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Møkkelvatnet Project: The Skiftesmyr and Godejord Deposits

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Råstoffgruppe	Råstofftype
Malm/metall	Cu, Zn, Pb,Ag, Au

Sammendrag, innholdsfortegnelse eller innholdsbeskrivelse

Rapporten gir en kort geologisk beskrivelse av geologien i Grongfeltet og oppsummering av geologi og malmletingsresultater i Sanddølaområdet, på engelsk.
De 2 forekomstenes malm, sideberg, strukturer og malmreserver blir gjennomgått, samt den historiske utviklingen av undersøkelsene i området.
Rapporten er appendix til BV 4575.

THE MØKLEVATNET PROJECT

The Skiftesmyr and Godejord deposits

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MØKLEVATNET PROJECT:

The Skiftesmyr and Godejord Deposits

The Grong District covers a 3000 km^2 area in central Norway, bounded to the East by the Swedish border, to the west by the River Namsen, to the south by the Sandøla Valley and to the north by the large Lake Namsvattnet and the Børgefjell national park.

The Grong District is underlain dominantly by Lower Palaezoic metavolcanic, metasedimentary and intrusive rocks, of Mid. Ordovician age, that comprises the Gjersvik Nappe, part of the larger Køli Nappe of the Upper Allochthon tectanostratigraphy within this part of the central Scandinavian Caledonides. These nappe sheets contain thrust emplaced terrains that are far transported slices of volcanic, intrusive and sedimentary rocks of ocean floor, rifted-arc and back-arc marginal basin infill that have been thrust eastward onto the Baltoscandinavian basement (Baltic Shield).

The Gjersvik Nappe consists mainly of a magmatic complex that is dominated by a mafic volcanite and subvolcanic intrusive complex which are overlain by sediments that have been derived, for the most part, from erosion of the magmatic arc during a period of extensive uplift and erosion.

Mafic volcanites dominate the island arc - rifted arc complex with felsic volcanites forming only a minor component. The felsic volcanites occur at several stratigraphic levels, often associated with massive sulphide mineralizations that are generally overlain by thin layers of banded iron formation (BIF), which regionally can form extensive marker horizons throughout the district.

The whole sequence has undergone extensive folding and shearing deformation related to thrusting and Nappe emplacement. The rocks are generally moderate to strongly sheared (well foliated) and have undergone Upper Greenschist, grading into Lower Amphibolite facies metamorphism within the western part of the district.

Volcanic hosted massive sulphide (VHMS) mineralization is common in the volcanic complex, occurring at several stratigraphic levels. Although most of the deposits are small (< 1M metric tons = tonnes), several major deposits occur in the district (Joma = 20M, Skorovass = 10M and Skiftesmyr = 4M tonnes). Three deposits have been exploited or are currently under production. Skorovass was mined from 1952 to 1984, divided into 2 periods; 1952-76, 3.9M tonnes, grading 39.1% S and 1.1% Cu of pyrite fines mined for the production of sulphuric acid, and 1976-84, 1.7M tonnes grading 1.15% Cu and 2.71% Zn mined for production of Cu and Zn concentrates. When production started at Joma in 1972, the total reserves were calculated at c. 20M tonnes of massive and disseminated ore containing 32% S, 1.3% Cu, 1.7% Zn with only minor amounts of Pb and recoverable Ag and Au. Production at Joma is forecast to stop around mid summer next year (1997). At the end of 1994, 9.6M tonnes of ore has been mined at Joma, grading 1.50% Cu and 1.46% Zn. The Gjersvik deposit (c. 1.6M tonnes, grading 1.60% Cu and 1.0% Zn), which lies 25 km to the west of Joma, is currently being mined and the ore transported to Joma for processing. Mining starterd in 1993, based on c. 500 000 tonnes grading 2.15% Cu and 0.60% Zn.

