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Yucca Mountain Site Characterization Project

Geology of the USW SD-7 Drill Hole Yucca Mountain, Nevada

Christopher A. Rautman, Dale A. Engstrom

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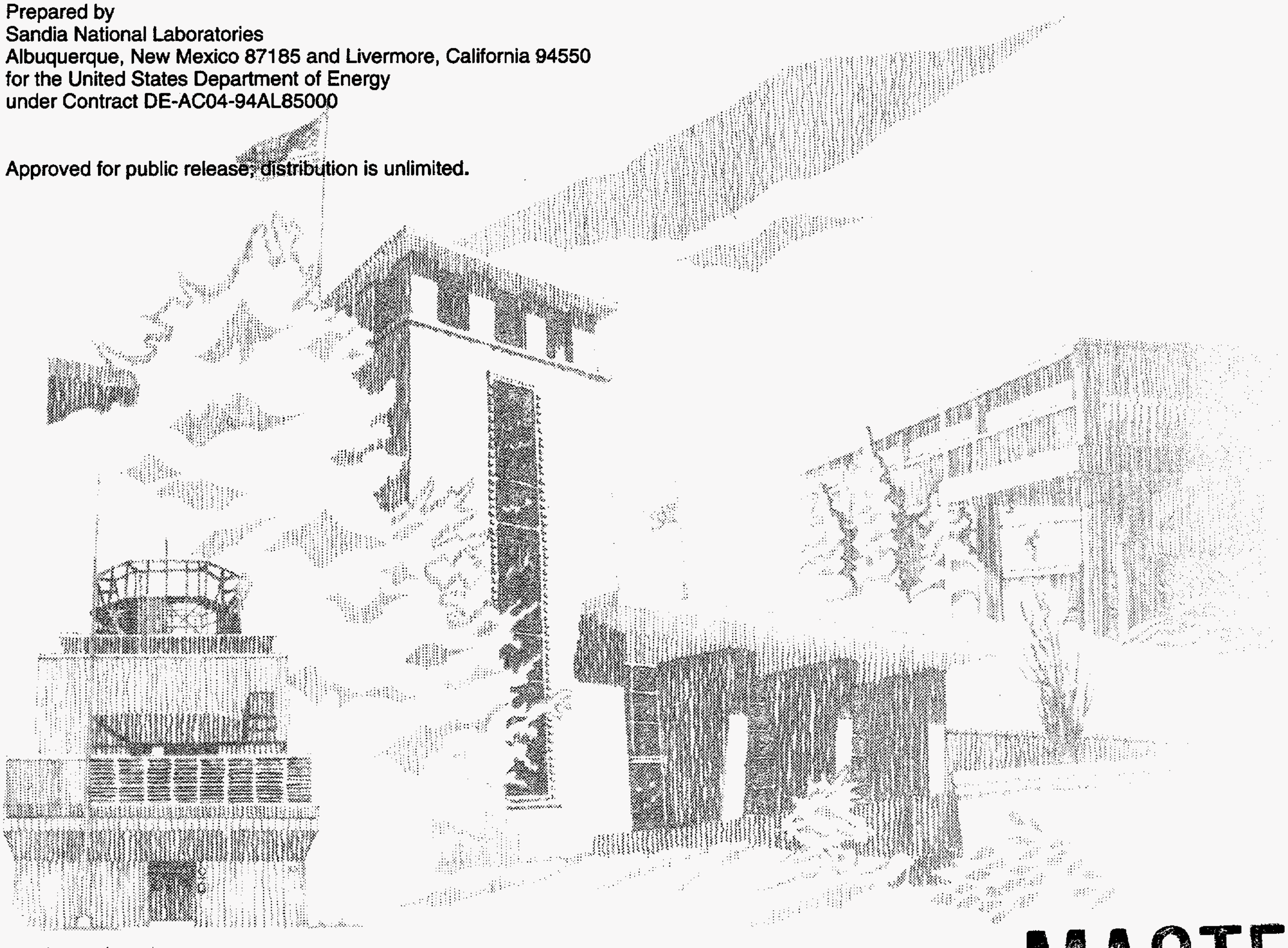

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Geology of the USW SD-7 Drill Hole Yucca Mountain, Nevada

Christopher A. Rautman
Geohydrology Department
Sandia National Laboratories
Albuquerque, New Mexico 87185

Dale A. Engstrom
Spectra Research Institute
Albuquerque, New Mexico 87106

Abstract

The USW SD-7 drill hole is one of several holes drilled under Site Characterization Plan Study 8.3.1.4.3.1, also known as the Systematic Drilling Program, as part of the U.S. Department of Energy characterization program at Yucca Mountain, Nevada. The Yucca Mountain site has been proposed as the potential location of a repository for high-level nuclear waste. The SD-7 drill hole is located near the southern end of the potential repository area and immediately to the west of the Main Test Level drift of the Exploratory Studies Facility. The hole is not far from the junction of the Main Test Level drift and the proposed South Ramp decline. Drill hole USW SD-7 is 2675.1 ft (815.3 m) deep, and the core recovered nearly complete sections of ash-flow tuffs belonging to the lower half of the Tiva Canyon Tuff, the Pah Canyon Tuff, and the Topopah Spring Tuff, all of which are part of the Miocene Paintbrush Group. Core was recovered from much of the underlying Calico Hills Formation, and core was virtually continuous in the Prow Pass Tuff and the Bullfrog Tuff. The SD-7 drill hole penetrated the top several tens of feet into the Tram Tuff, which underlies the Prow Pass and Bullfrog Tuffs. These latter three units are all formations of the Crater Flat Group.

The drill hole was collared in welded materials assigned to the crystal-poor middle nonlithophysal zone of the Tiva Canyon Tuff; approximately 280 ft (85 m) of this ash-flow sheet was penetrated by the hole. The Yucca Mountain Tuff appears to be missing from the section at the USW SD-7 location, and the Pah Canyon Tuff is only 14.5 ft thick. The Pah Canyon Tuff was not recovered in core because of drilling difficulties, suggesting that the unit is entirely nonwelded. The presence of this unit is inferred through interpretation of down-hole geophysical logs. The Topopah Spring Tuff consists of 1005.5 ft (306.5 m) of mostly densely welded pyroclastic flow deposits. Lithophysae are well developed in two principal vertical intervals within the Topopah Spring, and these features include lithophysal cavities that are up to several feet (many tenths of a meter) across. The Calico Hills Formation in drill hole SD-7 consists of about 220 ft (67 m) of nonwelded and mostly zeolitized tuffaceous materials. The top of the formation has been lost during drilling, but contacts have been reconstructed through interpretation of geophysical logs. The Calico Hills formation has been subdivided into three units dominated by pyroclastic-flow materials and underlain by a reworked, "bedded tuff" interval and a basal tuffaceous sandstone.

The upper two units of the Crater Flat Group, the Prow Pass Tuff (554 ft; 170 m thick) and the Bullfrog Tuff (418 ft; 127 m thick), have each been subdivided into four units dominated by pyroclastic-flow material that may include some reworked tuffaceous materials near the base of each ash-flow sequence. Ash-flow unit 3 (numbered sequentially from the bottom) of both the Prow Pass and the Bullfrog is at least moderately welded in part. The remaining ash-flow units consist generally of nonwelded and generally zeolitized tuffs. Each of the four-unit sequences is underlain by reworked tuffaceous deposits: a bedded tuff unit at the base of the Prow Pass Tuff and a tuffaceous sandstone unit at the base of the Bullfrog. SD-7 cored only 77 ft (23 m) of the lowest unit of the Crater Flat Group, the Tram Tuff, which at this location consists of nonwelded, partially zeolitized ash-flow tuff.

Quantitative and semiquantitative data are included in this report for core recovery, rock-quality designation (RQD), lithophysal cavity abundance, and fracturing. These data are spatially variable, both within and among the major formational-level stratigraphic units. Rocks of the Calico Hills Formation and Crater Flat Group yielded markedly higher recoveries and RQD values than did the densely welded units of the Paintbrush Group. Both core recovery and RQD are particularly low in the two lithophysal intervals of the Topopah Spring Tuff; RQD values indicate “very poor” ground conditions in these zones. RQD is “fair” within the proposed repository horizon of the crystal-poor middle nonlithophysal Topopah Spring. Nonwelded intervals within the Paintbrush Group tuffs exhibited extremely poor core recovery. This is attributed to essentially unconsolidated lithologies in these reworked and distal pyroclastic units.

This report includes quantitative data for the “framework” material properties of porosity, bulk and particle density, and saturated hydraulic conductivity. These data confirm previously reported first-order control of material properties by the degree of welding and presence of zeolite alteration minerals. Many of the finer-scale lithostratigraphic subdivisions identifiable in core are not well expressed in the material-property profiles. Approximate in-situ saturation and volumetric water content data for core samples preserved immediately upon recovery from the drill hole are included in the data tabulation. Quantitative mineralogical analyses by X-ray diffraction are also included for samples taken from the vitric-to-zeolitic transition interval underlying the Topopah Spring Tuff.

Geophysical well-log data have been obtained from virtually the entire SD-7 drill hole. The suite of petrophysical traces include density, gamma-ray, epithermal-neutron porosity, electrical resistivity, and caliper profiles. The density log provides perhaps the best stratigraphic information and most of the major material-property subdivisions described using core samples can be identified in the petrophysical profiles. Petrophysically based measurements may also be more appropriate for capturing “bulk-effective” properties of the in-situ rock because of limitations on the size of the core that can be retrieved from the hole or tested in laboratory equipment. The identification and quantification of properties of lithophysal rocks within the Paintbrush Group tuffs is particularly affected by this mechanical limitation.

Material-property based subdivisions of the USW SD-7 drill hole do not correspond in detail to the major lithostratigraphic subdivisions, although some of the lower-order lithostratigraphic subdivisions do approximate units of substantially different material-property character. Material-property based subdivisions of the SD-7 drill hole appear to correspond essentially to the thermal/mechanical stratigraphic units of historical usage.

Acknowledgments

This work was performed for the U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Project Office under contract EA9012M5X. Scientific investigations involving the Systematic Drilling Program are conducted under the descriptions of work contained in the Yucca Mountain Site Characterization Plan and in Study Plan 8.3.1.4.3.1; the work-breakdown structure element is 1.2.3.2.2.2.1. The planning document that directed this work activity is WA-

0301; prior to the effective date of WA-0301, work activities for this WBS element were conducted under WA-0014. The information and data documented in this report was collected under a fully qualified quality assurance program. Full details associated with all reported data may be located in the Yucca Mountain Site Characterization Project records using the data-tracking numbers (DTNs) provided in the relevant sections of this report. The authors thank the many principal investigators who have shared their data and insights into the geology of Yucca Mountain.

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Introduction

The U.S. Department of Energy is evaluating a site in volcanic tuffs at Yucca Mountain, located in southern Nye County, Nevada, as the potential location for an underground high-level nuclear-waste repository (fig. 1). This report contains the results of the geologic logging and lithologic description of core from drill hole USW SD-7, which is one of a number of holes being drilled at the Yucca Mountain site to characterize the subsurface geology of the proposed repository block. A suite of framework bulk and hydrologic properties are also reported in the context of the geologic description. These logging activities have been conducted under Site Characterization Plan (SCP) Study 8.3.1.4.3.1, "Systematic Acquisition of Site-Specific Subsurface Information" (DOE, 1988), which is also referred to as the Systematic Drilling Program.

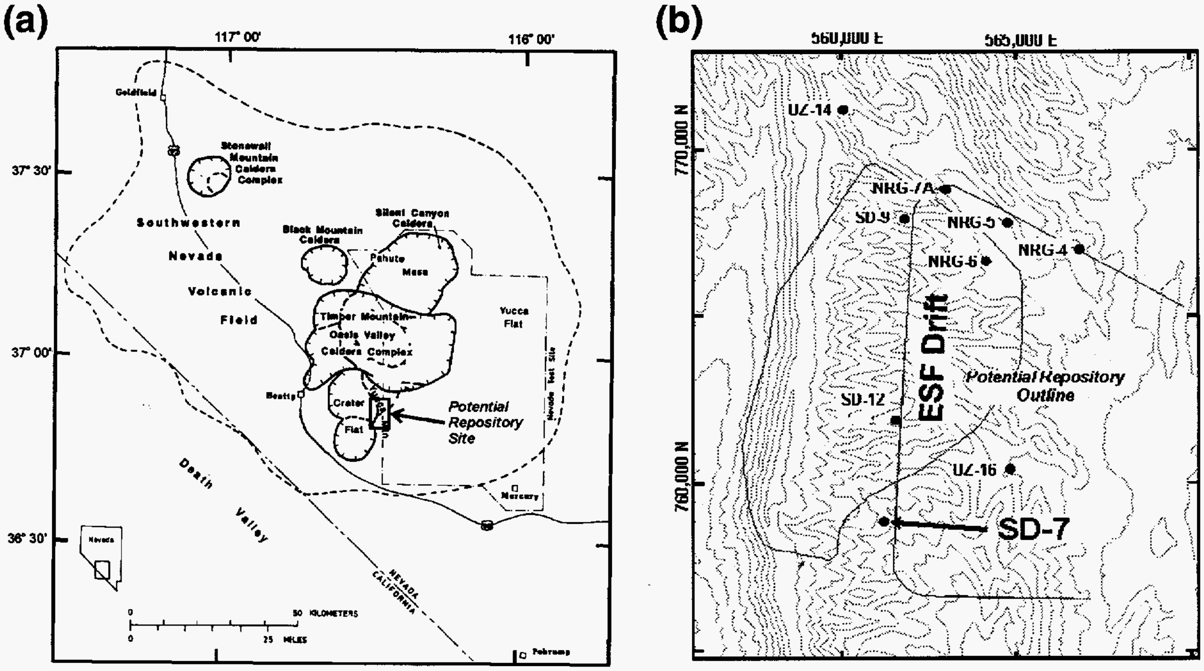

Figure 1. (a) Index map showing location of the potential Yucca Mountain repository site in southern Nevada in relationship to the southwestern Nevada volcanic field (after Byers and others, 1989). (b) Expanded map of the Yucca Mountain site showing location of drill hole USW SD-7 and selected other site characterization drill holes.

Purpose of the Systematic Drilling Program

The Systematic Drilling Program (Rautman, 1993) was proposed to provide critical information for repository design and performance assessment in a systematic sampling pattern (fig. 2) from the volume of rock to be occupied by the potential Yucca Mountain repository. Holes of the Systematic Drilling Program were believed to be particularly important in the geologic characterization of the Yucca Mountain site because they generally are located within the proposed conceptual-design

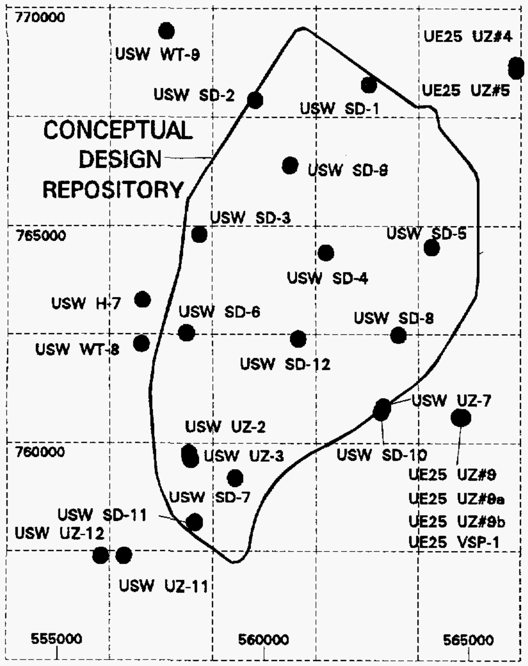

Figure 2. Gridded drilling pattern for the Systematic Drilling Program as proposed in Study Plan 8.3.1.4.3.1 (Rautman, 1993).

perimeter drift (the SD-7 drill hole is a modest exception, being located 800 ft (240 m) outside this design boundary [fig. 1(b)]). The drilling program is to provide descriptions and samples of the repository host rock and of rocks both above and below the repository horizon along the postulated flow path(s) of deep, unsaturated-zone ground-water percolation. The Systematic Drilling Program will also provide descriptive information and samples of rocks within the upper portion of the saturated zone, which includes zeolitically altered materials that may act to retard radionuclides migrating away from a constructed repository.

In addition to descriptive geologic information, core samples provide the raw material for quantitative measurements of thermal, mechanical, hydrologic, and geochemical material properties necessary for numerical modeling and regulatory evaluation of the waste-isolation performance of a potential nuclear-waste repository at Yucca Mountain. A basic set of framework material properties from USW SD-7 is included as part of this report. Other site-characterization studies (DOE, 1988) are also testing samples obtained from the USW SD-7 drill hole. Pore waters extracted from appropriately preserved core specimens and drill cuttings can provide isotopic evidence relevant to the age or residence time and source of the ground water, including data on the infiltration of water containing bomb-pulse isotopes from past atmospheric testing of nuclear weapons. The drill holes themselves provide access to the interior of Yucca Mountain for geophysical logging, down-hole video examination of the boreholes walls, air-permeability testing, water table monitoring and geochemical sampling, and in-situ instrumentation for monitoring temperatures, gas pressures, and changes in gas chemistry with time. Simple, down-hole plots of geophysical logs from the USW SD-7 drill hole are included at a reduced scale in this report.

Regional Geologic Setting

Yucca Mountain is located within the southern portion of the southwestern Nevada volcanic field (Lipman and others, 1966; Christiansen and others, 1977; Byers and others, 1976; 1989). The southwestern Nevada volcanic field [fig. 1(a)] consists of a thick sequence of widely distributed, 7- to 15-million-year-old silicic volcanic rocks, centered around the Timber Mountain, Oasis Valley, and Silent Canyon caldera complexes (Noble and others, 1968; Sawyer and others, 1994).

Yucca Mountain itself consists of a series of north-trending, eastward-dipping structural blocks that are bounded by mostly west-dipping normal faults (Carr and others, 1986). These fault blocks are composed principally of thick, welded ash-flow tuff deposits that are separated by thinner, nonwelded ash-flow tuffs, silicic lavas, and tuffaceous sedimentary units. Previous drilling at Yucca Mountain has shown that Tertiary volcanic rocks are in excess of 6000 feet (1800 m) thick in the vicinity of the potential repository. Pre-Tertiary rocks underlying Yucca Mountain include thick carbonate and clastic assemblages varying in age from Precambrian to Mississippian. A Mesozoic or Tertiary pluton may lie beneath the Calico Hills on the north end of the site (Carr, 1984).

Volcanic Stratigraphy

Yucca Mountain comprises a thick sequence of variably welded and nonwelded ash-flow tuffs intercalated with thinner intervals of bedded (reworked) and air-fall tuffs. The general sequence of stratigraphic units is illustrated in table 1. Surface exposures within the main repository block are formed by the several formations of the Miocene Paintbrush Group. In descending sequence, these are the Tiva Canyon, Yucca Mountain, Pah Canyon, and Topopah Spring Tuffs (Sawyer and others, 1994). The Tiva Canyon and Topopah Spring Tuffs occur as thick sheets that are regionally extensive and generally densely welded. The Yucca Mountain and Pah Canyon Tuffs are generally nonwelded to only moderately welded, and they are much less extensive in thickness and laterally, thinning to extinction toward the south. Each formational level unit of the Paintbrush Group is separated from its neighbors by thin nonwelded ash-flow tuffs, air-fall tuffs, pumice-fall units, and reworked tuffaceous bedded deposits. These intervening tuffaceous materials are typically referred to collectively as "bedded tuff" without specific consideration of their actual lithologic character

The Paintbrush Group is underlain by a heterogeneous sequence of rhyolitic rocks known as the Calico Hills Formation (Sawyer and others, 1994). Within the repository vicinity, the Calico Hills consists of a downward sequence of five nonwelded ash-flow tuffs underlain by bedded tuffs and a basal tuffaceous sandstone unit (table 1; Moyer and Geslin, 1995). Elsewhere in the Yucca Mountain region, the Calico Hills Formation consists of rhyolitic lava flows, ash-flow tuffs, air-fall tuffs, and tuffaceous sediments. Much of the Calico Hills Formation has been zeolitized; vitric tuffs are preserved principally in the southwestern portion of the Yucca Mountain site.

The Calico Hills Formation in the general vicinity of the potential repository is underlain by the Crater Flat Group (Sawyer and others, 1994; Moyer and Geslin, 1995), which comprises, in descending sequence, the Prow Pass, Bullfrog, and Tram Tuffs. Each of these three units represents a large-volume ash-flow eruption. Generally, the degree of welding in these units is much less than that exhibited by the tuffs of the Paintbrush Group. The greater part of each ash-flow sequence is nonwelded, with welded tuffs constrained to the interior of each unit. The three formational-level units are separated from one another by thin intervals of nonwelded tuff and tuffaceous sediments ("bedded tuff") in a manner similar to that of the Paintbrush Group.

Volcanic units underlying the Crater Flat Group are somewhat poorly known by comparison. They have been encountered at Yucca Mountain only in the deeper drill holes (for example, Spengler and others, 1981; Maldonado and Koether, 1983; Scott and Castellanos, 1984; Whitfield and others, 1984). None of these units were encountered in drill hole USW SD-7.

Petrogenesis and Zonation of the Paintbrush Group Tuffs

Early field and petrologic descriptions of the stratigraphic units of the southwestern Nevada volcanic field include works by Lipman and Christiansen (1964), Christiansen and Lipman (1965), and Lipman and others (1966). In later work more directly focused on the potential Yucca Mountain repository site, the thick, welded intervals of the Tiva Canyon and Topopah Spring Tuffs were subdivided by Scott and Bonk (1984) into a large number of informally named zones (table 1). This early zonation was based on a number of outcrop-based characteristics, including weathering character and color, in addition to more exposure-independent lithologic characteristics such as phenocryst content, alteration phenomena, and rock type.

More recently, Buesch and others (1996) have proposed a redefined zonation of the Paintbrush Group tuffs. These changes affect principally the thick, welded intervals of the Tiva Canyon and Topopah Spring Tuffs. According to the nomenclature of Buesch and others, these two major ash-flow sheets are divided informally into crystal-rich upper members and crystal-poor lower members (table 2). This fundamental change in phenocryst content, which is paralleled by a downward change in whole-rock chemical composition from quartz latite to high-silica rhyolite, originates in the eruption of these ash-flow sequences from a compositionally zoned magma chamber underlying the

Table 1: Comparison of several stratigraphic subdivisions of volcanic rocks at Yucca Mountain and encountered on the Yucca Mountain Site Characterization Project (no scale).

Geologic Unit (from Sawyer and others, 1994)		**Older hydrologic zonation** (modified after Scott and Bonk, 1984)			**Zonation of Buesch and others** (1996, also Moyer and Geslin, 1995)	**Thermal/mechanical unit** (Ortiz and others, 1985)
Paintbrush Group	**Tiva Canyon Tuff**	Paintbrush Tuff	**Tiva Canyon Member**	ccr - caprock	Tpcrv	**TCw**
				cuc - upper cliff	Tpcrn	
				cul - upper lithophysal	Tpcrl	
					Tpcpul	
				cks - clinkstone	Tpcpmn	
				cll - lower lithophysal	Tpcpll	
				ch - hackly	Tpcplnh	
				cc - columnar	Tpcplnc	
					Tpcpv3	
				ccs - shardy base	Tpcpv2	**PTn**
					Tpcpv1	
	Yucca Mtn. Tuff		Yucca Mtn. Mbr.			
	Pah Cyn. Tuff		Pah Cyn. Mbr.			
	Topopah Spring Tuff		**Topopah Spring Member**	upper nonwelded	Tptrv3	
					Tptrv2	
				tc - caprock	Tptrv1	**TSw1**
				tr - rounded	Tptrn	
				tul - upper lithophysal	Tptrl	
					Tptpul	
				tn - nonlithophysal	Tptpmn	**TSw2**
				tll - lower lithophysal	Tptpll	
				tm - mottled	Tptpln	
				tv - basal vitrophyre	Tptpv3	**TSw3**
				nonwelded base	Tptpv2	**CHn1**
					Tptpv1	
Calico Hills Formation		**Tuffaceous Beds of Calico Hills**		(not subdivided)	Tac_ Unit 5 Unit 4 Unit 3 Unit 2 Unit 1	
					bedded tuff unit basal sandstone unit	CHn2
Crater Flat Group	**Prow Pass Tuff**	Crater Flat Tuff	**Prow Pass Member**	Not subdivided	Tcp_ Unit 4	**CHn3**
					Unit 3	**PPw**
					Unit 2 Unit 1	**CFUn**
	"bedded tuff"		"bedded tuff"		bedded tuff unit	
	Bullfrog Tuff		**Bullfrog Member**		Not subdivided (?)	**BFw**
						CFMn1
	"bedded tuff"		"bedded tuff"			CFMn2
						CFMn3
	Tram Tuff		**Tram Member**			**TRw**
						Not Recognized

source calderas to the north (Lipman and others, 1966). More differentiated, rhyolitic magma in the upper portions of the magma chamber erupted first, followed by less-differentiated quartz latitic material from lower levels as the eruption progressed. A gradational compositional-transition interval is observed in both the Tiva Canyon and the Topopah Spring Tuffs that exhibits attributes of both rock types. Crystal settling within the magma chamber prior to eruption produced phenocryst-rich quartz latite and phenocryst-poor rhyolite compositions corresponding to the two-member subdivision.

Table 2: Zonation of the Tiva Canyon and Topopah Spring Tuffs Showing Parallel Subdivisions (simplified after Buesch and others, 1996)
[Lithophysal intervals are shaded]

Tiva Canyon Tuff (Tpc)	Topopah Spring Tuff (Tpt)
crystal-rich member (Tpcr)	crystal-rich member (Tptr)
vitric zone (Tpcrv)	vitric zone(Tptrv)
non- to partially welded subzone (Tpcrv3)	non- to partially welded subzone (Tptrv3)
moderately welded subzone (Tpcrv2)	moderately welded subzone (Tptrv2)
vitrophyre subzone (Tpcrv1)	vitrophyre subzone (Tptrv1)
nonlithophysal zone (Tpcrn)	nonlithophysal zone (Tptrn)
subvitrophyre transition subzone (Tpcrn4)	
pumice-poor subzone (Tpcrn3)	
mixed pumice subzone (Tpcrn2)	
crystal transition subzone (Tpcrn1)	crystal transition subzone (Tptrn1)
lithophysal zone	lithophysal zone
crystal transition subzone (Tpcrl1)	crystal transition subzone (Tptrl1)
crystal-poor member	crystal-poor member
upper lithophysal zone	upper lithophysal zone
spherulite-rich subzone (Tpcpul1)	cavernous lithophysae subzone (Tptpul2)
	small lithophysae subzone (Tptpul1)
middle nonlithophysal zone (Tpcpmn)	middle nonlithophysal zone (Tptpmn)
upper subzone (Tpcpmn3)	upper subzone (Tptpmn3)
lithophysae-bearing subzone (Tpcpmn2)	lithophysae-bearing subzone (Tptpmn2)
lower subzone (Tpcpmn1)	lower subzone (Tptpmn1)
lower lithophysal zone (Tpcpll)	lower lithophysal zone (Tptpll)
lower nonlithophysal zone (Tpcpln)	lower nonlithophysal zone (Tptpln)
hackly subzone (Tpcplnh)	hackly subzone (Tptplnh)
columnar subzone (Tpcplnc)	columnar subzone (Tptplnc)
spherulitic pumice interval (Tpcplnc3)	spherulitic pumice interval (Tptplnc3)
argillic pumice interval (Tpcplnc2)	argillic pumice interval (Tptplnc2)
vitric pumice interval (Tpcplnc1)	vitric pumice interval (Tptplnc1)
vitric zone (Tpcpv)	vitric zone (Tptpv)
vitrophyre subzone (Tpcpv3)	vitrophyre subzone (Tptpv3)
moderately welded subzone (Tpcpv2)	moderately welded subzone (Tptpv2)
non-to partially welded subzone (Tpcpv1)	non-to partially welded subzone (Tptpv1)
Pre-Tiva Canyon Tuff bedded tuff (Ppbt4)	Pre-Topopah Spring Tuff bedded tuff (Tpbt1)

Buesch and others (1996) further subdivide the crystal-rich and crystal-poor members into a number of informal, smaller zones and subzones (tables 1, 2). Some of these zones are based on widespread petrogenetic phenomena, principally cooling processes, that affected the ash-flow tuffs during and shortly after deposition. Both the Tiva Canyon and Topopah Spring Tuffs exhibit a quenched, nonwelded, vitric zone at the upper and lower margins, where the hot mass of glassy pyroclastic shards cooled rapidly from exposure to ambient air or to the relatively cold existing topography. Welded vitric zones, usually expressed as vitrophyres that compacted, fused, and cooled before devitrification could begin, are found inside the nonwelded vitric zones. The vitrophyre zones are thicker and more laterally extensive at the base of each ash-flow sequence because of the weight of the overlying, progressively accumulating pyroclastic deposit. The major part of both the Tiva Canyon and Topopah Spring Tuffs compacted and cooled slowly because of the insulating effect provided by the quenched and largely nonwelded upper and lower margins of the deposits. The interior parts of each ash-flow sheet thus consist of moderately to densely welded, devitrified tuff.

Buesch and others also define other zones and subzones (tables 1, 2) that are related more to later-stage alteration phenomena. Residual magmatic gasses exsolved from the compacting and devitrifying mass of glassy shards and these gasses produced vapor-phase alteration consisting principally of microcrystalline, open-space growths of high-temperature silica and feldspar minerals. These phases are distinct from the more "primary" assemblages of minerals resulting from devitrification. Locally, the vapor pressure of the exsolving gas was sufficient to inflate secondary "bubbles," known as lithophysal cavities, along crudely horizontal horizons where the internal pressure exceeded the weight of the overlying column of compacting tuff. These lithophysal cavities are themselves rimmed by vapor-phase alteration minerals and alteration may extend some distance into the groundmass surrounding the cavity as rims and borders, The resulting, alternating lithophysae-bearing and non-lithophysae bearing intervals figure prominently into the zonation of Buesch and others (table 2, shaded intervals). Additional factors, such as presence, quantity, and composition of pumice, foreign lithic clasts, presence of spherulites, and fracturing habit, also have been used to define some of the subzones shown in table 2.

The tabular nature of a cooling and compacting ash-flow sheet forces most of the thermal and pressure gradients that control alteration to be oriented essentially normal to the long dimensions of the deposit. Thus, the alteration phenomena of vapor-phase alteration zones, intervals of lithophysal cavity development, and zones of strong, near-vertical cooling joint development tend to be subhorizontal and roughly stratiform. However, because these features are the result of secondary alteration phenomena, they can—and do—cross-cut "primary" stratification features such as the crystal-rich/crystal-poor transition.

Subdivisions of the Calico Hills Formation and Prow Pass Tuff (Crater Flat Group)

Recent review by Moyer and Geslin (1995) of older samples, data, and published lithologic descriptions of rocks underlying the Paintbrush Group tuffs has led to a refined subdivision of both the Calico Hills Formation and the Prow Pass Tuff, as these units were redefined by Sawyer and others (1994). The names and sequence of the informal units described by Moyer and Geslin from the Calico Hills Formation and the Prow Pass Tuff are also illustrated in table 1.

Moyer and Geslin (1995) indicate that the Calico Hills Formation in the vicinity of Yucca Mountain comprises five pyroclastic units, a dominantly reworked "bedded-tuff," unit and a basal volcaniclastic sandstone. Some of these units appear regionally discontinuous. The pyroclastic intervals are generally ash-flow tuff deposits separated by locally preserved air-fall tuff horizons; the content and composition of pumice clasts and lithic fragments are locally diagnostic of the different ash-flow groupings. The Calico Hills Formation, in notable contrast to the tuffs of the entire Paintbrush Group, contains volumetrically significant quantities of quartz phenocrysts, whereas the Paintbrush Group Tuffs are virtually quartz-free. There are indications that the basal sandstone may represent material reworked from the Wahmonie Formation, a distinctive, more mafic volcanic assemblage

(Sawyer and others, 1994) not generally present in the Yucca Mountain region.

Moyer and Geslin have concluded that the Prow Pass consists of four correlative pyroclastic tuff units plus an underlying interval of bedded tuff. Separation of the different ash flows is based in part on differences in welding and in the proportions and types of phenocrysts, pumices, and lithic fragments. The Prow Pass Tuff is crystal rich in comparison with the volumetrically dominant crystal-poor lower members of the Topopah Spring and Tiva Canyon Tuffs. In contrast with the Paintbrush units, the Crater Flat Group tuffs are quartz-bearing.

The USW SD-7 Drill Hole

Location

Drill hole USW SD-7 is located about halfway up Highway Ridge, approximately 3300 feet (1000 m) to the east of the crest of Yucca Mountain. SD-7 is located at Nevada State Plane coordinates (North American Datum of 1927) 758,949.9 ft North, 561,240.3 ft East[†] [fig. 1(b)], and the collar of the hole is at an elevation of 4472.0 feet (1363.1 m). The hole is 500 feet (152.4 m) to the west of the proposed ESF Main Test Level drift, as it was shown on design documents current when the hole was sited (fig. 3). The hole was sited to be near the southern end of the north-south Main Test Level where it turns to form the South Ramp. The hole is approximately 3000 feet (915 m) south of drill hole USW SD-12 and 9000 feet (2745 m) south of USW SD-9 near the north corner.

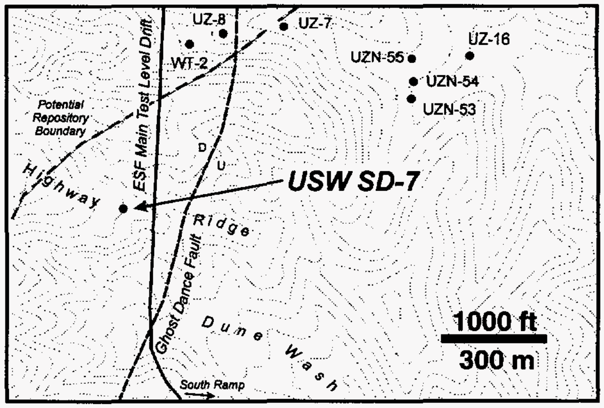

Figure 3. Location map of the potential repository region showing the USW SD-7 drill hole in relationship to nearby drill holes and the Exploratory Studies Facility.

Drilling History

Drilling at USW SD-7 was started on October 3, 1994, when the top of the borehole was drilled to set a 20-inch surface-conductor pipe to eight feet, and then drilled with a 17-1/2 inch hammer and cased with 13-3/8 inch pipe to a depth of 50 feet through drill pad-fill and colluvium. Continuous coring operations commenced in bedrock consisting of the Tiva Canyon Tuff at 50.1 feet (15.27 m) on November 8, using PQ-sized tools (3.27-inch core). Drilling problems involving very low core recovery were encountered immediately; these mechanical difficulties were attributed to the fractured nature of rocks at the top of the hole. Because of continuing hole-collapse and bridging problems, coring was halted temporarily at a depth of 256.4 feet (78.2 m). The hole was reamed to 6 inches in diameter to a depth of 248 feet beginning December 1, then to a diameter of 8-3/4 inches beginning December 5, and finally to 12-1/4 inches beginning December 13. A string of 7-inch casing was successfully set to a depth of 255.0 feet on January 5, 1995, and coring was resumed using PQ tools.

Extremely low core recovery continued through the soft, nonwelded materials lying between the welded Tiva Canyon and Topopah Spring intervals. The average core recovery through this zone was 35.2 percent (27.1 feet of core recovered from 77.0 feet drilled), including 44.5 continuous feet of zero recovery near the base of the nonwelded section. Recovery through the non- to partially welded uppermost Topopah Spring Tuff was only 17.7 percent. Recovery problems were also encountered in the upper and lower lithophysal zones of the Topopah Spring Tuff, and

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[†] Note: Nevada State Plane coordinates in feet are widely used on the Yucca Mountain Project. These coordinates are for the central zone of Nevada and are based on a Transverse Mercator projection. The origin of this projection for the central zone of Nevada is latitude 34°45'N., and the central meridian is at longitude 116°40'W. Metric conversions of Nevada State Plane Coordinates are distinctly separate from true metric coordinates obtained using the 10,000 metre Universal Transverse Mercator grid, Zone II.

in the nonwelded basal Topopah Spring Tuff, pre-Topopah Spring Tuff bedded tuff, and Calico Hills Formation.

The top of the proposed repository horizon (base of the Topopah Spring Tuff upper lithophysal zone) was encountered at a depth of 682.5 feet (208 m) on January 25. Damp core was encountered on March 6 at a depth of 1489.8 feet (454.1 m) in the upper ash-flow unit of the Calico Hills Formation (unit Tac3, table 1). Perched water was encountered on March 7 between depths of about 1592.4 and 1602.0 feet (485.34–488.27 m); this water quickly rose 27.8 feet (8.5 m) to a depth of 1574.1 feet. At that time, drilling was suspended so that water samples could be collected. Extended pump tests were conducted by U.S. Geological Survey scientists working under Study Plan 8.3.1.2.2.3 between March 17 and May 25. Following this period of testing and water-level monitoring, casing was removed and the hole was reamed from a depth of 232.0 to 1575 feet (70.77–480.04 m). Open-hole geophysical logs were run on July 11 from a depth of 1575 feet (481.0 m) to the surface, following completion of the reaming operation.

A string of 7-inch casing was set to a depth of 1576.1 feet (480 m) on July 21 to prevent further collapse of the hole, the PQ core track was deepened to 1632.2 feet (497 m), and additional pump testing of the perched water table was conducted. On August 28, coring resumed using PQ tools and the hole was drilled to a depth of 1660.8 feet (506.2 m). A string of 4-1/2-inch casing and a packer were set to a depth of 1661.4 feet (506 m, and coring resumed at HX-size (nominal 3.0-inch core) on September 1, advancing the hole to 1997 feet. The packer on the 4-1/2 inch casing was then perforated and the casing pulled from the hole. The hole was reamed from a depth of 1660 to 2020 feet (506–616.67 m), ending on September 20, and the 4-1/2 inch casing was reset to a depth of 2020.9 feet (615.94 m). HX-size coring resumed and the regional water table was encountered at a depth between 2179.0 and 2185.3 feet (664.2–666.1 m) on October 4. The water level immediately rose approximately 100 feet (30 m) to a depth of 2085 feet (635.48 m). Once wet drilling conditions were encountered, injection of water became necessary to wash the drill cuttings from the hole beginning on October 10; drilling water was taken from NTS well J-13. Drill hole SD-7 reached a final depth of 2675.1 feet (815.4 m) on November 9, 1995 (in 297 drilling shifts).

Method of Study

Geologic Logging and Core Description

Geologic logging and description of drill core is principally an interpretive activity. As such, the resulting geologic log is dependent upon the skill and experience of the individual performing the examination. The logging procedure used to describe core from drill hole USW SD-7 and other holes of the Systematic Drilling Program emphasizes physical description in an attempt to eliminate partially dependence on stratigraphic nomenclature that may change over time (compare Scott and Bonk, 1984; Buesch and others, 1996). A standardized geologic log form is used to record observations of lithology, composition, alteration, structure, and similar features, and of changes in those multiple characteristics with depth. The observations are thus effectively independent of the names applied to units of similar or contrasting character.

Interpretive geologic logging and core description consists of observing the rock in its intact, relatively undisturbed state. Core was laid out in continuous profile on examination tables at the Yucca Mountain Project Sample Management Facility. A graphical geologic log was prepared at a scale of 1:120 (one inch equals 10 feet) after macroscopic visual examination using a hand lens, binocular microscope, videotaped images and photographs of cored intervals previously removed for laboratory measurement of selected materials properties. The geologic log includes description of:

- contacts between geologic units
- degree of welding
- degree of devitrification
- size, type, and abundance of pumice
- size, type, and abundance of lithic clasts
- size, type, and abundance of phenocrysts
- size, type, and abundance of lithophysal cavities
- type, nature, and degree of alteration

- presence or absence of bedding or other depositional features
- fault zones or shear zones
- joints or fractures and fracture frequency
- percent core recovery
- RQD (rock quality designation)

Rock color descriptions follow the naming conventions prescribed in the rock-color chart published by the Geological Society of America (1991).

Laboratory Hydrologic Properties

A limited suite of framework material properties were measured in the laboratory for core samples taken from the USW SD-7 drill hole. Adjoining core samples were preserved at the drilling rig in sealed steel cans and plastic Lexan tubing. In-situ water contents were determined by gravimetry from the canned samples. Porosity, bulk density and particle density also were determined by gravimetry for the canned samples using Archimedes' principle. Initial gravimetric water contents and porosities were used to determine approximate in-situ saturations and volumetric water contents. Machined core plugs were cut from the larger samples preserved in Lexan and used to determine saturated hydraulic conductivity using Darcy's law relating water flow and pressure drop; the corresponding porosity values for these plugs were also determined. The laboratory property determinations were a collaborative effort of Sandia National Laboratories and the U.S. Geological Survey, Hydrologic Research Facility (USGS, 1991a).

Geology of Drill Hole USW SD-7

Overiew

Drill hole USW SD-7 is located approximately halfway up Highway Ridge on the eastern slope of Yucca Mountain; the hole was located to be roughly 500 feet to northwest of one west-dipping splay of the Ghost Dance-Abandoned Wash fault. This topographic and structural position allowed sampling and examination of the lower 250 feet (75 m) of the Tiva Canyon Tuff. The drill hole also encountered the depositionally thin Paintbrush nonwelded interval and all of the welded Topopah Spring Tuff. Mostly nonwelded units underlie the densely welded Topopah Spring section, and these units tested by the SD-7 drill hole include the lowermost Topopah Spring Tuff, the Calico Hills Formation, and the Prow Pass and Bullfrog Tuffs of the Crater Flat Group. Drilling was terminated slightly below the upper contact of the Tram Tuff (also of the Crater Flat Group). A summary of the interpreted geologic unit contacts is presented in Table 3. Lithologic descriptions of the rocks encountered in drill hole USW SD-7 are presented in Appendix A and the corresponding detailed geologic log sheets are in Appendix B.

Table 3: Stratigraphic Unit Upper Contacts and Unit Thicknesses for the USW SD-7 Drill Hole
[--: not present in this hole, or otherwise not identified]

Lithostratigraphic Unit	Abbreviation	Depth to Upper contact (ft)	Apparent thickness (ft)	Tops from Stratigraphic Compendium (ft)
Tiva Canyon Tuff (Tpc) — 277.9 ft thick[†]				
Crystal-poor middle nonlithophysal zone	Tpcpmn	50.1[†]	24.7[†]	50.2
lower nonlithophysal subzone	Tpcpmnl	50.1[†]	24.7[†]	50.2
Crystal-poor lower lithophysal zone	Tpcpll	74.8	120.2	140.0
Crystal-poor lower nonlithophysal zone	Tpcpln	195.0	100.4	195.2
hackly subzone	Tpcplnh	195.0	60.8	--
columnar subzone	Tpcplnc	255.8	39.6	--
Crystal-poor vitric zone ("shardy base")	Tpcpv	295.4	32.6	295.0
moderately welded subzone	Tpcpv2	295.4	21.0	--

Table 3: Stratigraphic Unit Upper Contacts and Unit Thicknesses for the USW SD-7 Drill Hole (Continued)

Lithostratigraphic Unit	Abbreviation	Depth to Upper contact (ft)	Apparent thickness (ft)	Tops from Stratigraphic Compendium (ft)
nonwelded subzone	Tpcpv1	316.4	11.6	--
Pre-Tiva Canyon Tuff bedded tuff	Tpcbt4	328	2.5	326.0
Yucca Mountain Tuff (Tpy) — not present		--	0.0	
Pre-Yucca Mountain Tuff bedded tuff	Tpbt3	330.5[‡]	0.0[‡]	
Pah Canyon Tuff (Tpp) — 14.5 ft thick		345[‡]	14.5[‡]	
Pre-Pah Canyon Tuff bedded tuff	Tpbt2	357[‡]	1.5[‡]	
Topopah Spring Tuff (Tpt) — 1005.5 ft thick				
Crystal-rich vitric zone	Tptrv	358.5[‡]	29.8	366.0
nonwelded subzone	Tptrv1	358.5[‡]	22.5	366.0
moderately welded subzone	Tptrv2	381	6.2	--
densely welded subzone	Tptrv3	387.2	1.1	387.0
Crystal-rich nonlithophysal zone	Tptrn	388.3	99.5	393.0
Crystal-rich lithophysal zone	Tptrl	--	0.0	--
Crystal transition interval	--	473?–487.8	14.8	--
Compositional transition	--	472.2–532.0	59.8	--
Crystal-poor upper lithophysal zone	Tptpul	487.8	194.7	490.0
Crystal-poor middle nonlithophysal zone	Tptpmn	682.5	120.8	640.0
Crystal-poor lower lithophysal zone	Tptpll	803.3	216.7	829.0
Crystal-poor lower nonlithophysal zone	Tptpln	1020.0	171.4	1020.0
Crystal-poor vitric zone	Tptpv	1191.4	172.6	1182.1
densely welded subzone	Tptpv3	1191.4	83.1	1182.1
moderately welded subzone	Tptpv2	1274.5	20.5	1274.6
nonwelded subzone	Tptpv1	1295.0	69.0	--
Pre-Topopah Spring Tuff bedded tuff	Tpbt1	1364[‡]	41[‡]	1357.0
Calico Hills Formation (Tac) — 221.2 ft thick				
unit 3	Tac3	1405[‡]	88.3[‡]	1381.0
unit 2	Tac2	1493.3	30.5	
unit 1	Tac1	1523.8	43.4	
bedded tuff unit	Tacbt	1567.2	43.1	
basal sandstone unit	Tacbs	1610.3	15.9	
Prow Pass tuff (Tcp) — 554.0 ft				
unit 4	Tcp4	1626.2	28.8	
unit 3	Tcp3	1655.0	182.8	
unit 2	Tcp2	1837.8	40.2	
unit 1	Tcp1	1878.5	289.0	
bedded tuff unit	Tcpbt	2167.5	12.7	
Bullfrog Tuff (Tcb) — 417.8 ft				
unit 4	Tcb4	2180.2	37.8	
unit 3	Tcb3	2218.0[††]	260.0[††]	

Table 3: Stratigraphic Unit Upper Contacts and Unit Thicknesses for the USW SD-7 Drill Hole (Continued)

Lithostratigraphic Unit	Abbreviation	Depth to Upper contact (ft)	Apparent thickness (ft)	Tops from Stratigraphic Compendium (ft)
unit 2	Tcb2	2478.0††	3.5††	
unit1	Tcb1	2481.5	97.9	
tuffaceous sandstone unit	Tcbts	2579.4	18.6	
Tram Tuff (Tct) — 77.1 ft†				
upper ash-flow unit		2598.0	77.1†	

† Entire unit not penetrated; partial thickness only.

‡ Extremely poor core recovery in this general interval makes it impossible to determine exact contacts, or in some cases, the presence/absence of units; contacts have been inferred through interpretation of petrophysical logs. See geologic log sheets in Appendix B for interpretation and detailed descriptions of available evidence.

†† Fault contact; partial thickness only.

Drill hole USW SD-7 is collared in the densely welded, crystal-poor middle nonlithophysal zone of the Tiva Canyon Tuff. Only the lower nonlithophysal subzone (Buesch and others, 1996) of this zone was actually recovered in the core, which begins at a depth of 50.1 ft (15.3 m). Small, flattened irregularly-shaped lithophysae mark the gradational top of the crystal-poor lower lithophysal zone at a depth of approximately 74.5 feet (22.7 m). The intensity of lithophysal-style alteration, including a slight decrease in the degree of flattening and an increase in lithophysae size and volume fraction of open lithophysal cavities, increases between about 135 and 140 ft (41.1–42.7 m). The most intense lithophysal-style alteration occurs between depths of 168 and about 195 ft (51.2–59.4 m). Lithophysae that are visible in core are absent below 195.0 ft (59.4 m); however, 2- to 5-ft (0.6–1.5-m) intervals of lost core that potentially may represent lithophysal cavities (?) are present to a depth of 236.4 ft (72.0 m). The crystal-poor lower nonlithophysal zone is defined beginning at a depth of 195 feet (59.4 m). Hackly fractures, diagnostic of the hackly subzone of Buesch and others (1996), are not well developed in the SD-7 drill core, but high-angle, columnar-style joints are present below about 255 ft (77.7 m).

The base of the lower nonlithophysal zone of the Tiva Canyon Tuff is marked by a progressive decrease in the intensity of high-temperature devitrification and in the degree of welding. Preserved vitric pumice clasts are identifiable below a depth of about 279.1 ft (85.1 m), and the amount of glass preserved in the core increases sharply from 291.4 to 303 ft (88.8–92.4 m). The degree of flattening (welding) decreases below about 295 ft to nonwelded at 316.4 ft (96.4 m), and the base of the Tiva Canyon Tuff has been defined at 325.7 ft (99.3 m). The pre-Tiva Canyon Tuff bedded tuff (Tpbt4) underlies the Tiva Canyon ash-flow deposits from 325.7 to 330.5 ft (99.3–100.7 m); the upper contact of this reworked unit is marked by a weakly hematitic paleosol.

Rocks identifiable as the Yucca Mountain Tuff were not encountered in the SD-7 drillhole. The fact that the drill hole is located in a distal position with respect to the distribution of this small-volume ash-flow deposit, plus similar apparent absence of the Yucca Mountain Tuff in drill hole USW SD-12 (Rautman and Engstrom, in press), suggests that the absence is depositional. However, pre-Tiva-Canyon-Tuff faulting cannot be ruled out based on the evidence from this drill hole (see further discussion in Appendix A, “Yucca Mountain Tuff (Tpy)” beginning on page 50). Rocks assigned to the pre-Yucca Mountain Tuff bedded tuff interval consist of a complex sequence of pumice-fall deposits, pumiceous ash-flow beds, and reworked sandy bedded tuffs. The lower contact of the pre-Yucca Mountain Tuff bedded tuff interval, the Pah Canyon Tuff (if present) and the upper, nonwelded part of the crystal-rich vitric zone of the Topopah

Spring Tuff were lost in an interval of more than 35 ft (10 m) for which no core or significant drill cuttings were recovered.

The top of the Topopah Spring Tuff has been estimated at a depth of 358.5 ft (109 m), and the formation has an apparent thickness of 1005.5 ft (306.5 m). The crystal-rich to crystal-poor transition in SD-7 is relatively sharp between depths of about 473–487 ft (144–148.4 m), but crystal-rich quartz latite cognate lithic masses are present throughout a compositional transition interval that extends from 472 to 532 ft (143.9–162.2 m). The Topopah Spring becomes densely welded at a depth of 387.2 ft (118.0 m), just below the thick unrecovered interval containing the upper contact. The crystal-rich, densely welded vitric subzone ("caprock vitrophyre") appears quite thin in the SD-7 drill core, and the rock becomes progressively devitrified below 388.3 ft (118.4 m); this depth marks the top of the crystal-rich nonlithophysal zone.

The uppermost lithophysae observed in the SD-7 core occur at 455.4 ft (138.8 m), within the crystal-rich member of the Topopah Spring Tuff, but the crystal-rich lithophysal zone effectively is not present at this geographic location. Widely spaced, oval lithophysae increase in abundance at 487.8 ft (148.7 m), marking the gradational top of the crystal-poor upper lithophysal zone. Closely spaced lithophysae with significant vapor-phase alteration rims are abundant below 533.5 ft (162.6 m), and larger-than-core-diameter lithophysal cavities are inferred from extensive broken and unrecovered intervals below about 560 ft (170 m). Lithophysae are absent below the top of the crystal-poor middle nonlithophysal zone at 682.5 ft (208.0 m). The middle nonlithophysal zone (proposed repository host horizon) is 120.8 ft (36.8 m) thick in the SD-7 core; both the upper and lower contacts are relatively sharp and well defined. The top of the crystal-poor lower lithophysal zone is defined by the presence of intense lithophysal-style alteration and lithophysae below a depth of 803.3 ft (244.8 m). Lithophysae are less common below about 900 ft (275 m), although the rock continues to exhibit moderate lithophysal-style alteration, including the vapor-phase "spots" and incipiently lithophysal, very flat relict pumice. Essentially only vapor-phase alteration spots occur below the top of the crystal-poor lower nonlithophysal zone at approximately 1020 ft (310 m). The crystal-poor vitric zone is preserved below 1191.4 ft (363.1 m). Welding decreases rapidly below 1274.5 ft (388.4 m), and the nonwelded basal subzone extends from 1295.0 to approximately 1363 ft (415 m). The lower contact of the Topopah Spring Tuff, the underlying pre-Topopah Spring Tuff bedded tuff, and the upper contact of the Calico Hills Formation occur within a thick unrecovered interval that extends almost continuously from 1350.9 to 1410.0 ft (411.7–429.8 m).

The top of the Calico Hills Formation is inferred at a depth of 1405 feet (428 m) and the unit is 221.2 feet (67.4 m) thick. The Calico Hills in SD-7 has been subdivided into three nonwelded ash-flow tuff units, a reworked bedded tuff unit, and a basal tuffaceous sandstone. The upper two Calico Hills ash-flow units (numbers 5 and 4) described by Moyer and Geslin (1995) and found elsewhere at Yucca Mountain appear to be absent here. Their absence tentatively is inferred to be depositional, as only Calico Hills ash-flow unit 5 was missing in drill hole USW SD-12 to the north (Rautman and Engstrom, in press), which is closer to the source terrane. However, removal by these units by pre-Topopah-Spring-Tuff faulting cannot be excluded. Calico Hills ash-flow unit 3 is nonwelded and at least partially altered from 1402 to 1493.3 ft (427.2–455.1 m). A thin, Calico Hills ash-flow unit 2 was encountered between depths of 1493.3 and 1523.8 ft (455.1–464.4 m); a 6.7-ft (2-m)-thick bedded interval marks the base of this unit. Both vitric and zeolitic materials of Calico Hills ash-flow unit 1 extend from 1523.8 to 1567.2 ft (464.4–477.6 m). A relatively thick, zeolitized "bedded tuff" interval containing alternating pumice-fall deposits and reworked, ashy beds, underlies ash-flow unit 1 from 1567.2 to 1610.3 ft (477.6–490.8 m). A ill-defined basal tuffaceous sandstone unit that exhibits evidence of more significant reworking by sedimentary processes extends from 1610.3 ft to the base of the Calico Hills Formation at 1626.2 ft (495.6 m).

The Calico Hills Formation is underlain by the Prow Pass Tuff; this unit of the Crater Flat Tuffs is 554.0 feet (168.8 m) thick in SD-7. The four pyroclastic flow units plus the underlying "bedded tuff" unit that were described by Moyer and Geslin (1995) all appear to be represented in the SD-7 core. The Prow Pass Tuff is dominated volumetrically by ash-flow unit 3 (183 ft, 55.8 m thick) and unit 1 (289 ft, 90.8 m thick). Ash-flow unit 3 is moderately welded through most of its vertical extent, but ash-flow unit 1 is essentially completely nonwelded. This latter unit is zeolitized essentially throughout, whereas ash-flow unit 3 is effectively 100-percent devitrified and consists of high-temperature silica and feldspar phases. The basal bedded tuff unit of the Prow Pass Tuff is zeolitized and approximately 13 ft (4.0 m) thick; this interval includes a thin volcanic breccia at its base.

The Bullfrog Tuff underlies the Prow Pass Tuff beginning at a depth of 2180.2 ft (664.5 m), and the unit has an apparent thickness of 417.8 ft (127.3 m). Four pyroclastic units plus a basal bedded sandstone unit can be defined in the USW SD-7 drill core. Ash-flow units 4 and 2 are very thin: 37.8 and 3.5 ft (11.4 and 1.1 m) thick, respectively. Ash-flow unit 3 is 260 ft (79.2 m) thick, and the unit appears to be bounded below by a fairly significant fault zone that also may have cut-out a large thickness of the highly pumiceous ash-flow unit 2. Unit 3 exhibits a well defined welding profile and appears to form a single cooling unit. Bullfrog ash-flow unit 1 is almost 100 ft (30 m) thick, and this lower nonwelded interval is characterized by extensive silica veining. Unit 1 is also the most intensely zeolitized of the Bullfrog subdivisions. The basal zeolitized tuffaceous sandstone unit of the Bullfrog Tuff is 18.6 ft (5.7 m) thick.

Drill hole USW SD-7 encountered some 77 ft (23.5 m) of the Tram Tuff, which is the third and lowest formation of the Crater Flat Group, beginning at a depth of 2598.0 ft (791.8 m). The recovered core consists of nonwelded and partially zeolitized ash-flow tuff. The top of the interval is hematite stained and may represent a paleosol.

Thermal/Mechanical Units

A somewhat formalized thermal, mechanical, and hydrologic stratigraphy was defined originally by Ortiz and others (1985), based upon preliminary concepts put forward by Lappin and others (1982). The concept was to define coherent rock units for performance analyses based on rock properties, rather than on more classical geologic criteria. According to the original citation, "Two properties used to differentiate units are porosity and grain density" (p. 8). Further reading of the Ortiz reference indicates that this subdivision based on porosity and grain density translates to a first-order subdivision between welded and nonwelded materials, with additional subdivisions determined by whether the rocks are still vitric, or whether they have been altered either to a devitrification (high-temperature "crystallization") mineral assemblage or to zeolites. The so-called thermal/mechanical units were correlated with the more conventional geologic stratigraphy in table 1 of Ortiz and others; this correlation is essentially reproduced intact in table 1 of this report. The thermal/mechanical stratigraphy, as originally described, also subdivided the Topopah Spring welded interval into a lithophysae-rich upper portion in contrast with the lower part, which was presumed to be relatively poor in lithophysae (p. 11). In fact, the distribution of lithophysal alteration and lithophysal cavities is more complex than was recognized by Ortiz and her coworkers.

It is important to note that the major changes in material properties recognized as the basis for subdividing the volcanic section at Yucca Mountain by Ortiz and others do not correspond to the boundaries of the geologic units, which are identified principally by major breaks and changes in the genetic process that produced the southwestern Nevada volcanic field. The descriptive but unfortunate use by Ortiz and her coworkers of the conventional geologic names as the "base" for the thermal/mechanical unit names can cause confusion if the critical distinction between property-based and process-based nomenclature is not fully understood. Nevertheless, this physical-property subdivision that aggregates materials that behave in a similar manner has proven to be an enduring feature of the Yucca Mountain Project..

Table 4 presents the thermal/mechanical units identified in the SD-7 drill core. In keeping with Ortiz and others (1985), who presented a series of surfaces representing the *bottom* of each thermal/mechanical unit, table 4 gives the depths to

Table 4: Basal Contacts and Thicknesses of Thermal/Mechanical Units for Drill Hole USW SD-7

[Definitions of thermal/mechanical units from Ortiz and others (1985), p. 11–12]

Thermal/Mechanical Unit		Lower Contact (ft)	Apparent Thickness (ft)
TCw:	Tiva Canyon welded	305.5†	255.4†
PTn:	Paintbrush nonwelded	387.2	81.7
TSw1:	Topopah Spring welded, "lithophysae rich"	682.5	295.3
TSw2:	Topopah Spring welded, "lithophysae poor"	1191.4	508.9
TSw3:	Topopah Spring welded, vitrophyre	1274.5	83.1
CHn1:	Calico Hills nonwelded unit 1—lower nonwelded part of Topopah Spring Tuff plus ash-flow tuffs of Calico Hills Formation	1567.2	292.7
CHn2:	Calico Hills nonwelded unit 2—basal reworked zone and "bedded tuffs" of Calico Hills Formation	1626.2	59.0
CHn3:	"Calico Hills" nonwelded unit 3—upper nonwelded ash-flow tuffs of the Prow Pass Tuff	1655.0	28.8
PPw:	Prow Pass welded—welded ash-flow tuffs of the Prow Pass Tuff	1837.8	182.8
CFUn	Upper Crater Flat nonwelded—lower nonwelded ash-flow tuffs of the Prow Pass Tuff	2218.0	380.2
BFw	Bullfrog welded—welded ash-flow tuffs of the Bullfrog Tuff	2478.0	260.0
CFMn1	Middle Crater Flat nonwelded unit 1—zeolitic partially welded to nonwelded ash-flow tuffs of the lower Bullfrog Tuff	2579.4	101.4
CFMn2	Middle Crater Flat nonwelded unit 2—zeolitic basal bedded and reworked portion of the Bull Frog Tuff	2598.0	18.6
CFMn3	Middle Crater Flat nonwelded unit 3—zeolitic partially welded ash-flow tuffs of the Tram Tuff	2675.1†	77.1†

† Entire unit not penetrated; partial thickness only

each basal contact as well as the apparent thickness of each unit

Structural Geology of SD-7

Faulting

A moderately large number of small faults and fractures exhibiting at least some evidence of differential movement are present in the USW SD-7 drill core. One fault appears to have experienced sufficient movement to remove an unknown, but probably substantial interval of the Bullfrog Tuff. Faulting also may be partially responsible for some of the very poor core recovery that was experienced during drilling of the SD-7 drill hole.

That the rocks penetrated at this location would be highly faulted is not unexpected. The hole is located only about 500 ft (150 m) west of the west-dipping Ghost Dance-Abandoned Wash structural zone. It is in this vicinity that the dominantly southerly trending Ghost Dance Fault changes orientation to a more south-southwest trend and appears to form a diffuse zone of structural offset that connects to the north-south Abandoned Wash Fault to the south (Scott and Bonk, 1984). More recent, but still preliminary mapping

(W.C. Day, U.S. Geological Survey, written communication, 1996) shows the SD-7 drill site located about 650 ft (200 m) northwest of a reinterpreted Ghost Dance Fault that trends N 20° E. This same mapping also shows a smaller fault, also trending N 20° E, exposed on the hillside of Highway Ridge (fig. 3) about 250 ft (75 m) south of the SD-7 location; the projection of this fault passes only 150 ft (45 m) to the east of the drill hole collar. A set of small faults trending N 10° W is exposed on the south-facing hillside of the drainage immediately north of Highway Ridge. These faults, which are mapped as forming a series of small graben structures, project directly toward the SD-7 drill pad.

Note that faults may be difficult to distinguish from more generally rubblized core. Thus, even though a large fraction of the rubble intervals logged from the SD-7 drill core may be attributed with some degree of confidence to in-situ disaggregation of unconsolidated tuffaceous materials, mechanical breakage of the rock during drilling or, more particularly, to breakage associated with lithophysal cavities, it is likely that other rubble zones or intervals of highly fractured but poorly recovered rock may represent unrecognized faults or fault zones. This may be true particularly for lost-core intervals that are directly associated with unit contacts. For example, a thick interval of lost core is associated in the SD-7 drill core with the top of the Calico Hills Formation (approximate depth 1400 ft or 425 m; see additional discussion in Appendix A, "Calico Hills Formation (Tac)" beginning on page 57) and a lesser lost-core interval is associated with the intra-formational tops of units 2 and 1 of the Bullfrog Tuff (approximate depth 2500 ft or 760 m). Normal faults frequently are associated with omitted stratigraphic sections. Moreover, fault displacements are known (Scott and Bonk, 1984; Scott, 1990) generally to increase from north to south through the repository region, suggesting that drill hole SD-7 might well be more affected than drill holes located farther to the north.

Zelinski and Clayton (1996), who have developed a volume model of Yucca Mountain requiring a full three-dimensional accounting of observed elevations of unit contacts, stratigraphic unit thicknesses, and fault offsets, have documented that there are a number of faults at Yucca Mountain that exhibit markedly more offset at stratigraphic levels deeper than the Tiva Canyon Tuff than is identifiable in surface exposures of this latter unit. Some faults that exhibit no surface expression whatsoever are required by the three-dimensional geometry at deeper levels; see also work by Majer and others.[†] The model constructed by Zelinski and Clayton extends to the Paleozoic basement underlying the Tertiary volcanic section. Although constrained by only sparse drill hole information at stratigraphic levels underlying the general Calico Hills–Crater Flat interval, their model attempts to integrate drill hole data with information obtained from gravity and reflection-seismic surveys (Brocher and others, 1996). These latter data strongly suggest major (thousands of feet of vertical offset) down-to-the-west gradients in the inferred depth-to-Paleozoic isopleth surface that have been interpreted by Zelinski and Clayton as preserved fault scarps at this basement structural level. Although control on the location of this gradient is not sufficient to correlate it directly with the Ghost Dance-Abandoned Wash structural zone (a correlation with either or both of the Bow Ridge Fault or the Paintbrush Canyon Fault is more likely; Scott and Bonk, 1984; unpublished mapping by W. C. Day, U.S. Geological Survey, written communication, 1996), the gradient is located to the east of the crest of Yucca Mountain. A feature of this magnitude is likely to be associated with structural complexity higher in the section, and its effects are likely to be spread somewhat horizontally.

Yet another factor complicating the identification of faults in the drill core is that a significant fraction of the recovered core material was removed within minutes of retrieval to preserve the in-situ hydrologic properties of samples for laboratory testing. These intervals were not available for detailed study during creation of the geologic log for this report. We thus also rely on indicators of faulting recorded on the preliminary drill-site logs

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[†] Majer, E.L., Feighner, M., Johnson, L., Lee, K., Daley, T., Karageorgi, E., Parker, P., Smith, T., Williams, K., Romero, A., and McEvilly, T., 1995, Results of geophysical surveys along the north-south and south ESF alignment, Yucca Mountain Project Milestone 0BB02; also Summary report: Interpretation of multiple geophysical surveys, Yucca Mountain Project Milestone 0BB03; both submitted by Lawrence Berkeley National Laboratory, Berkeley, Calif.

that also produced the core recovery and drill-site RQD measurements. The amount of time available to the drill-site geologists, however, was extremely limited.

Indicators of small-displacement faulting were observed in a number of relatively short intervals separated by substantial thicknesses of rock apparently devoid of explicit indicators of movement. Two small faults that may represent conjugate breaks, each at about 20° to the core axis but dipping in opposite directions were observed at a depth of about 164.5 ft (50.1 m) within the crystal-poor lower lithophysal zone of the Tiva Canyon Tuff. Another small fault for which no definitive orientation could be measured was observed at 168.7 ft (51.4 m) depth. A fourth small fault, also lacking a reasonable orientation, was observed within the lower lithophysal zone at a depth of 186.1 ft (56.7 m).

A zone of small, but better-defined faulting is present within the lower nonlithophysal zone of the Tiva Canyon between depths of 220 and 245 ft (67–75 m) (geologic log sheet 4, Appendix B). Specific features were observed as follows: at 223.4 (68.1 m), a thin zone of fault breccia dips at 25° to the core axis (c.a.); at 224.1 ft (68.3 m), an oxidized surface exhibiting coatings of manganese oxides dips at 55° c.a.; at 224.3 ft (68.4 m), a thin breccia dips at only 45° c.a.; at 231.2 (70.6 m), a small fault dips at 30° c.a.; at 239.4 (72.9 m), a 1-cm wide fault breccia dips 30° c.a. and has been cemented by white calcite; and at 241.0 (73.5 m), a thin interval of breccia was observed but no orientation could be measured for the bounding surfaces. Other calcite veining also was observed in this general interval.

Two discrete faults were identified associated with the top of the crystal-poor lower lithophysal zone of the Topopah Spring Tuff. At 802.8 ft (246.5 m), a fault surface exhibiting clay gouge dips at 20° c.a., and a similar feature, also containing clay gouge, dips 5–10° c.a. at a depth of 810.9 ft (247.2 m). Core recovery was exceedingly poor in this lower lithophysal interval (see discussion of "Core Recovery" beginning on page 19), so it is possible that other faults are present but could not be identified.

Two well defined faults, both containing clay gouge and exhibiting slickensides, are present in Calico Hills Formation, ash-flow unit 2. One slickensided fracture at 1511.1 ft (460.6 m) is present near the base of this ash-flow sequence; this fault dips at 60° c.a. A second slickensided fracture or small fault is at a depth of 1517.3 ft (462.5 m), associated near the contact of the ash-flow sequence with the basal bedded tuff interval of Calico Hills unit 2. This latter feature dips at 75° to the core axis. Another group of two slickensided fault planes is present slightly deeper in the Calico Hills Formation; these are associated generally with the contact between ash-flow unit 1 and the Calico Hills bedded tuff unit at 1567.2 ft (477.7 m). The slickensides on the upper of these two faults (at 1566.8 ft; 477.5 m) are oriented at a nearly flat-lying 85° to the core axis., whereas those on the lower feature (at 1567.2 ft (477.7 m) dip much more steeply at 25° to the core axis. Note that flat-lying faults may have undergone large displacements with only minimal effect on the stratigraphic sequence (i.e., producing omission of units)

Limonite-stained high-angle (10° c.a.) fractures that may or may not have experienced differential movement are present at 1728.8 and 1729.8 ft (526.9 and 527.2 m) in ash-flow unit 3 of the Prow Pass Tuff. However, a clay-filled presumed fault was observed only 5.4 ft (1.6 m) deeper within ash-flow unit 3 at a depth of 1734.4 ft (528.6 m). The clay was weakly iron-stained, and the high-angle feature dips at only 5° c.a. A completely separate small fault was observed in Prow Pass ash-flow unit 1 at a depth of 1943.6 ft (592.4 m). A poorly defined, possible fault surface was also observed by drilling-support geologists at a depth of 2178.7 ft (664.0 m), immediately above the base of the Prow Pass bedded tuff unit. This last feature is near a weakly hematite-stained probable paleosurface and is associated with a breccia that has been interpreted as volcanic in origin.

Well developed slickensides that rake 10° across a fault surface at 70° to the core axis are present at a depth of 2404.4 ft (732.8 m) in ash-flow unit 3 of the Bullfrog Tuff. Iron-staining and doubtful chloritic(?) alteration appear to be associated with this feature. The contact between Bullfrog ash-flow unit 3 and the underlying pumiceous unit 2 at a depth of 2478.0 ft (755.3 m) appears to be a fault contact (geologic log sheet 36). The fault contains 0.2 ft (6 cm) of slickensided and hematite-stained clay gouge, and the fault is oriented at a 10° to the core axis. The general interval is intensely broken, and there are a number of quartz veinlets both above and below the fault. Because the pumiceous Bullfrog unit 2 below the fault is only 3.5 ft (1.1 m) thick, it appears that some section of the Bullfrog may have been cut-out by the fault. Inference of the amount of section missing because of the fault is difficult because there is little information available regarding the stratigraphy of the Bullfrog Tuff in this vicinity. It should be noted that a fault has removed roughly 100 ft (30 m) of the Calico Hills Formation plus the entire Prow Pass Tuff, plus an unknown thickness of the Bullfrog Tuff in drill hole USW WT-1 (Muller and Kibler, 1985[†]), which is located some 3000 ft (900 m) to the southeast of SD-7. Note that drill hole WT-1 is located in a completely separate fault block from SD-7 and that WT-1 is immediately west of the Dune Wash fault/structural zone (Scott and Bonk, 1984) rather than the west of the Ghost Dance Fault. The point, however, is that *substantial stratigraphic intervals can be removed by faulting*, particularly in the southern part of the Yucca Mountain region.

A small fault was observed near the bottom of the SD-7 drill core within the upper nonwelded ash-flow unit of the Tram Tuff. This flat-lying feature, which dips at approximately 80° c.a., was encountered at a depth of 2644.9 ft.

Lithophysal Zones

The definition of lithophysal zones within the welded tuffs at Yucca Mountain is a complex problem that has a long history within the Yucca Mountain Project. The issue involves distinguishing (informally) named "lithophysal zones" from other intervals that may contain lithophysae. T.C. Moyer (Science Applications International Corporation/U.S. Geological Survey, personal communication, 1994), originally indicated that lithophysal zones were to be defined simply based on "the presence of lithophysae." Ortiz and others (1985, p. 11) gave a threshold of "approximately 10% by volume lithophysal cavities" as the criterion for separating their "lithophysae-rich" (TSw1) and "lithophysae-poor" (TSw2) subunits of the Topopah Spring welded tuff.

Buesch and others (1996) present a more specific description of criteria for the identification of specifically named lithophysal zones (page 18; quoted almost in its entirety):

> *Lithophysal zones occur where vapor concentrates in the densely welded parts of ignimbrites* [ash-flow tuffs] *to form lithophysal cavities (Ross and Smith, 1961).... Lithophysae consist of a cavity, which is commonly coated with vapor-phase minerals on the inner wall of the cavity, a fine-grained rim surrounding the cavity wall, and a thin very fine-grained border.... Many lithophysae in the Tiva Canyon and Topopah Spring Tuffs have light-gray (N8) to grayish-orange pink (10R8/2) rims of microscopic to barely macroscopic elongate crystals that radiate from the walls of the lithophysae into the surrounding groundmass. These rims are up to 3-cm wide. Locally, rims have 1- to 3-mm-wide, grayish red-purple (5YR4/2) borders. Associated with the lithophysae are light-gray (N8) to grayish-orange pink (10R8/2) spots 1- to 5-cm in diameter. Some spots may represent the cross sections of rims on lithophysae, whereas others have a crystal or lithic clast in the core that could have acted as a nucleation site. There is no genetic interpretation for the spots; however, they are characteristic for some lithophysal zones.* ***Lithophysal zones in the Tiva Canyon and Topopah Spring Tuffs are identified by a combined occurrence of lithophysae and spots*** [emphasis added]. *The shape of the lithophysae and spots and width of the rims on the lithophysae can also be diagnostic of specific zones. Locally surface exposures contain lithophysae with diameters of up to 1 m; thus* ***regions of poor core recovery might indicate large lithophysae*** [emphasis added].

Vapor-phase altered rocks containing abundant (greater than 10 percent) lithophysae, with or without significant open-space cavities, are readily

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[†] more detailed information from DTN GS930208314211.004; NNA.930701.0065

recognized and are easily assigned to discrete lithophysal zones. The real complication appears to be the recognition and treatment of lithophysal-style alteration associated with cavities that are too large to be recognized *directly* in the core (and by extension, recognition of the mere presence of lithophysae). Where very large lithophysae are penetrated by the drill string, the thin, brittle septae of rock dividing the cavities typically are shattered by the force of the rotating drill bit; this logically results in intervals of rubble and unrecovered core (cavity plus rubble blown away from the bit face into other parts of the cavity). Diagnostic, remnant vapor-phase alteration rims and distinctive cavity-coating minerals frequently can be identified in the recovered rubble fragments. The question essentially reduces to whether or not an interval exhibiting these very large lithophysal cavities, but *without* significant numbers of the small-scale lithophysae or vapor-phase-altered spots, can be classified as a "lithophysal zone."

Descriptions of the SD-7 drill core for this report use multiple criteria derived from the description of lithophysal zones presented by Buesch and others (quotation above). In keeping with the logging philosophy presented in the section on core description beginning on page 8, the *principal emphasis* of the Systematic Drilling Program has been placed on *objective description of the core* and associated down-hole video imagery (particularly that presented in the foot-by-foot geologic log sheets contained in Appendix B). Association of unit names with these descriptions is distinctly secondary. Generally, named "lithophysal zones" identified in this report contain rocks exhibiting small- to medium-sized lithophysae and/or "spots" whose matrix is grayish red-purple in color, as recommended by Buesch and others (1996, p. 18). This type of material typically is associated with vapor-phase alteration of varying, but relatively strong, intensity immediately adjacent to observable lithophysae. The matrix of rocks from named ***non***lithophysal zones is typically more brownish or orangish in color; note that description of rock colors is somewhat subjective, even when using standard rock-color charts (Geological Society of America, 1991). The finer-scale texture of the rock between lithophysal cavities in lithophysal zones is typically stretched and foliated, as if distorted by the inflating lithophysal cavities. Fracturing within named lithophysal zones is generally distinctive as well; fractures tend to be shorter and more irregular in form, and to exhibit rougher surfaces than those encountered outside the named lithophysal zones. Unquestionably, some of the names assigned in this report are somewhat in conflict with the description of the corresponding interval. The descriptions should take precedence, as these do reflect local heterogeneities in the tuff mass.

Drill hole USW SD-7 was collared in the crystal-poor middle nonlithophysal zone of the Tiva Canyon Tuff. The contact of this unit with the underlying crystal-poor lower lithophysal zone is anything but distinct. The uppermost lithophysal cavities visible in core occur at 74.8 feet (22.8 m; log sheet 2, Appendix B); these are accompanied by a definite increase in the intensity of vapor-phase alteration. Lithophysae are quite flattened and are widely spaced down to a depth of about 130–140 feet (40–43 m). Vapor-phase alteration is variable but relatively intense, and there are a modest number of thin vapor-phase silica veinlets cutting the core at various angles. The frequency of flat, vuggy lithophysae increases somewhat below 140 ft (43 m), but these features become crowded (log sheet 3) only between about 167.5 and 195.0 ft (51.0–59.4 m). There are a number of unrecovered and rubblized intervals throughout the lower lithophysal zone that may be attributed in part to the presence of additional, potentially somewhat larger lithophysae. The lower contact, in contrast, is relatively sharp with the intensity of lithophysal-style alteration and the number of mesoscopically observable lithophysal cavities diminishing virtually to zero at about 195 feet (59 m).

Within the Topopah Spring Tuff, the uppermost lithophysae are encountered at a depth of approximately 455.4 ft (138.8 m). These lensoidal features are widely spaced, and their frequency decreases by about 465–472 ft (142–144 m). Widely spaced lithophysae without alteration rims increase in number beginning at about 487.8 ft (148.7 m), becoming closely spaced by about 507.6 ft (154.5 m). The 487.8-ft depth has been taken as the contact of what appears to be the crystal-poor upper lithophysal zone. Mesoscale lithophysae appear virtually absent from a 18–20-ft (roughly 6-m) interval between 526 and 534 feet (160–163 m) that consists of highly rubblized core and unrecovered intervals. Lithophysae increase markedly at a depth of 533.3 ft (162.5 m), and at this depth the lithophysae exhibit significant vapor-phase alteration rims. Lithophysal cavities throughout the upper lithophysal zone appear to be bimodal in size. Mesoscale cavities in core are interspersed with what appear in down-hole video imagery to be very large (larger than core diameter), vapor-phase-coated lithophysal cavities. Inferred large cavities are most abundant between depths of about 560 and 625 ft (170–190 m). The abundance of mesoscale lithophysae in core diminishes rapidly at about 646 ft (197 m), although lithophysae are present in variable numbers down to a relatively abrupt contact with the middle nonlithophysal zone at 682.5 ft (208.0 m).

The intensity of lithophysal-style alteration associated with the crystal-poor lower lithophysal zone increases rapidly over a 1–2 ft (0.3–0.7 m) interval beginning at 801.6 ft (244.3 m). The contact is placed at a depth of 803.3 ft (244.8 m), at the beginning of a rubble zone associated with very frequent "lost-core" intervals and other rubble zones. Significantly more of the core throughout the lower lithophysal zone was "lost" or rubblized than was recovered intact. Down-hole video imagery suggests that the large lithophysal cavities interpreted as responsible for the exceedingly poor core recovery encountered in this interval are largest near the top of the zone and that they decrease in size progressively down to a depth of roughly 875 to 890 ft (265–270 m). Mesoscale lithophysae dominate recovered core below about 890 ft, and these lithophysae become more flattened downward. Several intervals between about 900 and 1050 ft (257–320 m) appear to be nonlithophysal, but are still affected by quite intense vapor-phase (almost lithophysal-style) alteration and mineralization. The base of the lower lithophysal zone is placed at a depth of about 1020 ft (311 m) at the lowest occurrence of opened lithophysal cavities that are accompanied by significant vapor-phase rims. Relatively rare, flattened lithophysae without alteration rims occur down to a depth of 1042 ft (317.5 m).

Rock Quality Considerations

Core Recovery

Percent core recovery was determined at the drill site by Yucca Mountain Project drilling support staff during the coring of hole USW SD-7. Recording core recovery information is a relatively mechanical process and follows a set procedure. Core recovery data are presented in Appendix C, Table C-1; this information is also presented graphically in summary form in figure 4. Core recovery information is presented in more detail on the geologic log sheets of Appendix B, which allows inference of possible lithologic controls of lost core and as means of qualifying the reliability of the associated lithologic descriptions. Description of intervals with exceptionally poor core recovery requires a subjective "reading" of multiple lines of indirect evidence.

A generalized summary of the procedure used to determine core recovery is as follows.

1) The core is laid out in an appropriate manner. Broken segments are fitted back together as best possible to represent in-situ dimensions. Rubble is reaggregated to continuous piles of approximately the core diameter.
2) The start and stop depths of the core run are identified from information provided by the driller and the length of the core run is determined.
3) The total length of core recovered from a given run is measured using a steel tape measure and the footage is recorded.
4) Recovery is computed as the percentage of material actually recovered from that interval.

Core recovery data are only estimates. The accuracy of these estimates in reflecting the actual recovery for a core run can be quite precise for intervals of generally good recovery of essentially intact core. Accuracy diminishes markedly as the integrity of the core decreases, because loose rubble recovered in the core barrel must be approximated back to in situ dimensions prior to measurement.

