
Proterozoic to Quaternary events of fracture mineralisation and oxidation in SE Sweden

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ABSTRACT

Fracture minerals and altered wall rock have been analysed to reveal the low-temperature evolution, especially regarding redox conditions, of the Simpevarp area, SE Sweden. This area is one of the two areas in Sweden investigated by the Swedish Nuclear fuel and Waste Management Co. (SKB) in order to find a potential geological repository for spent nuclear fuel. The 1.8 Ga granitic to dioritic rocks in the area are generally un-metamorphosed and structurally well-preserved, although low-grade ductile shear zones and repeatedly reactivated fractures exist. Investigations of cross-cutting fractures along with a wide variety of fracture mineral analyses, such as stable isotopes and $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology, have been used to distinguish a sequence of fracture filling generations. The characteristics of these generations indicate the low-temperature evolution of the area, including information of e.g. fluid origin, formation temperature, paleo stresses and relation to known geological events. Knowledge of the fracture mineral evolution is important for the conceptual geological and hydrogeochemical understanding of the site and supports predictions of future scenarios in the safety assessment. The fracture mineral generations identified have been formed at widely varying conditions starting in the Proterozoic with formation from inorganic hydrothermal fluids, continuing in the Paleozoic with formation from lower temperature brine type fluids with organic influence, and ranging into minerals formed from waters of varying salinity and with significant organic influence at conditions similar to the present conditions. However, the amount of potentially recent precipitates is very small compared to Proterozoic and Paleozoic precipitates. The fracture mineral parageneses have been associated, with varying confidence, to far-field effects of at least four different orogenies; the Svecokarelian orogeny (>1.75 Ga), the Danapolonian orogeny (~1.47-1.44 Ga), the Sveconorwegian orogeny (~1.1-0.9 Ga) and the Caledonian orogeny (~0.5-0.4 Ga). The fracture minerals related to the Danapolonian orogeny were mainly formed in relation to the intrusion of two granites nearby. Periods of extension and influence from overlying sedimentary successions have also been indicated in the fracture mineral record.

Demonstration of long term preservation of stable reducing conditions at repository depth is an important task in the safety assessment of a nuclear waste repository. This is because oxygen may harm the copper canisters and may cause increased mobility of some radionuclides in case of canister leakage. It is therefore important to demonstrate the extent of past oxygen intrusion in the bedrock, i.e. the position of the redox front, at which originally present oxygen have been reduced along the fractures. It is also important to obtain information on the available reducing capacity (mainly Fe^{2+}) of the wall rock, especially regarding the widespread hydrothermally altered, red-stained and supposedly oxidised wall rock. The results from two comprehensive studies on these tasks are satisfying and robust and can be summarised as: 1) The recent redox front is indicated to be located in the uppermost twenty meters of the bedrock, as shown by the depth distribution of redox sensitive minerals pyrite and goethite, Ce-anomalies and U-series nuclides, and 2) red-stained wall rock still has a high reducing capacity, which is largely similar to that of the unaltered rock.

Keywords: fracture minerals, low-temperature evolution, paleohydrogeology, redox front, wall rock alteration, stable isotopes, geochemistry, Ar-Ar dating, fluid inclusions, Mössbauer spectroscopy, U-series disequilibrium, Simpevarp, Laxemar, SE Sweden, nuclear waste repository.

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