

---

# Paleogeothermal and Paleohydrologic Conditions in Silicic Tuff from Yucca Mountain, Nevada

David L. Bish<sup>1</sup> and James L. Aronson<sup>2</sup>

<sup>1</sup> Earth and Environmental Sciences Division, Mail Stop D469, Los Alamos National Laboratory Los Alamos, New Mexico 87545

<sup>2</sup> Geology Department, Case Western Reserve University Cleveland, Ohio 44106

**Abstract:** The clay mineralogy of tuffs from Yucca Mountain, Nevada, the potential site of the nation's first high-level radioactive waste repository, has been studied in order to understand the alteration history of the rocks and to predict potential future alterations. Bulk-rock samples and clay-mineral separates from three drill holes at Yucca Mountain (USW G-1, USW G-2, and USW GU-3/G-3) were studied using X-ray powder diffraction, and supporting temperature information was obtained using fluid inclusion data from calcite. Twelve K/Ar dates were obtained on illite/smectite (I/S) separated from the tuffs from the two northernmost drill holes, USW G-1 and G-2. The predominant clay minerals in the Yucca Mountain tuffs are interstratified I/S, with minor amounts of chlorite and interstratified chlorite/smectite. The I/S reactions observed as a function of depth are similar to those observed for pelitic rocks; I/S transforms from R = 0 interstratifications through R = 1 and R  $\geq$  3 interstratifications to illite in USW G-2 and to R  $\geq$  3 I/S in USW G-1. The R = 0 I/S clays in USW GU-3/G-3 have not significantly transformed. K/Ar dates for the I/S samples average 10.4 my. These data suggest that the rocks at depth in the northern portion of Yucca Mountain were altered 10.0 – 11 my ago, soon after creation of the Timber Mountain caldera to the north. Both I/S geothermometry and fluid inclusion data suggest that the rocks at depth in USW G-2 were subjected to postdepositional temperatures of at least 275° C those in USW G-1 reached 200° C, and rocks from USW GU-3/G-3 probably did not exceed 100° C. These data suggest that no significant hydrothermal alteration has occurred since Timber Mountain time, ~10.7 my ago.

Estimates of the temperature of formation of illite/smectites yield probable stability limits for several minerals at Yucca Mountain. Clinoptilolite apparently became unstable at about 100° C mordenite was not a major phase above 130° C and analcime transformed to albite above 175° – 200° C. It appears that cristobalite transformed to quartz at 90° – 100° C in USW G-2 but must have reacted at considerably lower temperatures (and for longer times) in USW GU-3/G-3. The reactions with increasing depth appear coupled, and clinoptilolite and cristobalite disappear approximately simultaneously, supporting aqueous silica activity as a controlling variable in the clinoptilolite-to-analcime reaction. The reaction of clinoptilolite to analcime also coincides with the appearance of calcite, chlorite, and interstratified chlorite/smectite. Although the hydrothermal fluids may have been a source for some cations, breakdown of clinoptilolite (and mordenite) probably provided the source of some of the Ca for calcite, Mg for chlorite, K for the I/S found deeper in the section, and Na for analcime and albite.

Using the rocks in USW G-1, G-2, and GU/G-3 as natural analogs to repository-induced thermal alteration suggests that the bulk of the clinoptilolite- and mordenite-bearing rocks in Yucca Mountain will not react to less sorptive phases such as analcime over the required lifetime of the potential repository. The zeolites in zeolite interval I, directly underlying the proposed repository horizon, may transform at the predicted repository temperatures. However, the reaction of clinoptilolite to analcime in interval I may require the transformation of all of the abundant opal-CT and glass to quartz, an unlikely scenario considering the unsaturated nature of these rocks and the predicted temperatures of < 100° C.

**Key Words:** Geothermal gradients • Illite/smectite • K/Ar dating • X-ray powder diffraction • Yucca Mountain

*Clays and Clay Minerals*; April 1993 v. 41; no. 2; p. 148-161; DOI: [10.1346/CCMN.1993.0410204](https://doi.org/10.1346/CCMN.1993.0410204)

© 1993, The Clay Minerals Society

Clay Minerals Society ([www.clays.org](http://www.clays.org))

---