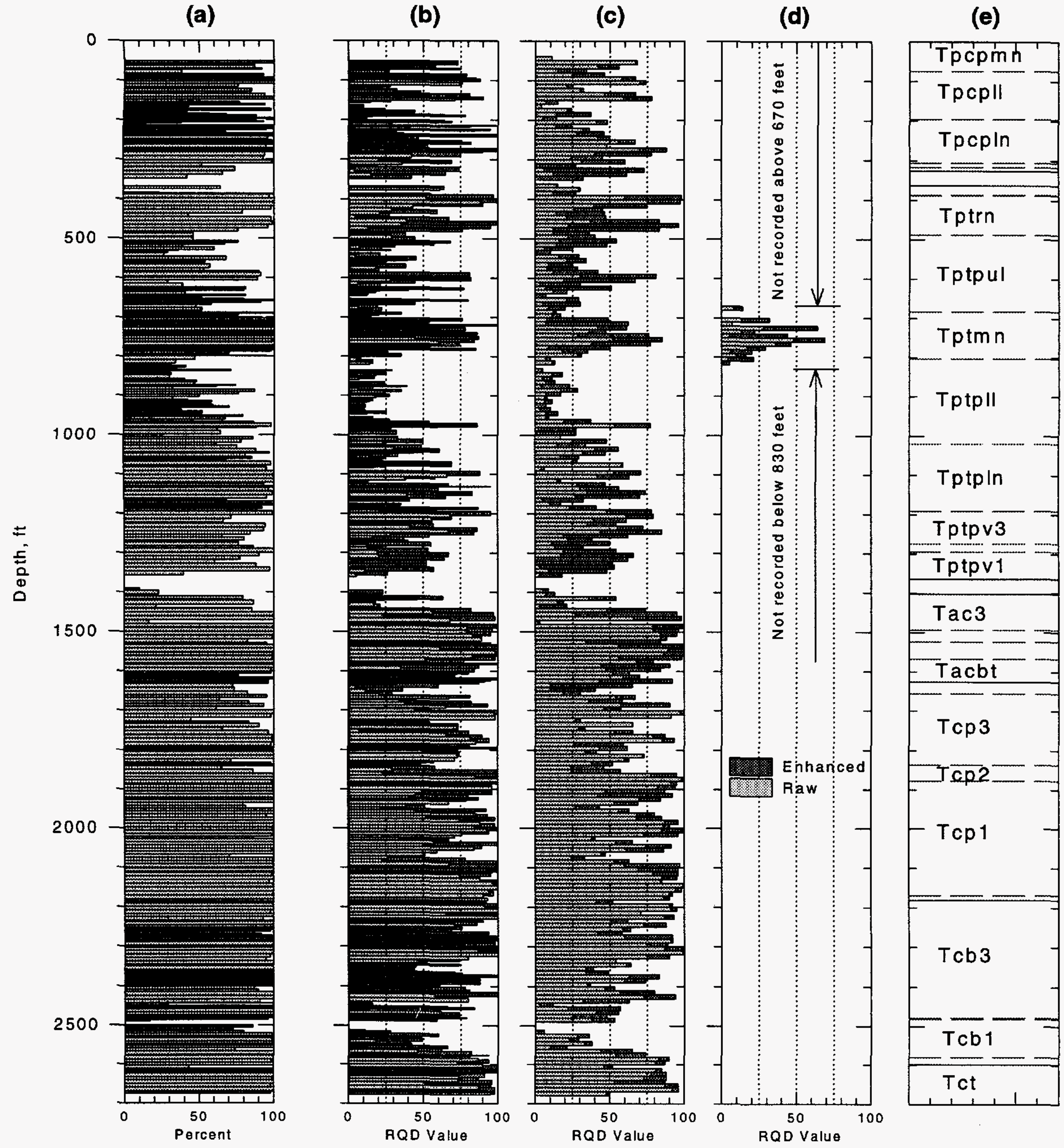

Figure 4. Plots showing (a) core recovery, (b) field measured core-run RQD, (c) 10-ft averaged field-measured RQD, (d) 10-ft averaged video-analysis RQD, and (e) geologic unit contacts for the USW SD-7 drill hole as a function of depth. Dark grey bars are “enhanced” or original RQD values of Deere and Deere (1989); lighter grey bars are raw RQD values uncorrected for coring-induced fractures. Dotted vertical lines are RQD classes from table 5. Thinner geologic units not labeled.

Reference to figure 4(a) and the geologic log sheets of Appendix B indicates that core recovery was generally fairly good down through the base of the welded Tiva Canyon Tuff, although achieving this good recovery required the use of very short core runs. Core recovery decreased markedly through the Paintbrush nonwelded interval (PTn unit) between about 300 and 375 ft (90–115 m). Recovery was particularly poor in the lower part of this interval in what appear to be completely unconsolidated pumice-fall deposits, and no core was recovered from a 20-ft (6.1-m) interval beginning at 342.0 ft (104.24 m). Identification of geologic units is difficult in this depth range, and the presence of the distal part of the Pah Canyon tuff could not be confirmed in the SD-7 drill core.

Core recovery was quite good (exceeding 90 percent) in the uppermost welded units of the Topopah Spring Tuff (fig. 4). However, recovery was typically only about 50 percent through the majority of the two lithophysal zones, and much of what material was recovered was simply rubble. Poor recovery in the lithophysae-bearing intervals is attributed to breakage of the rock during the drilling process followed by displacement of the broken fragments into lithophysal cavities by the force of circulating air and to the presence of significant intervals of large in-situ cavities. Core recovery was excellent in the crystal-poor nonlithophysal zone (the repository horizon) and relatively good in the crystal-poor lower nonlithophysal zone underlying the lower lithophysal interval. Note in figure 4 that the transition from low recoveries of 40–50 percent in the upper half of the lower lithophysal zone to recoveries approaching 100 percent in the lower half of the lower nonlithophysal zone is gradational and that there is no well defined "contact" between rock "units" defined on the basis of core recovery. This is in contrast to the relatively abrupt change in core recovery observed associated with the base of the crystal-poor upper lithophysal zone, where geologic log sheet 10 (Appendix B) indicates that lithophysal-style alteration decreases markedly over a relatively thin 11-ft (3.35-m) interval beginning at 646 ft (197 m) and is virtually absent below a depth of 682.5 ft (208.0 m). Geologic log sheets 13–15 indicate that the size of lithophysal cavities and the overall intensity of lithophysal-style alteration within the lower lithophysal interval decrease progressively over a nearly 200-ft (60-m) interval from roughly 860 ft (260 m) to below 1040 ft (320 m). Rautman and Engstrom (in press) have documented for drill hole USW SD-12 that the presence of large lithophysal cavities, in particular, is not limited to the more strictly defined "lithophysal zones" of Buesch and others (1996).

Core recovery was effectively zero through the lowermost part of the nonwelded vitric subzone of the Topopah Spring and the pre-Topopah Spring Tuff bedded tuff, including approximately 45 continuous feet of total core loss. The detailed geology of this interval is nearly uninterpretable using core. Core recovery improved markedly within the Calico Hills Formation, and this improvement is attributed to partial to moderate zeolitization (or other alteration) of these nonwelded tuffs. Recovery in the lower half of the SD-7 drillhole (below the Paintbrush Group) typically exceeded 90 to 95 percent. An approximately 150-ft (45-m) interval of lower (roughly 70–80 percent recovery) was encountered associated with Prow Pass ash-flow unit 3 (1600–1750 ft; 485–535 m). Ash-flow unit 3 is moderately to densely welded throughout much of its thickness, and the lower core recoveries observed in these more brittle rocks is attributed to fracturing potentially associated with the west-dipping Ghost Dance-Abandoned Wash fault system. A second zone of very low core recovery and highly fractured rock is associated with the lower Bullfrog Tuff at a depth of almost exactly 2500 ft (760 m).

RQD (Rock Quality Designation)

Measurement of RQD is also a relative mechanical process, and it is usually performed as an adjunct to measurement of core recovery. Like core recovery, RQD has been defined on a per-run basis for each drilling interval (Deere and Deere,1989). RQD generally is also reported on the basis of a standardized interval, typically 10 feet (approximately 3 m). The use of a standard-length measurement interval reduces the occurrence of interspersed, wildly erratic RQD values that may be associated with numerous very short core runs (particularly in broken rock).

The procedure for determining RQD data is as follows.

1) The core is laid out in an appropriate manner as for core-recovery measurements.
2) The length of the core run is determined as for core-recovery measurements.
3) The cumulative footage of intact, whole core segments of sound rock longer than 4 inches (100 mm) as measured along the centerline of the core is measured using a steel tape measure. Ends that result from diagonal fracturing of the rock mass are excluded from the measurement (fig. 5). There are two alternatives for the treatment of fractures:
   (a) all extant fractures are considered as breaks in the core, regardless of whether or not the fractures appear to be natural or drilling induced; or
   (b) only natural fractures are considered to be breaks in the core.
4) The cumulative footage thus measured is converted to a percentage of the drilling interval and recorded to the nearest percent.

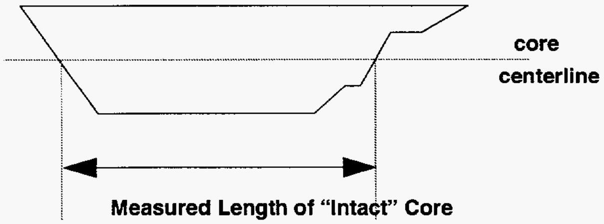

Figure 5. Conceptual sketch for measuring the length of "intact" core segments for RQD determinations. Ends, "ears," and other segments are not included in the length measurement. Segments must be longer than 4 inches (100 mm) to count toward RQD.

The originator of the RQD measurement system (Deere, 1963; see also Deere and Deere, 1989, p. 15, 43) recommended that only natural breaks in the core be considered. Deere and Deere explicitly state that breaks that are obviously an artificial result of the drilling and/or core-handling process are to be discounted in the determination of "broken" core. Criteria for identifying natural fractures may include: fracture in-filling or mineralization; obvious non-matching sides; the presence of gouge, slickensides, or other structures suggestive of relative movement; and potentially other site-specific features. Criteria for induced fractures include: actual observation of core breakage during handling; absence of any fracture-filling material other than drilling mud (which was not used in site-characterization drill holes at Yucca Mountain); clean, sharp edges that fit tightly together; and breaks at 90° to the core axis. If the origin of a particular break is in doubt, their procedure is to count it as a natural break, which would produce an RQD value that is conservative from a rock-stability standpoint. If all fractures are considered breaks in the core, the value that results is referred to in this report as "raw RQD." If induced fractures are discounted, the value is referred to as "enhanced RQD" or "Deere RQD."

The requirement for "sound rock" is also subjective, but it is intended (Deere and Deere, 1989, p. 16) to exclude intervals of altered, weathered, or otherwise unstable material that might conceivably be recovered "intact" (not fractured or broken). If the soundness of a particular core segment that would otherwise qualify is in doubt, it is excluded from the cumulative piece-length measurement for RQD determination. The intent is to be conservative from a design standpoint of estimating ground stability. In practice, such subjective decisions involving Yucca Mountain core are not an issue, as the type of alteration that typically produces "soft," intact core is virtually unknown from the upper part of the volcanic section.

Measured RQD data for the individual core runs of drill hole USW SD-7 are given in Appendix D, table D-1. The 10-ft composite (averaged) RQD values are in table D-2. RQD values for the SD-7 drill hole are presented in graphical form in figure 4, parts (b), (c), and (d). RQD values are also included graphically on the detailed geologic log sheets in Appendix B.

Note that there are two sources of RQD data and RQD composites. The data in table D-1 and the columns in table D-2 that are headed "Drilling Support" are based on actual physical measurement of the core by drilling support staff at the time of recovery of the core from the hole. The values in the columns of table D-2 that are headed "Study 8.3.1.14.2" are based on interpretation of video images of the core that were filmed immediately upon opening of the core barrel in the field. The field-measured values benefit from direct physical observation of the core, including the ability to examine actual fracture surfaces for the presence of mineralization and other phenomena that may bear on the issue of natural versus induced. However, the logistics of sampling the core at the rig site and preserving those samples in near-in-situ hydrologic conditions limits the time that can be spent examining a core run to a few minutes. The video-based RQD measurements, which were actually obtained as part of SCP Study 8.3.1.14.2 (Soil and Rock Properties of Potential Locations of Surface Facilities; USGS, 1991b), are not subject to this time limitation; however, these data are limited by the inability to examine the core itself physically. The values portrayed on the detailed geologic log of drill hole SD-7 are the 10-foot composite, field-measured, raw and enhanced RQD values from table D-2.

A relatively minor, potentially confounding lack of information for the SD-7 drill hole results from the fact that the video-analysis-derived RQD values were developed specifically for use in design of the Exploratory Studies Facility, and because of accelerating design schedules and budgetary restrictions, these data were obtained only for the immediate repository-host horizon (the crystal-poor middle nonlithophysal zone of the Topopah Spring Tuff). The video-analysis values simply were not recorded above 670 ft (204 m) nor below 830 ft (253 m), as the shallower and deeper parts of the SD-7 drill hole are outside the zone of short-term engineering interest. In fact, the differences between the RQD values derived from the two different sources are relatively insignificant in light of the fact that RQD is a rough, preliminary estimate of rock mass integrity. Design decisions for ground support of underground openings, such as the Exploratory Studies Facility or a potential repository, are generally based on large categorical groupings of RQD values (table 5), or on the basis of more sophisticated indicators of rock mass stability, such as those provided by the "RMR" or "Q" rating systems (Barton and others, 1974; Bieniawski, 1989). Engstrom and Rautman (in press) and Rautman and Engstrom (in press) have presented data which indicate that the drilling support RQD information [parts (b) and (c) of fig. 4] should be completely adequate as simple indicators of rock mass integrity and stability. These data are available for the entire SD-7 drill hole down to TD.

Table 5: RQD and Rock-Quality Descriptors
[after Deere and Deere (1989)]

RQD	Description
90–100	Excellent
75–90	Good
50–75	Fair
25–50	Poor
0–25	Very poor

As anticipated, the core-run RQD values [column (b) of fig. 4] are noticeably more variable than the ten-foot composites ($\sigma^2_{run} = 35.4$; $\sigma^2_{10\text{-ft}} = 30.0$ for enhanced RQD). For these composite values, the enhanced or Deere RQD values are logically higher than the raw values ($\mu_{enh} = 55$; $\mu_{raw} = 37$), for which the impact of drilling and sample handling have not been discounted. Note that in many intervals, such as that from 430 to 530 ft (130–160 m), the effect of ostensibly coring-induced fractures may be rather significant. Generally, the integrity of the thick welded Topopah Spring interval (400–1200 ft; 120–365 m) is rather poor by any measure. The presence of abundant lithophysal cavities and brittle welded materials combine to produce very low values of RQD (very poor ground conditions; table 5). Typically the nonlithophysal zones (for example, 390–490 ft; 119–149 m) exhibit higher values than do the lithophysal zones (compare 800–960 ft; 244–293 m). Rock quality is markedly higher in the largely nonwelded and in general at least partially zeolitized intervals below 1450 ft (440 m). Note however that there are moderately thick intervals even in these lower units that exhibit only "fair" to "good" ground conditions (table 5). Although once-planned excavation of a "Calico Hills test-level drift" as part of the Exploratory Studies Facilities currently appears to have very low priority, thus reducing any near-term design need for this information, the fact that RQD is a quantity directly related to the spacing of open fractures may provide relevant, indirect information on fracture frequency for more hydrologic-related studies.

Measured Lithophysal Cavity Information

A very minor amount of quantitative information regarding the abundance of the smaller lithophysal *cavities* (as distinct from the abundance of lithophys*ae* and of large cavities) was obtained from the USW SD-7 drill hole *for the proposed repository-host horizon only* (Tptpmn) because of resource restrictions (similar to the case of the video-analysis RQD measurements). These data were obtained by comparing the surface area of the core and core-video images occupied by actual cavities with standard charts for estimating mineral percentages in thin sections. This minimal data is reported in Appendix E, table E-1. Because the middle nonlithophysal zone typically contains very few lithophysae and in SD-7 the unit is virtually free of lithophysae, the data are rather uninteresting and a graphical representation of these data is not warranted. Only the uppermost 10-ft (3-m) interval ending at a depth of 680.0 ft (207.25 m) contained lithophysae; the areal fraction of lithophysal cavities in this single depth increment is only 2 percent.

Fracture Information

Fracture information has been recorded as part of logging of the core from drill hole USW SD-7. Fractures are represented schematically on the geologic log sheets in Appendix B. This representation is qualitative; however, it does capture much of the general style of fracturing. Fracture density is approximately shown, and fracture orientations are shown with respect to the core axis (effectively vertical at SD-7). The simultaneous presentation of fracture style with the other geologic indicators allows some understanding of controls on fracture density, orientation, and mineralization. This qualitative fracture description is available for the entire drill core. Only minimal more quantitative fracture information from detailed counting and measurement in the style of Engstrom and Rautman (in press, fig. 7) and Rautman and Engstrom (in press, fig. 7) has been obtained from the SD-7 drill core, and this information is available effectively for only the potential repository host horizon, the crystal-poor middle nonlithophysal zone of the Topopah Spring Tuff. These few data have been summarized in 10-foot depth increments and are presented in Appendix F, table F-1.

The quantitative fracture data for the crystal-poor middle nonlithophysal zone are presented in figure 6. The fracture density log shown in part (a) of figure 6 distinguishes coring- and handling-induced fractures from natural fractures. The "natural" category actually includes both natural fractures and fractures of "indeterminate" origin. Part (b) of figure 6 portrays fracture orientations by 30-degree increments; a somewhat expanded frequency scale has been used to allow better visualization of the different orientation classes. The appendix contains a more detailed 10-degree categorization of fractures. Neither the fracture data of Appendix F nor figure 6 has been corrected for the well-known effect of fracture dip on the numbers of fractures observed in a vertical borehole (Scott and others, 1983):

$$F_c = \frac{F_m}{\cos\alpha}, \tag{1}$$

where F_c is the fracture frequency *c*orrected for fracture dip, α (from the horizontal), and F_m is the *m*easured fracture density. The impact of this cosine-correction factor will be relatively large in some intervals.

Part (c) of figure 6 provides a breakdown of clean fractures in contract to fractures that contain some degree of mineralization or veining. Mineralized fractures are fairly common in this part of the drill hole, accounting generally for at least half of the total fractures from this limited vertical interval.

RQD values and core recovery information are also shown in figure 6 for comparison [columns (d) and (e) respectively]. Although rock quality and RQD values should be inversely related to fracturing, there appears to be a clear *direct* correspondence between the more highly fractured intervals and intervals of high RQD (presumably less broken rock). The cause of this correlation is that actual counting and measurement of fractures cannot be accomplished for core that is not recovered. Mea-

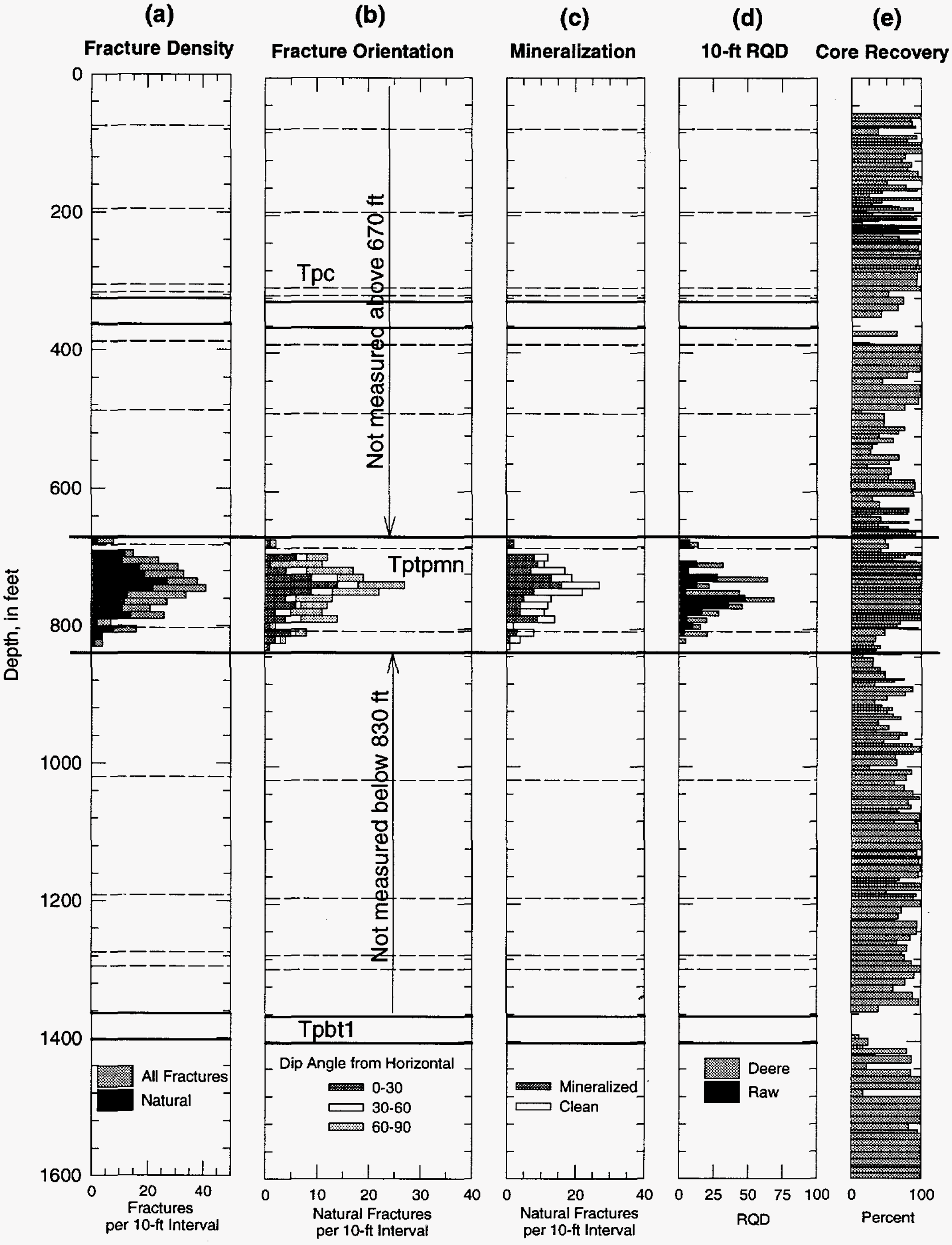

Figure 6. Graphs showing (a) measured fracture density, (b) fracture orientation (dip angle), (c) mineralized fractures, (d) 10-ft video-analysis RQD, and (e) core recovery for the upper part of the USW SD-7 drill hole. Solid horizontal lines indicate top and bottom contacts of the Tiva Canyon and Topopah Spring Tuffs. Dashed horizontal lines are contacts of selected zonal subunits.

surement of RQD is affected in a similar manner in that missing core adds zero footage to the cumulative footage of core segments greater than four inches.

Rautman and Engstrom (in press) discuss the implications of this somewhat illogical observed relationship between fracturing and rock quality in drill hole USW SD-12, for which quantitative fracture data were available for nearly the entire Paintbrush Group. They also attempted to correct the observed fracture frequencies for the impacts of lost core, lost core plus rubble (highly broken material for which individual fractures were not individually counted), and for the combined influence of these two confounding factors. The almost trivial amount of quantitative fracture data available for the USW SD-7 drill hole renders this type of analysis virtually meaningless. However, equations 2–4 of Rautman and Engstrom (in press) could be applied to the data in table F-1. The impact would be relatively small for the influence of "lost core, as the core recovery log (column (e) of fig. 6) indicates nearly 100-percent core recovery in the repository host horizon. The "lost core" and "rubble" data required for the adjusting equations can be found in table E-1.

Framework Hydrologic Properties

Laboratory Techniques

Core samples were obtained from SD-7 at approximately regular intervals for laboratory measurements of framework material properties. "Framework material properties" are defined in Study Plan 8.3.1.4.3.1 (Rautman, 1993) as porosity, bulk and particle density, and saturated hydraulic conductivity. Water contents were also determined and used to compute approximate in-situ saturations and volumetric water contents.

Approximately 800 eight-inch long core samples were collected for hydrologic analyses on a nominal 3-foot, regular sampling interval. Each core sample was subdivided into two subsamples. A 2-inch long core fragment was placed in a metal container and sealed within minutes of core retrieval from the hole. An immediately adjacent 6-inch subsample was preserved in a Lexan tube that was capped and sealed with duct tape. The intent was to preserve in-situ moisture contents as closely as possible, and especially to prevent dry-out of the core and subsequent changes in pore geometry caused by desiccation of clays and zeolites. Such changes have been demonstrated to affect permeability measurements irreversibly.

Porosity, bulk density, particle density, and water content were determined in the laboratory for the hermetically sealed 2-inch core fragments. Separately, a subset of the 6-inch core samples were subcored to produce specimens suitable for measurement of saturated hydraulic conductivity. Core plugs were trimmed using a small diamond saw to approximate right-circular cylinders approximately 2.5 cm in diameter and 3–10 cm long prior to testing. Porosity, bulk density, and particle density were also measured for these prepared specimens.

Water content was determined by gravimetry and is reported as volumetric water content in cubic centimeters per cubic centimeter. Porosity (ϕ, in cubic centimeters per cubic centimeter and expressed as a decimal fraction for simplicity), bulk density (ρ_b, in grams per cubic centimeter), and particle density (ρ_p, in grams per cubic centimeter) were determined using gravimetry and Archimedes' principle to determine sample volume. There were two departures from the classical application of this technique. First, the samples were saturated initially with carbon dioxide gas by introducing the gas into an evacuated bell jar containing the samples; this process, repeated three times, prevents air entrapment in small pores within the densely welded tuff samples because the CO_2 is water-soluble. The samples were then saturated with degassed distilled water under a vacuum. Scoping studies have indicated that saturated weights did not change meaningfully following a single iteration of this vacuum-saturation process, even with the addition of a pressure-saturation step. Second, the samples were dried in a relative-humidity (RH)-controlled oven at 60°C and 65-percent RH (after concepts of Bush and Jenkins, 1970), rather than at 105°C and associated ambient RH. Soeder and others (1991) advocated the use of a lower temperature, humidified technique, not only to preserve water present in the crystal structure of any clays or hydrated minerals (such as zeolites), but also to retain water loosely bound to grain surfaces which is otherwise unavailable for unsaturated flow. The selected RH of 65 percent translates to an estimated residual-saturation pressure for Yucca Mountain samples of approximately -700 bars (L.E. Flint, U.S. Geological Survey, written communication, 1996).

Particle density, as used in this report, is similar to the more commonly reported grain density. However, because particle density is a property computationally derived from intact core samples, totally encapsulated void space (which thus is inaccessible to water flow) is not considered. Particle density is almost invariably lower than a grain density determination obtained by crushing the rock and measuring the change in total volume. Particle density will approach grain density for rocks that have little totally encapsulated pore space. Bulk-property measurements were repeated after more conventional sample drying at 105°C to allow for comparison with other reported data (ASTM, 1990). Sample weights were reduced to the desired bulk properties as follows:

$$\rho_b = \frac{\text{dry weight}}{\text{bulk volume}}\ , \tag{2}$$

$$\phi = \frac{\text{pore volume}}{\text{bulk volume}}\ , \text{ and} \tag{3}$$

$$\rho_p = \frac{\text{dry weight}}{\text{bulk volume} - \text{pore volume}}\ , \text{ where} \tag{4}$$

pore volume =

$$\frac{(\text{saturated weight} - \text{dry weight})}{\rho_w}\ , \tag{5}$$

and ρ_w is the temperature-adjusted density of water (in grams per cubic centimeter). Bulk volume is simply the mass of the fully saturated sample submerged in water (by Archimedes' principle). "Dry" weight is the weight of the sample for either the RH- or 105°C-dried conditions. Volumetric water content (VWC) was determined as:

VWC =

$$\left(\frac{\text{saturated weight} - \text{dry weight}}{\text{dry weight}}\right) \cdot \rho_b\ . \tag{6}$$

Saturated hydraulic conductivity, K_s, in meters per second and usually presented as $\log_{10} K_s$ throughout this report, was measured using a constant-head method. The core plugs were saturated with tap water using the vacuum evacuation/CO_2 flooding technique. Each sample was encased in heavy vinyl tubing and placed in a chamber (Hassler permeameter) that produced a hydraulic confining pressure (~0.41–0.55 MPa), slightly exceeding the gradient across the sample, to prevent escape flow around the sides of the sample. Confining pressures of this magnitude do not affect the permeability of the rock, especially since welded samples have compressive strengths on the order of 100 MPa (Nimick and Schwartz, 1987). Even the nonwelded tuffs within the Paintbrush Group typically exhibit unconfined compressive strengths of at least 3 to 5 MPa (Martin and others, 1994). A separate system provided J-13 tap water under pressure for flow through the sample. Effluent was weighed on a top-loading balance and the mass was recorded as a function of time as the water left the sample. Saturated hydraulic conductivity was computed from Darcy's law:

$$K_s = \frac{Q}{A} \cdot \frac{L}{\Delta H}\ , \tag{7}$$

where Q is the quantity of water flowing through the sample (cm^3/sec), A is the cross-sectional area of the sample core plug (cm^2), ΔH is the change in total head (cm) across the sample, and L is the length (cm) of the core plug. Note that K_s has been converted to units of meters per second in all tables and figures in this report.

Material-Properties Data

Results of the laboratory material-properties determinations are presented in Appendix G. Table G-1 contains bulk properties (porosity, bulk density, particle density) and initial water contents and apparent saturations for both relative-humidity oven-dried and 105°C-dried samples. Saturated hydraulic conductivity measurements are presented in table G-2. Separate porosity measurements were also obtained from the permeability-plug samples. These latter porosity data are given in the table of conductivity values.

Data from table G-1 are presented graphically in log format in figures 7 and 8. Figure 7 shows the laboratory results for the entire Paintbrush Group

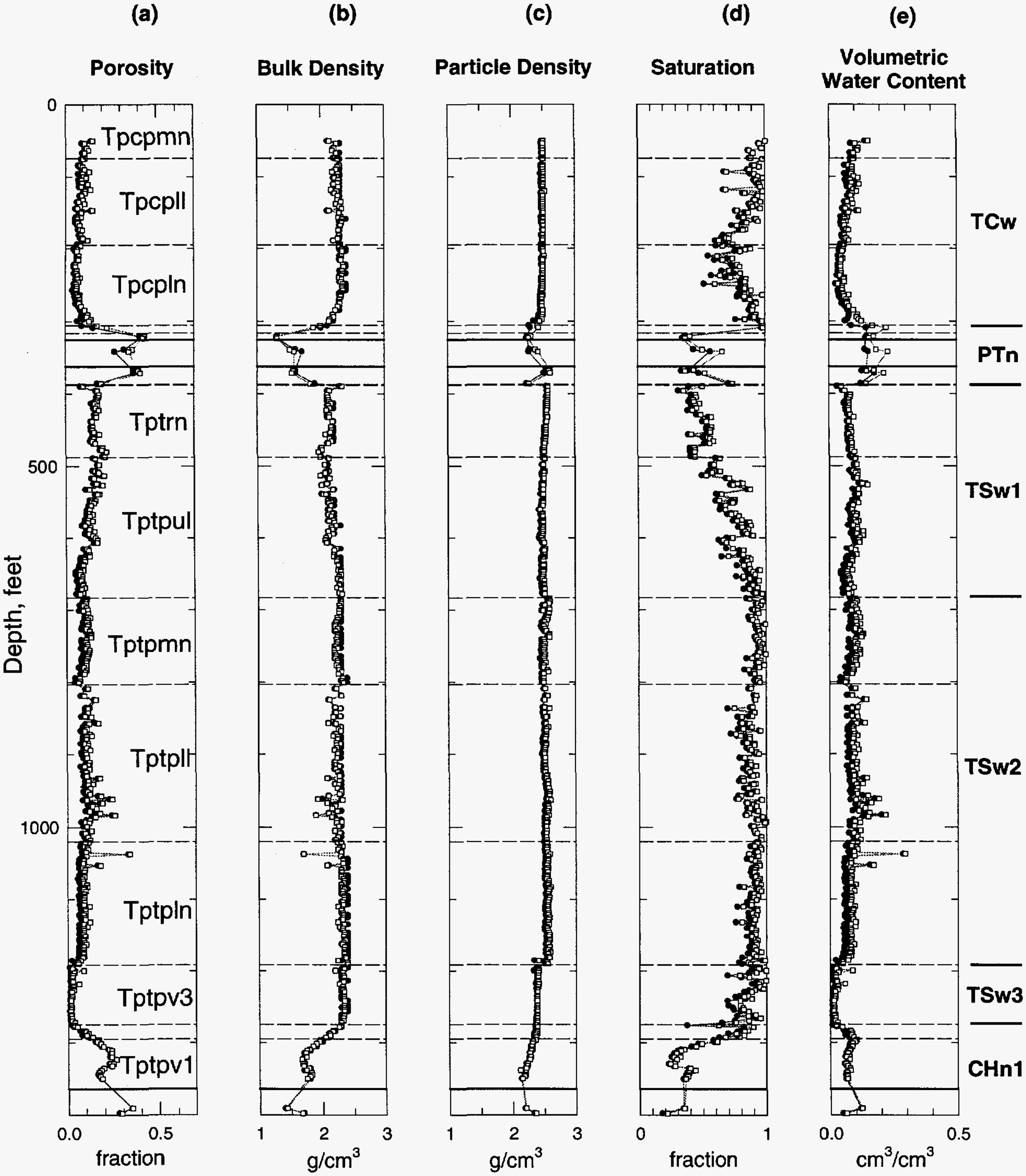

Figure 7. (a) Porosity, (b) bulk density, (c) particle density, (d) saturation, and (e) water content profiles of core samples collected from the upper portion of the USW SD-7 drill core. Solid circles–relative-humidity oven-dried samples; open squares–105°C-dried samples. Horizontal lines indicate top and bottom contacts of the Tiva Canyon and Topopah Spring Tuffs (solid) and internal zones (dashed).

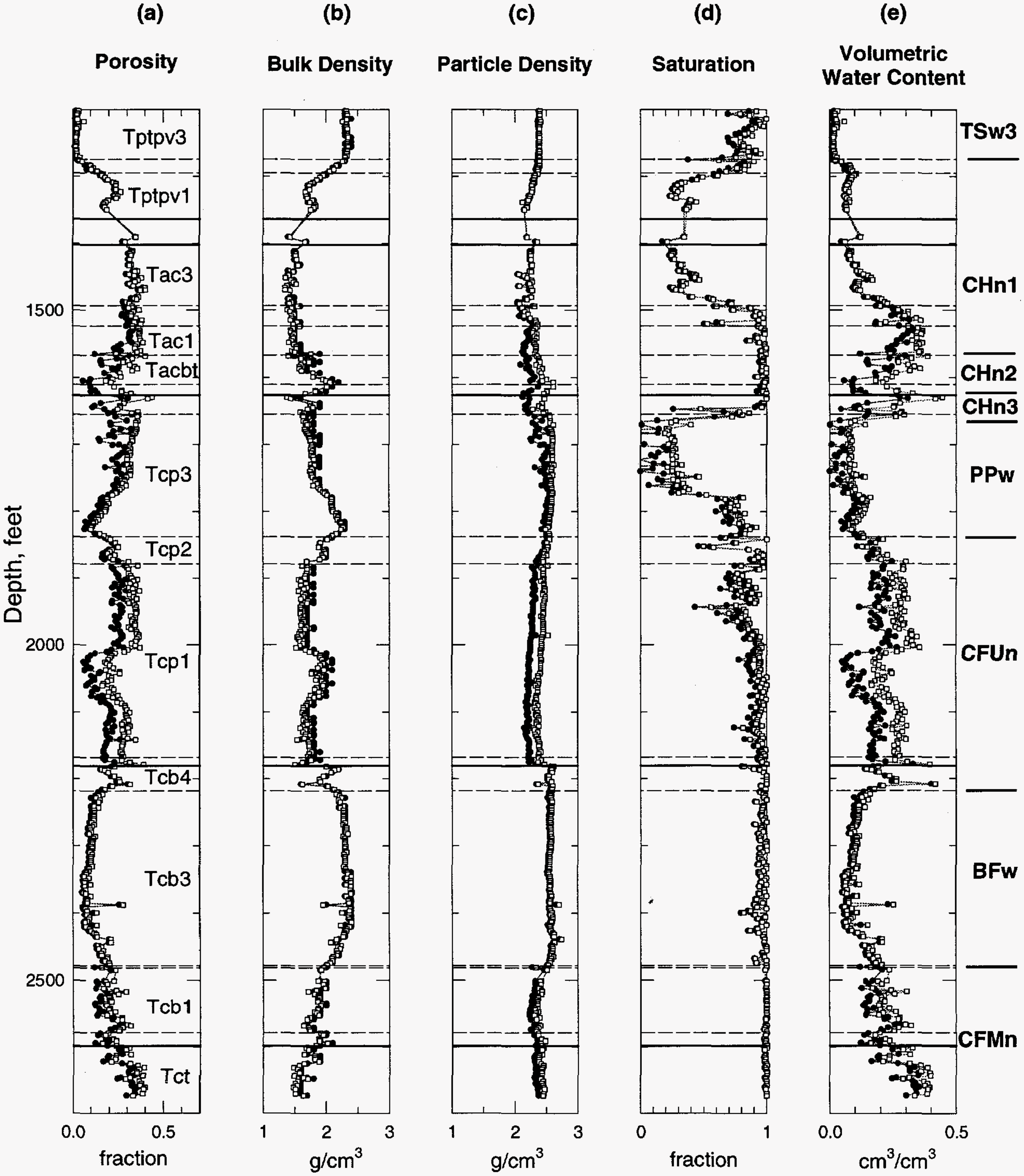

Figure 8. (a) Porosity, (b) bulk density, (c) particle density, (d) saturation, and (e) volumetric water content profiles of core samples collected from the lower portion of the USW SD-7 drill core. Solid circles–relative-humidity oven-dried samples; open squares–105°C-dried samples. Horizontal lines indicate top and bottom contacts of the Topopah Spring Tuff, Calico Hills Formation, and the Prow Pass, Bullfrog, and Tram Tuffs (solid) and internal zones (dashed).

interval down to the pre-Topopah Spring Tuff bedded tuff. Figure 8 is an identical presentation, only the displayed interval extends from just above the base of the Topopah Spring Tuff through the Calico Hills Formation and the Prow Pass and Bullfrog Tuffs of the Crater Flat Group. this two-part presentation allows both halves of the hole to be displayed without excessive vertical compression. The figure includes both the relative-humidity and 105°C data, which are represented by different symbols. Note that the two values for each sample are essentially identical throughout most of the upper portion of the drill hole. Major differences in the properties measured under these two test conditions occur only in the presence of hydrated minerals, such as clays and particularly zeolites. Generally, the picture that emerges from the material-properties data is reflective of the thermal/mechanical units identified in table 4 (marginal labels on figs. 7 and 8). The saturated hydraulic conductivity data from table G-2 are presented in graphical format in figure 9, together with the corresponding porosity measurements from these subcored sample plugs.

The major lithologic subdivisions of the rock column penetrated by drill hole USW SD-7 can be identified in the material-property profiles shown in figures 7 and 8. The welded portion of the Tiva Canyon Tuff is represented by measured porosity values of approximately 0.10, extending down to a depth of about 300 ft (90 m). Below this depth, porosity values increase progressively through the lower vitric zone of the Tiva Canyon (the shardy-base interval), and they remain high (0.30–0.50) through the interval from the base of the Tiva Canyon Tuff to the top of the Topopah Spring welded interval (much of this interval was lost during drilling leading to very sparse sample spacings). The bottom of this latter subzone is at about 387 ft (118 m). Welded materials with porosities typically less than 0.10–0.12 form the bulk of the remainder of the Topopah Spring Tuff below 387 ft (118 m) and extending through the base of the basal vitrophyre subzone of the lower vitric zone (Tptpv3) at 1191.4 ft (363.1 m).

A few of the internal zones of the Topopah Spring Tuff can be identified within the thick welded portion of this unit. Notably, the thin vitro-

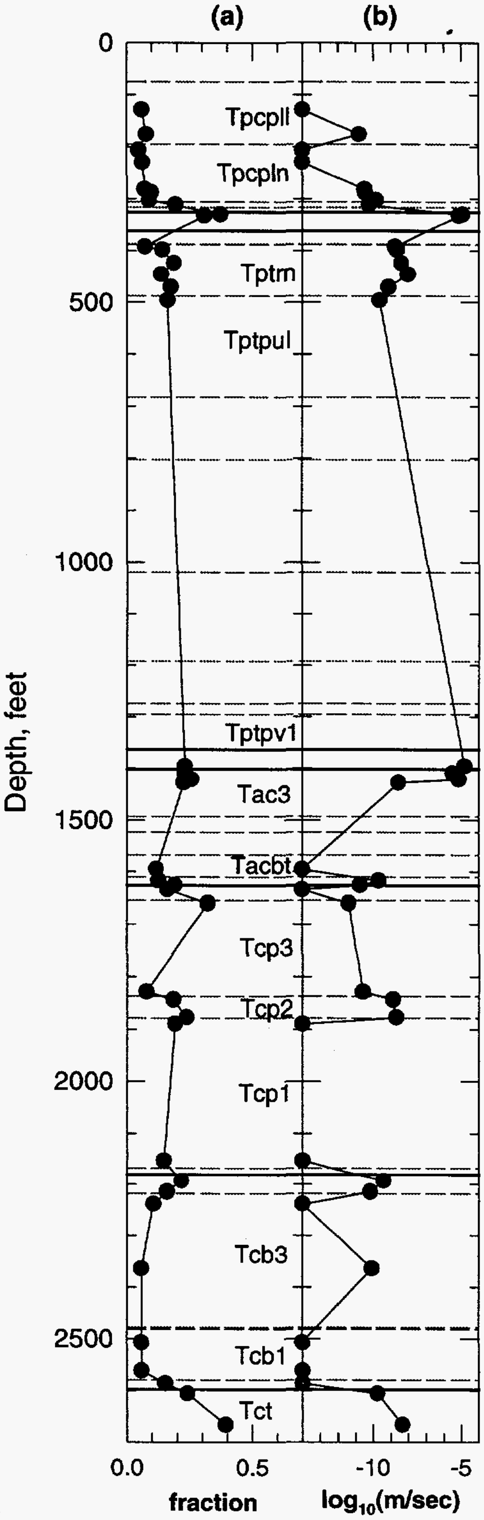

Figure 9. Porosity and saturated hydraulic conductivity of core samples collected from the USW SD-7 drill core.

phyre subzone of the upper vitric zone (Tptrv1, or "caprock" vitrophyre) is easily identifiable by its particularly low porosity values, 0.05 or less) at approximately 390 ft (118 m). The much thicker "basal" vitrophyre subzone of the lower vitric zone (Tptpv3) is also easily identified as the 83-ft (25-m) interval below 1200 ft (365 m) of uniformly low (less than 0.05) porosity values. Note also that the lower vitrophyre subzone also exhibits uniform and distinctly lower values of particle density compared to the devitrified materials that overlie this unit. A pronounced low-particle-density spike is associated with the caprock vitrophyre as well.

With the exception of a part of the upper Topopah Spring, specifically the intensely vapor-phase altered crystal-rich nonlithophysal and crystal-poor upper lithophysal zones between 400 and 600 ft (122–183 m), the majority of the many zones and subzones identified within the Topopah Spring Tuff (table 1) are not particularly distinct in the porosity profile. Both of the exception intervals appear to exhibit higher porosity values of 0.15 to as much as 0.20. A fairly prominent porosity "break" is associated with the base of the crystal-poor middle nonlithophysal zone at about 800 ft (245 m), and porosity values are noticeably higher in the lower part of the lower lithophysal zone (about 950–1020 ft; 290–310 m).

The lowermost zones of the Topopah Spring Tuff exhibit a general increase in porosity and constitute a largely nonwelded, high-porosity interval (including the pre-Topopah Spring Tuff bedded tuff, Tptbt1, much of which was not recovered in core) that extends downward to about the middle of Prow Pass ash-flow unit 3 to approximately 1750 ft (533 m) or somewhat deeper. The two porosity values (RH- and 105°C-dried) begin to diverge markedly at approximately about 1520 ft (463 m), indicating the presence of probable zeolitized materials in unit 1 of the underlying Calico Hills Formation. The dichotomy between the relative-humidity dried samples and their 105°C-dried counterparts is particularly well displayed by the particle density data [profile (c) in figs. 8]. The base of the Calico Hills Formation is present at 1626.2 ft (495.6 m), although the most prominent change in porosity is associated with the transition from ash-flow-type material to the bedded tuff and basal tuffaceous sandstone units of the Calico Hills (1567.2–1626.2 ft; 477.7–495.6 m). The upper part of ash-flow unit 3 of the Prow Pass Tuff also contains loosely bound water, as indicated by separation of the relative-humidity and 105°C data (fig. 8). The lower part of Prow Pass ash-flow unit 3 is marked by much smaller differences between the two laboratory property values and it appears to be much less affected by hydrous-phase alteration. Prow Pass ash-flow unit 1 appears to have been intensely zeolitized.

The nonzeolitized ash-flow unit 3 of the Bullfrog Tuff, beginning at a depth of about 2118 ft (645 m), exhibits a classic ⊂-shaped welding profile of high porosity values at the base and top with lower values in the interior. The ⊂ shape is reversed (⊃) in the bulk density profile of figure 8(b). It seems unlikely that the single, isolated high-porosity value at 2387.7 ft (727.7 m) represents an actual cooling break in this pyroclastic sequence. Zeolitic material become prevalent in the lower Bullfrog (ash-flow unit 1) and in the uppermost Tram Tuff.

Saturation and initial water content (volume/volume) data are also presented in figures 7 and 8. Water contents [column (e)] invariably are higher in the nonwelded than in the welded intervals throughout the entire drill hole. There is simply more void space in these materials to contain moisture. Note that a non-negligible fraction of the total water content of the zeolitic samples, those obtained from below a depth of about 1500 ft (455 m), consists of weakly bound water that is driven off with heating above 105°C.

Saturations are extremely high in the upper two zones of the Tiva Canyon Tuff that were encountered in drill hole SD-7. These intervals are immediately below approximately 50 ft (15 m) of colluvial cover and pad fill, and they presumably are well connected to the bedrock surface via fracture networks. Saturations decrease toward the top of the crystal-poor lower lithophysal interval of the Tiva Canyon, but with increasing depth the samples become essentially fully saturated immediately above the gradational transition to nonwelded materials below the lower nonlithophysal zone (shardy base interval). Saturations associated with the caprock vitrophyre subzone of the Topopah

Spring Tuff are sharply higher than in samples taken immediately above or below this densely fused vitric unit.

Within the main part of the welded Topopah Spring Tuff, saturations increase progressively from about 40 percent at the top to greater than 90 percent in the crystal-poor middle nonlithophysal zone (Tptpmn). Saturations decrease below the middle non-lithophysal zone and remain relatively constant at about 80 percent throughout most of the remainder of the welded-devitrified unit, increasing to nearly fully saturated in the top portion of the lower vitrophyre subzone (Tptpv3).

Saturation decreases progressively through the "shardy base" of the Topopah Spring Tuff as the porosity increases gradationally to between 20 and 40 percent. Both saturation and volumetric water content increase sharply at approximately 1500 ft (460 m) near the base of the ash-flow unit 2 of the Calico Hills Formation. Saturations approach 100 percent, and perched water was encountered at a depth of approximately 1600 ft (488 m). The perched water apparently had been confined by the low-permeability zeolitic materials in this interval, as the water level rose rapidly to a depth of only 1574.1 ft (479.76 m), a rise of more than 25 ft (nearly 8 m).

Saturations of core samples collected from below a depth of about 1650–1660 ft (500–505 m) are significantly lower that those measured on samples collected immediately above this depth. Note that the perched water interval was cased-off after pump testing with the bottom of casing at 1660 ft (506 m). This spatial coincidence suggests that some of the high and/or erratic saturation values measured near the top of Prow Pass ash-flow unit 3 may have been influenced by seepage from the overlying perched water zone, perhaps after penetration of this sequence by the drill hole. The less-than-saturated condition of these deeper samples also suggests that the perched water is not contained within the matrix porosity of the rock mass, but rather is present essentially only in fractures. Saturations within the welded part of Prow Pass ash-flow unit 3 are quite low: approximately 30 percent. The general level of saturation increases markedly in the lower third of ash-flow unit 3 at approximately 1780 ft (540 m); this increase is associated with a decrease in the intensity of vapor-phase alteration between about 1750–1780 ft (533–543 m). Values continue to increase gradually, if somewhat erratically, with depth to more than 90 percent at approximately 2000 ft (610 m). The regional saturated zone was encountered at approximately 2180 ft (665 m), after which the water level rose rapidly to a depth of 2085 ft (635.48 m). Core samples were near full saturation at a depth of approximately 2050 ft (625 m) and again below the first water at 2180 ft. However, a broad interval from slightly deeper than 2200 to approximately 2450 ft (670–747 m) produced core samples that are noticeably less than fully saturated (~0.85–0.95). This anomalously undersaturated interval is directly associated with the welded part of Bullfrog ash-flow unit 3, which extends from 2218 to 2178 ft in depth (676.0–666.6 m). Samples from the nonwelded units underlying Bullfrog ash-flow unit 3 are virtually 100-percent saturated within the limits of laboratory error.

A relatively small number of samples from the USW SD-7 core were selected for laboratory measurements of saturated hydraulic conductivity. These samples were *not* selected on a quasi-regular, systematic sampling pattern, as were the samples for bulk hydrologic property determinations, because of resource and time limitations. The K_S values reported in Appendix G, table G-2 thus cannot be presented as necessarily "representative" of the entire SD-7 drill hole. However, these available data are valuable in that they represent the only "fully qualified" hydraulic conductivity values (as of June 1996) from the Bullfrog Tuff. They are also a major fraction of the qualified conductivity data obtained from the Prow Pass Tuff. Sampling of the SD-7 core for measurement of hydraulic conductivity emphasized nonwelded intervals in general, and "bedded tuff" intervals in specific. The vertical spatial distribution of saturated hydraulic conductivity measurements is presented in figure 9.

Examination of figure 9 indicates that the "missing" intervals generally consist of welded tuff, notably the thick, densely welded main part of the Topopah Spring Tuff. Engstrom and Rautman (in press, their fig. 10) have presented a moderately detailed, systematic sampling of the Topopah Spring Tuff in drill hole USW SD-9. These data indicate that the permeability of the welded Topopah Spring is uniformly low at about 10^{-10} m/sec. The apparent variability shown on their illustration is caused by the presence of a number of sample for which the hydraulic conductivity was less than the sensitivity of the Hassler permeameter. These samples were assigned a uniform "no flow" value of 10^{-14} m/sec. The need for systematic sampling and measurement of thick intervals of uniform, low-permeability materials probably is not worth the time and expense of more detailed characterization.

Figure 9 confirms that the hydraulic conductivity of the nonwelded and vitric intervals are up to 4 or 5 orders of magnitude greater (10^{-6}–10^{-5} m/sec) than that of the more welded materials at Yucca Mountain. Nonwelded but zeolitic rocks below a depth of about 1425 ft (434.3 m) exhibit very low permeability values, approximately equivalent to those of densely welded tuff.

Table G-2 (Appendix G) also includes a set of six hydraulic conductivity measurements from within and immediately below the crystal-rich nonlithophysal zone of the Topopah Spring Tuff. These data confirm the earlier measurements in hole SD-9 (Engstrom and Rautman, in press), which suggested that this intensely vapor-phase altered zone typically exhibits permeabilities at least an order of magnitude greater than the densely welded but less vapor-phase altered tuffs that constitute much of the remainder of the Topopah Spring Tuff.

Mineralogical Data

A limited number of samples from the deeper part of the USW SD-7 drill hole were collected for quantitative X-ray diffraction analyses (D.T. Vaniman, Los Alamos National Laboratory, written communication, 1996[†]). The specific purpose of these analyses was to examine the mineralogical transition from vitric to zeolitic materials beneath the potential repository and within the unsaturated zone. Mineralogical compositions were not obtained above a depth of approximately 1100 ft (30 m) nor from below a depth of approximately 2525 ft (770 m). An overview of the mineralogical data is presented in figure 10 using major groupings of specific, individual mineral species. The actual data, including more specific mineral identifications are given in Appendix H, table H-1. The data are also shown on the appropriate geologic log sheets of Appendix B at their proper vertical position.

The mineralogical data indicate a relatively broad overlapping or interfingering of vitric and zeolitic horizons in the SD-7 drill hole; this phenomenon has not been reported previously. A significant amount of alteration appears to involve the presence of opal-CT, both in association with zeolite minerals and with high-temperature, presumed vapor-phase alteration assemblages involving tridymite and/or cristobalite plus feldspar. Note that opal-CT alteration may be confused visually with zeolitic alteration. Because the quantitative mineralogic information is available only as spot sampling at relatively widely spaced vertical intervals, it is likely that some rocks indicated as zeolitically altered of the geologic log sheets of Appendix B may not, in fact, be zeolitic, but rather weakly silicified. Smectite clays are present locally within the vitric-to-zeolitic transition interval, but are typically less than 10 percent of the whole rock composition. A notable exception is the presence of a sample from a depth of 1187.0 ft (361.8 m) that contained nearly 60 percent smectite (Appendix H, table H-1). The mineralogic data are interesting to compare with the quantities of loosely bound structural water indicated by the difference between the relative-humidity oven-dried and 105°C-dried laboratory material property data, which are also presented on the geologic log sheets of Appendix B.

Geophysical Data

Down-hole petrophysical logs were recorded in drill hole USW SD-7 on several dates, specifically during July, September, and December of 1995, for depths consistent with the major phases of drilling and casing. The composite suite of logs acquired at SD-7 consists of a bulk density log, epithermal and thermal neutron porosity logs, two induction-conductivity logs from which resistivity

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[†] Chipera, S.J., Vaniman, D.T., and Bish, D.L., 1996, Zeolite abundances and the vitric-to-zeolitic transition in drill holes USW SD-7, -9, and -12, Yucca Mountain, Nevada: LA-EES-1-TIP-96-005, Yucca Mountain Project Milestone LA4244, submitted by Los Alamos National Laboratory, Los Alamos, N. Mex.

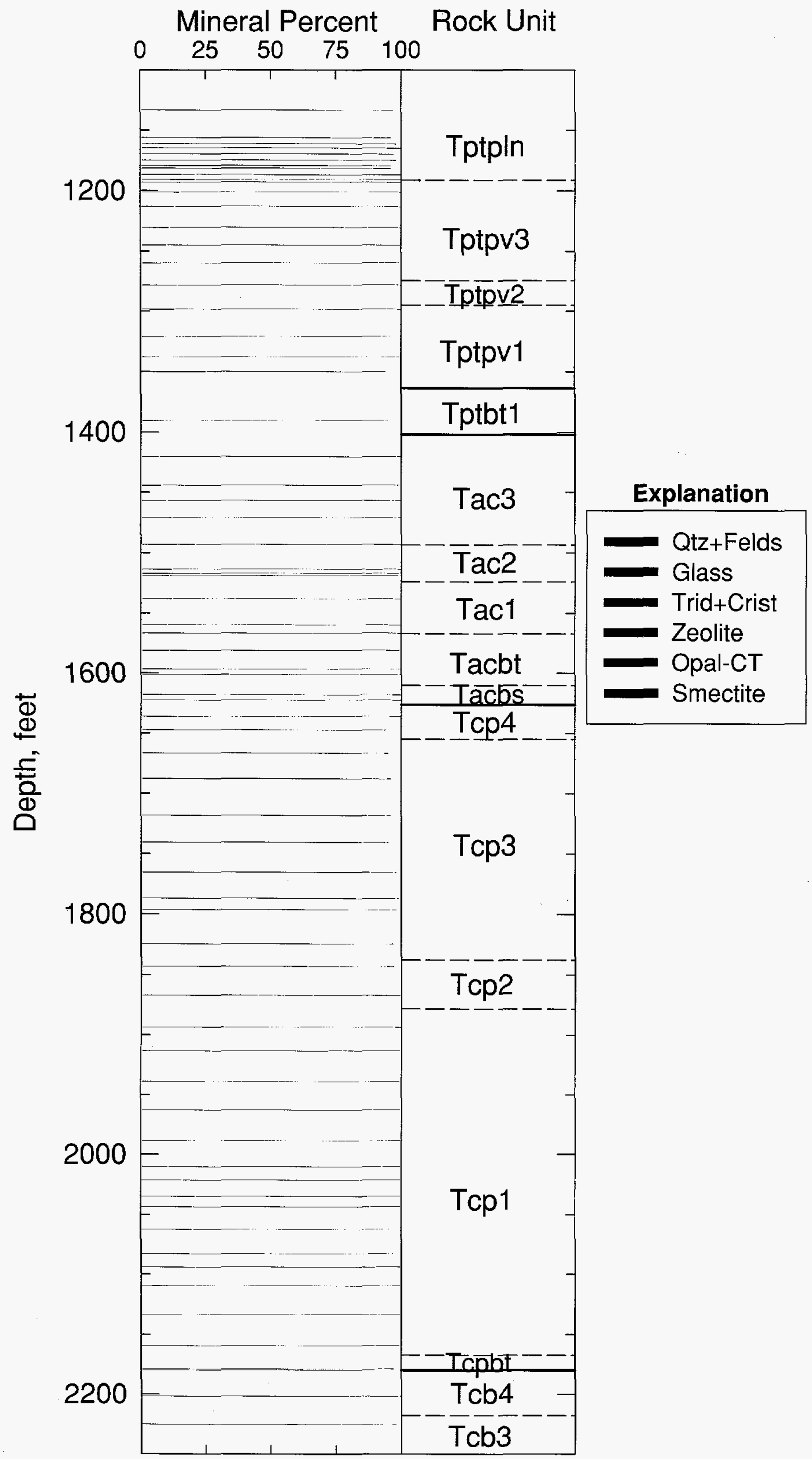

Figure 10. Mineralogical compositions of selected samples from the vitric-to-zeolitic transition interval underlying the Topopah Spring Tuff.

traces were computed, a spectral gamma-ray log (K, U, Th, plus total γ), and a set of 4-arm caliper traces. The set of log composites extends from near the ground surface to approximately TD at a depth of 2675 ft (815 m). Selected log traces are presented in figures 11 (upper part of the hole) and 12 (lower part), similar to the style of presentation in figures 7 and 8. Because the geophysical logs consist of digital data on 0.5-ft (15-cm) vertical spacings, these data are not included as an appendix to this report. The actual trace values can be obtained from the Yucca Mountain Project records center using data-tracking number TMUSWSD7000096.001.

Density Log Response

The bulk density log is the principal stratigraphic tool available through petrophysics at Yucca Mountain, and the density trace [column (a) on figs. 11 and 12] displays the expected geophysical response to intensity of welding and development of lithophysal-style alteration. The bulk density log was first recorded in the crystal-poor lower nonlithophysal zone of the Tiva Canyon tuff (the log begins below the lower lithophysal zone); density values are typical for densely welded units without significant lithophysae at about 2.4 g/cm^3. Bulk density values decrease rapidly at the base of the welded interval through the shardy base transition interval, and they remain at values of approximately 1.5 g/cm^3 (or less) through the PTn nonwelded interval. At the top of the Topopah Spring caprock vitrophyre (crystal-rich densely welded subzone), rock density increases abruptly to 2.5 g/cm^3, and then drops as rock is encountered that has been subjected to devitrification and vapor-phase alteration typical of the crystal-rich nonlithophysal zone of the Topopah Spring Tuff.

The intensely vapor-phase altered and lithophysae-bearing zones of the Topopah are fairly readily identified from the bulk density trace (see also log sheets 7–10 and 12–15 in Appendix B). Geophysical bulk density values in the two main lithophysal zones of the Topopah at SD-7 are typically about 2.0 g/cm^3, plus or minus. The crystal-poor upper lithophysal zone typically exhibits somewhat lower densities than the lower lithophysal zone. Note that these lithophysal density values are distinctly lower than the corresponding bulk density values obtained using laboratory methods on core specimens [fig. 7, column (b)]. These latter density values almost never are less than 2.0 g/cm^3, and more typically they are in the neighborhood of 2.25 g/cm^3. The difference in magnitude corresponds to the presence of larger-than-core-diameter lithophysal cavities that cannot be measured in the laboratory, particularly within the upper lithophysal interval.

The gradational and non-definitive nature of the contacts between lithophysal and nonlithophysal intervals is clearly indicated in the 0.5-ft (15-cm) spacings of the geophysical data. Note that bulk density within the crystal-rich nonlithophysal zone progressively decreases below a depth of about 460–470 ft (140.2–143.25 m), which is almost exactly the depth at which geologic log sheet 7 (Appendix B) indicates the uppermost lithophysae were encountered. There is a prominent change in the character of the bulk density log trace at about 530 to 540 ft (161.5–164.8 m), which is where log sheet 8 indicates that lithophysae become crowded and exhibit vapor-phase alteration rims. The gradational lower contact of the crystal-poor upper lithophysal zone is clearly defined in the bulk density trace from a depth of about 620–630 ft (189–192.0 m) down to approximately 690–700 ft (210.3–213.4 m) (compare with geologic log sheets 9 and 10). In similar manner, the base of the crystal-poor middle nonlithophysal zone could be picked on the bulk density log as high as 780 ft (237.7 m). However, no mesoscopic lithophysae were observed in the core at this depth (log sheet 12), although there is a fairly pronounced increase in the number of rubble zones recovered with the core at about that depth. The lower contact of this lower lithophysal interval could be placed as deep as almost 1080 ft (329.2 m), however, no mesoscale lithophysae were observed below 1042 ft (317.0 m) (log sheet 15). Note that the interval between 1042 and 1080 ft does include some vapor-phase “spots” and a number of rather intensely veined intervals (log sheets 15 and 16).

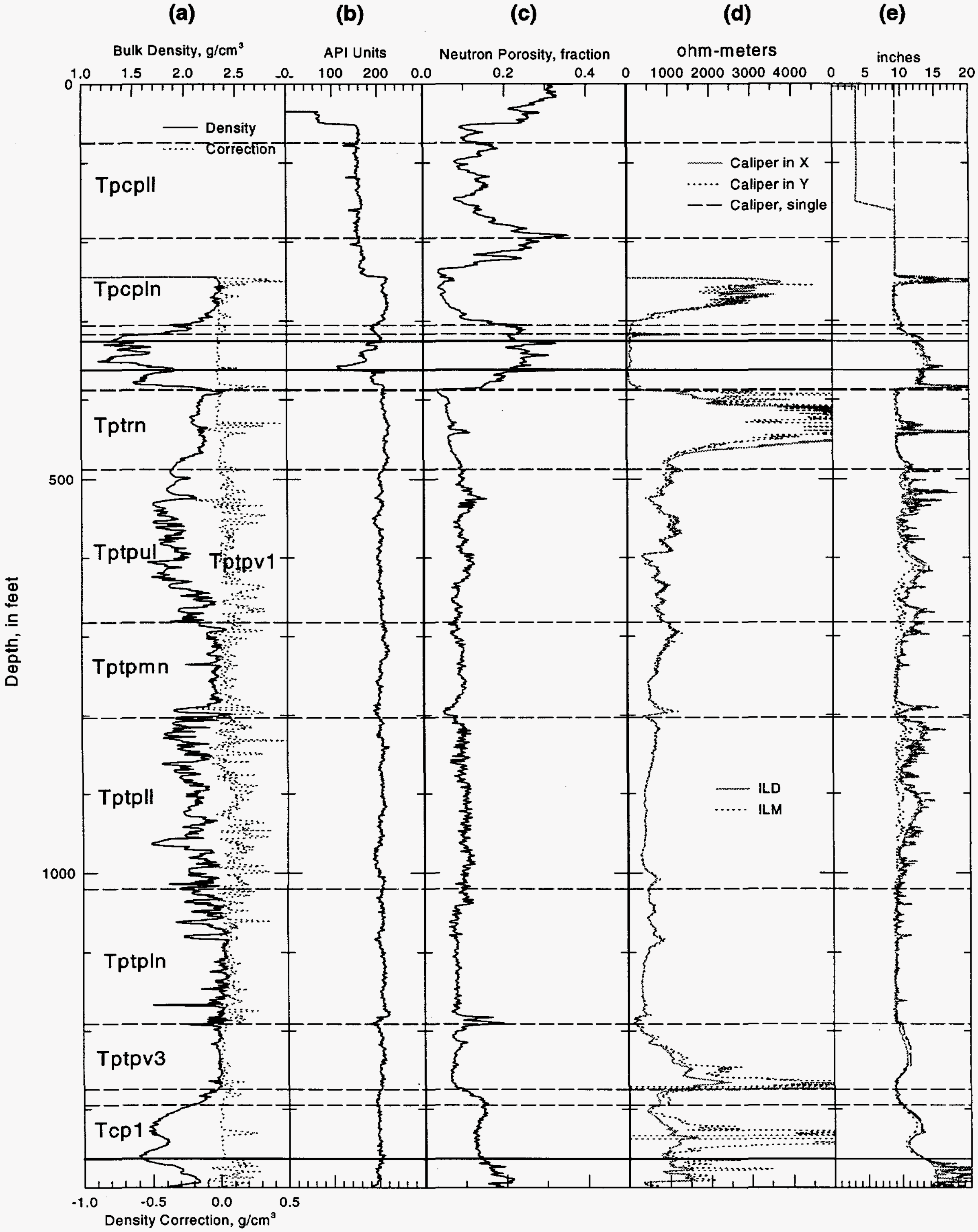

Figure 11. Geophysical log traces from the upper part of the USW SD-7 drill hole: (a) density log; (b) gamma-ray log; (c) epithermal neutron log; (d) dual-induction resistivity log; (e) caliper log.

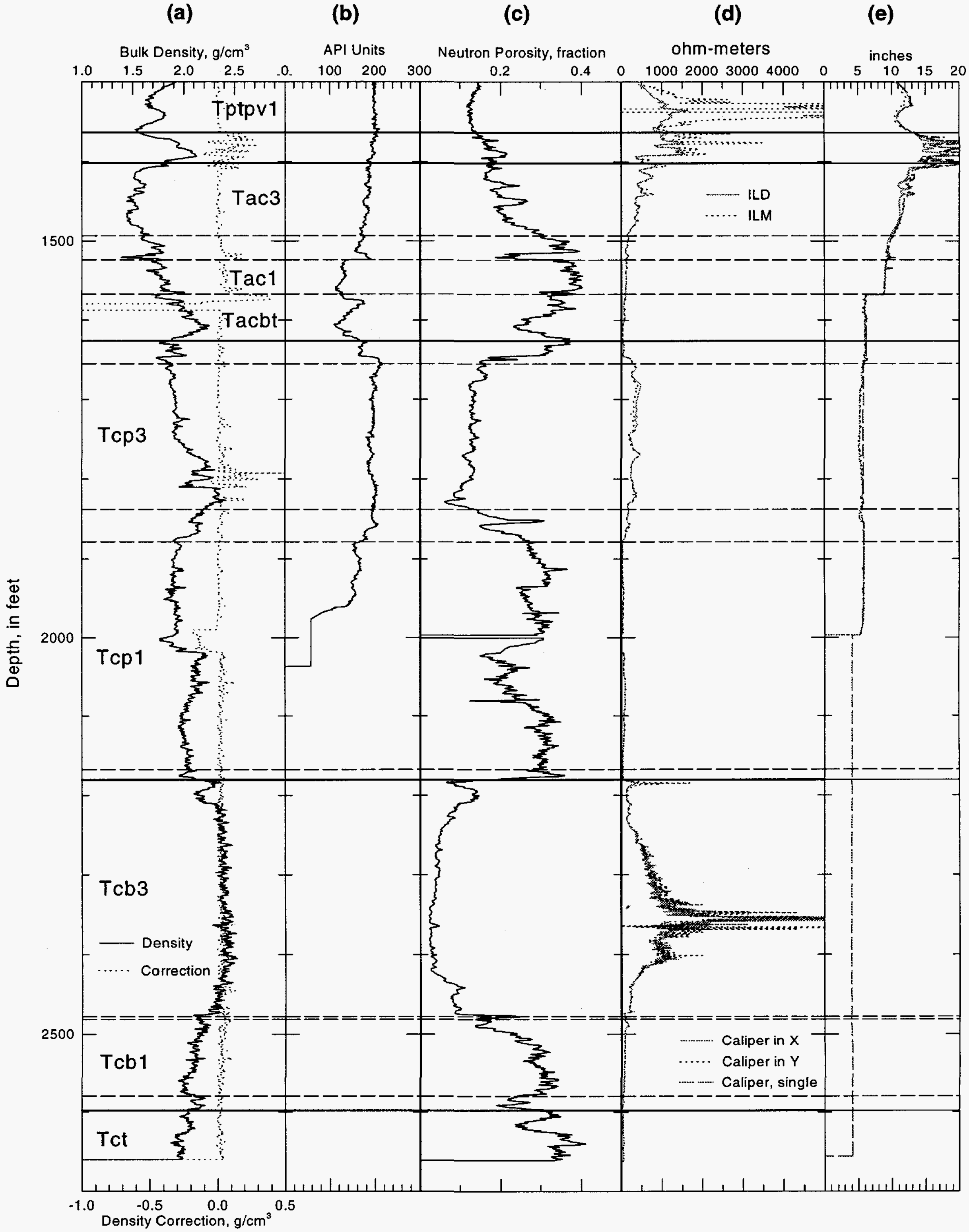

Figure 12. Geophysical log traces from the lower part of the USW SD-7 drill hole: (a) density log; (b) gamma-ray log; (c) epithermal neutron log; (d) dual-induction resistivity log; (e) caliper log.

Bulk density values decrease gradationally at the base of the Topopah Spring lower vitrophyre (crystal-poor densely welded subzone) to typical nonwelded values of approximately 1.5 g/cm^3 (see also log sheets 18–19). Density is markedly higher in the pre-Topopah Spring Tuff bedded tuff; this higher-density phenomenon is fairly typical of the "bedded" and reworked materials throughout the section. Presumably reworking and weathering of these intervals increased the quartzose (sand) content at the expense of less-dense pumiceous components. The bulk density log provides almost the only lithologic information available from this interval, most of which was not recovered in core.

Density increases somewhat erratically but progressively through the subunits of the Calico Hills Formation, varying from 1.5 g/cm^3 at the top to about 2.0 at the base (and higher in the bedded tuff unit. The bulk density log is relatively constant through the majority of the Prow Pass Tuff, indicating values of approximately 2.0 g/cm^3. The noticeable increase in density in the lower half of moderately welded Prow Pass ash-flow unit 3 below approximately 1750 ft (530 m) is spatially associated with a marked decrease in the intensity of vapor-phase alteration shown on geologic log sheet 26 (Appendix B). The marked change in character of the bulk density trace midway through Prow Pass ash-flow unit 1 does not correspond to a change in defined units. However, geologic log sheet 29 does note an increase in pumice content at about this depth, and also describes a subtle change in the style of alteration of the groundmass. Also, the caliper log [column (e)] indicates that the diameter of the borehole changes at approximately this depth, suggesting that the shift in magnitude may represent either borehole effects or calibration/adjustment problems associated with two different logging sondes.

Bullfrog Tuff ash-flow unit 3 is a moderately to densely welded tuff (Appendix B, log sheets 32–36); this intensity of welding is reflected by a progressive increase in bulk density in figure 12 to values of approximately 2.0 g/cm^3, similar to values observed higher in the hole associated with the densely welded Topopah Spring Tuff. Figure 8(a) indicates a classical ⊂-shaped porosity welding profile from high porosity at the nonwelded base and top to low porosity values in the more welded center. This welding profile is inverted (⊃), but quite evident in the petrophysical density log trace of figure 12. Bullfrog ash-flow unit 1 is a low-density, nonwelded, and modestly zeolitized interval underlain by a higher density tuffaceous sandstone unit immediately above 2600 ft (790 m).

Gamma-Ray Log Response

The gamma-ray logging tool responds principally to the presence of radioactive potassium (^{40}K) in the whole rock. The log response [figs. 11 and 12, profile (b)] indicates noticeably lower count rates (in API units) associated with the "bedded-tuff" intervals underlying the Tiva Canyon Tuff at a depth of roughly 325–365 ft (99–110 m). Presumably, these reworked intervals were weathered sufficiently that some of the radioactive potassium was leached from the rock. A much more subtle low count rate is observed at the base of the Topopah Spring Tuff, however, noticeable gamma-ray lows are associated with the bedded tuff at the base of the Calico Hills Formation. This "bedded" interval is an amalgamation of a number of different lithologies, including a basal sandstone unit (Tacbs). No explanation for the distinct gamma-ray low associated with Calico Hills ash-flow unit 1 is immediately apparent in the geologic log of this interval.

Epithermal Neutron Porosity

The epithermal neutron porosity log responds principally to the presence of water (hydrogen atoms). Higher "porosity" values indicate greater absorption of neutrons by moisture. This log trace (figs. 11 and 12, profile (c)] indicates very high moisture contents (30 percent on a volume/volume basis) in the near-surface colluvium and pad-fill materials above about 50 ft (15 m), followed by a rapid decrease within the bedrock of the crystal-poor middle nonlithophysal zone of the Tiva Canyon Tuff. Moisture contents are typically above 0.10 throughout the Tiva Canyon welded interval, with the exception of the very densely welded lower nonlithophysal zone. Very high moisture contents are present from approximately 175 to 225 ft (50–70 m), near the contact between the lower lithophysal and lower nonlithophysal zones of the Tiva. Reference to the geologic log sheets of

Appendix B (sheet 3, especially) indicates that this interval of very high moisture is associated within and immediately below an interval of very intense vapor-phase and lithophysal-style alteration, including a well defined zone of small, closely spaced, flattened lithophysae that end abruptly at 195.0 ft (59.43 m) defining the base of the lower lithophysal zone. It is presumed that this relatively near-surface, intensely lithophysal interval has received percolating ground water, probably via fracture flow, and has retained this moisture for lengthy periods of time allowing the water to imbibe into the vapor-phase altered, but nonlithophysal tuff below. Indicated moisture contents increase gradationally through the shardy-base interval at the base of the welded Tiva Canyon [see also fig. 7(d) and (e)]. Moisture contents remain high through the nonwelded interval of the PTn overlying the caprock vitrophyre of the Topopah Spring Tuff.

The epithermal-neutron porosity log indicates relatively constant and low values of moisture throughout the densely welded main body of the Topopah Spring Tuff. Neutron-porosity values may be somewhat higher in the more intensely vapor-phase altered lithophysal zones; however, the indicated values invariably are lower than 0.10. Several pronounced "spikes" of high neutron-porosity values occur at and slightly above the upper contact of the lower vitrophyre (crystal-poor densely welded vitric subzone). Buesch and others (1996) describe the general occurrence of an "argillic pumice subzone" near the base of the crystal-poor lower nonlithophysal zone in approximately this position within the Topopah Spring. Moisture associated with montmorillonitic clays in the argillized pumice clases may account for these epithermal neutron highs, even though the geologic log sheets (sheets 17–18, Appendix B) do not describe any particular abundance of argillized pumice clasts at this depth. Figure 7 does indicate separation between the RH- and 105°C-dried bulk property values, which is consistent with the presence of structurally bound water as would be present in clays.

The epithermal neutron log trace on figure 12 indicates increasing moisture contents through the base of the Topopah Spring Tuff and throughout the ash-flow sequences of the Calico Hills Formation. The lower part of this interval, particularly that below Calico Hills ash-flow unit 3, is presumed to be moderately to intensely zeolitized, as indicated by divergence of the RH- and 105°C-dried laboratory property measurements shown in figure 8. The neutron-porosity log responds to water structurally bound in zeolite minerals as well as to water in the pores of the rock. Mineralogical data (Appendix H) suggest alternating glassy and zeolitic units within this interval. The more general separation of the two types of laboratory data (fig. 8) in Calico Hills ash-flow unit 2 and below suggests that some of the glass may be partially hydrated as well (?).

The neutron log response drops markedly at the upper contact of partially to moderately welded Prow Pass ash-flow unit 3. The upper part of this unit is moderately vapor-phase altered and the overall hydrogen content of the unit is distinctly lower here than in the less vapor-phase altered and nonwelded materials both above and below this stratigraphic interval. Prow Pass Tuff ash-flow unit 1 is intensely zeolitized (fig. 8), and the neutron-porosity values in this interval are quite high (0.30–0.40).

Bullfrog ash-flow unit 3 is virtually unzeolitized (coincidence of RH and 105°C laboratory measurements on figure 8), and the extremely low neutron-porosity values reflect the moderately to densely welded nature of this portion of the Bullfrog Tuff. Bullfrog unit 1 and the underlying Tram Tuff are again nonwelded, zeolitic, and exhibit high interpreted moisture contents.

Dual-Induction Log Response

The dual-induction log tool responds to the electrical conductivity of the rocks surrounding the bore hole; the tool response has been recalculated and is displayed as apparent resistivity. Both the induction log deep (ILD) and medium (ILM) traces are portrayed in figures 11 and 12, column (d).

Stratigraphic interpretation of resistivity logs in unsaturated tuff is somewhat problematic, and these logs have been acquired principally to support quantitative calculations of various bulk material properties using petrophysical relationships.

For purposes of this report, resistivity values throughout the hole generally decrease from roughly 1000 Ω-m in the upper Topopah Spring Tuff to values less than 100 Ω-m in Bullfrog Tuff near TD. Superimposed on this general trend are a number of quite high resistivity spikes and zones of increased resistivity. Resistivity values exceed 3000 Ω-m in the crystal-poor lower nonlithophysal zone of the Tiva Canyon Tuff (fig. 11) over an interval of roughly 30 feet (10 m). Resistivity values are very low (<100 Ω-m) in the PTn nonwelded interval between the Tiva and the Topopah Spring, but increase rapidly to off-scale values in excess of 5000 Ω-m throughout much of the crystal-rich nonlithophysal zone underlying the caprock vitrophyre interval of the Topopah Spring. Resistivities are much more variable through the crystal-poor upper lithophysal and middle nonlithophysal zones of the Topopah than they are in the remainder of the hole. Another zone of high resistivity values (to 2000 Ω-m) with off-scale spikes in the ILM tool response is present in the lower vitrophyre (crystal-poor densely welded vitric subzone) and continues through the "shardy base" (vitric nonwelded subzone) of the Topopah Spring (spikes >20,000 Ω-m). Elevated resistivity values are also associated with the pre-Topopah Spring Tuff bedded tuff interval (fig. 12). Resistivity readings are noticeably higher in ash-flow unit 3 of the Prow Pass Tuff (the partially welded unit). The moderately to densely welded unit 3 of the Bullfrog also exhibits markedly higher values, including resistive spikes exceeding 15,000 Ω-m recorded by both the medium and deep induction tools.

Caliper Log Response

Drilling and hole-stability problems at drill hole USW SD-7 required the use of a number of different sizes of down-hole tools. Several intervals were drilled using one bit size but were later reamed to a larger diameter. The caliper traces, shown in figures 11 and 12, column (3), reflect this complex drilling history. Two different caliper logs are shown. An oriented 4-arm caliper produced two traces in mutually perpendicular directions A single-arm caliper was also run in conjunction with the bulk density tool [column (a) of the figures], and the divergence of these two different logs, particularly in the upper 150 ft (50 m) of the hole reflect differing hole sizes at different times and/or the presence or absence of casing.

Generally, the different caliper tools correlate quite well with one another for the intervals that clearly were run in the open hole. Markedly out-of-gauge hole is indicated throughout most of the two major lithophysal intervals of the Topopah Spring Tuff. Here the nominal 8-3/4-inch (20-cm) hole diameter commonly is washed-out or caved to diameters approaching 14-15 inches (38 cm). The 4-arm caliper traces in figure 11 indicate that some of the hole enlargement in these intervals are markedly asymmetrical; for example, at 900–960 ft; 275–290 m). Washed-out intervals that extend up or down into the crystal-poor middle nonlithophysal or lower nonlithophysal zones may reflect the continuing presence of larger-than-hole-diameter lithophysal cavities in these otherwise "non-" lithophysal intervals (see discussion of lithophysae beginning on page 17; also the geologic log sheets of Appendix B). Significantly enlarged hole sizes are also associated with some of the nonwelded, and particularly vitric nonwelded, intervals, such as the PTn interval (fig. 11) and the base of the Topopah Spring Tuff through the upper part of the Calico Hills Formation (fig. 12). Enlarged hole diameters in these zones may exceed 20 inches (50 cm) over short intervals. The relatively continuous nature of these washed-out zones (in contrast to the more "spikey" washed and caved intervals in the welded Topopah Spring) most likely is reflecting the poorly consolidated nature of these units, particularly of the reworked bedded tuffs and tuffaceous sandstones.

Summary

The USW SD-7 drill hole is one of several holes drilled under Site Characterization Plan Study 8.3.1.4.3.1, also known as the Systematic Drilling Program, to provide geologic characterization of the potential Yucca Mountain nuclear-waste repository site. The SD-7 drill hole is located near the southern end and immediately to the west of the north-south-trending Main Test Level drift of the Exploratory Studies Facility. The hole is also located near the junction of the Main Test Level drift and the proposed ESF South Ramp. The drill site, which is located adjacent to the road to the crest of Yucca Mountain atop Highway Ridge, is positioned to the west of the Ghost Dance fault, approximately where the surface trace of this mostly north-south fault swings to the west and eventually merges with the north-south trending Abandoned Wash fault.

Location of the drill hole in the down-dropped block west of the Ghost Dance fault allowed penetration of approximately the lower half of the Tiva Canyon Tuff, totaling some 280 ft (85 m). The hole was collared in the lower nonlithophysal subzone of the crystal-poor middle nonlithophysal zone of the Tiva Canyon. The drill hole also penetrated the crystal-poor lower lithophysal, the lower nonlithophysal, and the vitric zones of the Tiva Canyon Tuff. The pre-Topopah Spring Tuff bedded tuff interval was also encountered. Core recovery was extremely poor through the nonwelded units underlying the pre-Topopah Spring Tuff bedded tuff. Although confidence in stratigraphic unit identifications is decreased by poor core recovery, interpretation of short intervals of recovered core and of petrophysical logging traces suggests that the Yucca Mountain Tuff is absent at the SD-12 location, but that thin intervals of the pre-Yucca Mountain Tuff bedded tuff, the Pah Canyon Tuff, and the pre-Pah Canyon Tuff bedded tuff are present.

