

Geohydrologic Data from Test Hole USW UZ-6s, Yucca Mountain, Nye County, Nevada

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CONVERSION FACTORS

Multiplied	By	To obtain
gram per cubic centimeter	0.03613	pound per cubic inch
kilometer (km)	0.6214	mile
kilopascal (Kpa)	0.1450	pounds per square inch
kilopascal (Kpa)	0.01	bar (14.5 pounds per square inch)
liter (L)	1.057	quart
meter (m)	3.281	foot
meter per hour (m/hr)	3.281	feet per hour
milliliter (mL)	0.06102	cubic inch
millimeter (mm)	0.03937	inch

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

$$^{\circ}\text{F} = 9/5(^{\circ}\text{C})+32.$$

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

$$^{\circ}\text{C} = 5/9(^{\circ}\text{F}-32).$$

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

gram per gram (g/g)

microvolt (μv)

molality (*m*)

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Abstract

As part of the investigation of Yucca Mountain, Nevada, as a potential site for storing high-level radioactive wastes in an underground mined geologic repository, the U.S. Geological Survey, in cooperation with the U.S. Department of Energy, in 1982, began drilling a series of test holes in and near the southwestern part of the Nevada Test Site to determine the geologic and hydrologic characteristics of the area. Test hole USW UZ-6s is part of that series of test holes, and this report presents data obtained from test hole USW UZ-6s. The data include those from drilling operations, lithology, coring, and laboratory analyses of hydrologic properties, which include gravimetric water content, water potential, and bulk- and grain-density values.

The gravimetric water content of the densely welded section of the Tiva Canyon Member of the Paintbrush Tuff averages 0.027 gram per gram for test hole USW UZ-6s; water potential averages -7,200 kilo-pascals; gravimetric water content of the moderately to densely welded tuffs range from 0.054 gram per gram for the Tiva Canyon Member of the Paintbrush Tuff to 0.027 gram per gram for the Topopah Spring Member of the Paintbrush Tuff; and water potentials range from -6,700 to -3,400 kilopascals. Gravimetric water content for the partially welded to unnamed bedded tuffs average 0.123, 0.106, and 0.085 gram per gram for the Tiva Canyon Member, the unnamed bedded tuffs, and the Topopah Spring Member in test hole USW UZ-6s; average water potentials for these units are -1,700, -480, and -820 kilopascals.

INTRODUCTION

Yucca Mountain in southwestern Nevada (fig. 1) is being studied as a potential site for storing high-level radioactive wastes in an underground mined geologic repository. In 1982, the U.S. Geological Survey, in

cooperation with the U.S. Department of Energy under interagency agreement DE-AI08-78ET44802, began a series of investigations to provide information about the geology and hydrology of the area. These investigations are a part of the Yucca Mountain Project (YMP), formerly known as Nevada Nuclear Waste Storage Investigations, (NNWSI).

The principal method of investigation has been test drilling. A series of relatively shallow (160 m or less) and deep (160 to 770 m) unsaturated-zone test holes have been (or are projected to be) drilled at Yucca Mountain in rocks of volcanic and volcanic-clastic origin. The main objectives of this unsaturated-zone test-hole program are: (1) To determine the flux of water moving through the units of the nonwelded and bedded tuff in the unsaturated rock; (2) to determine the vertical distribution of water content, water potential, and other geohydrologic characteristics in the rock units penetrated; and (3) to monitor changes in test-hole characteristics with time.

Test hole USW UZ-6s (hereinafter referred to as UZ-6s) is the sixth test hole in the series of unsaturated-zone test holes. Test hole UZ-6s was primarily drilled to provide an uncased zone for instrumentation because the upper 80.8 m of a nearby deeper test hole (USW UZ-6) had to be cased off during drilling. This zone was in the highly fractured, densely welded Tiva Canyon Member of the Paintbrush Tuff (Whitfield and others, 1992).

Purpose and Scope

This report presents geologic and hydrologic data collected from UZ-6s in 1985 during the drilling and coring of this test hole. These data were used to partially fulfill the second objective of the shallow, unsaturated-zone test-hole program. The report also presents data for methods for drilling, coring, sample collection and handling, and testing. The laboratory results of tests on the drill cuttings and cores obtained are included. Work done in UZ-6s was in accordance with procedures established by the YMP Quality Assurance Program.

Location and Geohydrologic Setting

Test hole UZ-6s is located in Nye County, Nevada, approximately 145 km northwest of Las Vegas near the Nevada Test Site. Coordinates of the well site are based on the Nevada State Coordinate System, Nevada Central Zone. The coordinates of UZ-6s are N 231,609.1 and E 170,085.5 m. Test hole UZ-6s is located on the crest of Yucca Mountain at an altitude of 1,508.52 m, approximately 95 m west of test hole USW-UZ-6. Drilling and coring of UZ-6s started on April 23, 1985, and was completed June 19, 1985. Work was suspended from June 21 to August 26, 1985. From August 30, 1985, to September 6, 1985, the test hole was cleaned out and the casing removed.

Test hole UZ-6s is drilled into the Paintbrush Tuff of Miocene age to a depth of 158.2 m. The members of the Paintbrush Tuff penetrated, in descending order, are the Tiva Canyon Member, an unnamed bedded tuff, and the Topopah Spring Member.

DRILLING AND CASING METHODS

Drilling, coring, and casing methods used in UZ-6s are described in detail by Hammermeister and others (1985); therefore, these methods are only briefly described in this report. These authors also have reported that these methods minimally disturb the water content of the formation rock, core, and, in some places, drill cuttings.

Drilling and casing of UZ-6s was conducted using the Odex 165 drilling system, which uses air as the drilling fluid. The method involves percussion-hammer drilling and casing driving that are conducted simultaneously downhole. A pilot bit and an eccentric reamer are used to drill a hole slightly larger than the outside diameter (O.D.) of the casing. The percussion hammer impacts on the casing through a casing shoe attached to the bottom joint of the casing (fig. 2). Thus, the casing is advanced as the hole is drilled deeper. Drill cuttings are returned to the surface through the inside of the casing, thereby minimizing disturbance to the test-hole walls. Compressed air is injected into the casing through the drill pipe to aid in removal of drill cuttings.

A sulfur hexafluoride tracer (SF_6) was injected into test hole UZ-6s during drilling and coring from the surface to a depth of 88.4 m, and bromochlorofluoromethane (CBrClF_2) was injected from 88.4 m to the total depth of the borehole at 158.2 m. Subsequent gas sampling in the borehole will determine the presence or absence of atmospheric contamination caused by the drilling and coring.

