DRILLING AND GEOHYDROLOGIC DATA FOR

TEST HOLE USW UZ-1, YUCCA MOUNTAIN,

NYE COUNTY, NEVADA

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(formerly with Fenix & Scisson, Inc.)

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CONVERSION FACTORS

Metric (International System) units used in this report may be converted to inch-pound units by using the following conversion factors:

Multiply	*By*	*To obtain*
centimeter (cm)	0.3937	inch
cubic centimeter per minute (cm^3/min)	0.06102	cubic inches per minute
cubic meter (m^3)	35.315	cubic feet
gram (g)	0.03527	ounce
kilometer (km)	0.6214	mile
kilopascals (kPa)	0.1450	pounds per square inch
liter (L)	0.2642	gallon
liter per second (L/s)	15.85	gallon per minute
meter (m)	3.281	foot
millimeter (mm)	0.03937	inch

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F=9/5\ (°C)+32\ .$$

The following terms and abbreviations also are used in this report:

milligram per liter (mg/L)
micrometer (μm)
microvolts (μV)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

This report presents data collected to determine the hydrologic characteristics of tuffaceous rocks penetrated in test hole USW UZ-1. The borehole is the first of two deep, large-diameter, unsaturated-zone test holes dry drilled using the vacuum/reverse-air-circulation method. This test hole was drilled in and near the southwestern part of the Nevada Test Site, Nye County, Nevada, in a program conducted in cooperation with the U.S. Department of Energy. These investigations are part of the Yucca Mountain Project (formerly the Nevada Nuclear Waste Storage Investigations) to identify a potentially suitable site for the storage of high-level radioactive wastes.

Data are presented for bit and casing configurations, coring methods, sample collection, drilling rate, borehole deviation, and out-of-gage borehole. Geologic data for this borehole include geophysical logs, a lithologic log of drill-bit cuttings, and strike and distribution of fractures. Hydrologic data include water-content and water-potential measurements of drill-bit cuttings, water-level measurements, and physical and chemical analyses of water. Laboratory measurements of moisture content and matric properties from the larger drill-bit cutting fragments were considered to be representative of in-situ conditions.

INTRODUCTION

The U.S. Geological Survey has been conducting investigations at Yucca Mountain, Nevada, to evaluate the hydrologic and geologic suitability of this site for storing high-level nuclear waste in an underground mined repository. These investigations are part of the Yucca Mountain Project conducted in cooperation with the U.S. Department of Energy, Nevada Operations Office. Test drilling has been a principal method of investigation. This report presents borehole, geologic, and hydrologic data for test hole USW UZ-1, the first of two deep, large-diameter (444 mm), unsaturated-zone test holes dry drilled into tuff in or near the southwestern part of the Nevada Test Site using the vacuum/reverse-air-circulation drilling method.

The primary objectives in drilling test hole USW UZ-1 were to: (1) Obtain a vertical moisture-content profile of the rocks drilled; (2) check for the presence of perched-water zones; and (3) emplace hydrologic instruments at selected depths so that a long-term record of pressure and moisture-potential data could be collected. The unsaturated section in the Yucca Mountain area consists of nonwelded to densely welded tuff ranging in thickness from 457 to 762 m.

Test hole USW UZ-1 is located in Nye County, about 140 km northwest of Las Vegas in the southern part of the State (fig. 1). The drill site is in Drill Hole Wash, a southeasterly draining canyon of Yucca Mountain northwest of Jackass Flats (fig. 1). The test hole is about 9 km northwest of water-supply well J-13 and is at Nevada State Central Zone Coordinates N. 771,276, E. 560,221. The test hole is about 0.3 km northwest of test hole USW G-1; the test hole is about 0.7 km west-northwest of test hole USW H-1. The altitude of the land surface at test hole USW UZ-1 is 1,348.48 m above sea level.

DRILLING AND CASING METHODS

The first large-diameter (444 mm) test hole for which vacuum/reverse-air-circulation drilling was used to collect hydrologic data from the unsaturated zone in the Yucca Mountain area was test hole USW UZ-1. Drilling started on April 27, 1983, and the total depth of 387.1 m was reached on July 16, 1983. A vacuum/reverse-air-circulation drilling method (Houghton, 1969) was used. A dual-walled string of pipe, which had an inside diameter of 14 cm and an outside diameter of 22 cm, was connected to a vacuum unit at the land surface that was used to remove cuttings from the borehole. From the inner string, the drill-bit cuttings were routed via the kelly hose to a dry separator for sample collection (fig. 2). (The diameter of the inner string of pipe needs to be large in order to minimize the head losses due to excessive friction that might occur during the drilling of deep boreholes.) The dry separator contained two chambers that could be separated by a hydraulic slide gate, which prevented vacuum loss in the system when drill-bit cuttings were being collected from the lower part of the dry separator. When closed, the slide gate enabled drilling to continue and the drill-bit cuttings to accumulate in the upper compartment of the dry separator as cuttings were collected from the lower compartment of the separator; thus, simultaneous drilling and sample collection could occur. After samples were collected for lithologic and hydrologic analyses, the remaining drill-bit cuttings were vibrated out of the lower chamber of the dry separator and removed from the collection area by a conveyor belt.

The dust particles that did not settle out in the dry separator were vacuumed into a wet separator where the dust was removed by a water spray, and the remaining clean air was exhausted to the atmosphere through the vacuum unit and exhaust muffler (fig. 2). The water spray removed almost all of the dust before it passed through the vacuum unit and exhaust muffler to the atmosphere.

Advantages of using vacuum/reverse-air-circulation for drilling are: (1) Continuous, representative drill-bit cuttings can be obtained, which permits a moisture profile to be made of the unsaturated rocks that are drilled; (2) excessive drying is not a factor, because only a minimal quantity of air flows in the well bore; (3) contamination of drill-bit cuttings does not occur, because no drilling fluids are used; (4) most of the drill cuttings and small rock fragments are vacuumed from the borehole which reduces the potential for plugging of fractures and provides a cleaner borehole for air or water injection tests; (5) detection of perched-water or moist zones occurs as soon as the zone is penetrated; and (6) atmospheric contamination can be detected after completion of the test hole by sampling for tracer gas.

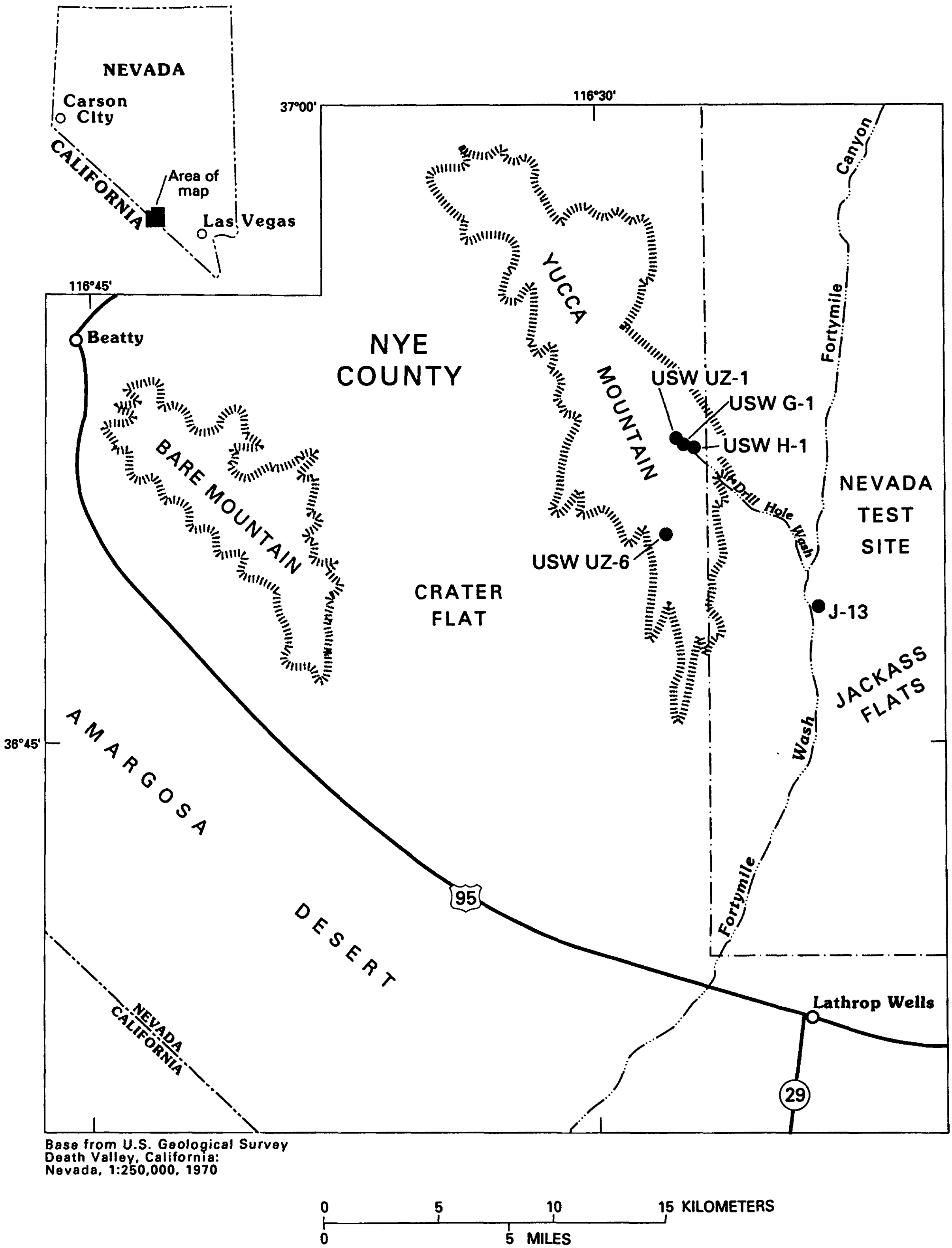

Figure 1.--Location of test hole USW UZ-1, nearby test holes, and geographic features.