The Topopah Spring Tuff is approximately 1040 ft (320 m) thick in USW SD-7 and dominated by densely welded tuffs. Lithophysae are prominently developed in two major intervals. The 194.7-ft (59.3-m)-thick upper lithophysal interval is entirely crystal-poor at this location, and the lower, also crystal-poor, lithophysal zone is 216.7 ft (66.0 m) thick. Lithophysae vary widely in size and frequency within the lithophysal zone. Cavities that are larger than core size are present in the middle portion of the upper zone and near the top of the lower lithophysal zone; these intervals contribute locally to poor core recovery and intervals of total core loss. The lower vitrophyre of the Topopah Spring Tuff (densely welded vitric subzone) is quite thick (83.1 ft; 25.3 m) in the SD-12 drill hole.

Nonwelded units at and below the base of the Topopah Spring Tuff were mostly lost in drilling. These lost-core intervals include the lower contact of the Topopah Spring Tuff, the pre-Topopah Spring Tuff bedded tuff, and the top of the Calico Hills Formation. The contacts and lithologic character of these units have been reconstructed using recovered core fragments, cuttings, and petrophysical log traces. The Calico Hills Formation is approximately 225 ft thick in the SD-7 drill hole, and these rocks have been subdivided (downward) as ash-flow units 3 through 1 of Moyer and Geslin (1995), plus a bedded tuff unit and a basal tuffaceous sandstone unit.

All three formations of the Crater Flat Group were encountered in drill hole USW SD-7. The upper unit, the Prow Pass Tuff, is 554.0 ft (168.9 m) thick, and has been subdivided into four pyroclastic-dominated units plus a lowermost bedded tuff interval. Unit 3 (numbered from the base) is mostly moderately welded; the remaining units are effectively nonwelded. The Bullfrog Tuff is 417.8 ft (127.3 m) thick, and it also has been subdivided into a series of four ash-flow intervals plus a basal tuffaceous sandstone. A fault contact separates Bullfrog ash-flow units 2 and 3 (numbered from the base), and the very thin interval of ash-flow unit 2 suggests that a substantial thickness of section may have been removed by the fault. Bullfrog unit 3 is partially welded to locally densely welded in character. The SD-7 drill hole penetrated 77.1 ft (23.5 m) into the top of the Tram Tuff, which is the lowermost unit of the Crater Flat Group. These rocks consisted of nonwelded, weakly zeolitized ash-flow deposits.

Quantitative and semiquantitative data are included in this report for core recovery, rock-quality designation (RQD), lithophysal cavity abundance, and fracturing. These data are spatially variable, both within and among the major formational-level stratigraphic units. Rocks of the Calico Hills Formation and Crater Flat Group yielded markedly higher recoveries and RQD values than did the densely welded units of the Paintbrush Group. Both core recovery and RQD are particularly low in the two lithophysal intervals of the Topopah Spring Tuff; RQD values indicate "very poor" ground conditions in these zones. RQD is "fair" in the proposed repository horizon of the crystal-poor middle nonlithophysal Topopah Spring. Nonwelded intervals within the Paintbrush Group tuffs exhibited extremely poor core recovery. This is attributed to essentially unconsolidated lithologies in these reworked and distal pyroclastic units.

This report also presents quantitative data for the "framework" material properties of porosity, bulk and particle density, and saturated hydraulic conductivity. Graphical analysis of variations in these laboratory hydrologic properties confirm previously reported first-order control of material properties by the degree of welding and presence of zeolite alteration minerals. Many of the finer-scale lithostratigraphic subdivisions identifiable in core are not well expressed in the material-property profiles. Approximate in-situ saturation and volumetric water content data for core samples preserved immediately upon recovery from the drill hole are included in the data tabulation. Quantitative X-ray diffraction mineralogical analyses of samples collected from the lower vitrophyre of the Topopah Spring Tuff to the water table indicate that the nature of the vitric-to-zeolitic transition interval in SD-7 and the southern part of the repository region is more complex than previously assumed. Vitric and zeolitic horizons alternate over a broad stratigraphic interval within the Calico Hills Formation and Prow Pass Tuff.

Geophysical well-log data have been obtained from virtually the entire USW SD-7 drill hole. The suite of petrophysical traces include density, gamma-ray, epithermal-neutron porosity, electrical resistivity, and caliper profiles. The density log provides perhaps the best stratigraphic information and most of the major lithologic subdivisions of the Paintbrush Group tuffs (in particular) can be identified readily using the downhole density trace. The other petrophysical logs may be most useful in computing quantitative values for various material properties as well as for moisture saturation in the unsaturated zone using established geophysical logging relationships. Geophysical logs have been used successfully at SD-7 to infer rock-unit and contact identification in intervals of total core loss.

Units with generally consistent material properties are of major concern in numerical modeling of physical processes such as hydrologic flow and radionuclide transport at Yucca Mountain. In general, the material property units identified in the SD-7 drill hole, as defined using either laboratory measurements of core samples, downhole petrophysical measurements, or both, do not correspond to the more genetic, first- and second-order lithostratigraphic unit boundaries defined by classical geology. Some third- and lower-order lithostratigraphic units are well expressed as distinctive material-property units; however, other low-order lithostratigraphic subdivisions appear to exhibit little if any differences in material properties or petrophysical character from those of adjacent rocks. Rock property units identified in the SD-7 drill hole correspond fairly exactly to the so-called thermal/mechanical stratigraphic units.

The laboratory core measurements fail to identify lithophysal zones clearly, as many lithophysae appear to be sufficiently large that it is impossible to measure the "bulk" porosity of the rock because of laboratory-apparatus limitations. Lithophysal zones are clearly expressed in the raw downhole density log, although the "contacts" of lithophysal horizons inferred from geophysical signature are distinctly gradational and may extend beyond the same contacts selected by more conventional geologic criteria. Other "bulk-effective" characteristics of the volcanic section at Yucca Mountain may be better characterized using downhole petrophysics in addition to simple core observations.

The data and interpretations contained in this summary report for drill hole USW SD-7 provide a fundamental basis for more comprehensive interpretations of the geology and physical behavior of the Yucca Mountain site. Descriptive information and contact "picks" should be useful for modeling of the geologic framework of the site. Measured rock properties data presented in this report, together with the indicated references to the underlying data packages, should be crucial in quantitative material-properties modeling and provide the basis for performance assessment modeling and regulatory assessment of the waste-isolation potential of the Yucca Mountain site.

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Appendix A: Lithologic Unit Descriptions

Lithologic Unit Descriptions

The following are unit-by-unit descriptions of the USW SD-7 core. The SD-7 borehole was rotary drilled through pad-fill materials and colluvial surface deposits to a depth of 50.1 feet (15.27 m); these materials have not been described. These lithologic descriptions of core from the USW SD-7 drill hole are presented graphically on the detailed core-log sheets in Appendix B.

The descriptions in this report attempt to use stratigraphic nomenclature recently proposed by Buesch and others (1996) for the various units of the Paintbrush Group, as that interval was redefined by Sawyer and others (1994). The unit descriptions are also cross-referenced where feasible to the older zonation of the Paintbrush Group tuffs used by Scott and Bonk (1984). The older names and some of their historical modifications are still frequently encountered and they appear in earlier Yucca Mountain Project publications. Nomenclature and descriptions for subunits of the Calico Hills Formation and the Prow Pass Tuff (the upper formation of the Crater Flat Group; Sawyer and others, 1994) follow those of Moyer and Geslin (1995).

Little precedence exists with respect to geologic subdivisions of the Bullfrog Tuff or the Tram Tuff (middle and lower units of the Crater Flat Group). No other Site Characterization Plan (DOE, 1988) drill hole has penetrated to these stratigraphic levels, although "older" drill holes at the Yucca Mountain site have cored rocks belonging to the Bullfrog and Tram Tuffs (for example: Spengler and others, 1981; Maldonado and Koether, 1983; Scott and Castellanos, 1984). Because the genetic-descriptive approach adopted by Buesch and others and by Moyer and Geslin differs significantly from the older, more purely descriptive methods applied to the pre-1986, non-site characterization drill holes, we have attempted to emulate the genetic-descriptive approach adopted by these more recent authors.

Tiva Canyon Tuff (Tpc)

Crystal-poor middle nonlithophysal zone (Tpcpmn) 50.1–74.8 ft (15.2–22.8 m)

The crystal-poor middle nonlithophysal zone of the Tiva Canyon section, formerly known as the "clinkstone" or "rounded step" zones of Scott and Bonk (1984) in the general vicinity of the potential repository, has been divided by Buesch and others (1996) into upper and lower nonlithophysal subzones separated by a lithophysae-bearing subzone. Only the lower 24.4 feet (7.44 m) of the lower nonlithophysal subzone were cored at the USW SD-7 location. This subzone does not contain lithophysae, but 10–15 percent of the rock is altered to vapor-phase streaks and halos surrounding highly flattened pumices; these features decrease downward toward a depth of about 60 feet (18.3 m). The rock itself throughout the crystal-poor lower member of the Tiva Canyon contains between 3 and 5 percent small sanidine phenocrysts with or without minor biotite. The groundmass is 35 to 40 percent vapor-phase altered. There is strong subvertical jointing, and rare low-dip silica veining.

Crystal-poor lower lithophysal zone (Tpcpll) 74.8–195.0 ft (22.8–59.4 m)

Widely spaced, flattened and irregularly-shaped lithophysae are present at a depth of 74.8 feet (22.8 m), defining the gradational upper contact of the crystal-poor lower lithophysal zone (lower lithophysal zone of Scott and Bonk, 1984). The intensity of lithophysal-style alteration increases below the upper contact to a local maximum at about 80–90 feet (24–27 m), and then decreases between approximately 95 and 135 feet (29–41 m). Flattened, vuggy, irregular lithophysae increase in number and size from 135 to about 144 feet (41–44 m); the interval between 167.5 and 195.0 feet (51.0–59.4 m) contains abundant closely spaced, flattened lithophysae that exhibit distinct alteration halos of vapor-phase alteration 1–2 mm thick. Lithophysal cavities are typically coated by light-colored, coarsely crystalline vapor-phase mineralization. An interval between roughly 155 and 168 feet (47–51 m) within the crystal-poor lower lithophysal zone contains distinctly fewer lithophysae.

Crystal-poor lower nonlithophysal zone (Tpcpln) 195.0–295.4 ft (59.4–90.0 m)

The contact between the crystal-poor lower lithophysal zone and the lower nonlithophysal zone is relatively sharp and well defined, although a 3-ft (1-m) interval of lost core was encountered just above the contact. Two subzones typically can be recognized in outcrop, formerly known as the hackly and columnar zones of Scott and Bonk (1984). Buesch and others (1996) have maintained this distinction in subsurface investigations at Yucca Mountain.

Hackly subzone (Tpcplnh) 195.0–255.8 ft (59.4–78.0 m)

Hackly fracturing is not particularly well developed in the lower nonlithophysal zone at USW SD-7; however, the style of fracturing does appear different above and below this contact. The dominant change marking this subzone in the SD-7 core is the absence of even weakly opened lithophysal cavities and the presence of identifiable flattened, vapor-phase-corroded vuggy pumice clasts that probably served as the initiation sites for lithophysae in the overlying zone. Some relict pumices are spherulitic, and siliceous vapor-phase veining locally is weakly developed.

Columnar subzone (Tpcplnc) 255.8–295.4 ft (78.0–90.0 m)

High-angle, columnar-style joints can be observed in the core below a depth of about 255.8 feet (77.9 m). The three subintervals of columnar zone that were described by Buesch and others (1996) based on the type of alteration exhibited by the larger pumice clasts can be identified in the columnar subzone at SD-7, although the demarcation between the several intervals is not clear-cut. Spherulitic, flattened pumice clasts that are set in dense groundmass are characteristic of the upper alteration interval. These pumices are locally argillized to a pink clay material within a spherulitic border in SD-7. A relatively distinct interval of crowded pink pumice clasts is present from 266.0 to 269.6 feet (81.0–28.2 m), and other intervals of altered pumice can be identified at 288.9–289.8 and 291.4–298.0 feet (88.0–88.3 and 88.8–90.8 m). The lower alteration interval is characterized by dark, vitric, flattened pumice clasts that may exhibit a 2–3 mm pink, argillic alteration border, and the rock preserves more glass downward marking a transitional contact with the underlying crystal-poor vitric zone.

Crystal-poor vitric zone (Tpcpv) 295.4–325.7 ft (90.0–99.3 m)

The contact between welded, devitrified rock and vitric materials belonging to the crystal-poor vitric zone is gradational over an interval of as much as 18 feet (about 3 m; log sheet 5). The change from devitrified rock to preserved vitric pumice clasts and shardy matrix is more rapid than the decrease in the degree of welding (flattening). This lower vitric interval was incorporated by Scott and Bonk into their lowermost columnar zone. Istok and others (1994) distinguished this mostly vitric interval from the overlying, devitrified columnar interval and referred to it as the "shardy base" of the Tiva Canyon Tuff.

Moderately welded subzone (Tpcpv2) 295.4–316.4 ft (90.0–96.4 m)

The upper contact of the moderately welded subzone is placed immediately below a pronounced change in the style of fracturing that is associated with the relatively rapid decrease in the intensity of devitrification (Rautman and others, 1995). This partially-moderately welded section of the lower vitric zone is composed of a matrix of moderately deformed honey-colored bubble-wall shards and 1–2 percent black shards containing black, mostly flattened vitric pumice fragments. The unit exhibits a progressive downward decrease in the degree of welding.

Nonwelded subzone, (Tpcpv1) 316.4–325.7 ft (96.4–99.3 m)

The nonwelded vitric subzone is distinguished by an absence of flattening or deformation in the constituents of the rock. The matrix is vitric, nonwelded and comprised of weakly argillized, honey-orange bubble-wall shards. Up to 10–15 percent of the shards making up the matrix are black and vitric. Pumice clasts appear to be absent from this unit in the SD-7 drill core.

Nonwelded Units in the Poorly Recovered Interval Between the Tiva Canyon and Topopah Spring Tuffs

Buesch and others (1996) have aggregated nonwelded and mostly reworked tuffaceous materials separating the formational level units (i.e., the major ash-flow tuff deposits) of the Paintbrush Group into a pre-Tiva Canyon Tuff bedded tuff (Tptbt4), a pre-Yucca Mountain Tuff bedded tuff (Tptbt3), a pre-Pah Canyon Tuff bedded tuff (Tptbt2), and a pre-Topopah Spring Tuff bedded tuff (Tptbt1). Although identification of these "bedded tuff" intervals is relatively straightforward where all four formations are present, the Yucca Mountain and Pah Canyon Tuffs thin to extinction towards the south, and the local absence of these distinctive units complicates identification, particularly of the upper three bedded tuffs. Identification and description of these units in the SD-7 core are further complicated by the total loss of core from nearly 65 percent of the 91.8-ft (28.0-m) interval lying between the densely welded portions of the Tiva Canyon and the Topopah Spring Tuffs. Continuous core loss through this interval of rapidly varying lithology exceeded 44 feet (13 m).

Figure A-1 summarizes the basis for attempts to reconstruct the lithologic and stratigraphic framework of this PTn interval for the USW SD-7 drill hole. Hole USW SD-12, which is located approximately 3000 (900 m) almost due north of SD-7, recovered essentially continuous core from this mostly nonwelded interval. Comparison of geophysical logs from the two holes should provide information regarding the correlation of physical property units between the drill holes; Presumably these units of similar, though not identical, petrophysical appearance approximate the stratigraphic (genetic) units described from core.

Figure A-1 presents the bulk density and gamma-ray traces for SD-12 and SD-7. The logs of both holes are presented at the same vertical scale, and the two profiles have been "hung" (perched?) vertically on a prominent high-density peak [arrow (a) on the figure] that corresponds approximately to the relatively thin caprock vitrophyre of the Topopah Spring Tuff (unit Tptrv1). The core profile from USW SD-12 is essentially continuous, although core from this interval did recover some rubble zones; nevertheless, the lithologic control in this hole is quite good. This profile has been annotated with the lithologic abbreviations used in this report (descriptions taken from Rautman and Engstrom, in press). The profile from USW SD-7 has been annotated with indicators of unrecovered core runs and intervals of core loss within runs. Note that by YMP drilling support convention, all core lost from a particular core run is assigned arbitrarily to the bottom of that run, even though the loss may have occurred at multiple intervals within any particular drilling episode. The petrophysical profile has also been annotated with the appropriate lithologic abbreviations where the stratigraphic unit assignment has been relatively firmly established by examination of recovered core.

Pre-Tiva Canyon Tuff Bedded Tuff (Tptpb4) 328–330.5 ft (100.0–100.7 m)

The pre-Tiva Canyon Tuff bedded tuff unit is a sandy, reworked, low-ash bedded interval with a weakly hematite-stained paleosurface at the top. The unit grades downward into a fine-grained pumice-fall deposit at 328.7 feet (100.2 m). The unit contains 7 to 10 percent small, light-grey lithic fragments and it has a high percentage of black shards in the matrix. The basal pumice-fall bed is composed of 1–2 mm pumice clasts in an ash-free matrix. The upper contact of this unit has been defined based on the very prominent, somewhat "pointed" density log low [arrow (c)]. A gamma-ray low [immediately above the gamma-ray high "shoulder" of arrow (e)] is directly associated with this density low, suggesting weathering of the bedded tuff and leaching of radioactive potassium. The lower contact of this unit is present in the recovered core at 330.5 ft (100.7 m).

Yucca Mountain Tuff (Tpy)

The Yucca Mountain Tuff (Tpy) appears to be missing at the geographic location of the SD-7 drill hole. It is possible that materials equivalent to the Yucca Mountain Tuff are present in the interval represented by 3.2-ft (1.0 m) interval of lost core drilled between 334.8 and 338.0 feet (102.0–103.0 m); however, the Yucca Mountain Tuff is also not identified in drill hole USW SD-12, which is located approximately 3000 feet (915 m) to the north of the SD-7 hole (Rautman and Engstrom, in

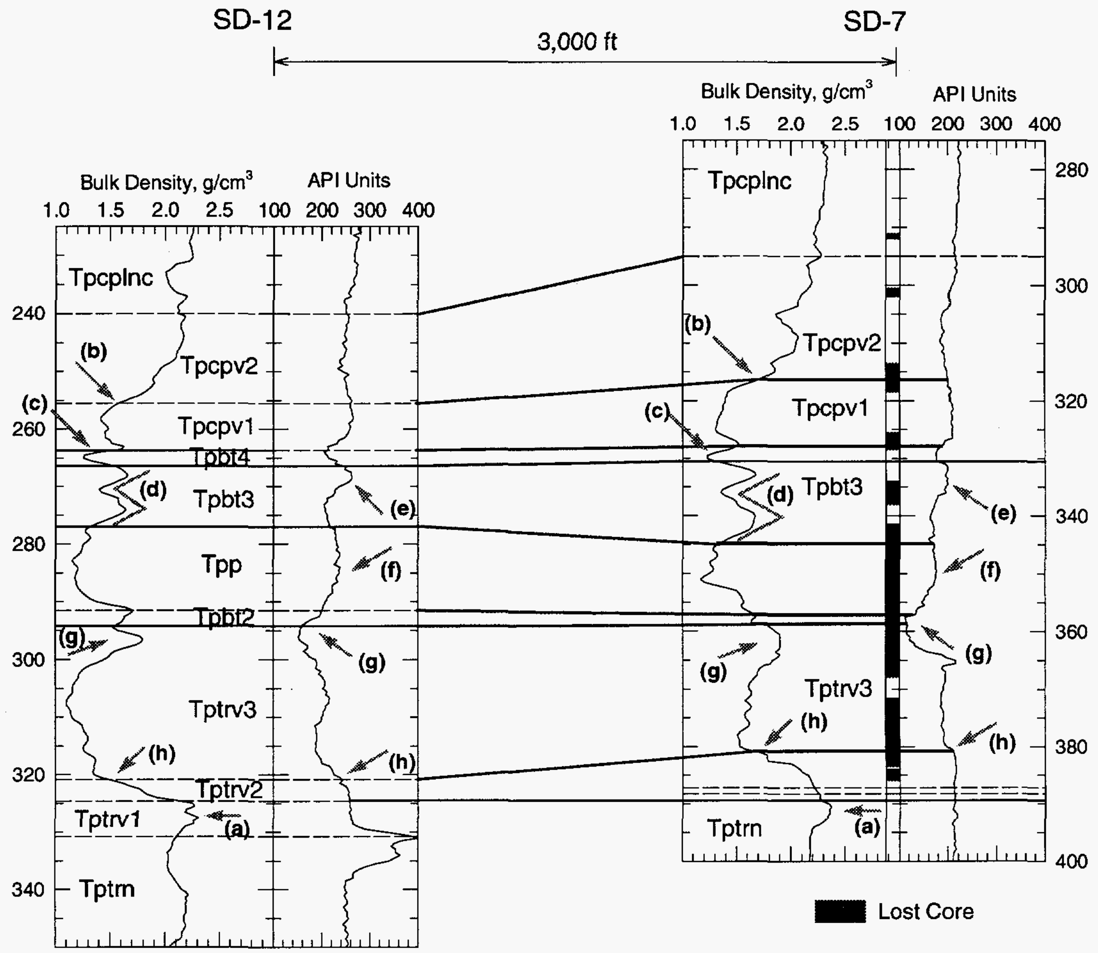

Figure A-1. Petrophysical profiles from the USW SD-7 and SD-12 drill holes through the interval between the lowermost welded Tiva Canyon Tuff and the uppermost welded Topopah Spring Tuff showing likely stratigraphic correlations involved in the interval of major core loss in SD-7.

press). USW SD-12 obtained essentially continuous core recovery through this stratigraphic interval and there is no evidence of additional geologic units in the density profile of figure A-1. There is also no evidence for omission of this part of the stratigraphic section by faulting at the SD-12 location.

Pre-Yucca Mountain Tuff Bedded Tuff (Tptpb3) 330.5–345(?) ft (100.7–105.2? m)

The recovered core from the pre-Yucca Mountain Tuff bedded tuff unit comprises four distinct units in the SD-7 drill core. The upper unit is a sandy, clast-supported bedded tuff with 3–5 percent white rhyolitic lithic fragments. This reworked upper unit grades downward into a pumiceous ash-flow deposit at a depth of 331.2 feet (100.9 m). The ash-flow deposit contains 40–80 percent small pumice clasts in a sandy, but ashy matrix. A coarse-grained pumice-fall unit underlies the pumiceous ash-flow unit from 332.9 to 333.7 feet (101.5–101.7 m). the pumice-fall bed is composed of coarse pumice clasts, with 10–15 percent of the rock volume composed of dark-brown bubble-wall shards plus 2–3 percent dark vitric lithics. The lowest recovered unit of the pre-Yucca Mountain Tuff bedded tuff is a lithic-rich pumice-fall deposit that is distinguished from the overlying unit by its ashy matrix and a quartz-latite lithic content of 10–15 percent.

Petrophysically, the pre-Yucca Mountain Tuff bedded tuff is characterized by a prominent zig-zag density profile [feature (d), fig. A-1]. This unit is correlated to the pre-Yucca Mountain Tuff bedded tuff in drill hole SD-12 by the presence of a prominent gamma log “shoulder” [arrow (e)] at the top of the unit. The lowermost part of the pre-Yucca Mountain Tuff bedded tuff unit in SD-7 has been lost in an unrecovered interval. However, the basal contact is relatively prominent and characterized by the major break at 345 ft (105.2 m) toward lower density rocks that marks the base of the zig-zag profile of feature (d). A distinct break toward lower gamma-ray activity is also observed at this same depth as the top of the broad gamma-ray high marked as feature (f) on the figure.

Pah Canyon tuff (Tpp) 345(?)–357(?) ft (105.2?–108.1? m)

The Pah Canyon Tuff appears to have been lost in the thick unrecovered interval that extends from 342.0 to 362.6 feet (104.2–110.5 m) at the USW SD-7 location. The Pah Canyon Tuff is known to thin to the south, and the unit is only 14.5 feet (14.4 m) thick in the SD-12 core in an interval of near 100 percent core recovery (Rautman and Engstrom, in press). However, the petrophysical character of the interval identified as Pah Canyon Tuff in SD-12 is moderately well reproduced in the petrophysical profile for SD-7. The contacts indicated on figure A-1 at depths of 345 and 357 ft (105.2–108.1 m) would make the unit 12 ft (2.9 m) thick in SD-7.

The most obvious correlative log feature is that indicated by arrow (f): a broad, gently curving gamma-ray high that is marked above by a sharp “notch” toward lower count rates and bounded below by an equally broad but very pronounced gamma-ray low [feature (g)]. The inferred Pah Canyon Tuff in SD-7 is marked by a bulk-density low, and although the shape of the two density traces is somewhat different in the two profiles, the location of these density lows at the same depths as the gamma-ray high of feature (f) and the presence of the density lows immediately below the characteristic zig-zag density profile of the pre-Yucca Mountain Tuff bedded tuff [feature (d)] argue strongly that the rocks are most likely correlative between the two drill holes.

The Pah Canyon Tuff *in the SD-12 drill core* contained 30–40 percent pastel-colored pumice clasts set in an weakly altered, mostly vitric, nonwelded matrix. The pumice clasts were bimodal in appearance: a light gray, densely-textured, vitric variety and a finely-laminated vesicular type that varied in size from 0.5–1.75 inch (12–45 mm); the unit also contained 1 percent dark, small, vitric lithic fragments. A characteristic, vaguely-pumiceous basal “white zone” was encountered at the base of the unit (Rautman and Engstrom, in press)

Pre-Pah Canyon Tuff Bedded Tuff (Tpbt2) 357(?)–358.5(?) ft (108.8?–109.3? m)

The pre-Pah Canyon Tuff bedded tuff has also been lost in the unrecovered interval between 342.0 and 362.6 feet (104.2–110.5 m), and the only evidence for its presence in the SD-7 drill hole is through interpretation of the geophysical well log traces shown in figure A-1. Although lithologic variability is to be expected between the SD-7 and SD-12, which are some 3000 ft (900 m) apart, there appear to be several petrophysical similarities in the general interval indicated by arrow (g) in the figure. Notably, both drill holes are characterized by quite pronounced changes in the bulk density curves (toward markedly higher densities) and in the gamma-ray curves (toward much lower counts). Under the presumption that the gamma-ray values are influenced by weathering and leaching of radioactive ^{40}K from feldspar phenocrysts in the reworked “bedded” intervals, we have associated the lowest-count part of the gamma-ray log trace in SD-7 with the pre-Pah Canyon Tuff bedded tuff.

The bedded tuff unit is very thin (1.5 ft; 0.5 m) in drill hole USW SD-7, as the contacts have been inferred on figure A-1. *In the SD-12 drill core*, the pre-Pah Canyon Tuff bedded tuff was vitric, reworked, sandy-textured, and nonwelded. This unit contained 8–10 percent small, light-gray, laminated pumice clasts, 2–4 percent dark vitric lithic clasts, 3–5 percent feldspar phenocrysts and 2 percent biotite flakes in an altered matrix (Rautman and Engstrom, in press).

Topopah Spring Tuff (Tpt)

Crystal-rich vitric zone (Tptrv) 358.5(?)–388.3 ft (109.3?–118.35 m)

The top of the Topopah Spring Tuff in drill hole USW SD-7 has been lost in the unrecovered interval that extends from 342.0 to 367.7 feet in depth (104.2–112.1 m). The upper contact of the crystal-rich vitric zone has been estimated at 358.5 ft (109.3 m), based, in part, on a change in the color of the fine-grained drill cuttings that were recovered from the hole starting at 362.6 ft (110.5 m). This inferred depth of the upper contact is roughly compatible with the petrophysical character of the profiles shown in figure A-1. In drill hole SD-12, for which core recovery was essentially 100 percent throughout the PTn nonwelded interval, the top of the crystal-rich vitric zone of the Topopah Spring Tuff is associated with a small, but fairly prominent high-low-high reversal [feature (g)] in the bulk density values. This reversal is part of a much thicker interval of pronounced low density rocks corresponding to the nonwelded ash-flow units of the Pah Canyon Tuff and upper Topopah Spring Tuff. This same prominent density low is present in the SD-7 drill hole although the sharp high-low-high trace reversal is much subdued in this hole. A pronounced gamma-ray low is generally associated with the contact in both holes as well. This interval of lower activity is compatible with an interpretation of weathering at the top of the unit that may have leached both radioactive and nonradioactive potassium from feldspars.

Nonwelded subzone, (Tptrv3), 358.5–381 ft (109.3–116.1 m)

The only core recovered from the nonwelded subzone of the crystal-poor vitric zone of the Topopah Spring Tuff was retrieved by drill run number 78, the top of which was at 367.7 feet; only 4.5 feet (64 percent) of this 7-ft core run was actually recovered (table C-1).

Based upon the core and poor-quality cuttings (at about 362.6 ft) that were recovered from upper nonwelded subzone, it appears that this interval of the Topopah Spring Tuff can be described as pumice rich, containing 40 percent clasts of light-pink fine-grained pumice and 30 percent clasts of a darker and more altered pumice variety. The rock also contains sanidine phenocrysts with a trace of oxybiotite, 1–2 percent partially altered (argillized?) black vitric shards, and about 1 percent iron-stained small lithic fragments. The iron staining is consistent with the presence of a paleosol or other weathering horizon at the top of the Topopah Spring Tuff.

The base of the nonwelded vitric subzone has been lost in the SD-7 drill core. The transition to more welded rocks is quite well defined in the bulk density profile from this hole, and it correlates well with the character of the nonwelded to moderately welded transition in drill hole SD-12 to the north. This contact has been picked at a depth of 381 ft (116.1 m) as indicated in figure A-1 by arrow (h). This contact in USW SD-12 is also marked by a well defined drop in the gamma-ray log values. This same feature can be observed at arrow (h) on the right hand side of the SD-7 profile as well.

Moderately welded subzone (Tptrv2), 381–387.2 ft (116.1–118.0 m)

No additional core was recovered from the crystal-poor vitric zone down to 384.4 feet (core run 81); recovery in this 2.1-ft interval was only 24 percent. This one-half-foot core segment consists of crystal-rich, moderately welded and pumice-rich ash-flow tuff containing 12–15 percent sanidine phenocrysts, less than 1 percent oxybiotite, and about 5 percent dark-colored, partially altered (argillized or devitrified) vitric lithic fragments. Vapor-phase alteration appears to have affected this material, and the cores of pumice clasts are vuggy and recrystallized. The commonly observed “sintered zone” of the uppermost Topopah Spring Tuff may be contained in this interval. The basal contact at 387.2 ft (118.0 m) was recovered in core.

Densely welded (“caprock vitrophyre”) subzone (Tptrv1), 387.2–388.3 ft (118.0–118.4 m)

The densely welded (“caprock vitrophyre” of Scott and Bonk, 1984) subzone is composed of dark-colored, densely fused, crystal-rich glass. Feldspar phenocrysts constitute 20–25 percent of the rock, with 1 percent oxybiotite and rare pyroxene. The subhorizontal, platy joints typically observed in this unit in outcrop are coated by red-brown clay (?) minerals. The unit is extremely thin, only 1.1 ft (33 cm) thick, in the SD-7 drill core.

Crystal-rich nonlithophysal zone (Tptrnl) 388.3–487.8 ft (118.4–148.7 m)

The crystal-rich nonlithophysal zone, formerly known as the "rounded" zone of Scott and Bonk (1984), is distinguished from the caprock vitrophyre by the presence of devitrification, or high-temperature crystallization minerals that replace the original densely fused glass. The contact of this unit with the overlying "caprock vitrophyre" subzone is gradational over 2–3 feet (less than 1 m). The unit is composed of 20–25 percent white feldspar phenocrysts and 5–10 percent flattened, recyrstallized pumice with a densely welded groundmass that appears somewhat "grainy" and which becomes increasingly vapor-phase altered downward. The upper part of the crystal-rich nonlithophysal zone also contains a few percent lighter-colored, indistinct bodies that appear to be more rhyolitic composition blebs that are deformed along with the welding foliation of the rest of the rock. These are likely small cognate lithic clasts related to the much larger "soft lithics" that are more abundant deeper in the hole and which are characteristic of the compositional transition interval (see below).

Although most of the upper crystal-poor nonlithophysal zone exhibits what may be termed weak "lithophysal-style" alteration with corroded and vuggy pumice cores and diffuse white vapor-phase alteration, the uppermost significant lithophysae occur at a depth of 455.4 ft (138.8 m). These features are widely spaced and lensoidal in shape. They appear to originate as more altered versions of the vuggy and recyrstallized cores of flattened pumice clasts.

Crystal transition interval – 473?–487.8 ft (144–148.7 m): The crystal-transition interval—that interval over which the phenocryst content of the rock matrix changes from about 10–12 percent at the top to 2–3 percent at the bottom—is identifiable only with difficulty in the USW SD-7 drill hole. The general interval overlying the lower contact of the crystal-rich member of the Topopah Spring Tuff is relatively intensely vapor-phase altered, and the core itself has been extensively sampled and the remaining material is heavily coated by drilling dust. Sample Management Facility procedures prohibit washing of the core to remove this obscuring material. The crystal transition has been identified tentatively as extending from a depth of very roughly 473 ft (144 m) to the top of the crystal-poor upper lithophysal zone at a depth of 487.8 ft (148.7 m).

Compositional transition interval – 472.2–532.0 ft (143.9–162.2 m): A roughly 60-ft (20-m) interval that begins within the crystal-rich nonlithophysal zone at a depth of 472.2 ft (143.9 m) is characterized by an overall downward change in composition of the Topopah Spring from quartz latite to rhyolite. Crystal-rich quartz latite containing deformed clasts of crystal-poor rhyolite dominates the top of the transition interval, and the relative proportions of the two rock types change downward to crystal-poor rhyolite containing deformed clasts of crystal-rich quartz latite. The two materials unquestionably are comagmatic and represent intermixed products of a compositionally zoned source magma chamber (Lipman and others, 1966). The groundmass in the lower part of the compositional transition interval exhibits a "swirled" texture, also presumably caused by intermixing of the quartz latite (above) and rhyolitic (below) magmas on a much smaller scale than the identifiable, discrete soft lithic clasts. The compositional transition interval is very weakly lithophysal at the top, but becomes increasingly lithophysal and more intensely vapor-phase altered downward.

Crystal-poor upper lithophysal zone (Tptpul) 487.8–682.5 ft (148.7–208.0 m)

The transition from "nonlithophysal" to "lithophysal" rocks in the SD-7 drill core is gradational, as indicated on geologic log sheets 7–8 of Appendix B. Small, widely spaced lithophysae that are moderately coated by vapor-phase mineralization, but which do not exhibit any particular alteration rim extending outward into the groundmass, are widely spaced in the core beginning at a depth of about 487.8 ft (148.7 m); this depth has been selected as the top of the crystal-poor upper lithophysal zone. Note, however, that there is no crystal-rich lithophysal zone at the SD-7 location, as the "alteration front" of lithophysal cavity development is below the crystal-rich/crystal-poor "member" transition. The rock also exhibits millimeter-scale, white, vapor-phase, lithophysal-style alteration spots and wispy streaks that probably represent the altered cores of highly compressed former pumice clasts. Buesch and others (1996) cite the presence of lithophysal-style "spots" as one of the defining features of named lithophysal zones.

Between 497.9 and 507.6 ft (151.75–154.7 m), the intensity of lithophysal-style alteration increases as does the frequency of the small, ragged lithophysae themselves. An essentially nonlithophysal interval is associated with the lower 18–20 ft (about 6 m) of the compositional transition interval at 516.1–533.3 ft (157.3–162.5 m). At 533.3 ft, there is a marked increase in the abundance of small, closely spaced lithophysae; these lithophysal features exhibit cavities that are coated by vapor-phase mineralization and have altered rims that extend several millimeters into the intensely vapor-phase altered groundmass. The first larger-than-core-sized lithophysal cavities are inferred at a depth of about 561.1 ft (171.0 m), based on examination of down-hole video imagery and the presence of thick unrecovered intervals associated with intervals of rubblized core.

Well developed lithophysae of varying size, spacing, degree of flattening and general intensity of associated vapor-phase alteration continue downward to about a depth of 646 ft (197 m). Below this depth, the intensity of lithophysal style alteration decreases markedly, and thin, apparently nonlithophysal intervals can be distinguished in the core. The last prominent very large lithophysal cavities are probably at a depth of about 623.1 ft (189.9 m). Distinct mesoscale lithophysae, lithophysal-style alteration, and thin rubblized zone are present to a depth of 682.5 ft (208.0 m); this depth has been selected as the lower contact.

Crystal-poor middle nonlithophysal zone (Tptpmn) 682.5–803.3 ft (208.0–244.8 m)

The crystal-poor middle nonlithophysal zone, which was also identified simply as a nonlithophysal zone by Scott and Bonk (1984), is characterized by the near-total absence of lithophysal-style alteration. The rock contains 1–3 percent sanidine phenocrysts and a trace of biotite. Weakly vapor-phase corroded, relict pumice cores are nearly indistinguishable from the groundmass. More typical vapor-phase alteration is restricted to wavy, subhorizontal wisps that potentially may represent original pumice clasts. An interval of sparse, white, subangular small lithic fragments of mixed compositions is present between 694.1 and 714.7 ft (211.6–217.8 m). The abundance of small, fine-grained lithic fragments appears to increase near the bottom of the middle nonlithophysal zone.

Crystal-poor lower lithophysal zone (Tptpll) 803.3–1020.0 ft (244.8–310.9 m)

Lithophysal-style alteration associated with the lower lithophysal zone (known by essentially the same name in the terminology of Scott and Bonk, 1984) in SD-7 begins fairly abruptly at a depth of about 801.6 ft (244.3 m) as a patchy increase in the intensity of vapor-phase alteration. By a depth of 802 ft (244.4 m), relict pumice sites are rimmed and bordered by lithophysal-style alteration, and the first identifiable lithophysae are present at a depth of 803.3 ft (244.8 m), which depth has been selected as "the" contact. Unlike in the crystal-poor upper lithophysal zone, the majority of lithophysae in the lower lithophysal zone must be inferred from interpretation down-hole video logs and from the recovery of highly broken, intensely vapor-phase altered lithophysal fragments in the core. The upper 60 to 80 feet (18–24 m) of the crystal-poor lower lithophysal zone consist more of unrecovered intervals than of recovered rubble and core fragments (log sheets 12–13, Appendix B). Moderately spaced large lithophysal cavities are visible in down-hole video imagery.

The apparent size of lithophysae decreases gradually beginning at a depth of about 840 to 860 ft (256–262 m), and the general intensity of lithophysal-style alteration appears to decrease gradually over a much broader interval. Flattened lithophysae are present at a depth of 886.5 ft (270.2 m); lithophysae become flatter and more vuggy downward. Several intensely vapor-phase altered but otherwise non-lithophysae-bearing intervals that exhibit 10- to 15-mm alteration spots are present below a depth of about 900 ft (275 m).

Crystal-poor lower nonlithophysal zone (Tptpln) 1020.0–1191.4 ft (310.9–363.1 m)

The contact between the crystal-poor lower lithophysal zone and the lower nonlithophysal zone is gradational and was placed at a depth of approximately 1020.0 ft (310.9 m) based principally on differences in the style of alteration of the groundmass. Below this depth, the groundmass is more dense and less grainy in appearance. The crystal-poor lower nonlithophysal was referred to by Scott and Bonk (1984) as the "mottled" zone. Sparse (one or two every few feet), flattened lithophysae are present down to a depth of 1042.0 ft (318 m). ft; these lithophysae lack significant vapor-phase rims and borders. Pervasive vapor-phase alteration in the lower nonlithophysal zone forms light-pink alteration halos and wisps that surround relict pumice clasts, lithic fragments, and phenocrysts. Vapor-phase alteration is visible as thin (mm-width) selvages along micro-fractures throughout the rock. The rock contains 1–2 percent phenocrysts and 3–5 percent small, white, altered rhyolite lithics. These lithic fragments, principally white, altered, "hard" rhyolitic clasts, increase in abundance downward from 1029.0 to 1032.8 ft 313.6–314.8 m). Lithic clasts appear to be present in poorly-defined swarms, particularly from about 1140 to 1175 ft in depth (347–358 m), and these contrasting-color lithics add to the mottled appearance of this zone in outcrop.

Crystal-poor vitric zone (Tptpv) 1191.4–1364 ft (363.12–415.7 m)

Densely welded ("basal vitrophyre") subzone (Tptpv3) 1191.4–1274.5 ft (363.1–388.5 m)

The contact of the crystal-poor lower nonlithophysal zone with the underlying densely welded subzone of the crystal-poor vitric zone (the lower vitrophyre of Scott and Bonk, 1984) is somewhat transitional in the SD-7 drill core. The highest evidence of incomplete devitrification was encountered at a depth of 1159.0 ft (353.25 m) as the upper limit of somewhat blotchy, vitric texture. The core is noticeably less devitrified below 1177.0 ft (358.7 m), and the highest definitely vitrophyric material was encountered at a depth of 1181.8 ft (360.2 m). Devitrified welded tuff was encountered below this thin glassy interval, and again below a second vitrophyric zone at 1187.2 ft (361.8 m), suggesting that these highest occurrences of quenched glass are remnant "islands" of the much thicker, main part of the densely welded vitric subzone interval that is present below a depth of 1191.4 ft (363.1 m).

The majority of the "basal" vitrophyre of the Topopah Spring Tuff below 1191.4 ft (363.1 m) is dark colored, densely welded, and almost entirely vitric. The unit is thick (83.1 ft, 25.3 m) in SD-7, and extends down hole to a gradational lower contact at 1274.5 ft (388.4 m). The rock contains approximately 15–20 percent coarse, black, vitric, flattened pumice clasts or fiamme, 3 to 5 percent small rhyolite and quartz latite lithic fragments, and 3–4 percent phenocrysts. The lithic fragments exhibit thin vapor-phase alteration rims and typically average 5 mm (0.2 inch) in diameter but may be as large as 10 mm. The vitrophyre typically exhibits a densely spaced rectilinear fracture pattern and major joints are coated by pale-blue, vapor-phase siliceous material. Some core fragments exhibit conchoidal fracturing.

Moderately welded subzone (Tptpv2) 1274.5–1295.0 ft (388.5–394.7 m)

The moderately welded subzone of the crystal-poor vitric zone (partially welded zone of Scott and Bonk, 1984) is distinguished with difficulty from the overlying vitrophyre subzone by a progressive down-hole decrease in the degree of welding and the presence of incipient alteration. Subangular, orange pumice fragments are the highest indicators of decreased welding, and the entire core becomes pale orange and only partially welded by about 1288.0 ft (392.6 m). Large, ragged, black vitric pumice clasts up to 60 mm across are rimmed by weak alteration (argillization?); note, however, that X-ray diffraction analyses from this general interval indicate that the groundmass of those samples is essentially wholly vitric (Appendix H, table H-1; Appendix B, geologic log sheets 19–20). Approximately 5–10 percent of the groundmass is composed of black bubble-wall shards. Lithic fragments consisting of porphyritic volcanic clasts averaging 4 mm in size constitute 2–4 percent of the unit. Fracturing is less intense downward and becomes dominantly subhorizontal as the intensity of welding decreases.

Nonwelded subzone (Tptpv1) 1295.0–1364 ft (394.7–415.7 m)

The contact between the moderately welded and nonwelded vitric subzones is defined at a depth of 1295.0 ft (394.7 m) at the uppermost occurrence of undeformed pumice clasts. The nonwelded subzone contains 15 to 20 percent light orange-brown pumice fragments surrounded by 1–2 mm reaction or alteration rims, 2–4 percent crystal-rich and crystal-poor devitrified volcanic lithics, and 1–3 percent phenocrysts in a vitric matrix containing as much as 5 to 10 percent black, glassy shards. The pumice fragments are locally spherulitic. At a depth of 1295.5 ft (394.8 m), the black shard content increases to 10–15 percent and the core is dark orange-gray in color. The matrix is speckled by 2 percent finely crystalline black spots of manganese oxide. The lower contact of the nonwelded vitric subzone of the Topopah Spring Tuff has been lost in a thick interval of lost core and poor core recovery that extends from approximately 1350 to 1420 ft (410–433 m) (fig. A-2). This contact has been placed at a depth of approximately 1364 ft (415.7 m) for reasons that are discussed in the immediately following section describing the identification and character of the pre-Topopah Spring Tuff bedded tuff interval.

Pre-Topopah Spring Tuff Bedded Tuff (Tpbt1) 1364(?)–1405 ft (415.7?–428.2 m)

Virtually all of the pre-Topopah Spring Tuff bedded tuff unit was lost in the 40-ft (12-m) unrecovered interval that extends from 1350.9 to 1390.7 feet (411.7–423.9 m). The contact between the base of the crystal-poor Topopah Spring Tuff and the underlying bedded and reworked interval is estimated at approximately 1364 feet (415.7 m) because of the rather marked change to increased density values recorded by the down-hole density tool [fig. A-2, feature (a)], in keeping with a somewhat general observation that "bedded tuffs" appear to consist of materials with higher, rather than lower, densities. This empirical observation may be because low-density ashy materials have been removed in the sedimentary reworking process leaving a more sandy residue of higher density phenocrysts. In contrast to the density log obtained from drill hole USW SD-12 (Rautman and Engstrom, in press) where the pre-Topopah Spring Tuff bedded tuff is absent from an interval of good core recovery, the density trace from SD-7 shows a prominent reversal toward higher densities at this depth, and the next 40 ft (12 m) exhibit markedly higher density values [arrow (a) in fig. A-2] than anything observed in USW SD-12 [arrow (b) and below]. Also in contrast between the two holes, the gamma-ray log from SD-12 exhibits a broad peak of higher values underlying the base of the crystal-poor vitric zone of the Topopah Spring Tuff [arrow (c)], whereas the corresponding interval in SD-7 exhibits relatively constant to somewhat lower gamma-ray readings [arrow (d)].

Very fine-grained, pinkish, soft, clayey drill cuttings that are speckled by black iron(?) oxide minerals were recovered between 1390.7 and 1391.2 feet (423.9–424.0 m). Fragments of core that were recovered between approximately 1321.0 and 1398.1 feet (402.6–426.1 m) consist of medium-grained, sandy bedded tuff with an ash content of about 10–20 percent. The lower contact of the pre-Topopah Spring Tuff bedded tuff was also lost in an unrecovered interval. The contact has been placed at a depth of 1405 ft (428.2 m) because of the shift to distinctly lower density values in the down-hole density log (fig. A-2; feature (e) in both drill holes) and because core that appears to belong to the Calico Hills Formation was recovered from 1405.6 to 1406.3 ft (428.4–428.6 m). This lower contact is thus well constrained by high values of the density trace above and actual core material below.

Calico Hills Formation (Tac)

The top of the Calico Hills Formation has been lost in an unrecovered interval extending from 1398.1 to 1405.6 feet (426.1–428.4 m), and the possibility that this unrecovered interval represents a major fault cannot be ruled out. The upper contact of the preserved Calico Hills Formation has been estimated at a depth of approximately 1405 feet (428.2 m), as described in the immediately preceding section (see also fig. A-2). Calico Hills ash-flow units 4 and 5, identified elsewhere at Yucca Mountain and described by Moyer and Geslin (1995), appear to be absent in the USW SD-7 drill hole. No iron-stained paleosol or reworked material was observed at the top of the Calico Hills unit in SD-7, although it is unclear that the extent

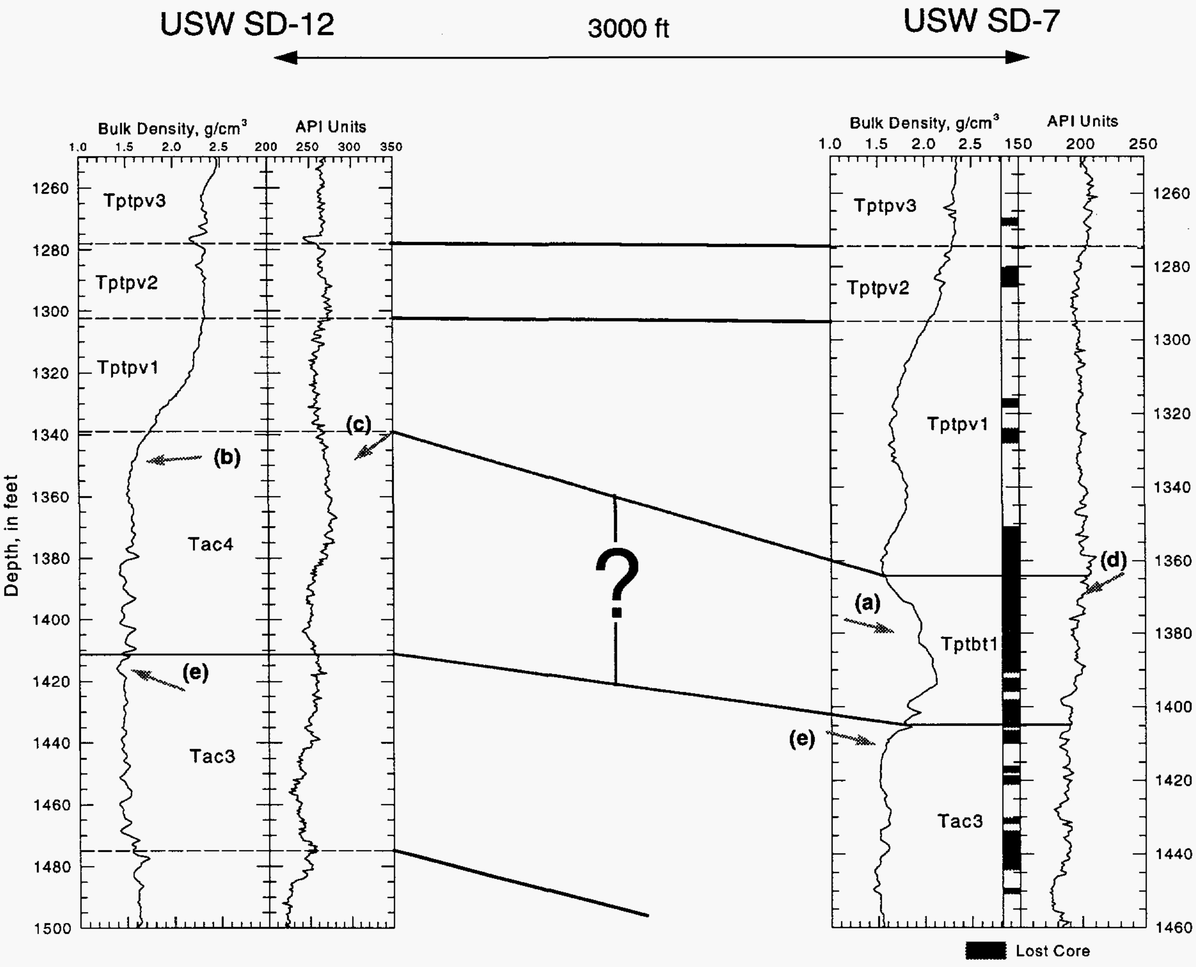

Figure A-2. Petrophysical profiles from the USW SD-7 and SD-12 drill holes for the interval between the Topopah Spring lower vitrophyre and the Calico Hills Formation showing likely stratigraphic correlations involved in the interval of major core loss in SD-7 (black bars).

of core and cuttings recovery from this interval is sufficient to have much confidence in this (non) observation.

Rocks belonging to Calico Hills ash-flow unit 4 were described by Rautman and Engstrom (in press) in core from drill hole USW SD-12, located some 3000 ft (900 m) to the north of SD-7. A comparison of the petrophysical character of the uppermost units of the Calico Hills Formation for these two holes is presented in figure A-2, and the differences in character strongly suggest that the two drill holes are not correlative in this interval. Preservation of Calico Hills ash-flow unit 4 in SD-12 to the north and its absence in SD-7 are compatible with an interpretation of southward depositional thinning away from the source of the Calico Hills Formation (Carr, 1984), particularly if the intensity of eruptive activity waned progressively during Calico Hills time. Work by Moyer and Geslin (1995) that was completed prior to the drilling of holes SD-7 and SD-12 also indicated that Calico Hills ash-flow unit 5 was absent in drill hole UE-25 UZ-16 (fig. 3) and that ash-flow unit 4 was very thin in the UE-25 “c-hole” complex, which is located about 8300 ft (2530 m) almost due east of SD-7. Moyer and Geslin (1995, their fig. 2) present a stratigraphic cross section that is highly suggestive of either post-depositional erosion of the Calico Hills Formation or lobate deposition from a source to the northeast of the main Yucca Mountain repository region (Carr, 1984).

Conversely, fault displacements are known to increase generally from north to south through the repository region (Scott and Bonk, 1984; Scott, 1990). Greater vertical displacement along the Ghost Dance Fault at SD-7 compared to at SD-12 might have produced significant stratigraphic differences at the SD-7 location; this is wholly compatible what is observed in the SD-7 core. Note that the inferred absence of an iron-stained, weathered profile at the top of the Calico Hills in SD-7 also would be compatible with a faulted or fault-influenced contact characterized by aggressive erosion, as is the extreme loss of core directly at the contact.

Calico Hills ash-flow unit 3 (Tac3) 1405(?)–1493.3 ft (428.2?–455.2 m)

The uppermost unit of the Calico Hills Formation in drill hole SD-7 is inferred to be ash-flow unit 3 of Moyer and Geslin (1995). Calico-Hills ash-flow unit 3 is nonwelded and pumice-rich. The ash-flow unit contains up to 25–30 percent pale yellow-orange pumice clasts and 2–3 percent quartz latite lithics down to a depth of 1431.8 feet (436.4 m). Below this depth, the groundmass appears to have been altered (potentially vapor-phase alteration?), although X-ray diffraction studies indicate a very large content of glass in samples taken from this interval (Appendix H, table H-1). The pumice fragments also appear altered and they are virtually indistinguishable from the matrix. Core recovery near the top of the unit is poor, and an argument could be made that the upper 20 ft (about 6 m) of the Calico Hills could be assigned to Moyer and Geslin's "pumiceous" ash-flow unit 4 based on the abundance of pumice clasts and relatively low content of lithic clasts. The gamma-ray trace from this interval in SD-7 appears to lack the broad, generally increasing count-rate appearance of the log from SD-12 [feature (c) in fig. A-2], and the gamma character is more akin to that exhibited by ash-flow unit 3 in SD-12.

The content of lithic clasts increases markedly between 1433.0 and 1442.0 feet, including 10–15 percent large, clear, perlitic, vitric lithics up to 25 mm, 5–7 percent small devitrified volcanic lithics and 2–3 percent 5- to 7-mm subrounded, dark colored crystal-rich lithics. Although core was lost from 1430.3 to 1431.8 ft (435.9–436.4 m) and again between 1433.8 and 1441.3 ft (437.0–439.3 m), the top of the lithic-rich interval appears to have been recovered, and there is no evidence of the "sharp depositional contact" overlain by bedded and reworked tuffs, as described by Moyer and Geslin (1995, p. 50). The total content of smaller lithic clasts increases below a depth of 1455.0 feet (443.5 m) and the ash-flow tuff is lithic-rich (10–15 percent) near the bottom of the unit. A bedded unit from 1493.0–1493.3 ft (455.0–455.2 m) consists of a coarse basal lithic lag overlying a very fine-grained ashy deposit that fines and become lithic-poor downward. This thin, bedded interval at the base of the unit may represent basal-surge deposition.

Calico Hills ash-flow unit 2, (Tac2) 1493.3–1523.8 ft (455–2464.5 m)

Calico Hills ash-flow tuff unit 2 is broadly similar to unit 3. Pumice clasts are visible and constitute about 25 percent of the rock, and the lithic content remains constant at about 3–5 percent red-brown devitrified volcanic and dark, vitric, perlitic fragments. The pumice fragments are equally divided between dense-textured and laminated varieties. The fine, ashy matrix of ash-flow unit 2 has been heavily altered to an orange-pink color. Again, X-ray diffraction analyses indicate a preponderance of glass in this unit (Appendix H, table H-1). A basal "bedded" interval of ash-flow unit 2 is present between 1517.1 and 1523.8 feet (462.4–464.4 m). This bedded tuff can be subdivided into a coarse, lithic-rich upper zone containing a 0.2-ft (6-cm) coarse-grained, lithic-rich pumice fall, a 1.1-ft (34-cm) fine-grained volcaniclastic sandstone, and a 2.6-ft (80-cm) medium-grained pumice bed, underlain by a 2.2-ft (67-cm) thick lower zone composed of ash-flow materials with sandy texture and 10 percent small lithics. A crowded lithic zone is present between 1506.7 and 1508.3 feet (459.2–459.7 m). Clay-covered fractures with slickensides dipping at 60–75 degrees to the core axis, indicating at least some differential movement, are present at depths of 1511.1 and 1517.3 feet. (460.6–462.4 m). Vitric and zeolitized materials may be finely interlayered at the base of this unit ((Appendix H, table H-1).

Calico Hills ash-flow unit 1, (Tac1) 1523.8–1567.2 ft (464.5–477.7 m).

Calico Hills ash-flow unit 1 is a zeolitized pyroclastic-flow deposit containing 30–40 percent light-green pumice clasts, 2–3 percent lithics of varying compositions and textures, and 1–2 percent phenocrysts of feldspar, quartz and lesser biotite in pink, microgranular, devitrified and very weakly zeolitized groundmass. The lithic clasts are divided between red-brown, sub-rounded, devitrified volcanic fragments up to 10 mm across and dark-gray to black, perlitic, vitric lithics that average 5 mm in size. Differences between the relative-humidity and 105°C-dried laboratory material property measurements plotted on the geologic log sheets of Appendix B (also fig. 8) suggest that zeolitic alteration increases in intensity down hole reaching maximum (macroscopic) intensity at approximately a depth 1564 feet. The X-ray diffraction mineralogic analyses indicate that some parts of this interval may preserve significant amounts of glass (Appendix H, table H-1); potentially the glass itself is hydrated (?). A 5-ft (1.5-m) swarm of large lithics is present at 1551.5–1116.5 ft. A lithic-rich, pumice-fall marker bed forms the bottom of the unit.

Calico Hills bedded tuff unit (Tacbt) 1567.2–1610.3 ft (477.7–490.8 m)

The complex, bedded tuff deposit that underlies the main ash-flow units of the Calico Hills Formation comprises a moderately to heavily zeolitized sequence dominated by bedded (reworked) tuffs, separated by alternating layers of ash-fall and pumice-fall deposits. The bedded tuff intervals exhibit a more sandy texture and lower matrix-ash contents than unreworked ash-flow materials. Thin, presumably unreworked, ash-fall layers are typically more heavily zeolitized than the bedded intervals. A number of individual coarse-grained pumice-fall beds are present at depths of 1569.5, 1571.1, 1583.0, and 1597.1 feet (478.4, 478.9, 482.4, and 486.8 m). Rhythmically interlayered pumice-fall and ash-flow materials are present at depths of 1582.5 and 1587.7 feet (482.3, 483.9 m).

Calico Hills basal tuffaceous sandstone (Tacbs) 1610.3–1626.2 ft (490.8–495.7 m)

The basal, tuffaceous sandstone unit of the Calico Hills tuff lies below an indistinct upper contact at about 1610.3 feet (490.8 m) unmarked by any obvious paleosol or hematitic staining, as the top of the unit is more typically described by Moyer and Geslin (1995). The rock texture exhibits a sandier texture with less fine-grained matrix than is present in the overlying bedded tuffs. The sandstone is fine- to medium-grained and contains 2–3 percent devitrified volcanic lithic fragments, 2–3 percent quartz, feldspar and biotite crystals, and 10–15 percent small, pale-tan pumice fragments with about 50–60 percent black, ashy altered, intergranular matrix. Larger, altered pumice fragments up to 75 mm in size increase in number below 1613.7 feet (491.8 m); these clasts locally may constitute approximately 35 percent of the rock. At about 1620 feet (494 m), the large pumice fragments appear to be slightly vapor-phase altered. The base of the tuffaceous sandstone unit is marked by a thin pumice-fall bed.

Prow Pass Tuff (Tcp)

Prow Pass ash-flow unit 4 (Tcp4) 1626.2–1655.0 ft (495.7–504.5 m)

Prow Pass ash-flow unit 4 is a relatively thin unit in the SD-7 drill core. The rock is nonwelded and zeolitized, and it contains 30–40 percent pale yellow, rounded pumice clasts, 2–3 percent small lithic fragments in dark volcanic or siltstone compositions and 2–3 percent phenocrysts. The groundmass appears approximately one-third zeolitized. Weak vapor-phase alteration, apparently related to the underlying ash-flow unit 3 (see following section), produces lighter-colored rock below a depth of 1647.0 feet (502.0 m). Zeolitization appears to overprint the vapor-phase alteration. No basal bedded tuff interval is associated with this unit at the SD-7 drill hole.

Prow Pass ash-flow unit 3 (Tcp3), 1655.0–1837.8 ft (504.5–560.2 m)

Prow Pass ash-flow unit 3 has been moderately welded and vapor-phase altered, and the unit may have been overprinted by zeolitic alteration near the top of the interval. The rock itself is quite similar to the units above and below, containing 20–30 percent pumice clasts, 1–4 percent siltstone and small devitrified volcanic lithics, and 5–10 percent phenocrysts in a highly altered matrix. Welding increases below the upper contact to a maximum at about 1750 feet (533 m), and then gradually decreases; welding ends abruptly at 1837.8 feet (560.2 m) at the base of the unit.

Vapor-phase alteration associated with the cooling and welding of ash-flow unit 3 appears to have affected about 5 ft (1.5 m) of the overlying Prow Pass ash-flow unit 4 as well, in that vapor-phase alteration is present below a depth of 1647.0 feet (502.0 m) in Prow Pass unit 4 (geologic log sheet 24). Vapor-phase altered core is lighter in color, and the rock is almost white and textureless in the most intensely altered intervals. Vapor-phase alteration appears to peak at a depth of 1735–1750 feet (529–533 m), and then decreases below this depth to a somewhat weak, but relatively constant intensity below about 1760 feet (536 m). Vapor-phase alteration appears absent below 1805 feet (550.1 m). The change in intensity of alteration at approximately 1750–1760 ft (533–536 m) is clearly reflected both in the bulk-property profiles (fig. 8) and in the geophysical density profile (fig. 12).

The presence of zeolitic minerals overprinting vapor-phase alteration and devitrification near the top of Prow Pass ash-flow unit 3 is suggested by separation of the RH- and 105°C-dried laboratory bulk property measurements shown on the geologic log sheets of Appendix B [see also fig. 8(a)]. However, the few samples for which X-ray diffraction mineralogical results are available from the top of Prow Pass ash-flow unit 3 (Appendix H, table H-1) do not confirm the presence of zeolites in this interval. Separation of the RH- and 105°C-dried property measurements is less pronounced below a depth of 1702 ft (518.7 m).

Prow Pass ash-flow Unit 2 (Tcp2), 1837.8–1878.5 ft (560.2–572.6 m)

Prow Pass ash-flow unit 2 is a devitrified but nonwelded, lithic-rich (Moyer and Geslin, 1995) ash-flow tuff, roughly similar in composition to unit 3, except that the lithic content is higher at 3–5 percent. Ash-flow unit 2 contains 20–25 percent altered, white, pumice clasts up to 15–20 mm in size and 10–15 percent phenocrysts including feldspar, quartz, oxybiotite, and pseudomorphs after pyroxene. Lithics of red siltstone or devitrified volcanic compositions occur in two size fractions: one-third of the lithics are 4–12 mm in size and two-thirds are 3 mm or less. Very fine-grained vapor-phase alteration appears to decrease downward in the lower part of the unit (fig. 8), and the lower 10–15 ft (3–5 m) appear to be zeolitic. An intensely altered (zeolitized?) pumice-fall bed forms the base of the unit from 1873.0–1878.5 ft (570.9–572.6 m).

Prow Pass ash-flow unit 1 (Tcp1), 1878.5–2167.5 ft (572.6–660.7 m)

Ash-flow unit 1 of the Prow Pass Tuff comprises three zeolitic subunits, including an upper subunit, a lithic-rich middle subunit, and a lower subunit (log sheets 27–28ff). The upper subunit is nonwelded and zeolitized (and possibly silicified; see Appendix H, table H-1), with the intensity of alteration decreasing downward. The upper subunit contains 15–25 percent 10-mm zeolitized pumice clasts, 2–3 percent siltstone and devitrified volcanic lithics up to 8 mm in size, and 8–10 percent phenocrysts of quartz, feldspar, biotite, and possibly pyroxene. A 0.2-foot thick zone of crowded red siltstone lithics from 8 to 30 mm in size is present at 1886.7 feet (575.1 m). The middle, lithic-rich subzone, between depths of 1910.4 feet and 1949.2 feet (582.3–594.1 m), is defined by an increase in the lithic content to 4–6 percent, with a slightly higher fraction of volcanic fragments. The thin ash-fall marker bed that typically caps this unit (Moyer and Geslin, 1995) was not identified in the SD-7 core. The lithic content of the lower subzone decreases to 2–3 percent, and red siltstone clasts become the dominant lithic species; the average fragment size is much smaller, typically less than 3 mm. The lower subunit is thick and it contains 15–25 percent large, subrounded pumice clasts that are generally less than 10 mm in size near the top of the interval, but which increase in abundance to 25–30 percent near the bottom and attain sizes up to 45 mm. The pumice fragments are altered zeolitically to pale pink or green-gray with green intensely zeolitized spots. The rock contains 1–3 percent small, angular, red-brown volcanic lithics up to 15 mm in size that occur with the pumice clasts in swarms, less than 1 percent red siltstone lithics that are generally less than 5 mm, and 4–8 percent phenocrysts of quartz, feldspar, and biotite. A four-foot-thick (1.25-m) zone of flattened, large pumice up to 100 mm in length with no associated lithics is present near the base of ash-flow unit 1 between 2136.6 and 2140.6 feet (651.2–652.5 m; log sheet 31); the degree of flattening suggests partial welding. The tuff below the pumice-rich zone exhibits an increased lithic content up to 5–7 percent; some clasts may be as large as 10 mm in size.

Prow Pass bedded tuff unit (Tcpbt), 2167.5–2180.2 ft (660.4–664.5 m)

The bedded tuff unit of the Prow Pass Tuff consists of several thin units of different lithologies underlain by a relatively thick (8.5-ft, 2.6-m), lithic-rich ash-flow deposit that exhibits a reworked but still ash-rich matrix. A 2.5-foot thick pumiceous, basal volcanic(?) breccia forms the base of the Prow Pass sequence. The uppermost layered units (log sheets 31–32) consist of a 1.0-ft (30-cm) fine-grained, laminated, reworked ash fall, a 0.9-ft (0.3-m) pumiceous ash-flow deposit, and a 0.9-ft medium-grained pumice-fall bed. All of the subunits have been weakly to moderately zeolitized. Iron-manganese oxides commonly coat the constituent phenocrysts and lithic grains in the uppermost laminated ash-fall subunit.

Bullfrog Tuff (Tcp)

Little precedent exists for subdivision of the Bullfrog Tuff, as USW SD-7 is the first site characterization (post-1986) drill hole to penetrate more than a few feet (meters) into this stratigraphic interval. The unit has been divided provisionally into four pyroclastic flow units plus a basal tuffaceous sandstone interval.

Bullfrog upper nonwelded unit 4 (Tcb4), 2180.2–2218.0 ft (664.5–676.0 m)

The thin, upper nonwelded unit of the Bullfrog Tuff in the USW SD-7 drill hole, hereby designated as unit 4, contains roughly 10 percent pumice clasts, 20–25 percent dark quartz and feldspar phenocrysts, 5–10 percent oxybiotite, altered pyroxene or hornblende, and 1–2 percent lithic clasts of mixed composition. Lithic types include red siltstone, pumiceous and laminated-pumiceous volcanic fragments up to 60 mm, and rare, dark vitric clasts. Black iron-manganese oxides form thin coatings on some of the lithic clasts and phenocrysts. The unit is devitrified, and this is reflected in coincidence of the RH- and 105°C-dried material property measurements shown in figure 8 and on geologic log sheet 32. The groundmass has been devitrified and much of the rock has been intensely vapor-phase altered, resulting in a micrgranular, ashy texture at the top of this unit. The intensity of recrystallization of the original tuffaceous material increases downward.

Bullfrog welded unit 3 (Tcb3), 2218.0–2478.0 ft (676.0–755.3 m)

Bullfrog unit 3 comprises a thick, devitrified ash-flow tuff sequence that is partially to moderately welded in its interior (geologic log sheets 32–36). The unit is composed of 10–15 percent small, flattened pumice clasts that average 7 mm in length, 20–25 percent quartz and feldspar phenocrysts, 5–10 percent phenocrysts of biotite, hornblende and pyroxene, and 1–2 percent coarse-grained, mixed lithics of siltstone and crystal-rich, devitrified volcanic compositions. The amount of pumice increases downward to 50–60 percent of rock volume between 2354 and 2385 feet (717.5–726.9 m). Lithics vary in size and abundance from very small (50 percent less than 2 mm) to large (more than 30 mm across); soft, deformed lithics of quartz latite that are up to 75 mm in size may constitute up to 10 percent of the rock volume locally. Large lithics are found less frequently below a depth of 2242.0 ft (683 m).

Welding, expressed as flattening of the rock texture, is observed beginning at a depth of about 2218.0 feet (676 m), and the degree of welding increases down hole to a peak at approximately

2240 feet (683 m). Welding decreases below this depth and ends abruptly at a faulted contact with the underlying pumiceous unit 2 of the Bullfrog Tuff at 2478.0 feet (755.3 m). The intensity of vapor-phase alteration (fig. 8) decreases downward toward a minimum intensity at a depth of about 2360–2380 feet (720–725 m; log sheet 35–35), concomitantly with the decrease in the degree of welding. Decreasing grainy vapor-phase alteration produces a locally prominent mottled devitrification texture. Vapor-phase alteration increases downward below about 2380 feet, and becomes quite intense below 2445 feet (745.2 m; log sheet 35). The thickness of Bullfrog unit 3 that has been omitted by the fault at the base of the unit is unknown.

Bullfrog pumiceous unit 2 (Tcb2), 2478.0–2481.5 ft (755.3–756.4 m)

Bullfrog unit 2 is a medium-grained, pumice-rich ash-flow tuff containing 35–45 percent oval-shaped, devitrified or very weakly zeolitized (fig. 8) pumice fragments that average 10 mm in size plus 20–25 percent quartz and feldspar phenocrysts, 2–3 percent biotite and pyroxene, and less than 5 percent red siltstone and dark gray, devitrified volcanic lithics.

The upper contact is faulted (log sheet 36) and this fault has removed an unknown, but presumably substantial thickness of unit 2. Only the lowest 3.5 feet of the pumiceous unit was intersected in the USW SD-7 drill hole. The fault contains 0.2 feet of gouge on a fault surface with an 80-degree dip (10° to core axis), slickensides, and hematite coating. Intensely broken, unrecovered and quartz veined (probably fault-related) intervals occur both above and below the fault gouge from 2466.0 to 2473.5 feet (751.6–753.9 m) and from 2464.1 to 2566.2 feet (751.1–782.2 m).

Bullfrog lower nonwelded unit 1 (Tcb1), 2481.5–2579.4 ft (756.4–786.2 m).

The lower nonwelded ash-flow unit of the Bullfrog Tuff contains 5–10 percent pumice clasts that average 10 mm in size, 15–20 percent quartz and feldspar phenocrysts, 5–10 percent biotite and possibly pyroxene phenocrysts, 3–5 percent very small red siltstone and black devitrified volcanic lithics that occasionally reach 12–15 mm. The groundmass is entirely altered and aphanitic, however the unit appears mostly to be devitrified and only weakly zeolitic based on minimal separation of the RH- and 105°C-dried bulk properties (fig. 8). A distinctive feature of Bullfrog unit 1 is sparse, 2–3-mm clear quartz veinlets with opaline borders that cut through the rock, principally along what are now open fractures.

Bullfrog basal tuffaceous sandstone unit (Tcbs), 2579.4–2598.0 ft (786.2–791.9 m)

The lowermost unit of the Bullfrog Tuff in the USW SD-7 drill hole consists of a medium-grained tuffaceous sandstone unit containing 10–15 percent small pumice grains (average size 5 mm), 15–20 percent quartz and feldspar grains, and 3–5 percent small devitrified volcanic and red siltstone lithic fragments. Reworked pyroxene and/or hornblende crystals are also present. A finer-grained matrix is ashy and weakly hematite stained. The sandstone is noticeably coarser between 2588.0–2588.4 and 2592.0–2592.8 ft. Subvertical joints throughout the unit exhibit very weak siliceous veining (fracture coatings).

Tram Tuff (Tct)

Tram Tuff nonwelded unit (Tct), 2598.0–2675.1 ft (791.9–815.4 m)

The SD-7 drill hole penetrated 77.1 feet (23.5 m) into nonwelded ash-flow tuff assigned to the Tram Tuff, the lowest formation of the Crater Flat Group, before drilling was terminated at a depth of 2675.1 feet (815.4 m). The upper part of the Tram Tuff in the SD-7 core consists of a nonwelded, devitrified and partially zeolitized (fig. 8) ash-flow deposit containing 10–15 percent pumice clasts smaller than 4 mm, 7–12 percent phenocrysts of dark quartz and feldspar with lesser biotite, and 3–5 percent dark-colored, devitrified volcanic lithic fragments. The top of the unit is hematite stained, and probably represents a former weathering surface. The unit becomes light tan and with depth and it appears to have been weakly zeolitized.

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Appendix B: Geologic Core Logs

Geologic Core Logs

The geologic core logs in this appendix are reproduced in color at their original full scale of 1:120 (1 inch equals 10 feet). Full-size reproduction means that the log sheets that follow have not been formatted or numbered in the same manner as the remainder of this document, although the page count of this report is continuous and the log-sheet pages are themselves numbered consecutively. Copies of the original log forms may be retrieved from the Yucca Mountain Project records system under data-tracking number SNT02110894001.002.

The log form (figure B-1) contains a graphic representation of the actual geology of the core. Bedding within reworked units, clasts representing lithic fragments, lithophysal cavities, fractures, and similar textural features are drawn in a "cartoon," but still highly realistic, fashion. For example, large lithophysal cavities are drawn larger than small cavities, and flattened cavities in the core are represented as more oval features than spherical lithophysae. Near-vertical fracturing is represented by stylized fracture lines nearly parallel to the depth axis of the diagram, as such jointing is nearly parallel to the core axis in an essentially vertical drill hole, such as USW SD-7.

The degree of welding, devitrification, and the intensity of secondary alteration of the core is represented semiquantitatively by several parallel bars of vertically varying width. A blank column represents "no alteration" of the indicated type; a fully shaded column indicates "extremely intense alteration." This style of presentation can be very exact over short core distances (feet to tens of feet) and it allows relatively subtle, small-scale variation in these phenomena to be represented quite precisely. The gradational nature of several lithostratigraphic "contacts" becomes quite obvious in this manner. The representation, however, is not rigorously quantitative, and a 3-mm-wide bar at one depth should not be presumed to represent precisely the same intensity of that phenomenon as a 3-mm-wide bar several hundred feet away. Note that the type of alteration indicated by a particular column may change with depth to conserve space on the log form; the column headings are kept consistent over broad depth ranges, however.

Engineering and geologic information related to the core itself is also presented on the log sheets. Highly broken or rubblized zones are indicated by a shaded pattern in the fracturing column, and intervals of core loss are indicated by arrows extending through the indicated interval of nonrecovery. The geology of these unrecovered intervals has been interpreted through the intervals of core loss where there is reasonable evidence for such an interpretation (for example, down-hole-video imagery or a relatively consistent lithology in a known, thick geologic unit) Large intervals of lost core in geologic units known from outcrop or other drill holes to be highly variable vertically have been left uninterpreted. Note that drilling support staff assigned lost-core intervals by convention to the bottom of the core run, whereas the actual core loss may have occurred at multiple levels during the drilling of a particular run. Quantitative information (varying from 0 to 100) for per-run core recovery and 10-ft-composite, drilling-support Deere RQD values (from tables C-1 and D-2) are presented in columns to the right of the geologic descriptions.

The framework material properties, porosity and bulk density (from table G-1) are presented in similar columnar-graphic form to the right of the core-recovery and RQD information. Saturated hydraulic conductivity information does not present well because the wide (orders-of-magnitude) variability of this framework property requires a logarithmic scale; these values have been omitted from the core log. Saturation values, however, have been included as this information may bear on the identification of geologic controls of perched-water bodies. These graphic representations of materials-property data contain quantitative information. Porosity values are scaled from 0 to 70 percent, bulk density values are scaled from 1.0 to 3.0 g/cm^3, and saturation is scaled from 0 to 1. The locations of changes in the porosity and density of core samples clearly indicate that the boundaries between material property units do not correspond exactly to the boundaries of the different formation-level lithostratigraphic units (Tiva Canyon Tuff, Bullfrog Tuff, etc.).

Mineralogical compositions for the units from the Topopah Spring lower vitrophyre to the water table (Appendix H) have been included on the geologic log sheets in this appendix. X-ray diffraction analyses indicating the volume fraction the various mineral species (table H-1) have been aggregated into six categories. These categories are: the sum of quartz plus feldspar, glass, the vapor-phase and devitrification silica minerals of tridymite plus cristobalite, total (combined) zeolite, opal-CT, and smectite clay. The data are presented on the log sheets as thin bars centered on the sample depth and scaled from zero to 100 percent. The different mineral aggregations are stacked as bar segments of differing color keyed to the scheme presented in figure B-1. This style of presentation conveys the approximate volumetric proportions of the different mineral phases and it underscores that the data are from essentially spot sampling of the core.

(Note: The actual log-sheet pages that follow figure B-1 are single sided.)

