 USGS-OFR-83-321

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

COMMERCIAL GEOPHYSICAL WELL LOGS FROM THE USW G-1 DRILL HOLE, NEVADA TEST SITE, NEVADA

by

D. C. Muller and J. E. Kibler

Open-File Report 83-321

1983

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S.G.S.

Prepared by the U.S. Geological Survey

for the

Nevada Operations Office
U.S. Department of Energy
(Interagency Agreement DE-AI08-78ET44802)

Copies of this Open-File Report
may be purchased from

Open-File Services Section
Branch of Distribution
U.S. Geological Survey
Box 25425, Federal Center
Denver, Colorado 80225

PREPAYMENT IS REQUIRED

Price information will be published
in the monthly listing
"New Publications of the Geological Survey"

FOR ADDITIONAL INFORMATION
CALL: Commercial: (303)234-5888
FTS: 234-5888

CONTENTS

ILLUSTRATIONS

TABLE

ABSTRACT

Drill hole USW G-1 was drilled at Yucca Mountain, Nevada Test Site, Nevada, as part of the ongoing exploration program for the Nevada Nuclear Waste Storage Investigations. Contract geophysical well logs run at USW G-1 show only limited stratigraphic correlations, but correlate reasonably well with the welding of the ash-flow and ash-fall tuffs. Rocks in the upper part of the section have highly variable physical properties, but are more uniform and predictably lower in the section.

Introduction and Acknowledgments

Drill hole USW G-1 (Fig. 1) was drilled in 1980 as part of the continuing exploration program for the Nevada Nuclear Waste Storage Investigations. Contract geophysical logs were obtained from six episodes of logging during and after completion of drilling (Table 1). Plates 1 and 2 are plots of the contract logs compared with the lithology, stratigraphy, fracturing, and core index (Spengler and others, 1981). The plots of the log traces were made by computer from log data digitized at 0.6 m increments. All traces have been depth adjusted to correlate with the caliper log.

The purpose of this report is to document the contract log data from USW G-1 and present the log data in a usable form for use by other investigators. Where data is missing on Plates 1 and 2, either no data was obtained, or the data that was obtained was discarded due to poor quality. Where duplicate logs were obtained, only one is presented. Above the static water level in the unsaturated zone, efforts were made to fill the hole with viscous mud for logging tools that require fluid to operate. These efforts were only partially successful as can be seen on Table 1 and where data is missing on Plate 1.

We acknowledge and appreciate the efforts of the Fenix & Scission drilling department for their efforts to accommodate the logging requirements, particularly the efforts to achieve a mud-filled hole for wet-hole logging. Carl Douglass of Fenix & Scission merits personal mention for his efforts in scheduling all contract logs and in working our contractual difficulties with logging companies. Fenix & Scisson keeps detailed records of the logging activities of the companies and their logging equipment for quality assurance purposes.

Geophysical Logs

This section briefly addresses each individual log plotted on Plates 1 and 2 as to the type of logging tool used, log response characteristics and lithologic correlations. For more detailed discussion of logging tools and log response characteristics the reader is referred to the reference list at the end of this report.

Caliper log

All caliper traces shown on Plates 1 and 2 are of average borehole diameter from logs made during one of the six logging episodes. The interval from about 88.4 m to 304.8 m has two traces on the caliper plot. The hole was cored with a 9.8 cm diameter bit and neutron and gamma ray logging was performed (Plates 1 and 2). The hole was reamed to 15.9 cm diameter and logged a second time to obtain the remaining traces shown on Plates 1 and 2.

The lithophysal zone in the Paintbrush Tuff (Plate 1) from 133.5 m to 392.3 m is characterized by a very rough borehole wall that correlates with the higher core index in the interval, which is a measure of less competent core and greater fracture frequency.