The Møklevatnet Area

The Skiftesmyr and Godejord deposits occur in the Møklevatnet area at the SW corner of the Grong District, c. 20-30 km east of the Grong community centre. The Skiftesmyr deposit occurs at roughly the same stratigraphic level in the Gjersvik Gp. magmatic complex as the Skorovass and Gjersvik deposits to the north. These two deposits are overlain by a pronounced layer of felsic volcanites. The Skiftesmyr deposit occurs in a slightly different environment and is overlain by a thicker sequence of mixed felsic/mafic tuffs and/or volcaniclastics which grades upwards into more mafic dominated tuffs and massive to pillowed lava flows. These rocks are metamorphosed under Upper Greenschist to Lower amphibolite facies conditions. Regionally, the rocks show varying degrees of shearing and are for the most part moderately foliated, and in some areas volcanic structures and textures are preserved. On approaching the massive ore zone, however, the country rocks become extreamly sheared.

Skiftesmyr

The orebody at Skiftesmyr consists mainly of Zn-Cu rich massive pyritic ore that occurs as thin layers or as a continuous series of ore lenses forming a relatively thin, plate-like orebody. The thickness of the ore zone varies between 2-20m, with 4-6m being most common. The massive ore contains many fragments of country rock near its contact with the host rock, especially within the upper and easern parts of the orebody. These fragments appear to be remnants of fold hinges that have been ripped apart and now occur as loose fragments, floating within the strongly sheared orebody.

The orebody

The orebody at Skiftesmyr consists dominantly of massive sulphide layers and lenses enclosed within a quartz-sericite, albite and chlorite rich schistose country rocks that contain variable quantities of disseminated and veined sulphides, dominantly pyrite. Minor quantities of chalcopyrite (cpy) and sphalerite (sl) are also present within these altered and sheared rocks, cpy being mostly confined to the darker chlorite rich rocks and sl in the pale, quartz-sericite and albite rich rocks. The massive ore is dominantly pyritic with varying subordinate quantities of cpy and sl and minor amounts of pyrrhotite (po). The Ag and Au mineralogy at Skiftesmyr has to date not been studied and the distribution of these precious metals within the orebody is little known because of the sparse amount of analytical data presently available. The main gangue minerals are quartz, chlorite and calcite.

Copper and Zinc are antipathetically related to each other and show a clear zonal distribution within the massive pyrite orebody, which is typical for most VHMS deposits. The Cu rich ore dominates within the eastern and upper levels of the orebody and Zn rich ore is consentrated in the western part and at depth in the orebody. The deposit is open at depth and towards the west, where the orebody also becomes distinctly thinner.

The massive pyritic ore at Skiftesmyr is a compact, homogeneous ore type of medium-grained size, generally in the range of 1-5mm. Although no detailed mineralogical study has been done here, the individual pyrite grains appear to be granular in nature haveing well developed grain boundaries and are relatively clean with few sulphide incluisions.

Chalcopyrite and sphalerite usually form grains at the boundaries between the larger pyrite grains. Pyrrhotite occurs only as a minor constituent within the massive ore and is found

mainly along shear planes and late fractures that cut across the pyrite grain boundaries. Thus, mineral separation of the Skiftesmyr ore should give relatively clean products and should not cause great problems, as did for i.e., the extremely fine-grained, complex pyritic ores from Skorovass and Joma.

Host rocks

The massive orebody is enclosed in intensely altered rocks that adjacent to the orebody are strongly sheared and schistose. On the south side of the orebody, the FW rocks are dominated by pale coloured, quartz-sericite and albite rich rock carrying large quantities of disseminated pyrite and quartz-pyrite veins. These grade into darker, chlorite rich rocks that contain minor quantities of pyrrhotite. The altered rocks are arranged in a zonal pattern around the orebody. Quartz-sericite rich rocks occur adjacent to the orebody and grade outwards away from the massive orebody into albite- and chlorite-rick rocks. Further into the FW, the chlorite-rich rocks grade into more normal chloritic greenstones rich in epidote and carbonate and with minor disseminations of po and py. Volcanic structures such as pillows are present in these rocks.