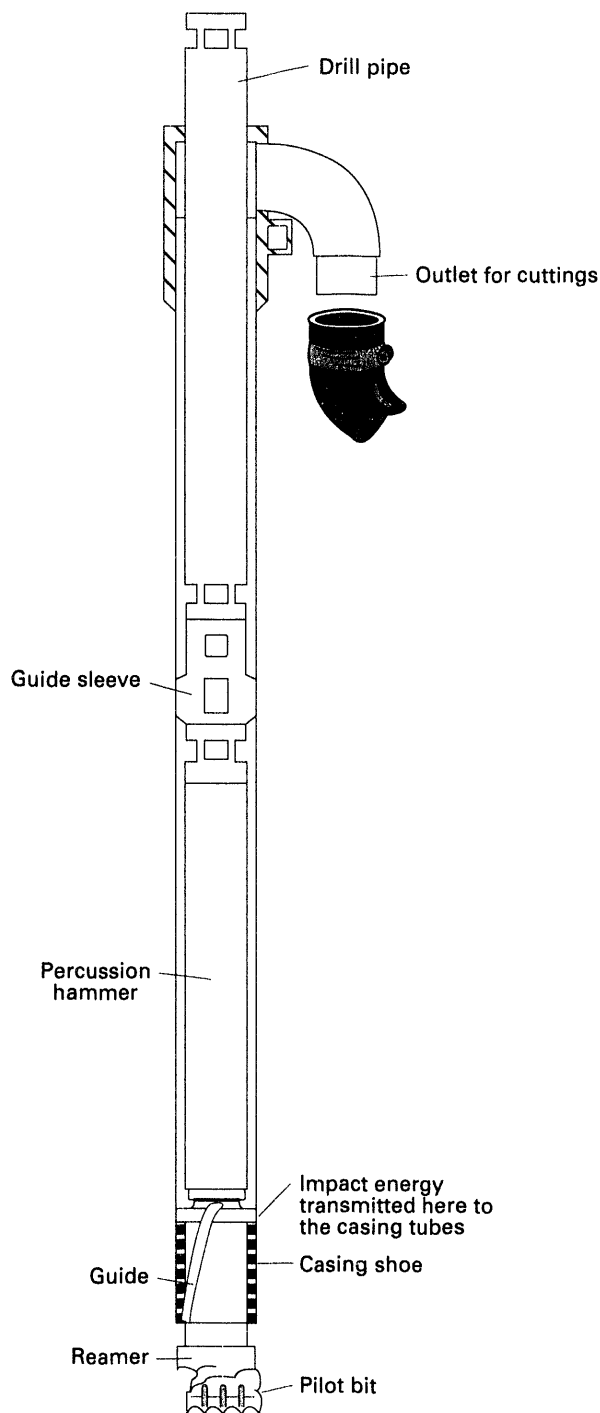


Figure 2. Drilling system used for test hole USW UZ-6s (from Hammermeister and others, 1985, p. 512).

The casing for UZ-6s had a 194-mm O.D. and a 177-mm inside diameter (I.D.). Each casing section was 6.1-m long. The drill hole was 212 mm in diameter. Test hole UZ-6s was drilled, cored, and cased to a depth of 120.7 m when the pilot bit almost separated from the casing shoe. Because the contact with the lower vitrophyre zone of the Tiva Canyon Member had been penetrated, coring continued to a total depth of 158.2 m. Test hole UZ-6s then was continuously reamed and cased to a depth of 150.6 m when the pilot bit completely separated from the casing shoe. The bit was recovered; reaming and casing ceased at this depth. As the casing was being pulled out, it separated at a depth of 79.2 m. Only the upper section was removed at this time. Between August 30, 1985, and September 6, 1985, the upper section of the casing was reinserted, and the hole was cleaned out. The lower section of the casing was then hooked, and the upper and the lower sections of casing were removed.

CORING METHODS

A wireline, split-tube core barrel was used to obtain rotary cores from the hard, densely welded tuffs.

The core barrel had a 61-mm I.D. and was 1.52 m in length, modified by Norton Christensen, Inc., for air coring. Surface-set diamond bits were used to core the densely welded tuffs and tungsten-carbide, face-discharge bits were used to core nonwelded and bedded tuffs that were relatively soft and poorly sorted. These bits were a pilot-type that had staggered teeth. A total of 46.10 m was cored from UZ-6s with 84-percent recovery.

The drill rate for rotary coring in the different rock units penetrated by UZ-6s is shown in figure 3. The densely welded tuffs penetrated by UZ-6s generally were cored at a rate of about 0.25 to about 0.50 m/hr. The coring rates in the nonwelded and bedded units generally ranged from about 1 to 10 m/hr.

GEOLOGY AND LITHOLOGY

The rocks penetrated by UZ-6s are of volcanic and volcanic-clastic origin. No alluvial-colluvial material was encountered in this test hole. A summary of the stratigraphic units penetrated is provided in table 1. Ash-flow and ash-fall tuffs, which comprise the Tiva Canyon Member, the unnamed bedded tuffs, and the

Table 1. Stratigraphic units penetrated by test hole USW UZ-6s

[Michael Chornack, U.S. Geological Survey, written commun., 1985]

Geologic formation	Thickness of intervals (meters)	Depth to bottom of interval (meters)
Paintbrush Tuff (Miocene age)		
Tiva Canyon Member (upper unit)	116.4	¹ 116.4
Tiva Canyon Member (lower vitrophyre)	7.9	¹ 124.3
Tiva Canyon Member (shardy base)	6.9	131.2
Unnamed bedded tuff	9.0	140.2
Topopah Spring Member (vitric unit)	7.1	¹ 147.3
Topopah Spring Member (caprock)	10.9	158.2

¹Estimated contact

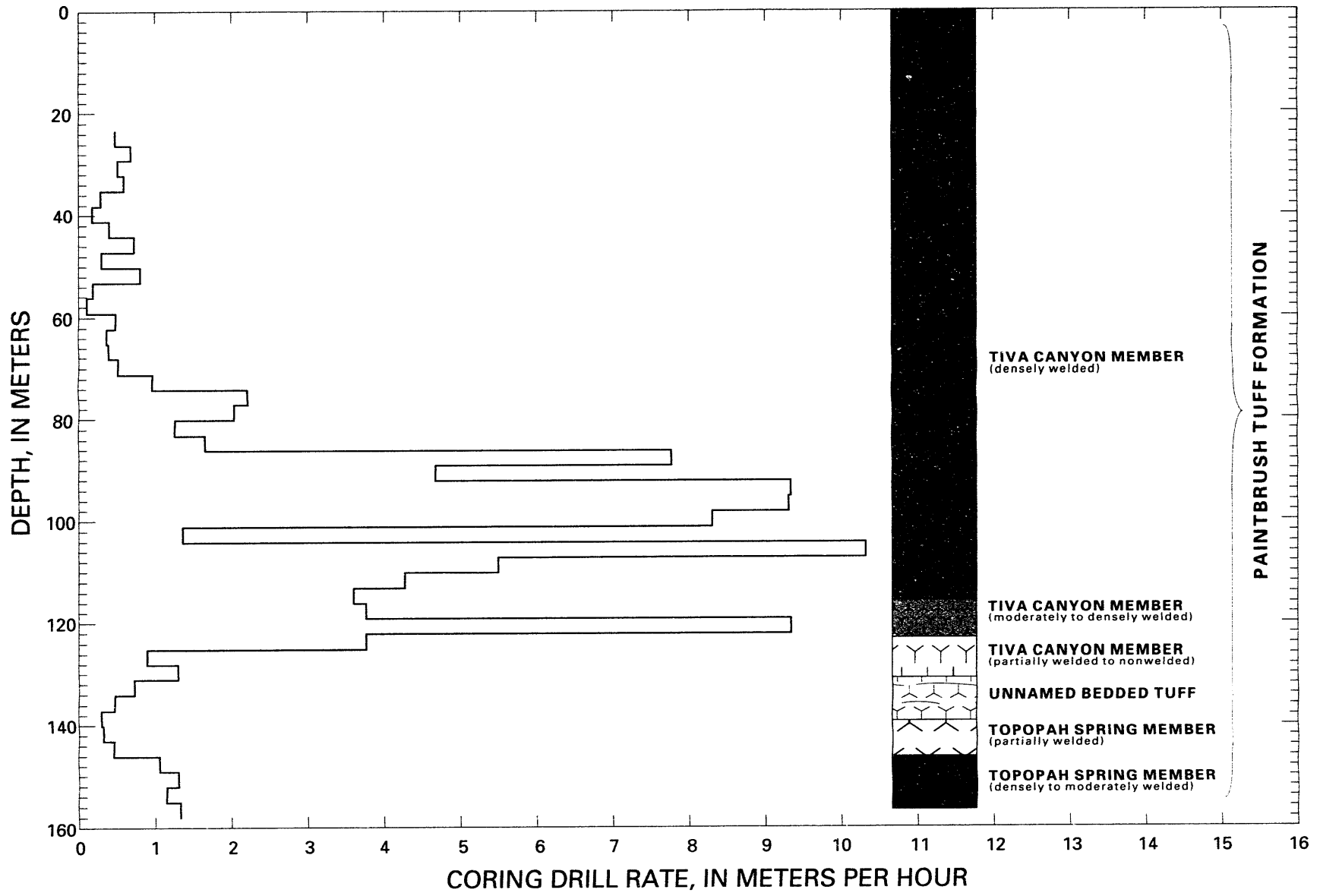


Figure 3. Rotary coring drill rate and degree of welding at test hole USW UZ-6s.

