

USE OF THERMAL DATA TO ESTIMATE INFILTRATION, YUCCA MOUNTAIN, NEVADA

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ABSTRACT

Temperature and pressure monitoring in a vertical borehole in Pagany Wash, Yucca Mountain, Nevada measured disruptions of the natural gradients associated with the February, 1998 El Nino precipitation events. The temperature and pressure disruptions indicated infiltration and percolation through the 12.1 m of Pagany Wash alluvium and deep percolation to greater than 35.2 m into the Yucca Mountain Tuff.

INTRODUCTION

The Yucca Mountain Project Surface-Based Monitoring Program personnel instrumented boreholes with thermistors and pressure transducers to provide data on the temperature and pressure of the unsaturated zone at Yucca Mountain, Nevada. One of these boreholes is the UE-25, unsaturated zone borehole # 4 (UZ#4). Borehole UZ#4 has a diameter of 152 mm and is located in the alluvial deposits of Pagany Wash northeast of Yucca Mountain. One goal of the borehole UZ#4 monitoring was to provide some insight on infiltration and percolation through the alluvial deposits of the usually dry stream channels.

The winter of 1997-98 was an El Nino winter and was wetter than normal. During the winter of 1997-98 flowing water was seen and measured in some of the usually dry channels, including Pagany Wash, at Yucca Mountain (C.S. Savard, written commun., 1999). The average annual precipitation at Yucca Mountain ranges from 130 mm over the southern part of the mountain to 250 mm at the higher elevations in the north.¹ Rain-gage data from stations located near Yucca Mountain (WT-2 Wash and Jackass Flats) had precipitation values of 173.2 and 134.6 mm for the period February 3, 1998, to February 25, 1998 (W.J. Davies, written commun., 1999). These large precipitation events can result in surface runoff and concentrated flow in the washes, resulting in a high potential for infiltration beneath the washes. Because the winter precipitation is generally much cooler than the subsurface temperature, the

infiltrated water can cause temperature depressions in the subsurface. This report presents some of the UZ#4 temperature and pressure data that relate to the 1997-98 winter El Nino precipitation and presents analytical and numerical estimates of the associated infiltration flux.

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WORK DESCRIPTION

Borehole UZ#4 penetrates 12.1 meters of the Pagany Wash alluvium/colluvium (Figure 1). The borehole also penetrates the Tiva Canyon Tuff lower nonlithophysal and vitric zones,² bedded tuff number 4, the Yucca Mountain Tuff and bedded tuff number 3. The Yucca Mountain Tuff and the bedded tuffs are members of the Paintbrush Tuff nonwelded unit.³

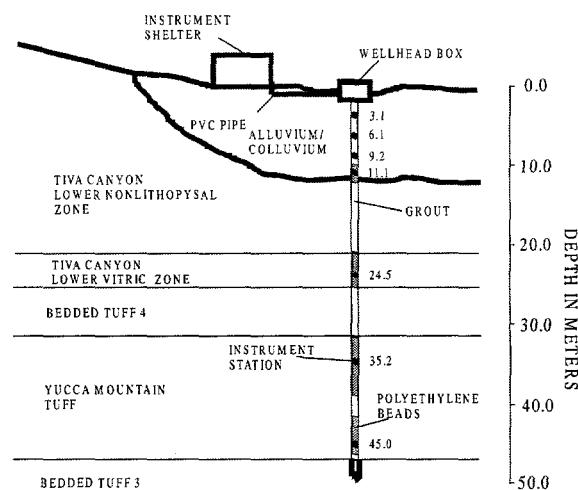


Figure 1. Schematic diagram showing the UE-25 UZ#4 instrument stations and generalized geology.

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Borehole UZ#4 was instrumented in June 1995. The borehole was uncased with the exception of the upper 18.4 m, where slotted casing was required to keep the hole open through the alluvium. The three shallowest stations (3.1, 6.1, and 9.2) were instrumented with thermistors to measure temperature. The deeper stations (11.1, 24.5, 35.2, and 45.0) were instrumented with thermistors to measure temperature and pressure transducers to measure absolute pressure. Stations 3.1, 6.1, 9.2, and 11.1 were located in the alluvium/colluvium of Pagany Wash. Station 24.5 was located in the lower vitric zone of the Tiva Canyon Tuff, and stations 35.2 and 45.0 were located in the Yucca Mountain Tuff.

The station sensors were calibrated over a narrow operational range to maximize precision and accuracy. The thermistors were accurate to $\pm 0.005^\circ\text{C}$ (95 percent confidence) with a sensitivity of 0.0005°C and the pressure transducers were accurate to ± 20.0 pascals (Pa) with a sensitivity of 1.0 to 3.0 Pa.⁴ The computer-controlled data-acquisition program allowed automated reading of the downhole sensors.