Near the surface, within the immediate HW to the orebody, the country rocks are visibly paler in colour, harder and are richer in quartz-albite with less quartz-sericite and chlorite. Deeper within the orebody, along the HW, the rocks are more schistose and become richer in quartz-sericite and chlorite.

On surface, to the NE of the main showing along the western edges of the Storedalen valley, pale coloured quartz-sericite and albite rich rocks occur that contain zones rich in pyrite disseminations and quartz-pyrite veining surrounded by darker chlorite rich rocks with only minor pyrite. These intensly altered and strongly sulphide impregnated rocks are thought to represent the feeder zone to the massive sulphide ores at Skiftesmyr that lie to the W and SW.

This N-NE trending zone of strong pyrite disseminated rocks corresponds with a strong EM anomaly found in the overburden covered lowland area to the N of the main showing. This anomali can be traced for several km to the NE.

North of the surface expression to the massive ore horizons, the HW rocks to the orebody consists of a of sequence of variably layered, massive felsic volcanites and/or intrusive sills (?) that are interlayered with fine-laminated felsic to mafic tuffs or tuffites? Some of these felsic layers show clearly turbiditic/ volcaniclastic textures (fine- to coarse-grained beds) and soft sediment slumping folds are observed. The quartz and albite rich felsic layers are generally variably magnetic in nature. Some extremely magnetic layers have been observed in drill core. The high magnetite contents in certain quartz rich layers may be derived from reworking of earlier magnetite bearing felsic volcanic rocks. This layered felsic tuff/ volcaniclastic sequense grades upwards into mafic dominated tuffs with minor felsic layers, which in turn grades stratigraphically upwards into a mafic massive and pillowed flow sequence.

The layered felsic-mafic tuffite/volcaniclastic and overlying mafic lava unit that lies to the north of the orezone is interpreted to be younger than the massive sulphide mineralization and associated altered HW and FW mafic volcanic rocks that host the massive orebody at Skiftesmyr. On surface, near the main showing, massive sulphide ore is in contact with irregular lenses (overlain by), bands and fragments of magnetite bearing quartzites

(recrystallized chert), which are interpreted as silica rich exhalites. Magnetite-bearing chert, with minor amounts of po and py, occur as layers and lenses of varying thickness and extent, at the contact between the two main rock units at Skiftesmyr. In simplest terms, the altered mafic volcanic complex forms the stratigraphic FW and the mixed felsic/mafic tuff-volcaniclastic complex forms the HW to the massive orebody.

Late, feldspar-phyric felsic and pale green gabbroid dykes are found cutting the ore zone and the overlying tuff/volcaniclastic complex.

Structures

The orebody occurs partially within a major shear zone. The massive pyritic ore, containing numerous fragments of folded country rocks, occurs as parallel ore layers and lenses within what appears to be a major shear zone along the HW side, throughout the whole length of the orebody. This is well demonstrated in most vertical sections. The shear zone appears to be an early structure and the ore zone plunges steeply to the NW within this structure. The distribution of Cu- and Zn-rich zones within the orebody and the ore thickness also appears to plunge in a NW direction, suggesting that they also may be related to later folding and shearing deformation.

The surface geological map over Skiftesmyr shows that the area has been folded into a major open flexure. The rocks to the NE and E of the main showing trend to the north and dip steeply to the west and rocks within the ore zone and to the west, trend roughly E-W and dip steeply (60-65°) to the north. This is a late crenulation type fold having NE steeply plunging fold axes.

Ore reserves and production plans

The earliest ore reserve calculation quoted for the Skiftesmyr deposit was carried out in 1977 by Grong Gruber A/S and gave a geological ore reserve of 3.5M tonnes grading 1.16% Cu and 1.79% Zn. Later drilling has not changed to any degree this figure from 1977, as much of the later drilling (1980-92) was confined to filling in details within the upper levels of the orebody.

