Pb-isotope constraints on the metallogeny in the Meråker Nappe

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Introduction

The Pb-isotope compositions of ten sulphide deposits in the Caledonian Meråker Nappe are presented and discussed. The purpose of the investigation has been to characterise the metal sources of the sulphide deposits and in this way determine whether all the deposits were part of the same mineralising system or if there are variations throughout the district.

Regional geology

The deposits are hosted by rocks with different tectonostratigraphic positions in the Sulåmo Group and the Kjølhaug Group. Together with the tectonically overlying Fundsjø Group to the west and the underlying Slågan Group to the east, these rocks constitute the Meråker Nappe (Wolff 1979) of the Upper Allochthon (Gee et al. 1985). Based on one fossil discovery (Getz 1890) and correlations with other districts in the Upper Allochthon, the Sulåmo Group is considered to be of Middle Ordovician age, and the Kjølhaug Group of Late Ordovician age (Wolff 1967). Inversion of the lithological successions is believed to have occured during the Caledonian orogeny (Roberts 1967).

The Sulåmo Group is dominated by phyllites and a metasandstone, but also comprises two greenstone units, referred to as the Turifoss (Fig. 1) and Drivsjøfjell Formations (Siedlecka 1967). The greenstones are believed to be metavolcanites (Chaloupsky & Fediuk 1967); geochemically they show a somewhat depleted tholeiitic affinity similar to ocean floor basalts (Hardenby 1986).

The Kjølhaug Group is a thick unit of phyllites and metagreywackes (Fig. 1), interpreted as flysch and turbidite formations (Siedlecka 1967), which are intruded by numerous, Caledonian, hornblende metagabbros (Siedlecka 1967, Wolff 1973, Hardenby 1980). The gabbros in the northern part of the area form large bodies (Fig. 1) which are generally coarse-grained and have a mineralogical layering.Those in the southern part of the area are smaller and form sheets or sills, and are usually fine-grained and without laye-

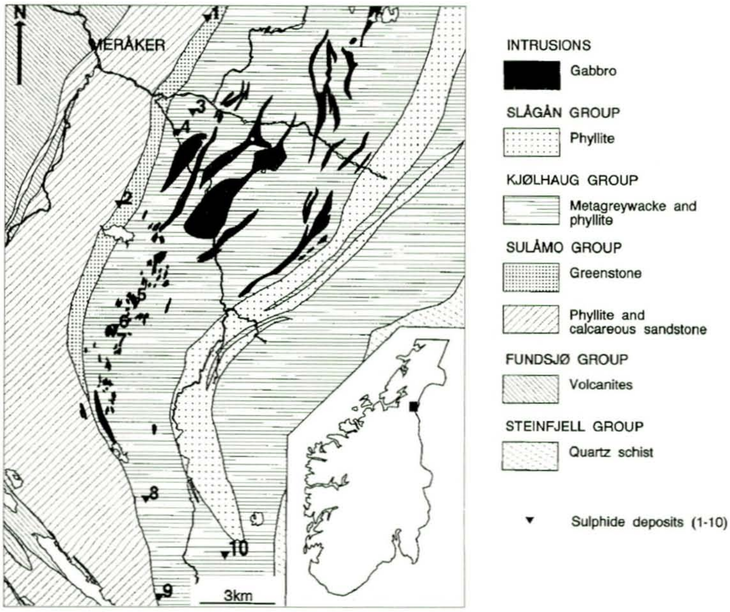

Fig. 1. Simplified geological map of the Meråker district. Mineralisations:
1. Geitberget
2. Sagskjerpet
3. Hammerskallen
4.Skomakermoen
5. Søndre Knoll Skjerp
6. Duddu, 7.Ebba, 8. Lillefjell
9.Gilså Gruver,
10. Dronningen

ring. The sulphide deposits are hosted by the metagreywackes in the Kjølhaug Group, commonly at contacts with small gabbros.

The rocks in the Meråker district exhibit deformation structures ascribed to at least two phases of folding (Wolff 1973). According to Tor Grenne (pers. comm., 1994) and the present author, there are also internal thrust and shear zones in the Sulåmo and Kjølhaug Groups. The amount of lateral movement on these zones is not known, but the rocks affected are severely deformed and original contacts may be obliterated.

Sulphide deposits

Although the deposits were briefly mentioned by Wolff (1967), no modern account has been published. Only a brief description will be given here. Work is in progress on a more detailed description (Birkeland et al. in prep.).

