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Follow-up studies in the Okstindan Area, the Rödingsfjäll Nappe Complex, Nordland, Norway

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REPORT

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Title:
Follow-up studies in the Okstindan Area, the Rödingsfjäll Nappe Complex, Nordland, Norway

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Summary:

Follow-up work has been conducted in three restricted areas of the 1200 km^2 large Okstindan Area on the basis of earlier anomalies found during regional surveys. The three areas have been subjected to detailed geophysical mapping, mineralogical studies and sampling for whole-rock geochemistry. Mineralizations in the area consist of non-economic sulfide-impregnations with restricted thickness and extent. Skarn-type mineralizations consisting of mainly clinoamphibole, garnet, quartz and biotite, found in the Brunesbekken and Grasvatnet areas, have not previously been reported from the Okstindan Area. Similar types of mineralizations are, however, typical for the Plurdalen Group in the Mofjellet Area. The mineralization in Rabotsbekken is hosted by quartzite and quartzitic schists and can be classified as a low-grade sulfide mineralization or a high-grade exhalite. Deep geophysical anomalies (Transient Field EM) are connected to the mineralizations in both Brunesbekken and Rabotsbekken. However, graphitic schists are associated with the mineralizations and the cause of the anomalies may be graphite or massive sulfides.

A 1.5 to 2 km long horizon of banded garnet-magnetite-quartz rock (coticules) was mapped and sampled at Kongsfjellet. Based on mineralogical and petrologic evidence, this rock most likely represents hydrothermal sediments, which could be distal facies of some lead-zinc mineralization in the area. However, no mineralizations were found directly associated with these rocks.

Keywords: Ore Geology	Nordland	Rödingsfjäll Nappe Complex
Sulfides	Whole rock geochemistry	Exhalite
Professional report		

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INTRODUCTION

This report presents the results of detailed geological follow-up studies in the Okstindan Area, Nordland, Norway. The fieldwork was done in the period June to August 1996, and is based on previous regional geology, geophysics and geochemistry surveys, mainly in the earlier stages of the Bleikvassli Project between 1993 and 1995 (Bjerkgård et al. 1995, Krog 1995 a,b, Dalsegg 1996 a, Elvebakk & Dalsegg 1996, Mogaard 1996). The follow-up work was conducted in three areas, Brunesbekken, Grasvatnet and Kongsfjell (Fig. 1), and includes studies of mineralizations found in these areas. This report describes the results of field work, whole-rock geochemistry and microscope studies from these areas.

Geologic overview

The Okstindan area comprises four lithological units; the Mofjellet, Anders Larsa/Lifjell and Kongsfjell Groups and the Målvatn Unit (Fig. 1). All units are dominated by metasediments, mainly garnet-mica and calcareous mica schists. Calcite and dolomite marbles are abundant in the Anders Larsa and Lifjell Groups, whereas various quartz-feldspathic schists are typical of the Målvatn Unit. Amphibolites, which are metabasalts and andesites of probable transitional MORB to island arc affinity, according to geochemistry, are present in all units. They are particularly abundant in the Kongsfjell Group close to the contacts with the Anders Larsa/Lifjell Groups and between calcareous mica schists and garnet-mica schists. Isolated bodies of ultramafics, partly chromite-bearing, are present within the Målvatn Unit, close to Kongsfjell Group. Taking into account the geochemistry of the amphibolites and the association with mainly continent-derived sediments, the Okstindan lithologies have most probably formed in a crustal spreading regime behind an ensialic arc (Bjerkgård et al. 1995).

SULFIDE MINERALIZATIONS

Geology and mineralogy

Brunesbekken

A weakly mineralized zone was previously discovered in Brunesbekken, about 1.5 km south of the Bleikvassli Mine (Figs.1, 2). Based on this discovery, and geophysical measurements (SP) in the area, the mineralized zone was drilled in 1987, but with negative results (Rui 1987).

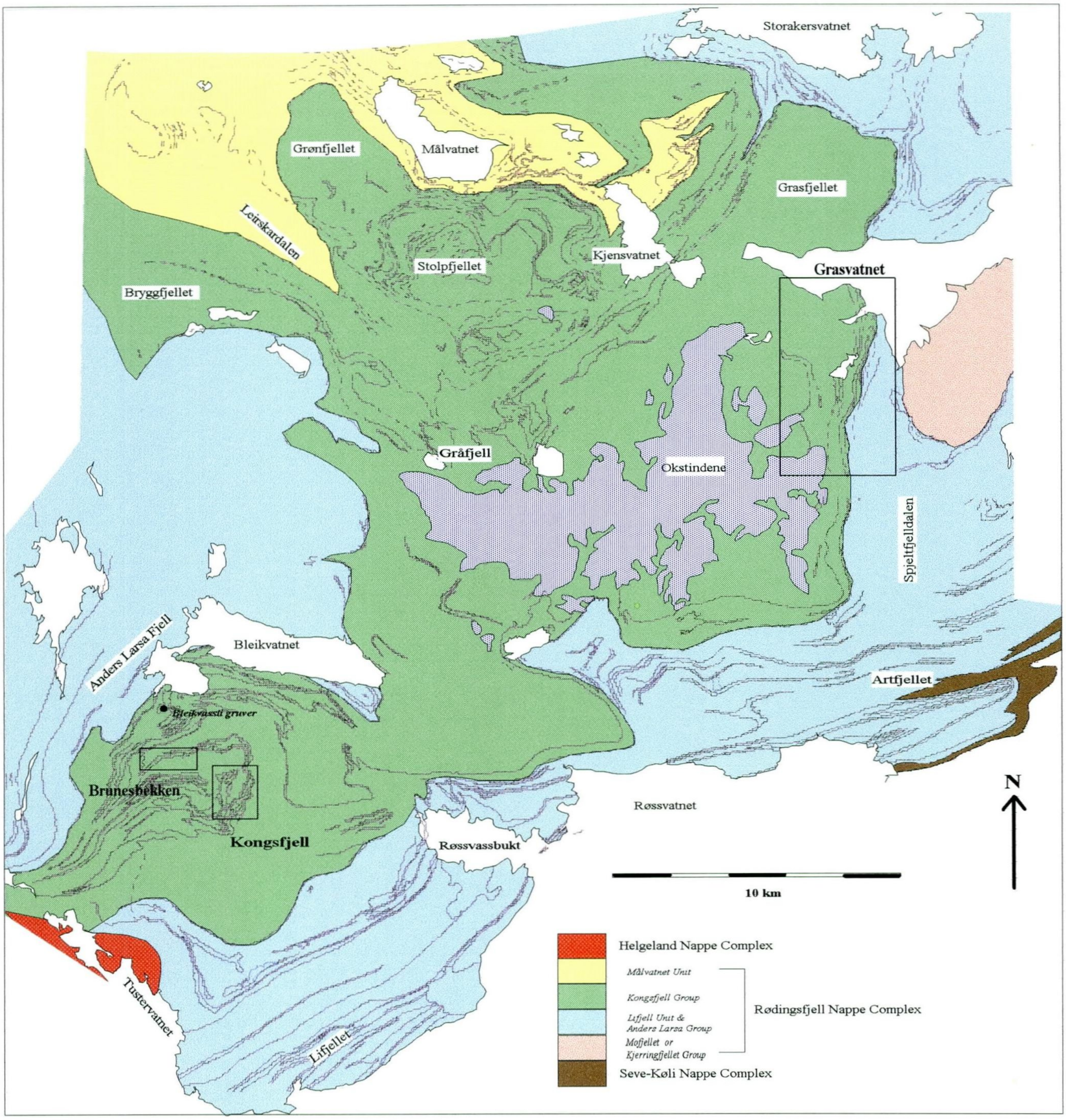

Figure 1: Overview of the Okstindan Area showing the main lithological and tectonic units. The location of the areas for follow-up studies, Brunesbekken (Fig.2), Grasvatnet (Fig.7) and Kongsfjell (Fig.10) are indicated by boxes.

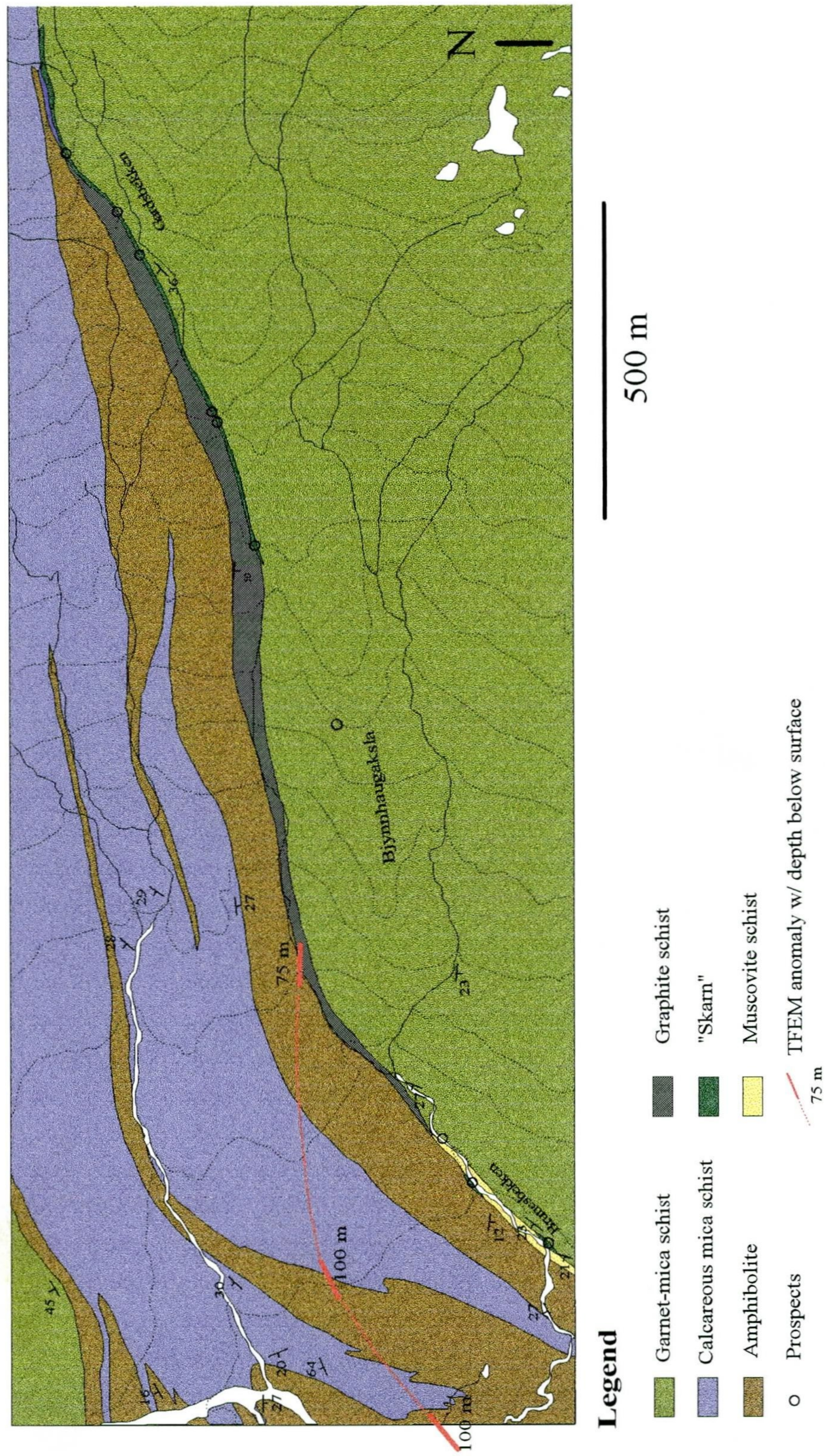

Figure 2: Geology in the Brunesbekken Area, based on mapping by I.J. Rui (Aspro report no. 1766, 1987) and revised in 1996. The TFEM anomaly is shown superimposed on the geology.