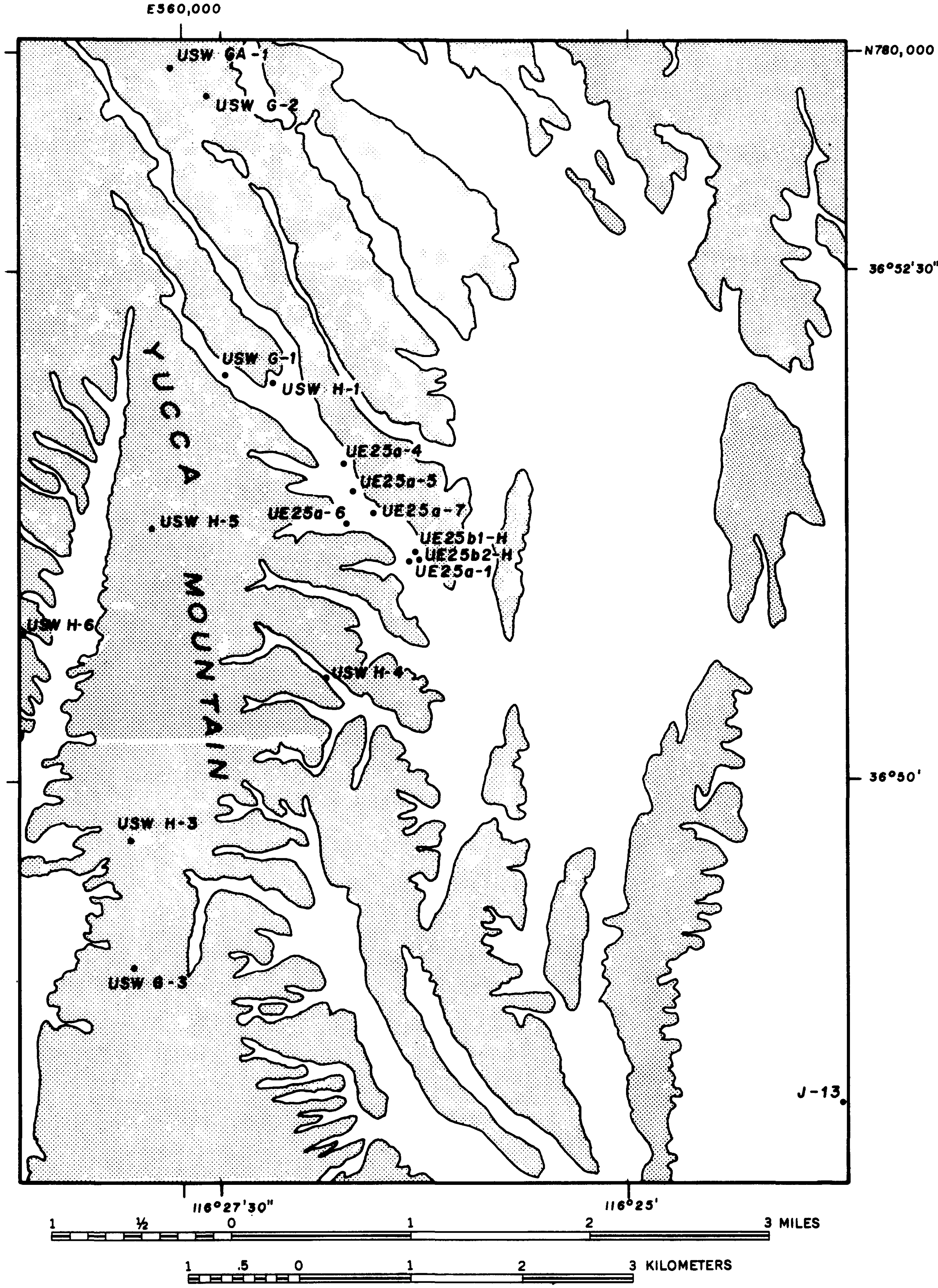

Figure 1.--Map of Yucca Mountain, Nevada Test Site, Nevada; showing the location of drill hole USW G-1.

Table 1.--Summary of drill hole USW G-1 logging operations

Date and Borehole Conditions		Geophysical Logs
March 16, 1980		
Casing depth	8.2 m	Caliper - 6 arm, 3 diameter
Bit size	44.5 cm	Density - single detector w/proximity
Hole depth	85.3 m	Resistivity - short and long normal and lateral
Approx. mud depth	0 m	Neutron - single detector epithermal
April 2, 1980		
Casing depth	89.0 m	Caliper - 3 arm, average diameter
Bit size	9.8 cm	Density - single detector
Hole depth	303.9 m	Neutron - single detector thermal
Approx. mud depth	225.6 m	Sonic velocity - 0.9 m and 1.8 m 3-D logs
		Gamma ray - natural
April 19-20, 1980		
Casing depth	88.4 m	Caliper - 6 arm, 3 diameter
Bit size	15.9 cm	Density - borehole compensated
Hole depth	306.6 m	Neutron - borehole compensated
April 21-22, 1980		
Approx. mud depth	106.7 m	Neutron - borehole compensated
		Neutron - single detector epithermal
		Resistivity - short and long normal, lateral and guard
		Sonic velocity - 0.9 m and 1.8 m 3-D logs
		Density - borehole compensated
August 9-12, 1980		
Casing depth	309.7 m	Caliper - 3 arm, average diameter
Bit size	9.8 cm	Neutron - single detector thermal
Hole depth	1828.8 m	Resistivity - short and long normal and lateral
Approx. mud depth	381.0 m	Sonic velocity - 0.9 m and 1.8 m 3-D logs
		Density - single detector
		Gamma ray - natural
September 14, 1980		
Approx. mud depth	370.6 m	Caliper - 4 arm, 2 diameter
		Density - borehole compensated
		Neutron - borehole compensated