Based on field relations, the sulphide mineralisations may be divided into two groups. Deposits of both groups occur in both the Sulåmo and the Kjølhaug Groups (Fig. 1), indicating that both groups have been affected by the same ore-forming processes. The first group comprises massive, stratabound deposits, in places with a primary sulphide layering. Pyrite, pyrrhotite, sphalerite and chalcopyrite are the major component minerals. The mineralisations exhibit extensive wall-rock alteration, including sericitisation, silicification, chloritisation and pyritisation. These features indicate a hydrothermal syngenetic origin for this group of deposits. Among the sampled deposits, Sagskjerpet in the Turifoss Greenstone, and Søndre Knoll Skjerp and the Lillefjell deposit in the Kjølhaug Group may be assigned to this group. The Gilså deposit (Kjølhaug Group) probably also belongs to this group, but the very limited wall-rock alteration makes this deposit enigmatic.

The second group of deposits comprises those in shear zones. The mineralisations are strongly tectonised. Pyrrhotite, chalcopyrite, pyrite and sphalerite constitute a semi-massive ore, containing abundant fragments of the host rocks and eyes of clear quartz. Wall-rock alteration is limited to 1-2 cm of chloritisation of the immediate wall-rock. These deposits have been regarded as belonging to the same generation of deposits as the syngenetic massive sulphide deposits, and have been compared to the Røros type of deposits (e.g. Wolff 1967). They could represent feeder systems to stratabound deposits. However, due to the tectonisation this is hard to confirm. The Geitberget (the Turifoss Greenstone), Ebba, Duddu, Skomakermoen, Hammerskallen and Dronningen deposits (all in the Kjølhaug Group) belong to this group.

The sulphides in both types of mineralisations exhibit a metamorphic texture. The ore showings are generally small, the largest being the Lillefjellet deposit estimated to about 100,000 tons of ore.

Pb-isotope results and discussion

Galena is rare and the Pb abundance generally low in the sulphide deposits in the Meråker district (Karlstrøm 1993). Pb-isotope analyses were carried out by Geospec Consultants Ltd. on composite sulphide mineral concentrates from ore. These sulphide concentrates were leached to produce a residue containing lead from the crystal lattice, giving the initial Pb-isotope composition at the time of metal deposition or metamorphic recrystallisation. For all deposits, except for the Søndre Knoll Skjerp, two samples were analysed. The Søndre Knoll Skjerp is represented by one sample only. The data are available from the author.

The analytical results are plotted in conventional Pb-isotope diagrams in Figs 2a and 2b. As evident from the diagrams, the host rocks, and not the type of deposit, relates to the Pb-isotope composition of the mineralisations. The two deposits from the Turifoss Greenstone are identical within errors, in spite of one being of the stratabound type (Sagskjerpet) and the other of the tectonised type (Geitberget). The $^{206}Pb/^{204}Pb$-composition for the deposits in the Turifoss Greenstone varies between 17.747 and 17.780, the $^{207}Pb/^{204}Pb$-composition between 15.423 and 15.444, and the $^{208}Pb/^{204}Pb$-composition between 37.171 and 37.249. For deposits in the Kjølhaug Group the three isotope ratios are 18.127 to 18.512, 15.537 to 15.590 and 37.908 to 38.499, respectively. Such Pb-isotope compositions are normal for Scandinavian Caledonian massive sulphide deposits in the Upper Allochthon and denote a mixture of normal Caledonian lead in the actual region (Bjørlykke et al. 1993, Sundblad & Stephens 1983). They plot on the Upper Allochthon trend of Bjørlykke et al. (1993). The mineralisations in the Turifoss greenstone are within the composition of Caledonian depleted mantle, and the deposits in the Kjølhaug Group have Pb-isotope compositions similar to deposits in the Upper Allochthon influenced by sedimentary and volcanic metal source rocks (Bjørlykke et al. 1993).

The mineralisations in the Turifoss greenstone in the Sulåmo Group have homogeneous Pb-isotope compositions, within the standard deviation, that are less radiogenic than the deposits in the Kjølhaug Group. This lead must have been derived from a source low in U, Th and radiogenic Pb. The isotope values are at a level usually seen in rocks derived from the depleted mantle (e.g. Doe & Zartman 1979). The metal source for the sulphides is probably the Turifoss greenstone, which shows a depleted trace element geochemistry (Hardenby 1986).