Transient Field EM investigations (TFEM) at the western part of Kongsfjellet in the fall 1995 revealed a new anomaly at depth, west of Brunesbekken (Elvebakk & Dalsegg 1996). TFEM did not pick up the known mineralizations at the surface, which seem to indicate that a stronger conductor exists at depth. However, the anomaly could be generated by graphite, as well as a sulfide occurrence. Based on the outcrop of the mineralized zone, strike and dip of the rocks in the area, the old drill holes and the depth indicated from TFEM, the anomaly is at the same stratigraphic level as the known mineralizations.

Given these results, more detailed investigations of the known mineralization and surrounding lithologies were necessary to try to reveal if the anomaly most likely was caused by graphite or by more massive sulfide mineralizations. Furthermore, detailed structural analysis was a prerequisite for planning of a successful drilling program.

The field work in the area, conducted in early June 1996, revealed discontinuous mineralizations along the same stratigraphic horizon for a strike length of more than 2 km, from Brunesbekken in the west to Gardsbekken in the east (Fig. 2). Unfortunately, no outcrops occur along this level between Brunesbekken and north of Bjynnhaugaksla. The descriptions of the mineralized horizon is therefore divided into two parts: The Gardsbekken and Brunesbekken occurrences.

The Gardsbekken mineralization are weaker than those in Brunesbekken, and also occur in a slightly different host rock. It can be followed for about 1 km along strike, mainly along Gardsbekken. It is situated at the contact between a garnet-mica schist and a graphite schist, structurally below a thick unit of amphibolite. The amphibolite is the same which structurally underlies the Bleikvassli deposit.

The mineralized zone has a thickness of 0.5 to 5 m and is characterized by weak impregnations of chalcopyrite, sphalerite and pyrrhotite with minor galena, in a rock composed of quartz, garnet and pale green amphibole. Biotite and carbonate occur locally. The green amphibole dominates and occurs as unoriented coarse-grained aggregates. Quartz, garnet and the sulfides occur interstitially between the amphibole aggregates, all of which gives the rock a very massive and competent appearance. This mineralized rock occurs as several 2 - 10 cm thick layers and lenses intercalated with nonmineralized, partly graphitic quartz-feldspar-muscovite schists. The high content of muscovite distinguishes these schists from the underlying garnet-mica schists.

Three polished thin sections of the quartz-garnet-amphibole rock have been studied from the Gardsbekken Area (Samples TB96001-3 in Table 1a). The rock consists of nematoblastic, partly poikiloblastic, amphibole in unoriented aggregates, lesser amounts of quartz, primarily occurring in monomineralic domains, and more evenly-distributed grains of garnet (Fig. 3). The minerals are mainly coarse-grained. The amphibole is pale green, has up to 2nd order blue interference colors and a Z ^c angle of 16-21°, which makes it likely that it is tremolite or hastingsite, i.e. an amphibole with a low Fe/Mg-ratio. Biotite, which partially replaces amphibole, is pale, nut-brown and has a low Fe-content. Garnet is typically deformed, occurring as elongated poikiloblastic grains.

Chalcopyrite and pyrrhotite typically form larger aggregates which are often intergrown along mutual crystallographic directions (Fig. 4). Galena is very coarse-grained in one of the sections, and contains small inclusions of native bismuth and a presently unknown green phase with a high reflectance (Fig. 5). Two small grains of electrum are present as inclusions in chalcopyrite.

In Brunesbekken, in the western part of the area, continuous mineralizations can be followed for 250 m along strike. As in Gardsbekken, the mineralizations generally consist of weak impregnations of chalcopyrite, sphalerite, pyrrhotite and galena. The mineralizations are partly associated with similar garnet-amphibole-quartz rocks as in Gardsbekken, but also with quartz-lenses in biotite-muscovite-rich schists and in carbonate-rich rock. In addition, weak impregnation, mostly of chalcopyrite, occurs in the surrounding muscovite-rich garnet-mica schists. The mineralizations in Brunesbekken are generally richer than in Gardsbekken.

One of the richest mineralizations occurs in a rock composed of carbonate with lesser amounts of quartz, chlorite and amphibole (sample TB96008, Table 1a). The rock has a very massive appearance with fine-grained, unoriented amphibole and chlorite grains making the rock very competent. In outcrop this rock occurs as ≤ 0.5 m-large, rounded lenses in a garnetiferous schist very rich in muscovite and biotite and weakly impregnated with

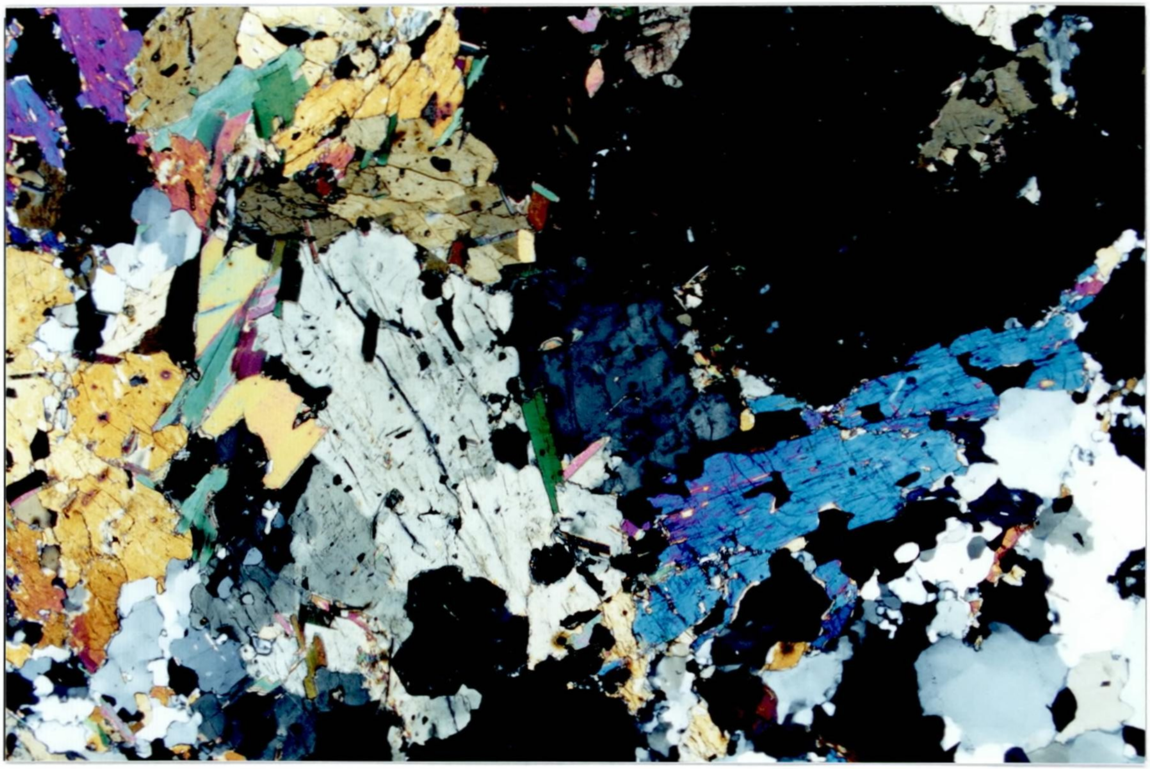

Figure 3: Typical skarn assemblage with garnet, clinoamphibole, biotite and quartz from Brunesbekken. Transmitted light, crossed polars. Width of field is 5.49 mm.

Figure 4: Chalcopyrite and pyrrhotite in epitaxial intergrowth, from Brunesbekken. Reflected light. Width of field is 1.51 mm.

Figure 5: Galena (bluish gray) with inclusions of chalcopyrite (yellow) and native bismuth (white, high reflectance), from Brunesbekken. A presently unknown phase with greenish color is associated with bismuth in lower left corner of photo. Reflected light. Width of field is 1.51 mm.

chalcopyrite. Pyrrhotite intergrown with chalcopyrite is present together with galena and occurs in large aggregates evenly distributed throughout the host rock. Native bismuth occurs as common fine-grained inclusions in galena. This mineralization was drilled in 1987, but nothing more promising was found at a depth of about 10 m following dip (Rui 1987).

In the easternmost outcrop, a quartz-garnet-amphibole rock, similar to what was found in Gardsbekken, contained native bismuth, electrum, hessite, tetradymite and fahlore in addition to about 10 % chalcopyrite, sphalerite, pyrrhotite and galena (TB96004a and b, Table 1a, Fig.6 a, b). The mineralized zone at this locality has a thickness of at least 1 m. This mineralization was also drilled in 1987, but only weak impregnation was found at a depth of about 10 m following dip (Rui 1987). A laminated quartzitic schist is situated structurally about 20 m above this mineralization. Small amounts of carbonate and pink, probably Mn-rich garnet are also present (sample TB96004c, table 1a). The rock has a mm-scale lamination and looks very similar to quartzitic schists associated with the Bleikvassli deposit.

