The Aitik Cu-Au deposit, Gellivare area, northern Sweden

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Aitik is Sweden´s largest sulphide mine and one of Europe´s most important copper producers at the end of 1999. About 322 Mt of ore, grading 0.4 % Cu, 0.2 ppm Au and 4 ppm Ag, has been produced since production started in 1969. The deposit is situated 15 km southeast of Gellivare, close to a structurally important NW-SE striking shear zone in the northern Norrbotten ore province (Fig. 1a). Several other Cu-Au mineralizations and Fe-deposits occur in the region, and the entire ore province stands for about 90 % of the ore production in Sweden. About 200 km to the south lies the Skellefte district, a massive sulphide province interpreted as a volcanic arc formed during a period of subduction in the Palaeoproterozoic (Weihed et al. 1992). Host rocks to the Aitik deposit were probably formed during this c. 1.9 Ga event of crustal growth along the southwestern border of the Archaean nuclei to the Baltic Shield (Wanhainen & Martinsson, 1999).

The Aitik open pit occupies an area of about 3000x500 meter, and the mining area is divided into footwall, main ore zone and hanging wall, based on tectonic boundaries and copper grades. Biotite-amphibole gneiss and porphyritic quartz monzodiorite are the main lithologies forming the footwall to the ore body (Fig. 1b). These rocks contain less than 0.26 % Cu, and are separated from the main ore zone by a fault zone affected by K-feldspar alteration and epidotization. The diorite has an age of c. 1.87 Ga (Witschard, 1996). The main ore zone comprises biotite-garnet schist and gneiss towards the footwall, and quartz-muscovite (sericite) schist towards the hanging wall (Fig. 1b, c). The original character of these rocks is obscured by strong alteration and deformation, but based on the knowledge from areas outside the mine a volcaniclastic origin is suggested (Wanhainen & Martinsson, 1999). The ore minerals, chalcopyrite, pyrite and pyrrhotite, with magnetite, bornite and molybdenite as minor components, occur disseminated and in veinlets. Veins consisting of quartz and sulphides are common, as are sulphides concentrated in veinlets of amphibole and biotite. Barite veins containing varying amounts of magnetite, actinolite, chalcopyrite, and pyrite are partly abundant. A minor content of sulphides is also found in the K-feldspar/epidote altered rock at the contact between the footwall and the ore zone, and in small restricted areas of tourmaline fels. The hanging wall mainly comprises unmineralized biotite-amphibole gneiss, which is separated from the main ore zone by a thrust fault (Fig. 1c). Pegmatite dykes are most frequent in the hanging wall and the ore zone, where they occur both along strike and crosscutting the foliation (Fig. 1b). Within the ore zone both types often carry chalcopyrite and pyrite, and occasional molybdenite.

