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U-Series Transport Studies at the Peña Blanca, Mexico Natural Analog Site

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RESEARCH OBJECTIVES

Natural analogs provide a line of evidence that supports the understanding of how natural and engineered processes would occur over long time frames and large spatial scales at a potential nuclear waste repository at Yucca Mountain, Nevada. Studies of U-series disequilibria within and around uranium deposits can provide valuable information on the timing of actinide mobility and hence the stability of a potential repository over geologic time scales. The Nopal I uranium deposit at Peña Blanca, Mexico, is situated in unsaturated tuff that is similar in composition to the Topopah Spring Tuff of Yucca Mountain and closely matches other evaluation criteria for suitable natural analogs. By modeling the observed radioactive isotope disequilibria at Nopal I, we can estimate the rates of sorption-desorption and dissolution-precipitation of the radionuclides over time. Such information is vital to the testing or validation of performance assessment models for geologic nuclear waste disposal.

APPROACH

The goal is to construct a three-dimensional conceptual model of the transport of uranium and radiogenic daughter products at Peña Blanca. A number of boreholes through and surrounding the ore deposit will be drilled to the water table (a depth of ~200 m); from these solid core and water samples will be taken. Isotopes of ²³⁴U, ²³⁸U, ²³²Th, ²³⁰Th, ²²⁸Th, ²³⁴Th, ²²⁶Ra, ²²⁸Ra, ²¹⁰Po, and ²¹⁰Pb will be measured in the fluid samples. Radioactive disequilibria in sorbed phases will be obtained using leaching methods on the core samples. To correct for the possible effect of evaporative concentration on model results, Cl⁻ or δ¹⁸O and δD compositions of water samples from the unsaturated zone will be compared with those of rainwater. The final report will include recommendations on the application of model results from the Peña Blanca analog site to testing the unsaturated zone process models that provide input to performance assessment models for Yucca Mountain.

ACCOMPLISHMENTS

Water has twice been sampled at a perched water horizon and at points along a water collection system in the mine adit. Shown in Figure 1 are the stable isotope data and uranium concentrations for the samples collected in 2000. Samples AS-1 and AS-2 exhibit higher U concentrations because of proximity to the ore body (exposed from 0 to 2 m into the adit), indicating the rapid decrease in U concentration with distance from the ore body. Samples AS-5 and AS-6 have significantly lower δD and δ¹⁸O values than the other samples. They fall on the global meteoric water line (GMWL) and probably represent the average composition for the precipitation at the site. The other samples were all collected from an adit in the unsaturated zone. Of these, AS-1 lies on the GMWL, but probably does not represent a rainwater sample (it is relatively enriched in D and ¹⁸O for meteoric water at this latitude). The other 3 samples all fall significantly to the left of the GWML and may represent atmospheric water vapor that has condensed in the cooler, underground environment followed by some evaporation in the collection bottles. Detailed U-series isotopic data on these samples will be obtained.

SIGNIFICANCE OF FINDINGS

U-series modeling provides a means to characterize the kinetically controlled radionuclide transport and residence time at Peña Blanca. Using an earlier data set collected by Southwest Research Institute, we estimated the ²³⁴U alpha-recoil rate into fluids to be 9 dpm/L/y at Peña Blanca vs. dissolution rates of 8.3 dpm/L/y for ²³⁸U and ²³⁴U. The kinetic model also allows determination of fluid transit time in the unsaturated zone. ²³⁸U increases linearly with increasing transit time, while ²³⁴U/²³⁸U decreases. The transit time for the seep water infiltrated into the adit 8 m below surface is estimated to be 6–29 days, and that for the perched water at 10.7 m depth in an old borehole is 0.4–0.5 years. The large values of transit time for the perched water may reflect the long residence time of water in the borehole. Although the

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water transit time in the unsaturated zone is quite short, detectable dissolution of U from fractured rocks does occur in this low-water flux, high-U concentration setting near the Nopal I uranium deposit.

RELATED PUBLICATIONS

Murrell, M.T.; Paviet-Hartmann, P.; Goldstein, S.J.; Nunn, A.J.; Roback, R.C.; Dixon, P.A.; and A. Simmons. U-Series natural analog studies at Peña Blanca, Mexico: how mobile is uranium?, EOS, Transactions, AGU Volume 80, p. F1205, 1999.

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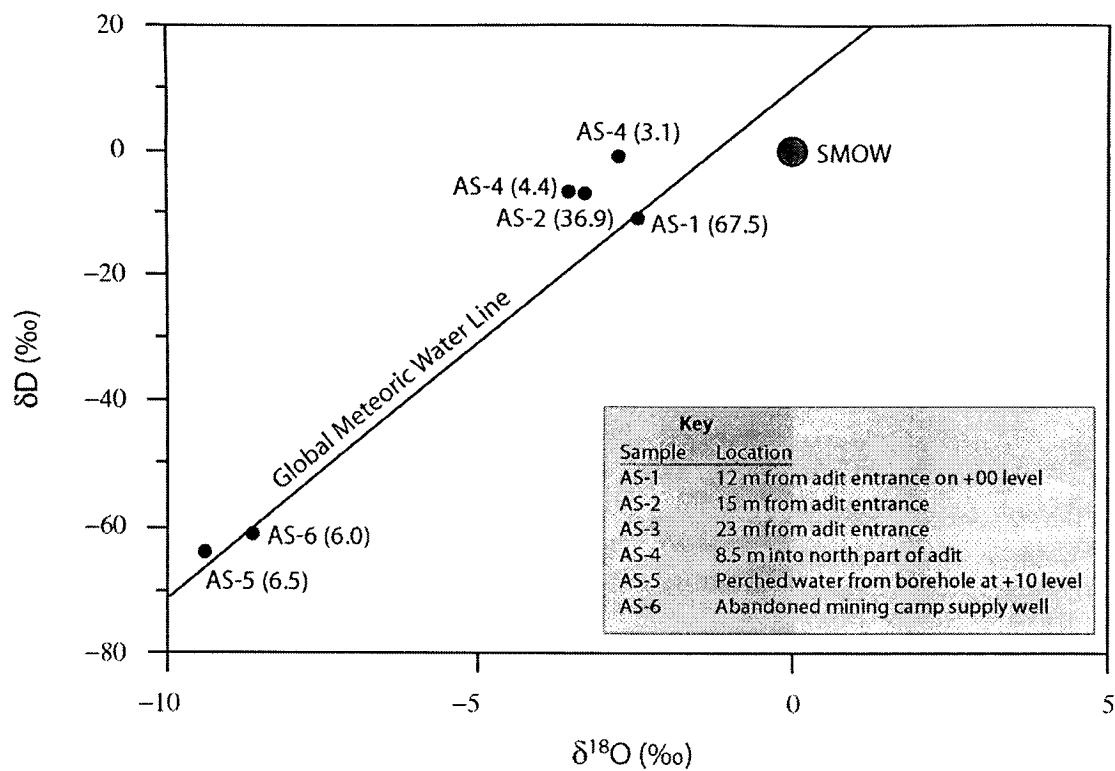


Figure 1. Uranium and stable isotope data for water samples collected (black circles) from Peña Blanca during February 2000. Also shown is the position of the global meteoric water line and SMOW (Standard Mean Ocean Water). Uranium concentrations in parts per billion (ppb) are indicated in parentheses after the sample number. Sample locations are shown on key.