Topopah Spring Member of the Paintbrush Tuff Formation of Miocene age, are the predominant rock types in this section. The tuffs exhibit various degrees of welding, ranging from nonwelded to densely welded. The upper unit of the Tiva Canyon Member of the Paintbrush Tuff consists of a devitrified tuff that is densely welded and underlain by a lower vitrophyre zone that is moderately to densely welded, which grades into a shaly base that is partially welded to nonwelded. The portion of the Topopah Spring Member of the Paintbrush Tuff penetrated in UZ-6s consists of a thin, partially welded upper vitric unit, which is underlain by a caprock that is moderately to densely welded.

SAMPLE COLLECTION AND HANDLING

Sample collection and handling followed approved YMP quality-assurance procedures. All procedures were designed to minimize the disturbance of the water content of the samples from the time the samples were removed from the test hole until gravimetric water-content and water-potential measurements were made.

Drill Cuttings

Drill cuttings were collected for the determination of a lithologic record as well as hydrologic properties. Cuttings returned to the surface through the casing during drilling were diverted through a flexible hose to a dry cyclone separator located nearby. After a prescribed interval of the test hole had been drilled, the gate valve on the bottom of the separator was opened, and the cuttings fell into the collection containers. The cyclone separator was emptied at each collection interval to avoid any mixing of samples. If the cuttings were moist, a hammer was used to loosen the cuttings off the inside walls of the separator. Drilling generally did not stop during sample collection.

A 0.5-L sample of cuttings was collected for lithologic description at the same time that 1 or 2 L of cuttings were collected at each sampling interval for laboratory measurements of water content and water potential. If the cuttings consisted mainly of fine-grained material, 2 L were collected. The cuttings were placed in 1-L glass mason jars. These jars were capped immediately with air-tight lids, taken into the onsite laboratory as soon as possible, and placed inside a humidified glove box.

Drill cuttings from UZ-6s were collected at 0.6-m intervals from a depth of 2.1 to 150.3 m. The drill cuttings were processed inside the humidified

glove box. Coarse-particle-size fraction of drill cuttings from UZ-6s were used for water-content and water-potential measurements. If an insufficient volume of coarse cuttings was collected for water-content measurements and for water-potential measurements, fine- or composite-particle-size cuttings were used for the water-content measurements. Coarse samples were defined as those cuttings that would not pass through a screen that had about 1.6-mm openings, whereas fine samples were defined as those cuttings that would pass through this size opening. Samples taken directly from the jars were designated as composite samples. Coarse cuttings were always collected for water-potential measurements because only a small sample was necessary for testing. Samples for gravimetric water content were placed in preweighed 420-mL moisture cans and immediately weighed. Samples for water-potential measurements were placed in small glass jars (approximately 120 mL or less), capped, taped, labeled, sealed in wax, and stored at room temperature (about 20 to 25°C) until the measurements could be made.

Rotary Core

Test hole UZ-6s was continuously cored from 120.7 to 158.2 m before the hole was reamed and the casing set at a depth of 150.6 m. A 0.61-m core generally was collected from every 6.1-m interval drilled in the moderately to densely welded tuffs in UZ-6s, beginning at a depth of 23.16 to 120.70 m. After obtaining the 0.61-m core, the hole was reamed and the 6.1-m-long casing inserted. In highly fractured zones of the densely welded tuff, shorter cores or no cores were occasionally collected due to poor recovery.

Cores from the partially welded, nonwelded, and bedded tuff units beginning at 120.70 to 158.19 m were obtained using a 1.52-m-long HWD4 core barrel with a split inner tube. The top one-half of the split inner tube was removed in the humidified glove box. The natural fractures of the core were described, and a preliminary lithologic description was made. For each 1.52-m-long core, a 91-mm-long segment of core from near the bottom and another from near the midsection of the core generally were removed for gravimetric water-content and water-potential measurements. If the core was highly fragmented, more samples were obtained for gravimetric water-content and water-potential measurements that did not require solid pieces of core; solid pieces of core were required, however, for other hydrologic testing. Whenever possible, one 1.52-m-long core segment that was relatively unfragmented was taken from each one-half of the core for matric-potential measurements, and one additional

91-mm-long core segment that was relatively unfragmented was taken for permeability-related tests. Finally, a 91-mm-long section of core was selected from most core runs for the extraction and geochemical analysis of pore water (Mower and others, 1990). All core segments, except for those used for gravimetric water-content and water-potential measurements, were placed in split polyvinyl (PVC) liners, capped, taped, labeled, waxed, and stored at about 20 to 25°C for future hydrologic testing.

Core that was designated for gravimetric water-content measurements was put in a preweighed moisture can. Core to be used for water-potential measurements was broken into small fragments inside a humidified glove box, placed in a 120-mL, or smaller, container, capped, taped, labeled, and waxed for later measurements. All cored intervals and recovered cores for UZ-6s are listed in table 2.

SAMPLE TESTING PROCEDURES AND RESULTS

Gravimetric Water-Content Measurements

Gravimetric water-content measurements were done onsite at the U.S. Geological Survey field laboratory, using standard gravimetric oven-drying methods (Gardner, 1965) following approved YMP quality-assurance procedures. Moisture cans of known weight were filled with drill cuttings or core and immediately weighed. These moisture cans were weighed again after baking in an oven at 105°C for a minimum of 18 hours. Gravimetric water content, in gram per gram, equals the water lost through drying, divided by the weight of the dried sample. Results of laboratory analyses for gravimetric water content for UZ-6s cuttings and core are listed in tables 3 and 4. The depths of cuttings listed in table 3 represent the midpoints, or average depths, of the sample-collection intervals of the drill cuttings. Gravimetric water-content measurements of composite core samples and coarse-size fractions of drill cuttings for UZ-6s are shown in figure 4.

The gravimetric water content of the volcanic tuffs are related to the degree of welding. A summary of gravimetric water-content measurements of composite core samples related to geologic formation and degree of welding is listed in table 5. Only the core data for UZ-6s are tabulated because the cores are less disturbed than the drill cuttings and, therefore, are assumed to be more representative of in-situ hydrologic conditions. The densely welded part of the Tiva Canyon Member of the Paintbrush Tuff averaged

0.027 g/g for gravimetric water content, and the moderately to densely welded part averaged 0.054 g/g.

The partially to nonwelded part of the Tiva Canyon Member of the Paintbrush Tuff averaged 0.123 g/g. The unnamed bedded tuff unit had an average gravimetric water content of 0.106 g/g. The Topopah Spring Member of the Paintbrush Tuff is the deepest tuff unit penetrated; the gravimetric water content of the partially welded vitric subunit of this unit averaged 0.085 g/g, then decreased to an average of 0.027 g/g in the densely to moderately welded caprock.

Test hole UZ-6s was continuously cored from the interval of 120.7 to 158.2 m before the hole was reamed. The gravimetric water content of cuttings from this interval averaged 0.058 g/g, which is lower than the gravimetric water content of core, which averaged 0.087 g/g.

After determination of the gravimetric water content, the dried core samples were placed in paper cartons and labeled. These samples were later tested by Holmes & Narver Materials Testing Laboratory, Inc., at Mercury, Nev., for measurements of bulk density and grain density.

Water-Potential Measurements

Water potential is defined as the sum of matric and osmotic potentials. Water potentials were measured using a Richards' SC-10 thermocouple psychrometer and an NT-3 nanovoltmeter. The SC-10 psychrometer is a stationary device that has ten rotating chambers into which sample cups are placed. The Richards' method (Richards and Ogata, 1958) is based on dipping a ceramic bead attached at the thermocouple junction into distilled water, then letting it reach vapor equilibrium while positioned over a sample. The ceramic bead is located inside the SC-10 psychrometer. The rate of evaporation of distilled water on the ceramic bead is measured as voltage-output readings, generally for 10 minutes, on the nanovoltmeter while vapor equilibrium occurs. Drier samples of more than approximately -25 bars generally reach equilibrium in less than 10 minutes; moister samples of approximately -25 bars or less generally require 10 minutes. Voltage outputs are recorded at 1-minute intervals.

