GEOHYDROLOGIC DATA FROM TEST HOLE USW UZ-7,

YUCCA MOUNTAIN AREA, NYE COUNTY, NEVADA

By Jack Kume and Dale P. Hammermeister

U.S. GEOLOGICAL SURVEY

Open-File Report 88-465

Prepared in cooperation with the

NEVADA OPERATIONS OFFICE,

U.S. DEPARTMENT OF ENERGY, under

Interagency Agreement DE-AI08-78ET44802

Denver, Colorado
1990

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

Chief, Nuclear Hydrology Program
U.S. Geological Survey
Box 25046, Mail Stop 421
Federal Center
Denver, CO 80225-0046

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Box 25425
Federal Center
Denver, CO 80225-0425

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS

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

Metric unit	*Multiply by*	*To obtain inch-pound unit*
gram per cubic centimeter (g/cm^3)	0.03613	pound per cubic inch
kilometer (km)	0.6214	mile
kilopascal (kPa)	0.1450	pound per square inch
kilopascal (kPa)	0.01	bar, 14.5 pounds per square inch
liter (L)	0.2642	gallon
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot

Degree Celsius (°C) may be converted to degree Fahrenheit as follows:

$$F = 9/5\ (°C) + 32.$$

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

gram per gram (g/g)
milliliter (mL).

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.

GEOHYDROLOGIC DATA FROM TEST HOLE USW UZ-7,
YUCCA MOUNTAIN AREA, NYE COUNTY, NEVADA

by Jack Kume and Dale P. Hammermeister

ABSTRACT

This report contains a description of the methods used in drilling and coring of test hole USW UZ-7; a description of the methods used in collecting, handling, and testing of test-hole samples; lithologic information from the test hole; and water-content, water-potential, bulk-density, grain-density, porosity, and tritium data for the test hole. Test hole USW UZ-7 is the third of a series of shallow unsaturated-zone test holes drilled in and near the southwestern part of the Nevada Test Site, Nye County, Nev., in cooperation with the U.S. Department of Energy. All of these test holes are a part of the Nevada Nuclear Waste Storage Investigations to identify potential sites suitable for underground storage of high-level radioactive wastes.

Test hole USW UZ-7 was drilled and cored to a total depth of 62.94 meters. The drilling was done using air as a drilling fluid to minimize disturbance to the water content in cores, drill-bit cuttings, and borehole wall rock. Beginning at the land surface, the unsaturated rock that was penetrated consisted of alluvium; welded and partially welded to nonwelded ash-flow tuff; bedded and reworked ash-fall tuff; nonwelded ash-flow tuff; bedded and reworked ash-fall tuff; nonwelded ash-fall tuff; and welded ash-flow tuff. The alluvium is of Quaternary age and the tuff is of Tertiary age. Alluvium and welded ash-flow tuffs were cored at selected intervals, whereas partially welded to nonwelded ash-flow tufts and reworked ash-fall tuffs were continuously cored. Drill-bit cuttings were obtained for 0.61-meter intervals from the land surface to a depth of 62.94 meters.

Gravimetric water-content measurements of drive and rotary cores generally were larger than the same measurements of coarse drill-bit cuttings obtained from the same or nearby depths. Values of gravimetric water content and water potential of drive cores obtained from the alluvium overlying the tuffs were intermediate between the extreme values of densely welded and nonwelded and bedded tuffs. Gravimetric water content of rotary cores was largest for partially welded to nonwelded ash-flow tuffs, bedded and reworked ash-fall tuffs, and nonwelded ash-fall tuffs, and was smallest for densely welded ash-flow tuffs. Water potential of rotary cores was more negative for densely welded ash-flow tuffs and was less negative for bedded, reworked, and nonwelded ash-fall tuffs. Water-potential measurements of drive and rotary cores generally had less negative values than the same measurements of coarse drill-bit cuttings obtained from the same or nearby depths.

Values of bulk density of rotary cores were largest for densely welded ash-flow tuffs from the Tiva Canyon and Topopah Spring Members of the Paintbrush Tuff and was smallest for nonwelded ash-flow tuffs from the Pah Canyon Member of the Paintbrush Tuff and for nonwelded and bedded ash-fall tuffs from the bedded tuffs. Values of grain density of rotary cores generally were uniform throughout the various lithologic units, but the values were slightly larger for nonwelded and bedded ash-fall tuffs than for welded ash-flow tuffs. The values of porosity of rotary cores were largest for nonwelded and bedded ash-fall tuffs and were smallest for densely and moderately welded ash-flow tuffs. The tritium content of drive-cores of alluvium was smallest near the bedrock-alluvium contact, but markedly increased to a maximum content in the middle zone of the alluvium deposit, then decreased to a much smaller content near the land surface.

INTRODUCTION

The U.S. Geological Survey is investigating Yucca Mountain, Nev. (fig. 1), to evaluate the hydrological and geological suitability of this potential site for the storage of high-level radioactive wastes in an underground mined repository (Waddell, 1982; Roseboom, 1983; Montazer and Wilson, 1984; Squires and Young, 1984; Waddell and others, 1984). These investigations are a part of the Nevada Nuclear Waste Storage Investigations (NNWSI) that are being done in cooperation with the U.S. Department of Energy, Nevada Operations Office, as part of Interagency Agreement DE-AI08-78ET44802. The investigation was done in accordance with the NNWSI Quality Assurance (QA) Program. Test-hole drilling has been a principal method of investigation (Bentley and others, 1983; Thordarson and others, 1984).

Test hole USW UZ-7 is the third test hole in a series of shallow (total depth less than 150 m) unsaturated-zone test holes that are being drilled on and in the vicinity of Yucca Mountain in different geological and unsaturated hydrological environments. Test holes UE-25 UZ #4 and UE-25 UZ #5 were the first in this series of test holes (C.L. Loskot and D.P. Hammermeister, U.S. Geological Survey, written commun., 1986). Test hole USW UZ-13 is the fourth in this series of test holes (Jack Kume amd D.P. Hammermeister, U.S. Geological Survey, written commun., 1986). The main objectives of the test-hole series of investigations are: (1) To determine the flux of water moving through the nonwelded and bedded tuffs in the upper 150 m of unsaturated rock; (2) to determine the vertical distribution of water content, water potential, and other relevant in-situ hydrologic characteristics and conditions of the rock units penetrated; and (3) to monitor changes through time in relevant in-situ hydrologic characteristics of rocks penetrated.

Work is in progress (1986) to fulfill the first and third objectives listed. Hydrologic characteristics are being measured in minimally disturbed cores obtained from test hole USW UZ-7, which will enable the calculation of flux in the penetrated nonwelded and bedded ash-fall tuffs. Work is planned to instrument this test hole by installing moisture-sensing probes downhole to measure temporal changes versus time in hydrologic characteristics and conditions.

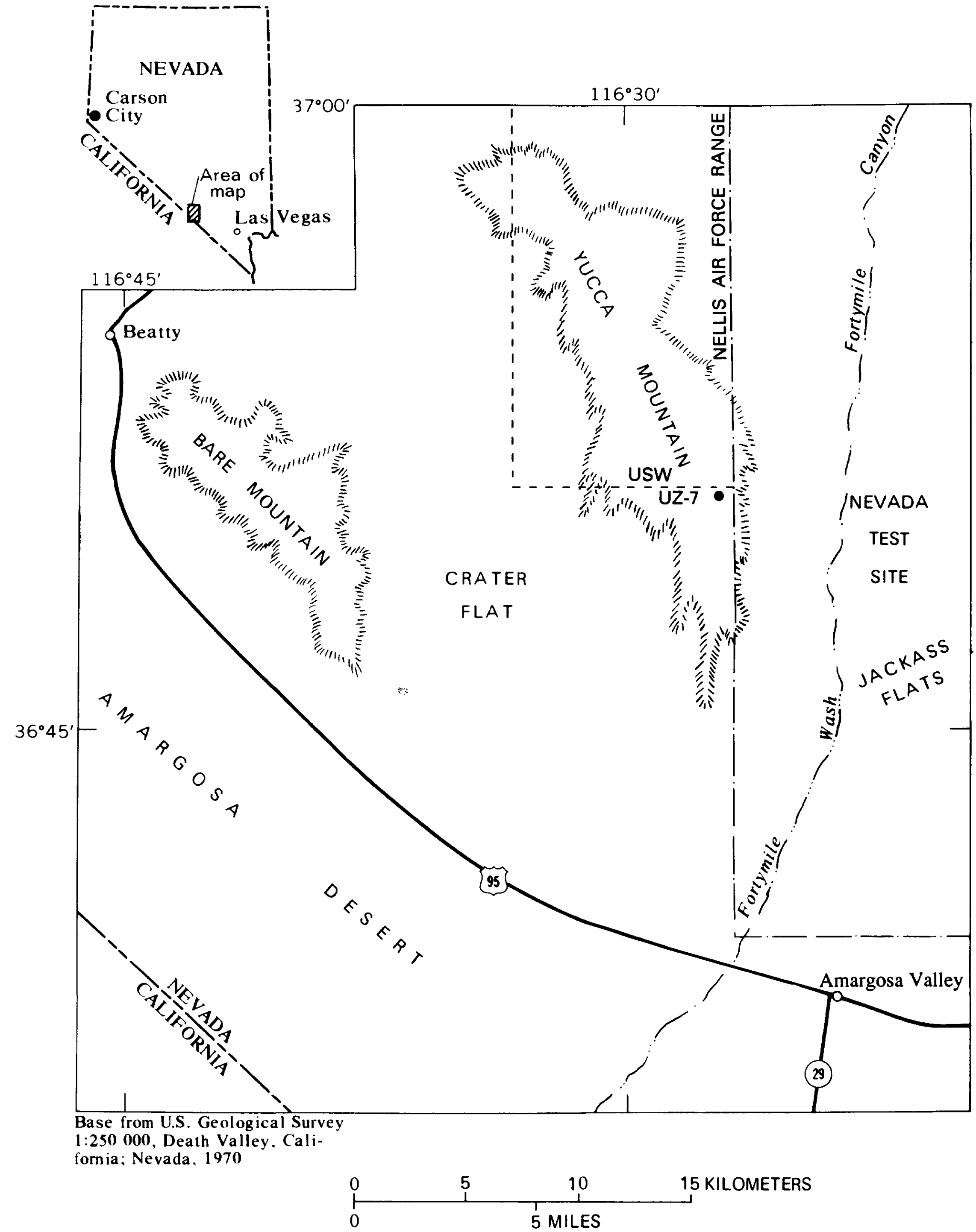

Figure 1.--Location of test hole USW UZ-7.

Test hole USW UZ-7 is located in Nye County, Nev., near the southeastern corner of Nellis Air Force Range about 140 km northwest of Las Vegas, Nev., in the southern part of the State (fig. 1). The site of the test hole is in an easterly draining canyon on the eastern flank of Yucca Mountain, northwest of Jackass Flats near the southwestern corner of the Nevada Test Site. The Nevada State Central Zone Coordinates of the test-hole site are N. 231,902.8 m and E. 171,575.4 m. Altitude of the land surface at the test-hole site is 1,271 m above sea level. The location and altitude of the test-hole site were determined by Holmes & Narver, Inc.[1], Mercury, Nev.

Purpose and Scope

The purpose of this report is to describe the methods used in drilling and coring of test hole USW UZ-7 and to describe the methods used in collecting, handling, and testing of test-hole samples. The report also provides lithologic descriptions and water-content, water-potential, bulk-density, grain-density, porosity, and tritium data of the rocks penetrated in the test hole.