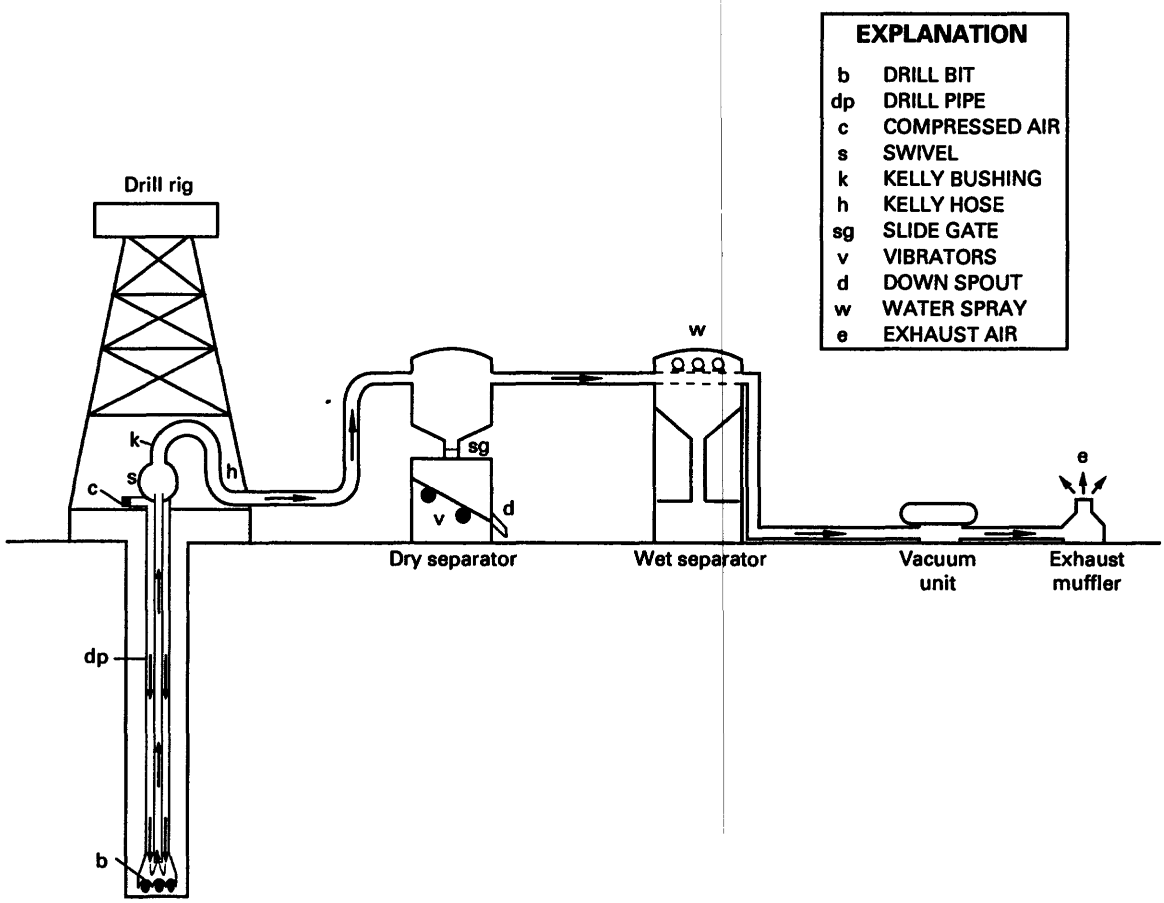

Figure 2.--Schematic diagram of separators, vacuum unit, and exhaust muffler.

One method to determine the presence or absence of atmospheric gas in the rocks adjacent to the borehole is by using a tracer gas, such as sulfur hexafluoride, injected into the borehole during drilling. Small quantities of this gas are piped to the intake manifold of an air compressor, which injects compressed air into the annulus between the inner pipe and the inside of the larger dual-wall pipe. Sulfur hexafluoride was added to the compressed air injected into this test hole at a concentration of 50 to 60 cm^3/min. The compressed air, in addition to adding a tracer gas, also helped cool the drill bit and assisted the vacuum system in the removal of drill cuttings from the bit. When necessary, the outer pipe also was used to inject small quantities of water to clean the bit. Therefore, any atmospheric gas that enters the borehole during the drilling process can be detected later. To make accurate age determinations of water contained in rocks, it is essential that rocks not be contaminated by ambient atmospheric gases, such as carbon dioxide. Prior to stemming and instrumenting the test hole, the test hole was vacuumed for several hours to remove contaminated atmospheric air. Subsequent gas samples from different depths, however, indicated that some atmospheric air contamination still was present in the test hole.

Disadvantages of using vacuum/reverse-air-circulation for drilling are that: (1) More extensive equipment and a larger drilling site are needed than for conventional drilling methods; (2) unstable hole conditions are produced by vacuuming, resulting in frequent caving and redrilling; (3) the method is unsuitable for collection of representative hydrologic cores; and (4) in most zones, plugging of the drill bit by mud encrustation of the inner string and kelly hose restricts movement of drill-bit cuttings to the land surface.

When the rock-moisture content exceeds 5 percent by weight, plugging of the system occurs and drilling needs to be stopped, or the drill bit will be buried in drill cuttings, and will become stuck. Drilling can be resumed only after the bit, inner string, and kelly hose are cleaned and dried by blowing dry compressed air through them.

Initially, a 1,219-mm-diameter conductor hole was augered to a depth of 12.6 m at the site of test hole USW UZ-1, and a 1,067-mm-diameter conductor pipe was cemented to a depth of 12 m. On June 1, 1983, drilling of a 914-mm-diameter borehole began, using vacuum/reverse-air drilling, in alluvium to a depth of 29.6 m. Then, a 610-mm-diameter borehole was drilled from 29.6 to 30.8 m, a 444-mm-diameter borehole was drilled from 30.8 to 385.6 m, a 381-mm-diameter borehole was drilled from 385.6 to 386.8 mm, and a 235-mm borehole was drilled from 386.8 to 387.1 m, the total depth. Bit, casing, and cementing data are listed in table 1. Drilling through the alluvium was difficult because it caved in around the drilling assembly. Because the caved-in material caused the bit to clog, water in quantities ranging from 0.076 to 0.13 L/s was added with the air to clean and cool the bit. This small quantity of added water, however, made a muddy mixture that was difficult to remove from the hole. About 0.44 L/s of water would have been needed to remove the cuttings using conventional drilling methods, but such methods were not used because too much water would have been added to the borehole. At a depth of 17 m, the drill bit encountered hard rock. At a

Table 1.--*Bit, casing, and cementing data*

[--, no data]

Drilled interval (meters)	Bit diameter (millimeters)	Cased interval (meters)	Casing inside diameter (millimeters)	Intervals cemented and volume of cement used	
				Depth (meters)	Volume (cubic meters)
0 to 12.6	1,219	0 to 12.0	1,041	0 to 12.0	12.2
12.6 to 29.6	914	--	--	--	--
29.6 to 30.8	610	--	--	--	--
[1]30.8 to 385.6	444	--	--	372.2 to 378.9	1.0
[1]30.8 to 385.6	444	--	--	382.5 to 385.6	0.4
[2]385.6 to 386.8	381	--	--	385.6 to 386.5	0.1
[2]386.8 to 387.1	235	--	--	--	--

[1]Junk basket, 381 millimeters in diameter, and crossover sub left in hole from 378.9 to 382.5 meters.

[2]Fill in hole from 386.5 to 387.1 meters.

depth of 17.5 m, the penetration rate decreased due to an accumulation of water in the borehole that could not be vacuumed out. A diaphragm pump was installed in the borehole. About 1,514 L of water were removed in addition to 1,970 L of water that probably were removed with 2.5 m^3 of fill that caved in from the sides of the borehole. This total approximates the 3,445 L of water added to the borehole during drilling. After removing the diaphragm pump, the borehole was dried by circulating air.

During drilling at a depth of 13 to 17 m, small quantities of water from well J-13 were added with the air to clean the pulverized rock from the drill bit. About 20 mg/L of lithium bromide was added to the water as a tracer. Water was stored and mixed with this tracer in a Baker tank.[1]

The drilling continued using compressed air and vacuum/reverse-air circulation without water. Dry drilling progressed slowly because it was necessary to pull the drill pipe and bit from the hole periodically either to remove pulverized rock material from the teeth of the bit or to clean out the vacuum hose between the swivel and dry separator. A 610-mm-diameter borehole was drilled from 29.6 to 30.8 m. From depths of 30.8 to 385.6 m, the borehole was drilled with a 444-mm-diameter bit. The combination of smaller borehole diameter and the use of a Gardner Denver vacuum pump enabled the volume of drill-bit cuttings to be removed as soon as they were cut, thus preventing them from being pulverized and clogging the bit. When the pulverized drill-bit cuttings became wet from moisture condensation, the hoses became clogged, thus blocking the vacuum from the blower, and had to be cleaned.

Drilling continued without major problems until water was encountered at 383 m in the densely welded Topopah Spring Member. A water sample was collected, and chemical analysis of water indicated that it had a large concentration of polymer mud identical to that used during the coring of geologic test hole USW G-1, located about 0.3 km southeast of test hole USW UZ-1. The daily fluid losses from test hole USW G-1 averaged almost 77,600 L throughout the entire drilling period. Most of this loss was in a fractured zone that exists in the thick, densely welded zone of the Topopah Spring Member, and it is thought that the drilling fluid "lost" during the drilling of test hole USW G-1 formed a temporary, linear water zone that extended along this fracture to test hole USW UZ-1.

Bailing attempts to dry the water-producing zone proved unsuccessful. The borehole was deepened to a total depth of 387.1 m. Fill was left in the bottom of the borehole from 386.5 to 387.1 m. The borehole was plugged with cement from 372.2 to 378.9 m and from 382.5 to 386.5 m in an effort to seal off the water inflow so dry drilling could be resumed. In an attempt to core through the cement plugs, the junk basket and a crossover sub became stuck in the cement from 378.9 to 382.5 m, and the drilling operation was discontinued after the drill pipe was retrieved.

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[1]The use of trade or firm names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

One of our initial objectives was to drill through the entire unsaturated zone at this location. When water was encountered at a shallower depth than was expected and when it was determined by a chemical analysis that this water was contaminated with the polymer that was used during drilling of test hole USW G-1, the possible occurrences of the water encountered were (1) a contaminated perched water zone, (2) the contaminated natural water table, or (3) a zone of polymer drilling fluid. A future, deep, unsaturated-zone test hole, USW UZ-14, has been planned, which should help determine the natural unsaturated-saturated contact at this location.

The drilling rate and borehole deviation are shown in figure 3. Borehole deviation was 1.5 degrees or less from the vertical. A detailed drilling history is contained in the files of the engineering contractor, Fenix & Scisson of Nevada (formerly Fenix & Scisson, Inc). Instrumenting, stemming, and grouting of this test hole was completed on October 24, 1983, so that fluid-flow potentials in the unsaturated zone could be monitored.

CORING METHODS

Most coring attempts were made using a Globe junk basket. One coring attempt, however, was made using a drive-core method, and another attempt was made using a rotary-coring method. The cored intervals are listed in table 2.

Coring with the Junk Basket

Coring using the Globe junk basket was complicated and had limited success. The junk basket was impeded by fill between the rock and the cutting edge, causing much friction and blockage of the core into the core barrel. Only short cores, about 1 m long, could be collected, and recovered material generally was rubble. The friction resulted in the production of heat that in turn resulted in moisture loss from the recovered core. Water-content and water-potential measurements made in core samples were not considered representative of the formation conditions. Total recovery of core was only 42 percent. The junk basket frequently became stuck in the fill at the bottom of the hole.

Drive Core

The drive-core method was used in an attempt to collect a core sample from the depth interval from 76.07 to 76.20 m. Drive coring was attempted by repeatedly driving or dropping the drill string with a 0.91-m-long section of 273-mm-outside-diameter casing that had a beveled outside edge. No penetration could be made after driving the first 127 mm. No core was recovered by using this method because the hard, poorly consolidated rock fell out of the drive casing.

Rotary Core

Rotary coring using a Kore-King core barrel and a 216-mm-diameter by 102-mm-long core bit was attempted in the interval from 304.80 to 307.85 m. However, most of the core fell out of the core catcher, and only 0.15 m of core was recovered, which represented only a 5-percent recovery.

