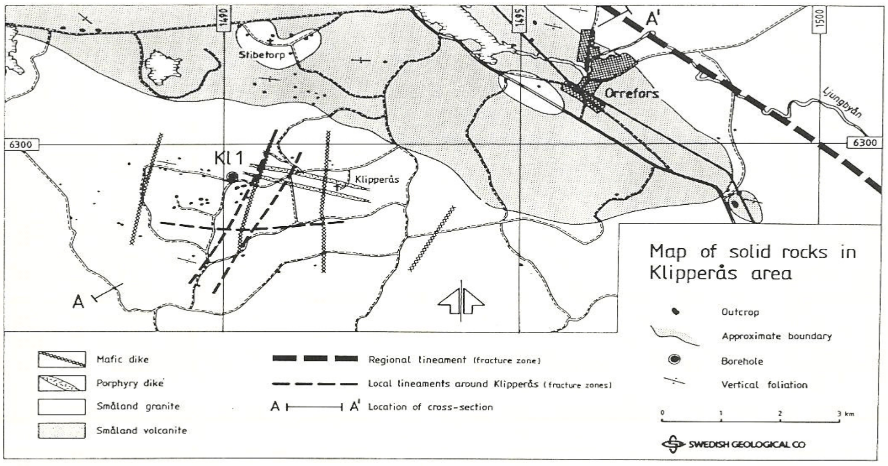
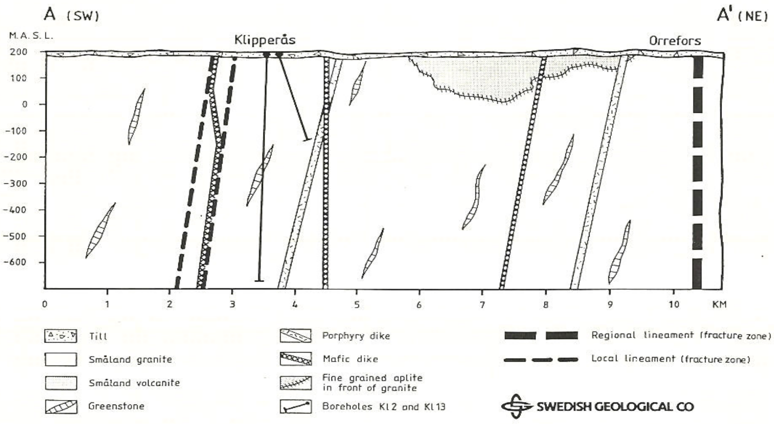
Klipperås (Sweden)

Description: Mineral fillings from water-conducting fractures and fracture-free bedrock at different depths have been studied from the SKB Klipperås test site in SE Sweden (Tullborg, 1986; Landström and Tullborg, 1990). The geology of the site and the location of some of the boreholes sampled are illustrated below (after Olkiewicz and Stejekal, 1986)



Map of solid rocks in the Klipperås area (Olkiewicz & Stejskal 1986).



Schematic vertical cross section of the Klipperås area (Olkiewicz & Stejskal, 1986).

The geology (Olkiewicz and Stejekal, 1986 and references therein) is characterised by a red to grey porphyritic granite-granodiorite (known regionally as the "Småland-type") dated to 1760-1840 Ma (Jarl and Johansson, 1988), i.e. late- to post-orogenic in relation to the Svecokarelian (1800-1850 Ma). These are often intruded by approx. E-W trending composite porphyry dykes and also by east-west trending lenses/sheets of fine-grained greenstone (metabasalt) which are usually strongly altered. These intrusions have been dated to around 1620 Ma (Åberg, 1978). The site area has been subjected to a later period of intrusions of dolerite dykes dated from 875-1048 Ma (Patchett, 1978). The site is bounded to the east by a major vertical NW-SE trending lineament and two major sub-vertical NNE-SSW trending regional fracture zones traverse the site area itself.

In addition to the geology, the site has been well characterised with respect to hydrogeology (Gentzschein (1986) and hydrogeochemistry (Laurent, 1986; Smellie et al., 1987). The fracture relationships based on geophysics have been presented by Sehlstedt and Stenberg (1986) and mineral fillings have been reported by Tullborg (1986). Consequently, the availability of a substantial body of geological/geophysical data, core samples with fracture fillings and preserved groundwater samples, made the Klipperås site highly suitable for study.

This study reported here has addressed the behaviour of elements classified as chemical analogues (U, Th and REEs) as well as certain additional major and trace elements (Fe, Na, Sr, Ba, Rb, Cs, Hf, Ta and Sc) in a fractured crystalline rock. The main objectives were to:

- Study the mobilisation, migration and sorption processes (past and present) responsible for the present distribution of these elements in fracture filling minerals.

- Determine the *in situ* distribution coefficients from analyses of fracture filling/groundwater pairs and compare them with laboratory-based data (i.e. parameter validation).

- Utilise the redox sensitivity of Ce and Eu to, if possible, trace REE pathways and determine past and present redox conditions.

The mineral parageneses based on tectonic events are:

1. Dislocation in feldspars associated with the formation of subgrains in quartz - (during porphyry and mafic dyke intrusion); quartz sealings in fractures.