In 1992, Norsulfid A/S presented an ore reserve calculations for the Skiftesmyr deposit which included all drilling done on the deposit up to 1992 (Norsulfid A/S company report to the Mining Commission, BV 2882). Plans for both underground and an open pit mining was also presented in 1992 (Norsulfid A/S company report to the Mining Commission, BV 2883):

1) cut-off 1%Cu equivalent: total 2 746 470 tonnes grading 1.23% Cu, 1.86% Zn, 11.37 ppm Ag, 0.35 ppm Ag and 37.52% S. The calculated ore zone has a strike length of 400m and a vertical length of 400m. The thickness of the ore zone varies between 2-21m.

2) cut-off 2% Cu equivalent: total 1 759 417 tonnes grading 1.38% Cu, 2.13% Zn, 12.99 ppm Ag and 0.37 ppm Au.

3) According to underground mining plans reported by Norsulfid A/S (report BV 2883), a total of 2 684 000 tonnes of ore was planned to be taken out (cut off 1% Cu equivalents), grading 1.08% Cu, 1.63% Zn, 8.65 ppm Ag, 0.31 ppm Au and 34.6% S. The reduced tonnage and grades quoted here results from ore being tied up in pillars and from waste rock dilution.

Godejord

The Godejord deposit lies c. 3-4 km SSW of Skiftesmyr, in a slightly different geological environment. The rocks at Godejord consist of a complex dominated by mafic volcanites and minor tuffite/ sediments that have been strongly deformed and metamorphosed under Lower Amphibolite facies conditions. The whole sequence appears to be inverted at Godejord. Mafic volcanites dominate. The lower part of the sequence is dominated mostly by thick layers of massive flows, dykes and subvolcanic high level doleritic intrusions or sills and the upper part by pillowed flows. These two units are separated by a very persistent BIF/tuffite horizon that forms a prominant marker horizon throughout the district. At Godejord, this unit forms the HW to the main (East) orebody.

This sequence of mixed mafic volcanites/ tuffitic rocks is distinctly different from those found at Skiftesmyr. Trace element characters of the volcanic rocks are distinctly different from those found at Skiftesmyr, and of those in the Gjersvik Gp. in general. It has been suggested (Grenne and Erichsen, 1996) that the Godejord volcanites may in fact be older than the Gjersvik Gp. rocks, and possibly of late Proterozoic (Cambrian?) age. The Godejord volcanites may be related to a belt of amphibolitic greenstones that host a major Fe deposit (BIF) found to the west of the Grong District.

Only minor intrusive rocks are found at Godejord. Thin feldspar-phyric felsic dykes are present near the ore zone and pale coloured gabbroic bodies are found to the north.

The Godejord ore zone lies at a level in the thick volcanic sequence that is dominated by calc. rich tuffites with iron formations and cherts intercalated with mafic volcanites and minor felsic unites. The total strike length of the mineralized zone is in excess of 2km. However, the most interesting mineralization is confined to a c. 500 m long zone centered around the main Godejord showing. The ore zone has roughly a E-W trend and dips steeply (60-70°) to the north. The thickest part of the orebody appears to plunge steeply to the NE, which is in agreement with interpretations made by Outokumpu OY in 1992 for down-hole geophysics on the whole eastern ore zone.

The East orebody at Godejord lies adjacent to a prominant magnetite-bearing quartzite (recrystallized chert). This silica exhalite unit that forms the HW to the ore, is folded into a tight isocline just west of Godejord, the northern limb of this fold continues for many km to the east. The rocks immediately surrounding this quartzite horizon is strongly sheared and the quartzite is often found as lenses along the strongly sheared extended limbs. Rocks that are in contact with the quartzite are also strongly altered into pale albite-epidote- carbonate rich assemblages that often show zonal arrangements, grading from quartz-sericite-pyrite to quartz-albite through to chlorite-epidote-carbonate (siderite-ankerite-dolomite?) rich rocks trending away from the most intensely altered, central parts of the mineralized zone. Several parallel zone of altered rocks have been noted surrounding the Godejord mineralization.