Gamma-ray log

The gamma-ray log is a continuous measure of the natural gamma-ray radiation emitted from the formation. The volcanic tuffs at Nevada Test Site characteristically exhibit high gamma radiation levels compared with most sedimentary rocks. The gamma-ray response also shows little or no variation within and between units. As a result the gamma log has not proven to be very useful as a lithologic or stratigraphic correlation tool. The gamma-ray log is normally run simultaneously with other logs and used to make depth correlations between logs.

Spontaneous potential

Spontaneous potential is the measure of electrical potential resulting from electrochemical and electrokinetic formation effects between the borehole and a buried surface electrode. Due to a combination of fresh-water mud, fresh formation water, high porosities, very low rock permeabilities, and variations in rock alteration products, the spontaneous potential is unpredictable and not useful as a stratigraphic or lithographic correlation tool. It is presented on Plates 1 and 2 for information because it is one of the standard traces obtained with the resistivity logs.

Resistivity

The resistivity tools require electrical coupling with the formation through borehole fluid. They measure the resistance to a flow of electric current through the formation. Since the rock is nearly an insulator, the resistivity response is primarily due to pore water content. High resistivity indicates low water content or low porosity and low resistivity is a result of high water content or high porosity. Where resistivity is missing on Plate 1 above the static water level, a fluid-filled hole could not be established at the time of logging. All resistivities are uncorrected for the borehole and borehole fluid effects. The resistivity values are generally high in densely welded tuff and vitrophyre to low in nonwelded and bedded tuffs. The lowest resistivities (less than 20 ohm-m) are where alteration has resulted in significant zeolitization and argillization.

Neutron

The neutron log is produced by bombarding the formation with neutrons from a neutron source such as PuBe or AmBe, and counting the number of scattered neutrons arriving at a detector some distance away from the source. The primary scattering mechanism is the elastic collisions of neutrons with single protons, which are almost exclusively found in the nucleus of hydrogen atoms. Hydrogen in most rocks is primarily in water molecules. Thus the neutron log like the electric log primarily responds to pore water, and this is verified by the high degree of visual correlation between the resistivity and neutron logs on Plates 1 and 2. In the upper part of the hole above the fluid level the tools respond differently to air filled holes and tend to correlate more with the caliper log than with porosity or water content. This effect in unsaturated welded tuffs has been noted by Daniels and others (1981).

The lithophysal interval in the Paintbrush Tuff is characterized by a high geologic "noise" level on the neutron trace on Plate 1 from 133.5 to 392.3 m.

Density

The density log measures electron density, but is calibrated to read bulk density. The density tool bombards the formation with gamma-rays from Cs^{137} or Co^{60} and counts the Compton-scattered gamma rays at 1 or 2 detectors located away from the gamma-ray source. Since Compton-scattered gamma rays result from collisions between gamma rays and electrons, the tool can be calibrated to read double the electron density, which is equivalent to bulk density if the atomic and molecular structure of the formation is such that there is a proton-neutron pair for every electron. This is based on the fact that protons and neutrons make up almost the total mass of any substance, and also on the fact that the ratio of electrons to protons and neutrons is 1:2 for most elements that make up siliceous rocks like tuffs. Water has an electron density of 1.11 g/cc and a bulk dnesity of 1.00 g/cc. So, for saturated higher porosity rocks a water correction should be made.

The lithophysal zone from 133.5 to 392.3 m is characterized by a very noisy trace consisting of frequent high-amlitude low-density "spikes" throughout the interval. These are the result of borehole wall rugosity and lithophysae in the formation.