Approach

The work included test-hole drilling and coring; examination and lithologic description of the drill-bit cuttings and cores; borehole geophysical logging; measurements of the gravimetric and volumetric water-content and water-potential values of drill-bit cuttings and of drive and rotary cores; measurements of values of bulk-density and grain-density of drive and rotary cores; calculation of porosity values of drive and rotary cores; and measurements of the tritium content of drive cores of alluvium. The drilling and coring of test hole USW UZ-7 was done primarily to determine the vertical distribution or profiles of water-content, water-potential, and other relevant in-situ hydrologic characteristics and conditions of the rock units penetrated.

DRILLING AND CASING METHODS

Drilling of test hole USW UZ-7 started on January 4, 1985, and a total depth of 62.94 m was reached on January 21, 1985. The test hole (fig. 2) was drilled using a Joy core rig and the Odex 115 drilling system; air was used as the drilling fluid. This drilling method has been described in detail by Hammermeister and others (1986); therefore, only a brief description is included here. The Odex 115 drilling system is a method that minimally disturbs the in-situ water content of cores, drill-bit cuttings and borehole wall rock. This method uses a downhole percussion hammer to drill and ream at the bottom joint of the casing. A pilot bit in conjunction with an eccentric reamer drill a hole slightly larger than the outside diameter of the casing. The percussion hammer forces the casing down the borehole by impacting on a shoe attached to the bottom joint of the casing. Thus, the casing is advanced

---

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

downward as the borehole is drilled deeper. Drill-bit cuttings are brought to the land surface through the casing, thereby minimizing the disturbance to the borehole wall rock. The casing is advanced downhole until the desired depth for rotary coring is reached. The desired interval then is cored, and the core is collected; then the cored interval is enlarged (reamed) and the casing is advanced to the bottom of the cored interval. This drilling, coring, reaming, and casing sequence is repeated until the total depth of the test hole is reached.

The diameter of the borehole is 152 mm from a depth of 0 to 62.94 m. Initially, the entire borehole was cased using 1.52-m-long casing sections with an 140-mm outside diameter and an 127-mm inside diameter. When drilling and coring were completed, the casing was removed except for the interval from 0 to 6.71 m. A detailed history of the drilling and coring of test hole USW UZ-7 is contained in the Hole History Data file of the engineering firm, Fenix & Scisson, Inc., Las Vegas, Nev. (written commun., 1986).

CORING METHODS

Two coring methods were used for test hole USW UZ-7. In the unconsolidated deposits consisting of alluvium, drive coring was used. In the consolidated deposits consisting of volcanic tuff, rotary coring was used.

Drive Core

The drive-core methods used for test hole USW UZ-7 to obtain samples from the unconsolidated bouldery alluvium of Yucca Mountain are described by Hammermeister and others (1986). The drive core was obtained by the use of a heavy-duty, solid-tube sampler that is 0.61-m long with an inside diameter of 102 mm. Core was collected from selected 0.61-m depth intervals in the alluvium. The sampler was lined with two 152-mm long by 102-mm inside-diameter brass liners and four 76-mm-long by 102-mm-inside-diameter brass liners that had a sample-retaining catcher at the bottom. The liners were used to contain the various segments of the unconsolidated sample as it was removed from the sampler by the use of an extruder. The sampler was attached to the percussion hammer for driving the tube into the alluvium. This unusual method of driving the sampler proved successful, and drive-core samples were obtained even from the most bouldery alluvium.

The drive-core methods for test hole USW UZ-7 yielded minimally disturbed core samples for gravimetric water-content analysis. However, the drive-core process disturbs the in-situ volume-related properties of core samples, as reported by Hammermeister and others (1986). The process seems to compact samples from near the land surface and to expand the samples from deeper depths.

Rotary Core

Rotary coring using air as the drilling fluid was done using a 1.52-m-long, triple-tube, HWD4-size wireline core barrel modified by Norten Christensen, Inc., Salt Lake City, Utah, for air coring. This air method of

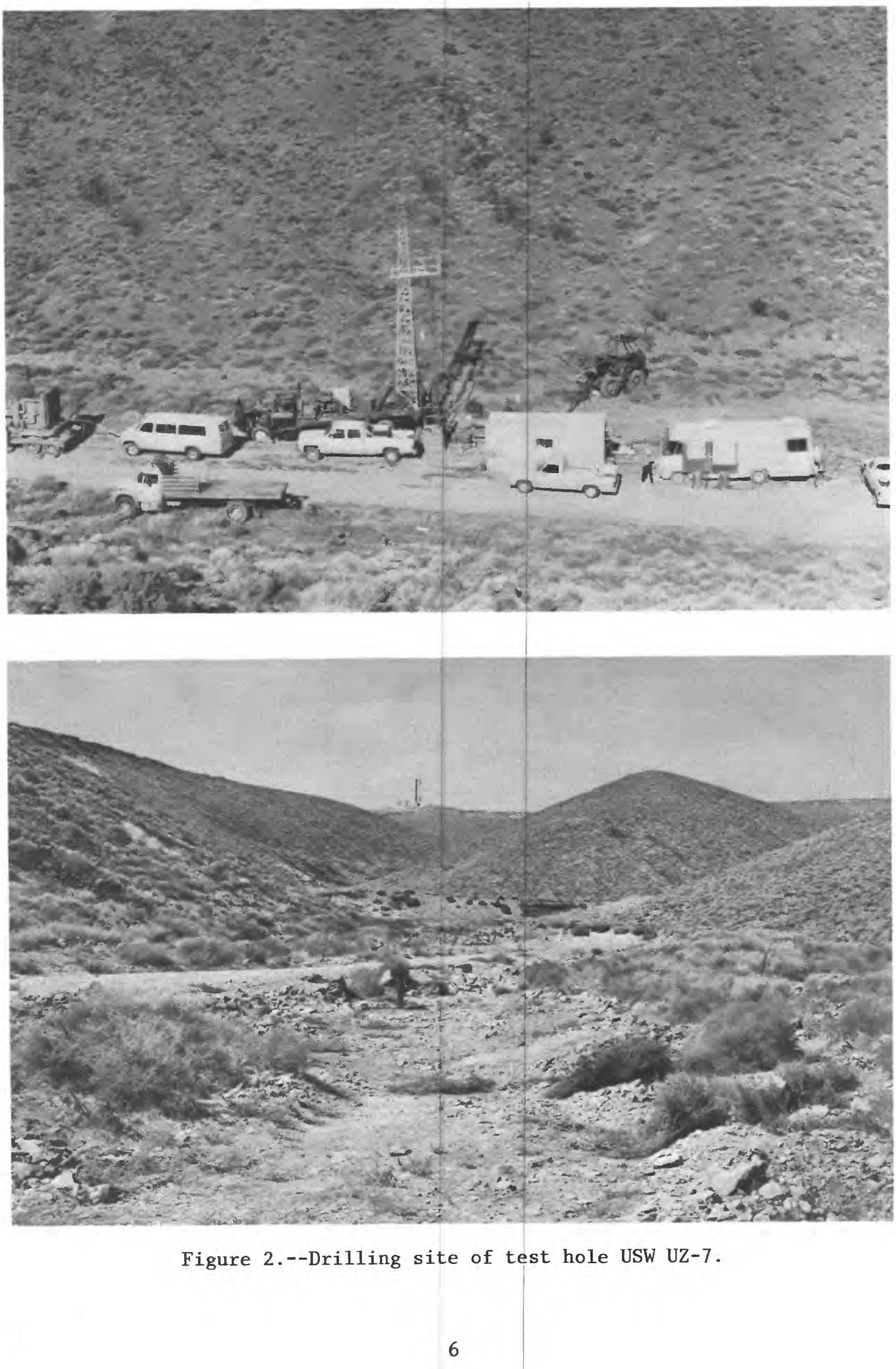

Figure 2.--Drilling site of test hole USW UZ-7.

rotary coring is described in detail by Hammermeister and others (1986). These authors also reported that this method of coring does not substantially disturb the water content of the core sample or of the borehole wall rock. In relatively soft, poorly consolidated, and nonwelded ash-fall tuffs, a tungsten-carbide, stagger-tooth, pilot-type, face-discharge bit was used. In hard, densely welded ash-flow tuffs, a surface-set diamond bit was used. The diameter of the rotary core was 61 mm.

SAMPLE COLLECTION AND HANDLING

During the sampling and handling operations described in this section for drill-bit cuttings and cores, every effort was made to minimize water evaporation from the rock samples. A method was followed for identification, transport, and handling of drill cuttings, samples, and core from unsaturated-zone boreholes (C.M. McBride, U.S. Geological Survey, written commun., 1984). This method was designed to minimize disturbance to the water content of the drill-bit cuttings and cores from the time the samples are removed from the borehole to the time water-content and water-potential measurements and other water-dependent measurements are made.

Drill-Bit Cuttings

Fresh drill-bit cuttings were diverted from the borehole through a flexible hose to a nearby dry cyclone separator. As drilling progressed, samples of drill-bit cuttings were collected from the bottom of the cyclone separator through a gate valve that was opened by a hand lever after an interval in the borehole of 0.61 m had been drilled. The drill-bit cuttings then fell into several collection vessels. A 0.47-L paper carton was filled first; the samples were used for describing the lithology of the interval drilled and for archiving samples in the U.S. Geological Survey Core Library in Mercury, Nev. Next, one or two 0.95-L glass jars also were filled and capped using airtight lids. These samples were used for laboratory measurement of water content and water potential. When the collection of samples was completed, the drill-bit cuttings that remained in the separator were discarded on the land surface. If the drill-bit cuttings were moist and stuck to the inside walls of the separator and gate valve, a large hammer was used to knock the drill-bit cuttings from the inside walls and through the gate valve, thereby completely emptying the cyclone separator in preparation for collection of the sample of the next 0.61-m interval drilled. Drilling usually did not stop during these sampling activities.

After the collection of drill-bit cuttings was completed, the cuttings in glass jars usually were taken immediately to the onsite laboratory (fig. 2; the motorhome is the laboratory) for processing. If drill-bit cuttings could not be taken immediately to the onsite laboratory, the glass jars were stored temporarily in a large water cooler to minimize condensation inside the jar caused by the heating and cooling of the drill-bit cuttings as a result of ambient-temperature fluctuations and solar radiation.

Once inside the onsite laboratory, the glass jars containing the drill-bit cuttings were placed inside a humidified glove box to minimize evaporation from the samples during subsequent sample preparation. The samples of drill-bit cuttings then were sieved through a screen that had openings of about 5.0-mm to separate the drill-bit cuttings into coarse- and fine-sized fractions. Unsieved drill-bit cuttings were called composite-sized fractions. Coarse drill-bit cuttings were collected from the top of the screen and fine drill-bit cuttings were collected from below the screen. Part of the coarse particle-size fraction was placed in a 113-mL glass jar for temporary storage until water-potential measurements could be done, and another part was placed in a 420-mL moisture can for gravimetric water-content measurements. The lid on the jar was taped and waxed to minimize evaporation losses from the drill-bit cuttings during storage. Measurements of gravimetric water content of samples in moisture cans were started immediately in the onsite laboratory. Coarse drill-bit cuttings were collected from alluvium and welded, nonwelded, and bedded tuffs penetrated in test hole USW UZ-7. Fine drill-bit cuttings were collected from alluvium and densely welded tuffs penetrated in the test hole.

Previous investigations of the shallow unsaturated-zone hydrology of Yucca Mountain in which the same drilling, casing, and coring methods were used have indicated that the water content of core samples correlates more accurately with the water content of coarse drill-bit cuttings than with any other size of drill-bit cuttings (C.L. Loskot and D.P. Hammermeister, U.S. Geological Survey, written commun., 1986). A good correlation or degree of relation (linear-regression coefficient of 0.80) was obtained from the water content of composite core and the water content of coarse drill-bit cuttings from nonwelded and bedded ash-fall tuffs from test hole UE-25 UZ #4 (C.L. Loskot and D.P. Hammermeister, U.S. Geological Survey, written commun., 1986).

