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Geological features in and around the Kiirunavaara ore body, northernmost Sweden, and some implications

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The Kiirunavaara ore is the type locality for 'Kiruna-type', or iron oxide-apatite ores, and among the largest of its kind (4-5 km long, up to >200m wide, reaching depths of >2000m); it has yielded almost two billion tonnes of ore.

The ore does not consist of one uninterrupted tabular body, but is highly irregular in shape, and has minor associated parallel ores. Previous interpretations have suggested numerous fault offsets across the ore, but none of these have been possible to confirm. Instead, we consider most of the ore outline a primary feature, rather than tectonic. The ore is emplaced in between the footwall trachyandesites, partly Fe-rich (partly nodular), and the hanging wall rhyodacites. The contacts are partly sharp, and in part ore occurs as both dykes and inclusions in both country rocks. A cogenetic relation between the ore and the Fe-rich nodular footwall rocks has been suggested, and field structures suggest that all three rocks may have been penecontemporaneous liquids. Mafic and composite mafic-granophyric dykes, and granite cut the ore shortly after its emplacement. The footwall is characterized by abundant irregular veins dominantly of amphibole+titanite. Numerous calcite veins, often with pyrite, chalcopyrite, anhydrite, gypsum and quartz penetrate the ore and its surroundings. Pyrite also occurs disseminated in the ore.

A prominent feature is the close association of major clay-altered rock volumes in the ore and particularly following the contacts in both country rocks. The clays are hydrothermal bentonites and seem to be of several generations where the earliest may be related to the ore emplacement. Locally, the ore and its country rocks are porous, or extremely fragmented by brittle fracturing. Porous rocks are often associated with clay. Sometimes the porous material consists of crosscutting hydrothermal sulphide-rich veins, which are even seen to cut brittly crushed rocks. Numerous open cavities also exist, in size from some centimetres to tens of metres. The walls of these are typically covered by crystals of pyrite, actinolite, apatite, calcite, and quartz. Occasionally a spatial connection to the porous rocks is observed. Ductile shearing has only been observed along the contacts in some instances. A large number of major brittle fractures and faults (>100 000), often with slickenlines, cut the rocks in fairly consistent directions (sets). Rough fractures with thick mineral filling (mostly calcite) run near-EW across the ore, while hematite-coated slickensided faults of large extensions (>10m) run near-NS along the ore. In cases brittle faults cut the clay-altered rocks.

Interpretation: The ore was emplaced as a highly volatile-rich Fe-P magma, together with silicic magmatism in a partly strongly Fe-enriched volcanic system. Crystallization caused extensional fractures filled with minerals precipitating from expelled fluids, as well as cavities, porous rock volumes and brittle deformation. Minor ductile shearing along contacts. The first clay alteration took place already during magmatic cooling. Later episodes of hydrothermal activity affected the system and emplaced e.g. sulphide veins and caused additional clay alteration. Subsequently, brittle tectonics tilted the sequence and caused extensive faulting mainly in the NS direction.

The highly irregular distribution of cavities, porous and clay-altered rocks that cannot take load influences the shifting stress field during mining and thus affects construction of geomechanical models. Additionally, the interaction of the near-NS faults (with variable dips), with tunnels of similar directions, and an EW-directed σ_1 create a challenge in a seismically active mine.