Needle's Eye (Scotland)

Description: The Needle's Eye natural analogue site lies on the northern shore of the Solway Firth at Southwick near Dalbeattie, southwest Scotland (National Grid Reference NX 915 562). Needle's Eye itself is a natural rock arch formed by coastal erosion of the cliff. The area contains a suite of uranium and other metal-rich veins radiating out from the Criffel Granodiorite. The Needle's Eye site comprises an ancient sea-cliff forming the edge of the granodiorite where the largest mineralised vein is partially exposed. At the foot of the cliff is an area of anoxic, organic-rich soil which extends for about 10 m. Between this soil zone and a sea-inlet or creek is a flood plain (known as the Merse) composed of vegetated salt marsh and intertidal mudflats. Figure 1 shows a schematic cross-section of the site; however, the main source of dissolved uranium, the pitchblende vein, is not shown in the cliff. An east-west trending fault zone runs sub-parallel to the cliff-line and may be a second route for heavy metals entering the Merse sediment pile.

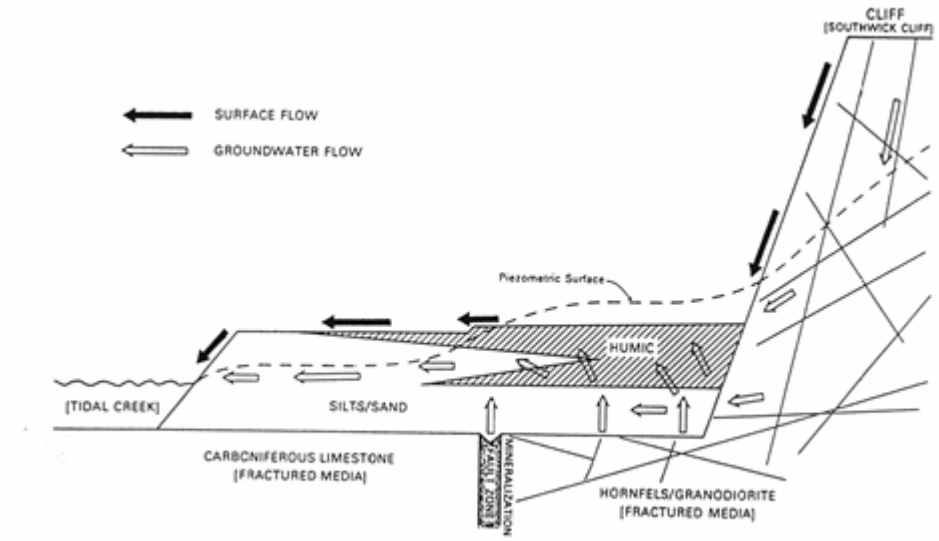

Figure 1: Schematic cross-section of the Needle's Eye natural analogue site (from Hooker, 1991).

The study focussed on the processes involving the transport and retardation of uranium and its daughter isotopes (MacKenzie et al., 1991). The data obtained from investigating uranium radionuclide migration behaviour were used in geochemical codes and databases in speciation and chemical transport modelling exercises (Hooker, 1991; Ledoux et al., 1991; Falck and Hooker, 1992; Crawford and Hooker, 1994).

Uranium is present in the vein as pitchblende (UO_2) associated with secondary minerals such as uranophane (Ca-U-silicate). The pitchblende has undergone dissolution by two processes. The first is slow leaching over a long time period, probably by reducing waters, resulting in preferential loss of ^{234}U relative to ^{238}U. The second is rapid contemporary dissolution by oxidising waters. Some mobilised uranium is re-deposited in close proximity to the vein as oxidised uranium minerals, which are stable under present-day conditions and contribute little dissolved uranium to the groundwater.

Hydrocarbon is associated with the pitchblende vein and there is evidence of ancient micro-organisms present within these bitumen-type phases (Milodowski et al., 1990).

The majority of the mobilised uranium (80 - 90%) migrated with the shallow groundwater into the anoxic silty sediments where it was fixed by sorption onto humic substances and iron oxyhydroxides. In contrast to uranium, dissolution and transport of thorium was negligible.

This EC-funded study was ended in about 1990.

Relevance: The study is relevant for understanding the processes of near-surface migration of U and its decay-series nuclides by groundwater flow and its fixation in organic-rich coastal sediments in southwest Scotland. The data were used to test speciation models and chemical transport research codes.

The Needle's Eye site is an example of a coastal geosphere-biosphere interface (GBI), involving U nuclide dispersion into soils and sediments of a coastal plain.

Position(s) in the matrix tables: The study occupies a box in the Geosphere matrix table.

Limitations: The study is limited to a near-surface/surface environment for U/Th nuclide migration processes in a temperate maritime climate. The redox conditions were oxidising in the fractured granodiorite cliff and reducing in some sections of the Merse sediments.

Quantitative information: The Needle's Eye system is well characterised, with quantitative hydraulic conductivity values for the different sediment zones and some sorption data for U onto silty and organic-rich sediments. This study has quantified sub-surface mobility behaviour of U and its decay series nuclides in coastal sediments at Needle's Eye.

Uncertainties: There are some uncertainties associated with the rates of pitchblende leaching and dissolution. Also the current groundwater flow rates may not be representative of past rates. The effects of marine inundation of the Merse on the distribution of U in the sediments were not quantified.

Time-scale: The time-scale of the Needle's Eye natural analogue is geological (Quaternary <2 Ma), covering the period from the end of the last Ice Age to the present day i.e. the past 12,000 years or so.

PA/safety case applications: The UKAEA have considered some of the Needle's Eye study findings in terms of background soil and process information for developing natural safety indicators for the 'Run 1' safety assessment of a hypothetical LLW repository at Dounreay.

Communication applications: None known.

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Added value comments: Use of the Needle's Eye data as an analogue of U nuclide migration across a coastal GBI could be developed further. The U-decay series nuclide migration data are potentially useful for further testing of coupled chemical transport codes.

Potential follow-up work: Data on the upwelling of groundwater through the mineralised fault zone could be used to simulate/model geochemical transport for a coastal GBI.

Keywords: Far-field, U dispersion, U sorption, coastal sediments, geosphere-biosphere interface

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