C.L. Loskot and D.P. Hammermeister (U.S. Geological Survey, written commun., 1986) also reported that the borehole wall rock tended to dry out when exposed to circulating air for long periods during continuous core runs. This disturbed rind of borehole wall rock was removed when the borehole was enlarged and cased using the Odex 115 drilling system. In test hole USW UZ-7, continuous rotary-core intervals purposely were kept short to minimize the drying of the borehole wall rock before reaming. Coarse drill-bit cuttings have the smallest surface area per unit of volume of any sized fraction and have the smallest chance for the water content to be disturbed by the drilling air. Based on this fact and on information from previous investigations at Yucca Mountain, coarse drill-bit cuttings were the primary particle-size fraction collected from most rock units penetrated by test hole USW UZ-7 that were used for water-content and water-potential measurements. However, samples of fine drill-bit cuttings were obtained from alluvium and from the first few sample depths of welded ash-flow tuffs. These data were added to the data base to help define the distribution of water content between the various-sized fractions of these rock types.

Drive Core

Alluvium samples in brass liners were removed easily by a custom-built core-extrusion device. These samples were removed without further disturbing the volume or density of the samples. However, as previously stated, the actual drive-core process disturbs the in-situ volume-related properties of core samples. The process did yield minimally disturbed samples for gravimetric water-content analysis. For each drive core, one 76-mm-long segment was selected for gravimetric water-content and water-potential measurements; one 76-mm-long segment generally was selected for volumetric water-content, bulk-density, grain-density, and porosity analyses; one 152-mm-long segment was selected for tritium analysis; and two 76-mm-long segments usually were selected for matric-potential and permeability-related measurements. A part of the segment selected for gravimetric water-content and water-potential measurements was sieved into coarse- and fine-sized fractions to determine the distribution of water in the various sized fractions. Sieving was done as described in the "Drill-Bit Cuttings" section. The sample segments in brass liners were capped, taped, waxed, and stored in an air-conditioned environment until additional laboratory measurements, such as matric-potential and permeability-related measurements, could be made. The drive-core-sampling record for test hole USW UZ-7 is listed in table 1.

Table 1.--*Drive-core-sampling record for test hole USW UZ-7*

[A indicates sample for gravimetric water-content and water-potential measurements; B indicates sample for gravimetric and volumetric water-content and physical properties measurements; C indicates sample for tritium analysis; D and E indicate samples for matric-potential and permeability-related measurements.]

Core number	Depth interval (meters)	Core length (meter)	Core recovered (meter)	Core-sampling records
1	1.53 to 2.13	0.60	0.60	A B C D E
2	3.05 to 3.66	.61	.61	A B C D E
3	4.57 to 5.18	.61	.61	A B C D E
4	6.10 to 6.71	.61	.61	A B C D E

Rotary Core

A 1.52-m-long, triple-tube core barrel, which has a split tube inside an inner tube, was used to obtain a 64-mm-diameter rotary core. An oversized carbide-tipped drag bit or a diamond-tipped bit was used with air to drill the core. After each core operation, the split tube containing core was removed from the core barrel at the drill site, immediately taken to the onsite laboratory, and placed in a humidified glove box for processing. The first step included an examination of the natural fractures in the core, which were then described, followed by a preliminary description of lithology. The next step included the removal of several core segments from the split tube for laboratory analysis. For a split tube full of core, two segments about 76-mm-long were removed from the bottom and from about 760 mm above the bottom of the split tube for gravimetric water-content and water-potential measurements. Additionally, two 76-mm-long and two 152-mm-long core segments also were obtained from the bottom and midsections of the split tube. Of these segments, the two smaller segments were designated for future matric-potential measurements and the two larger segments for future physical-property and permeability-related measurements. These segments and any other remaining core segments were placed in several split polyvinyl-chloride (PVC) liners (64-mm inside diameter), capped, taped, waxed, labeled, and stored in an air-conditioned environment until laboratory tests could be done. For a less than full split tube, the segment sizes and number collected depended on the length of core recovered. For example, if the split tube was only one-half filled, then only one set of segments was collected rather than two sets for a full split tube.

The rotary-core-sampling record for test hole USW UZ-7 is summarized in table 2. Thirty-four cores were collected; a total of 33.68 m of rock was cored. Core recovery was 33.03 m, which is a 98-percent recovery; 27 cores had 100-percent recovery. Rotary cores were continuously collected from partially welded to nonwelded ash-flow tuffs and from bedded, reworked, and nonwelded ash-fall tuffs and were selectively collected from welded ash-flow tuffs. Six core recoveries (table 2) were longer than the length of the core barrel. This additional core projected out of the open bottom end of the core barrel. Extra core can be recovered during continuous coring because the cored rock does not always break off at the end of the cored interval. The cored rock may break off above the total depth of coring; when this occurs, a stub of core remains in the borehole as the core barrel is brought to the land surface. This core stub then is recovered when the next cored interval of rock is recovered after the next core run. This core recovery may be longer than the cored interval and core barrel.

GEOPHYSICAL LOGS

Not all of the geophysical surveys for test hole USW UZ-7 have been completed. Borehole-television and neutron moisture-meter logs are available from the U.S. Geological Survey.

LITHOLOGY

A lithologic log of the alluvium of Quaternary age and of the volcanic rocks of Tertiary age that were penetrated during the drilling of test hole USW UZ-7 was made from drill-bit cuttings, drive cores, and rotary cores and is listed in table 3. Welded ash-flow tuff is the predominant rock type penetrated. Bedded, reworked, and nonwelded ash-fall tuffs are present between the two major ash-flow tuffs. These tuffs have various degrees of welding and induration, as described in table 3.

SAMPLE-TESTING PROCEDURES AND RESULTS

Cores and drill-bit cuttings were collected for five types of laboratory tests: water-content and water-potential measurements, bulk-density and grain-density measurements, and tritium analysis. Porosity was calculated from bulk density and grain density. These laboratory tests were done at the Nevada Test Site in laboratories near the drill site, at Test Cell C, in Mercury, Nev., and off the Nevada Test Site in Reston, Va. The results of these tests are summarized in tables in this report.

Table 2.--*Rotary-core-sampling record for test hole USW UZ-7*

[A indicates samples for gravimetric water-content and water-potential measurements; B indicates samples for matric-potential measurements; and C,D,E, indicate samples for physical-property and permeability-related measurements]

Core number	Depth interval (meters)	Core length (meters)	Core recovered (meters)	Core-sampling records
1	11.28 to 11.61	0.33	0.33	A C D
2	14.33 to 14.94	.61	.36	A D E
3	18.90 to 19.20	.30	.30	A E
4	21.95 to 22.25	.30	.30	A D E
5	25.60 to 26.21	.61	.49	A B C D E
6	28.04 to 28.96	.92	.85	A B C D E
7	28.96 to 29.87	.91	.88	A B D E
8	29.87 to 31.21	1.34	1.34	A B C D E
9	31.21 to 32.16	.95	.95	A B C D E
10	32.16 to 33.59	1.43	1.43	A B C D E
11	33.59 to 35.07	1.48	1.48	A B C D E
12	35.07 to 36.59	1.52	1.52	A B C D E
13	36.59 to 36.97	.38	.38	A B C D
14	37.19 to 38.77	1.58	1.58	A B C D E
15	38.77 to 40.08	1.31	1.31	A B C D E
16	40.08 to 41.53	1.45	1.45	A B C D E
17	41.53 to 43.11	1.58	1.49	A B C D E
18	43.11 to 44.15	1.04	1.04	A B C D E
19	44.15 to 45.71	1.56	1.56	A B C D E
20	45.71 to 47.29	1.58	1.58	A B C D E
21	47.29 to 48.78	1.49	1.49	A B C D E
22	48.78 to 50.37	1.59	1.59	A B C D E
23	50.37 to 51.95	1.58	1.58	A B C D E
24	51.95 to 52.84	.89	.89	A B C D E
25	52.84 to 52.99	.15	.15	E
26	52.99 to 53.14	.15	.15	E
27	53.14 to 53.90	.76	.76	A B C D E
28	53.90 to 54.15	.25	.25	E
29	54.15 to 55.09	.94	.94	A B C D E
30	55.09 to 55.25	.16	.16	E
31	56.39 to 57.91	1.52	1.51	A B C D E
32	57.91 to 59.10	1.19	1.19	A B C D E
33	59.10 to 59.94	.84	.84	A B C D E
34	59.94 to 60.96	1.02	.91	A B C D E

Table 3.--*Lithologic log for test hole USW UZ-7*

[Modified from a condensed log by R.W. Spengler, U.S. Geological Survey, written commun., 1985]

Stratigraphy and lithologic description	Thickness of interval (meters)	Depth of interval (meters)
Alluvium of Quaternary age	6.71	0 to 6.71
Paintbrush Tuff of Tertiary age		
Tiva Canyon Member (6.71 to 34.75 meters)		
Tuff, ash-flow, densely welded, devitrified	12.19	6.71 to 18.90
Tuff, ash-flow, moderately to densely welded, devitrified (slightly glassy)	6.09	18.90 to 24.99
Tuff, ash-flow, moderately welded, vitric (slightly argillic)	2.44	24.99 to 27.43
Tuff, ash-flow, partially welded to nonwelded, vitric	7.32	27.43 to 34.75
Bedded tuff (unnamed, but informally referred to as the upper unit of bedded tuff in this report, 34.75 to 40.66 meters)		
Tuff, reworked, moderately indurated, moderately sorted, vitric	.61	34.75 to 35.36
Tuff, ash-fall, moderately indurated, moderately to well sorted, vitric	.91	35.36 to 36.27
Tuff, ash-fall, slightly indurated, slightly sorted, vitric, slightly argillic	2.44	36.27 to 38.71
Tuff, reworked, moderately indurated, slightly to moderately sorted, vitric	1.89	38.71 to 40.60
Tuff, ash-fall, slightly indurated, moderately sorted, vitric	.06	40.60 to 40.66
Pah Canyon Member (40.66 to 42.00 meters)		
Tuff, ash-flow, nonwelded, vitric	1.34	40.66 to 42.00
Bedded tuff (unnamed, but informally referred to as the lower unit of bedded tuff in this report, 42.00 to 48.77 meters)		
Tuff, ash-fall, reworked from 42.92 to 42.98 meters, moderately indurated, vitric	1.59	42.00 to 43.59
Tuff, ash-fall, slightly indurated, slightly sorted, vitric	5.18	43.59 to 48.77
Topopah Spring Member (48.77 to 62.94 meters)		
Tuff, ash-fall (?), nonwelded, vitric	2.13	48.77 to 50.90
Tuff, ash-fall, well indurated [fused (?)], vitric	1.53	50.90 to 52.43
Tuff, ash-flow, densely welded, vitrophyre	1.67	52.43 to 54.10
Tuff, ash-flow, densely welded, devitrified	1.98	54.10 to 56.08
Tuff, ash-flow, moderately welded, vapor-phase crystallization	6.86	56.08 to 62.94
	Total depth	62.94 meters

Water-Content Measurements

Gravimetric water-content measurements were done in the U.S. Geological Survey onsite laboratory at the drill site using standard gravimetric oven-drying methods (Gardner, 1965), as described in a method for monitoring moisture content of drill-bit cuttings from unsaturated zone (C.M. McBride, U.S. Geological Survey, written commun., 1985) and as described in a method for hydrologic-laboratory testing of core and drilling-cutting samples from unsaturated-zone test holes (C.M. McBride, U.S. Geological Survey, written commun., 1985). The results of gravimetric water-content measurements of samples of drive cores, rotary cores, and drill-bit cuttings are summarized in tables 4, 5, and 6 and are shown in figures 3 and 4.

