

Kråkemåla and Kamlunge (Sweden)

Description: Drillcore profiles traversing water-conducting fractures and fracture-free bedrock at different depths have been studied from the Kråkemåla test site in SE Sweden (Figure 1; Smellie and Stuckless, 1985; Smellie et al., 1986) and the Kamlunge test site in northern Sweden (Figure 2; Smellie et al., 1993).

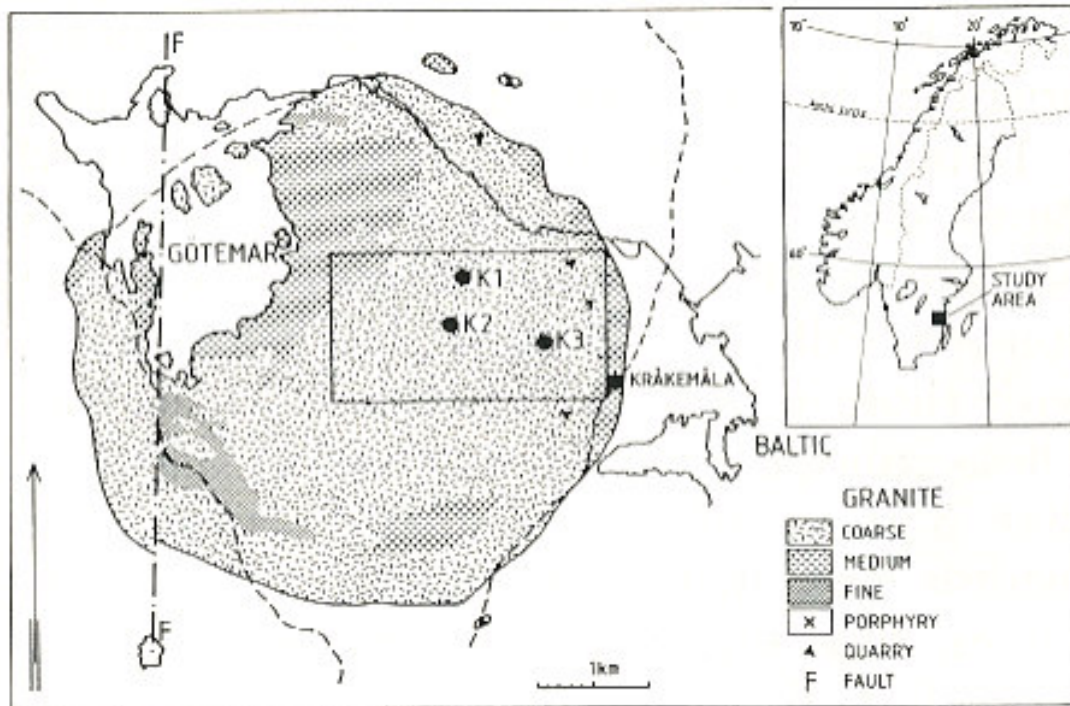


Figure 1 Geological map of the Götömar massif showing the location of the Kråkemåla test site area, S.E. Sweden, and the positions of the sampled boreholes K1, K2 and K3 (after Smellie and Stuckless, 1985; Smellie et al., 1986).

Kråkemåla, located in the Götömar massif, is typified by a coarse-grained biotite granite emplaced around 1400 Ma ago. The granite is highly evolved by either a high degree of differentiation or a low degree of partial melting and is typical of anorogenic granites in this part of Scandinavia. It is characterised by enhanced amounts of uranium (up to 13.5 ppm) and thorium (up to 55.6 ppm) with a mean Th/U ratio of 4.12; the main radioactive phases are monazite and zircon. Drillcore samples were selected from representative, unfractured parts of drillcores K1 and K2 (Figure 1) at depths of approximately every 50 m; a profile taken tangential to a fracture plane at approx. 280 m depth was also studied from K2.

The main objectives of the study were: 1) to characterise the large-scale (bedrock as a whole) and small-scale (fracture zones in particular) trace element mobilisation (especially U) within the geosphere over long timescales, and relate this to far-field repository performance, and 2) to assess implications of the study for site characterisation investigations.

The results showed:

- Following crystallisation, subtle and pervasive open-system modifications occurred in the granite.
- Modifications are evident from trace elements such as U, Rb and Pb; in contrast major element chemistry and mineralogy emphasised homogeneity.
- Modifications can be linked to:

- a. widespread hydrothermal mobilisation at around 420 ± 171 Ma, and
- b. more recent low temperature ambient conditions.
- Alterations are evident up to at least 600 m depth, and are most prevalent along major fracture zones and more generally where there is a large fracture frequency.
- The fracture zone/matrix profile at approx. 280 m was characterised by higher Rb, higher Fe oxidation ratios, lower U and higher Th/U ratios.

Kamlunge (Figure 2) is located in a geologically stable area characterised by metamorphic and migmatitic rocks of Precambrian age. The oldest rocks exposed at the test site are Svecokarelian metasediments and metavolcanics (1900-2500 Ma); these have been intruded by the Lina granite (1565-1800 Ma). Two major and one minor fracture/crush zones have been intercepted during the investigations thus providing a suitable opportunity to directly relate the water chemistry with the fracture mineral chemistry within the bedrock.

