SwRI: Mineralogic Studies of The Pena Blanca Natural Analog Project

Applied Geochemistry, Vol. 9, pp. 713-732, 1994

Alteration of uraninite from the Nopal I deposit, Peña Blanca District, Chihuahua, Mexico, compared to degradation of spent nuclear fuel in the proposed U.S. high-level nuclear waste repository at Yucca Mountain, Nevada

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Abstract

At the Nopal I uranium deposit, primary uraninite (nominally $UO_{2_{+x}}$) has altered almost completely to a suite of secondary uranyl minerals. The deposit is located in a Basin and Range horst composed of welded silicic tuff; uranium mineralization presently occurs in a chemically oxidizing and hydrologically unsaturated zone of the structural block. These characteristics are similar to those of the proposed U.S. high-level nuclear waste (HLW) repository at Yucca Mountain, Nevada. Petrographic analyses indicate that residual Nopal I uraninite is fine grained (5-10 microns) and has a low trace element content (average about 3 weight percent). These characteristics compare well with spent nuclear fuel. The oxidation and formation of secondary minerals from the uraninite have occurred in an environment dominated by components common in host rocks of the Nopal I system (e.g. Si, Ca, K, Na and H_2O) and also common to Yucca Mountain. In contrast, secondary phases in most other uranium deposit form from elements largely absent from spent fuel and from the Yucca Mountain environment (e.g. Pb, P and V). The oxidation of Nopal I uraninite and the sequence of alteration products, their intergrowths and morphologies are remarkably similar to those observed in reported corrosion experiments using spent fuel and unirradiated UO_2 under conditions intended to approximate those anticipated for the proposed Yucca Mountain repository. The end products of these reported laboratory experiments and the natural alteration of Nopal I uraninite are dominated by uranophane [nominally $Ca(UO_2)_2SiO_2O_7$ **?** $6H_2O$] with lesser amounts of soddyite [nominally $(UO_2)2SiO_4{\cdot}_2H_2O$] and other uranyl minerals. These similarities in reaction product occurrence developed despite the differences in time and physical-chemical environment between Yucca Mountain-approximate laboratory experiments and Yucca Mountain-approximate uraninite alteration at Nopal I, suggesting that the results may reasonably represent phases likely to form during long-term alteration of spent fuel in a Yucca Mountain repository. From this analogy, it may be concluded that the likely compositional ranges of dominant spent fuel alteration phases in the Yucca Mountain environment may be relatively limited and may be insensitive to small variations in system condition.