RESULTS

Figure 2 shows the July 1995 to July 1999 temperature data for the four UZ#4 stations located in the alluvium/colluvium of Pagany Wash (3.1, 6.1, 9.2, and 11.1). The temperature data indicated that the annual temperature wave was measurable to a minimum depth of 11.1 m.

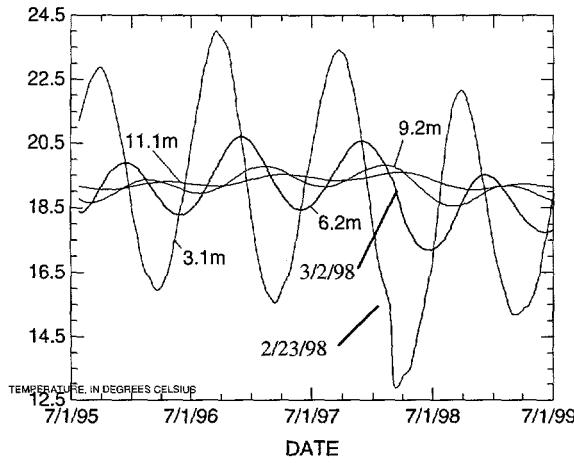


Figure 2. Temperatures at stations 3.1, 6.1, 9.2, and 11.1 for July 1, 1995 through July 1, 1999.

Following the February 1998 El Nino rainfall events abrupt temperature disruptions were measured at stations 3.1 (February 23) and 6.1 (March 2). In addition, figure 2 shows an overall decrease in the temperatures at all four stations following the February 1998 El Nino rainfall. Figure 3 shows the temperature data from stations 24.5 (Tiva Canyon Tuff vitric zone) and 35.2 (Yucca Mountain Tuff) and the barometric pressure difference data from station 24.5 (Tiva Canyon Tuff vitric zone). The barometric pressure difference data is the difference between the station pressure and the surface barometric pressure. The March 21, 1998 temperature increase at station 24.5 indicated a downward movement of shallow warmer water. The presence of shallow warmer water is due to a reversal of the geothermal gradient associated with the annual temperature wave. From March 21, 1998 to April 2, 1998 (12 days) the differential pressure at station 24.5 increased by about 2 kPa (the normal annual pressure variation is less than 0.5 kPa). The pressure increase indicated that station 24.5 was temporarily pneumatically isolated from the shallower stations. The isolation and pressure increase was associated with the downward-moving wetting front.

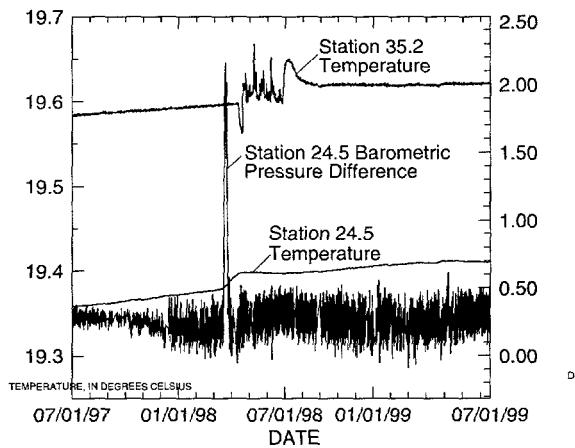


Figure 3. Temperature data for stations 24.5 and 35.2 and barometric pressure differences for station 24.5 for July 1, 1997 to July 1, 1999.

Figure 3 shows a 0.04°C temperature decrease at station 35.2 (April 16, 1998) followed by a period of instability where temperatures spiked to higher levels but never dropped below the initial trendline temperature. The temperature instabilities at station 35.2 may be associated with compressed air moving ahead of the wetting front and the opening of air-flow pathways below the station. The open air-flow pathways below the station would allow deeper, warmer air to move

upward and laterally in response to barometric lows, whereas the water filled pore space above the station prevented shallow, cooler air from moving downward. The temperature restabilization at station 35.2 indicated that the wetting front had moved below the station.

Analytical and numerical methods were used to estimate the infiltration and percolation flux associated with the February 1998 El Nino precipitation. The analytical method indicated that the percolation flux between stations 3.1 and 6.2 was 940.0 mm. Numerical models using the multiphase transport computer code TOUGH2⁵ indicated that the measured temperature depressions were due to an infiltration flux of 700 to 1300 mm of water. The numerical models showed that the best match to the field data included a pre-wetting period.

CONCLUSIONS

Temperature disruptions measured at borehole UZ#4 stations located in the alluvium/colluvium of Pagany Wash indicated infiltration into Pagany Wash associated with the February 1998 El Nino precipitation. Analytical and numerical infiltration flux estimates ranged from 700 to 1300 mm. Temperature and pressure disruptions at stations located in the vitric zone of the Tiva Canyon Tuff (24.5 meters deep) and the Yucca Mountain Tuff (35.2 meters deep) indicated deep percolation of some portion of the infiltration flux.

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