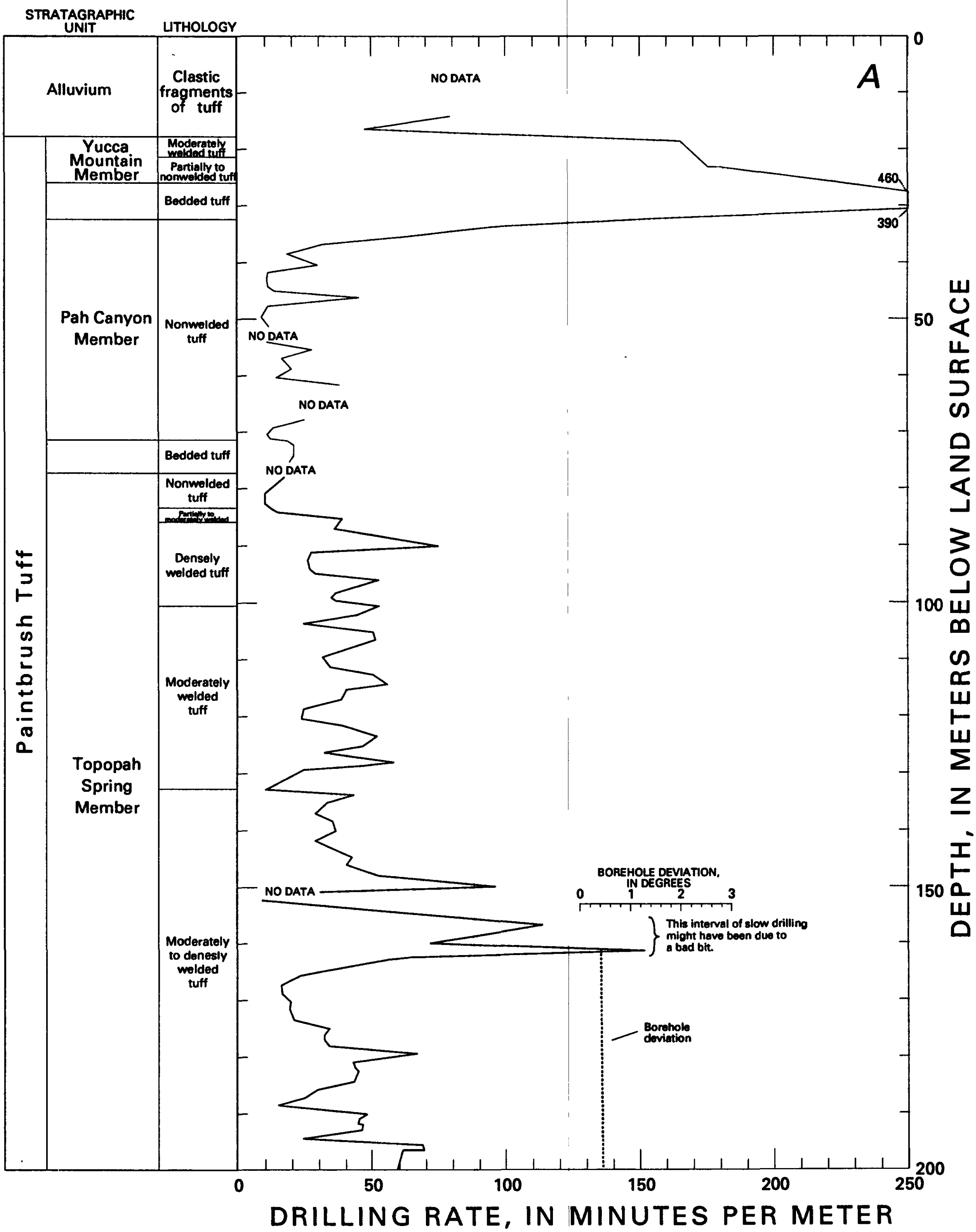

Figure 3.--Drilling rate and borehole deviation from depths of: *A*, 0 to 200.0 meters; and *B*, 200.0 to 382.5 meters.

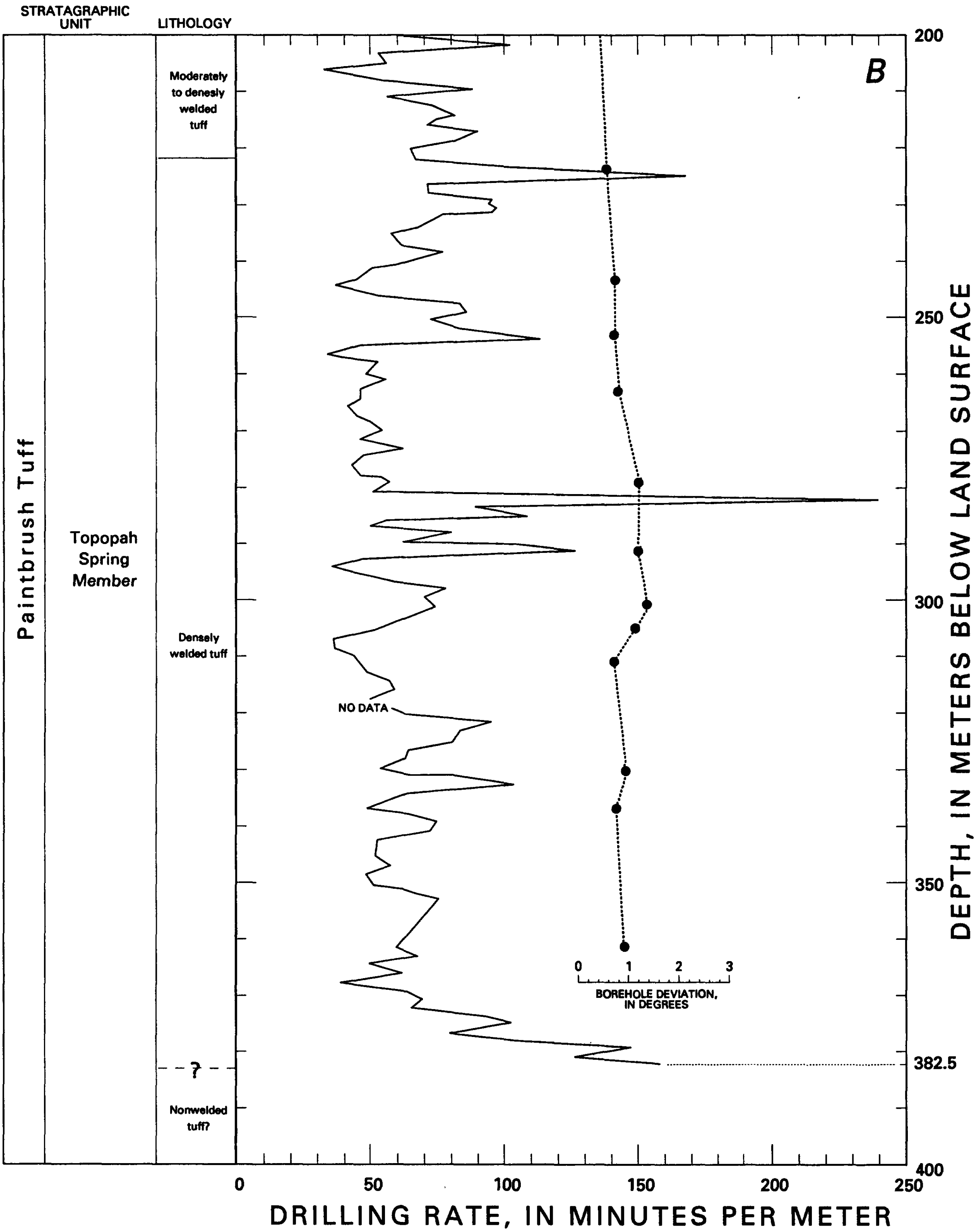

Figure 3.--Drilling rate and borehole deviation from depths of: *A*, 0 to 200.0 meters; and *B*, 200.0 to 382.5 meters--Continued.

Table 2.--*Cored intervals (Globe junk basket)*

Core number	Depth interval (meters)	Interval thickness (meters)	Core recovered (meters)
1	16.76 to 17.22	0.46	0
2	21.95 to 24.08	2.13	.61
3	29.57 to 30.78	1.21	.61
4	51.82 to 52.43	.61	.43
5	52.43 to 53.04	.61	.61
6	53.04 to 53.64	.60	.30
7	[1]76.07 to 76.20	.13	0
8	76.20 to 76.81	.61	.53
9	106.68 to 107.11	.43	.43
10	152.40 to 153.01	.61	.15
11	[2]304.80 to 307.85	3.05	.15
12	383.44 to 384.20	.76	.61
13	385.27 to 386.18	.91	0
14	386.18 to 386.48	.30	0
15	385.57 to 386.48	.91	0
16	386.03 to 387.10	1.07	0

[1]Attempted to drive core by repeatedly driving or dropping the drill string with a 0.91-meter-long section of 273-millimeter-outside-diameter casing.

[2]Drilled with conventional circulation using air and a core barrel that had a 216-mm-diameter by 102-mm-long core bit.

SAMPLE COLLECTION AND HANDLING

Rock samples were collected for lithologic and hydrologic determinations. Samples consisted of drill-bit cuttings and cores.

Drill-Bit Cuttings

Samples of drill-bit cuttings were collected at about 0.6-m intervals at depths from 20.7 to 29.9 m and at about 1.5-m intervals at depths from 32 to 387.1 m. Drill-bit cuttings also were collected during the coring attempts and reaming. After a prescribed interval had been drilled, cuttings were vibrated out of the dry separator by mechanical vibrators onto a conveyor belt, and a representative sample of these cuttings was immediately collected and placed into a 0.95-L glass sample jar and capped with an airtight lid for laboratory analysis of water content and matric properties. A sample of coarse, sieved drill-bit cuttings also was collected for hydrologic laboratory determinations from each interval from a depth of 36.6 m to the total depth. Drill-bit cuttings from the conveyor belt were sieved rapidly through a 1.6-mm mesh screen, and the coarse fragments were collected and placed in a second 0.95-L glass jar and capped with an airtight lid. Sample cuttings that were first released from the bottom of the dry separator were not collected because of longer residence time in the separator and because of the possibility of contamination from the cuttings left in the separator from the previous interval. An effort also was made to obtain a representative sample of the interval drilled by collecting portions of the total sample from different locations on the conveyor belt. More importantly, hydrologic sample collection and sieving were done quickly to minimize evaporation of water from the cuttings.

After sample collection was completed, the samples were taken immediately to a laboratory trailer on the drill site. At that time, a subsample from each container for each type of cutting was removed for water-content measurements. The lids of the glass sample jars then were sealed with vinyl tape for additional protection against evaporation, and the jars were stored until water-potential measurements could be made. In some instances, as many as 36 hours elapsed before water-content measurements could be made because of a backlog of samples.

Core

Core from the Globe junk basket was placed into 0.3-m-diameter-polyvinyl-chloride (PVC) pipe containers that had PVC caps affixed immediately after the shoe of the junk basket was removed. The heat produced by coring welded tuff without drilling fluids was too great to obtain valid water-related measurements. Core in the lower part of the junk basket generally was virtually dry and extremely hot from heat produced by the cutting bit. Core in the upper part of the junk basket usually was moist; in some instances, water collected on the top of the core. Apparently, interstitial water from the lower part of the core evaporated and condensed on the cooler metal of the upper part of the junk basket.

GEOPHYSICAL LOGS

Geophysical logs of test hole USW UZ-1 were made by the Birdwell Division of the Seismograph Service Corp., a subsidiary of Raytheon Co. The main objectives were to: (1) Determine exact depths of major stratigraphic units and lithologic changes; (2) obtain porosity and fracture data; and (3) gage the diameter of the open hole to determine volume of stemming material needed around the hydrologic instruments. The types of logs and the depth intervals logged are listed in table 3.

Caliper logs were obtained to determine a vertical profile of borehole diameter. A vertical distribution of the depths where out-of-gage intervals of the borehole occurred is listed in table 4; the percentage of out-of-gage borehole for each stratigraphic unit penetrated is summarized in table 5. Out-of-gage is defined in this report as a diameter that is 100 mm greater than the diameter of the bit used to drill the borehole. Some of the enlarged zones identified by the caliper log are associated with rock fracturing.