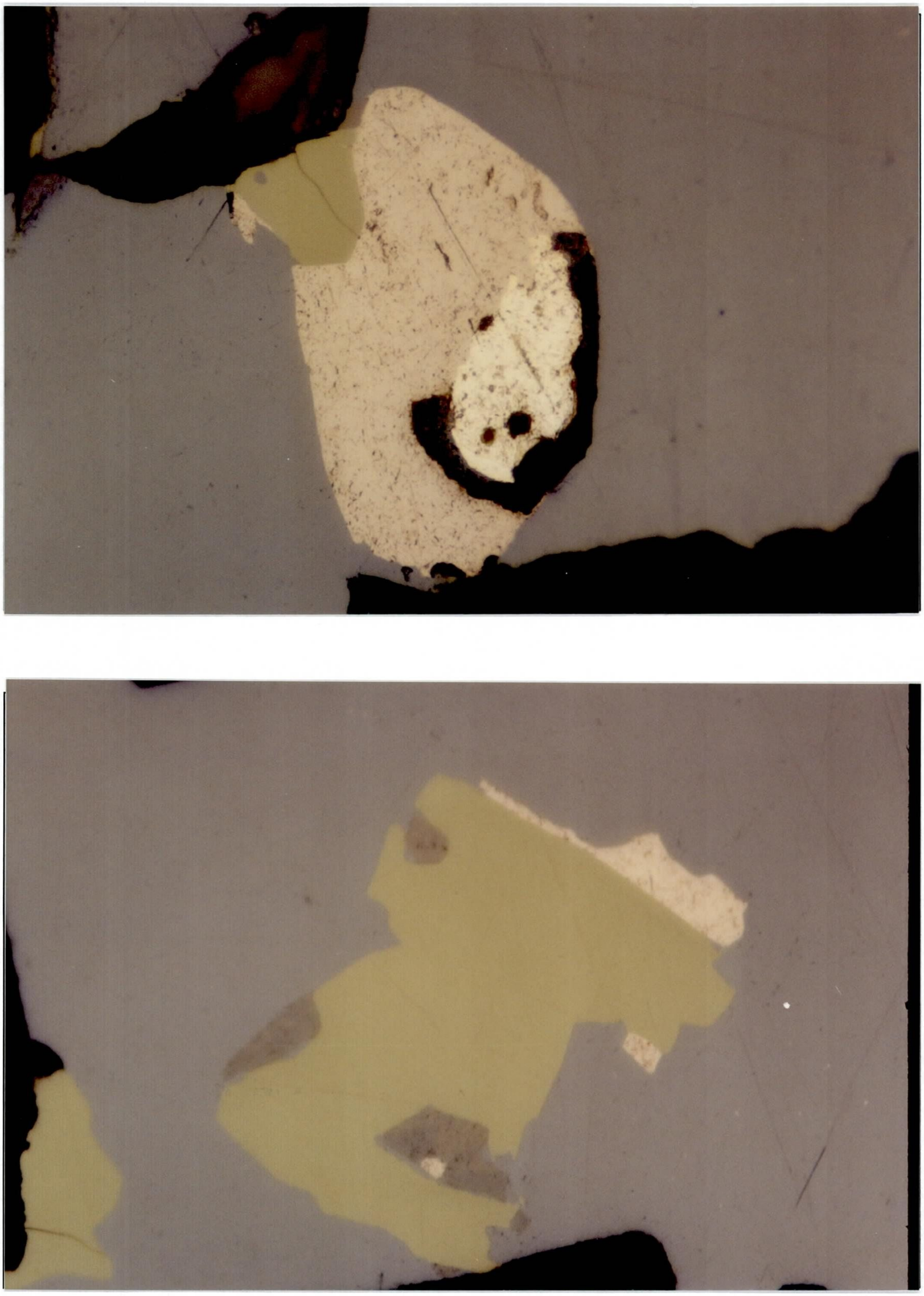

Figure 6 a: Galena with large inclusion of native bismuth (pinkish), chalcopyrite (yellow) and probably tetradymite (white, high reflectance). b: Galena with large inclusion of chalcopyrite (yellow), native bismuth (pinkish) and hessite (dull gray, low reflectance). For both photos: From Brunesbekken. Reflected light. Oil immersion. Width of field is 0.135 mm.

Table 1: Mineralogy in the Brunesbekken and Grasvatnet mineralizations

a) Brunesbekken

Sample	TB96001	TB96002	TB96003	TB96004a	TB96004b	TB96008	TB96005	TB96004c
Quartz	30	15	20	20	24	15	18	50
Clinoamphibole	40	65	50	60	35	10	-	-
Garnet	5	2	15	10	13	-	30	5
Biotite	2	5	7	1	20	-	45	-
Carbonate	10	10	-	-	tr.	50	-	5
Chlorite	3	-	-	-	-	15	tr.	-
Muscovite	-	-	-	-	-	-	-	40
Epidote	-	tr.	-	-	-	-	-	tr.
Other	ti,ap,zr	ti	ti	-	ti,zr	-	rt-2,st-5	-
Chalcopyrite	4	3	3	2	2	4	0.5	tr.
Sphalerite	3	-	2	5	3	tr.	-	tr.
Galena	1	-	tr.	1	1	4	tr.	-
Pyrrhotite	3	-	3	2	2	2	0.5	tr.
Pyrite	-	-	-	-	tr.	-	tr.	-
Other	bi,el,?	bn,cv,cc	cv	bi,hs,td,fo	el,bi,?	bi	bi,ptl	-

b) Grasvatnet

Sample	TB96016	TB96017a	TB96017b	TB96018	TB96019	TB96021	TB96022	TB96024
Quartz	10	tr.	10	95	2	3	35	45
Clinoamphibole	13	60	60	-	10	40	-	-
Garnet	25	-	5	-	68	30	tr.	tr.
Biotite	35	-	20	-	-	tr.	18	5
Carbonate	-	-	-	-	5	-	-	-
Chlorite	7	30	-	-	5	10	5	-
Muscovite	1	tr.	-	2	-	-	5	37
Epidote	-	-	-	-	-	5	14	2
Plagioclase	-	-	-	-	-	-	5	-
Other	zr,ap,rt	ti	ti,ap	-	?	rt-1	ti-2,rt-1	rt-1,ti
Chalcopyrite	6	9	5	1.5	6	5	tr.	-
Sphalerite	tr.	0.5	tr.	-	1	3	-	-
Galena	-	-	-	-	-	1	-	-
Pyrrhotite	3	1	-	1.5	3	2	tr.	-
Pyrite	-	-	-	-	-	-	15	10
Other	?	mb,cv	mb,?,?	-	-	bi,mc,cv	ptl	-

The numbers are estimated content in vol%

***abbrev**: zr-zircon, ap-apatite, ti-titanite, rt-rutile, st-staurolite*
mb-molybdenite, cv-covellite, bn-bornite, cc-chalcocite, bi-bismuth, el-electrum, hs-hessite
td-tetradymite, fo-fahlore, ptl-pentlandite, ?-unknown phase
tr.-trace amounts

grains of sphalerite, galena and pyrrhotite. Locally graphite is present, and except for the mineralization, it is quite similar to the schists in Gardsbekken. The sulfides are particularly concentrated to lenses rich in garnet and in quartz-segregations, the latter often with coarse (1-5 cm long) euhedral, deep blue kyanite. A thin-section of these schists (TB96005, Table 1a) shows that it contains large amounts of garnet and lenses of monomineralic quartz. Large porphyroblasts of staurolite are also present. Biotite is the only mica mineral in this particular section, but muscovite is more typical in generic varieties of these schists. Chalcopyrite and pyrrhotite occur together in scattered aggregates, whereas pyrite and galena are found in trace amounts.

The area south of Grasvatnet

The area immediately to the south of Grasvatnet, close to Spjeltfjelldalen (see Fig.1), yielded high values of Cu, Au and Pb in the regional soil geochemistry done in 1993 and 1994 (Krog 1995 a, b). To locate the origin of this anomaly, detailed geological mapping was done during the summer 1996 (Fig. 7). A weak *in situ* Cu-Pb-Zn mineralization in Rabotsbekken, about 3 km south of Grasvatnet, which was found during the regional geological mapping in 1993, was followed up by sampling 1996. The two areas are described below.

Grasvatnet

In situ sulfide mineralizations were found very close to the soil sampling sites for the geochemical anomalies. The mineralizations consist of weak impregnations of chalcopyrite, sphalerite and galena in garnet-quartz-amphibole-biotite rock. This rock is locally schistose, but more typically is a massive, competent rock which consists of unoriented needles of amphibole with other interstitial silicates and sulfides or with the silicates in a porous, rusty matrix of limonite, in a gossan-like rock. The amphibole in the gossan is generally colorless and is probably grunerite. The mineralized gossans occur in thin lenses (2 to 10 m) with limited extent (10 to 50 m) along strike. It is probable that the lenses represent parts of a previously continuous layer, which was disrupted during folding and boudinage.

The mineralized rock has a very variable mineralogy, and is locally dominated by clino-amphibole, garnet, quartz or biotite (Table 1b). Locally the content of chlorite is also very high. Texturally the rocks generally resemble the mineralized quartz-garnet-amphibole rocks in the Brunesbekken Area (see above), with unoriented, coarse-grained aggregates of generally colorless amphibole, resulting in a strongly competent rock. The sulfides occur