Two SC-10 psychrometers were used for measuring water potentials of rock samples. Sample cups were placed in the ten rotating chambers of the SC-10 psychrometer. Three of the ten sample cups (cups 1 through 3) were lined with filter paper and wetted with three of six calibration standards of known molality; six of the sample cups (cups 4 through 9) were filled with cuttings or core samples; the last sample cup

Table 2. Rotary-core record for test hole USW UZ-6s

[A, gravimetric water-content, water-potential, bulk-density, and grain-density measurements; B, matric-potential measurements; C, D, E, permeability-related and miscellaneous measurements; --, no data. The core intervals and lengths were measured to the nearest 0.1 foot, or approximately plus or minus 0.015 meter; core intervals are listed to plus or minus 0.005 meter for convenience and as a result of conversion from inch-pound units.]

Core run number ¹	Cored interval (meters)	Cored length (meters)	Core recovered (meters)	Laboratory tests
1	23.16-23.77	0.61	0.49	ADE
2	29.26-29.87	0.61	0.61	ACE
3	35.36-35.96	0.60	0.61	ACDE
4	41.45-42.06	0.61	0.61	ADE
5	47.55-48.16	0.61	0.61	ACDE
6	53.64-53.95	0.31	0.30	ACDE
7	59.74-60.35	0.61	0.61	ADE
8	65.83-66.44	0.61	0.61	ABCDE
9	78.02-78.63	0.61	0.61	ACDE
10	84.12-84.73	0.61	0.61	ACDE
11	90.22-90.52	0.30	0.27	ACD
12	90.52-90.58	0.06	0.00	--
13	96.31-96.92	0.61	0.58	ACDE
14	102.41-103.02	0.61	0.55	ACDE
15	108.50-109.11	0.61	0.43	ADE
16	114.60-115.21	0.61	0.53	ADE
17	120.69-122.22	1.53	1.52	ABCDE
18	122.22-123.74	1.52	1.52	ABCDE
19	123.74-125.27	1.53	1.52	ABCDE
20	125.27-126.79	1.52	1.52	ABCDE
21	126.79-128.31	1.52	1.52	ABCDE
22	128.31-129.84	1.53	1.22	AE
23	129.84-130.75	0.91	0.61	ABCD
24	130.75-131.97	1.22	1.52	ABCDE
25	131.97-133.50	1.53	1.22	ABCDE
26	133.50-134.72	1.22	1.52	ABCDE
27	134.72-136.24	1.52	0.76	ABDE
28	136.24-137.76	1.52	0.55	ABDE
29	137.76-139.29	1.53	1.28	ACDE
30	139.29-140.81	1.52	1.07	ABCDE
31	140.81-142.03	1.22	0.98	ABDE
32	142.03-143.55	1.52	0.64	ABCDE
33	143.55-144.77	1.22	0.46	ADE
34	144.77-146.30	1.53	0.00	--
35	146.30-146.60	0.30	0.06	A
36	146.60-147.21	0.61	0.61	ABDE
37	147.21-148.43	1.22	1.04	ABCDE
38	148.43-149.19	0.76	0.64	ABDE
39	149.19-149.50	0.31	0.35	ADE
40	149.50-150.87	1.37	1.37	ABCDE
41	150.87-152.39	1.52	1.52	ABCDE

Table 2. Rotary-core record for test hole USW UZ-6a--Continued

Core run number ¹	Cored interval (meters)	Cored length (meters)	Core recovered (meters)	Laboratory tests
42	152.39-153.92	1.53	1.07	A B C D E
43	153.92-155.14	1.22	1.52	A B C D E
44	155.14-156.66	1.52	1.52	A B C D E
45	156.66-158.18	1.52	1.52	A B C D E

¹Core runs 1-16 were drilled in the upper unit of the Tiva Canyon Member, a densely welded unit; cores were selectively collected from this unit.

(cup 10) was filled with distilled water. The calibration standards were measured concurrently with the cuttings or core samples to compensate for the zero drift of the nanovoltmeter amplifier due to change in temperature. The calibration standards used, and their approximate kilopascal equivalents, were: 0.02 *m* (molality), -100 Kpa; 0.05 *m*, -230 Kpa; 0.1 *m*, -460 kPa; 0.4 *m*, -1,800 kPa; 0.8 *m*, -3,700 kPa; and 1.5 *m*, -7,200 kPa.

The same calibration standards were not used for all cuttings and core samples. As much as possible, samples that had similar water contents, based on gravimetric water-content measurements, were processed together. Three calibration standards then were selected within a range that spanned the expected possible water-potential range of the six cuttings or core samples in the SC-10 psychrometer.

The SC-10 psychrometer sample cups are loaded with calibration standards and rock samples in a humidified glove box to minimize evaporation. The ten sample cups then are placed into the ten sample chambers of the SC-10 psychrometer. Samples in the SC-10 psychrometer are allowed to equilibrate for a minimum of 30 minutes before any measurements are made. All measurements were made inside the humidified glove box, at a relatively constant room temperature, generally at 20 to 25°C.

The procedure for taking water-potential measurements begins by first taking a temperature reading from the nanovoltmeter of the calibration standard in the first chamber (cup 1). The NT-3 nanovoltmeter, by Decagon Devices, is designed to measure both resistance and temperature. The sample cups in the chambers are rotated, and the ceramic bead of the thermocouple is wetted in the distilled water (cup 10). The samples are rotated back until the thermocouple is located again over the first chamber (cup 1). As long as

10 minutes are allowed for vapor equilibrium to occur; voltage outputs are recorded at 1-minute intervals. Another temperature reading is then taken. The calibration chambers are rotated, and the ceramic bead is wetted again in the distilled water (cup 10). The calibration chambers are then rotated until the thermocouple is located over the second chamber (cup 2). Voltage-output readings are again taken at 1-minute intervals for as long as 10 minutes. This continues until voltage-output readings have been recorded for all the calibration standards and the rock samples (cups 1 through 9).

At the end of 10 minutes of recording the voltage outputs, an averaged representative voltage-output reading is selected based on the evidence of a plateau. This plateau in voltage-output readings occurs when the system is in equilibrium, and little change is evident in the voltage-output readings. Once sufficient evaporation has occurred, the meniscus of the water on the ceramic bead loses its cohesiveness, evaporation proceeds more quickly, and the voltage-output readings begin dropping off rapidly. For moister samples of more than -2,000 kPa, the plateaus tend to be more evident during the last 5 minutes of the voltage-output readings and tend to last longer; for very moist samples of more than -400 kPa, the plateau drop-off may not be noted in the 10 minutes of voltage-output readings. For drier samples of less than -5,000 kPa, the plateaus tend to occur during the first 5 minutes of voltage-output readings and may only last for a couple of minutes before the readings begin dropping off rapidly. Very dry samples with readings of less than -10,000 kPa generally level off sufficiently fast that the voltage-output reading recorded at 1 minute is considered to be the plateau.

Table 3. Results of laboratory analyses for gravimetric water content and water potential of coarse drill cuttings from test hole USW UZ-6s

[--, no data]

Depth of midpoint of sample (meters)	Gravimetric water content (gram per gram)	Water potential (kilopascals)
2.1	0.026	-790
2.7	0.028	-630
3.4	--	--
4.0	0.021	-670
4.6	0.004	-25,000
5.2	0.012	-8,200
5.8	0.020	-2,400
6.4	0.013	-4,700
7.0	0.015	-2,600
7.6	0.025	-1,100
8.2	0.018	-2,700
8.8	0.026	-2,100
9.4	0.033	-940
10.1	0.042	-420
10.5	0.032	-750
10.8	0.022	-2,600
11.3	0.025	-1,600
11.9	0.030	-740
12.5	0.031	-710
13.1	0.031	-520
13.7	0.028	-390
14.3	0.044	-390
14.9	0.052	-570
15.5	0.037	-1,300
16.2	0.042	-790
16.8	0.039	-8,300
17.2	0.023	-2,900
17.7	0.024	-3,400
18.3	0.027	-3,000
18.7	0.030	-2,100
19.2	0.034	-1,300
19.8	0.031	-2,400
20.4	0.030	-2,600
21.0	0.029	-2,700
21.6	0.029	-2,300
22.3	0.028	-3,800
22.9	0.029	-2,800
23.5	0.022	-5,800
24.1	0.027	-2,500
24.7	0.033	-1,400
25.3	0.036	-950
25.9	0.036	-1,500