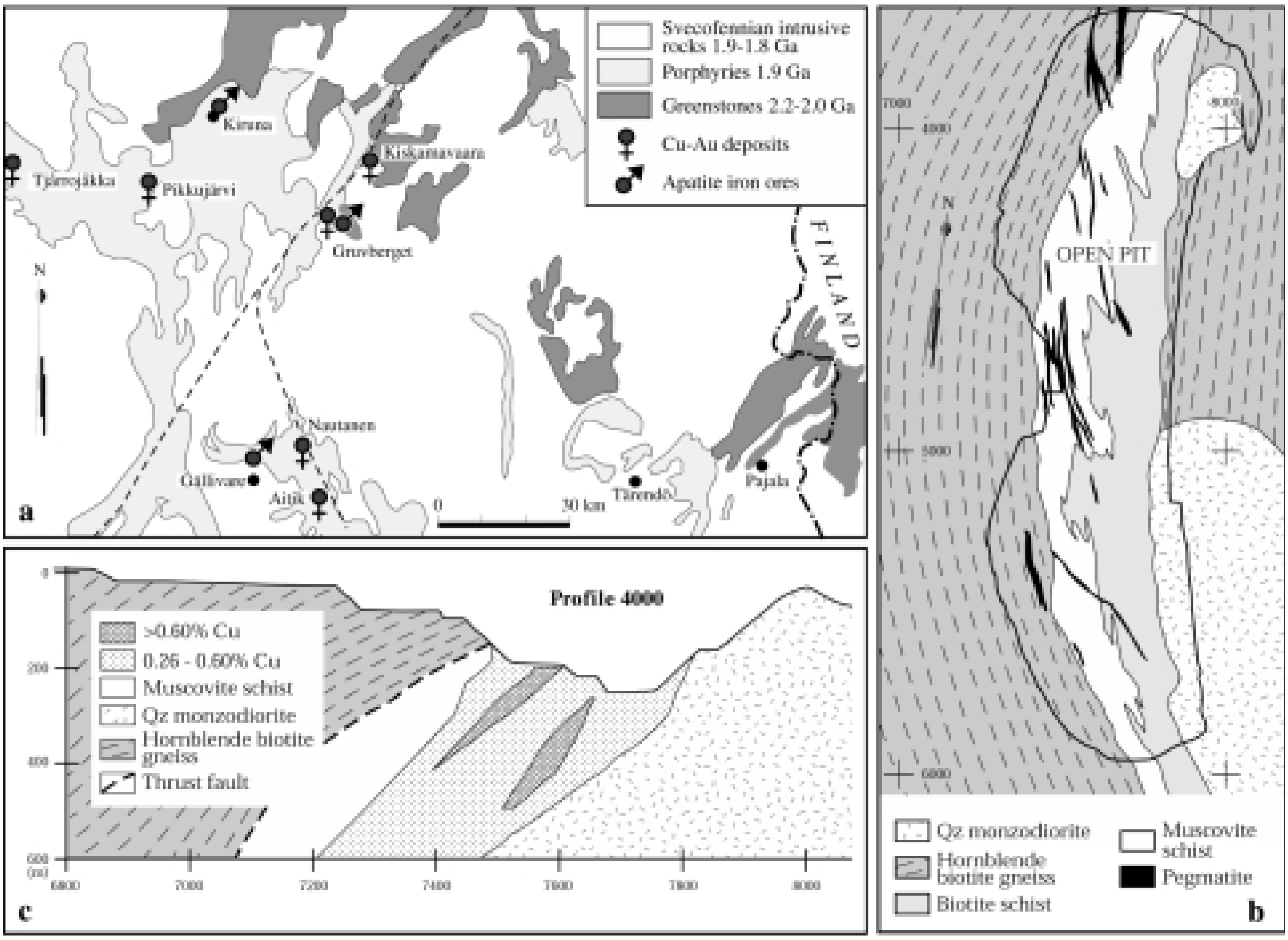

Figure 1. Simplified geological map of northern Norrbotten and the Aitik deposit (plan view and west-east vertical cross section). Map of the Aitik deposit modified from Monro (1988).

Strong alteration in Aitik occurs as extensive biotitization and sericitization in the ore zone, accompanied by garnet porphyroblasts, quartz and pyrite. Small areas comprising the mineral assemblage epidote + calcite + chlorite + quartz are distributed randomly within the ore zone. K-feldspar alteration and epidotization are mainly developed at the fault zones demarcating the ore zone, but occur also locally within the whole mining area, most often adjacent to pegmatites. Tourmalinization is less common and mainly restricted to the immediate wall rocks of quartz-tourmaline veins and pegmatites. Scapolitization is observed adjacent to amphibole schlieren in the northern part of the open pit (Monro, 1988) and in the footwall intrusion in the southern part of the open pit. The existence of several different types of mineralization and alteration suggest a complex evolution with several phases of hydrothermal activity and ore formation.

