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Discussion

Commentary: Assessment of past infiltration fluxes through Yucca Mountain on the basis of the secondary mineral record—is it a viable methodology?

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Abstract

Two papers recently published in the Journal of Contaminant Hydrology by Marshall et al. [Marshall, B.D., Neymark, L.A., Peterman, Z.E., 2003. Estimation of past seepage volumes from calcite distribution in the Topopah Spring Tuff, Yucca Mountain, Nevada. J. Contam. Hydrol. 62–63, 237–247] and Xu et al. [Xu, T., Sonnenthal, E., Bodvarsson, G., 2003. A reaction–transport model for calcite precipitation and evaluation of infiltration fluxes in unsaturated fractured rock. J. Contam. Hydrol. 64, 113–127] attempt to assess past volumes of seepage and infiltration fluxes through the vadose zone of Yucca Mountain, Nevada, on the basis of the modeling of the spatial distribution of secondary calcite. In this commentary, we argue that the employed methodology is not viable. In addition, the thermal boundary conditions used in simulations do not correspond to the temperatures of the mineral forming fluids established on the basis of the fluid inclusion studies.

Keywords: Yucca Mountain; Calcite; Percolation flux; Seepage; Modeling; Nuclear waste

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1. Introduction

Open fractures and lithophysal cavities in the Miocene rhyolitic tuffs of Yucca Mountain host a suite of secondary minerals: calcite, various polymorphs of silica (quartz, chalcedony, opal), minor fluorite, zeolites, strontianite, and barite (e.g., Broxton et al., 1987, Paces et al., 2001, Smirnov and Dublyansky, 2001; Whelan et al., 2002; Wilson et al., 2003). The minerals occur within a thick, ca. 500–800 m, vadose (unsaturated) zone, which is being studied as a potential medium for a high-level nuclear waste repository. It is thought that the vadose zone was formed ca. 11.5 million years ago, shortly after emplacement of the Paintbrush Group tuffs (U.S. DOE, 2001). Since it is generally asserted by U.S. DOE aligned researchers that the minerals were deposited from meteoric waters that infiltrated into the vadose zone of Yucca Mountain (e.g., U.S. DOE, 2001 and references therein), a number of attempts have been made to use these minerals to assess the volumes of seepage and infiltration fluxes through the mountain in the past (e.g., Marshall et al., 1998, 1999). Two papers describing the most recent attempts at such an assessment were published in the Journal of Contaminant Hydrology in 2003. These are: Marshall et al. (2003) and Xu et al. (2003). Below, we discuss the problems with the boundary conditions employed in the modeling, as well as a more serious problem with the selection of the phenomenological model for the studied process.

2. Inappropriate boundary conditions

Although the authors of the subject publications use different modeling techniques, the models reported in both papers employ similar thermal boundary conditions. In their hydrochemical model calculations, Marshall et al. (2003) use the modern-day vadose zone temperatures, which increase along a hypothetical infiltration path from 20 °C in alluvium, to 20.3 °C in the PTn non-welded tuff unit and increase to 23.8 °C in the Topopah Spring Tuff (TSw) at a depth of approximately 200 m ($dT/dz \cong 19$ °C/km; Table 1 in Marshall et al., 2003). Similarly, Xu et al. (2003) use temperatures from borehole WT-24: 15.6 °C at the surface, and 28 °C at a depth of ca. 750 m ($dT/dz \cong 16.5$ °C/km; Fig. 3 in Xu et al., 2003). Both models operate under the assumption that the deposition of secondary minerals occurred at a constant infiltration rate and steady-state water flow conditions over an extended period of time: Marshall and others postulate that the subject minerals "*were formed over most of the 12.8 m.y. history of the host rock*" (p. 239) and assume a 10 million year time interval for the formation of coatings (p. 244); Xu and others use the "*simulation time period of 10 million years*" (p. 116). Thus, both models implicitly assume that the temperatures in the vadose zone of Yucca Mountain (in the vicinity of the ESF tunnel in the case of Marshall and others' model and around borehole WT-24 located some 3 km to the NNW of the ESF in the case of Xu and others' model) were similar to the modern day temperatures during the last 10 million years. This is a very important assumption, since the models appear to be strongly temperature-sensitive. For example, Xu et al. (2003, p. 125) reported that the decrease of the model temperature by as little as 2 °C resulted in substantial change and spatial redistribution of calcite precipitation.