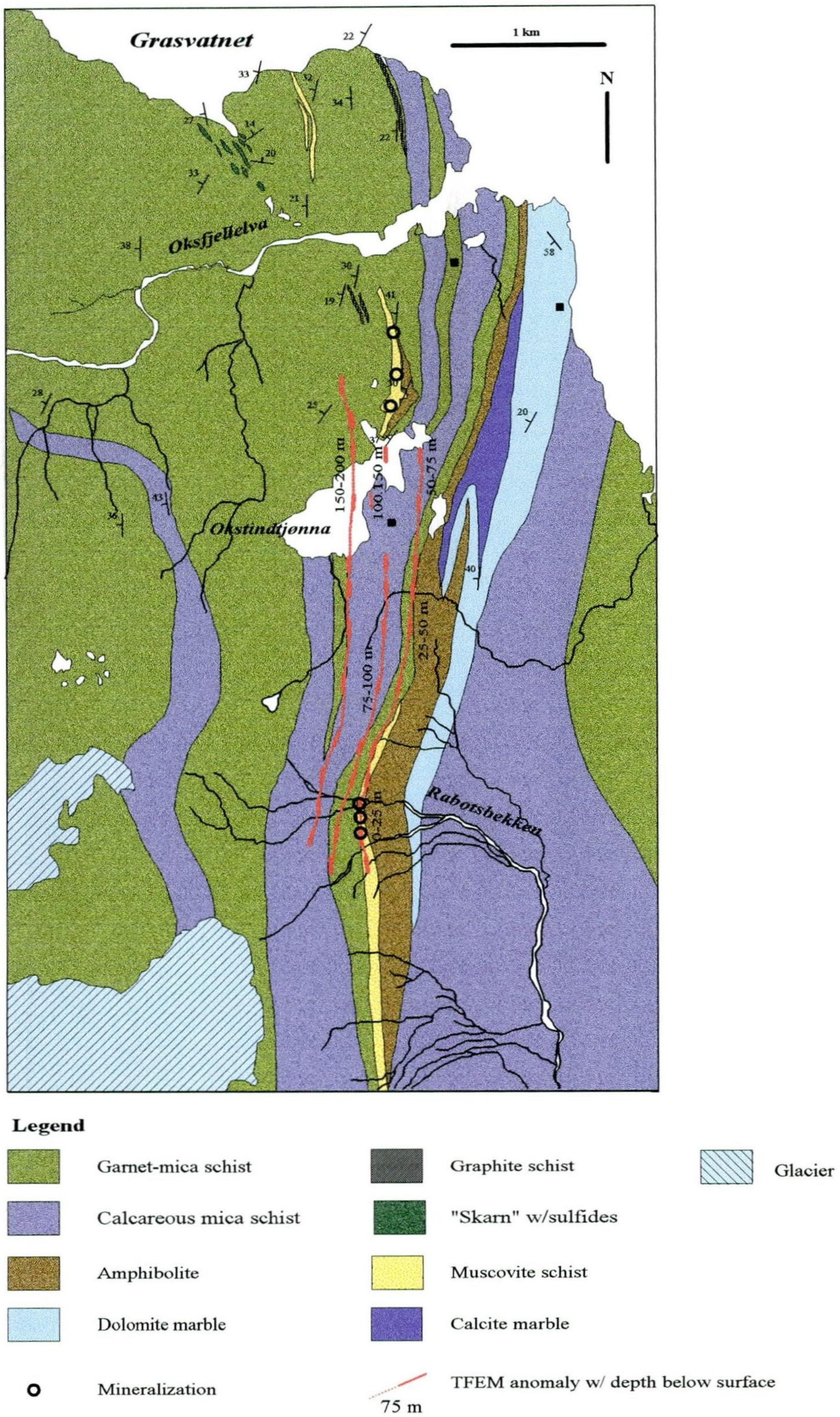

Figure 7: Geology in the Grasvatnet Area with the location of mineralizations indicated. TFEM anomalies are shown superimposed on the geology.

interstitially between the silicates, often in coarse-grained aggregates. Chalcopyrite dominates and is typically associated with pyrrhotite, often in lamellar, epitaxial intergrowths. The content of sphalerite varies, but is usually present in small amounts. Galena has only been found in one thin-section. Sparse, relatively coarse-grained laths of molybdenite are typically dispersed in the rock (Fig. 8).

About 1.5 km SSE of these mineralizations, and at a lower stratigraphic level, a pyrite-impregnated quartz-sericite schist occurs. The mineralized schist is between 30 and 100 m thick and can be followed for about 700 m along strike. It disappears in Okstindtjønna to the south and is covered by overburden to the north, towards Grasvatnet. It is situated between a thin unit of amphibolite in the structural footwall and a garnet-mica schist in the hangingwall. The content of pyrite varies between 5 and 20 %, typically in bands following the schistosity, which in the richer intervals, are generally less than 10 cm wide. Pyrite is evenly distributed in the schist as mm-sized grains in the individual bands. Sericite or muscovite has a greenish shade, possibly because of a high chromium content.

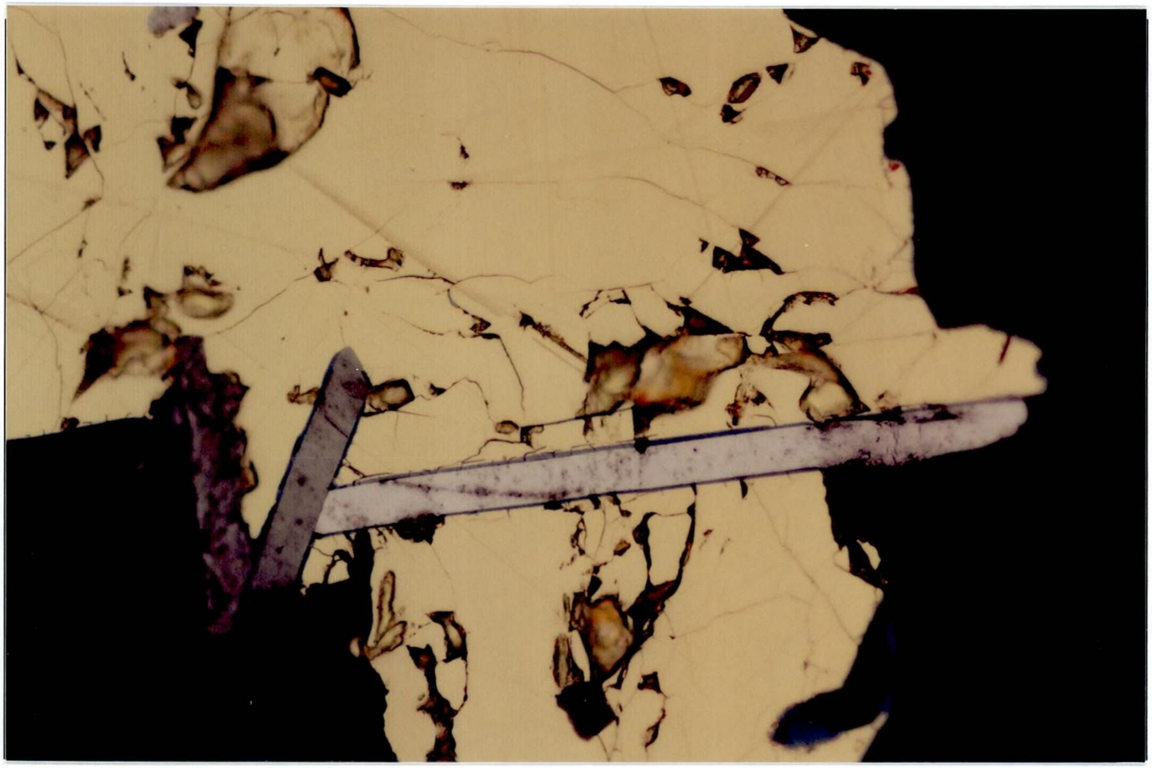

Figure 8: Chalcopyrite with large laths of molybdenite (various shades of dark gray), from Grasvatnet. Reflected light. Width of field is 0.27 mm.

Thin sections of two samples (TB96022, -24, Table 1b), show that the content of biotite locally is high and that epidote is common. Chlorite, plagioclase, sphene and rutile are minor phases, whereas garnet occurs in trace amounts. Pyrite occurs in xenoblastic grains, generally concentrated in bands or lenses following the foliation. A few grains of pyrrhotite and chalcopyrite are found in one of the sections, pyrrhotite with flame-like, small inclusions of pentlandite.

Rabotsbekken

The Rabotsbekken mineralizations are confined to a composite unit dominated by impure quartzite intercalated with garnet-mica schist, two-mica schist, graphitic schist and amphibolite (Fig. 9). Together, these lithologies obtain a maximum thickness of 31 meters comprising an integrated part of the 'Muscovite Schist' shown in Fig. 7. Base-metal mineralized, impure quartzites can be followed along strike for about 250 m after which they disappear under the overburden. The lateral extent is probably not much longer because quartzite was not observed in river sections north and south of the two arms of Rabotsbekken. Also, the geometry of the quartzite corresponds to a tapering lens.

Given the large proportion of quartzite confined to a discontinuous unit, it was decided to examine the Rabotsbekken mineralization in greater detail to decide if it represented a distal exhalite unit that could be associated with a subsurface massive sulfide deposit.

Particularly the upper 13 meters of the composite unit comprise abundant disseminations of sulfide and are also the most «quartzitic» part of the mineralization (Fig. 9). Based on indicative minerals in hand specimens, three types of mineralizations could be distinguished: 1) disseminated polymetallic mineralization in the structurally central part of the unit; 2) disseminated arsenopyrite-rich mineralization in the upper part; and 3) cross-cutting galena mineralization in the lower part.

The polymetallic mineralization is hosted in a quartzite with lepidoblastic white and green muscovite and biotite, smeared out lenses of calcite, clinozoizite and subordinate garnet, sphene, rutile and chlorite. Quartz is granoblastic but somewhat sheared and shows a fine, lamellar banding. The coarser crystals is recrystallized to fine-grained aggregates, or subgrains, along grain boundaries. Ore-minerals in decreasing order of abundance include

Profile through the Rabotsbekken Mineralization

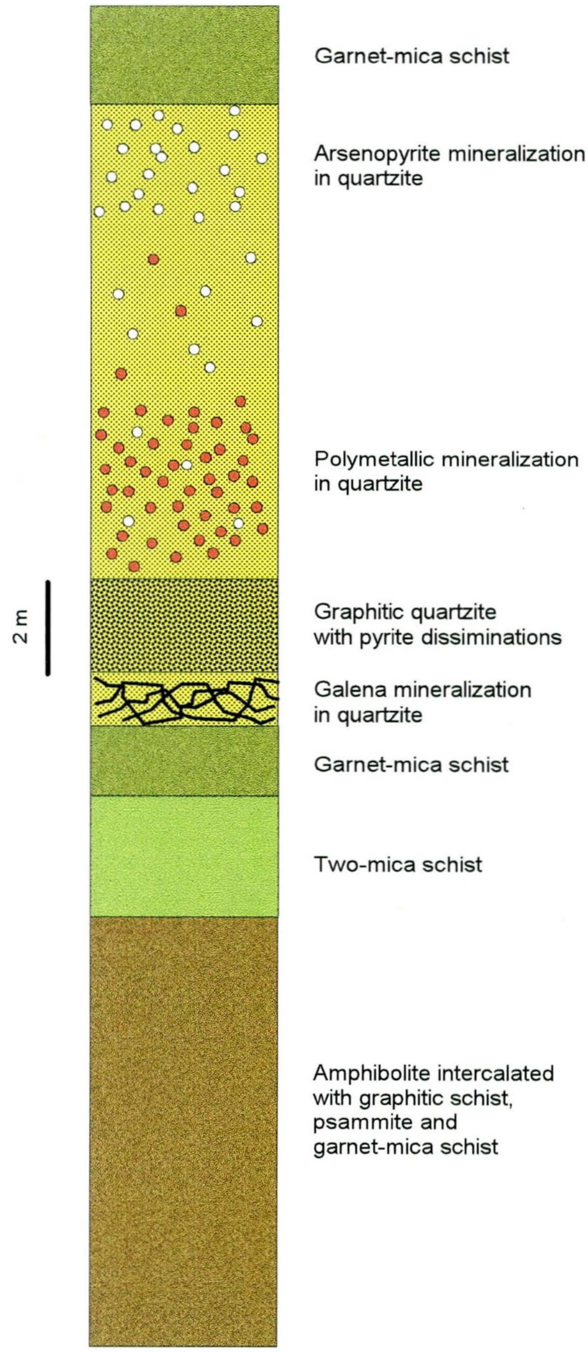

Figure 9: Profile through the Rabotsbekken mineralization (top is west) showing the position of the different types of mineralization.

pyrrhotite, pyrite, sphalerite, chalcopyrite, galena, magnetite and arsenopyrite. Pyrrhotite is locally heavily replaced by marcasite. Arsenopyrite, pyrite and magnetite exhibit subhedral crystals whereas the other sulfides, in particular pyrrhotite and chalcopyrite, occur in elongated anhedral grains. Most of the ore-minerals aggregate in discontinuous zones parallel to the foliation, even though they seem uniformly disseminated in hand specimen.