Table 3.--*Geophysical logs obtained in the borehole*

Types of geophysical log	Run number	Depth interval (meters)
Caliper	1	380 to 383
Caliper	2	3 to 383
Casing-collar locator	1	299 to 380
Casing-collar locator	2	351 to 369
Casing-collar locator	3	358 to 360
Casing-collar locator	4	305 to 345
Density	1	6 to 29
Density, borehole compensated	1	27 to 384
Water locator	1	351 to 371
Water locator	2	351 to 360
Water locator	3 to 169	3 to 371
Fluid density for water location	1-A	357 to 382
Fluid density for water location	1-B	357 to 382
Fluid density for water location	2	335 to 379
Fluid density for water location	3	375 to 385
Fluid density for water location	4	357 to 369
Fluid density for water location	5	357 to 369
Gamma ray	1	3 to 380
Gamma ray	2	3 to 25
Spectralog gamma ray (5-inch)	1	0 to 383
Spectralog gamma ray (2-inch)	1	0 to 383
Epithermal neutron porosity	1	24 to 385
Epithermal neutron porosity	2	3 to 30
Induction	1	3 to 383
Dielectric log (5-inch)	1	12 to 383

Table 4.--*Out-of-gage borehole intervals*

[Based on caliper logs]

Stratigraphic unit	Depth interval (meters)	Interval thickness (meters)
Alluvium	[1]12.04 to 13.50	1.46
	16.76 to 17.40	.64
Yucca Mountain Member	17.40 to 17.68	.28
	18.04 to 18.35	.31
	18.53 to 18.90	.37
	19.29 to 20.12	.83
	20.60 to 21.37	.77
	21.92 to 22.71	.79
	23.16 to 25.60	2.44
Bedded tuff	25.60 to 28.53	2.93
	29.57 to 29.87	.30
	30.78 to 32.00	1.22
Pah Canyon Member	32.00 to 39.01	7.01
	40.39 to 41.45	1.06
	42.98 to 44.20	1.22
Bedded tuff	71.93 to 77.70	5.77
Topopah Spring Member	77.70 to 79.71	2.01
	150.11 to 150.54	.43
	170.05 to 170.14	.09
	260.15 to 260.30	.15
	261.12 to 261.31	.19
	262.71 to 263.96	1.25
	264.14 to 264.81	.67

[1]Well cased to 12.04 meters.

Table 5.--*Percentage of out-of-gage borehole for stratigraphic units penetrated*

Stratigraphic unit	Percentage of unit out-of-gage	Distribution within stratigraphic unit
Alluvium	39	Top and bottom of uncased interval
Yucca Mountain Member	71	Throughout unit
Bedded tuff	70	Throughout unit
Pah Canyon Member	23	Upper one-half
Bedded tuff	95	Throughout unit
Topopah Spring Member	2	Top and middle

Four television videotapes of borehole conditions were made, three in July 1983 and one in September 1983. The distribution of observed fractures is listed in table 6; a Rose diagram of strikes of fractures is shown in figure 4. Measurements were made using a compass attached below the camera. No water seeps in the borehole were observed by the television camera or on the videotapes.

Table 6.--*Fracture distribution observed using a downhole television camera*

Depth (meters)	Description
	Alluvium
0 to 12	Well casing
12 to 17	No fractures
	Yucca Mountain Member of Paintbrush Tuff
17 to 26	No fractures
	Bedded Tuff
26 to 32	No fractures
	Pah Canyon Member of Paintbrush Tuff
32 to 72	1 fracture, north-northeasterly strike
	Bedded Tuff
72 to 78	No fractures
	Topopah Spring Member of Paintbrush Tuff
78 to 85	No fractures
85 to 127	32 fractures, strike northeast to northwest
127 to 211	12 fractures, strike north-northwest to northwest
211 to 236	12 fractures, general strike north-northwest
236 to 345	13 fractures, strike north-northeast to northwest
345 to 357	9 fractures, strike north-northeast to northwest
357 to 382	9 fractures, strike north-northeast to northwest

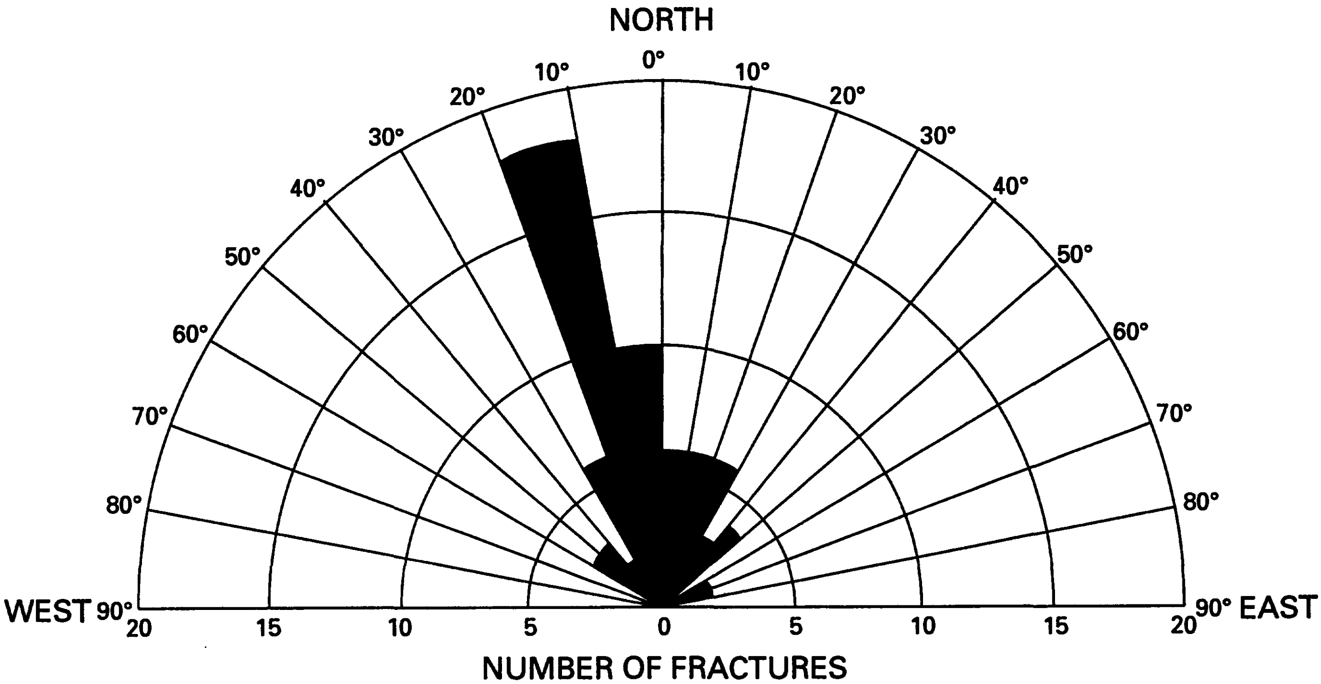

Figure 4.--Strikes of fractures.

LITHOLOGY

A lithologic log of rocks of Quaternary and Tertiary age penetrated during the drilling of test hole USW UZ-1 was made from drill-bit cuttings and cores and is listed in table 7. Contacts between the geologic units were cross-checked with geophysical logs, and the depths were corrected accordingly. Ash-flow tuff was the dominant rock type penetrated. The thick ash-flow-tuff beds are separated by bedded-tuff units that are each 6 m thick. The tuffs have various degrees of welding and induration as described in table 7. Black glass shards were recovered during bailing when the borehole was 383.29 m deep indicating that the friable, nonwelded tuff at the base of the Topopah Spring Member was penetrated. Drill-rate-penetration curves (figs. 3*A* and 3*B*) support the varying hardness of the tuffs caused by degree of welding and induration.

Table 7.--*Lithologic log of drill-bit cuttings*

[Log compiled by Richard W. Spengler, U.S. Geological Survey, subject to revision]

Stratigraphic and lithologic description	Thickness of interval (meters)	Depth to bottom of interval (meters)
Alluvium		
Clastic fragments of nonwelded to densely welded tuff, to 12.8 meters; monolithologic from 12.8 to 17.4 meters, consisting almost entirely of densely welded tuff of the Tiva Canyon Member; some caliche coated	17.4	17.4 (?)
Paintbrush Tuff		
Yucca Mountain Member		
Tuff, ash flow, pale brown, moderately welded, devitrified; extremely rare phenocrysts	3.3	20.7
Tuff, ash flow, dark yellowish-brown, partially welded to nonwelded, vitric, pumice commonly grayish-orange-pink, argillic (?); abundant black glass shards in matrix	4.9	25.6
Bedded Tuff		
Tuff, ash fall, light gray to white and pinkish-gray; predominantly composed of subrounded vitric pumice clasts, some of which are slightly altered to clays (?); poorly consolidated to unconsolidated	6.4	32.0
Pah Canyon Member		
Tuff, ash flow, light brown, nonwelded, (poorly consolidated), vitric; pumice, light olive-gray, vitric, relatively large; 5-percent phenocrysts of sanidine, plagioclase, biotite, and hornblende; sparse, pale reddish-brown, lithic volcanic fragments	10.7	42.7

Table 7.--*Lithologic log of drill-bit cuttings*--Continued

Stratigraphic and lithologic description	Thickness of interval (meters)	Depth to bottom of interval (meters)
Paintbrush Tuff--Continued		
Tuff, ash flow, medium brown, nonwelded, (poorly consolidated), vitric; pumice, commonly dusky yellow, vitric, large; 7- to 8-percent phenocrysts of quartz, sanidine, plagioclase, biotite, hornblende; rare blackish-gray, lithic volcanic fragments	12.2	54.9
Tuff, ash flow, dark yellowish-brown, nonwelded (poorly consolidated), vitric [slightly argillic (?)]; pumice, commonly dark yellowish-brown to very pale orange, vitric; 10-percent phenocrysts of sanidine, biotite, hornblende; abundant black minute glass shards; sparse grayish-red, lithic volcanic fragments	16.7	71.6
Bedded Tuff		
Tuff, ash fall, reworked, light gray to very light gray, and dark yellowish-brown, vitric; poorly consolidated; poorly sorted	6.1	77.7
Topopah Spring Member		
Tuff, ash flow, medium orange-pink to medium reddish-brown, nonwelded, vitric; pumice, medium orange-pink to medium reddish-brown, vitric; 2- to 3-percent phenocrysts of sanidine, biotite (black)	1.5	79.2
Tuff, ash flow, yellowish-gray, nonwelded, vitric; pumice, yellowish-gray, vitric; 2- to 3-percent phenocrysts of sanidine and biotite	4.6	83.8

Table 7.--*Lithologic log of drill-bit cuttings*--Continued

Stratigraphic and lithologic description	Thickness of interval (meters)	Depth to bottom of interval (meters)
Paintbrush Tuff--Continued		
Topopah Spring Member--Continued		
Tuff, ash flow, brownish-gray and medium gray, partially to moderately welded (appears fused), vitric; pumice, light brownish-gray and brownish-gray, vitric; 1- to 2-percent phenocrysts of sanidine, biotite; rare, dark-gray, lithic volcanic fragments	2.5	86.3
Tuff, ash flow, grayish-red, densely welded, glassy (vitrophyre); 15-percent phenocrysts, dominantly sanidine	1.2	87.5
Tuff, ash flow, grayish-brown to dusky brown, densely welded devitrified (caprock); some pumice displaying vapor-phase crystallization; 10-percent phenocrysts of sanidine, bronze biotite, hornblende	13.1	100.6
Tuff, ash flow, pale brown, moderately welded, devitrified; pumice, pale red, dominately vapor-phase crystallization; 5- to 7-percent phenocrysts of sanidine, biotite	32	132.6
Tuff, ash flow, pale brown and light gray (mottled), moderately to densely welded, devitrified [upper lithophysal (?) zone]; pumice, light gray and pale brown, devitrified; 2- to 3-percent of phenocrysts, dominantly sanidine	89.9	222.5
Tuff, ash flow, medium brown and medium light gray (slightly mottled), densely welded, devitrified; less than 1-percent phenocrysts of sanidine	12.2	234.7

Table 7.--*Lithologic log of drill-bit cuttings*--Continued

Stratigraphic and lithologic description	Thickness of interval (meters)	Depth to bottom of interval (meters)
Paintbrush Tuff--Continued		
Topopah Spring Member--Continued		
Tuff, ash flow, grayish-brown and light brown (mottled), densely welded, devitrified (might contain sparse lithophysae); less than 1-percent phenocysts of sanidine	135.6	[1]370.3

[1]Samples were not available below a depth of 370 meters to the total depth.