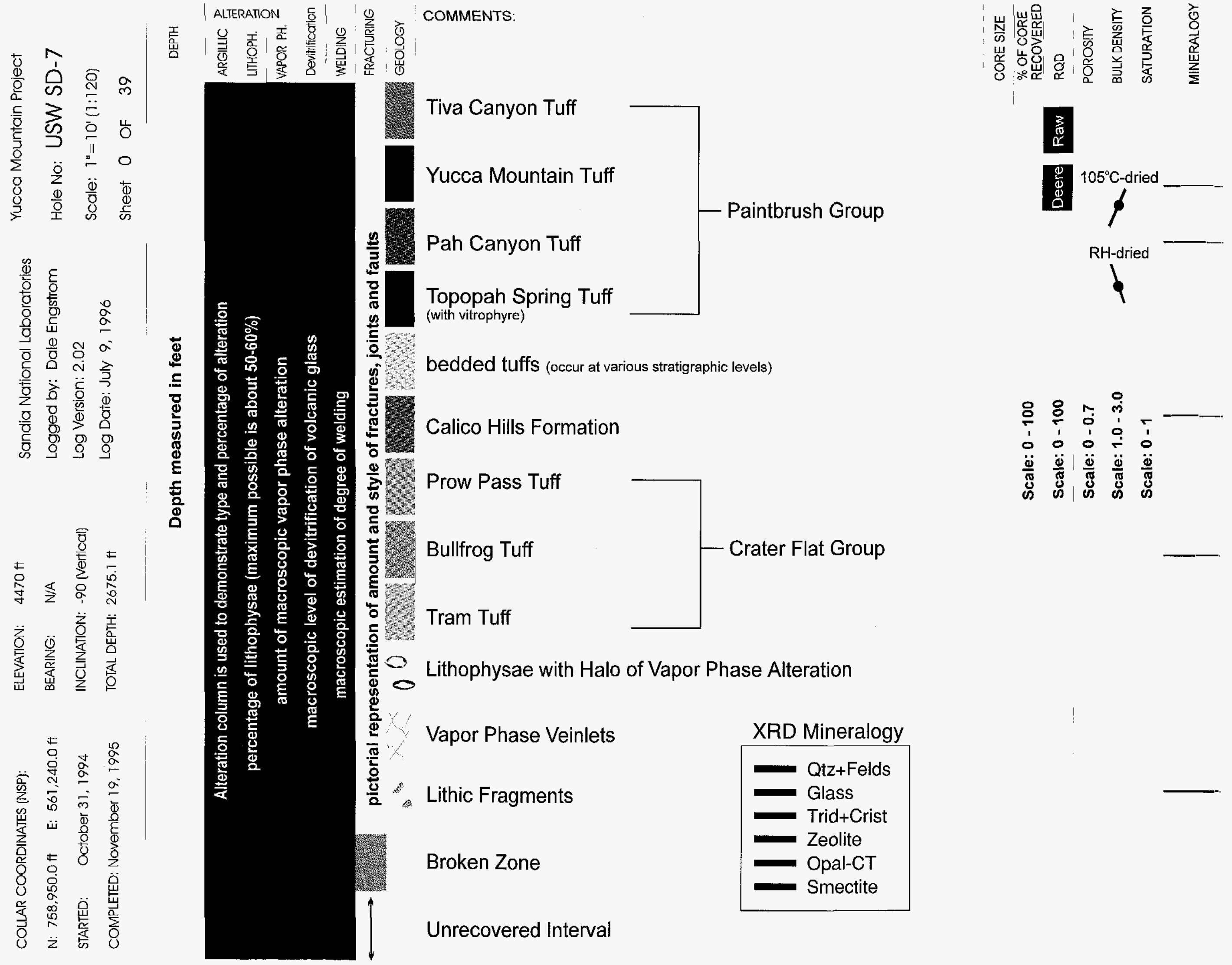
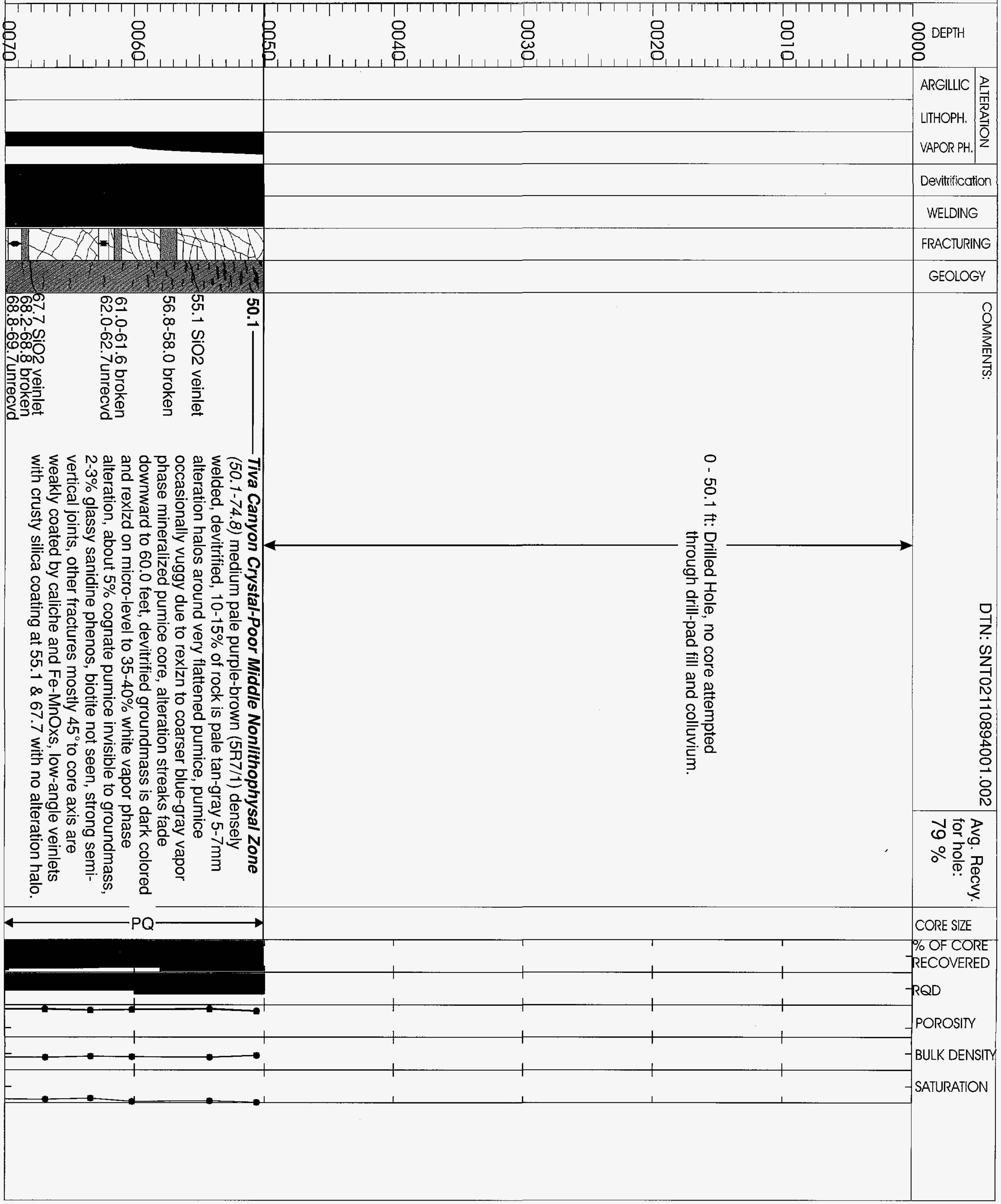


Figure B-1. Example geologic core log form with parallel columns for representing various geologic features and

COLLAR COORDINATES (NSP):		ELEVATION:	4470 ft	Sandia National Laboratories	Yucca Mountain Project
N: 758950.0 ft	E: 561240.0 ft	BEARING:	N/A (vertical)	Logged by: Dale Engstrom	Hole No: USW SD-7
STARTED:	October 31, 1994	INCLINATION:	-90	Log Version: 2.02	Scale: 1"=10' (1:120)
COMPLETED:	November 19, 1995	TOTAL DEPTH:	2675.1 ft	Log Date: July 9, 1996	Sheet 1 OF 39



0 - 50.1 ft: Drilled Hole, no core attempted through drill-pad fill and colluvium.

50.1 ——— ***Tiva Canyon Crystal-Poor Middle Nonlithophysal Zone*** *(50.1-74.8)* medium pale purple-brown (5R7/1) densely welded, devitrified, 10-15% of rock is pale tan-gray 5-7mm alteration halos around very flattened pumice, pumice occasionally vuggy due to rexlzn to coarser blue-gray vapor phase mineralized pumice core, alteration streaks fade downward to 60.0 feet, devitrified groundmass is dark colored and rexlzd on micro-level to 35-40% white vapor phase alteration, about 5% cognate pumice invisible to groundmass, 2-3% glassy sanidine phenos, biotite not seen, strong semi-vertical joints, other fractures mostly 45° to core axis are weakly coated by caliche and Fe-MnOxs, low-angle veinlets with crusty silica coating at 55.1 & 67.7 with no alteration halo.

55.1 SiO_2 veinlet
56.8-58.0 broken
61.0-61.6 broken
62.0-62.7 unrecvd
67.7 SiO_2 veinlet
68.2-68.8 broken
68.8-69.7 unrecvd

DTN: SNT02110894001.002

Avg. Recvy. for hole: 79 %

COLLAR COORDINATES (NSP):

N: 758950.0 ft E: 561240.0 ft

STARTED: October 31, 1994

COMPLETED: November 19, 1995

ELEVATION: 4470 ft

BEARING: N/A (vertical)

INCLINATION: -90

TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories

Logged by: Dale Engstrom

Log Version: 2.02

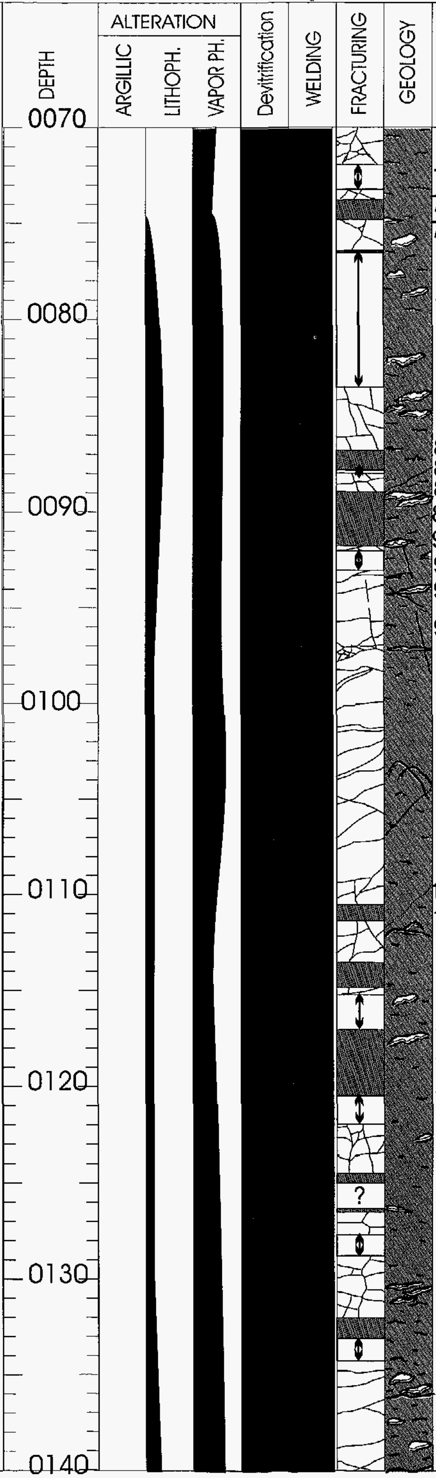
Log Date: July 9, 1996

Yucca Mountain Project

Hole No: USW SD-7

Scale: 1"=10' (1:120)

Sheet 2 OF 39



COMMENTS: DTN: SNT02110894001.002

71.9-73.2 unrecovered
73.8-74.7 broken
74.8

Tiva Canyon Crystal-Poor Lower Lithophysal Zone _(74.8-195.0)_ Uppermost lithophysae at 74.8, medium-pale purple-brown (5R7/1) densely welded, devitrified, very flat (4x25mm) irregular-shaped widely spaced lithophysae where pumice core has been rexlzd to light- medium blue-gray xlln vapor phase mineralization, speckled by very small black crystals (MnOx?), 2-3mm light pink-gray alter'tn halo, alteration decreasing slightly downward, 3-4% phenos of sanidine, biotite not seen, devitrified dark-colored groundmass 35-40% altered, vertical jointing less prominant, hairline vapor phase silica veinlet with pale 2mm alteration halo at 94.5, clear sparry sometimes fan-form calcite fracture coating at 88.7, 91.7, 96.3, 105.2, and 111.3, Fe-MnOx dendrites on fractures, esp. more vertically oriented joints.

76.6-83.5 unrecvd

86.8-87.7 broken
87.7-88.0 unrecvd
88.7 calcite on 45° fract
88.9-91.7 broken
91.7 calcite on vert fract
92.1-93.1 unrecovered
94.7 SiO2 veinlet

96.3 sparry calcite on vert fracture

102.7 thin vuggy lithophysae follows fractures(?), crosses pumice & other fracts haloed by zone of vapor phase rexlztn and alteration

105.2 sparry calcite with MnOx on fracture 60° to core axis.

Vapor phase intensity decreasing downward
Fe-MnOx dendrites on fractures

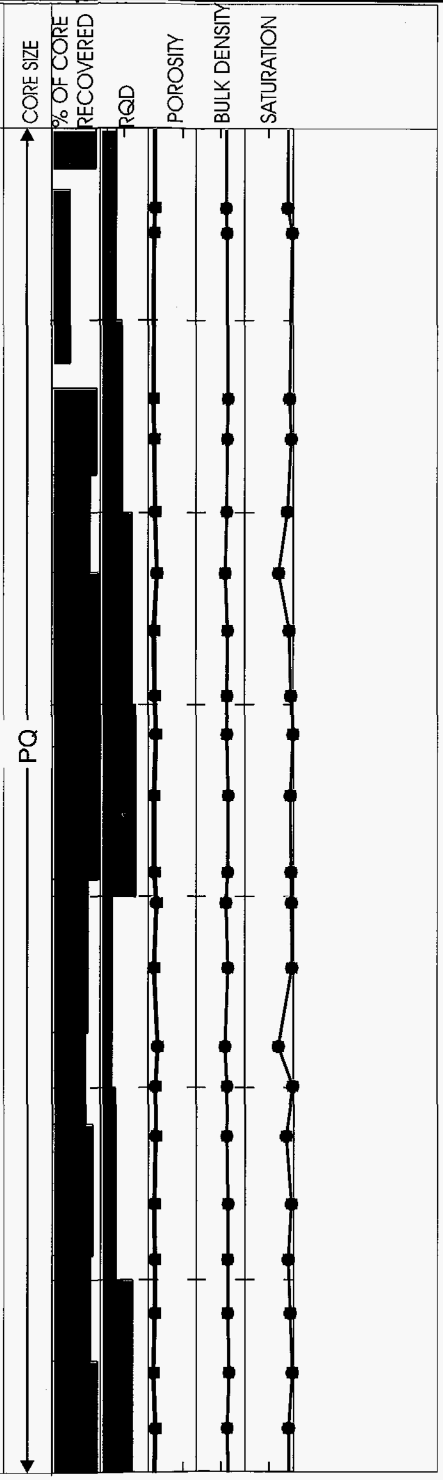
110.6-111.3 broken
111.3 sparry calcite on fracture 45° to core axis
111.7 thin vuggy lithophysae follows horizontal fracturing, in alteration halo
113.5-114.8 broken

115.2-117.1 unrecovered
117.1-120.5 broken
120.5-121.9 unrecovered

124.4-124.9 broken
126.3-126.5 broken
127.7-128.7 unrecovered

Thin vuggy very flat lithophysae (2-3x50mm) coated by 1-2mm mixed medium blue-gray coarse xlln vapor phase crust, light pink-tan dusty (poss. argillic?) 3-5mm alteration halo around irreg.-shaped flattened lithophysae

132.0-133.1 broken
133.1-134.2 unrecvd
136.1-0.1' zone of rexlzn & alteration along horizontal fracture(?)



Yucca Mountain Project

Hole No: **USW SD-7**

Scale: 1"=10' (1:120)

Sheet 3 OF 39

Sandia National Laboratories

Logged by: Dale Engstrom

Log Version: 2.02

Log Date: July 9, 1996

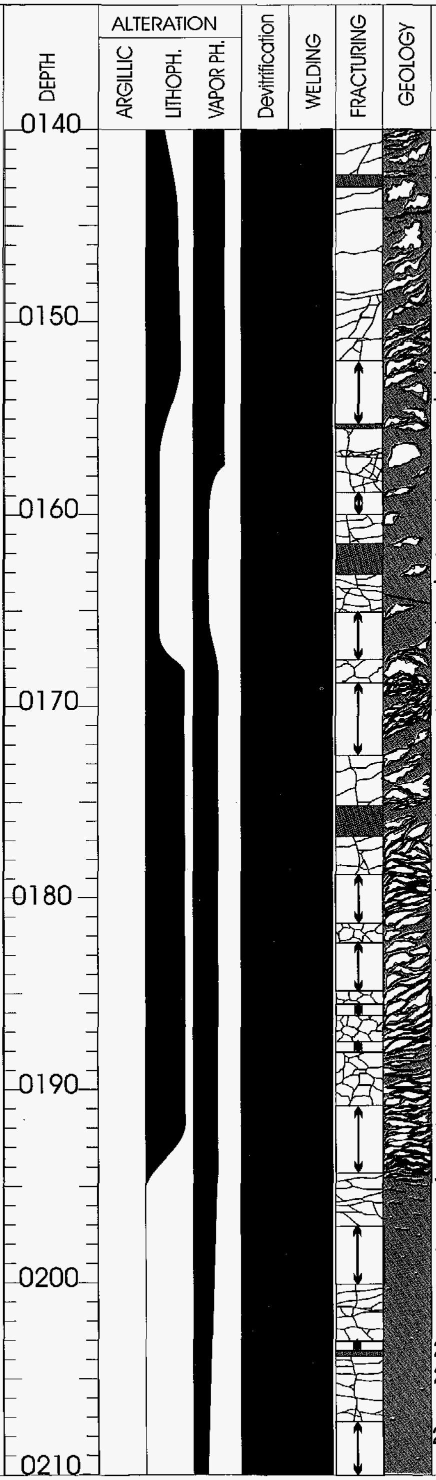
COLLAR COORDINATES (NSP): ELEVATION: 4470 ft

N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)

STARTED: October 31, 1994 INCLINATION: -90

COMPLETED: November 19, 1995 TOTAL DEPTH: 2675.1 ft

DTN: SNT02110894001.002



COMMENTS:

142.3-142.9 broken
145.6-70mm lithoph.
151.9-155.3 unrecvd
155.3-155.6 broken
158.9-160.0 unrecvd
161.4-163.1 broken
164.5 drilling support log: CO3-filled fault
165.1-167.5 unrecvd
168.7 small fault
168.7-172.6 unrecvd
175.2-175.9 broken
178.7-181.3 unrecovered
182.3-184.7 unrecvd
185.5-186.1 unrecvd
186.1 small fault
187.4-188.0 unrecvd
190.8-194.2 unrecvd
195.0
197.1-200.1 unrecvd
203.0-203.4 unrecvd
203.4-203.7 broken
207.2-210.1 unrecvd

Tiva Canyon Crystal-Poor Lower Lithophysal Zone *(74.5-195.0)* (continued) -- medium-pale purple-brown (5R7/1), densely welded, devitrified; crystal poor: 3-4% sanidine phenos, no biotite seen; small flat vuggy irregularly-shaped widely-spaced lithophysae, increase slightly in number downward; lithophysal hiatus 155.6-156.9?; groundmass becomes grainier, less dense and much less vapor-phase altered, 3-5mm light pink-gray alteration halo around each lithophysae, interiors coated by light blue-gray coarsely xlln vapor-phase crust; fracturing dominantly subhorizontal, fractures locally intense contributing to numerous unrecovered or broken zones.

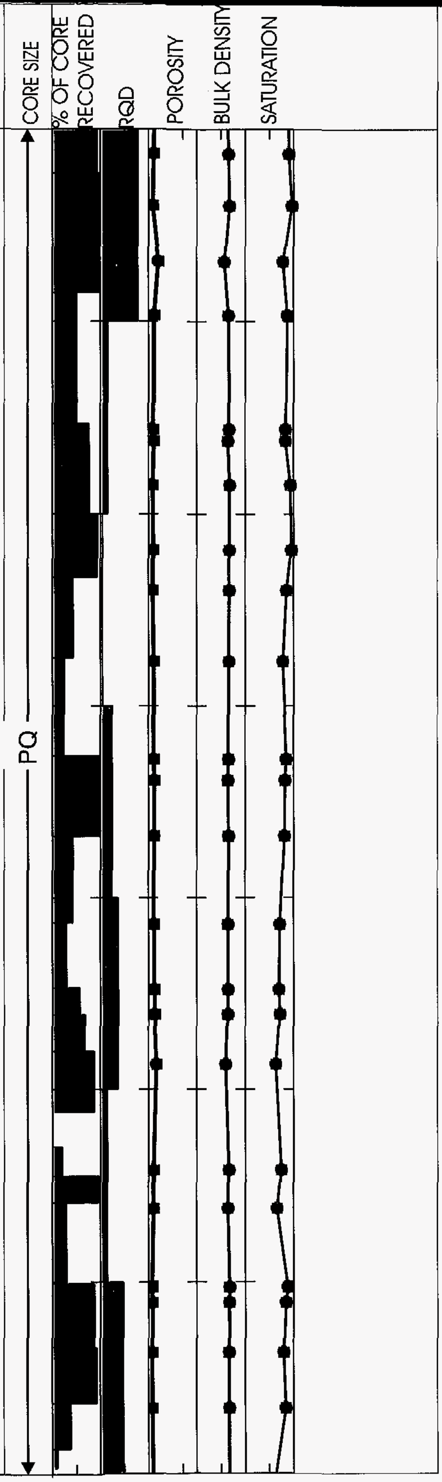
vapor phase alteration gradually decreases 50.0-167.5

164-165 groundmass texture changes from dense consistent grainy to splotchy pebbly texture.

167.5-195.8 zone of small close-spaced flattened lithophysae with pale gray microcrystalline coating, 1-2mm pink-gray alteration halo, groundmass alteration decreases while over-all percent of alteration as rims increases, semi-vertical joints armored by dark silica selvage and coated by pale blue-gray SiO2, 3-6% sanidine, trace coppery biotite

Tiva Canyon Crystal-Poor Lower Nonlithophysal Zone *(195.0-295.4)*

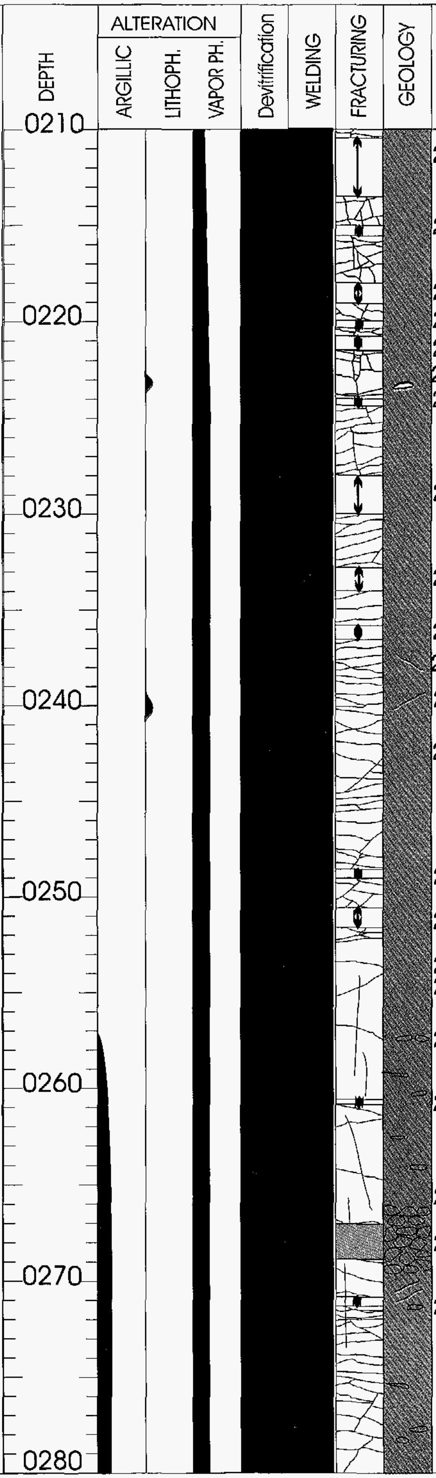
Hackly subzone (195.0- 255.8)-- medium-light red-purple (5RP7/1), crystal poor: 3-5% feldspar, trace coppery biotite; Style of lithophysal alt'n changes from barely opened lithophysae to 5-7% rexlzd flat pumice with light-medium blue-gray xlln interior; pumice is vuggy from rexlzn, pale gray alt'n rim up to 1mm roughly preserves original pumice texture; 195.6 - replaced pumices without alt'n rim become medium-dark gray; spherulitic below 202.5; very irregular fracture (not typical hackly); intensity of vapor-phase alt'n decreases abruptly at 196.5.



Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
Sheet 4 OF 39

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

COLLAR COORDINATES (NSP): ELEVATION: 4470 ft
N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)
STARTED: October 31, 1994 INCLINATION: -90
COMPLETED: November 19, 1995 TOTAL DEPTH: 2675.1 ft



COMMENTS: DTN: SNT02110894001.002

210.6-213.6 unrecvd
215.0-215.5 unrecvd
218.0-219.1 unrecvd
219.9-220.3 unrecvd
220.8-221.4 unrecvd
223.2-alt.rim around 75mm lithophysae
224.1-224.3 unrecvd
227.0-229.9 unrecvd
232.7-234.0 unrecvd
235.8-236.4 unrecvd
237.6-co.xlln calcite vein
239.4 calcite bx-vein
239.5-240.6 weakly lithophysal
248.6-248.9 unrecvd
250.6-251.5 unrecvd
253.0-.4' anast.calct vein
255.8
257.2 pink arg'd pumice
260.6-260.8 unrecvd
266.0-269.6
266.9-268.7 rubble
270.7-271.2 unrecvd

Hackly subzone (195.0- 255.8) (continued) --light-medium red-gray (5R5/2), blotchy textured, densely welded; crystal poor: 4-6% feldspar, trace coppery biotite; 3-5% white angular lithics averaging 5-7mm; 3-5% dark, altered slightly vuggy, spherulitic pumices with no alteration rim. Devitrified groundmass is divided into approx. 60% 3-5mm islands of medium-dark gray weakly vapor-phase altered material surrounded by 40% medium red-gray less-altered material; irregular fracturing.

Small faults noted in drilling support log at: 223.4 (bxa) @25° c.a; 224.1(?) w/ FeOx, MnOx; 224.3 (bxa) @ 45° c.a.; 231.2 @ 30° c.a.; 239.4 (bxa) @ 30° c.a.; 241.0 (bxa).

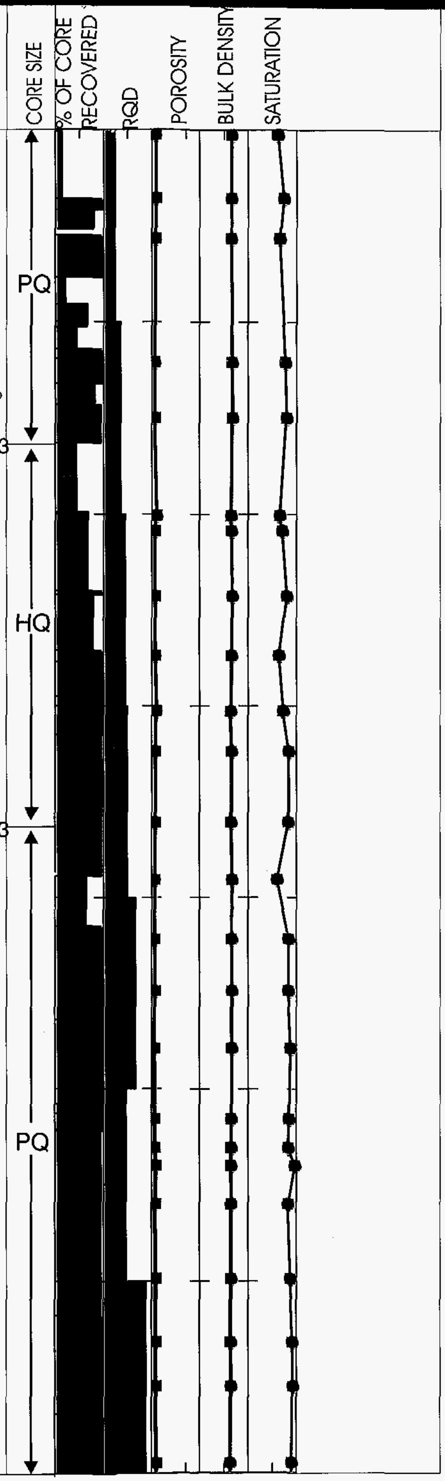
Coarsely crystalline light-med. gray vuggy calcite vein at 237.6; approx. 10mm wide white calcite breccia vein at 239.4, white sparry 2-3mm anast. calcite vein 253.0-253.4.

238.1 slightly streaked texture, light-medium orange streaks that are apparently not related to phenos, lithics, pumice, etc., replaced pumice are xlln, vuggy & slightly darker medium gray

251.5-256.0 rough textured; hairline partings with uneven surface from pumice sites altered to light pink-gray aphanitic vapor phase minzn & FeMnOx specks

Columnar subzone (255.8-295.4) -- light-med. red-gray (5R6/2), color becomes lighter downward; densely welded with smooth, dense texture; devitrified; crystal poor: 4-5% white feldspar, 1% coppery oxybiotite; 3-5% *pumice altered* to less-vuggy, med-dark gray material; at 257.2, larger pumice are argillized to pink clay inside spherulitic border;

266.0-269.6: crowded pink pumice zone;
crusty calcite veinlets 45° to core axis at 270.2 and 270.7



COLLAR COORDINATES (NSP):
N: 758950.0 ft E: 561240.0 ft
STARTED: October 31, 1994
COMPLETED: November 19, 1995

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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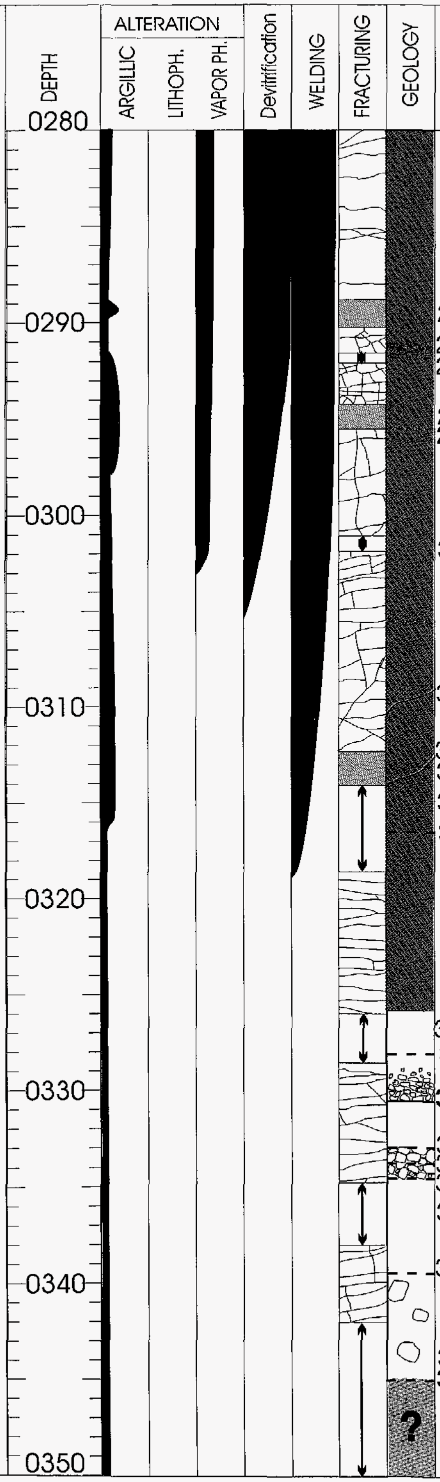


COMMENTS: DTN: SNT02110894001.002

288.4-290.2 rubble
291.4-pink pum.zone
291.5-292.1 unrecvd
294.2-295.4 broken
295.4
301.1-301.8 unrecvd
309.6-3mm calcite vein 30° to core axis
312.3-314.1 rubble
313.1-calcite veinlet
314.1-318.6 unrecvd
316.4
325.9-328.5 unrecvd
328
330.5
332.9
333.7 lithic pumice fall
334.4
334.8-338.0 unrecvd
339.4
342.0-362.6 unrecvd
345

Columnar subzone (254.4-305.5) (continued) -- light red-brown (2.5 YR7/4) dense-smooth texture, densely welded, devitrified; color lightens to more tan downward; spherulitic, argillized (pink-clay) pumice end at 279.1, then 6-8% vuggy (weakly lithophysal), crystal-rich, flattened, vitric pumice; intervals of altered pink pumice are present at 288.9-289.8 and 291.4-298.0.

Transition interval (291.4-305.5) more brown, less devitrified below crowded pink-pumice zone at 291.4 feet: less dense, rougher texture w/ polygonal *glassy* fracture; black, vitric pumice cores bordered by 2-3mm pink argillic(?) alteration.

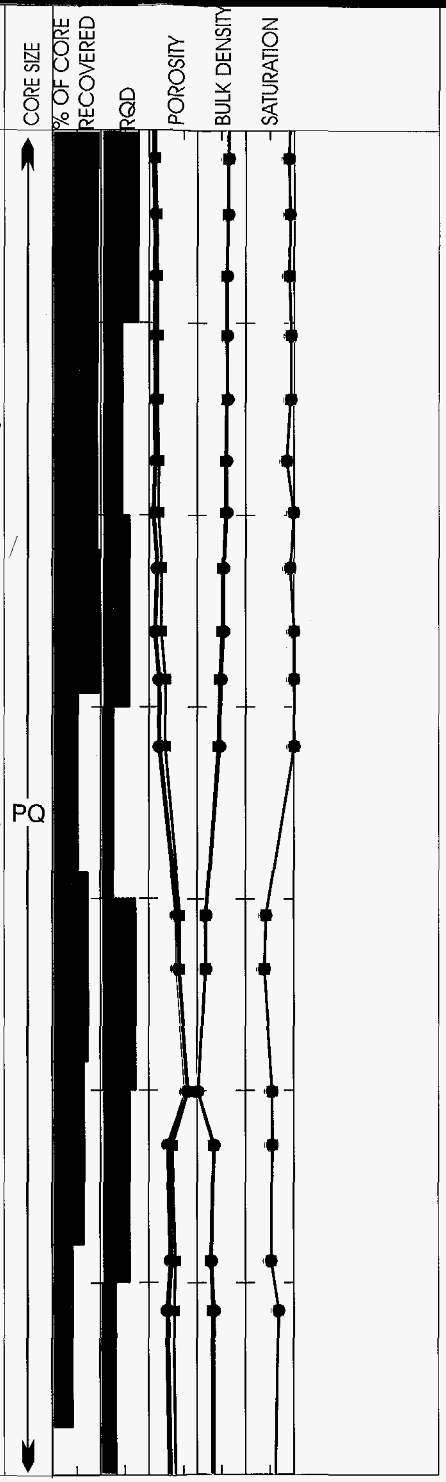
***Tiva Canyon Crystal-Poor Vitric Zone** (295.4-328) ("shardy base")*
Moderately welded subzone (295.4-316.4) -- light red-brown (5YR6/3), partially welded; crystal poor: 2-4% white feldspar phenos, 1% biotite flakes; 2-3% subangular cognate lithics up to 7mm rimmed by weak argillic(?) alteration; <1% black rounded vitric lithics up to 5mm. Groundmass consists of honey-orange shards with interlocking fabric, 1-2% of shards are black; small black vitric pumice mostly flattened (partially welded), less-black pumice tend to disappear into groundmass; very irregular, mostly vertical jointing.
Nonwelded subzone (316.4-328) -- orange-gray (10YR7/4), crystal poor: 2-3% feldspar phenos, trace biotite flakes; 7% dense textured subangular lithics up to 12-15mm, some are finely laminated; <1% red-brown subangular lithics in the 5mm range. Abundant honey-orange vitric shards, 10-15% black shards; pumice not seen.

***Pre-Tiva Canyon Tuff Bedded Tuff** (328?-330.5)* -- weakly hematitic paleosurface (paleosol), sandy reworked clast-supported texture with low ash content, 10-15% black vitric shards, 7-10% mm-size light gray subangular lithic fragments, 3-5% feldspar phenos, trace biotite; at *328.7* grades into **pumice fall** (7.5YR8/2) -- fine-grained (1-2mm) light-gray subrounded pumice in nearly ash-free matrix; 5-7% black shards, 2-3% feldspar phenos, trace biotite.

Yucca Mountain Tuff is missing from the section.

***Pre-Yucca Mountain Tuff Bedded Tuff** (330.5-345?)* -- medium pink-gray (7.5R7/2), sandy clast-supported texture, low ash content; composed of light-brown bubble-wall shards, 2-4% black shards, 3-5% small white lithics, 1-2% feldspar and poss. quartz phenos; at *331.2* grades into *pumiceous ashflow(?)* -- 40-50% light pink-gray 2-5mm pumice in ashy, sandy matrix, 1-2% black shards, 2-3% lithics up to 5mm, 2-3% feldspar phenos. at *332.9 pumice fall* -- light pink-gray (7.5YR7.2) coarse pumice clasts, 10-15% dark-brown shards up to 2mm, 2-3% dark vitric lithics, 2-4% feldspar phenos.
lithic-rich pumice fall (333.7-334.4) -- coarse pumice, in ashy matrix; 10- 15% red-brown Fe-stained subangular lithics (quartz latite).
bedded tuff (334.4-339.4) -- reworked sandy texture, well-sorted mixture of 1-2mm white pumice, brown and black glass shards, feldspar phenos and small red-brown lithics, 45% 60-70mm light-gray round fuzzy lithics.
lithic-rich pumiceous bedded tuff (339.4-362.6) -- medium orange-gray (7.5YR6/6), sandy clast-supported texture; contains 5-7% pumice clasts increasing downward in number and size to 75% of volume, up to 10mm; 2-4% 1-2mm dark vitric lithics, 2-4% feldspar phenos, 1% biotite and rare sericite; groundmass sandy and granular but with 30-40% ash content.

***Pah Canyon Tuff** (345?-357?)* -- Presence of the Pah Canyon Tuff within this unrecovered interval is inferred from geophysical logs.



Sandia National Laboratories Yucca Mountain Project

Logged by: Dale Engstrom Hole No: USW SD-7

Log Version: 2.02 Scale: 1"=10' (1:120)

Log Date: July 9, 1996 Sheet 6 OF 39

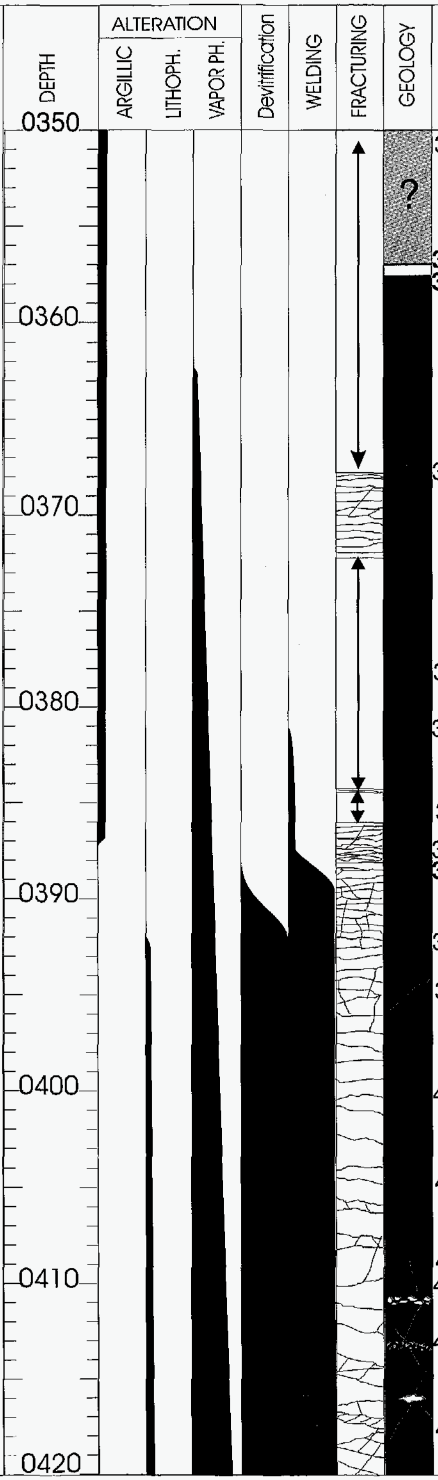
COLLAR COORDINATES (NSP): ELEVATION: 4470 ft

N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)

STARTED: October 31, 1994 INCLINATION: -90

COMPLETED: November 19, 1995 TOTAL DEPTH: 2675.1 ft

DTN: SNT02110894001.002



COMMENTS:

342.0-367.7 unrecvd

357

358.5

367.7

372.2-384.2 unrecvd

381

384.4-386.0 unrecovd

387.2

388.3

392.2 lighter color

394.3- 2mm calcite vn

400.0 lighter color(alt?)

404.6 "bubble" lithoph.

409.4 HL calcite vnlt

410.7 lithoph.zone

413.1 lithic zone

415.9 calcite lithoph.

416.9 calcite vnlts

Pah Canyon Tuff *(345?-357?) (continued)* -- presence inferred from geophysical logs.

Pre-Pah Canyon Tuff Bedded Tuff *(357?-358.5?)* -- presence of the pre-Pah Canyon Tuff bedded Tuff in this unrecovered interval has been inferred from geophysical logs. (recovered only tan fine-grained cuttings from dust collector)

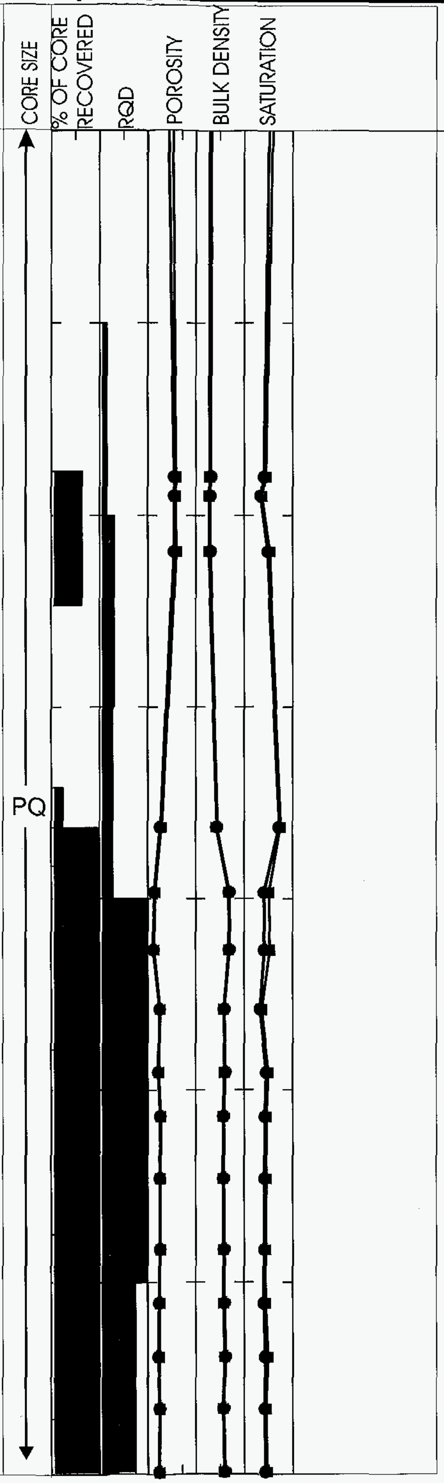
Topopah Spring Crystal-Rich Vitric Zone *(358.5?-388.3)*

Nonwelded subzone (358.5-381?) -- contacts inferred from geophysical logs; medium purple-gray (5RP5/2); recovered purple-brown cuttings at 362.6; crystal-rich(?): 3-5% feldspar phenos, trace oxybiotite; 1-2% partly devitrified black shards, 1% Fe-stained red- brown angular hard lithics under 5mm. squashed recrystallized white & gray pumice in mixed ashy matrix produces "lumpy" texture; 40% light pink-gray aph. pumice, 30% altered, medium-gray pumice; microcrystalline, recrystallized groundmass.

Moderately welded subzone (381?-387.2) -- contact inferred from geophysical logs; *384.2 (below unrecovered zone)* -- crystal rich: 12-15% feldspar phenos and <1% oxybiotite, 5% dark vitric partly devitrified "webby" lithics. Rock is pumice-rich, heavily altered (N8), more dense, with white, vapor-phase(?) altered *micro-crystalline matrix; former pumice cores* are vuggy, recrystallized to vapor-phase minls including SiO2, magnetite, hematite.

Densely welded "caprock vitrophyre" subzone (387.2-388.3)-- medium red-brown (5R5/1) vitric, well fused; crystal rich: 20-25% feldspar phenos, 1% oxybiotite, 3-5% <10mm light pink-gray, angular, weakly vapor-phase altered lithics; 1-3% dark gray xl-rich pumice with remnant core textures; horizontal foliation planes coated by red-brown clays(?);, cm-spaced horizontal joints create "hockey-puck" shaped core fragments.

Topopah Spring Crystal-Rich Nonlithophysal Zone *(388.3-487.8)* -- light-medium red-brown, welded, devitrified; crystal rich: 20-25% white feldspar phenos, 1-2% oxybiotite, 5-10% flattened pumice up to 50mm replaced by dark crystalline alt'n minls crudely preserving core texture of larger pumice, 1% rounded fuzzy cognate lithics. *392.2* - color becomes lighter (10R6/2) w/ increasing alteration; groundmass becomes grainy w/ mod.-well flattened (welded) fabric. *400.0-401.5* - increasing alteration causes pumice to become lighter in color (7.5RP7/2), vugs in pumice begin to look smoother (rounded by alt coating). *404.5* - "bubbles" in horizontal plane may be incipient lithophysae coated by vapor-phase alteration. *409.4-416.9* - thin, sparry calcite veinlets. *415.9* - vuggy lithophysae coated by coarsely xlln calcite. *410.7* - weak 0.2' lithoph. zone, small ragged close-spaced lithoph up to 30mm, small vuggy weakly lithophysal pumice continue downhole. *413.1* - 0.1-ft. crowded angular lithics zone.



COLLAR COORDINATES (NSP):
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STARTED: October 31, 1994
COMPLETED: November 19, 1995

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: **USW SD-7**
Scale: 1"=10' (1:120)
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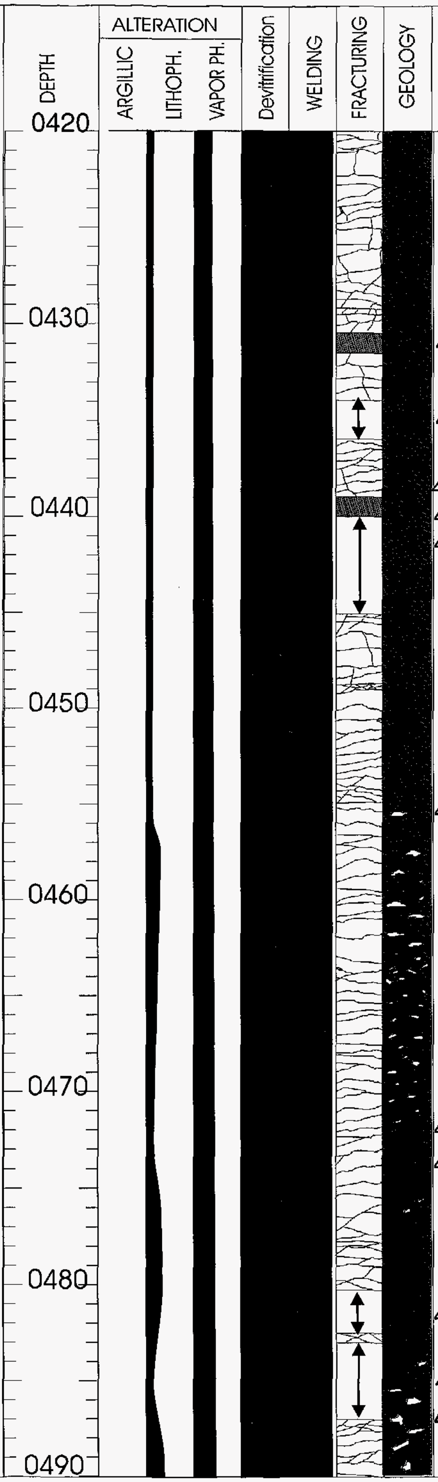


COMMENTS:

DTN: SNT02110894001.002

430.6-431.4 broken
433.9-435.9 unrecvd
438.7-clear CO_3 on frax
438.9-439.9 broken
439.9-445.1 unrecvd
455.4
472.2
473.3-473.7 unrecvd
480.3-482.4 unrecvd
483.0-486.9 unrecvd
487.8

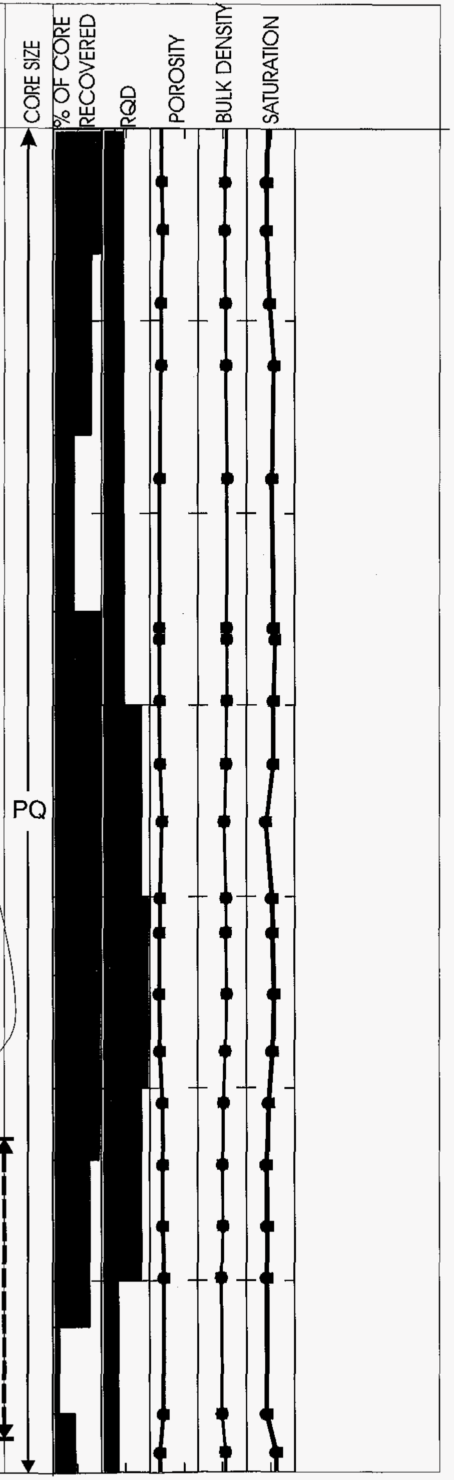
Topopah Spring Crystal-Rich Nonlithophysal Zone (Tptrn) *(388.3-487.8)* (continued) -- Light red-gray (7.5R6/2), densely welded, devitrified: xl-rich: 15-20% white feldspar phenos, trace biotite; 10-15% cognate pumice nearly invisible against matrix except for vuggy rexlzed/altered cores; 1-2% light- gray crystal-poor rhyolite soft lithics with fuzzy borders and deformed with rock texture, increasing in number downward; quartz latite groundmass 20% altered to white vapor-phase minls, remainder is 30% blue altered and 15% rexlzed;, very irregular fracturing.

Crystal-transition interval (473?-487.8) -- cannot be identified with confidence because of vapor-phase alteration, extensive prior sampling, and large quantity of drilling dust coating core. Phenocryst content appears to change from ~10-12% at top of interval to ~2-3% at base.

uppermost lithophysae -- rounded-lensoidal shape, widely spaced, with vugs after pumice between; lithophysal-style alteration decreases in intensity downward to weakly lithophysal close-spaced oval-shaped pumice cores.

Compositional-transition interval (472.2-532.0) -- Gradational change from light-gray crystal-poor rhyolite soft lithics in crystal-rich quartz latite groundmass to medium-brown crystal-rich quartz latite soft lithics in crystal-poor rhyolite; cognate pumice altered to light gray with vuggy rexlzed cores with SiO2, and minor specular hematite, rutile; rock texture flattened crenulated.

Topopah Spring Crystal-Poor Upper Lithophysal Zone (Tptpul) *(487.8-682.5)* -- medium red-gray (5R5.5/2) changing to light red-purple (5RP7/2) downward; densely welded, flattened texture; crystal poor: 2-3% feldspar phenos, trace biotite; crystal-rich nonlithophysal pumice clasts are rexlzed with little remnant core texture; small, oval, widely spaced lithophysae are moderately coated by vapor-phase minlz, no alteration rims; groundmass variably blue altered with intensity increasing downward; groundmass speckled by white mm-size spots of alteration and mm-thick streaks (along partings?); no lithophysal halos.



Yucca Mountain Project

Hole No: USW SD-7

Scale: 1"=10' (1:120)

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Sandia National Laboratories

Logged by: Dale Engstrom

Log Version: 2.02

Log Date: July 9, 1996

ELEVATION: 4470 ft

BEARING: N/A (vertical)

INCLINATION: -90

TOTAL DEPTH: 2675.1 ft

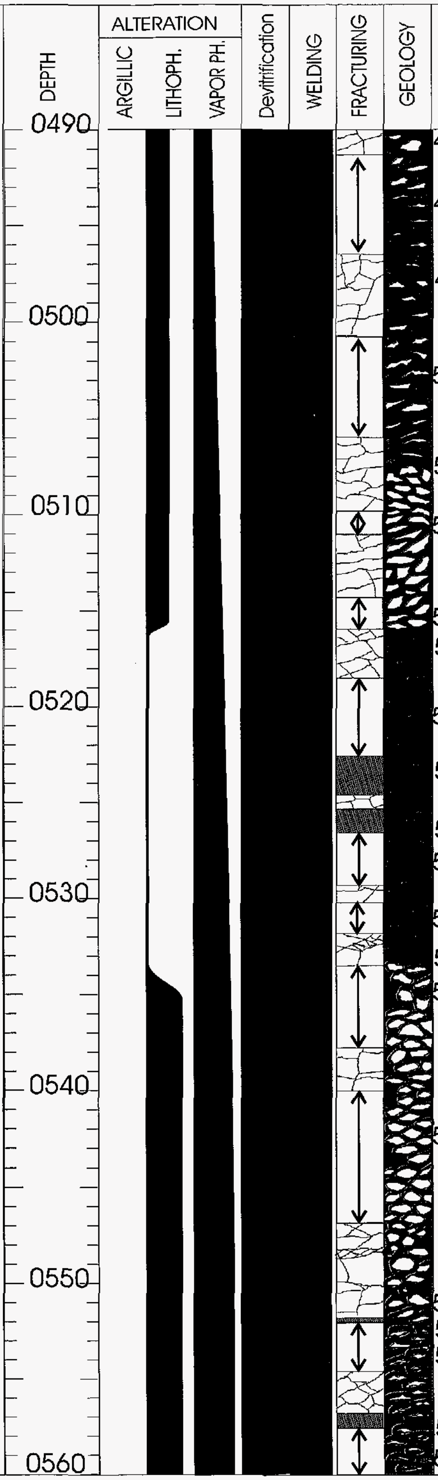
COLLAR COORDINATES (NSP):

N: 758950.0 ft E: 561240.0 ft

STARTED: October 31, 1994

COMPLETED: November 19, 1995

DTN: SNT02110894001.002



COMMENTS:

490.0-490.7 broken
491.3-496.4 unrcvd
497.9
500.8-505.9 unrcvd
507.6
509.8-511.0 unrcvd
514.3-515.9 unrcvd
516.1-533.3 - nonlithophysal interval.
518.5-522.6 unrcvd
522.6-524.6 broken
525.3-526.6 broken
526.6-529.3 unrcvd
530.2-531.8 unrcvd
533.3
533.5-537.7 unrcvd
540.1-546.7 unrcvd
551.0
551.7-551.9 broken
551.9-554.4 unrcvd
556.8-557.4 broken
557.4-560.0 unrcvd

Topopah Spring Crystal-Poor Upper Lithophysal Zone (Tptpul) *(487.8-682.5)* (continued) -- light red-purple (5RP7/2), densely welded, devitrifed; crystal poor: 2-3% feldspar phenos, trace biotite; small, oval, widely spaced lithophysae, mod. coated by vapor phase minls but no rims; intensity of lithophysal-style alt'n decreases downward to 479.9; groundmass 30-40% blue altered, speckled with mm-size alteration spots or streaks; nonlithophysal pumice completely altered.

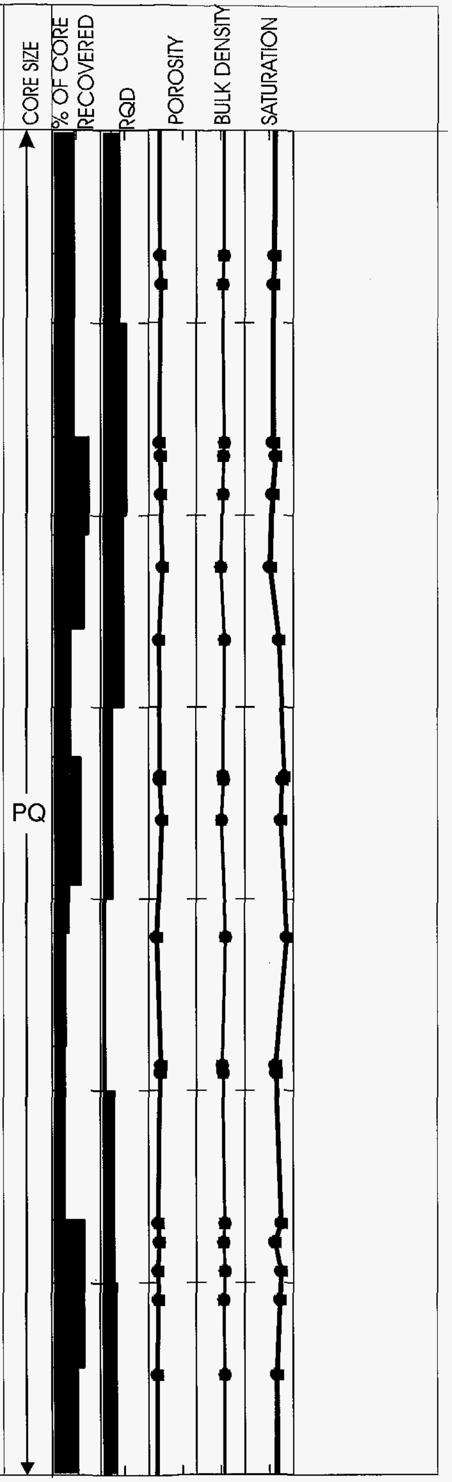
497.9 - intensity of lithophysal-style alt'n increases; small, ragged moderately-spaced lithophysae, coated by vapor-phase mins, no alt'n rims.

507.6 - close-spaced small, ragged lithophysae.

Compositional-transition interval (472.2-532.0) -- Gradational change from light-gray crystal-poor rhyolite soft lithics in crystal-rich quartz latite groundmass to medium-brown crystal-rich quartz latite soft lithics in crystal-poor rhyolite; cognate pumice alt to light gray with vuggy rexlzed cores with SiO2, and minor specular hematite, rutile; rock texture flattened and crenulated .

533.3 - marked increase in small (15mm), closely-spaced ragged lithophysae coated by vapor-phase SiO2, specularite, rutile, and poss. pyroxene; 2-4mm light pink-gray alteration rims; dark red-purple (5RP5/2) grainy groundmass, 70-75% blue altered; 25-30% mm-size white alteration spots; brown quartz latite crystal-rich soft lithics becoming less common downward (1-2%); rock is crystal poor: 2-3% feldspar phenos, <1% biotite.

551.0 - Lithophysae slightly less open.



Yucca Mountain Project
Sandia National Laboratories
Hole No: USW SD-7
Logged by: Dale Engstrom
Scale: 1"=10' (1:120)
Log Version: 2.02
Sheet 9 OF 39
Log Date: July 9, 1996

COLLAR COORDINATES (NSP): ELEVATION: 4470 ft
N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)
STARTED: October 31, 1994 INCLINATION: -90
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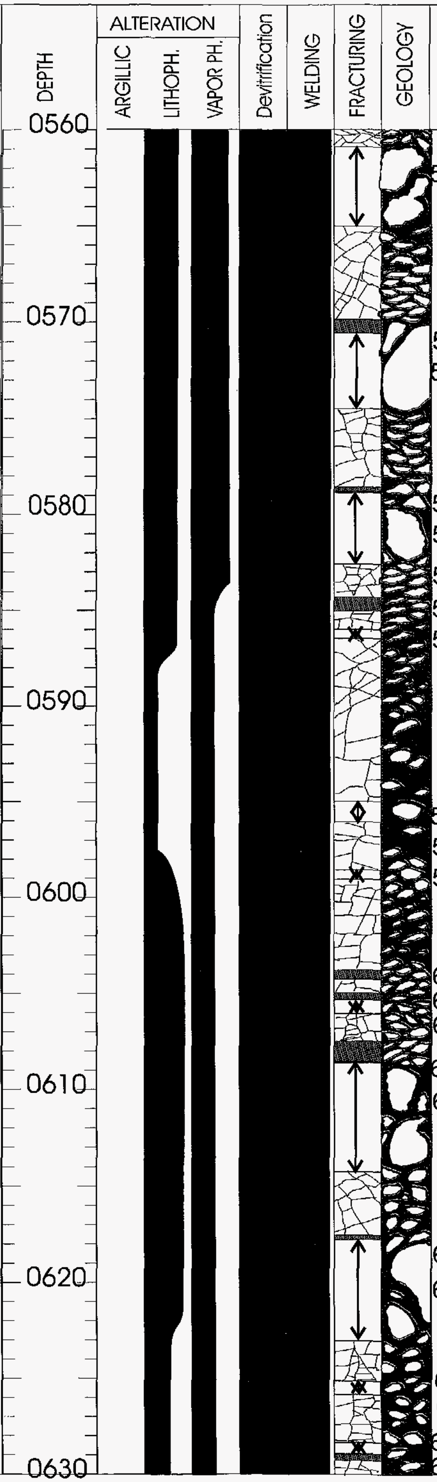


COMMENTS:

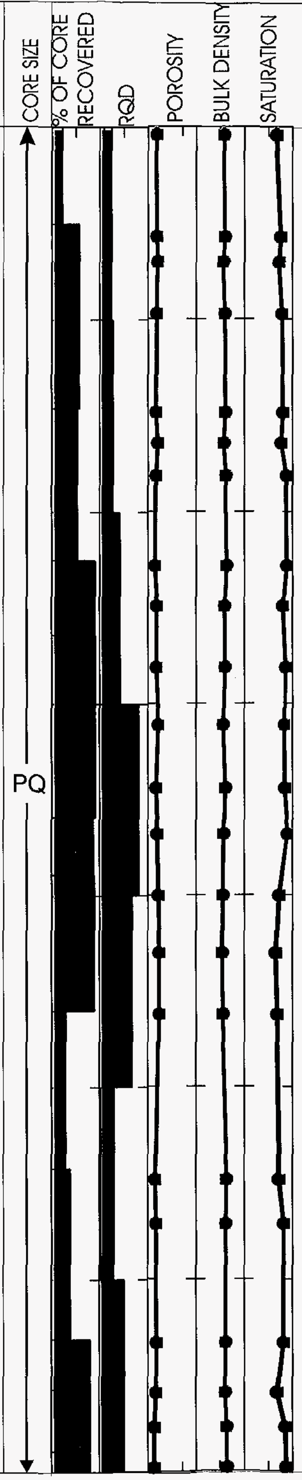
561.1-565.0 unrcvd
569.9-570.5 broken
570.5-574.6 unrecvd
578.4-578.8 broken
578.8-582.5 unrecvd
583.6
584.2-584.9 broken
586.0-586.4 unrecvd
595.0-595.9 unrecvd
597.5
598.5-598.9 unrecvd
603.7-604.2 broken
604.9-605.2 broken
605.2-606.0 unrecvd
607.8-608.4 broken
608.4-614.2 unrecvd
617.5-617.7 broken
617.7-623.1 unrcvd
625.2-625.7 unrcvd
626.8
628.3-628.9 unrcvd
628.9-629.2 broken

Topopah Spring Crystal-Poor Upper Lithophysal Zone (Tptpul) *(487.8-682.5)* (continued) -- medium red-purple gray (5RP5/2), densely welded, devitrified: crystal poor: 2-3% feldspar phenos, trace biotite; 15-20% small, closely spaced, ragged lithophysae with light-gray fine-grained coating of SiO2, specularite, rutile; 2-4mm light pink-gray, very fine-grained alteration halos, 1% med. brown crystal-rich quartz latite soft lithics decreasing in number downward; groundmass is deep red-purple with 70% blue alteration and 30% mm-size spots of white alteration.

583.6 - color lightens as dark alteration decreases in intensity, islands of unaltered groundmass appear; also downward decrease in intensity of lithophysal-style alteration.

597.5-625.8 - interval of more intense lithophysa; 15-25% 30mm ragged, oval, widely spaced lithophysae with little or no halo interspersed with crowded, 5-10mm lithophysae with 1-2mm light pink-gray halo; weakly foliated groundmass becomes less altered, lighter (2.5YR6/4), with 3-5% blue alteration in anastamosing. streaks around white alteration sites and 2-5mm borders around white alteration; rock is crystal poor with 2-3% feldspar phenos, trace oxybiotite; 2-3% crystal-rich quartz latite soft lithics up to 6x50mm.

626.8 - small irregularly-shaped lithophysae with coated interiors and 2-4mm light pink-gray alteration halos bordered by 1-3mm blue alteration; 5-7% mm-thick blue alteration streaks through groundmass; groundmass is 15-20% pink alteration, 75% unaltered.



COLLAR COORDINATES (NSP): ELEVATION: 4470 ft
Sandia National Laboratories
Yucca Mountain Project

N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)
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Hole No: **USW SD-7**

STARTED: October 31, 1994 INCLINATION: -90
Log Version: 2.02
Scale: 1"=10' (1:120)

COMPLETED: November 19, 1995 TOTAL DEPTH: 2675.1 ft
Log Date: July 9, 1996
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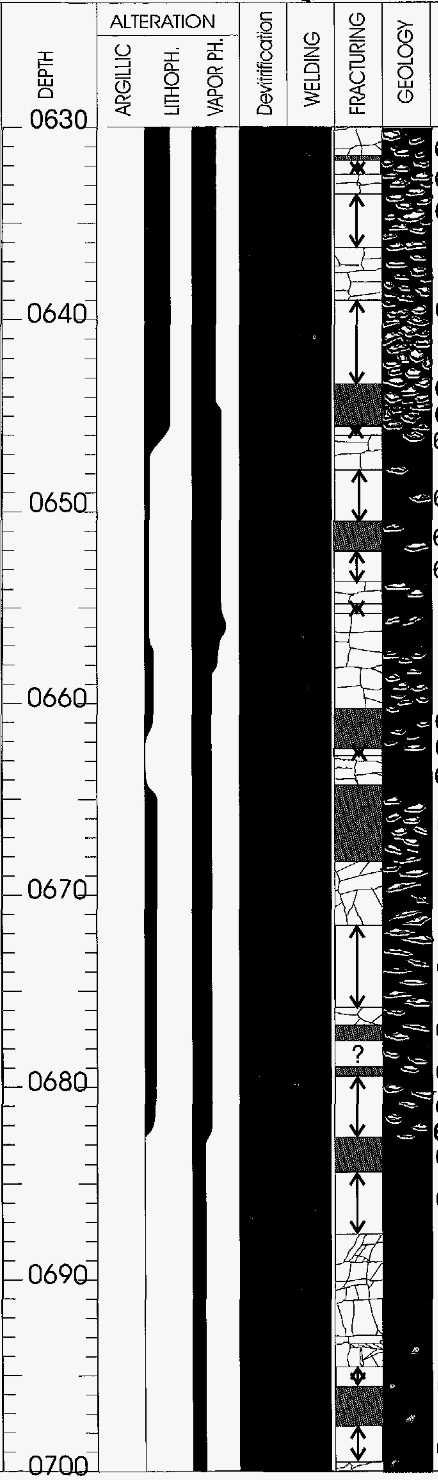


COMMENTS: DTN: SNT02110894001.002

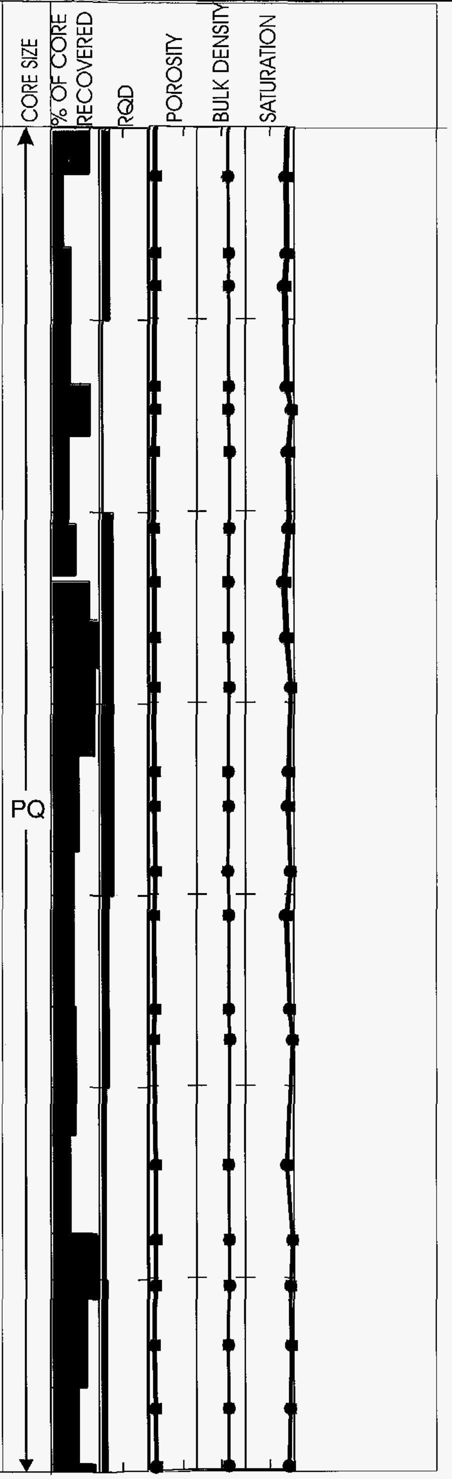
631.5-631.7 broken
631.7-632.4 unrecvd
633.4-636.2 unrecvd
639.1-643.3 unrecvd
644.2
643.3-645.5 broken
645.5-646.0 unrecvd
647.7-650.6 unrecvd
650.6-652.0 broken
652.0-653.6 unrecvd
660.3-662.3 broken
662.3-662.7 unrecvd
662.3-664.0 - thin nonlithophysal interval.
664.3-668.2 rubble
671.6-675.8 unrecvd
676.7-677.6 broken
678.9-679.3 rubble
679.3-682.5 unrecvd
682.5
682.5-684.3 rubble
684.3-684.6 unrecvd
694.5-695.6 unrecvd
695.6-697.6 broken
697.6-699.6 unrecvd

Topopah Spring Crystal-Poor Upper Lithophysal Zone (Tptpul) *(487.8-682.5)* (continued) -- pale red-brown (2.5R7/4), densely welded, devitrified; weakly foliated texture: crystal-poor: 2-3% feldspar phenos, trace biotite; crowded closely spaced, small, irregularly shaped lithophysae, coated by vapor-phase minlz and with 2-4mm light pink-gray alteration halos constitute 15-20% of rock volume; 5-6% of rock is 1-3mm blue alteration borders and mm-size blue alteration streaks through groundmass; 75% of groundmass is unaltered; 2-3% quartz latite soft lithics up to 50mm.

644.2-658.1 slight increase in blue alteration intensity.

646.0-657.2 - intensity of lithophysal-style alt'n decreases markedly.

Topopah Spring Crystal-Poor Middle Nonlithophysal Zone (Tptpmn) *(682.5-803.3)* -- pale orange-gray (5YR7/2), densely welded, devitrified; crystal-poor: 2-3% feldspar phenos, trace biotite; very weakly lithophysal cognate pumice are nearly indistinguishable from matrix; wavy, subhorizontal lines of alteration may be relacement of highly flattened nonlithophysal pumice; 5-7% 3-5mm long streaks of alteration apparently nucleated by small pumice; rare small 5mm white subangular lithics slightly more common between 694.1-714.7.



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Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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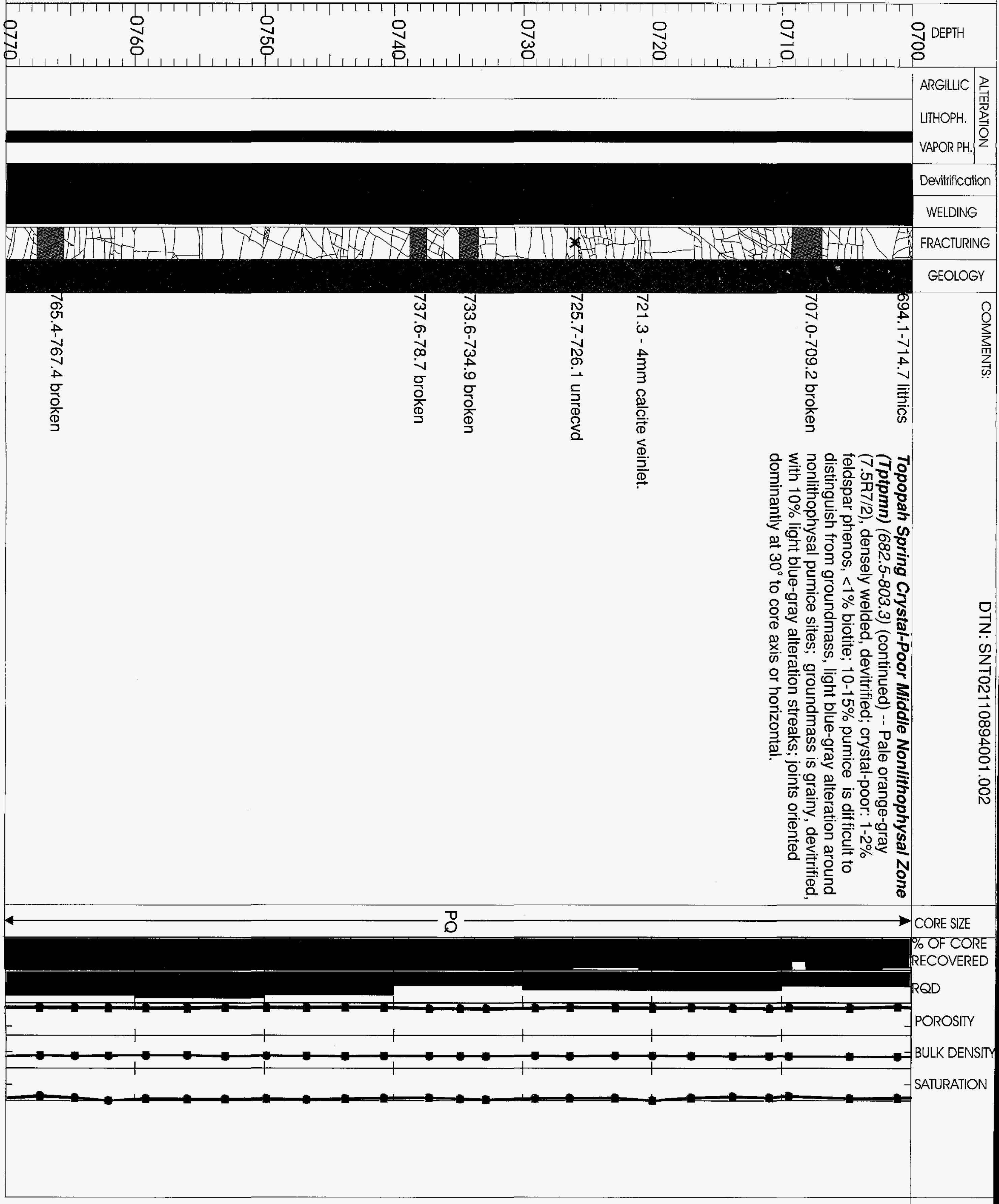

DTN: SNT02110894001.002

694.1-714.7 lithics

707.0-709.2 broken

721.3 - 4mm calcite veinlet.

725.7-726.1 unrecvd

733.6-734.9 broken

737.6-78.7 broken

765.4-767.4 broken

Topopah Spring Crystal-Poor Middle Nonlithophysal Zone (Tptpmn) *(682.5-803.3)* (continued) -- Pale orange-gray (7.5R7/2), densely welded, devitrified; crystal-poor: 1-2% feldspar phenos, <1% biotite; 10-15% pumice is difficult to distinguish from groundmass, light blue-gray alteration around nonlithophysal pumice sites; groundmass is grainy, devitrified, with 10% light blue-gray alteration streaks; joints oriented dominantly at 30° to core axis or horizontal.

Yucca Mountain Project

Sandia National Laboratories

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Scale: 1"=10' (1:120)

Log Version: 2.02

Sheet 12 OF 39

Log Date: July 9, 1996

COLLAR COORDINATES (NSP): ELEVATION: 4470 ft

N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)

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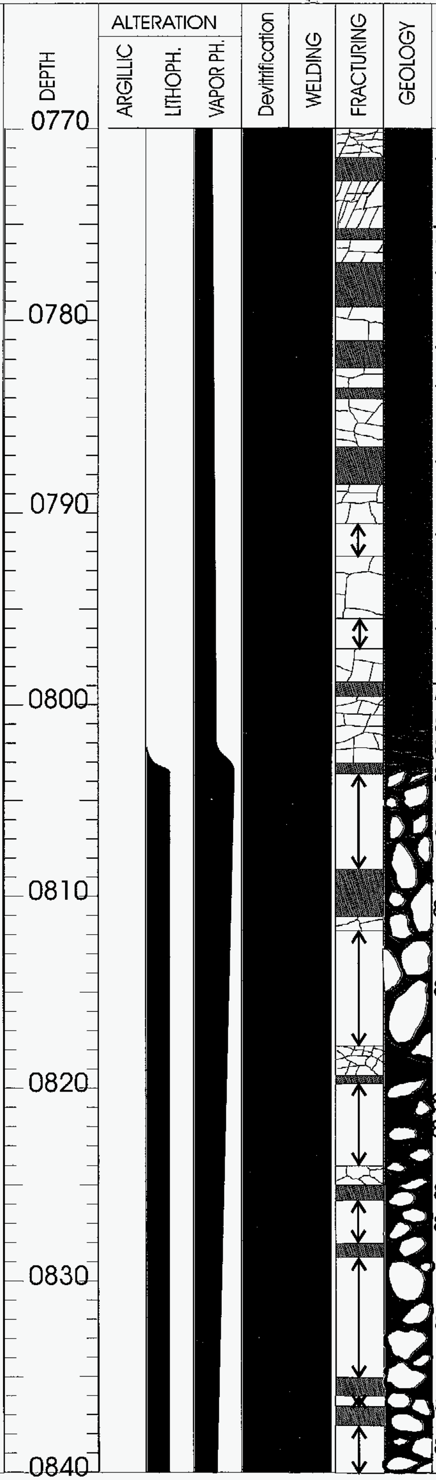
COMPLETED: November 19, 1995 TOTAL DEPTH: 2675.1 ft

DTN: SNT02110894001.002



COMMENTS:

771.4-772.8 broken
775.2-775.8 broken
777.1-779.3 broken
781.1-782.4 broken
783.4-784.1 broken
786.5-788.4 broken
790.6-792.2 unrecvd
795.4-797.1 unrecvd
798.7-799.5 broken
801.6
802.0
803.3
803.0-811.1 broken
803.6-808.6 unrecvd
810.9
811.7-817.8 unrecvd
819.3-819.7 broken
819.7-824.0 unrecvd
825.0-841.7 broken
825.7-828.1 unrecvd
828.8-834.9 unrecvd
836.1-836.6 unrecvd
837.4-841.7 unrecvd

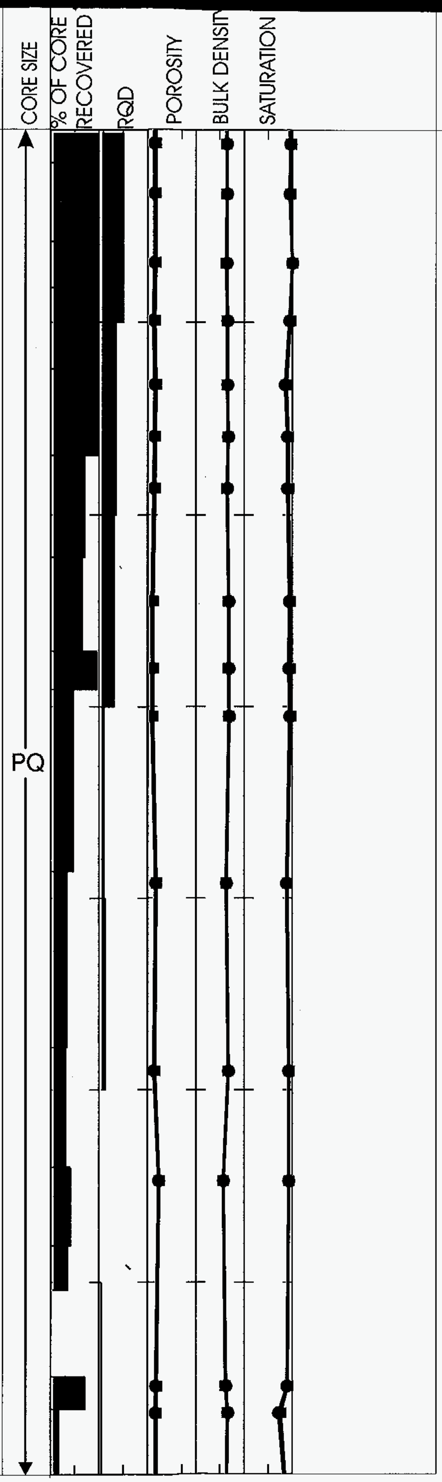
Topopah Spring Crystal-Poor Middle Nonlithophysal Zone (Tptpmn) *(682.5-803.3)* (continued) -- Pale orange-gray (7.5YR7/3), densely welded, although shard remnants can still be distinguished under the microscope, devitrified; crystal-poor: 3-5% feldspar phenos, no biotite seen; 15-20% cognate pumice nearly indistinguishable from matrix; 2-4% elongated to subangular crystal-rich soft lithics up to 30mm length; 2-3% small rounded mixed composition hard lithics mostly dense red-gray or altered light gray; most of groundmass contains fuzzy 5x10mm light-pink alteration spots; mostly low-angle fractures that are weakly coated by Fe-MnOx dendrites.

801.6 - patchy blue alteration increases in intensity downward.
802.0 - increase in intensity of light pink-gray alteration (10%) rimming weakly lithophysal pumice sites; intensity and volume of blue alteration borders also increases downward (to 40%).

802.8 - Drilling Support log indicates presence of fault.

Topopah Spring Crystal-Poor Lower Lithophysal Zone (Tptpll) *(803.3-1020.0)* Pale red-gray (7.5R7/2), densely welded, devitrified; crystal poor: 3-4% rounded feldspar phenocrysts, biotite not seen; majority of lithophysae are unseen but are inferred from severely broken or rubblized core fragments typically coated by thin, white xlln vapor-phase minlz with alteration halo; lithophysae observed in down-hole video imagery appear to be medium-sized & moderately-spaced, with 10-15% light-pink alteration halos: groundmass up to 50-55% blue altered.