The arsenopyrite mineralization is hosted in a quartzite with lepidoblastic muscovite, aggregates of calcite, and euhedral crystals of apatite. Arsenopyrite and pyrite are the dominating ore-minerals and occur in almost equal proportions. In descending order, pyrrhotite, sphalerite, chalcopyrite, galena and magnetite occur in subordinate to accessory amounts. Arsenopyrite and pyrite are mostly euhedral and, in places, intergrown with one another. Magnetite is also euhedral whereas the other ore-minerals are anhedral. The ore-minerals are uniformly disseminated throughout the mineralized section.

The galena mineralization occurs in an almost pure and strongly sheared quartzite which in isolated parts comprises lepidoblastic muscovite, sphene, clinozoizite and rutile. Under crossed nichols, the granoblastic quartz crystals show extensive recrystallization and subgrain formation along grain boundaries, and the coarser grains often exhibit a fine pressure-induced lamination. Galena is constrained to almost monomineralic, massive, mm- to cm-thick veins intersecting the quartzite in a complex braided pattern. Other ore-minerals, in descending order, include sphalerite, pyrite, pyrrhotite and covellite. Galena is partially replaced by presently unknown phases, probably sulfosalts, along grain boundaries and micro-cracks.

Whole-rock Geochemistry

Brunesbekken

Samples from the mineralizations in both Brunesbekken and Grasvatnet have been analyzed by XRF at NGU and ICP at ACME laboratories in Canada. The results are presented in Table 2 a-c.

Seven samples of the skarn mineralizations in Brunesbekken have been analyzed (Table 2 a). The major elements show low contents of Al_2O_3, Na_2O and K_2O, whereas the contents of Fe_2O_3 and CaO are high. Because the content of sulfur is at most only 2.2 %, the Fe must to a large degree be incorporated in silicates, such as amphibole, chlorite and biotite. CaO has

Table 2 a: Whole-rock geochemistry of the Brunesbekken mineralizations

XRF - Major elements (NGU Lab)

	Skarn-type							Schist-type		Quartzite
	TB96-001	TB96-002	TB96-003	TB96-004a	TB96-004b	TB96-007	TB96-008	TB96-005	TB96-006	TB96-004c
SiO_2	51.91	55.07	51.80	56.13	50.38	62.61	47.42	43.70	66.69	80.25
Al_2O_3	6.82	8.38	10.00	7.19	9.82	8.43	6.85	18.86	13.34	11.48
Fe_2O_3	10.78	9.32	11.94	9.81	11.80	8.52	10.09	17.54	9.85	1.31
TiO_2	0.41	0.50	0.50	0.41	0.85	0.28	0.37	0.79	0.74	0.06
MgO	8.97	9.29	9.70	7.99	7.44	7.35	9.16	10.29	4.08	0.66
CaO	10.33	10.40	8.76	6.49	4.82	5.82	6.93	1.60	0.75	0.23
Na_2O	0.28	0.45	0.75	0.66	0.34	0.39	<0.10	0.42	<0.10	0.16
K_2O	0.25	0.35	0.23	0.43	2.05	1.01	0.95	3.85	1.90	3.32
MnO	0.82	0.89	1.29	1.01	1.27	0.37	0.48	1.78	0.40	0.06
P_2O_5	0.17	0.21	0.16	0.11	0.18	0.24	0.42	0.07	0.12	0.02
LOI	1.61	2.91	1.88	1.87	2.26	2.36	10.52	1.10	0.88	1.66
Sum	92.34	97.76	97.00	92.10	91.19	97.39	93.03	100.00	98.73	99.21
Cl	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F	0.20	0.13	0.19	0.18	0.26	<0.10	0.18	0.18	<0.10	<0.10
S	1.31	0.22	1.04	1.58	2.23	0.54	0.74	0.18	0.19	<0.10

XRF - Trace elements (NGU Lab)

	Skarn-type							Schist-type		Quartzite
	TB96-001	TB96-002	TB96-003	TB96-004a	TB96-004b	TB96-007	TB96-008	TB96-005	TB96-006	TB96-004c
Ga	21	19	21	32	38	16	26	21	18	15
Cu	11693	4581	7619	6667	9192	5781	9409	823	866	100
Pb	2847	1544	3031	3980	5811	1014	6236	222	100	111
Zn	8409	3071	9184	27969	32370	3360	8190	2052	1266	164
Yb	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	<10
Ce	26	53	50	38	49	24	36	< 10	89	36
Nd	24	26	26	29	40	13	26	< 10	48	31
Nb	7	9	9	6	6	< 5	6	< 5	12	52
Zr	108	124	130	109	118	71	82	33	213	122
Y	15	21	21	14	19	18	9	40	41	66
Rb	< 5	< 5	< 5	14	109	82	84	149	83	159
Th	51	21	32	44	50	12	61	< 10	16	106
Cr	39	40	49	49	65	35	30	984	53	<5
As	30	20	61	33	63	< 10	21	< 10	< 10	<10

ICP total digestion (ACME Labs.)

	Skarn-type							Schist-type		Quartzite
	TB96-001	TB96-002	TB96-003	TB96-004a	TB96-004b	TB96-007	TB96-008	TB96-005	TB96-006	TB96-004c
Mo	9	6	3	4	6	4	< 2	2	10	3
Cu	9693	4610	7936	7041	9748	6328	11907	991	1022	163
Pb	2497	1502	3762	5132	10315	1341	10508	435	120	212
Zn	6340	3074	11207	32048	40215	4238	9653	564	193	363
Ag	15.1	6.2	9.9	9	14.9	4.2	23.4	1.1	0.6	0.7
Ni	8	16	5	6	12	16	23	87	20	2
Co	5	7	4	8	10	7	17	24	9	< 2
U	< 10	< 10	11.0	< 10	< 10	12.0	< 10	18.0	14.0	24
Sr	83	80	23	19	45	17	38	2	18	32
Cd	12.9	4.2	16.9	45.2	58.4	10.7	23.3	3.8	1.0	0.4
Sb	5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	9
Bi	101	12	42	59	121	19	130	13	< 5	7
V	61	85	87	60	116	292	72	213	64	5
La	16	19	16	12	15	14	14	< 2	35	21
Cr	42	43	50	97	126	27	33	575	27	4
Ba	34	57	12	62	338	108	62	404	465	625
W	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Sn	3	< 2	4	2	2	3	5	< 2	< 2	16
Y	18	24	26	17	23	14	7	49	40	72
Nb	< 2	3	3	< 2	< 2	< 2	< 2	< 2	< 2	42
Be	< 1	< 1	2	2	2	1	< 1	< 1	< 1	2
Sc	9	11	11	9	17	7	7	52	17	1
Au*	68	21	14	62	139	92	86	6	8	7

Au - Wet extraction/AA*

probably originally been mainly present in carbonates, but is now largely incorporated in amphibole, formed as a result of metamorphism. However, the samples have low totals, which is probably due to a high carbonate content; up to 10 vol.% carbonate has been estimated in a few sections. The most probable origin of this rock type is as a reaction skarn, formed as a result of reaction between a carbonate layer and the schists. The carbonate is observed as a horizon with thin discontinuous layers in the easternmost part of the area (Fig. 2).

The skarn-type mineralization contains on average 0.82 % Cu (range (0.46-1.19 %), 1.53 % Zn (0.31-4.02 %), 0.50 % Pb (0.13-1.05 %), 12 ppm Ag (4.2-23.4 ppm) and 69 ppb Au (14-139 ppb). There are no clear differences between the mineralizations in the eastern Gardsbekken versus Brunesbekken occurrence, with respect to their metal ratios, although the mineralizations in Brunesbekken are richer. The bismuth content of is locally very high in the Brunesbekken mineralizations, and may reach up to 130 ppm. This element is present in its native state as inclusions in galena. The content of cadmium is also high and is closely correlated with lead. Cadmium is probably lattice-bound in galena.

Two mineralized sericite schists have also been analyzed (samples TB96005-006, Table 2 a). They have, as expected, low contents of base-metals (about 1000 ppm Cu, 100-500 ppm Pb and 200-2000 ppm Zn).

The quartzite associated with one of the mineralizations in Brunesbekken contains virtually only SiO_2, Al_2O_3 and K_2O, which agrees with its content of mainly quartz and muscovite. The quartzite has a barium content of 625 ppm, which is higher than in the sulfide mineralizations in Brunesbekken. This suggests formation of the quartzite as an exhalite, distal from major sulfide mineralizations.

Grasvatnet

Seven samples of the skarn mineralizations south of Grasvatnet have been analyzed by XRF and ICP (table 2 b). Both major and trace elements show that the host rock is inhomogeneous (e.g. SiO_2 - 35.8-63.1 %, MgO - 2.2-11.6 %, CaO - 1.9-12.9 %, Fe2O3 - 9.6-27.7 %), and concurs which is also what can be seen in outcrop and microscope (see above). Of note is a

Table 2 b: Whole-rock geochemistry of the Grasvatnet mineralizations

XRF - Major elements (NGU Lab)

	Skarn-type							Sericite schist type	
	TB96-016	TB96-017a	TB96-017b	TB96-018	TB96-019	TB96-020b	TB96-021	TB96-022	TB96-024
SiO2	63.09	41.11	46.89	44.27	43.78	36.51	35.79	68.62	55.53
Al2O3	10.90	10.91	12.42	7.76	14.13	14.57	11.36	15.91	15.97
Fe2O3	9.61	16.86	14.69	27.69	12.75	20.06	16.56	3.52	11.33
TiO2	0.63	0.73	0.70	0.45	0.28	0.80	0.55	0.60	0.89
MgO	7.32	11.61	10.52	2.17	9.93	7.53	8.49	1.36	1.63
CaO	3.54	6.68	6.63	1.89	12.94	9.23	9.69	3.10	1.20
Na2O	0.33	0.23	0.64	<0.10	<0.10	0.28	0.30	2.75	0.41
K2O	1.30	0.28	0.88	0.68	0.12	0.14	0.20	2.55	4.75
MnO	0.34	1.06	1.37	0.41	2.73	2.66	1.98	0.06	0.04
P2O5	0.15	0.16	0.11	0.04	0.17	0.11	0.17	0.17	0.25
LOI	1.54	4.40	2.94	4.58	1.39	3.29	3.89	1.10	7.56
Sum	98.75	94.04	97.80	89.43	98.27	95.18	88.98	99.74	99.55
Cl	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F	<0.10	0.33	0.20	0.42	0.22	0.46	0.42	<0.10	<0.10
S	0.48	2.94	0.98	7.70	0.85	1.92	3.00	<0.10	7.27

XRF - Trace elements (NGU Lab)

	Skarn-type							Sericite schist type	
	TB96-016	TB96-017a	TB96-017b	TB96-018	TB96-019	TB96-020b	TB96-021	TB96-022	TB96-024
Ga	13	13	21	< 10	16	26	33	16	21
Cu	5229	34246	10084	84092	10981	15242	16619	137	99
Pb	24	460	1040	17	67	4436	6005	95	42
Zn	181	2487	1405	245	1345	5277	22331	90	83
Yb	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Ce	17	26	43	70	29	59	89	158	< 10
Nd	< 10	28	20	< 10	16	31	52	64	< 10
Nb	9	13	8	10	< 5	13	7	23	9
Zr	125	144	136	85	43	141	115	353	158
Y	18	15	23	14	18	18	19	46	13
Rb	53	< 5	23	23	< 5	< 5	5	98	74
Th	26	11	18	< 10	< 10	43	44	14	< 10
Cr	61	89	93	35	27	114	81	80	633
As	< 10	< 10	25	< 10	< 10	125	96	< 10	13

ICP total digestion (ACME Labs.)