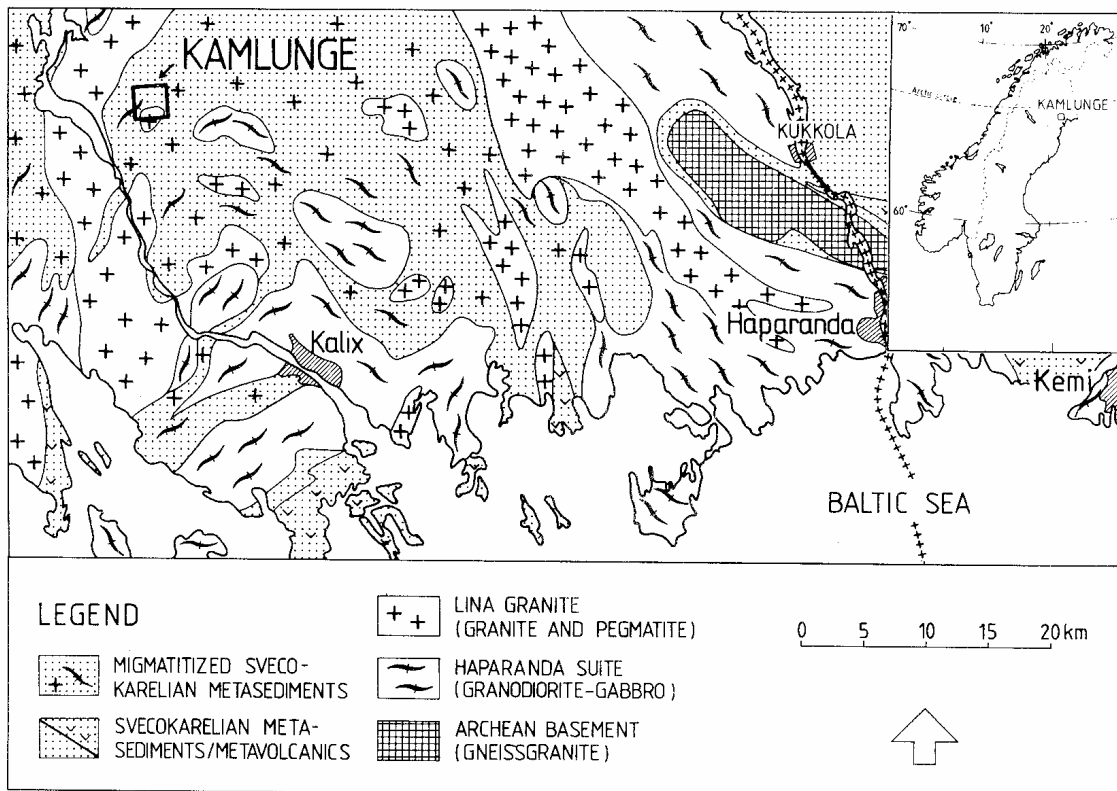


Figure 2 Regional geological setting of the Kamlunge test site area, northern Sweden (after Smellie, 1985).

The main objective of the study was to use U-decay series measurements on profiles perpendicular to water conducting fracture zones to assess geologically recent uranium mobility and retention that may help to establish the long-term performance of a repository far-field environment in fractured crystalline rock.

Drillcore samples from borehole Km3 were selected from fracture zones at depths of 105.5 m, 286.5 m and 375 m; fracture free bedrock samples were collected down to 508.5 m. Hydrothermal alteration was evident some 3-4 cm into the host rock marginal to the fractures.

The results showed:

- There is no evidence of geologically recent (< 1 Ma) water/rock interaction processes in the surrounding host bedrock; prevalent redox conditions are reducing.

- Rock/water interaction processes have been occurring in the hydraulically active major fracture zones within recent geological time (< 0.5 Ma).
- Interaction has occurred under marginally oxidising groundwater conditions which have extended to 375 m.

Relevance: The relevance of the studies is focussed 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 in a saturated crystalline bedrock environment.

Limitations: The number of samples studied is inadequate to characterise fully the far-field bedrock environment.

Quantitative information: No quantitative information has been obtained.

Uncertainties: Because of an inadequate sample coverage, uncertainties associated with the qualitative information from these studies are 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: There are no examples of their use in published PAs.

Communication applications: There are no examples of their use in communication and dialogue material.

References:

Smellie JAT and Stuckless JS. 1985. Element mobility studies of two drill-cores from the Götemar granite (Kråkemåla test site), southeast Sweden. Chem. Geol., 51, 55-78.

Smellie JAT, MacKenzie AB and Scott RD. 1986. An analogue validation study of natural radionuclide migration in crystalline rocks using uranium-series disequilibrium studies. Chem. Geol., 55, 233-254.

Smellie JAT, Fallick AE, Hållenius U, MacKenzie AB, Scott RD and Tullborg E-L. 1993. Isotopic and Mössbauer studies of a single conducting fracture in crystalline rock.

Added value comments: These analogues could be better used in illustrating the long-term behaviour of a fractured granitic rock identified in many disposal concepts as a potential (or alternative) repository host rock for radioactive waste disposal. Although qualitative in nature, these analogues show that over repository timescales (~ 1Ma) the low permeable bedrock at repository depths remains unaltered and reducing in character. Furthermore, if large-scale hydraulically active fractures or fracture zones are isolated by design from the disposed of radioactive wastes, any negative impact should be minimal.

Potential follow-up work: This would entail a greater sampling campaign linked closely with available hydraulic information. The analysis of a larger suite of trace elements and relevant isotopes would also be necessary.

Keywords: Granite, metavolcanics/sediments, radionuclides, U-decay series.

Reviewers and dates: John Smellie (Conterra, June, 2004).