested, the granite providing the heat source for the hydrothermal system.

Magnetite has been produced in small quantities from a gabbroic sill near the northern end of Gaggajav'ri. The magnetite is disseminated in the coarse gabbro and small amounts of copper sulphides are also present.

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