	Skarn-type							Sericite schist type	
	TB96-016	TB96-017a	TB96-017b	TB96-018	TB96-019	TB96-020b	TB96-021	TB96-022	TB96-024
Mo	< 2	163	197	< 2	17	239	105	< 2	< 2
Cu	5201	38231	12865	54898	12966	15820	13808	55	83
Pb	24	581	1558	17	73	5520	6103	57	18
Zn	194	2743	1717	348	1345	5867	29233	88	78
Ag	3.4	12.0	9.5	24.9	6.6	86.0	15.3	< .5	0.5
Ni	19	12	10	15	13	10	18	27	138
Co	16	12	6	8	12	6	28	7	43
U	< 10	< 10	< 10	< 10	< 10	< 10	< 10	38	11
Sr	9	12	12	7	68	81	130	304	92
Cd	0.5	8.3	3.5	5.8	4.0	13.0	40.5	< 0.4	< 0.4
Sb	< 5	< 5	< 5	9	< 5	< 5	< 5	5	< 5
Bi	29	44	36	46	8	71	44	< 5	< 5
V	102	90	108	66	66	120	84	36	205
La	8	15	17	8	18	10	33	86	2
Cr	50	67	71	33	25	83	113	59	493
Ba	114	36	89	41	9	46	148	961	38
W	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Sn	3	6	2	5	6	4	4	4	2
Y	21	22	25	20	25	27	26	48	15
Nb	< 2	< 2	< 2	< 2	< 2	< 2	< 2	12	3
Be	< 1	< 1	< 1	3	< 1	5	4	3	< 1
Sc	17	12	14	16	9	24	15	14	38
Au*	50	140	256	127	188	641	207	5	7

Au - Wet extraction/AA*

relatively high content of MnO in some of the samples, up to 2.7 %. This coincides with high contents of CaO and Al_2O_3, indicating that the element is present in Mn-rich garnet or/and in amphibole.

Regarding base metals these mineralizations are very copper-rich and the average content of seven samples is 2.20 % Cu (range 0.52-5.50 %), 0.59 % Zn (0.02-2.92 %), 0.20 % Pb (0.002-0.61 %). The content of precious metals is very high, 23 ppm Ag (3.4-86 ppm) and 230 ppb Au (50-641 ppb), especially when taking into account that this is only a weak impregnation with a maximum of 10-11% sulfides. Also notable is a high content of molybdenum (103 ppm and range < 2 to 239 ppm).

Two samples of the schist north of Okstindtjønna have been analyzed both by XRF and ICP (TB96022, -24, Table 2 b). The contents of base-metals are very low (≤ 100 ppm), which agrees with the fact that mainly pyrite was observed in the thin-sections. One of the samples is very rich in Ba (961 ppm), as well as La, Ce, Nd. Zr, Y and Sr. The cause for enrichment in these elements is not readily explicable.

Rabotsbekken

Trace element ICP-AES analysis of the principal ore types belonging to the Rabotsbekken mineralizations are presented in Table 2 c. In general, the chemistry of the different ore types is in good agreement with field observations and microscopic examinations. The polymetallic ore comprises equal proportions of Cu, Pb and Zn yielding a combined concentration of about 1 wt.%. No other analyzed elements obtained notably high concentrations. As expected, the arsenopyrite ore yielded relatively high concentrations of arsenic, whereas the combined concentration of Cu, Pb and Zn is less than 0.2 wt.%, with Zn as the dominant constituent. The content of gold was disappointingly low despite the high proportions of arsenopyrite. The galena ore yielded 1 to 5 wt.% Pb with an average of 3.2 %, and subordinate concentrations of Cu and Zn. A nearly perfect correlation occurs between Pb and Ag, with a Pb:Ag ratio of 1000:1.

Table 2 c: The Rabotsbekken mineralization (ICP - total digestion - ACME labs., Canada)

	galena ore				arsenopyrite ore			polymetallic ore			
	RBL96042	RBL96043	RBL96044	RBL96045	RBL96049	RBL96050	RBL96051	RBL96046	RBL96047	RBL96048	RBL96052
Mo	<2	<2	<2	<2	<2	<2	<2	5	2	4	2
Cu	49	48	47	32	781	567	547	3556	4070	2990	3132
Pb	9494	38712	28386	53369	731	544	1572	2310	2213	2491	644
Zn	553	569	788	1540	1175	1222	1076	3492	3639	3300	2777
Ag	8.3	33.0	21.4	50.7	1.6	1.2	3.1	1.8	1.9	1.4	3.2
Ni	14	4	3	4	10	10	12	10	10	11	11
Co	<2	<2	<2	<2	28	26	35	21	31	45	23
Mn	18	18	26	30	271	199	377	610	597	782	256
Fe	0.61	0.48	0.52	0.52	4.05	4.06	4.73	5.43	5.49	6.14	4.42
As	37	<5	15	<5	179	878	1353	6	6	8	7
Sr	3	7	<2	<2	41	36	38	39	38	32	37
Cd	2.4	8.9	6.2	15.2	1.4	1.4	1.4	12.3	10.0	9.1	7.5
Sb	23	54	53	102	<5	< 5	6	<5	< 5	< 5	<5
Bi	11	45	34	72	8	<5	13	28	22	20	19
V	6	5	6	2	13	16	13	13	15	15	16
La	2	<2	2	<2	9	13	10	7	5	6	9
Cr	4	5	4	5	12	11	11	14	13	12	19
Ba	14	13	15	7	99	98	88	29	57	47	78
Sn	6	16	15	23	8	8	7	7	9	7	7
Y	<2	<2	<2	<2	6	7	7	8	7	8	6
Nb	<2	<2	<2	<2	<2	<2	<2	2	3	3	<2
Be	< 1	< 1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sc	<1	<1	<1	<1	2	3	2	2	2	2	2
Au*	32	62	51	44	59	41	54	7	4	5	18

Au - Wet extraction/AA*

Discussions

The mineralizations in both the Brunesbekken and Grasvatnet area can be classified as skarn-type mineralizations. The host rocks are characterized by Ca-Mg-Fe silicates, like clinoamphibole and garnet, and probably formed by hydrothermal reactions between carbonates and silicates.

The mineralizations consist of disseminated sulfides, uniformly distributed in the host rock. At Brunesbekken the combined concentration of base-metals is on average 2.3 wt.%, mainly Zn and at Grasvatnet 2.9 wt.%, mainly Cu, but also 23 ppm Ag and 230 ppb Au. These are high values, especially taking into consideration that they are disseminated mineralizations. However, the mineralizations are related to irregular and discontinuous, thin lenses of very limited extent (a few meters) and thus have no intrinsic economic potential.

These skarn-type mineralizations are very different from what has been found in the Bleikvassli Area previously. Mineralizations with similar host rocks are known from the Mofjellet Area, in the Plurdalen Group (Marker 1983, Larsen et al. 1995). A possible formation model for these mineralizations is that metalliferous solutions have reacted with the carbonates, depositing the metals and forming the mineralizations. In the Brunesbekken Area the surrounding schists also contain graphite, meaning that low oxygen fugacity may also have been important for controlling deposition of the sulfides. Formation may have been related to the high-grade metamorphism in the area, which lead to transport and redeposition of sulfides in metamorphic fluids.

An important question is whether or not these mineralizations could be distal parts of more massive and economic mineralizations. In the Brunesbekken Area the mineralized horizon has a considerable length along strike. More massive parts could be found at depth and the presence of a strong TFEM anomaly at depth is promising. No evidence of strong folding was found during mapping, and the shape of the TFEM anomaly mimicks the structure found at the surface, with a gentle undulation of the rocks, with an E-W strike in the eastern and a NE-SW strike in the western part of the area (Fig. 2). However, the presence of a thick unit of graphite-rich schist at the same structural level as the mineralized rock, makes it also possible that the anomaly could be due to massive graphite.

The Grasvatnet skarn-type mineralization has a more restricted extent, and probably represents a strongly folded and boudinaged layer. This mineralization is at a stratigraphically higher level than the pyrite horizon close to Okstindtjønna and the Rabotsbekken mineralization (Fig. 7) and can not be geologically connected to them. Because of the limited extent and limited thickness, it is probable that this mineralization has no roots in a massive mineralization at depth.

Depending on the final interpretation of the Rabotsbekken mineralizations, which awaits more data, this occurrence can be classified as a low-grade sulfide mineralization or a high-grade exhalite horizon.

The strongest arguments in favor of an exhalative origin is the fact that this unit is an arsenic-rich quartzite which can only be followed for a few hundred meters along strike. Other quartzites observed in the Kongsfjell Group can be followed for several kilometers even though they only obtain a thickness of 2 to 5 meters, i.e. much thinner than the quartzites at Rabotsbekken.

The polymetallic and arsenopyrite mineralization probably represents the primary mineralizations given that the ore-forming phases are evenly disseminated throughout the rock. The galena mineralization, which has an obvious cross-cutting relationship to its host rock, must represent a secondary remobilized mineralization.