Table 4.--*Results of laboratory analyses for hydrologic properties of drive cores from test hole USW UZ-7*

[Dashes indicate no data]

Depth interval (meters)	Gravimetric water content (gram per gram)			Water potential (kilopascals)	
	Composite-sized fraction	Coarse-sized fraction	Fine-sized fraction	Composite-sized fraction	Coarse-sized fraction
1.52 to 2.13	0.058	--	0.081	--	-450
1.83 to 1.91	.067	--	--	--	-300
3.12 to 3.28	.050	0.049	.087	-500	-510
4.65 to 4.80	.024	.027	.051	-1,800	-2,600
6.17 to 6.32	.031	.025	.038	-3,100	-5,500

Table 5.--*Results of laboratory analyses for hydrologic properties of rotary cores from test hole USW UZ-7*

[Dashes indicate no data]

Depth interval (meters)	Gravimetric water content (gram per gram)	Water potential (kilopascals)
11.28 to 11.43	0.019	-2,400
14.33 to 14.42	.022	-1,500
19.05 to 19.20	.018	-2,900
22.04 to 22.19	.024	-8,700
25.74 to 25.82	.048	-320
28.21 to 28.29	.059	-5,600
28.59 to 28.67	.055	-900
29.29 to 29.35	.084	-4,000
29.75 to 29.84	.118	-600
30.48 to 30.57	.138	-530

Table 5.--*Results of laboratory analyses for hydrologic properties of rotary cores from test hole USW UZ-7*--Continued

Depth interval (meters)	Gravimetric water content (gram per gram)	Water potential (kilopascals)
30.92 to 31.01	0.186	-520
31.33 to 31.43	.200	-440
31.65 to 31.78	.194	-590
32.00 to 32.43	.242	-460
32.83 to 33.12	.285	-430
33.97 to 34.09	.333	-490
34.58 to 34.70	.267	-510
35.14 to 35.28	.238	-460
36.13 to 36.24	.394	-470
36.58 to 36.67	.244	-480
37.64 to 37.75	.204	-400
38.45 to 38.53	.258	-540
39.00 to 39.08	.188	-430
39.75 to 39.81	.233	-370
40.58 to 40.66	.390	-410
41.45 to 41.53	.370	-470
42.00 to 42.08	.405	-300
43.42 to 43.48	.222	-360
43.42 to 43.48	.461	-350
44.39 to 44.47	.277	-450
45.23 to 45.31	.275	-310
46.15 to 46.22	.262	-280
46.91 to 47.00	.254	-320
47.92 to 48.56	.265	-260
48.49 to 48.56	.291	-300
49.45 to 49.55	.269	-300
50.00 to 50.08	.324	-360
50.52 to 50.67	.243	-290
51.59 to 51.65	.239	-360
52.72 to 52.79	.030	-340
53.31 to 53.36	--	-710
53.49 to 53.58	.013	-2,900
54.21 to 54.32	.018	-11,000
56.59 to 56.67	.022	-530
57.81 to 57.90	.035	-440
58.11 to 58.19	.032	-750
58.83 to 59.02	.036	-580
59.51 to 59.59	.035	-520
60.61 to 60.78	.035	-510

Table 6.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings from test hole USW UZ-7*

[Dashes indicate no data]

Depth (meters)	Gravimetric water content (gram per gram) of coarse drill-bit cuttings	Gravimetric water content (gram per gram) of fine drill-bit cuttings	Water potential (kilopascals) of coarse drill-bit cuttings
0.31	0.072	0.069	-390
.91	.084	.067	-480
1.37	.063	.076	-470
1.83	.062	.072	-500
2.29	.061	.063	-400
2.74	.053	.061	-460
3.35	.055	.062	-510
3.96	.045	.051	-710
4.57	.026	.036	-3,800
5.18	.022	.030	-5,600
5.79	.025	.028	-5,400
6.40	--	--	-4,700
7.01	.022	.025	-6,600
7.62	.019	.024	-7,000
8.23	.018	.018	-10,000
8.84	.027	.067	-5,900
9.45	.017	--	-7,500
10.06	.019	--	-7,700
10.52	.020	--	-7,800
10.97	.021	--	-7,200
11.43	.020	--	-5,300
11.89	.020	--	-7,500
12.50	.022	--	-5,700
13.11	.023	--	-5,000
13.72	.022	--	-5,500
14.17	.026	--	-3,200
14.63	.019	--	-5,000
15.09	.021	--	-5,300
15.55	.021	--	-4,200
16.15	.021	--	-4,500
16.76	.026	--	-1,000
17.22	.020	--	-3,400
17.68	.019	--	-4,200
18.29	.019	--	-3,100
18.75	.019	--	-2,200

Table 6.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings from test hole USW UZ-7*--Continued

Depth (meters)	Gravimetric water content (gram per gram)		Water potential (kilopascals)
	of coarse drill-bit cuttings	of fine drill-bit cuttings	of coarse drill-bit cuttings
19.05	0.013	--	-6,900
19.36	.019	--	-3,500
19.81	.021	--	-3,400
20.42	.024	--	-2,300
21.03	.019	--	-2,500
21.64	.017	--	-5,000
22.10	.018	--	-3,300
22.56	.024	--	-4,800
23.01	.022	--	-4,500
23.47	.024	--	-3,000
24.08	.022	--	-4,600
24.69	.024	--	-3,900
25.30	.029	--	-3,600
25.91	.036	--	-5,000
26.52	.039	--	-5,900
27.13	.065	--	-6,900
27.74	.077	--	-5,600
28.35	.092	--	-6,100
28.96	.090	--	-7,500
29.42	.097	--	-10,000
29.41	.113	--	-8,300
30.18	.150	--	-2,400
30.79	.183	--	-1,000
31.39	.218	--	-820
32.00	.201	--	-1,000
32.46	.213	--	-350
32.77	.219	--	-400
33.22	.248	--	-320
33.83	.250	--	-310
34.44	.250	--	-370
35.05	.275	--	-320
35.36	.303	--	-330
35.97	.328	--	-450
36.58	.388	--	-430
37.03	.285	--	-390

Table 6.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings from test hole USW UZ-7*--Continued

Depth (meters)	Gravimetric water content (gram per gram) of coarse drill-bit cuttings	Gravimetric water content (gram per gram) of fine drill-bit cuttings	Water potential (kilopascals) of coarse drill-bit cuttings
38.41	0.211	--	-530
39.01	.215	--	-460
39.78	.183	--	-470
40.54	.246	--	-330
41.15	.294	--	-370
41.91	.255	--	-290
42.37	.195	--	-320
42.98	.382	--	-270
43.59	--	--	-490
44.20	.264	--	-500
44.65	.242	--	-540
44.96	.213	--	-730
45.42	.196	--	-1,100
46.03	.223	--	-360
46.63	.234	--	-310
47.24	.248	--	-320
47.70	.220	--	-260
48.01	.192	--	-350
48.46	.209	--	-290
49.07	.242	--	-300
49.68	.218	--	-250
50.29	.202	--	-300
50.75	.256	--	-280
51.05	.232	--	-360
51.51	.201	--	-290
52.12	.176	--	-370
52.73	.050	--	-8,300
53.34	.009	--	-17,000
53.80	.006	--	-17,000
54.10	.007	--	-17,000
54.56	.010	--	-5,300
55.17	.014	--	-7,800
55.78	.008	--	-5,400
56.24	.017	--	-830
56.69	--	--	-380

Table 6.--*Results of laboratory analyses for hydrologic properties of drill-bit cuttings from test hole USW UZ-7*--Continued

Depth (meters)	Gravimetric water content (gram per gram) of coarse drill-bit cuttings	Gravimetric water content (gram per gram) of fine drill-bit cuttings	Water potential (kilopascals) of coarse drill-bit cuttings
57.15	0.019	--	-1,100
57.61	.026	--	-930
58.22	.026	--	-970
58.83	.024	--	-3,000
59.44	.025	--	-2,000
59.89	.026	--	-2,200
60.20	.024	--	-2,600
60.66	.026	--	-1,500
61.87	.031	--	-1,100
62.48	.030	--	-1,000
62.94	.031	--	-1,100

Generally, especially for deeper sample depths, the gravimetric water-content measurements of drive and rotary cores were consistently larger than the same measurements of coarse drill-bit cuttings (figs. 3 and 4). Linear regression analysis indicate a good correlation (coefficient of determination, r^2 = 0.808) between the gravimetric water content of rotary cores and that of coarse drill-bit cuttings (table 7). A comparison of the gravimetric water content of the various fractions (composite, coarse, and fine) from the drive cores, for the same or nearby depth intervals, indicated that the measured water content was always larger for the fine-sized fraction, but it was quite similar for the composite and coarse-sized fractions (fig. 3). The differences in water content of rotary cores compared to that of drill-bit cuttings at the same depths were as much as 0.150 g/g and as small as 0.001 g/g; generally, the differences were less than 0.050 g/g for most measurements. These differences probably are due to the drying of the borehole wall rock during rotary coring and to the drying that occurs when the thin (about 25 mm) rind of formation is removed from the borehole wall during the reaming process.

The gravimetric water content of volcanic tuffs probably is directly related to the degree of welding. The relation of the gravimetric water content of drive and rotary cores and of coarse drill-bit cuttings to the lithology and degree of welding of rocks penetrated in test hole USW UZ-7 are summarized in tables 8 and 9. The water content of the cores was the least disturbed during drilling and is, therefore, the most representative of in-situ hydrologic conditions. Fine and coarse drill-bit cuttings and composite-, fine-, and coarse-sized fractions of drive cores also were analyzed. A complete sampling record for these drill-bit cuttings was available, whereas several gaps existed in the sampling record for the drive and rotary cores.