Table 3. Results of laboratory analyses for gravimetric water content and water potential of coarse drill cuttings from test hole USW UZ-6s--Continued

Depth of midpoint of sample (meters)	Gravimetric water content (gram per gram)	Water potential (kilopascals)
26.5	0.017	-780
27.1	0.030	-1,000
27.7	0.033	-1,300
28.3	0.028	-1,600
29.0	0.030	-1,200
29.6	0.031	-2,900
30.2	0.037	-1,100
30.8	0.035	-1,600
31.4	0.040	-820
32.0	0.045	-950
32.6	0.049	-720
33.2	0.046	-760
33.8	0.044	-900
34.4	0.047	-980
35.1	0.048	-650
35.7	0.048	-660
36.3	0.049	-630
36.9	0.044	-740
37.5	0.044	-710
38.1	0.043	-800
38.7	0.041	-810
39.3	0.044	-650
39.9	0.043	-710
40.5	0.041	-790
41.1	0.043	-610
41.8	0.028	-3,000
42.4	0.027	-3,900
43.3	0.031	-1,800
44.2	0.033	-1,100
44.8	0.034	-1,200
45.4	0.034	-1,300
46.0	0.029	-2,900
46.6	0.025	-4,100
47.2	0.031	-1,900
47.9	0.017	-6,700
48.5	0.021	-2,300
49.1	0.013	-15,000
49.6	--	-8,400
50.2	0.029	-7,500
50.9	0.035	-1,300
51.5	0.032	-1,600
52.1	0.031	-2,600
52.7	0.029	-3,100

Table 3. Results of laboratory analyses for gravimetric water content and water potential of coarse drill cuttings from test hole USW UZ-6s--Continued

Depth of midpoint of sample (meters)	Gravimetric water content (gram per gram)	Water potential (kilopascals)
53.3	0.033	-1,400
53.9	0.019	-5,700
54.6	0.025	-4,300
55.2	0.025	-4,100
55.8	0.028	-2,800
56.4	0.025	-3,600
57.0	0.027	-3,100
57.6	0.033	-2,000
58.2	0.035	-1,900
58.8	0.033	-2,900
59.4	0.033	-2,300
60.0	0.017	-5,900
60.7	0.019	-5,200
61.3	0.028	-3,900
61.9	0.027	-4,500
62.5	0.028	-4,200
63.1	0.034	-2,000
63.7	0.025	-5,800
64.3	0.029	-4,700
64.9	0.028	-4,400
65.5	0.027	-2,800
66.1	0.022	-6,500
66.8	0.026	-3,200
67.4	0.025	-3,800
68.0	0.025	-3,600
68.6	0.027	-2,900
69.2	0.024	-3,400
69.8	0.027	-2,900
70.4	0.023	-9,000
71.0	0.026	-4,400
71.6	0.026	-3,200
72.2	0.026	-4,000
72.8	0.026	-3,700
73.5	0.032	-1,300
74.1	0.036	-670
74.7	0.034	-830
75.3	0.033	-1,200
75.9	0.030	-1,300
76.5	0.027	-2,500
77.1	0.028	-2,000
77.7	0.025	-4,100
78.3	0.016	-8,200
78.9	0.017	-9,200

Table 3. Results of laboratory analyses for gravimetric water content and water potential of coarse drill cuttings from test hole USW UZ-6s--Continued

Depth of midpoint of sample (meters)	Gravimetric water content (gram per gram)	Water potential (kilopascals)
79.6	0.018	-10,000
80.2	0.019	-9,800
80.8	0.020	-8,500
81.4	0.019	-6,600
82.0	0.019	-9,600
82.6	0.023	-6,100
83.2	0.021	-8,200
83.8	0.018	-9,700
84.4	0.011	-16,000
85.0	0.012	-9,500
85.6	0.016	-8,900
86.3	0.020	-5,100
86.9	0.024	-3,800
87.5	0.023	-5,400
88.1	0.023	-6,700
88.7	0.024	-4,700
89.3	0.024	-5,600
89.9	0.023	-6,900
90.5	0.015	-9,900
91.1	0.016	-9,100
91.7	0.017	-6,900
92.4	0.017	-8,300
93.0	0.016	-9,500
93.6	0.018	-5,000
94.2	0.017	-6,700
94.8	0.019	-8,100
95.4	0.017	-6,800
96.0	0.018	-5,300
96.6	0.015	-7,900
97.2	0.015	-11,000
97.8	0.015	-14,000
98.5	0.019	-12,000
99.1	0.018	-12,000
99.7	0.018	-12,000
100.3	0.017	-12,000
100.9	0.018	-9,100
101.5	0.017	-11,000
102.1	0.017	-12,000
102.7	0.013	-21,000
103.3	0.014	-15,000
103.9	0.008	-24,000
104.5	0.006	-30,000
105.2	0.012	-18,000

Table 3. Results of laboratory analyses for gravimetric water content and water potential of coarse drill cuttings from test hole USW UZ-6s--Continued

Depth of midpoint of sample (meters)	Gravimetric water content (gram per gram)	Water potential (kilopascals)
105.8	0.011	-16,000
106.4	0.011	-23,000
107.0	0.011	-19,000
107.6	0.009	-37,000
108.2	0.005	-42,000
108.8	0.005	-49,000
109.4	0.007	-43,000
110.0	0.010	-35,000
110.6	0.013	-21,000
111.3	0.011	-15,000
111.9	¹ 0.005	-30,000
112.5	0.012	-20,000
113.1	0.012	-18,000
113.7	0.010	-25,000
114.3	0.012	-19,000
114.9	0.012	-18,000
115.5	0.010	-27,000
116.1	0.014	-23,000
116.7	0.013	-31,000
117.3	0.011	-32,000
118.0	0.009	-27,000
118.6	0.013	-47,000
119.2	0.011	-54,000
119.8	0.009	-52,000
120.4	0.010	-47,000
121.0	--	--
121.6	0.082	-31,000
122.2	--	--
122.8	0.068	-27,000
123.4	0.052	-31,000
124.1	0.040	-42,000
124.7	0.040	-38,000
125.3	0.050	-33,000
125.9	0.074	-23,000
126.5	0.080	-22,000
127.1	0.088	-18,000
127.7	0.093	-17,000
128.3	0.070	-16,000
128.9	0.070	-12,000
129.5	0.060	-41,000
130.1	0.068	-36,000
130.8	0.073	-80,000
131.4	0.073	-55,000

Table 3. Results of laboratory analyses for gravimetric water content and water potential of coarse drill cuttings from test hole USW UZ-6s--Continued

Depth of midpoint of sample (meters)	Gravimetric water content (gram per gram)	Water potential (kilopascals)
132.0	0.166	-5,600
132.6	0.124	-9,100
133.2	0.082	-7,000
133.8	0.055	-5,600
134.4	0.101	-16,000
135.0	0.096	-3,900
135.6	0.102	-1,300
136.2	0.074	-8,500
136.9	0.082	-23,000
137.5	0.070	-14,000
138.1	0.063	-59,000
138.7	--	-91,000
139.3	² 0.007	-45,000
139.9	0.010	-64,000
140.5	0.064	-57,000
141.1	0.050	-44,000
141.7	0.092	-22,000
142.3	0.081	-24,000
143.0	0.081	-13,000
143.6	0.027	-39,000
144.2	0.027	-57,000
144.8	0.009	-68,000
145.4	0.008	-80,000
146.0	0.017	-66,000
146.6	0.025	-69,000
147.2	0.030	-73,000
147.8	0.024	-40,000
148.4	0.009	-54,000
² 149.0	0.011	-51,000
149.7	0.009	-57,000
150.3	0.008	-54,000

¹ Fine drill cuttings

² Composite drill cuttings

Table 4. Results of laboratory analyses for gravimetric water content and water potential of composite core samples from test hole USW UZ-6s

[--, indicates no data]