If the Rabotsbekken mineralization represents an exhalite, it might be related to a massive ore at depth. In the autumn of 1996, TFEM measurements were conducted over this mineralization, and strong anomalies were found at depths of 75-100 m and 150-200 m, in addition to one at the surface that picked up the mineralization. (see Fig. 7, Dalsegg 1996 b). The anomalies are exactly at the depths expected if the strike and dip of the rocks are correlated downward. However, as was the case for Brunesbekken, graphitic schists are associated with this mineralization, too (see Fig.9). So the anomalies could instead be caused by massive graphite.

COTICULES AT KONGSFJELLET

Regional helicopter geophysics revealed a strong magnetic anomaly at the southern slopes of Kongsfjellet. Reconnaissance studies in 1995, with a hand-held susceptibility instrument, documented that a banded garnet-magnetite-quartz rock was the origin of the magnetic anomaly (see also report 95.153).

This rock type, which is also known as a coticule, is typically associated with sulfide deposits and represents a distal facies of the mineralizations (e.g. Spry 1990). Coticules have also been found in close association with the Bleikvassli deposit (Skauli 1992). Follow-up studies this year were directed toward finding the extent of the coticule rock, whether or not it was associated with any mineralizations and to determine if lateral zonations were present and could reveal the direction in which a sulfide deposit would occur.

Field observations, mineralogy and whole-rock geochemistry

With the help of a hand susceptibility instrument, a horizon with high contents of magnetite, and locally with pink garnet, was followed for about 1 km along strike (fig.10). Taking into

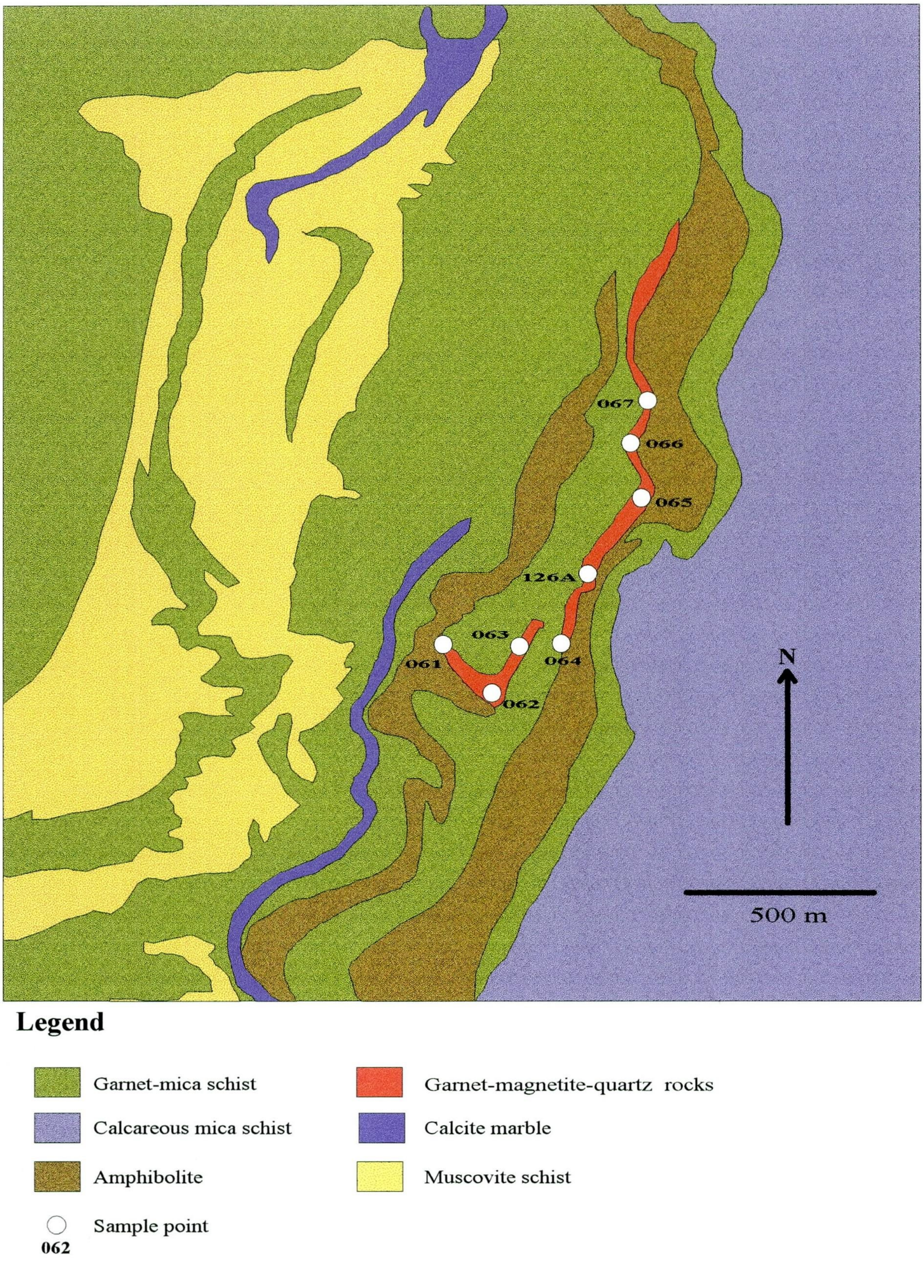

Figure 10: Geology in the central part of the Kongsfjell Area (see Fig. 1 for location), showing the extent of the horizon with garnet-magnetite-quartz rock. The position of samples for microscopic (Table 3) and geochemical investigations (Table 4) are indicated.

consideration the strong folding in the area, it is probably closer to 1.5- 2 km in length. The horizon is strongly folded between an amphibolite in the structural footwall and garnet-mica schists and quartz-feldspathic schists in the hangingwall. The amphibolite is the same unit which underlies the Bleikvassli deposit, thus the coticule is at the same stratigraphic level as this deposit.

The magnetite-rich horizon consists of magnetite-biotite-muscovite-quartz schists intercalated with thin lenses of garnet-magnetite-quartz rock or coticules. The coticules have lengths up to 6 m and a thickness up to 10-20 cm (report 95.153). According to the susceptibility measurements, the content of magnetite in the coticules varies between 5 and 15 %; this was later confirmed by microscopy (Table 3). Magnetite is concentrated in mm- to cm-thick bands in alternation with quartz- and garnet-rich bands. In many of the lenses garnet is absent. Green, Fe-rich clinoamphibole, deep brown Fe-rich biotite, epidote and muscovite are present in minor to trace amounts. Occasionally a few grains of chalcopyrite are also present.

Table 3: Mineralogy of the magnetite-rich rocks at Kongsfjell

Sample	**TB96061**	**TB96062**	**TB96063**	**TB96064**	**TB96065**	**TB96067**	**TB95126a**
Quartz	65	40	88	30	25	85	75
Muscovite	-	15	tr.	-	30	-	-
Biotite	5	10	-	20	25	-	tr.
Garnet	2	tr.	-	20	-	-	15
Epidote	3	5	tr.	13	10	tr.	tr.
Clinoamphibole	10	-	tr.	5	-	-	tr.
Plagioclase	-	20	-	7	5	-	-
Magnetite	15	3	12	2	2	10	10
Hematite	-	4	-	1	2	-	-
Ilmenite	-	3	-	2	1	-	-
Other	cpy,po	ap	-	tm,cpy	-	carb-5,cpy	carb

The numbers are estimated content in vol%

***abbrev**: ap-apatite,carb-carbonate, tm-tourmaline, cpy-chalcopyrite, po-pyrrhotite*
tr.-trace amounts

The content of magnetite in the surrounding quartz-mica schists is 1-5 %, which is 10-50 times more than in a typical garnet-mica schist. The schists contain typically 20 to more than 50 % mica, including both muscovite and biotite, 5-13 % epidote and locally, plagioclase as a major phase. Another characteristic feature of these schists is that they contain 3-7 % ilmenite + hematite, occurring in lath-shaped grains and typically in delicate epitaxial intergrowths, following crystallographic directions.

XRF (NGU) and ICP data (ACME, Canada) show that the coticules are very rich in SiO_2 (72.5-86.7 %) and Fe (7.9-20.7 % Fe_2O_3), whereas the contents of other elements generally are very low, showing that this is a magnetite-quartzite rock with no other major phases (Table 4). The content of MnO is also low, except in the cases where garnet is present. The analyses show no zonations with respect to either Fe/Mn ratio or base-metal ratios and contents.

Discussion on origin

Fe-Mn enriched sediments can form in different ways, and not necessarily related to sulfide mineralization. These processes involves halmyrolysis of basalt and sediment, low-temperature formation of nodules and crusts, and diagenetic enrichment in the sediment package (Wonder et al. 1988). To find out if the rocks found at Kongsfjell are related to any of the above-mentioned processes or are related to sulfide mineralization, it is necessary to look in more detail on the whole rock geochemistry and mineralogy of the rocks.

Electron microprobe analysis on one sample (TB96-126A) reveals garnets of grossular-spessartine-almandine composition (grs_{12-17} sps_{28-30} alm_{45-50}). Small amounts of calcite contain up to 4 % MnO and inclusions of Fe-Mn hydroxides.

The whole-rock data can be used to determine source components of such rocks (Wonder et al. 1988, Spry 1990). The SiO_2 versus Al_2O_3 diagram (Fig. 11 a) can be used to distinguish hydrothermally formed metalliferous sediments from those metalliferous sediments formed during diagenesis (hydrogenous sediments) or as deep sea sediments. In deep waters, sediments are dominated by clays which are very Al-rich and Al is practically immobile

Table 4: Whole-rock geochemistry of the magnetite-rich rocks at Kongsfjellet

XRF - Major elements (NGU Lab)

	coticule/banded magnetite-quartzite				garnet-magnetite-quartz-muscovite schist			
Sample	TB95126A	TB96-061	TB96-067	TB96-063	TB96-064	TB96-062	TB96-065	TB96-066
SiO2	85.37	72.46	86.73	83.35	55.74	61.80	51.22	51.50
Al2O3	1.42	2.40	0.61	1.62	15.09	15.51	19.64	16.26
Fe2O3	7.87	20.72	12.15	12.64	11.75	11.38	12.00	17.69
TiO2	0.05	0.11	0.05	0.13	1.20	1.71	1.53	1.44
MgO	0.08	0.86	0.21	0.44	3.21	1.22	2.80	2.67
CaO	2.15	2.59	0.47	0.89	6.35	2.18	3.11	1.93
Na2O	0.21	<0.10	<0.10	<0.10	1.63	4.82	2.31	2.46
K2O	0.02	0.42	0.03	0.27	2.52	1.87	4.91	4.13
MnO	0.87	0.08	0.02	0.16	0.48	0.11	0.15	0.11
P2O5	0.06	1.00	0.02	0.04	0.20	0.37	0.24	0.23
LOI	0.53	-0.16	-0.07	0.16	0.84	0.35	1.69	1.08
Sum	98.62	100.43	100.19	99.57	99.01	101.32	99.61	99.49
Cl	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
S	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10