References:

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Geodynamic evolution of the Skellefte district: current ideas and problems

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Since the mid 1970-ies, modern plate tectonic concepts have been applied for the geodynamic evolution of the Skellefte district. Today there is a general agreement among earth scientists that the Skellefte district is a remnant of a Palaeoproterozoic volcanic arc accreted towards the Karelian craton at c. 1.8–1.9 Ga. Since the Skellefte district is extremely mineralized with over 85 massive sulphide deposits, several lode gold deposits, subeconomic porphyry style deposits, and Ni-deposits, the detailed knowledge of the 4D-evolution is vital.

Only about 5 good age determinations on volcanic rocks exist. They indicate depositional ages for the volcanic rocks between 1.87 and 1.89 Ga. Age determinations on associated early calc-alkaline intrusions indicate emplacement ages above 1.90 Ga for some intrusions. South and east of the Skellefte district proper both intrusive rocks and volcanic units have been dated at c. 1.95 Ga. Archaean rocks are exposed as mega-xenoliths less than 100 km north of the Skellefte district. A few studies of detrital zircons in the metasediments south of the Skellefte district (the Bothnian basin) indicate major contributions of material from Archaean sources, 2.1–2.0 Ga sources, and also from typically "Svecofennian" source rocks at 1.89–1.87 Ga. The current knowledge of the ages of rock assemblages thus poses some problems:

1) Are calc-alkaline, tonalite-granodiorite intrusions "basement rocks" to the Skellefte volcanism or, as presumed, comagmatic with the felsic volcanic rocks?
2) Are the supracrustal units to the south and west "basement rocks" to the Skellefte volcanism or "exotic terrains"?
3) Are the ages so far obtained from the ore-bearing Skellefte Group volcanic rocks reliable or can we expect older ages of units not yet dated?
4) What is the provenance to the detrital zircons in the metasediments?
5) Does Archaean crust exist beneath the Skellefte district?

The understanding of the timing of deformation and metamorphism is also rather limited in the Skellefte district. The Vargfors Group of coarse epiclastic rocks and interlayered volcanic rocks has been dated at 1.87 Ga. These rocks have experienced the same main deformation and metamorphism as rocks of the older Skellefte Group, while the 1.80 Ga Revsund granitoids post-date this period of deformation and metamorphism. Recent observations of a fabric that predates the Jörn GIII intrusions but post-dates the Jörn GI intrusions indicate that deformation occurred at c. 1.88 Ga. This age of deformation is also suggested from Finland and from areas north of the Skellefte district in Sweden. Titanite ages of late brittle-ductile shear zones associated with a second spaced cleavage in the Skellefte district indicate ductile deformation at c. 1.79–1.80 Ga. Metamorphism in the central parts of the Skellefte district is in greenschist facies while areas to the west, south and east are in middle to upper amphibolite facies. Rapid changes in metamorphic grade seem to partly be related to major 1.79–1.80 Ga NNE trending shear zones, but high grade rocks are also spatially related to areas with major c. 1.80 Ga intrusions. Further questions regarding the geodynamic evolution of the Skellefte district arise from the present knowledge of timing of deformation and metamorphism.

1) What is the absolute age of the main deformation in the area?
2) Does the main deformation overprint important earlier phases of deformation and metamorphism hitherto not really recognized?
3) How do we explain the apparent age difference between major deformation at 1.88 Ga in Finland (and possibly in northern Sweden) and the probably 30–70 Ma younger deformation and metamorphic peak in the Skellefte district and southwards? Are there discrete events or a continuous process?
4) Is metamorphism related to the intrusion of "post-orogenic" granite suites?
5) How important are crustal scale shear zones for the present rock configuration?

Present tectonic models for the evolution of the Skellefte district propose a north directed subduction beneath the Skellefte district and the development of an island arc above an active subduction zone. In addition, it has been suggested that the existence of Archaean megaxenoliths in the Proterozoic to the north of the Skellefte district was caused by major thrusting of basement rocks towards north. Reflection seismic profiles (BABEL-profiles) have revealed a possible north dipping slab remnant at the lower crust immediately south of the Skellefte district. The VMS deposits in the Skellefte arc have furthermore been attributed to a stage of