Depth interval (meters)	Gravimetric water content (gram per gram)	Water potential (kilopascals)
23.26-23.32	0.033	-1,500
23.32-23.41	0.032	-1,500
29.41-29.50	0.034	-1,000
35.36-35.96	0.040	-1,100
41.45-41.57	0.034	-3,100
41.97-42.06	0.035	-3,800
48.01-48.16	0.030	-4,900
53.77-53.84	0.034	-5,400
60.26-60.35	0.026	-3,500
66.08-66.17	0.031	-5,200
78.02-78.14	0.019	-7,700
84.12-84.73	0.022	-6,100
90.22-90.49	0.018	-13,000
96.71-96.90	0.022	-11,000
102.82-102.96	0.019	-18,000
108.72-108.81	0.017	-16,000
114.60-114.73	0.014	-20,000
120.93-121.10	0.040	-7,900
122.53-122.62	0.059	-3,600
122.93-122.99	0.050	-9,300
123.84-123.93	0.068	-5,900
124.45-124.54	0.103	-7,800
125.27-125.39	0.140	-710
126.13-126.22	0.109	-3,000
127.10-127.19	0.160	-720
127.86-127.96	0.136	-580
128.32-128.44	0.126	-580
128.93-129.02	0.120	-580
129.84-130.12	0.114	-550
130.58-130.67	0.098	-500
131.37-131.46	0.205	-530
131.98-132.10	0.076	-480
132.47-132.59	0.094	-480
133.29-133.41	0.104	-600
133.84-133.96	0.119	-410
134.84-134.97	0.149	-360
135.39-135.48	0.107	-320
136.61-136.79	0.058	-310
137.95-138.07	0.050	-280
138.47-138.59	0.057	-280
139.39-139.48	0.143	-780
139.78-139.90	0.107	-960

Table 4. Results of laboratory analyses for gravimetric water content and water potential of composite core samples from test hole USW UZ-6s--Continued

Depth Interval (meters)	Gravimetric water content (gram per gram)	Water potential (kilopascals)
140.94-141.06	0.081	-1,200
141.61-141.70	0.209	-520
142.19-142.28	0.077	-800
143.90-144.02	0.047	-1,300
146.30-146.36	0.062	-570
146.97-147.16	0.032	-560
147.34-147.46	0.010	-5,600
148.10-148.19	0.020	-940
148.44-148.56	0.018	-1,100
148.96-149.08	0.016	-9,200
149.15-149.29	0.019	-12,000
149.50-149.60	0.028	-2,000
150.75-150.88	0.015	-9,500
150.88-151.06	0.026	-8,100
151.97-152.03	0.032	-1,700
152.40-152.55	0.031	-1,400
153.25-153.31	0.034	-650
153.77-153.92	0.031	-1,200
155.05-155.14	0.035	-580
155.36-155.48	0.034	-520
156.09-156.18	0.036	-700
157.31-157.46	0.040	-1,100
157.76-157.86	0.038	-760

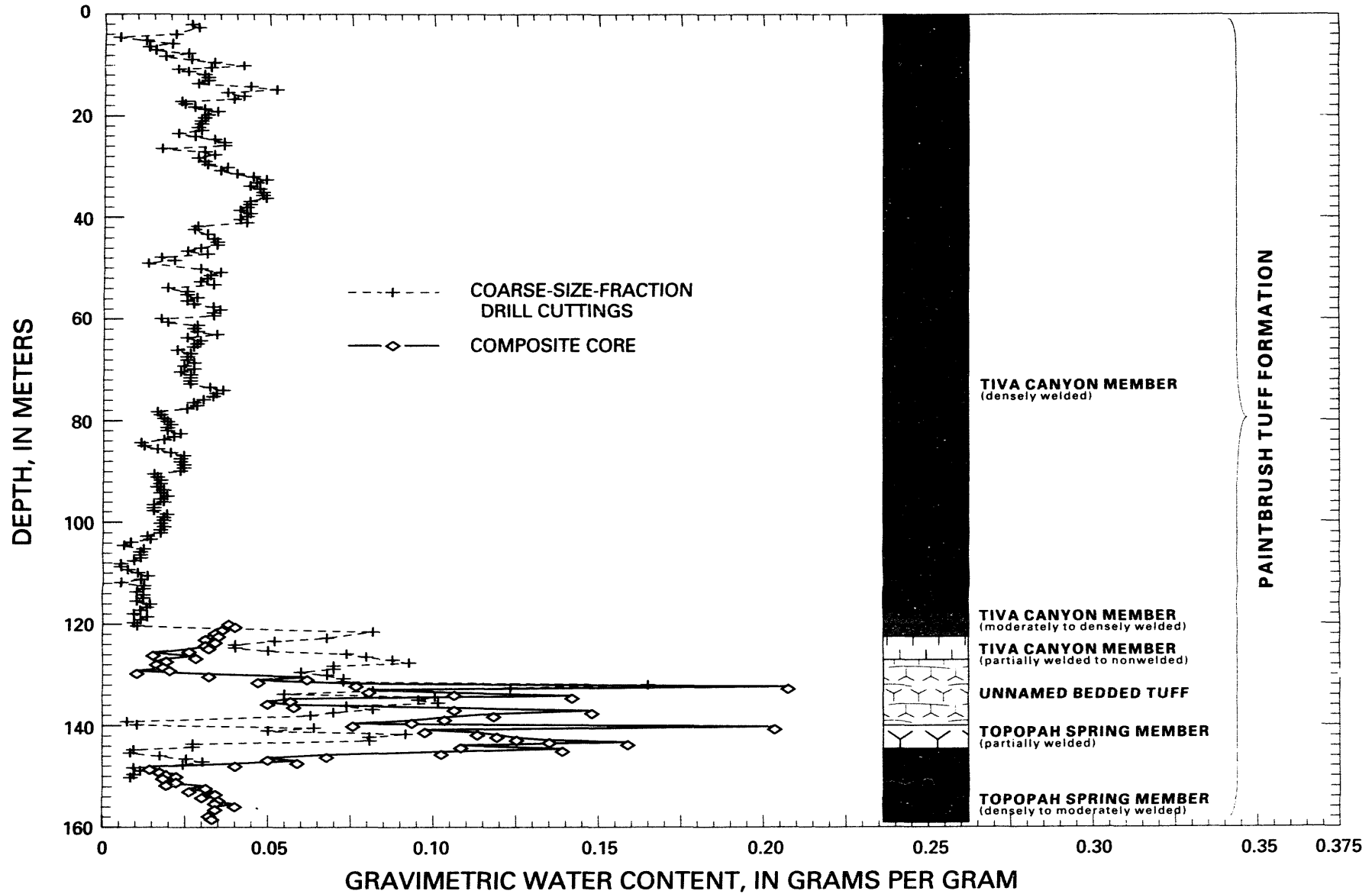


Figure 4. Gravimetric water-content measurements from coarse-size fraction drill cuttings and composite core from test hole USW UZ-6s.

Table 5. Summary of relation of gravimetric water-content measurements of composite core from test hole USW UZ-6s to lithology and degree of welding

[Michael Chornack, U.S. Geological Survey, written commun., 1985; all data values in gram per gram]

Geologic formation	Number of data points	Data range	Average	Median	Standard deviation	Degree of welding
Tiva Canyon Member (upper unit) of the Paintbrush Tuff	17	0.014 to 0.040	0.027	0.030	0.008	Dense
Tiva Canyon Member (lower vitrophyre) of the Paintbrush Tuff	4	0.040 to 0.068	0.054	0.054	0.012	Moderate to dense
Tiva Canyon Member (shardy base) of the Paintbrush Tuff	9	0.098 to 0.160	0.123	0.120	0.020	Partial to non-welded
Unnamed bedded tuffs	12	0.050 to 0.205	0.106	0.106	0.044	Not applicable
Topopah Spring Member (vitric unit) of the Paintbrush Tuff	6	0.032 to 0.209	0.085	0.070	0.064	Partial
Topopah Spring Member (caprock) of the Paintbrush Tuff	17	0.010 to 0.040	0.027	0.031	0.009	Dense to moderate

Thermocouple-voltage outputs are measured first on the calibration standards from lowest to highest molality, followed by the rock samples; then the measurements are repeated on the calibration standards from lowest to highest molality. The before-and-after selected voltage-output plateaus for each calibration standard are averaged to compensate for any drift in temperature (Brown, 1970). Each voltage-output plateau has two temperature readings, one taken before and one taken after the 10-minute period of voltage-output measurements. The four temperature readings for each calibration standard are averaged. Each rock sample has a selected voltage-output plateau. The sample cups that contained the cuttings or core are carefully cleaned and dried after each set of measurements.

