The Aitik porphyry Cu-Au-Ag-(Mo) deposit in Sweden

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Abstract. The Aitik porphyry Cu-Au-Ag-(Mo) deposit is located in northern Sweden. Since the start of production, over 529 Mt of ore has been mined averaging 0.38% Cu, 0.20 ppm Au and 3.7 ppm Ag. Ore reserves at the end of 2010 were 733 Mt. A major mine expansion program is recently finished. The deposit is situated within metamorphosed plutonic and volcano-sedimentary rocks of 1.9-1.8 Ga age in the Fennoscandian Shield. Aitik is situated along a deformation zone which has elongated the deposit in a northwest-southeast direction. The local mine stratigraphy dips c. 45-60° west. The footwall complex comprises a multiphase quartz-monzodiorite intrusion which intruded supracrustal rocks that now are feldspar-biotite-amphibole gneisses. The main ore zone consists of biotite gneisses and biotite schists and quartz-muscovite-(sericite) schists, which are strongly altered. All units are mineralized with 2-7% chalcopyrite, pyrite, pyrrhotite and trace amounts of molybdenite. The overlying barren hanging wall rock consists of banded feldspar-biotite-amphibole gneiss, which is separated from the main ore zone by a thrust. The favoured ore model is that of a deformed and metamorphosed Palaeoproterozoic porphyry Cu deposit, related to a 1.87 Ga intrusive quartz-monzodiorite.

Keywords. Porphyry Cu deposit, Au, Sweden, Palaeoproterozoic

1 Aitik Mine

The Aitik porphyry Cu-Au-Ag-(Mo) deposit is located 60 km north of the Arctic Circle in northern Sweden (Fig. 1A). The mineralization is about 5,000 m long, 400 m wide and about 800 m thick in the deepest investigated parts. The Aitik mine is the largest open-pit metal mine in Europe. The original Aitik main pit measures at the present over 3,000 m in length, 1,100 m in width and 435 m in depth. The second open pit, called Salmijärvi, situated south of the main Aitik pit is planned to be 800 m in length, 400 m in width and 275 m in depth (Fig. 1C). The deposit was discovered in 1932. Aitik has been in production since 1968 when it started as a 2 Mt/y open-pit operation. Since the start 1968, over 529 Mt of ore has been mined averaging 0.38% Cu, 0.20 ppm Au and 3.7 ppm Ag. Production in 2010 was 28 Mt of ore and 27 Mt of waste rock with an output of 67,168 tons of Cu, 2,208 kg of Au, and 36,468 kg of Ag. Ore reserves at the end of 2010 were 733 Mt grading 0.25% Cu, 0.14 ppm Au, 1.7 ppm Ag and 29 ppm Mo, with remaining mineral resources totalling 1,717 Mt.

A major mine expansion program is recently finished to reach 36 Mt of annual ore production in 2014. The production in the Salmijärvi open-pit started at the end of 2010. Production in the Aitik area will, at the currently planned rates, continue until 2030.

2 Geology

The deposit is situated within metamorphosed (upper amphibolite facies) plutonic and volcano-sedimentary rocks of 1.9-1.8 Ga age in the Fennoscandian Shield. The host rocks have experienced strong deformation and alteration at several stages and they were formed in a compressional, volcanic arc environment related to subduction of oceanic crust beneath the Archaean craton at ca. 1.9 Ga (Wanhainen et al 2006). Aitik is situated along a branch of a deformation zone called the Nautanen Deformation Zone (NDZ). The NDZ is a major crustal feature in the region, which can be traced from the lake Ladoga in Russia, to the Kiruna District, Sweden over a distance of ca. 1,500 km. The NDZ has elongated the deposit in a northwest-southeast direction (Monro 1988) after emplacement of the deposit.

The upper ore contact of the local mine stratigraphy dips c. 45° west and the lower ore contact dips 60° west, thus creating a wedge-shaped ore body, which becomes larger at depth (Fig. 1D). Within the mine stratigraphy, folds with the fold axis parallel to foliation plunge 20° south. The mine stratigraphy is divided into three major zones, the footwall complex (FWC), the main ore zone (MOZ) and the hanging wall (HW) (Nordin et al 2007).