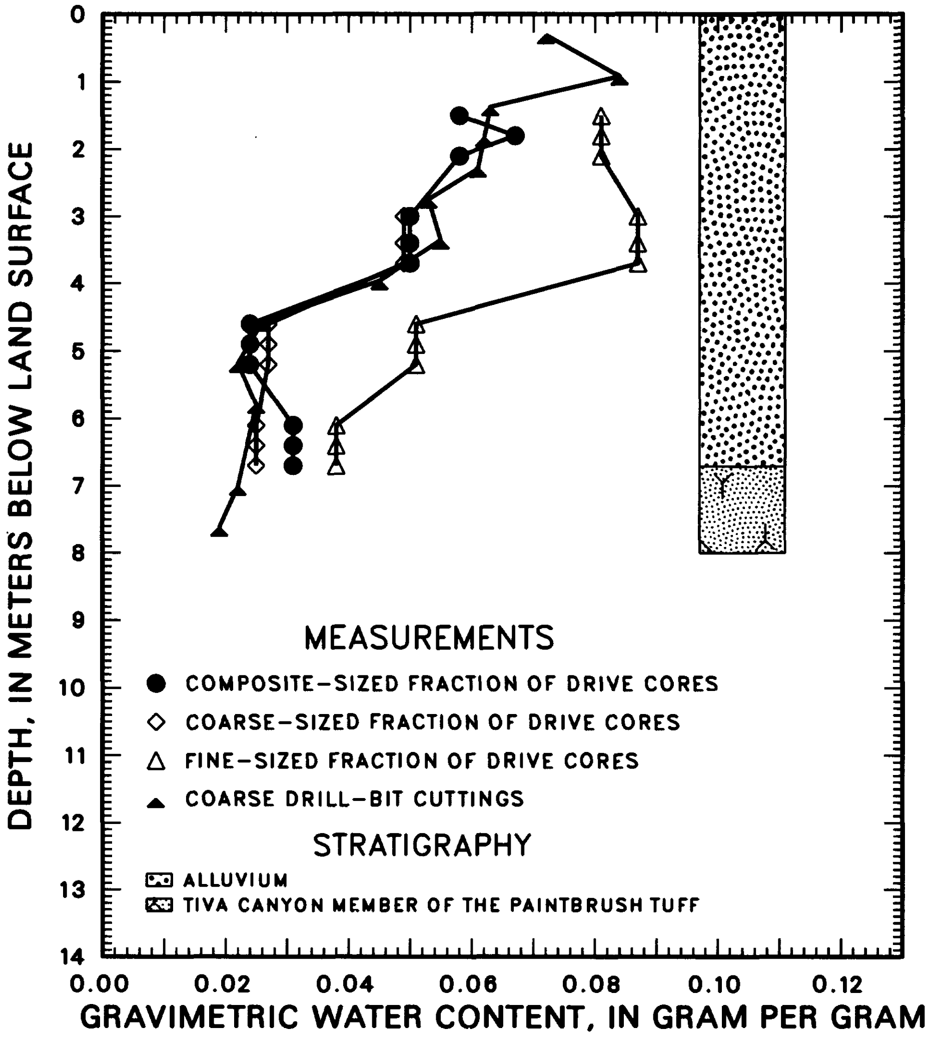

Figure 3.--Gravimetric water-content measurements and stratigraphy of drive cores and coarse drill-bit cuttings from test hole USW UZ-7.

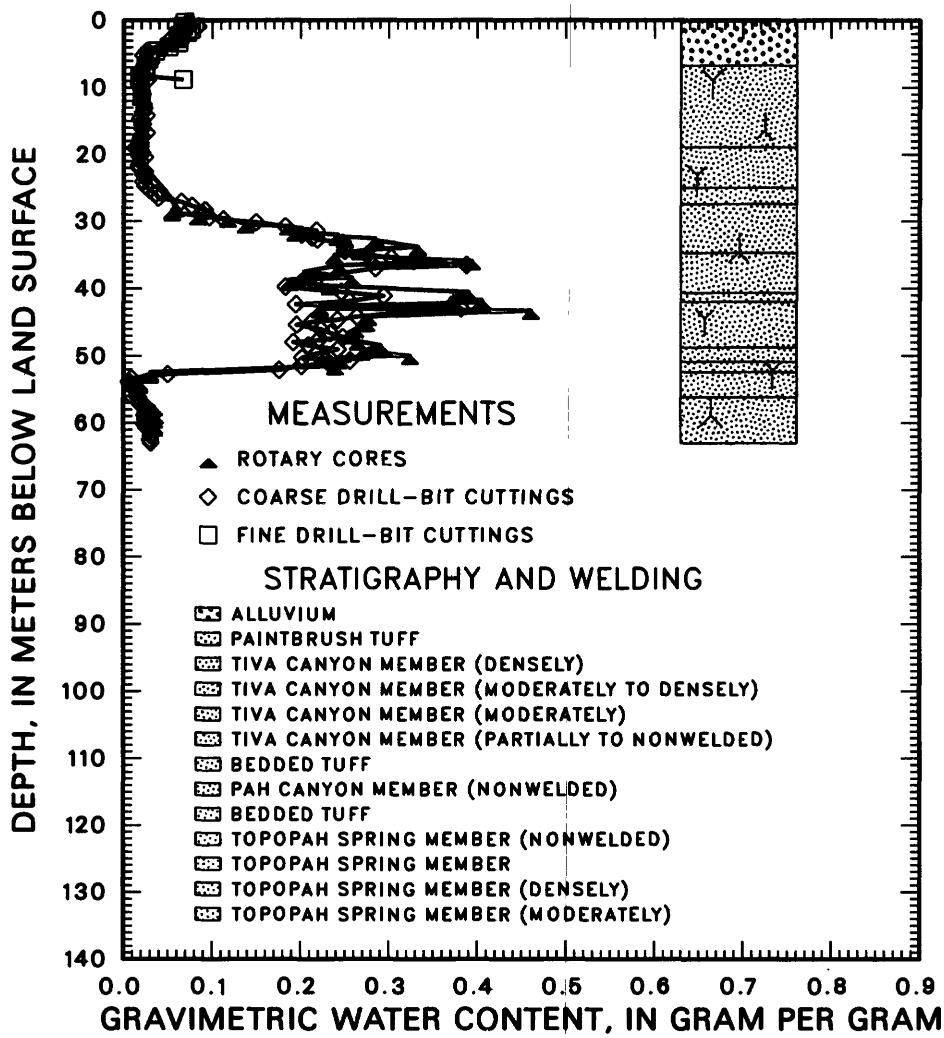

Figure 4.--Gravimetric water-content measurements, stratigraphy, and welding of rotary cores and drill-bit cuttings from test hole USW UZ-7.

Table 7.--*Summary of linear-regression analysis of gravimetric water content of rotary cores versus drill-bit cuttings from test hole USW UZ-7*

[Y = a + bX; dependent variable, Y; gravimetric water content of rotary cores from welded, partially welded to nonwelded, and bedded tuffs; independent variable, X; gravimetric water content of coarse drill-bit cuttings from welded, partially welded to nonwelded, and bedded tuffs]

Number of data points, n	Coefficient of determination, r^2	Intercept a	Slope b
47	0.808	0.02	0.78

Gravimetric and volumetric water-content measurements were made on selected, intact drive-core segments by Holmes & Narver Materials Testing Laboratory, Mercury, Nev. The results of the measurements are listed in the following table:

Depth interval (meters)	Water content	
	Gravimetric (gram per gram)	Volumetric (cubic centimeter per cubic centimeter)
1.68 to 1.75	0.077	0.143
3.28 to 3.35	.071	.116
4.80 to 4.88	.044	.085
6.25 to 6.40	.036	.064

Because of the disturbing effects of the drive-core process on porosity, the volumetric water-content data probably does not represent in-situ conditions.

The densely welded ash-flow tuffs have the smallest average gravimetric water content, and the nonwelded and bedded ash-fall tuffs have the largest average gravimetric water content. The few data from moderately welded samples have average gravimetric water-content values between these extremes. The largest gravimetric water content (0.461 g/g) was for ash-fall tuffs in the lower unit of the bedded tuff of the Paintbrush Tuff, and the smallest gravimetric water content (less than 0.020 g/g) was for the densely welded ash-flow tuffs of the Tiva Canyon and Topopah Spring Members of the Paintbrush Tuff (table 8). Similar trends were determined for the gravimetric water-content data of coarse drill-bit cuttings (table 9).

Water-Potential Measurements

Water-potential measurements were made in accordance with the methods describing hydrologic laboratory testing of core and drilling-cuttings samples

Table 8.--*Summary of gravimetric water-content and water-potential measurements for drive and rotary cores from different lithologic units penetrated in test hole USW UZ-7, and degree of welding*

Lithologic unit	Gravimetric water content (gram per gram)			Water potential (kilopascals)			Degree of welding
	Range	Arithmetic mean average	Median	Range	Arithmetic mean average	Median	
Alluvium	0.024 to 0.087	0.046	0.050	-300 to -5,500	-1,900	-510	Not applicable
Paintbrush Tuff							
Tiva Canyon Member	.018 to .024	.021	.021	-1,500 to -8,700	-3,900	-2,700	Densely welded
	[1].048	.048	.048	[1]-320	-320	-320	Moderately welded
	.055 to .333	.180	.190	-430 to -5,600	-1,300	-530	Partially welded to nonwelded
Bedded Tuff	.188 to .390	.269	.275	-260 to -450	-330	-310	Not applicable
Pah Canyon Member	[1].370	.370	.370	[1]-470	-470	-470	Nonwelded
Bedded Tuff	.222 to .461	.301	.275	-260 to -450	-330	-310	Not applicable
Topopah Spring Member	.239 to .324	.269	.256	-290 to -360	-330	-330	Nonwelded
	.013 to .030	.020	.018	-340 to -11,000	-3,700	-1,800	Densely welded
	.022 to .036	.033	.035	-440 to -750	-560	-530	Moderately welded

[1]One sample.

Table 9.--*Summary of gravimetric water-content and water-potential measurements for coarse drill-bit cuttings from different lithologic units penetrated in test hole USW UZ-7, and degree of welding*

Lithologic unit	Gravimetric water content (gram per gram)			Water potential (kilopascals)			Degree of welding
	Range	Arithmetic mean average	Median	Range	Arithmetic mean average	Median	
Alluvium	0.022 to 0.084	0.052	0.055	-390 to -5,600	-2,000	-510	Not applicable
Paintbrush Tuff							
Tiva Canyon Member	.013 to .027	.027	.020	-1,000 to -10,000	-4,900	-4,200	Densely welded
	.029 to .065	.042	.038	-3,600 to -6,900	-5,300	-5,500	Moderately welded
	.077 to .250	.172	.192	-310 to -10,000	-3,200	-1,000	Partially welded to nonwelded
Bedded Tuff	.183 to .388	.270	.275	-320 to -530	-410	-430	Not applicable
Pah Canyon Member	.255 to .294	.275	.275	-290 to -370	-330	-330	Nonwelded
Bedded Tuff	.192 to .382	.235	.222	-260 to -1,100	-450	-350	Not applicable
Topopah Spring Member	.176 to .256	.218	.218	-250 to -370	-310	-300	Nonwelded
	.006 to .050	.015	.009	-5,300 to -17,000	-11,100	-8,300	Densely welded
	.017 to .026	.022	.023	-380 to -1,100	-840	-930	Moderately welded

from unsaturated-zone test holes (C.M. McBride, U.S. Geological Survey, written commun., 1985). Water potential (Rawlins, 1966; Brown, 1970; Phene and others, 1971) is the sum of the matric and osmotic potentials. Water potential was measured during this investigation using a SC-10 thermocouple psychrometer and a NT-3 nanovoltmeter (Decagon Devices, Pullman, Wash.). 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, 1942; Richards and Ogata, 1958) was used to apply water to the thermocouple junction for the measurements described here. Calibration solutions were measured concurrently with the actual rock samples to compensate for the zero drift of the amplifier of the nanovoltmeter. Generally, three of the sample chambers contained calibration solutions equivalent to known water potentials; six of the sample chambers contained samples of drive and rotary cores or drill-bit cuttings, or both; and the remaining chamber contained distilled water. Thermocouple output (voltage) was measured first for the known calibration standards, second for the output from rock samples, and third for the output from the calibration standards again. The average of the before-and-after outputs for each calibration standard was used to determine the calibration curve. Calibration curves of water potential versus output were nearly linear from about -100 to -7,000 kPa. Regression coefficients ranged from 0.994 to 1.000; most coefficients were equal to 1.000. The water potential was measured in negative bars (bar = 100 kPa) but was converted to negative kilopascals for this report.

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 0.5 hour passed to enable temperature and vapor to achieve equilibrium before measurements were made. To avoid temperature fluctuations, all measurements were made inside the glove box at room temperature between 20 and 25 °C. All equipment, including the thermocouple junction, was meticulously cleaned after each set of measurements to prevent carryover of salts or dust to the next set of measurements.

