**AN EXPERIMENT TO DETERMINE DRILLING
WATER IMBIBITION BY IN SITU
DENSELY WELDED TUFF**

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Abstract : Experiments were performed to determine the extent of penetration of drill water into Grouse Canyon densely welded tuff during use of normal drilling practices. Core samples were examined from a borehole cored in a rib of the Rock Mechanics drift in C-Tunnel at the Nevada Test Site, Nye County, Nevada. Methylene blue dye was added to the drill water to act as a tracer which stained the rock blue on contact. We found the rock stained blue only in a thin layer about 0.5 mm thick at the surface of the core. However we were concerned about the uniformity of penetration depth observed in the core and this prompted a simple experiment to test the ability of methylene blue to penetrate the matrix of densely welded tuff. We found that in the imbibition process, the dye and water separated such that the water penetrated the matrix to a much greater depth. This result meant that any interpretation of drill water imbibition in borehole core based on this dye as a tracer is unreliable. More important, however, is the conclusion that the presence of methylene blue dye on the rock indicates the presence of tracer water flow, but the absence of the dye does not rule out the presence of water flow.

Introduction

The Nevada Nuclear Waste Storage Investigations (NNWSI) Project is studying the suitability of the tuffaceous rocks at Yucca Mountain, Nevada Test Site, for the construction of a high-level nuclear waste repository. Lawrence Livermore National Laboratory (LLNL),

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Livermore, California, has been given the task of designing and assessing the performance of waste packages for the NNWSI Project.

The properties of geologic environment around a waste package. Various in situ tests will be conducted within the Topopah Spring member of the Paintbrush Tuff at Yucca Mountain to investigate rock mass behavior in the vicinity of simulated waste packages. A key objective of this work is to study the hydrologic behavior of rock mass. The in situ tests will require the drilling of an assortment of boreholes near the simulated waste package from which various geophysical measurements will be made. The use of water as a drilling fluid may perturb the hydrology so that the results of the tests are not indicative of pristine conditions.

Experiment Description

The experiment was conducted in Tunnel G complex at the Department of Energy, Nevada Test Site, Nye County, Nevada. This tunnel provides access to a welded ash flow tuff formation of the Grouse Canyon member of the Belted Range tuff. This formation was of interest because it has similar properties to the proposed repository horizon, the Topopah Spring tuff, at Yucca Mountain (Zimmerman, *et al.*, 1984).

A borehole was cored into the rib of the small diameter heater alcove of the Rock Mechanics Incline. This 5.8 meter long, HQ hole had a dip of 2 degrees from the horizontal and in a part of the rock mass more than 4 meters from (and above) any other drilling which had been conducted. This borehole was cored using standard coring procedures as part of ongoing work in G-Tunnel. However, it provided an opportunity to examine the extent of drill water imbibition into the rock matrix. Therefore, methylene blue, a dye that stains the rock dark blue on contact, was added to the drill water.

Results and Discussion

Six pieces of the core from this hole were examined. Each core piece was broken roughly perpendicular to the core axis exposing the core interior and the extent to which the drill water had been imbibed into the rock matrix was determined by observing the depth of dye penetration. Figure 1 is typical of the highly welded pieces without

any pumice or fracturing. The drill water was apparently imbibed very uniformly into the matrix to a depth of approximately 0.2 mm.

Penetration of methylene blue was so uniform that we became concerned whether or not the properties of the dye may have affected interpretation of the results. We wanted to know if this penetration depth was due to a characteristic of the dye and not of the rock. As a result an experiment was designed to examine the dye distribution in small tuff samples after they had been saturated by tracer laden water.

Three pieces of Topopah Spring tuff were chosen from the depth interval 374.8 m in borehole USW-G1 drilled in Yucca Mountain. This rock was chosen instead of the Grouse Canyon tuff because our ultimate interest was in the characteristics of dye interaction with the Topopah Spring tuff. Their volumes were measured by water displacement and they were then dehydrated in a vacuum oven at 50 C for 14 days. At this point, they were considered irreducibly dry, weighed and placed for 20 days in a solution of methylene blue. Each sample imbibed about 7 % of its volume in water during this time. Another sample which we had used in other work, from the same depth in this borehole, had a measured effective porosity of 8.1% by volume (Lin and Daily, 1984). It is likely therefore, that our three samples were nearly saturated with the water-tracer solution. Each sample was then broken in such a way to expose a cross section of the matrix interior.

Figure 2 shows an example of the dye distribution as revealed by one of these broken surfaces. The scale of tick marks along the top shows millimeter spacing. The dye tracer penetrates the matrix about 0.5 mm yet the water must have penetrated essentially the entire sample to result in the water content near 100% saturation for the sample. A similar, and very uniform, dye penetration depth was observed in the other samples, some of which were broken to reveal many different sections of matrix. Apparently during water imbibition some mechanism was responsible for separation of the dye and the water. The dye was deposited only in a very narrow band near the surface and the water continued to penetrate the matrix until it had invaded most of the available porosity.

Methylene blue is a large organic molecule which is used as a dye for fabrics and as a stain for biological and bacteriological samples.

Its usefulness as a dye to trace water in a geologic setting may be limited because it is filtered out of the water by the very small pores of the tuff or because it is adsorbed on clay minerals. Narine and Guy (1981) report that methylene blue is bound on bentonite by amounts equal to the cation-exchange of the clay. Although there are only small amounts of clay minerals in either the Grouse Canyon or Topopah Spring tuffs (Bish *et al.*, 1981 and Knauss, 1984), that which is present may be responsible for adsorption of the methylene blue as the water penetrates the rock matrix. Which ever mechanism is responsible for separation of the water and dye with flow through the matrix, we conclude that penetration of drill water into the rock formation can not be inferred from our initial experiment in G-Tunnel.

Any dye that is useful as a water tracer must mark the rock and this will remove dye from the water. As the water flows (and continues to stain the rock), dye concentration must decrease until eventually its mark on the rock is not discernable. However, it was a surprise to the authors that methylene blue is useful as a tracer for flow of less than 1 mm in the matrix of this particular densely welded tuff. On the other hand, our experience (Ramirez and Daily, 1985) as well as that of others (Talbutt, 1988, personal communication; Warpinski *et al.*, 1982), is that methylene blue is a useful tracer for fracture flow in this rock type. It is known to stain the rock surfaces after flowing on the *surface* many tens of meters from the source. It should be noted, however, that the results reported herein indicate that the presence of methylene blue stain on the rock surface indicates water flow but the absence does not imply lack of water flow.*

* This conclusion has important implications for the results of an experiment reported by Ramirez and Daily (1985) wherein methylene blue was used to mark water flow through fractures in G Tunnel densely welded tuff. Geotomography was also used to infer fracture flow paths and the two data sets compared. They reported that each place blue dye was observed in the rockmass, geotomography also required water flow at that point during the experiment. However, geotomography predicted water flow in some places where no methylene blue was found on the fracture surfaces. These discrepancies in the two data sets were most prevalent at the extreme distances from the water source. Therefore the apparent discrepancies may have resulted from adsorption of the dye on altered fracture infilling material somewhere in the flow path before the place where geotomography predicted flow.

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Figure Captions

Figure 1. Edge of core sample from borehole HFEM C at about the 3 m depth. The tick marks along the photograph edge are at 1 mm spacing. This sample was cored using normal drilling practices except that the drill water was a solution of methylene blue.

Figure 2. Edge of sample from borehole USW-G1 at a depth of 374.8 m. The tick marks along the photograph edge are at 1 mm spacing. This sample was saturated with a water solution of methylene blue.

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Fig 1

Fig 2 ...