

Grimsel underground laboratory (Switzerland)

Description: Drillcore profiles perpendicular to water-conducting fractures have been studied from the Nagra Grimsel Test Site underground laboratory facility located at the Grimsel Pass in the Central Alps, central-south Switzerland. The Grimsel Test Site was initially developed as an underground hydroelectric power scheme which had tunnelled through the Juchlistock mountain chain. In 1979 an exploratory drilling programme was initiated by Nagra which was completed in 1984. Since then to the present day the facility has been used mainly for *in situ* experiments related to the construction and long-term performance of a deep geological repository.

The geology of the region is summarised in several early publications (e.g. NTB 81-07 and NTB 85-34). The Aar massif of Hercynian age dominates the area; it is aligned in a SW-NE direction with a maximum extension of 115 km and a width of 23 km. This massif, which is the largest in the Swiss Alps, is surrounded by metasediments (mostly schists) and is itself mainly composed of plutonic rocks of granitic/granodioritic composition. These granitoid bodies were intruded during the Hercynian orogeny (~280 Ma). The Gastern granite was probably early Hercynian (located to the NW) and this was later followed by the Grimsel granite/granodiorite. The test site is located within the Central Aar granite which is thought to be Hercynian. Soon after emplacement the granitoids were intruded first by aplitic dykes and then by a variety of mafic lamprophyres. The interfaces between these latter dykes and the Aar granite mainly control the groundwater conductive system in the bedrock (Ohse, 1983). The Aar granite is typically grey-coloured, fresh, mineralogically homogeneous in hand specimen, and medium to coarse-grained; the granite also is characteristically gneissose.

Two suitable fracture zones hosted by the Aar granite, and considered water-conducting, were selected from drillcore material. The main objective of the study was to apply U-decay series measurements to detailed rock profiles across both fractures and into the host granite. To the extent that the U-series disequilibrium is a product of rock/water interaction, these measurements may help to evaluate the effective addition or removal of uranium within the vicinity of an open water-bearing fracture zone. Evidence of such a migration profile occurring into the host bedrock under ambient temperatures, should lend or detract support to models involving far-field radionuclide retardation processes.

Fracture zone section FLG: 94.12-94.52 m (Smellie et al., 1986; Alexander 1990a) was fresh in appearance and showed no alteration on a macro-scale and no evidence of any fracture filling minerals. The age of the fracture is uncertain but at least late Alpine to recent. Since the region is still considered tectonically unstable continuous formation of new fractures/joints cannot be excluded. The granite host rock shows some alteration (i.e. feldspar alteration to sericite, biotite to chlorite and magnetite is partly oxidised) but these are considered as being hydrothermally induced and not the result of recent low temperature water/rock reactions.

Analysis of U and its daughter decay products, Fe and two REEs, La and Ce, were carried out on thin slices of the drillcore material (Smellie et al., 1986). This showed:

- Most of the trace elements, including U and Th, are distributed relatively homogeneously through the core profile and any heterogeneities can be explained by mineralogical inconsistencies.
- There is therefore no obvious relationship between U and Th; however, it cannot be ruled out that U could have been redistributed with Th remaining immobile.
- Plots of $^{234}\text{U}/^{238}\text{U}$, $^{234}\text{Th}/^{234}\text{U}$ and $^{226}\text{Ra}/^{230}\text{Th}$ were interpreted as showing secular equilibrium within the limits of analytical precision, which essentially indicated that no water/rock interaction had occurred at least during the last 1Ma.

Studies on another drillcore profile are reported by Alexander et al. (1990a) and these results are illustrated in Figure 1. The U and Th show values close to secular equilibrium. However, assuming immobility of Th, the $^{226}\text{Ra}/^{230}\text{Th}$ activity ratios indicate preferential mobility of ^{226}Ra in a region 30

to 40 mm deep at either side of the fracture. This profile also suggests diffusion of ^{226}Ra towards the fracture over the last 1 600 to 8 000 a

In terms of matrix diffusion along a connected pore system, Alexander et al. (1990b) found no evidence at Grimsel that such a porosity extended throughout the rock mass as had been assumed for Swedish granites in the KBS-3 performance assessment (KBS, 1983). Grimsel has shown that for crystalline rock which has undergone little hydrothermal and physical alteration, a connected pore depth of around 50 mm for diffusion is realistic.

