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## **Mobility of Metal Tracers in Unsaturated Tuffs of Busted Butte, Nevada**

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A complex tracer mixture was injected continuously for over two years into a 10 m x 10 m x 7 m block of unsaturated tuff as part of the Busted Butte unsaturated-zone tracer test at Yucca Mountain. The test was designed to measure tracer transport within the Topopah Springs and Calico Hills tuffs, units that occur between the potential high-level nuclear waste repository at Yucca Mountain and the water table below. The mixture included nonreactive (Br, I, and fluorinated benzoic acids (FBAs)) and reactive tracers (Li, Ce, Sm, Ni, Co, and Mn). Bromide, I, FBAs, and Li were detected during the test on absorbent pads emplaced in a series of solute collection boreholes located beneath the injectors but the more strongly sorbing metals did not reach the collection boreholes during this period. To determine the distribution and mobility of these metals, tracer constituents were extracted from tuff samples collected during overcoring and mineback of the test block. Tracers were extracted from the tuff samples by leaching with a 5% nitric acid solution for metals and a bicarbonate-carbonate buffer for anions. Results from the overcore sample suite show that metals have migrated through the tuff in the region adjacent to and immediately below the tracer injectors.

Consistent with laboratory sorption measurements and observed breakthrough in the collection boreholes, rock analyses showed that Li is the most mobile of the metals. Co and Ni behave similarly, traveling tens of cm from the injection sites, while Sm and Ce moved far less, possibly due to precipitation reactions in addition to sorption. Determination of Mn transport is complicated by high background concentrations in the tuff; additional background samples are currently being evaluated. As expected, our rock analyses show that the nonreactive tracers Br and FBAs have moved beyond the overcore region, corroborating results from collection boreholes.