The Pb-isotope compositions of some of the deposits in the Kjølhaug Group are heterogeneous, while others are homogeneous. The Pb-isotope variation giving the spread in the $^{207}Pb/^{204}Pb$- and $^{208}Pb/^{204}Pb$-direction for the heterogeneous deposits (Figs. 2a and 2b) is larger than the analytical standard deviation. Generally speaking, the metal source must be one or other of the rocks in the Caledonian nappes, the dominant source probably being the thick pile of greywackes in the Kjølhaug Group. The slightly more radiogenic samples are evidence for an influence from a somewhat more evolved source.

Both syngenetic and tectonic types of deposits in the Kjølhaug Group contain heterogeneous lead, whereas others have homogeneous Pb-isotope compositions. Hence, the processes leading to different morphologies of the deposits in the region did not determine the lead-isotope composition of the deposits. Two metal sources containing slightly different lead were available, but the mineralising process(es) did not homogenise metals from the two sources. The present author suggests that syngenetic hydrothermal massive sulphides were deposited in the sedimentary basin, the main metal source being the greywacke. The greywacke may have been inhomogeneous; or alternatively a different source rock may have been present. The convection cells below the mineralisations may have been isolated from one another, thus preventing a complete mixing between mineralising fluids. Alternatively, the two sources could have acted at different stages during the mineralising event. During a later compressional event, which could be that related to the final thrusting of the Meråker Nappe, these syngenetic deposits were deformed to varying degrees and some of them even remobilised into shear zones. Lead giving rise to the spread in the $^{206}Pb/^{204}Pb$-direction may have been introduced at this stage. The variation in the $^{206}Pb/^{204}Pb$-ratio is most easily explained by incorporation of radiogenic Pb into the sulphides during metamorphism. Due to the low Pb abundance in the deposits, even small amounts of radiogenic lead may have affected the Pb-isotope composition and been incorporated in the sulphides as a result of metamorphic growth.

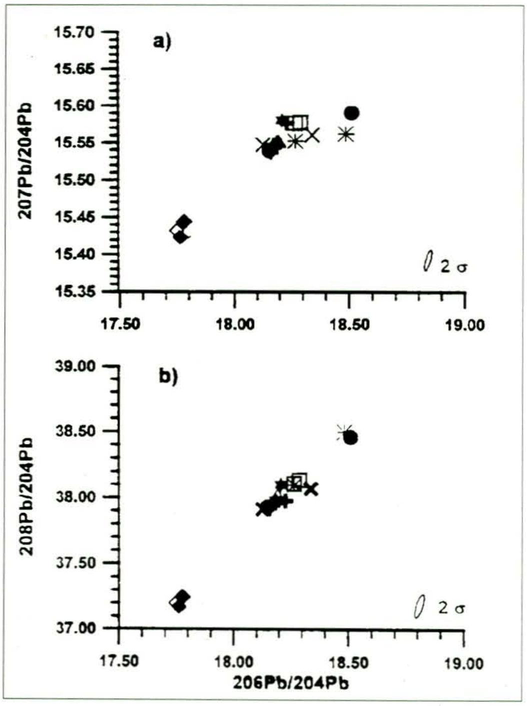

Fig. 2. Lead isotope ratios for sulphide mineralisations in the Sulåmo and Kjølhaug Groups. a) $^{207}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$ and b) $^{208}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$. ◇ Geitberget, ◆ Sagakjerpet, □ Ebba, ● Duddu, ▲ Søndre Knoll, △ Dronningen, + Skomakermoen, × Gilså, ✳ Hammerskallen and ✱ Lillefjell.

Conclusions

In both the Sulåmo and the Kjølhaug Groups in the Meråker Nappe, the primary ore-forming process was that of syngenetic, hydrothermal, sulphide deposition. The Pb-isotope investigation revealed that the metal source for deposits in the Sulåmo Group was a depleted rock, probably the Turifoss Greenstone in which the deposits are situated. The deposits in the Kjølhaug Group contain more radiogenic lead than the deposits in the Sulåmo Group and many of them are isotopically heterogeneous. The action of the hydrothermal convection cells in the Kjølhaug Group did not homogenise lead from different sources, or from one heterogeneous source, completely. At a later stage the already deposited mineralisations were deformed, some sulphides were remobilised into shear zones, giving semi-massive mineralisations with a tectonised style. The possibility that some of the semi-massive mineralisations are, in fact, feeder zones for hydrothermal fluids is likely, but cannot be proven due to the strong deformation. Deposits of both the massive stratabound and the tectonised type contain lead with the same isotopic characteristics. Slightly younger, more radiogenic lead was introduced into the mineralisations in the Kjølhaug Group and incorporated in the sulphides during metamorphism.

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