Dunarobba Forest (Italy)

Description: The Dunarobba forest, near Todi in central Italy, is an exceptional case of the natural preservation of wood by burial in clay. In the Dunarobba and Cava Topetti quarries, dead tree trunks can be found still in their original, upright position, indicating a stable burial environment with little mechanical disturbance of the trees (Figure 1). The soils and sediment they were growing in have been dated to the Upper Pliocene, making the trees c.2 Ma old (Ambrosetti et al., 1992; Benvegnú et al., 1988).

Figure 1 Fossil forest trees, Dunarobba, Italy. The clay horizon which preserved the trees is the cream-coloured material in the middle ground (from Miller et al., 2000).

Hydrogen, oxygen and carbon isotopic ratios measured on material sampled from the Dunarobba trees are very similar to those of modern plants, indicating that very little alteration to the organic material has taken place. This is supported by the fact that the wood can be sawn, polished and even burned.

In normal circumstances, if buried wood does not decompose completely, it is altered to lignite and is lithified. The trees at Dunarobba are enclosed in lacustrine clay lying beneath sand deposits with freely circulating, oxidising water. There is a large difference in hydraulic conductivity between the two materials, with the clay layer having a hydraulic conductivity in the range $2x10^{-13}$ to $2x10^{-10}$ m/s compared to an estimated hydraulic conductivity for the sand deposits of 10^{-4} m/s (Lombardi and Valentini, 1996). The wood has been protected from degradation or lithification by the impermeable clay envelope which had restricted ingress of oxygenated groundwater (Bozzano et al., 1996).

The clay at Dunarobba has clearly had a major role in retarding microbial degradation of the tree wood. Wood is analogous to the organic and cellulosic materials which may be placed in some L/ILW repositories. This analogue study suggests that if anaerobic conditions can be maintained, organic matter decomposition and thus gas generation would be minimised in a repository near-field.

The Dunarobba study examined the long-term breakdown of cellulosic materials in the fossil trees situated in their reducing environment. Organic leachates from samples of the Dunarobba wood were compared with leachates obtained from modern oak, oak from the Roman period and 150 million year old lignites (Chapman, 1990). The total organic carbon (TOC) content produced from the Dunarobba wood was comparable to the steady state values from cellulose breakdown in the modern oak sample. The TOC from the Dunarobba wood contained significant polymeric material. The isolation of the wood from oxidising conditions and advective water flow had significantly

reduced the rate at which the wood degraded, thus minimising any gas generation and also the release of any organics that could be potential ligands for increased trace element migration.

The soluble breakdown products of cellulose (leachates) include organic molecules that can act as complexants for some of the poorly soluble radionuclides from the radioactive waste. Consequently, the products of cellulose degradation might increase radionuclide solubility in the repository. The effects of organic leachates from the Dunarobba wood on plutonium complexation and solubility were examined under controlled laboratory conditions. It was found that the Pu solubility increased from 10^{-11} M in NaOH to about 10^{-8} M in the leachate from the Dunarobba wood. If the cellulose degradation process was inhibited in a repository environment to the same extent observed at Dunarobba, then neither increased radionuclide solubility nor gas production would be significant problems.

Relevance: The study gives a clear demonstration of the long-term effectiveness of a natural clay barrier, and is an analogue of the potential long-term isolating capacity of a clay backfill in a repository.

The Dunarobba trees are generally used as qualitative illustrations of the isolating capacity of clay in terms of compacted bentonite buffer in HLW and spent fuel repository designs. However, this may be unreasonable considering the relatively higher temperatures (c.100 ^{o}C) that would be encountered in a buffer.

The Dunarobba trees also have relevance for L/ILW repository concepts, since the wood can be considered to be analogous to organic/cellulosic material, which can comprise a significant proportion of the waste.

Position(s) in the matrix tables: The Dunarobba study belongs to the Buffer/Backfill Bentonite Clay – Physical Integrity box and the Buffer/Backfill Bentonite Clay – Chemical Integrity box of the Near-field matrix table.

Limitations: Unfortunately, there is currently no detailed geochemical or mineralogical information to characterise the clay in detail.

The hydrolysis of bulk cellulose proceeds much more rapidly under alkaline conditions. However, Dunarobba does not mimic a cementitious L/ILW repository by having a hyperalkaline environment. Therefore the extremely slow rate of decomposition of the wood at Dunarobba may not be representative of the degradation behaviour of cellulose in cementitious repositories.

Quantitative information: The total organic carbon (TOC) content produced from leaching the Dunarobba wood was comparable to the steady state values from cellulose breakdown in a modern oak wood sample (Chapman, 1990), implying that there had been a negligible rate of cellulose degradation over a period of about 2 Ma.

Uncertainties: Full characterisation data on the sealant clay are not available.

Time-scale: The time-scale covered by the Dunarobba natural analogue is geological, involving about 2 Ma since the forest was buried.

PA/safety case applications: Dunarobba information was used as evidence that clay would be a barrier to microbial activity in the Swedish SR-97 PA of a deep geological repository (IAEA, 1999).

The Yucca Mountain Project quotes Dunarobba in its technical information report supporting the site recommendation (USDOE/OCRWM, 2002). It was used as an illustration of how well sorptive materials in a backfill can perform, by analogy with the preservation of ancient wood fibre seen at Dunarobba.

Communication applications: The study has provided graphic illustrations of the isolating capacity of clay. These illustrations are considered especially useful as non-technical demonstrations for a general public audience.

Current uses of the analogue study in communication and dialogue include Nagra e.g. see the website http://www.nagra.ch/english/forsch/natur.htm. In its 2nd Progress Report (AKEND, 2001), the Arbeitskreis Auswahlverfahren Endlagerstandorte or AKEND, the Committee on repository site selection procedures for Germany, documents the current state of its discussions and activities. The AKEND Committee is part of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The 2nd Progress Report presents interim, preliminary results as of August 2001 before the second public workshop held in September 2001, and included in it is a discussion and review of some selected natural analogue studies, including Dunarobba. This analogue was used to demonstrate the effectiveness of natural barriers. It would be interesting to know whether the public workshop revealed any feedback on the use of analogues in site selection procedures.

References:

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Added value comments: The analogue is useful for communicating the idea that clay can be an effective isolation barrier. Having actual specimens of Dunarobba wood available at public meetings for hand examination would help engage some members of the audience.

Potential follow-up work: Any follow-up work that could be undertaken would focus on quantifying better the nature of the clay that had preserved the wood.

Keywords: wood, clay, bentonite, backfill, buffer

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