XRF - Trace elements (NGU Lab)

	coticule/banded magnetite-quartzite				garnet-magnetite-quartz-muscovite schist			
Sample	TB95126A	TB96-061	TB96-067	TB96-063	TB96-064	TB96-062	TB96-065	TB96-066
Ga	11	14	11	10	17	21	21	22
Cu	12	73	86	32	122	43	44	212
Pb	< 10	< 10	< 10	< 10	28	17	< 10	12
Zn	< 5	119	< 5	15	81	92	102	122
Yb	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Ce	< 10	24	< 10	12	71	43	22	17
Nd	< 10	< 10	< 10	< 10	20	25	21	12
Nb	< 5	< 5	< 5	< 5	11	9	18	5
Zr	< 5	27	< 5	17	160	143	121	100
Y	< 5	37	< 5	5	31	37	42	34
Rb	< 5	< 5	< 5	8	72	58	89	98
Th	< 10	< 10	< 10	< 10	20	< 10	< 10	< 10
Cr	< 5	256	< 5	11	119	70	346	383
As	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10

ICP total digestion (ACME Labs.)

	coticule/banded magnetite-quartzite				garnet-magnetite-quartz-muscovite schist			
Sample	TB95126A	TB96-061	TB96-067	TB96-063	TB96-064	TB96-062	TB96-065	TB96-066
Mo	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Cu	6	54	67	30	107	39	35	167
Pb	7	8	< 5	< 5	26	14	< 5	5
Zn	12	112	12	23	91	115	110	130
Ag	0.6	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.8	< 0.5
Ni	14	51	7	14	50	27	128	154
Co	7	15	< 2	5	32	14	45	55
U	< 10	< 10	< 10	< 10	< 10	32	14	13
Th	2	3	< 2	2	8	< 2	4	< 2
Sr	14	14	7	22	269	227	166	187
Cd	< 0.4	< 0.4	< 0.4	< 0.4	1.1	0.9	1.5	1
Sb	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Bi	< 5	7	< 5	< 5	< 5	< 5	< 5	< 5
V	79	699	49	96	197	138	108	113
La	< 2	11	< 2	4	29	15	13	6
Cr	2	284	7	11	94	69	328	353
Ba	6	14	3	53	333	751	331	243
W	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Sn	4	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Y	2	45	2	7	44	46	54	54
Nb	< 2	< 2	< 2	< 2	8	4	12	3
Be	< 1	5	< 1	< 1	< 1	< 1	< 1	< 1
Sc	< 1	5	1	3	30	38	52	42
Au*	2	< 1	1	5	2	37	1	2

Au - Wet extraction/AA*

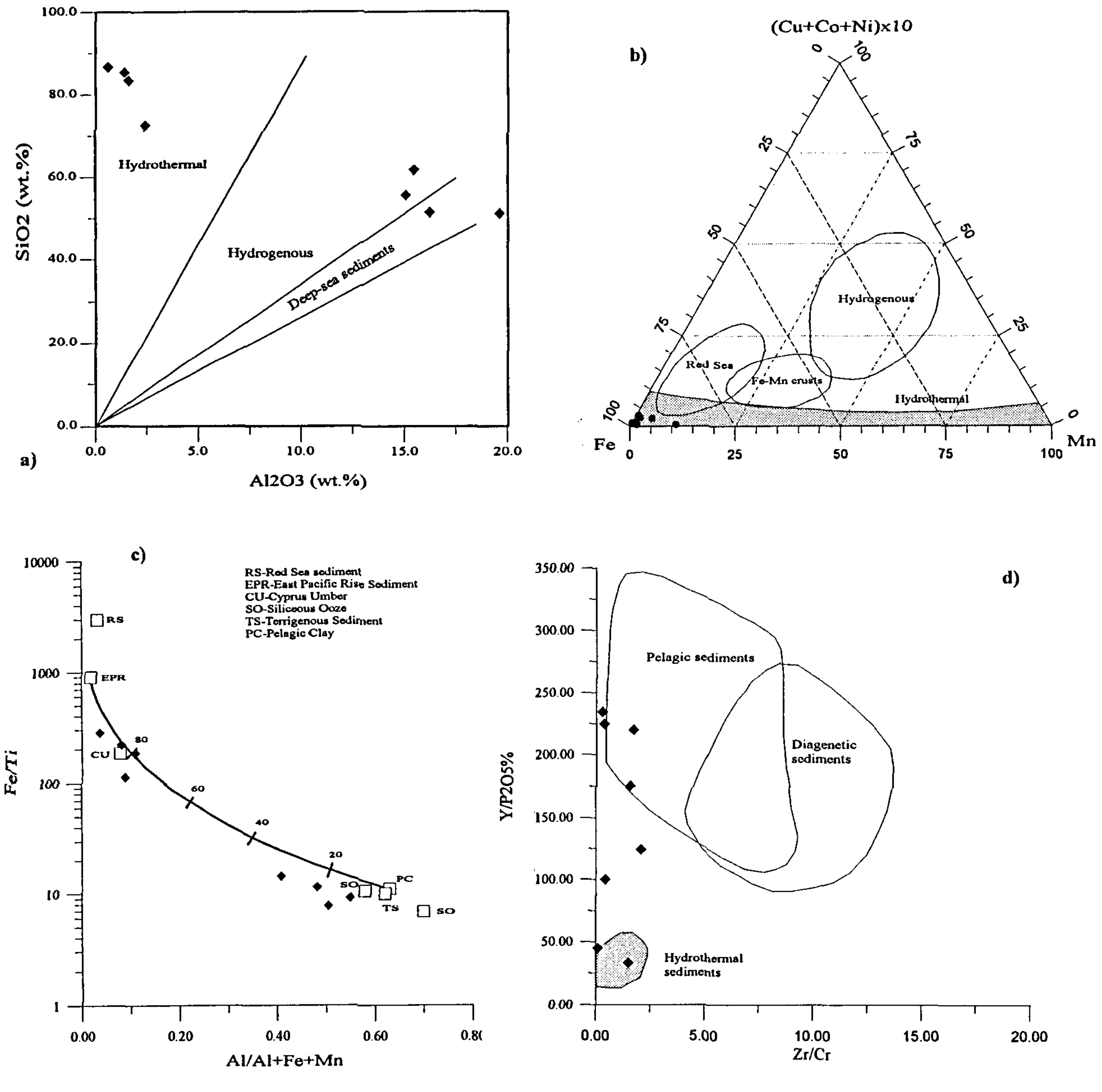

Figure 11 a-d: Diagrams for classification of and discrimination between various types of Fe-Mn rich rocks. Original diagrams from Wonder et al. 1988 and Spry 1990. For explanations, see text.

during hydrothermal activity. However, incorporated clay-rich material in hydrothermal sediments may move these into the field of hydrogenous or deep-sea sediment. The magnetite-quartz rocks from Kongsfjell plot in the hydrothermal field, whereas the magnetite-mica-quartz schists plot partly as deep-sea sediments and partly as hydrogenous or diagenetic rocks.

The elements Cu, Co and Ni are known to be concentrated more strongly in hydrogenous Fe-Mn sediments than in hydrothermal sediments. This is mainly due to the low accumulation rate of Fe-Mn sediments, which allows them to scavenge the sea water for these elements (Toth 1980). In the Cu+Co+Mn-Fe-Mn diagram (fig.11 b), all the samples from Kongsfjell plot in the hydrothermal field.

The plot of Y/P_2O_5 vs. Zr/Cr diagram (Fig.11 c) distinguishes between fields for deep-sea sediments, diagenetic sediments and hydrothermal sediments. P and Y are enriched during diagenesis due to formation of biogenic apatite, and Zr is much lower in hydrothermal sediments than in pelagic or diagenetic formed sediments, in addition to being relatively more immobile than Cr during hydrothermal activity. At Kongsfjell, the magnetite-quartz rocks plot partly in the hydrothermal field, whereas the associated schists plot in the field for pelagic sediments.

The Fe/Ti vs. Al/Al+Fe+Mn diagram (fig. 11 d) can be used to distinguish between hydrothermal and deep-sea sediment end-members as well as the degree of mixing between the two. Hydrothermal sediments have a very low Al content (as stated above) and a high Fe/Ti-ratio, compared to deep sea sediments. Mixing between the two end-members is revealed in such a diagram as a hyperbolic curve. The magnetite-quartz rocks and the magnetite-mica-quartz schists from Kongsfjell plot in two distinct groups, close to both end-members, exemplified by East Pacific Rise metalliferous sediments (EPR) and terrigeneous sediments (TS), respectively.

From the mineralogical and petrologic evidences shown above, the magnetite-rich rocks most likely are hydrothermal sediments representing distal facies of the lead-zinc mineralizations in the area. The more schistose varieties were partly mixed with surrounding clastic sediments.

However, no mineralizations were found directly associated with these rocks. It cannot be ruled out that these mineralizations are distal facies of the Bleikvassli deposit.

SUMMARY AND CONCLUSIONS

1: Follow-up work has been conducted in three restricted areas of the 1200 km^2 large Okstindan Area. The areas were chosen on the basis of anomalies identified during earlier regional geological, geophysical and geochemical work.

2: Mineralizations found in the areas are not economic and consists of impregnations of chalcopyrite, pyrrhotite, sphalerite and galena in mica schists, quartzites and «skarn-like» assemblages.

3: The skarn-type mineralizations found in Brunesbekken and south of Grasvatnet consist mainly of clinoamphibole, garnet, quartz and biotite and have not previously been found in the Okstindan Area. They are largely similar to mineralizations typical of the Plurdalen Group in the Mofjellet Area.

4: The Rabotsbekken zone consists of three distinguishable types of mineralization hosted in quartzite and quartzitic schists: Polymetallic mineralization bounded by arsenopyrite-rich mineralization (above) and cross-cutting galena mineralization (below). This occurrence can be classified as a low-grade sulfide mineralization or a high-grade exhalite horizon.

5: Deep geophysical anomalies (Transient Field EM) are connected to the mineralizations in both Brunesbekken and Rabotsbekken. However, graphitic schists are associated with the mineralizations and the cause of the anomalies may be either graphite or massive sulfides.

6: A 1.5-2 km long horizon of banded garnet-magnetite-quartz rock (coticules) was mapped out and sampled at Kongsfjellet. Based on mineralogical and petrologic evidence, this rock most likely represents hydrothermal sediments, which could be distal facies of some lead-zinc mineralization in the area. However, no mineralizations were found directly associated with these rocks.

Recommendations

On the basis of this geological work and the geophysical measurements it is recommended that the Transient Field EM anomalies are investigated by drilling. It is impossible to decide if these deep anomalies are caused by graphite or massive sulfides on the basis of geology and geophysics.

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