Hyrkkölä (Finland)

Description: Hyrkkölä is a small native copper-bearing uranium occurrence in southern Finland, at Nummi-Pusula (Figure 1). The site was discovered at the same time as the Palmottu U-mineralization, in 1979, by the Geological Survey of Finland (GTK) in the course of a systematic regional U-ore exploration survey. During the local exploration phase, the site was mapped, drilled and samples taken from both the bedrock and the overlying Quaternary till beds.

The studies of the natural materials and processes at Hyrkkölä offered insights into the long-term performance of native copper as an analogue for copper canisters and the interactions between copper corrosion products and uranium. Copper corrosion products are sulfides and oxides. The current process is oxidation. The sulfidation process ended probably more than 1 Ma ago, but copper sulfides are shown to retain up to 25 % of uranium as U(IV) even in the prevailing oxidizing conditions.

As in the Swedish SKB-concept, nuclear waste disposal in Finland is based on the direct disposal of non-reprocessed spent fuel in copper-iron canisters, emplaced in bentonite-filled cavities deep in the bedrock (Vieno and Nordman 1999). Natural analogues of the metallic copper overpack were discussed by Marcos (1989), who also highlighted the Hyrkkölä site. Visible metallic copper was known to exist in drill cores and surface outcrops from Hyrkkölä, but the groundwater-physicochemical conditions of the site were not known. During the period 1997–1999, a site study was performed under the auspices of Posiva Oy and SKB. Two new research boreholes were drilled in order to obtain new copper samples with associated water samples and redox-pH data. Results of the study were reported by Marcos and Ahonen (1999) and Marcos et al. (1999).

Hyrkkölä is situated within the Proterozoic (1.8 Ga) Svekofennian orogenic belt, extending from SE Finland to central Sweden. The bedrock of the site is composed of mica gneiss, quartz feldspar gneiss and amphibolite. The uraninite-native copper association is hosted in granite pegmatite veins within amphibolite country rock. Tectonically the site is situated within a triangular block (about 50 km^2) bordered by regional shear zones. The U-Cu mineralisation within the block is associated with an old, probably Precambrian, localised shear zone. Most of the drill holes pass through the zone (fig 1, small insert), which is indicated in cores by a penetrative reddish colouration (due to the presence of hematite), dense microfracturing and the existence of recrystallised breccia.

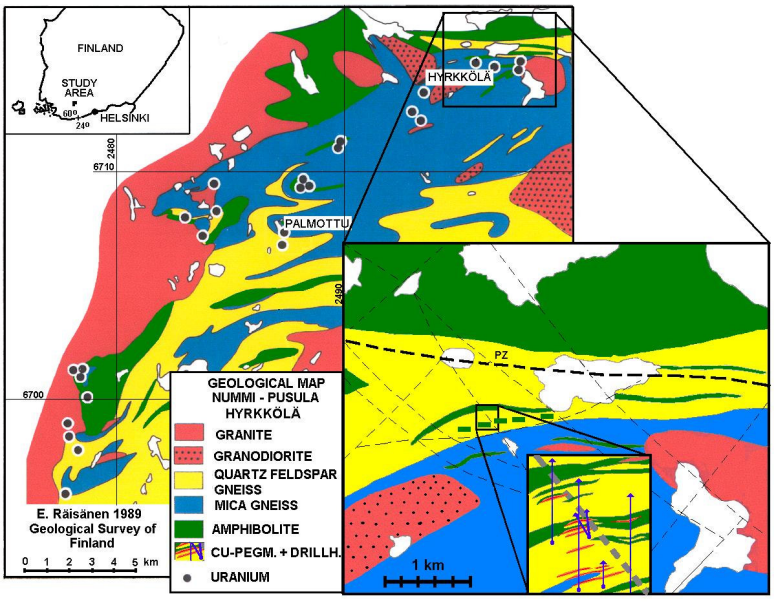

Figure 1: Geological map of Hyrkkölä, with inserts at more detailed scales. Shear zones are denoted by broken lines, the thicker line showing the regional Perniö shear zone (PZ). Horizontal traces of drill holes are shown by arrows (small insert).

Figure 2: Copper in fissures (broken during drilling)

Visual inspection has revealed several occurrences of metallic copper in the fissured pegmatites, one of the most interesting being shown in fig 2. A borehole TV-survey shows the presence of fissures in the bedrock at that depth. Porosity of the rock samples, determined by the impregnation technique (Hellmuth et al 1993) and by water immersion, was around 0.4 %. Typically, native copper was observed to fill microfractures, voids and cleavage planes.

