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DRAFT

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SUBJECT: CAPABILITIES AND LIMITATIONS OF BOREHOLE GEOPHYSICS IN FELSIC TUFFS AND RELATED ROCKS AT YUCCA MOUNTAIN, NV

Introduction

This report is a general summary of the capabilities and limitations of borehole geophysical logging for the determination of geotechnical properties of felsic tuffs and related rocks at the Yucca Mountain site. The conclusions contained within this report are based on information in the USGS Open File Reports referenced in the text.

This summary is divided into two sections denoted, "Capabilities of Borehole Geophysics in Felsic Tuffs at Yucca Mountain" and Limitations of Borehole Geophysics in Felsic Tuffs at Yucca Mountain", which highlight primary applications and problems. Although a lot of information can be extracted from the geophysical logs run in wells at Yucca Mountain, several significant limitations exist and are a result of:

(1) Logging in the unsaturated zone, where the neutron, acoustic, resistivity, and spontaneous potential logs respond unreliably or anomalously without a fluid couple between the borehole and the rock formation.

(2) Logging in sections of rock with little bulk chemical variation.

(3) Logging volcanic rocks - Due to a historical lack of logging in volcanic sequences, the investigations must make analyses/interpretations without the benefit of previously-published literature on this topic.

Capabilities of Borehole Geophysics in Felsic Tuffs at Yucca Mountain

(1) In the saturated zone or in unsaturated zone rock saturated with drilling fluid, the degree of welding and/or vitrophyre development is fairly well reflected by the density, neutron, acoustic, and resistivity logs. Highly welded tuffs are characterized by high density, high neutron counts/second (the opposite relationship has been observed in the unsaturated zone; see Daniels et al., 1981), high sonic velocity, and high resistivity (Daniels et al., 1981; Muller and Kibler, 1983). Unwelded tuffs produce the opposite responses. Although these relationships are well-documented and consistently observed, there are cases where the logs did not produce responses that are consistent with the degree of welding seen in core (see limitations section (3)).

(2) The highly fractured and lithophysal portion of the Topopah Spring Member, although in the unsaturated zone where geophysical logging is difficult, produces a distinctive geophysical log signature that is observed in all wells analyzed for this report. This zone is characterized by erratic caliper increases and "spiky" high frequency density and neutron signatures indicating an enlarged and rough borehole (Hagstrum et al., 1980; Muller and Kibler, 1983, 1984, and 1986; and Spengler and Chornack, 1984). This borehole condition has been attributed to the presence of fracturing and lithophysae.

(3) An acoustic televiewer log run in an uncased hole can be used to determine the strike and dip of bedding, fractures, and faults where they intersect the borehole. If the acoustic log is used following hydraulic fracturing, the orientation and magnitude of in situ stresses can be determined (Stock et al., 1984; Stock et al., 1986).

(4) Unsuccessful attempts to keep the borehole fluid-filled for geophysical logging in the unsaturated zone are a direct indication of the high permeability of the unsaturated and fractured volcanic sequence (for example, see Muller and Kibler, 1983).

Limitations of Borehole Geophysics in Felsic Tuffs at Yucca Mountain

(1) Neutron, acoustic, resistivity, and spontaneous potential log surveys were designed for use in fluid saturated rocks; thus, the log responses are anomalous or unreliable in zones where the borehole and radius of influence of the tools cannot be saturated with drilling fluid. On many of the stratigraphic/geophysical log sections reviewed, the neutron, sonic, resistivity, and Sp traces are missing in portions of the unsaturated zone where borehole saturation wouldn't be achieved. Even in intervals where the fluid level was maintained in the borehole, the logs should be interpreted with caution as the rocks adjacent to the hole may have only been partially saturated.

One anomalous, but seemingly consistent (thus useful?) response is that of the neutron log, which gives high values in densely welded rocks below the water table. In boreholes UE 25 a-4, -5, -6, and -7 the neutron log showed an inverse relationship to the degree of welding in the unsaturated zone (Daniels et al., 1981).

(2) Stratigraphic correlation with geophysical logs at Yucca Mountain has produced some successful results. An example is the highly fractured and lithophysal portion of the Topopah Spring Member, which produces a distinctive geophysical-log signature that can be correlated between wells. This correlative capability of the logs is reflected in Muller and Kibler (1984) and Spengler and Chornack (1984), who state that the geophysical logs from UE-25 p#1 and USW G-4 correlate well with logs through the same geologic units in other holes. However, all of the studies reviewed for the this report appear to have relied upon core or chip samples for stratigraphic delineations, and the geophysical logs seem to have been used as supplemental information. Furthermore, many contacts between stratigraphic units in the unsaturated and saturated portions of the section are not marked by distinctive geophysical log excursions. An example is the Tram Member through Prow Pass Member section in UE-25 p#1 (Muller and Kibler, 1984; see plate 1).

(3) The physical properties that could possibly affect the responses of the geophysical logging tools include the degree of welding, devitrification, lithophysal development, fracturing, porosity, saturation (or lack of), borehole rugosity, secondary mineralization, rock chemistry, etc. Correlation of the log signatures with specific properties observed in core sections has produced positive results (see capabilities section (1) and (2)); however, the interpretation of the logs is complicated by the textural/compositional variations throughout the section and within a given unit throughout space. For example, the core-derived lithology logs of USW G-1 (Muller and Kibler, 1983) and USW G-4 (Spengler and Chornack, 1984) show many variations in the degree of welding that are are not consistent with the geophysical log responses that are similar to or appear less-welded then non-to slightly-welded zones). This indicates that some other rock properties had a dominant influence on the logs in these sections. From this brief analysis, it seems that systematic or definitive interpretations with the geophysical logs are not always possible.

(4) The spontaneous potential log, which is ordinarily used to identify permeable intervals in saturated rocks, will not be useful unless the investigators use brine drilling fluid (in contrast to the fresh formation water).

Conclusions

Geophysical logging in felsic tuffs at Yucca Mountain can provide useful lithologic/textural/structural information; however due to the previously-discussed limitations of geophysical logging, some of which are inherent to the hydrogeologic system, site characterization will require a significant amount of coring and shaft excavation to resolve many licensing issues.

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