



The Kiruna-type apatite-iron oxide system in central Sweden: geology and geochemical character

K Högdahl (1), E Jonsson (1,2), K Nilsson (2), and V Troll (1)

(1) Department of Earth Sciences, Uppsala University, Sweden, (2) Geological Survey of Sweden, Uppsala, Sweden

The only apatite-iron oxide ores in the classic Palaeoproterozoic Bergslagen ore province, central Sweden, occur semi-continuously between Grängesberg and Idkerberget. Together, they represent the largest concentration of iron ore in this part of the Fennoscandian shield. Their mineralogy, geochemistry, geometry and host rock relations all suggest that they belong to the Kiruna-type class of deposits.

The apatite-iron oxide ores in Bergslagen are hosted by 1.9 Ga variably altered, metavolcanic to meta-subvolcanic rocks ranging from rhyolitic to andesitic in composition. The region has been affected by three episodes of deformation (D1-3) and regional, greenschist to amphibolite facies metamorphism during the c. 1.9-1.8 Ga Svecofennian orogeny. The Grängesberg deposits occur as narrow, moderately SE-dipping lenses that are concordant to S_0 surfaces in the host rocks. Magnetic anomaly data indicate that they extend to a depth of at least 1.7 km. The lens geometry is mainly controlled by deformation during D2. Reverse, oblique, top-to-the NNW shear is evident in the footwall, and strain partitioning due to competence contrasts between the ore and altered host rocks resulted in flattening at competent ore lens crests, leading to asymmetrical folds with opposite vergence towards pinch areas where prolate strain prevailed. D1 is evident as a crenulated cleavage and D3 appears as gentle, large-scale open folds.

Geochemical data on host rocks show a systematic enrichment in REE from the least to the most altered rocks. The ore-associated alteration assemblages and the apatite-iron oxide ore feature similar and elevated REE concentrations and profiles, suggesting a link between hydrothermal alteration and oxide ore formation. However, most ore magnetite has $\delta^{18}\text{O}$ values between +0.3 and +3.4 ‰ (ranging from -0.4 to +4.9 ‰, consistent with fractionation of oxygen between magnetite and a felsic to intermediate magma at high temperatures (Jonsson et al. 2011)). These values partly overlap with published data from the Kiruna ores, as well as with young Chilean deposits of a comparable type (Nyström et al. 2008). The lighter values can be explained by either (or a combination of both) later oxidation of the ores and a hydrothermal process of formation. A majority of moderately altered host rock $\delta^{18}\text{O}$ (+5 to +10 ‰ (V-SMOW)), plot within the normal spectrum of igneous rocks.

Based on isotope systematics, geochemistry and geological observations, we conclude that formation of these ores included a hydrothermal component, most likely directly related to an orthomagmatic process.

References:

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