SAMPLE-TESTING PROCEDURES AND RESULTS

Several hydrologic properties were determined in the laboratory from the drill-bit cuttings. These properties included measurements of water content and water potential. Laboratory measurements of moisture content and matric properties from the larger drill-bit-cutting fragments were considered to be representative of in-situ conditions.

Water-Content Measurements

Water-content measurements by weight were obtained by using standard gravimetric, oven-drying methods (Gardner, 1965). Weight measurements were recorded to 0.01 g, and samples were oven-dried for 18 hours at 105 °C in a forced-air drying oven. Sample size was as large as the moisture cans would permit, usually from 100 to 400 g. Measurements were not replicated. The data from these measurements are presented in table 8 and are shown in figure 5. The fractions listed in table 8 consist of sieved (coarse) and unsieved samples that were collected directly from the conveyor belt.

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*

[Analyses made in U.S. Geological Survey laboratory, Nevada Test Site; --, no data]

Depth interval (meters)	Water content (gram per gram)		Water potential (kilopascals)		Time of day sample collected (hours)	Apparent moisture in cuttings when collected
	Sieved coarse fraction	Unsieved fraction	Sieved coarse fraction	Unsieved fraction		
20.73 to 21.33	--	0.089	[1]-1,950	--	1442	--
21.33 to 21.95	--	.121	--	--	1710	--
[2]21.95 to 22.56	--	.147	--	--	1520	Slightly moist
[2]22.56 to 23.16	--	.153	--	--	1625	Dry
[2]23.47 to 23.77	--	.156	--	--	0550	Moist
23.77 to 23.93	--	.122	--	--	2000	Dry
24.38 to 24.69	--	.095	--	--	2010	Moist
24.69 to 24.99	--	.124	--	--	2100	Moist
24.99 to 25.60	--	.089	--	--	2300	Moist
25.60 to 26.21	--	.119	--	--	1120	Moist
27.74 to 28.04	--	.123	--	--	1435	Dry
35.05 to 36.58	--	.176	--	--	0520	Moist
36.58 to 39.62	0.210	.163	--	--	0825	Moist
39.62 to 41.15	.206	.185	--	--	0900	Moist
41.15 to 42.67	.206	.185	--	--	0954	Moist
42.67 to 44.20	.191	.164	--	--	1011	Moist
44.20 to 45.72	.180	.152	--	--	1040	Moist
45.72 to 47.24	.147	.166	-340	-240	1130	Moist
47.24 to 48.77	.166	.156	--	--	1156	Moist
48.77 to 50.29	.193	.171	--	--	1218	--

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram) Sieved coarse fraction	Water content (gram per gram) Unsieved fraction	Water potential (kilopascals) Sieved coarse fraction	Water potential (kilopascals) Unsieved fraction	Time of day sample collected (hours)	Apparent moisture in cuttings when collected
50.29 to 51.82	0.182	0.160	-180	--	1248	--
51.82 to 54.86	.188	.155	--	--	0114	--
54.86 to 56.39	.222	.191	-170	-180	0205	--
56.39 to 57.91	.222	.190	--	--	0248	--
57.91 to 59.44	.213	.176	--	--	0321	--
59.44 to 60.96	.224	.203	--	--	0343	--
60.96 to 62.48	.220	.209	-110	-150	0511	Slightly moist
62.48 to 64.01	.195	.182	--	--	0645	Dry
64.01 to 65.53	.167	.168	--	--	0726	Dry
65.53 to 67.06	.172	.214	--	--	0940	Dry
67.06 to 68.58	.203	.162	--	--	1314	Dry
68.58 to 70.10	.173	.153	--	--	1345	Dry
70.10 to 71.63	.152	.148	--	--	1416	Dry
71.63 to 73.15	.185	.173	--	--	1458	Slightly moist
73.15 to 74.68	.117	.099	-330	-290	1549	Slightly Moist
74.68 to 76.08	.104	.088	--	--	1630	--
[2]76.20 to 76.81	.093	.079	--	-280	0533	--
77.72 to 79.25	.101	.097	--	--	0633	Slightly moist
79.25 to 80.77	.112	.103	--	--	0705	Slightly moist
80.77 to 82.30	.120	.095	--	--	0728	Slightly moist

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram)		Water potential (kilopascals)		Time of day sample collected (hours)	Apparent moisture in cuttings when collected
	Sieved coarse fraction	Unsieved fraction	Sieved coarse fraction	Unsieved fraction		
82.30 to 83.82	0.135	0.120	-190	-230	0750	Slightly moist
83.82 to 85.34	.128	.123	--	--	0820	Slightly moist
85.34 to 86.87	.182	.086	-160	-300	0930	Dry
86.87 to 88.39	.052	.047	-410	-370	1031	--
88.39 to 89.92	.072	.093	-130	-430	1150	--
89.92 to 91.44	.009	.012	-2,100	-11,200	1409	Dry
91.44 to 92.96	.012	.015	--	--	1500	Dry
92.96 to 94.49	.013	.013	-3,800	-6,400	1640	--
94.49 to 95.77	.015	.013	--	--	1733	--
96.62 to 97.54	.022	.024	--	--	1928	--
97.54 to 99.06	.048	.042	-1,000	-4,900	2045	--
99.06 to 100.58	.059	.028	--	--	2149	--
100.58 to 102.11	.030	.041	--	--	2321	--
102.11 to 103.63	.046	.021	--	--	0012	--
104.55 to 105.77	.029	.020	--	--	0154	--
105.77 to 106.68	.050	.019	--	--	0255	--
107.11 to 108.20	.028	.011	-4,200	-24,100	1648	Very dry
108.20 to 109.73	.024	.021	-5,000	-13,800	1806	Very dry
109.73 to 111.25	.028	.026	--	--	1905	Very dry
111.25 to 112.78	.032	.015	--	--	2008	--

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram)		Water potential (kilopascals)		Time of day sample collected (hours)	Apparent moisture in cuttings when collected
	Sieved coarse fraction	Unsieved fraction	Sieved coarse fraction	Unsieved fraction		
112.78 to 114.30	0.023	0.019	--	--	2137	--
114.30 to 115.52	.032	.016	--	--	2257	--
115.52 to 117.35	.021	.021	--	--	0033	--
117.35 to 118.87	.022	.016	--	--	0141	--
118.87 to 120.40	.030	.028	--	--	0227	--
120.40 to 121.82	.029	.021	--	--	0315	--
121.82 to 123.44	.026	.021	-4,000	-5,800	0429	Very dry
123.44 to 124.97	.022	.016	--	--	0608	Very dry
124.97 to 126.49	.022	.018	[3]-4,400	--	0752	Very dry
126.49 to 127.41	.020	.019	--	--	0820	Very dry
127.41 to 129.54	.023	.018	--	--	1047	Very dry
129.54 to 131.06	--	.017	--	--	1122	Very dry
131.06 to 132.59	.033	.031	--	--	1200	Slightly moist
132.59 to 134.11	.038	.040	-2,000	--	1220	Slightly moist
134.11 to 135.15	.042	.042	--	--	1312	Dry
135.15 to 135.64	.038	.036	--	--	--	--
135.64 to 137.16	.036	.039	--	--	1432	Nearly dry
137.16 to 138.68	.033	.025	--	--	1524	Nearly dry
138.68 to 140.21	.028	.024	-3,300	--	1625	Nearly dry
140.21 to 141.73	.034	.027	[3]-1,300	--	1729	Nearly dry

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram) Sieved coarse fraction	Water content (gram per gram) Unsieved fraction	Water potential (kilopascals) Sieved coarse fraction	Water potential (kilopascals) Unsieved fraction	Time of day sample collected (hours)	Apparent moisture in cuttings when collected
141.73 to 143.26	0.043	0.040	--	--	1820	Slightly moist
143.26 to 144.78	.045	.038	-1,400	--	1920	--
144.78 to 146.30	.036	.031	--	--	2036	--
146.30 to 147.83	.038	.034	--	--	2146	--
147.83 to 149.35	.033	.031	--	--	2316	--
149.35 to 150.88	.032	.027	--	--	0154	--
150.88 to 152.40	.030	.030	--	--	0250	--
153.01 to 153.62	.022	.018	--	--	1325	Nearly dry
153.62 to 155.45	.021	.016	-7,600	--	1631	Nearly dry
155.45 to 156.97	.016	.014	-12,100	--	1848	Nearly dry
156.97 to 158.50	.018	.015	--	--	2154	--
158.50 to 160.02	.026	.017	--	--	0024	--
160.63 to 161.54	.034	.035	--	--	0425	Dry
161.54 to 162.76	.032	.032	--	--	0757	Dry
162.76 to 164.59	.043	.041	--	--	0055	Dry
164.59 to 165.81	.040	.042	--	--	0137	Dry
165.81 to 167.64	.055	.056	--	--	0210	Slightly moist
167.64 to 169.16	.054	.057	-1,100	--	0245	Slightly moist
169.16 to 170.69	.050	.056	--	--	0309	Slightly moist
170.69 to 172.21	.055	.054	[3]-1,000	--	0338	Slightly moist

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram)		Water potential (kilopascals)		Time of day sample collected (hours)	Apparent moisture in cuttings when collected
	Sieved coarse fraction	Unsieved fraction	Sieved coarse fraction	Unsieved fraction		
172.21 to 173.74	0.047	0.050	--	--	0407	--
173.74 to 175.26	.053	.055	--	--	0448	--
175.26 to 176.78	.050	.048	--	--	0540	Dry
176.78 to 178.31	.042	.045	-1,500	--	0628	Dry
178.31 to 179.83	.047	.045	--	--	0718	Dry
180.44 to 181.36	.040	.048	--	--	0928	Dry
181.36 to 182.58	.049	.049	--	--	1020	--
182.58 to 184.40	.048	.042	--	--	1210	Dry
184.40 to 185.93	.040	.036	--	--	1446	Dry
186.99 to 187.45	.033	.034	[3]-1,700	--	1529	Dry
187.45 to 188.98	.043	.039	--	--	1535	Dry
188.98 to 190.50	.036	.035	--	--	1655	Dry
190.50 to 192.02	.024	.029	--	--	1820	Dry
192.02 to 193.55	.025	.027	-6,400	--	1931	Dry
193.55 to 195.07	.029	.030	--	--	2119	Dry
195.07 to 196.60	.042	.049	--	--	2149	--
196.60 to 198.12	.036	.038	--	--	0525	Dry
198.12 to 199.64	.034	.044	--	--	0649	Dry
199.64 to 201.17	.030	.029	--	--	0930	Dry
201.17 to 202.39	.043	.026	[3]-4,300	--	1138	Dry