2.1 Footwall Complex (FWC)

The FWC comprises a multiphase intrusion of quartz-monzodiorite, locally containing strong potassic alteration (monzodiorite), porphyritic diorite, and a feldspar-porphyritic gabbro intrusion (Wanhainen et al 2006). All these units intruded supracrustal rocks that are now metamorphosed to feldspar-biotite-amphibole gneisses. Geochemically the gneisses seem to be mafic to intermediate igneous rocks, presumably metamorphosed basaltic andesites (Wanhainen and Martinsson 1999). Chloritization and sericitization is common in the FWC. The quartz-monzodiorite hosts weak chalcopyrite>pyrite-mineralization, with traces of molybdenite and local bornite. The sulfide content is normally 1-2% and sulfides occur as disseminations and in weakly developed quartz veinlet stockworks. The FWC is up to 600 m thick in the southern part of the deposit.

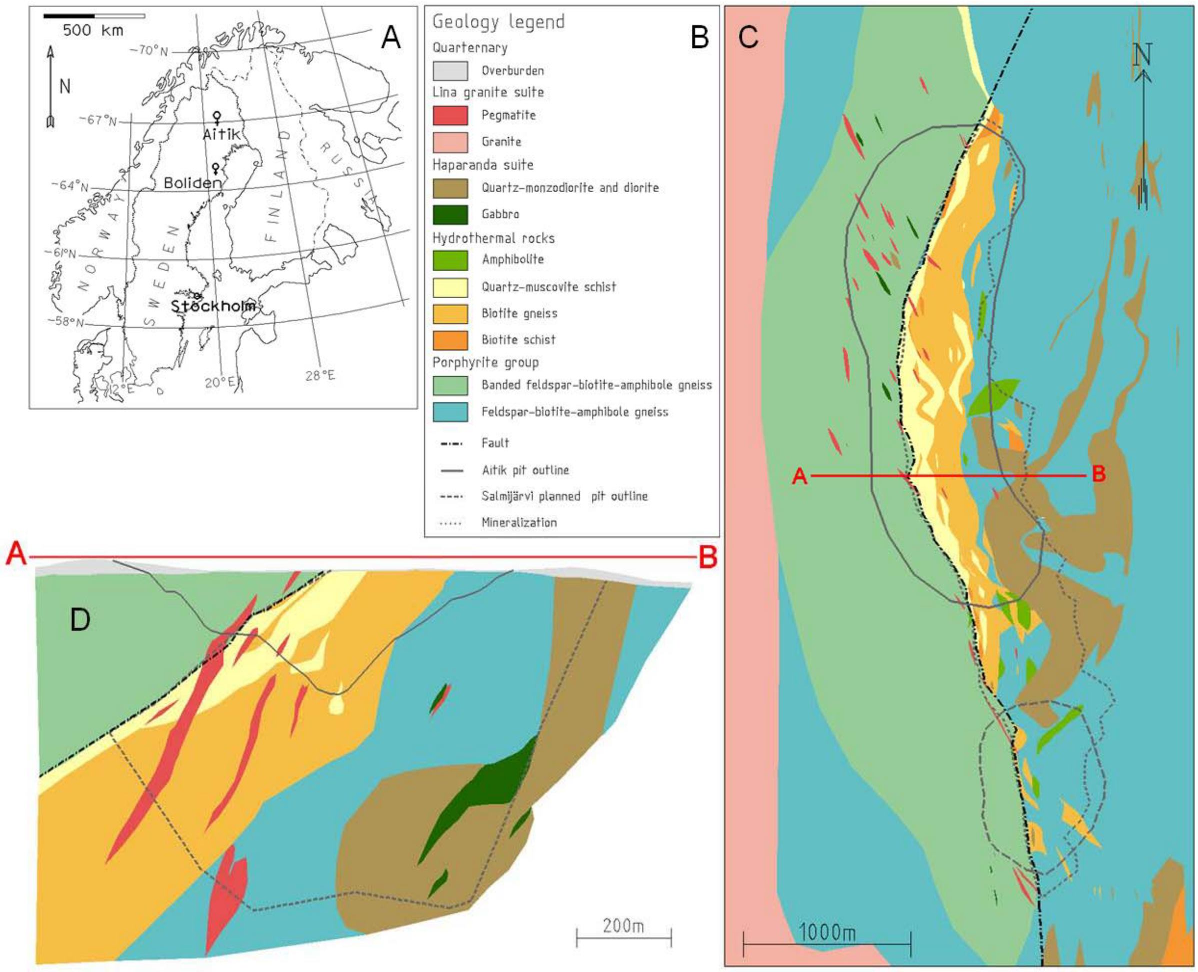

Figure 1. The location of Aitk mine in Scandinavia. B Aitik geology legend. C Geologial map of Aitik. D Profile A-B in Figure 1C.

