South Terras (UK)

Description: Situated near the village of St. Stephen in Cornwall, England (National Grid Ref. SW 935 523), the abandoned South Terras Mine (formally Union Mine) was originally worked for iron ore until the uranium lode was discovered in 1873. The uranium lode was up to 1.2 m wide and was one of many located immediately to the south of the St. Austell granite (Figure 1, scanned from Read et al., 1991). The bulk of the ore had been worked out when the mine closed in 1900. It was the largest and most important producer of uranium in the region. The mine was re-opened several times and ore recovered from the dumps before finally closing in 1929. A total of 736 tons of ore was produced up to 1910, including 286 tons from the dumps (Dines, 1956).

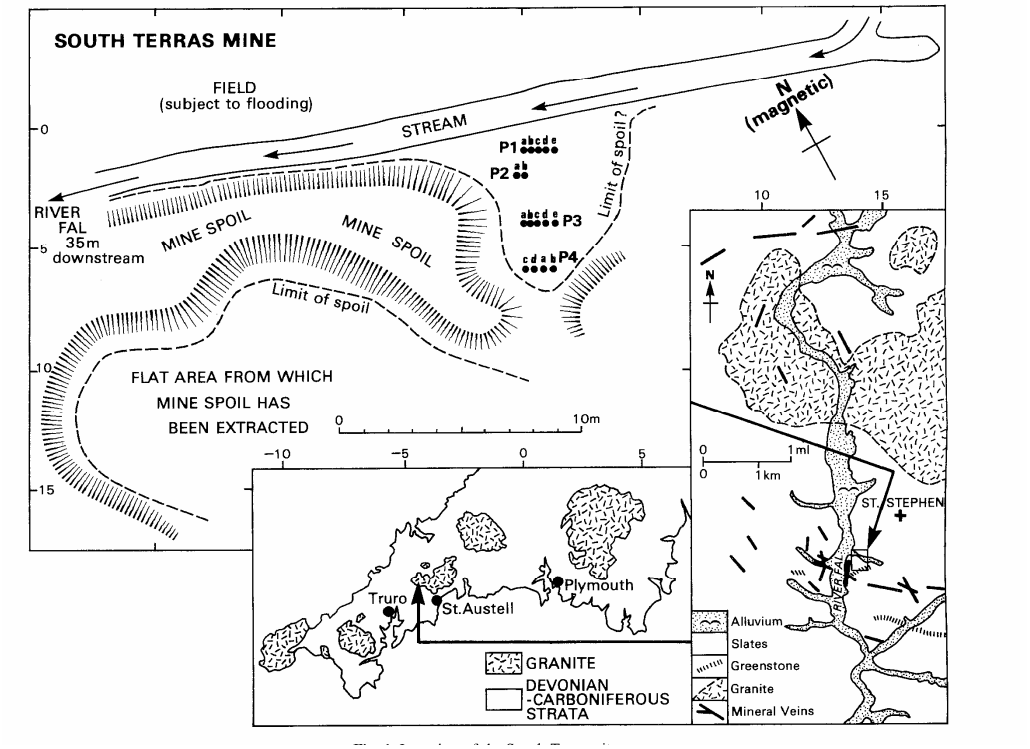

Figure 1: Location of the South Terras site

The early production was sent to Germany for making green glass, and contained on average about 11 wt % U_3O_8, although the best ore had up to 36 wt % of the oxide. The primary uranium phase excavated was pitchblende but secondary minerals such as zippeite, torbernite and autunite were also common. Although the main lode is no longer accessible, all of these minerals are present in the dumps now seen on the surface.

Migration of U-series radionuclides from the spoil heaps was the focus of the South Terras analogue study led by the British Geological Survey and carried out between 1986 and 1990. Rain water was leaching uranium from the spoil heap minerals and the leachate was infiltrating into the underlying and adjacent alluvial deposits. Groundwater was transporting the mobilised uranium through these clay-rich sediments towards a small tributary stream of the nearby River Fal (see Figure 1). Uranium migration data were obtained for testing geochemical and chemical transport models, in particular the CHEMTARD code (Read et al., 1991).