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram)		Water potential (kilopascals)		Time of day sample collected (hours)	Apparent moisture in cuttings when collected
	Sieved coarse fraction	Unsieved fraction	Sieved coarse fraction	Unsieved fraction		
203.30 to 204.22	0.035	0.027	--	--	1903	Slightly moist
204.22 to 205.74	.040	.038	--	--	1953	Slightly moist
205.74 to 207.26	.033	.031	--	--	2116	Slightly moist
207.26 to 208.79	.033	.028	-2,700	--	2334	Slightly moist
208.79 to 210.31	.036	.038	--	--	0100	Slightly moist
210.31 to 211.84	.032	.036	--	--	0255	Slightly moist
211.84 to 213.36	.037	.035	--	--	0523	Slightly moist
213.36 to 214.88	.035	.039	--	--	0714	--
214.88 to 216.41	.027	.025	--	--	0935	Dry
216.41 to 217.93	.023	.022	--	--	1140	Dry
217.93 to 219.46	.032	.060	--	--	1332	Slightly moist
219.46 to 220.98	.025	.019	--	--	1525	Slightly moist
220.98 to 222.50	.020	.014	--	--	1545	Dry
222.50 to 224.03	.017	.042	-7,300	--	1832	Dry
224.03 to 225.55	.032	.033	--	--	0114	Slightly moist
225.55 to 227.08	.030	.031	--	--	0458	Slightly moist
227.08 to 228.60	.026	.022	--	--	0727	Dry
228.60 to 230.12	.035	.015	--	--	1000	Dry
230.12 to 231.65	.024	.022	--	--	1155	Dry
231.65 to 233.17	.028	.023	--	--	1352	Slightly moist

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram)		Water potential (kilopascals)		Time of day sample collected (hours)	Apparent moisture in cuttings when collected
	Sieved coarse fraction	Unsieved fraction	Sieved coarse fraction	Unsieved fraction		
233.17 to 234.70	0.020	0.023	--	--	1522	Dry
234.70 to 236.22	.020	.021	--	--	1658	Dry
236.22 to 237.74	.023	.023	--	--	1900	Dry
237.74 to 239.27	.028	.034	-3,200	--	2044	Slightly moist
239.27 to 240.79	.029	.030	--	--	2202	Slightly moist
240.79 to 242.32	.044	.031	--	--	2312	Slightly moist
242.32 to 243.84	.026	.034	--	--	0440	Dry to slightly moist
243.84 to 245.36	.034	.046	--	--	0604	Dry to slightly moist
245.36 to 246.89	.028	.035	--	--	0815	Dry
246.89 to 248.41	.022	.016	--	--	1030	Dry
248.41 to 249.94	.017	.017	--	--	1223	Dry
249.94 to 251.46	.016	.017	--	--	1435	Dry
251.46 to 252.98	.009	.010	--	--	1828	Dry
252.98 to 254.51	.021	.032	-4,000	--	1940	Slightly moist
254.51 to 256.03	.030	.034	--	--	2033	Slightly moist
256.03 to 257.56	.029	.034	--	--	2156	Slightly moist
257.56 to 259.08	.031	.036	--	--	2311	Slightly moist
259.08 to 260.60	.030	.034	--	--	0038	Slightly moist
260.60 to 261.82	.038	.036	--	--	0136	Slightly moist
261.82 to 263.65	.036	.040	--	--	0304	Slightly moist

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram) Sieved coarse fraction	Water content (gram per gram) Unsieved fraction	Water potential (kilopascals) Sieved coarse fraction	Water potential (kilopascals) Unsieved fraction	Time of day sample collected (hours)	Apparent moisture in cuttings when collected
263.65 to 265.18	0.034	0.036	--	--	0408	Slightly moist
265.18 to 266.70	.033	.036	--	--	0517	Slightly moist
268.22 to 269.75	.028	.028	-1,800	--	1230	Very slightly moist
269.75 to 271.27	.030	.034	--	--	1341	Dry
271.27 to 272.80	.028	.028	--	--	1517	Dry
272.80 to 274.32	.030	.029	--	--	1631	Dry
274.32 to 275.84	.033	.027	--	--	1738	Dry
275.84 to 277.37	.035	.036	--	--	1850	Dry
277.37 to 278.89	.034	.034	--	--	2020	Dry
278.89 to 280.42	.028	.032	--	--	2140	Dry
280.42 to 281.94	.030	.034	--	--	0350	Dry
281.94 to 283.46	.026	.028	--	--	0610	Dry
283.46 to 284.99	.023	.020	-4,000	--	0911	Dry
284.99 to 286.51	.018	.018	--	--	1857	Dry
286.51 to 288.04	.014	.015	--	--	2103	Dry
288.04 to 289.56	.029	.032	--	--	2240	Dry
289.56 to 291.08	.025	.024	--	--	0202	Dry
291.08 to 292.61	.036	.038	--	--	0320	Dry
292.61 to 294.13	.033	.035	--	--	0415	Very dry
294.13 to 295.66	.033	.034	--	--	0519	Very dry

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram)		Water potential (kilopascals)		Time of day sample collected (hours)	Apparent moisture in cuttings when collected
	Sieved coarse fraction	Unsieved fraction	Sieved coarse fraction	Unsieved fraction		
295.66 to 297.18	0.046	0.030	--	--	0648	Very dry
297.18 to 298.70	.018	.015	--	--	0852	Very dry
298.70 to 300.23	.023	.017	[4]-5,600	--	1041	Very dry
300.23 to 301.75	.025	.023	--	--	1238	Dry
301.75 to 303.28	.020	.026	--	--	1421	Dry
303.28 to 304.80	.032	.052	--	--	1450	Dry
[2]304.80 to 306.32	.046	.052	--	--	0551	Very moist, moisture due to coring
[2]306.32 to 307.84	.054	.070	-1,600	--	0642	Very slightly moist, moisture due to coring
307.84 to 309.37	.043	.054	--	--	0840	Slightly moist, moisture due to coring
309.37 to 310.90	.040	.036	--	--	1128	Dry
310.90 to 312.42	.031	.045	--	--	1245	Dry
312.42 to 313.94	.035	.045	--	--	1415	Dry
313.94 to 315.47	.032	.038	[4]-3,000	--	1549	Dry
315.47 to 316.99	.030	.036	--	--	1707	Dry
316.99 to 318.52	.026	.030	--	--	1836	Dry
318.52 to 320.04	.027	.029	--	--	2020	Dry
320.04 to 321.56	.019	.020	--	--	2250	Dry
321.56 to 323.09	.018	.020	--	--	0100	Dry
323.09 to 324.61	.017	.016	-10,300	--	0307	Dry
324.61 to 326.14	.029	.028	--	--	0447	Dry

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram)		Water potential (kilopascals)		Time of day sample collected (hours)	Apparent moisture in cuttings when collected
	Sieved coarse fraction	Unsieved fraction	Sieved coarse fraction	Unsieved fraction		
326.14 to 327.66	0.033	0.029	--	--	0626	Dry
327.66 to 329.18	.030	.028	--	--	0749	Dry
329.18 to 330.10	.029	.029	[4]-4,400	--	0847	Dry
330.10 to 330.71	.015	.013	--	--	1330	--
330.71 to 332.23	.014	.013	--	--	1612	Dry
332.23 to 333.76	.014	.015	--	--	1752	Dry
333.76 to 335.28	.027	.019	--	--	1924	Dry
335.28 to 336.80	.022	.025	--	--	2050	Dry
336.80 to 338.33	.019	.027	--	--	2220	Slightly moist
338.33 to 339.85	.026	.028	--	--	0016	Slightly moist
339.85 to 341.38	.036	.037	--	--	0210	Slightly moist
341.38 to 342.90	.037	.049	-1,800	--	0331	Slightly moist
342.90 to 344.42	.036	.043	--	--	0451	Slightly moist
344.42 to 345.95	.031	.037	-3,300	--	0612	Dry
345.95 to 347.47	.037	.037	--	--	0741	Dry
347.47 to 349.00	.035	.037	--	--	0856	Dry
349.00 to 350.52	.025	.028	--	--	1045	Very dry
350.52 to 352.04	.023	.025	--	--	1227	Very dry
352.04 to 353.57	.021	.017	--	--	1425	Very dry
353.57 to 355.09	.012	.009	-21,800	--	2350	Dry

Table 8.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings*--Continued

Depth interval (meters)	Water content (gram per gram) Sieved coarse fraction	Water content (gram per gram) Unsieved fraction	Water potential (kilopascals) Sieved coarse fraction	Water potential (kilopascals) Unsieved fraction	Time of day sample collected (hours)	Apparent moisture in cuttings when collected
355.09 to 356.62	0.033	0.036	--	--	0607	Very dry
356.62 to 358.14	.035	.037	-2,700	--	0749	Dry
358.14 to 359.36	.034	.035	--	--	0909	Dry
359.36 to 361.19	.023	.026	[4]-7,900	--	1121	Dry
361.19 to 362.71	.019	.014	--	--	1307	Dry
362.71 to 364.24	.019	.020	[5]-14,200	--	1422	Dry
364.24 to 365.76	.025	.023	--	--	1557	Dry
365.76 to 367.28	.019	.022	--	--	1658	Dry
367.28 to 368.81	.021	.019	--	--	1836	Dry
368.81 to 370.33	.012	.011	--	--	1131	Very dry
370.33 to 371.86	.011	.011	--	--	1312	Dry
371.86 to 373.38	.010	.009	--	--	1529	Dry
373.38 to 374.90	.011	.010	--	--	1810	Dry
374.90 to 376.43	.010	.012	-34,600	--	2013	Dry
376.43 to 377.95	.012	.013	--	--	2300	Dry
377.95 to 379.48	.011	.010	--	--	0250	Dry
379.48 to 381.00	.013	.012	--	--	0608	Dry
381.76 to 382.52	.009	.009	-37,400	--	1014	Very dry

[1]Average potential of four measurements.
[2]Cuttings from reamed core interval.
[3]Average potential of five measurements.
[4]Average potential of two measurements.
[5]Average potential of three measurements.

