Attachment 2.

LR-287-13
10/4/85

LETTER REPORT

TITLE: "Review of 'Minerals in Fractures of the Unsaturated Zone from Drill Core USW G-4, Yucca Mountain, Nye County, Nevada, LA-10415-MS,' B. A. Carlos"

AUTHOR: J. G. Blencoe

PROJECT TITLE: Technical Assistance in Geochemistry

PROJECT MANAGER: Susan K. Whatley

ACTIVITY NUMBER: ORNL #41 37 54 92 4 (189 #B0287)/NRC #50 19 03 01

SUMMARY

This informative report describes the mineralogical characteristics of open and sealed fractures transected by borehole USW G-4 from 800 ft below the surface down to the level of the local water table (1770 ft). (Note: Drill hole USW G-4, the most recent cored hole within the proposed repository block at Yucca Mountain, is also currently the closest borehole to the proposed NNWSI exploratory shaft.) The bulk of the commentary consists of descriptions of the identities and modes of occurrence (especially textures) of the minerals in the fractures, but there are also some important discussions of mineral parageneses and systematic changes of mineralogy with depth and type of host rock. To highlight observed changes in mineralogy with depth and type of host rock, the data acquired in the study are described on a stratigraphic unit-by-stratigrapic unit basis, starting with the shallowest unit (the Topopah Spring Member of the Paintbrush Tuff). In places, the commentary becomes extremely involved because the mineralogical characteristics of the fractures are highly variable, both within a given stratigraphic unit and (especially) between stratigraphic units.

This report is clearly a valuable addition to the literature on geochemical conditions in the tuffaceous rocks beneath Yucca Mountain. However, it also exhibits some significant deficiencies, the most salient of which are itemized below:

1. It is very difficult to keep track of the myriad mineralogical characteristics of fractures that are described in great detail in this report. This difficulty could have been avoided by tabulating the data obtained for each stratigraphic unit, but this was not done and, therefore, it is unnecessarily difficult for a reader to compare and contrast the data obtained for rocks from different depths in the borehole.

2. Another important drawback of the report is that the author did not attempt to fully explain why the types and textures of fracture-filling and fracture-lining minerals vary so greatly within and between stratigraphic units. Some of this variability is ascribed to a "paleo water table" that reached stratigraphic levels much higher than the level of

the present-day water table, but no explanation is provided for the variations in mineralogical characteristics of fractures at stratigraphic levels above those reached by the inferred paleo water table.

3. The author states that fracture mineralogies and host-rock mineralogies are significantly different at stratigraphic levels above those reached by the inferred paleo water table, but these differences are not fully explained. Therefore, the reader is forced to turn to other reports to obtain this valuable information.

4. In order to obtain sufficient material for XRD analysis, the fractures examined by the author were those with the most extensive coatings or fillings of secondary minerals. Therefore, the mineralogical data acquired for this report are not truly "representative data" for the fractures in the tuff units. It is uncertain whether or not this is a serious difficulty. At a given stratigraphic level, it is likely that the types of secondary minerals present in fractures are the same regardless of the total abundance of these minerals. Therefore, the principal uncertainty centers on whether the ratios of secondary minerals vary with total abundance of these minerals.

5. The proportions of minerals in fractures were measured by semiquantitative XRD analysis, an analytical method that only yields approximate values for percent concentrations of minerals. Therefore, the mineral-concentration data presented in this report, like the analytical method that was used to obtain the data, should be viewed as only semi-quantitative.

6. Compositions of fracture-lining zeolites were investigated via electron probe microanalysis using feldspar standards, and therefore, zeolite analyses have anomalously low totals. For this reason, the author states that zeolite analyses are almost certainly not as accurate as the analyses obtained for other silicate minerals.

LR-287-4
06/11/85

LETTER REPORT

TITLE: Review of "The Dissolution of Rainier Mesa Volcanic Tuffs, and Its Application to the Analysis of the Groundwater Environment," MS Thesis of M. S. Henne, University of Nevada, Reno, NV, 1982.

AUTHOR: J. G. Blencoe

PROJECT TITLE: Technical Assistance in Geochemistry

PROJECT MANAGER: Susan K. Whatley

ACTIVITY NUMBER: ORNL #41 37 54 92 4 (189 #B0287)/NRC #50 19 03 01

This thesis describes research that was conducted to ascertain groundwater travel times in the unsaturated zone beneath Rainier Mesa (NTS). The data obtained by Henne shows that some of the groundwaters that infiltrate Rainier Mesa may be capable of percolating downward very rapidly through the underlying unsaturated tuffaceous rocks.