810.9 Drilling Support log indicates presence of fault gouge.



COLLAR COORDINATES (NSP):
N: 758950.0 ft E: 561240.0 ft
STARTED: October 31, 1994
COMPLETED: November 19, 1995

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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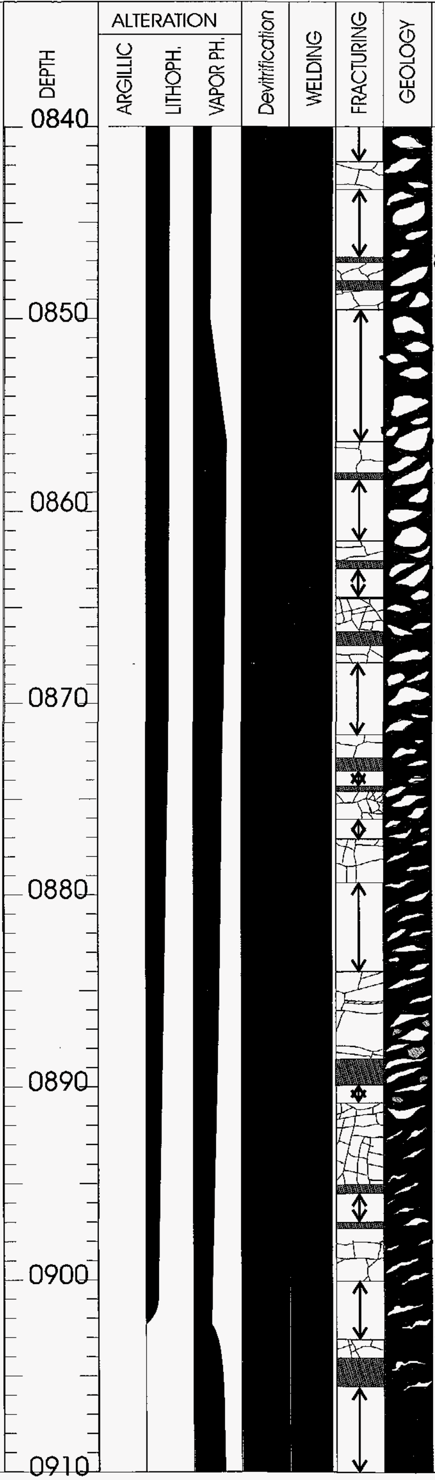


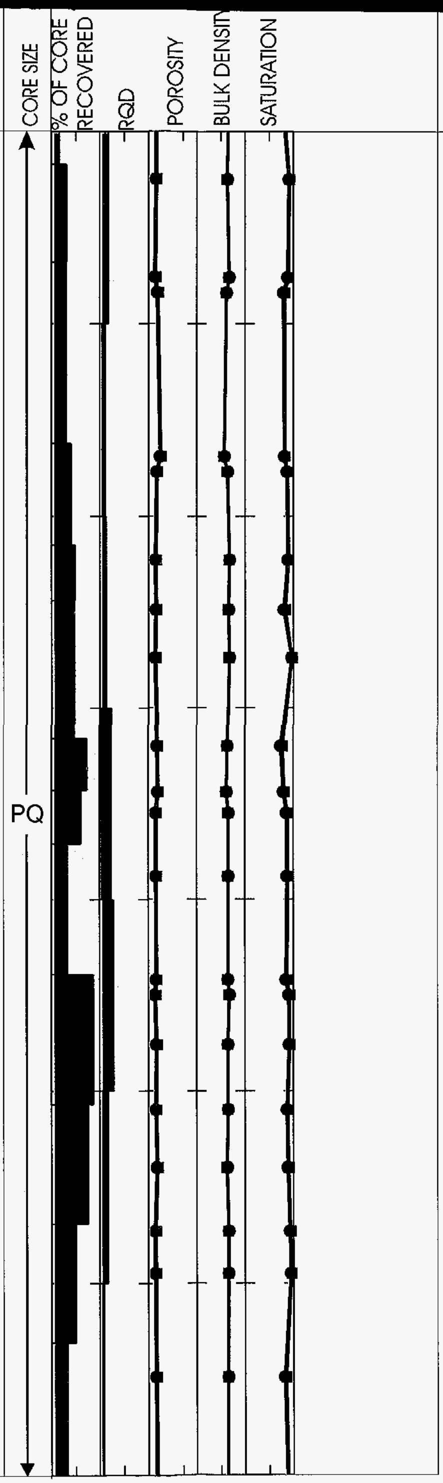
COMMENTS: DTN: SNT02110894001.002

837.4-841.7 unrecvd
843.3-846.8 unrecvd
846.8-847.1 broken
848.1-848.4 broken
849.6-856.2 unrecvd
856.2
857.9-858.3 broken
858.3-861.5 unrecvd
862.6-864.5 broken
862.9-864.4 unrecvd
866.2-866.9 broken
867.8-871.6 unrecvd
872.7-874.4 broken
873.6-874.3 unrecvd
876.0-877.1 unrecvd
879.3-883.9 unrecvd
886.5 lithophysae flatten
886.8-891.0 - large rhyolite lithic-bearing zone
888.6-889.8 broken
889.8-890.7 unrecvd
888.6-897.3 generally broken zone
894.5 - very flat vuggy lithophysae
895.0-897.3 broken
895.4-896.9 unrecvd
900.0-903.1 unrecvd
904.0-910.4 broken
905.4-910.4 unrecvd

Topopah Spring Crystal-Poor Lower Lithophysal Zone (Tptpll) *(803.3-1020.0)* (continued) -- Pale red-gray (2.5YR7/2), densely welded, devitrified; crystal poor: 1-3% feldspar phenos, <1% biotite; 1-2% small subangular banded rhyolite hard lithics up to 5mm. Rock is moderately to badly broken; core fragments exhibit remnants of coated & haloed lithophysae on some breaks; hairline white vapor-phase mineralization replaces flat pumice haloed by 3mm light pink-gray alteration and bordered by 1-2mm blue alteration that also streaks into groundmass and armors joint surfaces.

856.2 - intensity of vapor phase alteration increases markedly, then gradually decreases downward; intensity of lithophysal-style alteration decreases downward.

903.3-910.5 - nonlithophysal interval - intensity of vapor-phase alteration increases markedly, esp. on joints/fractures; 10-12% 10-15mm pink alteration spots, 15-25% 2-3mm blue alteration borders.



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Yucca Mountain Project
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Scale: 1"=10' (1:120)
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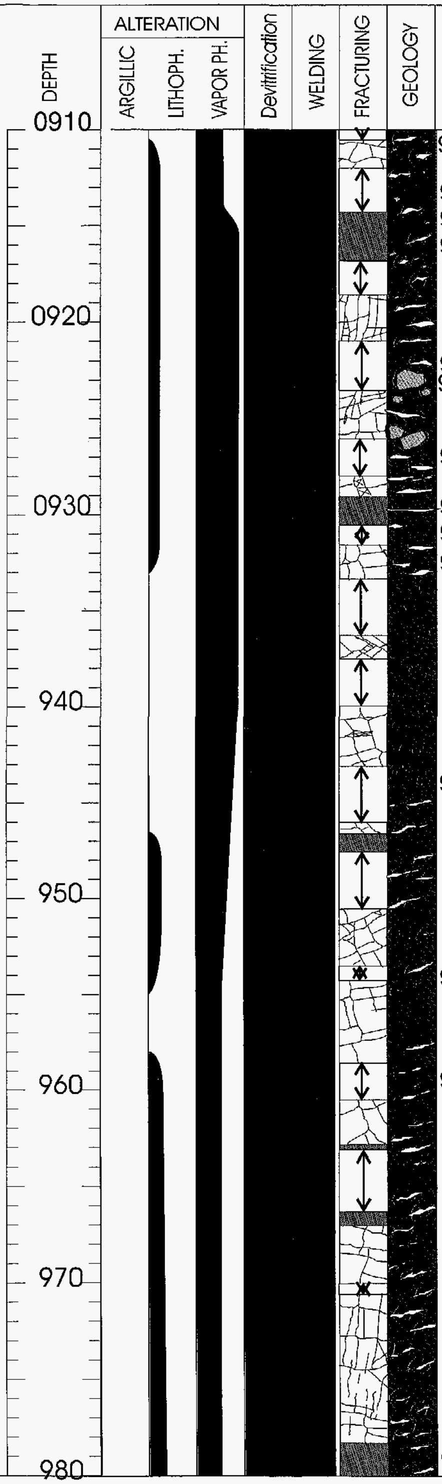


COMMENTS: DTN: SNT02110894001.002

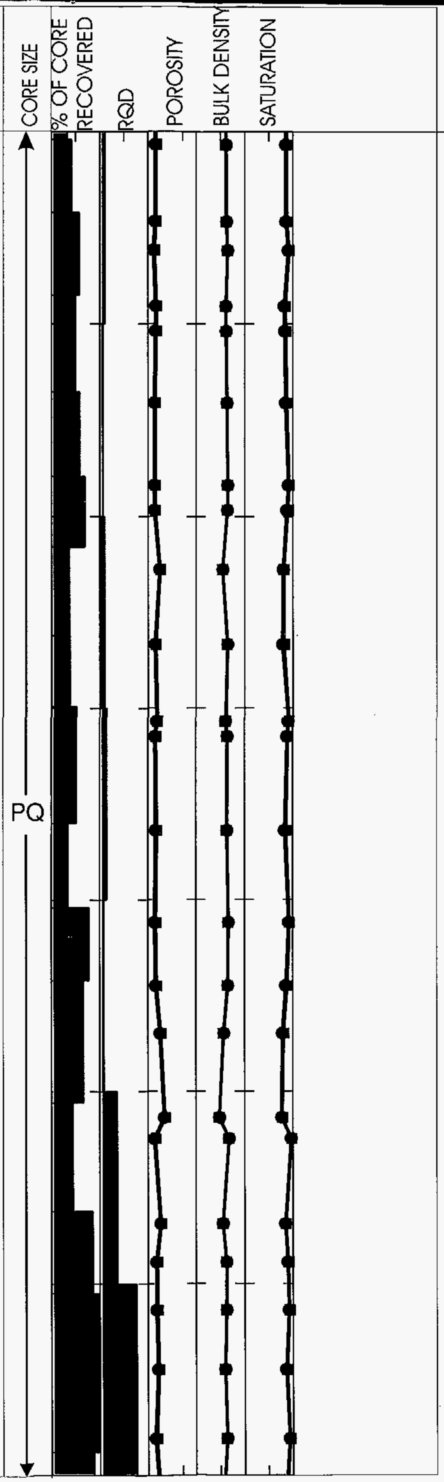
905.4-910.4 unrecvd
912.0-914.2 unrecvd
914.2-918.5 broken
916.7-918.5 unrecvd
921.0-923.5 unrecvd
923.7 50mm rhyolite lithic clast
926.0
926.1-927.9 unrecvd
929.1-930.5 broken
930.5-931.6 unrecvd
933.1
933.3-936.2 unrecvd
937.6-939.9 unrecvd
943.1-946.0 unrecvd
946.6-947.5 broken
947.5-950.4 unrecvd
953.4-954.2 unrecvd
958.5-960.6 unrecvd
962.8-966.9 broken
963.1-966.2 unrecvd
969.9-970.5 unrecvd
977.0
978.3-989.5 rubble

Topopah Spring Crystal-Poor Lower Lithophysal Zone (Tptpll) *(803.3-1020.0)* (continued) -- medium orange-gray (2.5YR6/2), densely welded, devitrified; crystal poor: 1-2% feldspar phenos, no biotite seen; 3-5% white subrounded altered rhyolite lithics up to 12mm in length. Rock moderately broken;15-20% thin flattened lithophysae coated by crystalline vapor phase minlz, haloed by up to 35mm light pink-tan alteration, bordered by 5-10mm blue alteration that coalesces in the groundmass comprising 30-40% of rock volume; blue alteration armors joints and fractures.

926.0 - 70mm quartz latite lithic and 35mm rhyolite lithic with 15mm light pink-tan alteration halo; 90% of groundmass is blue altered.

933.1-946.6 - nonlithophysal interval; intense vapor-phase continues downward..

977.0 - 55mm circular, light pink-tan alteration spots become common but disappear by 978.6.



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Scale: 1"=10' (1:120)
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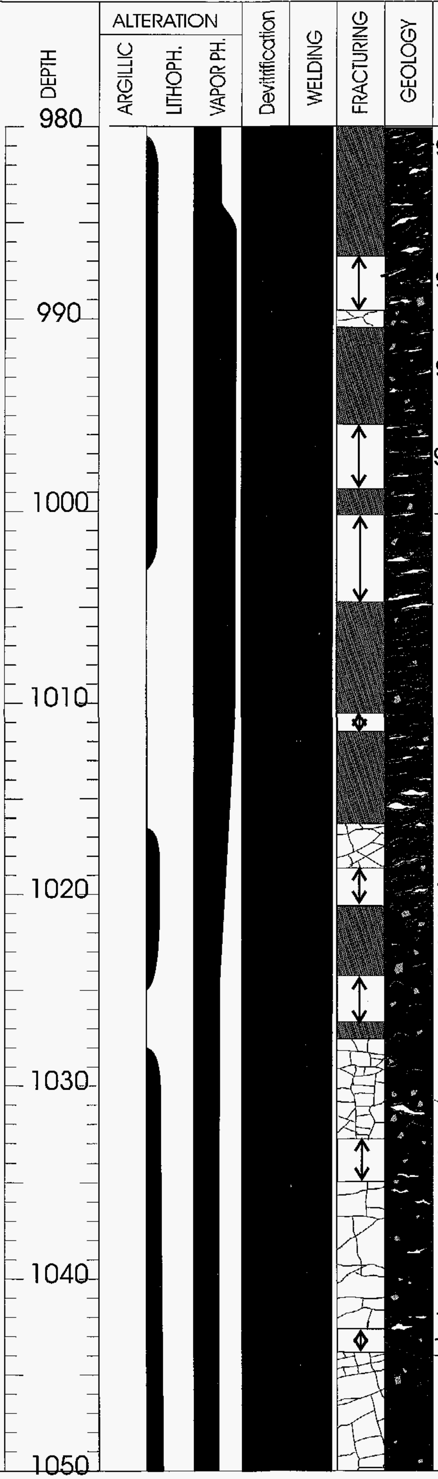
Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

COLLAR COORDINATES (NSP):
N: 758950.0 ft E: 561240.0 ft
STARTED: October 31, 1994
COMPLETED: November 19, 1995

DTN: SNT02110894001.002



COMMENTS:

978.3-989.5 rubble

Topopah Spring Crystal-Poor Lower Lithophysal Zone (Tptpll) *(803.3-1020.0)* (continued) -- Pale orange-gray (2.5YR7/2) densely welded, devitrified; crystal poor: 1-2% feldspar phenos, biotite not seen; 1-2% white subangular rhyolite lithics that average 10mm appear more abundant (5-7%) below large lithic fragment at 489.5; rare, barely opened small lithophysae coated by 2-3mm thick coarse vapor phase mins with 4-5mm halos of light pink-tan alteration and 1-2mm borders of blue alteration; blue alteration also replaces 40% of groundmass and armors joints; blue alteration replaces nonlithophysal pumices that have no pink alteration halos.

986.7-989.5 unrecvd

990.4-1016.2 rubble

995.4-998.7 unrecvd

Below 999.8, rock takes a strong horizontal texture, 10% very flat pumice replaced by vuggy coarse xlln vapor-phase minlz within 5mm pink-tan alteration halos; horizontal, pink-tan alteration streaks along unseen very flat pumice sites throughout rock fabric; 60% blue altered, 10-15% unaltered groundmass; vertical fractures dominate; rock is highly broken, esp. between 990.4-1016.2.

1000.2-1004.8 unrcvd

1010.5-1011.4 unrecvd

1015.8 - large pink-tan alteration spots with thin blue alteration borders occur in core.

1015.8

1020.0

Topopah Spring Crystal-Poor Lower Nonlithophysal ("mottled") Zone (Tptpln) *(1020.0-1191.4)* -- Pale orange-gray (2.5YR7/2), densely welded, devitrified; crystal poor: 1-2% feldspar phenos, no biotite seen; 1-2% altered white rhyolite lithics that average 5mm; rare flat lithophysae are coated by vapor-phase minerals with a porcelaneous texture (probably mix of SiO2, clays, calcite), speckled by MnOx & FeOx, and bordered by 1-3mm blue alteration; very flat pumice replaced by vapor phase minlz as hairline "veins" with 2mm blue alteration halos; other flattened pumice with rounded ends mostly replaced by blue alteration; 65% of groundmass is blue altered.

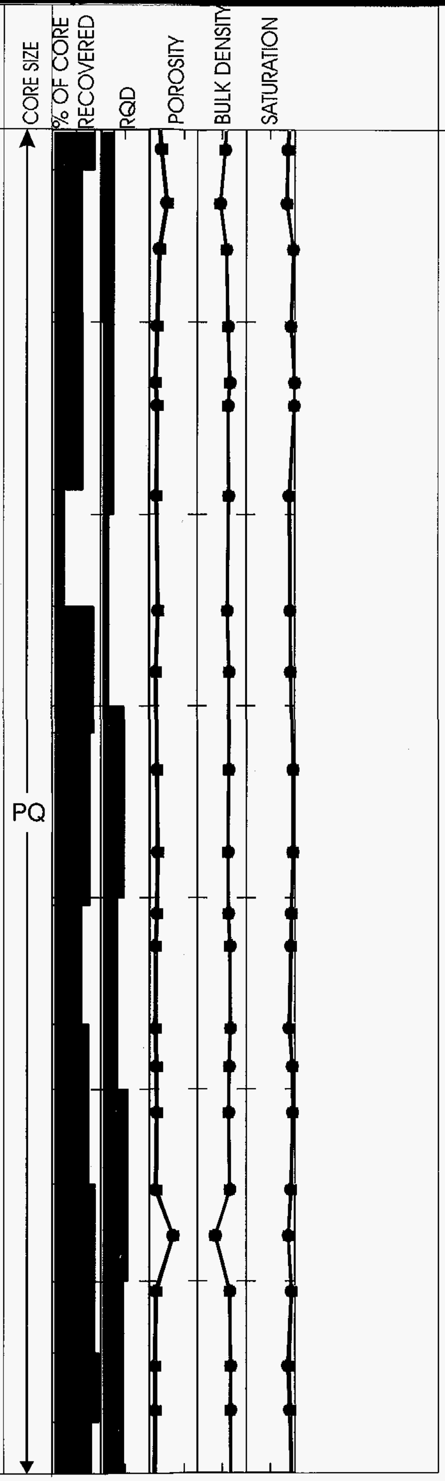
1018.4-1020.4 unrcvd
1020.4-1027.4 broken
1024.2-1026.6 unrcvd

1032.8-1034.9 unrcvd

1029.0-1032.8 Lithic-rich?, slight increase in lithic content.

1042.0-lowest lithophysae, very little alteration.
1042.6-1043.7 unrecvd

1040.3-med.-gray, vuggy pumice mostly replaced by mix of vapor-phase SiO2, red-brown platy minl (phlogopite?), and blue-green minl (pyroxene?); vugs contain a few rutile and zeolite needles.



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BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
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Scale: 1"=10' (1:120)
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COMMENTS:

DTN: SNT02110894001.002

Topopah Spring Crystal-Poor Lower Nonlithophysal Zone (Tptpln) *(1020.0- 1191.4)* (continued) -- Pale orange-gray (2.5YR7/2), densely welded, devitrified; crystal poor: 2% white feldspar phenos, no biotite seen; 3-5% altered white rhyolite lithics averaging 3-4mm, other lithics rounded with remnant layering totally blue altered; thin "veinlets" of white crystalline vapor-phase replacement of very flat pumice; partings exhibit porcelaneous coating, speckled with Mn-FeOx, 2mm lavendar-blue alteration halos.

1054.2-1055.8 unrcvd

1057.3-1066.0 broken

1060.4-1061.2 unrcvd

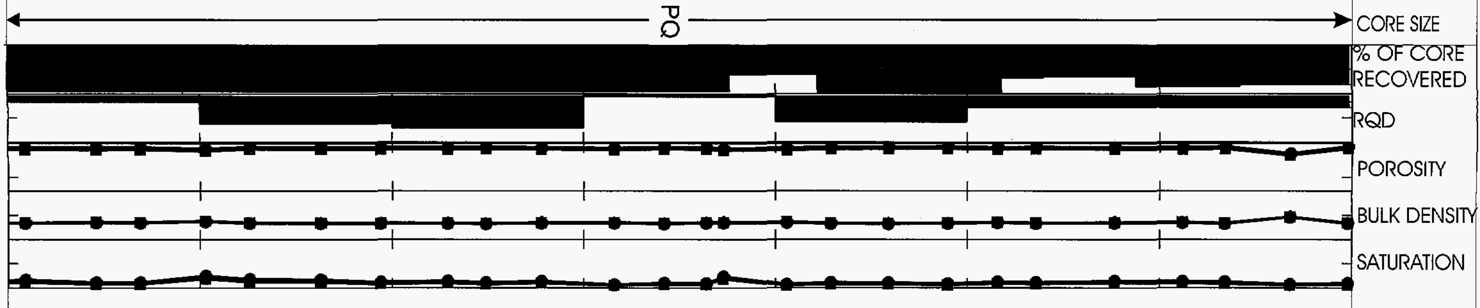
1064.3-1066.0 unrcvd

1067.5-1068.2 unrecvd

1076.4 — Blotchy texture caused by exaggerated dark brown-gray alteration centers separated by light-orange, devitrified unaltered zones (50:50); vapor-phase alt'n increases in intensity to typically 85-90%; much less broken, dominantly vertical or horizontal joints; 3-5% well-altered lithics.

1080.6-1082.4 unrcvd

1091.4-1091.9 unrecvd



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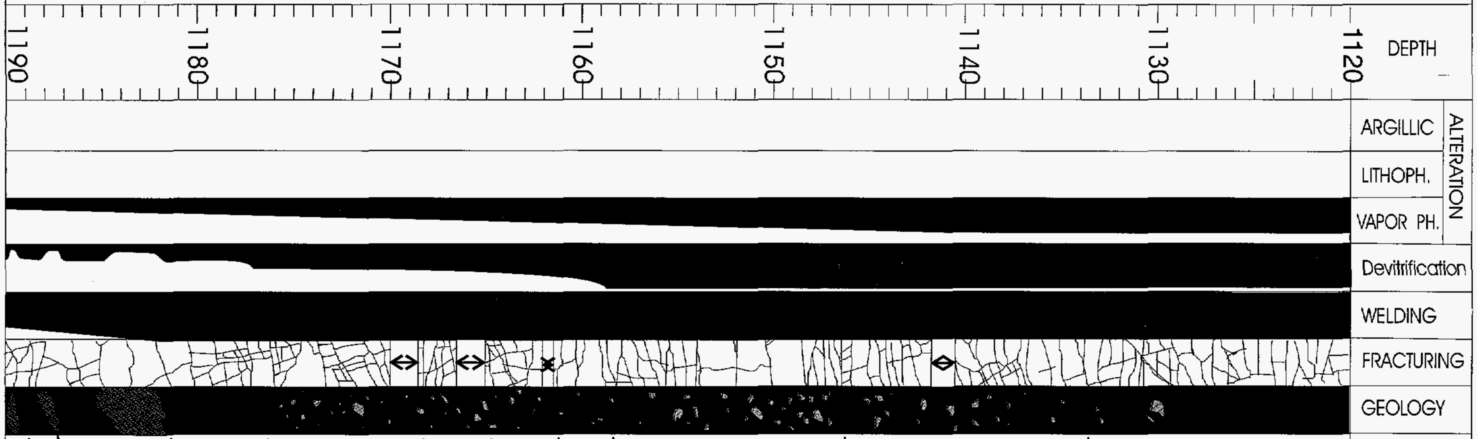


COMMENTS:

DTN: SNT02110894001.002

Topopah Spring Crystal-Poor Lower Nonlithophysal Zone (Tptpln) *(1020.0-1191.4 feet)* (continued) -- Pale orange-gray (5YR7/2), densely welded, devitrified; crystal poor: 1-3% small feldspar phenos, no biotite seen; 3-5% 5-10mm subangular lithics, mostly altered to light gray material; large, fuzzy zones (up to 20% of rock) may be altered cognate pumice; flat. very thin veinlets of white crystalline vapor-phase minlz replaace probable flattened pumice sites, each with 2-3mm pink-gray alteration halo. Groundmass is blotchy textured and 70% blue-altered, with 30% grainy, orange, devitrified unaltered material between altered spots; overall 90% altered. Rock is broken with dominant horizontal ("bedding") joints, with fewer irregular vertical joints; vapor phase alteration gradually diminishes downward, especially below 1140.

1140.6-1141.7 unrcvd

1147.0-1156.5 - lithic-rich zone with mixed light and dark colored chips.

1159.0 - upper limit of blotchy, vitric texture; marks proximity to vitrophyre

1161.6-1162.1 unrecvd

1165.1-1166.5 unrecvd

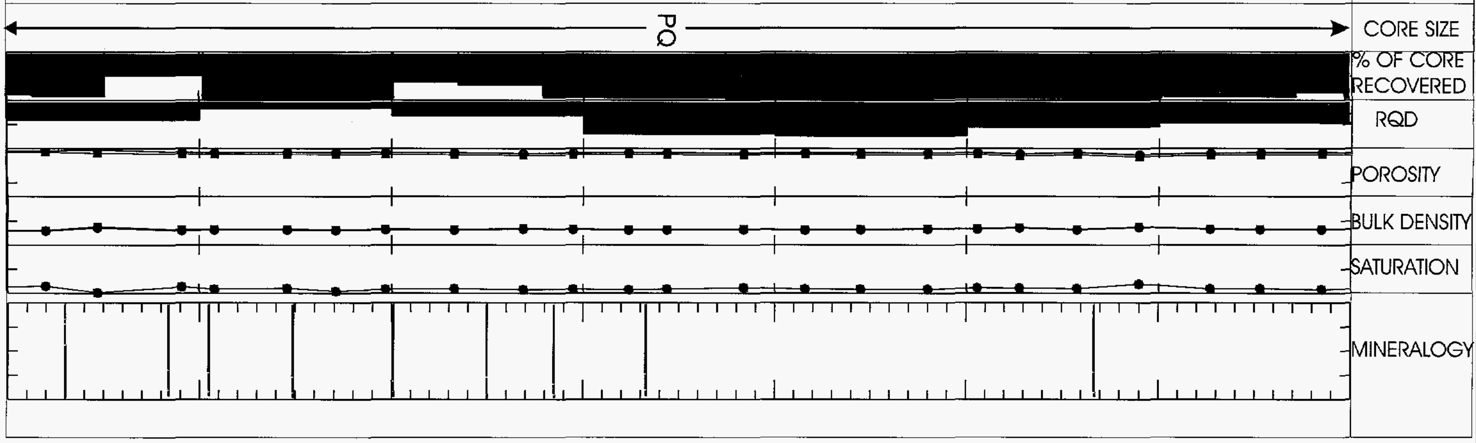
1168.6-1169.9 unrecvd

1177.0 - more vitric than above.

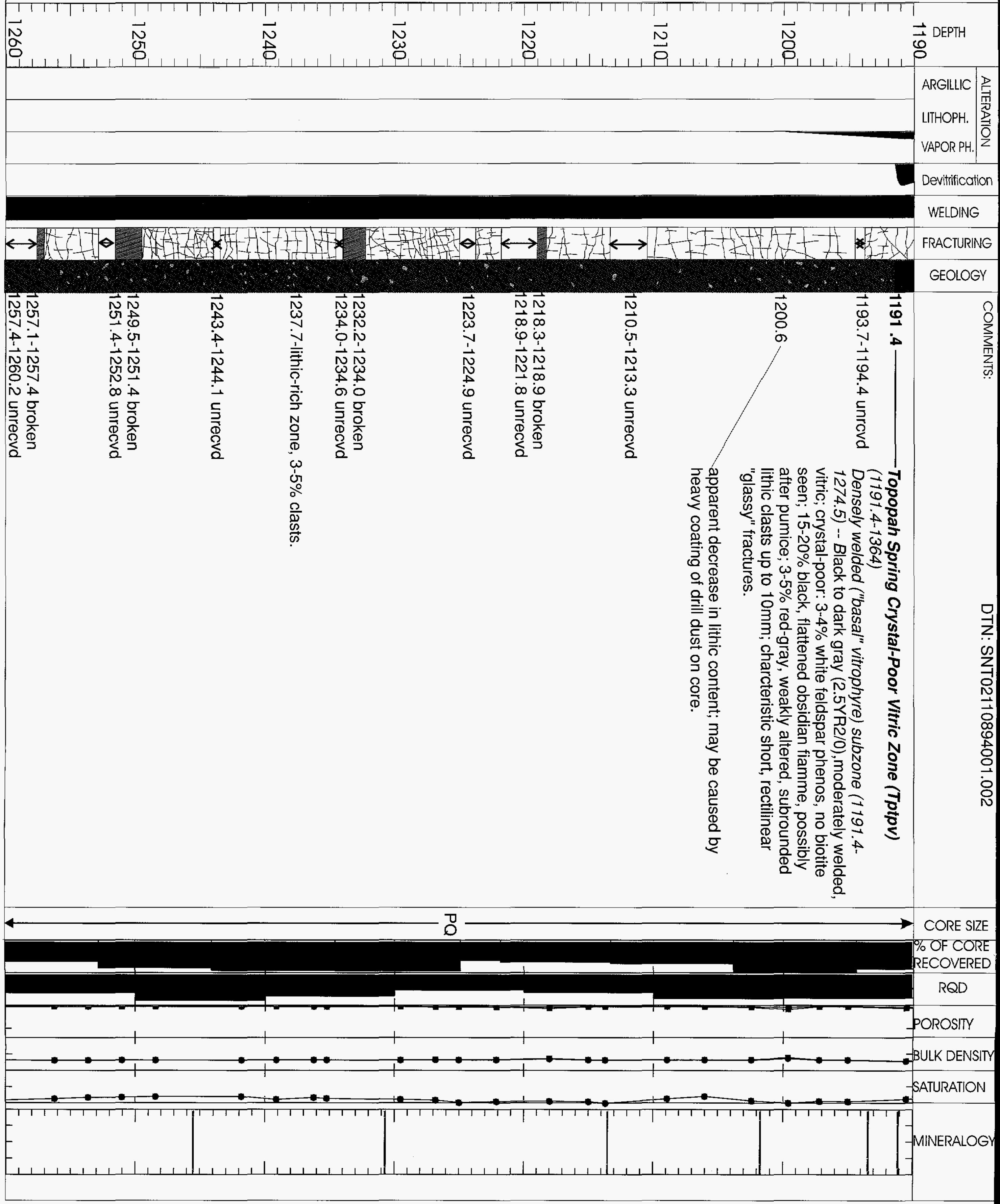
1181.8-1185.5 -prominent vitrophyre "island" (lack of devitrification)

1187.2 - vitrophyre island.

1189.4-1189.5 - vitrophyre island.



COLLAR COORDINATES (NSP):	ELEVATION: 4470 ft	Sandia National Laboratories	Yucca Mountain Project
N: 758950.0 ft E: 561240.0 ft	BEARING: N/A (vertical)	Logged by: Dale Engstrom	Hole No: USW SD-7
STARTED: October 31, 1994	INCLINATION: -90	Log Version: 2.02	Scale: 1"=10' (1:120)
COMPLETED: November 19, 1995	TOTAL DEPTH: 2675.1 ft	Log Date: July 9, 1996	Sheet 18 OF 39



1191.4 — **Topopah Spring Crystal-Poor Vitric Zone (Tptpv)** *(1191.4-1364)*

Densely welded ("basal" vitrophyre) subzone (1191.4-1274.5) -- *Black to dark gray* (2.5YR2/0),moderately welded, vitric; crystal-poor: 3-4% white feldspar phenos, no biotite seen; 15-20% black, flattened obsidian fiamme, possibly after pumice; 3-5% red-gray, weakly altered, subrounded lithic clasts up to 10mm; charcteristic short, rectilinear "glassy" fractures.

1193.7-1194.4 unrcvd

1200.6 — apparent decrease in lithic content; may be caused by heavy coating of drill dust on core.

1210.5-1213.3 unrecvd

1218.3-1218.9 broken
1218.9-1221.8 unrecvd

1223.7-1224.9 unrecvd

1232.2-1234.0 broken
1234.0-1234.6 unrecvd

1237.7-lithic-rich zone, 3-5% clasts.

1243.4-1244.1 unrecvd

1249.5-1251.4 broken
1251.4-1252.8 unrecvd

1257.1-1257.4 broken
1257.4-1260.2 unrecvd

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INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

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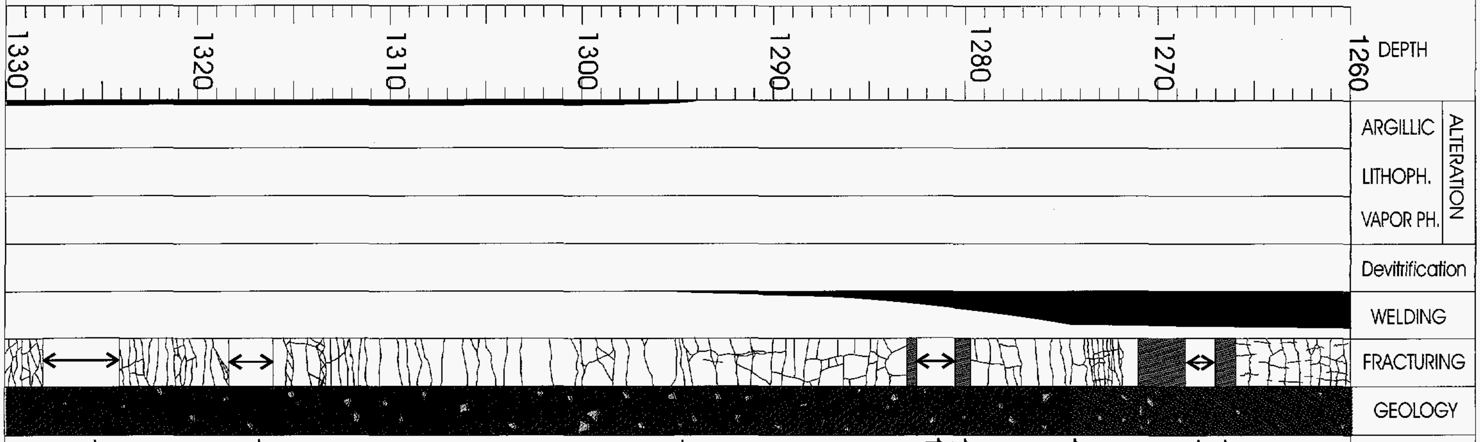


COMMENTS:

DTN: SNT02110894001.002

1265.9-1270.9 broken
1266.9-1268.6 unrcvd

Topopah Spring Crystal-Poor Vitric Zone (1191.4-1364) (continued)
Densely welded ("caprock" vitrophyre) subzone (1191.4-1274.5) (continued) -- Black to dark gray (2.5YR2/0), moderately welded, vitric; crystal poor: 3-4% white feldspar phenos, no biotite seen groundmass; 15-20% flattened black obsidian fiamme possibly after pumice; 3-5% red-gray weakly altered lithic clasts up to 10mm; characteristic, rectilinear "glassy" fracture.

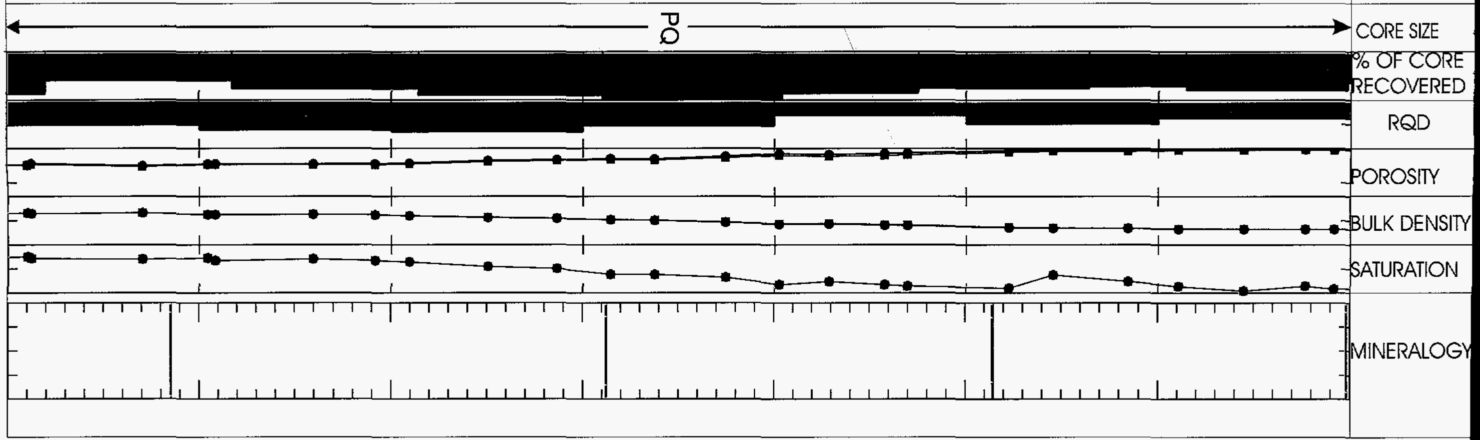
1274.5 — *Moderately welded subzone (1274.5-1295.0 feet)* -- Incipient alteration of constituents creates moderate-to-partially welded, pale orange (7.5YR7.5/2) core by 1288.0; crystal poor: 1-3% feldspar phenos, no biotite seen; 2-4% subround 4mm lithics dominantly of red-purple porphritic volcanic with lesser altered medium gray variety; large, ragged, black vitric clasts, up to 12x60mm, average 3x12mm near top of zone; 5-10% black bubble-wall shards.

1279.8-1283.1 broken
1280.4-1282.5 unrcvd

1295.0 — *Nonwelded subzone (1295.0-1364)* -- gradational contact marked as upper limit of unflattened, light orange-brown pumice clasts; clasts have 1-2mm reaction rim; in all other respects rock is virtually identical to above.
1295.5 - black shard content of groundmass increases from 5-10% to 10-15%, creating dark orange-gray matrix with medium orange-brown pumice clasts with 1-2mm light orange reaction rims.

1316.1-1318.3 unrecvd

1324.1-1328.0 unrecvd



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COLLAR COORDINATES (NSP):	ELEVATION: 4470 ft
N: 758950.0 ft E: 561240.0 ft	BEARING: N/A (vertical)
STARTED: October 31, 1994	INCLINATION: -90
COMPLETED: November 19, 1995	TOTAL DEPTH: 2675.1 ft

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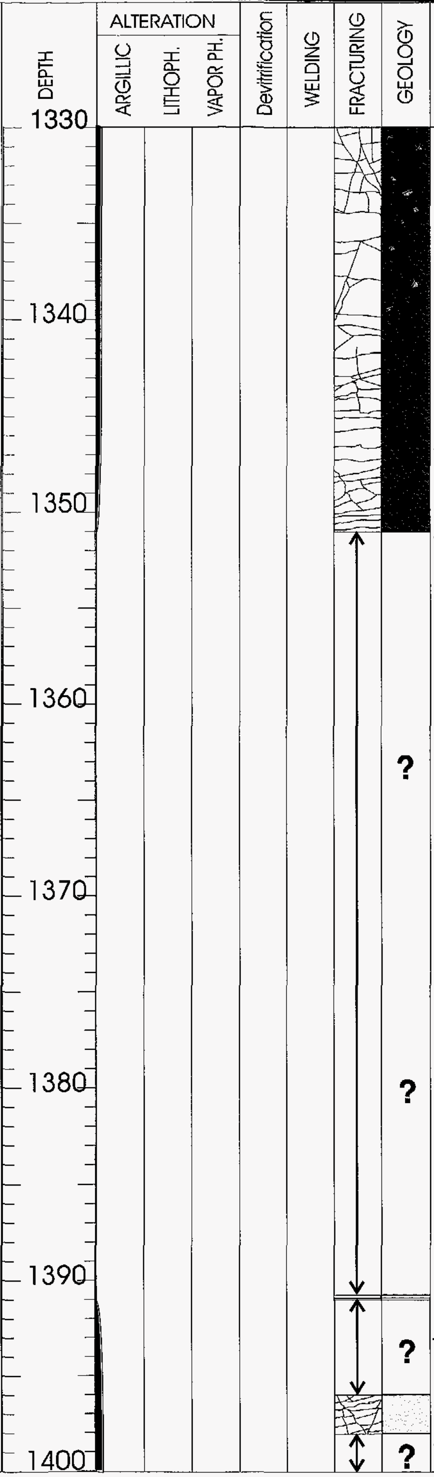


COMMENTS:

***Topopah Spring Crystal-Poor Vitric Zone** (1191.4-1364)* (continued)
Nonwelded subzone (1295-1363±) (continued) -- vitric, dark orange-gray groundmass containing medium orange-brown pumice clasts with 1-2mm reation rims; black shard content of groundmass 10-15%; crystal poor: 1-3% feldspar phenocrysts, no biotite seen; 2-4% subround lithics averaging 4mm, most of red-purple crystal-rich volcanic rock with fewer, altered, medium-gray rock.

1346.8-1347.1 unrecvd

1350.9-1390.7 unrecvd (40.2 feet) -- *interval contains Topopah Springs basal contact*

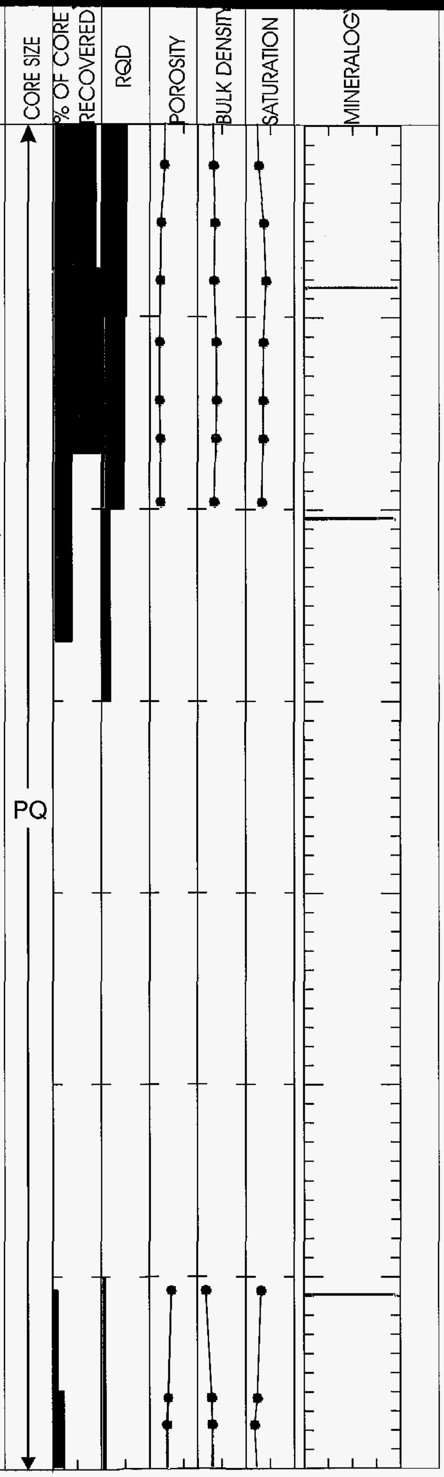
1364 ------------------- ***Pre-Topopah Spring Tuff Bedded Tuff (Tptbt1)** (1364 - 1405)* -- contacts inferred from geophysical logs; very fine-grained, pale pink-gray drill cuttings that are soft and clay-rich were recovered from 1390.7-1391.2, black Fe(?)Ox fragments speckle the cuttings.

1395.9 -- light medium-brown, medium-grained, sandy textured bedded tuff, 10-20% ash in matrix.
1396.6 medium gray, medium-grained, sandy textured bedded tuff with 10-20% ash content.

1390.8-1391.0 unrcvd

1391.2-1395.9 unrcvd

1398.1-1405.6 unrcvd



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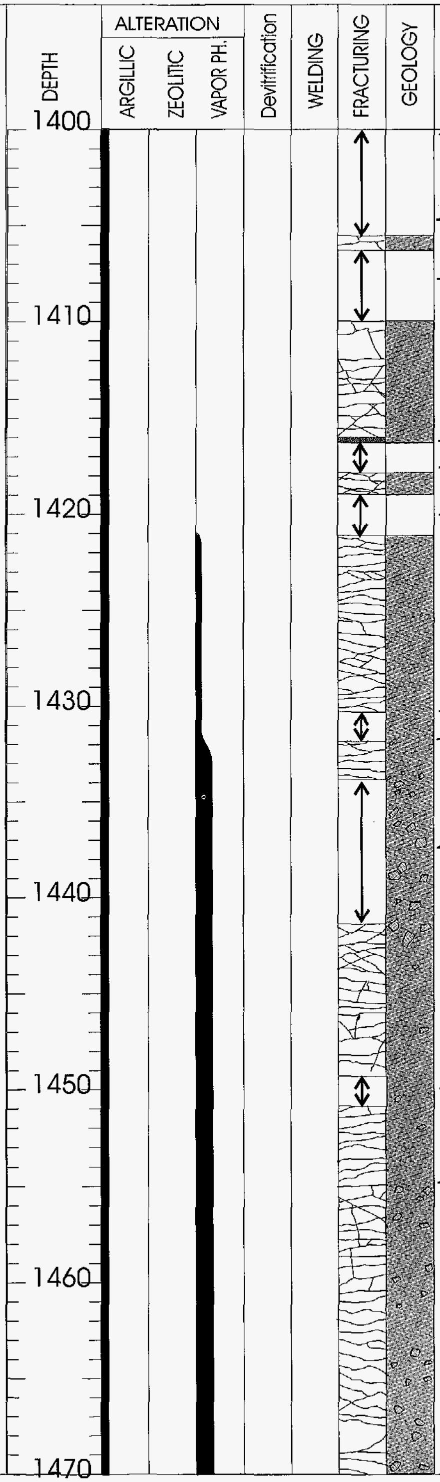


COMMENTS:

DTN: SNT02110894001.002

Alteration relogged: 7/96

1398.1-1405.6 unrecovered

1405 - approximate Pre-Topopah Spring Tuff Bedded Tuff/Calico Hills Tuff contact in unrecovered interval; contact inferred from geophysical logs.

1406.3-1410.0 unrecvd

Calico Hills Formation, Unit 3 *(1405-1493.3)* -- Very pale yellow-gray (10YR8/1); 25-30% pale yellow-orange slightly flattened, subrounded partially argillized or otherwise weakly alt'd.pumice; 2-3% feldspar plus quartz phenos, 1% biotite, 2-3% 1-3mm dark red-brown devitrified volcanic lithics; fine-grained, ash groundmass is friable, medium-gray, mostly vitric but partially vapor-phase altered.

1415.9-1416.2 broken

1416.2-1417.8 unrecvd

1418.9-1421.1 unrecvd

1430.3-1431.8 unrecvd

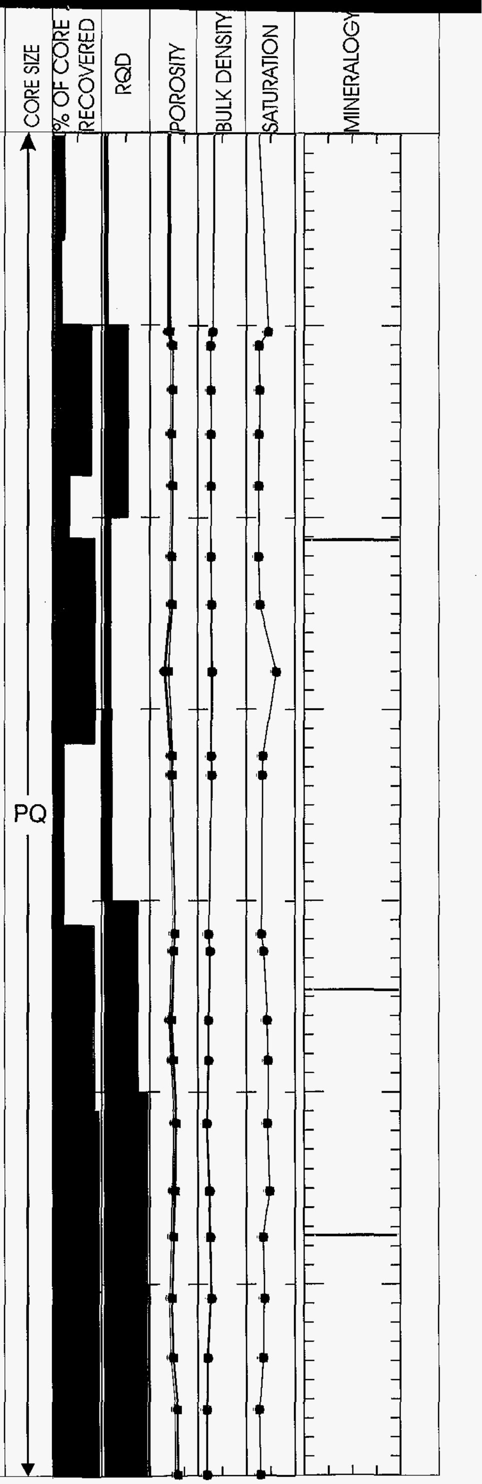
1431.8 — 1431.8 Groundmass is 90-100% vapor-phase altered, sugary and white; pumice virtually indistinguishable from matrix; relict pumice are light pea-green color farther downhole; 3-5% dark lithics, vitric lithics up to 5-6mm.

1433.8-1441.3 unrecvd

1433.0-1442.0 -- Increased lithic content: 10-15% clear, perlitic, vitric lithics up to 25mm; 5-7% 1-2mm red-brown devitrified or black vitric lithics and 2-3% 5-7mm subrounded dark gray or red-brown crystal-rich lithics; 25-30% pale orange-yellow, slightly flattened, subrounded 25mm pumice fragments; 3-4% phenos of feldspar & quartz, <1% biotite.

1449.3-1450.8 unrecvd

1455.0-content of small lithic increases to 10-15%.



Sandia National Laboratories Yucca Mountain Project

Logged by: Dale Engstrom Hole No: USW SD-7

Log Version: 2.02 Scale: 1"=10' (1:120)

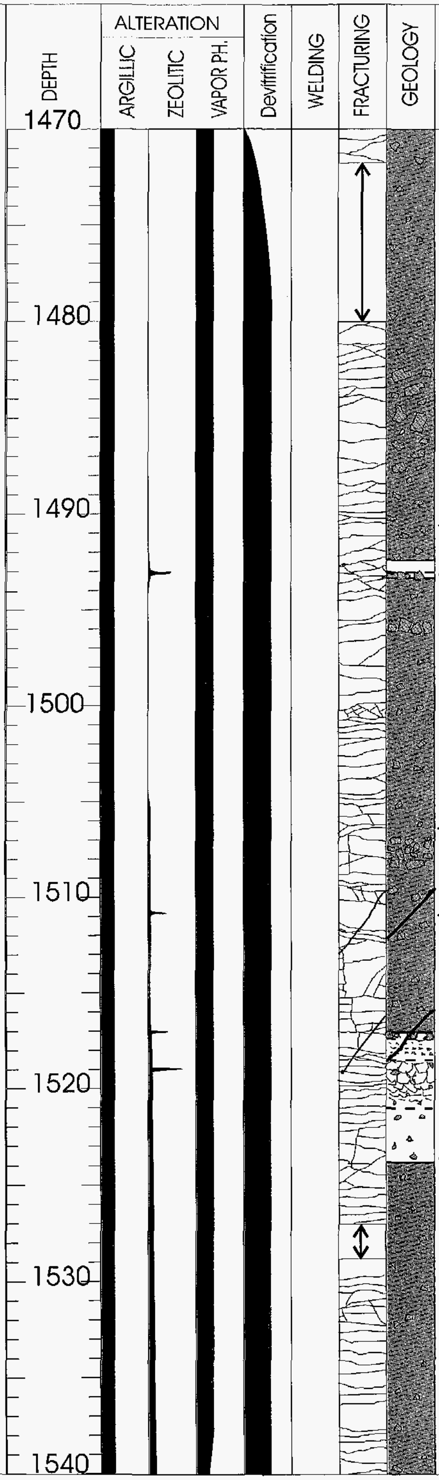
Log Date: July 9, 1996 Sheet 22 OF 39

COLLAR COORDINATES (NSP): ELEVATION: 4470 ft

N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)

STARTED: October 31, 1994 INCLINATION: -90

COMPLETED: November 19, 1995 TOTAL DEPTH: 2675.1 ft



COMMENTS: DTN: SNT02110894001.002

Alteration relogged: 7/96

1471.8-1480.1 unrcvd

Calico Hills Formation, Unit 3 (Tac3) *(1402.0-1493.3)* (continued) -- Pale red-gray (2.5R8/1); 10-15% light pink-gray 5mm pumice; 3-5% small, red-brown or black vitric lithics up to 3-4mm, many vitric lithics incipiantly altered; 2-3% feldspar & quartz phenos, <1% oxybiotite.

1482.6

1482.6-1487.5 - Lithic-rich interval: 10-15% red-brown subangular lithics up to 25mm and rarely 35-40mm; most are crystal-rich porphyry,
1487.5 - Lithic content decreases to 5-10% lithics that average 3-5mm.

1492.4
1493.0-bedded

1492.4 - lithic-free interval
1493.0-1493.3 - Coarse basal lithic lag followed by very fine-grained ashy layers, fining and with fewer lithics downward; vent-forming deposit(?), possible bedding-surge deposition.

1493.3

Calico Hills Formation, Unit 2 (Tac2) *(1493.3-1523.8)* -- Pale red-gray (2.5R8/1), very fine-grained granular groundmass totally replaced by light-pink vapor-phase(?) alteration; 25% pale pink-gray 12mm pumice, equally divided between dense-textured and laminated varieties; 3% *medium-dark gray, subrounded, perlitic, vitric lithics up to* 10mm; 1-2% red-brown, devitrified, subangular lithics up to 7-8mm; 1-2% feldspar & quartz phenos, <1% biotite. Prominent thin (1-3 cm), green, zeolitic layers.

1506.7-1508.3 - lithic-rich interval, coarsens downward to average size of 30mm.

1511.1-clay-covered fracture with slicks at 60° to c.a..

1517.1
1517.3 slicks on fract. 75° to c.a..

Bedded Interval (1517.1-1523.8) -- Coarse-grained, lithic-rich unit, consisting of an upper, 0.2' coarse-grained lithic-rich pumice fall, 1.1' of fine-grained light-brown volcaniclastic sandstone, and a lower 2.6' medium-grained pumice fall with dark lithics fining downward; 1521.7-1523.8 Light-brown sandy matrix (poss. reworked) with weak ashflow texture, 5-10% small angular red-brown lithics .

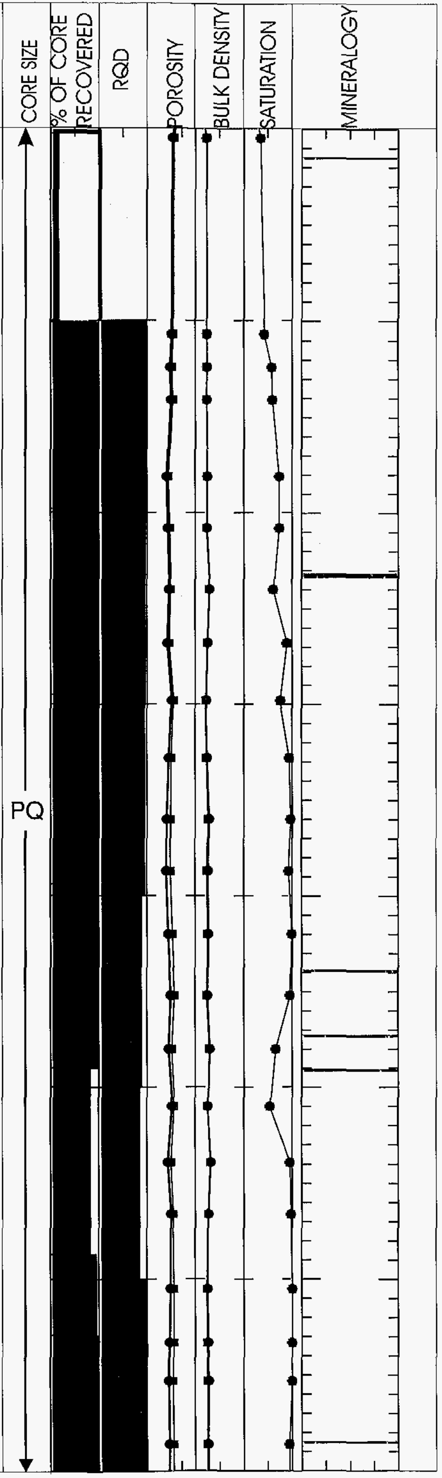
1523.8

Calico Hills Formation, Unit 1 (Tac1) *(1523.8-1567.2)* -- Light pink-gray (2.5R9/1); pink microgranular vapor-phase(?) altered groundmass; 30-40% light green-gray to light-pink 10mm pumice; 1-2% red-brown subrounded lithics up to 10mm; 1% dark gray-black, perlitic, vitric lithics that average 5mm; 1% feldspar & quartz phenos; <1% biotite. 1525 - light-green zeolitic alteration nucleated on pumice increases in intensity down hole.

1527.0-1528.7 unrcvd

1538.5

1538.5-1542.0 - gradual increase in pink color (intensity of vapor-phase alteration).



Yucca Mountain Project

Sandia National Laboratories

Hole No: **USW SD-7**

Logged by: Dale Engstrom

Scale: 1"=10' (1:120)

Log Version: 2.02

Sheet 23 OF 39

Log Date: July 9, 1996

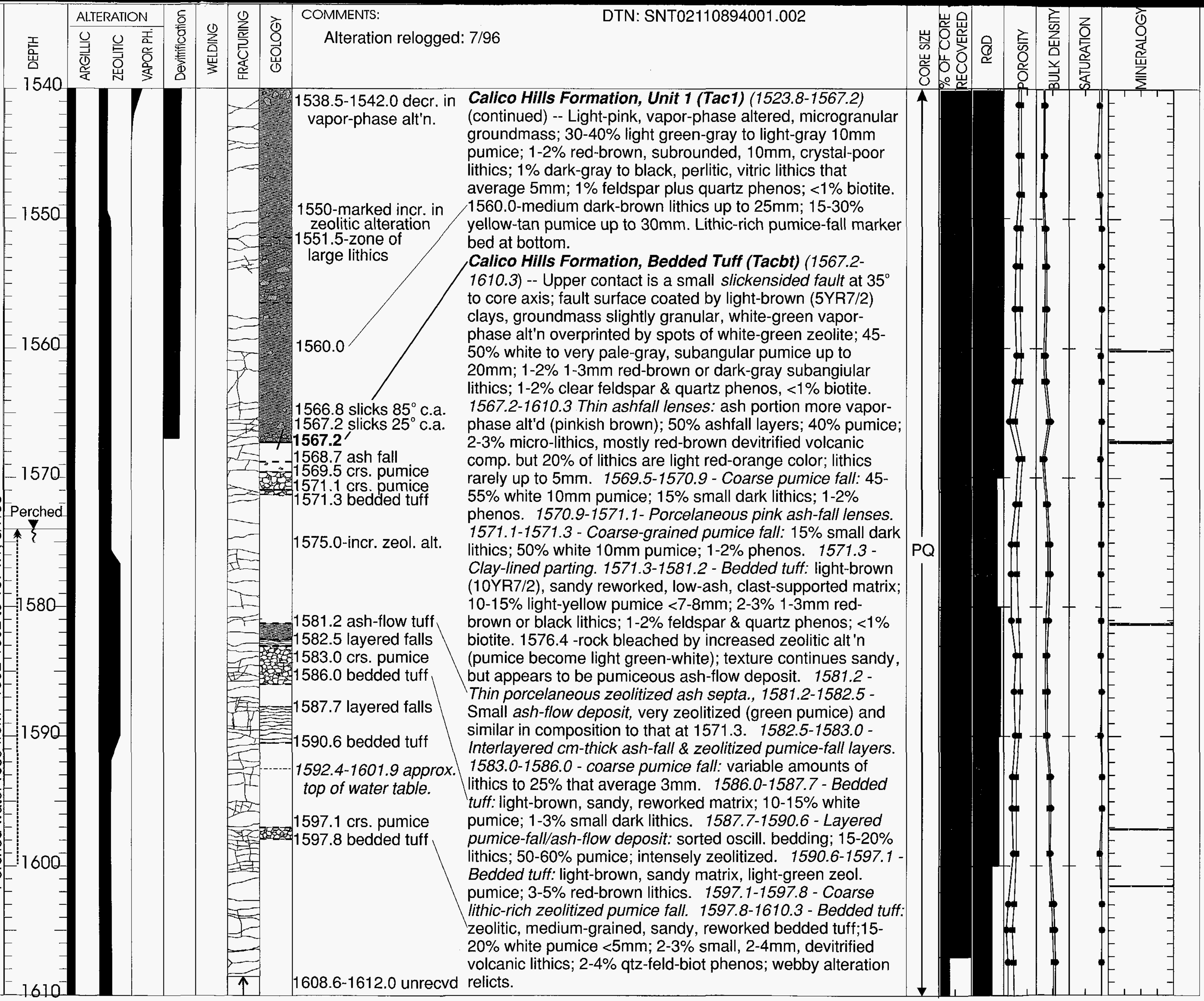
COLLAR COORDINATES (NSP): ELEVATION: 4470 ft
N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)
STARTED: October 31, 1994 INCLINATION: -90
COMPLETED: November 19, 1995 TOTAL DEPTH: 2675.1 ft

Perched water rose from ~1592-1602 to 1574.1; 3/7/95

DTN: SNT02110894001.002

COMMENTS:

Alteration relogged: 7/96



Calico Hills Formation, Unit 1 (Tac1) *(1523.8-1567.2)* (continued) -- Light-pink, vapor-phase altered, microgranular groundmass; 30-40% light green-gray to light-gray 10mm pumice; 1-2% red-brown, subrounded, 10mm, crystal-poor lithics; 1% dark-gray to black, perlitic, vitric lithics that average 5mm; 1% feldspar plus quartz phenos; <1% biotite. 1560.0-medium dark-brown lithics up to 25mm; 15-30% yellow-tan pumice up to 30mm. Lithic-rich pumice-fall marker bed at bottom.

Calico Hills Formation, Bedded Tuff (Tacbt) *(1567.2-1610.3)* -- Upper contact is a small *slickensided fault* at 35° to core axis; fault surface coated by light-brown (5YR7/2) clays, groundmass slightly granular, white-green vapor-phase alt'n overprinted by spots of white-green zeolite; 45-50% white to very pale-gray, subangular pumice up to 20mm; 1-2% 1-3mm red-brown or dark-gray subangiular lithics; 1-2% clear feldspar & quartz phenos, <1% biotite. *1567.2-1610.3 Thin ashfall lenses:* ash portion more vapor-phase alt'd (pinkish brown); 50% ashfall layers; 40% pumice; 2-3% micro-lithics, mostly red-brown devitrified volcanic comp. but 20% of lithics are light red-orange color; lithics rarely up to 5mm. *1569.5-1570.9 - Coarse pumice fall:* 45-55% white 10mm pumice; 15% small dark lithics; 1-2% phenos. *1570.9-1571.1- Porcelaneous pink ash-fall lenses. 1571.1-1571.3 - Coarse-grained pumice fall:* 15% small dark lithics; 50% white 10mm pumice; 1-2% phenos. *1571.3 - Clay-lined parting. 1571.3-1581.2 - Bedded tuff:* light-brown (10YR7/2), sandy reworked, low-ash, clast-supported matrix; 10-15% light-yellow pumice <7-8mm; 2-3% 1-3mm red-brown or black lithics; 1-2% feldspar & quartz phenos; <1% biotite. 1576.4 -rock bleached by increased zeolitic alt'n (pumice become light green-white); texture continues sandy, but appears to be pumiceous ash-flow deposit. *1581.2 - Thin porcelaneous zeolitized ash septa., 1581.2-1582.5 -* Small *ash-flow deposit,* very zeolitized (green pumice) and similar in composition to that at 1571.3. *1582.5-1583.0 - Interlayered cm-thick ash-fall & zeolitized pumice-fall layers. 1583.0-1586.0 - coarse pumice fall:* variable amounts of lithics to 25% that average 3mm. *1586.0-1587.7 - Bedded tuff:* light-brown, sandy, reworked matrix; 10-15% white pumice; 1-3% small dark lithics. *1587.7-1590.6 - Layered pumice-fall/ash-flow deposit:* sorted oscill. bedding; 15-20% lithics; 50-60% pumice; intensely zeolitized. *1590.6-1597.1 - Bedded tuff:* light-brown, sandy matrix, light-green zeol. pumice; 3-5% red-brown lithics. *1597.1-1597.8 - Coarse lithic-rich zeolitized pumice fall. 1597.8-1610.3 - Bedded tuff:* zeolitic, medium-grained, sandy, reworked bedded tuff;15-20% white pumice <5mm; 2-3% small, 2-4mm, devitrified volcanic lithics; 2-4% qtz-feld-biot phenos; webby alteration relicts.

Sandia National Laboratories   Yucca Mountain Project

Logged by: Dale Engstrom   Hole No: **USW SD-7**

Log Version: 2.02   Scale: 1"=10' (1:120)

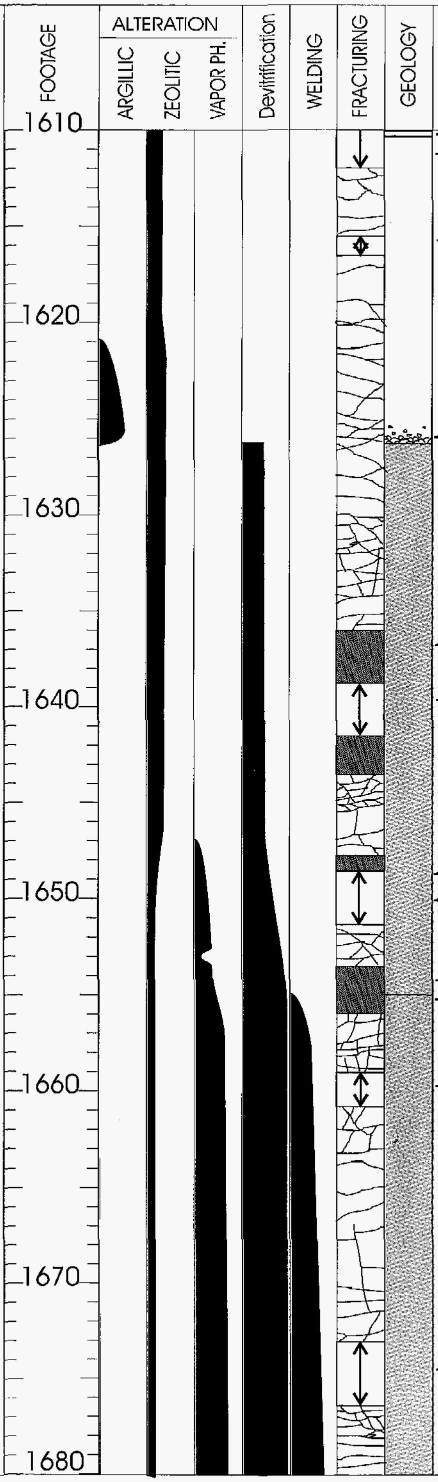
Log Date: July 9, 1996   Sheet 24 OF 39

COLLAR COORDINATES (NSP):   ELEVATION: 4470 ft

N: 758950.0 ft   E: 561240.0 ft   BEARING: N/A (vertical)

STARTED: October 31, 1994   INCLINATION: -90

COMPLETED: November 19, 1995   TOTAL DEPTH: 2675.1 ft



COMMENTS: DTN: SNT02110894001.002

Alteration relogged: 7/96

1610.3
1608.6-1612.0 unrecvd
1615.4-1616.6 unrecvd

Calico Hills Formation Basal Sandstone Unit (Tacbs) *(1610.3-1626.2)*-- Not a sharp upper contact; no distinct paleosol or hematite-stained top. Light-brown (7.5YR7/2); changes downward to slightly sandier texture with less matrix; 10-15% pale tan pumice <5-7mm; large, altered pumice up to 75mm that increase in number below 1613.7 to approx. 35%; by 1620, large pumices become pale-purple, soft and zeolitically altered; 2-3% lithics of black or red-brown devitrified volcanic comp. <3mm; 2-3% quartz, feldspar, and biotite phenos; biotite appears fresh; black, sandy-ashy matrix between clasts is about 50-65% zeolitized. Basal *pumice fall.*

1626.2

Prow Pass Tuff, Unit 4 (Tcp4) *(1626.2-1655.0)* -- Pale brown-gray (2.5YR7/2), nonwelded, zeolitized; 30-40% pale yellow-gray, rounded pumice <20mm; 2-3% black or red-brown, devitrified, volcanic or red siltstone lithics <4mm; 2-3% quartz, feldspar, and biotite phenos; Pumiceous groundmass approximately 1/3 zeolitized.

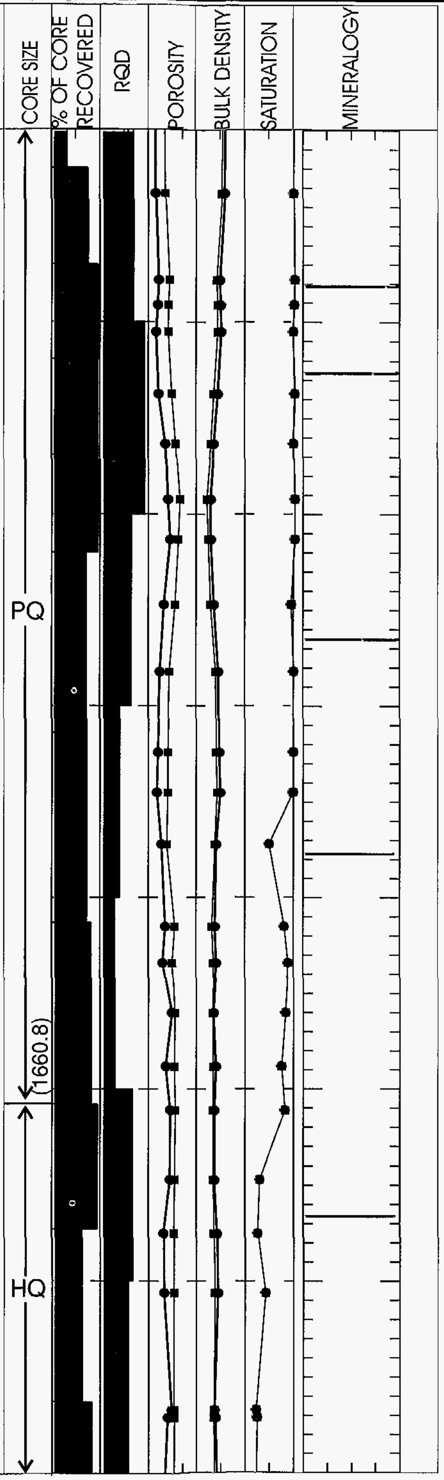
1636.1-1643.5 broken
1638.8-1641.4 unrecvd

1647.0 apparent top of vapor-phase alteration (lighter color) related to underlying unit 3; overprinted by zeolitic(?) alteration.

1647.7-1648.6 broken
1648.6-1651.3 unrecvd
1653.6-1656.0 broken
1655.0

Prow Pass Tuff, Unit 3 (Tcp3) *(1655.0-1837.8)* -- Pale pink (2.5YR8/2), gradational increase from nonwelded to moderately welded at 1770.0; vapor-phase alt'd and overprinted by weak zeolitic(?) alteration; 10-15% altered 25mm pumice nearly indistinguishable from matrix; 10% large blocky pumiceous lithics up to 50mm, these decrease in number rapidly downward; 2-3% red-brown, devitrified, volcanic and red-orange siltstone lithics <5mm; 3-4% phenos of quartz, feldspar, and biotite in highly altered (and realtered) microgranular matrix. Textural details disappear and color becomes lighter with downward increased intensity of vapor-phase alteration.

1659.1-1660.8 unrecvd
1673.0-1676.3 unrecvd



COLLAR COORDINATES (NSP):
N: 758950.0 ft E: 561240.0 ft
STARTED: October 31, 1994
COMPLETED: November 19, 1995

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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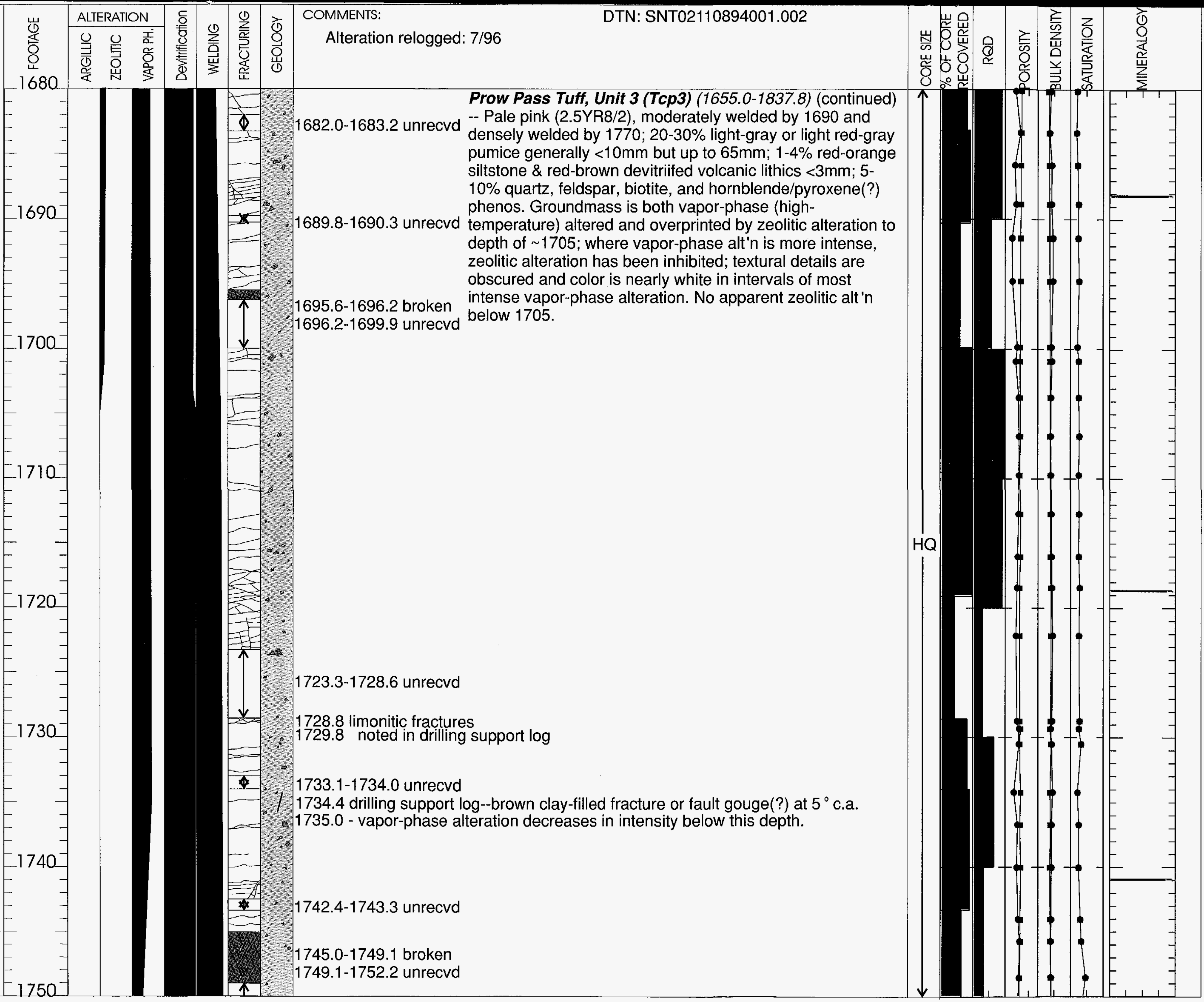
DTN: SNT02110894001.002

COMMENTS:
Alteration relogged: 7/96



1682.0-1683.2 unrecvd
1689.8-1690.3 unrecvd
1695.6-1696.2 broken
1696.2-1699.9 unrecvd

Prow Pass Tuff, Unit 3 (Tcp3) *(1655.0-1837.8)* (continued) -- Pale pink (2.5YR8/2), moderately welded by 1690 and densely welded by 1770; 20-30% light-gray or light red-gray pumice generally <10mm but up to 65mm; 1-4% red-orange siltstone & red-brown devitriifed volcanic lithics <3mm; 5-10% quartz, feldspar, biotite, and hornblende/pyroxene(?) phenos. Groundmass is both vapor-phase (high-temperature) altered and overprinted by zeolitic alteration to depth of ~1705; where vapor-phase alt'n is more intense, zeolitic alteration has been inhibited; textural details are obscured and color is nearly white in intervals of most intense vapor-phase alteration. No apparent zeolitic alt'n below 1705.

1723.3-1728.6 unrecvd
1728.8 limonitic fractures
1729.8 noted in drilling support log
1733.1-1734.0 unrecvd
1734.4 drilling support log--brown clay-filled fracture or fault gouge(?) at 5 ° c.a.
1735.0 - vapor-phase alteration decreases in intensity below this depth.
1742.4-1743.3 unrecvd
1745.0-1749.1 broken
1749.1-1752.2 unrecvd

COLLAR COORDINATES (NSP):
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INCLINATION: -90
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Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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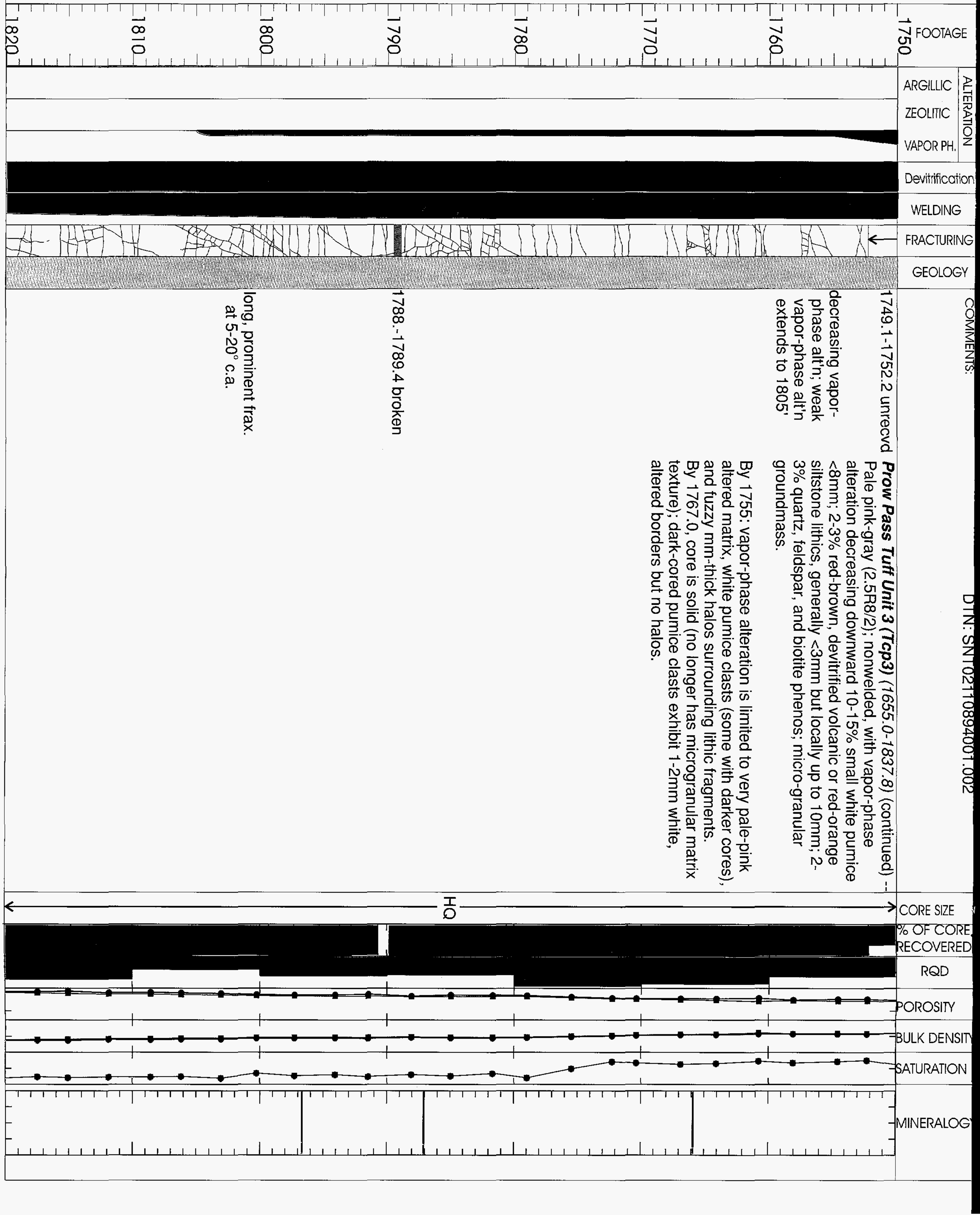


1749.1-1752.2 unrecvd

decreasing vapor-phase alt'n; weak vapor-phase alt'n extends to 1805'

1788.-1789.4 broken

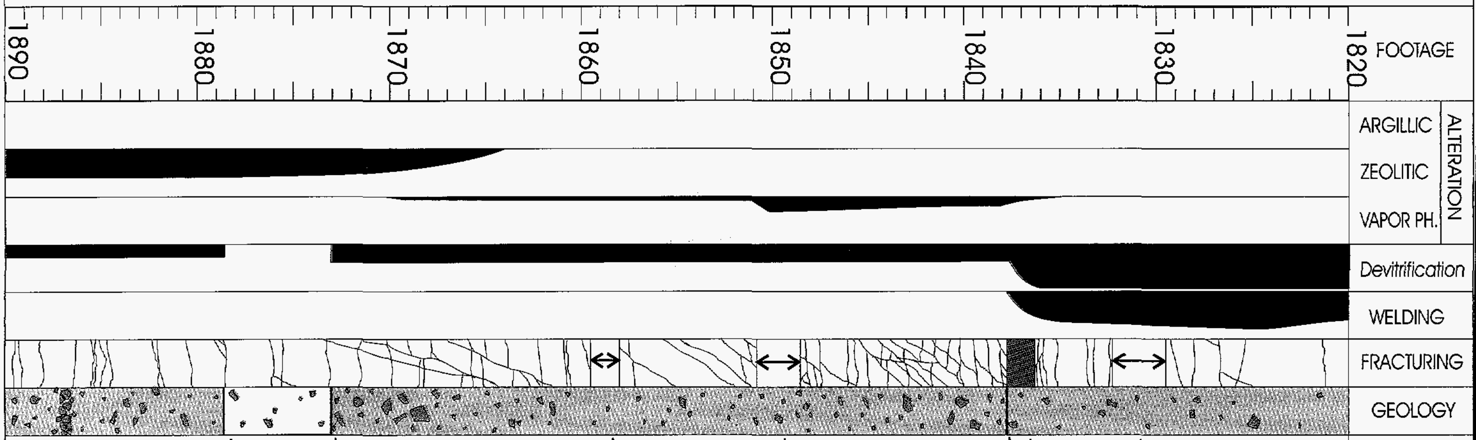
long, prominent frax. at 5-20° c.a.