After all voltage-output readings are collected and voltage-output plateaus determined for calibration standards and rock samples, water potential is then calculated for each calibration standard. The calculated water potential is based on the molality of the calibration standard and the average temperature from the voltage-output measurement for that calibration standard. A linear-regression equation is run based on these calculated water potentials and the average of the before-and-after voltage-output plateaus for each calibration standard. The results of the linear-regression

equation are used to construct the calibration curve and included intercept, slope, and coefficient of determination (r^2). Using this calibration curve, the voltage-output plateau reading from each cutting or core sample is entered into the linear-regression equation, and the output value is the water-potential value of the sample.

Generally, measurements of water potential of rock samples were rerun if the r^2 was less than 0.990 or if the readings did not plateau sufficiently. The calibration curves for cuttings and core from UZ-6s were almost linear, and r^2 values ranged from 0.995 to 1.000, with most r^2 values equal to 1.000.

Results of water-potential measurements for UZ-6s are listed in tables 3 and 4 and shown in figure 5. For depths 120.7 to 150.6 m, the water potential for coarse cuttings averaged -37,000 kPa and that for composite core averaged -2,300 kPa.

Water-potential measurements are related to the degree of welding of tuff. Water-potential data of composite core from UZ-6s, as related to geological formation and degree of welding, are summarized in table 6. Only core data are tabulated; they are most representative of the rock units drilled.

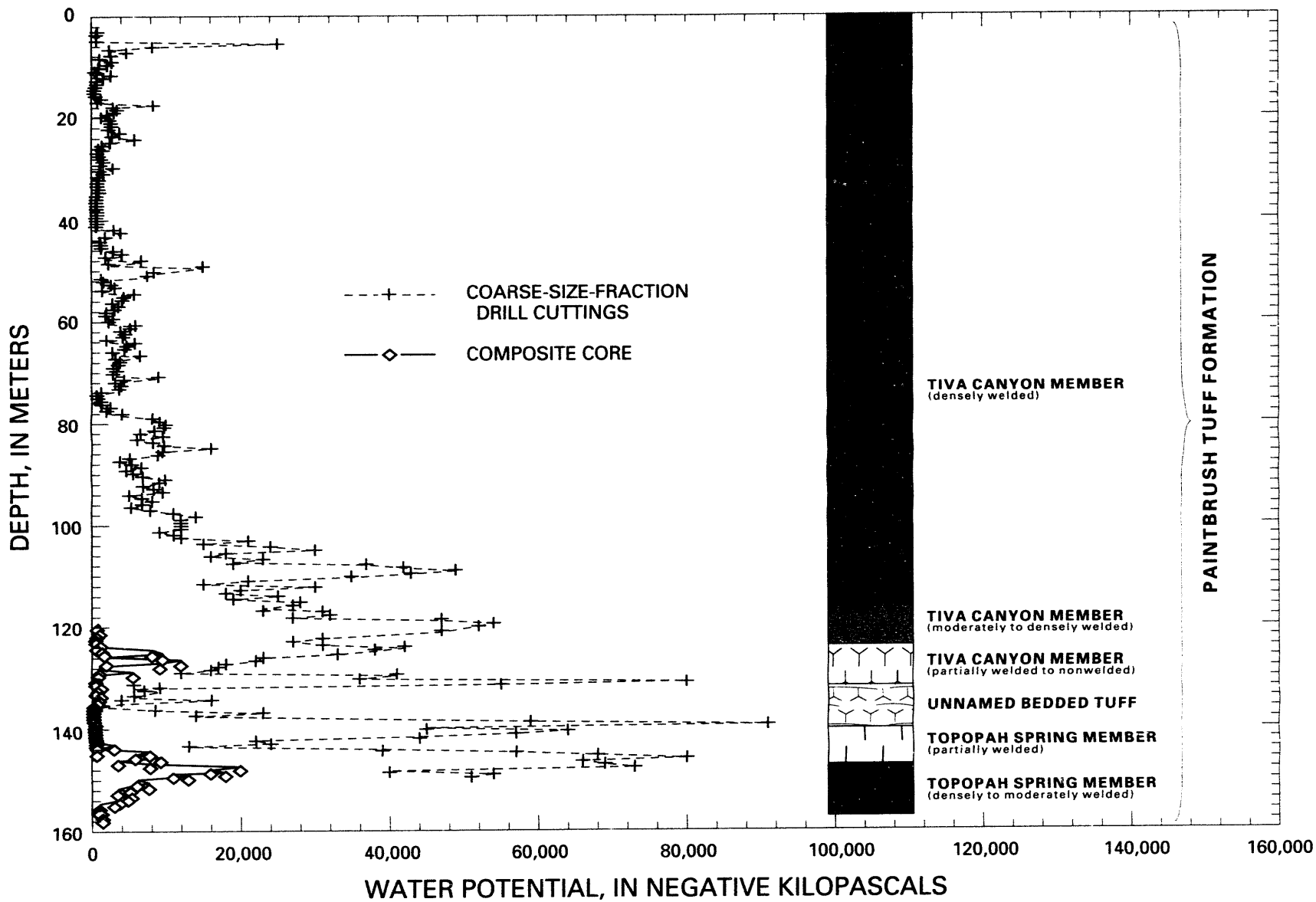


Figure 5. Water-potential measurements from coarse-size fraction drill cuttings and composite core from test hole USW UZ-6s.

Table 6. Summary of relation of water-potential measurements of composite core from test hole USW UZ-6s to lithology and degree of welding

[Michael Chornack, U.S. Geological Survey, written commun., 1985; all data values in kilopascals]

Geologic formation	Number of data points	Data range	Average	Median	Standard deviation	Degree of welding
Tiva Canyon Member (upper unit) of the Paintbrush Tuff	17	-1,000 to -20,000	-7,200	-5,200	-6,100	Dense
Tiva Canyon Member (lower vitrophyre) of the Paintbrush Tuff	4	-3,600 to -9,300	-6,700	-4,800	-2,500	Moderate to dense
Tiva Canyon Member (shardy base) of the Paintbrush Tuff	9	-500 to -7,800	-1,700	-580	-2,400	Partial to nonwelded
Unnamed bedded tuffs	12	-280 to -960	-480	-440	-210	Not applicable
Topopah Spring Member (vitric unit) of the Paintbrush Tuff	6	-520 to -1,300	-820	-680	-340	Partial
Topopah Spring Member (caprock) of the Paintbrush Tuff	17	-520 to -12,000	-3,400	-1,200	-3,900	Dense to moderate

Bulk- and Grain-Density Measurements

The bulk- and grain-density measurements of core samples from UZ-6s were determined by Holmes & Narver Materials Testing Laboratory, Inc., at Mercury, Nev., in accordance with ASTM Procedure D-1188 (American Society for Testing and Materials, 1980a). Bulk density was calculated from bulk specific gravity.

After the bulk-density measurement was determined, each sample was pulverized to pass through a

200-mesh sieve, was oven-dried, and was tested in accordance with ASTM Procedure D-854 (American Society for Testing and Materials, 1980b), and grain density was calculated. Grain density refers to the weight of a substance compared with the weight of an equal volume of pure water at 4°C. Results of laboratory analyses for bulk- and grain-density measurements for UZ-6s are listed in table 7 and are summarized in table 8. The bulk- and grain-density measurements of UZ-6s are shown in figure 6.