The research included both laboratory investigations and field studies. The principal objective of the laboratory work was to establish experimentally the effects of pH, temperature, and surface area on the dissolution of glass-rich tuff from Rainier Mesa. Also, the experiments were designed to elucidate the quantitative relationship between: (1) reaction time, (2) tuff surface area to water volume ratio, and (3) the concentration of SiO_2, Na^+, K^+, Ca^{2+}, and Mg^{2+} in Rainier Mesa groundwaters. This quantitative relationship (eventually cast in the form of a rate equation for dissolution of silica from Rainier Mesa tuff) was employed to estimate the retention times of Rainier Mesa groundwaters. The field studies consisted mainly of collecting samples of (1) soil waters from the surface of Rainier Mesa and (2) groundwaters from various tunnel excavations beneath the Mesa. Groundwaters in the tunnels were collected with lysimeters and at the sites of natural seeps.

The laboratory studies showed:

1. The results of tuff dissolution experiments performed at 25, 30, 50, and 70°C for up to 20 d are in fairly good agreement with results obtained previously by White and Claassen (1980). It was found that pH did not affect the dissolution of SiO_2, had only a slight effect on the dissolution of Na^+, but had a major effect on the dissolution of Ca^{2+} and Mg^{2+}. (The amounts of dissolved calcium and magnesium were greater at the lower values of pH). By contrast, potassium exhibited irregular behavior: at low values of pH the concentration of K^+ increased at first but subsequently began to decline. However, at values of pH above approximately 6.4, the quantities of dissolved potassium increased steadily during experimentation.

2. It was observed that the rates of mass transfer of SiO_2, Na^+, K^+, Ca^{2+}, and Mg^{2+} from Rainier Mesa tuff to contiguous water were greater for the experiments with higher tuff surface-area-to-water-volume ratio. Therefore, Henne concluded that, in using dissolution kinetics to estimate the retention time of a groundwater in tuffaceous rocks, it is essential to have an accurate value for the reactive surface area of the rocks.

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3. Experiments performed at 25, 50 and 70°C indicate collectively that, for a given tuff surface-area-to-water-volume ratio and reaction time, silica solubility increases sharply with increasing temperature.

4. At 70°C, steady-state concentrations of Na^+, K^+, Ca^{2+}, and Mg^{2+} were achieved in 40 hr, but the concentration of dissolved SiO_2 continued to rise steadily for up to 284 hr. Similar behavior of silica solubility was observed at 25 and 50°C.

5. The results of all epxeriments indicate that silica concentrations provide the most reliable means of estimating groundwater retention time.

The field studies showed:

1. Meteoric waters that flow from the soils on Rainier Mesa into the subjacent rocks experience an increase in pH.

2. The chemistries of groundwaters in Rainier Mesa tunnels vary with geochemical environment, but show only slight variation with time.

3. Retention times of Rainier Mesa groundwaters were estimated in two ways. The first method utilized a long-term trend in the cation-to-silica ratio observed in lysimeter 2 and showed that the maximum in this ratio was observed in June. This observation implies groundwater infiltration six weeks to three months prior to this time (i.e., during the annual spring thaw on the surface of Rainier Mesa when infiltrating meltwaters dissolve "extra" cations from the thin soils on the Mesa). The second method employed silica-dissolution kinetics to estimate the retention time of the groundwaters. Assuming that the tuff surface-area-to-water-volume ratio is approximately 100 square meters per liter, and using the minimum silica concentration of the groundwaters collected in the tunnels — 33 mg/L — the retention time of groundwater in the Mesa was calculated to be as short as 3 months. The values obtained by the two methods agree closely but "are approximations made with unproven estimates."

There are three apparent deficiencies of the research described in this thesis:

1. The silica-dissolution rate equation developed by Henne is of uncertain accuracy. There is no discussion of potential sources of error in the data used to derive the rate equation. Also, Henne fails to describe his regression methods in sufficient detail to permit an assessment of his methodology, and appropriate statistical data concerning the "goodness of fit" of his equation are not presented.

2. Henne's calculation of a minimum three-month travel time for groundwater sampled using lysimeter 2 is based on an assumed value of 100 square meters per liter for the tuff surface-area-to-groundwater-volume ratio. Since, no justification is provided for the use of this particular number (and for the reasons discussed above), the accuracy of the calculated three-month travel time is very uncertain.

3. Henne does not state what fraction of percolating groundwaters reach the tunnels beneath Rainier Mesa in just three months. It is almost certain that Henne does not believe that all groundwaters in Rainier Mesa percolate downward that rapidly, but he does not address this important subject at all.

Despite these concerns, the research performed by Henne remains noteworthy. The finding that some groundwaters in tunnels beneath Rainier Meas contain very little dissolved silica is interesting and possibly very significant. Likewise the discovery that the ratio of cations to silica in these groundwaters exhibits an annual maximum in June, an observation that is explained nicely by the hypothesis that "extra" cations released from the thin soils on Rainier Mesa during the annual spring thaw reach the tunnels beneath Rainier Mesa in just a few weeks. Collectively, the data obtained by Henne should be viewed as permissive evidence that some of the groundwaters that infiltrate Rainier Meas are capable of percolating downward very rapidly through the underlying unsaturated tuffaceous rocks.

Reference

White, A. F., and Claassen, H. C., 1908, Kinetic Model for the Short-Term Dissolution of a Rhyolitic Glass, Chemical Geology, Vol. 28, pp. 91-109.