LR-287-70
03/03/87

LETTER REPORT

Title: Review and Evaluation of Mineralogic Summary of Yucca Mountain, Nevada, LA-10543-MS, Oct., 1985, by D. L. Bish and D. T. Vaniman

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ACTIVITY NUMBER: ORNL #41 88 54 92 4 (FIN No. B0287)
NRC #50 19 03 01

OVERVIEW

This report offers preliminary observations on the patterns of distribution of primary and secondary minerals in the tuffaceous rocks at the Yucca Mountain, candidate, HLW repository site. Most of the authors' conclusions are based on data obtained from semi-quantitative X-ray powder diffraction analyses of Yucca Mountain tuffs. These data indicate that there are six mappable "mineral types" at Yucca Mountain: primary glass plus tridymite, primary and secondary quartz, secondary smectite, clinoptilolite plus mordenite, secondary analcime, and secondary albite. Two additional primary minerals, cristobalite and K-bearing alkali feldspar, are nearly ubiquitous in Yucca Mountain rocks.

REVIEW

Introduction

DOE-NNWSI is currently conducting detailed petrologic and mineralogic studies of the rocks in and adjacent to Yucca Mountain, Nevada (e.g., Bish et al., 1981; Caporuscio et al., 1982; Levy, 1984; and Vaniman et al., 1984). The ultimate goal of these investigations is to obtain a three-dimensional petrologic-mineralogic model of the Yucca Mountain area. Toward this end, tuffs from Yucca Mountain are being subjected to systematic X-ray powder diffraction (XRD) analysis. This analytical method is being employed extensively because Yucca Mountain tuffs have very fine-grained groundmasses that are not amenable to quantitative mineral analysis by optical techniques and electron probe microanalysis.

The DOE-NNWSI mineralogic studies have three immediate objectives. First, DOE-NNWSI wishes to obtain an improved understanding of the relationship between retardation of radionuclides and the minerals present in Yucca Mountain tuffs. This effort has prompted studies to investigate the correlation between mineralogy and sorption for numerous radionuclides (Bish et al., 1984b). The sorption data obtained to date indicate that the minerals clinoptilolite, mordenite, and smectite are effective sorbents for many cationic radionuclides.

A second objective of DOE-NNWSI mineralogic studies is to determine the thermal stability of hydrous minerals — particularly clinoptilolite and smectite — under temperature conditions similar to those that are expected to develop near the Yucca Mountain engineered facility after repository closure. Bish et al. (1981) and Smyth (1982) have discussed the potential for clinoptilolite and smectite to react to form other minerals (e.g., analcime and albite) if a repository is constructed at Yucca Mountain. These reactions would occur primarily in response to increased temperature, and two important consequences of these reactions would be release of water and decreases in rock volume.

Finally, Lappin (1982) and Lappin et al. (1982) note that the thermal properties of tuff (both matrix thermal conductivity and thermal expansion) are partly a function of mineralogy. These investigators also describe the relationship between the mechanical properties of tuff and mineralogy, emphasizing that data on rock fabric are required to accurately predict bulk mechanical properties.

In view of the potential effects of mineralogy and dehydration reactions on the thermal and mechanical properties of tuff, DOE-NNWSI has concluded that it is desirable to determine the distributions of minerals (and particularly hydrous minerals) in the reference repository horizon.

The discussions presented by Bish and Vaniman summarize current mineralogic investigations of Yucca Mountain rocks. Much of the text is devoted to explaining the methods used to obtain XRD data and the limitations of the data. The report also lists XRD data for samples of core, cuttings, and sidewall material obtained from various drill holes at Yucca Mountain.

Spatial Distributions of Minerals at Yucca Mountain

The semi-quantitative XRD data obtained by Bish and Vaniman indicate that there are six mappable "mineral types" at Yucca Mountain: primary glass plus tridymite, primary and secondary quartz, secondary smectite, clinoptilolite plus mordenite, secondary analcime, and secondary albite. Also, the XRD data reveal that primary K-bearing alkali feldspars and cristobalite are nearly ubiquitous in Yucca Mountain tuffs.

Glass

Glass-rich rocks (vitric zones) occur both above and below the reference repository horizon at Yucca Mountain (the Topopah Spring Member). The glasses in vitric zones can be divided into two categories: vitrophyre and nonwelded glass. Vitrophyre is composed predominantly of dense (low-porosity) welded glass. A prominant zone of vitrophyre occurs at the base of the Topopah Spring Member.

In contrast to dense vitrophyre, nonwelded glass consists of open shards and pumice and, for this reason, contains much more pore space than vitrophyre. Nonwelded glass occurs both above and below the Topopah Spring Member, and is more abundant than vitrophyre in Yucca Mountain.

Silica polymorphs

The silica polymorphs tridymite, quartz, and cristobalite are abundant in Yucca Mountain tuffs. Tridymite occurs in surficial rocks and persists in subsurface rocks down to the Topopah Spring Member (i.e., to a depth of approximately 300 m). The disappearance of tridymite with increasing depth is marked by the initial appearance of abundant groundmass quartz. Bish and Vaniman hypothesize that this tridymite/quartz transition in part reflects the passage from zones of high-temperature vapor-phase crystallization (tridymite) to zones of lower-temperature devitrification (quartz) within the Topopah Spring Member. The third abundant silica polymorph at Yucca Mountain, cristobalite, is widespread above the water table and persists to depths greater than 500 m above sea level.