2.2 Main Ore Zone (MOZ)

The MOZ close to the FWC comprises biotite gneisses (chalcopyrite=pyrite) and biotite schists (pyrite>chalcopyrite), and towards the thrusted HW a quartz-muscovite-(sericite) schist (pyrite>chalcopyrite) dominates. Small intrusions of strongly deformed and altered quartz-monzodiorite are also present in the MOZ (Wanhainen et al 2006). Strong biotitization, sericitization and potassic alteration accompanied by garnet porphyroblasts, quartz and pyrite are common in the MOZ. Minor areas comprising the mineral assemblage epidote-calcite-chlorite-quartz occur mainly along fault zones. All MOZ units are mineralized with 2-7% chalcopyrite and pyrite as well as pyrrhotite and traces of molybdenite. The sulfide mineralization occurs as disseminations and tectonically stretched bands. The maximum thickness of the MOZ is between 350-400 m. Intermineral pegmatite dykes intruded in the MOZ containing chalcopyrite and pyrite, plus local molybdenite and magnetite.

The main (>98%) Cu-bearing mineral in Aitik is chalcopyrite. Bornite and chalcocite are present in trace amounts. Other opaque minerals include pyrite, magnetite, pyrrhotite, ilmenite, and molybdenite, where pyrite is by far the dominant sulfide. Ore minerals occur in several different settings: disseminated, as veinlets, as patches and clots, in several types of veins together with varying amounts of other minerals such as e.g. quartz, amphibole, garnet, magnetite, zeolite, tourmaline, barite, and thaumasite, and in pegmatite dykes (Wanhainen and Martinsson 2003). The disseminated mineralization style is quantitatively the most important (Wanhainen 2005).

2.3 Hanging Wall (HW)

The overlying barren HW is composed of fine-grained banded feldspar-biotite-amphibole gneiss, which is separated from MOZ by a major thrust (Monro 1988). The HW gneiss contains abundant magnetite and titanite. Chloritization and sericitization is common in the HW. Late-mineralization pegmatite dykes locally intruded into the HW rocks caused local silicification and potassic alteration. Mineralization is absent in these pegmatites inside the hanging wall (Wanhainen et al 2003).

2.3 Mining geology

The mining area is also divided into footwall, ore zone and hanging wall, based on tectonic boundaries and Cu grades. Mineralized rocks with low Cu-grades occur in the footwall area, while the hanging wall rocks are barren. The ore body shows a vertical metal zoning (Wanhainen et al 2003). The volume of Au-rich mineralization (>0.6 ppm Au) increases with depth, while the volume of Cu-rich mineralization (>0.6% Cu) decreases. The ore body also shows horizontal metal zoning. A 'high-grade' area (>0.6% Cu and >0.3 ppm Au) of disseminated sulfides is situated in biotite gneiss and schists in the northern part of the ore zone. Towards the hanging wall, grades are lower (<0.4% Cu and <0.3 ppm Au) and the host rocks are strongly sericite altered, pyrite-rich schists (Wanhainen et al 2003).

2.3 Ore model

The favoured ore model is that of a deformed and metamorphosed Palaeoproterozoic porphyry Cu deposit, related to a 1.87 Ga intrusive quartz-monzodiorite. However, all features of the Aitik ore are not typical for porphyry systems and it probably has a more complex origin, including later remobilization and possible overprinting of mineralizing events (Wanhainen et al 2005; Wanhainen 2005).

3 Plans for Aitik Mine

Aitik is one of the largest Cu producer in Europe, and the largest Au deposit in Scandinavia. Future plans include increasing the recovery of Au and commencing extraction of Mo. Exploration in the Aitik area will also continue.

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