Groundwater compositions and physicochemical properties were carefully studied in packed-off (1.5 – 14 m) drill-hole sections associated with the copper-bearing pegmatites. In order to obtain representative Eh-values, the SKB mobile field laboratory was used. The measurements are based on long-term pumping (several weeks) and continuous monitoring of redox potential using different inert redox-electrodes (Pt, Au, C), both down-hole and on the surface. Results indicated that waters in the Hyrkkölä bedrock are very oxidizing (Eh-values around +400 – 500 mV) at pH around 7. Chemically, the groundwaters are fresh Ca-Na-HCO_3 waters. Elevated nitrate contents indicate rapid infiltration of surface waters.

It is evident that waters in microfractures differ from those extracted by pumping, with Eh-values being lower and pH higher than in the circulating water. Bearing in mind the strong contribution of iron-oxyhydroxides in Hyrkkölä bedrock, it can be assumed that the Eh-values in microfractures may of the order of 0 to –100 mV. Very reducing conditions cannot be expected. Typically, the surfaces of copper grains in the microfractures were fresh, without detectable signs of corrosion. Consequently, oxygen in the waters from hydraulically active fractures has not diffused into the microfractures, but has been consumed in water-rock interaction processes.

Native copper in fissures

Breccia

Native copper grains occurring on the surface of a clearly open, water-conducting fracture were observed to be coated by rims of cuprite (CuO) 0.01 to 0.1 mm thick. The grains were associated with, and often at least partially embedded in, smectite. Several uranium-bearing smectite samples were selected for U-series isotope analyses. The results indicate a very low $^{234}U/^{238}U$ ratio, which was attributed to the presence of oxidizing conditions. To attain such a low activity ratio, more than 240 000 years are required. Therefore, the oxidized native copper grains within the smectite have been and still are in contact with circulating oxic groundwaters. Despite this copper still occurs in its metallic state.

Relevance: Hyrkkölä demonstrates the long-term stability of metallic copper in a crystalline bedrock environment, with special reference to its stability in oxidizing, non-sulphidic conditions. The study demonstrates worst-case conditions, given that the Cu occurs within a tectonic zone.

Position(s) in the matrix tables: Mechanical integrity of barriers=>corrosion=>copper package

Limitations: Copper stability in reducing, sulphidic conditions cannot be demonstrated in Hyrkkölä. The depth range of the study was limited to the uppermost 100 meters of bedrock.

Quantitative information: An estimate of the minimum contact time between metallic copper and oxidizing water can be made.

Uncertainties: Geochemical conditions in the microfractures, where copper was mainly observed.

Time-scale: Geological.

PA/safety case applications: Demonstration of copper canister longevity in crystalline bedrock. The copper-smectite association demonstrates the behaviour of the canister-bentonite system.

Communication applications: Pictures have been used in a number of brochures.

References:

Hellmuth, K.-H., Siitari-Kauppi, M. & Lindberg, A. 1993. Study of porosity and migration pathways in crystalline rock by impregnation with ^{14}C-polymethyl-methacrylate. J. Contaminant Hydrol. 13, 403-418.

Marcos, N. 1989. Native copper as a natural analogue for copper canisters. Report YJT-89-18. Nuclear Waste Commission of Finnish Power Companies.

Marcos, N., 2002. Lessons from Nature - The behaviour of Technical and Natural Barriers in the Geological Disposal of Spent Nuclear Fuel. Acta Polytechnica Scandinavica, Civil Engineering and Building Construction Series No. 124, Espoo 2002.

Marcos, N. & Ahonen, L. 1999. New data on the Hyrkkölä U-Cu mineralization: The behaviour of native copper in a natural environment. POSIVA 99-23.

Marcos, N., Ahonen, L., Bros, R., Roos, P., Suksi, J., and Oversby, V., 1999. New data on the Hyrkkölä native copper mineralization: A natural analogue for the long-term corrosion of copper canisters. In: Scientific Basis for Nuclear Waste Management XXII, Mater. Res. Soc. Symp. Proceedings 556, 825-832.

Vieno, T. & Nordman, H. 1999. Safety assessment of spent fuel disposal in Hästholmen, Kivetty, Olkiluoto and Romuvaara TILA-99. POSIVA 99-07.

Added value comments: Detailed characterization of an old shear zone is available, as well as a video recording of the (2) drill holes.

Potential follow-up work: Both drill holes and drill cores are still available

Keywords*:* near-field, copper, corrosion, granite

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