NATURAL ANALOGUES FOR YUCCA MOUNTAIN COUPLED PROCESSES: GEOTHERMAL SYSTEMS

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RESEARCH OBJECTIVES

Geothermal systems provide an ideal opportunity for examining the long-term effects of coupled thermal-hydrological-chemical (THC) processes expected for the proposed radioactive waste repository at Yucca Mountain, Nevada. Active and fossil geothermal systems provide important insights into the consequences of processes such as boiling, condensation, fluid mixing, and water-rock interaction associated with fluid flow in matrix and fractures, and can be used to test coupled-process models. Geothermal systems also allow observation of the effects of processes over much larger volumes and longer time scales than would be possible in laboratory or field experiments. The objective of this study is to evaluate potential changes in fluid flow resulting from the thermal impacts of storing high-level radioactive waste in fractured ash flow tuffs through characterization of the effects of water-rock interaction in geothermal systems.

APPROACH

An extensive literature review was performed to identify well-characterized examples of THC processes in active and fossil geothermal systems. Special attention was given to processes such as heat and fluid flow, chemical transport, boiling and dryout, condensation and mineral dissolution, and mineral alteration and precipitation. In addition, a detailed examination of core samples from the Yellowstone geothermal system was conducted to evaluate the effects of lithology and hydrothermal alteration on porosity and permeability.

ACCOMPLISHMENTS

The review identified key THC processes in geothermal systems and evaluated their relevance to Yucca Mountain. Fluid flow in low-permeability rocks (such as the welded tuffs found at Yucca Mountain) occurs predominantly in fractures. Precipitation of minerals can be triggered by boiling, water-rock interaction, heating and cooling of fluids, and fluid mixing. Mineral solubilities, reaction-rate kinetics, and the flux, chemistry, and temperature of circulating fluids control the rates and volumes of mineralization. Mineral precipitation (typically silica, clays, zeolites, anhydrite, and calcite) occurring within fracture flow pathways can form effective permeability barriers. Self-sealing zones observed in core samples in the Yellowstone geothermal system appear to have resulted from boiling events that led to the development of supersaturated fluids (Figure 1).

SIGNIFICANCE OF FINDINGS

Effects of THC processes such as boiling, condensation, dissolution, and precipitation for Yucca Mountain's higher-temperature operating mode will be most significant in the near-field environment (near the proposed repository). However, unsaturated conditions, lower temperatures, and the much lower fluid flow rates predicted for the Yucca

Mountain system (in comparison to geothermal systems) should result in less extensive water-rock interaction than is observed in geothermal systems. Current THC models for Yucca Mountain predict that while both amorphous silica and calcite will precipitate in the near-field environment, significant fracture sealing is unlikely.

RELATED PUBLICATIONS

Simmons, A.M., Natural Analogue Synthesis Report. Report TDR-NBS-GS-000027 REV00 ICN 02, Bechtel SAIC Company, Las Vegas, Nevada, 2002.

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ACKNOWLEDGMENTS

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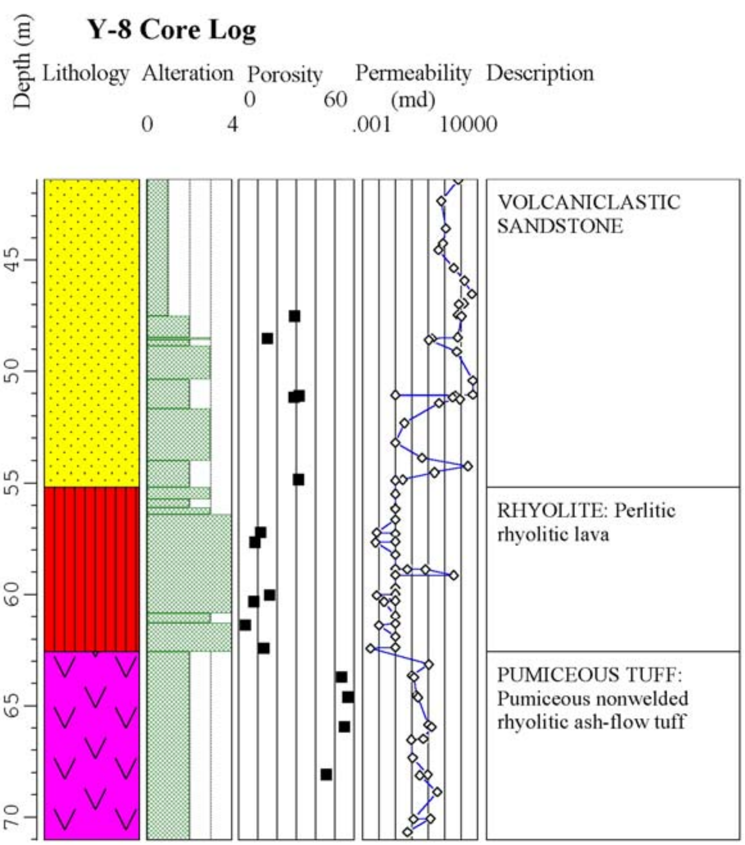

Alteration: 0 = unaltered, 4 = strongly altered

Figure 1. Simplified log of the geology, porosity, and matrix permeability of the Y-8 Yellowstone core. Silicification in the lower portion of the volcaniclastic sandstone unit has resulted in reductions in porosity and permeability, thereby forming an effective seal to the underlying convecting geothermal reservoir.