Table 7. Results of laboratory analyses for bulk- and grain-density measurements of rotary-core samples from test hole USW UZ-6s

[Analyses by Holmes & Narver Materials Testing Laboratory, Inc., Mercury, Nev.; --, no data]

Depth interval of sample (meters)	Density (grams per cubic centimeter)	
	Bulk	Grain
23.26-23.32	2.23	2.48
23.41-23.47	2.21	2.47
29.41-29.50	2.17	2.45
35.36-35.97	2.19	2.47
41.45-41.57	2.22	2.50
41.97-42.06	2.23	2.49
48.01-48.16	2.25	2.50
60.26-60.35	2.21	2.51
78.03-78.14	2.33	2.51
84.12-84.73	2.21	2.49
90.22-90.50	2.34	2.49
96.71-96.90	2.31	2.54
102.82-102.96	2.34	2.49
108.72-108.81	2.32	2.49
114.60-114.73	2.34	2.44
120.93-121.10	1.69	2.48
122.53-122.62	2.02	2.41
122.93-123.02	2.02	2.39
123.84-123.93	1.85	2.39
124.45-124.54	1.75	2.43
125.27-125.39	1.70	2.47
126.13-126.22	1.81	2.43
127.10-127.19	1.57	2.41
127.86-127.96	1.50	2.35
128.32-128.44	1.46	2.38
128.93-129.02	1.40	2.38
129.84-130.12	1.40	2.35
130.58-130.67	1.36	2.35
131.37-131.46	1.27	2.45
131.98-132.10	1.28	2.40
132.47-132.59	1.57	2.40
133.29-133.41	1.48	2.44
133.84-133.96	1.50	2.50
134.84-134.97	1.12	2.42
135.39-135.48	1.38	2.46
136.61-136.79	1.50	2.38
137.95-138.07	1.61	2.38
138.47-138.59	1.65	2.41
139.39-139.48	1.31	2.50
139.78-139.90	1.74	2.50
140.94-141.06	1.58	2.50

Table 7. Results of laboratory analyses for bulk- and grain-density measurements of rotary-core samples from test hole USW UZ-6s--Continued

Depth interval of sample (meters)	Density (grams per cubic centimeter)	
	Bulk	Grain
141.61-141.70	1.29	2.65
142.19-142.28	1.66	2.53
143.87-144.02	1.53	--
146.30-146.36	1.61	2.45
146.97-147.16	2.16	2.51
147.34-147.46	2.34	2.54
148.10-148.19	2.23	2.57
148.44-148.56	2.31	2.58
148.96-149.08	2.24	2.58
149.15-149.29	2.28	2.54
149.50-149.60	2.17	2.60
150.75-150.88	2.23	2.57
150.88-151.06	2.15	2.58
151.97-152.03	2.13	2.56
152.40-152.55	2.12	2.59
153.25-153.31	2.14	2.58
153.77-153.92	2.15	2.59
155.05-155.14	2.16	2.57
155.36-155.48	2.14	2.56
156.09-156.18	2.13	2.57
157.31-157.46	2.08	2.56
157.76-157.86	2.07	2.59

Table 8. Summary of relation of bulk- and grain-density measurements of composite core from test hole USW UZ-6s to lithology and degree of welding

[Michael Chomack, U.S. Geological Survey, written commun., 1985; all data values in grams per cubic centimeter]

Geologic formation	Range of values	Average	Range of values	Average	Degree of welding
Tiva Canyon Member (upper unit) of the Paintbrush Tuff	2.17 to 2.34	2.26	2.44 to 2.54	2.49	Dense
Tiva Canyon Member (lower vitrophyre) of the Paintbrush Tuff	1.69 to 2.02	1.90	2.39 to 2.48	2.42	Moderate to dense
Tiva Canyon Member (shardy base) of the Paintbrush Tuff	1.36 to 1.81	1.55	2.35 to 2.47	2.39	Partial to non- welded
Unnamed bedded tuffs	1.12 to 1.74	1.45	2.23 to 2.50	2.42	Not applicable
Topopah Spring Member (vitric unit) of the Paintbrush Tuff	2.07 to 2.34	1.64	2.45 to 2.65	2.53	Partial
Topopah Spring Member (caprock) of the Paintbrush Tuff	2.07 to 2.34	2.18	2.54 to 2.60	2.57	Dense to moder- ate

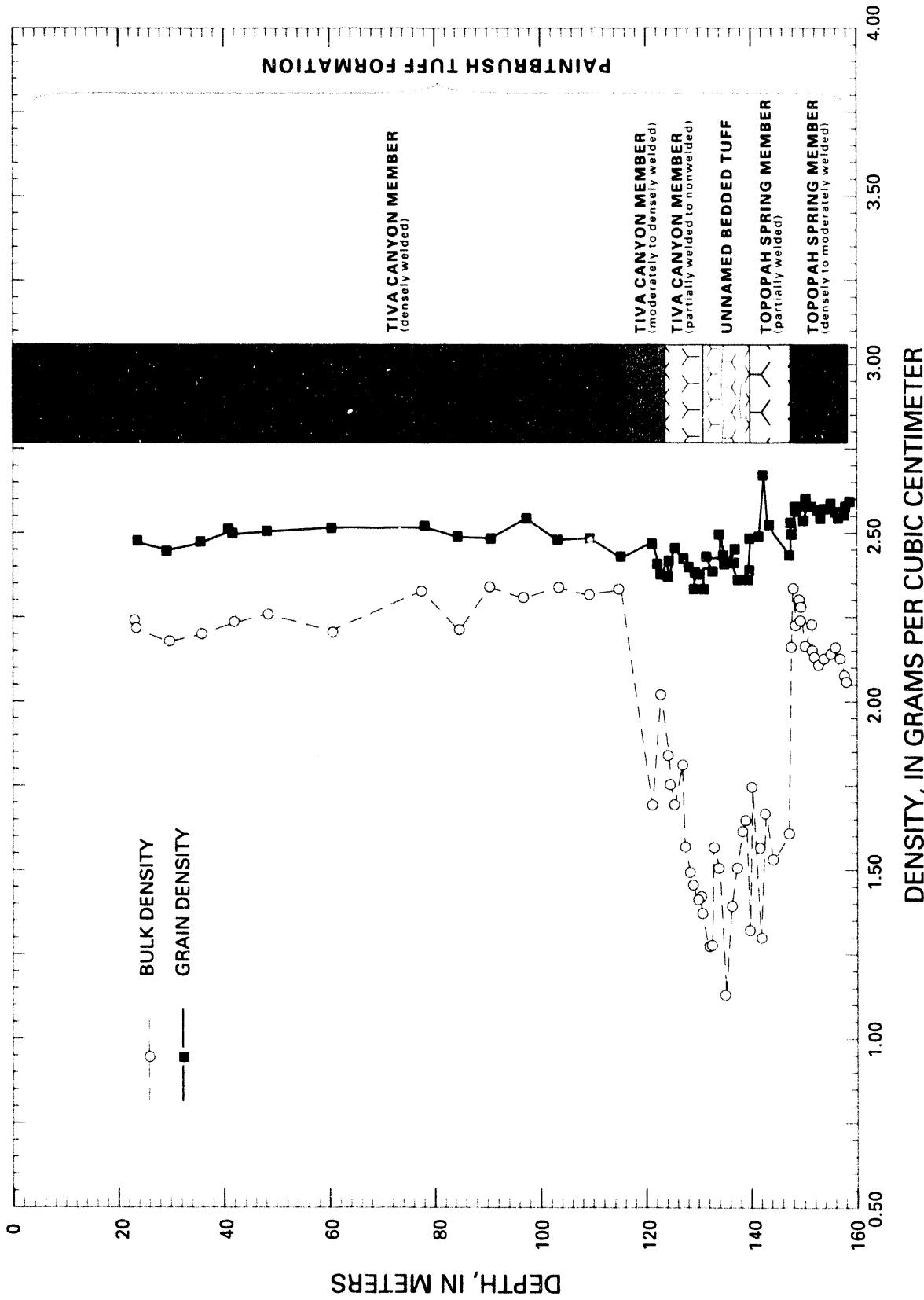


Figure 6. Bulk- and grain-density measurements of rotary core from test hole USW UZ-6s.

SUMMARY

Test hole UZ-6s located on the crest of Yucca Mountain was drilled to a depth of 158.2 m. Cutting and core samples were collected to determine gravimetric water-content, water-potential, bulk-density and grain-density measurements. Geologic formations penetrated are the Tiva Canyon Member, unnamed bedded tuff, and Topopah Spring Member of the Paintbrush Tuff.

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