Smectite

Smectite is a common accessory mineral in Yucca Mountain tuffs. However, in addition to its widespread presence as a minor secondary mineral, smectite also occurs as a major mineral in restricted locales. For example, there are mappable layers of abundant smectite situated at the top of the vitric, nonwelded base of the Tiva Canyon Member and at the top of the basal vitrophyre of the Topopah Spring Member. The smectite-rich layer in the Tiva Canyon Member contains 7 to 35%

smectite, while the layer near the base of the Topopah Spring Member contains 5 to 45% smectite. These smectite layers are generally less than 1 m thick but are notably thicker in several areas (e.g., in the rocks transected by drill holes USW G-1, USW G-2 and UE-25a#1). In addition to these laterally continuous smectite-bearing intervals, smectites are abundant in subsurface rocks near several "major structures" which are believed to be major strike-slip faults (Scott and Bonk, 1984). Abundant smectite in these rocks is accompanied by interstratified illite that becomes more abundant with increasing depth (Caporuscio et al., 1982).

Clinoptilolite and Mordenite

Bish et al. (1984a) and Vaniman et al. (1984) claim that there are at least four mappable zones of clinoptilolite (or heulandite) plus mordenite in the rocks beneath Yucca Mountain. These zeolite-rich zones occur principally in the nonwelded tops, bottoms, and distal edges of ash flows. Zeolites are also observed in fractures crossing devitrified layers (Carlos, 1985). The various occurrences of zeolites at Yucca Mountain underscore the complexities of zeolite formation at the site and suggest multiple origins for these minerals (Moncure et al., 1981).

Analcite and Albite

Secondary analcite and albite are only observed in the deepest tuffaceous rocks beneath Yucca Mountain. Analcite typically first occurs at a depth of approximately 250 m above sea level, but it is observed in the rocks transected by drill hole USW G-2 at a depth of 600 m above sea level. The occurrence of authigenic albite is restricted to depths below 500 m above sea level. Like analcite, the shallowest occurrence of authigenic albite is in drill hole USW G-2; in this borehole, secondary albite is first observed at a depth of 1080 m.

Conclusions

Semi-quantitative X-ray powder diffraction data for Yucca Mountain tuffs indicate that there are six mappable "mineral types" at Yucca Mountain: primary glass plus tridymite, primary and secondary quartz, secondary smectite, clinoptilolite plus mordenite, secondary analcime, and secondary albite. These mineralogic zones have the following broad characteristics.

- Glass-rich rocks (vitric zones) occur both above and below the reference repository horizon at Yucca Mountain (the Topopah Spring Member). The glasses in vitric zones can be divided into two categories: vitrophyre and nonwelded glass.

- Tridymite, quartz, and cristobalite are abundant in Yucca Mountain tuffs. Tridymite occurs in surficial rocks and persists in subsurface rocks down to the Topopah Spring Member. The disappearance of tridymite with increasing depth is marked by the initial appearance of abundant groundmass quartz. Cristobalite is widespread above the water table and persists to depths greater than 500 m above sea level.

- Smectite is a common accessory mineral in Yucca Mountain tuffs, but it also occurs as a major mineral in (1) two thin, laterally extensive layers and (2) near several major structural features.

- Clinoptilolite and mordenite occur principally in the nonwelded tops, bottoms, and distal edges of ash flows. These zeolites are also observed in fractures crossing devitrified layers.

- Secondary analcite and albite are only observed in the deepest tuffaceous rocks beneath Yucca Mountain.

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EVALUATION

This report offers preliminary observations on the patterns of distribution of primary and secondary minerals in the tuffaceous rocks at the Yucca Mountain, candidate, HLW repository site. Most of the authors' conclusions are based on data obtained from semi-quantitative X-ray powder diffraction analyses of Yucca Mountain tuffs. These data indicate that there are six mappable "mineral types" at Yucca Mountain: primary glass plus tridymite, primary and secondary quartz, secondary smectite, clinoptilolite plus mordenite, secondary analcime, and secondary albite. Two additional primary minerals, cristobalite and K-bearing alkali feldspar, are nearly ubiquitous in Yucca Mountain rocks.

Despite fairly clear-cut patterns of zonation (or stratigraphic control) of minerals such as smectite, clinoptilolite, and mordenite in the rocks beneath Yucca Mountain, this report reveals that it is not yet possible to accurately predict the proportions of minerals in the rocks at a given subsurface location beneath the mountain. Furthermore, even when zonation permits crude predictions of the relative abundances of minerals, XRD analysis affords only semi-quantitative checks on these predictions. For these reasons, it is evident that much progress remains to be made in the DOE-NNWSI effort to determine the abundances of minerals in rocks along potential radionuclide-release pathways beneath the Yucca Mountain Site.

It would seem that one potentially useful avenue of future DOE-NNWSI mineralogic research would be to make additional correlations between CIPW norm mineralogy and measured mineralogy (the latter determined by XRD analyses and any other appropriate analytical techniques). These correlations could be made not only for many more whole-rock samples of Yucca Mountain tuff, but also for mineral separates obtained from these rocks. Due to the fine-grained textures of the groundmasses of Yucca Mountain tuffs, complete separation of the minerals in these tuffs is impossible at present. However, this restriction should not deter attempts to obtain partial mineral separates and to identify the proportions of minerals in these materials. This recommendation is based on the assumption that classical methods of mineral separation would, at the very least, yield rock materials in which the proportions of minerals are significantly different from the original rock sample. These materials could be analyzed compositionally and mineralogically in a fashion similar to the way whole-rock samples are analyzed, thereby permitting validation of XRD analyses over wider ranges of composition and mineralogy. This approach would foster greater confidence in the ability of XRD to accurately predict the proportions of minerals in a suite of tuffaceous rocks in which individual rock samples contain significantly different proportions of minerals.

Finally, the accuracy of XRD analyses of Yucca Mountain tuffs would also be improved by obtaining additional data on the compositions of the glasses in these rocks.