2. High temperature infillings of epidote + muscovite + calcite + quartz + chlorite + adularia + haematite (complex period during dolerite dyke intrusions associated with extensive brecciation and mylonitisation)

3. Infillings of calcite + chlorite + haematite (possibly contemporary with or later than the intrusion of dolerite dykes)

4. Infillings of calcite + clay minerals + Fe-oxyhydroxides (at low ambient temperatures and probably on-going at the present time)

Based on samples selected and analysed from fracture fillings and the intact host granite, the following observations were noted:

- Elemental contents varied widely between fracture fillings and the host granite (e.g. U from 9-400 ppm and 3.5-10.6 ppm respectively, and Th from 2.6-307 ppm and 16-27 ppm respectively).

- These large variations reflect the wide range in sorption capacities of the different mineral groups.

- U appears to be selectively sorbed on Fe phases. *In situ* K_d measurements concluded that U is more mobile than suggested from laboratory experiments.

- Th has been mobilised, the main sink being the Fe phases; no mobilisation was observed in connection with clay alteration processes.

- REEs show a wide range of distribution due to the sometimes extreme fractionation between heavy and light REEs. LREEs tended to be associated with Fe phases and HREEs were selectively sorbed on calcites. REE sorption on clay phases was considered insignificant.

- Ce is mobile and appears to be selectively sorbed on the clay mineral phases.

Determination of the *in situ* K_d's was based on the net element concentration added to the fracture filling sample from the fluid phase as the result of a complex of processes taking place over a very long time period. It is probable that only the fracture fillings have reacted with the present groundwater and this, together with the time effect, are the main considered reasons for the higher *in situ* K_d's (on average a factor of 100 higher for Sr, Cs, Co and Eu, and about 10 higher for U) when compared to the laboratory-derived values.

Any correlation between *in situ* and laboratory derived K_d's would indicate that the relative mobilities of the studied radionuclides as predicted from laboratory experiments would be valid in a fractured granitic environment over repository time scales. The *in situ* K_d's suggest, however, a higher mobility for U relative to the other elements than is expected from the laboratory-derived K_d's.

Relevance: The relevance of these studies to the repository safety case is their focus on the function of the geosphere as a natural barrier to far-field radionuclide transport.

Position(s) in the matrix tables: Relevant boxes in the matrix table relate to far-field radionuclide transport and retardation in a saturated bedrock environment.

Limitations: The major limitation is the difficulty of integrating fracture filling phases, which can be derived with some certainty, with the precise contact hydrochemistry, which at best is very often only semi-quantitative. In addition, the difficulty of distinguishing between sorption and precipitation/co-precipitation processes limits the usefulness of *in situ* K_d determinations in PA.

Quantitative information: No quantitative information has been obtained from Klipperås. Good semi-quantitative information has been obtained on the fracture filling mineralogy and the nature of radionuclide and other trace elemental retardation on these fracture infilling phases.

Uncertainties: The main uncertainties have already been described under 'Limitations' and can be classified as medium to high in a scale of low, medium to high.

Time-scale: The time-scales addressed by these studies are geological, both recent (<1 Ma) and beyond (>1Ma).

PA/safety case applications: No known applications.

Communication applications: No known applications.

References:

Gentzschein, B., 1986; Hydrogeological investigations at the Klipperås study site. SKB Tech. Rep. (TR-86-06), SKB, Stockholm, Sweden.

Jarl, L.G. and Johansson, Å., 1988; U-Pb zircon ages of granitoids from the Småland-Värmland granite-porphry belt, southern and central Sweden. Geol. Fören. Stock. Förh., 110, 21-28.

Laurent, S., 1986; Analyses of groundwater from deep boreholes in Klipperås. SKB Tech. Rep. (TR-86-17), SKB, Stockholm, Sweden.

Landström, O. and Tullborg, E-L., 1990; The influence of fracture mineral/groundwater interaction on the mobility of U, Th, REEs and other trace elements. SKB Tech. Rep. (TR-90-37), SKB, Stockholm, Sweden.

Olkiewwicz, A., and Stejskal, V., 1986; Geological and tectonical description of the Klipperås study site. SKB Tech. Rep. (TR-86-06), SKB, Stockholm, Sweden.

Patchett, P.J., 1978; Rb/Sr ages of Precambrian dolerites and syenites in southern and central Sweden. Swedish Geol. Surv., C 747, 1-63.

Sehlstedt, S. and Stenberg, L., 1986; Geophysical investigations at the Klipperås study site. SKB Tech. Rep. (TR-86-17), SKB, Stockholm, Sweden.

Smellie, J., Larsson, N-Å., Wikberg, P., Puigdoménech, I. and Tullborg, E-L., 1987; Hydrochemical investigations in crystalline bedrock in relation to existing hydraulic conditions: Klipperås test-site, Småland, Southern Sweden. SKB Tech. Rep. (TR-87-21), SKB, Stockholm, Sweden.

Tullborg, E-L., 1986; Fissure fillings from the Klipperås study site. SKB Tech. Rep. (TR-86-10), SKB, Stockholm, Sweden.

Åberg, G., 1978; Precambrian geochronology of south-eastern Sweden. Geol. Fören. Stockholm Förh, 100, 125-154.

Added value comments: The direct transfer of *in situ* K_d data to PA's is not yet possible. However, until the derivation of quantitative data is forthcoming, such natural analogue *in situ* K_d's can be used in a semi-quantitative manner to provide a 'reality check' to the range of laboratory-derived values presently used in PA's.

Potential follow-up work: None planned.

Keywords: Granite, fracture fillings, radionuclides, REEs, *in situ* K_d's

Reviewers and dates: John Smellie (December, 2004).