Four piezometer arrays (marked as P1 – P4 in Figure 1) were constructed in the alluvial sediments between the spoil heaps and the stream in order to measure the uranium plume in a 2-D profile. Radiometric measurements were performed on augered sediment and water samples collected from these arrays. Field and laboratory evidence along this 5 m long section demonstrated that the

saturated alluvial deposits were strongly modifying the plume of U-charged groundwater by a process of strong U-sorption.

Solubility modelling of the groundwaters indicated that the groundwater system was undersaturated with respect to pitchblende and secondary U-minerals, which implies that sorption was the mechanism of fixation. Sorption had minimised the contribution of U-series elements to the stream, where it was difficult to distinguish the spoil-derived U from its normal U-loading. At a depth of about 1.2 m within this sediment section, the U groundwater concentration decreased from 214 μg/l (ppb) near the heaps to a much lower value of 0.77 μg/l nearest the stream. The $^{230}Th/^{234}U$ activity ratios for the sediments were less than unity, explained by the addition of U from solution (Hooker et al., 1989). Read et al. (1991) modelled the sorption behaviour of U using surface-complexation theory to describe the interaction of aqueous U-species (mainly uranyl-phosphate anions) with the sediment minerals. It was argued that this approach provides a more fundamental description of the U-sorption process than the simpler Kd concept.

Relevance: The analytical data provide an information base for testing aqueous uranium speciation and groundwater transport research models applied to near-surface, saturated, clay-rich alluvial sediments. The research study's relevance is highest for near-surface low-level radioactive waste repositories associated with similar sedimentary environments.

The information from this near-surface site study is relevant to the retardation performance of clay-rich sediments acting as a barrier to uranium migration by groundwater flow.

Position(s) in the matrix tables: The South Terras study belongs to the boxes RN migration and retardation under low temperatures (<100°C) advection and chemical retardation in mudrocks of the far-field matrix table. The study would also occupy the Bentonite Clay/Chemical (<100 °C) Retardation box of the Near-field matrix table.

Limitations: The study was limited to uranium and some of the U-series nuclides. Other trace elements occur in the spoil heap minerals e.g. Co, Ni, Cu, As, but these were not analysed in detail to add to the generic value of the analytical database for geochemical modelling of contaminant migration in alluvial sediments.

Quantitative information: The study provided U concentration data for both sediment samples and associated groundwater. Reasonable controls were possible for estimating flow rates. Sufficient quantitative information was collected to allow U-speciation modelling and U-transport modelling.

Uncertainties: Distinguishing the relevant processes (physical, chemical and microbiological) that affect the distribution of U can be problematic. In addition, U sorption can be highly dependent on the presence of organic coatings on mineral surfaces and small changes in pH and Eh.

Time-scale: The time-scale of the analogue is human (0 – 100 years), involving over 80 years of uranium leaching from the dumps and migration into the alluvial sediments.

PA/safety case applications: Previous uses of the analogue study in a PA or safety case are not known.

Communication applications: There are probably no previous uses of the analogue study in communication and dialogue material.

References:
Dines HG (1956) The metalliferous mining region of South-West England. Mem. Geol. Survey of Great Britain, Volume 2, 541-543.

Hooker PJ, Ivanovich M, Milodowski AE, Ball TK, Dawes A and Read D (1989) Uranium migration at the South Terras mine, Cornwall. British Geological Survey Technical Report No. WE/89/13 and DOE report no. DOE/RW/89.068.

Read D, Hooker PJ, Ivanovich M and Milodowski AE (1991) A natural analogue study of an abandoned uranium mine in Cornwall, England. *Radiochimica Acta*, 52/53, 349-356.

Added value comments: The analogue study could be used to demonstrate the efficiency of a 5 m section of clay-rich sediments to retard the groundwater migration of uranium. The study could be used as an analogue of the potential isolating capacity of a clay backfill in a repository.

Potential follow-up work: If suitable concrete samples were available from the foundations of the abandoned mine buildings, it may be possible to obtain analytical evidence of the interactions between cement and U-series nuclides. It may be possible to investigate the migration of other contaminant elements at the site.

Keywords: uranium, sorption, sediments, clay, backfill

Reviewers and dates: Paul Hooker, Enviros Consulting (August, 2003)