Prow Pass Tuff Unit 3 (Tcp3) *(1655.0-1837.8)* (continued) -- Pale pink-gray (2.5R8/2); nonwelded, with vapor-phase alteration decreasing downward 10-15% small white pumice <8mm; 2-3% red-brown, devitrified volcanic or red-orange siltstone lithics, generally <3mm but locally up to 10mm; 2-3% quartz, feldspar, and biotite phenos; micro-granular groundmass.

By 1755: vapor-phase alteration is limited to very pale-pink altered matrix, white pumice clasts (some with darker cores), and fuzzy mm-thick halos surrounding lithic fragments. By 1767.0, core is solid (no longer has microgranular matrix texture); dark-cored pumice clasts exhibit 1-2mm white, altered borders but no halos.

DTN: SN02110894001.002

COLLAR COORDINATES (NSP):	ELEVATION: 4470 ft	Sandia National Laboratories	Yucca Mountain Project
N: 758950.0 ft E: 561240.0 ft	BEARING: N/A (vertical)	Logged by: Dale Engstrom	Hole No: USW SD-7
STARTED: October 31, 1994	INCLINATION: -90	Log Version: 2.02	Scale: 1"=10' (1:120)
COMPLETED: November 19, 1995	TOTAL DEPTH: 2675.1 ft	Log Date: July 9, 1996	Sheet 27 OF 39



COMMENTS:

Alteration relogged: 7/96

DTN: SNT02110894001.002

Prow Pass Tuff, Unit 3 (Tcp3) *(1655.0-1837.8)* (continued)- - Medium brown-gray (2.5YR6/4); most intense welding at 1825, decreases in intensity to nonwelded at 1837.8; 10-15% moderately welded pink-white pumice <10mm; 1-4% red-orange siltstone and red-brown, devitrified, volcanic lithics <5mm, relative abundance of lithics increases slightly downward to contact at 1837.8; 5-10% phenos of quartz, feldspar, biotite, and hornblende/pyroxene(?); groundmass partly devitrified. Texture of rock becomes rectilinear-granular as intensity of vapor-phase alteration and welding decrease.

1829.5-1832.2 unrecvd

1836.3-1837.8 broken

1837.8

Prow Pass Tuff, Unit 2 (Tcp2) *(1837.8-1878.5)* -- *Note*: ash-fall marker bed that normally caps this unit was not found. Light pink-brown (2.5YR7/2); nonwelded, devitrified but with relict shard structure preserved; 20-25% devitrified, white pumice clasts up to 15-20mm; 3-7% red-orange siltstone and red-brown devitrified volcanic lithics in two size fractions: 1-2% 4-12mm, 2-5% <1-3mm; 10-15% quartz, feldspar, biotite, and hornblende/pyroxene(?) phenocrysts.

1848.4-1851.7 unrecvd

1857.9-1859.4 unrecvd

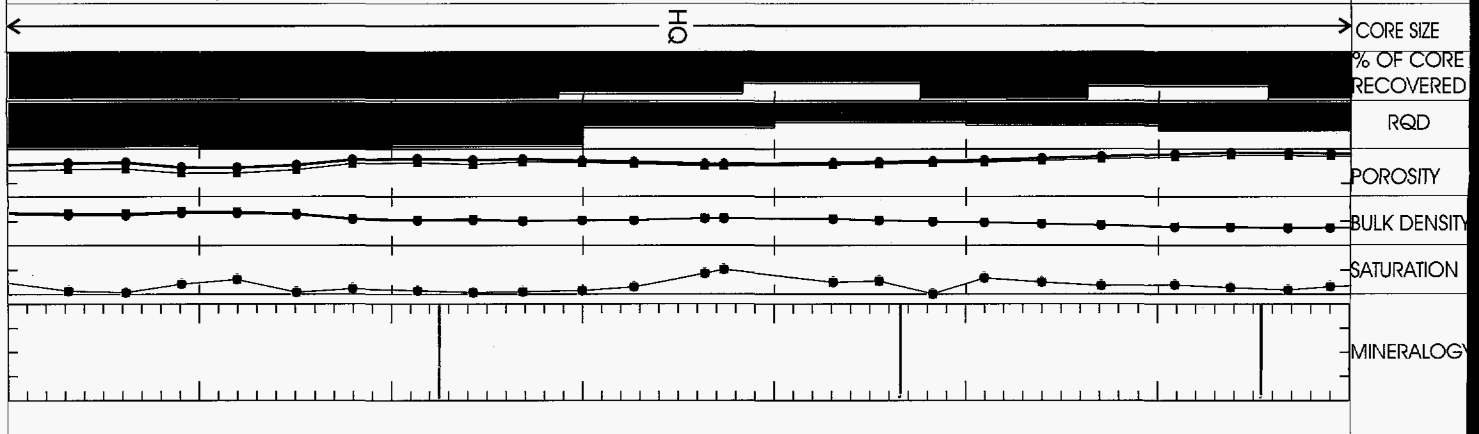
1873.0 pumice fall

Basal pumice fall (1873.0-1878.5), gradational contact -- light-medium pink-gray (5R6/3); nonwelded; partially devitrified and zeolitized; 25-35% pale-pink, altered, uniformly sized, pumice clasts up to 10mm, larger pumice zeolitized to light-pink zeolitic druze; 3-5% lithics of red-orange siltstone and red-brown or black, devitrified volcanic compositions up to 8mm; 8-12% quartz, feldspar, biotite and hornblende/pyroxene(?) phenos; intergranular surfaces speckled by micro-leaflets of FeMnOx. Groundmass texture changes downward from dense to porous/oriented-pumiceous.

1878.5

Prow Pass Tuff, Unit 1 (Tcp1) *(1878.5-2167.5)* -- Light pink-gray (5R7/4); nonwelded; zeolitized, but with intensity of alteration decreasing downward; 15-20% pale pink pumice <10mm; 2-3% red-orange siltstone and red-brown devitrified volcanic lithics up to 8mm.

1886.7-1886.9 - zone of mostly red-orange siltstone lithics from 8-30mm; 8-10% quartz, feldspar, biotite, and hornblende/pyroxene(?) phenos.



Yucca Mountain Project

Hole No: USW SD-7

Scale: 1"=10' (1:120)

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Sandia National Laboratories

Logged by: Dale Engstrom

Log Version: 2.02

Log Date: July 9, 1996

COLLAR COORDINATES (NSP): ELEVATION: 4470 ft

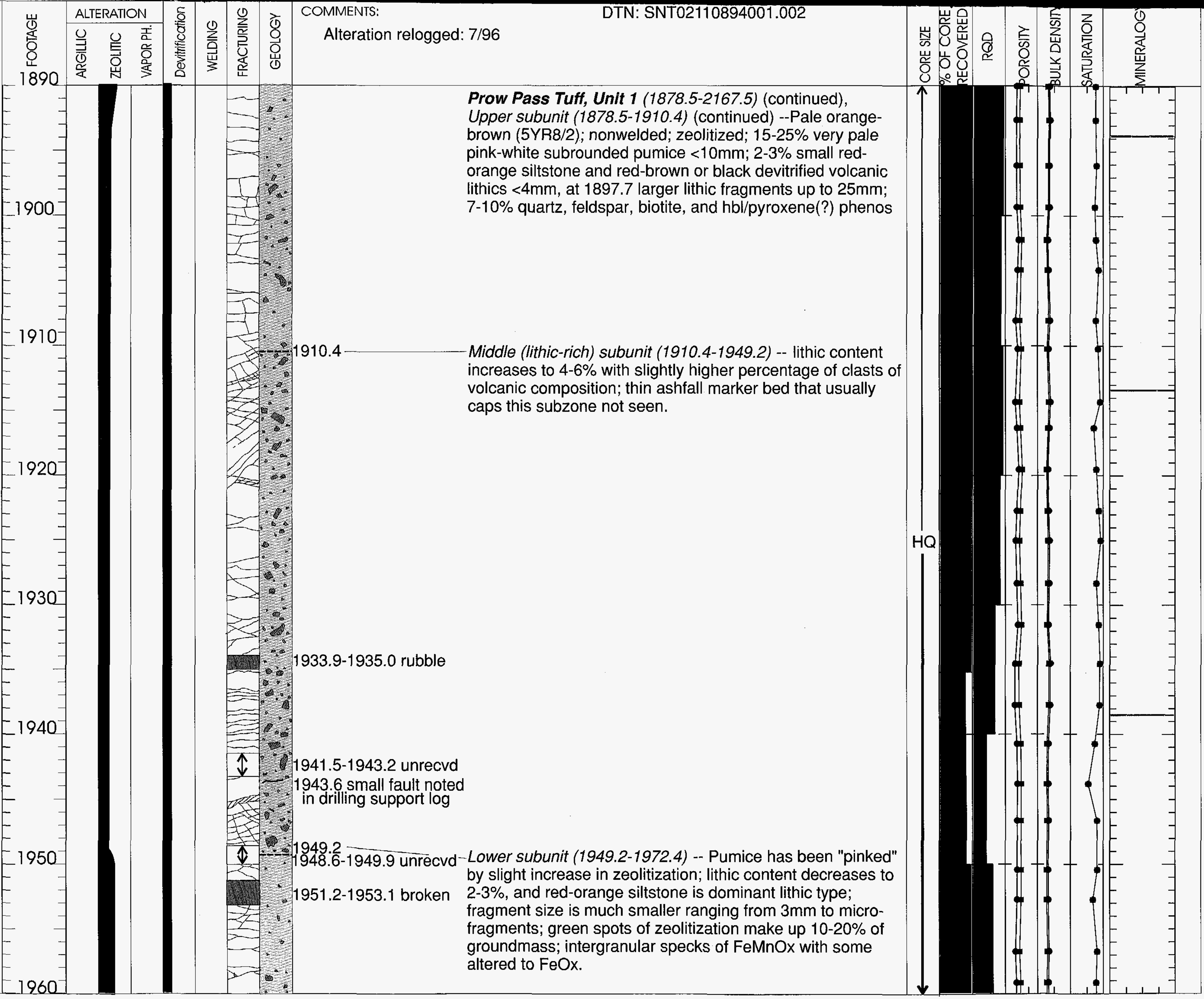
N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)

STARTED: October 31, 1994 INCLINATION: -90

COMPLETED: November 19, 1995 TOTAL DEPTH: 2675.1 ft

COMMENTS: DTN: SNT02110894001.002

Alteration relogged: 7/96



***Prow Pass Tuff, Unit 1** (1878.5-2167.5)* (continued), *Upper subunit (1878.5-1910.4)* (continued) --Pale orange-brown (5YR8/2); nonwelded; zeolitized; 15-25% very pale pink-white subrounded pumice <10mm; 2-3% small red-orange siltstone and red-brown or black devitrified volcanic lithics <4mm, at 1897.7 larger lithic fragments up to 25mm; 7-10% quartz, feldspar, biotite, and hbl/pyroxene(?) phenos

Middle (lithic-rich) subunit (1910.4-1949.2) -- lithic content increases to 4-6% with slightly higher percentage of clasts of volcanic composition; thin ashfall marker bed that usually caps this subzone not seen.

Lower subunit (1949.2-1972.4) -- Pumice has been "pinked" by slight increase in zeolitization; lithic content decreases to 2-3%, and red-orange siltstone is dominant lithic type; fragment size is much smaller ranging from 3mm to micro-fragments; green spots of zeolitization make up 10-20% of groundmass; intergranular specks of FeMnOx with some altered to FeOx.

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Hole No: USW SD-7
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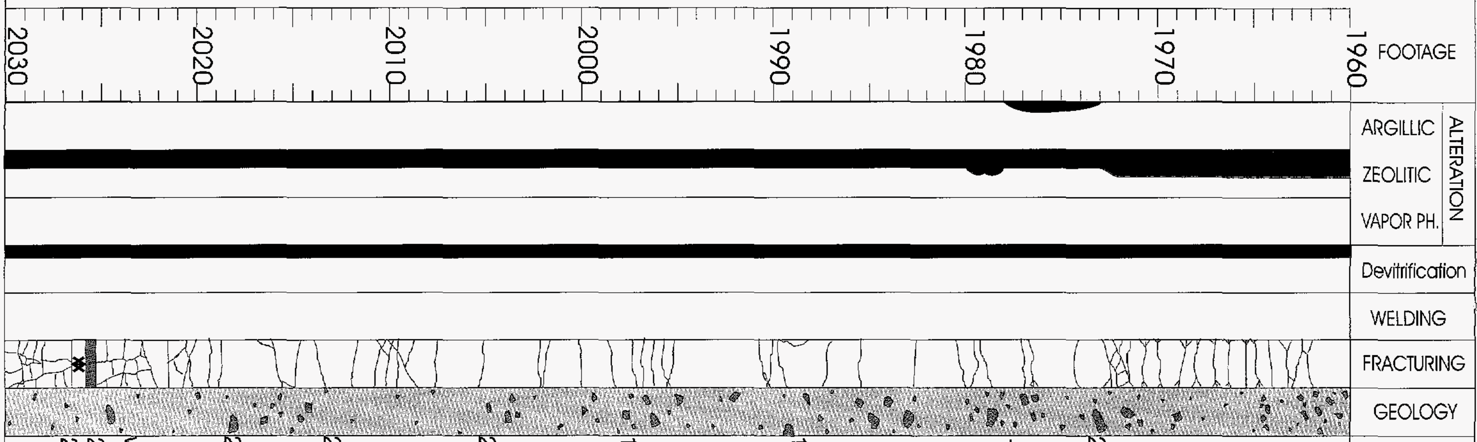


COMMENTS:

Alteration relogged: 7/96

DTN: SNT02110894001.002

Prow Pass Tuff, Unit 1 *(1878.5-2167.5)* (continued) -- Pale pink-tan (10R8/2), nonwelded to partially welded, zeolitized; 15-25% very pale pink-white subround pumice <10mm; 2-3% small red-orange siltstone and red-brown or black devitrified volcanic lithics <4mm, occasional larger lithics up to 25mm in swarms with pumice clasts; 7-10% quartz, feldspar, biotite, and hornblende/pyroxene(?) phenos; groundmass and pumice have been "pinked" by weak zeolitic alteration, 10-20% groundmass consists of dark green zeolitic spots; FeMnOx specks on intergranular surfaces.

relict froth textures preserved in pumice

20mm cavity after lithic

1978.0-1980.0 - interval of deformed (flattened) pumice

1988.7- 65mm cavity after plucked pumice

1997.5 - large pumices more common (up to 75mm)

2005-2007 - core pockmarked by plucked, softened pumice, leaving cavities up to 15-20mm diameter.

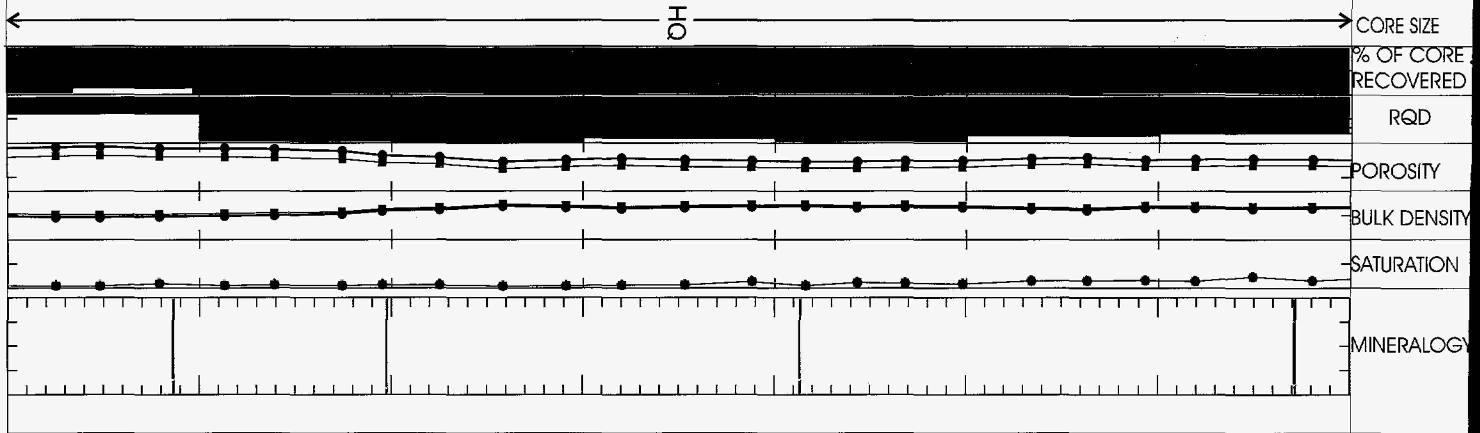
Rock has changed to 20-30% light pink-white or pale-gray pumice up to 20mm; 3-5% quartz, feldspar phenos, 1-2% biotite, pyroxene(?), hornblende(?) phenos; 1-3% <5mm lithics, mostly red-brown dense-textured quartz latite composition, some quartz latite lithics up to 15mm exhibit zeolitically altered borders approx. 3mm thick; small percentage (<1%) of red siltstone variety; pumice and lithics occur in swarms. Groundmass has been "pinked" by weak zeolitic alteration and appears dense but not recrystallized.

2013.-2016 lithic zone

2018.0 25mm cavity

vertical fracture coated by metallic, black oxide (MnOx?).

2025.3-2025.7 broken
2025.7-2026.6 unrecvd



COLLAR COORDINATES (NSP):
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Sandia National Laboratories
Logged by: Dale Engstrom
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Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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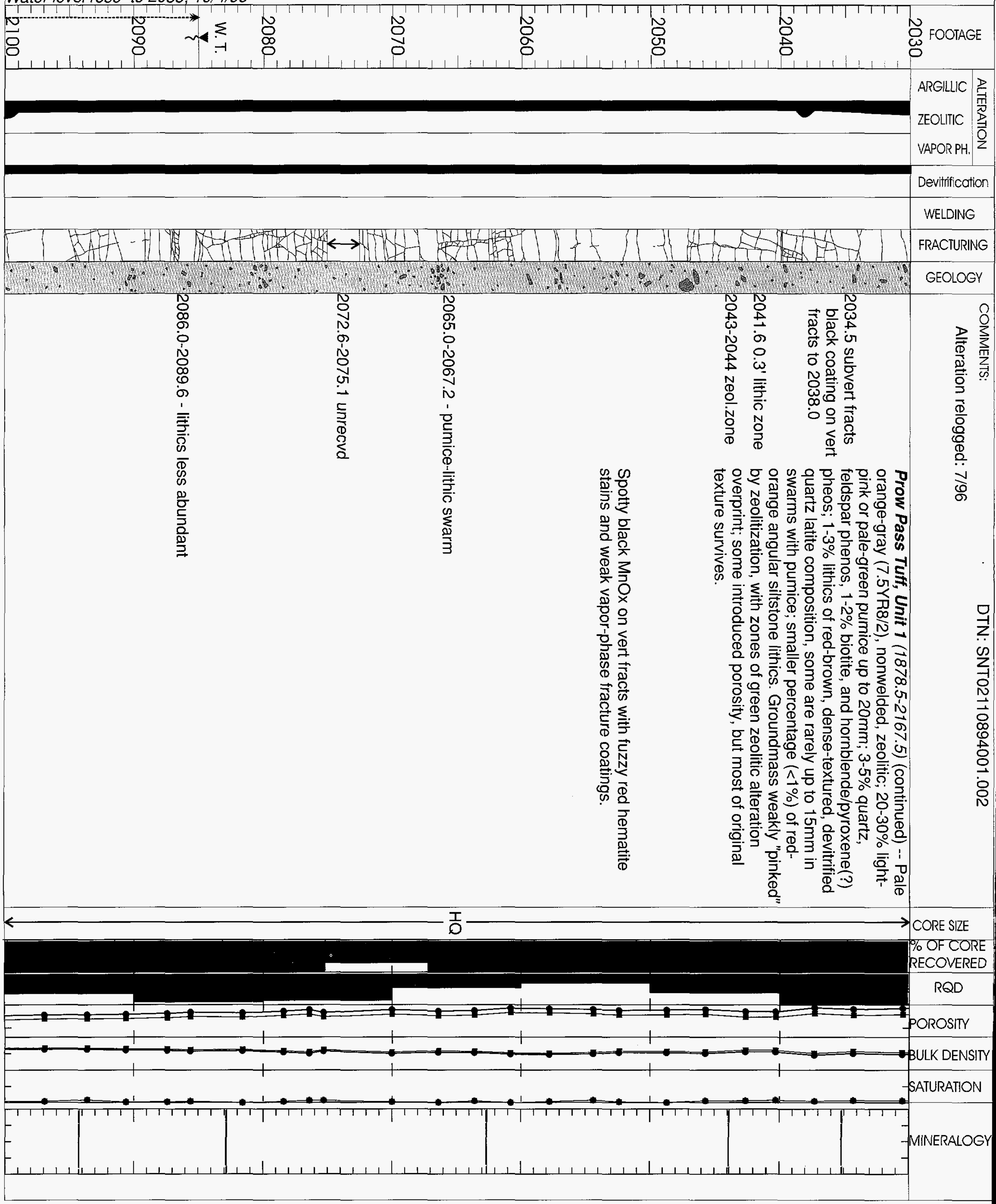
Water level rose to 2085; 10/4/95



COMMENTS:

Alteration relogged: 7/96

DTN: SNT02110894001.002

Prow Pass Tuff, Unit 1 *(1878.5-2167.5)* (continued) -- Pale orange-gray (7.5YR8/2), nonwelded, zeolitic; 20-30% light-pink or pale-green pumice up to 20mm; 3-5% quartz, feldspar phenos, 1-2% biotite, and hornblende/pyroxene(?) phenos; 1-3% lithics of red-brown, dense-textured, devitrified quartz latite composition, some are rarely up to 15mm in swarms with pumice; smaller percentage (<1%) of red-orange angular siltstone lithics. Groundmass weakly "pinked" by zeolitization, with zones of green zeolitic alteration overprint; some introduced porosity, but most of original texture survives.

2034.5 subvert fracts black coating on vert fracts to 2038.0

2041.6 0.3' lithic zone

2043-2044 zeol.zone

Spotty black MnOx on vert fracts with fuzzy red hematite stains and weak vapor-phase fracture coatings.

2065.0-2067.2 - pumice-lithic swarm

2072.6-2075.1 unrecvd

2086.0-2089.6 - lithics less abundant

COLLAR COORDINATES (NSP): ELEVATION: 4470 ft

N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)

STARTED: October 31, 1994 INCLINATION: -90

COMPLETED: November 19, 1995 TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories

Logged by: Dale Engstrom

Log Version: 2.02

Log Date: JJuly 9, 1996

Yucca Mountain Project

Hole No: USW SD-7

Scale: 1"=10' (1:120)

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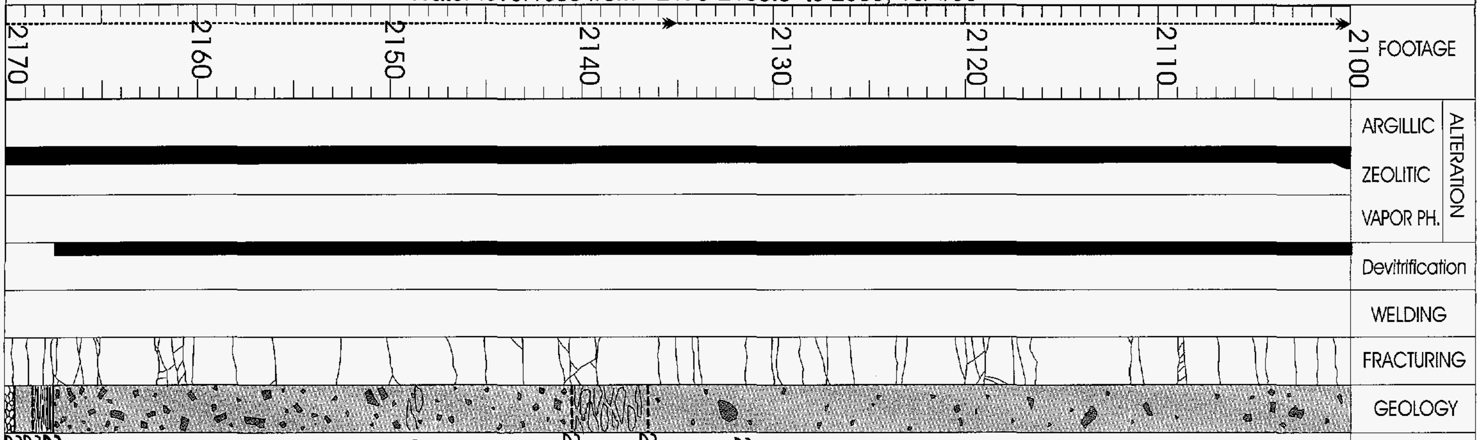
Water level rose from ~2179-2185.3 to 2085; 10/4/95



COMMENTS:

DTN: SNT02110894001.002

Alteration relogged: 7/96

Prow Pass Tuff, Unit 1 _(1878.5-2167.5)_ (continued) -- Pale orange-green (10YR8/1), nonwelded; 25-30% laminated, pale-orange or-ruddy pink pumice that are generally <25mm but rarely up to 45mm; pumice usually contain dark-green zeolitized spots, 1-2% quartz, feldspar, and biotite phenos; 1-3% lithics <5mm of red-brown devitrified volcanic and red siltstone compositions. Increasing alteration creates secondary porosity with micro-globular zeolite mineralization within the voids; about 1/3 of rock is zeolitized, original texture obliterated; groundmass 100% altered.

2132 - patchy greenish-white alt'n.

2136.6

2136.6-2140.6 - zone of large, elongated white pumice up to 100mm in length with almost no assocated lithics.

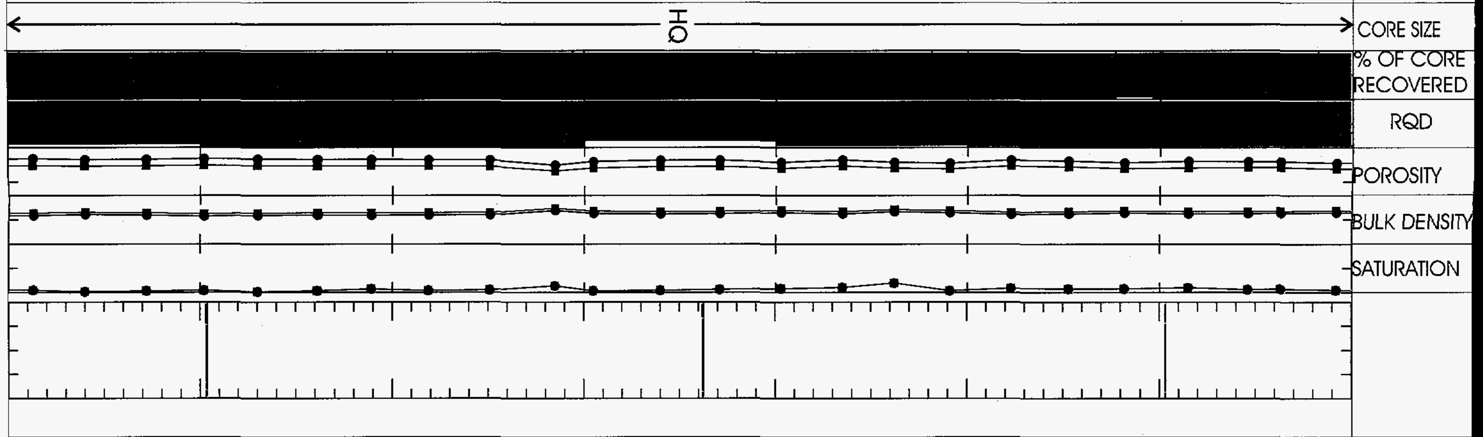
2140.6

2140.6 - Increase in lithic content to 5-7%; 1/3 of lithics are red silstone, 2/3 are red-brown devitrified volcanic composition; most lithics <5mm, locally up to 10mm.

elongate pumice clasts

Prow Pass Tuff, Bedded Tuff Unit _(2167.5-2180.2)_ -- _2167.5-2168.5 - laminated ashfall:_ fine-grained, ashy, bedded tuff with 1% angular volcanic lithics <3mm; <1% green zeolitized pumice <3mm; 1% quartz, feldspar, and biotite crystals; <1% rounded reworked blebs of MnOx <2mm.
2168.5-2169.4 - pumiceous ash-flow deposit: red-gray, medium-grained; 2-4% black lithics <3mm (MnOx coated?).
2169.4-2170.3 - pumice fall, medium-grained pumice fall with 4-5% black and dark mottled-brown lithics mostly <3mm, up to 5mm; some pumice altered to green zeolite; middle 0.2 feet of unit is slightly coarser with "pinked" pumices and slight larger content of lithics.

2167.5 lam. ashfall
2168.5 pum. ashflow
2169.4 pumice fall



COLLAR COORDINATES (NSP):
N: 758950.0 ft E: 561240.0 ft
STARTED: October 31, 1994
COMPLETED: November 19, 1995

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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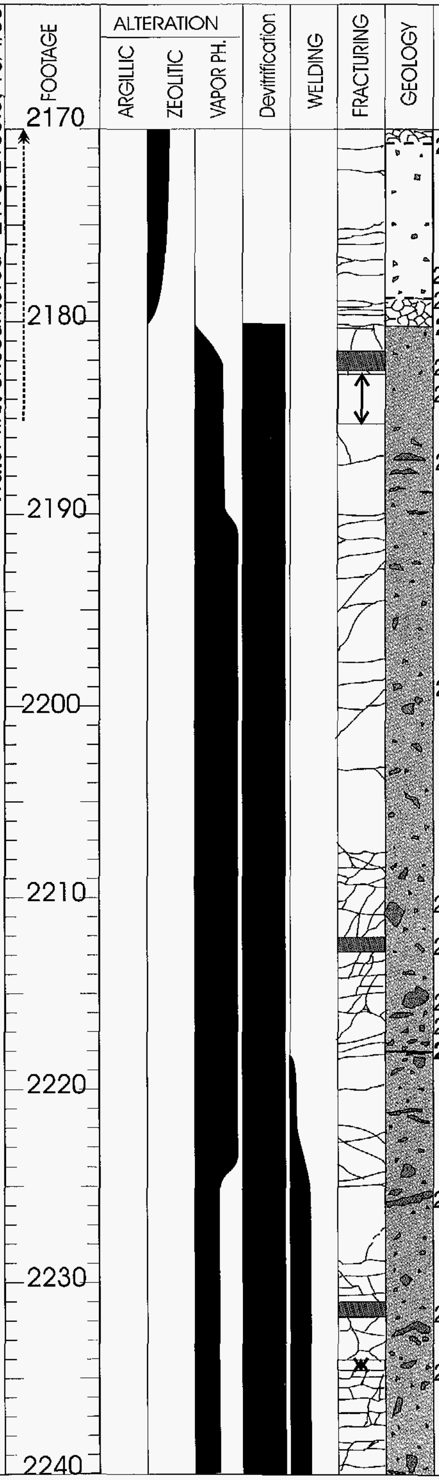
Water first encountered ~2179-2185.3; 10/4/95



COMMENTS:

DTN: SNT02110894001.002

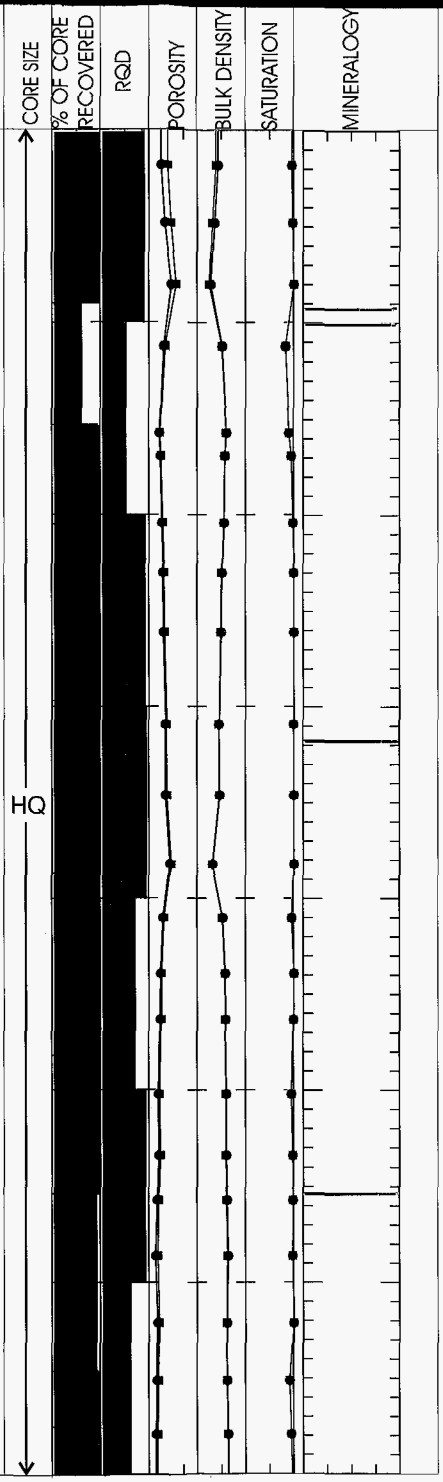
Alteration relogged: 7/96

2170.3
2178.7 fault (?)
2178.8 basal bxa
2180.2
2181.4-2182.5 broken
2182.8-2185.3 unrecvd
2187.7-2190.5 - large soft lithics
2195.6-2204.1 - mud covered
2210.2-75mm c.g. qtz latite lithic
2212.0-2212.7 broken
2215.2-60mm c.g. qtz latite lithic
2216-2225.5 large,flat qtz latite lithics
2218.0
2225.5 - large flat deformed quartz latite lithic (could be parting to new unit); decr. in intensity of pervasive, grey, vapor-phase alt'n.
2230.9-2231.7 broken
2234.0-2234.6 unrecvd

Prow Pass Tuff, Bedded Tuff *(2167.5-2180.2)* (continued) - *2170.3-2178.8 - reworked ashflow tuff:* Pale orange-gray (5YR8/2); 15-20% pale pink-gray pumice <5mm; 5-10% micro- to 7mm lithics, dominantly brown-gray devitrified volcanic with lesser red siltstone; 3-5% quartz, feldspar, biotite, and pyroxene(?) phenos coated by MnOx; ashy, reworked matrix hosts clastic grains.
2170.3-2172.2 - weakly hematite stained (paleosurface?).
2178.7 drilling support log indicates possible fault
2178.8-2180.2 - basal vocanic breccia.

Bullfrog Tuff, Unit 4 *(2180.2-2218.0)* -- medium red-gray (10R7/2), nonwelded, devitrified, pervasively, grey, vapor-phase altered; 7-10% pale gray pumice <2mm, difficult to distinguish from the groundmass; 20-25% dark, glassy quartz and feldspar phenos, 5-10% oxybiotite, altered pyroxene or hornblende; 1-2% red siltstone lithics <4mm; sparse medium-gray pumiceous or laminated pumiceous. lithics up to 60mm. Groundmass is fine-grained, shardy, pervasively vapor-phase altered between fragments but with intensity of alteration increasing gradually downward; small but abrupt change in alteration intensity at 2190.0.

Bullfrog Tuff, Unit 3 *(2218.0-2478.0)* -- Medium orange-gray (5yR6/2), weakly to moderately welded from 2218.0-2225.5, strongly welded by 2226.5; constituents as above, but with addition of flattened texture.



COLLAR COORDINATES (NSP):
N: 758950.0 ft E: 561240.0 ft
STARTED: October 31, 1994
COMPLETED: November 19, 1995

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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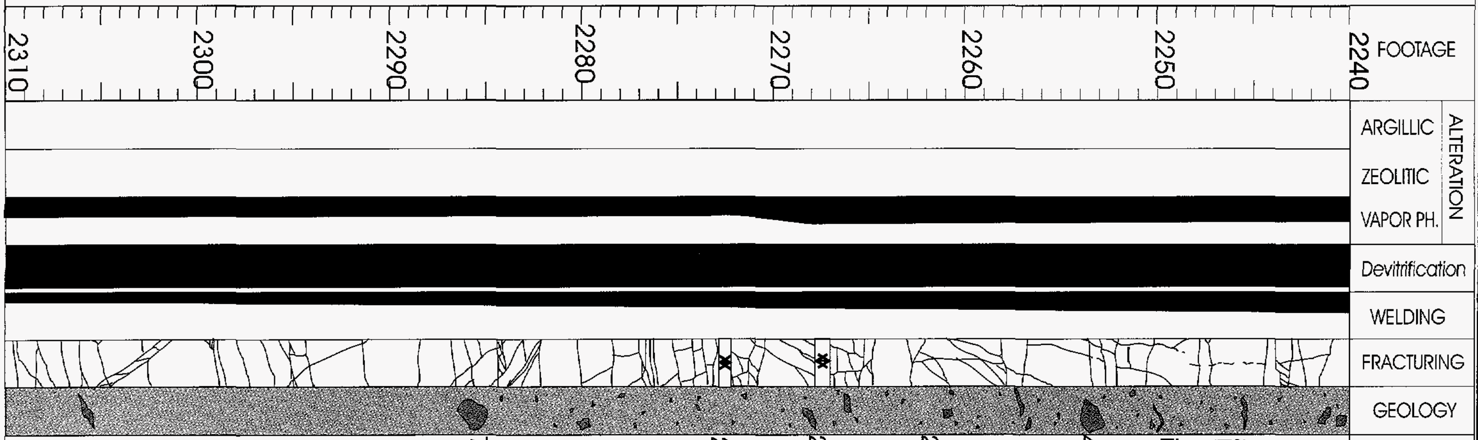


COMMENTS:
Alteration relogged: 7/96
DTN: SNT02110894001.002

approx. peak welding
healed irreg. vert. fract.

irreg. fract sets at 30° to core axis extend downward

40mm c.g. xl-rich lithic

2262.1-2267.0 mud covered

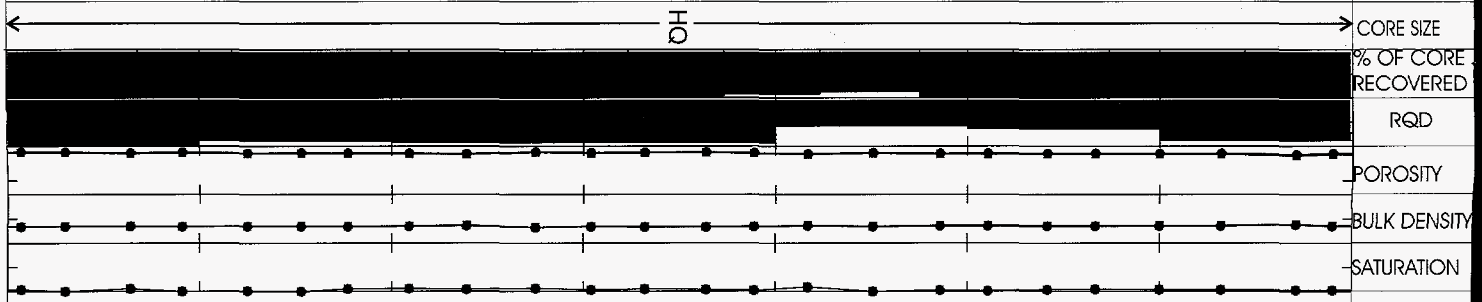
2267.0-2267.7 unrecvd

2272.3-2272.7 unrecvd

75mm c.g. xl-rich lithic

Bullfrog Tuff, Unit 3 *(2218.0-2478.0)* (continued) -- Medium orange-gray (5YR6/2); flattened, welded texture; degree of welding decreases below 2246. 7-10% pale orange-gray flattened pumice ~7mm in length; 20-25% quartz and feldspar phenos, 5-10% oxybiotite, pyroxene(?) and hornblende(?) phenos; 1-2% red siltstone and coarse-grained crystal-rich volcanic lithics, 50% of lithics very small (<2mm), 40% large (>30mm); 10% are deformed, dense-textured quartz latite >30mm; large soft lithics less frequent below 2242.

Alteration: Vapor-phase alt'n above approx. 2265-68 ft is grey and exhibits classical "sugary" granular texture. Alteration below approx 2273-75 ft is more "mottled" in appearance. Darker orange-grey portion appears more microcrystalline and may represent earlier, higher temperature devitrification assemblage, whereas lighter orange-grey part that preferentially affects small pumice clasts appears more grainy and may represent vapor-phase alteration under different oxidation conditions than grey style of vapor-phase alt'n above 2265.



COLLAR COORDINATES (NSP):
N: 758950.0 ft E: 561240.0 ft
STARTED: October 31, 1994
COMPLETED: November 19, 1995

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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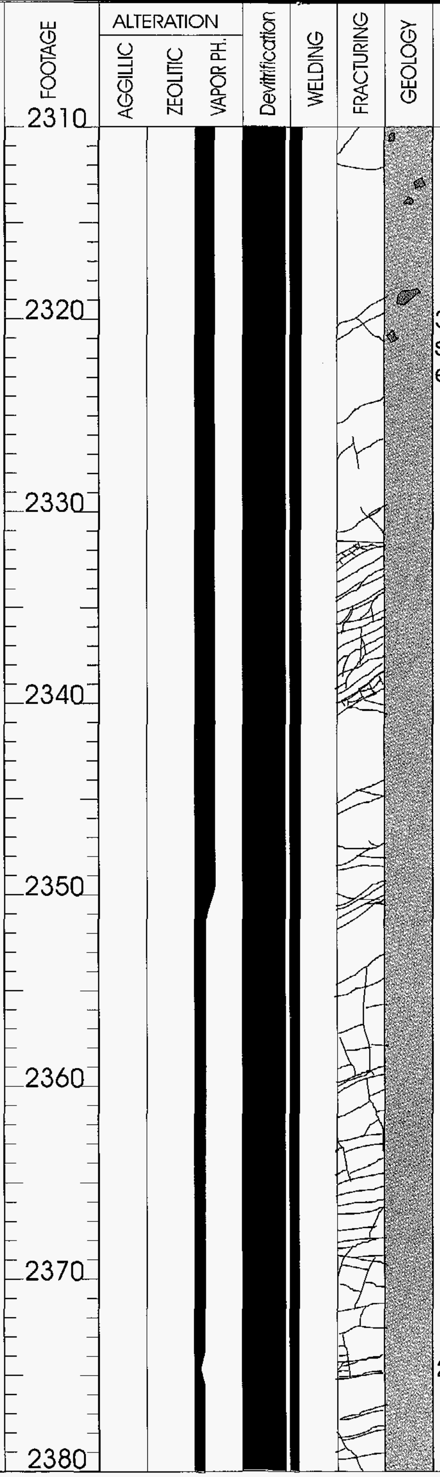


COMMENTS:

DTN: SNT02110894001.002

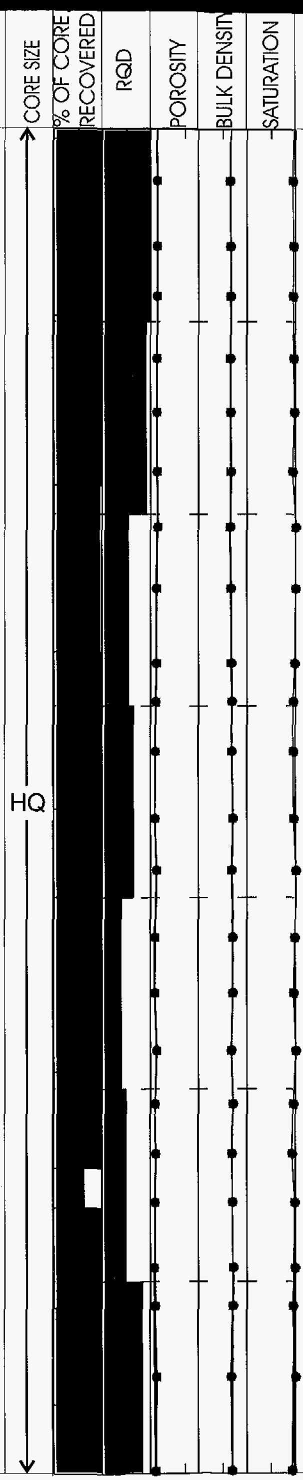
Alteration relogged: 7/96

Bullfrog Tuff, Unit 3 *(2218.0-2478.0)* (continued) -- Medium orange-gray (5YR6/2); devitrified; flattened but less welded than above. 10-15% small, flattened pumice vapor-phase alt'd to medium purple-gray, pumice increase in number to 50-60% of rock volume between 2354-2385, but degree of welding remains approx. constant; 20-25% quartz and feldspar phenos; 2-3% biotite, pyroxene(?), hornblende(?) phenos, 1-2% small angular red siltstone lithics; rare, large, crystal-rich volcanic lithics up to 75mm. Groundmass is devitrified, microcrystalline and partially vapor-phase altered, producing strong mottled appearance.

30°fracts become dom. structural element, esp. 2330-2340

2350 ± : stronger mottled appearance; light-orange-grey vapor-phase(?) alt'n changes from widely distributed within rock mass to affecting much more discrete areas.

2374-2376- stronger mottled texture

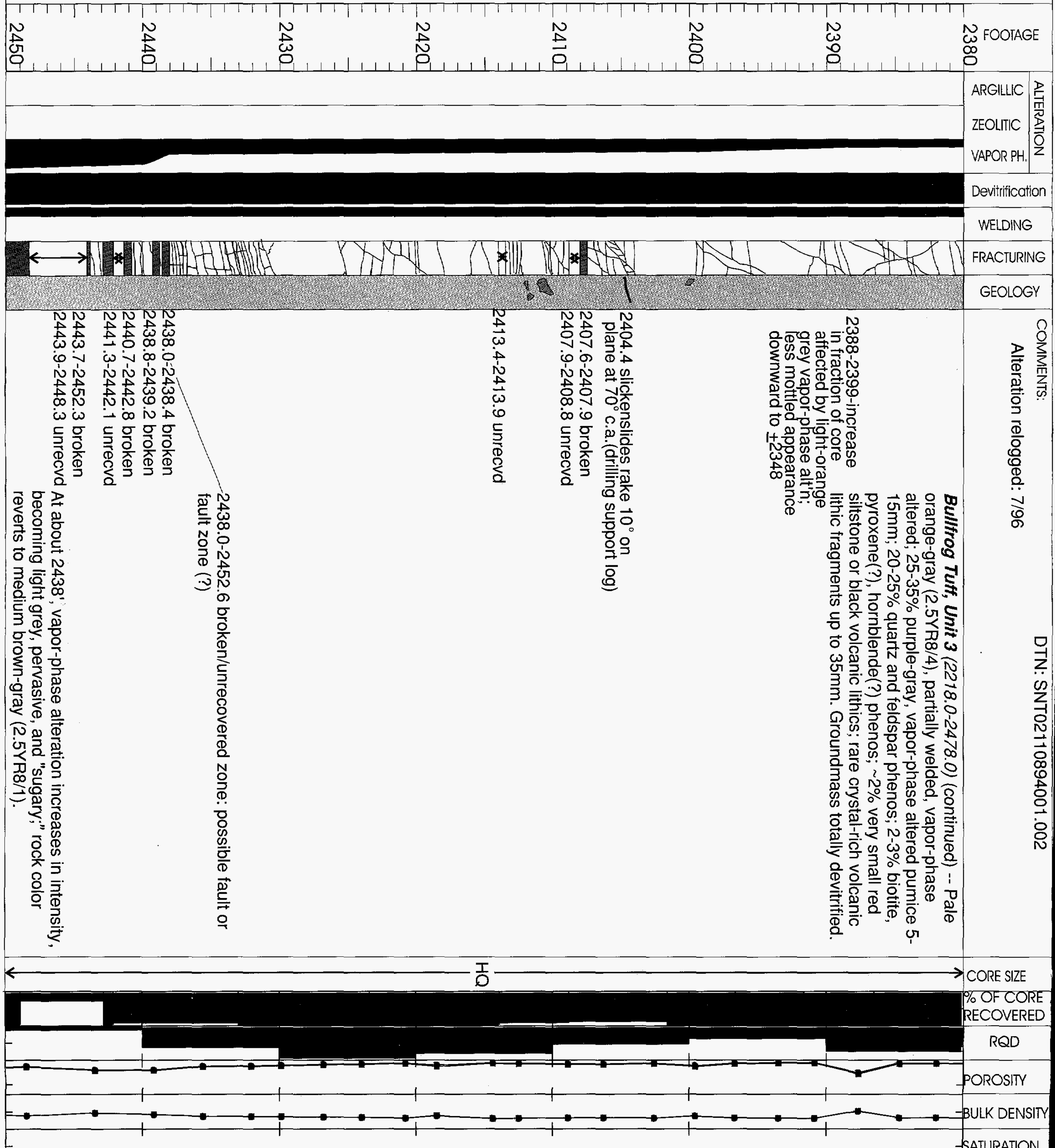


COLLAR COORDINATES (NSP):
N: 758950.0 ft E: 561240.0 ft
STARTED: October 31, 1994
COMPLETED: November 19, 1995

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
Sheet 35 OF 39



Alteration relogged: 7/96

DTN: SNT02110894001.002

Bullfrog Tuff, Unit 3 *(2218.0-2478.0)* (continued) -- Pale orange-gray (2.5YR8/4), partially welded, vapor-phase altered; 25-35% purple-gray, vapor-phase altered pumice 5-15mm; 20-25% quartz and feldspar phenos; 2-3% biotite, pyroxene(?), hornblende(?) phenos; ~2% very small red siltstone or black volcanic lithics; rare crystal-rich volcanic lithic fragments up to 35mm. Groundmass totally devitrified.

2388-2399-increase in fraction of core affected by light-orange grey vapor-phase alt'n; less mottled appearance downward to ±2348

2404.4 slickensides rake 10° on plane at 70° c.a.(drilling support log)
2407.6-2407.9 broken
2407.9-2408.8 unrecvd

2413.4-2413.9 unrecvd

2438.0-2452.6 broken/unrecovered zone: possible fault or fault zone (?)

2438.0-2438.4 broken
2438.8-2439.2 broken
2440.7-2442.8 broken
2441.3-2442.1 unrecvd
2443.7-2452.3 broken
2443.9-2448.3 unrecvd At about 2438', vapor-phase alteration increases in intensity, becoming light grey, pervasive, and "sugary;" rock color reverts to medium brown-gray (2.5YR8/1).

COLLAR COORDINATES (NSP):
N: 758950.0 ft E: 561240.0 ft
STARTED: October 31, 1994
COMPLETED: November 19, 1995

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.01
Log Date: June 1, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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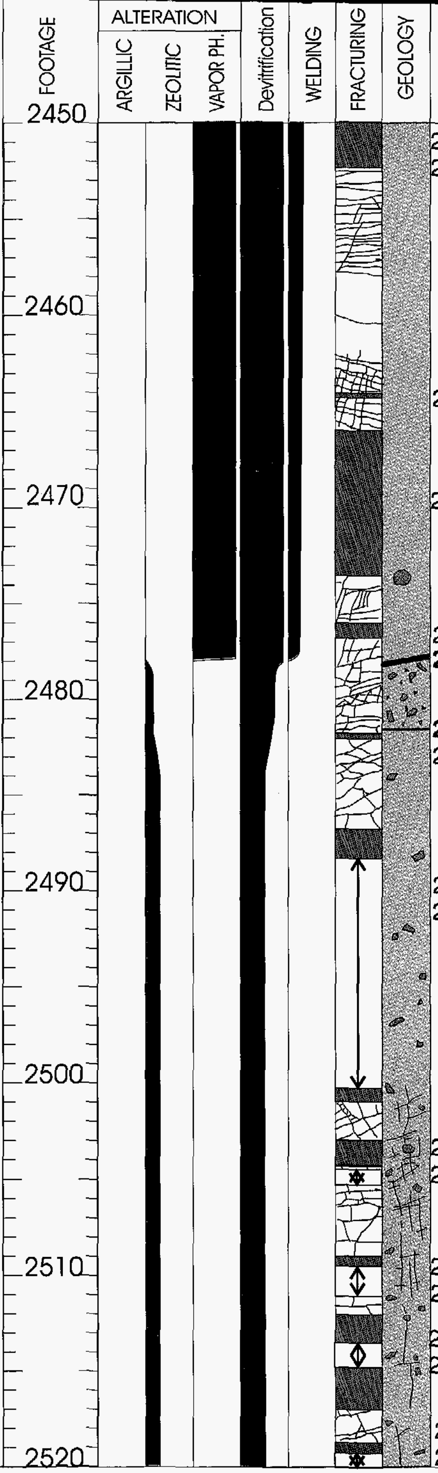


COMMENTS:

DTN: SNT02110894001.002

Alteration relogged: 7/96

2449.3-2452.3 broken
2452.3-2452.6 unrecvd

Bullfrog Tuff Unit 3 *(2218.0-2478.0)* (continued) -- Medium brown-gray (2.5YR8/1), partially welded; 35-45% medium brown-gray pumice 10mm size, flattened 1:6-8; 20-25% quartz and feldspar phenos; 2-3% biotite, pyroxene(?), hornblende(?) phenos; ~2% red siltstone and black devitrified volcanic lithics that are <2mm. Core badly broken between 2464.1-2566.2' (possible fault related).

2464.1-2464.3 broken

2466.0-2473.5 rubble, possible fault zone

2473.5, core becomes soft with ragged vertical fractures.
2478.0, 0.2' fault gouge, 10° to core axis with slickensides and hematite on the slicks.

fault contact

Bullfrog Tuff, Pumiceous Unit 2 *(2478.0-2481.5)* -- Medium grained pumice-rich unit. Pale yellow-gray (10YR8/1.5), nonwelded; 35-45% medium brown-gray ovoid pumice averaging 10mm; 20-25% medium-grained quartz and feldspar phenos; 2-3% fine-grained biotite and pyroxene(?) phenos; ~5% red siltstone and dark-gray, devitrified volcanic lithics; 10-15% of pumice altered to yellow-orange zeolite(?). 2381.5 - 2-3 cm clay or zeolite layer.

2476.1-2476.8 broken
2478.0 fault w/ gouge, slicks at 10° c.a.
2481.5
2481.7-2482.1 broken

Bullfrog Tuff, Unit 1 *(2481.5-2579.4)* -- Pale orange-gray (5YR7/3), nonwelded; 5-10% 10mm pumice difficult to distinguish from matrix; 15-20% quartz, feldspar phenos; 5-10% biotite, pyroxene(?) phenos abundant end-on biotite); 3-5% red-brown siltstone and black devitrifed volcanic lithics <2mm, but occasionally up to 12-15mm. Groundmass approx 2/3 recrystallized to zeolite. Core badly broken from 2464.1-2566.2 (possible fault related). Silica veins on mostly open, vertical fractures from 2500.2-2511.3; veins average 2-3mm wide; mostly clear crystalline quartz with bluish, opaline wall coating.

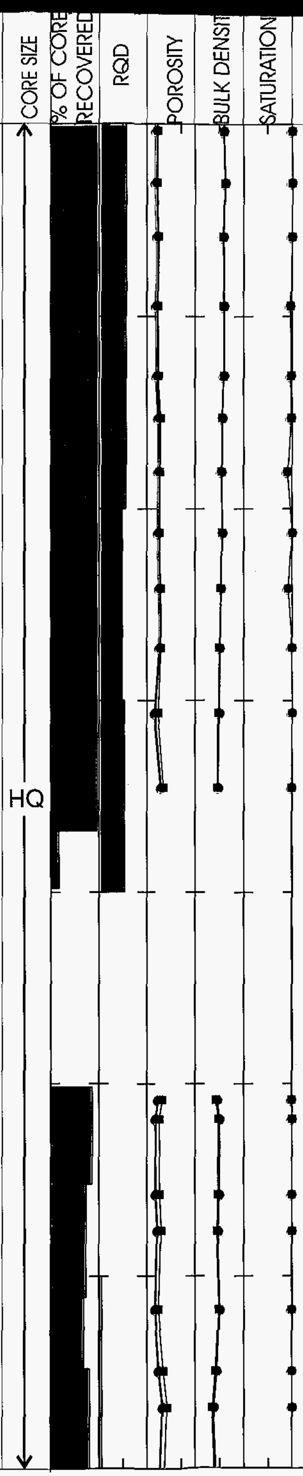
2486.8-2500.9 broken
2487.3-2500.2 unrecvd
(12.9' missing)

2502.9-2504.3 broken
2504.5-2505.2 unrecvd

2509.0-2509.5 broken
2509.5-2511.1 unrecvd

2512.1-2516.9 rubble
2513.6-2514.8 unrecvd

2518.8-2519.2 broken
2519.2-2520.3 unrecvd



COLLAR COORDINATES (NSP):
N: 758950.0 ft E: 561240.0 ft
STARTED: October 31, 1994
COMPLETED: November 19, 1995

ELEVATION: 4470 ft
BEARING: N/A (vertical)
INCLINATION: -90
TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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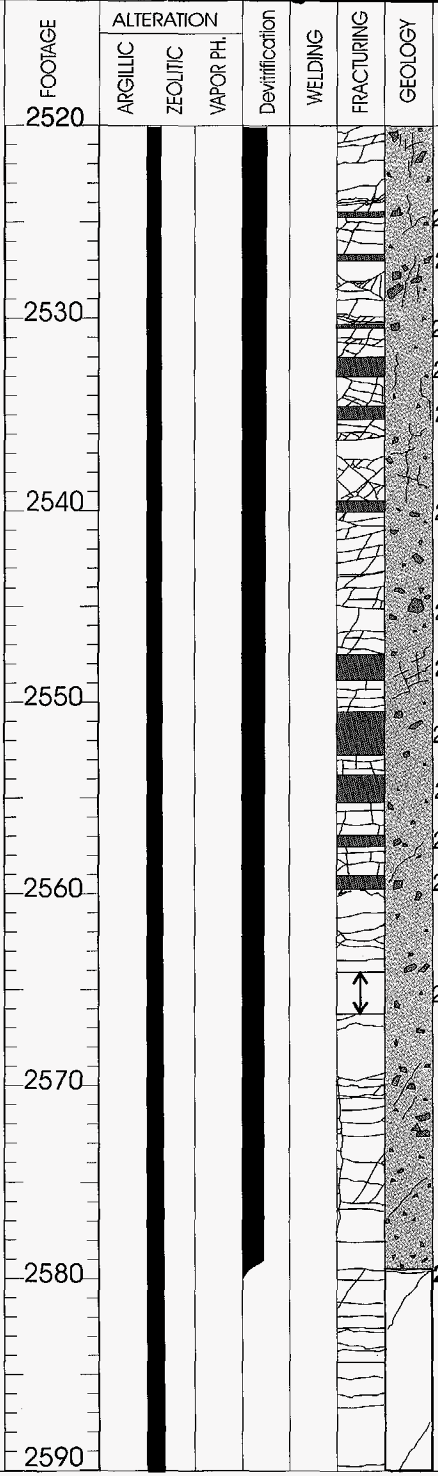


COMMENTS:

DTN: SN02110894001.002

Alteration relogged: 7/96

2524.5-2524.7 broken

2526.7-2527.1 rubble

2530.3-2530.5 rubble

2532.0-2533.0 broken

2534.6-2535.2 broken

2539.5-2540.1 broken

2545.0 black rimmed, soft yellow-cored lithic

2547.4-2548.7 broken

2550.4-2552.8 rubble

2553.7-2555.2 rubble, sand for the last foot (possible fault residue).

2556.9-2557.6 broken

2559.1-2559.7 broken

2564.1-2565.2 unrecvd

2568-alt'n becomes "patchy" over 2-5 cm

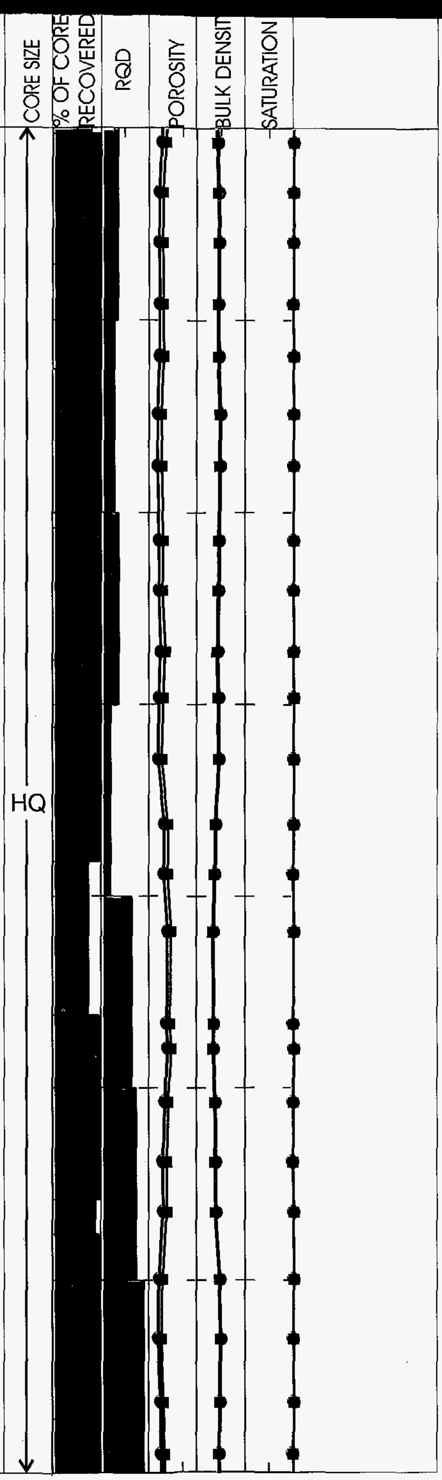
2575-core becomes progressivel more "bleached" toward basal contact

2579.4

2588.4

Bullfrog Tuff, Unit 1 *(2481.5-2579.4)* (continued) -- Light red-gray (10R7/5), nonwelded, zeolitic; 5-10% pale-gray pumice up to 10mm; 2-3% quartz, feldspar phenos; 1% or less biotite, pyroxene(?); 3-4% small (<2mm) lithics of red-brown devitrified volcanic or of lesser red siltstone compositions; Groundmass is pink, aphanitic, totally zeolitized; Sparse silica veining (one per 3-5 ft or so); veins average 2-3mm in width and are composed of clear crystalline quartz with opaline wall coating.

Bullfrog Tuff, Basal Tuffaceous Sandstone *(2579.4-2598.0)* -- Light-medium red (10R7/4); unit is capped by 25mm thick, deep red-brown (7.5R5/2), dense, ashfall parting. 10-15% pale- pink, 5mm pumice clasts; 15-20% quartz, feldspar crystals; 3-5% biotite, pyroxene(?), hornblende(?) crystals; 3-5% red-brown devitrified volcanic or lesser red siltstone lithics <2mm .Matrix is ashy and weakly hematite-stained. Subvertical joints exhibit very weak silica veining (fracture coatings); particle size becomes coarser from 2588.0-2588.4 and 2592.0-2592.8; coarser material at 2588.4 may represent basal lag deposition with a bedding parting at the contact.



COLLAR COORDINATES (NSP): ELEVATION: 4470 ft
N: 758950.0 ft E: 561240.0 ft BEARING: N/A (vertical)
STARTED: October 31, 1994 INCLINATION: -90
COMPLETED: November 19, 1995 TOTAL DEPTH: 2675.1 ft

Sandia National Laboratories
Logged by: Dale Engstrom
Log Version: 2.02
Log Date: July 9, 1996

Yucca Mountain Project
Hole No: USW SD-7
Scale: 1"=10' (1:120)
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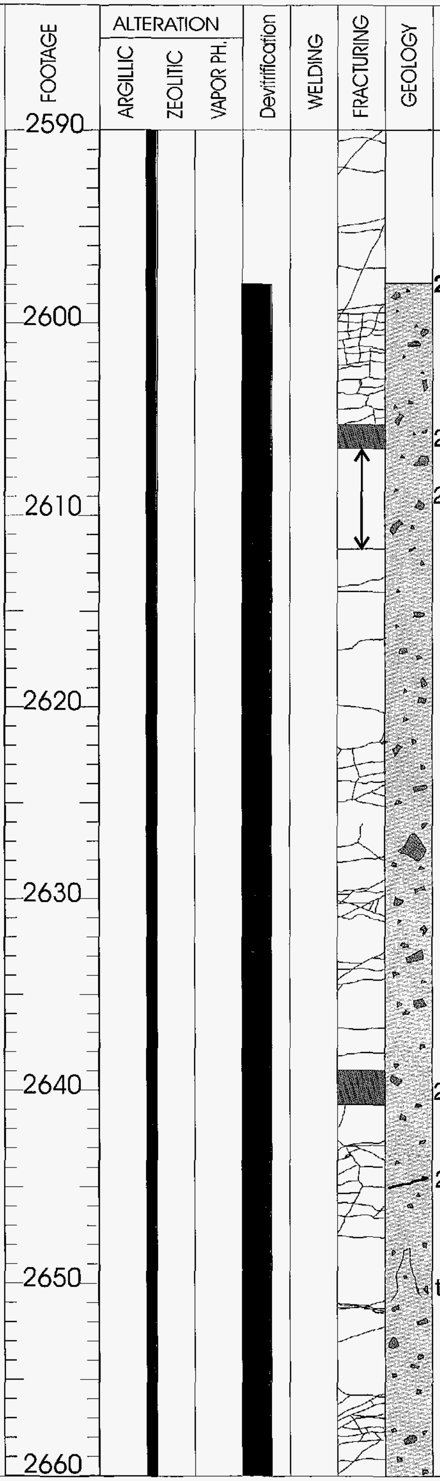


COMMENTS:

DTN: SNT02110894001.002

Alteration relogged: 7/96

2598.0

2605.2-2606.6 rubble

2606.6-2611.8 unrecvd

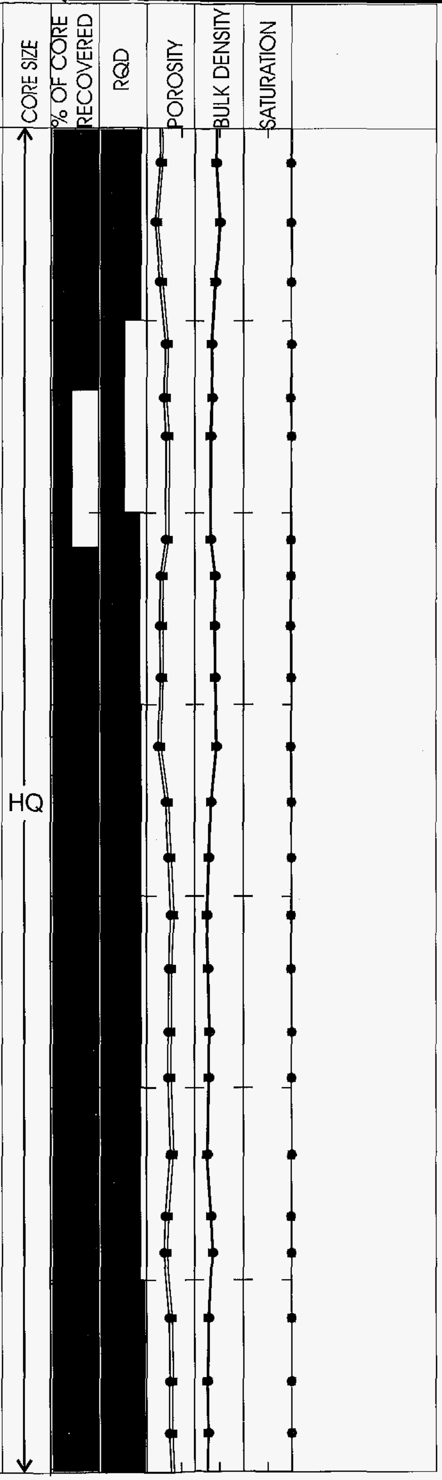
2638.9-2640.8 rubble

2644.9 fault w/slicks at 80° c.a. (drilling support log)

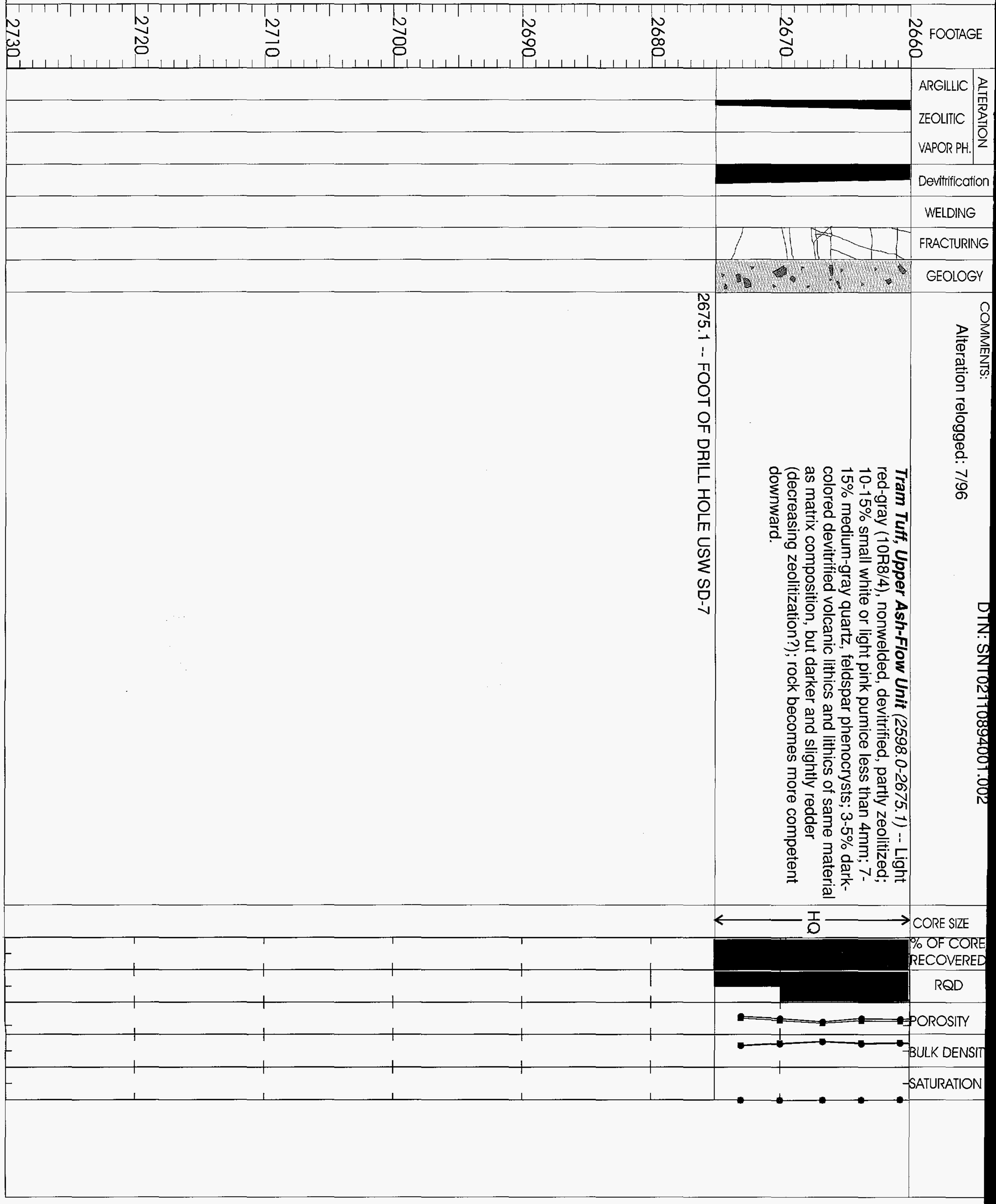
thin syndepositional dike(?)

Bullfrog Tuff, Basal Tuffaceous Sandstone *(2579.4-2598.0)* (continued) -- Light medium-red (10R7/5), weakly bedded, mostly unsorted or only crudely sorted. 10-15% pale pink pumice clasts up to 5mm; 10-15% quartz, feldspar crystals; 3-5% botite, pyroxene(?), hornblende(?) crystals; 3-5% <2mm red-brown devitrified volcanic or lesser red siltstone lithics; Matrix is ashy, reworked, and weakly hematite-stained. Silica coats on vertical joints. Coarser grained zone from 2592.0-2592.8'.

Tram Tuff, Upper Ash-Flow Unit *(2598.0-2675.1)* -- Light red-gray (10R8/4), nonwelded, devitrified, partly zeolitized; 10-15% small white or light pink pumice <4mm; 7-12% medium gray quartz, feldspar phenos; <1% biotite phenos; 3-5% lithics of dark-colored, devitrified, volcanic composition and material that resembles the matrix but is slightly redder and darker; tuff is hematite-stained at the top of the unit (paleosurface?), becoming light red-tan to beige with depth.



COLLAR COORDINATES (NSP):	ELEVATION: 4470 ft	Sandia National Laboratories	Yucca Mountain Project
N: 758950.0 ft E: 561240.0 ft	BEARING: N/A (vertical)	Logged by: Dale Engstrom	Hole No: USW SD-7
STARTED: October 31, 1994	INCLINATION: -90	Log Version: 2.02	Scale: 1"=10' (1:120)
COMPLETED: November 19, 1995	TOTAL DEPTH: 2675.1 ft	Log Date: July 9, 1996	Sheet 39 OF 39



COMMENTS:

Alteration relogged: 7/96

DTN: SNF02110894001.002

Tram Tuff, Upper Ash-Flow Unit *(2598.0-2675.1)* -- Light red-gray (10R8/4), nonwelded, devitrified, partly zeolitized; 10-15% small white or light pink pumice less than 4mm; 7-15% medium-gray quartz, feldspar phenocrysts; 3-5% dark-colored devitrified volcanic lithics and lithics of same material as matrix composition, but darker and slightly redder (decreasing zeolitization?); rock becomes more competent downward.

