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SIMULATING THE THERMAL HISTORY OF THE UNSATURATED ZONE AT YUCCA MOUNTAIN, NEVADA

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Heat transfer within Earth's upper crust is primarily by conduction, and conductive thermal models adequately explain the cooling history of deep, batholith-scale intrusions and surrounding wall rocks, as confirmed by numerous thermochronometric studies. However, caldera magmatic systems require consideration of the small and localized component of hydrothermal convection and numerical models to simulate additional boundary conditions, irregular magma chamber shapes, and complex intrusive histories. At Yucca Mountain, Nevada, the site of a potential high-level nuclear waste repository, simulating the detailed thermal history at any location in the unsaturated zone requires knowledge of the shape of the magma chamber and its proximity to Yucca Mountain (the southern margin of the Timber Mountain caldera complex is approximately 8 km north of the potential repository site), the temporal and spatial extent of hydrothermal convection, the erosional history of the area, and past levels of the water table.

Several lines of evidence from site characterization studies at Yucca Mountain indicate that the 500-m-thick unsaturated zone cooled from ~70 °C to modern temperatures from ~10 Ma to ~5 Ma. This prolonged thermal perturbation most likely is related to the heat associated with three major episodes of magmatic activity beneath the Timber Mountain caldera complex from ~15 Ma to ~11 Ma. Simulations were performed using HEAT, a two-dimensional, numerical model that simulates conductive and convective heat transport in magmatic systems[1], to determine the model sensitivity to the thermal structure of the crust, magmatic history, and hydrothermal history. The magma chamber was assumed to be a 5000-km^3 disc, 7 km high, 30 km wide, and emplaced at a depth of 5 km. For this magma chamber, the simulations indicate that modern geothermal gradients were reached at 6 Ma to 3 Ma. These results are in general agreement with paleotemperature data from fluid inclusions in and isotopic compositions of secondary calcite at Yucca Mountain.

[1]Wohletz and others, 1999, Journal of Volcanology and Geothermal Research, v. 91, p. 381-414.