Host rocks

Interpretation of the host rocks is difficult as many different geologists have logged the drill core over the years. Because of the sheared nature of these rocks, it is difficult to compare the lithological data from drill holes over the whole deposit to the surface geology. The drill holes are dominated by rocks that are strongly banded to laminated, often on a cm-dm scale. These laminated rocks were originally interpreted as tuffites, showing variable contents in felsic to mafic type laminae and layers rich in carbonate, and all posible gradations

of these. However, much of these layered units are stongly sheared and some are mylonitic in nature. Much of the carbonate 'tuffites' up in the HW to the ore zone (surface and down to 110-150m above HW of the ore zone) are rich in calcite, ankerite and siderite (dolomite?) porphyroblasts, and some zones rich in large hornblend sheaths are also common. These rocks can also be interpreted as resulting from alteration during a period of intense hydrothermal activity related to the formation of ore mineralization at Godejord.

Below the ore zone, tuffite sequence with felsic layers is more common and an up to 10m thick quartz keratophyre unit, possibly intrusives/dykes are also common.

Greenstones, present as relatively homogeneous fine to medium grained metabasalts, are more common away from the ore zone, both above and below the ore zone. A 35-50m thick sequence occurs 20m below the ore zone. Pillowed and dykes like structure are observed locally within the drill core and are both also observed on surface to the north of the drill sites.

Banded Iron Formation (BIF) horizons occur at several places in the stratigraphy, as thin, partly fine-laminated bands. Pure BIF is most common at levels 190-230m (called the New Godejord zone) and 35-40m above the main ore horizon. Within these zones, the BIF can occur as pure Fe-sulphide, magnetite or pink Mn-rich garnet rich bands. Band thicknesses from mm to several dm are common, often intercalated with layers of pure quartzite (recrystallized chert). Gradations between the 3 types (sulphide-, oxide- and garnet-chert) are common and gradations between pure BIF and various tuffitic rocks is also common, such as felsic to mafic tuffites with varying contents of magnetite, pink garnet and Fe-sulphides and quartz-rich tuffites.

Godejord orebody

The Godejord deposit is a strongly tectonized Zn-Cu-(PB-Ag-Au) mineralization with variable contents of pyrite. The deposit occurs in an area that is strongly covered by overburden and the mineralized zone is uncovered in several small workings over a distance of 1100 m along its E-NE strike direction. Mineralization is concordant with the enclosing strongly foliated rocks that dip steeply (50-75°) to the N-NW. Most of the zone contains relatively weak sulphide mineralization.

Semi-massive to massive mineralization is only found in the eastern part of the zone, around the main showing at Godejord. Here, the ore zone is closely associated to a magnetite-bearing quartzite lens (recrystallized chert), that for the most part forms the HW to the deposit and locally can reach thicknesses up to 10m. The mineralized zone at Godejord is confined to the FW of a prominant quartzite (chert) horizon that trends roughly E-W and dips 60-70° to the north. The orebody is thickest and richest around the main showings (called the John Godejord skjerp) and the most interesting mineralization plunges steeply to the NE.

Ore mineralization ocurs within a zone containing a variety of host rocks ranging from quartz, carbonate, quartz-sericite and actinolite-tremolite rich layers. Pyrite dissemination is most common and quite variable and interlayered with bands of semi-massive to massive pale, honey yellow coloured sphalerite and chalcopyrite rich disseminations in dark hornblend-actinolite rich layers. The individual layers vary from cm to dm in thickness (i.e., 10-30cm thick layers of massive sphalerite). Au mineralization may be found associated with quartzite lenses and layers within the mineralized zone, as is the case to the west of here. Au

may have been derived through remobilization from chert/BIF layers that have been tectonically reworked and hydrothermally altered during the period of sulphide deposition.

The richest parts of the deposit occurs within a zone up to 60m long and 15m thick, where grades can reach up to several % Cu, 0.7%Pb, 80 ppm Ag, 5 ppm Au and 25% Zn. This ore type, with relatively high values of Zn, Pb, Au and Ag is somewhat atypical for the Godejord sulphide ore zone. Another anomalous trait of the Godejord deposit is its large quantities of extremely Fe-poor, pale honey-coloured sphalerite.