The results of water-potential measurements are summarized in tables 4, 5, 6, 8, and 9, and are shown in figures 5 and 6. A comparison of measurements of water potential versus drill-bit-cuttings texture (composite-, coarse-, and fine-sized fractions) for the same depth interval indicated that the values of water potential always were more negative (less water content) for the coarse-sized fraction than for the composite- and fine-sized fractions of drill-bit cuttings. The differences were as much as -2,400 kPa. Linear--regression analysis indicated a poor correlation (coefficient of determination, $r^2 = 0.53$, in table 10) between the water potential of the rotary cores and coarse drill-bit cuttings.

The differences between the water potential of drive and rotary cores and that of coarse drill-bit cuttings are shown in figures 5 and 6. Generally for the same depths, the water-potential values are less negative for coarse drill-bit cuttings than for drive and rotary cores. These differences are even more noticeable than for gravimetric water content. The differences in the values were as much as -16,300 kPa; but, for most of the values, the differences were less than -500 kPa. The large differences in value were expected between the water potential of drive and rotary cores and the differences in the water potential of drill-bit cuttings obtained from the

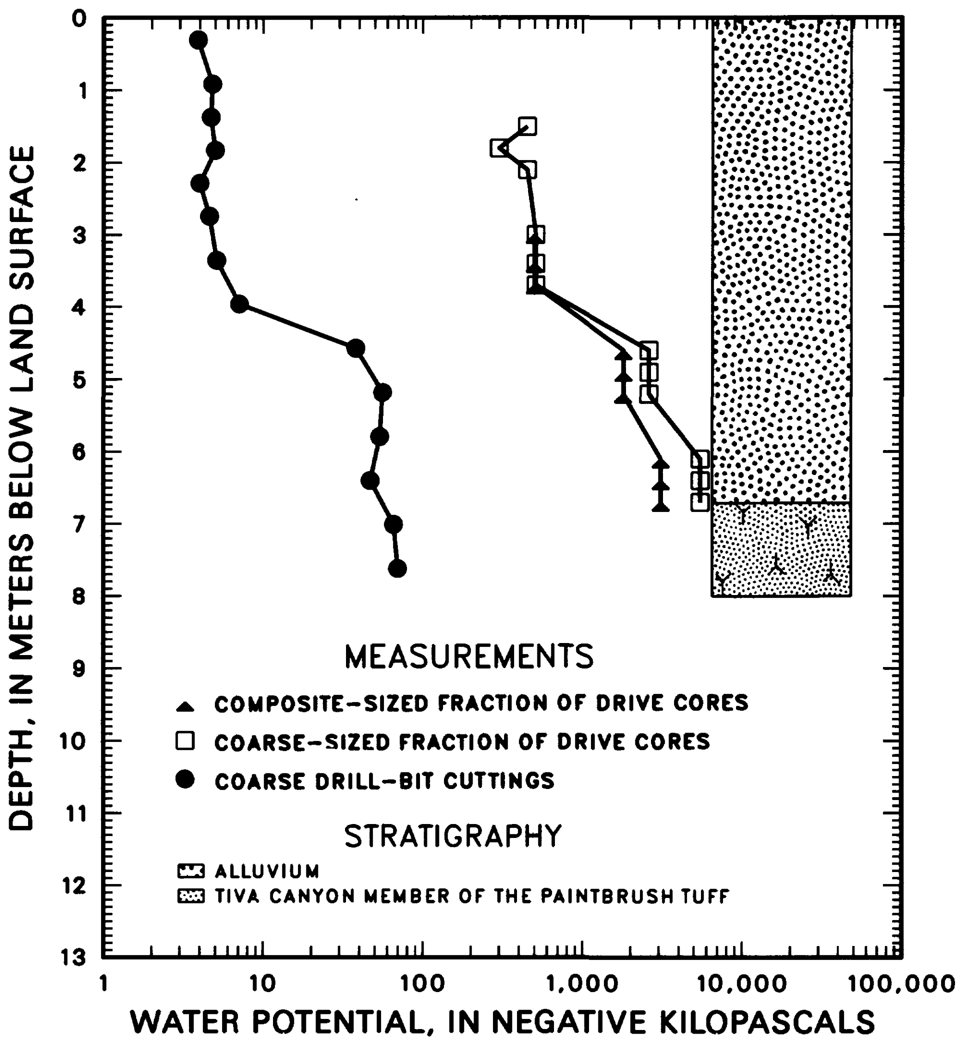

Figure 5.--Water-potential measurements and stratigraphy of drive cores and coarse drill-bit cuttings from test hole USW UZ-7.

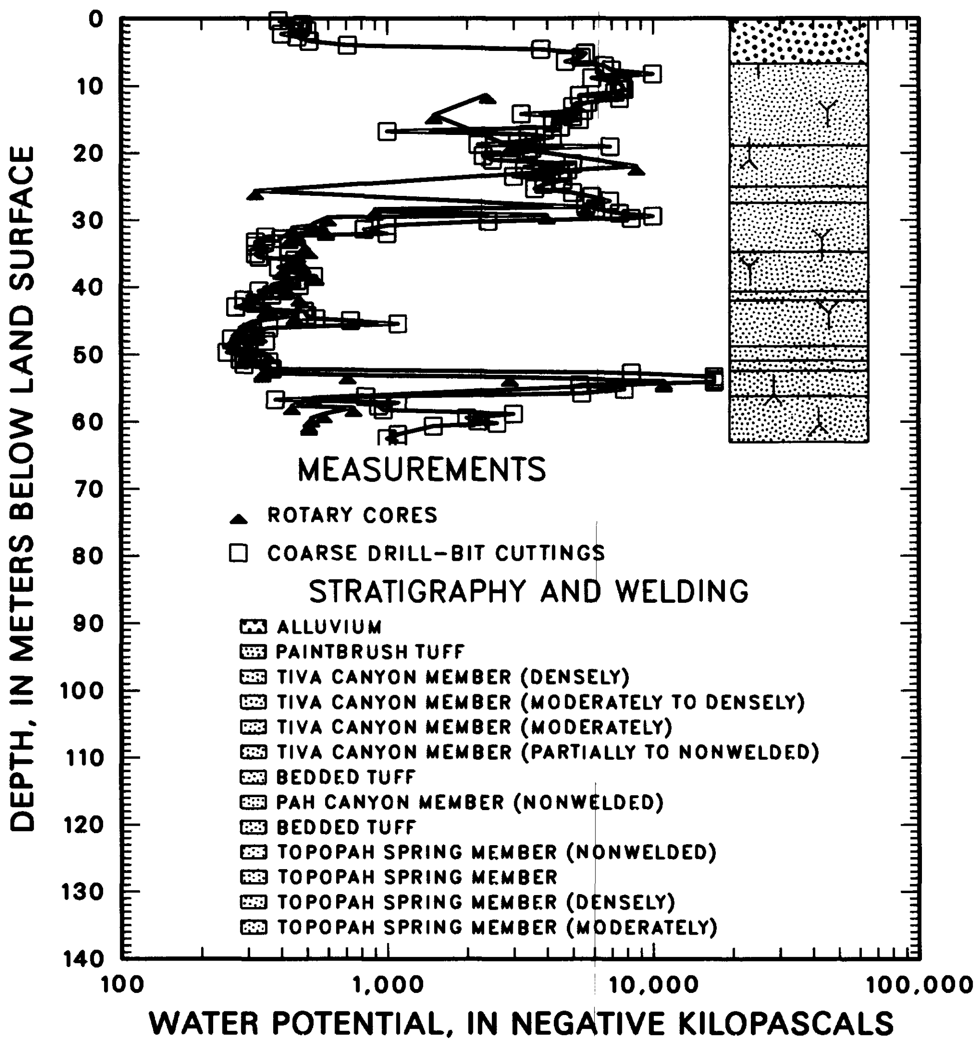

Figure 6.--Water-potential measurements, stratigraphy, and welding of rotary cores and coarse drill-bit cuttings from test hole USW UZ-7.

Table 10.--*Summary of linear-regression analysis of water potential of rotary cores versus drill-bit cuttings from test hole USW UZ-7*

[Y = a + bX; dependent variable, Y; water potential of rotary cores from welded, partially welded to nonwelded, and bedded tuffs; independent variable, X; water potential of coarse drill-bit cuttings from welded, partially welded to nonwelded, and bedded tuffs]

Number of data points, n	Coefficient of determination, r^2	Intercept, a	Slope, b
52	0.53	-4.82	0.21

same approximate depth. Data in this report indicate that some drying of drill-bit cuttings does occur for various reasons. Water potential is dependent (nonlinear) on water content and, in many instances, a small change in water content caused by drying can result in a large change in water potential. This phenomenon is discussed in more detail by Hammermeister and others (1986).

A comparison was made of the water potential of geologic samples (tables 8 and 9) between the various lithologic units penetrated in test hole USW UZ-7. The comparison indicated that trends in the water-potential data are similar to trends of water-content data. Water potentials of tuffaceous samples generally decrease with increasing welding. The most negative values were measured of densely and moderately welded ash-flow tuffs; the least negative values were measured of nonwelded ash-fall and ash-flow tuffs and bedded ash-fall tuffs. These trends are noted for both drive and rotary-core data and drill-bit-cuttings data.

Although the water potentials of rotary-core data are the most representative of in-situ hydrologic conditions of the rock units penetrated, coarse drill-bit cuttings also were analyzed. A complete sampling record for these coarse drill-bit cuttings was available.

The densely welded ash-flow tuffs from the Tiva Canyon and Topopah Spring Members of the Paintbrush Tuff were relatively dry, compared to the wetter, moderately welded ash-flow tuffs. The water-potential negative values were small from the relatively wetter nonwelded ash-fall and partially welded to nonwelded ash-flow tuffs and bedded and reworked ash-fall tuffs.

Bulk-Density and Grain-Density Measurements, and Porosity Calculations

Natural and dry-moisture state bulk-density measurements, grain-density measurements, and porosity calculations were made on selected, intact drive-core segments and on the rotary cores by Holmes & Narver Materials Testing Laboratory. Porosity was calculated from bulk density and grain density. The results of these measurements and calculations are summarized for the drive cores in table 11 and for the rotary cores in table 12. Because the drive-

Table 11.--*Results of laboratory analyses of physical properties of drive cores from test hole USW UZ-7*

[Data from Holmes & Narver Materials Testing Laboratory, Mercury, Nev.; dashes indicate no data]

Depth or depth interval (meters)	Bulk density (grams per cubic centimeter)		Grain density (grams per cubic centimeter)	Porosity (cubic centimeter per cubic centimeter)
	Natural moisture state	Dry moisture state		
1.53	--	2.16	2.53	0.146
1.68 to 1.75	1.99	1.85	2.53	.269
1.83	--	2.13	2.49	.145
3.05	2.18	2.16	2.50	.136
3.28 to 3.35	1.75	1.63	2.52	.353
4.57	2.25	2.17	2.50	.132
4.80 to 4.88	2.02	1.94	2.50	.224
6.10	2.28	2.16	2.47	.126
6.25 to 6.40	1.87	1.81	2.50	.276

coring process disturbs the porosity and bulk density of the alluvium samples, these data (table 11) probably are not representative of in-situ formation conditions. Grain-density data are not dependent on porosity and, therefore, reflect in-situ conditions.

Table 12.--*Results of laboratory analyses of physical properties of rotary cores from test hole USW UZ-7*

[Data from Holmes & Narver Materials Testing Labratory, Mercury, Nev.]