Appendix C: Core Recovery Data

Table C-1: Core Recovery Data

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
0	51.0	--	--	--	1
1	58.0	7.0	7.0	100	1
2	62.7	4.7	4.0	85	1
3	69.7	7.0	6.1	87	1
4	72.1	2.4	2.2	92	1
5	73.2	1.1	0.0	0	1
6	82.2	9.0	3.4	38	1
7	83.5	1.3	0.0	0	1
8	88.0	4.5	4.2	93	1
9	93.1	5.1	4.1	80	1
10	96.6	3.5	3.5	100	1
11	102.2	5.6	5.6	100	1
12	109.1	6.9	6.9	100	1
13	117.1	8.0	6.1	76	1
14	121.9	4.8	3.4	71	1
15	128.7	6.8	5.8	85	1
16	134.2	5.5	4.4	80	1
17	142.3	8.1	7.6	94	1
18	148.5	6.2	6.2	100	1
19	155.3	6.8	3.4	50	1
20	160.0	4.7	3.6	77	1
21	163.3	3.3	3.1	94	1
22	167.5	4.2	1.8	43	1
23	172.6	5.1	1.2	24	1
24	176.8	4.2	4.1	98	1
25	181.3	4.5	1.9	42	1
26	184.7	3.4	1.0	29	1
27	186.1	1.4	0.8	57	1
28	188.0	1.9	1.3	68	1

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
29	191.2	3.2	2.8	88	1
30	193.0	1.8	0.0	0	1
31	194.5	1.5	0.3	20	1
32	195.9	1.4	1.4	100	1
33	200.1	4.2	1.2	29	1
34	203.4	3.3	2.9	88	1
35	206.3	2.9	2.7	93	1
36	208.7	2.4	0.9	38	1
37	209.7	1.0	0.1	10	1
38	210.1	0.4	0.0	0	1
39	213.6	3.5	0.5	14	1
40	214.2	0.6	0.6	100	1
41	215.2	1.0	0.8	80	1
42	215.5	0.3	0.0	0	1
43	217.7	2.2	2.2	100	1
44	219.1	1.4	0.3	21	1
45	220.3	1.2	0.8	67	1
46	221.4	1.1	0.5	45	1
47	221.9	0.5	0.5	100	1
48	223.2	1.3	1.3	100	1
49	224.3	1.1	0.9	82	1
50	226.3	2.0	1.9	95	1
51	229.9	3.6	1.6	44	1
52	234.0	4.1	2.8	68	1
53	234.2	0.2	0.2	100	1
54	237.1	2.9	2.3	79	1
55	237.7	0.6	0.6	100	1
56	239.5	1.8	1.8	100	1
57	241.5	2.0	2.0	100	1

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
58	248.9	7.4	7.1	96	1
59	251.5	2.6	1.7	65	1
60	256.4	4.9	4.9	100	1
61	260.8	4.4	4.4	100	1
62	261.3	0.5	0.5	100	1
63	262.1	0.8	0.8	100	1
64	262.2	0.1	0.1	100	1
65	271.8	9.6	9.1	95	1
66	276.9	5.1	5.1	100	1
67	282.0	5.1	5.1	100	1
68	292.1	10.1	9.5	94	1
69	301.8	9.7	9.0	93	1
70	309.3	7.5	7.4	99	1
71	318.6	9.3	4.8	52	1
72	328.5	9.9	7.3	74	1
73	338.0	9.5	6.3	66	1
74	347.5	9.5	4.0	42	1
75	356.8	9.3	0.0	0	1
76	362.6	5.8	0.0	0	1
77	367.7	5.1	0.0	0	1
78	374.7	7.0	4.5	64	1
79	381.2	6.5	0.0	0	1
80	384.2	3.0	0.0	0	1
81	386.3	2.1	0.5	24	1
82	388.3	2.0	2.0	100	1
83	397.9	9.6	9.3	97	1
84	407.5	9.6	9.6	100	1
85	417.1	9.6	9.6	100	1
86	426.5	9.4	9.2	98	1

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
87	435.9	9.4	7.4	79	1
88	445.1	9.2	4.0	43	1
89	454.9	9.8	9.6	98	1
90	464.1	9.2	9.1	99	1
91	473.7	9.6	9.2	96	1
92	482.4	8.7	6.6	76	1
93	486.9	4.5	0.6	13	1
94	496.4	9.5	4.4	46	1
95	505.9	9.5	4.4	46	1
96	511.0	5.1	3.9	76	1
97	515.9	4.9	3.3	67	1
98	522.6	6.7	2.6	39	1
99	529.3	6.7	4.0	60	1
100	531.8	2.5	0.9	36	1
101	537.7	5.9	1.7	29	1
102	546.7	9.0	2.4	27	1
103	554.4	7.7	5.2	68	1
104	560.0	5.6	3.0	54	1
105	565.0	5.0	1.1	22	1
106	574.6	9.6	5.5	57	1
107	582.5	7.9	4.2	53	1
108	586.4	3.9	3.5	90	1
109	595.9	9.5	8.6	91	1
110	598.9	3.0	2.6	87	1
111	606.0	7.1	6.3	89	1
112	614.2	8.2	2.4	29	1
113	623.1	8.9	3.5	39	1
114	625.7	2.6	2.1	81	1
115	628.9	3.2	2.6	81	1

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
116	632.4	3.5	2.8	80	1
117	636.2	3.8	1.0	26	1
118	643.3	7.1	2.9	41	1
119	646.0	2.7	2.2	81	1
120	650.6	4.6	1.7	37	1
121	653.3	2.7	1.4	52	1
122	653.6	0.3	0.0	0	1
123	655.6	2.0	1.6	80	1
124	658.1	2.5	2.5	100	1
125	662.7	4.6	4.2	91	1
126	667.7	5.0	2.9	58	1
127	675.8	8.1	3.9	48	1
128	682.5	6.7	3.5	52	1
129	687.6	5.1	2.1	41	1
130	691.0	3.4	3.4	100	1
131	695.6	4.6	3.5	76	1
132	699.6	4.0	2.3	58	1
133	702.2	2.6	2.4	92	1
134	708.1	5.9	5.9	100	1
135	709.2	1.1	0.8	73	1
136	712.7	3.5	3.5	100	1
137	717.9	5.2	5.2	100	1
138	721.0	3.1	3.1	100	1
139	726.1	5.1	4.7	92	1
140	733.7	7.6	7.6	100	1
141	738.8	5.1	5.0	98	1
142	743.3	4.5	4.5	100	1
143	748.0	4.7	4.7	100	1
144	755.0	7.0	7.0	100	1

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
145	762.8	7.8	7.7	99	1
146	771.7	8.9	8.9	100	1
147	775.8	4.1	4.1	100	1
148	778.2	2.4	2.4	100	1
149	782.4	4.2	4.2	100	1
150	786.9	4.5	4.4	98	1
151	792.2	5.3	3.7	70	1
152	797.1	4.9	3.2	65	1
153	799.1	2.0	1.9	95	1
154	808.6	9.5	4.5	47	1
155	817.8	9.2	3.1	34	1
156	824.0	6.2	1.9	31	1
157	828.1	4.1	1.7	41	1
158	830.4	2.3	0.8	35	1
159	834.9	4.5	0.0	0	1
160	836.6	1.7	1.2	71	1
161	841.7	5.1	0.8	16	1
162	846.8	5.1	1.6	31	1
163	856.2	9.4	2.8	30	1
164	861.5	5.3	2.1	40	1
165	864.4	2.9	1.4	48	1
166	871.6	7.2	3.4	47	1
167	874.3	2.7	2.0	74	1
168	877.1	2.8	1.7	61	1
169	883.9	6.8	2.2	32	1
170	890.7	6.8	5.9	87	1
171	896.9	6.2	4.7	76	1
172	903.1	6.2	3.1	50	1
173	910.4	7.3	2.3	32	1

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
174	914.2	3.8	1.6	42	1
175	918.5	4.3	2.5	58	1
176	923.5	5.0	2.5	50	1
177	927.9	4.4	2.6	59	2
178	931.6	3.7	2.6	70	2
179	936.2	4.6	1.7	37	2
180	939.9	3.7	1.4	38	2
181	946.0	6.1	3.2	52	2
182	950.4	4.4	1.5	34	2
183	954.2	3.8	3.0	79	2
184	960.6	6.4	4.3	67	2
185	966.2	5.6	2.5	45	2
186	970.5	4.3	3.7	86	2
187	978.8	8.3	8.1	98	2
188	982.1	3.3	2.9	88	2
189	989.5	7.4	4.6	62	2
190	998.7	9.2	5.9	64	2
191	1004.8	6.1	1.5	25	2
192	1011.4	6.6	5.7	86	2
193	1020.4	9.0	7.0	78	2
194	1026.6	6.2	3.8	61	2
195	1034.9	8.3	6.2	75	2
196	1043.7	8.8	7.7	88	2
197	1047.3	3.6	3.5	97	2
198	1055.8	8.5	6.9	81	2
199	1061.2	5.4	4.6	85	2
200	1066.0	4.8	3.1	65	2
201	1068.2	2.2	1.5	68	2
202	1077.8	9.6	9.4	98	2

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
203	1082.4	4.6	2.8	61	2
204	1091.9	9.5	9.0	95	2
205	1101.6	9.7	9.7	100	2
206	1110.9	9.3	9.3	100	2
207	1120.4	9.5	9.5	100	2
208	1122.9	2.5	2.1	84	2
209	1129.8	6.9	6.4	93	2
210	1129.9	0.1	0.0	0	2
211	1130.9	1.0	1.0	100	2
212	1133.5	2.6	2.6	100	2
213	1141.7	8.2	7.9	96	2
214	1143.1	1.4	1.4	100	2
215	1152.6	9.5	9.4	99	2
216	1162.1	9.5	9.0	95	2
217	1166.5	4.4	3.0	68	2
218	1169.9	3.4	2.1	62	2
219	1175.1	5.2	5.2	100	2
220	1179.8	4.7	4.7	100	2
221	1184.9	5.1	2.5	49	2
222	1188.7	3.8	3.5	92	2
223	1194.4	5.7	5.0	88	2
224	1203.8	9.4	9.3	99	2
225	1213.3	9.5	6.7	71	2
226	1221.8	8.5	5.6	66	2
227	1224.9	3.1	1.9	61	2
228	1234.6	9.7	9.1	94	2
229	1244.1	9.5	8.8	93	2
230	1252.8	8.7	7.3	84	2
231	1260.2	7.4	4.8	65	2

Table C-1: Core Recovery Data (Continued)
{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
232	1268.6	8.4	6.7	80	2
233	1273.6	5.0	3.6	72	2
234	1282.5	8.9	6.8	76	2
235	1289.6	7.1	6.1	86	2
236	1299.0	9.4	9.4	100	2
237	1308.6	9.6	8.6	90	2
238	1318.3	9.7	7.5	77	2
239	1328.0	9.7	5.8	60	2
240	1337.5	9.5	8.4	88	2
241	1347.1	9.6	9.3	97	2
242	1356.9	9.8	3.8	39	2
243	1366.4	9.5	0.0	0	2
244	1375.9	9.5	0.0	0	2
245	1381.2	5.3	0.0	0	2
246	1390.7	9.5	0.0	0	2
247	1395.9	5.2	0.5	10	2
248	1405.6	9.7	2.2	23	2
249	1410.0	4.4	0.7	16	2
250	1417.8	7.8	6.2	79	2
251	1421.1	3.3	1.1	33	2
252	1431.8	10.7	9.2	86	2
253	1441.3	9.5	2.0	21	2
254	1451.0	9.7	8.2	85	2
255	1460.4	9.4	9.4	100	2
256	1470.3	9.9	9.9	100	2
257	1480.1	9.8	1.6	16	2
258	1489.8	9.7	9.7	100	2
259	1499.5	9.7	9.7	100	2
260	1509.4	9.9	9.9	100	2

Table C-1: Core Recovery Data (Continued)
{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
261	1519.0	9.6	9.5	99	2
262	1528.7	9.7	8.0	82	2
263	1532.9	4.2	4.0	95	2
264	1542.3	9.4	9.4	100	2
265	1551.9	9.6	9.6	100	2
266	1561.5	9.6	9.5	99	2
267	1571.1	9.6	9.5	99	2
268	1580.2	9.1	9.1	100	2
269	1583.0	2.8	2.8	100	2
270	1592.4	9.4	9.4	100	2
271	1602.0	9.6	9.4	98	2
272	1607.0	5.0	4.9	98	3
273	1612.0	5.0	1.6	32	3
274	1617.0	5.0	3.8	76	3
275	1621.9	4.9	4.9	100	3
276	1626.9	5.0	4.8	96	3
277	1632.0	5.1	4.9	96	3
278	1641.4	9.4	6.8	72	3
279	1651.3	9.9	7.2	73	3
280	1660.8	9.5	7.8	82	3
281	1667.3	6.5	6.2	95	3
282	1676.3	9.0	5.7	63	3
283	1683.2	6.9	5.7	83	3
284	1690.3	7.1	6.6	93	3
285	1699.9	9.6	5.9	61	3
286	1709.5	9.6	9.6	100	3
287	1719.1	9.6	9.4	98	3
288	1728.6	9.5	4.2	44	3
289	1734.0	5.4	4.5	83	3

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
290	1743.3	9.3	8.4	90	3
291	1752.2	8.9	5.8	65	3
292	1761.6	9.4	9.0	96	3
293	1771.1	9.5	9.4	99	3
294	1780.6	9.5	9.4	99	3
295	1789.8	9.2	9.0	98	3
Drilled	1790.7	0.9	0.0	0	3
296	1792.8	2.1	2.0	95	3
297	1793.7	0.9	0.9	100	3
298	1795.3	1.6	1.6	100	3
299	1797.3	2.0	2.0	100	3
300	1799.3	2.0	2.0	100	3
301	1805.3	6.0	5.7	95	3
302	1814.8	9.5	9.5	100	3
303	1824.3	9.5	9.5	100	3
304	1833.7	9.4	6.7	71	3
305	1837.9	4.2	4.1	98	3
306	1842.4	4.5	4.5	100	3
307	1851.7	9.3	6.0	65	3
308	1861.3	9.6	8.3	86	3
309	1869.8	8.5	8.5	100	3
310	1877.9	8.1	8.1	100	3
311	1886.6	8.7	8.6	99	3
312	1889.0	2.4	2.4	100	3
313	1897.1	8.1	8.1	100	3
314	1905.2	8.1	8.1	100	3
315	1913.3	8.1	8.1	100	3
316	1921.4	8.1	8.1	100	3
317	1927.3	5.9	5.9	100	3

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
318	1935.2	7.9	7.9	100	3
319	1943.2	8.0	6.3	79	3
320	1950.1	6.9	5.6	81	3
321	1957.1	7.0	7.0	100	3
322	1964.8	7.7	7.7	100	3
323	1972.9	8.1	7.7	95	3
324	1980.9	8.0	8.0	100	3
325	1989.0	8.1	8.1	100	3
326	1997.2	8.2	8.2	100	3
327	2005.2	8.0	7.9	99	3
328	2013.2	8.0	8.0	100	3
329	2020.3	7.1	7.0	99	3
330	2026.6	6.3	5.4	86	4
331	2034.8	8.2	8.2	100	4
332	2043.0	8.2	8.2	100	4
333	2051.1	8.1	8.1	100	4
334	2059.0	7.9	7.8	99	4
335	2067.2	8.2	8.2	100	4
336	2075.2	8.0	5.6	70	4
337	2083.2	8.0	8.0	100	4
338	2091.5	8.3	8.3	100	4
339	2099.8	8.3	8.3	100	4
340	2101.8	2.0	2.0	100	4
341	2109.9	8.1	8.1	100	4
342	2110.4	0.5	0.5	100	4
343	2112.3	1.9	1.8	95	4
344	2121.9	9.6	9.5	99	4
345	2131.2	9.3	9.3	100	4
346	2140.6	9.4	9.1	97	4

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
347	2150.3	9.7	9.7	100	4
348	2159.8	9.5	9.5	100	4
349	2169.4	9.6	9.6	100	4
350	2179.0	9.6	9.6	100	4
351	2185.3	6.3	3.8	60	4
352	2190.5	5.2	5.2	100	4
353	2199.7	9.2	9.2	100	4
355	2218.2	9.5	9.3	98	4
356	2225.4	7.2	7.2	100	4
357	2234.6	9.2	8.6	93	4
358	2237.5	2.9	2.9	100	4
359	2245.6	8.1	8.1	100	4
360	2252.6	7.0	7.0	100	4
361	2257.6	5.0	5.0	100	4
362	2262.5	4.9	4.8	98	4
363	2267.7	5.2	4.5	87	4
364	2272.7	5.0	4.6	92	4
365	2277.7	5.0	5.0	100	4
366	2282.7	5.0	5.0	100	4
367	2284.1	1.4	1.4	100	4
368	2289.1	5.0	5.0	100	4
369	2298.3	9.2	9.2	100	4
370	2303.2	4.9	4.9	100	4
371	2310.5	7.3	7.3	100	4
372	2319.7	9.2	9.2	100	4
373	2328.5	8.8	8.6	98	4
374	2337.2	8.7	8.3	95	4
375	2345.4	8.2	8.2	100	4
376	2350.0	4.6	4.6	100	4

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
377	2359.1	9.1	9.1	100	4
378	2364.1	5.0	5.0	100	4
379	2366.2	2.1	1.3	62	4
380	2371.4	5.2	5.2	100	4
381	2376.4	5.0	5.0	100	4
382	2381.5	5.1	5.1	100	4
383	2386.5	5.0	5.0	100	4
384	2391.6	5.1	5.1	100	4
385	2396.6	5.0	5.0	100	4
386	2401.6	5.0	5.0	100	4
387	2408.8	7.2	6.3	87	4
388	2413.9	5.1	4.6	90	4
389	2423.4	9.5	9.5	100	4
390	2433.0	9.6	9.6	100	4
391	2442.1	9.1	8.3	91	4
392	2442.8	0.7	0.7	100	4
393	2448.9	6.1	1.7	28	4
394	2452.6	3.7	3.7	100	4
395	2457.6	5.0	5.0	100	4
396	2466.6	9.0	9.0	100	5
397	2473.5	6.9	6.9	100	5
398	2478.5	5.0	5.0	100	5
399	2481.7	3.2	3.2	100	5
400	2486.8	5.1	4.9	96	5
401	2489.8	3.0	0.5	17	5
402	2491.8	2.0	0.0	0	5
403	2492.1	0.3	0.0	0	5
Drilled	2500.2	8.1	0.0	0	5
404	2505.2	5.0	4.3	86	5

Table C-1: Core Recovery Data (Continued)

{Sources (TDN numbers): 1–TM0000000SD7RS001; 2–TM0000000SD7RS002; 3–TM0000000SD7RS003; 4–TM0000000SD7RS004; 5–TM0000000SD7RS005]

Run Number	Interval Bottom (feet)	Drilled (feet)	Recovered (feet)	Core Recovery (percent)	Source
405	2511.1	5.9	4.3	73	5
406	2514.8	3.7	2.5	68	5
407	2520.3	5.5	4.4	80	5
408	2527.1	6.8	6.7	99	5
409	2532.5	5.4	5.4	100	5
410	2540.8	8.3	8.2	99	5
411	2547.7	6.9	6.8	99	5
412	2551.2	3.5	3.5	100	5
413	2558.2	7.0	7.0	100	5
414	2566.2	8.0	5.9	74	5
415	2575.8	9.6	9.6	100	5
416	2577.6	1.8	1.6	89	5
417	2587.2	9.6	9.6	100	5
418	2595.6	8.4	8.3	99	5
419	2603.6	8.0	8.0	100	5
420	2611.8	8.2	3.5	43	5
421	2616.6	4.8	4.8	100	5
422	2621.7	5.1	5.1	100	5
423	2623.7	2.0	2.0	100	5
424	2633.4	9.7	9.7	100	5
425	2641.1	7.7	7.6	99	5
426	2650.2	9.1	9.1	100	5
427	2659.8	9.6	9.4	98	5
428	2669.6	9.8	9.8	100	5
429	2675.1	5.5	5.4	98	5

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Appendix D: Rock Quality Designation (RQD) Data

Table D-1: Core-Run RQD Data
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
1	58.0	9.5	6.90	73	6.90	73	1
2	62.7	4.7	2.05	44	2.35	50	2
3	69.7	7.0	2.90	41	4.07	58	2
4	72.1	2.4	1.28	53	1.80	75	3
5	73.2	1.1	0.00	0	0.00	0	4
6	82.2	9.0	0.44	5	2.40	27	4
7	83.5	1.3	0.00	0	0.00	0	5
8	88.0	4.5	2.13	47	3.55	79	5
9	93.1	5.1	0.71	14	1.30	25	6
10	96.6	3.5	2.85	81	2.96	85	7
11	102.2	5.6	4.21	75	4.92	88	7
12	109.1	6.9	5.15	75	5.23	76	8
13	117.1	8.0	1.75	22	2.20	28	9
14	121.9	4.8	0.95	20	0.95	20	10
15	128.7	6.8	2.20	32	2.20	32	10
16	134.2	5.5	1.85	34	2.64	48	11
17	142.3	8.1	4.40	54	6.55	81	12
18	148.5	6.2	4.40	71	5.55	90	13
19	155.3	6.8	0.95	14	1.93	28	13
20	160.0	4.7	0.00	0	0.00	0	14
21	163.3	3.3	0.00	0	0.00	0	15
22	167.5	4.2	0.40	10	0.40	10	15
23	172.6	5.1	0.00	0	0.00	0	15
24	176.8	4.2	1.01	24	1.01	24	16
25	181.3	4.5	1.50	33	2.00	44	16
26	184.7	3.4	0.00	0	0.00	0	17
27	186.1	1.4	0.35	25	0.35	25	17
28	188.0	1.9	0.35	18	1.21	64	17
29	191.2	3.2	0.50	16	2.50	78	18
30	193.0	1.8	0.00	0	0.00	0	18

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
31	194.5	1.5	0.00	0	0.00	0	18
32	195.9	1.4	0.00	0	0.00	0	19
33	200.1	4.2	0.35	8	0.50	12	19
34	203.4	3.3	1.92	58	2.10	64	19
35	206.3	2.9	1.70	59	2.00	69	20
36	208.7	2.4	0.50	21	0.70	29	21
37	209.7	1.0	0.00	0	0.00	0	21
38	210.1	0.4	0.00	0	0.00	0	21
39	213.6	3.5	0.00	0	0.00	0	21
40	214.2	0.6	0.47	78	0.60	100	22
41	215.2	1.0	0.00	0	0.00	0	22
42	215.5	0.3	0.00	0	0.00	0	22
43	217.7	2.2	0.90	41	1.80	82	22
44	219.1	1.4	0.00	0	0.00	0	23
45	220.3	1.2	0.00	0	0.00	0	23
46	221.4	1.1	0.00	0	0.00	0	23
47	221.9	0.5	0.00	0	0.00	0	23
48	223.2	1.3	0.00	0	0.00	0	24
49	224.3	1.1	0.74	67	0.74	67	24
50	226.3	2.0	1.70	85	1.90	95	24
51	229.9	3.6	0.75	21	0.95	26	24
52	234.0	4.1	1.33	32	1.33	32	25
53	234.2	0.2	0.00	0	0.00	0	26
54	237.1	2.9	1.06	37	1.06	37	26
55	237.7	0.6	0.00	0	0.60	100	26
56	239.5	1.8	0.00	0	1.10	61	27
57	241.5	2.0	1.75	88	2.00	100	27
58	248.9	7.4	2.86	39	3.48	47	28
59	251.5	2.6	0.00	0	0.00	0	29
60	256.4	4.9	2.67	54	3.70	76	30

Table D-1: Core-Run RQD Data (Continued)

[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
61	260.8	4.4	3.61	82	3.61	82	30
62	261.3	0.5	0.00	0	0.00	0	31
63	262.1	0.8	0.00	0	0.00	0	31
64	262.2	0.1	0.00	0	0.00	0	32
65	271.8	9.6	5.08	53	5.08	53	32
66	276.9	5.1	5.10	100	5.10	100	33
67	282.0	5.1	1.55	30	4.60	90	33
68	292.1	10.1	4.22	42	7.55	75	34
69	301.8	9.7	1.90	20	3.65	38	36
70	309.3	7.5	2.70	36	5.20	69	37
71	318.6	9.3	0.00	0	1.80	19	38
72	328.5	9.9	0.42	4	7.33	74	40
73	338.0	9.5	1.42	15	6.20	65	40
74	347.5	9.5	0.00	0	4.00	42	42
75	356.8	9.3	0.00	0	0.00	0	42
76	362.6	5.8	0.00	0	0.00	0	42
77	367.7	5.1	0.00	0	0.00	0	42
78	374.7	7.0	4.30	61	4.50	64	42
79	381.2	6.5	0.00	0	0.00	0	43
80	384.2	3.0	0.00	0	0.00	0	43
81	386.3	2.1	0.00	0	0.00	0	43
82	388.3	2.0	0.35	18	1.10	55	43
83	397.9	9.6	5.00	52	9.30	97	44
84	407.5	9.6	8.42	88	9.60	100	45
85	417.1	9.6	4.11	43	8.62	90	46
86	426.5	9.4	2.77	29	3.50	37	47
87	435.9	9.4	1.97	21	5.51	59	49
88	445.1	9.2	0.40	4	2.50	27	50
89	454.9	9.8	3.80	39	6.60	67	51
90	464.1	9.2	3.21	35	9.10	99	53

Table D-1: Core-Run RQD Data (Continued)

[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
91	473.7	9.6	1.24	13	9.10	95	53
92	482.4	8.7	0.98	11	6.60	76	55
93	486.9	4.5	0.00	0	0.60	13	55
94	496.4	9.5	2.80	29	3.60	38	56
95	505.9	9.5	0.89	9	4.20	44	57
96	511.0	5.1	1.35	26	3.45	68	57
97	515.9	4.9	0.80	16	2.80	57	58
98	522.6	6.7	0.50	7	2.10	31	59
99	529.3	6.7	0.45	7	1.50	22	60
100	531.8	2.5	0.00	0	0.70	28	60
101	537.7	5.9	0.00	0	0.00	0	61
102	546.7	9.0	0.38	4	1.90	21	61
103	554.4	7.7	3.01	39	3.50	45	62
104	560.0	5.6	0.41	7	1.42	25	62
105	565.0	5.0	0.00	0	0.60	12	63
106	574.6	9.6	1.69	18	3.63	38	63
107	582.5	7.9	0.00	0	1.60	20	64
108	586.4	3.9	0.00	0	0.75	19	65
109	595.9	9.5	3.11	33	7.73	81	65
110	598.9	3.0	0.79	26	2.40	80	67
111	606.0	7.1	1.96	28	5.80	82	67
112	614.2	8.2	0.53	6	3.60	44	69
113	623.1	8.9	0.00	0	1.83	21	69
114	625.7	2.6	0.00	0	1.60	62	70
115	628.9	3.2	0.50	16	2.45	77	70
116	632.4	3.5	0.73	21	1.40	40	71
117	636.2	3.8	0.70	18	0.70	18	72
118	643.3	7.1	0.00	0	0.90	13	72
119	646.0	2.7	0.00	0	0.33	12	72
120	650.6	4.6	0.00	0	0.00	0	73

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
121	653.3	2.7	0.00	0	0.00	0	73
122	653.6	0.3	0.00	0	0.00	0	73
123	655.6	2.0	0.70	35	0.70	35	74
124	658.1	2.5	1.20	48	2.00	80	74
125	662.7	4.6	0.60	13	0.60	13	75
126	667.7	5.0	0.00	0	2.20	44	75
127	675.8	8.1	0.45	6	1.50	19	76
128	682.5	6.7	1.00	15	1.50	22	78
129	687.6	5.1	0.00	0	0.00	0	79
130	691.0	3.4	1.20	35	1.20	35	79
131	695.6	4.6	0.70	15	0.90	20	80
132	699.6	4.0	0.00	0	0.40	10	82
133	702.2	2.6	0.00	0	0.00	0	82
134	708.1	5.9	0.70	12	4.50	76	83
135	709.2	1.1	0.00	0	0.00	0	83
136	712.7	3.5	0.40	11	1.90	54	84
137	717.9	5.2	0.00	0	2.60	50	84
138	721.0	3.1	0.60	19	3.10	100	85
139	726.1	5.1	1.60	31	2.10	41	86
140	733.7	7.6	4.70	62	5.90	78	87
141	738.8	5.1	0.80	16	0.80	16	90
142	743.3	4.5	2.00	44	3.85	86	91
143	748.0	4.7	0.43	9	3.00	64	93
144	755.0	7.0	3.05	44	6.06	87	94
145	762.8	7.8	4.71	60	6.54	84	96
146	771.7	8.9	2.60	29	6.60	74	98
147	775.8	4.1	0.00	0	2.20	54	99
148	778.2	2.4	0.00	0	0.00	0	100
149	782.4	4.2	1.00	24	3.55	85	100
150	786.9	4.5	0.70	16	0.70	16	101

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
151	792.2	5.3	0.90	17	1.40	26	102
152	797.1	4.9	1.70	35	1.70	35	103
153	799.1	2.0	0.70	35	0.70	35	104
154	808.6	9.5	0.50	5	0.80	8	105
155	817.8	9.2	1.30	14	1.50	16	106
156	824.0	6.2	0.00	0	0.00	0	106
157	828.1	4.1	0.00	0	0.00	0	107
158	830.4	2.3	0.00	0	0.00	0	108
159	834.9	4.5	0.00	0	0.00	0	108
160	836.6	1.7	0.00	0	0.50	29	108
161	841.7	5.1	0.00	0	0.00	0	109
162	846.8	5.1	0.90	18	1.27	25	109
163	856.2	9.4	0.70	7	1.60	17	110
164	861.5	5.3	0.00	0	0.00	0	111
165	864.4	2.9	0.00	0	0.00	0	112
166	871.6	7.2	0.85	12	1.70	24	112
167	874.3	2.7	0.00	0	0.40	15	114
168	877.1	2.8	0.00	0	1.10	39	114
169	883.9	6.8	0.50	7	1.10	16	115
170	890.7	6.8	1.60	24	2.40	35	116
171	896.9	6.2	0.00	0	0.60	10	118
172	903.1	6.2	1.11	18	1.66	27	119
173	910.4	7.3	0.00	0	0.00	0	120
174	914.2	3.8	0.55	14	0.60	16	120
175	918.5	4.3	0.00	0	0.50	12	121
176	923.5	5.0	0.00	0	0.00	0	121
177	927.9	4.4	0.00	0	0.50	11	122
178	931.6	3.7	0.00	0	0.40	11	124
179	936.2	4.6	0.33	7	0.40	9	124
180	939.9	3.7	0.00	0	0.40	11	125

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
181	946.0	6.1	0.75	12	1.50	25	126
182	950.4	4.4	0.00	0	0.00	0	127
183	954.2	3.8	0.00	0	0.00	0	127
184	960.6	6.4	0.80	13	1.00	16	127
185	966.2	5.6	0.00	0	1.52	27	128
186	970.5	4.3	2.07	48	2.32	54	129
187	978.8	8.3	4.90	59	7.17	86	130
188	982.1	3.3	0.39	12	0.63	19	131
189	989.5	7.4	0.00	0	2.10	28	131
190	998.7	9.2	0.00	0	2.90	32	132
191	1004.8	6.1	0.00	0	0.00	0	134
192	1011.4	6.6	2.20	33	2.20	33	134
193	1020.4	9.0	2.10	23	4.50	50	135
194	1026.6	6.2	0.40	6	1.50	24	136
195	1034.9	8.3	2.50	30	4.10	49	138
196	1043.7	8.8	4.30	49	5.40	61	140
197	1047.3	3.6	1.00	28	1.50	42	141
198	1055.8	8.5	1.30	15	2.80	33	142
199	1061.2	5.4	1.00	19	1.30	24	143
200	1066.0	4.8	0.50	10	0.80	17	144
201	1068.2	2.2	0.50	23	0.50	23	145
202	1077.8	9.6	6.63	69	6.63	69	146
203	1082.4	4.6	0.78	17	1.13	25	147
204	1091.9	9.5	0.00	0	0.00	0	148
205	1101.6	9.7	6.40	66	8.50	88	149
206	1110.9	9.3	3.50	38	5.40	58	150
207	1120.4	9.5	1.20	13	1.20	13	152
208	1122.9	2.5	0.00	0	0.00	0	154
209	1129.8	6.9	2.68	39	4.59	67	154
210	1129.9	0.1	0.00	0	0.00	0	156

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
211	1130.9	1.0	0.95	95	0.95	95	156
212	1133.5	2.6	0.40	15	0.80	31	156
213	1141.7	8.2	2.17	26	4.93	60	157
214	1143.1	1.4	0.35	25	0.65	46	159
215	1152.6	9.5	3.73	39	7.90	83	160
216	1162.1	9.5	2.13	22	6.15	65	162
217	1166.5	4.4	0.00	0	0.40	9	164
218	1169.9	3.4	0.00	0	1.40	41	165
219	1175.1	5.2	0.00	0	0.00	0	166
220	1179.8	4.7	1.00	21	1.65	35	167
221	1184.9	5.1	0.00	0	0.00	0	168
222	1188.7	3.8	2.02	53	3.30	87	169
223	1194.4	5.7	1.20	21	3.30	58	170
224	1203.8	9.4	6.43	68	8.89	95	171
225	1213.3	9.5	5.30	56	6.55	69	173
226	1221.8	8.5	2.55	30	4.80	56	174
227	1224.9	3.1	0.88	28	1.48	48	175
228	1234.6	9.7	4.00	41	5.53	57	176
229	1244.1	9.5	6.37	67	8.14	86	177
230	1252.8	8.7	2.41	28	7.30	84	178
231	1260.2	7.4	1.18	16	4.00	54	180
232	1268.6	8.4	2.10	25	3.10	37	182
233	1273.6	5.0	0.40	8	2.00	40	183
234	1282.5	8.9	1.10	12	4.90	55	184
235	1289.6	7.1	0.90	13	1.60	23	186
236	1299.0	9.4	1.80	19	4.95	53	188
237	1308.6	9.6	1.90	20	6.40	67	189
238	1318.3	9.7	0.00	0	6.20	64	190
239	1328.0	9.7	0.00	0	5.00	52	191
240	1337.5	9.5	0.00	0	4.95	52	192

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
241	1347.1	9.6	1.10	11	5.45	57	193
242	1356.9	9.8	0.45	5	2.50	26	194
243	1366.4	9.5	0.00	0	0.00	0	195
244	1375.9	9.5	0.00	0	0.00	0	195
245	1381.2	5.3	0.00	0	0.00	0	195
246	1390.7	9.5	0.00	0	0.00	0	196
247	1395.9	5.2	0.00	0	0.00	0	196
248	1405.6	9.7	1.20	12	2.20	23	196
249	1410.0	4.4	0.00	0	0.00	0	197
250	1417.8	7.8	3.60	46	4.90	63	197
251	1421.1	3.3	0.00	0	0.80	24	198
252	1431.8	10.7	1.80	17	1.95	18	198
253	1441.3	9.5	0.00	0	2.00	21	199
254	1451.0	9.7	5.40	56	8.00	82	200
255	1460.4	9.4	2.20	23	9.10	97	201
256	1470.3	9.9	6.70	68	9.70	98	202
257	1480.1	9.8	0.00	0	0.00	0	204
258	1489.8	9.7	7.70	79	9.70	100	204
259	1499.5	9.7	7.62	79	9.35	96	205
260	1509.4	9.9	8.24	83	9.40	95	206
261	1519.0	9.6	8.56	89	8.56	89	207
262	1528.7	9.7	3.18	33	7.94	82	208
263	1532.9	4.2	1.85	44	4.00	95	210
264	1542.3	9.4	5.72	61	9.43	100	211
265	1551.9	9.6	9.38	98	9.63	100	212
266	1561.5	9.6	7.97	83	9.54	99	213
267	1571.1	9.6	4.88	51	9.40	98	214
268	1580.2	9.1	6.40	70	7.00	77	215
269	1583.0	2.8	1.84	66	2.76	99	216
270	1592.4	9.4	3.29	35	8.20	87	216

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
271	1602.0	9.6	4.88	51	8.02	84	218
272	1607.0	5.0	3.61	72	4.00	80	221
273	1612.0	5.0	0.96	19	1.10	22	221
274	1617.0	5.0	2.65	53	3.57	71	222
275	1621.9	4.9	4.66	95	4.90	100	222
276	1626.9	5.0	1.55	31	4.57	91	222
277	1632.0	5.1	1.59	31	4.43	87	223
278	1641.4	9.4	0.40	4	5.60	60	225
279	1651.3	9.9	1.10	11	3.60	36	225
280	1660.8	9.5	1.95	21	2.80	29	226
281	1667.3	6.5	4.33	67	5.24	81	227
282	1676.3	9.0	3.07	34	4.01	45	227
283	1683.2	6.9	2.63	38	5.65	82	228
284	1690.3	7.1	4.63	65	6.61	93	229
285	1699.9	9.6	4.27	44	5.30	55	229
286	1709.5	9.6	9.30	97	9.60	100	230
287	1719.1	9.6	9.40	98	9.40	98	230
288	1728.6	9.5	2.10	22	2.50	26	231
289	1734.0	5.4	2.90	54	2.90	54	232
290	1743.3	9.3	6.77	73	6.77	73	233
291	1752.2	8.9	0.65	7	1.25	14	233
292	1761.6	9.4	6.14	65	7.50	80	234
293	1771.1	9.5	7.70	81	8.42	89	234
294	1780.6	9.5	8.10	85	8.90	94	235
295	1789.8	9.2	2.25	24	5.77	63	236
Drilled	1790.7	9.9	0.00	0	0.00	0	237†
296	1792.8	2.1	1.71	81	1.71	81	237
297	1793.7	0.9	0.00	0	0.00	0	237
298	1795.3	1.6	1.60	100	1.60	100	237
299	1797.3	2.0	0.85	43	2.00	100	238

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
300	1799.3	2.0	0.00	0	0.40	20	238
301	1805.3	6.0	0.00	0	0.80	13	238
302	1814.8	9.5	6.90	73	6.90	73	239
303	1824.3	9.5	6.77	71	7.04	74	240
304	1833.7	9.4	4.89	52	5.15	55	241
305	1837.9	4.2	1.73	41	2.40	57	242
306	1842.4	4.5	0.40	9	1.70	38	242
307	1851.7	9.3	2.70	29	4.50	48	243
308	1861.3	9.6	2.20	23	5.60	58	243
309	1869.8	8.5	7.29	86	8.50	100	244
310	1877.9	8.1	8.10	100	8.10	100	245
311	1886.6	8.7	7.73	89	8.12	93	245
312	1889.0	2.4	2.24	93	2.40	100	246
313	1897.1	8.1	7.75	96	7.75	96	246
314	1905.2	8.1	3.99	49	7.40	91	246
315	1913.3	8.1	3.61	45	6.70	83	247
316	1921.4	8.1	3.33	41	7.80	96	248
317	1927.3	5.9	4.64	79	4.70	80	249
318	1935.2	7.9	5.30	67	6.90	87	249
319	1943.2	8.0	3.10	39	3.97	50	250
320	1950.1	6.9	1.52	22	2.76	40	251
321	1957.1	7.0	3.17	45	3.54	51	251
322	1964.8	7.7	6.51	85	7.10	92	252
323	1972.9	8.1	4.21	52	5.50	68	252
324	1980.9	8.0	5.91	74	7.40	93	253
325	1989.0	8.1	7.15	88	7.90	98	254
326	1997.2	8.2	6.85	84	7.15	87	254
327	2005.2	8.0	7.45	93	7.87	98	254
328	2013.2	8.0	6.06	76	8.00	100	255
329	2020.3	7.1	5.05	71	6.69	94	255

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
330	2026.6	6.3	1.60	25	1.60	25	357
331	2034.8	8.2	4.70	57	5.10	62	257
332	2043.0	8.2	4.20	51	5.50	67	258
333	2051.1	8.1	6.80	84	8.15	101	259
334	2059.0	7.9	4.70	59	7.00	89	260
335	2067.2	8.2	4.20	51	4.20	51	261
336	2075.2	8.0	2.10	26	2.80	35	261
337	2083.2	8.0	1.80	23	2.50	31	262
338	2091.5	8.3	5.60	67	6.50	78	263
339	2099.8	8.3	5.02	60	8.31	100	264
340	2101.8	2.0	0.00	0	2.00	100	264
341	2109.9	8.1	6.77	84	7.65	94	264
342	2110.4	0.5	0.50	100	0.50	100	265
343	2112.3	1.9	1.80	95	1.80	95	265
344	2121.9	9.6	7.13	74	9.17	96	265
345	2131.2	9.3	8.17	88	8.82	95	266
346	2140.6	9.4	7.88	84	7.88	84	267
347	2150.3	9.7	9.66	100	9.66	100	267
348	2159.8	9.5	8.92	94	9.29	98	267
349	2169.4	9.6	8.60	90	8.85	92	268
350	2179.0	9.6	8.95	93	9.30	97	268
351	2185.3	6.3	1.29	20	1.75	28	268
352	2190.5	5.2	3.30	63	4.10	79	269
353	2199.7	9.2	8.40	91	8.49	92	270
354	2208.7	9.0	8.50	94	9.00	100	270
355	2218.2	9.5	6.19	65	6.19	65	271
356	2225.4	7.2	7.20	100	7.20	100	271
357	2234.6	9.2	6.70	73	7.90	86	272
358	2237.5	2.9	0.00	0	0.00	0	273
359	2245.6	8.1	5.77	71	7.30	90	273

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
360	2252.6	7.0	5.30	76	6.00	86	274
361	2257.6	5.0	2.76	55	2.97	59	275
362	2262.5	4.9	2.43	50	2.43	50	275
363	2267.7	5.2	2.38	46	2.40	46	276
364	2272.7	5.0	1.23	25	4.70	94	277
365	2277.7	5.0	3.00	60	4.40	88	278
366	2282.7	5.0	5.00	100	5.00	100	278
367	2284.1	1.4	1.40	100	1.40	100	279
368	2289.1	5.0	4.32	86	4.32	86	279
369	2298.3	9.2	7.14	78	8.00	87	279
370	2303.2	4.9	3.74	76	4.79	98	280
371	2310.5	7.3	6.75	92	7.30	100	280
372	2319.7	9.2	9.20	100	9.20	100	281
373	2328.5	8.8	7.06	80	8.60	98	281
374	2337.2	8.7	4.03	46	4.03	46	282
375	2345.4	8.2	6.09	74	6.10	74	283
376	2350.0	4.6	2.07	45	2.40	52	283
377	2359.1	9.1	3.09	34	3.50	38	284
378	2364.1	5.0	1.54	31	2.20	44	284
379	2366.2	2.1	0.36	17	0.50	24	285
380	2371.4	5.2	2.44	47	3.50	67	285
381	2376.4	5.0	3.00	60	3.80	76	286
382	2381.5	5.1	3.78	74	5.10	100	286
383	2386.5	5.0	1.80	36	2.80	56	287
384	2391.6	5.1	4.50	88	4.50	88	288
385	2396.6	5.0	2.10	42	2.30	46	288
386	2401.6	5.0	0.00	0	0.00	0	289
387	2408.8	7.2	4.01	56	4.40	61	289
388	2413.9	5.1	2.86	56	4.00	78	290
389	2423.4	9.5	5.47	58	7.70	81	290

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
390	2433.0	9.6	7.71	80	9.60	100	291
391	2442.1	9.1	1.09	12	4.30	47	292
392	2442.8	0.7	0.00	0	0.00	0	293
393	2448.9	6.1	0.00	0	0.00	0	293
394	2452.6	3.7	0.00	0	0.60	16	293
395	2457.6	5.0	0.69	14	3.30	66	294
396	2466.6	9.0	5.54	62	7.60	84	295
397	2473.5	6.9	0.00	0	0.00	0	296
398	2478.5	5.0	1.80	36	3.70	74	296
399	2481.7	3.2	1.50	47	2.30	72	297
400	2486.8	5.1	3.00	59	4.04	79	298
401	2489.8	3.0	0.00	0	0.00	0	299
402	2491.8	2.0	0.00	0	0.00	0	299
403	2492.1	0.3	0.00	0	0.00	0	299
Drilled	2500.2	8.1	0.00	0	0.00	0	299
404	2505.2	5.0	0.00	0	0.00	0	299
405	2511.1	5.9	0.00	0	0.00	0	300
406	2514.8	3.7	0.00	0	0.00	0	300
407	2520.3	5.5	0.00	0	0.60	11	301
408	2527.2	6.9	1.71	25	1.90	28	301
409	2532.4	5.2	2.10	40	3.10	60	302
410	2540.8	8.4	1.50	18	1.60	19	303
411	2547.7	6.9	2.90	42	3.40	49	304
412	2551.2	3.5	0.40	11	0.40	11	305
413	2558.2	7.0	0.00	0	0.80	11	306
414	2566.2	8.0	3.70	46	5.30	66	307
415	2575.8	9.6	3.90	41	6.00	62	308
416	2577.6	1.8	0.98	54	1.48	82	309
417	2587.2	9.6	8.31	87	9.00	94	309
418	2595.6	8.4	6.16	73	6.80	81	310

Table D-1: Core-Run RQD Data (Continued)
[Source: DTN TM0000SD7SUPER.001]

Run No.	Interval Bottom (feet)	Drilled (feet)	Raw Length (feet)	Raw RQD	Adj. Length (feet)	Deere RQD	Source Page No.
419	2603.6	8.0	7.23	90	7.50	94	310
420	2611.8	8.2	1.78	22	2.40	29	311
421	2616.6	4.8	4.80	100	4.80	100	312
422	2621.7	5.1	4.30	84	4.70	92	312
423	2623.7	2.0	1.63	82	2.00	100	313
424	2633.4	9.7	7.22	74	8.12	84	313
425	2641.1	7.7	5.62	73	7.00	91	313
426	2650.2	9.1	4.60	51	7.90	87	314
427	2659.8	9.6	8.40	87	9.23	96	315
428	2669.6	9.8	9.00	92	9.35	95	316
429	2675.10	5.5	5.20	95	5.40	98	317

[†] adjusted to be compatible with DTN TM0000000SD7RS004

Table D-2: RQD Values by 10-foot Intervals

[Sources: "Drilling Support" values computed from table D-1; "Study 8.3.1.14.2"–taken from DTN No. SNF29041993002.067. Note: Study 8.3.1.14.2 recorded data only for the interval from 670–830 ft]

Interval Bottom (feet)	Drilling Support		Study 8.3.1.14.2	
	Raw RQD	Adj. RQD	Raw RQD	Adj. RQD
10.0	0	0	--	--
20.0	0	0	--	--
30.0	0	0	--	--
40.0	0	0	--	--
50.0	11	11	--	--
60.0	67	68	--	--
70.0	42	56	--	--
80.0	15	34	--	--
90.0	25	46	--	--
100.0	58	67	--	--
110.0	70	74	--	--
120.0	21	25	--	--
130.0	30	32	--	--
140.0	46	67	--	--
150.0	59	78	--	--
160.0	7	15	--	--
170.0	4	4	--	--
180.0	21	24	--	--
190.0	14	37	--	--
200.0	5	14	--	--
210.0	41	48	--	--
220.0	14	24	--	--
230.0	32	36	--	--
240.0	28	46	--	--
250.0	42	50	--	--
260.0	56	67	--	--
270.0	48	48	--	--
280.0	70	88	--	--

Table D-2: RQD Values by 10-foot Intervals (Continued)

[Sources: "Drilling Support" values computed from table D-1; "Study 8.3.1.14.2"–taken from DTN No. SNF29041993002.067. Note: Study 8.3.1.14.2 recorded data only for the interval from 670–830 ft]

Interval Bottom (feet)	Drilling Support		Study 8.3.1.14.2	
	Raw RQD	Adj. RQD	Raw RQD	Adj. RQD
290.0	40	78	--	--
300.0	24	45	--	--
310.0	31	60	--	--
320.0	1	27	--	--
330.0	6	73	--	--
340.0	12	61	--	--
350.0	0	32	--	--
360.0	0	0	--	--
370.0	14	15	--	--
380.0	29	30	--	--
390.0	12	27	--	--
400.0	60	98	--	--
410.0	76	97	--	--
420.0	39	75	--	--
430.0	26	45	--	--
440.0	14	46	--	--
450.0	21	47	--	--
460.0	37	83	--	--
470.0	22	96	--	--
480.0	12	83	--	--
490.0	12	36	--	--
500.0	22	40	--	--
510.0	16	54	--	--
520.0	14	48	--	--
530.0	6	25	--	--
540.0	1	10	--	--
550.0	16	29	--	--
560.0	21	34	--	--

Table D-2: RQD Values by 10-foot Intervals (Continued)

[Sources: "Drilling Support" values computed from table D-1; "Study 8.3.1.14.2"–taken from DTN No. SNF29041993002.067. Note: Study 8.3.1.14.2 recorded data only for the interval from 670–830 ft]

Interval Bottom (feet)	Drilling Support		Study 8.3.1.14.2	
	Raw RQD	Adj. RQD	Raw RQD	Adj. RQD
570.0	9	25	--	--
580.0	8	28	--	--
590.0	12	42	--	--
600.0	30	81	--	--
610.0	19	67	--	--
620.0	3	30	--	--
630.0	7	51	--	--
640.0	12	21	--	--
650.0	0	7	--	--
660.0	21	29	--	--
670.0	5	30	--	--
680.0	9	20	8	14
690.0	12	14	0	0
700.0	11	17	0	0
710.0	8	49	13	32
720.0	7	62	7	7
730.0	42	61	28	64
740.0	36	47	13	22
750.0	28	76	5	44
760.0	52	85	48	69
770.0	38	77	36	46
780.0	9	50	17	29
790.0	18	35	6	20
800.0	28	31	10	16
810.0	7	10	4	21
820.0	11	13	0	5
830.0	0	0	0	0
840.0	0	5	--	--

Table D-2: RQD Values by 10-foot Intervals (Continued)

[Sources: "Drilling Support" values computed from table D-1; "Study 8.3.1.14.2"–taken from DTN No. SNF29041993002.067. Note: Study 8.3.1.14.2 recorded data only for the interval from 670–830 ft]

Interval Bottom (feet)	Drilling Support		Study 8.3.1.14.2	
	Raw RQD	Adj. RQD	Raw RQD	Adj. RQD
850.0	11	18	--	--
860.0	5	11	--	--
870.0	7	13	--	--
880.0	4	23	--	--
890.0	17	28	--	--
900.0	7	17	--	--
910.0	6	8	--	--
920.0	6	11	--	--
930.0	0	7	--	--
940.0	3	10	--	--
950.0	7	15	--	--
960.0	7	9	--	--
970.0	19	37	--	--
980.0	53	77	--	--
990.0	2	27	--	--
1000.0	0	27	--	--
1010.0	17	17	--	--
1020.0	25	48	--	--
1030.0	15	34	--	--
1040.0	40	56	--	--
1050.0	32	47	--	--
1060.0	17	29	--	--
1070.0	25	28	--	--
1080.0	58	59	--	--
1090.0	4	6	--	--
1100.0	53	71	--	--
1110.0	42	63	--	--
1120.0	15	17	--	--

Table D-2: RQD Values by 10-foot Intervals (Continued)

[Sources: "Drilling Support" values computed from table D-1; "Study 8.3.1.14.2"–taken from DTN No. SNF29041993002.067. Note: Study 8.3.1.14.2 recorded data only for the interval from 670–830 ft]

Interval Bottom (feet)	Drilling Support		Study 8.3.1.14.2	
	Raw RQD	Adj. RQD	Raw RQD	Adj. RQD
1130.0	28	47	--	--
1140.0	30	56	--	--
1150.0	35	74	--	--
1160.0	27	70	--	--
1170.0	5	32	--	--
1180.0	10	17	--	--
1190.0	23	41	--	--
1200.0	48	78	--	--
1210.0	61	79	--	--
1220.0	39	61	--	--
1230.0	35	54	--	--
1240.0	55	72	--	--
1250.0	44	85	--	--
1260.0	19	62	--	--
1270.0	22	38	--	--
1280.0	11	50	--	--
1290.0	13	32	--	--
1300.0	19	54	--	--
1310.0	17	66	--	--
1320.0	0	62	--	--
1330.0	0	52	--	--
1340.0	3	53	--	--
1350.0	9	48	--	--
1360.0	3	18	--	--
1370.0	0	0	--	--
1380.0	0	0	--	--
1390.0	0	0	--	--
1400.0	5	9	--	--

Table D-2: RQD Values by 10-foot Intervals (Continued)

[Sources: "Drilling Support" values computed from table D-1; "Study 8.3.1.14.2"–taken from DTN No. SNF29041993002.067. Note: Study 8.3.1.14.2 recorded data only for the interval from 670–830 ft]

Interval Bottom (feet)	Drilling Support		Study 8.3.1.14.2	
	Raw RQD	Adj. RQD	Raw RQD	Adj. RQD
1410.0	7	13	--	--
1420.0	36	54	--	--
1430.0	15	19	--	--
1440.0	3	21	--	--
1450.0	48	74	--	--
1460.0	27	95	--	--
1470.0	66	98	--	--
1480.0	2	3	--	--
1490.0	79	99	--	--
1500.0	79	96	--	--
1510.0	84	95	--	--
1520.0	84	88	--	--
1530.0	34	84	--	--
1540.0	56	99	--	--
1550.0	89	100	--	--
1560.0	86	100	--	--
1570.0	56	98	--	--
1580.0	68	79	--	--
1590.0	44	90	--	--
1600.0	47	84	--	--
1610.0	52	63	--	--
1620.0	59	70	--	--
1630.0	43	92	--	--
1640.0	10	65	--	--
1650.0	10	40	--	--
1660.0	19	30	--	--
1670.0	54	67	--	--
1680.0	36	58	--	--

Table D-2: RQD Values by 10-foot Intervals (Continued)

[Sources: "Drilling Support" values computed from table D-1; "Study 8.3.1.14.2"–taken from DTN No. SNF29041993002.067. Note: Study 8.3.1.14.2 recorded data only for the interval from 670–830 ft]

Interval Bottom (feet)	Drilling Support		Study 8.3.1.14.2	
	Raw RQD	Adj. RQD	Raw RQD	Adj. RQD
1690.0	57	90	--	--
1700.0	46	57	--	--
1710.0	97	100	--	--
1720.0	91	91	--	--
1730.0	27	30	--	--
1740.0	65	65	--	--
1750.0	29	33	--	--
1760.0	53	65	--	--
1770.0	79	87	--	--
1780.0	85	93	--	--
1790.0	26	59	--	--
1800.0	43	62	--	--
1810.0	34	41	--	--
1820.0	72	73	--	--
1830.0	60	63	--	--
1840.0	38	52	--	--
1850.0	24	46	--	--
1860.0	24	57	--	--
1870.0	78	95	--	--
1880.0	98	99	--	--
1890.0	91	95	--	--
1900.0	82	94	--	--
1910.0	47	87	--	--
1920.0	42	92	--	--
1930.0	70	84	--	--
1940.0	53	69	--	--
1950.0	27	43	--	--
1960.0	56	63	--	--

Table D-2: RQD Values by 10-foot Intervals (Continued)

[Sources: "Drilling Support" values computed from table D-1; "Study 8.3.1.14.2"–taken from DTN No. SNF29041993002.067. Note: Study 8.3.1.14.2 recorded data only for the interval from 670–830 ft]

Interval Bottom (feet)	Drilling Support		Study 8.3.1.14.2	
	Raw RQD	Adj. RQD	Raw RQD	Adj. RQD
1970.0	68	80	--	--
1980.0	68	85	--	--
1990.0	87	96	--	--
2000.0	86	90	--	--
2010.0	85	99	--	--
2020.0	73	96	--	--
2030.0	38	40	--	--
2040.0	54	65	--	--
2050.0	74	91	--	--
2060.0	61	86	--	--
2070.0	44	47	--	--
2080.0	24	33	--	--
2090.0	53	63	--	--
2100.0	60	97	--	--
2110.0	69	96	--	--
2120.0	79	96	--	--
2130.0	85	95	--	--
2140.0	84	85	--	--
2150.0	99	99	--	--
2160.0	94	98	--	--
2170.0	90	92	--	--
2180.0	86	90		

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Appendix E: Lithophysal Cavity Data

Table E-1: Measured Lithophysal Cavity Abundances for 10-foot Composite Intervals

[< – less than. Source: DTN No. SNF29041993002.067]

Depth to Base of Interval (feet)	Estimated Cavities (percent)	Lost Core (feet)	Rubble (feet)
680.0	2.0	4.9	3.4
690.0	<1	5.5	4.5
700.0	<1	2.8	5.3
710.0	<1	0.5	4.1
720.0	<1	0.0	2.5
730.0	<1	0.4	1.0
740.0	<1	0.1	4.2
750.0	<1	0.0	0.8
760.0	<1	0.0	0.6
770.0	<1	0.1	0.1
780.0	<1	0.0	4.8
790.0	<1	0.1	5.0
800.0	<1	3.4	4.9
810.0	<1	5.0	1.5
820.0	<1	6.4	2.7
830.0	<1	7.6	1.9

Appendix F: Fracture Information

Table F-1: Measured Fracture Data for 10-foot Composite Intervals

[N–natural, I–indeterminate, C–coring-induced, V–Vug; dip classes are 10-degree intervals ending with the indicated value. Source: TDIF SNF29041993002.067]

Depth to Base of Interval (feet)	Type of Fracture				Dip of Natural Fracture (degrees)									Natural Only	
	N	I	C	V	10	20	30	40	50	60	70	80	90	Clean	Mineralized
680	1	1	6	0	0	0	1	0	0	0	0	1	0	0	2
690	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
700	7	5	3	0	6	0	0	1	0	1	1	0	3	4	8
710	9	2	13	0	1	0	0	0	0	0	0	2	8	2	9
720	10	7	14	0	4	0	0	1	2	1	1	1	7	10	7
730	13	6	14	0	3	2	4	4	1	0	0	2	3	6	13
740	18	9	11	0	9	0	5	0	1	3	2	0	7	11	16
750	12	10	19	0	5	2	2	3	1	0	5	3	1	14	8
760	5	8	21	0	3	1	0	0	2	0	1	3	3	8	5
770	6	6	15	0	5	0	1	0	1	0	1	0	4	8	4
780	7	4	10	0	2	0	0	0	3	0	0	3	3	7	4
790	11	3	12	0	4	0	0	1	1	1	2	2	3	5	9
800	0	2	5	0	1	0	0	0	0	0	1	0	0	2	0
810	5	3	8	0	3	1	1	0	1	0	0	2	0	5	3
820	1	3	0	0	1	0	1	0	0	1	1	0	0	3	1
830	0	1	3	0	1	0	0	0	0	0	0	0	0	1	0

Appendix G: Laboratory Material Properties

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
50.6	15.42	2.14	0.138	2.48	0.139	1.009	2.13	0.150	2.50	0.152	1.008
54.2	16.52	2.26	0.088	2.47	0.083	0.948	2.24	0.105	2.50	0.101	0.957
60.2	18.35	2.22	0.107	2.48	0.104	0.970	2.21	0.118	2.50	0.114	0.973
63.4	19.32	2.19	0.119	2.49	0.103	0.867	2.18	0.127	2.50	0.111	0.875
66.9	20.39	2.26	0.092	2.48	0.082	0.894	2.24	0.105	2.50	0.095	0.907
74.1	22.59	2.24	0.096	2.48	0.084	0.875	2.23	0.109	2.50	0.097	0.889
75.4	22.98	2.28	0.085	2.49	0.083	0.978	2.26	0.096	2.50	0.094	0.981
84.0	25.60	2.31	0.068	2.48	0.061	0.900	2.29	0.083	2.50	0.076	0.919
86.1	26.24	2.28	0.079	2.47	0.075	0.946	2.26	0.094	2.50	0.090	0.955
89.9	27.40	2.26	0.091	2.48	0.079	0.861	2.24	0.104	2.50	0.091	0.878
93.1	28.38	2.19	0.123	2.49	0.083	0.677	2.18	0.131	2.51	0.091	0.697
96.1	29.29	2.30	0.068	2.46	0.060	0.881	2.27	0.095	2.51	0.087	0.914
99.5	30.33	2.27	0.087	2.48	0.082	0.937	2.25	0.102	2.51	0.096	0.946
101.5	30.94	2.23	0.099	2.48	0.097	0.981	2.22	0.115	2.51	0.113	0.983
104.7	31.91	2.30	0.070	2.47	0.063	0.911	2.28	0.090	2.51	0.084	0.931
108.7	33.13	2.29	0.074	2.47	0.069	0.931	2.27	0.093	2.50	0.088	0.945
110.3	33.62	2.21	0.110	2.48	0.104	0.949	2.20	0.124	2.51	0.118	0.955
113.7	34.66	2.30	0.074	2.48	0.070	0.956	2.28	0.087	2.50	0.084	0.963
117.8	35.91	2.17	0.130	2.50	0.088	0.673	2.16	0.138	2.51	0.095	0.692
119.9	36.55	2.26	0.099	2.51	0.097	0.981	2.25	0.110	2.53	0.108	0.983
122.5	37.34	2.23	0.098	2.47	0.080	0.824	2.22	0.109	2.49	0.092	0.842
126.0	38.41	2.29	0.078	2.48	0.073	0.936	2.27	0.091	2.50	0.086	0.945
128.9	39.29	2.28	0.083	2.48	0.071	0.861	2.26	0.096	2.50	0.084	0.880
131.7	40.14	2.28	0.084	2.48	0.076	0.910	2.26	0.096	2.50	0.089	0.922
134.8	41.09	2.33	0.062	2.48	0.060	0.961	2.32	0.074	2.50	0.072	0.968
137.7	41.97	2.25	0.092	2.48	0.081	0.875	2.24	0.105	2.50	0.094	0.890
141.3	43.07	2.31	0.070	2.48	0.062	0.887	2.30	0.082	2.50	0.074	0.904
144.0	43.89	2.34	0.055	2.48	0.052	0.955	2.33	0.067	2.50	0.065	0.964
146.9	44.78	2.14	0.140	2.49	0.107	0.766	2.13	0.150	2.51	0.117	0.782
149.7	45.63	2.31	0.073	2.49	0.062	0.845	2.29	0.088	2.51	0.077	0.871
155.6	47.43	2.34	0.058	2.48	0.046	0.794	2.32	0.074	2.51	0.062	0.838
156.2	47.61	2.29	0.072	2.47	0.058	0.800	2.28	0.087	2.50	0.072	0.833
158.5	48.31	2.35	0.053	2.48	0.049	0.917	2.34	0.067	2.51	0.063	0.934
161.9	49.35	2.34	0.060	2.49	0.057	0.938	2.32	0.072	2.51	0.068	0.948
164.0	49.99	2.35	0.055	2.48	0.045	0.826	2.33	0.068	2.50	0.058	0.859
167.7	51.12	2.32	0.066	2.49	0.049	0.736	2.31	0.079	2.51	0.062	0.779
172.8	52.67	2.31	0.069	2.49	0.057	0.823	2.30	0.082	2.51	0.070	0.850

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

Depth (feet)	Depth (m)	Relative Humidity Oven-Dried					105C Oven-Dried				
		Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
173.9	53.01	2.29	0.081	2.49	0.065	0.799	2.28	0.094	2.51	0.077	0.827
176.8	53.89	2.31	0.075	2.50	0.058	0.780	2.30	0.087	2.52	0.070	0.810
181.4	55.29	2.30	0.074	2.48	0.050	0.671	2.29	0.086	2.50	0.062	0.717
184.8	56.33	2.29	0.080	2.49	0.053	0.661	2.28	0.090	2.51	0.063	0.698
186.1	56.72	2.28	0.085	2.49	0.058	0.680	2.27	0.096	2.51	0.069	0.716
188.7	57.52	2.21	0.113	2.49	0.069	0.609	2.20	0.123	2.50	0.078	0.639
194.2	59.19	2.32	0.066	2.49	0.046	0.694	2.31	0.080	2.51	0.060	0.748
196.2	59.80	2.30	0.073	2.48	0.045	0.615	2.29	0.084	2.50	0.056	0.666
200.3	61.05	2.37	0.046	2.48	0.040	0.851	2.35	0.061	2.50	0.054	0.887
201.1	61.30	2.35	0.053	2.48	0.043	0.807	2.34	0.067	2.50	0.057	0.847
203.7	62.09	2.36	0.053	2.49	0.040	0.762	2.34	0.065	2.51	0.052	0.806
206.6	62.97	2.35	0.052	2.48	0.042	0.806	2.34	0.065	2.50	0.055	0.845
210.3	64.10	2.35	0.063	2.50	0.035	0.553	2.33	0.075	2.52	0.047	0.625
213.6	65.11	2.33	0.063	2.48	0.044	0.701	2.32	0.074	2.50	0.055	0.745
215.7	65.75	2.33	0.061	2.49	0.037	0.602	2.32	0.073	2.50	0.048	0.666
222.1	67.70	2.36	0.048	2.48	0.035	0.732	2.35	0.058	2.50	0.046	0.780
225.0	68.58	2.37	0.046	2.49	0.035	0.754	2.36	0.057	2.50	0.046	0.801
230.1	70.13	2.31	0.073	2.49	0.045	0.615	2.30	0.082	2.51	0.054	0.657
230.9	70.38	2.35	0.054	2.49	0.036	0.660	2.34	0.065	2.50	0.047	0.717
234.3	71.42	2.37	0.048	2.49	0.036	0.758	2.35	0.060	2.51	0.049	0.807
237.4	72.36	2.35	0.056	2.49	0.032	0.575	2.33	0.068	2.50	0.044	0.647
240.3	73.24	2.30	0.071	2.48	0.049	0.686	2.29	0.082	2.50	0.060	0.728
242.4	73.88	2.35	0.056	2.48	0.046	0.819	2.33	0.068	2.50	0.058	0.851
246.1	75.01	2.33	0.058	2.48	0.046	0.804	2.32	0.072	2.50	0.061	0.844
249.1	75.93	2.37	0.049	2.49	0.025	0.519	2.35	0.060	2.50	0.036	0.605
252.2	76.87	2.36	0.050	2.48	0.040	0.809	2.35	0.063	2.50	0.053	0.849
254.9	77.69	2.36	0.049	2.48	0.039	0.794	2.34	0.063	2.50	0.053	0.840
257.9	78.61	2.37	0.041	2.47	0.035	0.843	2.35	0.059	2.50	0.052	0.890
261.6	79.74	2.35	0.047	2.47	0.038	0.805	2.33	0.064	2.49	0.055	0.857
263.1	80.19	2.34	0.050	2.47	0.039	0.786	2.33	0.067	2.49	0.056	0.840
264.0	80.47	2.32	0.058	2.46	0.057	0.975	2.30	0.079	2.50	0.078	0.982
266.0	81.08	2.33	0.052	2.46	0.040	0.779	2.32	0.070	2.49	0.059	0.837
269.9	82.27	2.32	0.057	2.46	0.048	0.842	2.30	0.077	2.49	0.068	0.883
273.2	83.27	2.31	0.059	2.46	0.053	0.899	2.30	0.079	2.49	0.073	0.924
275.5	83.97	2.32	0.056	2.46	0.051	0.908	2.30	0.076	2.49	0.071	0.932
279.5	85.19	2.29	0.070	2.46	0.062	0.887	2.27	0.087	2.49	0.079	0.908
281.5	85.80	2.29	0.071	2.46	0.060	0.850	2.27	0.091	2.50	0.081	0.883

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
284.4	86.69	2.25	0.083	2.46	0.073	0.874	2.23	0.106	2.50	0.096	0.901
287.6	87.66	2.22	0.093	2.45	0.080	0.860	2.19	0.121	2.50	0.108	0.893
290.7	88.61	2.22	0.089	2.44	0.080	0.899	2.19	0.122	2.50	0.113	0.927
294.0	89.61	2.23	0.087	2.44	0.077	0.887	2.20	0.118	2.49	0.108	0.917
297.2	90.59	2.19	0.096	2.42	0.074	0.766	2.14	0.140	2.49	0.117	0.840
299.9	91.41	2.20	0.065	2.35	0.062	0.958	2.13	0.130	2.45	0.127	0.979
302.8	92.29	2.08	0.128	2.39	0.112	0.874	2.03	0.181	2.48	0.165	0.911
306.1	93.30	2.07	0.090	2.28	0.087	0.971	1.99	0.172	2.41	0.170	0.985
308.6	94.06	1.96	0.150	2.31	0.146	0.974	1.88	0.227	2.44	0.224	0.983
312.1	95.13	1.91	0.157	2.27	0.156	0.992	1.84	0.231	2.39	0.229	0.995
320.9	97.81	1.34	0.405	2.25	0.148	0.366	1.31	0.432	2.31	0.175	0.406
323.7	98.66	1.32	0.410	2.24	0.144	0.351	1.31	0.423	2.27	0.157	0.371
330.1	100.61	1.01	0.539	2.20	0.277	0.513	1.00	0.557	2.25	0.295	0.529
332.9	101.47	1.66	0.280	2.31	0.131	0.468	1.62	0.318	2.38	0.169	0.531
338.9	103.30	1.56	0.321	2.29	0.140	0.436	1.51	0.366	2.38	0.185	0.505
341.5	104.09	1.66	0.269	2.27	0.153	0.567	1.58	0.346	2.42	0.230	0.663
368.0	112.17	1.59	0.372	2.54	0.147	0.396	1.57	0.401	2.61	0.177	0.440
369.0	112.47	1.58	0.378	2.54	0.128	0.339	1.56	0.398	2.59	0.148	0.371
371.9	113.36	1.58	0.372	2.51	0.178	0.479	1.54	0.409	2.61	0.215	0.526
386.3	117.74	1.86	0.173	2.25	0.124	0.713	1.83	0.195	2.28	0.145	0.745
389.7	118.78	2.35	0.079	2.55	0.032	0.399	2.33	0.097	2.58	0.049	0.506
392.7	119.70	2.37	0.071	2.55	0.029	0.410	2.35	0.089	2.58	0.047	0.532
395.8	120.64	2.14	0.164	2.56	0.052	0.318	2.13	0.174	2.58	0.062	0.358
399.1	121.65	2.19	0.144	2.56	0.065	0.451	2.18	0.157	2.58	0.078	0.498
401.4	122.35	2.11	0.173	2.56	0.073	0.420	2.10	0.184	2.58	0.084	0.454
404.6	123.32	2.12	0.168	2.55	0.070	0.418	2.11	0.181	2.58	0.083	0.457
408.3	124.45	2.13	0.168	2.56	0.068	0.406	2.12	0.177	2.58	0.078	0.437
411.1	125.30	2.14	0.159	2.55	0.063	0.397	2.13	0.172	2.57	0.076	0.441
413.9	126.16	2.18	0.142	2.54	0.059	0.418	2.16	0.161	2.57	0.078	0.485
416.6	126.98	2.13	0.166	2.55	0.069	0.418	2.12	0.176	2.57	0.080	0.453
419.9	127.99	2.15	0.153	2.54	0.064	0.421	2.14	0.165	2.57	0.076	0.462
422.8	128.87	2.11	0.170	2.54	0.066	0.389	2.10	0.182	2.56	0.078	0.429
425.3	129.63	2.08	0.182	2.54	0.071	0.389	2.07	0.191	2.55	0.079	0.417
429.1	130.79	2.14	0.158	2.54	0.073	0.461	2.13	0.168	2.56	0.083	0.493
432.3	131.77	2.14	0.160	2.55	0.089	0.553	2.13	0.170	2.57	0.098	0.578
438.2	133.56	2.19	0.137	2.54	0.070	0.508	2.18	0.146	2.56	0.079	0.540
446.0	135.94	2.18	0.138	2.53	0.074	0.540	2.16	0.151	2.55	0.087	0.580

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

Depth (feet)	Depth (m)	Relative Humidity Oven-Dried					105C Oven-Dried				
		Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
446.6	136.12	2.19	0.137	2.54	0.080	0.584	2.18	0.144	2.55	0.087	0.605
449.8	137.10	2.18	0.139	2.53	0.075	0.541	2.17	0.148	2.55	0.084	0.569
453.1	138.11	2.16	0.147	2.53	0.080	0.542	2.15	0.156	2.55	0.089	0.569
456.1	139.02	2.08	0.179	2.54	0.071	0.395	2.07	0.186	2.55	0.078	0.418
460.1	140.24	2.15	0.145	2.52	0.074	0.511	2.14	0.157	2.54	0.086	0.549
461.9	140.79	2.16	0.141	2.51	0.074	0.526	2.14	0.154	2.54	0.088	0.567
465.1	141.76	2.18	0.134	2.52	0.074	0.556	2.17	0.146	2.54	0.087	0.593
468.1	142.68	2.14	0.148	2.51	0.078	0.524	2.12	0.162	2.53	0.091	0.564
470.8	143.50	2.05	0.183	2.51	0.082	0.446	2.04	0.194	2.53	0.093	0.478
474.0	144.48	2.02	0.191	2.50	0.078	0.406	2.01	0.203	2.52	0.090	0.441
477.2	145.45	2.03	0.187	2.50	0.077	0.413	2.02	0.199	2.52	0.090	0.450
479.9	146.27	1.97	0.211	2.50	0.087	0.413	1.96	0.224	2.52	0.100	0.447
487.0	148.44	1.99	0.200	2.49	0.082	0.410	1.98	0.212	2.51	0.094	0.444
489.0	149.05	2.13	0.146	2.49	0.088	0.607	2.12	0.159	2.52	0.102	0.640
496.5	151.33	2.12	0.153	2.50	0.089	0.581	2.10	0.165	2.52	0.101	0.612
498.0	151.79	2.06	0.169	2.48	0.096	0.568	2.05	0.181	2.50	0.108	0.596
506.2	154.29	2.13	0.143	2.49	0.080	0.556	2.12	0.158	2.51	0.094	0.596
506.9	154.50	2.09	0.159	2.49	0.097	0.608	2.08	0.174	2.52	0.112	0.641
508.9	155.11	2.08	0.163	2.48	0.088	0.542	2.06	0.178	2.51	0.104	0.582
512.7	156.27	2.00	0.193	2.48	0.096	0.497	1.98	0.209	2.51	0.112	0.534
516.5	157.43	2.14	0.139	2.49	0.095	0.684	2.13	0.153	2.51	0.109	0.713
523.6	159.59	2.09	0.157	2.47	0.126	0.804	2.07	0.173	2.50	0.142	0.822
523.8	159.65	2.11	0.150	2.48	0.114	0.755	2.09	0.167	2.51	0.130	0.779
525.9	160.29	2.02	0.184	2.47	0.133	0.722	2.00	0.201	2.50	0.150	0.745
532.0	162.15	2.20	0.107	2.46	0.091	0.853	2.18	0.129	2.50	0.114	0.879
538.7	164.20	2.04	0.168	2.45	0.102	0.610	2.03	0.184	2.48	0.118	0.644
539.1	164.32	2.08	0.159	2.48	0.099	0.622	2.07	0.174	2.50	0.114	0.655
546.9	166.70	2.16	0.130	2.48	0.096	0.735	2.14	0.144	2.50	0.109	0.760
547.9	167.00	2.11	0.149	2.48	0.090	0.605	2.10	0.161	2.50	0.102	0.636
549.4	167.46	2.16	0.129	2.48	0.094	0.727	2.15	0.142	2.51	0.107	0.753
550.9	167.91	2.13	0.140	2.48	0.101	0.719	2.12	0.153	2.50	0.114	0.743
554.8	169.10	2.16	0.122	2.46	0.079	0.645	2.15	0.137	2.49	0.093	0.683
560.4	170.81	2.15	0.114	2.43	0.073	0.637	2.13	0.131	2.45	0.089	0.683
565.7	172.43	2.18	0.113	2.46	0.082	0.727	2.17	0.129	2.49	0.098	0.761
567.0	172.82	2.13	0.131	2.45	0.092	0.696	2.11	0.148	2.48	0.108	0.731
569.7	173.65	2.18	0.113	2.46	0.086	0.757	2.16	0.131	2.49	0.104	0.791
574.8	175.20	2.21	0.104	2.47	0.081	0.777	2.19	0.123	2.50	0.100	0.811

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
576.4	175.69	2.14	0.128	2.45	0.095	0.742	2.12	0.147	2.48	0.114	0.774
578.1	176.21	2.22	0.101	2.46	0.086	0.848	2.20	0.121	2.50	0.105	0.873
582.8	177.64	2.25	0.086	2.47	0.073	0.856	2.23	0.106	2.50	0.094	0.884
584.9	178.28	2.18	0.116	2.47	0.091	0.783	2.16	0.135	2.50	0.110	0.814
588.1	179.25	2.19	0.108	2.46	0.090	0.839	2.17	0.128	2.49	0.110	0.864
591.1	180.17	2.12	0.142	2.48	0.117	0.822	2.11	0.158	2.50	0.132	0.839
594.4	181.17	2.20	0.102	2.45	0.083	0.819	2.18	0.126	2.49	0.107	0.853
596.8	181.91	2.15	0.121	2.44	0.107	0.880	2.12	0.148	2.49	0.133	0.902
600.0	182.88	2.10	0.136	2.43	0.094	0.692	2.07	0.161	2.47	0.119	0.740
603.0	183.79	2.08	0.154	2.46	0.097	0.628	2.06	0.173	2.49	0.115	0.669
606.2	184.77	2.10	0.152	2.48	0.100	0.655	2.08	0.171	2.51	0.118	0.692
614.8	187.39	2.26	0.095	2.49	0.066	0.689	2.24	0.115	2.53	0.085	0.742
617.1	188.09	2.22	0.105	2.48	0.083	0.793	2.20	0.124	2.51	0.102	0.825
623.3	189.98	2.21	0.110	2.49	0.087	0.789	2.19	0.130	2.52	0.107	0.822
625.9	190.77	2.21	0.109	2.48	0.071	0.649	2.19	0.130	2.52	0.092	0.706
627.7	191.32	2.27	0.081	2.47	0.066	0.825	2.24	0.104	2.50	0.090	0.865
629.8	191.96	2.27	0.076	2.46	0.064	0.843	2.25	0.101	2.50	0.089	0.881
632.6	192.82	2.26	0.080	2.46	0.066	0.815	2.24	0.104	2.50	0.089	0.856
636.6	194.04	2.29	0.073	2.47	0.060	0.831	2.27	0.093	2.51	0.081	0.869
638.3	194.55	2.29	0.072	2.46	0.055	0.771	2.26	0.095	2.50	0.079	0.828
643.5	196.14	2.31	0.067	2.47	0.056	0.837	2.28	0.088	2.51	0.078	0.877
644.7	196.51	2.28	0.072	2.46	0.068	0.942	2.26	0.094	2.50	0.090	0.956
646.9	197.18	2.33	0.052	2.46	0.044	0.851	2.30	0.077	2.50	0.070	0.900
650.9	198.39	2.33	0.051	2.46	0.044	0.875	2.31	0.076	2.50	0.069	0.917
653.7	199.25	2.29	0.067	2.46	0.051	0.765	2.27	0.090	2.50	0.074	0.824
656.6	200.13	2.28	0.064	2.44	0.053	0.822	2.25	0.090	2.48	0.079	0.873
659.2	200.92	2.33	0.058	2.47	0.053	0.921	2.30	0.083	2.51	0.078	0.945
663.6	202.27	2.29	0.069	2.46	0.060	0.877	2.27	0.094	2.50	0.085	0.910
665.4	202.81	2.30	0.068	2.47	0.059	0.862	2.28	0.092	2.51	0.083	0.898
668.8	203.85	2.26	0.083	2.47	0.076	0.918	2.24	0.103	2.50	0.096	0.934
671.1	204.55	2.33	0.062	2.48	0.051	0.823	2.30	0.085	2.52	0.074	0.872
676.0	206.05	2.31	0.071	2.48	0.064	0.902	2.28	0.093	2.52	0.086	0.925
677.6	206.53	2.35	0.054	2.48	0.052	0.961	2.32	0.077	2.52	0.075	0.973
684.1	208.51	2.31	0.094	2.55	0.079	0.844	2.29	0.113	2.59	0.099	0.871
688.0	209.70	2.33	0.089	2.56	0.086	0.967	2.31	0.109	2.60	0.106	0.973
690.4	210.43	2.33	0.086	2.55	0.079	0.920	2.31	0.106	2.58	0.099	0.935
693.5	211.38	2.30	0.071	2.48	0.067	0.945	2.28	0.095	2.52	0.091	0.959

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	**Depth (m)**	**Dry Bulk Density (g/cm^3)**	**Porosity (cm^3/cm^3)**	**Particle Density (g/cm^3)**	**Vol. Water Content (cm^3/cm^3)**	**Relative Satn.**	**Dry Bulk Density (g/cm^3)**	**Porosity (cm^3/cm^3)**	**Particle Density (g/cm^3)**	**Vol. Water Content (cm^3/cm^3)**	**Relative Satn.**
696.8	212.39	2.32	0.088	2.54	0.081	0.921	2.30	0.109	2.58	0.102	0.936
699.8	213.30	2.31	0.096	2.55	0.085	0.890	2.29	0.116	2.59	0.106	0.909
701.1	213.70	2.29	0.068	2.46	0.062	0.912	2.27	0.091	2.49	0.085	0.934
704.8	214.82	2.29	0.098	2.54	0.091	0.929	2.27	0.120	2.58	0.113	0.942
709.5	216.26	2.29	0.096	2.53	0.082	0.862	2.27	0.116	2.56	0.103	0.886
711.0	216.71	2.26	0.110	2.54	0.099	0.904	2.24	0.130	2.57	0.120	0.919
713.8	217.57	2.27	0.096	2.51	0.083	0.871	2.25	0.117	2.55	0.105	0.895
717.0	218.54	2.26	0.088	2.48	0.081	0.911	2.23	0.112	2.51	0.104	0.930
720.0	219.46	2.24	0.097	2.49	0.096	0.993	2.22	0.121	2.53	0.121	0.995
722.9	220.34	2.24	0.087	2.45	0.079	0.914	2.21	0.115	2.50	0.108	0.935
726.4	221.41	2.27	0.081	2.48	0.075	0.922	2.25	0.108	2.52	0.101	0.941
729.1	222.23	2.24	0.102	2.50	0.095	0.935	2.22	0.126	2.54	0.119	0.947
732.9	223.39	2.27	0.114	2.56	0.110	0.966	2.24	0.135	2.59	0.131	0.971
734.9	224.00	2.27	0.114	2.56	0.107	0.942	2.25	0.133	2.59	0.127	0.950
737.3	224.73	2.26	0.116	2.55	0.105	0.909	2.24	0.135	2.59	0.125	0.922
740.8	225.80	2.26	0.081	2.46	0.074	0.917	2.23	0.109	2.50	0.102	0.938
743.8	226.71	2.28	0.080	2.47	0.075	0.937	2.25	0.105	2.52	0.100	0.952
746.8	227.63	2.26	0.086	2.48	0.083	0.967	2.24	0.113	2.52	0.110	0.975
749.9	228.57	2.25	0.085	2.46	0.080	0.938	2.22	0.114	2.50	0.109	0.953
753.1	229.55	2.28	0.077	2.47	0.073	0.945	2.25	0.106	2.51	0.101	0.960
756.0	230.43	2.22	0.092	2.45	0.087	0.946	2.19	0.124	2.50	0.119	0.960
759.2	231.40	2.23	0.095	2.46	0.089	0.936	2.20	0.123	2.50	0.117	0.951
762.1	232.29	2.24	0.093	2.47	0.093	0.999	2.22	0.120	2.52	0.120	0.999
764.7	233.08	2.26	0.087	2.47	0.079	0.911	2.23	0.113	2.51	0.105	0.932
767.4	233.90	2.25	0.080	2.44	0.068	0.845	2.21	0.114	2.50	0.102	0.891
770.7	234.91	2.27	0.080	2.47	0.076	0.942	2.24	0.107	2.51	0.103	0.957
773.3	235.70	2.28	0.083	2.48	0.077	0.925	2.25	0.109	2.53	0.102	0.942
776.9	236.80	2.26	0.081	2.46	0.080	0.983	2.23	0.108	2.50	0.107	0.987
779.9	237.71	2.29	0.067	2.46	0.061	0.921	2.27	0.095	2.50	0.090	0.945
783.2	238.72	2.29	0.087	2.51	0.072	0.830	2.27	0.109	2.55	0.095	0.865
785.9	239.54	2.33	0.080	2.53	0.070	0.877	2.31	0.101	2.57	0.091	0.903
788.6	240.37	2.28	0.073	2.46	0.064	0.879	2.26	0.096	2.50	0.088	0.909
794.5	242.16	2.35	0.046	2.46	0.042	0.919	2.33	0.070	2.50	0.066	0.947
798.0	243.23	2.35	0.048	2.47	0.043	0.907	2.32	0.072	2.50	0.067	0.938
800.5	243.99	2.36	0.042	2.47	0.039	0.926	2.34	0.065	2.50	0.062	0.952
809.2	246.64	2.25	0.099	2.49	0.085	0.862	2.23	0.115	2.52	0.101	0.881
819.0	249.63	2.34	0.073	2.52	0.066	0.904	2.31	0.095	2.56	0.088	0.926

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

Depth (feet)	Depth (m)	Relative Humidity Oven-Dried					105C Oven-Dried				
		Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
824.7	251.37	2.13	0.146	2.49	0.133	0.911	2.12	0.157	2.51	0.144	0.917
835.4	254.63	2.23	0.103	2.48	0.090	0.874	2.21	0.123	2.52	0.110	0.894
836.8	255.06	2.31	0.096	2.55	0.067	0.698	2.29	0.116	2.59	0.087	0.751
842.5	256.79	2.24	0.096	2.48	0.086	0.891	2.22	0.116	2.51	0.105	0.909
847.6	258.35	2.32	0.078	2.51	0.067	0.862	2.29	0.099	2.55	0.088	0.892
848.4	258.59	2.21	0.114	2.49	0.088	0.775	2.19	0.135	2.53	0.109	0.811
856.9	261.18	2.11	0.156	2.50	0.124	0.794	2.10	0.172	2.53	0.139	0.813
857.7	261.43	2.24	0.101	2.50	0.086	0.845	2.22	0.121	2.53	0.105	0.870
862.3	262.83	2.32	0.084	2.53	0.072	0.863	2.30	0.105	2.57	0.093	0.890
864.9	263.62	2.29	0.089	2.51	0.069	0.778	2.26	0.110	2.54	0.090	0.821
867.4	264.38	2.32	0.073	2.50	0.069	0.942	2.30	0.097	2.54	0.093	0.956
872.0	265.79	2.24	0.108	2.51	0.078	0.720	2.22	0.128	2.54	0.098	0.764
874.4	266.52	2.20	0.120	2.50	0.092	0.772	2.18	0.136	2.53	0.109	0.800
875.5	266.85	2.28	0.085	2.49	0.071	0.835	2.25	0.108	2.53	0.094	0.870
878.8	267.86	2.27	0.087	2.48	0.074	0.844	2.25	0.106	2.52	0.093	0.872
884.2	269.50	2.25	0.093	2.48	0.077	0.821	2.23	0.113	2.52	0.096	0.852
885.0	269.75	2.31	0.075	2.50	0.066	0.879	2.29	0.098	2.54	0.089	0.907
887.6	270.54	2.26	0.096	2.50	0.085	0.888	2.23	0.117	2.53	0.106	0.908
891.0	271.58	2.26	0.090	2.49	0.076	0.843	2.24	0.109	2.52	0.095	0.870
894.0	272.49	2.22	0.107	2.49	0.093	0.864	2.20	0.127	2.52	0.113	0.885
897.3	273.50	2.28	0.078	2.48	0.070	0.904	2.26	0.100	2.51	0.093	0.925
899.5	274.17	2.28	0.080	2.47	0.074	0.924	2.25	0.105	2.51	0.098	0.942
904.9	275.81	2.26	0.090	2.49	0.071	0.793	2.24	0.110	2.52	0.092	0.831
910.7	277.58	2.23	0.102	2.49	0.087	0.855	2.21	0.122	2.52	0.107	0.878
914.7	278.80	2.25	0.097	2.49	0.083	0.854	2.23	0.117	2.52	0.103	0.879
916.2	279.26	2.30	0.075	2.49	0.067	0.902	2.28	0.096	2.52	0.088	0.923
919.1	280.14	2.23	0.105	2.49	0.086	0.818	2.21	0.124	2.52	0.105	0.846
920.4	280.54	2.24	0.102	2.49	0.085	0.831	2.22	0.122	2.53	0.105	0.858
924.1	281.67	2.27	0.087	2.49	0.073	0.847	2.25	0.105	2.52	0.092	0.874
928.4	282.98	2.30	0.084	2.52	0.076	0.903	2.28	0.106	2.55	0.098	0.923
929.7	283.37	2.29	0.085	2.50	0.074	0.871	2.27	0.105	2.53	0.094	0.895
932.8	284.32	2.09	0.164	2.50	0.131	0.798	2.08	0.178	2.53	0.145	0.814
936.7	285.51	2.29	0.094	2.53	0.074	0.781	2.27	0.114	2.56	0.093	0.819
940.7	286.73	2.22	0.120	2.52	0.108	0.903	2.20	0.140	2.55	0.128	0.917
941.5	286.97	2.28	0.095	2.52	0.083	0.879	2.26	0.114	2.56	0.103	0.900
946.4	288.46	2.27	0.102	2.53	0.084	0.825	2.24	0.126	2.57	0.108	0.858
951.2	289.93	2.33	0.085	2.54	0.077	0.906	2.30	0.110	2.59	0.102	0.927