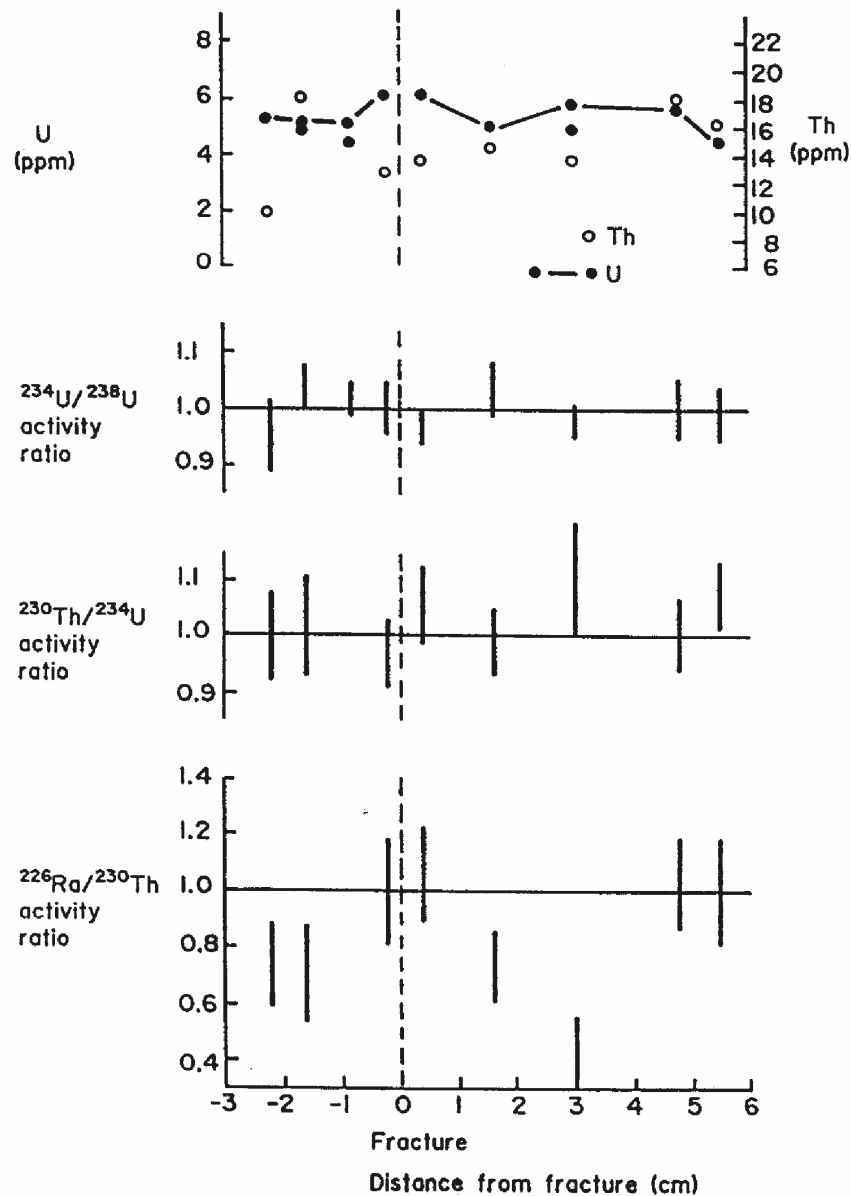


Figure 1. Natural decay series profiles measured in a core section perpendicular to a water conducting fracture from the Grimsel Test Site, Switzerland (Alexander et al. 1990a).

Relevance: The relevance of these studies is their focus on the function of a fractured crystalline rock as a natural barrier to far-field radionuclide transport.

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

Limitations: The number of samples studied is inadequate to characterise fully the far-field bedrock environment. Furthermore, the hydrogeological and hydrochemical boundary conditions are uncertain.

Quantitative information: Quantitative information has been obtained concerning potential radionuclide migration/diffusion depths into the host granite, in particular an extended connected porosity upper limit of around 5 cm.

Uncertainties: Because of logistics (i.e. limited number of boreholes etc.) an inadequate spatial sample coverage invariably results. Furthermore, the boundary conditions controlling the behaviour of U and Th over recent geological time (last 1Ma) are uncertain. Uncertainties associated with these studies on a repository scale therefore 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: Reference to matrix diffusion has been made in Kristallin-1 (Switzerland) where depths of matrix diffusion penetration (i.e. connected porosity) of 50 mm have been used in crystalline rock where hydrothermal and physical alteration is small.

Communication applications: Despite the use of matrix diffusion in some PAs, these data are usually too complex to be used in communication and dialogue material.

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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 mostly 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 to further assess the variation of penetration related to heterogeneities in the extent of the interconnected porosity.

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

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