Depth (meters)	Bulk density (grams per cubic centimeter)	Grain density (grams per cubic centimeter)	Porosity (cubic centimeter per cubic centimeter)
11.28	2.34	2.42	0.035
14.33	2.34	2.42	.035
19.05	2.35	2.50	.062
22.04	2.28	2.42	.060
25.74	2.15	2.47	.134
28.21	1.99	2.39	.174
28.59	1.98	2.28	.140
29.29	1.94	2.38	.193
29.75	1.84	2.41	.245
30.48	1.65	2.38	.320

Table 12.--*Results of laboratory analyses of physical properties of rotary cores from test hole USW UZ-7*--Continued

Depth (meters)	Bulk density (grams per cubic centimeter)	Grain density (grams per cubic centimeter)	Porosity (cubic centimeter per cubic centimeter)
31.01	1.56	2.40	0.364
31.42	1.40	2.38	.428
31.65	1.39	2.44	.444
32.00	1.34	2.38	.448
32.83	1.31	2.42	.470
33.97	1.26	2.43	.496
34.58	1.39	2.42	.444
35.14	1.39	2.42	.441
36.13	1.19	2.56	.566
36.58	1.51	2.44	.405
37.64	1.40	2.43	.444
38.45	1.37	2.50	.470
39.00	1.54	2.49	.404
39.75	1.42	2.47	.446
40.58	1.04	2.46	.594
41.45	1.08	2.47	.577
42.00	1.06	2.47	.592
42.93	1.45	2.52	.446
43.42	1.06	2.53	.603
44.39	1.13	2.55	.577
45.23	1.05	2.48	.591
46.15	1.16	2.52	.566
46.91	1.11	2.45	.565
47.91	1.09	2.58	.593
48.49	1.11	2.61	.589
49.45	1.08	2.58	.598
50.00	1.03	2.46	.604
50.52	1.21	2.48	.527
50.98	1.35	2.41	.453
52.72	2.21	2.46	.103
53.31	2.34	2.46	.048
53.49	2.40	2.41	.005
54.21	2.15	2.48	.135
56.59	2.06	2.52	.183
57.81	2.17	2.58	.159
58.11	2.15	2.56	.160
58.83	2.12	2.54	.165
59.51	2.13	2.59	.177
60.61	2.15	2.55	.157

A comparison was made between the bulk density, the grain density, and the porosity of drive and rotary cores in the various lithologic units penetrated in test hole USW UZ-7 (tables 13 and 14). Profiles of bulk density and grain density versus depth are shown in figure 7; a profile of porosity versus depth is plotted in figure 8. Porosity values of core samples, like water content and water potential, decrease with increasing welding. Welding directly affects the porosity and pore-size distribution of the rock, which, in turn, affects the volume and the energy of the water held in the porous matrix. Porosity also affects bulk density, which increases (rather than decreases) with increasing welding. The bulk density was largest for the densely welded ash-flow tuffs from the Topopah Spring Member (below a depth of 51 m) and the Tiva Canyon Member (above a depth of 26 m) of the Paintbrush Tuff, was intermediate for moderately welded tuffs from these same members, and was smallest for the nonwelded ash-flow tuffs from the Pah Canyon Member and bedded and reworked ash-fall tuffs from the bedded tuffs (fig. 7, table 13) of the Paintbrush Tuff. The bulk-density trends were opposite to the porosity trends (figs. 7 and 8; tables 13 and 14). The grain density generally was uniform throughout the various lithologic units, but it was slightly larger in the nonwelded ash-fall and partially welded to nonwelded ash-flow tuffs and bedded and reworked ash-fall tuffs than in the welded ash-flow tuffs (fig. 7 and table 13).

Table 13.--*Summary of bulk-density and grain-density measurements from drive and rotary cores in different lithologic units penetrated in test hole USW UZ-7, and degree of welding*

Lithologic unit	Bulk density (grams per cubic centimeter)			Grain density (grams per cubic centimeter)			Degree of welding
	Range	Arithmetic mean average	Median	Range	Arithmetic mean average	Median	
Alluvium	1.75 to 2.28	2.05	2.02	2.47 to 2.53	2.50	2.50	Not applicable
Paintbrush Tuff							
Tiva Canyon Member	2.28 to 2.35	2.33	2.34	2.42 to 2.50	2.44	2.42	Densely welded
	[1]2.15	2.15	2.15	[1]2.47	2.47	2.47	Moderately welded
	1.26 to 1.99	1.59	1.48	2.28 to 2.44	2.39	2.40	Partially welded to nonwelded
Bedded tuff	1.19 to 1.54	1.40	1.40	2.42 to 2.56	2.47	2.47	Not applicable
Pah Canyon Member	1.04 to 1.08	1.06	1.06	2.46 to 2.47	2.47	2.47	Nonwelded
Bedded tuff	1.05 to 1.45	1.15	1.11	2.45 to 2.61	2.53	2.53	Not applicable
Topopah Spring Member	1.03 to 1.35	1.17	1.15	2.41 to 2.58	2.48	2.47	Nonwelded
	2.15 to 2.40	2.28	2.28	2.41 to 2.48	2.45	2.46	Densely welded
	2.06 to 2.17	2.13	2.14	2.52 to 2.58	2.56	2.56	Moderately welded

[1]One sample.

Table 14.--*Summary of porosity calculations from drive and rotary cores in different lithologic units penetrated in test hole USW UZ-7, and degree of welding*

Lithologic unit	Porosity (cubic centimeter per cubic centimeter) Range	Arithmetic mean average	Median	Degree of welding
Alluvium	0.126 to 0.353	0.201	0.146	Not applicable
Paintbrush Tuff				
Tiva Canyon Member	.035 to .062	.048	.048	Densely welded
	[1].134	.134	.134	Moderately welded
	.140 to .496	.347	.396	Partially welded to nonwelded
Bedded tuff	.404 to .594	.471	.445	Not applicable
Pah Canyon Member	.577 to .592	.585	.585	Nonwelded
Bedded tuff	.446 to .603	.566	.583	Not applicable
Topopah Spring Member	.453 to .604	.546	.563	Nonwelded
	.005 to .135	.073	.076	Densely welded
	.157 to .183	.167	.163	Moderately welded

[1]One sample.

Tritium Analyses

Measurements of tritium content of drive cores were made on selected core segments by the U.S. Geological Survey, Reston, Va. The results of the laboratory analyses from test hole USW UZ-7 are summarized in table 15.

Tritium content of the drive cores of alluvium ranged from 12.6 tritium units at a depth of 6.48 to 6.63 m to 47.3 tritium units at a depth of 3.43 to 3.58 m (table 15, fig. 9). All tritium contents were larger than the tritium content generally present in ground water prior to atmospheric testing of nuclear weapons from the early 1950's to the mid 1960's (Freeze and Cherry, 1979). Normal background levels are less than 10 tritium units (Freeze and Cherry, 1979, p. 136-137). These larger tritium contents probably are due to bomb-produced tritiated water entering the unsaturated zone as precipitation on Yucca Mountain. Tritium, therefore, can be used as an environmental tracer to help characterize the infiltration of water at this site during the last 30 years. The tritium data indicate that at least some volume of infiltrating water has percolated to a depth of at least 6.6 m during the past 30 years. The peak tritium content is at a depth of about 3.5 m, indicating that this is an "average" depth reached by the largest volume of pecolating water. It should be noted that tritium has a half-life of 12.26 years, so the content decreases rapidly with time.

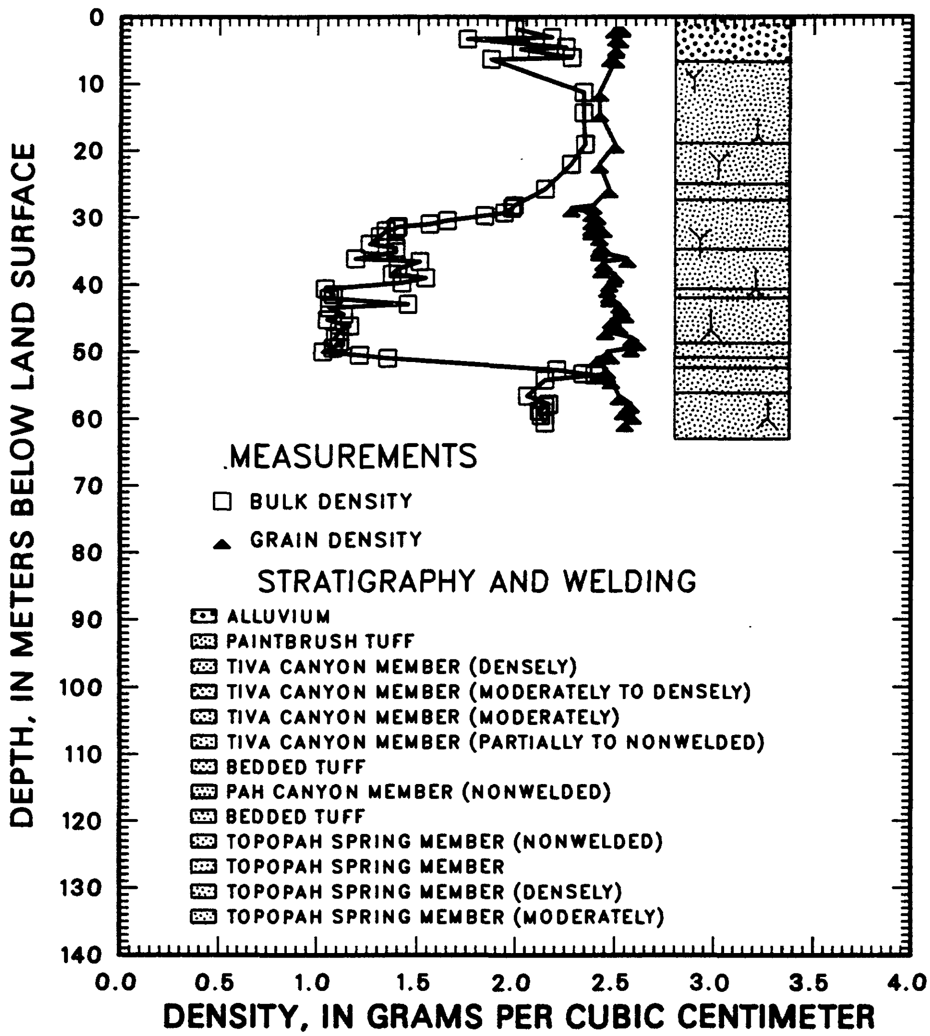

Figure 7.--Bulk-density and grain-density measurements, stratigraphy, and welding of drive and rotary cores from test hole USW UZ-7.