In general the log agrees with welding above the Tram unit of the Paintbrush Tuff. Denser welding corresponds to higher density and less welding of lower density. Below the Tram the densities do not reflect the changes in welding shown on the lithologic log. The lowest densities are in the nonwelded upper Paintbrush Tuff.

Velocity

Velocities were obtained by hand picking the first arrival times and shear arrival times on continuous full wave train logs designated 3-D velocity logs by Birdwell, Inc. The times were picked on 2 logs with 0.9 m spacing between source and detector and 1.8 m spacing between source and detector. The difference in spacing and the difference in time were used to calibrate the 0.9 spacing for compressional and shear velocity.

The sonic log requires fluid for coupling with the formation, and the logs run in the upper 304.8 m above the static water level were of too poor quality to give reliable velocities, so they were discarded. Velocity, like density and resistivity, seems to correspond to welding. Densely welded tuff has higher velocity, less densely welded has lower velocity. The primary reason for this phenomenon is that the densely welded tuff has lower porosity.

Porosity

Porosity is obtained from a dual-detector borehole-compensated thermal-neutron log which is calibrated to read porosity directly. The porosity shown on Plates 1 and 2 (dashed line) is based on calibration for sandstone. The solid line porosity is calculated from the density log assuming the grain density of sandstone. Both traces require complete saturation of the formation with water. Above the water table the values are unreliable. Where porosity is higher than about 25 percent the neutron porosity is low. The porosity based on sandstone calibration is a reasonable estimate for rhyolitic tuffs encountered at Yucca Mountain (Byers and others 1981). Where the tuffs have been altered or are bedded, the porosities are unreliable.

Calculated logs

Acoustic impedance logs are calculated from the density and velocity logs for both compressional and shear velocities. The largest change in acoustic impedance occurs at the base of the densely welded vitrophyre at 409.0 m. The magnitude of the change in acoustic impedance indicates this boundary could reflect -30 percent or more of incident seismic energy. No other significant seismic reflecting horizons are evident on this log.

The dynamic moduli and Poisson's ratio are calculated from density, and compressional and shear velocities. These logs do not appear to provide any lithologic information that is not apparent on the density and velocity logs. Poisson's ratio is relatively uniform and shows no major anomalies. The dynamic moduli tend to increase gradually with depth because of decreasing porosity with depth and the effect of the lithostatic load on the dynamic elastic properties of the rock.

Conclusion

The logs, shown on Plates 1 and 2, obtained in USW G-1 are of generally good quality. Their usefulness as lithologic indicators is limited primarily to correlations with welding in the tuffs, and to seemingly "noisy" density, caliper, and neutron traces in the lithophysal zone in the Paintbrush Tuff. Future comparisons of these logs with those from other holes and continuing studies will undoubtably yield more useful correlations. The major conclusion that can be drawn is that the physical properties of the tuffs above the Tram unit are quite variable while the Tram and tuff of Lithic Ridge are more uniform and predictable. Future work should include borehole gravimetry for surface gravity modeling, IP logs to determine sulfide mineral content, magnetometer logs for stratigraphic correlation and for paleomagnetic models, and magnetic susceptibility logs.

Reference List

Byers, F. M., Jr., Hawkins, W. L., 1981, Geology of drill hole UE18t and area 18, Timber Mountain Caldera Moat, Nevada Test Site with a section on geophysical logging by D. C. Muller: U.S. Geological Survey Report UAGS-474-312, 69 p.; available only from U.S. Department of Commerce, National Technical Information Service, Springfield, VA22161.

Daniels, J. J., Scott, J. H., 1981, Interpretation of geophysical well logs from drill holes UE25a-4, -5, -6, and -7: U.S. Geological Survey Open-File Report 81-289, 46 p.

Geyer, R. L., Myung, J. I., 1970, The 3-D velocity log; a tool for in-situ determination of the elastic moduli of rocks, in "Dynamic Rock Mechanics - Twelfth Symposium of Rock Mechanics", University of Missouri-Rolla, November 1970: Published by the Society of Mining Engineers of AIME, 1971, pp 71-107.

Pirson, S. J., 1963, Handbook of well log analysis: Prentice Hall, Inc., Englewood Cliffs, N.J., 326 p.

Spengler, R. W., Byers, F. M., Jr., Warner, J. B., 1981, Stratigraphy and structure of volcanic rocks in drill hole USW-G 1, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Open-File Report 81-1349, 50 p.

GPO 839-581