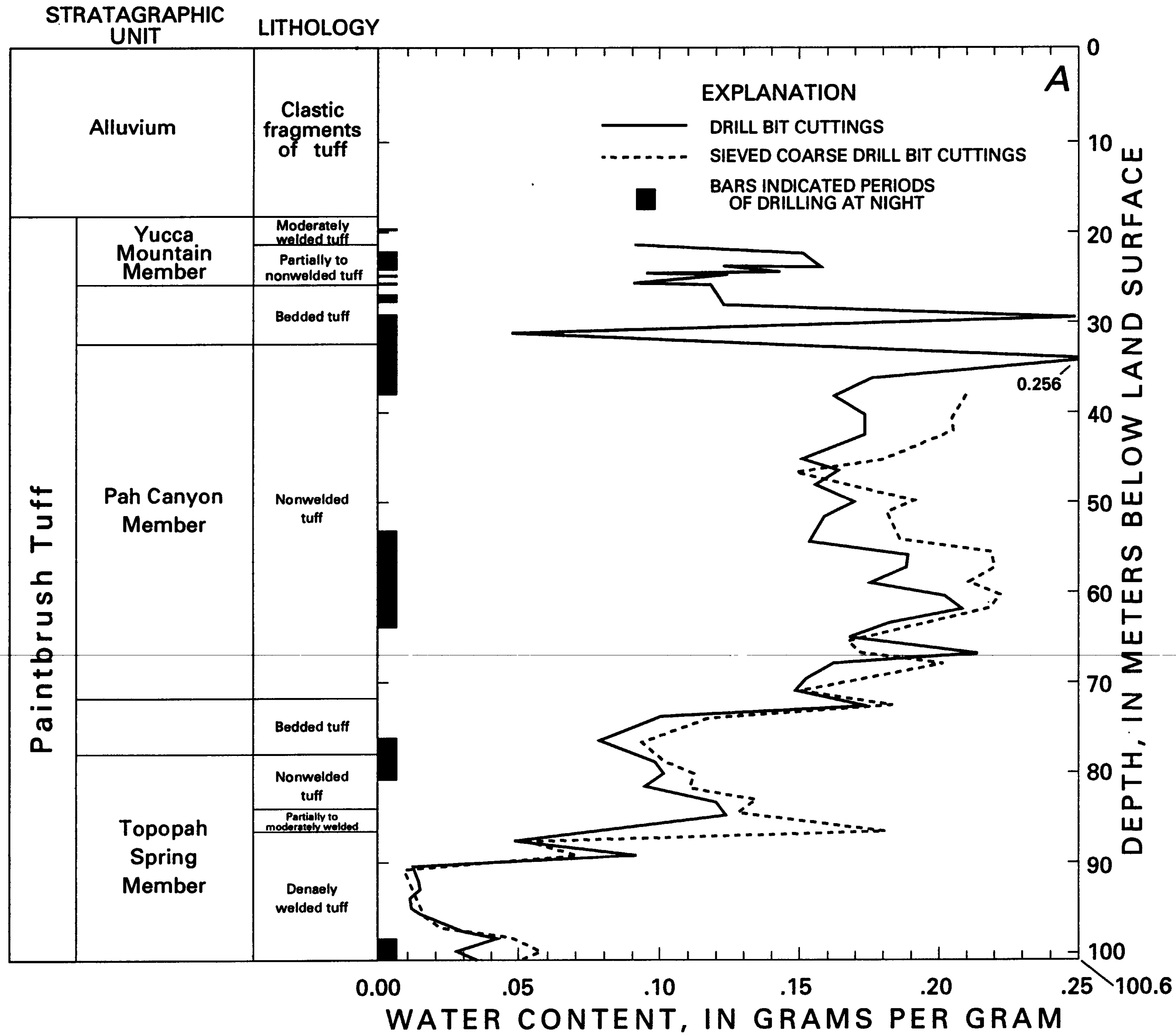

Figure 5.--Water content of drill-bit cuttings from depths of: *A*, 0 to 100.6 meters; *B*, 100.6 to 201.2 meters; *C*, 201.2 to 301.8 meters; and *D*, 301.8 to 382.5 meters.

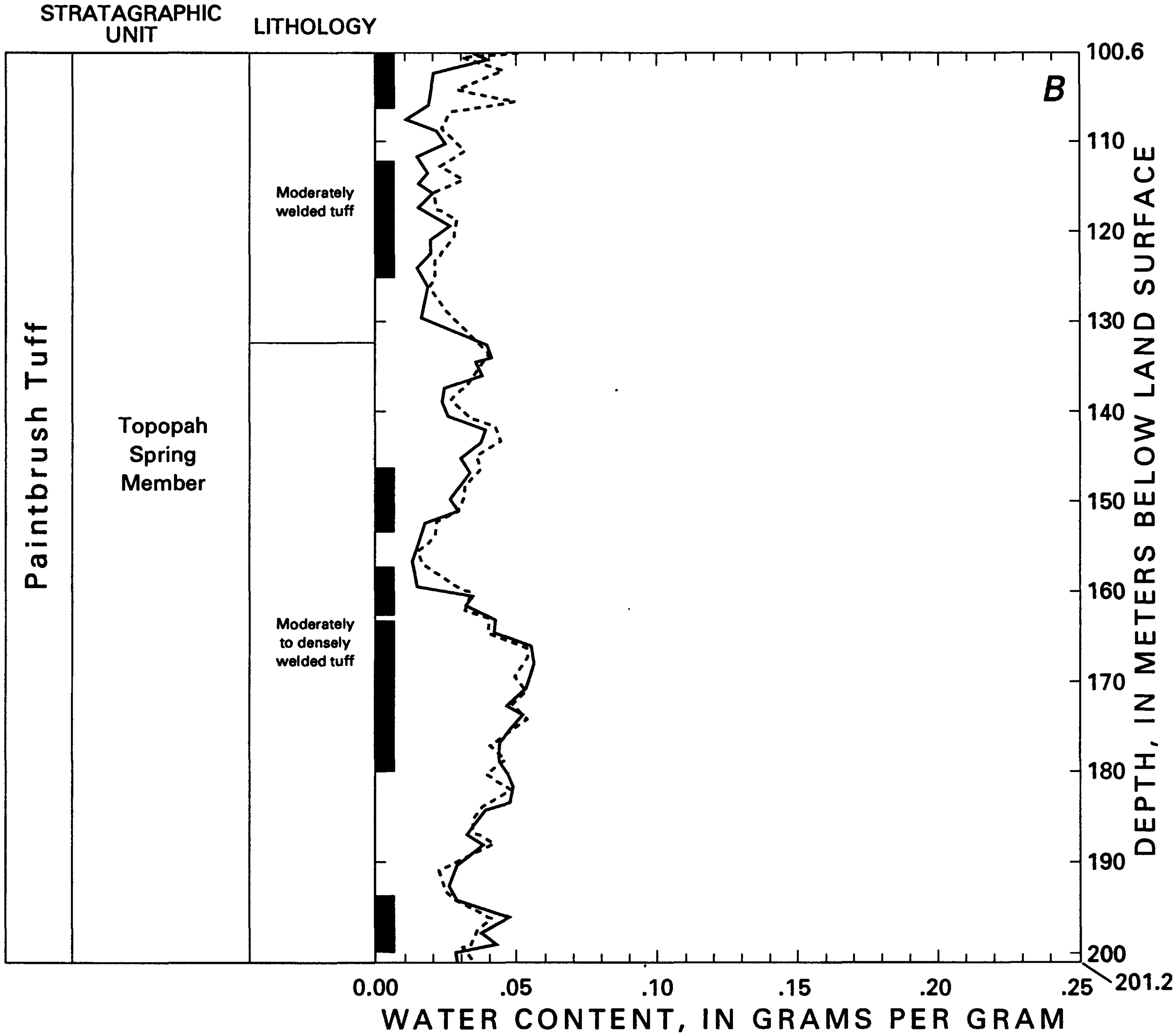

Figure 5.--Water content of drill-bit cuttings from depths of: *A*, 0 to 100.6 meters; *B*, 100.6 to 201.2 meters; *C*, 201.2 to 301.8 meters; and *D*, 301.8 to 382.5 meters--Continued.

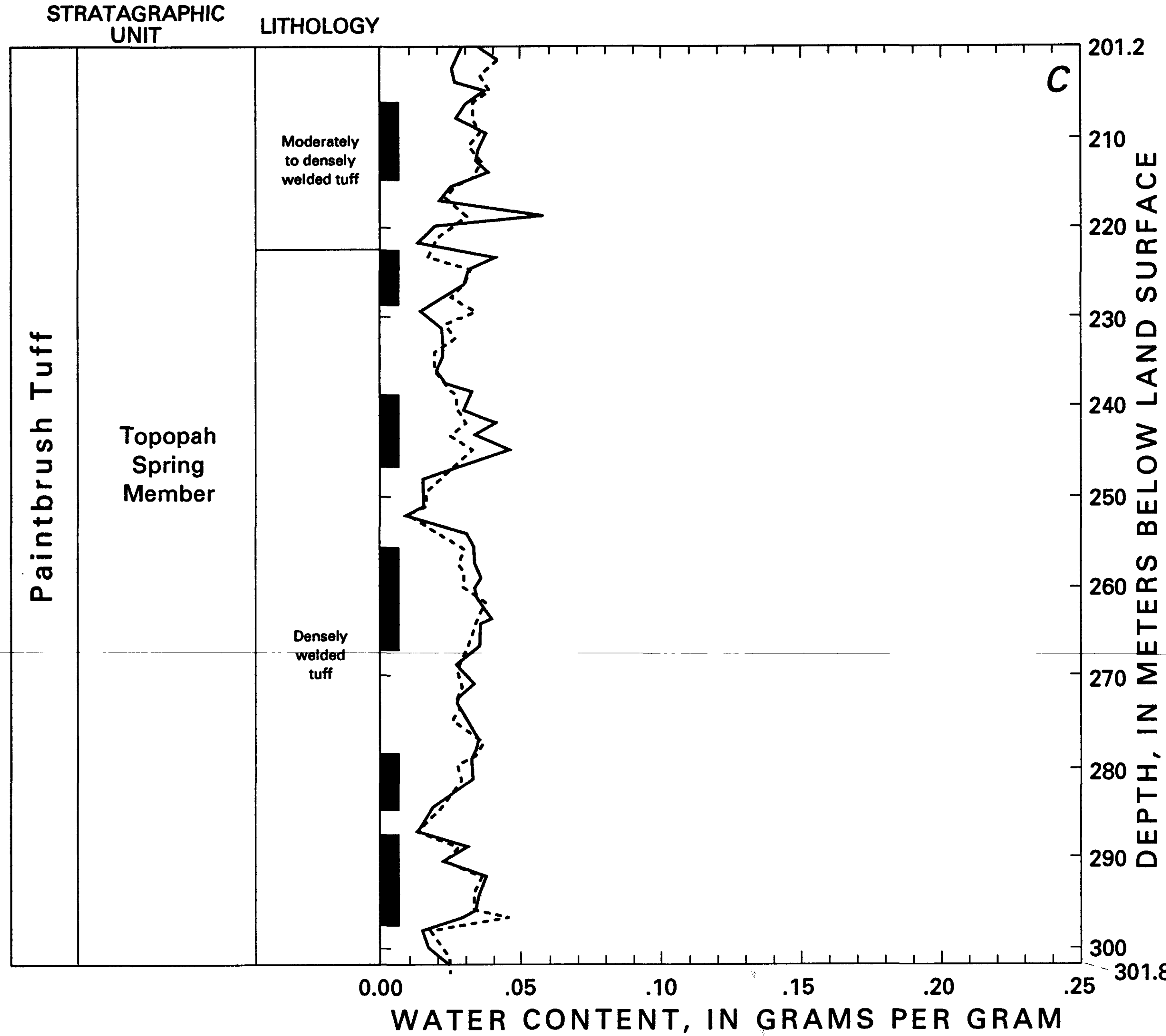

Figure 5.--Water content of drill-bit cuttings from depths of: *A*, 0 to 100.6 meters; *B*, 100.6 to 201.2 meters; *C*, 201.2 to 301.8 meters; and *D*, 301.8 to 382.5 meters--Continued.