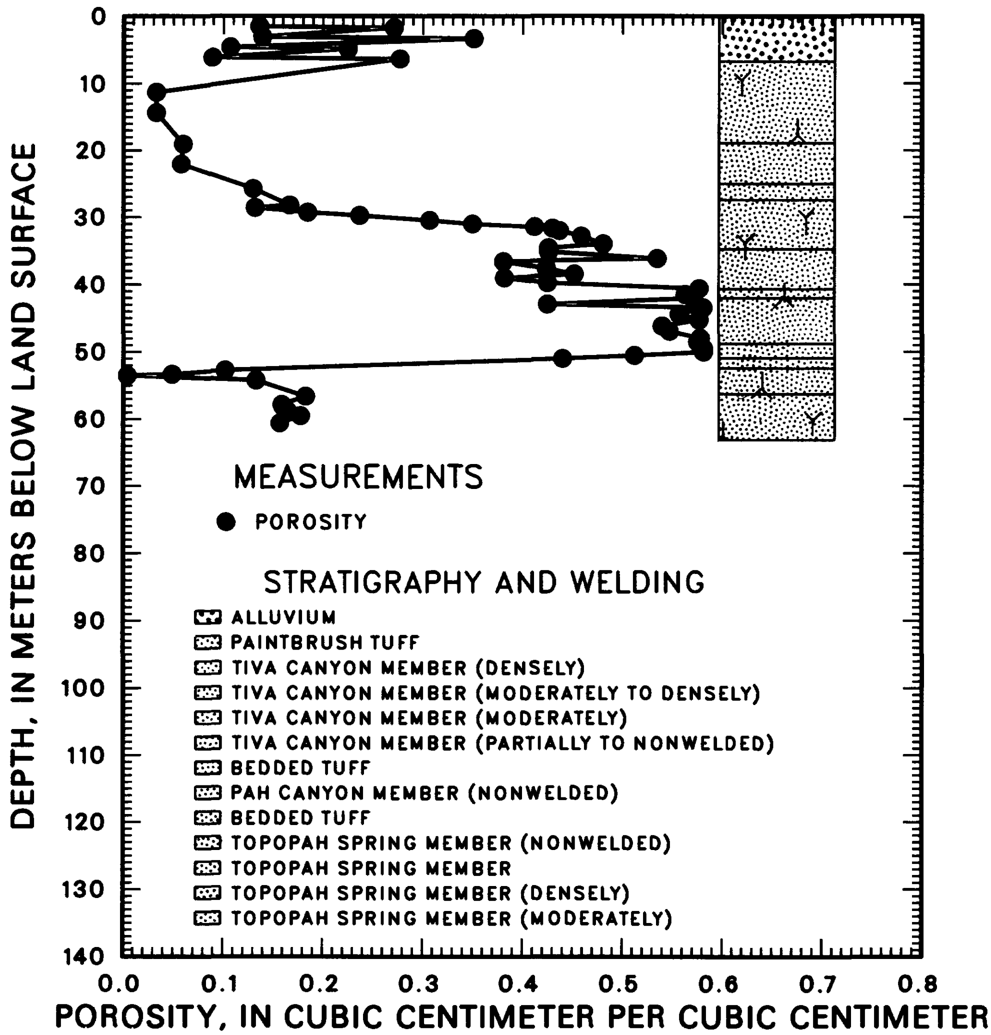

Figure 8.--Porosity calculations, stratigraphy, and welding of drive and rotary cores from test hole USW UZ-7.

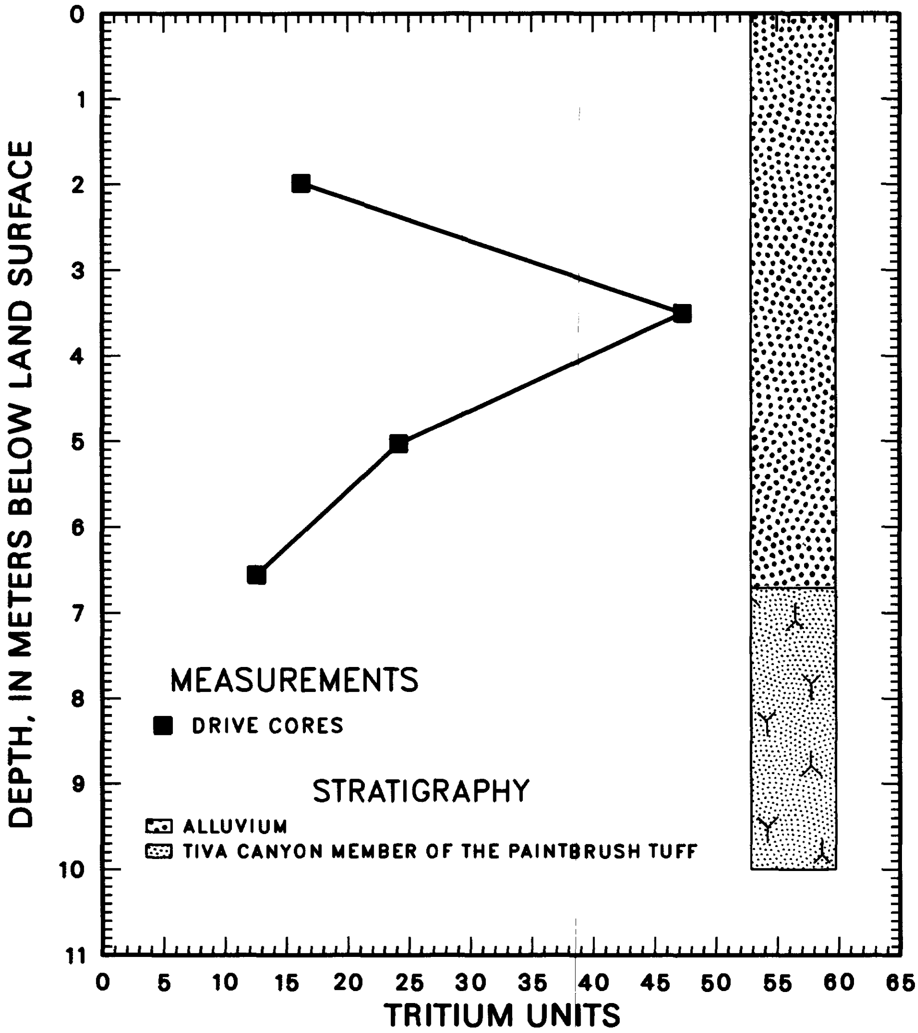

Figure 9.--Tritium-content measurements and stratigraphy of drive cores from test hole USW UZ-7.

Table 15.--*Results of laboratory analyses of tritium of drive cores from test hole USW UZ-7*

[Data from U.S. Geological Survey Tritium Laboratory, Reston, Va.; Decay date, January 8, 1985]

Depth interval (meters)	Tritium (tritium units)	Tritium (picocuries per liter)	Extracted water (gram per gram)
1.91 to 2.06	16.2 ± 0.7	51.7 ± 2.3	0.069
3.43 to 3.58	47.3 ± 2.7	151 ± 9	.059
4.95 to 5.11	24.2 ± 1.2	77.2 ± 3.8	.044
6.48 to 6.63	12.6 ± 0.8	40.3 ± 2.6	.031

SUMMARY AND CONCLUSIONS

Test hole USW UZ-7 was drilled and cored to a total depth of 62.94 m. The drilling was done using air as a drilling fluid to minimize disturbance to the water content of cores, drill-bit cuttings, and borehole wall rock. The unsaturated-zone rock consisted of alluvium, welded and partially welded to nonwelded ash-flow tuff, bedded and reworked ash-fall tuff, nonwelded ash-flow tuff, bedded and reworked ash-fall tuff, nonwelded ash-fall tuff, and welded ash-flow tuff. Alluvium and welded ash-flow tuffs were cored at selected intervals; nonwelded ash-fall and partially welded to nonwelded ash-flow tuffs, and bedded and reworked ash-fall tuffs were continuously cored.

Gravimetric water content and water potential of volcanic tuffs probably are directly related to the degree of welding. The values of gravimetric water content and water potential of drive cores obtained from the alluvium overlying the tuffs were intermediate between the extreme values in welded and nonwelded tuffs. Gravimetric water content of rotary cores was largest for the bedded, reworked and nonwelded ash-fall tuffs and was smallest for densely welded ash-flow tuffs. Water potential of rotary cores was more negative for the densely welded ash-flow tuffs and was less negative for the bedded, reworked and nonwelded ash-fall tuffs.

The data indicate that some drying of the drill-bit cuttings did occur. Gravimetric water-content measurements of drive and rotary cores generally were larger (more water content) than the same measurement of coarse drill-bit cuttings obtained from the same approximate depths. Water-potential measurements of drive and rotary cores generally had more negative values (less water content) than the same measurements of coarse drill-bit cuttings obtained from the same approximate depths.

Physical properties of volcanic tuff were directly related to the degree of welding. Bulk density was largest for the densely welded ash-flow tuffs, was intermediate for alluvium, and was smallest for the nonwelded and bedded and reworked ash-fall tuffs. Grain density was uniform throughout the different lithologic units but was slightly larger for nonwelded and bedded ash-fall tuffs than for welded ash-flow tuffs. Porosity was largest for the nonwelded and bedded and reworked ash-fall tuffs, was quite small for the moderately welded ash-flow tuffs and alluvium, and was smallest for the densely welded ash-flow tuffs.

Tritium content of the drive cores was smallest near the bedrock-alluvium contact, but markedly increased in the middle zone of the alluvium deposit, and then decreased to a much smaller content in the near-surface zone of the alluvium. The zone of larger content probably indicates a buildup from fallout as a result of air testing of nuclear weapons at the Nevada Test Site from the early 1950's to the mid-1960's. The occurrence of this zone represents the maximum depth of vertical migration of the tritium since fallout and may be useful in characterizing the general rate of infiltration of moisture.

REFERENCES CITED

Bentley, C.B., Robison, J.H., and Spengler, R.W., 1983, Geohydrologic data for test well USW H-5, Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey Open-File Report 83-853, 34 p.

Brown, R.W., 1970, Measurement of water potential with thermocouple psychrometers--Construction and applications: Ogden, Utah, U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station, Forest Service Research Paper INT-80, 27 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, 604 p.

Gardner, W.H., 1965, Water content, *in* Black, C.A., ed., Methods of soil analyses--Pt. 1, Physical and mineralogical properties, including statistics of measurement and sampling: Madison, Wis., American Society of Agronomy, Agronomy Series 9, p. 82-127.

Hammermeister, D.P., Blout, D.O., and McDaniel, J.C., 1986, Drilling and coring methods that minimize the disturbance of cuttings, core, and rock formations in the unsaturated zone, Yucca Mountain, Nevada, *in* Characterization and Monitoring of the Vadose (Unsaturated) Zone Conference, Denver, 1985, Proceedings: Worthington, Ohio, National Water Well Association, p. 507-541.

Montazer, Parviz, and Wilson, W.E., 1984, Conceptual hydrologic model of flow in the unsaturated zone, Yucca Mountain, Nevada: U.S. Geological Survey Water-Resources Investigations Report 84-4345, 55 p.

Phene, C.J., Hoffman, G.J., and Rawlins, S.L., 1971, Measuring soil matric potential in situ by sensing heat dissipation with a porous body--I, Theory and sensor construction: Soil Science Society of America Proceedings, v. 35, no. 1, p. 27-33.

Rawlins, S.L., 1966, Theory for thermocouple psychrometers used to measure water potential in soil and plant samples: Agricultural Meteorology, v. 3, no. 5/6, p. 293-310.

Richards, L.A., 1942, Soil moisture tensiometer materials and construction: Soil Science, v. 53, no. 4, p. 241-248.

Richards, L.A., and Ogata, G., 1958, Thermocouple for vapor pressure measurement in biological and soil systems at high humidity: Science, v. 128, no. 3331, p. 1089-1090.

Roseboom, E.H., Jr., 1983, Disposal of high-level nuclear waste above the water table in arid regions: U.S. Geological Survey Circular 903, 21 p.

Squires, R.R., and Young, R.L., 1984, Flood potential of Fortymile Wash and its principal southwestern tributaries, Nevada Test Site, southern Nevada: U.S. Geological Survey Water-Resources Investigations Report 83-4001, 33 p.

Thordarson, William, Rush, F.E., Spengler, R.W., and Waddell, S.J., 1984, Geohydrologic and drill-hole data for test well USW H-3, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Open-File Report 84-149, 28 p.

Waddell, R.K., 1982, Two-dimensional, steady-state model of ground-water flow, Nevada Test Site and vicinity, Nevada-California: U.S. Geological Survey Water-Resources Investigations Report 82-4085, 72 p.

Waddell, R.K., Robison, J.H., and Blankennagel, R.K., 1984, Hydrology of Yucca Mountain and vicinity, Nevada-California--Investigative results through mid-1983: U.S. Geological Survey Water-Resources Investigations Report 84-4267, 72 p.

*U.S. GOVERNMENT PRINTING OFFICE: 1990-0-773-204/20018