At depth, below the surface extent of the main showing at Godejord, the mineralized zone becomes more tectonized and strongly sheared, with quartzite lenses and remobilized quartz fragments occurring throughout the ore zone. The mineralized zone appears to form several en echelon ore lenses that are cut by several steeply dipping shear zones.

Deeper within the ore zone, at 150-200m depth in DDH 121,126 and 127, the ore zone is much thinner and more tectonized and irregular in nature. Here, the ore zone consists mainly of weak disseminations of mainly sphalerite and pyrite occurring as irregular slivers and sheared lenses within a breccia-like to irregular bands of quartz-sericite matrix. Bands of pure quartzite are found and bands rich in more or less pure pyite are also common. Sulphide disseminated tuffites interlayed with BIF bands (often garnet bearing) are found in the immediate HW to the mineralized zone. At the FW contact to the ore zone, the mineralization is generally in sharp contact with layered tuffites.

Rich ore, found near the surface around the main showing at Godejord, does not continue down to depth. At c. 250m depth the whole mineralized zone is less than 1m thick and strongly tectonic in nature.

From the East orebody (main showing area), the mineralized zone at Godejord continues to the west for c. 1.5km and for about c. 1km to the east. The thin mineralized zone corresponds to a prominant IP anomally in the strongly overburden cover terrain. To the west, the mineralized zone has a max. thickness of 4-5m consisting of stongly altered quartz-sericite-albite rich rock carrying variable quantities of pyrite and minor sphalerite that occur as dissemination and veins. This sulphide disseminated alteration zone appears to cut through a more or less homogeneous, massive dolerite complex. The orebody beneath the quartzite horizon at Godejord is interpreted as being a calc-silicate skarn mineralization, occurring as actinolite-tremolite, quartz, carbonate and quartz-sericite rich rocks that contain variable disseminations to semi-massive to massive mineralization rich in pyrite-sphalerite-chalcopyrite±galena.

Ore Reserves

An ore reserve calculation was done by Norsulfid A/S (Norsulfid A/S report to Mining Commission; BV 2882) in 1992 for a feasibilitty study for underground drift at Godejord (report BV 2884 for underground mining plans). The reserves were based on underground production taken at levels between the surface (307m) down to the 240m level (300, 280, 260 and 240m levels). Ore reserves for the planned production was calculated at 76 221 tonnes grading 0.76% Cu, 7.76% Zn, 24.47 ppm Ag and 0.83 ppm Au. A 16.5% waste rock dilution factor is included in these figures.

NGU did an ore reserve calculation for Godejord for the North Trøndelag Fylkeskommune in 1996, based on all drill holes (31 DDH) from the deposit. This includes 2-3 new deep hole that intersect the ore zones at a depth of 250m below the main showing. The mineralized zone of interest is called the 'East Orebody' and lies beneath the main showing at Godejord, over a strike length of 500m and down to a depth of 250m (NGU report 96.024). The NGU reserve is quoted in two figures base on a cut-off of ; 1) 1% Cu equivalent, and 2) 2% Cu equivalent:

1) cut-off = 1% Cu equivalent; deposit size, 250 000-300 000 tonnes (150m strike length plus 200m plunge length to depth) grading 0.6% Cu, 4.2% Zn, 0.1% Pb, 15 ppm Ag and 0.4 ppm Au.

2) cut-off = 2% Cu equivalent; deposit size 100 000 tonnes (100m strike length and 100-120m plunge length at depth) grading 0.8% Cu, 6.9% Zn, 0.2% Pb, 20 ppm Ag and 0.8 ppm Au.

References:

Grenne, T. and Erichsen, E., 1996: 3-D modellering, tonnasje- og gehaltberegning av Godejordforekomsten, Grong, Nord-Trøndelag. NGU Rapport nr. 96.024, 41p.