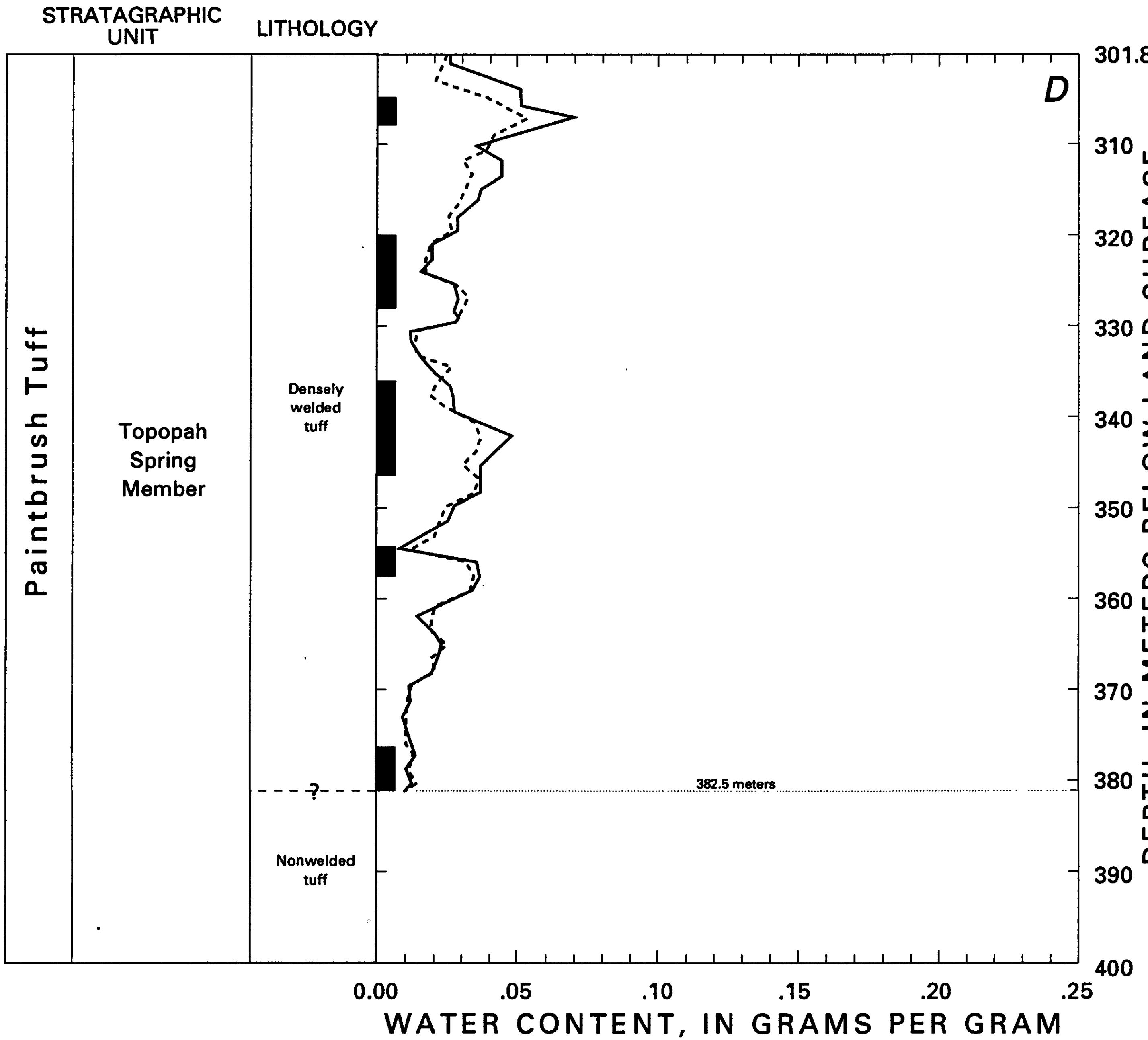

Figure 5.--Water content of drill-bit cuttings from depths of: *A*, 0 to 100.6 meters; *B*, 100.6 to 201.2 meters; *C*, 201.2 to 301.8 meters; and *D*, 301.8 to 382.5 meters--Continued.

Water-Potential Measurements

Water potential is defined here as the sum of matric and osmotic potentials. Water potential was measured in this study using a SC-10 thermocouple psychrometer from Decagon Devices, Pullman, Washington, and a Kiethly model 181 nanovoltmeter. The SC-10 consists of a stationary thermocouple psychrometer and 10 sample chambers that can be rotated to the thermocouple psychrometer. The Richards method (Richards and Ogata, 1958) was used in the measurements described herein to condense water on the thermocouple junction. In these measurements, calibration solutions were measured concurrently with actual rock samples to compensate for the zero drift of the nanovoltmeter amplifier. Generally, four of the chambers contained calibration solutions equivalent to known water potentials; five of the chambers contained samples; and the remaining chamber contained distilled water. Thermocouple output voltage was first measured on the known calibration standards, followed by measurements of output voltage from rock samples, and followed by output measurements of at least two of the calibration standards. If thermocouple output voltages differed because of zero drift between these replicate measurements of calibration standards by more than 0.1 μV, all calibration solutions were measured a second time, and the average was used for the construction of calibration curves. Calibration curves of water potential plotted against output voltage were nearly linear throughout the range of water potentials measured from -50 to -7,000 kPa. Regression coefficients ranged from 0.986 to 1.000; most coefficients were equal to 1.000.

The SC-10 sample chamber was filled with calibration solutions and rock samples in a humidified glove box to minimize evaporation. After filling was completed, at least one-half hour was allowed to elapse before measurements were made so temperature and vapor equilibrium was achieved. To avoid temperature fluctuations, all measurements were made inside the glove box and generally at night when the air-conditioning system in the onsite laboratory trailer was able to keep the temperature relatively constant. All equipment, including the thermocouple junction, was meticulously cleaned after each set of measurements to prevent carry-over of salts or dust to the next set of measurements. Data from the water-potential measurements are presented in table 8.

HYDROLOGIC TESTING AND WATER SAMPLING

Hydrologic testing was completed before a laboratory analysis indicated that this water contained a polymer identical to the one used in the drilling of nearby geologic test hole USW G-1, located about 0.3 km to the southeast. Water levels were measured, bailing was done, and a chemical analysis of the water sample collected was made.

Water-Level Measurements

Water levels were measured periodically in test hole USW UZ-1. Water-level measurements are listed in table 9.

Bailing

Bailing of the test hole was done on July 14 and 15, 1983, in the uncased depth interval from 383 to 386 m. During a 495-minute period, 491.0 L of water were removed by bailing; the bailing rate was 0.0165 L/s.

Physical and Chemical Analyses of Water

On July 6, 1983, water was encountered during the drilling of test hole USW UZ-1 when the borehole had reached a depth of 383 m; the depth of water below the land surface was 381.8 m. The borehole was cleared of cuttings and bailed as dry as possible on July 11, 1983, allowed to recover for 4 hours, and sampled using a bailer. The sample contained large quantities of light-brown suspended sediment. Measurements of specific conductance, pH, and temperature, and bromide concentration were made onsite. Samples for inorganic-constituent determinations were centrifuged for several minutes prior to 0.45-μm filtration to remove excess sediment. Raw samples for organic-constituent determinations were collected in glass bottles with foil-lined caps. Analytical results for the water sample from test hole USW UZ-1 are listed in table 10.

A total-organic-carbon analysis and a methylene-chloride extraction, concentration, and gas chromatographic analysis using a flame-ionization detector were made. Standards were polymer number 4, liquid; Chevron Dura-Lith grease, EP-2 number 3, Jet-Lube; and Z-50, metallic zinc-base tool-joint compound, pipe dope. Several peaks from the chromotogram of the water sample matched with similar peaks of the polymer number 4 standard. These apparent light hydrocarbons, as confirmed by mass spectroscopy, probably are due to the 28 percent light hydrocarbons present in the polymer number 4, also called NALCO Adamite WFR-2. The later eluting peaks and rise in baseline seemed to match the Jet-Lube number 1 standard. These peaks did not match as well as the polymer hydrocarbon peaks; however, the jet lube seemed to be the major contaminant in the samples. The grease and the pipe dope might have been present; however, even a large concentration did not present sufficient data. The analytical data seem to verify a connection between the water sample and the polymer and possibly the jet lube. Larger than normal concentrations of the standards were necessary to obtain chromatographic data.

Table 9.--*Water-level measurements*

[Altitude of the land surface at the test hole is 1,348.48 meters]

Date of measurement	Depth of test hole (meters)	Depth to water below land surface (meters)	Altitude of water level above sea level (meters)	Remarks
07-07-83	383	381.83	966.65	U.S. Geological Survey logging van
07-08-83	383	382.12	966.36	U.S. Geological Survey logging van
07-09-83	383	382.01	966.47	U.S. Geological Survey logging van
07-16-83	386	381.80	966.68	U.S. Geological Survey logging van

Table 10.--*Analytical results for water sample*

[Results in milligrams per liter except where noted; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; pCi/L, piococurie per liter; --, no units]

Date of collection	Specific conductance, onsite (μS/cm)	pH, onsite (standard units)	Temperature onsite (°C)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)
07-11-83	393	8.03	26.3	23	2.4	57	10	139	28	12

Date of collection	Bromide, onsite (Br)	Silica (SiO_2)	Carbon, organic (C)	Carbon-14 (^{14}C) age of water, uncorrected (years)	Carbon ($^{13}C/^{12}C$) ratio --	Deuterium/protium ($^{2}H/^{1}H$) ratio --	Oxygen ($^{18}O/^{16}O$) ratio --	Tritium (^{3}H) (pCi/L)
07-11-83	0.4	33	23.8	3,600	-12.1	-102	-13.00	3.1

SUMMARY

This report presents drill-hole, geologic, and hydrologic data for test hole USW UZ-1, the first of two deep, large-diameter (444 mm), unsaturated-zone test holes that were dry drilled into tuff in or near the southwestern part of the Nevada Test Site by using the vacuum/reverse-air-circulation drilling method. Drilling was through the alluvium and through the Yucca Mountain Member, the Pah Canyon Member, and the bedded tuffs of the Paintbrush Tuff. Drilling was stopped in the Topopah Spring Member of the Paintbrush Tuff. Dry drilling generally was difficult and progressed slowly. This method of drilling, however, enables large-diameter test holes to be drilled without the use of drilling fluids and enables geologic and hydrologic drill-bit cuttings to be collected during drilling.

Use of the vacuum/reverse-air-circulation drilling method to drill large-diameter test holes in the unsaturated zone for the purpose of installing hydrologic instruments has the following advantages: (1) Continuous, representative drill-bit cuttings can be obtained; (2) excessive drying is not a factor, because only a minimal quantity of air flows in the well bore; (3) contamination of drill-bit cuttings does not occur, because no drilling fluids are used; (4) most of the drill cuttings and small rock fragments are vacuumed from the borehole which reduces the potential for plugging of fractures and provides a cleaner borehole for air or water injection tests; (5) detection of perched-water or moist zones occurs as soon as the zone is penetrated; and (6) atmospheric contamination can be detected after completion of the test hole by sampling for tracer gas.

Disadvantages of using this method of drilling are that: (1) More extensive equipment and a larger drilling site are needed than for conventional methods; (2) unstable hole conditions are produced by vacuuming, resulting in frequent caving and redrilling; (3) the method is unsuitable for collection of representative hydrologic cores; and (4) in most zones, plugging of the drill bit by mud encrustation of the inner string and kelly hose restricts movement of drill-bit cuttings to the land surface.

Data are presented for bit and casing configurations, coring methods, sample collection, drilling rate, borehole deviation, and out-of-gage borehole. Geologic data for this borehole include geophysical logs, a lithologic log of drill-bit cuttings, and strike and distribution of fractures. Hydrologic data include water-content and water-potential measurements of drill-bit cuttings, water-level measurements, and physical and chemical analyses of water. Laboratory measurements of moisture content and matric properties from the larger drill-bit cutting fragments were considered to be representative of in-situ conditions.

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