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
954.5	290.93	2.29	0.098	2.54	0.083	0.847	2.27	0.122	2.58	0.107	0.877
957.0	291.69	2.13	0.163	2.54	0.127	0.778	2.10	0.184	2.58	0.148	0.803
961.4	293.04	1.95	0.228	2.53	0.174	0.762	1.93	0.245	2.56	0.191	0.779
962.5	293.37	2.35	0.082	2.56	0.078	0.956	2.32	0.105	2.60	0.101	0.965
966.9	294.71	2.09	0.175	2.53	0.147	0.839	2.08	0.190	2.56	0.161	0.851
968.9	295.32	2.24	0.110	2.51	0.097	0.881	2.22	0.131	2.55	0.117	0.900
971.4	296.08	2.23	0.112	2.52	0.102	0.905	2.21	0.137	2.56	0.126	0.922
974.5	297.03	2.18	0.136	2.53	0.116	0.850	2.16	0.159	2.57	0.138	0.871
978.1	298.13	2.26	0.096	2.50	0.088	0.918	2.24	0.120	2.55	0.113	0.935
981.0	299.01	2.12	0.158	2.52	0.133	0.846	2.10	0.178	2.56	0.154	0.864
983.8	299.86	1.92	0.241	2.53	0.200	0.831	1.91	0.258	2.57	0.217	0.842
986.2	300.59	2.18	0.130	2.50	0.126	0.965	2.15	0.153	2.54	0.149	0.970
990.2	301.81	2.26	0.099	2.50	0.091	0.918	2.23	0.123	2.55	0.115	0.934
993.1	302.70	2.33	0.074	2.52	0.074	0.995	2.31	0.097	2.55	0.097	0.996
994.3	303.06	2.25	0.098	2.50	0.097	0.985	2.23	0.118	2.53	0.117	0.988
999.0	304.50	2.28	0.087	2.50	0.076	0.878	2.26	0.106	2.53	0.095	0.900
1005.0	306.32	2.22	0.114	2.51	0.103	0.901	2.20	0.131	2.54	0.119	0.913
1008.2	307.30	2.30	0.079	2.49	0.072	0.909	2.28	0.099	2.53	0.092	0.927
1013.3	308.85	2.27	0.093	2.50	0.089	0.955	2.25	0.112	2.53	0.108	0.962
1017.6	310.16	2.24	0.103	2.50	0.098	0.952	2.22	0.125	2.54	0.120	0.961
1020.8	311.14	2.26	0.095	2.50	0.088	0.921	2.24	0.115	2.53	0.107	0.935
1022.5	311.66	2.32	0.075	2.51	0.068	0.909	2.30	0.096	2.54	0.089	0.928
1026.8	312.97	2.34	0.069	2.51	0.061	0.873	2.32	0.093	2.55	0.084	0.905
1028.8	313.58	2.29	0.085	2.51	0.080	0.942	2.27	0.108	2.54	0.103	0.954
1031.2	314.31	2.27	0.092	2.50	0.088	0.951	2.25	0.113	2.54	0.109	0.960
1035.2	315.53	2.32	0.078	2.52	0.071	0.910	2.30	0.101	2.55	0.094	0.930
1037.6	316.26	1.72	0.332	2.57	0.286	0.860	1.71	0.341	2.59	0.294	0.864
1040.5	317.14	2.32	0.081	2.52	0.074	0.922	2.29	0.103	2.56	0.096	0.938
1044.4	318.33	2.35	0.067	2.52	0.056	0.846	2.33	0.087	2.55	0.077	0.882
1046.7	319.03	2.35	0.067	2.52	0.059	0.886	2.33	0.090	2.56	0.082	0.915
1050.2	320.10	2.36	0.060	2.51	0.055	0.920	2.33	0.086	2.55	0.081	0.944
1053.2	321.02	2.10	0.165	2.51	0.155	0.944	2.08	0.180	2.54	0.171	0.948
1056.6	322.05	2.36	0.062	2.52	0.055	0.890	2.34	0.085	2.56	0.078	0.920
1058.8	322.72	2.32	0.073	2.50	0.064	0.881	2.30	0.095	2.54	0.086	0.908
1062.3	323.79	2.34	0.070	2.51	0.061	0.878	2.31	0.092	2.55	0.083	0.907
1066.4	325.04	2.35	0.064	2.51	0.058	0.900	2.33	0.088	2.55	0.081	0.927
1068.4	325.65	2.33	0.070	2.50	0.063	0.890	2.30	0.093	2.54	0.085	0.917

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
1071.0	326.44	2.35	0.058	2.50	0.054	0.929	2.33	0.083	2.54	0.079	0.950
1074.1	327.39	2.37	0.063	2.53	0.057	0.910	2.35	0.086	2.57	0.080	0.934
1077.1	328.30	2.36	0.065	2.53	0.059	0.905	2.34	0.088	2.57	0.082	0.930
1079.4	329.00	2.32	0.078	2.52	0.073	0.944	2.30	0.105	2.56	0.100	0.958
1082.7	330.01	2.33	0.090	2.56	0.071	0.787	2.32	0.108	2.60	0.089	0.823
1083.6	330.28	2.34	0.074	2.53	0.068	0.925	2.32	0.095	2.56	0.090	0.942
1085.8	330.95	2.37	0.065	2.54	0.060	0.919	2.35	0.089	2.58	0.084	0.942
1088.4	331.74	2.34	0.079	2.54	0.075	0.949	2.32	0.099	2.57	0.095	0.960
1092.2	332.90	2.34	0.071	2.52	0.062	0.878	2.32	0.091	2.56	0.082	0.904
1095.1	333.79	2.38	0.060	2.53	0.054	0.906	2.35	0.086	2.57	0.081	0.935
1097.1	334.40	2.36	0.070	2.54	0.061	0.872	2.34	0.093	2.58	0.084	0.904
1100.6	335.46	2.36	0.067	2.53	0.060	0.895	2.34	0.090	2.57	0.083	0.923
1103.7	336.41	2.35	0.068	2.52	0.058	0.847	2.33	0.092	2.56	0.081	0.886
1107.4	337.54	2.35	0.065	2.52	0.054	0.839	2.33	0.089	2.56	0.079	0.882
1109.7	338.24	2.27	0.094	2.51	0.072	0.769	2.25	0.119	2.55	0.097	0.817
1113.1	339.27	2.33	0.072	2.51	0.065	0.906	2.31	0.096	2.56	0.090	0.930
1115.4	339.97	2.32	0.073	2.51	0.066	0.907	2.30	0.098	2.55	0.091	0.931
1119.1	341.10	2.35	0.073	2.53	0.062	0.856	2.32	0.098	2.57	0.087	0.893
1121.5	341.83	2.36	0.063	2.52	0.056	0.889	2.33	0.089	2.56	0.082	0.922
1124.7	342.81	2.36	0.068	2.53	0.059	0.863	2.33	0.094	2.58	0.085	0.900
1127.3	343.60	2.34	0.074	2.53	0.066	0.884	2.32	0.098	2.57	0.090	0.912
1131.0	344.73	2.27	0.097	2.51	0.074	0.757	2.24	0.123	2.56	0.099	0.807
1134.2	345.70	2.36	0.064	2.53	0.055	0.861	2.34	0.090	2.57	0.081	0.900
1137.2	346.62	2.29	0.085	2.50	0.074	0.865	2.27	0.109	2.54	0.098	0.895
1139.4	347.29	2.34	0.063	2.50	0.053	0.845	2.32	0.088	2.54	0.078	0.889
1142.0	348.08	2.34	0.065	2.50	0.057	0.886	2.32	0.090	2.55	0.082	0.918
1145.5	349.15	2.36	0.066	2.53	0.058	0.885	2.34	0.090	2.57	0.083	0.917
1148.4	350.03	2.38	0.062	2.54	0.054	0.882	2.36	0.086	2.58	0.079	0.916
1151.6	351.01	2.36	0.070	2.53	0.059	0.844	2.33	0.095	2.58	0.084	0.886
1155.6	352.23	2.37	0.063	2.53	0.056	0.880	2.35	0.088	2.58	0.080	0.914
1157.6	352.84	2.38	0.061	2.54	0.055	0.901	2.36	0.087	2.58	0.081	0.931
1160.5	353.72	2.36	0.067	2.53	0.059	0.884	2.33	0.093	2.57	0.085	0.916
1163.1	354.51	2.33	0.074	2.52	0.067	0.898	2.31	0.101	2.57	0.093	0.925
1166.7	355.61	2.38	0.063	2.54	0.055	0.867	2.35	0.090	2.58	0.081	0.906
1170.3	356.71	2.36	0.061	2.52	0.054	0.886	2.34	0.087	2.56	0.080	0.919
1172.9	357.50	2.39	0.061	2.54	0.058	0.945	2.36	0.087	2.59	0.084	0.961
1175.4	358.26	2.37	0.059	2.52	0.050	0.851	2.34	0.087	2.56	0.078	0.899

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
1179.2	359.42	2.37	0.064	2.54	0.057	0.888	2.35	0.089	2.58	0.081	0.919
1180.9	359.94	2.39	0.058	2.54	0.047	0.806	2.37	0.083	2.58	0.072	0.865
1185.3	361.28	2.29	0.022	2.34	0.021	0.966	2.24	0.071	2.41	0.070	0.989
1188.0	362.10	2.41	0.037	2.51	0.029	0.782	2.40	0.056	2.54	0.048	0.855
1190.5	362.86	2.42	0.038	2.52	0.030	0.809	2.40	0.057	2.55	0.049	0.873
1195.0	364.24	2.35	0.011	2.38	0.010	0.889	2.34	0.025	2.40	0.023	0.949
1197.2	364.91	2.35	0.013	2.38	0.012	0.887	2.34	0.025	2.40	0.023	0.940
1199.6	365.64	2.25	0.037	2.34	0.036	0.997	2.20	0.087	2.41	0.087	0.999
1202.4	366.49	2.34	0.020	2.38	0.017	0.861	2.32	0.035	2.41	0.032	0.921
1206.0	367.59	2.34	0.019	2.39	0.013	0.691	2.33	0.028	2.40	0.022	0.790
1208.9	368.47	2.35	0.017	2.39	0.014	0.800	2.34	0.025	2.40	0.022	0.865
1213.7	369.94	2.35	0.014	2.39	0.014	0.997	2.34	0.023	2.40	0.023	0.998
1215.0	370.33	2.34	0.016	2.38	0.015	0.924	2.33	0.027	2.40	0.026	0.956
1218.0	371.25	2.29	0.032	2.36	0.028	0.886	2.26	0.062	2.41	0.058	0.941
1222.1	372.50	2.34	0.019	2.38	0.018	0.917	2.32	0.032	2.40	0.031	0.951
1225.0	373.38	2.34	0.015	2.38	0.015	0.958	2.33	0.028	2.39	0.027	0.977
1226.8	373.93	2.33	0.021	2.38	0.018	0.860	2.32	0.032	2.39	0.029	0.908
1229.5	374.75	2.35	0.014	2.38	0.012	0.826	2.34	0.021	2.39	0.019	0.884
1235.2	376.49	2.34	0.016	2.38	0.012	0.785	2.33	0.023	2.39	0.020	0.854
1236.2	376.79	2.34	0.017	2.38	0.013	0.754	2.34	0.024	2.39	0.020	0.825
1239.1	377.68	2.35	0.014	2.38	0.011	0.833	2.34	0.020	2.39	0.018	0.886
1241.8	378.50	2.35	0.012	2.38	0.009	0.691	2.35	0.018	2.39	0.015	0.793
1248.4	380.51	2.35	0.013	2.38	0.009	0.702	2.34	0.019	2.39	0.015	0.794
1251.0	381.31	2.35	0.015	2.38	0.011	0.734	2.34	0.021	2.39	0.017	0.813
1253.6	382.10	2.35	0.013	2.38	0.010	0.741	2.35	0.018	2.39	0.015	0.819
1256.2	382.89	2.35	0.011	2.38	0.009	0.795	2.35	0.016	2.39	0.014	0.859
1260.9	384.32	2.35	0.014	2.38	0.012	0.871	2.34	0.021	2.39	0.019	0.914
1262.4	384.78	2.35	0.012	2.38	0.009	0.765	2.34	0.019	2.39	0.016	0.855
1265.6	385.76	2.34	0.012	2.37	0.011	0.914	2.33	0.022	2.39	0.021	0.953
1269.0	386.79	2.34	0.013	2.37	0.010	0.750	2.33	0.024	2.39	0.021	0.862
1271.6	387.58	2.31	0.026	2.37	0.017	0.645	2.30	0.039	2.39	0.029	0.758
1275.5	388.77	2.31	0.023	2.36	0.009	0.376	2.30	0.037	2.38	0.023	0.622
1277.8	389.47	2.28	0.030	2.35	0.024	0.822	2.26	0.052	2.39	0.047	0.898
1283.1	391.09	2.20	0.065	2.35	0.052	0.795	2.17	0.091	2.39	0.078	0.854
1284.3	391.46	2.18	0.075	2.36	0.058	0.772	2.16	0.098	2.39	0.081	0.827
1287.2	392.34	2.13	0.088	2.34	0.061	0.697	2.11	0.113	2.38	0.086	0.763
1289.8	393.13	2.15	0.076	2.33	0.059	0.768	2.12	0.102	2.36	0.084	0.825

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
1292.6	393.98	2.07	0.117	2.35	0.073	0.627	2.05	0.134	2.37	0.091	0.676
1296.3	395.11	1.98	0.154	2.34	0.090	0.582	1.97	0.167	2.36	0.103	0.615
1298.6	395.81	1.96	0.149	2.30	0.087	0.585	1.95	0.159	2.32	0.097	0.611
1301.4	396.67	1.91	0.168	2.30	0.077	0.459	1.90	0.179	2.31	0.088	0.491
1305.0	397.76	1.87	0.182	2.28	0.074	0.409	1.85	0.193	2.30	0.086	0.445
1309.1	399.01	1.80	0.217	2.30	0.070	0.325	1.79	0.225	2.31	0.079	0.350
1310.9	399.56	1.76	0.229	2.28	0.068	0.298	1.75	0.238	2.29	0.077	0.323
1314.1	400.54	1.74	0.231	2.26	0.063	0.271	1.73	0.237	2.27	0.069	0.291
1319.2	402.09	1.75	0.228	2.26	0.069	0.302	1.74	0.234	2.27	0.075	0.321
1319.6	402.21	1.75	0.231	2.27	0.058	0.250	1.74	0.238	2.28	0.064	0.271
1323.0	403.25	1.68	0.259	2.26	0.072	0.278	1.67	0.264	2.27	0.077	0.293
1328.8	405.02	1.71	0.226	2.21	0.059	0.262	1.71	0.231	2.22	0.064	0.277
1329.0	405.08	1.69	0.244	2.23	0.056	0.230	1.68	0.248	2.24	0.061	0.244
1332.2	406.06	1.70	0.235	2.23	0.063	0.268	1.70	0.240	2.23	0.068	0.282
1335.2	406.97	1.78	0.192	2.20	0.075	0.388	1.78	0.196	2.21	0.078	0.399
1338.2	407.88	1.74	0.176	2.12	0.074	0.422	1.74	0.182	2.13	0.080	0.441
1341.4	408.86	1.83	0.166	2.19	0.062	0.373	1.82	0.170	2.20	0.066	0.388
1344.4	409.77	1.84	0.164	2.20	0.060	0.367	1.83	0.168	2.20	0.064	0.383
1346.4	410.38	1.81	0.172	2.19	0.063	0.365	1.81	0.176	2.19	0.067	0.381
1349.7	411.39	1.76	0.182	2.14	0.063	0.344	1.75	0.187	2.15	0.068	0.364
1390.8	423.92	1.43	0.346	2.19	0.118	0.341	1.43	0.351	2.20	0.123	0.350
1396.4	425.62	1.66	0.298	2.36	0.074	0.248	1.65	0.306	2.38	0.082	0.268
1397.8	426.05	1.69	0.277	2.33	0.048	0.174	1.67	0.292	2.36	0.063	0.215
1410.3	429.86	1.61	0.272	2.22	0.112	0.413	1.60	0.291	2.25	0.132	0.451
1411.0	430.07	1.52	0.325	2.25	0.079	0.245	1.51	0.333	2.27	0.088	0.264
1413.3	430.77	1.53	0.323	2.25	0.082	0.253	1.52	0.330	2.27	0.089	0.270
1415.6	431.48	1.54	0.310	2.24	0.074	0.240	1.53	0.319	2.25	0.083	0.261
1418.3	432.30	1.53	0.316	2.24	0.072	0.228	1.52	0.325	2.26	0.081	0.249
1422.0	433.43	1.54	0.308	2.22	0.072	0.234	1.53	0.316	2.24	0.079	0.252
1424.5	434.19	1.55	0.310	2.24	0.078	0.250	1.54	0.318	2.26	0.086	0.270
1428.0	435.25	1.59	0.221	2.04	0.119	0.540	1.55	0.264	2.10	0.163	0.616
1432.4	436.60	1.55	0.313	2.26	0.097	0.309	1.54	0.326	2.28	0.110	0.338
1433.4	436.90	1.57	0.307	2.26	0.093	0.302	1.56	0.317	2.28	0.103	0.324
1441.7	439.43	1.44	0.356	2.24	0.107	0.301	1.44	0.361	2.24	0.111	0.309
1442.6	439.70	1.50	0.334	2.25	0.111	0.331	1.48	0.346	2.27	0.123	0.356
1446.2	440.80	1.44	0.296	2.05	0.116	0.393	1.42	0.314	2.07	0.134	0.427
1448.3	441.44	1.43	0.324	2.11	0.133	0.411	1.41	0.343	2.15	0.152	0.443

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
1451.6	442.45	1.37	0.367	2.17	0.150	0.408	1.36	0.382	2.20	0.165	0.433
1455.1	443.51	1.47	0.340	2.23	0.148	0.435	1.45	0.362	2.27	0.170	0.469
1457.5	444.25	1.51	0.333	2.26	0.106	0.317	1.49	0.346	2.28	0.118	0.342
1460.7	445.22	1.54	0.305	2.21	0.103	0.338	1.53	0.319	2.24	0.117	0.366
1463.8	446.17	1.39	0.326	2.06	0.104	0.318	1.38	0.337	2.08	0.115	0.341
1466.5	446.99	1.37	0.390	2.24	0.093	0.239	1.35	0.402	2.26	0.105	0.262
1469.9	448.03	1.36	0.391	2.23	0.101	0.258	1.35	0.405	2.26	0.114	0.283
1470.5	448.21	1.44	0.362	2.26	0.108	0.299	1.43	0.376	2.28	0.122	0.325
1480.7	451.32	1.45	0.351	2.24	0.137	0.390	1.44	0.366	2.27	0.151	0.414
1482.4	451.84	1.46	0.326	2.16	0.175	0.536	1.44	0.345	2.19	0.195	0.563
1484.1	452.35	1.44	0.337	2.17	0.187	0.555	1.42	0.356	2.21	0.206	0.579
1488.1	453.57	1.48	0.278	2.05	0.196	0.706	1.46	0.299	2.08	0.218	0.727
1490.8	454.40	1.45	0.292	2.05	0.205	0.702	1.42	0.316	2.08	0.229	0.724
1494.0	455.37	1.57	0.314	2.29	0.184	0.585	1.55	0.331	2.32	0.200	0.606
1496.8	456.23	1.49	0.287	2.08	0.248	0.866	1.46	0.311	2.12	0.272	0.877
1499.8	457.14	1.41	0.349	2.17	0.252	0.723	1.39	0.369	2.20	0.272	0.738
1502.8	458.05	1.46	0.309	2.11	0.282	0.915	1.43	0.337	2.16	0.311	0.922
1506.0	459.03	1.54	0.276	2.12	0.260	0.941	1.49	0.326	2.21	0.310	0.950
1508.7	459.85	1.51	0.273	2.07	0.245	0.897	1.45	0.325	2.15	0.297	0.914
1512.0	460.86	1.51	0.298	2.15	0.289	0.970	1.46	0.352	2.25	0.343	0.974
1515.2	461.83	1.48	0.339	2.24	0.316	0.933	1.44	0.383	2.33	0.360	0.941
1518.0	462.69	1.58	0.306	2.27	0.185	0.606	1.54	0.343	2.34	0.222	0.648
1521.0	463.60	1.50	0.358	2.33	0.181	0.506	1.48	0.378	2.37	0.201	0.532
1523.9	464.49	1.62	0.296	2.29	0.275	0.930	1.58	0.332	2.36	0.311	0.938
1526.6	465.31	1.51	0.339	2.28	0.324	0.955	1.48	0.364	2.33	0.349	0.958
1530.5	466.50	1.48	0.333	2.22	0.329	0.987	1.44	0.373	2.30	0.369	0.988
1533.3	467.35	1.50	0.317	2.19	0.310	0.979	1.45	0.370	2.29	0.364	0.982
1535.3	467.96	1.54	0.313	2.24	0.309	0.988	1.49	0.367	2.35	0.363	0.990
1538.6	468.97	1.51	0.319	2.22	0.292	0.913	1.46	0.371	2.32	0.343	0.925
1541.2	469.76	1.54	0.312	2.23	0.286	0.918	1.48	0.371	2.35	0.345	0.931
1545.1	470.95	1.51	0.316	2.21	0.267	0.846	1.45	0.375	2.32	0.327	0.870
1548.1	471.86	1.47	0.329	2.18	0.307	0.935	1.41	0.389	2.30	0.367	0.945
1550.7	472.65	1.58	0.267	2.15	0.263	0.986	1.49	0.358	2.32	0.354	0.990
1553.6	473.54	1.63	0.251	2.17	0.247	0.985	1.53	0.347	2.34	0.343	0.989
1556.9	474.54	1.65	0.231	2.14	0.230	0.997	1.53	0.345	2.34	0.344	0.998
1560.5	475.64	1.57	0.268	2.14	0.255	0.951	1.46	0.374	2.33	0.361	0.965
1562.5	476.25	1.62	0.236	2.12	0.233	0.989	1.50	0.356	2.33	0.354	0.992

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
1565.6	477.20	1.88	0.122	2.14	0.122	0.995	1.76	0.240	2.32	0.240	0.997
1568.5	478.08	1.49	0.316	2.18	0.300	0.951	1.40	0.403	2.35	0.388	0.962
1572.0	479.15	1.68	0.244	2.23	0.237	0.973	1.60	0.330	2.38	0.324	0.980
1575.1	480.09	1.84	0.156	2.18	0.150	0.959	1.72	0.277	2.38	0.270	0.977
1577.4	480.79	1.85	0.155	2.19	0.147	0.945	1.73	0.280	2.40	0.272	0.970
1581.0	481.89	1.76	0.160	2.09	0.154	0.964	1.60	0.316	2.34	0.310	0.982
1583.7	482.71	1.66	0.256	2.23	0.246	0.959	1.57	0.345	2.40	0.335	0.970
1586.5	483.57	1.70	0.220	2.18	0.220	1.002	1.57	0.358	2.44	0.358	1.001
1589.9	484.60	1.69	0.248	2.24	0.237	0.955	1.61	0.328	2.39	0.317	0.966
1593.1	485.58	1.87	0.177	2.27	0.180	1.018	1.79	0.260	2.42	0.263	1.012
1595.5	486.31	1.89	0.171	2.28	0.172	1.007	1.80	0.264	2.44	0.266	1.005
1599.0	487.38	1.85	0.203	2.32	0.184	0.910	1.79	0.266	2.43	0.247	0.931
1602.9	488.56	2.07	0.096	2.29	0.097	1.011	1.95	0.222	2.50	0.223	1.005
1604.9	489.17	2.12	0.058	2.25	0.058	1.008	2.00	0.182	2.44	0.182	1.002
1607.4	489.94	2.18	0.093	2.40	0.091	0.976	2.06	0.212	2.61	0.210	0.989
1613.3	491.73	2.15	0.096	2.37	0.092	0.954	2.01	0.230	2.61	0.226	0.981
1617.8	493.11	1.94	0.138	2.25	0.154	1.120	1.78	0.290	2.51	0.307	1.057
1619.1	493.50	1.97	0.125	2.26	0.123	0.982	1.83	0.272	2.51	0.270	0.992
1620.5	493.93	2.00	0.100	2.22	0.093	0.924	1.83	0.271	2.51	0.263	0.972
1623.7	494.90	1.85	0.137	2.14	0.142	1.037	1.67	0.322	2.46	0.327	1.016
1626.3	495.70	1.69	0.236	2.22	0.228	0.967	1.55	0.376	2.49	0.368	0.979
1629.2	496.58	1.55	0.269	2.12	0.275	1.022	1.38	0.440	2.46	0.445	1.013
1631.3	497.22	1.55	0.305	2.23	0.308	1.009	1.44	0.415	2.47	0.418	1.007
1634.7	498.26	1.69	0.212	2.14	0.185	0.871	1.53	0.367	2.42	0.339	0.926
1638.2	499.32	1.87	0.154	2.21	0.147	0.959	1.74	0.283	2.43	0.277	0.978
1642.4	500.60	1.90	0.121	2.16	0.112	0.928	1.76	0.263	2.38	0.254	0.967
1644.5	501.24	1.95	0.108	2.18	0.098	0.908	1.80	0.261	2.43	0.251	0.962
1647.2	502.07	1.78	0.175	2.16	0.045	0.258	1.71	0.248	2.28	0.118	0.476
1651.5	503.38	1.72	0.231	2.24	0.152	0.661	1.59	0.361	2.49	0.283	0.784
1653.4	503.96	1.78	0.195	2.21	0.150	0.767	1.65	0.326	2.45	0.280	0.861
1656.0	504.75	1.66	0.326	2.46	0.256	0.784	1.62	0.364	2.55	0.293	0.807
1658.8	505.60	1.76	0.237	2.31	0.139	0.587	1.64	0.358	2.55	0.260	0.726
1661.1	506.30	1.70	0.302	2.44	0.226	0.749	1.64	0.367	2.59	0.291	0.794
1664.7	507.40	1.70	0.299	2.43	0.039	0.131	1.64	0.360	2.56	0.100	0.278
1667.5	508.25	1.81	0.206	2.28	-0.059[†]	-0.289[†]	1.67	0.349	2.56	0.083	0.239
1670.6	509.20	1.84	0.211	2.33	0.001	0.005	1.70	0.349	2.62	0.139	0.397
1676.7	511.06	1.70	0.324	2.51	0.046	0.142	1.67	0.348	2.57	0.070	0.202

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
1677.1	511.18	1.74	0.266	2.38	-0.009†	-0.034†	1.66	0.354	2.56	0.079	0.223
1680.2	512.13	1.80	0.226	2.33	-0.051†	-0.224†	1.68	0.350	2.58	0.073	0.210
1683.4	513.10	1.72	0.322	2.54	0.043	0.135	1.70	0.344	2.59	0.066	0.191
1685.9	513.86	1.86	0.202	2.33	-0.058†	-0.286†	1.72	0.334	2.59	0.074	0.223
1688.9	514.78	1.84	0.231	2.39	-0.018†	-0.077†	1.73	0.333	2.60	0.084	0.253
1691.5	515.57	1.93	0.144	2.25	-0.103†	-0.718†	1.74	0.326	2.59	0.079	0.243
1694.8	516.58	1.93	0.149	2.26	-0.091†	-0.612†	1.75	0.329	2.60	0.088	0.269
1699.9	518.13	1.83	0.255	2.46	0.007	0.026	1.77	0.318	2.59	0.070	0.219
1701.0	518.47	1.87	0.223	2.40	-0.012†	-0.054†	1.77	0.316	2.59	0.081	0.258
1703.8	519.32	1.81	0.288	2.54	0.053	0.183	1.78	0.317	2.60	0.082	0.259
1706.8	520.23	1.79	0.293	2.53	0.061	0.209	1.77	0.320	2.60	0.089	0.277
1709.8	521.15	1.80	0.293	2.55	0.061	0.210	1.79	0.311	2.59	0.080	0.257
1712.8	522.06	1.81	0.276	2.50	0.040	0.143	1.77	0.320	2.60	0.083	0.260
1716.1	523.07	1.83	0.260	2.47	0.022	0.086	1.77	0.318	2.59	0.080	0.252
1718.5	523.80	1.86	0.248	2.48	0.029	0.118	1.80	0.305	2.60	0.086	0.283
1722.2	524.93	1.89	0.223	2.44	-0.001†	-0.003†	1.82	0.301	2.60	0.077	0.256
1728.8	526.94	1.86	0.247	2.47	0.026	0.105	1.80	0.307	2.59	0.085	0.278
1729.4	527.12	1.79	0.293	2.53	0.054	0.184	1.76	0.321	2.59	0.082	0.256
1730.6	527.49	1.84	0.286	2.57	0.081	0.283	1.82	0.304	2.62	0.100	0.327
1734.3	528.62	1.90	0.181	2.32	-0.073†	-0.404†	1.76	0.323	2.59	0.069	0.213
1736.8	529.38	1.84	0.258	2.48	0.025	0.097	1.78	0.313	2.59	0.080	0.255
1740.1	530.38	1.83	0.242	2.41	0.000	0.000	1.75	0.323	2.58	0.081	0.252
1744.1	531.60	1.81	0.271	2.48	0.050	0.186	1.76	0.316	2.58	0.095	0.300
1745.8	532.12	1.79	0.303	2.57	0.089	0.294	1.78	0.319	2.61	0.105	0.329
1748.6	532.97	1.80	0.289	2.54	0.129	0.445	1.79	0.299	2.56	0.139	0.464
1752.3	534.10	1.87	0.248	2.49	0.034	0.137	1.83	0.288	2.58	0.074	0.258
1754.6	534.80	1.87	0.248	2.49	0.043	0.173	1.83	0.290	2.58	0.086	0.295
1758.1	535.87	1.87	0.267	2.56	0.082	0.308	1.86	0.279	2.58	0.094	0.338
1760.8	536.69	1.88	0.227	2.43	0.015	0.064	1.81	0.298	2.57	0.086	0.287
1764.1	537.70	1.92	0.237	2.51	0.061	0.258	1.88	0.274	2.59	0.098	0.358
1766.9	538.55	1.94	0.236	2.53	0.073	0.311	1.91	0.263	2.59	0.101	0.383
1770.4	539.62	1.97	0.233	2.56	0.070	0.299	1.95	0.248	2.59	0.084	0.341
1772.3	540.20	1.99	0.222	2.56	0.055	0.247	1.98	0.240	2.60	0.073	0.304
1775.5	541.17	2.04	0.198	2.55	0.092	0.464	2.02	0.221	2.59	0.115	0.521
1779.0	542.24	2.11	0.169	2.54	0.133	0.785	2.08	0.195	2.59	0.159	0.814
1781.7	543.06	2.13	0.158	2.53	0.096	0.608	2.09	0.190	2.59	0.128	0.673
1785.0	544.07	2.13	0.156	2.52	0.109	0.700	2.09	0.193	2.59	0.146	0.757

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					**105C Oven-Dried**				
Depth (feet)	**Depth (m)**	**Dry Bulk Density (g/cm^3)**	**Porosity (cm^3/cm^3)**	**Particle Density (g/cm^3)**	**Vol. Water Content (cm^3/cm^3)**	**Relative Satn.**	**Dry Bulk Density (g/cm^3)**	**Porosity (cm^3/cm^3)**	**Particle Density (g/cm^3)**	**Vol. Water Content (cm^3/cm^3)**	**Relative Satn.**
1788.1	545.01	2.09	0.183	2.56	0.126	0.688	2.08	0.200	2.59	0.143	0.716
1791.5	546.05	2.15	0.140	2.50	0.098	0.699	2.10	0.184	2.58	0.142	0.772
1794.1	546.84	2.13	0.152	2.51	0.098	0.647	2.09	0.187	2.57	0.133	0.713
1797.3	547.82	2.14	0.156	2.53	0.110	0.706	2.11	0.183	2.58	0.137	0.748
1800.3	548.73	2.14	0.147	2.51	0.088	0.597	2.11	0.179	2.57	0.120	0.670
1803.1	549.59	2.20	0.122	2.50	0.094	0.775	2.16	0.159	2.57	0.131	0.827
1806.2	550.53	2.20	0.111	2.48	0.075	0.680	2.16	0.156	2.56	0.121	0.773
1808.6	551.26	2.23	0.099	2.48	0.069	0.696	2.19	0.142	2.55	0.112	0.788
1811.9	552.27	2.22	0.107	2.49	0.077	0.720	2.18	0.143	2.55	0.113	0.790
1815.1	553.24	2.28	0.072	2.45	0.047	0.657	2.22	0.127	2.54	0.102	0.805
1817.5	553.97	2.27	0.086	2.49	0.060	0.704	2.24	0.116	2.54	0.090	0.781
1821.1	555.07	2.29	0.080	2.49	0.063	0.787	2.26	0.110	2.54	0.093	0.846
1823.3	555.74	2.31	0.071	2.48	0.063	0.883	2.27	0.103	2.53	0.094	0.919
1826.3	556.66	2.27	0.066	2.44	0.053	0.799	2.24	0.100	2.49	0.087	0.867
1829.2	557.54	2.26	0.092	2.49	0.069	0.750	2.23	0.121	2.54	0.098	0.810
1833.0	558.70	2.19	0.123	2.50	0.097	0.790	2.16	0.151	2.54	0.125	0.828
1836.1	559.64	2.13	0.150	2.50	0.108	0.717	2.10	0.174	2.55	0.131	0.755
1839.1	560.56	2.07	0.178	2.51	0.113	0.634	2.05	0.197	2.55	0.132	0.671
1841.8	561.38	2.03	0.193	2.52	0.193	1.002	2.02	0.209	2.55	0.210	1.002
1844.6	562.23	1.99	0.206	2.50	0.146	0.710	1.97	0.224	2.54	0.164	0.733
1847.0	562.97	1.93	0.218	2.47	0.160	0.737	1.91	0.237	2.51	0.180	0.758
1852.7	564.70	1.91	0.233	2.49	0.107	0.457	1.89	0.253	2.53	0.126	0.500
1853.7	565.01	1.90	0.235	2.48	0.129	0.547	1.88	0.252	2.52	0.146	0.578
1857.4	566.14	1.98	0.202	2.48	0.171	0.847	1.96	0.219	2.51	0.188	0.859
1860.1	566.96	1.98	0.187	2.44	0.174	0.927	1.97	0.205	2.47	0.192	0.934
1863.2	567.90	2.02	0.167	2.43	0.159	0.952	1.99	0.194	2.47	0.186	0.959
1865.8	568.70	1.98	0.177	2.41	0.171	0.964	1.93	0.233	2.51	0.226	0.973
1868.7	569.58	2.00	0.162	2.38	0.148	0.915	1.95	0.208	2.47	0.194	0.934
1872.1	570.62	1.95	0.175	2.36	0.152	0.870	1.90	0.223	2.45	0.201	0.899
1875.0	571.50	1.75	0.254	2.34	0.245	0.963	1.69	0.309	2.45	0.299	0.969
1878.1	572.45	1.70	0.290	2.39	0.183	0.632	1.63	0.358	2.53	0.251	0.701
1881.0	573.33	1.69	0.287	2.37	0.214	0.746	1.62	0.360	2.52	0.287	0.797
1883.9	574.21	1.78	0.216	2.27	0.208	0.965	1.70	0.299	2.42	0.291	0.975
1886.9	575.13	1.78	0.228	2.30	0.209	0.919	1.70	0.308	2.45	0.289	0.940
1890.1	576.10	1.72	0.253	2.30	0.177	0.702	1.65	0.324	2.44	0.249	0.768
1892.7	576.90	1.76	0.241	2.32	0.169	0.701	1.69	0.309	2.45	0.236	0.766
1896.2	577.96	1.74	0.253	2.32	0.191	0.754	1.67	0.321	2.46	0.259	0.806

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
1899.4	578.94	1.73	0.253	2.32	0.172	0.679	1.66	0.326	2.46	0.245	0.751
1901.9	579.70	1.63	0.292	2.30	0.214	0.731	1.56	0.358	2.44	0.280	0.780
1904.2	580.40	1.67	0.267	2.28	0.221	0.825	1.60	0.337	2.41	0.290	0.861
1908.1	581.59	1.77	0.232	2.30	0.164	0.706	1.68	0.317	2.47	0.249	0.785
1910.3	582.26	1.67	0.277	2.31	0.225	0.814	1.60	0.348	2.46	0.297	0.852
1914.4	583.51	1.79	0.220	2.29	0.193	0.877	1.70	0.310	2.46	0.283	0.912
1916.4	584.12	1.73	0.256	2.32	0.162	0.632	1.65	0.332	2.47	0.238	0.717
1919.6	585.09	1.64	0.294	2.32	0.219	0.744	1.56	0.368	2.47	0.292	0.795
1922.8	586.07	1.70	0.258	2.29	0.219	0.848	1.63	0.334	2.44	0.295	0.883
1925.1	586.77	1.75	0.233	2.28	0.214	0.918	1.67	0.314	2.44	0.295	0.939
1928.4	587.78	1.73	0.256	2.32	0.189	0.740	1.64	0.337	2.48	0.271	0.803
1931.6	588.75	1.68	0.278	2.33	0.232	0.834	1.60	0.354	2.48	0.308	0.870
1934.6	589.67	1.80	0.220	2.30	0.195	0.885	1.71	0.302	2.46	0.277	0.916
1937.8	590.64	1.79	0.216	2.29	0.186	0.863	1.70	0.311	2.46	0.281	0.905
1940.8	591.56	1.69	0.262	2.29	0.178	0.678	1.61	0.342	2.44	0.258	0.754
1943.9	592.50	1.67	0.273	2.29	0.117	0.429	1.59	0.351	2.45	0.194	0.555
1946.7	593.35	1.68	0.265	2.29	0.202	0.760	1.60	0.346	2.45	0.282	0.816
1950.5	594.51	1.67	0.274	2.29	0.215	0.786	1.59	0.353	2.45	0.295	0.834
1952.8	595.21	1.67	0.269	2.29	0.163	0.606	1.59	0.350	2.45	0.244	0.698
1956.8	596.43	1.73	0.233	2.25	0.179	0.766	1.64	0.320	2.41	0.266	0.830
1959.2	597.16	1.69	0.256	2.27	0.186	0.725	1.60	0.345	2.44	0.275	0.796
1962.0	598.02	1.72	0.244	2.27	0.195	0.798	1.63	0.333	2.44	0.283	0.852
1965.1	598.96	1.74	0.237	2.28	0.160	0.675	1.65	0.327	2.45	0.250	0.764
1968.1	599.88	1.71	0.245	2.26	0.198	0.807	1.61	0.342	2.45	0.295	0.862
1970.7	600.67	1.69	0.254	2.27	0.200	0.788	1.60	0.344	2.45	0.290	0.843
1973.7	601.58	1.79	0.214	2.27	0.167	0.780	1.69	0.307	2.44	0.260	0.847
1976.6	602.47	1.75	0.231	2.28	0.184	0.795	1.66	0.321	2.45	0.274	0.853
1980.2	603.57	1.68	0.262	2.28	0.233	0.886	1.59	0.352	2.46	0.323	0.915
1983.2	604.48	1.66	0.264	2.26	0.227	0.860	1.57	0.355	2.44	0.318	0.896
1985.7	605.24	1.69	0.275	2.33	0.234	0.848	1.60	0.366	2.52	0.324	0.885
1988.4	606.06	1.63	0.277	2.26	0.258	0.930	1.54	0.364	2.43	0.344	0.947
1991.2	606.92	1.65	0.266	2.25	0.219	0.822	1.56	0.354	2.42	0.307	0.867
1994.7	607.99	1.68	0.250	2.24	0.228	0.911	1.58	0.346	2.42	0.324	0.936
1998.0	608.99	1.73	0.228	2.24	0.208	0.911	1.63	0.323	2.41	0.303	0.937
2000.9	609.87	1.68	0.254	2.24	0.237	0.936	1.58	0.345	2.42	0.329	0.953
2004.2	610.88	1.61	0.279	2.24	0.264	0.945	1.52	0.370	2.42	0.355	0.959
2007.5	611.89	1.76	0.212	2.24	0.192	0.906	1.67	0.303	2.40	0.284	0.935

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
2010.5	612.80	1.82	0.186	2.24	0.166	0.891	1.73	0.284	2.41	0.264	0.929
2012.6	613.44	1.95	0.122	2.22	0.110	0.897	1.84	0.233	2.40	0.220	0.946
2016.1	614.51	2.01	0.098	2.23	0.083	0.853	1.90	0.213	2.41	0.199	0.933
2018.7	615.30	2.04	0.084	2.22	0.073	0.866	1.91	0.206	2.41	0.195	0.945
2022.1	616.34	2.05	0.086	2.25	0.067	0.780	1.94	0.197	2.42	0.178	0.904
2025.2	617.28	2.10	0.059	2.23	0.051	0.863	1.97	0.180	2.41	0.172	0.955
2027.5	617.98	2.08	0.065	2.22	0.055	0.852	1.96	0.190	2.41	0.180	0.950
2030.5	618.90	2.04	0.079	2.22	0.066	0.843	1.91	0.206	2.41	0.194	0.940
2034.3	620.06	1.99	0.101	2.22	0.087	0.860	1.87	0.226	2.41	0.211	0.937
2037.3	620.97	2.09	0.065	2.23	0.056	0.866	1.97	0.183	2.41	0.174	0.953
2040.3	621.88	1.89	0.153	2.23	0.133	0.872	1.78	0.260	2.41	0.241	0.925
2042.6	622.58	1.89	0.147	2.21	0.132	0.897	1.77	0.261	2.40	0.246	0.942
2045.7	623.53	1.99	0.102	2.22	0.091	0.887	1.89	0.200	2.37	0.188	0.942
2048.7	624.44	1.96	0.117	2.22	0.119	1.017	1.86	0.215	2.37	0.217	1.009
2052.4	625.57	1.93	0.121	2.20	0.115	0.956	1.84	0.213	2.34	0.208	0.975
2054.4	626.18	2.02	0.102	2.25	0.089	0.872	1.93	0.191	2.38	0.178	0.932
2057.8	627.22	2.05	0.086	2.25	0.080	0.929	1.97	0.170	2.37	0.164	0.964
2060.8	628.13	2.04	0.074	2.20	0.076	1.030	1.95	0.164	2.33	0.166	1.014
2063.6	628.99	1.94	0.124	2.22	0.113	0.912	1.85	0.216	2.36	0.205	0.950
2066.4	629.84	1.92	0.135	2.22	0.133	0.984	1.82	0.227	2.36	0.225	0.991
2070.0	630.94	1.99	0.105	2.22	0.100	0.952	1.89	0.199	2.36	0.193	0.974
2075.3	632.55	1.84	0.164	2.20	0.146	0.892	1.75	0.250	2.34	0.233	0.930
2076.4	632.89	1.98	0.104	2.21	0.090	0.870	1.89	0.194	2.34	0.181	0.930
2078.4	633.50	1.90	0.136	2.20	0.128	0.941	1.81	0.223	2.33	0.215	0.964
2081.6	634.47	1.82	0.172	2.20	0.171	0.994	1.73	0.260	2.35	0.259	0.996
2085.6	635.69	1.84	0.154	2.17	0.143	0.930	1.74	0.245	2.31	0.234	0.956
2087.4	636.24	1.79	0.184	2.19	0.176	0.957	1.70	0.270	2.33	0.262	0.971
2090.6	637.22	1.77	0.201	2.21	0.195	0.967	1.68	0.288	2.36	0.282	0.977
2093.6	638.13	1.72	0.209	2.18	0.183	0.877	1.64	0.291	2.32	0.266	0.912
2096.9	639.14	1.73	0.214	2.20	0.202	0.944	1.64	0.299	2.34	0.287	0.960
2100.8	640.32	1.71	0.229	2.21	0.213	0.932	1.62	0.314	2.36	0.298	0.950
2103.7	641.21	1.73	0.209	2.19	0.188	0.903	1.65	0.292	2.33	0.272	0.931
2105.4	641.73	1.75	0.208	2.20	0.190	0.917	1.66	0.295	2.35	0.278	0.941
2108.5	642.67	1.76	0.204	2.22	0.174	0.854	1.67	0.300	2.38	0.270	0.900
2111.8	643.68	1.73	0.225	2.23	0.202	0.899	1.64	0.309	2.38	0.287	0.927
2114.7	644.56	1.77	0.196	2.20	0.176	0.897	1.68	0.284	2.34	0.264	0.929
2117.7	645.48	1.79	0.185	2.20	0.163	0.880	1.70	0.272	2.34	0.250	0.918

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
2120.9	646.45	1.71	0.231	2.23	0.220	0.952	1.63	0.316	2.38	0.305	0.965
2123.8	647.33	1.68	0.220	2.15	0.163	0.740	1.59	0.304	2.29	0.247	0.812
2126.5	648.16	1.77	0.182	2.16	0.155	0.852	1.68	0.274	2.31	0.247	0.902
2129.7	649.13	1.72	0.219	2.20	0.197	0.896	1.63	0.310	2.36	0.287	0.926
2132.9	650.11	1.76	0.188	2.17	0.172	0.916	1.67	0.281	2.32	0.265	0.944
2136.0	651.05	1.77	0.189	2.18	0.179	0.944	1.67	0.285	2.34	0.274	0.963
2139.5	652.12	1.75	0.208	2.20	0.198	0.955	1.65	0.303	2.37	0.293	0.969
2141.5	652.73	1.63	0.261	2.21	0.216	0.826	1.54	0.347	2.36	0.302	0.869
2144.9	653.77	1.81	0.186	2.23	0.173	0.930	1.72	0.279	2.38	0.266	0.953
2148.1	654.74	1.82	0.183	2.23	0.173	0.948	1.73	0.277	2.39	0.268	0.966
2151.1	655.66	1.83	0.179	2.22	0.160	0.897	1.73	0.272	2.38	0.254	0.932
2153.9	656.51	1.82	0.180	2.22	0.172	0.955	1.73	0.275	2.38	0.267	0.970
2157.0	657.45	1.84	0.173	2.22	0.171	0.987	1.74	0.271	2.39	0.269	0.992
2159.8	658.31	1.87	0.168	2.25	0.158	0.940	1.77	0.264	2.41	0.254	0.962
2162.8	659.22	1.83	0.177	2.22	0.170	0.962	1.73	0.274	2.38	0.267	0.975
2166.0	660.20	1.80	0.185	2.21	0.181	0.983	1.71	0.279	2.37	0.276	0.988
2168.7	661.02	1.84	0.166	2.21	0.154	0.929	1.74	0.269	2.38	0.258	0.956
2171.8	661.97	1.86	0.179	2.26	0.167	0.931	1.76	0.270	2.42	0.258	0.954
2174.8	662.88	1.71	0.229	2.22	0.219	0.955	1.62	0.316	2.37	0.306	0.967
2178.0	663.85	1.57	0.326	2.33	0.330	1.013	1.50	0.391	2.47	0.395	1.010
2181.2	664.83	2.02	0.213	2.57	0.171	0.804	2.00	0.233	2.61	0.191	0.821
2185.7	666.20	2.19	0.153	2.59	0.136	0.894	2.19	0.160	2.60	0.144	0.899
2186.9	666.57	2.14	0.167	2.57	0.158	0.943	2.13	0.175	2.58	0.165	0.945
2190.4	667.63	2.09	0.186	2.57	0.182	0.976	2.08	0.197	2.60	0.193	0.977
2193.0	668.43	2.02	0.206	2.55	0.209	1.015	2.01	0.219	2.57	0.222	1.014
2196.1	669.37	1.98	0.211	2.51	0.217	1.025	1.96	0.229	2.54	0.235	1.023
2200.9	670.83	1.90	0.242	2.51	0.248	1.025	1.89	0.256	2.54	0.262	1.023
2204.6	671.96	1.93	0.242	2.54	0.244	1.010	1.91	0.259	2.58	0.262	1.010
2208.2	673.06	1.63	0.302	2.34	0.401	1.330	1.62	0.318	2.37	0.418	1.313
2211.0	673.91	2.04	0.207	2.57	0.198	0.954	2.03	0.219	2.60	0.210	0.957
2213.9	674.80	2.14	0.169	2.58	0.188	1.108	2.13	0.183	2.60	0.201	1.100
2216.3	675.53	2.15	0.160	2.56	0.158	0.991	2.13	0.177	2.59	0.175	0.992
2220.2	676.72	2.19	0.140	2.55	0.132	0.944	2.17	0.157	2.58	0.149	0.950
2223.4	677.69	2.18	0.143	2.54	0.138	0.969	2.16	0.164	2.58	0.159	0.973
2225.7	678.39	2.23	0.124	2.54	0.123	0.990	2.21	0.143	2.58	0.142	0.991
2228.6	679.28	2.27	0.100	2.52	0.097	0.972	2.24	0.129	2.57	0.126	0.978
2232.1	680.34	2.21	0.129	2.54	0.129	1.004	2.19	0.150	2.58	0.151	1.003

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
2235.1	681.26	2.24	0.121	2.55	0.110	0.906	2.22	0.142	2.59	0.131	0.920
2237.9	682.11	2.27	0.108	2.54	0.101	0.940	2.25	0.129	2.58	0.122	0.950
2241.0	683.06	2.29	0.101	2.55	0.098	0.969	2.27	0.119	2.58	0.116	0.974
2242.9	683.64	2.24	0.120	2.54	0.116	0.967	2.22	0.141	2.58	0.137	0.972
2246.8	684.83	2.29	0.102	2.55	0.098	0.959	2.27	0.119	2.58	0.114	0.965
2250.0	685.80	2.29	0.105	2.55	0.100	0.956	2.27	0.120	2.58	0.115	0.962
2253.3	686.81	2.29	0.099	2.55	0.094	0.948	2.28	0.116	2.58	0.111	0.956
2255.8	687.57	2.29	0.099	2.54	0.094	0.955	2.27	0.117	2.57	0.112	0.962
2258.9	688.51	2.29	0.100	2.54	0.099	0.987	2.27	0.118	2.57	0.116	0.989
2261.4	689.28	2.29	0.102	2.54	0.099	0.969	2.27	0.115	2.57	0.112	0.973
2264.9	690.34	2.31	0.092	2.54	0.099	1.079	2.30	0.104	2.56	0.111	1.070
2268.3	691.38	2.28	0.105	2.54	0.094	0.899	2.26	0.118	2.57	0.107	0.910
2271.1	692.23	2.31	0.093	2.55	0.091	0.975	2.30	0.105	2.57	0.103	0.978
2273.6	692.99	2.33	0.083	2.54	0.080	0.959	2.32	0.094	2.56	0.090	0.964
2276.8	693.97	2.33	0.086	2.55	0.081	0.948	2.32	0.096	2.57	0.091	0.954
2279.6	694.82	2.32	0.091	2.55	0.088	0.968	2.31	0.101	2.57	0.098	0.971
2282.5	695.71	2.35	0.080	2.55	0.074	0.928	2.34	0.090	2.57	0.084	0.936
2286.1	696.80	2.27	0.108	2.55	0.103	0.951	2.26	0.122	2.57	0.116	0.956
2289.1	697.72	2.30	0.100	2.55	0.094	0.936	2.29	0.113	2.58	0.106	0.943
2292.3	698.69	2.31	0.098	2.56	0.093	0.945	2.30	0.111	2.58	0.105	0.951
2294.7	699.43	2.31	0.096	2.55	0.096	1.006	2.30	0.106	2.57	0.106	1.005
2297.5	700.28	2.30	0.099	2.55	0.098	0.989	2.29	0.109	2.57	0.108	0.990
2300.9	701.31	2.32	0.088	2.54	0.089	1.014	2.31	0.100	2.56	0.102	1.013
2303.6	702.14	2.30	0.096	2.55	0.090	0.941	2.29	0.107	2.57	0.101	0.947
2307.0	703.17	2.31	0.089	2.54	0.090	1.003	2.30	0.100	2.56	0.100	1.003
2309.3	703.88	2.32	0.085	2.54	0.082	0.963	2.32	0.094	2.55	0.090	0.967
2312.7	704.91	2.29	0.095	2.53	0.089	0.938	2.28	0.105	2.55	0.099	0.944
2316.1	705.95	2.31	0.090	2.53	0.085	0.948	2.30	0.099	2.55	0.095	0.953
2318.7	706.74	2.30	0.090	2.53	0.084	0.934	2.30	0.099	2.55	0.093	0.941
2321.9	707.72	2.31	0.090	2.53	0.086	0.959	2.30	0.100	2.55	0.096	0.963
2324.7	708.57	2.31	0.087	2.53	0.085	0.970	2.30	0.098	2.55	0.095	0.973
2327.8	709.51	2.31	0.088	2.54	0.081	0.928	2.30	0.098	2.55	0.092	0.936
2330.7	710.40	2.29	0.098	2.54	0.100	1.028	2.28	0.108	2.55	0.111	1.025
2333.9	711.37	2.32	0.081	2.53	0.095	1.176	2.31	0.093	2.55	0.107	1.153
2337.8	712.56	2.33	0.077	2.52	0.075	0.973	2.32	0.088	2.54	0.086	0.976
2339.8	713.17	2.35	0.069	2.52	0.064	0.935	2.34	0.078	2.54	0.074	0.943
2342.4	713.96	2.36	0.065	2.52	0.062	0.941	2.35	0.075	2.54	0.071	0.948

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
2345.9	715.03	2.40	0.056	2.55	0.053	0.954	2.40	0.064	2.56	0.061	0.960
2348.6	715.85	2.35	0.079	2.55	0.087	1.105	2.33	0.090	2.56	0.098	1.092
2352.1	716.92	2.40	0.058	2.55	0.057	0.982	2.39	0.070	2.57	0.069	0.985
2355.0	717.80	2.40	0.059	2.55	0.056	0.953	2.39	0.067	2.56	0.064	0.959
2358.0	718.72	2.33	0.086	2.55	0.105	1.227	2.32	0.098	2.57	0.117	1.199
2360.8	719.57	2.40	0.059	2.55	0.056	0.938	2.39	0.067	2.56	0.063	0.944
2363.4	720.36	2.37	0.073	2.55	0.067	0.916	2.36	0.081	2.57	0.075	0.925
2365.9	721.13	2.38	0.063	2.55	0.062	0.980	2.38	0.071	2.56	0.069	0.982
2371.3	722.77	2.39	0.064	2.56	0.060	0.936	2.39	0.072	2.57	0.068	0.943
2375.0	723.90	2.33	0.087	2.56	0.095	1.094	2.32	0.100	2.58	0.108	1.081
2379.9	725.39	2.37	0.072	2.55	0.066	0.911	2.36	0.082	2.57	0.075	0.922
2369.3	722.16	2.42	0.052	2.55	0.051	0.984	2.41	0.059	2.56	0.059	0.986
2382.0	726.03	2.36	0.071	2.54	0.067	0.950	2.35	0.081	2.56	0.077	0.956
2384.7	726.86	2.37	0.069	2.54	0.067	0.965	2.36	0.080	2.56	0.077	0.970
2387.7	727.77	1.97	0.255	2.65	0.229	0.897	1.95	0.278	2.70	0.252	0.906
2390.9	728.75	2.40	0.055	2.54	0.050	0.912	2.39	0.065	2.55	0.061	0.926
2393.5	729.54	2.39	0.058	2.54	0.077	1.336	2.38	0.070	2.56	0.089	1.279
2396.7	730.51	2.38	0.068	2.55	0.058	0.853	2.37	0.079	2.57	0.069	0.872
2399.6	731.40	2.27	0.116	2.56	0.093	0.795	2.25	0.132	2.59	0.108	0.820
2402.6	732.31	2.38	0.066	2.55	0.059	0.894	2.37	0.077	2.57	0.070	0.909
2406.3	733.44	2.36	0.083	2.58	0.082	0.989	2.35	0.094	2.60	0.093	0.990
2408.9	734.23	2.37	0.080	2.58	0.074	0.925	2.36	0.091	2.60	0.085	0.934
2412.5	735.33	2.40	0.068	2.57	0.065	0.958	2.38	0.079	2.59	0.076	0.964
2414.4	735.91	2.41	0.059	2.56	0.057	0.962	2.40	0.068	2.58	0.065	0.967
2418.5	737.16	2.25	0.106	2.52	0.122	1.151	2.23	0.133	2.57	0.149	1.120
2420.8	737.86	2.38	0.063	2.54	0.060	0.958	2.37	0.073	2.56	0.070	0.963
2424.0	738.84	2.34	0.080	2.55	0.073	0.919	2.33	0.091	2.56	0.084	0.929
2426.8	739.69	2.33	0.089	2.56	0.076	0.853	2.32	0.100	2.57	0.087	0.869
2429.9	740.63	2.30	0.108	2.58	0.101	0.931	2.29	0.119	2.60	0.111	0.937
2432.1	741.30	2.29	0.120	2.60	0.118	0.982	2.28	0.130	2.62	0.128	0.983
2435.6	742.37	2.28	0.125	2.60	0.122	0.973	2.27	0.135	2.62	0.132	0.975
2439.2	743.47	2.17	0.201	2.71	0.197	0.984	2.16	0.211	2.74	0.208	0.985
2443.5	744.78	2.09	0.200	2.61	0.196	0.980	2.07	0.212	2.63	0.208	0.981
2448.5	746.30	2.24	0.129	2.58	0.128	0.988	2.23	0.140	2.60	0.139	0.989
2450.4	746.88	2.19	0.148	2.57	0.155	1.045	2.18	0.159	2.59	0.166	1.041
2453.1	747.71	2.23	0.133	2.58	0.145	1.090	2.22	0.143	2.60	0.155	1.083
2455.9	748.56	2.17	0.157	2.57	0.157	1.002	2.16	0.169	2.60	0.169	1.001

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
2459.5	749.66	2.19	0.146	2.57	0.140	0.965	2.18	0.157	2.59	0.152	0.968
2463.1	750.75	2.18	0.147	2.56	0.143	0.971	2.17	0.160	2.58	0.155	0.973
2465.3	751.42	2.13	0.173	2.57	0.170	0.981	2.11	0.193	2.61	0.190	0.983
2468.1	752.28	2.10	0.177	2.55	0.159	0.901	2.09	0.189	2.58	0.172	0.908
2471.3	753.25	2.12	0.165	2.54	0.182	1.099	2.10	0.178	2.56	0.194	1.093
2474.2	754.14	2.07	0.187	2.54	0.171	0.914	2.06	0.199	2.56	0.183	0.919
2477.3	755.08	2.03	0.192	2.51	0.195	1.014	2.01	0.204	2.53	0.207	1.013
2480.7	756.12	2.00	0.119	2.27	0.121	1.010	1.96	0.160	2.33	0.161	1.008
2484.6	757.31	1.95	0.209	2.46	0.207	0.988	1.92	0.237	2.51	0.235	0.990
2500.9	762.27	1.92	0.171	2.32	0.169	0.991	1.87	0.228	2.42	0.226	0.993
2501.9	762.58	2.02	0.133	2.32	0.142	1.068	1.97	0.181	2.40	0.190	1.050
2505.8	763.77	2.00	0.137	2.32	0.153	1.116	1.95	0.190	2.41	0.206	1.084
2507.7	764.35	1.95	0.158	2.32	0.158	0.999	1.90	0.209	2.40	0.209	0.999
2511.8	765.60	2.02	0.128	2.31	0.127	0.992	1.98	0.169	2.38	0.168	0.994
2515.0	766.57	1.90	0.178	2.31	0.181	1.020	1.84	0.240	2.42	0.243	1.015
2516.9	767.15	1.77	0.235	2.31	0.244	1.040	1.71	0.295	2.43	0.305	1.032
2520.7	768.31	1.87	0.189	2.31	0.194	1.027	1.81	0.252	2.42	0.257	1.020
2523.3	769.10	1.92	0.154	2.27	0.162	1.054	1.87	0.207	2.36	0.215	1.040
2525.9	769.89	1.94	0.149	2.28	0.151	1.012	1.89	0.202	2.37	0.204	1.009
2529.1	770.87	1.91	0.158	2.27	0.157	0.993	1.86	0.208	2.35	0.207	0.995
2531.8	771.69	1.92	0.152	2.26	0.156	1.026	1.86	0.213	2.36	0.217	1.019
2534.8	772.61	1.99	0.123	2.27	0.141	1.143	1.93	0.181	2.36	0.198	1.098
2537.5	773.43	1.98	0.125	2.26	0.132	1.058	1.92	0.187	2.36	0.194	1.039
2541.4	774.62	1.93	0.145	2.26	0.174	1.204	1.87	0.205	2.36	0.235	1.144
2544.0	775.41	1.91	0.147	2.24	0.147	1.001	1.86	0.199	2.32	0.199	1.000
2547.2	776.39	1.88	0.170	2.26	0.196	1.150	1.81	0.235	2.37	0.261	1.109
2549.6	777.12	1.91	0.144	2.23	0.148	1.025	1.85	0.207	2.33	0.210	1.017
2552.8	778.09	1.93	0.136	2.23	0.142	1.047	1.88	0.187	2.31	0.194	1.034
2556.2	779.13	1.79	0.225	2.31	0.230	1.018	1.74	0.272	2.40	0.276	1.015
2558.8	779.92	1.76	0.219	2.25	0.216	0.989	1.70	0.272	2.34	0.270	0.991
2561.8	780.84	1.68	0.271	2.30	0.278	1.026	1.63	0.316	2.38	0.323	1.022
2566.6	782.30	1.70	0.259	2.30	0.256	0.990	1.66	0.301	2.38	0.299	0.991
2567.9	782.70	1.68	0.274	2.32	0.275	1.004	1.64	0.320	2.40	0.321	1.004
2570.7	783.55	1.76	0.233	2.30	0.230	0.986	1.72	0.276	2.37	0.272	0.988
2573.8	784.49	1.79	0.207	2.25	0.202	0.977	1.73	0.259	2.34	0.254	0.982
2576.4	785.29	1.79	0.209	2.26	0.209	0.999	1.74	0.255	2.34	0.255	0.999
2579.9	786.35	1.95	0.151	2.30	0.151	1.001	1.91	0.195	2.37	0.196	1.001

Table G-1: Laboratory Material Properties and Water Contents Measured on Core Samples from Drill Hole USW SD-7 (Continued)

[Measurements reported by Lorraine E. Flint, U.S. Geological Survey Hydrologic Research Facility: DTN No. GS951108312231.009; J. Curtis and C. Vidano, analysts]

		Relative Humidity Oven-Dried					105C Oven-Dried				
Depth (feet)	Depth (m)	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)	Vol. Water Content (cm^3/cm^3)	Relative Satn.
2583.0	787.30	1.99	0.137	2.31	0.135	0.988	1.95	0.179	2.37	0.178	0.991
2586.3	788.30	1.96	0.169	2.36	0.169	1.000	1.92	0.206	2.42	0.206	1.000
2589.0	789.13	1.92	0.181	2.35	0.177	0.977	1.88	0.223	2.42	0.219	0.981
2591.8	789.98	1.93	0.200	2.41	0.198	0.992	1.89	0.238	2.48	0.236	0.993
2594.9	790.93	2.06	0.124	2.35	0.123	0.986	2.02	0.163	2.41	0.161	0.989
2598.0	791.87	1.89	0.190	2.33	0.196	1.033	1.84	0.240	2.42	0.247	1.026
2601.2	792.85	1.73	0.271	2.37	0.284	1.047	1.68	0.313	2.45	0.326	1.041
2604.0	793.70	1.76	0.252	2.35	0.247	0.982	1.72	0.294	2.43	0.289	0.984
2606.0	794.31	1.70	0.275	2.34	0.337	1.227	1.65	0.329	2.45	0.391	1.189
2611.4	795.96	1.70	0.275	2.34	0.272	0.989	1.65	0.321	2.43	0.318	0.990
2613.3	796.53	1.86	0.198	2.32	0.195	0.984	1.82	0.239	2.39	0.236	0.987
2615.9	797.33	1.86	0.193	2.30	0.188	0.978	1.81	0.239	2.38	0.234	0.982
2618.6	798.15	1.86	0.197	2.31	0.195	0.990	1.82	0.235	2.38	0.233	0.991
2622.2	799.25	1.93	0.166	2.31	0.163	0.980	1.88	0.212	2.38	0.209	0.984
2625.1	800.13	1.70	0.270	2.32	0.268	0.994	1.65	0.316	2.41	0.315	0.995
2628.0	801.01	1.62	0.309	2.34	0.310	1.004	1.57	0.359	2.45	0.360	1.003
2631.0	801.93	1.53	0.341	2.33	0.335	0.983	1.48	0.393	2.44	0.387	0.985
2633.8	802.78	1.58	0.319	2.32	0.317	0.991	1.54	0.365	2.42	0.362	0.992
2637.1	803.79	1.62	0.307	2.34	0.316	1.030	1.58	0.351	2.43	0.361	1.026
2639.5	804.52	1.61	0.307	2.33	0.350	1.141	1.57	0.353	2.42	0.396	1.123
2643.5	805.74	1.54	0.338	2.32	0.351	1.038	1.49	0.387	2.43	0.400	1.033
2646.7	806.71	1.70	0.266	2.31	0.263	0.987	1.64	0.317	2.41	0.314	0.989
2648.6	807.29	1.75	0.248	2.33	0.246	0.991	1.71	0.292	2.41	0.290	0.993
2652.0	808.33	1.60	0.323	2.36	0.329	1.018	1.55	0.367	2.45	0.373	1.015
2655.3	809.34	1.55	0.333	2.33	0.339	1.020	1.51	0.380	2.43	0.387	1.017
2658.0	810.16	1.58	0.325	2.35	0.330	1.015	1.54	0.373	2.45	0.377	1.013
2660.7	810.98	1.52	0.359	2.37	0.354	0.986	1.48	0.401	2.46	0.396	0.987
2663.7	811.90	1.55	0.343	2.37	0.341	0.994	1.51	0.391	2.47	0.389	0.995
2666.7	812.81	1.43	0.417	2.45	0.416	0.997	1.40	0.442	2.51	0.440	0.997
2670.0	813.82	1.56	0.343	2.37	0.344	1.003	1.51	0.385	2.46	0.386	1.003
2673.0	814.73	1.67	0.298	2.38	0.302	1.014	1.64	0.332	2.45	0.336	1.013

[†] Negative values for RH-dried volumetric water content or relative saturation indicate that the sample actually *adsorbed* water during the humidification process at 65-percent RH. This may indicate either that the sample was exposed to the dry Nevada atmosphere for too long a period before being sealed in its can or that the mineral assemblage(s) are actually undersaturated with respect to structural water at these test conditions. These saturation values have been set to zero in illustrations in this report. Saturation values greater than 1.0 have been set equal to 1.0 in the illustrations.

Table G-2: Porosity and Saturated Hydraulic Conductivity Values Measured on Core Samples From Drill Hole USW SD-7

[Measurements reported by L. E. Flint, U.S. Geological Survey Hydrologic Research Facility, DTN No. 123456789012.123. Ksat – saturated hydraulic conductivity; nf – no flow]

Depth (feet)	Depth (m)	Porosity (cm^3/cm^3)	Ksat (m/sec)
128.9	39.29	0.060	nf[†]
176.8	53.89	0.079	1.60E-11
206.6	62.97	0.047	nf
230.1	70.13	0.063	nf
281.5	85.80	0.071	3.03E-11
287.6	87.66	0.097	3.30E-11
302.8	92.29	0.089	1.40E-10
312.1	95.13	0.193	5.40E-11
330.1	100.61	0.373	1.10E-05
332.9	101.47	0.308	7.30E-06
392.7	119.69	0.072	1.80E-09
399.1	121.65	0.141	2.30E-09
425.3	129.63	0.187	3.90E-09
446.6	136.12	0.138	9.30E-09
470.8	143.50	0.176	7.60E-10
496.5	151.33	0.162	2.30E-10
1396.4	425.62	0.232	1.60E-05
1410.3	429.86	0.231	3.30E-06
1422.0	433.43	0.257	7.10E-06
1428.0	435.25	0.227	2.80E-09
1595.5	486.31	0.118	nf
1617.8	493.11	0.128	2.10E-10
1626.3	495.70	0.192	1.80E-11
1634.7	498.26	0.162	nf
1661.1	506.30	0.324	4.20E-12
1829.2	557.54	0.079	2.60E-11
1844.6	562.23	0.186	1.40E-09
1878.1	572.44	0.238	2.03E-09
1890.1	576.10	0.192	nf
2153.9	656.51	0.148	nf
2193.0	668.43	0.218	3.90E-10
2213.9	674.80	0.160	6.90E-11
2237.9	682.11	0.106	nf
2363.4	720.36	0.058	8.70E-11
2507.7	764.35	0.058	nf
2561.8	780.84	0.058	nf
2586.3	788.30	0.152	nf
2606.0	794.31	0.241	1.70E-10
2666.7	812.81	0.394	4.60E-09

[†] "no flow" samples have been set arbitrarily to a value of $1x10^{-14}$ for display in illustrations in this report.

Appendix H: X-Ray Diffraction Mineralogic Data

Table H-1: X-Ray Diffraction Data for the Vitric-to-Zeolitic Transition Underlying the Topopah Spring Tuff

[All values from DTN No. LASC831321DQ96001. Information provided by David T. Vaniman, Los Alamos National Laboratory. Intervals containing significant (more than 10 percent) zeolite or smectite are shaded. Note: original error estimates omitted]

Depth (feet)	Smectite	Clinoptilolite	Mordenite	Chabazite	Tridymite	Cristobalite	Opal-CT	Quartz	Feldspar	Glass	Mica	Other
1133.3	5	--	--	--	1	20	--	18	53	--	trace	trace[†]
1156.7	7	--	--	--	--	16	--	23	50	--	trace	trace[†]
1161.5	4	--	--	--	1	10	--	30	53	--	trace	trace[†]
1165.0	6	--	--	--	--	18	--	24	52	--	trace	trace[†]
1169.9	6	--	--	--	--	11	--	29	51	--	trace	trace[†]
1175.1	6	--	--	--	--	16	--	25	51	--	trace	trace[†]
1179.5	5	--	--	1	--	18	--	21	51	--	trace	trace[†]
1181.6	7	--	--	1	2	17	--	20	49	--	trace	trace[†]
1187.0	59	--	--	5	--	--	22	1	15	--	--	--
1191.1	19	38	--	5	--	--	25	7	14	--	trace	--
1193.4	6	--	--	--	--	--	21	1	15	57	trace	--
1201.7	1	--	--	--	--	--	17	1	14	67	trace	--
1213.5	1	--	--	--	--	--	17	1	12	69	trace	--
1230.7	1	--	--	--	--	--	12	2	9	76	trace	--
1245.5	trace	--	--	--	--	--	10	1	9	80	trace	--
1260.2	trace	--	--	--	--	--	9	1	7	83	trace	--
1278.6	1	--	--	--	--	--	18	1	13	67	trace	--
1298.8	2	--	--	--	--	--	14	1	12	71	trace	trace[‡]
1321.5	trace	--	--	--	--	--	4	2	7	87	trace	--
1338.5	trace	--	--	--	--	--	2	1	3	94	trace	--
1350.5	trace	--	--	--	--	--	16	5	20	52	trace	6[††]
1391.0	1	--	--	--	--	--	2	3	6	85	trace	3[††]
1421.1	trace	--	--	--	--	--	2	1	6	91	--	--
1444.6	trace	--	--	--	--	--	2	2	6	90	--	--
1457.4	trace	1	--	trace	--	--	3	3	7	86	trace	--
1471.5	trace	1	--	trace	--	--	2	4	8	85	trace	--
1493.2	trace	45	--	5	--	--	26	7	14	--	trace	--
1493.3	11	14	--	3	--	--	5	4	10	53	trace	--
1513.9	2	6	--	1	--	--	5	4	8	74	trace	--
1517.3	5	2	--	1	--	--	5	7	16	63	1	--
1519.1	trace	60	--	9	--	--	19	5	6	--	trace	--
1538.5	3	14	3	2	--	--	10	4	8	56	trace	--
1560.1	5	21	6	--	--	--	9	3	7	49	--	--
1567.1	1	49	--	--	--	--	33	7	10	--	--	--
1567.2	5	68	--	--	--	--	17	4	9	--	trace	--
1581.2	5	49	--	5	--	--	8	6	12	14	1	--
1581.3	1	53	--	--	--	--	37	6	5	--	trace	--
1597.1	3	46	--	--	--	--	25	11	19	--	1	--
1601.5	3	50	--	--	--	--	15	12	22	--	1	--
1618.1	7	55	--	--	--	--	12	5	24	--	trace	trace[††]

Table H-1: X-Ray Diffraction Data for the Vitric-to-Zeolitic Transition Underlying the Topopah Spring Tuff

[All values from DTN No. LASC831321DQ96001. Information provided by David T. Vaniman, Los Alamos National Laboratory. Intervals containing significant (more than 10 percent) zeolite or smectite are shaded. Note: original error estimates omitted]

Depth (feet)	Smectite	Clinop-tilolite	Morden-ite	Cha-bazite	Trid-ymite	Cristo-balite	Opal-CT	Quartz	Feld-spar	Glass	Mica	Other
1622.6	8	54	--	--	--	--	25	4	13	--	--	
1636.5	7	46	--	--	--	--	35	2	12	--	--	
1647.7	1	--	--	--	4	35	--	3	51	--	--	
1666.6	2	--	--	--	1	7	--	30	55	--	trace	
1688.2	2	--	--	--	3	2	--	33	56	--	trace	
1718.7	2	--	--	--	5	2	--	32	55	--	trace	
1741.0	1	--	--	--	6	3	--	28	57	--	trace	
1765.9	1	--	--	--	2	7	--	29	59	--	trace	
1787.1	1	--	--	--	--	15	--	25	58	--	trace	
1796.7	2	--	--	--	--	16	--	19	61	--	trace	
1824.6	2	--	--	--	--	26	--	12	57	--	trace	
1843.4	3	--	--	--	--	30	--	7	57	--	trace	
1867.5	2	35	--	--	--	21	--	6	39	--	trace	
1893.8	5	29	--	--	--	--	36	3	29	--	--	trace[††]
1913.4	4	42	3	--	--	--	28	4	23	--	--	--
1938.5	1	53	6	--	--	--	20	5	20	--	--	1[†]
1962.8	2	60	5	--	--	--	14	4	20	--	trace	2[†]
1988.6	3	54	12	--	--	--	18	3	15	--	trace	1[†]
2010.2	1	82	--	--	--	--	12	1	10	--	trace	1[†]
2021.3	2	68	--	--	--	--	19	2	14	--	trace	1[†]
2035.1	2	56	10	--	--	--	16	3	18	--	trace	trace[†]
2043.8	2	61	7	--	--	--	14	2	18	--	trace	trace[†]
2062.6	1	49	17	--	--	--	17	3	17	--	trace	trace[†]
2082.8	1	53	15	--	--	--	15	2	17	--	trace	trace[†]
2094.2	1	39	30	--	--	--	13	4	17	--	trace	trace[†]
2109.6	1	53	18	--	--	--	13	2	19	--	trace	trace[†]
2133.7	1	60	16	--	--	--	11	2	14	--	trace	trace[†]
2159.6	2	52	15	--	--	--	12	5	18	--	trace	--
2179.2	4	34	--	--	--	--	2	7	50	--	2	--
2180.0	1	--	--	--	--	5	--	34	56	--	1	1[†]
2201.7	1	--	--	--	--	19	--	18	62	--	1	1[†]
2225.3	2	--	--	--	--	19	--	18	59	--	1	1[†]

[†] Hematite
[‡] Hornblende
[††] Calcite

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Yucca Mountain Site Characterization Office
US Department of Energy
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Las Vegas, NV 89193-8608

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OCRWM
U. S. Department of Energy
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Washington, DC 20585

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c/o Technical Information Resource Center
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US Department of Energy
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Las Vegas, NV 89193-8518

10 Technical Information Officer
DOE Nevada Operations Office
US Department of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

1 J. R. Dyer, Deputy Project Manager
Yucca Mountain Site Characterization Office
US Department of Energy
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Las Vegas, NV 89193-88608

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Las Vegas, NV 87193-8608

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US NRC
Washington, DC 20555

1 Senior Project Manager for Yucca Mountain
Repository Project Branch
Division of Waste Management, MS T7J-9
US NRC
Washington, DC 20555

5 NRC Document Control Desk
Division of Waste Management, MS T7J-9
US NRC
Washington, DC 20555

1 Chad Glenn
NRC Site Representative
301 E Stewart Avenue, Room 203
Las Vegas, NV 89101

5 Center for Nuclear Waste Regulatory Analyses
Southwest Research Institute
6220 Culebra Road
Drawer 28510
San Antonio, TX 78284

1 Robert L. Strickler
Vice President & General Manager
TRW Environmental Safety Systems, Inc.
2650 Park Tower Dr.
Vienna, VA 22180

5 L. D. Foust
Technical Project Officer for YMP
TRW Environmental Safety Systems
101 Convention Center Drive; Suite P-110
Las Vegas, NV 89109

5 M. C. Brady
Laboratory Lead for YMP
M&O/Sandia National Laboratories
1261 Town Center Drive
Bldg. 4, Room 421A
Las Vegas, NV 89134

5 J. A. Canepa
Laboratory Lead for YMP
EES-13, Mail Stop J521
M&O/Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, NM 87545

5 W. L. Clarke
Laboratory Lead for YMP
M&O/ Lawrence Livermore Nat'l Lab
P.O. Box 808 (L-51)
Livermore, CA 94550

5 G. S. Bodvarsson
Head, Nuclear Waste Department
Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS 50E
Berkeley, CA 94720

5 Robert W. Craig
Acting Technical Project Officer/YMP
US Geological Survey
101 Convention Center Drive, Suite P-110
Las Vegas, NV 89109

3 Jim Krulik, Geology Manager
US Bureau of Reclamation
Code D-8322
P.O. Box 25007
Denver, CO 80225-0007

1 M. D. Voegele
Deputy of Technical Operations
M&O/SAIC
101 Convention Center Drive
Suite P-110
Las Vegas, NV 89109

2 A. T. Tamura
Science and Technology Division
OSTI
US Department of Energy
P.O. Box 62
Oak Ridge, TN 37831

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Nuclear Radiation Assessment Div.
US EPA
Environmental Monitoring Sys. Lab
P.O. Box 93478
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State of Nevada
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Carson City, NV 89710

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Inyo County Yucca Mountain Repository Assessment Office
P. O. Drawer L
Independence, CA 93526

1 Vernon E. Poe
Office of Nuclear Projects
Mineral County
P.O. Box 1600
Hawthorne, NV 89415

1 Les W. Bradshaw, Program Manager
Nye County Nuclear Waste Repository Project Office
P.O. Box 1767
Tonopah, NV 89049

1 Florindo Mariani
White Pine County Coordinator
P. O. Box 135
Ely, NV 89301

1 Tammy Manzini
Lander County Yucca Mountain Information Officer
P.O. Box 10
Austin, NV 89310

1 Jason Pitts, Manager
Lincoln County Nuclear Waste Program
P. O. Box 158
Pioche, NV 89043

1 Dennis Bechtel, Coordinator
Nuclear Waste Division
Clark County Dept. of Comprehensive Planning
P.O. Box 55171
Las Vegas, NV 89155-1751

1 Juanita D. Hoffman
Nuclear Waste Repository Oversight Program
Esmeralda County
P.O. Box 490
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1 Sandy Green
Yucca Mountain Information Office
Eureka County
P.O. Box 714
Eureka, NV 89316

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Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS 50E
Berkeley, CA 94720

3 D. T. Vaniman
EES-13, Mail Stop J521
M&O/Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, NM 87545

5 J. S. Stuckless, Chief
Geologic Studies Program
Yucca Mountain Project Branch
US Geological Survey
P.O. Box 25046; MS 425
Denver, CO 80225

5 Michael P. Chornack
US Geological Survey;
P.O. Box 25046; MS-425
Denver, CO 80225

5 Daniel C. Gillies
US Geological Survey;
P.O. Box 25046; MS-425
Denver, CO 80225

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US Geological Survey;
P.O. Box 25046; MS-425
Denver, CO 80225

20 B. T. Brady
Records Specialist
US Geological Survey
MS 421
P.O. Box 25046
Denver, CO 80225

2 A. L. Flint
U. S. Geological Survey
MS 721
P. O. Box 327
Mercury, NV 89023

1 L. E. Flint
US Geological Survey; MS-509
101 Convention Center Drive
Las Vegas, NV 89109

1 P. H. Nelson
U.S. Geological Survey
P. O. Box 25046; MS-425
Denver, CO 80225

3 W. C. Day
U.S. Geological Survey
P. O. Box 25046; MS-425
Denver, CO 80225

2 J. W. Whitney
U.S. Geological Survey
P. O. Box 25046; MS-425
Denver, CO 80225

2 R. W. Spengler
US Geological Survey
P.O. Box 25046; MS-425
Denver, CO 80225

2 D. C. Buesch
US Geological Survey; MS-509
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CWRMS M&O; MS-423
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Las Vegas, NV 89109

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CWRMS M&O; MS-423
101 Convention Center Drive
Las Vegas, NV 89109

3 Robert Elayer
CWRMS M&O; MS-423
101 Convention Center Drive
Las Vegas, NV 89109
Las Vegas, NV 89109

2 Robb Clayton
CWRMS M&O; MS-423
101 Convention Center Drive
Las Vegas, NV 89109

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CWRMS M&O; MS-423
101 Convention Center Drive
Las Vegas, NV 89109

3 Chris Lewis
YMP Sample Management Facility
CWRMS M&O; MS-719
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